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JRC TECHNICAL REPORTS

Level(s) – A common EU framework of core sustainability indicators for office and residential buildings

Part 3: How to make performance assessments using Level(s)

(Draft Beta v1.0)

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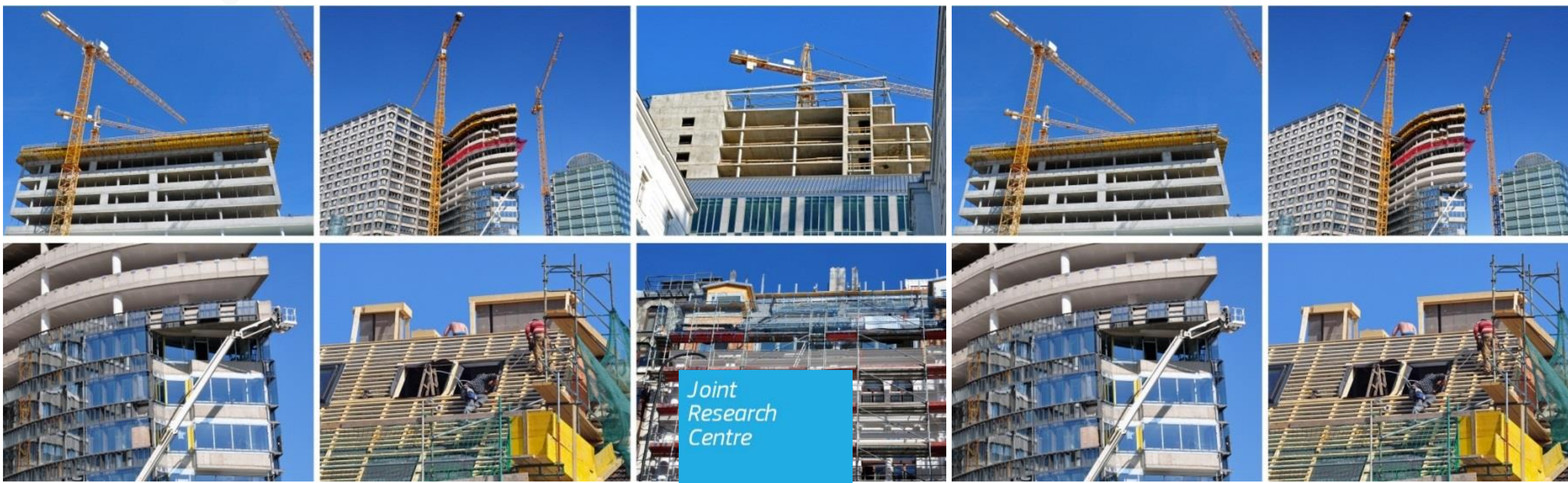

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Introduction to Part 3 of the Level(s) framework

How to make a performance assessments using Level(s)

This document is the companion to parts 1 and 2 of the guidance on how to use Level(s). In part 1 a general introduction to Level(s) is provided, together with in Part 2 an overview of the macro-objectives, performance indicators and the three Levels of performance assessment. The three Levels are briefly described in table i below.

Table i. Overview of the three performance Levels

Level 1: Common performance assessment	✓ The simplest and most accessible type of use for each indicator. ✓ A common reference point for the performance assessment of buildings across Europe.
Level 2: Comparative performance assessment	✓ For professionals that wish to make meaningful comparisons between functionally equivalent buildings. ✓ Lays down rules to support the comparability of results at national level or building portfolio level.
Level 3: Performance optimisation assessment	✓ The most advanced use of each indicator. ✓ Provides guidance to support professionals that wish to work at a more detailed level to model and improve performance, which may include: – making more accurate calculations; – carrying out modelling in order to optimise design and as-built performance; – anticipating future costs, risks and opportunities along the building's life cycle.

This part 3 of the documentation provides a complete set of technical guidance on how to make performance assessments at each of the three different Levels, and then to report on the results. In order to use the guidance it is recommended to follow the steps outlines in table ii.

In order to help users of Level(s) navigate to the indicators and performance assessment Levels they would like to use, table iii provides direct hyperlinks to the appropriate guidance.

Icons also help to identify the different assessment levels, guidance notes and reporting templates. Figure i provides a key to the icons used.

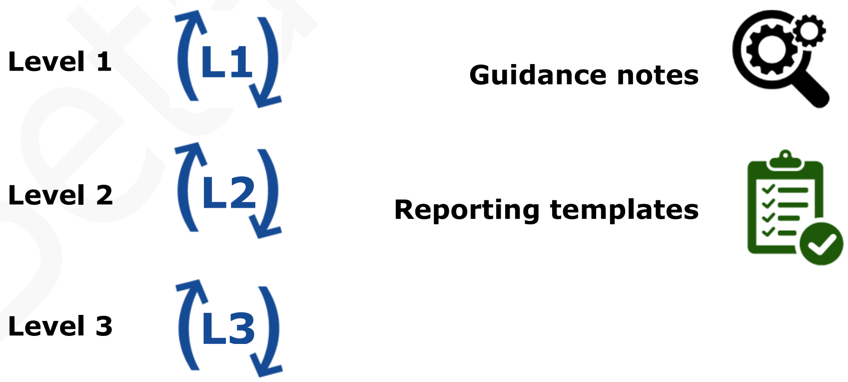


Figure i. Key to the icons used to identify the levels, guidance notes and reporting templates

Table ii. The stepwise approach to performance assessment and reporting

Step 1: Define the building to be reported on	✓ Part 3, section 1.1 should be followed in order to define the building, and the associated goal and scope of the performance assessment.
Step 2: Choose the level of performance assessment	✓ Based on the goal and scope of the performance assessment, the appropriate assessment level for the project should be selected from the three available options. ✓ Part 1, section 3.2 provides further guidance on the difference between the three levels.
Step 3: Follow the guidance and rules on how to carry out an assessment	✓ Part 2 provides a general introduction to each indicator. ✓ Part 3 should thereafter be consulted, where guidance is provided for each level on how to carry out a performance assessment. Rules are also laid down for reporting in the public domain. ✓ The Level 1 guidance forms the common basis for all assessments, and should be consulted before using Levels 2 and 3.
Step 4: Complete the reporting format	✓ In each set of technical guidance in Part 3, a format for reporting is provided.
Step 5: Determine the valuation influence and reliability of the assessment	✓ As an optional last step for each indicator, the potential influence on a property valuation and reliability of the data and calculation method may be rated and reported on. Part 3 provides a rating methodology for each indicator.

Table iii. Where to find each indicator, scenario or life cycle tool, and their Levels

Indicator	**Unit of performance measurement**	**Detailed guidance which can be found in Part 3**			
		Level 1 **Common assessment**	**Level 2** **Comparative assessment**	**Level 3** **Optimisation assessment**	**All levels** **Valuation influence and reliability rating**
Macro-objective 1: Greenhouse gas emissions along a buildings life cycle					
1.1 Use stage energy performance *1.1.1 Primary energy demand* *1.1.2 Delivered energy demand (supporting indicator)*	kilowatt hours per square metre per year (kWh/m^2 /yr)	Level 1 common performance assessment	Level 2 comparative performance assessment	Level 3 performance optimisation assessment	Valuation influence and reliability rating (all levels)
1.2 Life cycle Global Warming Potential	kg CO_2 equivalents per square metre per year (kg CO_2 eq./m^2/yr)	Level 1 common performance assessment	Level 2 comparative performance assessment	Level 3 performance optimisation assessment	Valuation influence and reliability rating (all levels)
Macro-objective 2: Resource efficient and circular material life cycles					
2.1 Life cycle tool: Building bill of materials	Reporting on the Bill of Materials for the building, as well as for the four main types of materials used.	Guidance common to all Levels	-	-	-

2.2 Life cycle tools: scenarios for building lifespan, adaptability and deconstruction	According to the performance assessment level: 1. Design aspects that are proposed/have been implemented (common performance assessment) 2. Semi-qualitative assessment giving a score (comparative performance assessment) 3. LCA-based assessment of scenario performance (design optimisation)	General rules applying to all levels Scenario 1 General rules applying to all levels Scenario 2 Level 1 common performance assessment Scenario 3 Level 1 common performance assessment	Scenario 2 Level 2 comparative performance assessment Scenario 3 Level 2 comparative performance assessment	Scenario 2 Level 3 performance optimisation assessment Scenario 3 Level 3 performance optimisation assessment	Valuation influence and reliability rating (all levels)
2.3 Construction and demolition waste and materials	kg waste and materials per m^2 of total useful floor area *(per life cycle and project stage reported on)*	Level 1 common performance assessment	Level 2 comparative performance assessment	Level 3 performance optimisation assessment	Valuation influence and reliability rating (all levels)
2.4 Overarching assessment tool: Cradle to grave Life Cycle Assessment	Seven environmental impact category indicators *(detailed guidance is provided under 4.4 Overarching assessment tool)*	See the last section 3 of Part 3	-	-	-
Macro-objective 3: Efficient use of water resources					

3.1 Total water consumption	m^3 of water per occupant per year	Level 1 common performance assessment	Level 2 comparative performance assessment	Level 3 performance optimisation assessment	Valuation influence and reliability rating (all levels)
Macro-objective 4: healthy and comfortable spaces					
4.1 Indoor air quality	4.1.1 Good quality indoor air: Parameters for ventilation, CO_2 and humidity 4.1.2 Target list of pollutants: Emissions from construction products and external air intake.	Level 1 common performance assessment	Level 2 comparative performance assessment	Level 3 performance optimisation assessment	Valuation influence and reliability rating (all levels)
4.2 Time outside of thermal comfort range	% of the time out of range of defined maximum and minimum temperatures during the heating and cooling seasons	Level 1 common performance assessment	Level 2 comparative performance assessment	Level 3 performance optimisation assessment	Valuation influence and reliability rating (all levels)
Macro-objective 5: Adaptation and resilience to climate change					
5.1 Life cycle tools: scenarios for projected future climatic conditions	*Scenario 1: Protection of occupier health and thermal comfort* Simulation of the building's projected time out of thermal comfort range for the years 2030 and 2050.	Level 1 common performance assessment	Level 2 comparative performance assessment	Level 3 performance optimisation assessment	Valuation influence and reliability rating (all levels)
Macro-objective 6: Optimised life cycle cost and value					

6.1 Life cycle costs	Euros per square metre of useable floor area per year (€/m^2/yr)	Level 1 common performance assessment	Level 2 comparative performance assessment	Level 3 performance optimisation assessment	Valuation influence and reliability rating (all levels)
6.2 Value creation and risk factors	Reliability ratings of the data and calculation methods for the reported performance of each indicator and life cycle scenario tool.	-	-	-	The potential for a positive influence on a market valuation Reliability rating of a Level(s) assessment Calculation of the technical rating

1. Description of the building to be assessed

This section provides guidelines on how to compile and report on the basic description of a building. This also sometime referred to as a 'goal and scope definition'. The description shall comprise the information outlined in table 1 and is required for all Levels of assessment. The key terms and definitions used in this section are defined in table 2. The suggested reporting format for the goal and scope of a building is provided in section 1.7.

Table 1. Information that makes up the description of the building to be assessed

1. The building and its elements	The building type (or use class) and the pre-defined minimum scope of building parts and elements.
2. The building type, ownership and market segment	A description of the building's market segment, ownership structure and intended service life.
3. The unit to be used for comparative purposes	The common methods to be used for measurement of the total useful floor area within a building.
4. How the building will be used and the lifespan of its elements	A description of the outdoor environment to which the building is exposed, the intended conditions of use, occupant related usage patterns. Default service lifespans for building parts and components are also provided.
5. The timescale for the performance assessment	The intended or default service life of the building being studied.
6. Which stages in the life cycle	The life cycle stages that shall be taken into account when making the performance assessment.

Together, this information will also provide a goal and scope definition that both supports comparisons of performance assessment results between the individual indicators and scenarios as well as for when carrying out a cradle to cradle LCA, if this form of performance assessment is chosen.

Table 2. Key terms and definitions used

Building element	A technical building system or an element of the building envelope.
Climate zone	A geographical region which may extend across several countries and which has distinct average seasonal weather conditions, taking into account variables such as temperature, precipitation and wind.
Full time person equivalents	The total number of employees working in a building that use the building as their main base and expect to work there for part of a typical working week. Each employee's occupation is adjusted to reflect the proportion of a working week they are in the building.
Functional unit	The quantified performance of a product system for use as a reference unit.
Heating and cooling degree days	The number of days of the year during which on average a building in a specific location and with specific conditions of use requires heating and cooling.

In-use conditions	Any circumstances that can impact on the performance of a building under normal use.
Investment holding period	The real or expected period of time during which an investment will be attributable to a particular investor.
Major renovation	A major renovation is where 1) the total cost of the renovation relating to the building envelope or the technical building systems is higher than 25 % of the value of the building, excluding the value of the land upon which the building is situated, or b) more than 25 % of the surface of the building envelope will undergo renovation.
Market segment	An identifiable group of property types, sharing one or more characteristics or needs in an otherwise homogeneous market.
Reference study period	Period over which the time-dependent characteristics of the building are analysed.
Reference unit	Measure of the outputs from processes in a given product system required to fulfil the function expressed by the functional unit.
Service life	Period of time after installation during which a building or an assembled system (part of works) meets or exceeds the technical requirements and functional requirements defined by the client, and/or by the users and/or by regulations.
System boundary	Interface in the assessment between a building and its surroundings or other product systems

1.1 The building and its elements

1.1.1 Building type and site

The object of a performance assessment is a building, including its foundations and all external works within the curtilage of the building site. The building may be:

- an office building;
- an individual residential building, providing one dwelling;
- an apartment building, providing multiple dwelling, and inclusive of communal areas and shared services;
- a residential building typology that form part of a housing development which consists of several typologies;
- a mixed use block comprising a vertical mix of office and residential property.

The building may be a new construction or a major renovation[1]. In the case of a residential apartment building, the object of assessment may be a representative sample of the apartment typologies within the building, rather than the whole building. In the same way, for a residential development or catalogue of property types, the objective of assessment may be a representative sample of the residential typologies.

In the case of mixed use buildings, the performance assessment shall be guided by the following rules:

1. Where possible try to assess internal environments as they relate to each use (e.g. energy demand, indoor air quality)
2. If this is not possible, then make an assessment of the whole building, excluding uses that are not office or residential
3. If comparability between uses is important, then allocation of shared resource use or environmental impacts shall be made in proportion to the floor area occupied by each respective use.

If the decision is made to allocate resource use or environmental impacts between different uses, this shall be applied provided that the shared facilities and services within the building:

- relate to the use of the office or residential units,
- are not already allocated according to another procedure (e.g. a set number of parking spaces per residential unit or per m^2 office space), or
- represent other building uses in their own right (e.g. a shop or canteen).

1.1.2 Building parts and elements

For consistency, the building shall be defined in terms of a minimum scope of building parts and associated elements from which they are made up. These are set out in table 1.1. Products that are procured and installed by occupiers are excluded from the scope.

Table 1.1. Minimum scope of building parts and elements

Building parts	**Related building elements**
Shell (substructure and superstructure)	
Foundations (substructure)	Piles Basements Retaining walls

[1] A major renovation is where 1) the total cost of the renovation relating to the building envelope or the technical building systems is higher than 25 % of the value of the building, excluding the value of the land upon which the building is situated, or b) more than 25 % of the surface of the building envelope will undergo renovation.

Load bearing structural frame	Frame (beams, columns and slabs) Upper floors External walls Balconies
Non-load bearing elements	Ground floor slab Internal walls, partitions and doors Stairs and ramps
Facades	External wall systems, cladding and shading devices Façade openings (including windows and external doors) External paints, coatings and renders
Roof	Structure Weatherproofing
Parking facilities	Above ground and underground (within the curtilage of the building and servicing the building occupiers) [2]
Core (fittings, furnishings and services)	
Fittings and furnishings	Sanitary fittings Cupboards, wardrobes and worktops *(where provided in residential property)* Ceilings Wall and ceiling finishes Floor coverings and finishes
In-built lighting system	Light fittings Control systems and sensors
Energy system	Heating plant and distribution Cooling plant and distribution Electricity generation and distribution
Ventilation system	Air handling units Ductwork and distribution
Sanitary systems	Cold water distribution Hot water distribution Water treatment systems Drainage system
Other systems	Lifts and escalators Firefighting installations Communication and security installations Telecoms and data installations
External works	
Utilities	Connections and diversions Substations and equipment
Landscaping	Paving and other hard surfacing Fencing, railings and walls Drainage systems

Adapted from CEN (2011), BCIS (2012), DGNB (2014), BRE (2016)

[2] If the share of underground car parking (usable area plus traffic area) accounts for more than 25% of the total useful floor area, the traffic area of the underground parking must be subtracted from the total useful floor area.

1.2 The building type, ownership and market segment

The functional equivalent shall be described in terms of the location, age and physical form of the building. In addition, the market segment and ownership structure shall be described. The description shall comprise the information presented in table 1.2.

Following the principle of functional equivalence, results shall be reported for a reference unit. In Life Cycle Assessment, a reference unit is also commonly referred to as a 'reference flow'. This shall be either:

- a reference unit of an office building, or
- a reference unit for a house, or
- a reference unit for each distinct house type or apartment type that forms part of a block, a larger property development or a housing stock.

In the case of multiple units of housing, the schedule of accommodation (the number of each different type of unit there are) shall be provided, together with the rationale for selection of the house or apartment types as being representative.

Table 1.2. Functional description of the building

Parameter	**Office buildings**	**Residential buildings**
Location	*Country and region*	
Climate zone	*Zone (selected from figure 1.1)* *Heating and cooling degree days* [3]	
Project type	*New build or major renovation*	
Year of construction	*For both new-build and major renovations*	
Original year of construction	*For major renovations only*	
Service life or holding period	Clients intended service life or investment holding period in years *(to be specified which)*	– *Clients intended service life* – *investment holding period* – *the warrantied service life of property for sale*
Building form	– Low rise office park – In-fill urban block – Perimeter urban block – Urban city block – Tower/skyscraper – *Other (to be described)*	– Free standing, detached house – Semi-detached house – Row or terraced house – Multi-family house or apartment block *(up to 4 floors/5-12 floors/more than 12 floors)*
Property schedule [4]	Total useful floor area	*Schedule of accommodation for the development or renovated stock* – *Number of units per bed space/form type* – *Net useful floor area of each form type in the schedule*
Market segment	Owner occupation or for rent, with reference to a combination of the following BOMA building class definitions [5]: *International base definitions:* – *Investment* – *Institutional* – *Speculative* *Metropolitan base definitions* *A: Premium rental* *B: Average rental* *C: Below average rental*	By tenure – Owner occupation – Leasehold, social – Leasehold, market rental – Leasehold, student – Leasehold, seniors – Other *(to be described)*

[3] This can be obtained from local weather data or the energy performance assessment for a building
[4] Measured in accordance with the International Property Measurement Standards (IPMS) as specified in Section 1.3.
[5] BOMA (Building Owners and Managers Association), Building class definitions, http://www.boma.org/research/Pages/building-class-definitions.aspx

Servicing	With/without centralised ventilation and/or air conditioning	With/without centralised heating, ventilation and/or air conditioning

For leasehold office buildings, assumptions about future void rates shall be used to calculate the proportion of the floor area, and therefore the associated resource use, that is anticipated to be unoccupied on average during the buildings service life. For residential buildings, the same may be done for leasehold properties if the intention is to report on average performance for unit types across a housing stock.

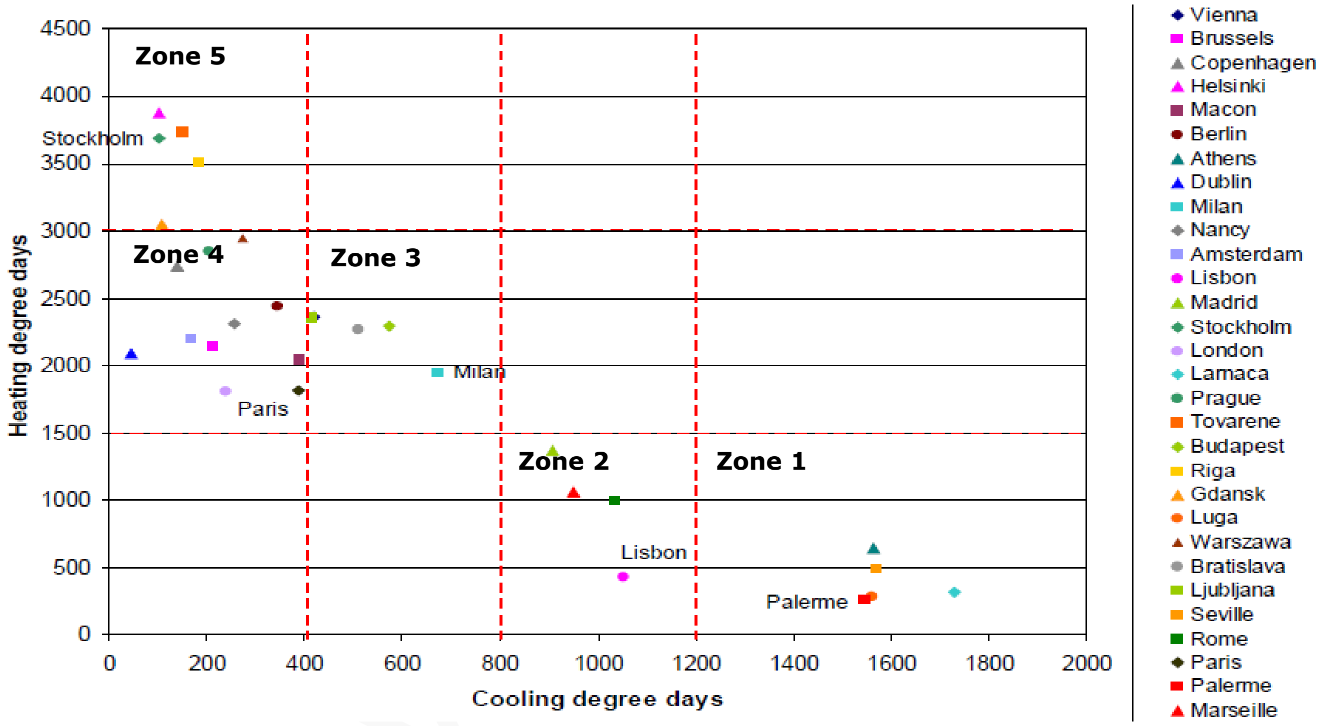


Figure 1.1 European climate zones defined by heating and cooling degree days

Source: Ecofys (2012) Keepcool II (2010)

1.3 The unit to be used for comparative purposes

1.3.1 Reference floor area measurement

A reference unit allows results to be normalised to a common measurement or parameter that is related to the building or its users.

The basic reference unit to be used throughout the Level(s) framework is one square metre (m^2) of useful internal floor area.

For the purposes of this framework, the Internal Property Measurement Standards for offices and residential buildings[6] shall be used as the reference standards. The IPMS standards are broadly equivalent to the reference area defined in EN 15603 and prEN ISO 52000-1, which is a measurement of the net internal area inclusive of shared circulation areas that are within the thermal envelope.

[6] International Property Measurement Standards Coalition, *International Property Measurement Standards: Office Buildings*, November 2014 and *Residential buildings*, September 2016

Table 1.3 identifies the specific IPMS standards that shall be used, together with those items that shall be included or excluded from a floor area measurement exercise. In all cases, the method used shall be reported on for comparative purposes.

Table 1.3. Reference internal floor area definitions to be used for office and residential buildings

	Office building **(IPMS measurement standard 3)**	**Residential building** **(IPMS measurement standard 3B)**
Inclusions	All internal walls and columns within each occupant's exclusive area. Circulation areas within an occupant's exclusive area, and those shared between different occupants. The floor area shall be measured to the internal dominant face of walls or the centre line of common walls shared between tenants.	The area in exclusive occupation, including the floor area occupied by internal walls and columns. The floor area shall be measured to the internal dominant face and the finished surface of all full height internal walls. Fully glazed partitions are not regarded as permanent internal walls.
Exclusions	Those parts of a building providing shared or common facilities that do not change over time: – stairs, – escalators, – lifts and motor rooms, – toilets, – cleaner's cupboards, – plant rooms, – fire refuge areas, and – maintenance rooms.	– Patios – Unenclosed parking areas, which may be measured or defined by the number of spaces – Staircase openings – Voids where the area, including the enclosing wall, is greater than 0.25 m^2.
Separate items	*To be reported separately:* – balconies, – covered galleries, and – rooftop terraces in exclusive use	*To be reported separately:* – Attics, basements and cellars – Balconies and verandas in exclusive use – Enclosed garages – Limits use areas

Source: IPMS (2014, 2016)

1.3.2 Optional additional comparative reference units

In some cases, two further reference units may be used to more accurately measure the resource intensity of a building:

- for office buildings: per area of workspace occupied by each full time person equivalent,
- for residential buildings: per bed space.

Performance normalised according to these alternative reference units shall be reported in addition to, and not as a substitute for, the basic reference unit.

1.4 How the building will be used and the lifespan of its elements

The degree of wear and tear that a building is exposed to will have an impact on the lifespan of the building and of its constituent elements. The main factors relate to the environment in which a building is located, how the occupants use a building and how it is maintained.

1.4.1 Building level in-use conditions

The typical in-use conditions for the building in its location shall be described. The general framework for describing in-use conditions provided by ISO 15686-8 shall be used. This standard lists seven factors of relevance (see table 1.4). These relate to the outdoor environment (local climate, surroundings) and how the building will be used (see the next section 1.4.2). Reporting shall as a minimum address factors D, E, F and G.

Table 1.4 Factor categories for building element service life estimation

Factor	Factor category
A	inherent performance level
B	design level
C	work execution level
D	indoor environment
E	outdoor environment
F	usage conditions
G	maintenance level

Source: ISO (2008)

1.4.2 Building occupation and conditions of use

The anticipated occupation and patterns of use shall be described, as well as the 'conditions of use'. The latter may be pre-defined by national calculation methods to assess energy performance. Some of the information to describe the conditions of use for a building may be provided by national calculation methods for energy performance, or if this is not available, by EN ISO 13790 (Annex G.8) or EN ISO 52016-1.

Table 1.5 Projected patterns of occupation and conditions of use

Parameter	**Office buildings**	**Residential buildings**
Conditions of use	*National calculation method for energy performance that defines the building's conditions of use*	
Projected occupancy density	*Area of workspace in m² per full time person equivalents* [7]	*n/a*
Projected pattern of occupation	*Number of hours and days per year*	*n/a*
Assumed void rate	*Applicable to leasehold property/space.* *Proportion of lettable floor space projected, on average, to be vacant/unoccupied.*	

[7] See the *IPD Global Estate Measurement code for occupiers*, Tenth edition, September 2013.

1.4.3 Building element service lifespan estimations

Service lifespans for the minimum scope of building parts and elements shall be estimated according to the factor methodology in ISO 15686-8. Specific standards relating to building elements may also be valuable, e.g. EN 15459 and heating systems.

In the absence of estimations made by manufacturers and suppliers, the typical service lifespans in table 1.5 may be used. More detailed, generic lifespans can be obtained from building costing tools, as well as some carbon footprinting and LCA tools.

Determination of specific building element service lifespans is addressed further and can be reported on as part of scenario 1 of the 2.2 Life cycle scenario tools.

Table 1.6 Typical service lives for the minimum scope of building parts and elements

Building parts	**Related building elements**	**Expected lifespan**
Shell (substructure and superstructure)		
Load bearing structural frame	– Frame (beams, columns and slabs) – Upper floors – External walls – Balconies	60 years
Non-load bearing elements	– Ground floor slab – Internal walls, partitions and doors – Stairs and ramps	30 years
Facades	– External wall systems, cladding and shading devices – Façade openings (including windows and external doors) – External paints, coatings and renders	30 years (35 years glazed) 30 years 10 years (paint) 30 years (render)
Roof	– Structure – Weatherproofing	30 years
Parking facilities	– Above ground and underground (within the curtilage of the building and servicing the building occupiers) [8]	60 years
Core (fittings, furnishings and services)		
Fittings and furnishings	– Sanitary fittings – Cupboards, wardrobes and worktops – Floor finishes, coverings and coatings – Skirting and trimming – Sockets and switches – Wall and ceiling finishes and coatings	20 years 10 years 30 years (finishes) 10 years (coatings) 30 years 30 years 20 years (finishes) 10 years (coatings)

[8] If the share of underground car parking (usable area plus traffic area) accounts for more than 25% of the total useful floor area, the traffic area of the underground parking must be subtracted from the total useful floor area.

In-built lighting system	– Light fittings – Control systems and sensors	15 years
Energy system	– Heating plant and distribution – Radiators – Cooling plant and distribution – Electricity generation – Electricity distribution	20 years 30 years 15 years 15 years 30 years
Ventilation system	– Air handling units – Ductwork and distribution	20 years 30 years
Sanitary systems	– Cold water distribution – Hot water distribution – Water treatment systems – Drainage system	25 years
Other systems	– Lifts and escalators – Firefighting installations – Communication and security installations – Telecoms and data installations	20 years 30 years 15 years 15 years
External works		
Utilities	– Connections and diversions – Substations and equipment	30 years
Landscaping	– Paving and other hard surfacing – Fencing, railings and walls – Drainage systems	25 years 20 years 30 years

Adapted from RICS (2017), ETool (2017)

1.5 The timescale for the performance assessment

The reference study period to be used for all buildings assessed according to the Level(s) framework is 60 years.

Users may additionally report on the performance of the building for a client's intended service life or investment holding period, which may be shorter or longer than the reference study period.

The overall building service life is the subject of scenario 1 of the 2.2 Life cycle scenario tools.

1.6 Which stages in the life cycle

The system boundary shall encompass all the life cycle stages illustrated in Figure 1.2. For renovated existing buildings, the system boundary shall encompass all life cycle stages that relate to the extension of the building's service life.

Any reduction in the scope of life cycle stages for the purpose of making a performance assessment using the Level(s) framework shall be clearly stated in the reporting. Guidance on the statements that should accompany the reporting is provided for indicator 1.2 and cradle to cradle LCA (see section 7).

For each life cycle stage (or module) to which impacts are assigned, the system shall include all upstream and downstream processes needed to establish and maintain the function of the building. This shall include the point where materials and energy exit the system boundary during or at the end of the building's life cycle – referred to in the reference standard EN 15978 as life cycle Module D.

In some cases, buildings that are already on the site to be developed may be required to be demolished prior to the construction of a new building, or an existing building may be the subject of strip out or remodelling works prior to a major renovation. In both of these cases, the benefits and loads arising from the recovery of demolition or strip out materials shall be considered to be outside of the system boundary. The benefits and loads must therefore be allocated to the previous building in order to avoid double counting.

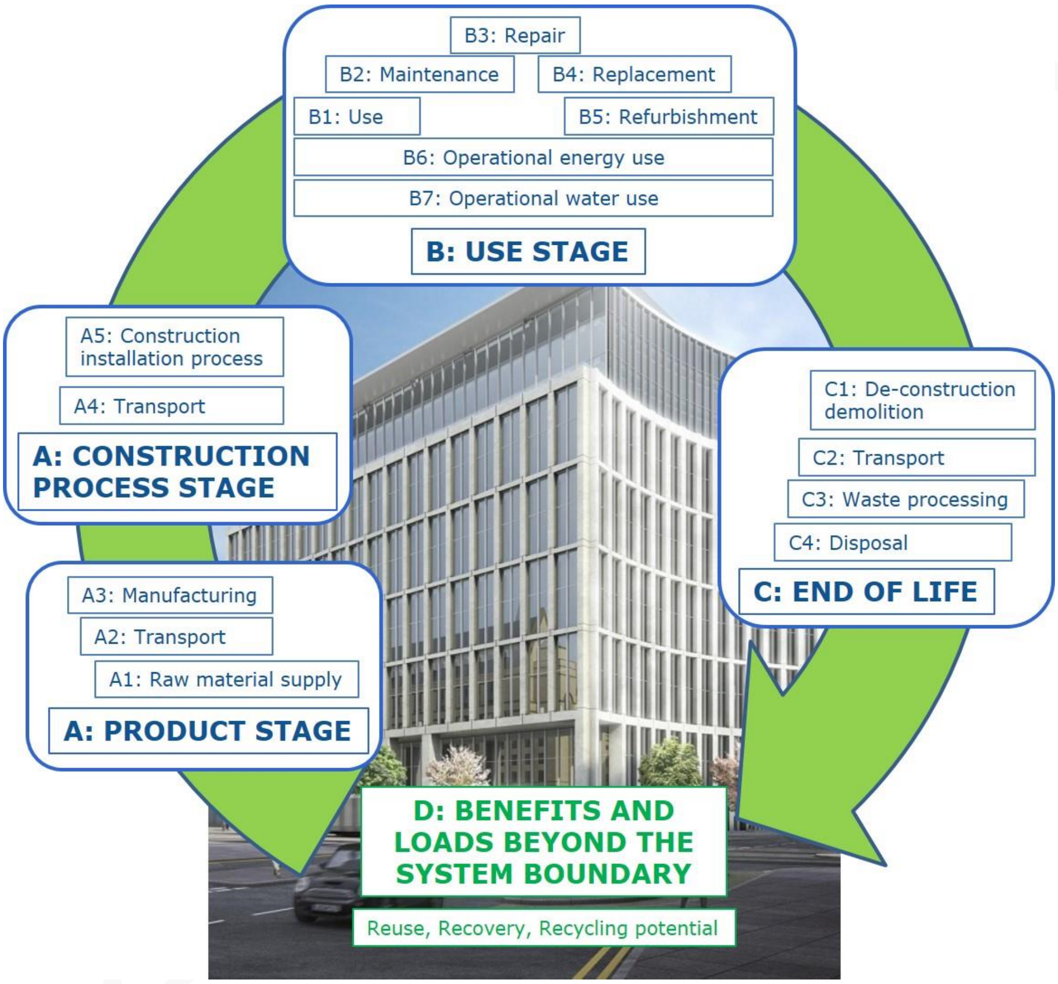


Figure 1.2. Modular schematic of building life cycle stages

Source: CEN (2011)

1.7 Suggested reporting format for the building description

The data collected according to guidance in sections 1.1 – 1.6 shall be compiled and reported on as presented in the reporting format below.

The building type shall in all cases be clearly identified in any reporting. In the case of a mixed use building the sub-division of floor areas shall additionally be identified.

Description of the building to be assessed

(to be compiled and reported on for all Levels of assessment)

Parameter	**Office buildings**	**Residential buildings**
Location	*Country and region*	
Climate zone	*Zone (selected from figure 1.1)* *Heating and cooling degree days*	
Project type	*New build or major renovation*	
Year of construction	*For both new-build and major renovations*	
Original year of construction	*For major renovations only*	
Service life or holding period	Clients intended service life or investment holding period in years *(to be specified which)*	*Clients intended service life or investment holding period.* *Warrantied service life of property for sale.*
Building form	*Please select from* – Low rise office park – In-fill urban block – Perimeter urban block – Urban city block – Tower/skyscraper – *Other (to be described)*	*Please select from:* – Free standing, detached house – Semi-detached house – Row or terraced house – Multi-family house or apartment block *(up to 4 floors/5-9 floors/more than 9 floors)*
Property schedule [9]	Total useful floor area	*Schedule of accommodation for the development or renovated stock* – *Number of units per bed space/form type* – *Net useful floor area of each form type in the schedule*
Floor area measurement	IPMS Office 3 *(or another standard that should be specified)*	IPMS Residential 3c *(or another standard that should be specified)*

[9] Measured in accordance with the International Property Measurement Standards (IPMS) as specified in Section 1.3 and to be reported in the following field.

Market segment	Owner occupation or for rent, with reference to a combination of the following BOMA building class definitions [10]: *International base definitions:* – *Investment* – *Institutional* – *Speculative* *Metropolitan base definitions* *A: Premium rental* *B: Average rental* *C: Below average rental*	By tenure – Owner occupation – Leasehold, social – Leasehold, market rental – Leasehold, student – Leasehold, seniors – Other *(to be described)*
Servicing	*With/without centralised ventilation and/or air conditioning*	*With/without centralised heating, ventilation and/or air conditioning*
Conditions of use	*National calculation method for energy performance that defines the building's conditions of use*	
Projected occupancy density	*Area of workspace in m² per full time person equivalents*	*n/a*
Projected pattern of occupation	*Number of hours and days per year*	*n/a*
Assumed void rate	*Applicable to leasehold property/space.* *Proportion of lettable floor space projected, on average, to be vacant/unoccupied.*	

[10] BOMA (Building Owners and Managers Association), Building class definitions, http://www.boma.org/research/Pages/building-class-definitions.aspx

2. The indicators by macro-objective

Macro-objective 1: Greenhouse gas emissions along a buildings life cycle

Key terms and definitions used

Biogenic carbon	carbon derived from biomass
Biomass	material of biological origin excluding material embedded in geological formations and material transformed to fossilized material, excluding peat
Building envelope	the integrated elements of a building which separate its interior from the outdoor environment;
Calculation step	discrete time interval for the calculation of the energy needs and uses for heating, cooling, ventilation, humidification and dehumidification
Carbon dioxide equivalent (CO_2e)	unit for comparing the radiative forcing of a greenhouse gas to that of carbon dioxide
Calculated energy assessment	energy rating based on calculations of the weighted delivered and exported energy of a building for heating, cooling, ventilation, domestic hot water and lighting
Carbon footprint (or whole life carbon measurement)	sum of greenhouse gas emissions and removals in a product system, expressed as CO_2 equivalents and based on a life cycle assessment using the single impact category climate change
Carbon storage	carbon removed from the atmosphere and stored as carbon in a product
Commissioning	Clarifying building system performance requirements set by the owner, auditing different judgments and actions by the commissioning related parties in order to realise the performance, writing necessary and sufficient documentation, and verifying that the system enables proper operation and maintenance through functional performance testing.
Delivered energy	energy, expressed per energy carrier, supplied to the technical building systems through the system boundary, to satisfy the uses taken into account (heating, cooling, ventilation, domestic hot water, lighting, appliances, etc.) or to produce electricity
Direct land use change (dLUC)	change in human use or management of land within the product system being assessed
Dynamic simulation	a method of building energy simulation that calculates the heat balance with short times steps (typically one hour) to take into account the heat stored in, and released from, the mass of the building.
Exported energy	energy, expressed per energy carrier, delivered by the technical building systems through the system boundary and used outside the system boundary
Fossil carbon	carbon which is contained in fossilised material

Functional performance testing	A set of tests that define the functionality and verify the behaviour of a system. These tests are usually defined by the commissioning authority in order to verify that building systems are completed to satisfy the owner's project requirements and demonstrate functional performance.
Global Warming Potential (GWP)	characterization factor describing the radiative forcing impact of one mass-based unit of a given greenhouse gas relative to that of carbon dioxide over a given period of time
Greenhouse gas (GHG)	gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiations at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds
Greenhouse gas emission	mass of a greenhouse gas released to the atmosphere
Greenhouse gas emission factor	mass of a greenhouse gas emitted relative to an input or output of a unit process or a combination of unit processes
Greenhouse gas sink	process that removes a greenhouse gas from the atmosphere
Indirect land use change (iLUC)	change in the use or management of land which is a consequence of direct land use change but which occurs outside the product system being assessed
Measured energy assessment	energy rating based on measured amounts of delivered and exported energy, as measured by meters or other means
Offsetting	mechanism for compensating for all or for a part of the carbon footprint through the prevention of the release of, reduction in, or removal of an amount of greenhouse gas emissions in a process outside the boundary of the product system
Primary energy	energy from renewable and non- renewable sources which has not undergone any conversion or transformation process.
(Total) Primary energy factor	for a given energy carrier, non-renewable and renewable primary energy divided by delivered energy, where the primary energy is that required to supply one unit of delivered energy, taking account of the energy required for extraction, processing, storage, transport, generation, transformation, transmission, distribution, and any other operations necessary for delivery to the building in which the delivered energy will be used
Quasi steady state simulation	a method of building energy simulation that calculates the heat balance over a sufficiently long time (typically one month or a whole season) to take dynamic effects into account by an empirically determined gain and/or loss utilization factor;
Set point temperature	internal (minimum intended) temperature as fixed by the control system in normal heating mode, or internal (maximum intended) temperature as fixed by the control system in normal cooling mode
Technical building system	technical equipment for heating, cooling, ventilation, domestic hot water, lighting and electricity production

1.1 Indicator of use stage energy performance

1.1 Use stage energy performance	**Where to find the guidance for each Level**
1.1.1 Primary energy demand	Level 1 common performance assessment
1.1.2 Delivered energy demand	Level 2 comparative performance assessment
(supporting indicator)	Level 3 performance optimisation assessment
	Valuation influence and reliability rating (all levels)

1.1.1 Level 1 - Making a common performance assessment

For a common performance assessment, the following calculation methodology and reporting format shall be used. This requires reporting on the assessment type and the calculation method used, which shall be based on those required for building permitting and/or for issuing Energy Performance Certificates (EPCs) in each Member State in accordance with the Directive 2010/31/EU for the Energy Performance of Buildings (EPBD). In practice, this means that the results from existing performance assessments can potentially be used for reporting.

1.1.1.1 Calculation methodology and data requirements

Calculation methodology to be used

Indicators 1.1.1 and 1.1.2 require the energy demands of a building to be simulated and calculated, with a focus on both the primary energy demand of the building's technical systems and the efficiency of the building envelope, and the delivered energy demand that can subsequently be monitored using data from metering.

The underlying calculation method for each component of a buildings energy demand is provided by the CEN standards that support the Directive 2010/31/EU for the Energy Performance of Buildings. However, Member States are not obliged to use the standards, but they can apply calculation methodologies according to national or regional circumstances. This means that national calculation methods that are required to be used in order to calculate the energy performance of buildings and to issue Energy Performance Certificates (EPCs) can also be used as the basis for reporting.

An important first step is to decide which input data shall be used. This shall be done through identification of the energy performance of building assessment type and sub-type from the table of those presented in prEN ISO 52000-1 (see table 1.1.1). Performance assessment results for the two indicators can be obtained from existing documents based on national calculation methods used to acquire a building permit and/or from EPCs already issued.

Further guidance on the aspects of energy demand addressed by each of the two sub-indicators and the relevant reference standards, is provided below:

- 1.1.1 Total primary energy demand: Weighting factors shall be applied to the calculated building energy needs according to EN 15603 or EN 52000-1 in order to obtain the total primary energy demand. This is a calculation of the overall system efficiency of the building's technical systems (HVAC installation, heat and power generation, domestic hot water supply, built-in lighting installation) and the fuels and energy carriers used. This energy use can then potentially be disaggregated into its non-renewable and renewable components;
  - Non-renewable primary energy demand: The primary energy demand of the building that is met by non-renewable sources, without accounting for any export of non-renewable energy generated on site (such as from CHP);
  - Renewable primary energy demand: The primary energy demand of the building that is met by renewable sources, without accounting for any export of renewable energy generated on site (such as from solar PV);.

- 1.1.2 Delivered energy demand: Delivered energy is the energy delivered to the building in the form of electricity, heat and fuel in order to satisfy uses within the building (heating, cooling, ventilation, domestic hot water, lighting, appliances, etc.). An important focus of the calculation method is on the thermal performance of the building envelope:
    - The building envelope (energy needs): This is the starting point for calculation methods developed according to EN ISO 13790 and EN ISO 52016. Orientation, control of solar gains and daylighting, thermal inertia and zoning have to be considered;

In the context of using this framework, it is important to note that exported renewable energy is to be reported separately. This is because the Level(s) framework takes a life cycle approach and, according to reference standard EN 15978, exported energy is reported as a benefit beyond the building's system boundary, under Module D. In-built lighting may not be specifically covered in all national or regional calculation methods. As a result, either the omission from the calculations, or a separate calculation method if used, shall be noted in the reporting. The reference standard for lighting estimates shall be EN 15193.

Table 1.1.1 Energy Performance of Building assessment types

Type	**Sub-type**	**Input data**			**Type of application**
		Use	**Climate**	**Building**	
Calculated (asset)	Design	Standard	Standard	Design	Building permit, certificate under conditions
	As built	Standard	Standard	Actual	Energy performance certificate, regulation
	Tailored	Depending on purpose			Optimisation, validation, retrofit planning, energy audit
Measured (operational)	Climate corrected	Actual	Corrected to standard	Actual	Monitoring, or energy audit
	Use corrected	Corrected to standard	Actual	Actual	Monitoring
	Standard	Corrected to standard	Corrected to standard	Actual	Energy performance certificate, regulation

Guidance note 1.1 for design teams

Options for ensuring the consistency of the energy calculation method used

The majority of national calculation methods are currently based on EN 15603 and its associated standards. It is anticipated that over time these methods will be updated to reflect the new EN ISO 52000 series. There will therefore be a transitional period during which either standard may be referred to.

Options available to users of the Level(s) framework across the EU could therefore include:

- Use of a national calculation method and associated software tools developed according to one of the reference CEN standard series;
- Use of independently developed and validated software tools developed according to one of the reference CEN standard series;
- Direct use of the calculation method laid down within one of the reference CEN standard series.

In each of these cases, it should be indicated in the reporting that a method developed according to a relevant CEN standard has been used or. If none is available, the CEN standard itself (or its nationally adopted equivalent) can be used.

Data requirements and sources

Table 1.1.2 summarises the potential data sources to use when making simplified calculations of performance, using the common metric.

Table 1.1.2 Specification of the main data requirements and potential sources

Data item	**Potential source**	
	Default EU values	**National, regional or locally specific values**
Conditions of use and occupancy	EN ISO 13790 (Annex G8) ISO/TR 52000-1/2 EN ISO 52016-1	National or regional calculation method
Thermal envelope description	EN ISO 13790 (Annex G) EN ISO 52016-1	National or regional calculation method: certified products and details
Building services description	EN ISO 13790 (Annex G) EN ISO 52016-1	National or regional calculation method: certified products
Reference year climate file	Three climate zones (EN 15265 test cases)	National or regional calculation method Member State Meteorological Offices
Primary energy factors	EN 15603 (Annex E) EN 52000-1 (Annex B.10)	National or regional calculation method

Internal temperature set points	EN ISO 13790 (Annex G) EN ISO 52016-1	National or regional calculation method
Ventilation and infiltration rates	EN 15241 EN 15242	National or regional calculation method
Internal gains as heat flows	EN ISO 13790 (Annex J) EN ISO 52016-1	National or regional calculation method
Heating/cooling system characteristics and capacity	-	National or regional calculation method: certified products [11]

[11] This may include reference to product characteristics laid down in Ecodesign Implementing Measures, Energy Labelling legislation or other relevant harmonised standards.

1.1.1.2 Suggested reporting format for results

Users shall identify from the options given, and with reference to table 1.1.1, the sub-type of energy performance of buildings assessment they have carried out.

In addition, the calculation method used, and whether it is based on the EN standards series or not, shall be indicated.

Indicator 1.1 Level 1 common assessment reporting format

Part 1: Type of performance assessment

Reporting item		**Reporting** **(select/delete as appropriate)**
Energy Performance of Buildings assessment type		– *Calculated (asset)* – *Measured (operational)*
Energy Performance of Buildings assessment sub-type		– *Calculated (asset): Design or as built or standard* – *Measured (operational): Standard*
Calculation method	EN standard compliant calculation method?	*Yes/no*
	Specific method used and related CEN standard series	*e.g. EN 15603, prEN 52000-1*

Part 2: Performance assessment results

Reporting headings	**Total (kWh/m²/yr)**	**Energy uses (kWh/m²/yr)**				
		Heating	**Cooling**	**Ventilation**	**Hot water**	**Lighting**
1.1.1 Use stage primary energy demand						
Total primary energy demand						
Non-renewable primary energy demand						
Renewable primary energy demand						
Exported energy generated						

1.1.2 Use stage delivered energy demand						
Fuels						
District energy						
Electricity						

1.1.1.3 Monitoring of as built and occupied performance

Evidence shows that a commitment to carry out quality and functional performance testing of a completed building focusses attention on design details, construction quality and the correct installation of services.

Performance targets can be laid down which will later be checked on site during completion of the building. For offices, this may be applied to the whole or a part of a building. For multi-unit residential building projects, these may be applied to a sample of properties. Reference standards that can be used are identified in guidance note 1.2.

Guidance note 1.2 for design teams and construction management

Checking the as built and completed energy performance of a building

Testing of the completed building envelope, combined with comprehensive commissioning, can help focusing attention on the quality of design and the execution of works and installations at earlier stages.

Quality and functional performance testing requirements can be specified with reference to specific tests, routines and standards:

- Testing of the quality and integrity of the building envelope, with reference standards to include:
  - Air tightness using a fan pressurisation test (EN ISO 9972)
  - Integrity by thermal imaging survey (EN 13187)
- Commissioning of Heating, Ventilation and Air Conditioning (HVAC) systems, with reference standards to include:
  - Functional performance testing of the system operating characteristics (EN 12599)
  - Checking of the integrity of ventilation duct work (EN 15727)
- Commissioning of low or zero carbon energy generation technologies, with reference to best practice for each technology.

The Intelligent Energy Europe funded project QUALICHeCK provides further guidance on ensuring the quality of works, including a range of case studies from across the EU [12].

1.1.2 Making Level 2 and 3 assessments

1.1.2.1 Level 2 - Comparative performance assessments

Basic rules for comparative reporting

Comparative performance assessments shall be made on the basis of the same type and sub-type. To use this reporting option, a number of inputs to the simulation of a building shall be fixed:

- Use of standard input data: Data provided at national level or the default data provided in Annex G of EN ISO 13790 shall be used. This shall include the use of standard occupancy data (see Annex G.8).
- Choice of calculation method: The quasi-steady state and simplified hourly dynamic methods described in EN ISO 13790 may be used. If a dynamic method is chosen, the results shall be validated according to the criteria and test cases in EN 15265 and the variance rating reported.

[12] QUALICHeCK (2016) *Source book on Guidelines for better enforcement of quality of the works*, www.qualicheck-platform.eu

- Climate data: For measured assessment, the performance shall be corrected in relation to the test reference year for the local area or region, following the method in EN 15603.
- Primary energy factor: The system boundary shall encompass the primary energy required to extract and transport the energy carried to the building, as well as any other associated operations.

The conditions of use will already have been fixed according to national/regional requirements for the purposes of a regulated energy performance assessment. Measured data shall be corrected in accordance with requirements in the CEN standards EN 15603 or prEN 52001-1.

Table 1.1.3 summarises potential data sources for simplified calculation of performance using fixed parameters. It is recommended that special attention is paid to the quality and compliance of third party input data, in relation to which further guidance is provided in this section.

Table 1.1.3 Default data sources to be used

Data item	**Potential source**	
	Default EU values	**National, regional or locally specific values**
Conditions of use and occupancy	EN ISO 13790 (Annex G8) ISO/TR 52000-1/2 EN ISO 52016-1	National or regional calculation method
Thermal envelope description	EN ISO 13790 (Annex G) EN ISO 52016-1	National or regional calculation method: certified products and details
Building services description	EN ISO 13790 (Annex G) EN ISO 52016-1	National or regional calculation method: certified products
Reference year climate file	Three climate zones (EN 15265 test cases)	National or regional calculation method Member State Meteorological Offices
Primary energy factors	EN 15603 (Annex E) EN 52000-1 (Annex B.10)	National or regional calculation method
Internal temperature set points	EN ISO 13790 (Annex G) EN ISO 52016-1	National or regional calculation method
Ventilation and infiltration rates	EN 15241 EN 15242	National or regional calculation method

Internal gains as heat flows	EN ISO 13790 (Annex J) EN ISO 52016-1	National or regional calculation method
Heating/cooling system characteristics and capacity	-	National or regional calculation method: certified products [13]

Ensuring the quality and compliance of input data

Input data may also be available that has been checked and certified for use – for example, performance data for architectural details that can minimise thermal bridging. Use of this input data may be a requirement of a national calculation method in order to ensure comparability. Its use may therefore help ensuring that calculations are compliant with national calculation methods. The QUALICHeCK project provides further orientation on ensuring the quality and compliance of input data (see guidance note 1.3).

> ***Guidance note 1.3 for design teams***
>
> **Ensuring the quality and compliance of the input data used in an performance assessment**
>
> The Intelligent Energy Europe funded project QUALICHeCK has sought to identify how the quality and compliance of input data can be ensured[14]. Examples of sources of compliant input data can include:
>
> - Pre-calculated values for certain technologies/aspects;
> - Procedures for generating reliable data for innovative products;
> - Databases of product characteristics;
> - Rules for consistent declarations of product performance.
>
> These sources may also be subject to third party verification.

1.1.2.2 Level 3 - Design performance optimisation

This type of assessment shall use input data that is as representative as possible of the location and intended conditions of use, to include a focus on the following aspects:

- ✓ Aspect 1.1 – Technical representativeness of the building use patterns
- ✓ Aspect 1.2 – Technical representativeness of the input data used
- ✓ Aspect 2.1 – Geographical representativeness of the weather data used
- ✓ Aspect 2.2 - Geographical representativeness of the primary energy factors used
- ✓ Aspect 3.1 –Time representativeness of the calculation method
- ✓ Aspect 3.2 – Time representativeness of the energy demand profiling

For each of these aspects, guidance is provided on how to improve the representativeness and precision of the calculations. For a calculated performance, the assessment may therefore be tailored, reflecting the assessment sub-type described in the CEN standards or in national/regional calculation methods. Building renovations

[13] This may include reference to product characteristics laid down in Ecodesign Implementing Measures, Energy Labelling legislation or other relevant harmonised standards.

[14] QUALICHeCK (2016) *Compliant and Easily Accessible EPC Input Data,* http://qualicheck-platform.eu/results/reports/

shall follow the guidance in the CEN standards on preparing a *'validated building calculation model'*.

Users should then report on which aspects they have focussed on. The more aspects addressed the better the reliability rating that will be obtained, as the rating improves in function of accuracy and representativeness.

Key aspects to focus attention on

The design optimisation aspects highlighted for indicator 1.1 focus on those that contribute to the representativeness and precision of the calculated performance of a building:

Aspect 1.1 – Technical representativeness of the building use patterns

Focus of attention: The use of input data that is representative of the conditions of use and occupancy patterns associated with the building.

The design team shall define in as a representative way as possible the input data for the simulation. The starting point shall be predicted occupancy pattern and density for the building and the conditions of use with respect to how areas will be heated and cooled. This shall then be used as the basis for defining:

- Internal temperature set points
- Ventilation and infiltration rates
- Internal gains and heat flows

In the case of building renovations, surveys of the existing occupants of a building or a building stock can provide additional refinement of the understanding of occupancy patterns and user behaviour. It is important to study user behaviour because evidence has shown that, particularly in residential building renovations, there can be a 'rebound effect' whereby the efficiency improvements are offset by greater energy use by occupants.

Aspect 1.2 – Technical representativeness of the input data used

Focus of attention: The extent to which the performance data for building materials and energy systems is representative of certified or actual performance.

Although input data may comply with standards or calculation method requirements, it is important to note that it may not result in a more accurate simulation of the as-built performance, rather it will help ensure a comparable performance assessment.

Greater precision can be achieved by calculating or obtaining input data for the performance of specific building details or, in the case of building renovations, calculating or obtaining input data for the performance of specific construction details identified from condition surveys.

The performance of technologies such as renewable energy generation can be modelled separately in order to provide more representative input data.

Aspect 2.1 – Geographical representativeness of the weather data used

Focus of attention: The use of weather files that are as representative as possible of the location of the building.

The most likely option for achieving greater representativeness would be a medium term (20 or 30 year) set of averages for a standard local weather station. The Joint Research Centre has created an open access weather file database that can be used across the

EU[15]. Further interpolation of weather datasets to take into account of urban heat island effects could add additional precision to datasets.

Aspect 2.2 Geographical representativeness of the primary energy factors used

Focus of attention: The use of primary energy factors that are representative of the location of the building.

The reference standards EN 15603 and prEN ISO 52000-1 provide default primary energy factors for on-site, nearby or distant energy sources. These represent averages for the EU. However it would preferable to use the primary energy factors provided as part of a national calculation method can be used. These would be more representative of the energy mix for the specific country.

Aspect 3.1 –Time representativeness of the calculation method

Focus of attention: The use of either a 'steady state' or a 'dynamic' method of simulating the energy performance of a building.

The two methods differ in how accurately they are able to simulate the thermodynamic performance of a building, particularly in terms of how solar heat gains are accounted for within a simulation.

Steady state simulations use weather data which has a seasonal or monthly time interval, whereas dynamic simulations use weather data with an hourly time interval, as well as taking into account many more factors that will influence performance.

Steady state models can estimate overall annual consumption to a reasonable accuracy but are unreliable when the building's performance is determined by variations in temperature and solar radiation that take place on a daily and hourly basis. For this reason, it is particularly beneficial to use dynamic simulation in Southern European countries, where there is a greater duration and intensity of solar radiation during the year, daily and hourly variations in which can have a significant influence on performance.

Dynamic simulation can also be used to model the potential contribution of daylighting, based on both the availability of daylight and the amount of building floor area illuminated. More information on daylighting simulation can be found under aspect 4.3 of macro-objective 4.

Currently, national calculation methods in EU may, in accordance with EN ISO 13790 and EN ISO 52016-1, be based on a seasonal or monthly steady state, simplified hourly or fully dynamic method. As a result, the precision of the performance assessment carried out for building permitting may differ.

A design team may choose to use a simple hourly or dynamic method in order to fine tune the building design to the local climate. However, it is important to note that the precision of the results will to some extent depend on the knowledge and experience of the professionals carrying out the simulation. This is because dynamic simulations are more complex and tend to require greater technical knowledge of the input data and the assumptions being made. Guidance note 1.4 provides some orientation on the use of dynamic simulation.

[15] The database will form an extension of PVGIS - http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php

Guidance note 1.4 for design teams

Getting started with dynamic building energy simulations

Setting up such a model can be time consuming, as it requires a great number of input parameters to reflect the specific detail about a building and its likely operating conditions.

It is recommendable to therefore start with a simplified tool that allows for a focus on one building aspect at a time and/or which restricts the number of inputs that are necessary. A good example is the daylighting tool Radiance[16].

It is also recommended to make an assessment of the local climate and relate this to case studies of buildings of the same type with a validated performance in the same climate. A good example is the tool *Climate Consultant*[17].

Once users have gained more experience, they can move on to use the full simulation capabilities. It is recommended to start with a dynamic tool that works on the basis of a limited number of inputs. Good examples are Example File Generator[18] (EnergyPlus) and eQuest[19] (DOE2.2).

In some Member States, the simulation model that supports the national calculation method is dynamic – for example, CALENER/HULC in Spain. Training and support in the use of the tool is therefore available.

Where a dynamic simulation tool is not available nationally, a number of international tools are available, some of which are free to obtain – for example, EnergyPlus. Suitable dynamic simulation tools shall have been validated according to the procedures of EN ISO 52016-1, EN 15265 or ASHRAE 140 (the latter two being based on the BESTEST method). Tools that are known to already have been validated accordingly include DOE2, BLAST, ESP, SRES/SUN (SERIRES/SUNCODE), SERIRES, S3PAS (LIDER/CALENER), TAS, TRNSYS and EnergyPlus.

Aspect 3.2 – Time representativeness of the energy demand profiling

Focus: The extent to which demand profiles for the building support optimisation of the matching of supply and demand.

The primary energy efficiency and CO_2 emissions of electricity supplied over a national electricity grid fluctuate according to the mix of generating plant and their associated emissions. More polluting fossil fuelled plants are commonly used to bring on additional capacity to meet peak loads in summer and winter, for example. This is illustrated by figure 1.1.1 which shows a winter period of hourly generation and consumption of electricity in Denmark.

If the primary energy and CO_2 emissions of an hourly demand profile are calculated with reference to the hourly electricity supply mix, the result may be different from that which may have been modelled on a quasi-steady state basis.

In a similar way, by matching the hourly demand profile of a building with different potential energy generation equipment, the potential for primary energy performance improvements and reductions in CO_2 emissions can be optimised. This is particularly the case for buildings with mixes of use, where the mix may result in a combined daily and

[16] US Department of Energy, *Radiance* https://energy.gov/eere/buildings/downloads/radiance
[17] University of California, *Climate Consultant*, http://www.energy-design-tools.aud.ucla.edu/climate-consultant/
[18] EnergyPlus Example File Generator, https://buildingdata.energy.gov/cbrd/resource/704
[19] eQuest, http://doe2.com/equest/index.html

seasonal demand profile that favours a different choice of energy generation equipment in comparison to a building with only a single use.

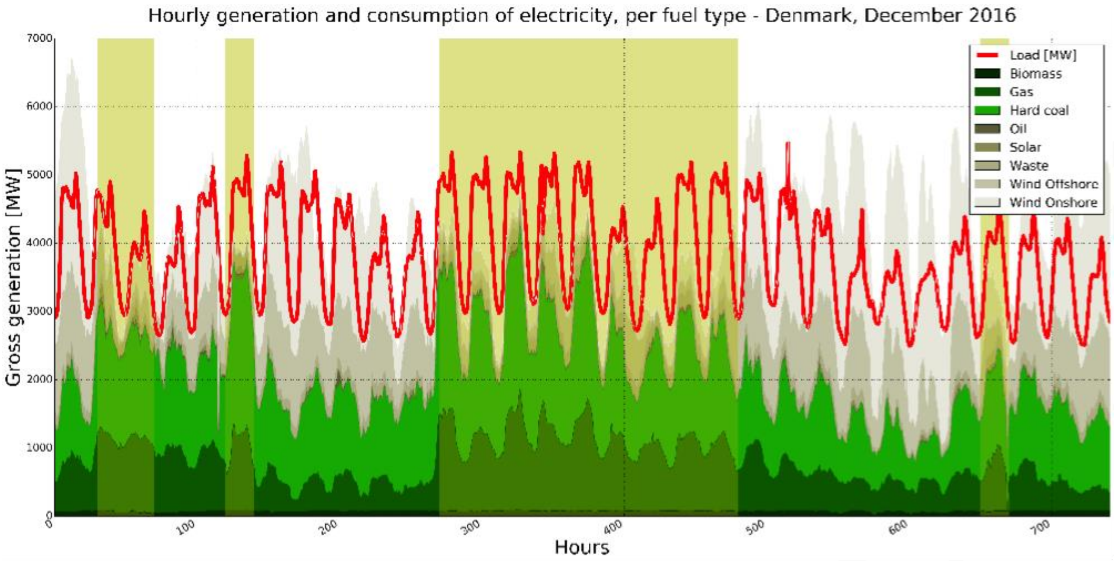


Figure 1.1.1 Hourly electricity generation and consumption, Denmark, December 2016.

Source: ENTSO-E (2016)

Suggested reporting format for results

This reporting format should be provided alongside the format for Level 1.

Indicator 1.1 Level 3 design optimisation reporting format

Optimisation aspects addressed

Aspect	**Addressed? (yes/no)**	**Notes on data sources and calculation method**
Aspect 1.1 - Technical representativeness of the building use patterns		
Aspect 1.2- Technical representativeness of the input data used		
Aspect 2.1 - Geographical representativeness of the weather data used		
Aspect 2.2 -Geographical representativeness of the primary energy factors		
Aspect 3.1 - Time representativeness of the calculation method		

1.1.3 Property valuation influence and reliability rating

The following tools are provided to inform the valuation of a property for which performance has been assessed according to indicator 1.1:

- Checklists for the potential positive influence on value and risk
  - Checklist 1: Potential positive influence on future performance
  - Checklist 2: Accounting for the performance assessment in valuation criteria
- Ratings of the performance assessment
  - Rating 1: Basis for the performance assessment
  - Rating 2: Professional capabilities
  - Rating 3: Independent verification

The completed reporting may be used separately alongside the Level 1, 2 or 3 results for indicator 1.1, or may form part of the overall reporting for indicator 6.2.

In the case that the ratings will be used as part of the overall reporting for indicator 6.2, then the rating 1 results shall be used to calculate the overall Indicator Reliability Index (IRI). The Indicator Reliability Index (IRI) for rating 1 shall be calculated from the individual ratings as follows:

$$\text{IRI} = \frac{(TeR\ min\{rating\ aspects\}) + (GR\ min\{rating\ aspects\}) + (TR\ \min\{rating\ aspect\})}{3}$$

Where:

TeR = Technical Representativeness

GR = Geographical Representativeness

TR = Time representativeness

To calculate the IRI the lowest score for each of the three types of rating aspect shall be used to calculate arithmetic mean of the reliability.

1.1.3.1 The potential for a positive influence on a market valuation

Checklist 1 – Evaluation of potentially positive influences on the market performance

Potential influence	***Evaluated?***	***Resulting assumptions used in the appraisal***
Potential influence 1 *Increased revenues due to market recognition and lower void rates.*	*Yes/no*	
Potential influence 2 *Reduced operational, maintenance, repair and/or replacement costs.*	*Yes/no*	
Potential influence 3 *Reduced future risk of increased overheads or loss of income.*	*Yes/no*	

Checklist 2 – Accounting for the Level(s) assessment in the valuation criteria used

Valuation criteria set used	*Identify the scheme or tool used*
Version of the criteria set used	

Criteria which the assessment has influenced		Influence on the valuation or rating
Valuation criterion	**Sub-criterion**	
Criterion x	Sub-criterion y	Notes on the extent of the influence and the supporting assumptions used

1.1.3.2 Reliability rating of the performance assessment

Rating 1 - Basis for the performance assessment

Rating aspect	Brief description of the aspect	Rating score (reflecting the degree of representativeness)			
		0	**1 Low**	**2 Medium**	**3 High**
1.1 Technical representativeness of the building use patterns	Reflecting the actual conditions of use, occupancy patterns and behaviour.				
1.2 Technical representativeness of the input data used	The extent to which building materials and services input data reflect the surveyed building or as-built construction.				
2.1 Geographical representativeness of the weather data used	The use of climate data that reflect the building location.				
2.2 Geographical representativeness of the primary energy factors	The use of primary energy factors that reflect the building location.				
3.1 Time representativeness of the calculation method	The extent to which simulations are a more dynamic representation of performance.				
3.2 Time representativeness of the energy demand profiling	The extent to which demand profiles support the optimisation of supply and demand				

Indicator 1.1 **Indicator Reliability Rating**	

Rating 2 – Professional capabilities

Rating aspect	Rating score			
	0	**1**	**2**	**3**
2. Technical capability of the personnel carrying out the assessment	*No formal training and limited experience in using the calculation method*	*Formal training or some applied experience in using the calculation method*	*Formal training and some applied experience in using the calculation method*	*Formal training*[20] *and significant applied experience in using the calculation method*

Rating 3 – Independent verification

Rating aspect	Rating score			
	0	**1**	**2**	**3**
3. Independent verification of the assessment	*Self-declaration of the performance assessment results*	*Peer review of the input data and calculation steps*	*Third party auditing and verification of the calculation steps*	*Third party auditing and verification of the input data and calculation steps*

[20] In accordance with Article 17 of the EPBD

1.2 Indicator of life cycle Global Warming Potential

1.2 Life cycle Global Warming Potential	**Where to find the guidance for each Level** Level 1 common performance assessment Level 2 comparative performance assessment Level 3 performance optimisation assessment Valuation influence and reliability rating (all levels)

1.2.1 Level 1 - Making a common performance assessment

1.2.1.1 Boundary and scope

The life cycle stages and documentation of the building

The scope comprises the evolution of the building from cradle to cradle. The setting of the system boundaries shall follow the 'modularity principle' according to the EN 15978. This means that the unit processes influencing the building's environmental performance during its life cycle shall be assigned to the module in the life cycle where they occur.

The building shall be documented as follows, following the scope defined in section 1.1:

- Components (elements, structural parts, products, materials) needed during its life time. This also includes the consideration of in-use conditions and time-dependent qualities.
- Associated processes such as maintenance, exchange and end of life processes and re-use, recycling and energy retrieval
- Energy and water use during the operation of the building.

Additional methodological rules and cut-off criteria are described in section 1.2.1.2 and 1.2.2

The end of life of a building starts when the building is decommissioned and no further use is intended. Components and materials have to be removed from the site so that it can be made ready for the next use. The end of life stage shall be defined according to Module C1-C4 of EN 15978. Loads or benefits outside the system boundary are included in Module D.

Simplified options based on an incomplete life cycle

The Level(s) framework promotes a method that encompasses all the life cycle stages defined in EN 15978 and for the scope of building elements defined in section 1.1, table 1.1. However, the Level(s) framework also recognises that, upon starting to calculate life cycle GWP, it may be challenging to compile sufficient life cycle inventory data for all the life cycle stages. Moreover, design professionals may not have the expertise to make meaningful assumptions and choices in relation to the use of generic data or data from other sources.

As a simplified life cycle GWP result will not present a true picture of the life cycle GWP of a building, it is important to follow a number of reporting rules:

- The results shall clearly be reported as being based on an 'incomplete life cycle'
- In each case, the minimum life cycle boundaries and scope of building elements shall be followed
- A reliability rating may not be reported on in full, because the basis for the reported life cycle will be incomplete

More detailed guidance on the minimum life cycle boundaries and scope of building elements is provided in guidance note 1.4.

Guidance note 1.5 for design teams

Simplified options for calculating life cycle GWP based on the modelling of selected life cycle stages

It is anticipated that, over time, the better availability of data and software tools, as well as improved access to professional training, will facilitate the calculation of life cycle GWP across the EU. In the short term, however, the Level(s) framework will encourage design professionals to start calculating life cycle GWP by supporting and allowing users to carry out simplified analyses that may focus on a reduced number of life cycle stages and building elements.

A simplified approach may be adopted by focussing first on those life stages in which material use and environmental impacts will have taken place upon completion of the building, and will be directly influenced by design decisions.

The use stage modules relating to maintenance, repair and replacement (B2, 3 and 4) shall be based on projections for the clients required service life. They shall be based on scheduled maintenance, repairs and replacements of construction products.

Stage D is intended to represent the net benefit of the materials used in the building if they were to be reused and/or recycled – sometimes referred to as the building material bank. Specific calculation rules shall be followed (see section 1.2.1.2).

Table 1.2.1 Suggested simplified reporting options

Simplified reporting option 1: 'incomplete life cycle: product stage, calculated energy performance and projected service life'	• The product stage (A1-3) • The use stage (B4, B5, B6)
Simplified reporting option 2: 'incomplete life cycle: product stage, calculated energy performance and the building material bank'	• The product stage (A1-3) • The use stage (B6) • End of life stage (C3-4) • Benefits and loads beyond the system boundary (D)

1.2.1.2 Calculation methodology and data requirements

Calculation methodology to be used

The general calculation rules for carrying out the performance assessment for indicator 1.2 are set out in Table 1.2.1 and cover the following aspects of calculating life cycle Global Warming Potential (GWP):

- Objective(s)
- Cut-off rules for the system boundary definition
- Energy and water consumption modelling
- Scenarios and End of Life
- LCI and LCIA datasets and software
- Data requirements
- Interpretation of the results and critical review

Calculations of the contribution of a building to global warming along its life cycle are standardised by ISO 14067, although the LCA standard ISO 14040/44 also provides a main general reference. Such a calculation is sometimes also referred to as a carbon footprint assessment or whole life carbon measurement.

GWP measures how much heat a greenhouse gas can potentially trap in the atmosphere compared to the amount of heat trapped by a similar mass of carbon dioxide. GWP is calculated over a specific time horizon, commonly 20, 100 or 500 years. GWP100 is considered in this context. GWP is expressed as equivalent mass of carbon dioxide (whose GWP is normalised to 1).

A list of Greenhouse Gases (GHGs) and relative GWPs (2013) can be found in http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf (see Annex III). The main specific greenhouse gases that are of interest are:

- Carbon dioxide (CO_2), by definition, has a GWP of 1 regardless of the time horizon considered, because it is the gas being used as the reference. CO_2 remains in the climate system for a very long time.
- Methane (CH_4) is estimated to have a GWP over 100 years that is 25 times that of CO_2[21]. CH_4 emitted today lasts about a decade on average, which is much less than the persistence time of CO_2. However, CH_4 absorbs much more energy than CO_2. The net effect of the shorter lifetime and higher energy absorption is reflected in the GWP. The GWP of CH_4 also accounts for some indirect effects, such as for the fact that CH_4 is a precursor to ozone, which is itself a GHG.
- Nitrous Oxide (N_2O) is estimated to have a GWP over 100 years that is 298 times that of CO_2. N_2O emitted today remains in the atmosphere for more than 100 years, on average.
- A climate feedback involving changes in the properties of land and ocean carbon cycle in response to climate change is also taken into account. In the ocean, changes in oceanic temperature and circulation could affect the atmosphere–ocean CO_2 flux; on the continents, climate change could affect plant photosynthesis and soil microbial respiration and hence the flux of CO_2 between the atmosphere and the land biosphere[22].

The overall GWP of a list of GHGs is given by the sum of the products between the emission *i* and the respective GWP100.

Table 1.2.1 Calculation rules for carrying out a Level 1 life cycle GWP assessment

	Level 1: Common performance assessment
Objective(s)	The main users of this option are intended to be professionals who are not LCA experts, but are interested in understanding and improving the overall environmental performance of the building. A simplified calculation method and data sources are therefore provided.
Minimum building scope	The building elements listed for the shell and core, and excluding external works. *See the building parts and element listing in Table 1.1*
System boundary and cut off rules	All life cycle stages shall be calculated, unless a simplified reporting option is selected as a starting point (see Guidance note 1.5) The modelling shall be as comprehensive and realistic as possible in describing the life cycle of the building.

[21] A revised GWP for methane of 28 was published in the IPCC's 5th Assessment Report but is not yet reflected in EU legislation or ISO 14067, http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf
[22] See IPCC, 5th Assessment Report http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_AnnexIII_FINAL.pdf

Energy modelling	Data to be obtained from Indicator 1.1
Water modelling	Data to be obtained from Indicator 3.1
Scenarios and End of Life	Data to be obtained from life cycle scenario tool 2.2.3
LCI and LCIA datasets and software	As a minimum, generic or default data has to be used for calculating the impacts associated with building parts and elements and life cycle processes. This data can be obtained in literature and/or by using freely available and simple software tools and databases. A list of databases and software tools is reported in LCA Section 7.2.4. For the Product and Construction Stage Modules (A1-A3), the calculation may be made using data at building elemental level (see table 1.2.3). GWP characterisation factors are available in the literature per direct emissions, per unit of energy delivered and per kg of material used. This would allow the quantification of the indicator also in an excel file.
Data requirements	Since the main objective of this option is to direct professionals towards the future use of comprehensive GWP assessment (as per Level 3) where they will focus on the same key environmental issues, there is less need in Level 1 to be prescriptive in terms of data quality. Nevertheless, the option is given for a data quality index calculated according to the method set in Section 1.2.3.2 is to be reported for transparency reasons, as well as data sources and dates.
Interpretation of the results and critical review	Result shall be interpreted critically through a sensitivity analysis in order to understand: • Environmental hot-spots, possible trade-offs between life cycle stages and improvement areas • Influence of data on the results • Data gaps, robustness of assumptions, and limitations Summary conclusions and recommendations shall be drafted.

Generic rules

GHG emissions from the use of a building can in general be split into:

1. Direct emissions, e.g. those coming from on-site power generation, refrigeration and air-conditioning equipment
2. Indirect emissions, i.e. those coming from production and distribution of electricity and steam/heat used in the building and from the production and supply of materials and construction products of which the building is made up. For construction products, the term 'embodied' emissions is often used.

The quantification of delivered energy in the use stage shall be based on the corresponding rules set in Indicator 1.1.

The quantification of the materials needed during the building life cycle shall be based on the corresponding rules set for the bill of materials (see Macro-objective 2 – 2.1 Life cycle tool: Building bill of materials).

Greenhouse gases associated with the delivery of energy and water and to the use of materials and construction products can be characterised through emission factors, which can be defined with the support of LCA databases (see section 1.2.1.2 on data modelling and sources). For instance, according to the database Ecoinvent 3.0.1.0, the consumption of 1 m^3 of tap water in Europe is on average associated with the emission of 378 grams of CO_2,eq.

Credits from 'temporary carbon storage' are to be excluded. Emissions shall be counted for as emitted 'now', *i.e. no discounting of emissions is permitted*.

Biogenic emissions and land use change

Biomass takes up CO_2 from air for its growth. Following the methodology in EN 16449, a 'biogenic carbon neutrality' approach shall be applied to the CO_2 stored as carbon in biomass materials which come from regenerative sources. This means that neither credits due to temporary removal and storage of CO_2 nor CO_2 emissions from transformation of 'renewable' biomass shall be taken into account.

An example of non-regenerative use of biomass is for example the deforestation of a tropical forest. In that case, the transformation of biomass shall be considered equivalent to that of a fossil source and CO_2 emissions shall be accounted.

Following the treatment of fossil and biogenic carbon in ISO 14067, the amount of CO_2 taken up in biomass and the equivalent amount of CO_2 emissions from the biomass at the point of complete oxidation (combustion) results in zero net CO_2 emissions when the biomass carbon is not converted into methane, non-methane volatile organic compounds (NMVOC) or other precursor gases.

If emissions occur of biogenic GHGs which differ from CO_2 (e.g. CH_4 from biomass decomposition in landfill), the GWP_{100} assigned to such emissions shall be considered equal to the difference between the GWP_{100} corresponding to the emission from fossil sources (e.g. 25 for methane) and the GWP_{100} of the CO_2 which would be emitted if the carbon contained in the emission itself were oxidised to CO_2 (i.e. a ratio of 1:2.25 based on the molecular weight of methane and CO_2).

Table 1.2.2 Indicative characterisation factors for GWP

Substance	**Compartment**	**GWP 100**
Carbon dioxide (fossil)	Air emission	1
Carbon dioxide (biogenic, non-renewable)	Air emission	1
Carbon dioxide (biogenic)	Resource from air	0
Carbon dioxide (biogenic)	Air emission	0
Carbon monoxide (fossil)	Air emission	1.57
Carbon monoxide (biogenic)	Air emission	0
Methane (fossil)	Air emission	25
Methane (biogenic)	Air emission	22.25
Carbon dioxide (land use change)	Resource from air	-1
Carbon dioxide (land use change)	Air emission	1

Calculation of loads and benefits from reuse, recycling and energy recovery (Module D)

When materials are recovered for reuse, recycling and recovery, they typically leave the system boundary as secondary raw materials or secondary fuels. The End of Life (EoL) scenario will specify the recovery rates and fate of each material leaving the system.

In order to avoid double accounting of reuse or recycling of secondary material already reported in A1-A3, the same secondary material cannot be considered twice in terms of environmental benefits. This means that any secondary materials used in A1-A3 is deducted from the secondary material entering Module D, which is equivalent to subtract the recycled content from the recycling rate. For example, if 100 kg of processed material containing 30% of secondary material is ready for recycling in Module C3, the net flow considered in Module D would be 70kg.

The environmental loads and benefits of these net material flows are then assessed in Module D:

- The loads include any additional processing required before the secondary material is able to substitute the equivalent material from primary sources. These processes are not included in, for example, module C3. This includes processes such as cutting to size or cleaning for re-use, re-melting metal or cleaning/sorting aggregates for recycling, and combustion processes for energy recovery.
- The benefits are reported by subtracting the substituted primary process impacts where the secondary material directly replaces primary material or fuel. This includes the avoided emissions from substituting products by re-used products, the avoided production of primary metal or natural aggregate by using recycled metal or concrete, and the avoided emissions from replacing primary fuel with secondary fuel.

For certain construction products, there is CO_2 data available on the net loads and benefits from their re-use, recycling and recovery. Production data from A1-A3 should be used to calculate net flows to Module D. If the production data contains a mix of primary and secondary production that cannot be separated, the same production mix in A1-A3 can be used as the substituted production. This will avoid double accounting without having to calculate net flows first.

1.2.1.3 Data modelling and sources

Modelling approach

In the same way as for the cradle to cradle Life Cycle Assessment (LCA)', an attributional approach [23] shall be followed also for this indicator. Cut off rules, where applicable, are described in tables 1.2.1 and 1.2.3 in section 1.2.2.

Software tools and data

A list of software tools and data sources which can be used to calculate indicator 1.2 are provided in a separate matrix which will be a dynamic list to be updated over time. These software tools generally contain reference data for the GWP_{100} characterisation factors for greenhouse gases, based on the Assessment Reports of the Intergovernmental Panel on Climate Change (the last updated one being from 2013).

[23] The attributional approach is a system modelling approach in which inputs and outputs are attributed to the functional unit of a product system (in this case the use of $1m^2$ of a building during 1 year) by linking and/or partitioning the unit processes of the system in direct proportion to the flows associated with the product. The alternative option is the consequential approach in which activities in a product system are linked so that activities are included in the product system to the extent that they are expected to change *as a consequence of a change in demand* for the functional unit.

Guidance note 1.6 for design teams

Carbon footprinting software tools

Because the Carbon footprint of a product is the most widespread and used impact category in LCA, specific software tools and databases have been developed for this purpose. Many of these tools require the payment of a fee for their use (e.g. Carbon Footprint Ltd, CarbonScopeData™).

A brief overview of what are understood to be two of the most commonly used tools is provided below:

- Carbon Footprint Ltd does allow free searching and downloads for individual GHGs emission factors to use for simplified Life Cycle Analysis (LCA)[24]. The free version of their calculator tool holds life cycle emission factors for over 4,500 common products, materials and processes, including Ecoinvent factors as well as extensive records from Carbon Footprint Ltd's Life Cycle Inventory (LCI) databases, drawn from internationally recognised and traceable sources. It allows for the modelling of a single building.
- CarbonScopeData™ is a life cycle inventory (LCI) database[25]. It provides data for a broad array of raw materials used in the economy, common industrial processes, energy sources, transport modes and waste disposal. The database contains LCI data for well over 1600 materials, products and processes representing a broad range of industries and geographical locations (and more are being added regularly), compiled from highly credible raw data sources and research literature and processed according to rigorous LCA standards.

Guidelines on how to evaluate data quality are provided in Section 1.2.3. The methodological consistency, conformity and completeness of specific data from other sources must be verified by independent external experts according to ISO 14071.

1.2.1.4 Suggested reporting format

The environmental impacts shall be reported in a tabular format at a disaggregated level, i.e. by life cycle stages. The template shown on the following page shall be used.

As is required for the 'cradle to cradle Life Cycle Assessment (LCA)', additional information shall be reported that is complementary to the reporting template, in the form of a summary report, which should include:

- The reason for carrying out the study, project stage during which the LCA was created, intended application and target audiences (including a statement if the study will support comparative assertions intended to be disclosed to the public)
- Information about the assessment methods used to characterise the life cycle impacts
- System boundary and processes considered in the study, including cut-off and allocation rules used for their definition
- Data sources used for the elements and systems that compose the building (as specified in section 1, table 1.1)
- Energy and water operational use (as per indicators 1.1 and 3.1)
- Calculation model used to quantify the elementary flows
- Analysis of hot-spots, trade-offs and improvement options
- Data quality evaluation and note on the limitations of the study

[24] Carbon Footprint Ltd, http://www.carbonfootprint.com/
[25] CleanMetrics, *CarbonScopeData*, http://www.cleanmetrics.com/html/database.htm

- Critical review according to ISO 14071, if applicable

All information shall be as complete, accurate and objective as possible and shall be transparently reported.

Indicator 1.2 Generic assessment reporting format

Global Warming Potential for each life cycle stage

Indicator	**Unit**	**Scenario**	**Product (A1-3)**	**Construction process (A4-5)**	**Use stage (B1-7)**	**End of life (C1-4)**	**Benefits and loads beyond the system boundary (D)**
(1) GWP - fossil	kg CO_2 eq	S_i / DO_j …					
(2) GWP - biogenic	kg CO_2 eq						
GWP – GHGs (1+2)	kg CO_2 eq						
(3) GWP – land use and land transformation	kg CO_2 eq						
GWP – overall (1+2+3)	kg CO_2 eq						

Notes:

Impacts referred to the use of 1 m^2 of useable internal floor per year for a default reference study period of 60 years[26].

Results shall be reported for Design Options and Scenarios that have been modelled.

S_i (= Scenario) and DO_j (= Design Option) can refer to:

- Reference study period
- Intended service life or investment holding period according to clients requirements
- Building and elemental service life planning (2.2 life cycle tools, scenario 1)
- Design for adaptability and refurbishment (2.2 life cycle tools, scenario 2)
- Design for deconstruction, reuse and recyclability (2.2 life cycle tools, scenario 3)
- Future climate change (5.1 life cycle tools, scenario 1)

[26] A further table shall be prepared if, in addition to the reference study period, an intended service life has been modelled.

1.2.1.5 Monitoring of as-built and occupied performance

A life cycle GWP assessment can be performed at different stages of a building project (e.g. design or occupation). In the context of this framework, it is primarily intended as a design tool. However, it is also important to understand how the building performs once occupied, i.e. based on as built-specifications, the real Bill of Materials and adapted condition of use. Monitoring beyond the design stage shall therefore include:

- Comparison between the life cycle GWP of the building as designed and as-built
- Traceability of the data that is required to verify the design stage estimated performance, conformity with relevant methodological references and a consistency check

A critical review carried out according to ISO 14071 may also be required to support the monitoring stage.

1.2.2 Making Level 2 and 3 assessments

In the following section, rules are laid down for how to use the additional types of performance assessment available for calculating life cycle GWP and how to report on the results.

The rules for Level 2 and 3 assessments are presented in a tabular form in table 1.2.3 and cover the following aspects of calculating life cycle GWP:

- Objective(s)
- Cut-off rules for the system boundary definition
- Energy and water consumption modelling
- Scenarios and End of Life
- LCI and LCIA datasets and software
- Data requirements
- Interpretation of the results and critical review

Table 1.2.3 Calculation rules for carrying out Level 2 and 3 life cycle GWP assessments

	Level 2: Comparative performance assessment	**Level 3: Design performance optimisation**
Objective(s)	The main users of this option are intended to be professionals who wish to report on the environmental performance of buildings. This performance could be compared with other buildings in a portfolio or with national/regional reference buildings. In this case, the GWP assessment is to be performed following a more comprehensive approach in order to obtain reproducible results using the same level of information detail. For this purpose, minimum requirements on the data quality are specified.	The main users of this option are intended to be professionals who want to use LCA at an early stage of the building project life cycle as a decision making support tool for improving the sustainability of the building. In this case, the GWP assessment is to be performed following a more comprehensive approach to obtain reproducible results using the same level of information detail. For this purpose, minimum requirements on the data quality are specified.
Minimum building scope	The building elements listed for the shell and core, and excluding external works. *See the building element listing in Table 1.1*	All building elements listed for the shell, core and external works. *See the building element listing in Table 1.1*

System boundary and cut off rules	All life cycle stages shall be calculated, unless a simplified reporting option is selected as a starting point (see Guidance note 1.5). Different rules shall apply to the construction products modelled depending on the calculation route: 1. Use of EPDs: The Product Category Rules for the EPDs used shall be compliant with EN 15804. 2. Use of a carbon footprint datasets - All elements and their components that make up less than 1% of the building's total mass can be excluded. The total amount of excluded elements and components must not exceed 5% of the total mass of the building. 3. Use of LCA database and tools: - All elements and their components that make up less than 1% of the building's total mass can be excluded. The total amount of excluded elements and components must not exceed 5% of the total mass of the building. - All input flows to unit processes that make up less than 1 % of primary energy usage and 1 % of the total mass input of that unit process. The total amount of excluded input flows per module must not exceed 5% of the total primary energy usage and mass input of that life cycle module	All the life cycle stages shall be calculated. The following cut-off rules are prescribed: - All elements and their components that make up less than 1% of the building's total mass and GWP impact can be excluded. The total amount of excluded elements and components must not exceed 5% of the total mass and the total GWP impacts of the building. - All input flows to unit processes that make up less than 1 % of primary energy usage and 1 % of the total mass input of that unit process. The total amount of excluded input flows per module must not exceed 5% of the total primary energy usage and mass input, or the total GWP impact depending on the complexity of the calculation tools, of that life cycle module.
Energy modelling	Data to be obtained from Indicator 1.1	Data to be obtained from Indicator 1.1
Water modelling	Data to be obtained from Indicator 3.1	Data to be obtained from Indicator 3.1
Scenarios and End of Life	Data to be obtained from life cycle scenario tool 2.2.3	Data to be obtained from life cycle scenario tool 2.2.3

LCI and LCIA datasets and software	Specific data should be used for foreground processes. Data for background processes shall be representative of the national/regional context analysed. Data from primary and secondary sources must be validated and third party certified. This option may rely on more complex software tools. Some of the software tools and databases reported in the separate dynamic list have these characteristics.	Data for foreground processes should refer to specific data. Data for background processes shall be representative of the national/regional context analysed. Data from primary and secondary sources must be validated and third party certified. This option relies on the use of more complex software tools, which may be specific for the analysis of buildings. Some of the software tools and databases reported in the separate dynamic list have these characteristics.
Data requirements	Since this option may be used for reporting the building's environmental performance in the public domain, data quality becomes an important issue. A data quality index is to be calculated according to the method set in Section 1.2.3. The overall data quality index shall score above 2. For transparency reasons, data sources shall moreover be reported.	Since this option aims at optimising the building's environmental performance, data quality becomes an important issue. A data quality index is to be calculated according to the method set in Section 1.2.3. The overall data quality index shall score above 2. For transparency reasons, data sources shall moreover be reported.
Interpretation of the results and critical review	Result shall be interpreted critically through a sensitivity analysis in order to understand: • Environmental hot-spots, possible trade-offs between life cycle stages and improvement areas • Influence of data on the results, • Data gaps, robustness of assumptions, and limitations Summary conclusions and recommendations shall be drafted. A critical review according to ISO 14071 is also needed to check the consistency of the study against the requirement of ISO 14040/44 and ISO 14067.	Result shall be interpreted critically through a sensitivity analysis in order to understand: • Environmental hot-spots, possible trade-offs between life cycle stages and scenarios and improvement areas • Influence of data on the results, • Data gaps, robustness of assumptions, and limitations Summary conclusions and recommendations shall be drafted. If conclusions are not consistent with the defined goal and scope, the phases of LCA should be repeated until convergence is reached. A critical review according to ISO 14071 is also needed to check the consistency of the study against the requirement of ISO 14040/44 and ISO 14067.

1.2.3 Property valuation influence and reliability rating

The following tools are provided to inform the valuation of a property for which performance has been assessed according to indicator 1.2:

- Checklists for the potential positive influence on a market valuation
  - Checklist 1: Potential positive influence on future performance
  - Checklist 2: Accounting for the performance assessment in valuation criteria
- Reliability rating of the performance assessment
  - Rating 1: Basis for the performance assessment
  - Rating 2: Professional capabilities
  - Rating 3: Independent verification

The completed reporting may be used separately alongside the Level 1, 2 or 3 results for indicator 1.1, or may form part of the overall reporting for indicator 6.2. The methodology for calculating the Indicator Reliability Index (IRI) for rating 1 is provided in section 1.2.3.2.

1.2.3.1 The potential for a positive influence on a market valuation

Checklist 1 – Evaluation of potentially positive influences on the market performance

Potential influence	***Evaluated?***	***Resulting assumptions used in the appraisal***
Potential influence 1 *Increased revenues due to market recognition and lower void rates.*	*Yes/no*	
Potential influence 2 *Reduced operational, maintenance, repair and/or replacement costs.*	*Yes/no*	
Potential influence 3 *Reduced future risk of increased overheads or loss of income.*	*Yes/no*	

Checklist 2 – Accounting for the Level(s) performance assessment in the valuation criteria used

Valuation criteria set used	*Indicate the scheme or tool used*
Version of the criteria set used	

Criteria which the assessment has influenced		**Influence on the valuation or rating**
Valuation criterion	**Sub-criterion**	
Criterion x	Sub-criterion y	Notes on the extent of the influence and the supporting assumptions used

1.2.3.2 Reliability rating of the performance assessment

Rating 1: - Basis for the performance assessment

The calculation of life cycle GWP generally works at two levels:

- Foreground processes, which affect directly the results (e.g. the actual content of concrete in a column, the consumption of electricity during the occupation of a building)
- Background processes, which are linked to and are nested behind the foreground processes (e.g. the production and supply of concrete, the production and supply of grid electricity).

The quantification of data for both foreground and background processes may require a combination of:

- Primary data, which is site-specific information based on direct measurements or the characterisation of parameters for a certain context;
- Secondary data, which is available from technical literature and data providers (e.g. specific studies, LCA databases);
- Assumptions, especially when satisfactory data is not available.

The data available can vary with respect to:

- Representativeness (its relevance and completeness);
- Accuracy.

Rating 1 is based on the assessment of the quality of data against these two main parameters. The rating has a matrix form, which is adapted from the European Commission's Product Environmental Footprint method's (PEF) data quality evaluation methodology, and which is based on four parameters:

- Technological representativeness of data (TeR)
- Geographical representativeness of data (GR)
- Time-related representativeness of data (TiR)
- Uncertainty of data (U)

A rating level is to be evaluated for each parameter according to the matrix in Table 1.2.4. The overall rating is equal to the Data Quality Index (DQI) which can be calculated from the individual ratings as follows:

$$DQI = ((TeR+GR+TiR)/3+U)/2$$

The rating shall be calculated for each hot spot of the environmental impacts identified from the life cycle GWP calculation. Hot spots are points in the life cycle of a product which have the highest impacts/importance in the overall life cycle GWP result. They may be related to a building's life cycle stages or modules, processes, components (elements, structural parts, products, materials) or elementary flow – or combinations thereof, for example the installation and replacement of a façade in life cycle modules B1-3 and B5. Together their contribution will, in total, be more than 50% of the total life cycle GWP result.

Once the hot spots have been identified, the data quality shall be rated for each hot-spot. The overall data quality shall then be calculated as the contribution-weighted average of the data quality for each hot-spot:

$$DQI_{overall} = \Sigma_i \left(DQI_{hot\text{-}spot,I} \times Contribution_{hot\text{-}spot,i}\right) / \Sigma_i \left(Contribution_{hot\text{-}spot,i}\right)$$

Rating 2 – Professional capabilities

Rating aspect	**Rating score**			
	0	**1**	**2**	**3**
Technical capability of the personnel carrying out the assessment	*No formal training and limited experience in using the calculation method*	*Formal training or some applied experience in using the calculation method*	*Formal training and some applied experience in using the calculation method*	*Formal training*[27] *and significant applied experience in using the calculation method*

Rating 3 – Independent verification

Rating aspect	**Rating score**			
	0	**1**	**2**	**3**
Independent verification of the assessment	*Self-declaration of the performance assessment results*	*Peer review of the input data and calculation steps*	*Third party auditing and verification of the calculation steps*	*Third party auditing and verification of the process data, life cycle inventory data and calculation steps*

[27] In accordance with Article 17 of the EPBD

Table 1.2.4 Data quality evaluation matrix

Rating aspect	***Brief description of each aspect***	**Rating score**			
		0	**1**	**2**	**3**
Technological representativeness	Degree to which the dataset reflects the true population of interest regarding technology (e.g. the technological characteristics, including operating conditions)	No evaluation made	The data used does not reflect satisfactorily the technical characteristics of the system (e.g. Portland Cement, without other specifications)	The data used reflects partially the technical characteristics of the system (e.g. Portland Cement type II, without further specifications)	The data used reflects the technical characteristics of the system (e.g. Portland Cement type II B-M)
Geographical representativeness	Degree to which the dataset reflects the true population of interest regarding geography (e.g. the given location/site, region, country, market, continent)	No evaluation made	The data used refer to a totally different geographic context (e.g. Sweden instead of Spain)	The data used refers to a similar geographic context (e.g. Italy instead of Spain)	The data used refers to the specific geographic context (e.g. Spain)
Time-related representativeness	Degree to which the dataset reflects the specific conditions of the system being considered regarding the time/age of the data (e.g. the given year compared to the reference year of the analysis)	No evaluation made	There are more than 6 years between the validity of the data used and the reference year to which the data applies.	There are between 2 and 4 years between the validity of the data used and the reference year to which the data applies.	There are less than 2 years between the validity of the data used and the reference year to which the data applies.

Uncertainty	Qualitative expert judgment or relative standard deviation expressed as a percentage.	No evaluation made	Modelled/similar data is used. Accuracy and precision of the data has been estimated qualitatively (e.g. by expert judgment of suppliers and process operators)	Modelled/similar data is used which is considered to be satisfactorily accurate and precise with the support of a quantitative estimation of its uncertainty (e.g. representative data from trade associations for which a sensitivity analysis has been carried out).	Site specific and validated data is used which is considered to be satisfactorily accurate and precise (e.g. window system for which a verified EPD is available) The allocation hierarchy has been respected.

Macro-objective 2: Resource efficient and circular material life cycles

Key terms and definitions used

Accessibility	The ability to allow for easy access to building components for disassembly, refurbishment, replacement, or upgrade.
Adaptability	The ability of the object of assessment or parts thereof to be changed or modified during its useful life to make it suitable to accommodate a new or adapted use.
Assembly	An arrangement of more than one material or component to serve specific overall purposes
Building fabric	All construction works that are fixed to the building in a permanent manner, so that the dismantling or replacement of the product constitute construction operations
Building component	Construction product manufactured as a distinct unit to serve a specific function or functions.
Deconstruction	A process of selectively and systematically dismantling buildings to reduce the amount of waste created and generate a supply of high value secondary materials that are suitable for reuse and recycling.
Disassembly	The taking apart of a building or a constituent element or assembly at the end of its useful life in such a way that allows components and parts to be re-used, recycled or recovered.
Estimated service life	Service life that a building or an assembled system would be expected to have in a set of specific in-use conditions, determined from reference service life data after taking into account any differences from the reference in-use conditions.
In-use condition	Any circumstance that can impact the performance of a building or assembled system under normal use.
Life cycle inventory analysis	Phase of a life cycle assessment involving the compilation and quantification of inputs and outputs for product throughout its life cycle.
Material separation	Operation to separate materials, including mechanical, chemical or thermal processes (e.g. shredding, smelting, sorting etc.) other than dismantling or disassembly.
Recovery	Any operation by which waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in a plant or in the wider economy.
Recycling	Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes.
Reuse	Operation by which a product, or a part thereof, having reached the end of one use stage is used again for the same purpose for which it was conceived.
Recyclability	Ability of waste product to be recycled, based on actual practices.

Reference service life	Service life of c construction product which is known to be expected under a particular reference set of in-use conditions and which may form the basis for estimating the service life under other in-use conditions.
Refurbishment	Modification and improvement to an existing building in order to bring it up to an acceptable condition.
Re-use	Any operation by which products or components that are no waste are used again for the same purpose for which they were conceived or used for other purposes without reprocessing
Scenario	Collection of assumptions and information concerning an expected sequence of possible future events
Selective demolition	Removal of materials from a demolition site in a pre-defined sequence in order to maximize recovery and recycling performance.
Service life (working life)	Period of time after installation during which a building or an assembled system meets or exceeds the technical performance and functional requirements
Waste audit	Assessment of construction and demolition waste streams prior to demolition or renovation of buildings and infrastructures. It

The macro-objective 2 life cycle tools

2.1 Life cycle tools: Building bill of materials	**Where to find the guidance for each Level** Guidance common to all Levels
2.2 Life cycle tools: scenarios for building lifespan, adaptability and deconstruction Scenario 1: Building and elemental service life planning	**Where to find the guidance for each Level** Level 1 common performance assessment Level 2 comparative performance assessment Level 3 performance optimisation assessment
Scenario 2: Design for adaptability and refurbishment	**Where to find guidance for each level** Level 1 common performance assessment Level 2 comparative performance assessment Level 3 performance optimisation assessment
Scenario 3: Design for deconstruction, reuse and recycling	**Where to find guidance for each level** Level 1 common performance assessment Level 2 comparative performance assessment Level 3 performance optimisation assessment

The macro-objective 2 indicators

2.3 Construction and demolition waste and materials	**Where to find the guidance for each Level** Level 1 common performance assessment Level 2 comparative performance assessment Level 3 performance optimisation assessment

2.1 Life cycle tool: Building bill of materials (BoM)

Aim: To provide guidance and reporting format to help users put together a Bill of Materials (BoM) for a building and to make aggregated reporting on the main materials used. *Focus of attention:* The compilation of data on what the building is composed of, using the Bill of Quantities as a starting point. This exercise provides the raw data for indicators such as 1.2 in order to calculate environmental impacts.
Links to other indicators: – A linked step is to understand how long each element of a building may last, which is addressed by 2.2 life cycle scenario tool 1. – Indicator 1.2 Life cycle GWP and overarching tool Cradle to cradle LCA require a BoM as the basis for calculating the life cycle inventory flows. – Indicator 6.1 requires the costing of the Bill of Quantities for a building on an elemental and component basis.

2.1 Life cycle tools: Building bill of materials	**Where to find the guidance for each Level** Guidance common to all Levels

2.1.1 Compiling a bill of materials

The Bill of Quantities (BoQ) is the starting point for compiling a Bill of Materials (BoM). A BoQ specifies the quantities of different elements of a building (e.g. foundations, columns), as well as their their technical specifications and expected lifetime. The BoQ comprises different categories of elements, which can have different functional performance characteristics. A Bill of Materials (BoM) describes the materials contained in the building's elements (e.g. concrete, steel, aluminium).

The following steps should be followed in order to compile the BoM (see a fictitious example in table 2.1.1.):

1. Compile the Bill of Quantities: A BoQ is compiled, comprising the elements accounting for at least 99% of the mass of the building.
2. Identify the basic composition of each building element: A breakdown in mass of the main materials that each building element is made up of should be compiled.
3. Identify the technical specification of each building element: This technical information will, later, if there is a lack of specific data from manufacturers, enable the selection of representative data from within a generic life cycle inventory database.
4. Aggregation by material: The materials should be aggregated to obtain the mass for each type of material. The materials should be further aggregated into the four material types accounted for by Eurostat:
   - Metal materials
   - Non-metallic mineral materials
   - Fossil energy materials
   - Biomass based materials

Table 2.1.1 Fictitious examples of a Bill of Quantities and its associated Bill of Materials

Steps 1 and 2

Bill of Quantities	**Technical Specifications**	**Composition**
100 m^2 of foundation	Strength: 50 MPa	• 1 m^3/m^2 of unreinforced concrete with strength of 50 MPa and density of 2370 kg/m^3 (of which, cement: 200 kg/m^3). • 10 kg/m2 of light-grade steel
10 columns	Strength of each column: 20 MPa	• 0.5 m^3/column of reinforced concrete with strength of 20 MPa and density of 2420 kg/m^3 (of which, cement: 290 kg/m^3, steel: 30 kg/m^3)
10 window units	Area of each unit: 3m^2 U: 1.5 W/m^2K	• Aluminium, 5 kg/unit • Plastic (PA), 0.1 kg/unit • Glass, 2.5 kg/unit
10 doors	Area of each door: 1 m^2 Thickness: 19 mm	• Hardwood (0.8 kg/dm^3), 15.2 kg/unit

Steps 3 and 4

Bill of Materials	**without considering the expected lifetime of the building's elements**	
Metals	1200 kg	Steel, 1000 kg (foundation) Steel, 150 kg (columns) Aluminium, 50 kg
Non-metallic mineral materials	248975 kg	Concrete, 237000 kg (foundation) Concrete, 11950 kg (columns) Glass, 25 kg
Fossil energy materials	1 kg	Plastic (PA), 1 kg
Biomass based materials	152 kg	Hardwood, 152 kg

As can be seen from the example in table 2.1.1, information on the materials contained in construction products is needed to quantify the BoM. The optimal solution would be to obtain such information directly from the suppliers to a building project. Alternatively, this information could be estimated from manufacturers' literature (e.g. the product brochures of similar products, or from Environmental Product Declarations (EPDs).

BoQ and BoM are an important tool for tracking material flows on a building project. As such they can play a number of purposes. These include, at an advanced level, providing the primary input data for modelling of the life cycle GWP or a cradle to cradle LCA. This is because environmental impacts result from elementary flows associated with the production and supply of construction products and materials (e.g. the extraction of raw material and the associated production of waste and pollutants).

Life cycle databases exist that can support a more comprehensive assessment of the life cycle inventory flows and associated environmental impacts of construction products and materials (See the separately published dynamic listing). The material composition of some reference construction products can be extracted from such databases.

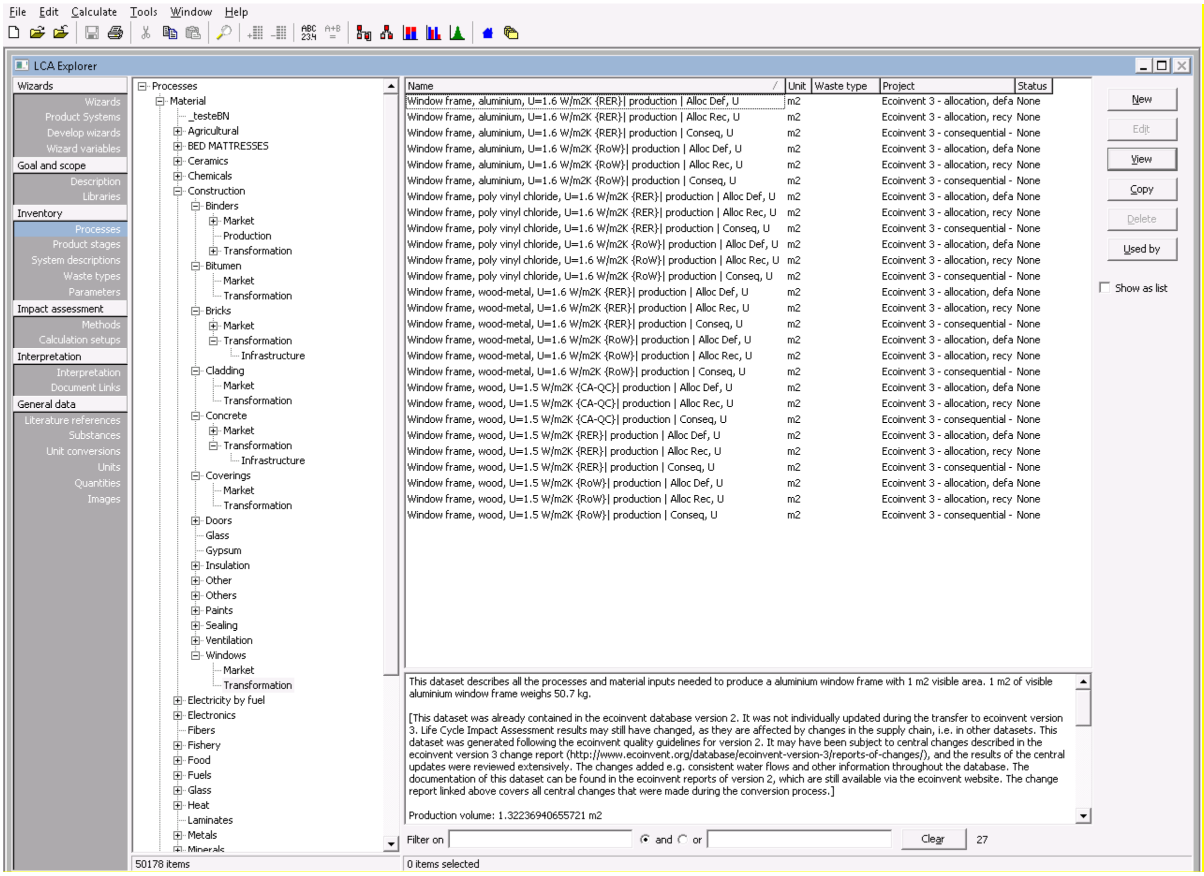
Guidance note 2.1 provides further information and examples of how a BoM can be estimated using life cycle GWP and LCA databases.

Guidance note 2.1 for design teams

The use of LCA databases for the estimation of a bill of materials

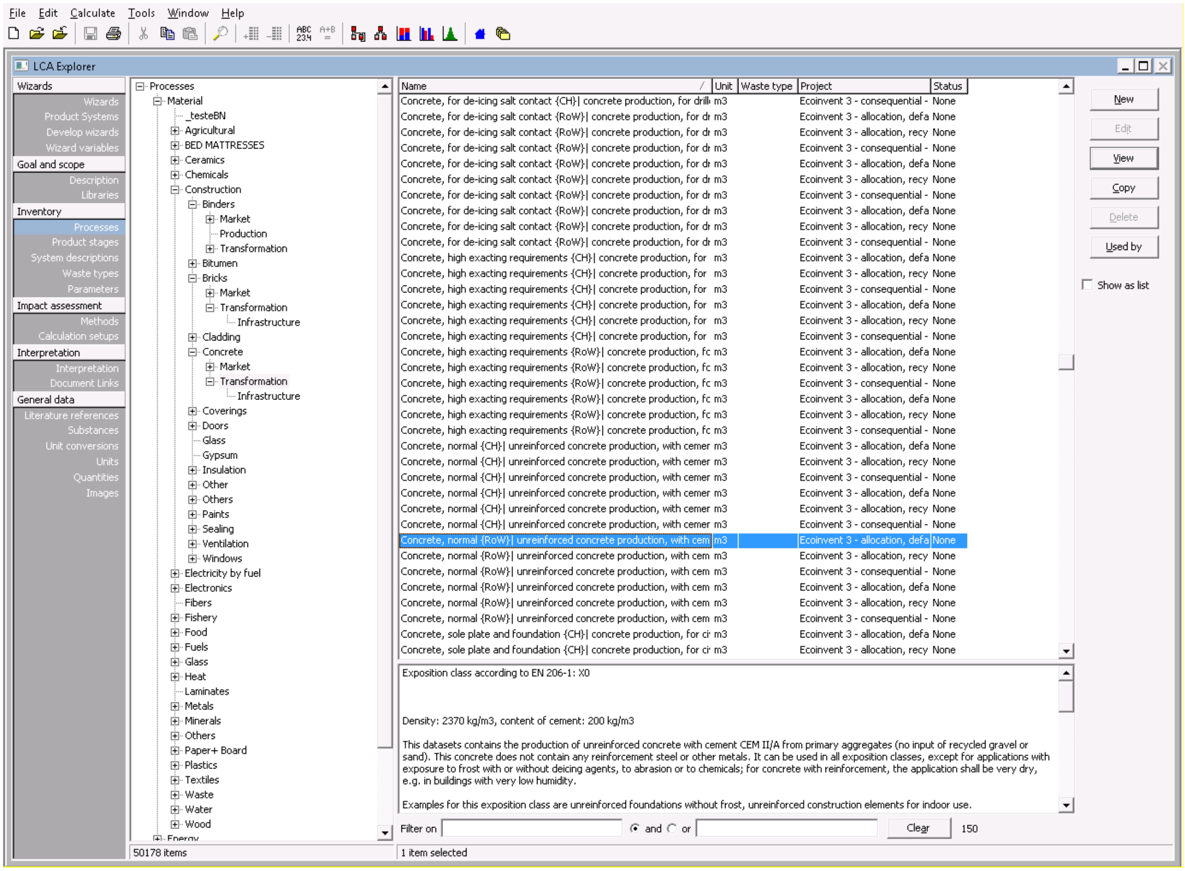
Once the target elements of a building are known, it is possible to obtain an estimation of the BoM by using an LCA database, where different types of construction products are listed, as shown in the example 1 screen grab below.

Example 1: Window frame options in an LCA software package



To make use of an LCA database, datasets must first be selected for products that are as similar as possible to the target elements considered. Example 2 below illustrates specifications for concrete, for which the strength requirements and mix design must be known.

Example 2: Concrete specification options in an LCA software package



Once a representative dataset has been identified from within the LCA database, the material inputs listed on screen need to be matched up to inventory flows of inputs and outputs associated with the production of each material using the LCA software. This will generate what is called a 'reference flow' for the target building element. Where complex building elements with many component parts are being modelled, it might be necessary to continue the analysis at the level of the components and sub-components.

Example 3: Concrete material inputs

Products	**Amount**	**Unit**
Normal concrete produced with cement CEM II/A (Average World's conditions)*	1	m^3
Material resources	**Amount**	**Unit**
Lubricating oil	0.02	kg
Sand	720	kg
Concrete mixing factory	4.17E-07	p
Gravel, round	1280	kg
Synthetic rubber	0.12	kg
Tap water (CA-QC)	0.1912	kg
Tap water (Europe without Switzerland)	67.95	kg
Tap water (Rest of the World)	101.9	kg
Cement, alternative constituents 6-20%	20.82	kg
Cement, alternative constituents 6-20%	179.2	kg

(*) Notes:

- Exposition class according to EN 206-1: X0
- Density: 2370 kg/m^3, content of cement: 200 kg/m^3

2.1.2 Suggested reporting format for results

Reporting on the Bill of Materials should be organised according to the building elements identified as the 'building and its elements' in section 1.1.2, table 1.1.

In line with Eurostat's data collection for material flow accounting at EU level, the Bill of Materials reporting should also be aggregated to report on the total mass of the four main types of materials.

Part 1 – Mass of different materials in the building material bank

Material type	Mass (t)
Metal	
Non-metallic mineral	
Biomass	
Fossil energy	

Part 2 – Bill of materials organised by the main building parts and elements

Building element	Bill of Quantities (units)	Bill of Materials by material type (kg)			
		Metal	Non-metallic mineral	Biomass	Fossil energy
Element x					
Element y					
Element z					

2.2 Life cycle scenario tools: Life span, adaptability and deconstruction

2.2 Life cycle tools: scenarios for building lifespan, adaptability and deconstruction	**Where to find the guidance for each Level** General rules applying to all levels Valuation influence and reliability rating (all levels)
Scenario 1: Building and elemental service life planning	General rules applying to all levels
Scenario 2: Design for adaptability and refurbishment	Level 1 common performance assessment Level 2 comparative performance assessment Level 3 performance optimisation assessment
Scenario 3: Design for deconstruction, reuse and recycling	Level 1 common performance assessment Level 2 comparative performance assessment Level 3 performance optimisation assessment

The three life cycle scenario tools provided by the Level(s) framework describe future events in the life cycle of a building that complement the physical description of the building (the Bill of Materials) and for which changes in potential future performance can be analysed (future potential for adaptability and deconstruction).

The guidance and reporting for each scenario provides users with qualitative and quantitative ways of reporting on how far the building addresses each of the three aspects of resource efficiency and circularity.

The method to be followed for each assessment level varies according to the detail, comparability and consistency in how they address each performance aspect:

1. Common performance level (qualitative): A checklist of the most important design aspects that can be taken into consideration and whether/how they are addressed.
2. Comparative performance level (semi-qualitative): Design aspects that are important to consider are given weightings and the scores achieved by a design are then added to give an overall performance which can be reported on. This performance can be compared if the same weighting methodology has been used.
3. Performance optimisation level (quantitative): The analysis of the environmental performance of designs using other indicators of this framework, such as 1.2 (life cycle GWP) or 2.4 (cradle to cradle LCA), so that they can be evaluated, compared and reported on.

Section 2.2.1 provides general rules that shall be followed when using each scenario tool. Then in section 2.2.2 detailed rules are provided for each scenario. Section 2.2.3 provides specific rules for analysis using Level 3.

2.2.1 General rules for describing and reporting on scenarios

Those choosing to use the scenario tools shall follow the accompanying set of rules for how to report on the results. These rules are designed to ensure the consistency of the underlying assumptions and calculations behind the reporting. The rules, which differ according to the three levels of performance assessment in the Level(s) framework, are summarised at the end of this guidance in table 2.2.6.

The use of indicator 1.2 Life cycle GWP or cradle to cradle LCA for design optimisation specifically allows for the performance of designs to be tested and evaluated. To do this, possible future scenarios for the use of the building should be developed and tested drawing upon expert input. When using life cycle GWP or LCA, the specific rules in section 2.2.1.2 shall additionally be followed.

2.2.2 Detailed rules for each scenario tool

2.2.2.1 Scenario tool 1: Building and elemental service life planning

Aim:

To encourage a medium to long term focus on the design life of major building elements, as well as their associated maintenance and replacement cycles.

Focus of attention:

Estimation of the service life for the entire building and for major building elements (e.g. the envelope and structure).

Links to other indicators:

- Building element service lives form the basis for calculation of maintenance, repair and replacement costs that contribute to indicator 6.1 (disaggregated reporting).

Service lifespans for each of the building parts and elements that form part of the minimum scope described in table 1.1 shall be identified. These lifespans may be obtained from a number of sources, which shall in each case be identified in the reporting. Possible sources are identified in Table 2.2.1.

In the absence of field data or estimations from manufacturers, the typical service lifespans in section 1.4.3, table 1.6 may be used.

Where the length of the reference study period, intended service life or investment holding period is longer than that of the service lifespan for a building element, the number of replacements will need to be calculated. Section 9.3.3 of the reference standard EN 15978 provides rules on the calculation of replacement cycles.

Table 2.2.1 Possible sources of building element service lifespans

Description of source	**Examples of sources**
Typical life spans based on reported averages	– *Building costing tools such as BCIS,* – *LCA and LCC methods used in building assessment scheme such as DGNB,* – *LCA tools such as ETool,*
Life span estimate calculated by building professional	*Calculated according to the factor methodology of ISO 15686-8.*
Life span estimate provided by building element manufacturer	*Based on a combination of standardised durability tests and feedback from the field.*
Life span estimate obtained from field experience	*Based on the recorded performance of building assets from the monitoring of individual projects or properties within a property portfolio.*

Generic service life planning reporting format

Building parts	**Related building elements**	**Expected lifespan (years)**	**Data sources ***
Shell (substructure and superstructure)			
Load bearing structural frame	– Frame (beams, columns and slabs) – Upper floors – External walls – Balconies		
Non-load bearing elements	– Ground floor slab – Internal walls, partitions and doors – Stairs and ramps		
Facades	– External wall systems, cladding and shading devices – Façade openings (including windows and external doors) – External paints, coatings and renders		
Roof	– Structure – Weatherproofing		
Parking facilities	– Above ground and underground (within the curtilage of the building and servicing the building occupiers) [28]		
Core (fittings, furnishings and services)			
Fittings and furnishings	– Sanitary fittings – Cupboards, wardrobes and worktops – Floor finishes, coverings and coatings – Skirting and trimming – Sockets and switches – Wall and ceiling finishes and coatings		
In-built lighting system	– Light fittings – Control systems and sensors		
Energy system	– Heating plant and distribution – Radiators – Cooling plant and distribution – Electricity generation – Electricity distribution		

[28] If the share of underground car parking (usable area plus traffic area) accounts for more than 25% of the total useful floor area, the traffic area of the underground parking must be subtracted from the total useful floor area.

Ventilation system	– Air handling units – Ductwork and distribution		
Sanitary systems	– Cold water distribution – Hot water distribution – Water treatment systems – Drainage system		
Other systems	– Lifts and escalators – Firefighting installations – Communication and security installations – Telecoms and data installations		
(*) Data source options: a. Typical life span based on reported averages b. Life span estimate calculated by building professional c. Life span estimate provided by building element manufacturer d. Life span estimate obtained from field experience			

2.2.2.2 Scenario tool 2: Design for adaptability and refurbishment

Aim:

To extend the service life of the building as a whole, either by facilitating continuation of the intended use or through possible future changes in use.

Focus of attention:

Options to improve the performance of the building with respect to life cycle stages B4 (Replacement) and B5 (Refurbishment).

Scenario 2: Design for adaptability and refurbishment	**Where to find guidance for each level** Level 1 common performance assessment Level 2 comparative performance assessment Level 3 performance optimisation assessment

Level 1: Common performance assessment

Users shall identify from the checklists provided those design aspects implemented in the building design. The reporting differs depending on whether the building is an office or residential:

- For offices, the checklist of design aspects focuses on flexibility within the office market, as well as flexibility to change use within the property market. The checklist is provided in table 2.2.2.
- For residential properties, the checklist focuses on the potential to adapt to changing family and personal circumstances over time, as well as flexibility to change use within the property market. The checklist is provided in table 2.2.3.

Table 2.2.2 Checklist of office adaptability and refurbishment design aspects

Focus area	**Design aspect**	**Description**
Change in user space requirements	Column grid spans	Broader column spans that allow for more flexible floor layouts
	Internal wall system	Non-loading bearing internal walls that allow for changes to floor layouts
	Unit size and access	Access/egress is ensured for possible sub-divisions in order to provide more letting options
Changes to building servicing	Flexible access to services	Services that are not embedded in the building structure
	Ease of access to plant rooms	Easy access to plant rooms in order to facilitate future changes of technical equipment
	Flexible cabling patterns	Use of ducts to provide flexibility in the location of service points
	Greater floor to floor heights	The use of greater ceiling heights to give more flexibility in the routing of services

Change to building structure	Facade design for flexibility	The design of facades that support flexibility to change internal and external aspects
	Future-proofing of load bearing capacity	Redundant load bearing capacity incorporated from the beginning in order to support potential future changes in the uses and total floor area, including vertical additions
	Structural design to support expansion	Structural designs can allow for additional storeys to expand the floor area

Table 2.2.3 Checklist of residential adaptability and refurbishment design aspects

Focus area	Design aspect	Description
Changes in user space requirements	Access and ability to manoeuvre within each residential unit	Ease of access to living spaces, kitchen and bathroom in cases of the need for pram or wheelchair mobility
	The potential for ground floor conversion to a contained unit	The potential for the ground floor to become a contained unit with bed space, kitchen, toilet and shower
	Ease of access to the building services	Location of services in the building structure so as to ensure they are flexible to change
Changes in building level requirements	Ease of access to each residential unit	Ease of access to residential units in cases of the need for pram or wheelchair mobility
Change of use for units or floors *(for multi-family buildings)*	Wall systems that support layout changes	Internal wall designs that allow for unit/floor/building level changes to floor layouts
	Greater floor to ceiling heights	The use of greater ceiling heights to give more flexibility in the routing of services

Scenario 1, Level 1 common performance assessment reporting format

Part 1 - Design aspects addressed

Aspects addressed		**Description of design solution(s)**
Design aspect	**Yes/no**	
Aspect x		
Aspect y		
Aspect z		

Part 2 – Supporting property market check

Check by local property market expert carried out?	*Yes/no*

Additional design aspects identified by them?	*List any additional aspects identified:* – *Aspect x* – *Aspect y* – *Aspect z*

Level 2: Comparative performance assessment

Users shall use a pre-existing index, scoring or calculator tool which provides a numerical output. The tool used shall be clearly identified in the reporting. This is to ensure that comparisons are only made between buildings assessed using the same tool. Guidance note 2.2 provides suggestions and more information about currently available tools that can be used.

Guidance note 2.2 for design teams

Existing tools for assessing the adaptability of a building

There are currently only a limited number of tools available to assess and compare the adaptability of an office building. Those identified as being suitable for use for the comparative performance assessment level are:

- DGNB CORE 14 (Germany, 2014 [29] Scores can be derived from the methods for two separate DGNB criteria:
  - Criterion ECO 2.1 Flexibility and adaptability score
  - Criterion TEC 1.4 Adaptability of technical systems score
- BREEAM-NL (Netherlands, 2014) [30]
  - Criterion MAT 8 Building flexibility calculator: Based on the Dutch Real Estate vacancy risk evaluation, the tool allows for reporting on aspects of the structure, facade, interior and installations.
- Lifetime Homes (UK, 2010) [31]
  - A design audit is suggested against 16 criteria. No scoring system is provided.

The DGNB and BREEAM-NL tools are more appropriate for office buildings. For residential buildings, there is some overlap with the aspects relevant to office buildings – for example, if someone wishes to carry out a major renovation, or in the case of a change of use from residential to office. However, there are also distinctive aspects that relate to life changes – for example, upon starting a family or having reduced mobility.

The Lifetime Homes criteria are an important reference. Developed in the 1990s, Lifetime Homes is a set of design criteria intended to reflect the changing needs of individuals and families at different stages of life. They are sometimes also referred to as criteria for 'inclusive design'.

A new ISO 20887 standard on design for deconstruction and adaptability is anticipated to be published in 2018 and will provide a harmonised international tool to assess adaptability. It is understood that this ISO standard may, in part, be based on the Canadian Standards Association's standard for disassembly and adaptability Z782/06. Either standard may be suitable for use at Level 2 of Scenario 2.

[29] The DGNB CORE International criteria can be requested from here: http://www.dgnb-system.de/en/system/criteria/core14/index_resp.php
[30] The BREEAM NL criteria can be obtained from here: https://www.breeam.nl/content/breeam-nl-english
[31] The Lifetime Homes criteria can be obtained from here: http://www.lifetimehomes.org.uk/pages/revised-design-criteria.html

Scenario 1, Level 2 comparative performance assessment reporting format

Part 1 – Selected design tool

Design tool used	*Select from those identified in Guidance note 2.2*
Version of the tool of standard used	
Building adaptability score or index result	

Part 2 - Supporting information

Aspects addressed		**Description of design solution(s)**
Design aspect	**Yes/no**	
Aspect x		
Aspect y		
Aspect z		

Level 3: Design optimisation assessment

Users choosing to carry out a life cycle GWP assessment or a cradle to cradle LCA for a building can additionally report on the improvement potential of their chosen adaptability measures. The results of the scenario are incorporated into the reporting format for both life cycle GWP (see indicator 1.2) and cradle to cradle LCA (see section 4.2.3).

To ensure consistency, the specific rules laid down in section 2.2.3 shall be followed, together with the following additional notes that are specific to scenario 2:

- Reference assumptions: The intended service life shall be defined by the client. This can be used as a reference point for the life cycle GWP or LCA modelling and the cost/value engineering of design options.
- Scenario definition: In conjunction with a property market expert that has knowledge of the local and regional market, the identification of worst, intended and best case scenarios for continued future use of the building. Design precedents may be identified and should be used to identify design pre-requisites for maintaining continued building use over time, as well as design deficiencies that may have contributed in the past to failure or voids:
    - Worst case: Local precedents for low/no occupation of buildings of the same use that lead to early demolition.
    - Intended case: Local precedents that reflect the intended service life as defined by the client.
    - Best case: Local precedents for continuation of the same use or changes of use that have avoided the need for demolition.
- Life cycle GWP or LCA modelling of the design option(s): The implications of adaptability measures shall be modelled for life cycle stage B5 (Refurbishment).
    - If a change of use is assumed, the use stage shall be modelled to reflect the new use over a second, default service life period. Variation from the default shall be justified.

If the life cycle GWP or LCA results are to be publicly reported, an independent critical review of the assumptions shall be carried out by a property market specialist and his or her opinion appended to the reporting.

Software tools may be used to support the probabilistic analysis of life cycle scenarios for the future occupation of a building (see guidance note 2.3).

Guidance note 2.3 for designers, developers and investors

A software tool for analysing building adaptability scenarios

The EU-funded CILECCTA project[32] has developed a software tool that allows users to analyse future scenarios for different building configurations and the influence that these scenarios would have on cost and environmental impacts.

The user may define, ideally based on professional knowledge and experience, the local market conditions, their probability of occurring during a defined study period, and building specifications that can allow for adaptation to potential future changes in market conditions. Examples include the potentials for either an increase in the height of a building or to change the primary uses of a building.

Present and future costs for adaptations can be defined, to then be triggered by runs of the model over a defined period of time using a Monte Carlo simulation. In this way, the net present cost of different adaptability measures can be evaluated based on reasoned assumptions about the future market conditions.

The CILECCTA software tool is available in a trial Beta form via an online platform. Access for non-commercial use can be requested from the software's designers.

Scenario 1, Level 3 performance optimisation assessment reporting format

Part 1 - Design aspects addressed

Aspects addressed		**Description of design solution(s)**
Design aspect	**Yes/no**	
Aspect x		
Aspect y		
Aspect z		

Part 2 – Supporting property market check

Local property market expert check carried out?	*Yes/no*
Identification of local design aspects	*List any design aspects with local relevance that have been implemented:* – *Aspects x* – *Aspects y* – *Aspects z*

[32] CORDIS (2014) *CILECCTA Report Summary* http://cordis.europa.eu/result/rcn/141443_en.html

2.2.2.3 Scenario tool 3: Design for deconstruction, reuse and recycling

Aim:

To facilitate the future circular use of building elements, components and parts that make up a building's material bank.

Focus of attention:

The potential for the reuse of recycling of major building elements following deconstruction. The scenario relates to the following life cycle stages and their associated modules:

- End of Life stage C1 (De-construction/demolition)
- End of Life stage C3 (Waste processing)
- Benefits beyond the system boundary D (Reuse/recycling/recovery potential)

Scenario 3: Design for deconstruction, reuse and recycling	**Where to find guidance for each level** Level 1 common performance assessment Level 2 comparative performance assessment Level 3 performance optimisation assessment

Level 1: Common performance assessment

Users shall identify from the checklists provided those design aspects implemented in the building design. Users should first consult the building parts identified in table 2.2.4, and then for each part identify from table 2.2.5 which design aspects have been implemented in some form .

Table 2.2.4 Scope of building parts to be assessed

Scope of parts	**Building parts**
Shell	○ Foundations ○ Load bearing structural frame ○ Non-load bearing elements ○ Facades (including windows and doors) ○ Roof
Core	○ Fit out (floors, walls and ceilings) ○ Services: – Lighting – Energy – Ventilation – Sanitation

Table 2.2.5 Deconstruction, reuse and recycling design aspects list

Focus area	**Design aspect**	**Description**
Ease of disassembly	Connections are mechanical and reversible	The use of mechanical, non-destructive connections as opposed to chemical bonding
	Elements and their parts are independent and easily separable	The potential to separate elements that are connected to each other [33] and to disassemble elements into their constituent components and parts
	Connections are easily accessible and reversible	Easy and sequential access in order to reverse mechanical connections and remove elements
	The number and complexity of the disassembly steps are low.	The disassembly should not suppose the need for complex preparatory steps, the intensive use of manpower and machinery and/or off-site processes
Ease of reuse	Prefabricated elements and parts use standardised dimensions	Specification of elements and parts that are of a standardised specification in order to provide consistent future stock
	Design supports future adaptation to changes in functional needs	Design of major building elements to support future adaptation to changes in functional needs
	Use of modular building services	Specification of modular systems that may retain value upon de-installation
Ease of recycling	Parts made of compatible or homogenous materials	Specification of components and constituent parts made of homogenous materials, the same materials or materials compatible with recycling processes. Finishes or coatings should not inhibit recycling.
	There are established recycling options for constituent parts or materials	The part or material is readily recyclable into products with a similar field of application and function, thereby maximising their value.
	Constituent materials can be easily separated	It should be possible to separate components and parts into their constituent materials.

[33] For example, the facade, building services and internal fit out can be easily removed without damaging the structure.

Scenario 3, Level 1 common performance assessment reporting format

Part 1 – General information

Element and systems inventory available?	*Yes/no*
Deconstruction plan made available?	*Yes/no*

Part 2 - Ease of disassembly reporting

Building part	***Design aspects checked/implemented***	
	Ease of disassembly aspect	***Description of design solution(s)***
See table 2.2.5 listing	*Aspect x*	

Part 3 - Ease of reuse reporting

Building part	***Design aspects checked/implemented***	
	Ease of reuse aspect	***Description of design solution(s)***
See table 2.2.5 listing	*Aspect y*	

Part 4 - Ease of recycling

Building part	***Design aspects checked/implemented***	
	Ease of recycling aspect	***Description of design solution(s)***
See table 2.2.5 listing	*Aspect z*	

Part 5 - Demolition and waste management expert check

Expert check carried out?	*Yes/no*
Additional design aspects identified?	*List any additional aspects identified:* – *Aspects x* – *Aspects y* – *Aspects z*

Level 2: Comparative performance assessment

Users shall use a pre-existing index, scoring or calculator tool which provides a numerical output. The tool used shall be clearly identified in the reporting. This is to ensure that comparisons are only made between buildings assessed using the same tool. See guidance note 2.4 for suggestions on currently available tools that can be used.

Assumptions relating to the ease of disassembly, reuse and recycling shall be based on solutions and technologies that have already proven to be economically and technically viable. In other words, assumptions should be based on existing solutions and technologies.

Guidance note 2.4 for design teams

Tools for assessing a building's deconstruction, reuse and recyclability potential

There are currently only a limited number of tools available to assess and compare the potential for deconstruction, reuse and recyclability of an office or residential building.

The DGNB new-build criterion TEC 1.6 Disassembly and recyclability (Germany, 2015)[34] is suitable for use at the comparative performance assessment level. The criterion method provides a scoring for the recyclability of material selection and ease of disassembly.

Other tools exist, such as the BRE Trusts 'Design for deconstruction' index[35]. The latter has been piloted on live projects and may be integrated into the tools being developed by the Buildings as Material Banks (BAMB) project, to be released in 2018.

A new ISO 20887 standard on design for deconstruction and adaptability is anticipated to be published in 2018 and will provide a harmonised international tool to assess adaptability. It is understood that this ISO standard may, in part, be based on the Canadian Standards Association's standard for disassembly and adaptability Z782/06. Either standard may be suitable for use at Level 2 of Scenario 3.

Scenario 3, Level 2 comparative performance assessment reporting format

Part 1 – Selected design tool

Design tool used	*Tools currently identified as being suitable:* o *DGNB Germany (2015)* – *TEC 1.6 Disassembly and recyclability* o *Canadian Standards Association, Z783/12 (2016)* – *Design for deconstruction methodology, scoring for separate parameters*
Version of the tool or standard used	
Building deconstruction score or indices	

[34] The DGNB Germany criteria can be obtained from here: http://www.dgnb-system.de/de/system/zertifizierungssystem/
[35] BRE Buzz, Design for deconstruction, BRE Trust, http://brebuzz.net/2015/12/04/design-for-deconstruction-helping-construction-unlock-the-benefits-of-the-circular-economy/

Part 2 - Supporting information

Aspects addressed		**Description of design solution(s)**
Design aspect	**Yes/no**	
Aspect x		
Aspect y		
Aspect z		

Level 3: Design optimisation assessment

Users choosing to carry out a cradle to cradle LCA for a building can additionally report on the improvement potential of their chosen deconstruction measures. The results of the scenario are incorporated into the reporting format for life cycle GWP (see indicator 1.2) and cradle to cradle LCA (see section 7.2.3).

To ensure consistency, the specific rules laid down in section 2.2.3 shall be followed, together with the following additional notes that are specific to scenario 3:

- Reference assumptions: The reference end-of-life scenario for demolition for the type of building shall be described for life cycle stages C1-4, with a focus on the recovery rate for the reuse and recycling of materials and elements. The scenario should reflect as accurately as possible current local practices.
- Scenario definition: In conjunction with a demolition contractor or waste management specialist that has knowledge of the local and regional practices, the identification of local precedents and best case scenarios for the selective deconstruction and disassembly of the same type of building in order to maximise reuse and recycling.
  - The improvement in reuse and recycling in the end of life stage for the benefits that could be reported under Module D shall be calculated. Assumptions relating to the ease of disassembly, reuse and recycling shall be based on solutions and technologies that have already proven to be economically and technically viable. In other words, assumptions should be based on existing solutions and technologies.

Project-specific scenarios should be built up from primary data for technology that is applied by the construction and demolition sector to the building type/design and, as specifically as possible, in the geographical location.

Default or reference end of life scenarios should be used as the basis for comparisons of project-specific scenarios. The default or reference scenario should ideally be built up from national data, but if this is not available for specific materials or parts, EU data may be used.

If the LCA results are to be publicly reported, an independent critical review of the assumptions shall be carried out by a demolition contractor or waste management expert, and their opinion appended to the reporting.

Guidance note 2.5 for design teams

Defining end of life scenarios for a building

Data on reuse, recycling, recovery and landfill rates, as well as the solutions and technologies used, can be obtained from a number of possible sources which include the following:

- Default EU and Member State scenarios developed to support the use of LCA.

  For example, the DGNB assessment schemes LCA criterion [36] or publicly available LCA studies.

- Waste diversion rates that are based on Member State statistical data and surveys. These may include information on the specific separation and treatment technologies used.

  For example, the Member State factsheets developed by the European Commission[37].

[36] The criterion document can be obtained by contacting DGNB - http://www.dgnb.de/en/services/request-dgnb-criteria/form/

- Primary data for the specific deconstruction technologies and regional or local diversion rates.

  For example, 'cradle to gate with options' or 'cradle to grave' EPDs for specific building elements and materials and their possible end of life scenarios.

The EeEBGuide project provides further general guidance on defining end of life scenarios[38].

Scenario 3, Level 3 performance optimisation reporting format

Part 1 – Demolition and waste management expert check

Local demolition/waste management expert check carried out?	*Yes/no*
Identification of local design aspects	*List any design measures with local relevance that have been implemented:* – *Aspects x* – *Aspects y* – *Aspects z*

Part 2 - End of life scenario selection

Default scenario used?	*Yes/no*
Scenario source	*Append description and data for the scenario*

Part 3 - Ease of disassembly reporting

Building part	***Design aspects checked/implemented***	
	Ease of disassembly aspect	***Description of design solution(s)***
See table 2.2.5 listing	*Aspect x*	

Part 4 - Ease of reuse reporting

Building part	***Design aspects checked/implemented***	
	Ease of reuse aspect	***Description of design solution(s)***
See table 2.2.5 listing	*Aspect y*	

[37] European Commission, *Resource efficient use of mixed wastes - Task 1 Member State factsheets*, http://ec.europa.eu/environment/waste/studies/mixed_waste.htm

[38] EeEBGuide Project, C-03 (Buildings) / C-08 (Products) LCA modelling of landfill/disposal, http://www.eebguide.eu/?p=2197

Part 5 - Ease of recycling

Building part	***Design aspects checked/implemented***	
	Ease of recycling aspect	***Description of design solution(s)***
See table 2.2.5 listing	*Aspect z*	

Part 6 – Building material bank passport [39]

Has a building material bank passport been developed?	*Yes/no*

[39] For more background on building material bank passports can be found under indicator 2.3, Level 3, Aspect 3

2.2.3 Specific rules for analysing scenarios using life cycle GWP or cradle to cradle LCA (Level 3)

If life cycle GWP or LCA results are to be reported in the public domain, it is necessary to ensure that the scenarios are modelled in a consistent way. To do so, and to maximise their value as a design optimisation tool, it is recommended that the following steps are followed during the concept design stage:

1. Reference assumptions and baseline scenario: The initial assumptions made about the parameters of the building shall be set out (e.g. internal floor layouts and level of flexibility). This shall inform a description of the baseline scenario.
2. Scenario definition: Hypothetical scenarios related to the design aspect (e.g. for adaptability, possible future trends in the property market) shall be developed and described based on expert judgement. These should generally include a worst, intended and best case. The intended case shall be based on the client's specifications and represent the baseline scenario.
3. Design aspects and measures based on precedents: Identify design measures that, based on the worst, intended and best case scenarios, could be incorporated into the building design. These could include precedents from other building designs (as appropriate for the scenario).
4. Cost and value engineering of measures: Based on the design measures identified in the previous step 3, and working within constraints of the project, one or more preferred design options can be developed.
5. Modelling of the design option(s): Life cycle GWP or LCA tools shall be used to model each of the resulting design options in order to identify the optimal environmental solution and/or the preferred option to be constructed. This shall include a design that reflects the baseline scenario, omitting the design measures identified in the previous step 3.
6. Reporting of the results: The life cycle GWP or LCA results for the worst case, intended case and the preferred option shall be reported on.

These steps imply the input of relevant experts – cost consultants, market specialists and demolition specialists - in order to ensure that the scenarios are realistic. Further notes are provided under each scenario.

Table 2.2.6 Overall rules for how the scenario tools shall be used

Scenario tools	**Level 1.** **Common performance assessment**	**Level 2.** **Comparative performance assessment**	**Level 3.** **Performance optimisation assessment**
Scenario tool 1 **Building and elemental service life planning**	No specific rules are provided for each Level. Service lifespan estimates shall be reported for the buildings main elements, with reference to ISO 15686-8, relevant building codes and EN/ISO standards (see the reporting format in section 2.2.2.1). *See section 1.4.3 for default building element service lifespans*		
Scenario 2 **Design for adaptability and refurbishment**	○ From the checklist provided in section 2.2.2.2, identify those aspects that have been implemented. ○ For each aspect, describe the specific design measures that have been implemented (see the reporting format in section 2.2.2.2). ○ Make a check of the relevance of the design measures using a property market expert with local knowledge.	○ Identification of which semi-qualitative assessment tool has been used to obtain a score for the building. ○ Reporting of the score obtained for the building's adaptability using the chosen semi-qualitative assessment tool. ○ Identify from the Level 1 checklists those aspects that have been implemented.	○ Reporting of the GWP or LCA results for – the baseline/reference building with default service life and without adaptability design measures. – the preferred design scenario with adaptability measures. ○ The design scenario shall be selected with reference to those aspects listed in the Level 1 checklist. ○ Critical review of the geographical representativeness of the preferred design measures by a property market expert with local knowledge.
Scenario 3 **Design for deconstruction, reuse and recyclability**	○ Identify, from the checklist provided in 2.2.2.3, those aspects addressed. ○ For each aspect, describe the specific design measures that have been implemented (see the reporting format in section 2.2.2.3).	○ Identification of which semi-qualitative tool has been used. ○ Reporting of the score obtained for the building's deconstruction potential using the chosen semi-qualitative assessment tool. ○ Identify from the Level 1 checklist those	○ Reporting of the GWP or LCA results for – the default end of life scenario. – the design scenarios modelled. ○ The design scenario shall be selected with reference to those aspects listed in the Level 1 checklist.

		aspects that have been implemented.	○ Critical review of the geographical representativeness of the preferred design by a demolition contractor or waste management specialist.

2.2.4 Property valuation influence and reliability rating

The scenarios can provide information and special assumptions to investors and valuers about the potential future robustness of the building design and structure to be adapted to market needs, as well as the potential to minimise future risks and liabilities that can arise from the failure or deterioration of building elements.

The following tools are provided to inform the valuation of a property for which performance has been assessed according to life cycle scenarios 1, 2 and 3:

- Checklists for the potential positive influence on value and risk
  - Checklist 1: Potential positive influence on future performance
  - Checklist 2: Accounting for the performance assessment in valuation criteria
- Reliability ratings of the performance assessment
  - Rating 1: Basis for the performance assessment
  - Rating 2: Professional capabilities
  - Rating 3: Independent verification

The completed reporting may be used separately alongside the Level 1, 2 or 3 results for scenario 2.2, or may form part of the overall reporting for indicator 6.2.

In the case that the ratings will be used as part of the overall reporting for indicator 6.2, then the rating 1 results shall be used to calculate the overall Indicator Reliability Index (IRI).

The Indicator Reliability Index (IRI) for rating 1 shall be calculated from the individual ratings as follows:

$$\text{IRI} = \frac{(TeR\ min\{rating\ aspects\})+(GR\ min\{rating\ aspects\})+\ (TR\ \min\{rating\ aspect\})}{3}$$

Where:

TeR = Technical Representativeness

GR = Geographical Representativeness

TR = Time representativeness

To calculate the IRI the score for each of the three scenarios shall be used to calculate the arithmetic mean of the reliability.

2.2.3.1 The potential for a positive influence on a market valuation

Checklist 1 – Evaluation of potentially positive influences on the market performance *(to be completed for each scenario)*

Potential influence	***Evaluated?***	***Resulting assumptions used in the appraisal***
Potential influence 1 *Increased revenues due to market recognition and lower voids*	*Yes/no*	
Potential influence 2 *Reduced operational, maintenance, repair and/or replacement costs*	*Yes/no*	
Potential influence 3 *Reduced future risk of increased overheads or loss of income*	*Yes/no*	

Checklist 2 – Accounting for the Level(s) assessment in the valuation criteria used

Valuation criteria set used	*Identify the scheme or tool used*
Version of the criteria set used	

Criteria which the assessment has influenced		**Influence on the valuation or rating**
Valuation criterion	**Sub-criterion**	
Criterion x	Sub-criterion y	Notes on the extent of the influence and the supporting assumptions used

2.2.3.2 Reliability rating of the performance assessment

Rating 1 - Basis for the performance assessment

Rating aspect	**Brief description of the aspect**	**Rating score (select based on the assessment level used for the scenario)**			
		0	**1**	**2**	**3**
Scenario 1 Building and elemental service life planning	Estimating the design service life of the building as a whole and the service lifespan of the major building elements				
Scenario 2 Design for adaptability and refurbishment	How the building's design can facilitate future adaptation to changing occupier needs and market conditions				
Scenario 3 Design for deconstruction, reuse and recyclability	The potential for deconstruction to facilitate the reuse and recycling major building elements				

Scenario tools 2.2 Indicator Reliability Rating	

Rating 2 – Professional capabilities

Rating aspect	Rating score			
	0	**1**	**2**	**3**
2. Technical capability of the personnel carrying out the assessment	*No formal training and limited experience in using the tool or calculation method*	*Formal training or some applied experience in using the tool or calculation method*	*Formal training and some applied experience in using the tool or calculation method*	*Formal training*[40] *and significant applied experience in using the tool or calculation method*

Rating 3 – Independent verification

Rating aspect	Rating score			
	0	**1**	**2**	**3**
3. Independent verification of the assessment	*Self-declaration of the performance assessment results*	*Peer review of the input data and calculation steps*	*Third party auditing and verification of the calculation steps*	*Third party auditing and verification of the input data and calculation steps*

[40] In accordance with Article 17 of the EPBD

2.3 Indicator on construction and demolition waste

2.3 Construction and demolition waste and materials	**Where to find the guidance for each Level**
	Level 1 common performance assessment
	Level 2 comparative performance assessment
	Level 3 performance optimisation assessment
	Valuation influence and reliability rating (all levels)

This indicator can be used to estimate and track performance for a number of different waste management processes during a project. The methodology to be followed for distinct processes is described in this section.

The boundary for calculation and reporting will depend on the point in the project and its life cycle at which the waste arises. Table 2.3.1 provides an overview of the different project processes and the related life cycle stages.

Table 2.3.1 Boundary for reporting at different points in the project and its life cycle

Project related processes	**Life cycle stages**
Deconstruction and demolition of a building(s) in order to clear a site for a new building construction	To avoid double counting, the impacts associated with these modules shall belong to the previous building's life cycle. – waste generated on-site during module B5 or C1, – subsequent materials recovery in Module C3 and disposal during C4.
Part deconstruction/remodelling of a building(s) in order to prepare useful parts for in-situ reuse	
Preparation of a building in order to facilitate a major renovation (as part of a previous life cycle).	
Construction on site of a new building or major renovation works	– all waste generated on-site during modules A5, – the prefabrication of parts and elements off site (life cycle stages A3).
Deconstruction and demolition of the building at a future point in time beyond the end of its service life (life cycle stages C1/3, D).	– waste generated on-site during module C1, – subsequent materials recovery in Module C3 and disposal during C4.

2.3.1 Level 1 - Making a common performance assessment

2.3.1.1 Calculation methodology and data requirements

In this section the different waste management processes are dealt with in turn, as well as data requirements and potential sources.

Deconstruction and demolition processes

For estimates of waste and materials that may arise from deconstruction processes, the reporting shall be based on an analysis of the bill of materials and quantities for the building in question:

- For an existing building, this shall be based on the carrying out of a pre-deconstruction/demolition audit (see guidance note 2.6). This shall identify which specific parts and elements can be recovered, as well as identifying any health and safety risks that may relate to specific types of structures or the presence of hazardous waste.
- For a new building design, this shall be based on analysis of the bill of materials and quantities at the design stage, with the results supported by the use of scenario tool 2.2.3 Design for deconstruction, reuse and recycling.

Upon deconstruction/demolition, a weighing, monitoring and tracking system shall be set up to record the weight of each waste and material processing batch and consignment. The data shall thereafter be aggregated and reported on upon completion of the works.

Construction processes

For estimates of waste and materials arising from construction processes (both on and off site), the reporting shall be based on an analysis of the design bills of quantities and materials. Estimates shall be based on the way that elements and materials will be delivered to the site. The scope shall include packaging from construction products, raw materials and application products used on site.

The estimates for reuse and recycling of these waste arisings shall be supported by a site waste management plan that describes the segregation systems that will be used for different material flows (see guidance note 2.7).

Upon commencement of construction, a weighing, monitoring and tracking system shall be set up to record the weight of each waste and material batch and consignment. This data shall be aggregated and reported on upon completion of the building.

Data requirements and sources

Estimates of building element mass in a building to be demolished shall be made using available yardsticks and guidelines. The European Commission has published a guide to carrying out pre-demolition audits. This provides some general guidelines on the process, as well as a set of templates for recording the associated inventory of building elements and materials[41]. Figure 2.3.1 illustrates the general scheme for carrying out a pre-demolition waste audit which is described in the guidelines.

[41] European Commission (2017) Waste audit guideline, prepared for DG GROW by VTT, Tecnalia and RPA, https://ec.europa.eu/docsroom/documents/24562/attachments/1/translations/

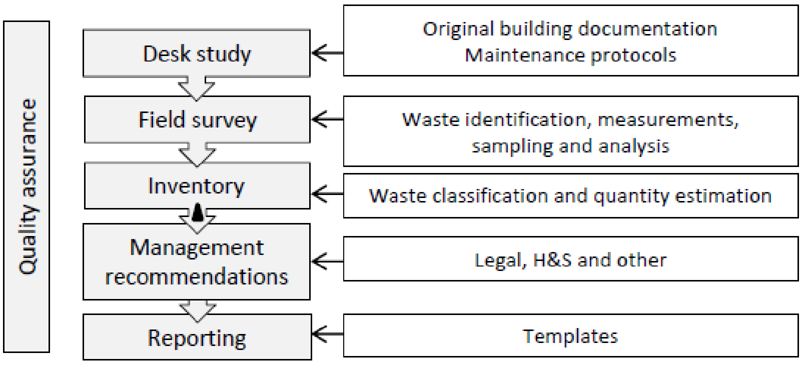


Figure 2.3.1 General scheme for conducting a pre-demolition waste audit

Source: European Commission (2017)

The packaging associated with construction products and materials shall be similarly estimated based on representative data sources.

Wherever possible, estimates of diversion rates should be based on data that is representative of the on-site and off-site waste processing operations that are to be used – for example, the crushing and grading of concrete waste. Actual diversion rates for waste and materials processed off site may be further validated with data from transfer stations and waste management companies that have been used.

2.3.1.2 *Suggested reporting format*

Users shall complete the reporting for each point in the project and life cycle that is relevant and for which data has been gathered.

Level 1, common performance assessment reporting format

Part 1 - Activity and waste sources being reported on

Deconstruction/demolition	Pre-estimate	Yes/no
	Actual from the site	Yes/no
	Module D estimate	Yes/no
Construction	Pre-estimate	Yes/no
	Actual from the site	Yes/no

Part 2 - Performance assessment results (for each activity identified in Part1)

Waste and material streams	**kg/m²**	**% of total mass flow**
Waste disposed of: – Hazardous – Non-hazardous		
Diversion for reuse and recycling		
Diversion for other material recovery operations (including backfilling and energy recovery)		

2.3.2 Making level 2 and 3 assessments

2.3.2.1 Level 2 - Making a comparative performance assessment

To support comparisons between projects, default figures shall be used for the following parameters:

- Mass estimations for the bill of materials of a building to be deconstructed/demolished prior to the construction of a new building,
- Estimates of the packaging likely to be discarded upon use of ready for construction products,
- Waste destinations and diversion rates for different materials in the EU, or at national or regional level.

Default values can be obtained from waste modelling tools that are designed to support the making of estimates. In all reported cases the source of the default figures shall be reported for the purpose of transparency and comparability.

Level 2, comparative performance assessment reporting format

Part 1 - Activity and waste sources being reported on

Deconstruction/demolition	Pre-estimate	Yes/no
	Actual from the site	Yes/no
	Module D estimate	Yes/no
Construction	Pre-estimate	Yes/no
	Actual from the site	Yes/no

Part 2 – Selected estimation tool (for each activity identified in Part1)

Default data aspect	**Estimation tool used**	**Version of the tool or standard used**
Demolition mass estimates		
Ready to use construction product packaging estimates		
Waste destination and diversion rates		
Other parameters *(please specify)*		

Part 3 - Performance assessment results (for each activity identified in Part1)

Waste and material streams	**kg/m²**	**% of total mass flow**
Waste disposed of: – Hazardous – Non-hazardous		
Diversion for reuse and recycling		

Diversion for other material recovery operations (including backfilling and energy recovery)		

2.3.2.2 Level 3 - Performance optimisation assessment

The design optimisation aspects for indicator 2.3 focus on those that can lead to a more precise estimate of waste arisings and the associated reuse and recycling potential, namely:

- ✓ Aspect 1 – The technical representativeness and precision of deconstruction/demolition waste estimates
- ✓ Aspect 2.1 – The technical representativeness and precision of construction site waste estimates
- ✓ Aspect 2.2 – The technical representativeness of off-site construction waste estimates
- ✓ Aspect 3 – Technical representativeness of the future deconstruction potential
- ✓ Aspect 4 – The precision of waste accounting on site

For each aspect a brief outline is provided of how they can improve performance, together with guidance notes which go into more detail.

Users should then report on which aspects they have focussed on. The more aspects addressed the better the reliability rating that will be obtained, as the rating improves in function of accuracy and representativeness.

Key aspects to focus attention on

Aspect 1 – The technical representativeness and precision of deconstruction/demolition waste estimates

Focus of attention: The carrying out of an audit of the target building(s) prior to strip-out, deconstruction and/or remodelling.

A pre-demolition/strip-out audit and plan allows for a more precise identification of the key building materials that will arise from demolition works. The typical information provided by such an audit comprises:

- Identification and risk assessment of hazardous waste that may require specialist handling and treatment, or hazardous emissions that may arise during demolition,
- A Demolition Bill of Quantities with a breakdown of different building materials and elements,
- An estimate of the % re-use and recycling potential based on proposals for systems of separate collection during the demolition process,
- An estimation of the % potential for other forms of recovery from the demolition process.

Guidance note 2.6 provides further details of auditing and planning tools that can support greater precision.

Guidance note 2.6 for demolition management

More about deconstruction and pre-demolition audits

A pre-demolition/strip-out audit and plan allows for identification of key building and materials that will arise from demolition and excavation works. From this information, the possibilities for reuse and recycling can be identified, although it is important to note that this will depend on the local market.

According to the European Commission's Construction & Demolition waste management protocol[42], an audit consists of two main parts:

- Information collection from the site: Identification of all waste materials that will be generated during the demolition with specification of the quantity, the quality and location in the building or civil infrastructure. All materials should be identified and the quantity to be recovered should be estimated.
- Determining handling and recovery routes:
  - which materials are mandatory to be separated at source and may require special handling or treatment (such as hazardous waste);
  - which materials or structures will require special equipment or techniques to deconstruct (such as tensioned structures);
  - which materials can/cannot be re-used or recycled based on the deconstruction processes and segregation/processing systems;

Figure 2.3.1 provided a general scheme for gathering this information using a combination of a desk study and a field survey.

Some of this information can then be collated in the form of a demolition Bill of Quantities, which will consist of an inventory of the different building materials and elements. Importantly, and as already highlighted, the audit will also take account of local markets for the building elements and materials that will arise and the technical and quality requirements for their reuse of recycling, as this can be a major market barrier.

As already noted in section 2.3.1.1, the European Commission has published a guide to carrying out pre-demolition audits[43]. Guidance on the preparation of audits is also provided in some Member States, such as Sweden[44]. Moreover, in some Member States such as Belgium the preparation of such a plan according to set procedures can be verified[45].

Following the audit, a deconstruction/demolition waste management plan can be developed, which will be used to organise and track subsequent activities on site.

An example of how this process can be managed is the Netherlands voluntary BRL SVMS-007 with its 'certified demolition process' steps[46].

[42] European Commission, *EU Construction & Demolition waste management protocol*, Compiled for the European Commission by Ecorys, September 2016.

[43] European Commission (2017) Waste audit guideline, prepared for DG GROW by VTT, Tecnalia and RPA, https://ec.europa.eu/docsroom/documents/24562/attachments/1/translations/

[44] Sveriges Byggindustrier (2016) *Resource and waste guidelines during construction and demolition* https://publikationer.sverigesbyggindustrier.se/Userfiles/Info/1094/160313_Guidelines.pdf

[45] Hiser Project, *TRACIMAT – Tracing Construction and Demolition Waste Materials*, http://hiserproject.eu/index.php/news/80-news/116-tracimat-tracing-construction-and-demolition-waste-materials

[46] The Netherlands, *Safe and Environmentally-friendly Demolition Directive (BRL SVMS-007)* http://www.veiligslopen.nl/en/brl+svms-007/steps+of+the+certified+demolition+process/

Aspect 2.1 – The technical representativeness and precision of construction site waste estimates

Focus of attention: The development of a plan to manage the flows of waste and materials, as well as associated costs that are estimated to arise from a site.

A site waste management plan is a tool for more precise planning, monitoring and implementing actions to manage waste during construction processes. Guidance note 2.7 describes further the planning process. Site waste management planning and tracking tools of the kind described further in the guidance note may be used to aid reporting, and will provide for more consistent recording of arisings.

Guidance note 2.7 for construction management

More about construction site waste management planning

A site waste management plan is a tool for planning, monitoring and implementing actions to manage waste during construction processes. Such a plan is usually prepared prior to the commencement of works on-site. A site waste management plan usually consists of:

- A bill of ordered materials with estimates for waste arisings and the potential for waste prevention based on good practice;
- Estimates of the % re-use potential based on the use of segregated collection systems during the construction process;
- An estimation of the % recycling and recovery potential (excluding backfilling) based on the use of segregated collection systems.

Such a plan can bring significant benefits in terms of economic savings and project efficiencies. This is because opportunities for the prevention of waste through better design, waste segregation, the recycling of waste produced and the re-use of materials on site can be identified more easily.

The European Commission's Construction & Demolition waste management protocol provides further general guidance[47]. The CIRIA Resource Efficiency KnowledgeBase provides detailed guidance related to both on-site and off-site practices under the 'waste minimisation' theme[48].

Aspect 2.2 – The technical representativeness of off-site construction waste estimates

Focus of attention: The accurate estimation of waste avoided both on-site and off-site based on data from fabricators.

As was noted in section 2.3.1.1, a reduction in site construction waste could lead to waste being created in a factory instead of on-site. In order to avoid burden shifting, comprehensive waste data should be obtained for any task that could have taken place

[47] European Commission, *EU Construction & Demolition waste management protocol*, Compiled for the European Commission by Ecorys, September 2016.
[48] Guidance formerly produced by the UK organisation WRAP can be accessed here following registration - http://www.ciria.org/Resources/REK/REK_Guidance.aspx

on-site and is shifted off-site to a factory (e.g. prefabricated wall panels or brick facings).

Aspect 3 – Technical representativeness of the future deconstruction potential

Focus of attention: The use of scenario tool 3 to make more realistic estimates of future material and elemental reuse and recycling potential. This can also form the basis for preparation of a 'building material bank passport'.

Scenarios for the potential future reuse or recycling of building elements and materials may have a high level of uncertainty. By improving the potential for the deconstruction, reuse and recyclability of a building at the design stage, and recording this information for future use in the form of a building material bank passport, this uncertainty can be reduced. Guidance note 2.8 provides further information on building material bank passports. A Building Information Model (BIM) also provides a way of storing this information alongside that held for other aspects of a building.

Assumptions relating to the ease of disassembly, reuse and recycling shall, in line with the guidance in the reference standard EN 15978, be based on solutions and technologies that have been proven to be economically and technically viable. In other words, they should be based on solutions and technologies that are currently available.

Guidance note 2.8 for construction management

Using building material bank passports to improve future deconstruction potential

A 'building material bank passport' is a relatively new concept which can support future reuse and recycling. It entails the recording of information about the building material bank (the elements and materials it is composed of) for future use and the design measures taken to facilitate ease of deconstruction to recover their value. The passport may also include important information to safely manage demolition processes – for example, where in the building tensioned structures have been used.

Passport formats are currently being developed by EU projects such as Buildings as Material Banks (BAMB) and organisations such as Madaster (the Netherlands).

http://www.bamb2020.eu/topics/materials-passports/

Aspect 4 – The precision of waste accounting on site

Focus of attention: The accurate tracking and accounting of waste arisings from demolition and construction sites.

The EU Construction & Waste management protocol identifies the need to strengthen record keeping and traceability mechanisms through the establishment of electronic registries. These records should be based on the actual weight of waste and material consignments. This data can be aggregated for reporting during and upon completion of the works.

The use of a tracking tool can facilitate more accurate and timely reporting as well as facilitating the later verification of the data. Guidance note 2.9 provides more details on tracking tools that can be used.

Guidance note 2.9 for construction management

More about waste monitoring and tracking systems

Site waste management planning and tracking tools may be used to aid reporting, and will provide for more consistent recording of waste arisings. They can also play an important role in providing confidence in the quality of segregated waste materials, by providing verification of segregation processes and the quality of the resulting recyclates.

Electronic tracking and verification tools such as Investigo (France)[49] , Tracimat (Belgium)[50] and SMARTwaste (UK)[51] provide a convenient way of recording, monitoring and reporting on waste management. Tools used shall use the European List of Waste in order to ensure the compatibility of reported data across the European Union[52].

Level 3 performance optimisation reporting format

Part 1 - Activity and waste source sources being reported on

Deconstruction/demolition	Pre-estimate	Yes/no
	Actual from the site	Yes/no
	Module D estimate	Yes/no
Construction	Pre-estimate	Yes/no
	Actual from the site	Yes/no

Part 2 - Performance assessment results (based on activities in Part 1)

Project stage	**Waste and material streams**	**kg/m²**	**% mass flow**
Select and report for each relevant process prior to construction taking place on site: – Deconstruction and demolition: site clearance – Part deconstruction/remodelling of a building(s) to facilitate in-situ reuse of the structure – Preparatory works prior to a major renovation	Waste disposed of: – Hazardous – Non-hazardous		
	Components for re-use		
	Materials for recycling		
	Other material recovery operations *(including backfilling and energy recovery)*		

49 Syndicat National des Entreprises de Démolition, *Investigo*, http://www.ivestigo.fr/

50 Hiser Project, *TRACIMAT – Tracing Construction and Demolition Waste Materials*, http://hiserproject.eu/index.php/news/80-news/116-tracimat-tracing-construction-and-demolition-waste-materials

51 BRE, *SMARTWaste*, http://www.smartwaste.co.uk/

52 Commission Decision 2000/532/EC on the European List of Waste, http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32000D0532

Construction on site: new building or major renovation works	Waste disposed of from the site: – Hazardous – Non-hazardous		
	Waste disposed of from offsite processes: – Hazardous – Non-hazardous		
	Components for re-use		
	Materials for recycling		
	Other material recovery operations *(including backfilling and energy recovery)*		
Deconstruction and demolition: *future scenario at end of life*	Waste disposed of: – Hazardous – Non-hazardous		
	Components for re-use		
	Materials for recycling		
	Other material recovery operations *(including backfilling and energy recovery)*		

Part 3 - Optimisation aspects addressed

Aspect	**Addressed? (yes/no)**	**Notes on data sources and calculation method**
Aspect 1 – Deconstruction/demolition waste technical representativeness and precision		
Aspect 2.1 – Construction site waste technical representativeness and precision		
Aspect 2.2 – Off-site construction technical representativeness		
Aspect 3 –Future deconstruction (Module D) technical representativeness		
Aspect 4 – Waste accounting precision		

2.3.3 Property valuation influence and reliability rating

The following tools are provided to inform the valuation of a property for which performance has been assessed according to indicator 2.3:

- Checklists for the potentially positive influence on value and risk
  - Checklist 1: Potentially positive influence on future performance
  - Checklist 2: Accounting for the performance assessment in valuation criteria
- Ratings of the reliability of performance assessment
  - Rating 1: Basis for the performance assessment
  - Rating 2: Professional capabilities
  - Rating 3: Independent verification

The completed reporting may be used separately alongside the Level 1, 2 or 3 results for indicator 2.3, or may form part of the overall reporting for indicator 6.2.

In the case that the ratings will be used as part of the overall reporting for indicator 6.2, then the rating 1 results shall be used to calculate the overall Indicator Reliability Index (IRI).

The Indicator Reliability Index (IRI) for rating 1 shall be calculated from the individual ratings as follows:

$$\text{IRI} = \frac{(TeR\ min\{rating\ aspects\})+(GR\ min\{rating\ aspects\})+(TR\ \min\{rating\ aspect\})}{3}$$

Where:

TeR = Technical Representativeness

GR = Geographical Representativeness

TR = Time representativeness

To calculate the IRI the lowest score for each of the three types of rating aspect shall be used to calculate arithmetic mean of the reliability.

2.3.3.1 The potential for a positive influence on a market valuation

Checklist 1 – Evaluation of potentially positive influences on the market performance

Potential influence	***Evaluated?***	***Resulting assumptions used in the appraisal***
Potential influence 1 *Increased revenues due to market recognition and lower voids*	*Yes/no*	
Potential influence 2 *Reduced operational, maintenance, repair and/or replacement costs*	*Yes/no*	
Potential influence 3 *Reduced future risk of increased overheads or loss of income*	*Yes/no*	

Checklist 2 – Accounting for the Level(s) assessment in the valuation criteria used

Valuation criteria set used	*Identify the scheme or tool used*
Version of the criteria set used	

Criteria which the assessment has influenced		Influence on the valuation or rating
Valuation criterion	**Sub-criterion**	
Criterion x	Sub-criterion y	Notes on the extent of the influence and the supporting assumptions used

2.3.3.2 Reliability rating of the performance assessment

Rating 1 - Basis for the performance assessment

Rating aspect	Brief description of the aspect	Rating score (reflecting the degree of representativeness)			
		0	**1 Low**	**2 Medium**	**3 High**
1. Technical representativeness of the deconstruction and demolition waste estimates	Reflecting the audited potential for deconstruction on site (present scenario)				
2.1 Technical representativeness of the on-site construction waste estimates	Reflecting the actual potential for diversion of construction waste on site				
2.2 Technical representativeness of the off-site construction waste estimates	Reflecting the actual potential for waste avoidance both on and off site.				
2.1 Technical representativeness of the future deconstruction potential	Reflecting the evaluated design potential for deconstruction on site (future scenario)				
2.2 Precision of the waste accounting on site	The accuracy of tracking and accounting systems for actual waste arisings.				

Indicator 2.3 **Indicator Reliability Rating**	

Rating 2 – Professional capabilities

Rating aspect	Rating score			
	0	**1**	**2**	**3**
2. Technical capability of the personnel carrying out the assessment	*No formal training and limited experience in using the calculation method*	*Formal training or some applied experience in using the calculation method*	*Formal training and some applied experience in using the calculation method*	*Formal training and significant applied experience in using the calculation method*

Rating 3 – Independent verification

Rating aspect	Rating score			
	0	**1**	**2**	**3**
3. Independent verification of the assessment	*Self-declaration of the performance assessment results*	*Peer review of the input data and calculation steps*	*Third party auditing and verification of the calculation steps*	*Third party auditing and verification of the input data and calculation steps*

Macro-objective 3: Efficient use of water resources

Key terms and definitions used

Blackwater	Waste water containing faecal matter or urine (e.g. from toilets and urinals).
Freshwater	Water having a low concentration of dissolved solids.
Greywater	Waste water not containing faecal matter or urine (EN 12056-1) (e.g. from sinks, showers, baths, washing machines and dishwashers).
Groundwater	Water which is being held in, and can be recovered from, an underground formation.
Operational water use	Water use of the building-integrated technical systems and of the user, as needed for the technically and functionally defined operation of the building.
Potable water	Water that is safe to drink or to use for food preparation, without risk of health problems.
Rainwater harvesting	The collection, accumulation, treatment or purification, and storing of water resulting from natural precipitation that has not been deliberately contaminated.
Water Exploitation Index (WEI)	The mean annual total abstraction of fresh water divided by the long-term average freshwater resources. It describes how the total water abstraction puts pressure on water resources.
Water withdrawal (or abstraction)	Anthropogenic removal of water from any water body or from any drainage basin, either permanently or temporarily.

3.1 Indicator of use stage water consumption

3.1 Use stage water consumption	**Where to find the guidance for each Level** Level 1 common performance assessment Level 2 comparative performance assessment Level 3 performance optimisation assessment Valuation influence and reliability rating (all levels)

3.1.1 Level 1 - Making a common performance assessment

3.1.1.1 Calculation methodology and data requirements

The generic calculation tool

The generic calculation method and accompanying tool to be used for performance assessments has been developed based on the current approaches to water consumption estimates in the EU. The calculation can be carried out using a dedicated excel spreadsheet tool, which is provided separately for users of Level(s).

Results are generated on a per occupant basis at both a daily and an annual level. When converting daily data to annual data, it is necessary to state how many days the building will be used in the year.

For normalising cleaning or irrigation water consumption, it is necessary to know how many people (full-time equivalents) will be using the building.

Guidance note 3.1 provides an overview of how the generic calculation tool should be used at each assessment level.

> ***Guidance note 3.1 for design teams***
>
> **Options for ensuring the consistency of water performance assessments with the generic calculation methodology provided**
>
> The spreadsheet tool provided has the following options, which can be used for different purposes:
>
> - ✓ Level 1: The Common performance assessment - a focus on the common sanitary devices/fittings and water consuming appliances for a particular building with flexibility for users to define usage factors (i.e. how many minutes a person is in the shower per day etc.) and occupancy rates (i.e. how many days per year the building is occupied) in order to be able to adapt to different assumptions used in different tools and regions.
> - ✓ Level 2: Comparative performance assessment - the same focus as for Option 1 except that usage factors and the occupation rate are fixed in the methodology in order to allow for a truer comparison of estimated inherent water efficiency of the sanitary devices/fittings in different buildings.
> - ✓ Level 3: Performance optimisation assessment - Demonstrating reductions in estimated water demand based on defined baseline scenarios and decisions that can make estimates more representative and precise at the design stage for a particular building.

Using the calculation tool

Step 1. Choice of scope, consumption rates, usage factors and occupancy rate

The user should identify which sanitary devices/fittings and water using appliances are to be included and if irrigation or cleaning is applicable. Default consumption rates for different sanitary devices and fittings are provided but may be replaced by specific data from suppliers. Default usage factors are also provided and these too may be replaced by specific usage factors chosen by the user if reporting under level 1 or level 3.

The number of days that the building is expected to be occupied per year is to be defined by the user too (except in level 2). Cleaning and irrigation are independent of the number of people using the building. When included in the scope, it will therefore be necessary for users to also define the average full time person equivalents in order to convert cleaning and irrigation water consumption into a per occupant per day value.

The principle of the per occupant water consumption calculation for taps and showers is as follows:

$$Total\ consumption\ \left(\frac{L}{occupant.d}\right) = \ Consumption\ rate\ \left(\frac{L}{min}\right) x\ Usage\ factor\ \left(\frac{min}{occupant.d}\right)$$

$$Total\ consumption\ \left(\frac{m^3}{ocucpant.year}\right) = Total\ consumption\ \left(\frac{L}{occupant.d}\right) x\ 0.001 \left(\frac{m^3}{L}\right) x\ occupancy\ rate\ \left(\frac{d}{year}\right)$$

The exact same principle applies for calculations for toilets (except that flushes are used instead of minutes) and for dishwashers and washing machines (except that cycles are used instead of minutes).

However, as stated above, for water consumption due to cleaning and irrigation, the principle of the calculation is different because this is essentially independent of the number of people using the building. For cleaning, the basis of the calculation is as follows:

$$Total\ consumption\ \left(\frac{L}{year}\right) = \ Consumption\ rate\ \left(\frac{L}{m^2}\right) x\ area\ (m^2)\ x\ no.cleans\ per\ year\ (year^{-1})$$

$$Total\ consumption\ \left(\frac{m3}{occupant.year}\right) = Total\ consumption\ \left(\frac{L}{year}\right) x\ 0.001 \left(\frac{m^3}{L}\right) \div\ full\ time\ eqivt.ocucpancy\ (occupant)$$

The same principle applies to the calculation for irrigation but there are a number of other factors that need to be considered and steps taken which are explained in the spreadsheet tool and summarised in guidance note 3.2.

Step 2. Contextualising the relative importance of water efficiency

Although water efficiency is important everywhere, it is even more important in areas of water stress. Figure 3.1.1 illustrates how a significant proportion of European river basins in the EU are considered, according to their summer Water Exploitation Index (WEI+), to be either under 'seasonal water stress' or 'severe seasonal water stress'. Guidance note 3.2 provides more background on the WEI+.

For all reporting options, users should therefore select from the dropdown menus on the spreadsheet tool which river basin the building will be located in. This will automatically generate a multiannual (2002-2014) average summer WEI+.

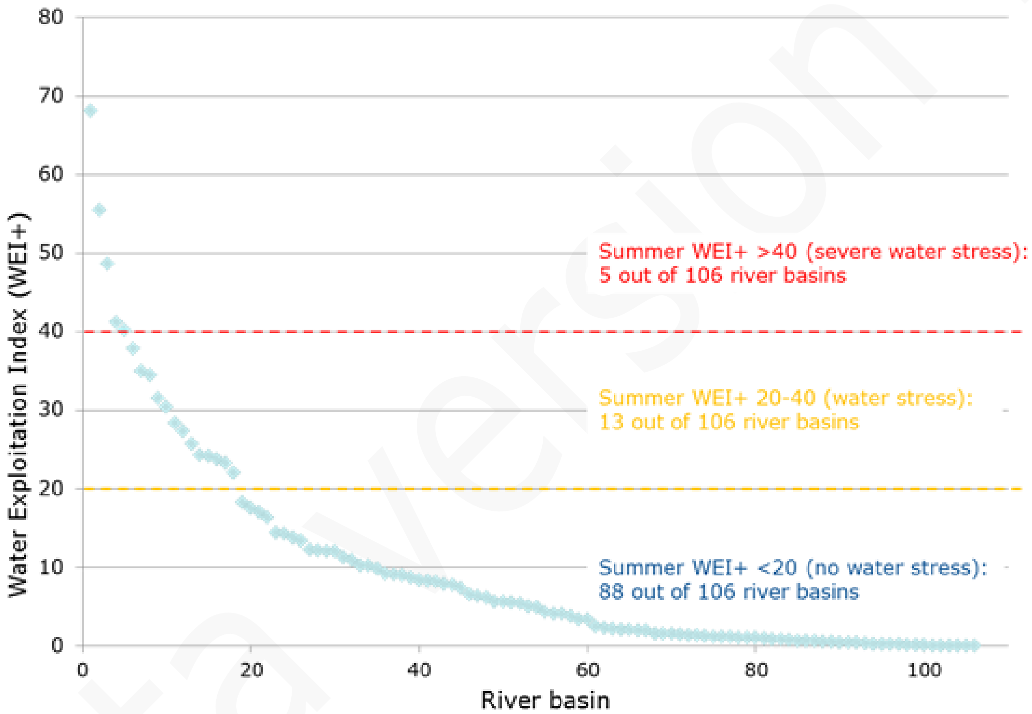


Figure 3.1.1 Plot of summer WEI+ values for EU river basins against commonly accepted levels of water stress and severe water stress

Source: European Environment Agency (2016)

Regardless of whether water consumption is estimated by level 1, 2 or 3 assessments, there is the option to divide water consumption into potable and non-potable water. Buildings located in river basins with a summer WEI+ of >20% must report consumption this way, even if no rainwater harvesting or greywater reuse is carried out.

Guidance note 3.2 for design teams

What is the 'Water Exploitation Index' (WEI+)?

The WEI+ value indicates the relative importance of water efficiency measures and applies equally to all reporting options. The higher the WEI+ value, the greater the water stress in the river basin. As a general rule, WEI+ values exceeding 20% are considered as areas under water stress and values exceeding 40% are considered as areas under severe water stress.

WEI+ is defined by the European Environment Agency using the following equation:

$$WEI+ = \frac{mean\ freshwater\ abstractions - mean\ freshwater\ returns}{mean\ renewable\ freshwater\ resources} \times 100\%$$

The WEI+ should be calculated at the river basin level as per the provisions of the Water Framework Directive (2000/60/EC). If available, data at the sub-basin level may optionally be reported.

The WEI+ is a dynamic number and will change over defined time periods and especially through the seasons. For this reason, a single WEI+ value is generated for each river basin based on summer data (i.e. July, August and September) averaged over 12 summers (2002-2014). This ensures that the values are not skewed by exceptional data for one or two years and that the values do not change depending on when the assessment was made.

Data requirements and sources

An outline of the data requirement needs is presented in table 3.1.1. Default values may be used, but users of the Level(s) framework are encouraged to collect data from manufacturers in order to make the estimates more representative.

Table 3.1.1 Data requirements in order to estimate water consumption

Data requirement	**Potential sources of data**
Specific water consumption values of devices and fittings (e.g. toilets, urinals, taps and showers)	Manufacturers, suppliers and labelling schemes (e.g. the European Water Label).
Specific water consumption values for appliances (i.e. dishwashers and washing machines)	Manufacturers, suppliers and labelling schemes (e.g. Energy Star, EU Energy Label, ANQUIP, BMA).
River basin evapotranspiration, soil moisture, surface runoff, deep percolation and rainfall flows and contents	European Environment Agency (Waterbase, ECRINS – European Catchments and Rivers Network System), Eurostat & LISFLOOD (JRC)
Water abstractions, returns and Water Exploitation Index	
Water demand co-efficient of plants to be planted	*VERDE building assessment scheme and "Manual de riego de jardines" by the Andalucian autonomous community*
Efficiency of irrigation distribution system	*Manufacturers and supply chain, VERDE building assessment scheme.*
Grey water / rainwater system efficiencies	Building regulations, BS8525 (UK), suppliers

3.1.1.2 *Suggested reporting format*

The indicator is to be reported via calculations at the *design stage* and can optionally be monitored and reported on in real time during the *use stage* of the building lifecycle. Actual water consumption shall be based on data collected starting from the point when the building can first be considered to be fully occupied to ensure that consumption patterns will be more predictable. Reporting on meter readings of actual consumption should be based on data from at least 12 consecutive months and ideally be averaged over at least 3 years.

The headline indicator must be reported although the spreadsheet tool provides the option to disaggregate this into different components (i.e. individual components like toilets, or aggregated components, i.e. bathroom or kitchen). The total value or the sub-totals can be split into potable and non-potable water use.

Level 1 Common performance reporting format

Part 1 - Performance assessment report

Sanitary fittings and devices (e.g. toilets, urinals, taps, baths and showers).	____m³/o/a
Water using appliances (e.g. dishwashers and washing machines).	____m³/o/a
Total water consumption	____m³/o/a

Part 2 - Optional reporting (mandatory in areas of water stress (i.e. WEI+ >20%)

Water Exploitation Index for location (summer multi-annual)	____%
Total potable water consumption	_____m³/o/a
Total non-potable water consumption	_____m³/o/a

3.1.1.3 *Monitoring of design and actual occupied performance*

Actual water consumption can be monitored via meter readings. For health and safety reasons, any use of harvested rainwater or greywater must run via separate tanks and pipework and so a separate metering system can easily be installed to quantify the use of non-potable water. When appropriate metering is in place, the ratio of potable to non-potable water use at the design stage can be compared to the same ratio for actual occupied performance.

When comparing design and actual occupied performance, users must be aware of the main potential sources of 'performance gaps', which may include:

- inaccurate estimates of the number of building users (occupants per day),
- actual occupation factors (i.e. days per year) differing from design estimates,
- inaccurate assumptions for some usage factors (especially the use of showers in office buildings),
- Significant other water uses not accounted for in the calculation (e.g. swimming pools, fountains and humidification systems) and
- possible leaks.

3.1.2 Making level 2 or 3 assessments

3.1.2.1 Level 2 - Making a comparative performance assessment

Data reporting and calculations for level 2 are the same as level 1 (the common metric) except that irrigation is excluded from the scope. This is because different climates would make building to building comparisons more difficult for irrigation water consumption.

The only other difference is that with level 2, the occupancy rates (days/year), number of full time equivalent building users (occupants/d) and usage factors (e.g. flushes/occupant/day) are fixed. Consequently, changes in numbers will only depend on the relative efficiencies of the sanitary fittings/devices and water using appliances, thus ensuring a better building to building comparability.

3.1.2.2 Level 3 - Design performance optimisation

Users who wish to demonstrate the effect of different design assumptions with the aim of improving the accuracy of estimated water consumption should use level 3. The calculation method is the same as level 1 but further flexibility is added for some aspects such as:

- Where multiple taps, showers and toilets of differing efficiencies are installed, the option to define if some will be used more frequently than others (based on their location and building use patterns) is provided.
- The option to calculate irrigation water consumption in line with intended irrigation protocols (i.e. days/year, minutes per day and L/min consumption rates) instead of simply estimating the minimum required irrigation water at a monthly time resolution is provided.
- The option to use more representative rainfall data (i.e. at sub-basin or site level) to better estimate rainwater harvesting potential is provided.
- The option to include other water consuming features of the building, such as swimming pools, fountains and HVAC if data is available is provided.

The effect of different design assumptions can be compared side by side in the spreadsheet tool for calculations under level 3. This may be important in decision making with clients about design features, or when attempting to market or value the water efficient features of the building.

Key aspects to focus attention on

The level 3 optimisation aspects for indicator 3.1 focus on how the estimated water consumption calculations can be made more representative of the water resources in the local area and how the building is to be used. The three main aspects are:

- ✓ Aspect 1. Technical and geographical representativeness of the estimated water fittings performance and use pattern
- ✓ Aspect 2. The technical and geographical representativeness of the irrigation water calculations
- ✓ Aspect 3. Technical opportunities to substitute fresh, potable water consumption

For each aspect a brief outline is provided of how they can improve performance, together with guidance notes which go into more detail.

Users should then report on which aspects they have focussed on. The more aspects addressed the better the reliability rating that will be obtained, as the rating improves in function of accuracy and representativeness.

Level 3 includes provision for the estimation of other water uses such as for irrigation, HVAC and building integrated systems. It also focusses attention on the potential use of alternative water treatment and supply systems based on rainwater or the reuse of grey water.

Aspect 1. The technical representativeness of the estimated water fittings performance and predicted use pattern

Focus of attention: Estimation of the buildings water use based on specifications for the fittings and predictions of the likely patterns of use and occupation of buildings.

In this option, the usage factors shall be tailored in order to represent both the actual fittings to be installed and the anticipated patterns and conditions of use for the building. The default specifications and consumption values listed in the spreadsheet tool can be used in this option as a baseline, and improvement from that baseline water consumption can be estimated by inputting specific data from suppliers of more efficient devices and fittings. This should always be done while keeping the tailored usage factors constant.

Additionally, adjustment factors are provided in the calculation tool that allow for the estimated performance to be adjusted in function of the average household consumption in that country or region. This allows for geographical and cultural variations in patterns of use to be taken into account at a generalised level.

Aspect 2. The technical representativeness of the opportunities to substitute fresh, potable water consumption

Focus of attention: In areas of water stress, additional measures can be taken to reduce the stress on fresh water resources by substituting with rainwater and/or grey water.

The capture and use of rainwater or the reuse of grey water can reduce estimated potable water consumption for low grade uses such as toilet flushing or irrigation. The total amount of substitute non-potable water supplied to the building shall be estimated, and from this data the percentage substitution of total potable water that would otherwise have had to be supplied shall be calculated and reported on.

For rainwater systems, it will be necessary to choose either the default or manufacturer specific yield co-efficient to account for any losses due to first flush diversion devices, filter efficiency and occasional tank overflows during heavy and prolonged rainfall periods. For grey water input calculations, the user simply has to select which flow (bathroom taps, shower, bath-tub and/or kitchen taps) will be diverted to the grey water system.

The Level(s) framework spreadsheet calculator tool enables estimates to be made of grey water and rain water flows based on a buildings location in Europe and potential grey water sources within a building. Guidance note 3.3 provides further details.

Guidance note 3.3 for design teams, asset and facilities managers

Estimating and monitoring the benefit of non-potable water systems

The calculation method in the spreadsheet tool links to rainfall data at the river basin level by default. If available, this default value can be substituted for more specific local data in level 3 reporting. The calculation assumes that all harvested rainwater or greywater is sent to a storage tank of adequate capacity and that 90% of the water entering the system remains available for reuse. Reuse can only permitted for flushing toilets or irrigation in the calculator.

In order to facilitate disaggregate reporting on potable and non-potable water upon occupation of the building, sub-metering would be required for low grade (non-potable) water supplied to a building. Specific local quality and hygiene standards may apply for low grade water supplies based on rain or grey water.

Aspect 3. The geographical representativeness of the irrigation water calculations

Focus of attention: Water consumption associated with the irrigation of green landscaping within the curtilage of the building.

Where a specific vegetated area within/around the building is defined and is to be irrigated, it shall be possible to explore how the choice of efficient irrigation systems, lower water demand plants and/or shading and windbreak features can reduce irrigation water requirements compared to a reference vegetated area sown with normal lawn grass.

The calculation method provided helps supporting design comparisons by providing reference evapotranspiration (ET) figures[53] for a given location and rainfall data to the river basin/sub-basin level. The main variables are the type of vegetation, water demand of plant species, micro-climate factors and irrigation system efficiency.

In order to make the results more comparable, all reference ET rates are chosen in a consistent way – that is based on data at the monthly time resolution and using multi-annual averages (2002-2014) reported by the European Environment Agency and that are linked to specific river basin or sub-basin catchments

Guidance note 3.4 for design teams

Basic principles of estimating irrigation water requirements

The following steps need to be followed to estimate the irrigation water needed using the calculation tool:

- ✓ The user must define the river basin in which the building is located (from a drop-down menu in the calculation spreadsheet). This will activate default data for actual evaporation rates and rainfall data from the EEA database.
- ✓ The user must then define the total vegetated area linked to the building.
- ✓ The total vegetated area should then be split by vegetation cover type (i.e. trees, bushes, climbing plants, mixed flowering plants or lawn grass).
- ✓ General water demand coefficients must then be chosen for each vegetation type (specific coefficients are also provided for around 850 different plant species as well, in case these details are known already).
- ✓ One of three micro-climate coefficients should then be chosen for each type of vegetation cover.
- ✓ Depending on the type of irrigation system to be installed, an efficiency factor needs to be specified.

Vegetation water demand will be generated on a monthly basis and compared to rainfall data for the same month. In months where rainfall exceeds vegetation needs, irrigation water consumption is assumed to be zero. In other months when vegetation water demand exceeds rainfall, the difference between the two values will be the estimated irrigation water consumption. The monthly values are then summed up to generate an annual irrigation water consumption value.

[54] The EU-LCI ratio for an individual compound in a mixture can be obtained by dividing its emission concentration by the corresponding EU-LCI value (Ci/LCIi).

Level 3 optimisation reporting format

Part 1 - Performance assessment report

Net potable water consumption	_____m^3/occupant/yr
Non-potable water consumption	_____m^3/occupant/yr
Potable water substitution rate	_____%

Part 2 – Breakdown of performance by operational water uses and water grade

Operational water uses	**Total for each use (m^3/occupant per year)**	**Water use by grade**	
		Potable water use (m^3/occupant per year)	**Non-potable water use (m^3/occupant per year)**
Sanitary fittings and devices (e.g. toilets, urinals, taps, baths and showers).			
Water using appliances (e.g. dishwashers and washing machines).			
Cleaning of floors and windows (office buildings only)			
Irrigation			
Total			

Part 3 - Optimisation aspects addressed

Aspect	**Addressed? (yes/no)**	**Notes on data sources and calculation method**
Aspect 1 – Technical representativeness of water fittings estimated performance and use pattern		
Aspect 2 – Technical representativeness of opportunities to substitute fresh, potable water consumption		
Aspect 3 – Irrigation water geographical representativeness		

3.1.3 Property valuation influence and reliability rating

The following tools are provided to inform the valuation of a property for which performance has been assessed according to indicator 3.1:

- Checklists for the potentially positive influence on value and risk
  - Checklist 1: Potential positive influence on future performance
  - Checklist 2: Accounting for the performance assessment in valuation criteria
- Ratings of the performance assessment
  - Rating 1: Basis for the performance assessment
  - Rating 2: Professional capabilities
  - Rating 3: Independent verification

The completed reporting may be used separately alongside the Level 1, 2 or 3 results for indicator 3.1, or may form part of the overall reporting for indicator 6.2.

In the case that the ratings will be used as part of the overall reporting for indicator 6.2, then the rating 1 results shall be used to calculate the overall Indicator Reliability Index (IRI).

The Indicator Reliability Index (IRI) for rating 1 shall be calculated from the individual ratings as follows:

$$\text{IRI} = \frac{(TeR\ min\{rating\ aspects\})+(GR\ min\{rating\ aspects\})}{2}$$

Where:

TeR = Technical Representativeness

GR = Geographical Representativeness

To calculate the IRI the lowest score for each of the two types of rating aspect covered by indicator 3.1 shall be used to calculate arithmetic mean of the reliability.

2.3.3.1 The potential for a positive influence on a market valuation

Checklist 1 – Evaluation of potentially positive influences on the market performance

Potential influence	***Evaluated?***	***Resulting assumptions used in the appraisal***
Potential influence 1 *Increased revenues due to market recognition and lower void rates.*	*Yes/no*	
Potential influence 2 *Reduced operational, maintenance, repair and/or replacement costs.*	*Yes/no*	
Potential influence 3 *Reduced future risk of increased overheads or loss of income.*	*Yes/no*	

Checklist 2 – Accounting for the Level(s) assessment in the valuation criteria used

Valuation criteria set used	*Identify the scheme or tool used*
Version of the criteria set used	

Criteria which the assessment has influenced		Influence on the valuation or rating
Valuation criterion	**Sub-criterion**	
Criterion x	Sub-criterion y	Notes on the extent of the influence and the supporting assumptions used

2.3.3.2 Reliability rating of the performance assessment

Rating 1 - Basis for the performance assessment

Rating aspect	Brief description of the aspect	Rating score (reflecting the degree of representativeness)			
		0	**1** Low	**2** Medium	**3** High
1. Technical representativeness of water fittings estimated performance and use pattern	The extent to which the parameters used represent the actual fittings to be installed and the anticipated patterns and conditions of use for the building.				
2. Technical representativeness of the opportunities to substitute fresh, potable water consumption	Estimation of the potential to substitute potable water and to reduce the quantity of wastewater produced.				
3. Irrigation water geographical representativeness	Accurate estimation of irrigation water needs based on local climatic data.				

Indicator 3.1 **Indicator Reliability Rating**	

Rating 2 – Professional capabilities

Rating aspect	Rating score			
	0	**1**	**2**	**3**
2. Technical capability of the personnel carrying out the assessment	*No formal training and limited experience in using the calculation method*	*formal training or some applied experience in using the calculation method*	*Formal training and some applied experience in using the calculation method*	*Formal training and significant applied experience in using the calculation method*

Rating 3 – Independent verification

Rating aspect	Rating score			
	0	**1**	**2**	**3**
3. Independent verification of the assessment	*Self-declaration of the performance assessment results*	*Peer review of the input data and calculation steps*	*Third party auditing and verification of the calculation steps*	*Third party auditing and verification of the input data and calculation steps*

Macro-objective 4: Healthy and comfortable spaces

Key terms and definitions used

Adaptation	Physiological, psychological or behavioural adjustment of building occupants to the interior (and exterior) thermal environment in order to avoid discomfort.
Buildings without mechanical cooling	Buildings that rely on other techniques to reduce high indoor temperature during the cooling season like moderately-sized windows, adequate sun shielding, use of building mass, natural ventilation, night time ventilation etc. to prevent overheating.
Handover	Step at which possession of the construction works is surrendered to the client upon completion with or without reservation.
Lowest Concentration of Interest (LCI) value	Health-based values used to evaluate emissions after 28 days from a single product during a laboratory test chamber procedure (as defined in the Technical Specification, TS 16516 of the horizontal testing method developed by CEN TC 351/WG 2).
Mechanical cooling	Cooling of the indoor environment by mechanical means used to provide cooling of supply air, fan coil units, cooled surfaces etc.
Operative temperature	Uniform temperature of an imaginary black enclosure in which an occupant would exchange the same amount of heat by radiation and convection as in the actual non-uniform environment.
Predicted Mean Vote (PMV)	An index that predicts the mean value of the votes of a large group of persons on a 7 point thermal sensation scale based on the heat balance of the human body.
Predicted Percentage Dissatisfied (PPD)	An index that establishes a quantitative prediction of the percentage of thermally dissatisfied people (those who would vote hot, warm, cool or cold on the 7 point thermal scale) who feel too cool or warm.
Ventilation rate	Magnitude of outdoor air flow to a room or building either through the ventilation system or infiltration through the building envelope.

4.1 Indicator of indoor air quality

4.1 Indoor air quality	**Where to find the guidance for each Level** Level 1 common performance assessment Level 2 comparative performance assessment Level 3 performance optimisation assessment Valuation influence and reliability rating (all levels)

4.1.1 Level 1 - Making a common performance assessment

4.1.1.1 Calculation methodology, measurement and data collection

When you measure indoor air quality it requires consideration of performance at a number of different project stages. This is because of the complex cause and effect relationships for indoor air parameters, which require measurements that take account of:

- the performance of ventilation systems,
- how effective design strategies are in controlling humidity,
- the combined contribution of building product emissions, and
- the impact on indoor air quality of emissions from occupants and their choice of furniture and fit out materials.

The performance assessment is divided into activities that relate to different stages in a building project:

- At design stage based on simulation and product testing
- At post-completion stage based on in-situ testing
- At occupation based on in-situ testing and inspection

For each stage assessment activities are specified, together with reference standards.

Design stage 1: Simulation of the ventilation strategy

A design simulation of the building's ventilation strategy in accordance with EN 16798-7 shall be used to check the modelled performance of the ventilation rate, CO_2 levels and relative humidity levels. Specification of filters for intakes air shall be based on an assessment of the outdoor air pollution, in accordance with EN 13779. Data is therefore required from manufacturers for filter specifications.

According to Directive 2010/31/EU for the Energy Performance of buildings, a ventilation system is part of the technical building system. The simulation shall therefore always form part of the performance assessment for the typical use of a building as a whole.

Design stage 2: Use of product testing as a means of source control

Test results showing the emissions after 28 days shall be reported for each material or finish to be installed that falls within the identified scope. The determination of emissions shall be in conformance with CEN/TS 16516. Test data is therefore required from manufacturers/suppliers of the selected building products, as defined in the scope. All testing shall be on the as-finished product.

Further guidance for design teams on source control by product selection is provided in guidance note 4.1.

Guidance note 4.1 for designers

Selecting building materials to control pollutant emissions at source

The indoor environmental quality standards EN 15251 and prEN 16798 both highlight the importance of considering building materials as indoor sources of pollution. The EN 15251 and prEN 16978 scope and thresholds for emissions from building materials includes emissions of formaldehyde and carcinogenic VOCs, with prEN 16798 extending the scope to include LCI ratios[54].

A range of third party verified labelling schemes for the emissions from building materials and products have emerged during the last 20 years. These have had the objective of protecting building users and occupants from health hazards by encouraging (or requiring) source control strategies that control building material emissions. Schemes in Finland, Germany, Denmark, Belgium and France are of particular note.

Of the schemes available in the market, some have been developed as voluntary initiatives by industry or NGOs (e.g. in Germany GUT and EMICODE, in Finland M1, the Danish Indoor Climate Label), whilst some have been mandated by regulation (e.g. the French emissions classes system, the Belgian VOC Regulation, the German AgBB). Various Type I Ecolabels certify low emission products, including the EU Ecolabel, the Blue Angel (Germany) and the Nordic Swan.

The JRC has highlighted the significant reductions in material emissions that have been driven by such schemes [55]. The emissions from these products are (as estimated by a material testing laboratory) approximately one fifth of the level they were in the early 1990’s. Mature schemes now also provide access to many thousands of products, making them more accessible.

A harmonised European test method for emissions of volatile organic compounds from construction products into indoor air, CEN/TS 16516, was published in 2013. This established a common method and test conditions based on a 'European reference room' in which products are to be tested. Verification of low emissions according to the 28 day emissions test therefore now provides a consistent basis for the selection of products.

Design stage 3: Risk assessment to prevent mould

A risk assessment shall also be carried out on building designs. This shall focus on measures to control point sources of humidity and the avoidance of areas of cold bridging and air infiltration into the building envelope. The risk assessment shall be made in accordance with the following two standards:

- ISO 6946 calculation method for the thermal resistance and transmittance of building materials[56].
- ISO 13788 calculation method for the hygrothermal performance of building components and elements[57].

These standards provide a calculation method for critical surface humidity that may lead to mould growth on the internal surfaces of buildings. To carry out the

[54] The EU-LCI ratio for an individual compound in a mixture can be obtained by dividing its emission concentration by the corresponding EU-LCI value (Ci/LCIi).

[55] European Commission Joint Research Centre IHCP (2012) *Harmonisation Framework for Indoor Products Labelling Systems in EU*, European Collaborative Action: Urban air, indoor environment and human exposure, Report No. 27.

[56] ISO Standards, ISO 6946: *Building components and building elements - Thermal resistance and thermal transmittance - Calculation method*.

[57] ISO Standards, *ISO 13788: Hygrothermal performance of building components and building elements -- Internal surface temperature to avoid critical surface humidity and interstitial condensation -- Calculation methods*.

risk assessment data is required on the thermal characteristics of building products and architectural design details, with a specific focus on thermal transmission. The latter may require calculation to provide estimates or performance data may be provided at national level for accredited architectural details. This data can potentially be obtained from existing documents based on national calculation methods used to acquire a building permit and/or to issue an EPC.

Post-completion stage 1: Functional performance testing of ventilation systems

The ventilation rate shall be tested as part of the commissioning process on site according to the methods described in Annex D of EN 12599. The average ventilation rate shall be reported. Measurements can be taken at a number of points in a system. The measurements shall be made for the related ducts and/or air terminals that supply air to the internal spaces as identified according to the guidance in section 2.1.2.2 of the reference standard.

Post-completion stage 2: Testing for target air pollutants

The actual success of design measures (and their combinations) to minimise emissions can only be assessed by measuring the indoor air after completion of a building.

Testing is, however, costly and requires careful consideration and programming. It is therefore only recommended as an optional step to check and optimise performance. Guidance on sampling and detection is provided under Aspect 5 of performance assessment level 3.

Guidance note 4.2 property managers and investors

Reference pollutant emission limit values to protect health

The performance of building products can be assessed based on the testing of emissions according to the reference standard CEN/TS 16516. This can inform the selection of products as part of a source control strategy to minimise the potential risk to occupiers.

Carcinogenic VOCs, formaldehyde and substances with LCI (Lowest Concentration of Interest) value for specific substances are included within the proposed new EU emissions class system for reporting on the performance of products[58]. The classes will enable products to be selected based on their relative performance.

The performance of internal environments requires reference to a different set of standards that address indoor air. The standards EN 15251 and prEN 16978 provide informative indoor air concentration limits for a number of pollutants. These are based on WHO Indoor Air Quality (IAQ) guidelines for the level of indoor exposure[59]. Those substances that are measured by indicator 4.1.1 and which have WHO guideline values are formaldehyde, benzene, particulates (PM 2.5 and 10.0) and radon.

[58] The LCI concept is introduced in the following Joint Research Centre report http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83683/eca%20report%2029_final.pdf

[59] WHO Europe (2010) *Selected pollutants: Guidelines for indoor air quality* and WHO Europe (2013) *Health effects of particulate matter.*

Occupation stage 1: Testing for target air pollutants

The actual success of design measures to minimise CO_2, relative humidity, radon and mould can only be assessed by measuring indoor air after occupation of a building. Guidance on sampling and detection is provided under Aspects 2 and 3 of performance assessment level 3.

In the case of mould, expert inspection is required. Testing for the presence of mould is possible. However it is costly and requires careful consideration and project programming. It is therefore only recommended in this framework as an optional additional measure to check and optimise performance.

Guidance note 4.3 for property managers, designers and construction managers

Quantitative testing of properties for the presence of mould

Whilst standard building evaluation methods are generally considered to be the most practical method for evaluating the visible presence of mould in a property, quantitative testing can play a role in the detection of hidden microbial sources in a building materials and structures, thereby facilitating an objective grading of damage.

There are currently few reference standards for quantitative testing. AFNOR XP X 43-401 (France) includes the unit of measurement Colony Forming Units (CFC)/m^3. This metric provides a starting point for measuring mould levels, but identification of the species present may be required to complete a more detailed evaluation.

Sophisticated DNA testing using Polymerase Chain Reaction (PCR) methods can now be used to identify the specific species of mould and bacteria that are present in a sample and which may be responsible for damage to building materials and structures. The US EPA’s Environmental Relative Moldiness Index (ERMI) has been applied in the EU and is based on DNA analysis of samples for comparison with a reference set of mould species[60].

This form of testing requires significant expertise as it entails careful sampling followed by characterisation and evaluation of the species present. Seasonal factors, species whose presence may be unrelated to moisture damage and contamination from outside a building must also be considered. The ERMI method in particular requires a cross-check with a reference list of species based on their geographical occurrence.

4.1.1.2 Suggested reporting format

For the common performance assessment the results of design simulations and the tested performance of building products shall be reported on. The carrying out of a design assessment for mould prevention can also be reported. The reporting shall be completed for each of the required aspects and parameters.

[60] The application of the ERMI in Finland is documented in this scientific paper - Täubel M, Karvonen AM, Reponen T, Hyvärinen A, Vesper S, Pekkanen J. 2016. *Application of the environmental relative moldiness index in Finland*. Appl Environ Microbiol 82:578 –584

Lev el 1 common performance reporting format

Indicator 4.1.1 Design indoor air conditions

Indoor air conditions	**Reporting**
Ventilation rate	*Performance category (according to EN 16978)*
CO_2 concentration	*Performance category (according to EN 16978)*
Relative humidity	*Performance category (according to EN 16978)*
Benzene	*Both according to EN 13779* *Outdoor air class of the site:* *Ventilation filter rating:*
Particulates (PM 2,5/10.0)	
Radon	*If relevant for the location*
Mould	*Design assessment carried out? Yes/no*

Indicator 4.1.2 Target air pollutants for source control

Potential performance for each building product

Building products	**Target pollutants**		
	Carcinogenic VOCs (µg/m³)	**LCI (Lowest Concentration of Interest) ratio (if > 1,0)**	**Formaldehyde** (µg/m³)
Ceiling tiles			
Paints and varnishes - walls and ceiling			
- floors and stairs			
- doors and windows			
Floor coverings - textile coverings			
- laminate and flexible coverings			

- wooden coverings			
- associated adhesives and sealants			
Renovation products - internal insulation			
- interior surface treatments (e.g. to resist damp)			

4.1.2 Making level 2 and 3 assessments

4.1.2.1 Level 2 - Making a comparative performance assessment

Where the performance of the indoor air conditions and quality is reported in the public domain, the following parameters shall be adhered to and, where applicable, shall be reported on in order to be able to make comparative assertions:

- The design simulation tool for indoor air quality conditions.
- The timing of the testing and the selection of sample rooms in accordance with the guidance provided in the sampling protocol for rooms and spaces (see guidance note 4.4).
- The sampling and detection methods laid down in Aspect 5 of the level 3 performance assessment.
- The expert assessment rating of mould presence and severity.

In all cases, the relevant reference standards as specified in this guidance shall also have been adhered to.

4.1.2.2 Level 3 - Performance optimisation assessment

Key aspects to focus attention on

The five design optimisation aspects for indicator 4.1.1 focus on two main aspects of performance:

- the representativeness and precision of design measures and simulations.
- the carrying out of post-completion and post-occupation testing in order to assess the impact of design stage decisions.

The specific aspects which are recommended to focus on are listed in the same sequence in which they are presented in section 4.1.1.1:

- ✓ Aspect 1 – Indoor air conditions: the time representativeness of design simulations
- ✓ Aspect 2 – Indoor air conditions: the technical representativeness of post-occupancy testing
- ✓ Aspect 3 – Target pollutants: Mould inspection to ensure the technical representativeness of remedial actions
- ✓ Aspect 4 – Target pollutants: Assessment of local air quality to ensure geographical representativeness
- ✓ Aspect 5 – Target pollutants: Performance upon completion and occupancy

For each aspect a brief outline is provided of how they can improve performance, together with guidance notes which go into more detail.

Users should then report on which aspects they have focussed on. The more aspects addressed the better the reliability rating that will be obtained, as the rating improves in function of accuracy and representativeness.

Aspect 1 – Indoor air conditions: the time representativeness of design simulations

Focus of attention: The use of either a 'steady state' or a 'dynamic' method of simulating the indoor air conditions of a building.

Design performance assessments of the ventilation rate, CO_2 levels and relative humidity may be obtained by simplified steady state calculation or a dynamic simulation, in accordance with EN 15242.

The two methods differ in how accurately they are able to simulate the occupied performance of a building, particularly in terms of how air movements and the interaction of occupants are accounted for within a simulation.

The precision of the results will depend on the knowledge and experience of the professionals carrying out the simulation. This is because dynamic simulations are more complex and tend to require greater technical knowledge of the input data and the assumptions being made.

Aspect 2 – Indoor air conditions: the technical representativeness of post-occupancy testing

Focus of attention: The testing of selected aspects upon occupation of the building in order to check whether the design conditions are being achieved.

Internal spaces within a building shall be tested and inspected on-site and upon full occupation of the building after a minimum of one year. The test routines for each room specification in the building shall conform to the requirements in table 4.4.

Table 4.1.1. Test specification for indoor air conditions

Testing target	**Testing parameters**
CO_2 concentration	Direct sampling of the air in rooms, or indirect sampling of exhaust air, over 1 week or 7 working days.
Relative humidity	
Radon	Sample of the air during a two month period of continuous occupation.

Aspect 3 – Target pollutants: Mould inspection to ensure the technical representativeness of remedial actions

Focus of attention: The expert inspection and rating of mould presence and severity in order to inform remedial actions.

An expert condition inspection and survey of properties shall be carried out prior to renovation. This will provide a basis for understanding and diagnosing problems that have occurred in an existing building. Remedial steps can then be taken in the new renovation design.

Mould inspections shall, as minimum, be carried out using a structured assessment format which provides a rating. Any rating used should, as a minimum:

- reflect both the presence and severity of mould.
- identify areas of potential damage to the building envelope.

Guidance note 4.4 provides a brief introduction to three example expert inspection formats. The format used and the basis for the rating shall be reported. Post-occupancy inspections shall be carried out after a minimum of two heating seasons (winters).

If damage to building materials and structures is identified which may be as a result of hidden mould, then quantitative testing for mould could be considered (see guidance note 4.3).

Guidance note 4.4 for designers, property managers and investors

Expert inspection to identify mould problems in buildings

There is no standardised reference for the expert inspection of buildings for mould. However, a number of assessment formats have been successfully used in the UK and the Nordic countries. All those presented here rely on qualified experts to use them.

The English Housing Condition Survey (2000-2013) used the Mould Severity Index (MSI) to quantify the presence of damp and mould. The MSI relies on visual inspection by a qualified expert with the scoring methodology consisting of three elements:

- Prevalence: 1 point is allocated per room where mould is present;
- Severity: for each room, 1 or 2 additional points are allocated based on the 'moderate' or 'severe' mould presence;
- Communal space: An additional 1 point is allocated if mould is present in a living room.

A three level classification system was developed in Finland to grade the severity of moisture damage from mould. The classification system was tested for the dose-response relationship between the damage and occupant health effects.

Table 4.1.2 Classification criteria for the severity and amount of moisture damage in a property

Grade I	**Grade II**	**Grade III**
• No visible moisture damage recorded • Minor moisture damage, but no further consequences expected • One patch of deteriorated interior finish or covering which needed repairing	• Single observation of a damaged interior structural component that needed opening, drying and renewal or minor repair • Single patch of deteriorated interior finish or covering, as in Grade I, plus other damage of the same or lower severity	• The presence of a damaged interior structural component, as in Grade II, together with other damage of the same level of severity or less • A functional element that needed partial or total renewal, together with or without the presence of other damage

Source: Haverinen et al (2001)

The Nordic countries have developed a classification of the condition of a building based on expert visual and non-destructive inspection. The occurrence and extent of dampness and mould shall be measured in each room and a sum of the areas used to determine the overall classification.

Table 4.1.3 Dampness and mould in building structures – proposed Nordic classification system

Classification criteria	**Class 1**	**Class 2**	**Class 3**	**Class 4**
Condition of the structures has been checked and the maintenance of structures and installations documented less than 5 years ago.	Yes	Yes		
Known water damages or occurrences of condensation or capillary water have been repaired.	Yes	Yes	Yes	

Visible mould in occupied spaces: - smaller areas (e.g. gasket in a window sash) - minor areas show signs of mould - larger areas show signs of mould	None	< 400 cm^2	< 2.500 cm^2	> 2.500 cm^2
Risks of water damage have been assessed and proactive measures taken to reduce the future risk.	Yes			
Moisture from recent construction phase (only for newly constructed buildings).	No	No	Yes	

Source: Danish Standards (2015)

Aspect 4 – Assessment of local air quality to ensure geographical representativeness

Focus of attention: The assessment of local air quality in order to inform the appropriate design of ventilation systems.

The quality of intake air in a building can be significantly affected by local air pollution. This is particularly the case for buildings with ventilation systems. In locations with poor air quality, there is the risk that concentrations of pollutants such as benzene and particulates are higher than WHO guidelines. In these locations, the location of the ventilation intakes and the filtration of ventilation intake air will need to be carefully designed in order to achieve good quality indoor air (see guidance note 4.5).

Guidance note 4.5 for design teams

Ventilation design to manage quality of intake air from outside

EN standard 13779 provides design criteria for ventilation systems to maintain indoor air quality. The criteria are graded to reflect the quality of urban air according to WHO guidelines. Table A.5 of the standard includes filter specifications to reduce the intake of urban pollution and in guidance A2.2 recommendations are provided on the location of ventilation intakes.

Poor urban air quality is described in EN 13779 as locations where *'…pollutant concentrations exceed the WHO guidelines or any National air quality standards or regulations for outdoor air by a factor greater than 1,5.*' Because under the Air Quality Directive 2008/50/EC, Member States are required to prepare air quality action plans and monitor pollution at a local level, this information is generally available from the local authority or from reported data in the public domain.

Aspect 5 – Testing of performance upon completion and occupancy to ensure technical representativeness

Focus of attention: The testing of indoor air upon occupation of the building in order to assess the concentration limits of target pollutants.

Selected internal spaces within a building shall be tested on-site following practical completion and prior to occupation. A protocol for the sampling of rooms and spaces is outlined in guidance note 4.6. The building should already have been fitted-out with the materials and finishes identified in table 4.1.1, but will not contain occupiers' furniture, because this can significantly affect the results at this stage.

Guidance note 4.6 for construction managers

Room and interior space sampling protocol to support the comparability of indoor air quality monitoring exercises

If comparisons are to be made between the performance of buildings, the sampling of rooms and spaces shall be according to the following protocol:

- For offices: Testing shall be carried out for each distinct room configuration in the building that accounts for >10% of the office space. Where room configurations are located in different façade aspects of the building, rooms from opposing aspects shall be tested.
- For apartment blocks and developments of multiple houses: Testing shall be carried out for a minimum of 10% of the properties, and be representative of any significant variations in the house or apartment typologies, configurations and materials. Samples shall be taken in the living room and the smallest bedroom of each property selected.

The selected internal spaces within a building shall be tested on-site following practical completion, the commissioning of ventilation systems and prior to occupation.

The sampling and detection methods to be used for each target pollutant are specified in table 4.1.4. Sampling devices shall be placed in the centre of a room so as not to be influenced by doors, windows or heating/cooling inputs.

Because benzene and particulate emissions are strongly linked to outside air, consideration needs to be given to the season. Peak exposure is likely to take place during the winter season, hence reporting should note the time of year when testing takes place.

Table 4.1.4 Test specification for in-situ pollutant testing

Concentrations to be tested	**Sampling and detection method**
Substances covered by EU LCI ratios	*Only applicable to product testing* [61]
Formaldehyde	30 minutes average in accordance with ISO 16000-3 or equivalent.

[61] This is because the LCI values on which R Values are based are health-based reference concentrations of VOCs for inhalation exposure used to assess emissions after 28 days from a single product during a laboratory test chamber procedure as defined in CEN/TS 16516

Benzene	Eight hour daytime average in accordance with ISO 16017-2 or equivalent.
Particulates	Eight hour daytime average for two particle sizes in accordance with ISO 7708 or equivalent: - PM10: 50 μ/m^3 - PM2.5: 15 μ/m^3

Level 3 performance optimisation reporting format

Part 1 - Performance aspects reporting format

Aspect	**Addressed? (yes/no)**	**Notes on the modelling and sampling routine adopted**
Aspect 1 – Time representativeness of the ventilation design simulation		
Aspect 2 – Post occupancy testing of indoor air conditions		
Aspect 3 – Mould inspection to ensure technical representativeness of remedial measures		
Aspect 4 – Geographical representativeness of the local air quality assessment		
Aspect 5 – Post completion and occupancy target pollutant testing		

Part 2 - Indoor air results from all project stages

Indoor air quality condition	Design stage	Completion stage	Post-completion	Occupation
Ventilation rate	l/s/m^2	l/s/m^2	-	-
CO_2 concentration	ppm	-	-	ppm
Relative humidity	%	-	-	%
EU LCI ratios	Substances with ratios > 1,0	-	-	-
Formaldehyde	-	-	µg/m^3	µg/m^3
Benzene	-	-	µg/m^3	µg/m^3
Particulates (PM 2,5/10.0)	-	-	µg/m^3	µg/m^3
Radon	Bq/m^3	-	-	Bq/m^3

Part 3 - Mould inspection reporting

Assessment and rating method used		*Country, method and version*
Expert inspection carried out prior to renovaton?		*Yes/no*
Expert inspection carried out post-occupancy?		*Yes/no*
Rated performance	Pre-renovation	*As applicable, derived from the method*
	Post-occupancy	*derived from the method*

4.1.3 Property valuation influence and reliability rating

The following tools are provided to inform the valuation of a property for which performance has been assessed according to indicator 4.1:

- Checklists for the potentially positive influence on value and risk
  - Checklist 1: Potential positive influence on future performance
  - Checklist 2: Accounting for the performance assessment in valuation criteria
- Ratings of the performance assessment
  - Rating 1: Basis for the performance assessment
  - Rating 2: Professional capabilities
  - Rating 3: Independent verification

The completed reporting may be used separately alongside the Level 1, 2 or 3 results for indicator 4.1, or may form part of the overall reporting for indicator 6.2.

In the case that the ratings will be used as part of the overall reporting for indicator 6.2, then the rating 1 results shall be used to calculate the overall Indicator Reliability Index (IRI).

The Indicator Reliability Index (IRI) for rating 1 shall be calculated separately for 4.1.1 and 4.1.2 from the individual ratings as follows:

$$\text{IRI} = \frac{(TeR\ min\{rating\ aspects\})+(GR\ min\{rating\ aspects\})+\ (TR\ \min\{rating\ aspect\})}{number\ of\ relevant\ aspects}$$

Where:

TeR = Technical Representativeness

GR = Geographical Representativeness

TR = Time representativeness

To calculate the IRI the lowest score for each of the three types of rating aspect shall be used to calculate arithmetic mean of the reliability.

4.1.3.1 The potential for a positive influence on a market valuation

Checklist 1 – Evaluation of potentially positive influences on the market performance

Potential influence	***Evaluated?***	***Resulting assumptions used in the appraisal***
Potential influence 1 *Increased revenues due to market recognition and lower void rates.*	*Yes/no*	
Potential influence 2 *Reduced operational, maintenance, repair and/or replacement costs.*	*Yes/no*	
Potential influence 3 *Reduced future risk of increased overheads or loss of income.*	*Yes/no*	

Checklist 2 – Accounting for the Level(s) assessment in the valuation criteria used

Valuation criteria set used	Identify the scheme or tool used in the appraisal

Version of the criteria set used	

Criteria which the assessment has influenced		Influence on the valuation or rating
Valuation criterion	**Sub-criterion**	
Criterion x	Sub-criterion y	Notes on the extent of the influence and the supporting assumptions used

4.1.3.2 Reliability rating of the performance assessment

Rating 1 - Basis for the performance assessment

Sub-indicator	Rating aspect	Rating score (reflecting the degree of representativeness)			
		0	**1 Low**	**2 Medium**	**3 High**
4.1.1 Indoor air quality	1. Ventilation design simulation time representativeness				
	2. Post occupancy technical representativeness of the indoor air conditions tested				
4.1.2 Target pollutants	3. Mould inspection to ensure technical representativeness of remedial measures				
	4. Local air quality geographical representativeness				
	5. Post completion and occupancy air quality testing technical representativeness				

Indicator 4.1 **Indicator Reliability Rating**	

Rating 2 – Professional capabilities

Rating aspect	Rating score			
	0	**1**	**2**	**3**
2. Technical capability of the personnel carrying out the assessment(s)	*No formal training and limited experience in using the calculation method*	*Formal training or some applied experience in using the calculation method*	*Formal training and some applied experience in using the calculation method*	*Formal training and significant applied experience in using the calculation method*

Rating 3 – Independent verification

Rating aspect	Rating score			
	0	**1**	**2**	**3**
3. Independent verification of the assessment	*Self-declaration of the performance assessment results*	*Peer review of the input data and calculation steps*	*Third party auditing and verification of the calculation steps*	*Third party auditing and verification of the input data and calculation steps*

4.2 Indicator of time outside of thermal comfort range

4.2 Time outside of thermal comfort range	**Where to find the guidance for each Level**
	Level 1 common performance assessment
	Level 2 comparative performance assessment
	Level 3 performance optimisation assessment
	Valuation influence and reliability rating (all levels)

4.2.1 Level 1 - making a common performance assessment

4.2.1.1 Calculation methodology and data requirements

The thermal simulation shall be conducted for the building both with and without mechanical cooling and heating. This shall ensure that the inherent thermal characteristics of the building envelope and structure are assessed.

Calculation of the reported performance shall be carried out in accordance with the method described in Annex F of EN 15251 and/or an overheating assessment that forms part of a national or regional calculation method.

For modelling of a building without mechanical cooling, the assumptions described in Annex F of EN 15251 that relate to adaptive conditions shall be followed (referred to as *'Acceptable indoor temperatures for design of buildings without mechanical cooling systems'*).

If intended to carry out post-occupancy evaluation of satisfaction/dissatisfaction of the thermal environment, and, depending on whether mechanical cooling is to be used in the building, either the Predicted Percentage Dissatisfied (PPD) shall be estimated based on EN ISO 7730 (for mechanically cooled buildings) or the acceptable summer indoor temperature range (for buildings without mechanical cooling). The thermal comfort categories can then be read across to the EN 15251 categories as shown in table 4.2.1.

Table 4.2.1 The read across between indoor thermal environment categories, PPD and acceptable (adaptive) indoor summer temperatures

EN 15251 category	Fanger method		Adaptive method (Nicol et al)
	PPD (%)	PMV	Operative temperature variance (°C)
I	≤ 6	$-0.2 \leq$ PMV $\leq +0.2$	± 2
II	≤ 10	$-0.5 \leq$ PMV $\leq +0.5$	± 3
III	≤ 15	$-0.7 \leq$ PMV $\leq +0.7$	± 4
IV	>15	PMV < -0.7 and PMV > 0.7	

Source: Athienitis and O'Brien (2015)

The overall thermal simulation of the building shall be according to the CEN standards that support the Energy Performance of Buildings Directive. This shall be as described in indicator 1.1.

Data requirements and sources

The data sources for the thermal simulation shall be as per those identified for indicator 1.1.

The PPD requires input data for six thermal parameters - clothing, activity, air- and mean radiant temperature, air velocity and humidity. Reference values provided at national level may be used, or alternatively bespoke values can be identified but the assumptions shall be reported.

The weather data shall be representative of present climatic conditions. For measured performance assessments, the results shall be corrected in accordance with EN 15603 or EN 52000-1.

Table 4.2.2 Data requirements and sources for indicator 4.2

Data item	**Potential source**	
	Default EU values	**National, regional or locally specific values**
Thermal simulation	*See indicator 1.1*	*See indicator 1.1*
PPD thermal parameters	ISO 8996, ISO 9920 EN ISO 7730 Annexes B/C EN ISO 7730 Annex E (overall estimate of PPD)	National or regional calculation method (overheating assessment) Building permitting requirements
Weather data	Three climate zones (EN 15265 test cases)	National or regional calculation method Member State Meteorological Offices

4.2.1.2 Suggested reporting format

The common performance assessment requires, as a minimum, reporting on:

- the type of building thermal simulation (usually carried out according to national or regional calculation methods),
- the results of and parameters for the thermal performance assessment, and
- in the case that a post-occupancy evaluation will be carried out, both predicted and actual satisfaction levels.

This means that the results of existing overheating assessments carried out according to national or regional requirements can be used for reporting, as long as they are based on CEN standards series developed to support the Directive 2010/31/EU for the Energy Performance of Buildings.

Users shall identify the type of performance assessment they have carried out, the calculation method and its compliance with an EN standards series as per the reporting for indicator 1.1.

Level 1 common performance reporting format

Part 1 - Type of performance assessment

Energy Performance of Buildings assessment type		– *Calculated (asset)* – *Measured (operational)*
Energy Performance of Buildings assessment sub-type		– *Calculated (asset): Design or as built or standard* – *Measured (operational): Standard*
Calculation method	EN standard compliant thermal simulation?	*Yes/no*
	Method and EN standard series	*Please indicate which*

Part 2 - Performance assessment results

Performance aspect	**Heating season**	**Cooling season**
Operative temperature range (ºC)	*Lower/upper limits*	*Lower/upper limits*
Time out of range (%) - without mechanical cooling - with mechanical cooling	*Proportion of time*	*Proportion of time*

Part 3 - Optional results for later comparison if a post-occupancy assessment is to be carried out [62]

Performance aspect	**Heating season**	**Cooling season**
Thermal environment categories - without mechanical cooling - with mechanical cooling	*According to EN 15251*	*According to EN 15251*

4.2.1.3 Monitoring of as-built and occupied performance

Evidence shows that a commitment to carry out functional performance testing of building services focusses attention on design precision and the correct installation of services.

Functional performance testing of HVAC systems shall be carried out as part of the commissioning process on site and according to the methods described in Annex D of EN 12599.

[62] These categories are based on estimation of the occupant dissatisfaction with the comfort conditions, providing the basis for comparison of design and occupied dissatisfaction levels.

Measurement of the performance of HVAC systems upon occupation of the building shall be in conformance with the protocols in ISO 7726.

For the post-occupancy evaluation of satisfaction/dissatisfaction, ISO 10551 (currently under revision) provides a reference evaluation method and survey format for thermal comfort.

4.2.2 Making level 2 and 3 assessments

4.2.2.1 Level 2 - making a comparative performance assessment

To use this reporting option, a number of parameters and items of input data used in the simulation of a building are required to be fixed. To do this, the following rules shall be followed:

- Choice of thermal simulation method: The quasi-steady state and simplified hourly methods described in EN ISO 13790 may be used. Alternatively, if a dynamic method is used, the results shall be validated according to EN ISO 52016-1 or the criteria and test cases in EN 15265.
- Use of standard input data for the thermal simulation: Data provided at national level or the default data provided in Annex G of EN ISO 13790 (or EN ISO 52016-1) shall be used. This shall include the use of standard occupancy and conditions of data for the building type (see Annex G.8).
- PPD thermal parameter input data: For the six parameters identified in EN ISO 7730, the default or reference national or regional data for the building type shall be used.
- Climate data: The test reference year stipulated by the national or regional calculation method shall be used, corrected in the case of measured data following the methods in EN 15603 and EN ISO 52000-1.
- Heating and cooling seasons: The heating and cooling seasons defined in the relevant national calculation method shall be used.
- Temperature ranges: The Category II temperature ranges, as stipulated in EN 15251 and EN 16978-1, shall be used in all cases.

The sampling protocol for determining the rooms to be monitored post-occupancy shall be as follows:

- Office buildings: All room configurations within the total useful floor area that are used for office-related work.
- Residential buildings: The main living rooms and all bed rooms within a home. In the case of assessment of multiple homes, each distinctive configuration and orientation shall be assessed.

4.2.2.2 Level 3 - performance optimisation assessment

The following key aspects are important focus areas of attention to improve the representativeness and precision of indicator 4.2 performance assessments:

- ✓ Aspect 1 - The geographical representativeness of the weather data used.
- ✓ Aspect 2 - The time representativeness of the calculation method used.
- ✓ Aspect 3 - The duration and intensity of heating and cooling weather events.
- ✓ Aspect 4 - Factors that can cause localised thermal discomfort.

These aspects broadly reflect those also identified for indicator 1.1, together with some additional considerations. For each aspect a brief outline is provided of how they can improve performance, together with guidance notes which go into more detail.

Users should then report on which aspects they have focussed on. The more aspects addressed the better the reliability rating that will be obtained, as the rating improves in function of accuracy and representativeness.

Key aspects to focus attention on

Aspect 1 – The geographical representativeness of the weather data used

Focus of attention: The use of weather files that are as representative as possible of the location of the building.

The most likely option for achieving greater representativeness would be a test reference year derived from a medium term (20 or 30 year) time series for a standard local weather station. The Joint Research Centre has created an open access weather file database that can be used across the EU[63].

Further interpolation of weather datasets to take into account the Urban Heat Island (UHI) effect can add precision to datasets. This is particularly important in major cities and locations where the urban design, commuting patterns and topography can exacerbate winter or summer conditions.

Guidance note 4.7 for design teams

Determining the extent of the urban heat island effect

The Urban Heat Island (UHI) effect is an additional factor to take into account when modelling the external air and radiative temperatures around a building. This is because the temperature in an urban area can be elevated compared to rural areas due to a combination of:

- vehicle exhaust,
- building air conditioning heat rejection,
- street canyon geometry,
- reduced evapotranspiration by vegetation and,
- absorption and re-radiation of heat by roads, paving and structures.

The effect can be generalized across an urban area or, where there are combinations of factors, it can be very localised within a district or at specific

[63] The database will form an extension of PVGIS - http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php

points.

Recognising the significance of this effect, a number of cities have put in place initiatives to support designers to better take it into account. Examples include London[64], Stuttgart[65] and Zaragoza[66].

Aspect 2 – The time representativeness of the calculation method used

Focus of attention: The use of a 'dynamic' method of simulating the time out of range of a building.

Quasi-steady state and dynamic energy simulation methods differ in how accurately they are able to simulate the thermodynamic performance of a building, particularly in terms of how solar heat gains, cold bridging and air infiltration are accounted for within a simulation.

Steady state simulations use weather data this has a seasonal or monthly time interval, whereas dynamic simulations use weather data with an hourly time interval, as well taking into account many more factors that will influence performance.

Steady state models can estimate overall annual consumption to a reasonable accuracy but are unreliable when the building’s performance is determined by factors that are variable on a daily and hourly basis. For this reason it is particularly beneficial to use dynamic simulation in Southern European countries, where there is a greater duration and intensity of solar radiation during the year.

Currently, national calculation methods in EU may, in accordance with EN ISO 13790 and EN ISO 52016-1, be based on a seasonal or monthly steady state, simplified hourly or fully dynamic method. As a result, the precision of an overheating assessment carried out for building permitting may differ. This will also dictate whether the time out of range is determined based on hours or days.

Obtaining additional precision from a dynamic simulation will depend on the knowledge and experience of the professionals carrying out the simulation. This is because dynamic simulations are more complex and tend to require greater technical knowledge of the input data and the assumptions being made. In some EU locations, a steady state simulation may produce equally valid and precise results.

Guidance note 1.3 under indicator 1.1 provides further information on dynamic simulation. The Zero Carbon Hub's 'assessing overheating risk' provides specific practical guidance in relation to overheating risk assessment[67].

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[64] London's urban heat island, https://data.london.gov.uk/dataset/london-s-urban-heat-island---average-summer
[65] Climate ADAPT case study of Stuttgart,http://climate-adapt.eea.europa.eu/metadata/case-studies/stuttgart-combating-the-heat-island-effect-and-poor-air-quality-with-green-ventilation-corridors
[66] José M. Cuadrat Prats, Sergio M. Vicente-Serrano y Miguel A. Saz Sánchez, *Los efectos de la urbanizacion en el clima de Zaragoza (España): La isla de calor y sus factores condictiontes*, Boletín de la A.G.E. N.º 40 - 2005, págs. 311-327
[67] Zero Carbon Hub (2015) *Assessing overheating risk*, UK

Aspect 3 – The time representativeness of the simulation of extreme weather events

Focus of attention: Assessment of the Continuously Overheated Intervals (COIs) during which the building is predicted to remain out of range for a longer period of time.

Whilst an estimation of the time out of range will provide a broad indication of the tolerance of the building, it will not provide information on persistent periods of temperature stress that may reduce influence occupants tolerance and willingness to adapt to higher temperatures, thereby affecting cooling energy use, as well as having an impact on the reliability of building services.

Analysis of the duration and intensity of heat waves can provide the basis for a more detailed risk assessment[68]. Figure 4.2.1 illustrates how during a seven day period a building's operative temperature exceeded a set temperature limit four consecutive days in a row for a total of 31 hours.

More detailed analysis of duration and intensity could have implications for how, for example, an excess of heat is managed over a 24 hour period or over several days. This is important because, during continuous overheated periods, the urban environment may re-radiate more heat at night, thereby maintaining ambient air temperatures. The effects of heat stress on the human body may also be compounded over time, reducing occupant’s willingness to adapt to higher temperatures in interior environments.

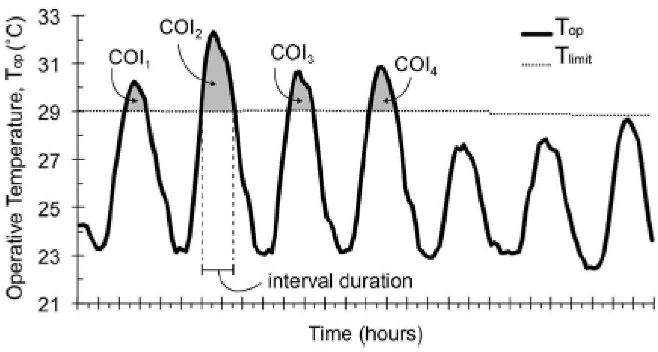

Figure 4.2.1 Example of Continuously Overheated Intervals (COIs) over a seven day period

Source: Lee and Steemers (2017)

Aspect 4 – Technical representativeness of the factors that can cause localised thermal discomfort

Focus of attention: Assessment of the potential for variation in the local thermal sensation felt at specific locations in the building.

The sensation of thermal comfort or discomfort is in practice more complex than defining an upper and lower temperature range, or considering the human body as a whole. Evidence from the study of low energy and passive buildings has shown that the following localised aspects are important to consider:

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68 W. Victoria Lee & Koen Steemers (2017) *Exposure duration in overheating assessments: a retrofit modelling study*, Building Research & Information, 45:1-2, 60-82

- Draughts,
- Vertical air temperature differences,
- Floor temperature, and
- Radiant temperature asymmetry.

Assessments of the relationship between occupant discomfort and the potential variation in the thermal sensation caused by these aspects are provided in EN ISO 7730. Indicative performance categories for each of these aspects are provided in EN 15251 and EN 16978.

Level 3 performance optimisation reporting format

Part 1 - Performance assessment results

Performance aspect	**Heating season**	**Cooling season**
Operative temperature range (°C)	*Lower/upper limits*	*Lower/upper limits*
Time out of range (%) - without mechanical cooling - with mechanical cooling	*Proportion of time*	*Proportion of time*

Part 2 - Optional results for later comparison if a post-occupancy assessment is to be carried out

Performance aspect	**Heating season**	**Cooling season**
Thermal environment categories - without mechanical cooling - with mechanical cooling	*According to EN 15251*	*According to EN 15251*

Part 3 - Design optimisation aspects addressed

Aspect	**Addressed? (yes/no)**	**Notes on data sources and calculation method**
Aspect 1 – Weather data geographical representativeness		
Aspect 2 – Calculation method time representativeness		
Aspect 3 – Extreme weather event time representativeness		
Aspect 4 – Technical representativeness of factors that can cause localised thermal discomfort		

4.2.3 Property valuation influence and reliability rating

The following tools are provided to inform the valuation of a property for which performance has been assessed according to indicator 4.2:

- Checklists for the potentially positive influence on value and risk
  - Checklist 1: Potential positive influence on future performance
  - Checklist 2: Accounting for the performance assessment in valuation criteria
- Ratings of the performance assessment
  - Rating 1: Basis for the performance assessment

- Rating 2: Professional capabilities
- Rating 3: Independent verification

The completed reporting may be used separately alongside the Level 1, 2 or 3 results for indicator 4.2, or may form part of the overall reporting for indicator 6.2.

In the case that the ratings will be used as part of the overall reporting for indicator 6.2, then the rating 1 results shall be used to calculate the overall Indicator Reliability Index (IRI).

The Indicator Reliability Index (IRI) for rating 1 shall be calculated from the individual ratings as follows:

$$\text{IRI} = \frac{(TeR\ min\{rating\ aspects\}) + (GR\ min\{rating\ aspects\}) + (TR\ \min\{rating\ aspect\})}{3}$$

Where:

TeR = Technical Representativeness

GR = Geographical Representativeness

TR = Time representativeness

To calculate the IRI the lowest score for each of the three types of rating aspect shall be used to calculate arithmetic mean of the reliability.

4.2.3.1 The potential for a positive influence on a market valuation

Checklist 1 – Evaluation of potentially positive influences on future performance

Potential influence	***Evaluated?***	***Resulting assumptions used in the appraisal***
Potential influence 1 *Increased revenues due to market recognition and lower void rates.*	*Yes/no*	
Potential influence 2 *Reduced operational, maintenance, repair and/or replacement costs.*	*Yes/no*	
Potential influence 3 *Reduced future risk of increased overheads or loss of income.*	*Yes/no*	

Checklist 2 – Accounting for the Level(s) assessment in the valuation criteria used

Valuation criteria set used	Identify the scheme or tool used in the appraisal
Version of the criteria set used	

Criteria which the assessment has influenced		Influence on the valuation or rating
Valuation criterion	**Sub-criterion**	
Criterion x	Sub-criterion y	Notes on the extent of the influence and the supporting assumptions used

4.2. 3.2 Reliability rating of the performance assessment

Rating 1 - Basis for the performance assessment

Sub-indicator	Rating aspect	Rating score (reflecting the degree of representativeness)			
		0	**1 Low**	**2 Medium**	**3 High**
1. Weather data geographical representativeness	The use of weather data that reflect the building location.				
	The extent to which the weather data that reflects the Urban Heat Island effect for the location.				
2. Calculation method time representativeness	The extent to which simulations are more dynamic.				
3. Extreme weather event time representativeness	The extent to which the risk associated with intense periods of heat has been assessed.				
4. Technical representativeness of factors that can cause localised thermal discomfort	The extent to which localised thermal parameters have been assessed in order to improve designs.				

Indicator 4.2 **Indicator Reliability Rating**	

Rating 2 – Professional capabilities

Rating aspect	Rating score			
	0	**1**	**2**	**3**
2. Technical capability of the personnel carrying out the assessment(s)	*No formal training and limited experience in using the calculation method*	*Accredited training or some applied experience in using the calculation method*	*Accredited training and some applied experience in using the calculation method*	*Accredited training*[69] *and significant applied experience in using the calculation method*

Rating 3 – Independent verification

Rating aspect	Rating score			
	0	**1**	**2**	**3**
3. Independent verification of the assessment	*Self-declaration of the performance assessment results*	*Peer review of the input data and calculation steps*	*Third party auditing and verification of the calculation steps*	*Third party auditing and verification of the input data and calculation steps*

[69] In accordance with Article 17 of the EPBD

Potential future aspects of Macro-objective 4

4.3 Future aspect: Lighting and visual comfort

4.3.1 Why measure this performance aspect?

The availability and quality of light are important factors in the design of healthy and comfortable homes and workspaces. Visual comfort can be understood both in terms of the light needed to carry out tasks but also in terms of what the human body requires and, where there is an excess of light, can tolerate.

Natural light makes a significant contribution to visual comfort. It is essential to the circadian rhythms – sleeping and waking cycles of the human body – and without sufficient exposure to natural light, a person's wellbeing and motivation can be affected.

As well as reducing the electricity use associated with artificial lighting, natural light has been shown to contribute to more conducive and productive working environments, as well as more attractive and healthy homes. Natural light is, for example, preferred by office workers, who tend to seek a window location.

Moreover, Directive 2010/31/EU for the Energy Performance of Buildings states that the positive influence of natural lighting shall, where relevant in the calculation of energy performance of a building, be taken into account. The performance of in-built lighting installations is, furthermore, highlighted as a minimum aspect of energy performance calculation methods.

4.3.2 Which aspects can be measured?

In this section the most important aspects relating to the quality and availability of light are briefly summarised, together with an overview of the most used and accepted indicators and metrics.

Table 4.3.1 then provides a general overview of possible focus areas for attention and related reference standards.

4.3.2.1 The availability and quality of light

The starting point for considering lighting in a building is the availability and quality of light. This can be understood in terms of a combination of the in-built, artificial lighting systems and the penetration of natural light into a building:

- Artificial luminaire quality: The design and specification of artificial lighting can be used to ensure that there is both sufficient light and of a suitable quality for the type of building. For example, workstations require a minimum of 300-500 lux at desk height. The colour quality of luminaires is also an important aspect and poor colour rendering can attenuate vision.
- Building plan depth and Daylight Factor: The plan depth of an office or home will dictate how much of the floor area can be illuminated with natural light. At a plan depth of more than 4-6 metres, a glazing ratio of less than 30% and a ceiling height of 3 metres, natural light levels will fall below the 500 lux (lumens/m^2) necessary for a working environment – equivalent to a Daylighting Factor (DF) of 2%.
- Discomfort glare: Without careful design, both artificial and natural light can make the internal environment uncomfortable and, potentially, result in more energy use than predicted. So, whilst a building design may achieve an ideal plan depth and Daylighting Factor for work or living spaces, this may result in unwanted glare and thermal gain. This can be the result of both direct sunlight and reflection from clouds. As a result, solar control strategies may be required.

The reference standards EN 12464-1, EN 16978-1 and prEN 15193-1 address indoor work area lighting requirements, indoor lighting quality and daylighting respectively. Standards relating to useful and discomfort daylight are further addressed in the following section.

4.3.2.3 Indicators and metrics for useful and discomfort daylight

A range of related metrics have been developed to measure both useful and discomfort daylight, as well and any associated glare. This can be simulated both on a steady state and dynamic basis. Some of the most commonly used metrics include:

- The percentage 'spatial daylight autonomy' of more than 300 lux at desk height for a stipulated percentages of the year and an 'Annual Sun Exposure' of >1000 lux for <10% of the year.
- An illuminance level of between 300 and 3,000 lux at desk height, either for the number of days of the year or as a percentage of the year.
- The Useful Daylight Illuminance (UDI) based on an upper and lower lux threshold of 100 and 2000 lux, reflecting levels below which daylight is insufficient or above which there may be visual discomfort

Some of these metrics are used in national building codes, for example the stipulation of minimum Daylighting Factors or a percentage of the surface area of a building that is glazed (e.g. France, UK, Denmark), but in general they tend only to apply to residential buildings and on a guidance basis.

In terms of estimating or measuring glare, EN 12464 provides a rating of glare from artificial lighting (the Unified Glare Rating), stating that there is currently no standardised rating of discomfort glare from windows. The most widely accepted metric for daylight glare assessment is currently Daylight Glare Probability (DGP).

DGP is based on an estimate of the number of occupants that may find the level of glare uncomfortable in a space. Field trials by Fraunhofer ISE in Germany have provided some indicative bands of performance which can provide for an indicative risk assessment of unwanted glare.

Table 4.3.1 Focus areas for possible attention on lighting and visual comfort

Performance aspects	**Technical rationale**	**Reference standards**
1. Building plan depth	The plan depth of an office or home will dictate how much of the floor area can be illuminated with natural light.	prEN 16978 EN 15193-1
2. Dynamic daylighting simulation	Dynamic simulation of daylighting potential can identify opportunities to maximise daylighting without glare, and to work in tandem with artificial lighting.	EN 15193-1
3. Lighting levels - Working plane - User control	Lighting design should ensure that there is both sufficient light and of a suitable quality for the type of building and functions carried out.	prEN 16978
4. Artificial lighting quality - Diffusion of light - Colour rendering	Artificial lighting design should ensure that luminaires provide lighting that is of a suitable quality and consistency.	EN 12464-1

5. Control of daylight glare	Excessive daylight can cause discomfort, artificial lighting use and contribute to overheating.	-

4.3.3 Initial reporting format for potential future aspect 4.3

Lighting and visual comfort addressed?	Yes/no

Specific design aspects addressed	Aspect x	Yes/no	*Reference standards and methods used*
	Aspect y	Yes/no	*Reference standards and methods used*
	Aspect z	Yes/no	*Reference standards and methods used*

4.4 Future aspect: Acoustics and protection against noise

4.4.1 Why measure this performance aspect?

The potential for acoustic disturbance from both inside and outside a building is cited as an important aspect of occupant satisfaction. Noise disturbance can have a significant detrimental effect on people's health and quality of life. It can also affect productivity in a work environment.

The importance of protecting citizens from noise is recognised in European policy, with Directive 2002/49/EC on the assessment and management of environmental noise[70], requiring external noise source mapping at local level, together with reporting on the number of residents exposed to differing levels of noise. Annex VI of the Directive provides a technical definition of a 'quiet façade', referring to buildings where residents are exposed to lower relative noise levels.

4.4.2 Which aspects can be measured?

The potential for disturbance from unwanted noise depends on the nature of the use of the buildings, servicing and internal layout. The potential issues related to office and residential buildings are briefly summarised below.

Table 4.4.1 then provides a general overview of possible focus areas for attention and related reference standards.

4.4.2.1 In office buildings

Noise problems may relate to disturbance in open plan environments or, in more traditional office layouts, poor acoustic separation between cellular offices or meeting rooms. Servicing such as air conditioning, as well as printers and server rooms, can also cause disturbance.

4.4.2.2 In residential buildings

In apartments, terraces and semi-detached homes, acoustic insulation of party walls and floors is particularly important to minimise sound transmission between properties. Consideration of both impact and airborne transmission of sound is important in these cases. The reverberation of sound is also an important factor, as it can affect concentration within a shared office space, as well as providing a means to control the extent of airborne sound.

In the case of both offices and homes, external sources of noise disturbance such as traffic and street activity can be of significance. In commercial buildings, this can lead to decisions to seal windows and mechanically ventilate spaces.

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[70] Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise

Table 4.4.1 Focus areas for possible attention on acoustic and noise

Performance aspects	**Technical rationale**	**Reference standards**
1. Façade acoustic performance	Protection of workers and residents from external sources of noise.	Directive 2002/49/EC, Annex VI ISO 16283-3 Homes: ISO 19488 (under development)
2. Impact noise - between offices or dwellings - between rooms	Protection from the sound of impacts or works on a floor or wall.	ISO 717-1 ISO 16283-1 Homes: ISO 19488 (under development)
3. Airborne noise - between offices or dwellings - between rooms	Protection from the sound of activities in a room or space.	ISO 717-1 ISO 16283-1 Homes: ISO 19488 (under development)
4. Reverberation time - disturbance within a room or space - extent of airborne noise	Protection from the reverberation of sounds within a room.	Homes: ISO 19488 (under development)

4.4.3 Initial reporting format for potential future aspect 4.4

Acoustics and protection against noise addressed?	Yes/no

Specific performance aspects addressed	Aspect x	Yes/no	*Reference standards and methods used*
	Aspect y	Yes/no	*Reference standards and methods used*
	Aspect z	Yes/no	*Reference standards and methods used*

Macro-objective 5: Adaptation and resilience to climate change

Key terms and definitions used

Climate	Average and variability of weather at a given location over a period of time, normally 30 years.
Climate change	Change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.
Climate change adaptation	Process of adjustment to actual or expected climate change and its effects.
Climate projections	Time-dependent information about the future climate, modelled on the basis of plausible assumptions about future greenhouse gas emissions and climatological relationships.
Resilience	Capacity of a social, ecological or economic system to cope with hazardous events or disturbance, responding or reorganizing in ways that maintain its essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation.

5.1 Life cycle tools: scenarios for projected future climatic conditions

5.1 Life cycle scenarios: projected future climatic conditions Scenario 1: Protection of occupier health and thermal comfort	**Where to find the guidance for each Level** Level 1 common performance assessment Level 2 comparative performance assessment Level 3 performance optimisation assessment Valuation influence and reliability rating (all levels)

The first life cycle scenario to be provided for this macro-objective focuses on extremes of temperature, with a focus on protecting the health and comfort of building occupiers.

The guidance and reporting provides users with qualitative and quantitative ways of reporting on how far the building addresses this specific aspect of climate change adaptation and resilience.

Section 5.1.1 provides general rules that shall be followed when using the scenario tool. Then in section 5.1.2 detailed rules are provided. Section 5.1.3 provides specific rules for life cycle-based analysis using Level 3.

5.1.1 Rules for describing and reporting on scenarios

5.1.1.1 General rules for each type of performance assessment

If a user chooses to model the scenario they shall follow the accompanying set of rules. These are designed to ensure the consistency of the underlying assumptions and calculations behind the reporting.

The rules, which differ according to the three types of performance assessment in the Level(s) framework, are set out in table 5.1.1. Specific rules shall be followed for the use of indicator 1.2 life cycle GWP or cradle to cradle LCA to analyse the scenario.

The use of life cycle GWP or LCA in level 3 allows for the performance of future scenarios to be tested and evaluated. In the case of level 3, the specific rules in section 5.1.3 shall additionally be followed.

Table 5.1.1 Overall rules for how the scenario tool shall be used

Type of performance assessment	**Scenario tool 1** **Protection of occupier health and thermal comfort**
Level 1 **Common performance assessment**	○ Use of the same calculation method and indicator metrics as for indicator 4.2 ○ Extension of the thermal simulation used to report on indicator 4.2 in order to calculate the performance using weather projections for 2030 and 2050. ○ The future performance shall be calculated using the same operative temperature range as for indicator 4.2 ○ If future projections are not available at national, regional or local level, weather files derived from heat wave events in the last 20-30 years may be used.
Level 2 **Comparative performance assessment**	○ Comparisons may be made of simulated thermal scenarios for 2030 and 2050 if the same parameters have been used for: – conditions of use – operative temperature range – thermal environment input data – weather projections
Level 3 **Design performance optimisation**	○ Identification and subsequent thermal simulation of design options that could improve the resilience of the initial design option. ○ Simulation should take into account the additional aspects identified in the guidance as potentially improving the reliability of the results. ○ Analysis of the design options using life cycle GWP or LCA in order to identify potential trade-offs against other performance aspects. ○ The life cycle GWP or LCA analysis shall be carried out according to the specific additional rules provided.

5.1.2 Detailed methodologies for obtaining results for each scenario

5.1.2.1 Scenario tool 1: Protection of occupier health and thermal comfort

Aim:

To encourage assessment of the potential medium to long term effects on the health and thermal comfort of building occupiers that may result of future climate change.

Focus of attention:

The ability of a building fabric to maintain pre-defined thermal comfort conditions under projected future climate change. This shall be for the summer season only.

Links to other indicators:

- The additional cooling energy required to maintain these conditions, with reference to indicator 1.1.
- The potential for trade-offs associated with changes in a building's design and bill of materials shall also be considered. See indicators 1.2 and 2.1.

Level 1: Common performance assessment

Users shall extend the thermal simulation of a building to include scenarios for the climate in the years 2030 and 2050. The simulation shall follow the calculation methodology stipulated for indicator 4.2.

The quasi-steady state (monthly) or simplified hourly methods described in EN ISO 13790 may be used. In all cases, the calculation method shall be reported. The future weather file may therefore be either a design summer year based on monthly data or hourly data for a defined summer season.

Simulations shall be carried out using projected future weather files for 2030 and 2050. The modelling shall, as a minimum, be based on the UN IPCC 'mitigation' (SRES E1) emissions scenario. A second worst case scenario 'medium-high' (SRES A1B) emissions scenario may also be considered. This second scenario is more extreme and will introduce greater variance into the 2050 simulation.

Level 1 Common performance reporting format

Part 1 - Climate change projections used

Weather file source	
Scenarios modelled	*e.g. E1, A1B*

Part 2 - Performance assessment results

Performance aspect	**2030 scenario**		**2050 scenario**	
	E1	**A1B**	**E1**	**A1B**
Time out of range (%) - without mechanical cooling - with mechanical cooling	*Proportion of time*	*Proportion of time*	*Proportion of time*	*Proportion of time*

L2

Level 2: Comparative performance assessment

The following parameters shall be fixed in order to ensure a consistent and comparable analysis of the impact of the climate scenarios on a building's performance:

- Temperature ranges: The Category II temperature ranges, as stipulated in EN 15251, shall be used in all cases.
- Summer season: The cooling seasons defined in the National Calculation method shall be used. The present weather data shall be the design summer year derived from time series with a minimum of 20 years for the nearest local weather station.
- PPD thermal parameter input data: For the six parameters identified in EN ISO 7730 the default or reference national or regional data for the building type shall be used.

Either the quasi-steady state (monthly) or the simplified hourly methods as described in EN ISO 13790 may be used. The method used may form part of a national calculation method/overheating assessment. In all cases, the calculation method shall be reported. The future weather file may be either:

- a design summer year based on monthly data, or
- hourly data for a defined summer season.

The same reporting format shall be used as for Level 1.

L3

Level 3: Performance optimisation assessment

The following key aspects shall be considered in order to improve the representativeness and precision of the scenario:

- ✓ Aspect 1 – Projected weather file time representativeness and uncertainty
- ✓ Aspect 2 – the inherent thermal resilience of the building design
- ✓ Aspect 3 – Shading and microclimate benefits of green infrastructure

The latter two aspects address the extent to which built assets integrate inherently resilient features, excluding services.

For each aspect a brief outline is provided of how they can improve performance, together with guidance notes which go into more detail.

Users should then report on which aspects they have focussed on. The more aspects addressed the better the reliability rating that will be obtained, as the rating improves in function of accuracy and representativeness.

Users choosing to carry out a life cycle GWP assessment or a cradle to cradle LCA in order to model the scenario can additionally report on the improvement potential of their chosen climate resilience measures. The results of the scenario are incorporated into the reporting format for life cycle GWP (see section 1.2.1.4) and cradle to cradle LCA (see section 7.2.3). To ensure consistency, the specific rules laid down in section 5.1.3 shall be followed.

Key aspects to focus attention on:

Aspect 1 – Projected weather file time representativeness and uncertainty

Focus of attention: The precision and uncertainty associated with the future climate projection for a building location.

The availability of detailed projections of climate change across the EU varies, with some Member States having used highly complex models to develop weather files.

In other Member States, only high level projections developed at EU level may be available, and designers may have to resort to the use of worse case existing scenarios for heat waves as a proxy for future extreme weather. Further information is provided in guidance note 5.1.

The baseline year for the projection shall, as far as possible, be chosen to be consistent with those of the present day weather file used. The level of probability for the 2030 and 2050 projections shall be reported, if available.

An additional level of precision can be introduced if any localised Urban Heat Island (UHI) effects have been factored into the present weather files, thereby ensuring that the baseline (and projected) climate reflects any significant local effects. This is described further under aspect 1 of indicator 4.2.

Guidance note 5.1 for design teams

Possible sources of future climate change projections

There are broadly three possible sources of climate change projections currently available to users of the Level(s) framework.   Each, in turn, is associated with an increasing level of precision and certainty:

1. Worst case scenario based on recent heat wave events: Average data for summers in which heat wave events[71] occurred in local area during the last 30 years. An example source at EU level is the European Climate Assessment & Dataset[72]. National meteorological offices can also provide this data based on established definitions of a heat wave event[73].
2. Dynamic downscaling of UN IPCC models to regional or local scale: Use of a weather file generator that is based on UN IPCC General Circulation Models, such as the Climate Change World Weather file generator[74] or the Climate Cost project[75].
3. Probabilistic downscaling of large-scale models and interpolation of regional or local weather station data: The interpolation of local or regional weather files based on statistical modelling at a larger scale, such as the Ensembles project[76].

Aspect 2 – the technical representativeness of building designs with inherent thermal resilience

Focus of attention: Taking into account the extent to which a building design has features that make it inherently more resilient and therefore provide an additional margin for adaptation over time.

The building structure and fabric may be designed in a way that provides inherent future resilience to overheating events. There are three main areas of focus for resilient design to manage the thermal balance of a building:

[71] According to the World Meteorological Organisation a heat wave is defined as when 'the daily maximum temperature of more than five consecutive days exceeds the average maximum temperature by 5 °C, the normal period being 1961-1990'
[72] European Climate Assessment & Dataset project, http://www.ecad.eu/
[73] See the following example for Spain – AEMET, *AEMET analiza las "olas de calor" registradas en España desde 1975* http://www.aemet.es/en/noticias/2015/05/olasdecalor
[74] University of Southampton, *Climate Change World Weather File Generator for World-Wide Weather Data – CCWorldWeatherGen*, Energy and Climate Change Division, UK http://www.energy.soton.ac.uk/ccworldweathergen/
[75] ClimateCost, http://www.climatecost.cc/
[76] ENSEMBLES, *Project overview*, http://ensembles-eu.metoffice.com/index.html

- Thermally activated building structures: These can, even in the present climate, allow for a significant reduction in the size of HVAC plant because of its inherent thermal inertia over a 24 hour operating period.
- Thermally resilient envelope and façade: The materials can be selected for both their albedo effect (solar reflectance) and their thermal resistance (insulation value), thereby reducing absorption and transmission of solar radiation to the interior of the building.
- Thermally resilient air intake systems: The design of fresh air intake pathways so that air is brought into buildings through shaded external spaces and through underground systems can minimise air intake temperatures

Dynamic thermal simulation is required to more accurately quantify the benefits of inherently resilient design features. It can also be used to optimise the design of facades and structures, as well as the operation of ventilation and cooling systems, in order to utilise this capacity.

Aspect 3 – the technical representativeness of the shading and microclimate benefits from green infrastructure

Focus of attention: Taking into account the shading and microclimate benefits of green infrastructure in the thermal simulation.

The presence of vegetation on buildings (e.g. green roofs) or between/within buildings (e.g. trees) can provide shading and moderate external air and surface temperatures. This is because it shades materials with a low albedo and a high thermal capacity, such as paving, thereby minimising the re-radiation of heat. The use of soil instead of hard 'sealed' surfacing can further moderate external temperatures.

Guidance note 5.2 provides some further information on the options available to factor the shading and cooling action of vegetation and soil into building designs.

Guidance note 5.2 for design teams

Options for modelling and assessing the performance improvements of green infrastructure features

Two main options exist for factoring the shading and cooling function of vegetation and soil into a building design:

1. Change building thermal simulation inputs: Some dynamic and quasi steady-state building simulations allow for the input of vegetation shading. However, the potential to do this is not currently well developed and representative input data is difficult to obtain.
2. Use of a 'green factor' scoring system: This can be used as a proxy for the ecosystem services provided by green infrastructure. It works by scoring the shading and cooling potential of green features on, in or around a building (e.g. trees according to their leaf area, evapotranspiration rate, soil water retention). This approach has been applied in cities such as Berlin, Stockholm and Southampton.

The second option can only be considered to provide a useful proxy if the potential ecosystem services that can be provided are weighted to reflect the shading and cooling potential of vegetation, soil or combinations of both. The maturity and extent of the vegetation in 2030 and 2050 should also be estimated.

To take an example of the second option, Malmö's 'Green Space Factor' (GSF) provides a simplified weighting system for green infrastructure[77]. The GSF is weighted as follows to take into account the extent of soil sealing, the depth of soil and the extent of vegetation (e.g. mature trees have a greater weighting).

$$GSF = \frac{(area\ A\ x\ factor\ A)+(area\ B\ x\ factor\ B)+(area\ C\ x\ factor\ C)+etc.}{total\ courtyard\ area}$$

Level 3 performance optimisation reporting format

To be reported in addition to the results using the format provided for Level 1, and those obtained for a life cycle GWP or LCA analysis.

Part 1 - Performance optimisation aspects addressed

Aspect	**Addressed? (yes/no)**	**Notes on data sources and calculation method**
Aspect 1 – Projected weather file time representativeness and uncertainty.		
Aspect 2 – The technical representativeness of inherently thermal resilience building designs		
Aspect 3 – The technical representativeness of shading and microclimate benefits from green infrastructure features		

[77] Kruuse.A, *the green space factor and the green points system*, GRaBs Expert paper 6, EU INTERREG project, TCPA, April 2001

5.1.3 Specific rules for analysing scenarios using life cycle GWP or LCA (level 3)

If results are to be reported in the public domain, it is important to ensure that the scenario is modelled in a consistent way. If life cycle GWP or LCA is used, the following steps shall be followed:

1. Reference assumptions: The initial assumptions about the building's thermal environment shall be set out. Parameters that are fixed at national or regional level according to the Directive 2010/31/EU for the Energy Performance of Buildings. Calculation methods for overheating assessments shall be reflected in these assumptions.
2. New scenarios based on a risk assessment: The thermal simulation shall be re-run in order to identify potential risks to the thermal comfort of occupiers in the future. This shall thereafter be used to develop improved design options for subsequent thermal simulation.
3. Life cycle modelling of the design option(s): Life cycle GWP or LCA shall be used to model the reference (initial design) case and the new design options in order to identify the optimal environmental solution, including any potential trade-offs.
4. Cost and value engineering of the design: Working within the constraints of the project, the preferred option to be constructed shall be identified and then remodelled using life cycle GWP or LCA.
5. Reporting of the results: The results for the reference (intended) case and the preferred (improved) option shall be reported on.

To maximise the value of these steps to optimise designs, they are recommended as taking place during the design concept stage.

These steps imply the input of the architect, energy specialist (if used), service engineers and the cost consultant in order to develop and test design scenarios.

5.1.4 Market valuation influence and reliability rating

The following tools are provided to inform the valuation of a property for which performance has been assessed according to indicator 5.1:

- Checklists for the potentially positive influence on value and risk
  - Checklist 1: Potential positive influence on future performance
  - Checklist 2: Accounting for the performance assessment in valuation criteria
- Ratings of the performance assessment
  - Rating 1: Basis for the performance assessment
  - Rating 2: Professional capabilities
  - Rating 3: Independent verification

The completed reporting may be used separately alongside the Level 1, 2 or 3 results for Scenario 1, or may form part of the overall reporting for indicator 6.2.

In the case that the ratings will be used as part of the overall reporting for indicator 6.2, then the rating 1 results shall be used to calculate the overall Indicator Reliability Index (IRI).

The Indicator Reliability Index (IRI) for rating 1 shall be calculated from the individual ratings as follows:

$$\mathrm{IRI} = \frac{(TeR\ min\{rating\ aspects\}) + (TR)}{2}$$

Where:

TeR = Technical Representativeness

TR = Time representativeness

To calculate the IRI the lowest score for each of the types of rating aspect shall be used to calculate arithmetic mean of the reliability.

5.1.4.1 The potential for a positive influence on a market valuation

Checklist 1 – Evaluation of potentially positive influences on the market performance

Potential influence	***Evaluated?***	***Resulting assumptions used in the appraisal***
Potential influence 1 *Increased revenues due to market recognition and lower void rates.*	*Yes/no*	
Potential influence 2 *Reduced operational, maintenance, repair and/or replacement costs.*	*Yes/no*	
Potential influence 3 *Reduced future risk of increased overheads or loss of income.*	*Yes/no*	

Checklist 2 – Accounting for the Level(s) assessment in the valuation criteria used

Valuation criteria set used	Identify the scheme or tool used in the appraisal
Version of the criteria set used	

Criteria which the assessment has influenced		Influence on the valuation or rating
Valuation criterion	**Sub-criterion**	
Criterion x	Sub-criterion y	Notes on the extent of the influence and the supporting assumptions used

5.1.4.2 Reliability rating of the performance assessment

Rating 1 - Basis for the performance assessment

Sub-indicator	Rating aspect	Rating score (reflecting the degree of representativeness)			
		0	**1** Low	**2** Medium	**3** High
1. Projected weather file time representativeness and uncertainty.	The extent to which simulations are based on a combination of probabilistic downscaling and local/regional interpolation.				
2. Technical representativeness of inherently resilience building design features	The extent to which the structure, envelope, façade and air intake systems contribute to thermal resilience.				
3. Technical representativeness of the shading and microclimate benefits of green infrastructure features	The extent to which the potential benefit of green infrastructure has been factored into designs and simulations.				

Scenario 1 **Indicator Reliability Rating**	

Rating 2 – Professional capabilities

Rating aspect	Rating score			
	0	**1**	**2**	**3**
2. Technical capability of the personnel carrying out the assessment(s)	*No formal training and limited experience in using the calculation method*	*Formal training or some applied experience in using the calculation method*	*Formal training and some applied experience in using the calculation method*	*Formal training*[78] *and significant applied experience in using the calculation method*

Rating 3 – Independent verification

Rating aspect	Rating score			
	0	**1**	**2**	**3**
3. Independent verification of the assessment	*Self-declaration of the performance assessment results*	*Peer review of the input data and calculation steps*	*Third party auditing and verification of the calculation steps*	*Third party auditing and verification of the input data and calculation steps*

[78] In accordance with Article 17 of the EPBD

Potential future aspects of macro-objective 5

5.2 Future aspect: Increased risk of extreme weather events

5.2.1 Why measure this performance aspect?

As well as a projected rise in average temperature, climate change is projected to lead to a greater frequency and intensity of extreme weather events. This could include floods, wind, rainfall and snowfall, as well as hot and cold conditions. By exposing them to greater stress, the increased weather loadings may have an impact on the life span of building elements and materials.

5.2.2 Which aspects can be measured?

The aspects that could be measured are those for which there may be an impact on the service life of a building component or material. Table 5.2.1 provides a general overview of possible focus areas for attention and related reference standards. Floods are addressed as a separate potential future aspect 5.3.

Table 5.2.1 Focus areas for attention on increased risk of extreme weather events

Resilience aspects	**Technical focus**	**Reference standards**
1. Increased wind loads	– the level of structural resistance required, – the fixing of cladding façade elements, – fabric air tightness.	EN 1991-1-4
2. Increased rainfall	– water tightness to rain ingress, – damage to walls and insulation, – sources of damp, – roof and drainage systems loadings.	EN 1991-1-1
3. Increased snowfall	– the need for greater structural resistance to snow loads, – the need for increased dimensions of eaves and gutters.	EN 1991-1-3
4. Temperature stress	– the resistance of cladding, render, paint and coatings to temperature changes.	EN 1991-1-5

5.2.3 Initial reporting format for potential future aspect 5.2

Risk of extreme weather events addressed?	Yes/no

Specific design aspects addressed	Aspect x	Yes/no	*Reference standards and methods used*
	Aspect y	Yes/no	*Reference standards and methods used*
	Aspect z	Yes/no	*Reference standards and methods used*

5.3 Future aspect: Increased risk of flood events

5.3.1 Why measure this performance aspect?

Climate change is projected to result in an increased frequency of flood events across many regions of the EU. In areas at risk, flood events can have a significant impact on people and the buildings they live and work in.

The direct impact on people's lives can be substantial, with the potential of displacement and disruption as a result of damage, or even drowning and injuries during event. The impacts on buildings can include damage to building structures, interiors and related infrastructure.

The direct impact of financial losses can be substantial, having a longer term impact on insurance premiums and property values in affected areas. The indirect financial impacts of business, supply chain and household disruption can in some cases be economically more severe than the direct impacts.

5.3.2 Which aspects can be measured?

Whilst flood risk management is usually most effectively addressed by large scale flood prevention and mitigation strategies at sub-regional/regional level[79], there is still scope for any remaining residual risk to be addressed and measured at building level. Performance aspects that could be measured include a focus on:

- flood risk at a fluvial, river basin level and as a result of localised, torrential rain events resulting from cloudbursts,
- the related level of protection of properties in function of an identified level of risk in a given location.

Table 5.3.1 provides a general overview of possible focus areas for attention and related reference standards.

Table 5.3.1 Focus areas for attention on increased risk of flood events

Resilience aspects	**Technical focus**
1.1 Fluvial flood risk	– Identification of the level of flood risk of the site, with reference to local hazard maps[80]. – Location in an area that already has larger scale mitigation measures will lower the site risk.
1.2 Cloudburst (localised) flood risk	– Examination of historical rainfall and landscape mapping to identify areas of potential risk[81].
2. Level of property protection	– The extent to which basement, ground floor access and habitable rooms (in residential buildings) are clear of design flood levels. – The extent to which drainage systems control and retain excess water flow[82].

[79] See Climate-ADAPT case study (2016) *Public-private partnership for a new flood proof district in Bilbao*, http://climate-adapt.eea.europa.eu/metadata/case-studies/public-private-partnership-for-a-new-flood-proof-district-in-bilbao

[80] European Environment Agency, *Adaptation of flood management plans*, 2015 http://climate-adapt.eea.europa.eu/metadata/adaptation-options/adaptation-of-flood-management-plans

[81] . An example from Denmark illustrates the potential risk and how mapping can be used - ArcGIS, *Lessons: Find areas at risk of flooding in a cloudburst*, https://learn.arcgis.com/en/projects/find-areas-at-risk-of-flooding-in-a-cloudburst/lessons/explore-the-cloudburst-issue.htm

[82] This could include the use of natural water retention measures, some of which are classified here http://ec.europa.eu/environment/water/adaptation/ecosystemstorage.htm

5.3.3 Initial reporting format for potential future aspect 5.3

Risk of flood events addressed?	Yes/no

Specific design aspects addressed	Aspect x	Yes/no	*Reference standards and methods used*
	Aspect y	Yes/no	*Reference standards and methods used*
	Aspect z	Yes/no	*Reference standards and methods used*

Macro-objective 6: Optimised life cycle cost and value

6.1 Life cycle costs	**Where to find the guidance for each Level** Level 1 common performance assessment Level 2 comparative performance assessment Level 3 performance optimisation assessment Valuation influence and reliability rating (all levels)
6.2 Value creation and risk factors	The potential for a positive influence on a market valuation Reliability rating of a Level(s) assessment Calculation of the technical rating

Key terms and definitions used

Discounted cost	resulting cost when the real cost is discounted by the real discount rate or when the nominal cost is discounted by the nominal discount rate
Discount rate	factor or rate reflecting the time value of money that is used to convert cash flows occurring at different times to a common time.
Elemental cost plan	the total construction cost for the project divided into building elements, estimated based on the actual quantities of work and materials that will be required to construct the project.
Life Cycle Cost (LCC)	cost of an asset or its parts throughout its life cycle, whilst fulfilling its performance requirements.
Maintenance	combination of all technical actions during the service life to retain a building or an assembled system in a state in which it can perform its required functions
Maintenance cost	total of necessarily incurred labour, material or other costs incurred to retain a building or its parts in a state in which it can perform its required functions
Net present cost	sum of the discounted future costs.
Nominal cost	expected price that will be paid when a cost is due to be paid, including estimated changes in price due to, for example, forecast changes in efficiency, inflation or deflation and technology.
Operation cost	cost incurred in running or managing a facility or the built environment, including administration support services.
Real cost	cost expressed as a value at the base date, including estimated changes in price due to forecast changes in efficiency and technology.
Reference service life	service life of c construction product which is known to be expected under a particular reference set of in-use conditions and which may form the basis for estimating

	the service life under other in-use conditions.
Repair	returning an item to an acceptable condition by the renewal replacement or mending of worn, damaged or degraded parts.
Replacement	substitution of a whole construction product, building element or installation with the same or an equivalent product, building element of installation in order to re-establish the required functional and technical performance.
Required (or intended) service life	service life required by the client or through regulation
Scenario	collection of assumptions and information concerning an expected sequence of possible future events

6.1 Indicator of life cycle costs

6.1 Life cycle costs	**Where to find the guidance for each Level** Level 1 common performance assessment Level 2 comparative performance assessment Level 3 performance optimisation assessment Valuation influence and reliability rating (all levels)

6.1.1 Level 1 - Making a common performance assessment

6.1.1.1 Calculation methodology and data requirements

Calculation methodology to be used

The calculation method is based on elemental cost estimates, i.e. the cost of land and labour are not included. Cost estimates shall be compiled for each of the building elements and their associated components, as identified by the minimum scope in section 1.1.2.

The costs shall include those related to construction of the building, as well as projected costs associated with the future operation of the building (utility costs) and the maintenance, repair and/or replacement of building elements and components. Further guidance on future cost planning and projections can be found in guidance note 6.2.

The reference standard for calculating the life time of each life cycle stage shall be ISO 15686-5. The accompanying reference standard ISO 15686-8 provides a methodology for calculating the design life of elements and components.

The cost data shall be used to create a cash flow of real costs along the life cycle of the building. A discount rate shall thereafter be applied in order to obtain a discounted cash flow and the net present costs. A default 'societal rate' of 3% may be used based on the European Commission's guidance for calculating cost optimal levels for minimum energy performance requirements[83].

[83] Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by

The net present costs should generally be calculated using real costs, i.e. excluding inflation. However, assumptions about inflation may also be included within the discount rate if nominal costs are required for the purpose of detailed financial planning[84]. Where there is evidence in a Member State of past utility or construction costs indices having escalated at a significantly different rate to inflation, a different rate may be applied to these costs.

In all cases, the material and energy costs shall be adjusted to reflect current prices from the reference year 2015. This adjustment shall be based on annual price indices for the country where the project is located. Where a national index time series is not available, the EU construction price index data published by Eurostat shall be used[85].

The defined reference study period of 50 years shall be used. In addition, the life cycle costs for a client's intended service life or investment holding period may be calculated. In all cases, elements and components are not assumed to be replaced until they have reached the end of their intended service life. Section 9.5 of EN 16627 provides further guidance on calculating replacement rates.

Data requirements and sources

Development of the life cycle cost plan for a building will require the collection of a range of cost data. For the whole life cycle this data will need to model costs at different points in time and that may, as a result, require a range of different types and sources to be used. The data requirements and associated professionals responsible for collecting and estimating costs are outlined in table 6.1.1.

Table 6.1.1 Data requirements and responsibilities by life cycle stage

Life cycle stage	**Professional involvement**	**Types of data required**
Construction costs	Obtained during the design and contracting stages by the cost consultant.	Cost data obtained from suppliers and contractors.
Operational (utility) costs	Dependant on the life cycle stage.	During the design and construction stage, on the basis of the energy and water use performance assessments. Upon completion, property managers and owner occupiers may obtain data from metering.

establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements

[84] The inflation rate shall reflect the Member State where the assessment takes place, and based on the Harmonised Index of Consumer Prices (HICP)

[85] Eurostat, http://ec.europa.eu/eurostat/statistics-explained/index.php/Construction_producer_price_and_construction_cost_indices_overview

Maintenance, repair and replacement costs	Estimated by cost consultants working with property managers during the acquisition of (a) building(s)	At a basic level, estimates require data on: – the design life of elements and components, – the environmental exposure conditions that they may be exposed to, – the service conditions they will be subjected to, – the potential causes and probability of early failures.
Refurbishment costs	Potential scenarios for the future adaptation of a property to changing market conditions will need to be developed and costed by cost and property surveyors	Based on currently available products and technologies at current prices. For offices, this could range from costing of a renewal of the fit-out and servicing, to a change of use from office to residential or short stay units (or vice versa).
End of life costs	Potential scenarios for the deconstruction and demolition of the building will need to be developed and costed.	Revised cost estimates could be obtained from contractors on the basis of design features intended to make the building easier to deconstruct, reuse and recycle. Cost estimates would need to be made based on current technologies and prices.

6.1.1.2 Simplified rules based on an incomplete life cycle

The Level(s) framework promotes an LCC method that encompasses all the life cycle stages defined in EN 16627 and ISO 15686-5 and for the scope of building elements defined in section 1.1, table 1.1. However, the Level(s) framework also recognises that upon starting to use LCC, it may be challenging to make meaningful assumptions and choices in relation to projected future costs along the life cycle.

In the short term, therefore, the Level(s) framework encourages design professionals to start using LCC by supporting and allowing users to carry out simplified assessments of life cycle costs that may focus on a reduced number of life cycle stages.

Because a simplified LCC will not present a true picture of all the life cycle costs of a building, a number of reporting rules shall be followed:

- The results shall clearly be reported as being based on an 'incomplete life cycle'
- In each case, the minimum life cycle boundaries and scope of building elements shall be followed
- A reliability rating cannot be reported on, because the basis for the LCC is incomplete

More detailed guidance on the minimum life cycle boundaries and scope of building elements is provided in guidance note 6.1.

Guidance note 6.1 for design teams

Simplified options for life cycle costing based on the modelling of selected life cycle stages

A simplified approach may be adopted by focusing first on those life cycle stages of short term concern to clients who need to finance the capital costs and require an outlook on the operational utility costs for potential occupiers.

Stages B2, 3 and 4 shall be based on projections for the clients required service life. They shall be based on scheduled maintenance, repairs and replacements of construction products.

Table 6.1.2 Suggested simplified reporting options

Simplified reporting option 1: 'incomplete life cycle: product stage and calculated energy and water performance'	• The product stage (A1-3) • The use stage (B6-7)
Simplified reporting option 2: 'incomplete life cycle: product stage, calculated energy performance and projected service life'	• The product stage (A1-3) • The use stage (B2-4,B6)

6.1.1.3 *Suggested reporting format*

The reporting of costs shall be by life cycle stage. The costs reported under each life cycle stage shall be disaggregated into one-off costs (e.g. construction of a building), annual recurrent costs (e.g. utility costs) and projected non-annual costs (e.g. unscheduled and planned maintenance).

Level 1 common performance assessment reporting format

Performance assessment results

Type of cost	**Cost by life cycle stage (€/m^2/yr)**			
	A **Product and construction stages**	**B** **Use stage**		**C** **End of life stage**
One off costs	*Construction*	*Refurbishment and adaption*		*Deconstruction and demolition*
Annual recurrent costs	-	*Energy*	*Water*	-
	-	*Maintenance, repair and replacement*		-
Projected non-annual costs	-	*Maintenance, repair and replacement*		-
Total costs				

6.1.1.4 Monitoring of as-built and occupied performance

The first opportunity to monitor the predicted life cycle costs occurs with the final as-built costs of the building elements, which can be obtained from the lead contractor or construction manager upon practical completion and final settlement.

Thereafter, asset and facilities managers can gather data on the performance of the building over time in comparison to design estimate values for energy and water demand, as well as annual spending on maintenance, repairs and replacements in comparison to projections.

The collection of accurate metered energy and water consumption data requires a metering strategy. Issues to consider in developing a metering strategy are outlined in Part 1, section 3.5.1, guidance note 2.

A range of software packages are available on the market to support asset and facilities managers to track maintenance, repair and replacement costs.

6.1.2 Making Level 2 and 3 comparative and optimisation assessments

6.1.2.1 Level 2 comparative performance assessment

A number of rules that fix parameters for the calculation of costs shall be followed if comparative reporting is required. These are described below:

- The reference study period shall be 50 years. The client's intended service life or investment holding period shall additionally be reported.
- A discount rate of 4% shall be used to calculate the net present costs reported on. The discount rate stipulated by the client for internal appraisal purposes shall additionally be reported.
- Construction costs shall be adjusted to reflect current prices from the reference year 2015.
- The cash flows generated shall be discounted over the reference study period to give the net present costs of the building.
- Average national utility costs for households or services shall be used[86]. The future projections provided by the European Commission in the guidance to Delegated Regulation (EU) No 244/2012 may be used as reference values.

Alternatively, the comparative reporting rules of another building assessment or reporting scheme may be chosen, in which case the scheme and the associated parameters used for cost modelling shall be reported in order to identify the comparative basis.

[86] see Eurostat, http://ec.europa.eu/eurostat/statistics-explained/index.php/Energy_price_statistics

The following life cycle stages shall be optional, subject to them being specified as taking place within the reference study period that will be reported on:

- Refurbishment: The following scenarios shall be costed and reported for comparative purposes:
  - Office building: Refurbishment of the interior fit out, as well as renovation of windows and the following systems - lighting and HVAC. The ease of carrying out the refurbishment shall be factored into the costs.
  - Residential apartment building: Refurbishment of the interior fit out and facades, as well as the following systems – lighting and energy.
  - Residential individual houses: Refurbishment of the interior fit out and facades, as well as the following systems – lighting and energy.
- End of life: The end of life stages shall be costed on the basis of current technology and prices. Some costs will in any case be incurred in relation to use stage investments (e.g. the replacement of equipment).

Level 2 comparative performance reporting format

Part 1 – The basis for reporting

Basis for reporting	*EU Level(s) framework or another assessment or reporting scheme?*

Part 2 - Parameters used in calculating the reported results

Reference discount rate	*If different from the EU Level(s) framework discount rate of 3%*
Comparative investors discount rate	*The discount rate used by the developer or investor in the building*
Reference year	*If reporting is according to another scheme*
Life cycle stages	*Specify if a simplified option has been used*

6.1.2.2 Level 3 performance optimisation assessment

Users of the Level(s) framework seeking to optimise life cycle costs are recommended to focus attention on the following two aspects:

- ✓ Aspect 1 – Quality and representativeness of cost data
- ✓ Aspect 2 – Quality and representativeness of maintenance, repair and replacement plans and projections

For each aspect a brief outline is provided of how they can improve performance, together with guidance notes which go into more detail.

Users should then report on which aspects they have focussed on. The more aspects addressed the better the reliability rating that will be obtained, as the rating improves in function of accuracy and representativeness.

In addition a number of parameters and associated assumptions used to make a more precise and accurate assessment of life cycle costs shall be reported, so as to ensure that there is a transparent basis for the reported performance.

Parameters that shall be reported on

The main parameters for the life cycle cost calculations may be selected by the user, but they shall be reported on in order to ensure transparency. These shall include:

- Discount rate: The rate shall reflect the investment performance requirements of the user (e.g. defined in terms of Weighted Average Cost of Capital (WACC), Internal Rate of Return (IRR) or yield) in order to use the costs as a component in calculating a building's Net Present Value.
- Intended service life: Selected to reflect the intended service life or investment holding period of the building and the duration of the reported maintenance, repair and replacement planning.
- Cost escalation over time
  - Inflation: Costs may be real or nominal (inclusive of inflation). The latter may be chosen if specific sums must be made available to meet payments at specific points in time in the future. Different rates may be used if there is evidence of higher escalation rates for the cost of construction materials.
  - Energy prices: The future projections provided by the European Commission in the guidance to Delegated Regulation (EU) No 244/2012 may be used as default values.
- Refurbishment scenario: Definition of a scenario for the refurbishment of the building in order to extend its service life. This may continue the same use, or require a change in the use.
- End of life scenario: Definition of a scenario for the deconstruction and demolition of the building, which may take into account design to facilitate reuse and recycling.

The reference year for cost data shall in all cases by 2015. Costs shall be adjusted according to the guidance in section 6.1.1.1.

Key aspects to focus attention on

Aspect 1 – Quality and representativeness of the cost data used

Focus of attention: Cost data used shall be as geographically, temporally and technically representative as possible of the building typology and elements.

Because of strong regional differences in construction and utility costs, users shall consider the data used, its quality and its representativeness.

A focus shall be made on obtaining data that is as high as possible in the following indicative hierarchy of cost data, in ascending order of representativeness:

1. Generic or default national or EU data
   - Default data provided at EU or national level
   - Default data provided by an existing assessment or reporting scheme
2. Older or less geographically specific benchmarked and averaged data
   - Published benchmark data, aggregated and averaged from similar projects
   - Estimates from published, average cost data obtained from contractors and suppliers
3. Recent tender and market estimates

- Analysis of the bills of quantities and schedules from other similar projects

4. Current tender and market estimates
   - Direct estimates based on offers from contractors and suppliers

Guidance on potential sources of default, generic and specific data is provided in guidance note 6.2. The sources of cost data used for each major building element shall be reported using the format provided for Level 3.

The energy and water consumption performance, and the savings potential relative to benchmarked performance for other buildings in the market, can be verified using a standard such as the International Performance Measurement and Verification Protocol (IPMVP)[87].

Guidance note 6.2 for design teams

Potential sources of elemental cost data for life cycle cost assessment

A range of sources of construction cost data exist, usually compiled based on averages for specific types of buildings at Member State level. These can provide a cost effective source of initial data. Some examples include:

- European Construction Costs: A private paid subscription service that provides access to data compiled from a number of Member States.
- National cost databases:
  - BCIS (Building Cost Information Service) online (UK): A paid service provided by the Royal Institute for Chartered Surveyors (RICS).
  - Catálogo de Elementos Constructivos del CTE (BEDEC, Spain): A national database of construction elements and materials which includes indicative LCC and LCA data.
  - Belgian Cost Database (ASPEN) (www.aspen-index.eu/benl/home.asp): A national database of construction elements and materials.
  - BKI (Germany): A paid service for design teams which provides access to cost yardsticks for typical building elements and for different building types [88].
  - OSCAR (Germany): A paid service compiled by property specialists that provides cost benchmarks for office buildings[89].

Aspect 2 – Quality and representativeness of maintenance, repair and replacement plans and projections

Focus of attention: Projected costs for maintenance, repairs and replacements shall be based on the best available data, knowledge and experience.

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[87] Efficiency Valuation Organisation, *International Performance Measurement and Verification Protocol (IPMVP),* https://evo-world.org/en/products-services-mainmenu-en/protocols/ipmvp

[88] Baukosteninformationszentrum Deutscher Architekten (BKI), *Statistische Kostenkennwerte für Gebäude*, 2010, www. baukosten.de.

[89] Jones Lang LaSalle, *Büronebenkostenanalyse* OSCAR – Office Service Charge Analysis Report, Jones Lang Lasalle, Germany, 2009 http://www. joneslanglasalle.de/Germany/DE-DE/Pages/Research-OSCAR.aspx

The development of a coherent set of cost projections requires the structuring of a range of data about the building into a coherent timeline and plan. Guidance note 6.3 provides some initial orientation on typical elements of such a plan.

Users of the Level(s) framework wishing to improve the reliability of plans and projections shall focus on the quality of the analysis of the data that will be used to develop the plan, as highlighted in section 6.1.1.1:

- Data for the design life of elements and components,
- Consideration of the environmental exposure conditions that they may be exposed to,
- Consideration of the service conditions they will be subjected to,
- The potential causes and probability of early failures.

Moreover, an expert review of the overall plan and the assumptions used by an experienced maintenance professional could highlight additional improvements.

Where indicator 1.2 Life cycle Global Warming Potential and/or 2.4 Cradle to cradle Life Cycle Assessment have been calculated, the consistency of the maintenance, repair and replacement assumptions shall be ensured.

Guidance note 6.3 for investors, property managers and owner occupiers

Developing maintenance, repair and replacement plans

Experience gained from long term management of building stock, such as social housing, provides a useful starting point for scheduling and estimating the future costs associated with the maintenance, repair and replacement of building elements and components.

A better understanding of the need for data and the types of estimates required can be gained by developing such a plan under the following headings:

- Unscheduled replacement, repairs and maintenance costs: These relate to unforeseen failure or damage before the design life expires. This might normally be estimated on the basis of probability.
- Cyclical replacement, repairs and maintenance costs: These relate to costs that reoccur during the service life, which can include the predicted failure rates over time of elements or systems. For example, the repainting of window frames and external render, the repair/replacement of window glazed units, the repair/replacement of domestic boilers.
- Minor replacement, repairs and maintenance costs: These relate to components that may require interventions several times during the service life, but which on their own represent relatively minor costs each time. For example, parts of the external fit-out.
- Major replacement costs: These relate to the planned replacement of major elements of the building upon expiry of their projected design life e.g. roofing, external render, cladding, windows and HVAC systems.

The resulting plan can be used to anticipate future costs as they occur. Sufficient money can thus be saved annually in a sinking fund to pay for known future replacements that will be required at different points in time.   Such a plan can also be used to manage potential risks and liabilities.

Further guidance can be found in section 5.4.2 of ISO 15686-5.

Level 3 performance optimisation reporting format

Part 1 - Optimisation aspects addressed

Aspect	**Addressed? (yes/no)**	**Notes on data sources and calculation method**
Aspect 1 – Quality and representativeness of the cost data used		
Aspect 2 – Quality and representativeness of maintenance, repair and replacement plans and projections		

Part 2 - Data transparency

Building elements	**Types of data source used for the identified life cycle stages ***			
	A **Product and construction stages**	**Basis for future assumptions**		
		B2 Maintenance	**B3 Repair**	**B4 Replacement**
Foundations				
Load bearing structural frame				
Non-load bearing elements				
Facades				
Roof				
Parking facilities				
Fixed lighting system				
Energy system				
Ventilation system				
Sanitary systems				
Miscellaneous systems				

** types of data sources:*

1. Generic or default national or EU data

   1a. Default data provided at EU or national level
   1b. Default data provided by an existing assessment or reporting scheme

2. Older or less geographically specific benchmarked and averaged data

- 2a. Published benchmark data, aggregated and averaged from similar projects
- 2b. Estimates from published, average cost data obtained from contractors and suppliers

3. Recent tender and market estimates

- 3a. Analysis of the bills of quantities and schedules from other similar projects

4. Current tender and market estimates

- 4a. Direct estimates based on offers from contractors and suppliers

6.1.3 Property valuation influence and reliability rating

The following tools are provided to inform the valuation of a property for which performance has been assessed according to indicator 6.1:

- Checklists for the potentially positive influence on value and risk
  - Checklist 1: Potential positive influence on future performance
  - Checklist 2: Accounting for the performance assessment in valuation criteria
- Ratings of the performance assessment
  - Rating 1: Basis for the performance assessment
  - Rating 2: Professional capabilities
  - Rating 3: Independent verification

The completed reporting may be used separately alongside the Level 1, 2 or 3 results for indicator 6.1, or may form part of the overall reporting for indicator 6.2.

In the case that the ratings will be used as part of the overall reporting for indicator 6.2, then the rating 1 results shall be used to calculate the overall Indicator Reliability Index (IRI).

The Indicator Reliability Index (IRI) for rating 1 shall be calculated from the individual ratings as follows:

$$\text{IRI} = \frac{(TeR\ \Sigma\{rating\ aspects\})}{2}$$

Where:

TeR = Technical Representativeness

6.1.3.1 The potential for a positive influence on a market valuation

Checklist 1 – Evaluation of potentially positive influences on future performance

Potential influence	***Evaluated?***	***Resulting assumptions used in the appraisal***
Potential influence 1 *Increased revenues due to market recognition and lower void rates.*	*Yes/no*	
Potential influence 2 *Reduced operational, maintenance, repair and/or replacement costs.*	*Yes/no*	
Potential influence 3 *Reduced future risk of increased overheads or loss of income.*	*Yes/no*	

Checklist 2 – Accounting for the Level(s) assessment in the valuation criteria used

Valuation criteria set used	*Identify the scheme or tool used*
Version of the criteria set used	

Criteria which the assessment has influenced		**Influence on the valuation or rating**
Valuation criterion	**Sub-criterion**	
Criterion x	Sub-criterion y	Notes on the extent of the influence and the supporting assumptions used

6.1.3.2 Reliability rating of the performance assessment

Rating 1 - Basis for the performance assessment

Sub-indicator	**Rating aspect**	**Rating score** **(reflecting the degree of representativeness)**			
		0	**1** **Low**	**2** **Medium**	**3** **High**
1. Quality and representativeness of the cost data used	The potential accuracy of the sources of cost data for building elements and components.				
2. Quality and representativeness of maintenance, repair and replacement plans and projections	The extent to which maintenance, repair and replacement plans and projections are based on the best available data, knowledge and experience.				

Indicator 6.1 **Indicator Reliability Rating**	

Rating 2 – Professional capabilities

Rating aspect	**Rating score**			
	0	**1**	**2**	**3**
2. Technical capability of the personnel carrying out the assessment(s)	*No formal training and limited experience in using the calculation method*	*Accredited training or some applied experience in using the calculation method*	*Accredited training and some applied experience in using the calculation method*	*Accredited training and significant applied experience in using the calculation method*

Rating 3 – Independent verification

Rating aspect	**Rating score**			
	0	**1**	**2**	**3**
3. Independent verification of the assessment	*Self-declaration of the performance assessment results*	*Peer review of the input data and calculation steps*	*Third party auditing and verification of the calculation steps*	*Third party auditing and verification of the input data and calculation steps*

6.2 Indicator of value creation and risk factors

6.2 Value creation and risk factors	The potential for a positive influence on a market valuation Reliability rating of a Level(s) assessment Calculation of the technical rating

This indicator relies on the gathering of the two types of results from each of the other indicators and life cycle scenarios:

- Valuation checklists: The information gathered from each of the two checklists per indicator is intended to provide an outlook on the potential for a positive influence of improved sustainability performance on a property valuation.
- Reliability ratings: The results of the ratings are intended to provide a semi-quantitative assessment of:
  - the reliability of a Level(s) performance assessment,
  - the professional capabilities of those carrying out a performance assessment, and
  - the extent to which the results have been third party verified.

The checklists are to be completed following the guidance provided for each indicator and scenario. Guidance is then provided in 6.2.2 as to how ratings from individual indicators can be aggregated to present an overall report for a Level(s) assessment.

6.2.1 The potential for positive influence on a market valuation

6.2.1.1 Using the reporting checklists

The reporting for this first component of indicator 6.2 comprises two checklists which are to be applied to each of the indicators in the Level(s) framework. It is envisaged that these checklists are used by valuation professionals.

The first checklist identifies three potential influences on project costs, revenues and exposure to risk. The user shall identify which have been evaluated for the relevant indicator, and if so, what the resulting assumptions were.

The second checklist requests that the criteria used to appraise the property value are identified. The criteria and sub-criteria which are considered to have been influenced by the performance assessment shall be identified. Notes shall be provided on the extent of the influence and the supporting assumptions.

The completed reporting may be used separately to report on the result for individual indicators or scenarios, or may form part of the overall reporting for indicator 6.2.

6.2.1.2 Suggested reporting format

Checklist 1 – Evaluation of potentially positive influences on the market performance

Potential influence	***Evaluated?***	***Resulting assumptions used in the appraisal***
Potential influence 1 *Increased revenues due to market recognition and lower void rates.*	*Yes/no*	
Potential influence 2 *Reduced operational, maintenance, repair and/or replacement costs.*	*Yes/no*	
Potential influence 3 *Reduced future risk of increased overheads or loss of income.*	*Yes/no*	

Checklist 2 – Accounting for a Level(s) assessment in the valuation criteria used

Valuation criteria set used	*Identify the scheme or tool used*
Version of the criteria set used	

Indicative example

Valuation criteria set used	*VOB (Germany)*
Version of the criteria used	*2005*

Criteria which the assessment has influenced		**Influence on the valuation or rating**
Valuation criterion	**Sub-criterion**	
Criterion x	Sub-criterion y	Notes on the extent of the influence and the supporting assumptions used

Indicative example

EU Level(s) framework indicator or scenario	***Valuation or risk rating criteria influenced***	
	Valuation criterion	***Sub-criterion***
Scenario 2.2.1 Design for refurbishment and adaptability	*Quality of the property cash flow*	*Tenant and occupier situation: duration and structure of rental contracts*
		Letting prospects
		Vacancy/letting situation
		Usability by third parties

6.2.2 Reliability rating of the performance assessment

6.2.2.1 Calculation methodology

Each indicator reliability rating consists of three separate ratings:

1. Technical rating - the extent to which performance optimisation aspects listed for Level 3 have been implemented. The aspects relate to the time, geographical or technical representativeness of the data and/or the precision of the calculation method used.
2. Professional capability - the professional capabilities of the personnel carrying out the performance assessment for a given indicator or scenario,
3. Independent verification - the extent to which the input data and calculation steps have been audited and third party verified.

The first rating is an aggregation of a number of ratings. It shall be determined from the arithmetic mean of the rating scores for each of the Level 3 performance optimisation aspects listed for a given indicator. If a performance aspect is not addressed, a zero score is assigned. The format used to present the rating of aspects for each indicator is shown in table 6.2.1.

Table 6.2.1 Format for the presentation of a semi-quantitative reliability rating

Rating aspect	**Brief description of the aspect**	**Rating score (reflecting the degree of representativeness)**			
		0	**1**	**2**	**3**
1. Time representativeness aspect	*Description of the aspect*	*Aspect not addressed*			
2. Geographical representativeness aspect					
3. Technical representativeness aspect					

Indicator x.y Indicator Reliability Rating	*Resulting IRI*

The Indicator Reliability Index (IRI) for each technical rating shall be calculated from the individual ratings as follows:

$$\text{IRI} = \frac{(TeR\ min\{rating\ aspects\}) + (GR\ min\{rating\ aspects\}) + (TR\ \min\{rating\ aspect\})}{3}$$

Where:

TeR = Technical Representativeness

GR = Geographical Representativeness

TR = Time representativeness

The lowest score for each of the three types of rating aspect shall be used to calculate the arithmetic mean of the reliability.

The scales for the rating of professional capabilities and independent verification are provided below.

Table 6.2.2 Format for the professional capability rating

Rating aspect	**Rating score**			
	0	**1**	**2**	**3**
2. Technical capability of the personnel carrying out the assessment(s)	*No formal training and limited experience in using the calculation method*	*Formal training or some applied experience in using the calculation method*	*Formal training and some applied experience in using the calculation method*	*Formal training and significant applied experience in using the calculation method*

Table 6.2.3 Format for the independent verification rating

Rating aspect	**Rating score**			
	0	**1**	**2**	**3**
3. Independent verification of the assessment	*Self-declaration of the performance assessment results*	*Peer review of the input data and calculation steps*	*Third party auditing and verification of the calculation steps*	*Third party auditing and verification of the input data and calculation steps*

6.2.2.2 Suggested reporting format

The reporting format requires users to report on the ratings made for all the indicator s selected for reporting by users of Level(s). For each performance assessment carried out, the results of each of the three ratings (technical, professional capability and independent verification) shall be reported on using the 'traffic light' scale provided. The colour code corresponds to the same categories as for the rating score.

Indicator 6.2 reporting format

Reliability ratings for each performance assessment

Indicator or scenario	**1. Technical reliability rating**	**2. Professional capabilities rating**	**3. Independent verification rating**
Indicator x.y	*Colour coded rating result*	*Colour coded rating result*	*Colour coded rating result*

Rating key:

(red)	*Rating aspect not addressed*
(amber)	*Low*
(light green)	*Medium*
(green)	*High*

Overarching assessment tool 7: Cradle to cradle Life Cycle Assessment (LCA)

Cradle to cradle LCA	**Where to find the guidance for each Level** Level 1 common performance assessment Level 2 comparative performance assessment Level 3 performance optimisation assessment Valuation influence and reliability rating (all levels)

The Level(s) framework seeks to address the life cycle environmental impacts of buildings in an integrated way. The quantitative assessment of the environmental impacts of a building using Life Cycle Assessment (LCA) is recognised at EU level as the best method to achieve this.

Whilst LCA was noted under macro-objective 2 as a method to assess the significant environmental impacts of building materials, LCA is promoted as an overarching method to assess performance within the Level(s) framework.

This section provides a toolkit to make LCA more accessible to new users. Guidance is provided on how to define the scope, boundaries, functional equivalent, time-related characteristics and scenarios required to carry out an LCA. Data quality is also addressed.

7.1 Terms and definitions used

Allocation	partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems.
Attributional LCA	system modelling approach in which inputs and outputs are attributed to the functional unit of a product system by linking and/or partitioning the unit processes of the system according to a normative rule.
Background processes	processes which are linked to the foreground processes (e.g. the production and supply of concrete / grid electricity).
Characterization factor	factor which is applied to convert an assigned life cycle inventory result to the common unit used for the respective environmental indicator
Component	construction product manufactured as a distinct unit to serve a specific function or functions.
Construction product	item manufactured or processed for incorporation in construction works.
Construction work	activities of forming a construction works.
Critical review	process intended to ensure consistency between a life cycle assessment and the principles and requirements of the International Standards on life cycle assessment.
Cut-off criteria	specification of the amount of material or energy flow or the level of environmental significance associated with unit processes or product system to be excluded from a study.

Data quality	characteristics of data that relate to their ability to satisfy stated requirements.
Elementary flow	material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation.
Environmental aspect	aspect of construction works, part of works, processes or services related to their life cycle that can cause change to the environment.
Environmental impact	change to the environment, whether adverse or beneficial, wholly or partially, resulting from environmental aspects.
Environmental impact category	class representing environmental issues of concern to which life cycle inventory analysis results may be assigned.
Environmental indicator	quantifiable value related to environmental impacts/aspects.
Environmental performance	performance related to environmental impacts and environmental aspects.
Estimated service life	service life that a building or an assembled system (part of works) would be expected to have in a set of specific in-use conditions, determined from reference service life data after taking into account any differences from the reference in use conditions.
Foreground processes	processes which affect directly the LCA results (e.g. the actual content of concrete in a column, the consumption of electricity during the occupation of a building).
Functional equivalent	quantified functional requirements and/or technical requirements for a building or an assembled system (part of works) for use as a basis for comparison.
Functional performance	performance related to the functionality of the construction works or an assembled system (part of works), which is required by the client and/or by users and/or by regulations.
Functional requirement	type and level of functionality of a building or assembled system which is required by the client and/or by users and/or by regulations.
Functional unit	quantified performance of a product system for use as a reference unit.
Functionality	suitability or usefulness for a specific purpose or activity.
Hotspots	aspects, areas or elements in the life cycle of a product which have the highest impacts/importance.
Primary data (specific data)	site-specific information based on direct measurement or characterisation of parameters for a certain context. Primary data can be obtained for instance through meter readings, purchase records, utility bills, engineering

	models, direct monitoring, mass balance, stoichiometry, or other methods.
Process	set of interrelated or interacting activities that transforms inputs into outputs.
Product system	collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product.
Reference flow	measure of the outputs from processes in a given product system required to fulfil the function expressed by the functional unit.
Reference study period	period over which the time-dependent characteristics of the object of assessment are analysed.
Required service life	service life required by the client or through regulations.
Scenario	collection of assumptions and information concerning an expected sequence of possible future events.
Secondary data	non-specific information which is gathered from LCA databases or other sources available in the literature (e.g. industry-average data from published databases, government statistics, literature studies, and industry associations, financial data, proxy data, and other generic data). Primary data that go through a horizontal aggregation step are also considered as secondary data.
Sensitivity analysis	systematic procedures for estimating the effects of the choices made regarding methods and data on the outcome of a study.
Service life / working life	period of time after installation during which a building or an assembled system (part of works) meets or exceeds the technical requirements and functional requirements.
System boundary	set of criteria specifying which unit processes are part of a product system interface in the assessment between a building and its surroundings or other product systems
Technical building system	technical equipment for heating, cooling, ventilation, hot water, lighting or for a combination thereof.
Technical performance	performance related to the capability of a construction works or an assembled system (part of works) to fulfil its required functions under the intended use conditions.
Technical requirement	type and level of technical characteristics of a construction works or an assembled system (part of works), which are required or are a consequence of the requirements made by either the client, and/or by the users and/or by regulations.
Unit process	smallest element considered in the life cycle inventory analysis for which input and output data are quantified.

7.2 Level 1 common performance assessment using the LCA method

7.2.1 Boundary and scope

7.2.1.1 The life cycle stages and documentation of the building

The scope comprises the evolution of the building from cradle to cradle. The setting of the system boundaries shall follow the "modularity principle" according to the EN 15978. This means that the unit processes influencing the building's environmental performance during its life cycle shall be assigned to the module in the life cycle where they occur.

The building shall be documented as follows, following the scope defined in section 1.1:

- Components (elements, structural parts, products, materials) needed during its life time. This also includes the consideration of in-use conditions and time-dependent qualities.
- Associated processes such as maintenance, exchange and End of Life processes and re-use, recycling and energy retrieval
- Energy and water use during the operation of the building.

Additional methodological rules and cut-off criteria are described in Sections 7.2.2 and 7.2.3.

The End of Life of a building starts when the building is decommissioned and no further use is intended. Components and materials to clear from the site have to be removed and the site has to be made ready for the next use. The End of Life stage shall be defined according to Module C1-C4 of EN 15978. Loads or benefits outside the system boundary are included in Module D.

7.2.1.2 Simplified options based on an incomplete life cycle

The Level(s) framework promotes an LCA method that encompasses all the life cycle stages defined in EN 15978 and for the scope of building elements defined in section 1.1, table 1.1. However, the framework also recognises that upon starting to use LCA it may be challenging to compile sufficient life cycle inventory data for all the building elements. Moreover, design professionals may not have the expertise to make meaningful assumptions and choices in relation to the use of generic data or data from other sources.

Because a simplified LCA will not present a true picture of the life cycle environmental impact of a building, a number of reporting rules shall be followed:

- The results shall clearly be reported as being based on an 'incomplete life cycle'
- In each case the minimum life cycle boundaries and scope of building elements shall be followed
- A reliability rating may not be reported on, because the basis for the LCA is incomplete

More detailed guidance on the minimum life cycle boundaries and scope of building elements is provided in LCA guidance note 1.

LCA guidance note 7.1 for design teams

Simplified options for LCA based on the modelling of selected life cycle stages

It is anticipated that over time, the availability of data and software tools, as well as improved access to professional training, will facilitate the use of LCA across the EU. In the short term, however, the Level(s) framework will encourage design professionals to start using LCA by supporting and allowing users to carry out simplified LCAs that may focus on a reduced number of life cycle stages.

A simplified approach may be adopted by focussing first on those life cycle stages in which material use and environmental impacts will have taken place upon completion of the building, and will be directly influenced by design decisions.

Stages B2, 3 and 4 shall be based on projections for the client's required service life.

They shall be based on scheduled maintenance, repairs and replacements of construction products.

Stage D is intended to represent the net benefit of the materials used in the building if they were to be reused and/or recycled – sometimes referred to as the building material bank. Specific calculation rules shall be followed (see section 7.2.2.1).

Table 7.1 Suggested simplified reporting options

Simplified reporting option 1: 'incomplete life cycle: product stage, calculated energy performance and projected service life'	• The product stage (A1-3) • The use stage (B4-5, B6)
Simplified reporting option 2: 'incomplete life cycle: product stage, calculated energy performance and the building material bank'	• The product stage (A1-3) • The use stage (B6) • The end of life stage (C3-4) • Benefits and loads beyond the system boundary (D)

7.2.2 Calculation methodology and data requirements

7.2.2.1 Calculation methodology to be used

The general methodology for carrying out an LCA is standardised by the reference standard ISO 14040/44 (2006) which describes four main phases:

1. Goal and Scope definition
2. Life Cycle Inventory (LCI) analysis
3. Life Cycle Impact Assessment (LCIA)
4. Interpretation

More specific guidance on how to carry out an LCA study for buildings and construction products can be found in the reference standards EN 15978 (2011) and EN 15804 (2012).

The *Life Cycle Inventory (LCI) analysis phase* is at the heart of the LCA calculation methodology. It consists of the compilation and quantification of inputs (e.g. raw materials, water and energy flows) and outputs (e.g. co-products, waste emissions to air, water and soil) for a product throughout its life cycle, and in accordance with the goal and scope definition. The LCI compilation is based on the following steps:

- Gathering of information about the resources consumed and the emissions released in the life cycle processes included in the system boundary. These are called foreground data, which are typically quantified through data collection sheets.
- Identification of sources of information for quantifying the associated elementary flows. These can be a mix of primary and secondary data, typically quantified with the support of LCA databases.
- Documentation of all data collected per life cycle stage:
  - Measurement method and the frequency of data collection
  - List of processes and primary/secondary data used
  - Detailed Bill of Materials, including names, units and quantities, as well as information on grade/purity and other technically and/or environmentally relevant characteristics
  - Evaluation of data quality (see Section 7.4)

- Implementation of the information gathered in spreadsheets and/or LCA software.
- Computer-aided quantification of input and output elementary flows.

The *Life Cycle Impact Assessment (LCIA) phase* aims at understanding and evaluating the magnitude and significance of the potential environmental impacts from the life cycle of the system under evaluation. Inputs and outputs quantified in the LCI need to be assigned to each impact category selected in the goal and scope of the study. Environmental impacts are then calculated for each category by converting LCI results into quantified impacts by applying characterisation factors. The outcome of the calculation is a numerical indicator result.

The *Interpretation phase* is the final step of LCA, where initial assumptions and outcomes from LCI and LCIA must be critically evaluated in relation to the defined goal and scope, and in order to ensure that robust conclusions and recommendations are achieved.

As described under macro-objective 2, additional rules for using LCA are provided within the Level(s) framework for the following life cycle scenarios which focus on resource efficiency:

Scenario tool 1: Building and elemental service life planning
Scenario tool 2: Design for adaptability and refurbishment
Scenario tool 3: Design for deconstruction, reuse and recyclability

For further guidance on each step in this process it is recommended to consult the EeB Guide project: http://www.eebguide.eu/

Table 7.2 Calculation rules for carrying out a Level 1 LCA

	Level 1: Common performance metric
Target end-users	The main users of this option are intended to be professionals who are not LCA experts, but they are interested in understanding and improving the overall environmental performance of the building. A simplified calculation method and data sources are therefore provided.
Building scope	The building elements listed for the shell and core, and excluding external works. *See the building element listing in Section 1,Table 1.1*
System boundary and cut off rules	All life cycle stages shall be calculated, unless a simplified reporting option is selected as a starting point. The modelling shall be as comprehensive and realistic as possible in describing the life cycle of the building.
Energy modelling	Inventory data to be obtained from indicator 1.1
Water modelling	Inventory data to be obtained from indicator 3.1
Scenarios and End of Life	With reference to scenarios in macro-objective 2
LCI and LCIA datasets and software	As a minimum, default data has to be used for calculating the impacts associated with building parts and elements and life cycle processes. This data can be obtained by a literature review and/or by using existing software tools and databases. This option should be possible based on freely available and simple software tools and databases. A list of databases and software

	tools is provided as a separate dynamic list.
Data quality requirements	Since the main objective of this option is to encourage professionals to use LCA and to focus on the same key environmental issues, the focus for data quality shall be on transparency. A data quality index calculated according to the method set out in Section 7.2.6 is to be reported for transparency reasons, as well as data sources.
Interpretation of the results and critical review	Result shall be interpreted critically through a sensitivity analysis in order to understand: • Environmental hot-spots, possible trade-offs between life cycle stages and improvement areas • The influence of data sources on the results, • Data gaps, robustness of assumptions, and limitations. Summary conclusions and recommendations shall be drafted.

7.2.2.2 Life Cycle Impact Assessment (LCIA) methods

A range of different environmental impact indicators have been developed by the scientific community. The indicators that shall be used in this framework are the midpoint indicators stipulated in the reference standards EN 15978 and EN 15804.

Midpoint indicators are considered to be a point in the cause-effect chain (or environmental mechanism) at which an impact on the environment can be quantified. An impact can be calculated by applying characterisation factors that reflect the relative importance of an emission or extraction in a Life Cycle Inventory (LCI) (e.g. the global warming potential of methane compared to CO_2).

A brief description of the environmental impact categories and their related indicators that users of the Level(s) framework shall characterise and report upon is given in the followings:

- **Global Warming Potential (GWP),** which measures how much heat a greenhouse gas can potentially trap in the atmosphere compared to the amount of heat trapped by a similar mass of carbon dioxide. GWP is calculated over a specific time interval, commonly 20, 100 or 500 years. GWP100 (for 100 years) is considered in this context. GWP is expressed as equivalent mass of carbon dioxide (whose GWP is normalised to 1).
- **Depletion potential of the stratospheric ozone layer (ODP)**, which measures the relative amount of degradation to the ozone layer caused by a chemical compound compared to trichlorofluoromethane (CFC-11, whose ODP is thus equal to 1.0). CFC 11 has the maximum ODP amongst chlorocarbons because of the presence of three chlorine atoms in the molecule
- **Acidification Potential of land and water (AP)**, which can be defined as the propensity of a chemical to form acidifying H+ ions. The main acidifying chemicals are oxides of sulphur (SOx), oxides of nitrogen (NOx), hydrochloric acid (HCl) and ammonia NH3, which are mainly produced by fossil fuel combustion. The acidification potential is expressed in terms of equivalent mass of SO_2.
- **Eutrophication Potential (EP),** expressed as equivalent mass of PO4, indicates the degree of hyper-productivity of ecosystems due to nutrients. While phosphorous is a critical factor for freshwater, nitrogen plays a more important

role in marine and terrestrial ecosystems. Too much nutrients in water can cause the excessive generation of biomass, which finally result in the depletion of the dissolved oxygen. Increased content of nitrogen in soil can lead to the undesired proliferation of fast growing plant species that can adapt easily to those levels.

- **Formation potential of tropospheric ozone photochemical oxidants (POCP)** is used to estimate the potential of air emissions to create ozone. The POCP value of a particular substance (NO_x and volatile organic compounds) measures how much the ozone concentration can vary compared to an equivalent mass of ethene (C_2H_4).
- **Abiotic Resource Depletion Potential for elements (ADP elements-ultimate reserves) and for fossil fuels (ADP fossil fuels),** respectively expressed as equivalent mass of Antimony (Sb) and equivalent feedstock energy (Lower Heating Value), are used to evaluate the consumption of resources.

LCA guidance note 7.2 for design teams

Selecting more comprehensive environmental impact categories

Building products and materials are responsible for a diversity of environmental impacts, with some being distinct to specific materials. Choices made at the design phase may therefore be affected by the type of environmental aspects considered by an LCA.

The impact categories included in the current versions of EN 15978 and EN 15804 address only a portion of the possible environmental effects of a building. This is due to the fact that methods for assessing other environmental impacts were not considered to be robust enough to be included in the standard.

A revision of the EN 15804 standard is under preparation, with final publication planned by the first quarter of 2019, and is likely to move towards closer alignment with the current Product Environmental Footprint (PEF) pilot project of the European Commission[90]. This could in particular result in the modification and/or update of the impact categories considered in the EN standard and of the associated impact assessment methods. Additional impact categories under consideration are:

- Eco toxicity and human toxicity
- Particulate matter / respiratory inorganics (dust particles)
- Ionising radiation
- Land use
- Water scarcity

Users of LCA will then have the option to assess the performance of buildings for a broader range of impacts. One drawback is that it will then take time for product specific data to be developed. Consequently, generic data may have to be initially used, making the results less accurate.

[90] http://ec.europa.eu/environment/eussd/smgp/ef_pilots.htm

LCA guidance note 7.3

Abiotic Depletion Potential (ADP) and other indicators for assessing the depletion of resources

Construction products are made of different types of materials like metals, non-metallic minerals, fossil and biomass-based materials. Depletion of some of these resources is assessed in the standards EN 15978 and EN 15804 by the following indicators:

1. ADP elements, in kg Sb_{eq} (which is considered representative for the consumption of metallic resources)
2. ADP fossil fuels, in MJ (which is considered representative for the consumption of fossil resources used for both material and energy purposes)

These indicators are in particular addressing the depletion of metallic and fossil resources. Two additional indicator for non-metallic mineral and biomass resources, in kg, are thus necessary to include in order to provide a more comprehensive assessement of resource depletion.

The amount of material input needed to make a construction product is in general higher that the mass of construction product itself, due to waste and material losses along the supply chain and depending on the efficiency of the manufacturing process.

Using the Bill of Quantities (BoQ) and the Bill of Materials (BoM) for a building, it is possible to quantify the Life Cycle Inventory (LCI) of resources. The LCI is effectively a compilation of elementary flows of resources associated to the production and supply of the construction products listed in the BoQ or materials listed in the BOM. These products and materials are considered as necessary during the entire service lifetime of the building (e.g. if the expected life of a window is 25 years and the lifetime of the building is 50 years, the amount of materials associated to a window must be doubled).

If ADP is taken as example, the ADP of a product A can be calculated as follows:

- Option 1) $\Sigma\ EF_i \times ADP_i$
- Option 2) $mass_A \times ADP_A$

Where,

- EF_i is the elementary flow i associated to the life cycle of A
- ADP_i is the ADP associated to EF_i
- ADP_A is the ADP factor associated to A.

To provide an example, the following construction product would result in 579 elementary flows of resources. Although this type of concrete is not reinforced, its $ADP_{elements}$ is assessed as 6.088 kg Sb_{eq} per m^3 of concrete. This results from 95 resources used in its production chain, with 4 of them contributing all together to more than 90% of the overall score, as reported below. Tables 7.3 and 7.4 present the results.

Table 7.3 BoM of an unreinforced concrete produced with cement CEM II/A

Products	**Amount**	**Unit**
Normal concrete produced with cement CEM II/A (Average World's conditions)*	1	m^3
Material resources	**Amount**	**Unit**
Lubricating oil	0.02	kg
Sand	720	kg
Concrete mixing factory	4.17E-07	p
Gravel, round	1280	kg
Synthetic rubber	0.12	kg

Tap water (CA-QC)	0.1912	kg
Tap water (Europe without Switzerland)	67.95	kg
Tap water (Rest of the World)	101.9	kg
Cement, alternative constituents 6-20%	20.82	kg
Cement, alternative constituents 6-20%	179.2	kg

(*) Notes:

- Exposition class according to EN 206-1: X0
- Density: 2370 kg/m3, content of cement: 200 kg/m^3

Table 7.4 Elementary flows of resources contributing to the ADPelements of the example above

Substance	**Amount (g Sb eq.)**	**Contribution**	
		Relative	**Cumulative**
1) Indium	4.763	78.2%	78.2%
2) Cadmium	0.572	9.4%	87.6%
3) Lead	0.129	2.1%	89.7%
4) Silver, 0.007% in sulfide, Ag 0.004%, Pb, Zn, Cd, In	0.105	1.7%	91.5%
5) Silver, Ag 9.7E-4%, Au 9.7E-4%, Zn 0.63%, Cu 0.38%, Pb 0.014%, in ore	0.0945	1.6%	93.0%
6) Zinc	0.0564	0.9%	94.0%
7) Nickel, 1.98% in silicates, 1.04% in crude ore	0.0563	0.9%	94.9%
8) Tin			

The approach described above can be used to calculate depletion of resources for the entire life cycle of the building.

7.2.2.3 Data modelling and sources

Software tools

An LCA study could theoretically be carried-out using only spreadsheets to compile the data and make the calculations. However, due to the amount of data to process, LCA modelling and calculations are typically supported by software tools, which can also constitute a source of LCI databases and datasets for elements, technologies and operations of relevance for buildings. LCA software tools can be classified as follows:

- Simplified tools based on excel and/or IT interface (where simplification is usually made at the level of life cycle aspects considered and data implemented) vs. more complex tools for full LCA (*e.g. GaBI, OpenLCA, Simapro*).
- Open-source (*e.g. OpenLCA*) vs. commercial (*e.g. GaBi, SimaPro*) software tools.
- Generic (*e.g. GaBi, SimaPro*) vs. building-specific software tools (*e.g. BEES*, which is a Windows-based software tool, and, ATHENA, ELODIE and SB Tool).

A non-exhaustive list of LCA software tools which may have the potential for use is provided in a separate dynamic list for users of the Level(s) framework.

Modelling rules

An attributional approach shall be followed in the modelling[91]. Cut off rules are to be used, which define which building elements and parts shall be considered in an LCA. The rules to be used are described in Section 7.2.2.1. Default cut-off rules are stipulated for reporting at the simplest level (for a common performance assessment).

An allocation procedure is necessary when input and output from a process must be split between more than one product (e.g. ground blast furnace slag from steel production which is used in cement mixes) or process. According to EN 15804, allocation should be avoided as far as possible by dividing the unit process to be allocated into different sub-processes that can be allocated to the co-products and by collecting the input and output data related to these sub-processes. When allocation is needed, inputs and outputs should be partitioned in a way that reflects the underlying relationships between the co-products:

1. Material flows carrying specific inherent properties, e.g. energy content, elementary composition (e.g. biogenic carbon content), shall always be allocated reflecting the physical flows, irrespective of the allocation chosen for the process
2. Allocation shall be based on physical properties (e.g. mass, volume) when the difference in revenue from the co-products/processes is low (i.e. of the order of 1%);
3. In all other cases allocation shall be based on economic values.

Module D recognises the "design for reuse, recycling and recovery" concept for buildings by indicating the potential benefits of avoided future use of primary materials and fuels while taking into account the loads associated with the recycling and recovery processes beyond the system boundary. In this case, the net credits associated to the potential substitution of primary material can be taken into account. Net credits are calculated as follows:

- by adding all output flows of a secondary material or fuel and subtracting all input flows of this secondary material or fuel from each sub-module first (e.g. B1-B5, C1-C4, etc.), then from the modules (e.g. B, C), and finally from the total product system thus arriving at net output flows of secondary material or fuel from the product system (this in order to avoid double counting);
- by adding the impacts connected to the recycling or recovery processes from beyond the system boundary (after the end-of-waste state) up to the point of functional equivalence where the secondary material or energy substitutes primary production and then subtracting the impacts resulting from the substituted production of the product or substituted generation of energy from primary sources;
- by applying a justified value-correction factor to reflect the difference in functional equivalence where the output flow does not reach the functional equivalence of the substituting process.

The amount of secondary material output, which is for all practical purposes able to replace one to one the input of secondary material on a closed loop basis is allocated to the product system under study and not to module D.

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[91] The attributional approach is a system modelling approach in which inputs and outputs are attributed to the functional unit of a product system (in this case the use of 1m^2 of a building during 1 year) by linking and/or partitioning the unit processes of the system in direct proportion to the flows associated with the product. The alternative option is the consequential approach which is a system modelling approach in which activities in a product system are linked so that activities are included in the product system to the extent that they are expected to change *as a consequence of a change in demand* for the functional unit.

Data sources

Carrying out an LCA relies on the compilation of data to describe as accurately as possible all the production processes, resource use and emissions related to the building and its elements. This data can be either specific or generic data for construction products and materials. Data must be relevant and accurate, irrespective of the selected type (e.g. specific LCI data, average LCI data). In general, specific and verified LCA data (i.e. from Environmental Product Declarations) is more precise than generic LCA data.

Databases are important resources when primary data related to the specific construction products used is not available. Databases can be:

- Specific (e.g. Bauteil katalog, EPDs) or generic (e.g. Ecoinvent, GaBi)
- Freely available (e.g. ELCD), partially costly (e.g. Bauteil katalog) or costly (e.g. Ecoinvent, GaBi)

A non-exhaustive list of databases and data sources of relevance for buildings is provided in a separate dynamic list for users of the Level(s) framework. LCA guidance note 4 provides design teams with further orientation.

LCA guidance note 7.4 for design teams

LCA software tools and databases

Most LCA software tools and databases are not freely accessible, instead a license has to be paid to be able to use them. There are some exceptions. The OpenLCA tool is an example of a software tool that can be downloaded and used for free. It allows for life cycle modelling and assessment based on the insertion of primary data and the link to (either free or commercial) databases. It does, however, suppose professional development to make correct use of it.

Alternatively, an accessible way to carry out the LCA of a building is to report in an excel file the bill of materials and any other relevant foreground data related to the building's life cycle modules (e.g. energy consumption in module B6, net credits in module D). Characterisation factors, expressing relative environmental impacts per unit of material or process (e.g. per kg or m^3), can then be assigned to each entry in order to calculate absolute impacts. This can be a long process but allows the user to have a transparent and effective tool for calculating the environmental impacts of a building.

An example of a partially free database of relevance for the building sector is the Bauteil katalog. The Bauteilkatalog supplies datasets for the most common building components, including product weight and LCIA data. The LCIA data provided with the free licence is for primary energy and GWP values. The user needs to have a basic knowledge of LCA to understand the data. Further data can be bought.

Software tools such as Athena allow for importing directly the bill of materials from CAD or BIM. The calculation of the building's environmental profile is much easier but at the same time, they cannot easily control the results and identify any odd assumptions and results.

Users of the Level(s) framework shall evaluate and report on the quality of the data they use. Guidance on how to evaluate data quality is provided in Section 7.4.

7.2.2.4 Monitoring of as-built and occupied performance

In the context of this framework, LCA is largely intended as a design tool. This is an early stage of a building project, which relies on design specifications and other expected characteristics (e.g. Bill of Materials, conditions of use). It is thus important to understand and compare how the building potentially performs once occupied, i.e. based on as built-specifications, real Bill of Materials, adapted condition of use.

Monitoring upon completion shall include:

- Comparison between an LCA of the building as designed and as-built.
- Verification of the completeness of the information needed for the quantification.
- Traceability of the data.
- Conformity with relevant methodological references and a consistency check.

7.2.3 Suggested reporting format for results

The environmental impacts shall be reported in a tabular format at a disaggregated level, i.e. by life cycle module for each of the impact category indicators. The template shown on the following page shall be used.

Supplementary information shall also be reported in a summary report, to include:

- The reason for carrying out the study, project stages during which the LCA was created, the intended application and target audiences (including a statement if the study will support comparative assertions intended to be disclosed to the public).
- Building characteristics, intended period of use and scenarios of analysis (as per section 1).
- Information about the assessment methods used to characterise the life cycle impacts
- System boundary and processes considered in the study, including cut-off and allocation rules used for their definition
- Data sources used for the elements and systems that compose the building (as per section 1, table 1.1)
- Energy and water operational use (as per the results for indicators 1.1 and 3.1)
- LCA model and calculations made to quantify elementary flows and environmental indicators
- Analysis of hot-spots, trade-offs, improvement options
- Data quality and limitations of the study
- Critical review according to ISO 14071, if applicable

All information shall be as complete, accurate and objective as possible and shall be transparently reported.

Cradle to cradle LCA generic assessment reporting format

Environmental impact category results for each life cycle stage

Indicator	**Unit**	**Scenario**	**Product (A1-3)**	**Construction process (A4-5)**	**Use stage (B1-7)**	**End of life (C1-4)**	**Benefits and loads beyond the system boundary (D)**
GWP	kg CO_2 eq	S_i / DO_j …					
ODP	kg CFC11 eq						
AP	kg SO_2 eq						
EP	kg $(PO_4)_{3-}$ eq						
POCP	kg C_2H_4 eq						
ADP elements	kg Sb eq						
ADP fossil fuels	MJ (LHV)						
Use of renewable primary energy resources used as raw material	MJ						
Use of non-metallic mineral resources	kg						

Notes:

Impacts referred to the use of 1 m^2 of useable internal floor per year for a default reference study period of 60 years[92].

Results shall be reported for Design Options and Scenarios that have been modelled.

S_i (= Scenario) and DO_j (= Design Option) can refer to

- Reference study period

[92] A further table shall be prepared if, in addition to the reference study period, an additional reference unit oran intended service life is to be usedhas been modelled.

- Intended service life or investment holding period according to clients requirements
- Building and elemental service life planning (2.2 Life cycle tools: scenario 1)
- Design for adaptability and refurbishment (2.2 Life cycle tools: scenario 2)
- Design for deconstruction, reuse and recyclability (2.2 Life cycle tools: scenario 3)
- Future climate change (5.1 Life cycle tools: scenario 1)

7.3 Making level 2 and 3 assessments using the LCA method

In the following section, rules are laid down for how to use the additional types of performance assessment available for carrying out an LCA and reporting on the results.

The rules are presented in a tabular form in table 3.5 and cover the following aspects of carrying out an LCA:

- Objective(s)
- Cut-off rules for the system boundary definition
- Energy and water consumption modelling
- Scenarios and End of Life
- LCI and LCIA datasets and software
- Data requirements
- Interpretation of the results and critical review

Table 7.5 Rules for carrying out a level 2 or 3 cradle to cradle LCA

	Level 2: Comparative performance assessment	**Level 3: Design performance optimisation**
Target end-users	The main users of this option are intended to be professionals who wish to report in the public domain on the environmental performance of buildings. This performance could be compared with other buildings in a portfolio or with national/regional reference buildings. In this case, the LCA is to be performed following a more comprehensive approach in order to obtain reproducible results using the same level of information detail. For this purpose, minimum requirements on the data quality are specified.	The main users of this option are intended to be professionals who want to use LCA at an early stage of the building project life cycle as a decision making support tool for improving the sustainability of the building. As for level 2, the LCA is to be performed following a more comprehensive approach in order to obtain reproducible results. For this purpose, minimum requirements on the data quality are specified.
Building scope	The building elements listed for the shell and core, and excluding external works. See the building element listing in section 1, table 1.1	All building elements listed for the shell, core and external works. See the building element listing in section 1, table 1.1
System boundary and cut off rules	All life cycle stages shall be calculated, unless a simplified reporting option is selected as a starting point. Different rules shall apply to the construction products modelled depending on the calculation route: 1. Use of EPDs: The Product Category Rules for the EPDs used shall be compliant with EN 15804. 2. Use of datasets at the level of LCIA: – All elements and their components that make up less than 1% of the building's total mass can be excluded. The total amount of excluded elements and components must not exceed 5% of the total mass of the building. 3. Use of LCA database and tools: – All elements and their components that make up less than 1% of the building's total mass can be excluded. The total amount of excluded elements and components must not exceed 5% of the total mass of the building. – All input flows to unit processes that make less than 1 % of primary energy usage and 1 %	All the life cycle stages shall be considered. The following cut-off rules are prescribed: – All elements and their components that make up less than 1% of the building's total mass and total environmental impacts can be excluded. The total amount of excluded elements and components must not exceed 5% of the total mass and the total environmental impacts of the building. – All input flows to unit processes that make less than 1 % of primary energy usage and 1 % of the total mass input of that unit process. The total amount of excluded input flows per module must not exceed 5% of the total primary energy usage and mass input, or the total environmental impacts depending on the complexity of the calculation tools, of that life cycle module.

	of the total mass input of that unit process. The total amount of excluded input flows per module must not exceed 5% of the total primary energy usage and mass input of that life cycle module.	
Energy modelling	Inventory data to be obtained from indicator 1.1	Inventory data to be obtained from indicator 1.1
Water modelling	Inventory data to be obtained from indicator 3.1	Inventory data to be obtained from indicator 3.1
Scenarios and End of Life	With reference to scenarios in macro-objective 2	With reference to scenarios in macro-objective 2
LCI and LCIA datasets and software	Data for foreground processes should refer to specific data. Data for background processes shall be representative of the national/regional context analysed. Data from primary and secondary sources must be validated and third party certified. This option may rely on more complex software tools. Some of the software tools and databases reported in Section 7.2.2 have these characteristics.	Data for foreground processes should refer to specific data. Data for background processes shall be representative of the national/regional context analysed. Data from primary and secondary sources must be validated and third party certified. This option supposes the use of building specific software tools. Some of the software tools and databases reported in Section 7.2.2 have these characteristics.
Data quality requirements	Since this option aims at reporting building's environmental performance, data quality becomes a more important issue. A data quality index is to be calculated according to the method set in Section 7.4. The overall data quality index shall score above 2. For transparency reasons, also data sources shall be reported.	Since this option aims at supporting professionals to optimise a building's environmental performance, data quality becomes a more important issue. A data quality index is to be calculated according to the method set in Section 7.4. The overall data quality index shall score above 2. For transparency reasons, also data sources shall be reported.
Interpretation of the results and critical review	Result shall be interpreted critically through a sensitivity analysis in order to understand: • Environmental hot-spots, possible trade-offs between life cycle stages and improvement areas • The influence of data sources on the results, • Data gaps, robustness of assumptions, and limitations. Summary conclusions and recommendations shall be drafted. If conclusions are not consistent with the defined goal and scope, the phases of LCA should be repeated until convergence is reached. A critical review carried out according to ISO 14071 is also	Result shall be interpreted critically through a sensitivity analysis in order to understand: • Environmental hot-spots, possible trade-offs between life cycle stages and scenarios and improvement areas • Influence of data on the results, • Data gaps, robustness of assumptions, and limitations Summary conclusions and recommendations shall be drafted. If conclusions are not consistent with the defined goal and scope, the phases of LCA should be repeated until convergence is reached. A critical review carried out according to ISO 14071 is also needed to check the consistency of the study against

	needed to check the consistency of the study against the requirement of ISO 14040/44. More in detail, the critical review process shall ensure that • the methods used to carry out the LCA are consistent with this International Standard, • the methods used to carry out the LCA are scientifically and technically valid, • the data used are appropriate and reasonable in relation to the goal of the study, • the interpretations reflect the limitations identified and the goal of the study, and • the study report is transparent and consistent. The critical review shall be carried out by an external independent expert in those cases when the results are to be publicly disclosed. Moreover, if the results are intended to be used to support comparative assertion, the critical review shall be carried out by a panel of interested parties. Moreover, if the study and the results are intended to be used to support comparative assertion among two or more products, the critical review shall be carried out by a panel of interested parties.	the requirement of ISO 14040/44. More in detail, the critical review process shall ensure that • the methods used to carry out the LCA are consistent with this International Standard, • the methods used to carry out the LCA are scientifically and technically valid, • the data used are appropriate and reasonable in relation to the goal of the study, • the interpretations reflect the limitations identified and the goal of the study, and • the study report is transparent and consistent. The critical review shall be carried out by an external independent expert in those cases when the results are to be publicly disclosed.

7.4 Property valuation influence and reliability rating

The following tools are provided to inform the valuation of a property for which performance has been assessed using a cradle to cradle LCA:

- Checklists for the potentially positive influence on a market valuation
  - Checklist 1: Potential positive influence on future performance
  - Checklist 2: Accounting for the performance assessment in valuation criteria
- Reliability rating of the performance assessment
  - Rating 1: Basis for the performance assessment
  - Rating 2: Professional capabilities
  - Rating 3: Independent verification

The completed reporting may be used separately alongside the Level 1, 2 or 3 results for an LCA, or may form part of the overall reporting for indicator 6.2.

In the case that the ratings will be used as part of the overall reporting for indicator 6.2, then the rating 1 results shall be used to calculate the overall Indicator Reliability Index (IRI).

7.4.1 The potential for a positive influence on a market valuation

Checklist 1 – Evaluation of potentially positive influences on market performance

Potential influence	***Evaluated?***	***Resulting assumptions used in the appraisal***
Potential influence 1 *Increased revenues due to market recognition and lower voids.*	*Yes/no*	
Potential influence 2 *Reduced operational, maintenance, repair and/or replacement costs.*	*Yes/no*	
Potential influence 3 *Reduced future risk of increased overheads or loss of income.*	*Yes/no*	

Checklist 2 – Accounting for the Level(s) assessment in the valuation criteria used

Valuation criteria set used	Identify the scheme or tool used
Version of the criteria set used	

Criteria which the assessment has influenced		**Influence on the valuation or rating**
Valuation criterion	**Sub-criterion**	
Criterion x	Sub-criterion y	Notes on the extent of the influence and the supporting assumptions used

7.4.2 Reliability rating of the performance assessment

Rating 1: - Basis for the performance assessment

The calculation of a cradle to cradle LCA generally works at two levels:

- Foreground processes, which affect directly the results (e.g. the actual content of concrete in a column, the consumption of electricity during the occupation of a building)
- Background processes, which are linked to and are nested behind the foreground processes (e.g. the production and supply of concrete, the production and supply of grid electricity).

The quantification of data for both foreground and background processes may then require a combination of:

- Primary Data, which is site-specific information based on direct measurements or the characterisation of parameters for a certain context.
- Secondary Data, which is available from technical literature and data providers (e.g. specific studies, LCA databases)
- Assumptions, especially when satisfactory data is not available.

The data available can vary with respect to:

- Representativeness (its relevance and completeness);
- Accuracy.

Rating 1 is based on the assessment of the quality of data against these two main parameters. The rating has a matrix form, which is adapted from the European Commission's Product Environmental Footprint method's (PEF) data quality evaluation methodology, and which is based on four parameters:

- Technological representativeness of data (TeR)
- Geographical representativeness of data (GR)
- Time-related representativeness of data (TiR)
- Uncertainty of data (U)

A rating level is to be evaluated for each parameter according to the matrix in Table 7.6. The overall rating is equal to the Data Quality Index (DQI) which can be calculated from the individual ratings as follows:

$$DQI = ((TeR+GR+TiR)/3+U)/2$$

The rating shall be calculated for each hot spot of the environmental impacts identified from LCA calculations. Hot spots are points in the life cycle of a product which have the highest impacts/importance in the overall LCA result. They may be related to a building's life cycle stages, processes, components (elements, structural parts, products, materials) or to elementary flows contributing in total to more than 50% of an impact category result).

Once the hot spots have been identified the data quality shall then be rated for each hot-spot. The overall data quality shall then be calculated as the contribution-weighted average of the data quality for each hot-spot:

$$DQI_{overall} = \Sigma_i (DQI_{hot\text{-}spot,I} \times Contribution_{hot\text{-}spot,i}) / \Sigma_i (Contribution_{hot\text{-}spot,i})$$

Rating 2 – Professional capabilities

Rating aspect	**Rating score**			
	0	**1**	**2**	**3**
Technical capability of the personnel carrying out the assessment	*No formal training and limited experience in using the calculation method*	*Accredited training or some applied experience in using the calculation method*	*Accredited training and some applied experience in using the calculation method*	*Accredited training and significant applied experience in using the calculation method*

Rating 3 – Independent verification

Rating aspect	**Rating score**			
	0	**1**	**2**	**3**
Independent verification of the assessment	*Self-declaration of the performance assessment results*	*Peer review of the input data and calculation steps*	*Third party auditing and verification of the calculation steps*	*Third party auditing and verification of the process data, life cycle inventory data and calculation steps*

Table 7.6 Data quality evaluation matrix

Rating aspect	***Brief description of each aspect***	**Rating score and criteria**			
		0	**1**	**2**	**3**
Technological representativeness	Degree to which the dataset reflects the true population of interest regarding technology (e.g. the technological characteristics, including operating conditions)	No evaluation made	The data used does not reflect satisfactorily the technical characteristics of the system (e.g. Portland Cement, without other specifications)	The data used reflects partially the technical characteristics of the system (e.g. Portland Cement type II, without further specifications)	The data used reflects the technical characteristics of the system (e.g. Portland Cement type II B-M)
Geographical representativeness	Degree to which the dataset reflects the true population of interest regarding geography (e.g. the given location/site, region, country, market, continent)	No evaluation made	The data used refer to a totally different geographic context (e.g. Sweden instead of Spain)	The data used refers to a similar geographic context (e.g. Italy instead of Spain)	The data used refers to the specific geographic context (e.g. Spain)
Time-related representativeness	Degree to which the dataset reflects the specific conditions of the system being considered regarding the time/age of the data (e.g. the given year and, if applicable, of intra-annual or intra-daily differences)	No evaluation made	There are more than 6 years between the validity of the data used and the reference year to which the data applies.	There are between 2 and 4 years between the validity of the data used and the reference year to which the data applies.	There are less than 2 years between the validity of the data used and the reference year to which the data applies.

Uncertainty	Qualitative expert judgment or relative standard deviation expressed as a percentage.	No evaluation made	Modelled/similar data is used. Accuracy and precision of the data has been estimated qualitatively (e.g. by expert judgment of suppliers and process operators)	Modelled/similar data is used which is considered to be satisfactorily accurate and precise with the support of a quantitative estimation of its uncertainty (e.g. representative data from trade associations for which a sensitivity analysis has been carried out).	Site specific and validated data is used which is considered to be satisfactorily accurate and precise (e.g. window system for which a verified EPD is available) The allocation hierarchy has been respected.

7.4.3 Calculation of the technical rating

The technical rating shall be calculated for each hot spot of the environmental impacts identified from the LCA study. Hot spots are points in the life cycle of a product which have the highest impacts/importance in the overall LCA result. They may be related to either a building's life cycle stages, processes, components (elements, structural parts, products, materials) or elementary flow contributing in total to more than 50% of an impact category result.

The calculation of the rating shall be based on the following steps:

1. Hot-spots shall be identified for each impact category indicator.
2. Hot-spots shall be listed according to their contribution to the environmental impacts, as shown in Table 3.7.
3. Data quality shall then be rated for each hot-spot according to Table 3.6, as shown in Table 3.8
4. The overall data quality shall be calculated as the contribution-weighted average of the data quality for each hot-spot:
   $DQI_{overall} = \Sigma_i \; (DQI_{hot\text{-}spot,I} \times Contribution_{hot\text{-}spot,i}) \; / \; \Sigma_i \; (Contribution_{hot\text{-}spot,i})$

For the example reported below in Table 7.7 and Table 7.8, the overall data quality would be calculated as 2.18[93].

Table 7.7 Example of how to list hot spots based on their contribution

Hot-spot	Contributions to the overall environmental impacts						
	GWP	ODP	AP	EP	POCP	ADP element	ADP fossil
Electricity demand during use	40%	45%	30%	30%	40%		45%
Heat demand during use	25%	20%	35%	30%	30%		30%
Reinforced concrete	10%	15%	15%	20%	15%	50%	10%
Insulation material	5%					30%	

[93] 2.18 = [(40% x 2 + 25% x 3 + 10% x 2 + 5% x 1) +(45% x 2 + 20% x 3 + 15% x 2) + (30% x 3 + 35% x 3 + 15% x 2) + (30% x 2 + 30% x 3 + 20% x 2) + (50% x 2 + 30% x 2) + (45% x 2 + 30% x 3 + 10% x 2)] / 570%

Table 7.8 Example of data quality evaluation for each hot-spot

Hot-spot	Data quality for each hot-spot						
	GWP	ODP	AP	EP	POCP	ADP element	ADP fossil
Electricity demand during use	2	2	3	2	2	3	2
Heat demand during use	3	3	3	3	3	3	3
Reinforced concrete	2	2	2	2	2	2	2
Insulation material	1	1	2	1	1	2	1