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# Identifying macro-objectives for the life cycle environmental performance and resource efficiency of EU buildings

*Working Paper 1*

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Abstract

#### **Identifying macro-objectives for the life cycle environmental performance and resource efficiency of EU buildings**

This working paper brings together the findings of the first stage of the Resource Efficient Buildings study, which focusses on the identification of 'macro-objectives' for the environmental performance of the EU building stock. This stage is intended to provide an initial 'top down' view of what the strategic priorities (the 'macro-objectives') should be for the building sector. These macro-objectives will in turn inform and set the scope for the identification of a common framework of performance indicators in the next stage of this study.

As a conclusion of this work package, two types of macro-objectives have been identified – those relating to 'life cycle environmental performance' and those relating to 'quality, performance and value'. In the short term, six of these macro-objectives are proposed to be taken forward in order to identify related performance indicators at building level which will make up the framework. In the medium to long term, a further set of up to ten macro-objectives have also been identified which may potentially be considered for the identification of performance indicators.

Further indicators at the building level could address productive workspaces and liveable and decent homes. The possibility of having indicators at the new-build neighbourhood level (for example, addressing travel patterns, urban pressure on land, green and low carbon infrastructure) and existing building stock level (for example, addressing overall stock performance and space utilisation efficiency) has also been identified.

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# Executive summary

## 1. Background to the study and this working paper

The European Commission's 2014 Communication on Resource Efficiency Opportunities in the Building Sector identified the need for a common EU framework of indicators for the assessment of the environmental performance of buildings. A study to develop this approach is being taken forward during 2015-2017 by DG ENV and DG GROW, with the technical support of DG JRC-IPTS.

This working paper brings together the findings of the first stage in this study, which focusses on the identification of 'macro-objectives' for the environmental performance of the EU building stock. This stage is intended to provide an initial 'top down' view of what the strategic priorities (the 'macro-objectives') should be for the building sector.

In the context of this study, macro objectives encompass not only resource efficiency considerations, but also other significant environmental or functional performance aspects that have an influence on the lifecycle of buildings which should be addressed at EU level. These macro-objectives will in turn inform and set the scope for the identification of a common framework of indicators in the next stage of this study.

## 2. Development of the evidence base and supporting stakeholder consultation process

In order to identify the macro-objectives, three broad areas of evidence have been the focus for analysis:

- EU and Member State policies and initiatives of relevance to the building sector;
- Technical evidence for 'hot spot' environmental impacts along the life cycle of buildings;
- The priorities of existing assessment and reporting tools in the EU property market.

A first draft of this working paper, bringing together evidence and initial findings in these three areas, together with initial broad brush proposals for macro-objectives were the subject of stakeholder consultation during the period May – July 2015. This stakeholder consultation, together with follow-up discussions with the main steering group for the study and the technical sub group, highlighted amongst other issues, the need to:

- Establish a prioritisation for the environmental issues and the resources that should be addressed by the macro-objectives;
- Ensure that the macro-objectives are technology neutral and avoid the promotion of 'macro-solutions';
- Take into account how environmental performance relates to building performance and value creation, focussing on aspects such as health, comfort, productivity and life cycle cost;
- Take into account a number of different perspectives, including those of occupiers, landlords, investors, construction companies, design teams and other property market actors.

## 3. Prioritisation of environmental issues as the basis for identifying the macro-objectives

As a result of the stakeholder consultation, a stepwise methodology was developed to prioritise the environmental issues that form the basis for the macro-objectives. This methodology uses as its starting point the European Environment Agency's 'State and Outlook' (SOER) reporting framework, which consists of twenty environmental issues grouped under the three thematic objectives of the EU's 7<sup>th</sup> Environmental Action Programme. It then relates the SOER reporting framework to the already identified 'hot spot' environmental impacts along the life cycle of buildings together with EU policies and strategies of relevance to the buildings sector.

The methodology provides a structured basis for the clustering of environmental issues relevant to the building sector, which in turn allows for the prioritisation and definition of the macro-objectives.

The eight '*life cycle environmental performance*' macro-objectives identified using this methodology were then, prior to finalisation, subject to critical review by the main steering group for the study and the special technical sub group.

#### 4. How macro-objectives and indicators form part of a common framework

Consultation and dialogue with stakeholders highlighted the need for a simple way of unifying and communicating the interactions between the different aspects of the common framework. Based on stakeholder input, the following underlying principles were identified as being important to guide development of the framework, and are illustrated in this working paper:

- The framework as a whole should be designed in a way that it recognises the priorities of different potential adopters;
- The framework should reflect the different scales at which actors in the sector work *e.g. building, neighbourhood and stock*;
- Human and economic factors should be at the heart of the framework, reflected by the themes of 'quality, performance and value';

In taking forward the framework it was also felt that a distinction should also be made between those macro-objectives that directly address '*life cycle environmental performance*' and those that address '*quality, performance and value creation*'. This reflects the need to ensure that 'quality, performance and value' is not achieved in a way that is to the detriment of the 'life cycle environmental performance' of a building.

#### 5. The final set of macro-objectives that have been identified

As a conclusion of this work package, two types of macro-objectives have been identified – those relating to '*life cycle environmental performance*' and those relating to '*quality, performance and value*'. In the short term, six of these macro-objectives are proposed to be taken forward in order to identify related performance indicators which will make up the framework. These macro-objectives focus on the building level:

*'Life cycle environmental performance' macro-objectives for buildings*

1. **Greenhouse gas emissions from building life cycle energy use:** Minimise the total GHG emissions along a buildings lifecycle, with a focus on building operational energy use emissions and embodied emissions.
2. **Resource efficient material life cycles:** Optimise building design, engineering and form in order to support lean and circular flows, extend long-term material utility and reduce significant environmental impacts.
3. **Efficient use of water resources:** Make efficient use of water resources, particularly in areas of identified long-term or projected water stress.

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

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

In the medium to long term, a further set of up to ten macro-objectives have been identified which may potentially be considered for the identification of performance indicators. Further indicators at the building level could address *productive workspaces* and *liveable and decent homes*. The possibility of having indicators at the new-build neighbourhood level (for example, addressing *travel patterns, urban pressure on land, green and low carbon infrastructure*) and existing building stock level (for example, addressing *overall stock performance and space utilisation efficiency*) has also been identified.

Further to identification of the final set of macro-objectives, it is also proposed that some rules are set for the translation of macro-objectives into measurable indicators of building performance. These proposed rules would take into account how resources are used, and should as a starting point address aspects related to the unit of consumption, comparisons between different options for a building's form and reference to engineering design parameters.

# 1. Introduction

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

The first stage in this study is the identification of 'macro-objectives' for the environmental performance of buildings. This working paper is intended to inform this exercise. It provides an analysis of:

- EU and Member State policies and initiatives on resource efficiency,
- Evidence for the most significant environmental impacts along the life cycle of buildings, and;
- The priorities of existing schemes and tools that are used in the EU property market.

The evidence brought together in this working paper, together with the input of stakeholders, has been used to identify a set of macro-objectives. These will then be used to set the scope for possible environmental indicators, although not all areas covered by the macro-objectives may be addressed.

## 1.1 The policy context, aims and objectives of this study

### 1.1.1 The 2014 Communication on resource efficiency opportunities in the building sector

In July 2014, as the result of an initiative lead jointly by DG ENV and DG GROWTH, the European Commission adopted the Communication on Resource Efficiency Opportunities in the Building Sector - COM(2014)445<sup>1</sup>. This Communication identified the need for a common European approach to assess the environmental performance of buildings throughout their lifecycle, taking into account the use of resources such as energy, materials and water. The anticipated potential benefits of such a framework, as set out in the 2014 Communication are summarised in Box 1.

#### ***Box 1.1 The anticipated benefits of a EU core framework of indicators***

- Allow easier communication of information to professional and non-experts;
- Provide reliable and comparable data to be used in decision-making covering the entire life-cycle of buildings;
- Enable the setting of clear objectives and targets, including system boundaries, for building performance, complementing already existing European legislation on buildings;
- Increase awareness of the benefits of sustainable buildings among actors engaged in providing buildings, as well as private and public clients, including users of buildings;
- Facilitate the effective transfer of good practices from one country to another;
- Reduce the cost to assess effectively and communicate the environmental performance of buildings;
- Provide public authorities with access to core indicators and to a critical mass of relevant data on which to base their policy initiatives, including Green Public Procurement;
- Widen the market for sustainable buildings to more countries than current trends indicate and to other buildings sectors such as non-residential buildings and eventually, to the residential market.

In addition to the sectoral benefits summarised in Box 1, the 2014 Communication also highlights the following potential advantages for building sector professionals (including SMEs).

- Architects, designers, manufacturers of construction products, builders, developers and investors, will be able to benefit from competitive advantages based on environmental performance;

<sup>1</sup> COM(2014)445 Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions on resource efficient opportunities in the building sector

- Manufacturers of construction products will only have to provide product information needed for building assessment in one way, resulting in cost savings;
- Architects and builders will be supported via greater information on both product and building level, with reduced costs when incorporating sustainability aspects;
- Developers will more easily be able to compare performance of projects;
- Investors, property owners and insurers will be able to improve the allocation of capital and to integrate environmental risk into their decisions.

In response to the need and potential benefits identified in the aforementioned Communication, a study to identify an EU common framework of indicators to assess the environmental performance of buildings will be carried out by the JRC, during 2015-2017. DG ENV and DG GROW will lead development of the framework with the technical support of the Joint Research Centre, its in-house science service, and in close co-operation with relevant stakeholders.

### **1.1.2 The aims and objectives of this study in the context of COM(2014)445**

The overall aim of the study is to develop a common framework of indicators that is flexible so that it can be integrated in existing and new assessment schemes, or be used on its own, although the intention is not to create a new standalone building certification scheme. The framework should be rigorous enough to drive improvement in performance and allow for comparison between buildings. Moreover, there should be a clear link between the indicators and a set of overarching macro-objectives, thereby ensuring that there is a clear and measurable contribution to strategic policy objectives.

Considering the wide range of buildings in the EU, as well as differences in constructing new buildings or renovating existing ones, the Communication considers that the framework will not cover all aspects of environmental performance, but comprise a set of core indicators, focusing on the most essential aspects, which will be identified together with stakeholders. This will allow comparability and provide consumers and policy makers with easier access to reliable and consistent information. The Communication goes on to exemplify areas for further investigation in the framework development, based on the results on an initial consultation with stakeholders in 2013.

- Total energy use, including operational energy,
- The embodied energy of products and construction processes,
- Material use and the embodied environmental impacts,
- The durability of construction products,
- Design for deconstruction,
- Management of construction as well as demolition waste (CDW),
- Recycled content in construction materials,
- Recyclability and reusability of construction materials and products,
- Water used by buildings,
- The use intensity of (mostly public) buildings (e.g. flexible functionality for different users during different times of the day),
- Indoor comfort.

These broad areas of focus therefore provide a starting point for the scope of the study which, based on evidence gathered and the input of stakeholders during the current process, could be adjusted. Moreover, it is open for discussion whether the indicators could be introduced in phases or tiers, with the most critical environmental impacts addressed by a first set of indicators, which could then be followed up by further sets.

Importantly, this process will closely follow the development of a European Voluntary Scheme for non-residential buildings, targeting energy efficiency, led by the European Commission, DG ENER, and will ensure compatibility between the two products.



## 1.2 How this working paper contributes to this study

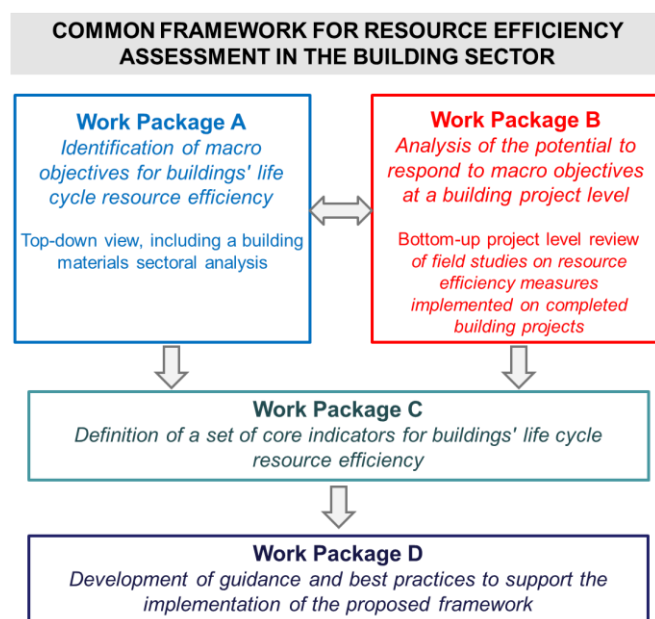
### 1.2.1 Work package A - the identification of 'macro-objectives'

The study programme consists of four work packages which are illustrated in Figure 1.1. The aim of work package A within the study programme is to identify 'macro-objectives' for a building's life cycle resource efficiency. Macro objectives are understood to encompass not only resource efficiency considerations as such, but also any significant environmental or functional performance aspects that have an influence on the lifecycle of buildings which should be addressed at EU level. An initial definition of 'macro-objectives' is proposed as follows:

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

Moreover, it is also important to establish from the outset of the study the principle that buildings shall provide comfortable, healthy and productive spaces for people to live and work in, now and into the future. The objective of achieving resource efficient buildings should, wherever possible, re-inforce and not contradict, the fundamental human, cultural and economic requirements of building owners and occupiers. Conversely, this social and economic capital should not be achieved at the expense of natural capital.

The work package will take a 'top-down' approach to the EU building sector as a whole and, if necessary, specific building typologies. The work package will review existing legislation, standards, building schemes, collaborative field-based research projects and other relevant literature. It will include the identification of environmental hot spots along the life cycle of buildings and buildings' materials directly impacting on the possibility to achieve the macro objectives. Potential trade-offs between different resource uses, impacts along the life cycle and functional performance will be identified for further analysis.



**Figure 1.1. Overview of the Work Packages that make up the common framework study**

### 1.2.2 The process of identifying 'macro-objectives' for the life cycle environmental performance of buildings

This working paper forms the main deliverable and outcome from work package A of the wider study. The aim of this working paper is to inform the identification of the most relevant macro-objectives for a building's life cycle resource efficiency. These macro-objectives will in turn inform and set the scope for the common framework of indicators in work packages B,C and D.

The first draft of this working paper was presented as the basis for discussion at the first stakeholder working group meeting, which was held in Brussels on the 16<sup>th</sup> June 2015. At that meeting the proposed boundaries, scope and coverage of the macro-objectives were discussed. Feedback from those discussions, together with

follow-up written feedback, has been used in Chapters 6 and 7 of this working paper to identify a final set of macro-objectives that will be used to set the scope for the framework of indicators.

In order to inform the initial proposals for discussion that were presented to stakeholders, this paper reviews existing legislation, scientific evidence, building schemes, collaborative research projects and other relevant literature. A high level scoping of environmental and resource efficiency 'hot spots' along the life cycle of buildings has also been carried out. Potential linkages and trade-offs between resource use, impacts along the life cycle and functional performance, with a specific focus on health and wellbeing aspects, have also been identified.

### **1.2.3 Research questions on the identification of 'macro-objectives'**

This working paper sets out to answer a number of key questions in relation to the identification of relevant macro-objectives for buildings. These questions are presented in Box 2 and are investigated further in chapters 2, 3 and 4 of the report, as well as part of an accompanying stakeholder consultation, the findings from which are summarised in Chapter 5.

#### ***Box 2. Key questions in relation to macro-objectives***

- To what extent are macro-objectives for buildings already defined by EU policy frameworks?
- Which significant environmental and resource efficiency 'hot spots' for buildings should be addressed by the macro-objectives?
- Which environmental and resource efficiency macro-objectives are currently used by building assessment and reporting tools in the EU market?
- How do these compare and contrast with those in EU policies and identified as 'hot spots' from technical evidence?
- Are there any contradictions between different macro-objectives from the point of view of resource efficiency and/or other functional aspects such as comfort, health and productivity?
- Based on the evidence reviewed, what should be the scope and boundary for defining the macro-objectives?
- To what extent should health, wellbeing, productivity and functional performance aspects be addressed as macro-objectives?

### **1.2.4 The structure of this working paper**

In order to investigate the questions listed in section 1.2.3, this working paper is structured in order to review three main areas of evidence that are considered important:

1. The existing EU policy framework for resource efficiency buildings: The focus of EU policies for improving the environmental performance of buildings, as well the broader policy framework and evidence base for making progress towards a more resource efficient economy, have been reviewed. Member State policies in these two areas have also been briefly reviewed, including selected examples of leading resource efficiency policies and initiatives.
2. Evidence for macro-scale environmental 'hot spots' along the life cycle of buildings: Top down LCA studies of the buildings and construction sector, bottom up LCA studies for commercial and residential building typologies, and technical research into material resource efficiency have been reviewed. The relevance of wider 'induced' environmental effects that may occur beyond the boundary of a single building or urban development – such as commuter journeys or new infrastructure to serve buildings - together with other factors that may influence the performance and life span of a building are also briefly reviewed.
3. Priorities, scope and boundaries of existing assessment and reporting tools: A selection of the leading building environmental assessment schemes and investor reporting tools used in the EU have been analysed in order to understand the basis on which they prioritise resource efficiency hot spots within their criteria, as well as to compare and contrast their scope and boundaries.

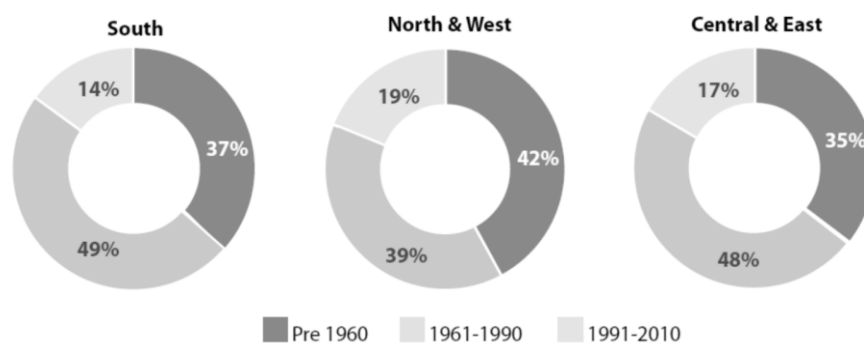
The insight and conclusions that can be drawn from these three sections is then summarised and used to inform a follow-up exercise to prioritise environmental issues that should be addressed and from the results of this exercise to formulate initial proposals for macro-objectives.

### 1.3 The scope of buildings typologies to be addressed

There were estimated in 2013 to be 233 million residential and commercial buildings in the EU <sup>2</sup>. Residential buildings account for the majority of the EU's total building stock, accounting for approximately 75% of the total floor area (m<sup>2</sup>) <sup>3</sup>. This is followed by retail (7%), offices (6%), education (4%), hotels and restaurants (3%) and healthcare (2%). Other uses such as industrial and sports facilities account for approximately 4% of the total floor area.

Residential buildings appear to be the most important in terms of the proportion of the EU building stock they account for, but in general they tend to have longer life and slower replacement rate, so it will be important to compare and contrast this with other building uses. The distinct variations in usage patterns, form and construction techniques between the other predominant other uses suggest that buildings designed for high intensity, day to day occupation by people – namely offices, education facilities and hotels – could be a further focus of attention. Retail, industrial and sports facilities tend to consist of large volume spaces with a very different construction form and servicing needs. It might therefore be more complex to address these uses within the same scope.

The age of the buildings to be addressed is also a major consideration. Figure 1.2 illustrates the age of the residential building stock, with the majority of the stock being pre-1990, in general predating more stringent building standards to regulate energy use. With an estimated annual replacement rate 1-2% and a renovation rate of between 0.5% and 1.2% for the EU building stock, the performance of the existing buildings is therefore significantly more important within the short to medium term than new buildings.



**Figure 1.2 The age of the housing stock in three broad areas of the EU (2010)**

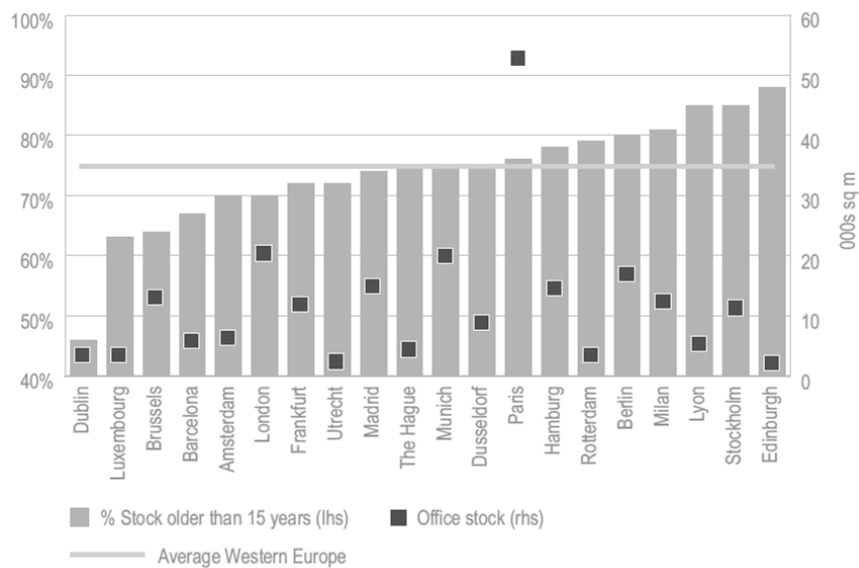
Source: BPIE (2011)

As can be seen in Figure 1.3, Europe's office building stock is also dated. For example, in Germany, 59% of the stock dates from between 1950 and 1990 and, in the UK, 22% dates from before 1960. The average rate of replacement of offices across Europe is cited as being between 1% and 2%, but can be closer to 3% in major centres such as London <sup>4</sup>. The market has seen an increased focus on better use of existing building assets, reflected in a wider trend in EU office markets – both public and private - for major renovations instead of new-build projects.

<sup>2</sup> Ecorys and the Copenhagen Resource Institute, *Resource efficiency in the building sector*, Final report to DG Environment, 23rd May 2014.

<sup>3</sup> Building Performance Institute Europe, *Europe's buildings under the microscope*, October 2011

<sup>4</sup> Jones Lang La Salle (2013) *From obsolescence to resilience*, 'Advance' white paper



**Figure 1.3 The proportion of office building stock older than 15 years in Western European cities**

Source: Jones Lang La Salle (2013) lhs=left axis rhs=right axis

Inclusion of existing buildings within the scope is also important because of the stock of materials and structures contained within those buildings. Estimates from Germany, for example, suggest that the country's built environment forms a repository of approximately 50 billion tonnes<sup>5</sup>.

<sup>5</sup> Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2012) *German Resource Efficiency Programme, (ProgRes)*

## 2. Review of existing EU and Member State policy frameworks for resource efficient buildings

In this section, the existing EU policy framework has been reviewed in order to identify environmental and resource efficiency policies that are of significance to the built environment and the construction sector. Member State policies of relevance to resource efficiency have also been briefly reviewed, together with selected examples of leading initiatives.

### 2.1 Current EU policy frameworks and their macro-objectives

The EU has developed a series of policy frameworks that establish relevant macro-objectives for the economy as a whole, cities and urban areas, individual building performance, construction products and specific industrial activities in the supply chain. These take a number of different forms:

- Programmes, strategies and blueprints for action: These encompass the 7<sup>th</sup> Environment Action Programme, EU climate change policy, urban policy, resource efficiency, circular economy, and the management of natural resources;
- Directives and Regulations requiring action: These encompass energy performance and supply, construction products and manufacturing, construction and demolition waste and the management of natural resources;
- Initiatives targeting and monitoring specific environmental issues and aspects of resource efficiency: These encompass the state and outlook for the European environment reporting, the scoreboard of Resource Efficiency indicators, Material Flow Accounting and the development and state of EU housing.

The policy frameworks identified, the form they take and their macro-objectives are in turn briefly reviewed for their relevance in the following sections.

Strategies and instruments that may be of broader relevance to the urban environment – including the Urban Wastewater Directive, the Clean Air Policy Package, the EU Biodiversity Strategy and the Environmental Noise Directive – are reviewed as part of a further more detailed prioritisation exercise in Chapter 6.

#### 2.1.1 Programmes, strategies and blueprints for action

##### 2.1.1.1 The 7<sup>th</sup> Environment Action Programme (2013)

The 7<sup>th</sup> Environment Action Programme of the European Union (EAP)<sup>6</sup> re-enforces the 2020 objective of creating a 'low carbon and resource-efficient economy'. Moreover, the EAP sets out objectives to reduce the overall impact of resource use, including the prevention and reduction of adverse impacts relating to a range of different resources and ecosystem services, as well as enhancing the sustainability of cities. Adverse impacts on the climate, forests, air quality, waste and land degradation are addressed.

Priority Objective 2 of the EAP places a specific focus on resource efficiency, in which the importance of reducing greenhouse gas emissions, improved industrial resource efficiency, improvements in the environmental performance of goods along their whole life cycle, and the need to move to a life cycle driven 'circular' economy are specifically highlighted. The EAP highlights the role of the Commission's Roadmap to a Resource Efficient Europe ('the Roadmap') as a framework for future action.

Priority Objective 8 of the EAP is of relevance to buildings because it seeks to 'enhance the sustainability of the Union's cities' and to place environmental sustainability at the core of urban development strategies. It states that, by 2020, the programme should ensure that the majority of the Union's cities '*are implementing policies for sustainable urban planning and design, including innovative approaches for urban public transport and mobility, sustainable buildings, energy efficiency and urban biodiversity conservation.*' Moreover, it states that there should be a focus on:

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<sup>6</sup> Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Action Programme to 2020 '*Living well, within the limits of our planet*'

*'the integration of urban planning with objectives related to resource efficiency, an innovative safe and sustainable low-carbon economy, sustainable urban land-use, sustainable urban mobility, urban biodiversity management and conservation, ecosystem resilience [and] water management....'*

### **2.1.1.2 EU climate change policy**

*The 2020 Climate and Energy package (2009)*

The EU is committed under the UN Framework Convention on Climate Change to reduce its greenhouse gas emissions. The climate and energy package is a set of binding legislation which aims to ensure that the European Union meets its ambitious climate and energy targets for 2020<sup>7</sup>. These targets, known as the '20-20-20' targets, set three key objectives for 2020:

- A 20% reduction in EU greenhouse gas emissions from 1990 levels;
- Raising the share of EU energy consumption produced from renewable resources to 20%;
- A 20% improvement in the EU's energy efficiency upon 1990 levels.

The targets were set by EU leaders in March 2007, when they committed Europe to become a highly energy-efficient, low carbon economy, and were enacted through the climate and energy package in 2009. A further set of targets for 40% reductions below 1990 levels have been proposed by the EU for 2030, together with the long-term objective to reduce greenhouse gas emissions by 80-95% below 1990 levels by 2050.

Obligations relating to the built environment were laid down in the Renewable Energy Directive 2009/28/EC, the recast Energy Performance of Buildings Directive 2010/31/EU and the Energy Efficiency Directive 2012/27/EU, which are described further in Section 2.1.2. Obligations relating to major producers of construction materials, such as cement and steel, were laid down in reforms of the EU Emissions Trading Scheme (EU ETS).

*EU Strategy on adaptation to climate change (2013)*

A related aspect of climate change that is now also being addressed is adaptation to ensure resilience in the face of predicted future adverse effects. An EU strategy on adaptation to climate change was published in 2013<sup>8</sup>. The strategy highlights the need for the 'climate proofing' of cities as well as physical infrastructure and assets. Major threats to buildings and constructions are identified as<sup>9</sup>:

1. Extreme precipitation;
2. Extreme summer heat events;
3. Exposure to heavy snow fall;
4. Rising sea levels increasing the risk of flooding.

The overheating of the built environment is also highlighted, with implications not just for building materials but also for the comfort and wellbeing of occupiers.

The Commission anticipates that the need for adaptation strategies are needed at local, regional, national and EU level. Due to the varying severity and nature of climate impacts between regions in Europe, most adaptation initiatives are envisaged as being taken at the regional or local levels. The ability to cope and adapt will also differ across populations, economic sectors and regions within Europe.

### **2.1.1.3 Urban policy**

*Thematic Strategy for the Urban Environment (2006)*

Although it dates from 2006, Communication COM/2005/0718 on a Thematic strategy for the urban environment is still of relevance to this study because buildings cannot be seen in isolation from their urban

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<sup>7</sup> European Commission, *The 2020 climate and energy package*, [http://ec.europa.eu/clima/policies/package/index\\_en.htm](http://ec.europa.eu/clima/policies/package/index_en.htm)

<sup>8</sup> COM(2013)216, Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, *An EU Strategy on Adaptation to Climate Change*

<sup>9</sup> Commission Staff Working Document, *Adapting infrastructure to climate change*, SWD(2013) 137, Brussels, 16.4.2013

context<sup>10</sup>. It is also notable for highlighting the multiple resource efficiency benefits of compact urban development forms.

The Communication highlights the importance of urban areas in delivering the objectives of the EU Sustainable Development Strategy and of taking an integrated approach to the environmental challenges facing cities. It identified a common set of complex and inter-related environmental problems facing cities and, in line with the preceding 6<sup>th</sup> Environment Action Programme suggested actions under four main priority themes – urban management, sustainable transport, construction and urban design. Measures suggested included:

- Better urban planning to support EU legislation, including the co-ordination of land use planning with sustainable urban transport;
- A priority focus on transport and buildings, including setting and enforcing standards on sustainable construction and supporting the retrofitting of existing buildings;
- Planning to avoid urban sprawl through high density and mixed use development patterns, with environmental advantages relating to land use, transport and heating which will contribute to less resource use per capita

#### *The urban dimension of EU policies (2014)*

The need for a new EU 'urban agenda' was the subject of a consultation in 2014. The consultation was supported by the publication of the Communication 'the urban dimension of EU policies' in 2014<sup>11</sup>. The Communication states that cities are '*...ideally placed to contribute to the reduction of energy consumption and CO<sub>2</sub> emissions as the density of urban areas allows for more energy efficient forms of housing and transport.*' Moreover, it also reflects on where action may be required to benefit from these potential advantages:

*'The resource efficiency gains made possible by compact urban settlements are being undermined by uncontrolled urban sprawl that puts public services under pressure and reduces territorial cohesion. Walking, cycling and public transport are not a sufficiently developed alternative to cars in many cities, resulting in congestion, bad air quality and high energy use.'*

#### **2.1.1.4 Resource efficiency and the circular economy**

##### *The Raw Materials Initiative (2011)*

In 2011, the Commission adopted the Raw Materials Initiative<sup>12</sup>, which set out a strategy for tackling the issue of access to raw materials in the EU. This strategy has three pillars which aim to ensure:

1. Fair and sustainable supply of raw materials from global markets: The EU has committed to pursue a Raw Materials Diplomacy reaching out to third countries through strategic partnerships and policy dialogues.
2. Sustainable supply of raw materials within the EU: The EU is dependent on the imports of many raw materials. Even though the potential for mining and quarrying in Europe is strong, the land area available for extraction is constantly decreasing. To facilitate the sustainable supply of raw materials from European deposits, the European Commission aims to secure the right legal and regulatory conditions.
3. Resource efficiency and supply of 'secondary raw materials' through recycling: Production using recycled materials is often much less energy intensive than manufacturing goods from virgin materials. Recycling can thus reduce production costs and GHG emissions and has a great potential to improve Europe's resource efficiency.

The European Innovation Partnership (EIP) on Raw Materials is the major EU initiative implementing the Raw Materials Initiative stakeholder platform. The main objective of the Partnership is to help raise industry's

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<sup>10</sup> COM(2005)718 Communication from the Commission to the Council and the European Parliament on a Thematic Strategy on the Urban Environment

<sup>11</sup> COM(2014) 490, Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, *the urban dimension of EU policies - key features of an EU urban agenda*

<sup>12</sup> COM(2011)25 Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, *Tackling the challenges in commodity markets and on raw materials*

contribution to the EU's GDP to around 20% by 2020 by securing its access to raw materials. It will also play an important role in meeting the objectives of the Roadmap to a Resource Efficient Europe (see the following section). It will do this by ensuring the sustainable supply of raw materials to the European economy whilst also increasing benefits for society as a whole.

#### *The Roadmap to a Resource Efficient Europe (2011)*

The Roadmap to a Resource-Efficient Europe COM(2011) 571 highlights the significant impact of construction on natural resources<sup>13</sup>. The Roadmap outlines how Europe's economy can be transformed into a sustainable one by 2050. It proposes ways to increase resource productivity and decouple economic growth from resource use and its environmental impact. Buildings are identified as a specific sector responsible for some of the most significant environmental impacts.

The Roadmap highlights how more efficient construction and use of buildings in the EU would influence approximately 42% of final energy consumption, 35% of greenhouse gas emissions, more than 50% of all extracted materials and up to 30% of water. It proposes that existing policies for promoting energy efficiency and renewable energy use in buildings should be complemented with policies for wider resource efficiency. Such policies would address a range of environmental impacts along the life-cycle of buildings.

The Roadmap suggests the use of the ratio of Gross Domestic Product (GDP) to Domestic Material Consumption (DMC) as a provisional indicator of resource efficiency at EU level. The need was identified to complement this with a 'dashboard' of indicators to measure environmental impacts on natural capital or ecosystems, as well as thematic sector indicators such as for buildings. The initial set of indicators, and the evidence supporting their selection, are analysed further in section 2.1.3.1.

#### *An EU action plan for the Circular Economy (2015)*

Following the withdrawal of the waste legislative proposals in 2014 and a public consultation process, a revised Circular Economy package was published in late 2015. The Package contains measures to address the whole materials cycle, from production and consumption through to waste management and the use of recycled (secondary) raw materials, with the aim of contributing to 'closing the loop' of product lifecycles through greater recycling and re-use. The action plan seeks to make links to other EU priorities, including creating jobs and growth, industrial innovation and tackling climate change.

The package also makes specific reference to the development of a common framework of indicators for buildings in application of COM(2014)445. Construction and demolition are identified as a priority area. The significant volume of waste, the wide variance in re-use and recycling rates across the EU and the role of the construction sector in influencing the performance of buildings throughout their life are highlighted. The need to establish common standards and protocols for waste sorting is identified, with specific reference also made to the treatment of hazardous waste. Design improvements to buildings to increase their durability and recyclability is also emphasised.

### **2.1.1.5 The management of natural resources**

#### *The EU forest strategy (2013)*

The new EU Forest strategy adopted in 2013<sup>14</sup> provides a framework for responding to the increasing demands put on forests in relation to environmental protection, bio-based industries and energy production. The strategy sets out the need for sustainable forestry management as the means to ensure that forests continue to provide a range of benefits to society. The strategy defines sustainable forestry management as:

*'Sustainable forest management means using forests and forest land in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems.'*

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<sup>13</sup> COM (2011) 571 Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, *Roadmap to a Resource Efficient Europe*

<sup>14</sup> COM(2013) 659, Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, *A new EU forestry strategy – for forests and the forest-based sector*



The objective is set of achieving sustainable forestry management for EU forests, but also that the EU's contribution to promoting sustainable forest management and reducing deforestation is strengthened at global level.

#### *The blueprint for forest-based industries (2013)*

The strategy is supported by a Blueprint for forest-based industries<sup>15</sup>. The Blueprint aims to support the development of the value chain with the aim of contributing towards the EU's Industrial Policy. The most significant sub-sector of relevance to buildings that is addressed in the Blueprint are the wood-working industries.

The Blueprint emphasises the need for a healthy and resilient forest resource to support its aims, noting an EU 2050 goal to 'provide a high standard of living from lower levels of energy and resource consumption, so long as it comes from sustainable forest management.' The 'cascade principle' should be integrated into the use of wood materials, with extension of the useful life of wood fibres so that the carbon they have sequestered can provide more added value and employment than the direct use of wood or its residues for energy.

#### *The Blueprint to Safeguard Europe's Water Resources (2012)*

The Blueprint Communication COM (2012)673<sup>16</sup> aims to achieve better implementation of current water legislation (including the Water Framework Directive<sup>17</sup>), the integration of water policy objectives into other policies, and to address gaps in policy on water quantity and efficiency. Its overall objective is to ensure that 'a sufficient quantity of good quality water is available for people's needs, the economy and the environment throughout the EU'.

The Blueprint recognises the influence of industry and urban development on water resources, with the pressures from pollutant emissions and over-use (water stress) being of particular relevance. Water is clearly identified as a resource that should be addressed by resource efficiency policies. The scope to improve water efficiency of industry and buildings is emphasised as being important in order to counter trends towards greater water scarcity and stress. Water efficiency targets are proposed to be established at river basin level, taking into account levels of water stress. Special objectives identified include increased metering take-up, efficiency in buildings and maximisation of water re-use.

### **2.1.1.6 Human health and indoor air**

#### *The EU environmental and health strategy (2003)*

The aim of the strategy was to develop an environment and health 'cause-effect framework' to provide the necessary information for the development of Community policy dealing with sources and the impact pathway of health stressors<sup>18</sup>. In particular it sought to:

- Reduce the disease burden caused by environmental factors in the EU;
- Identify and to prevent new health threats caused by environmental factors.

It identified that a range of health effects are suspected to be related to environmental factors, examples included respiratory diseases, asthma and allergies that are associated with indoor and outdoor air pollution. The approach taken supported the development of a new Clean Air policy package to revise the limit values for SO<sub>2</sub>, NO<sub>2</sub>, NO<sub>x</sub>, lead and particulate matter in ambient air. The overall approach was also to be integrated with EU chemicals policy.

As a follow-up to the emphasis placed on indoor air quality in the strategy, a supporting document and evidence base on promoting action for healthy indoor air was prepared<sup>19</sup>. This brought together an analysis of

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<sup>15</sup> SWD (2013) 343 final, Commission Staff Working Document, *A blueprint for the EU forest-based industries* accompanying COM(2013)659

<sup>16</sup> COM(2012)673 Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, *A Blueprint to Safeguard Europe's Water Resources*

<sup>17</sup> Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy

<sup>18</sup> COM (2003) 338 final, Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, *A European environment and health strategy*, Brussels, 11.6.2003

the Health Impacts for diseases from, exposures to and sources of indoor air pollution. This analysis highlighted the importance of both indoor and outdoor sources of pollution, including particulates from fuel combustion, building damp, bio-aerosols from outdoor air and Volatile Organic Compounds (VOCs).

## 2.1.2 Directives and Regulations requiring action

### 2.1.2.1 Energy performance and supply

#### *Energy Performance of Buildings Directive (2010)*

The construction and refurbishment of buildings in order to reduce energy use and CO<sub>2</sub> emissions is a central environmental policy objective for Europe. The recast *Energy Performance of Buildings Directive 2010/31/EU (EPBD)*<sup>20</sup> sets out requirements for buildings that contribute towards ambitious EU targets for energy efficiency by 2020. It requires Member States to transpose the following into national legislation:

- Minimum, cost optimal energy performance requirements for new buildings, for major renovation of buildings and for the replacement or retrofit of building elements (e.g. heating and cooling systems, roofs, walls);
- The inclusion of energy performance certificates in all advertisements for the sale or rental of buildings;
- All new buildings must be ‘nearly zero energy’ by 31 December 2020 and all public buildings by 31 December 2018.

Linked to this, Member States are additionally required to prepare national plans to ensure that all new buildings are ‘nearly zero energy’ by 2020. This is defined in Article 2(2) of the EPBD as:

*‘...a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources,’*

National plans should set requirements for primary energy use expressed in kWh/m<sup>2</sup> per annum. Intermediate requirements shall be set for 2015. It is understood that fifteen Member States have already set intermediate targets.

Notably the Directive broadens the focus from renewable energy generation to the integration of *low or zero carbon energy generation systems* into new building designs. In Article 6 it refers to ‘high efficiency’ systems that use the electricity from the grid more efficiently to provide heating or cooling (e.g. heat pumps) or which use fuels more efficiently to generate electricity, heating and cooling (e.g. Combined Heat and Power supplying district heating and cooling). It states that for new buildings:

*‘...the technical, environmental and economic feasibility of high-efficiency alternative systems such as those listed below, if available, is considered and taken into account:*

*(a) decentralised energy supply systems based on energy from renewable sources;*

*(b) cogeneration;*

*(c) district or block heating or cooling, particularly where it is based entirely or partially on energy from renewable sources;*

*(d) heat pumps.’*

The new Communication on the Energy Union<sup>21</sup> highlights the efficiency gains from district heating and cooling, noting that it will be addressed by a future Commission Strategy.

#### *The Energy Efficiency Directive (2012)*

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<sup>19</sup> Jantunen M., Oliveira Fernandes E., Carrer P., Kephelopoulou S., (2011) *Promoting actions for healthy indoor air (IAIAQ)* European Commission Directorate General for Health and Consumers. Luxembourg.

<sup>20</sup> Directive 2010/31/EC of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)

<sup>21</sup> COM (2015)80 Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, *The Energy Union package: A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy*

The Energy Efficiency Directive 2012/27/EU<sup>22</sup> establishes a binding package of energy efficiency measures that Member States must implement in order to meet the EU's 2020 target for energy efficiency. A key focus of the Directive is the raising of the energy efficiency of new and existing buildings. A central requirement is that EU countries must establish national plans for renovating their existing building stock which currently accounts for approximately 38% of the EU's CO<sub>2</sub> emissions. These plans shall include the '*identification of cost-effective approaches to renovations relevant to the building type and climatic zone*' and '*policies and measures to stimulate cost-effective deep renovations of buildings, including staged deep renovations*'. A specific renovation rate of 3% of the total floor area of central government buildings to the minimum EPBD levels is set as a target. The Directive also incorporates the definitions of 'high efficiency' cogeneration from the repealed Cogeneration Directive.

#### *The Renewable Energy Directive (2009)*

The Renewable Energy Directive 2009/28/EC states that '*Member States shall introduce in their building regulations and codes appropriate measures in order to increase the share of all kinds of energy from renewable sources in the building sector*'. Moreover, Member States shall also ensure that new public buildings and existing buildings subject to major renovation '*fulfill an exemplary role*'.

Whilst the definition of near zero energy buildings laid down in the recast EPBD highlights that remaining energy requirements should be '*covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby*' there is no consistent reference point in EU legislation for the minimum proportion of renewable energy that should be supplied, or the level of CO<sub>2</sub> emissions reduction to be achieved, by different forms of energy generation supplying buildings.

#### **2.1.2.2 Construction products and manufacturing**

##### *The Construction Products Regulation (2011)*

The aim of the Construction Products Regulation<sup>23</sup> is to provide reliable information on the performance of construction products. This is to be achieved by providing a 'common technical language' based on uniform assessment methods of the performance of construction products. This is to be implemented by:

- Manufacturers when declaring the performance of their products,
- The authorities of Member States when specifying requirements for them.
- Users (architects, engineers, constructors etc..) when choosing the products most suitable for their intended use in construction works.

Annex 1 of the Regulation lays down 'basic requirements for construction works' which include specific reference to emissions to the environment (requirement 3) and the sustainable use of natural resources (requirement 7). Basic requirement 7 states that:

*'the construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and in particular ensure the following:*

*(a) reuse or recyclability of the construction works, their materials and parts after demolition;*

*(b) durability of the construction works;*

*(c) use of environmentally compatible raw and secondary materials in the construction works.'*

##### *The Industrial Emissions Directive (2010)*

The Industrial Emissions Directive (IED)<sup>24</sup> is the successor of the Integrated Pollution Prevention and Control (IPPC) Directive. Its aim is to minimise pollution from various industrial sources throughout the European Union and to ensure the prudent management of natural resources. Operators of industrial installations

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<sup>22</sup> Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency

<sup>23</sup> Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products

<sup>24</sup> Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)

carrying out activities covered by Annex I of the IED are required to obtain an integrated permit from the authorities in the relevant EU countries.

The IED is relevant to this study because it applies to a range of production processes for materials and products that form a significant component of EU building material flows. Examples include cement works, the processing of metals, the manufacturing of glass, ceramics and polymers. Permitting shall take into account integrated performance standards, emissions limit values and Best Available Techniques (BAT) for the type of activity carried out.

### **2.1.2.3 Construction and demolition waste**

#### *The Waste Framework Directive (2008)*

Construction and demolition waste (CDW) accounts for between 25% and 30% of the waste generated in the EU<sup>25</sup>. CDW has been identified as a priority waste stream by the European Union because there is a high potential for recycling and re-use of this waste type, based on the potential value and the use of well developed technologies and strategies. The importance of CDW management is reflected in the Waste Framework Directive<sup>26</sup> which requires that:

*'Member States shall take the necessary measures designed to achieve that by 2020 a minimum of 70% (by weight) of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the List of Wastes shall be prepared for re-use, recycled or undergo other material recovery" (including backfilling operations using waste to substitute other materials).'*

The Waste Framework Directive has the high level aim of moving towards a 'European recycling society with a high level of resource efficiency'. Based on a recent assessment of CDW, the potential for increasing the level of recycling and re-use is significant, with performance at Member State level varying between under 10% and over 90%<sup>27</sup>. The average recycling rate was calculated as part of the same assessment to be 46% across the EU.

#### *The Landfill Directive (1999)*

The objective of the Landfill Directive is to prevent or reduce as far as possible negative effects on the environment<sup>28</sup>. It focusses in particular on potential impacts on surface water, groundwater, soil, air, and on human health from the landfilling of waste. It introduced stringent technical requirements for waste and landfills. The Directive defines the different categories of waste (municipal waste, hazardous waste, non-hazardous waste and inert waste) and applies to all landfills, defined as waste disposal sites for the deposit of waste onto or into land. A standard procedure is laid down for the acceptance of waste in a landfill so as to avoid any risks.

Of particular relevance to the construction sector are the designations for hazardous waste and inert waste. Wastes are coded and those waste codes that are acceptable for different classes of landfills are identified in Decision 2003/33/EC which establishes acceptance criteria and procedures<sup>29</sup>. Hazardous wastes may arise from demolition sites and strip-outs prior to the renovation of properties. The majority of construction and demolition waste falls within the criteria for landfills for inert waste, including the waste codes for concrete, bricks, tiles and ceramics, and mixes of all three.

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<sup>25</sup> European Commission, *Construction and Demolition Waste*, [http://ec.europa.eu/environment/waste/construction\\_demolition.htm](http://ec.europa.eu/environment/waste/construction_demolition.htm)

<sup>26</sup> Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste

<sup>27</sup> BIO Intelligence Service, *Management of construction and demolition waste*, Final report for DG Environment (task 2), February 2011

<sup>28</sup> Council Directive 1999/31/EC of 26<sup>th</sup> April 1999 on the landfill of waste

<sup>29</sup> Council Decision of 19th December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II of Directive 1999/31/EC

#### **2.1.2.4 The management of natural resources**

##### *The Legal sourcing of timber (2010)*

The Timber Regulation (EC) 995/2010<sup>30</sup> introduced new requirements for the sourcing of timber products from 2013. It prohibits illegally harvested timber from being placed on the EU market and introduces requirements for 'due diligence', which it defines as comprising:

*(a) measures and procedures providing access to the [origin of] the operator's supply of timber or timber products placed on the market;*

*(b) risk assessment procedures enabling the operator to analyse and evaluate the risk of illegally harvested timber or timber products derived from such timber being placed on the market.*

*(c) except where the risk identified in course of the risk assessment procedures referred to in point (b) is negligible, risk mitigation procedures which consist of a set of measures and procedures that are adequate and proportionate to minimise effectively that risk and which may include requiring additional information or documents and/or requiring third party verification.*

The Regulation defines legally harvested as wood and wood-based materials (excluding packaging and recycled wood) that have been 'harvested in accordance with the applicable legislation in the country of harvest'. EU FLEGT and UN CITES licenses are deemed to provide assurance of legality. Europe is in the process of introducing the FLEGT (Forest Law Enforcement Governance and Trade) licensing scheme. FLEGT is based on bilateral agreements between the EU and timber producing countries. Third party forest and forest products certification systems that meet the due diligence criteria set out in Article 6 of the Regulation can also be used.

#### **2.1.3 Initiatives targeting specific environmental issues and aspects of resource efficiency**

##### **2.1.3.1 The state and outlook for the European environment**

State and Outlook Environmental Reporting (SOER) for Europe is carried out by the European Environment Agency (EEA). Twenty environmental issues selected based on expert scientific judgement form the basis for the EEA's monitoring of the state and outlook of the EU environment<sup>31</sup>. In the most recent 2015 report these issues are now clustered under the three priorities of the EU's 7th Environmental Action Programme. The reporting framework is summarised in Table 2.1. These issues consist of a mix of drivers, pressures and changes in environmental state that have relevance at multiple levels, i.e. from local to global.

Whilst the reporting framework adopts a holistic perspective and is not specifically focussed on the built environment, there are many environmental issues within the framework that are likely to be relevant for buildings – for example, land use and soil functions, material resource efficiency and greenhouse gas emissions. In this respect, the framework and reporting highlight areas where more progress is identified as being needed in order to achieve EU policy targets, as well as issues for which no current targets exist.

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<sup>30</sup> Regulation (EU) No 995/2010 of the European Parliament and of the Council of 20 October 2010 laying down the obligations of operators who place timber and timber products on the market

<sup>31</sup> European Environment Agency, *The European environment state and outlook 2015 – synthesis report*

**Table 2.1 EEA reporting framework for the state and outlook for the EU environment**

	5-10 year trends	20+ years outlook	Progress to policy targets	Read more in Section ...
<b>Protecting, conserving and enhancing natural capital</b>				
Terrestrial and freshwater biodiversity			□	3.3
Land use and soil functions			No target	3.4
Ecological status of freshwater bodies			☒	3.5
Water quality and nutrient loading			□	3.6
Air pollution and its ecosystem impacts			□	3.7
Marine and coastal biodiversity			☒	3.8
Climate change impacts on ecosystems			No target	3.9
<b>Resource efficiency and the low-carbon economy</b>				
Material resource efficiency and material use			No target	4.3
Waste management			□	4.4
Greenhouse gas emissions and climate change mitigation			☑/☒	4.5
Energy consumption and fossil fuel use			☑	4.6
Transport demand and related environmental impacts			□	4.7
Industrial pollution to air, soil and water			□	4.8
Water use and water quantity stress			☒	4.9
<b>Safeguarding from environmental risks to health</b>				
Water pollution and related environmental health risks			☑/□	5.4
Air pollution and related environmental health risks			□	5.5
Noise pollution (especially in urban areas)		N.A.	□	5.6
Urban systems and grey infrastructure			No target	5.7
Climate change and related environmental health risks			No target	5.8
Chemicals and related environmental health risks			□/☒	5.9
<b>Indicative assessment of trends and outlook</b>		<b>Indicative assessment of progress to policy targets</b>		
	Deteriorating trends dominate	☒	Largely not on track to achieving key policy targets	
	Trends show mixed picture	□	Partially on track to achieving key policy targets	
	Improving trends dominate	☑	Largely on track to achieving key policy targets	

Source: European Environmental Agency (2015)

### 2.1.3.2 The development of EU Resource Efficiency indicators

As proposed in the Roadmap to a Resource Efficient Europe, a process was initiated to develop a 'dashboard' of resource efficiency indicators in order to guide action and progress at EU level. The provisional indicators as reported in the first 'resource efficiency scoreboard' provide a high level view of where attention on resource efficiency should be focussed at EU level<sup>32</sup>. They are structured in the following way, with only those indicators of relevance to the built environment highlighted for discussion in this paper:

- A lead indicator of resource productivity, linking Domestic Material Consumption (DMC) with Gross Domestic Product (GDP);
- 'Dashboard' indicators of environmental pressures, with greenhouse gas emissions, urban land use and water use;

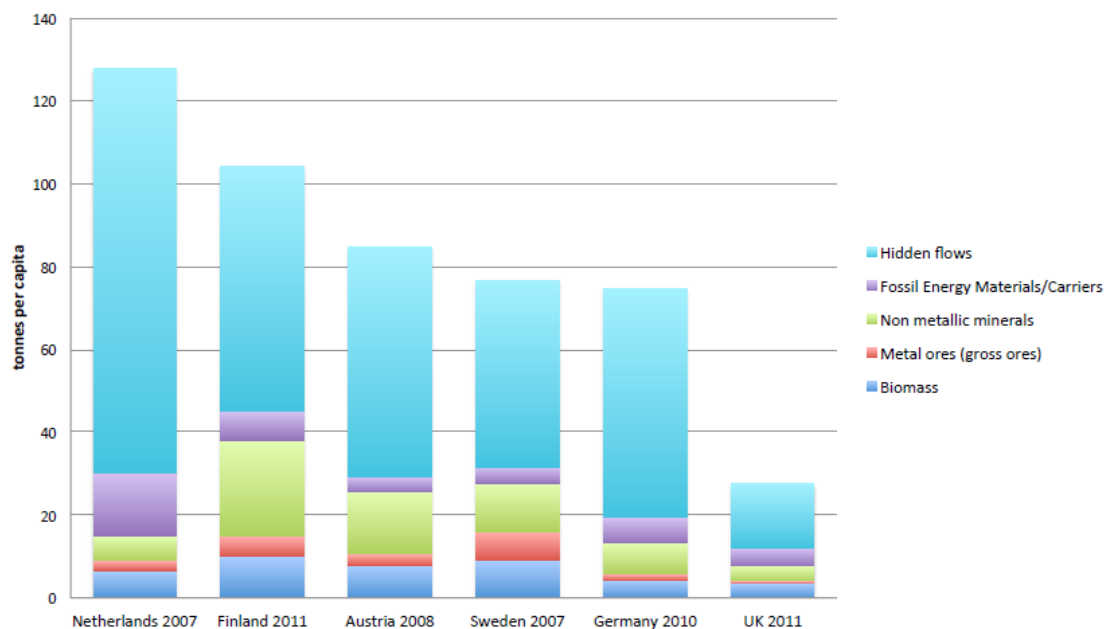
<sup>32</sup> European Commission (2014) *Resource Efficiency Scoreboard 2014 Highlights*, Directorate-General for Environment

- Thematic indicators relating to transformation of the economy (including 'turning waste into a resource' but excluding major mineral wastes) and natural capital (including 'safeguarding clean air' with a focus on urban PM<sub>10</sub> exposure).

A thematic indicator for 'improving buildings' was also proposed, with an initial focus on energy consumption for space heating.

The value of these indicators in defining and measuring progress was reviewed by experts from the European Resource Efficiency Platform (EREP)<sup>33</sup>. Three examples taken from the scoreboard of indicators – DMC, urban land use and PM<sub>10</sub> emissions - are briefly discussed below, both in terms of their potential relevance as macro-objectives for buildings and also to illustrate the challenges in using them to measure the resource efficiency of the built environment.

Material consumption could be particularly relevant to the large flows of materials associated with the construction sector. However, the difficulty was highlighted of simply focussing on (refined) material flows. This is because materials have a wide range of different upstream and potentially extra-EU impacts. These will be distinct to each type of material and could include environmental pollution, ecosystem damage and resource scarcity. The need to capture 'hidden' flows or 'Raw Material Equivalents' such as mine tailings and processing waste has also been highlighted in other research projects<sup>34</sup>. The potential scale and significance of these flows is illustrated at a Member State level in Figure 2.1. The nature of EU-wide construction resource flows is examined further in Section 2.1.3.3.



**Figure 2.1. Domestic material consumption inclusive of 'hidden' flows for selected MS at points in time**

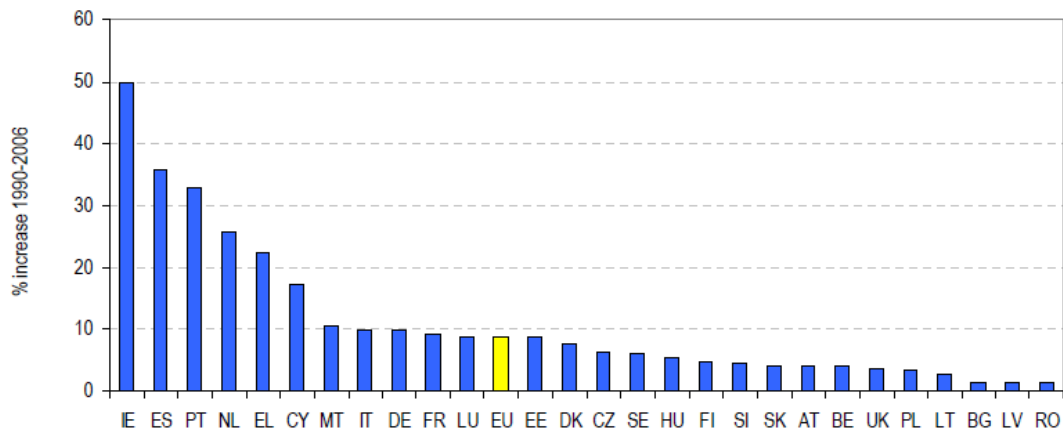
Source: POLFREE (2014)

Urban land use at the expense of agricultural land could be relevant as a measure of how efficient urban develop is. The importance of reducing soil degradation and urban soil sealing is highlighted in the Commission's 2006 Thematic strategy for soil protection<sup>35</sup>. Figure 2.2 illustrates how construction has exhibited pressures on land use in different Member States during the period 1990-2006. Spain, for example, saw an unprecedented period of urban expansion, which included a move to lower density residential and commercial development. The UK, in contrast, whilst also experiencing a property boom sought to reduce 'greenfield' development whilst increasing urban densities and in-fill. The potential relevance of urban density and form is examined further in Section 3.1.3.

<sup>33</sup> European Commission, *European Resource Efficiency Platform (EREP)*, [http://ec.europa.eu/environment/resource\\_efficiency/re\\_platform/index\\_en.htm](http://ec.europa.eu/environment/resource_efficiency/re_platform/index_en.htm)

<sup>34</sup> POLFREE, *Comparing trends and policies of key countries*, Deliverable D1.3, Prepared by Wuppertal Institute, 31st May 2014

<sup>35</sup> COM (2006)231 Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, *Thematic Strategy for Soil Protection*



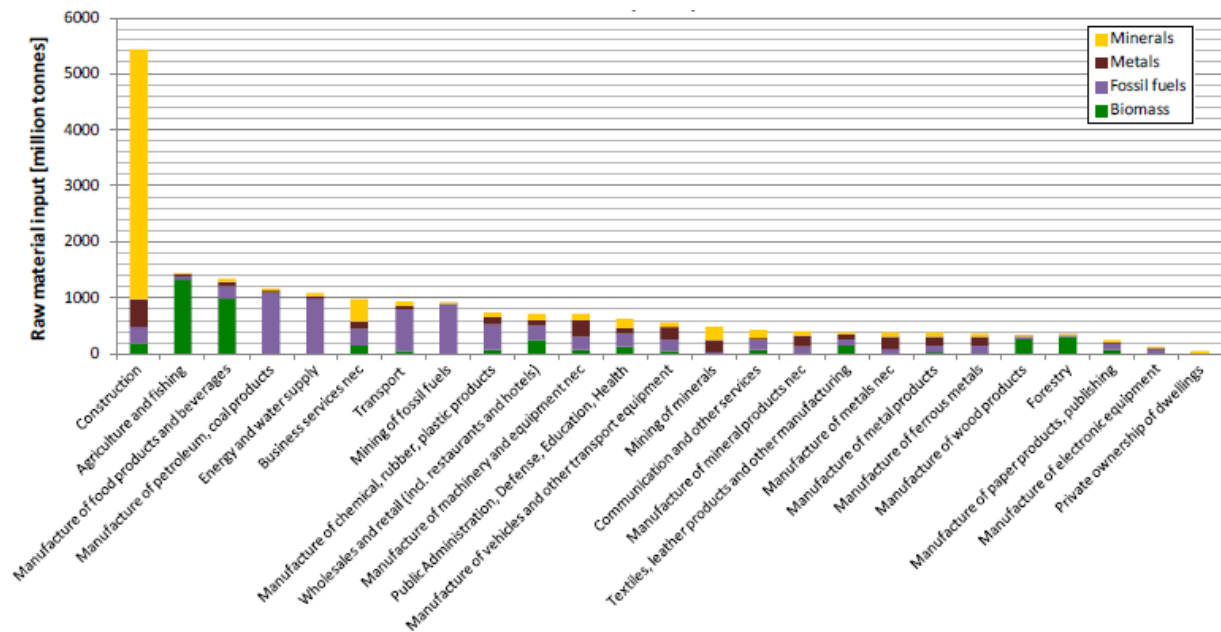
**Figure 2.2. Percentage increase in built up areas by member state, 1990-2006**

Source: Eurostat (2006), CORINE (1990)

Urban exposure to air pollution, including PM<sub>10</sub> emissions, is relevant in terms of construction sites, the physical proximity of a building to pollution sources (e.g. adjacent to major arterial roads) and also so-called 'induced' environmental impacts that may be generated as a result of the form and location of building (e.g. lower density residential areas, car based commuting to or from a location). The potential significance of 'induced' impacts is examined further in Section 3.1.3.

### 2.1.3.3 Material Flow Accounting (MFA)

In support of EU policies on resource efficiency, Eurostat compiles sectoral data for the European economy. According to an assessment of EU sectoral resource use based on Multi Regional Input Output (MRIO) modelling, the construction sector uses the largest amount of materials in the EU economy (5.4 billion tonnes in 2007). This is mainly accounted for by non-metallic minerals, sand and gravel, as illustrated in figure 2.3.



**Figure 2.3. The annual Raw Material Input of economic sectors in the EU-27 in 2007**

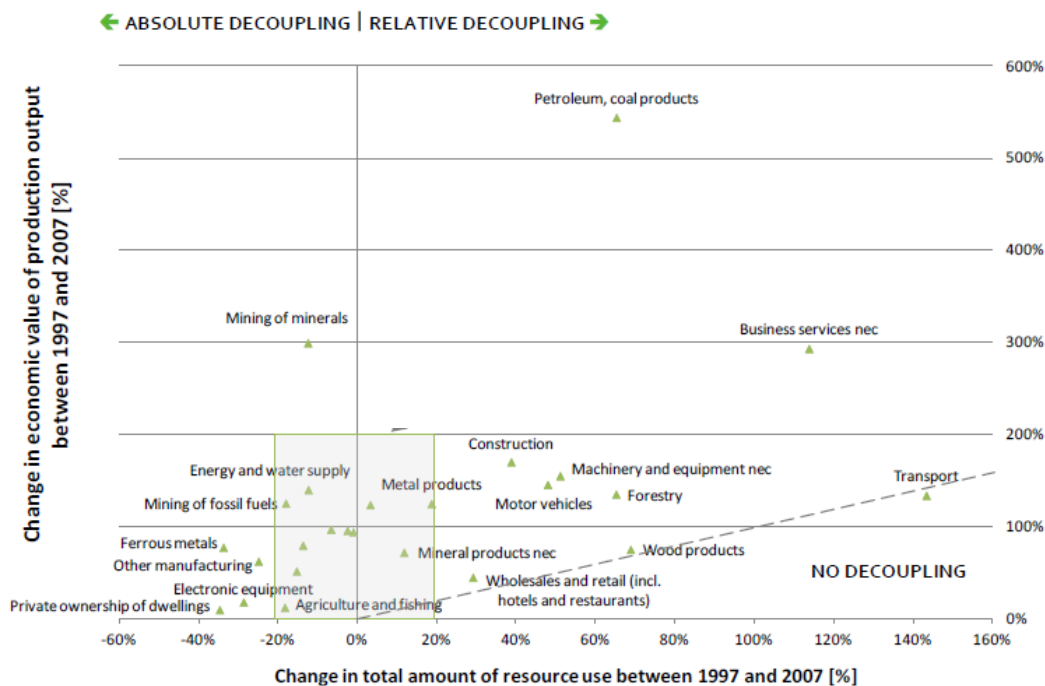
Source: European Commission (2013)

As already highlighted in Section 2.1.3.1, a high level resource efficiency objective for the EU is an improvement in resource productivity i.e. how much economic value is created for each kg of flow. The construction sector is resource intensive, which means that it generates relatively low economic value considering its resource use, compared with many other sectors of the EU economy. Recent analysis for the

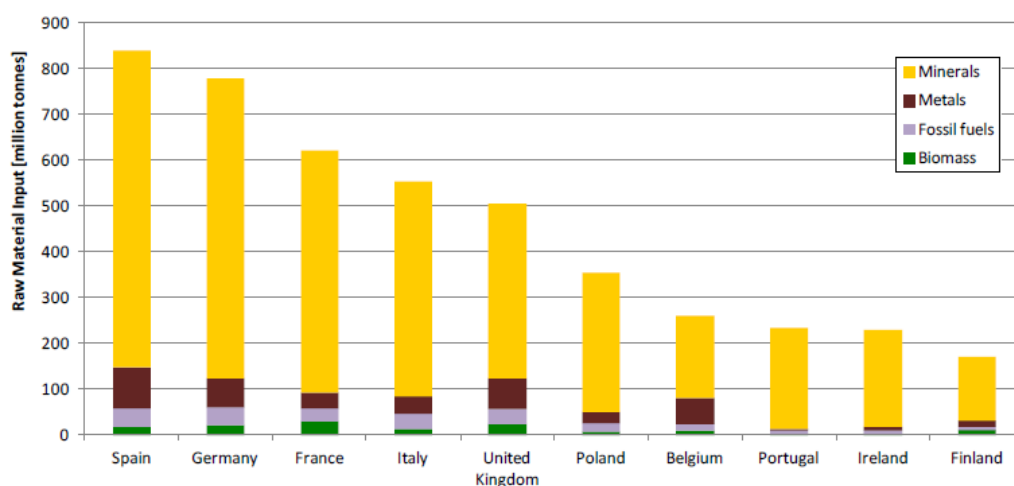


European Commission <sup>36</sup> showed that the sector has, however, shown a trend towards a ‘decoupling’ of economic growth from resource use, as illustrated in figure 2.4. Gross resource use increased over this period, so the increase in resource productivity could mask an overall increase in the sector's environmental impacts.

The most resource intensive Member States are illustrated in figure 2.5, which highlights how some smaller Member States such as Portugal, Ireland and Finland use large amounts of materials in proportion to their population. It also indicates the potential for variation in the split between mineral, metal, fossil fuel and biomass use, which may reflect different construction practices and material choices.



**Figure 2.4. The change in material resource use compared with the change in economic value generated over the same time period.** Source: European Commission (2013)



**Figure 2.5. Member States with the most material intensive construction sectors (2007)**

Source: European Commission (2013)

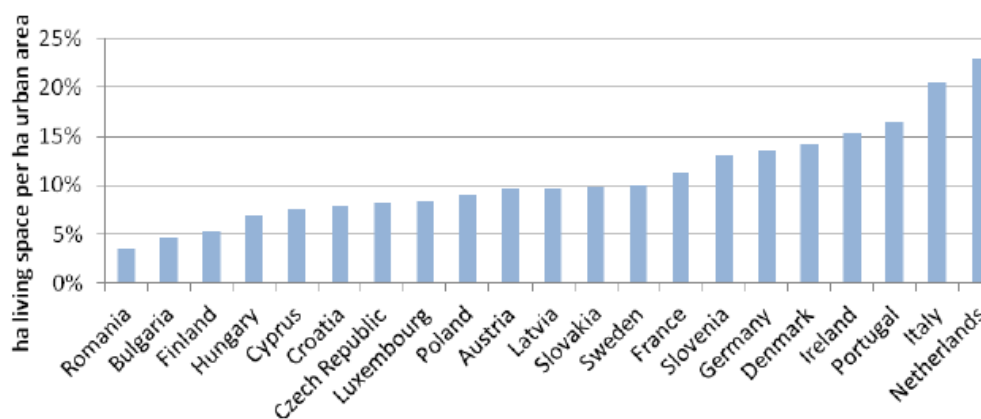
<sup>36</sup> European Commission, *Sectoral resource maps: information hub*, Report prepared by BIO Intelligence Service and SERI for DG Environment, March 2013

### 2.1.3.4 Development and state of EU housing

A special report was prepared for the European Environment Agency in 2013 that provides a useful outlook on resource consumption associated with the EU housing stock<sup>37</sup>. It identified that the composition of the EU housing stock varies considerably between Member States, both in terms of building form and tenure.

Resources addressed were land use, material flows, energy efficiency and water consumption. Some of the key points identified for each of these resources are as follows:

- Land use: Public demand for more and larger homes is a general trend that influences resource consumption and is leading to the expansion of urban areas and pressure on greenfield land. There is a three-fold variation in the average living space per capita between some countries in the EU. The relationship between living space and the urban area are compared for a number of Member States for which data is available, in order to indicate a generalised level of spatial efficiency (see figure 2.6).

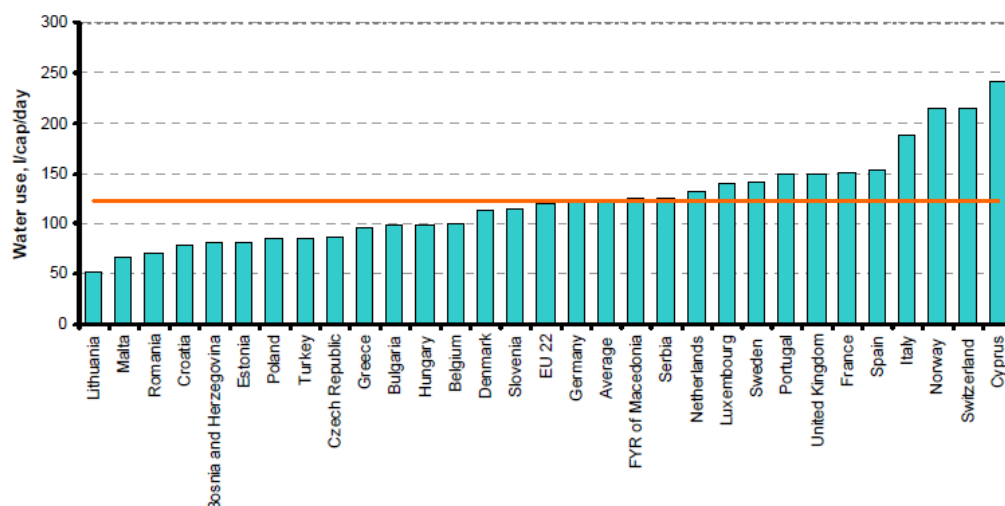


**Figure 2.6. Spatial efficiency as a relation of total living space to total urban area**

Source: ETC-SCP (2013)

- Material flows: Indicatively only 6% of aggregate demand is met by recycled aggregate from construction & demolition waste (as of 2008). Even if all Member States raised their construction & demolition recycling rates to the high levels achieved in Germany and the Netherlands (>90%) and this supply was able to meet relevant quality standards, there would still be the need for natural aggregate. The geographic distribution of construction & demolition waste compared to virgin materials lends recycled aggregate an environmental and economic advantage, as transport distances tend to be shorter. The potential for an increase in wood-based construction was also highlighted in that it may be constrained, given that European forestry is already intensive and that harvest levels in many forests may become a constraint.
- Water consumption: The data available reveals difficulties in making generalised observations about overall water consumption, with data problems in relation to geographical location, the use of water saving devices and overall water consumption per household highlighted (see Figure 2.7). Certain common uses of water, such as for personal washing, toilet flushing and washing clothes, have a similar geographical distribution of overall water use across several Member States. Lower GDP and higher water pricing is suggested as being the reason for markedly lower consumption in Eastern Europe. Surveys suggest that there remains significant potential for further water savings, with the ownership of water saving devices still in some countries and regions being relatively low.

<sup>37</sup> European Topic Centre on Sustainable Consumption and Production, *Housing assessment*, Final report prepared for the European Environment Agency, June 2013



**Figure 2.7. Water consumption of EU households per capita per day (2009)**

Source: ETC-SCP (2013)

## 2.2 Member State policies and objectives for resource efficiency

### 2.2.1 Review of Member State policies and objectives

The European Environment Agency has reviewed the policies and approaches to resource efficiency of the EU28<sup>38</sup>. The results of the survey which informed their 2011 report suggest that there is a lack of a clear definition and common understanding of the term resource efficiency, with other terms such as decoupling, sustainable use of resources or minimising use of natural resources used interchangeably. An overview of the findings is presented in Table 2.2. A new catalogue of policies is currently being finalised for publication during 2015 and may provide further insight into the evolution of these policies and objectives, as well as their impact.

With the exception of Austria, Cyprus, Hungary, Poland and Spain, which focus on raw material use, the term has been applied to a broad range of resources and natural capital. In 2011, only Austria, Germany and Belgium (Flanders) were highlighted as having a dedicated strategic policy with high level objectives, although sectoral policies applying to energy, waste and specifically building and construction were identified in some cases.

Resources that are prioritised are, in descending order of importance, energy, waste, minerals and raw materials, water, followed by forests and timber, biodiversity, biomass and renewable energy. Where priority resources are categorised, raw materials were identified as a specific category bringing together minerals, construction materials and metals.

In terms of objectives and targets for resource efficiency, the majority tended to be in areas where EU directives mandate action. An overview of the most common targets is provided in table 2.2. These include general targets for the economy as a whole and some that are specific to buildings or construction. Notably only six countries reported targets for material efficiency – Germany, Romania, Austria, Estonia, Italy and Sweden. Examples of selected specific targets are grouped below under common headings:

Greenhouse gas emissions

- *General target adopted across the EU:* Reduce greenhouse gas emissions associated with buildings, industrial sectors, infrastructure and transport

<sup>38</sup> European Environment Agency, *Resource efficiency in Europe: Policies and approaches in 31 EEA member and co-operating countries*, EEA Report No 5/2011

## Energy use

- *General targets adopted across the EU:* Increase the overall energy efficiency of buildings, increase the share of renewable energy in total energy use
- Double energy productivity by 2020 compared to 1990 (Germany)
- Reduction in energy intensity of at least 20% by 2020 (Austria)
- By 2020, new buildings shall use 75% less energy than in 2009 (Denmark)
- Reduce energy consumption of existing buildings by at least 38% by 2020 (France)
- Reduce district heating and fuel input by 30% in existing housing in comparison to 2004 (Lithuania)
- Achieve 'thermal rehabilitation' of all buildings built in the period 1950-1980 by 2020 (Austria)

## Material use and efficiency

- Resource productivity should increase by a factor of four (Austria)
- Double abiotic material productivity by 2020 compared to 1994 (Germany)
- Reduce the consumption of fossil fuels by 20% by 2020 (Switzerland)
- Reduce Total Material Requirement (TMR) 75% by 2030 and 90% by 2050 (Italy)
- Reduce annual extraction of natural gravel to not more than 12 million tonnes by 2010 (Sweden)
- Increase per capita consumption of wood from sustainable forestry from 1.1m<sup>3</sup> to 1.3m<sup>3</sup> (Germany)

## Waste

- *General targets adopted across the EU:* Reduce the amount of waste disposed of, increase the amount of waste separated, increase recycling rates
- Recycling at least 60-75% of construction-demolition waste by 2020 (Czech Republic, Estonia, Hungary, Latvia, Slovenia)

## Water

- Achieve 80% efficiency of water consumption within ten years (Portugal)
- Increase the use of rain water in order to preserve water resources (Belgium)

## Land use

- Growth in land use for housing, transport and soil sealing should be reduced to 30 hectare/day by 2020 (Germany)
- Use spatial planning to contribute to reducing energy consumption (Denmark)

A targeted review of national resource strategies by the UK's Department for the Environment, Food and Rural Affairs (DEFRA) highlighted the lead taken by Germany, France, Finland and the Netherlands in the area of raw material supplies<sup>39</sup>. The main focus of these strategies tend, however, to be on materials with a level of criticality i.e. their natural reserves are under physical, political or economic pressure.

A summary overview of the German ProgRes programme, which is recognised as a leading example of policy in this area, is provided in Section 2.2.3, including specific areas of focus in the building and construction sector.

### **Table 2.2. Resource efficiency target areas and indicators most commonly reported by EEA countries**

<sup>39</sup> DEFRA, *A review of national resource strategies and research*, UK, March 2012

Categories	Materials					Energy				Water			Land		Waste		Others					
	Indicators	Components of DMC/DMI	Total Material Requirement (TMR)	Domestic Material Consumption (DMC)/GDP/DMC/DMC/capita	Direct Material Input (DMI)/DMI/GDP or GDP/DMI	Domestic extraction (DE)	Energy efficiency of buildings	Biofuels share in transport	Share of renewable energy	Energy consumption	Energy efficiency	Exploitation index of renewable water resources	Water quality	Water use (total or by sector)	Forest area	Share of agricultural area under organic/agro-environmental farming	Land use/conversion of land/soil	Amount of waste recycled and/or the amount of waste deposited	Waste generation (total or per waste stream or sector)	Fisheries	Eco-efficiency of different sectors	Transport and infrastructure
Austria			•	•	•													•				
Belgium (FL)			•	•		•		•	•	•			•					•	•		•	•
Belgium (WA)		•								•			•								•	
Bulgaria	•		•															•	•	•		
Croatia			•				•	•	•		•	•	•	•	•	•	•	•	•	•		
Cyprus								•	•			•		•	•							
Czech Republic			•					•	•	•	•	•	•	•	•	•	•	•	•			•
Denmark				•		•		•	•				•					•	•		•	
Estonia					•			•				•		•		•		•		•		
Finland	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•		•	
Former Yugoslav Republic of Macedonia								•	•	•					•	•		•		•	•	
France			•					•	•	•		•			•			•	•			
Germany				•		•		•	•							•						•
Greece																						
Hungary										•			•		•	•		•	•			
Ireland			•						•			•						•				
Italy		•	•	•	•						•	•						•	•			
Latvia						•								•								•
Liechtenstein																		•	•			
Lithuania																						
Netherlands																						
Norway								•		•												
Poland			•		•		•	•	•	•	•	•	•	•	•	•	•	•	•		•	
Portugal			•					•	•	•								•	•			
Romania	•		•				•	•	•		•	•	•	•	•	•	•	•	•	•		
Slovakia			•	•	•			•	•	•		•	•	•	•	•	•	•	•		•	
Slovenia	•		•	•			•	•	•	•				•		•		•	•			•
Spain																						
Sweden			•	•	•			•	•					•	•	•		•	•	•		•
Switzerland			•			•		•	•	•		•	•	•	•	•		•	•			•
Turkey																						•
United Kingdom			•		•				•	•			•								•	
<b>Total</b>	<b>4</b>	<b>3</b>	<b>17</b>	<b>9</b>	<b>8</b>	<b>5</b>	<b>5</b>	<b>18</b>	<b>17</b>	<b>15</b>	<b>7</b>	<b>7</b>	<b>13</b>	<b>12</b>	<b>11</b>	<b>13</b>	<b>18</b>	<b>20</b>	<b>6</b>	<b>7</b>	<b>9</b>	

Source: European Environment Agency (2011)

## 2.2.2 Reviews of the progress and impact of EU and MS policy frameworks

A number of recent studies have highlighted slow progress in the implementation of requirements laid down in the recast Energy Performance of Buildings Directive and the Energy Efficiency Directive. These include a

focus on how to address the lack of progress towards targets and standards on 'nearly zero energy buildings'<sup>40</sup> and renovation strategies for existing public and private buildings<sup>41</sup>.

The FP7 project POLFREE, led by University College London, has analysed EU policy experiences in support of the aim of a resource-efficient economy<sup>42</sup>. The project highlights the need to consider the 'geological and economic framework conditions' for each MS – i.e. endowment with raw materials and raw material dependence – as these may shape resource efficiency plans and programmes<sup>43</sup>. Specific plans and programmes highlighted for analysis include those of Austria (the REAP plan), Germany (the ProgRes programme) and Italy (sustainability strategy 2002).

The project's work package on the role of national policies highlights the current lack of strong and coherent overall strategies, but points to the success of individual instruments targeting specific areas of resource use. Examples cited include the German building modernisation programme's impact on energy efficient renovations and the UK aggregates levy's impact on domestic material flow. In this respect the work of the European Environment Agency in bringing together MS policies is suggested as a helpful way of disseminate good practice.

### 2.2.3 Case studies of Member State plans, programmes and instruments

In this section, selected examples of high level Member State plans and programmes have been reviewed in order to identify their macro-objectives. Policy instruments that address specific aspects of resource efficiency – namely embodied greenhouse gas emissions, abiotic resource depletion and water use – are also briefly reviewed.

#### 2.2.3.1 The 'ProgRes' resource efficiency programme, Germany

The goal of Germany's RE programme is to make '*the extraction of and use of natural raw materials more sustainable and to reduce associated environmental pollution as far as possible*'<sup>44</sup>. The main focus is on raw materials, including abiotic and biotic non-energetic resources, with associated links to the use of natural resources such as water, air, land, soil, biodiversity and ecosystems, although these are addressed by other policies and programmes. The following strategic approaches are considered:

- Securing a sustainable raw material supply;
- Raising resource efficiency in production;
- Steering consumption towards resource efficiency;
- Enhancing resource efficient, closed cycle management;

The construction sector is identified as one of the country's most resource intensive, with environmental pressures identified in relation to:

- Raw materials extraction (e.g. gravel, sand and quarry stone);
- Processed raw material use (e.g. cement, metals and two thirds of national sawn timber production);
- Land take and high specific traffic density due to lower density urban fringe development;
- Use phase energy consumption.

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<sup>40</sup> Report from the Commission to European Parliament and the Council, *Progress by Member States towards Nearly Zero-Energy Buildings*, COM(2013)483, Brussels, 7.10.2013

<sup>41</sup> Buildings Performance Institute Europe (2014) *Renovation strategies of selected EU countries: A status report on compliance with Article 4 of the Energy Efficiency Directive* and The Coalition for Energy Savings, *Implementing the EU Energy Efficiency Directive: Analysis of Member State's plans to implement Article 5*, May 2015

<sup>42</sup> POLFREE, *Policy options for a resource efficient economy*, FP7 collaborative project, Accessed April 2015, <http://www.ucl.ac.uk/polfree>

<sup>43</sup> POLFREE, *Comparing trends and policies of key countries*, Deliverable D1.3, Prepared by Wuppertal Institute, 31st May 2014

<sup>44</sup> Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2012) *German Resource Efficiency Programme (ProgRes): Programme for the sustainable use and conservation of natural resources*, Germany Government

Also highlighted in relation to these objectives and targets is that existing structures represent a 50 billion tonne repository of mineral resources (estimate from 2000). Box 2 summarises the strategic objectives and targets relating to the construction sector.

**Box 2.1 Construction sector objectives and targets identified by the 'ProgRess' programme, Germany**

Energy use

- Improved building energy efficiency

Material use

- Improve the resource efficiency of material use e.g. lightweight timber use
- Concrete aggregate substitution and alternative materials and processes for cement production
- The greater use of 're-growable' raw materials e.g. timber

Waste reduction

- Avoid waste and close material cycles e.g. re-use or recycling of demolition materials
- Step up the cascade use of materials i.e. avoiding 'down cycling'

Urban sustainability

- Reduce land take to 30 hectares/day by 2020
- Making more sustainable use of existing urban land and infrastructure with a focus on compact development

Life span

- Extending the useful life of buildings, accompanied by energy efficient modernisation

*Source:* Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2012)

A revision of ProgRess by the German UBA is currently being undertaken and, it is understood, will see a move away from a simple focus on flows to the specific environmental impacts associated with these flows. Emissions from the manufacturing of construction products are to receive more attention, based on LCA evidence showing their increasing relative importance. Moreover, evidence from Best Available Technology (BAT) identification under the Industrial Emissions Directive (IED) Best available technology Reference documents (BREF) development process shows that there still exists significant improvement potential for processes such as cement production.

Further research is considered to be needed to ensure the fair comparison of construction practices and products, for example, in relation to timber for which indicators and data on the degradation of ecosystems are needed. The extension of the current focus of the CEN/TC 350 standards to hazardous substances and emissions is further areas of focus, reflecting the German public building assessment scheme BNB.

Land use and land use change will continue to be a focus. This will include land use associated with the supply of materials, where future constraints on mineral extraction because of ecological requirements have the potential to create scarcity of sites. It will also consider the combined constraints on landfill and end-markets for recycled aggregate in road construction which are creating pressure to find new end markets for waste materials.

Urban land use planning will also be a continued focus. It is considered that existing settlement areas should be densified in order to minimise vehicle traffic and re-use infrastructure. Moreover, the life of the existing building stock in these locations should be prolonged.

### **2.2.3.2 'Le Plan Bâtiment Durable' (sustainable building plan), France**

In 2012 a working group on 'responsible building' was launched within the frame of country's Sustainable Building Plan (Plan Bâtiment Durable). The plan has two overarching goals<sup>45</sup>:

<sup>45</sup>World Green Building Council, *Collaborative policy making case study:Le Plan Bâtiment Durable, France*

- To reduce the energy consumption of existing buildings by 38% (from 250 to 150 kWh/m<sup>2</sup>/year) by 2020, and by a further 100 kWh/m<sup>2</sup>/year before 2050;
- To ensure that France is building 'low consumption buildings' by 2012, and 'positive energy buildings' by 2020.

In total, 20 working groups have been launched since the creation of Plan Bâtiment Durable, with the latest focus on the development of a voluntary label for energy and environment performance of new buildings.

The proposed new label would consider not just energy in the use phase but along the whole life cycle in order to analyse the overall performance of a building<sup>46</sup>. The aim is to pilot test the label in 2016-2017 with three main criteria: total energy use, total water consumption and CO<sub>2</sub> emissions. Criteria on waste and public transportation may also be added in order to assess overall building performance.

Seven working groups have been created in order to define this label and are currently working on the following topics:

- Life-cycle assessment
- Environmental performance display
- Environmental data
- Economic stakes
- Users
- BEPOS (positive-energy building) and urban integration
- Quality of use

The focus of the label reflects a shift in French building energy efficiency policy to overall performance (energy, environment, cost) and from the building scale to the district scale, with the need to take district energy into consideration.

### **2.2.3.3 Technical building regulations for environmental construction, the Netherlands**

In January 2013, The Netherlands became the first EU country to require the measurement of greenhouse gases embodied in buildings. A new environmental requirement in the Dutch Building Decree requires Greenhouse Gas emissions and the depletion of abiotic resources to be reported for structural components of residential buildings and office buildings (over 100m<sup>2</sup>) upon application for a building permit<sup>47</sup>.

The two reporting requirements are to be fulfilled according to the Netherlands' Environmental Assessment Method for buildings and civil engineering works – Bepalingsmethode Milieuprestatie Gebouwen en GWW-werken. Benchmarking to set performance requirements may be considered once sufficient data has been collected.

### **2.2.3.4 Technical building regulations for water consumption, UK**

The UK Building Regulations were updated in 2010 and alongside changes to Part L which deals with energy performance, new requirements were introduced into Part G to reduce the design water consumption of new homes<sup>48</sup>. The requirements specify a combined consumption by hot and cold water systems of no more than 125 litres per head per day of potable ('wholesome') water.

Compliance can be demonstrated either on the basis of using the provided water efficiency calculation method or, as introduced in the 2015 edition of Part G, based on the water fittings installed. Alternative sources of lower grade water, such as harvested rainwater and reclaimed grey water, may also be used for functions such as toilet flushing, subject to specific measures.

<sup>46</sup> Background to the case study kindly provided by the World Green Building Council's European Regional Network

<sup>47</sup> Bouwbesluit 2012, Besluit van 29 augustus 2011 houdende vaststelling van voorschriften met betrekking tot het bouwen, gebruiken en slopen van bouwwerken, Artikel 5.9. Duurzaam bouwen, Netherlands, <http://www.bouwbesluitonline.nl/Inhoud/docs/wet/bb2012/hfd5/afd5-2/art5-9>

<sup>48</sup> HM Government, *The Building Regulations 2010 – Part G: Sanitation, hot water safety and water efficiency*, 2015 edition, UK.



Local authorities can, as additionally introduced into Part G in 2015, set a stricter requirement of 100 litres per head per day where a local needs justification is demonstrated. This may be based on the need to manage local demand and/or the adoption of pro-active strategies to adapt to climate change. This reflected a move by the UK Government to address a problem with a proliferation of local housing standards.

#### **Summary of findings on *EU and MS policies***

- Existing EU frameworks, regulation strategies, policy instruments and initiatives, as well as leading plans and programmes established by Member States, establish clear high level objectives which can form a starting point for this work to identify the identification of macro-objectives;
- Existing EU legislation has created clear regulatory framework for action to reduce building-related energy use and CO<sub>2</sub> emissions. This includes a near zero energy objective for new buildings and the progressive renovation of the existing building stock. Climate change adaptation is a related area of activity that is of particular relevance to existing buildings;
- Waste reduction and circular material flows are a specific focus for attention at EU level, including a new policy package and specific long term targets for the reduction of construction and demolition waste going to landfill;
- The management of natural resources such as wood and water are the focus for strategies and blueprints, in some cases supported by policy instruments. Their focus ranges from areas of pressure on resources in the EU to broader international obligations relating to imports.
- A set of resource efficiency indicators has been developed at EU level. Whilst these are not specifically targeted at the building sector, they could provide a useful initial reference point. The indicators includes measures of resource use, pressures on environmental capital and thematic indicators. Links can be made to EU strategies on raw material use, water use, forestry and air pollution;
- Reporting by the EEA on the state of the environment at EU level provides a broader holistic overview of environmental issues for which progress and the effectiveness of policies are monitored on a periodic basis. This could therefore also provide a broad framework for identifying issues of relevance to the built environment.
- Aspects of the EU's focus on resource efficiency also form part of Member State programmes, with Germany's ProgRes programme being the most complete example. ProgRes focusses on macro-objectives and a programme for action on raw material and natural resource efficiency.
- Various EU and Member State strategies highlight the need to interrelate urban planning, infrastructure, and building form and location. The multiple resource efficiency benefits of compact, land efficient and public transport connected buildings are highlighted and cited as an objective.
- Specific Member States have put in place legislation that requires buildings to use specific resources more efficiently – for example, water in the UK and Portugal – or to report on priority issues such as embodied greenhouse gas emissions and material use – for example, in the Netherlands.

### 3. Evidence for environmental ‘hot spots’ along the life cycle of buildings

In this section, the findings of a selection of technical studies that have analysed buildings and major construction materials from both a 'top down' sectoral and 'bottom up' building typology perspective are reviewed. The studies have been selected based on their quality, scope and representativeness. Based on these findings, environmental and resource efficiency ‘hot spots’ for the most significant environmental impacts of residential and commercial buildings, as well as indications of practical areas of focus for improvement, are then identified.

The different potential scope and boundaries for addressing the environmental and resource efficiency ‘hot spots’ of buildings are also explored. This includes a focus on ‘induced’ effects – those that relate to wider urban infrastructure and individual choices - as well as in-direct or consequential factors. The latter include the potential for comfort and health and wellbeing factors to influence the lifecycle environmental performance and financial value of buildings.

The need for further work to identify suitable indicators of resource efficiency for the construction sector has been identified in Chapter 2 and in literature<sup>49</sup>. The Commission and Member States' work on indicators, together with issues highlighted in literature, therefore also inform the analysis in this section, with a focus on the following areas:

- Abiotic and biotic materials flows, as well as related stocks and recycling loops;
- The relationship between material input and the functional unit of service;
- The design and service life of buildings, both as a whole and also with a focus on structures;

The findings from the analysis in this chapter will be compared and contrasted with those from the review of EU policy (Chapter 2) and existing assessment and reporting tools (Chapter 4) to then be brought together in Chapter 5.

#### 3.1 Top down sectoral analysis of building stock LCA impacts

##### 3.1.1 Construction sector life cycle impacts

###### 3.1.1.1 EREP EU construction resource efficiency scenarios

The most significant top down study of construction environmental impacts was carried out in support of the work of the European Resource Efficiency Platform (EREP). The study assessed ‘scenarios and options towards a resource efficient Europe’ in support of the EU Roadmap to a Resource Efficient Europe<sup>50</sup>. The study drew upon three analyses: economy-wide Material Flow Accounting (MFA) and environmentally extended input-output analysis (EI-IO) of the residential construction sector<sup>51</sup> and an LCA case study of the UK construction sector<sup>52</sup>.

The MFA and EI-IO analysis showed that 50% of bulk materials such as sand, gravel, clay and stone are used by the sector and between 10-20% of wood and bulk metals, with iron and copper being the most significant. The bulk materials are predominantly sourced from within each Member State, whereas metals are generally imported. Cradle to grave emissions for the sector are in line with the overall GDP contribution, at between 7-15%, although this rises to 35% when use phase energy is included. The main contributors to life cycle

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<sup>49</sup> Heite, M, *Material consumption in the construction sector: resource efficiency from an interorganisational perspective*, Center for Environmental Systems Research (CESR), University of Kassel, p-366 from papers submitted to the First International Conference on Resource Efficiency in Inter-organisational Networks, 13th – 14th November, 2013,

<sup>50</sup> European Commission, *Assessment of scenarios and options towards a resource efficient Europe – An analysis for the European built environment*, final report, March 2014

<sup>51</sup> European Commission, *Topical papers 1: Resource efficiency in the built environment – a broad brushed, top-down assessment of priorities*, Authored by CML and AAU-SEC, February 2013 and European Commission, *Topical papers 9: Indicators for resource efficiency – potential ways of representing results*, Authored by TNO, February 2014

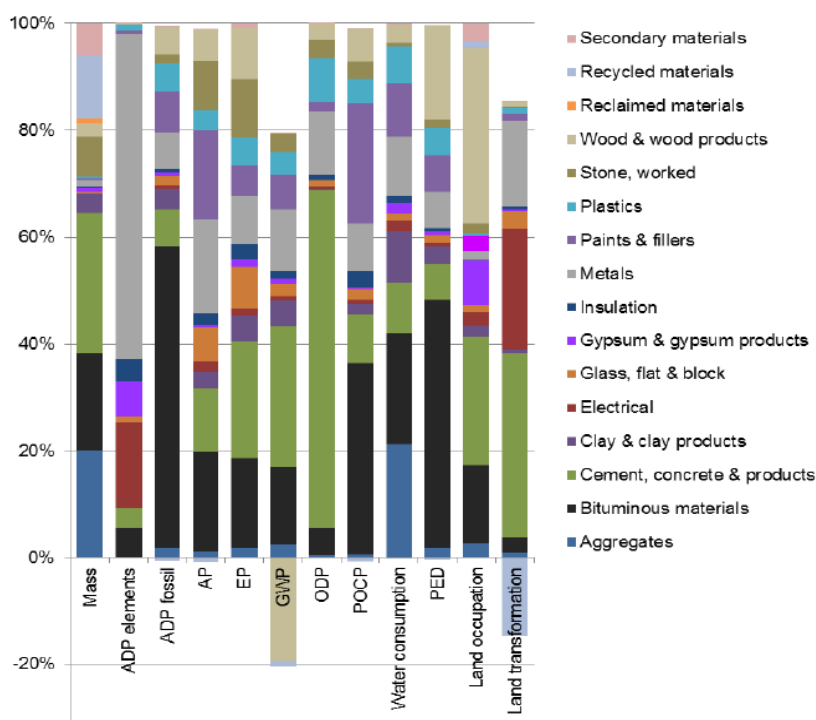
<sup>52</sup> European Commission, *Topical papers 2: Strategies for decoupling – options to consider in the field of buildings and infrastructure*, Authored by PE International, February 2014

environmental impacts, excluding the use phase, are energy related emissions for cement, clay and metal production, as well as construction itself on site.

This part of the study highlighted the importance of addressing the ‘stocks-in-use’, ‘waste generation’ and ‘recycling rates’. This is because of the large flows and relatively long lifespans of buildings. Due to the specifics of each resource, it is suggested to address stocks individually or for each broad type of material, with use normalised according to a unit of consumption<sup>53</sup>.

A case study LCA analysis was carried out of the consumption of the UK construction sector in one year, combining data for the building and road construction sectors<sup>54</sup>. The impact categories used reflect those specified in EN 15978, with primary energy and water also selected as resource use parameters. The impact categories land occupation and land transformation were additionally used because of their significance for timber products. An impact category to represent toxic emissions was considered for inclusion, but was not included as this areas was considered to be well regulated in the EU by the Industrial Emissions Directive Simplified assumptions relating to the overall building stock were used to model the material production, construction, use and end of life phases.

The results indicate that abiotic resource depletion is dominated by the production stage of materials, whilst the use stage of buildings dominates emission related indicators. In the production phase, significant environmental impacts are related to non-metallic minerals, with cement production and materials made from fossil fuels specifically highlighted, as illustrated by Figure 3.1. Metals such as copper are also very significant contributors to the sectors environmental impact. Impacts relating to the use of wood were captured by the inclusion of land use indicators, although it was noted that methodological problems may have meant that these were overstated. It is important to note that the construction of road infrastructure has an influence on the results, as can be seen from the significant contribution of bituminous materials to the majority of the impact categories.



**Figure 3.1. LCA results for the UK construction sector**

Source: European Commission (2014)

The study concluded that policy measures with a focus on large flows of materials will have the greatest impact. The areas of attention with the greatest potential to reduce environmental impacts were as follows:

<sup>53</sup> Ekins, P and J.H. Spangenberg, *Resource efficiency indicators and targets in relation to the resource efficiency roadmap*, EREP working paper – Expert group of economists on resource efficiency, January 2013

<sup>54</sup> *ibid* 50 and 52

- The production of products that are more resource efficient, based on evidence from EPDs for their embodied energy, abiotic resource depletion and water use. Examples cited include a shift from concrete/masonry to timber materials, hollow pre-cast concrete, concrete formwork with void formers and hollow blockwork;
- A reduction in the size of new housing and offices (i.e. a more efficient use of space per occupant). This is linked to an increased density of the built environment;
- A reduction in the amount of waste from construction, including upstream waste arising from extraction and processing;
- The recycling of large flows of construction and demolition waste, with a focus on closed loop recycling instead of down cycling from the building to the road construction sector;

In addition, further scenarios for long-term improvements in resource efficiency were modelled, with the following identified as priorities:

- Design for repair, disassembly and recycling (deconstruction). This is described as design to re-use modules or whole elements of constructions;
- Ensuring a high adaptability, flexibility and functionality of design in order to extend the service life of buildings.

Despite evidence for the significant potential reductions in use phase energy demand, renovation did not appear in the final list of significant measures. This is because the renovation scenario modelled resulted in increased abiotic resource depletion and high upfront capital costs. However, the potential saving in new construction and optimised energy savings from economies of scale achieved by large renovation programmes of the kind implement in Germany were not modelled.

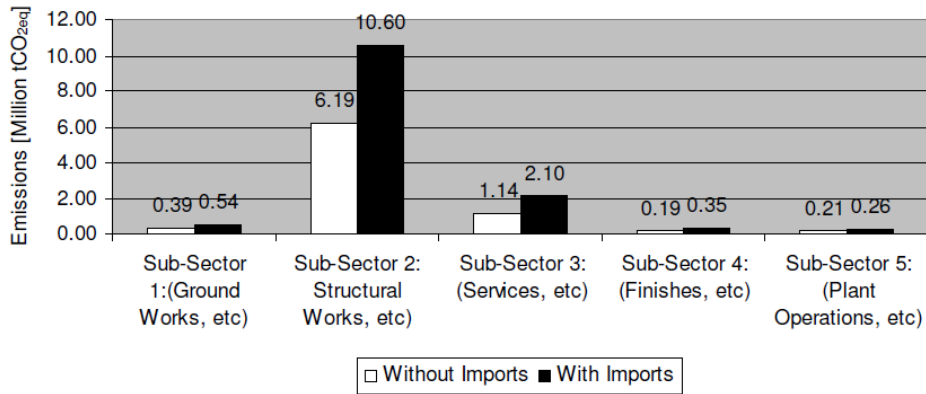
### **3.1.1.2 Environmentally extended input-output analysis for Ireland**

An environmentally extended input-output analysis was carried out on the contribution of the Irish construction sector to the countries greenhouse gas (GHG) emissions<sup>55</sup>. The analysis was based on data for 2005 for those activities classified as NACE 'civil and structural construction works'. The results showed that the sectors domestic emissions contributed towards 8.26% of national emissions, excluding use phase emissions from the energy use of buildings. Of this contribution the emissions were split between 17% direct on site emissions from construction works, 41% from upstream indirect domestic emissions and 42% from upstream indirect emissions outside of Ireland (i.e. emissions associated with imports).

The relative contribution of emissions from different construction activities, both with and without imported emissions, is illustrated by Figure 3.2 which separates out groundworks, structural works, services, fit-out/finishing and plant/operations. Indirect emissions associated with the supply chain were estimated to have made the most significant contribution. The study highlights that only the cement industry is regulated under the EU Emissions Trading Scheme (ETS). It concludes that the provision of product specific information about the embodied greenhouse gas emissions of construction materials would enable choices to be made to reduce the indirect greenhouse gas emissions intensity.

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<sup>55</sup> Acquaye, A and A.Duffy (2010) *Input-output analysis of Irish construction sector greenhouse gas emissions*, Building and Environment, Volume 45, Issue 3, Pages 784-791



**Figure 3.2. Total emissions of the Irish construction sector (2005)**

Source: Acquaye and Duffy (2010)

### 3.1.1.3 Environmentally extended input-output analysis for Sweden

An environmentally extended input-output analysis was carried out on the environmental impacts of the Swedish buildings and related construction and property management activities<sup>56</sup>. The analysis was based on data from 2005. The resource use and environmental effects analysed were broader than the Irish IO study referred to in 3.1.1.2, with energy use and CO<sub>2</sub> emissions supplemented by other Green House Gases and emissions to air (CH<sub>4</sub>, NO<sub>x</sub>, SO<sub>2</sub>, CO, NMVOC), emissions to water (COD, BOD, nutrients and metals), solid waste and hazardous waste.

The results showed that the building construction and property management were responsible for between 10% and 40% of the overall normalised environmental impacts of the Swedish economy, depending on the midpoint. The proportional contributions (excluding use phase heating) to waste (27-40%), CO<sub>2</sub> equivalents (16%) and the use of hazardous chemical products (16%) were the most significant. The latter is mainly attributed to the production of non-metallic mineral products. The most important upstream processes contributing to Green House Gas emissions related to the production of non-metallic mineral products, such as bricks and cement, followed by the production of metals and construction and supply chain related transport.

It is important to note that Sweden has a high proportion of renewable electricity and heat generation. This means that domestic emissions relating to energy generation reported in the study will be lower than for comparable building sectors in many other Member States.

### 3.1.2 The importance of the functional unit in capturing the intensity of resource use

The proposed thematic focus of EU resource efficiency indicators on 'improving buildings' has highlighted the importance of considering the functional unit of resource use. Expert commentary submitted to the EREP emphasised the need to ensure that progress is related to how the resource is consumed, so as to ensure that meaningful comparisons can be made. This commentary is summarised in Box 3. The intensity of use of a building resource may be temporal (e.g. proportion of time the space is used during the day or week) or spatial (e.g. per household, person or workstation). The choice of functional unit is also highlighted in relation to building structures, with design and engineering parameters cited as being as significant in determining overall resource efficiency per unit of load capacity per unit dimension<sup>57</sup>.

Whilst the functional unit is particularly relevant to the development of indicators, it is nevertheless also important when considering macro-objectives e.g. a simple comparison of building efficiency by floor area may mask significant variations in performance relating to density, form and space utilisation. Guidance on the normalisation of reported energy use and CO<sub>2</sub> emissions for offices suggests an increased focus on building efficiency and occupational density in the market<sup>58</sup>. To take an example cited during the development of EU

<sup>56</sup> Toller, S., Wadeskog, A., Finnveden, G., Malmqvist, T. and A. Carlsson, *Energy use and the environmental impacts of the Swedish building and real estate management sector*, Journal of Industrial Ecology, p.394-404 Vol.15 No.3 2011

<sup>57</sup> Purnell, T., *Material nature versus structural nurture: the embodied carbon of fundamental structural elements*, Environmental Science & Technology, 2012:46(p-454-461)

<sup>58</sup> Better Building Partnership (2010) *Sustainability Benchmarking Toolkit for Commercial Buildings - Principles for best practice*

Green Public Procurement criteria for office buildings, a refurbishment project was able to achieve a 70% increase in occupancy, together with an associated reduction in CO<sub>2</sub> emissions per desk space, whilst increasing satisfaction in the working conditions<sup>59</sup>.

### **Box 3.1 Choice of functional unit when measuring the resource efficiency of buildings**

DG Environment's expert group of economists on resource efficiency made specific comments on the Commission's proposals for 'improved buildings' sectoral resource efficiency indicators. Ekins and Spangenberg in their January 2013 paper<sup>60</sup> highlight that, taking the example of residential heating energy, resource use should be normalised per person, household and residential unit – i.e. floor space per person and household unit. This would ensure that the resource use is understood in terms of economics and social trends. If heating energy, or indeed material use, were to be measured solely in terms of usage per m<sup>2</sup> this would mask socio-economic trends relating to demand for the resource.

Source: Ekins and Spangenberg (2013)

### **3.1.3 'Induced' life cycle impacts of building spatial form and location**

A recurring theme in urban design and planning literature is the relationship between urban density, building form and transport energy use. Here a number of these relationships are briefly reviewed.

#### **3.1.3.1 Urban density and form**

Stemers (2003) outlined the potential to optimise the energy efficiency of the built form by increasing residential densities up to 200 dwellings per hectare (0.01 km<sup>2</sup>) whilst minimising building plan depths<sup>61</sup>. Strømten-Andersen and Sattrup (2011)<sup>62</sup> and Trigaux et al (2014)<sup>63</sup> examined the influence of the urban street layouts on energy use. Both used modelling to identify that, in contradiction to Stemers (2003), at increased densities passive solar gain and daylight can be adversely affected. Strømten-Andersen and Sattrup (2011) indicated impacts in the range of +19-30%, depending on the building use.

For office buildings Stemers (2003) considered that the layout and form was more important than density, with narrow plan depths to maximise daylighting and facilitate natural ventilation identified as being fundamental. Floor to ceiling heights were also cited as a factor influencing passive thermal control<sup>64</sup>. This relationship was also identified in LCA studies by, amongst others, Nemry et al (2008)<sup>65</sup> and Cuéllar-Franca and Azapagic (2012)<sup>66</sup> who identified that multi-family (semi-detached and terraced) and high rise buildings can be more energy and material efficient than single family dwellings.

#### **3.1.3.2 Urban infrastructure and material consumption**

Schiller (2007)<sup>67</sup> further highlights the relationship between material consumption and building density, extending the analysis to identify the material flows associated with urban infrastructure required to service buildings, including roads and utilities. This aspect can be linked to the promotion of heating and cooling

<sup>59</sup> WRAP (2012) *Refurbishment Resource Efficiency Case Study: Elizabeth II Court*, Winchester

<sup>60</sup> Ekins, P and J.H. Spangenberg, *Resource efficiency indicators and targets in relation to the resource efficiency roadmap*, January 2013

<sup>61</sup> Stemers, K, *Energy and the city, density, buildings and transport*, *Energy and Buildings* 35 (2003) 3–14

<sup>62</sup> Strømten-Andersen, J and P.A. Sattrup, *The urban canyon and building energy use: urban density versus daylight and passive solar gains*, *Energy and buildings*, 43(2011) p.2011-2020

<sup>63</sup> Trigaux, D, Allacker, K and F. de Troyer, *A simplified Approach to integrate Energy Calculations in the Life Cycle Assessment of Neighbourhoods*, Submission to the 30th International PLEA Conference, 16-18 December 2014, CEPT University, Ahmedabad

<sup>64</sup> Kimpian, J and S. Watts. *A blueprint for the future office*, Council on Tall Buildings and Urban Habitat (CTBUH) Conference, 2012

<sup>65</sup> Nemry et al (2008) *Environmental improvement potentials of residential buildings (IMPRO-Buildings)*, Joint Research Centre IPTS, European Commission.

<sup>66</sup> Cuéllar-Franca, R.M and A. Azapagic, *Environmental impacts of the UK residential sector: Life cycle assessment of houses*, *Building and Environment* 54 (2012) p.86-99

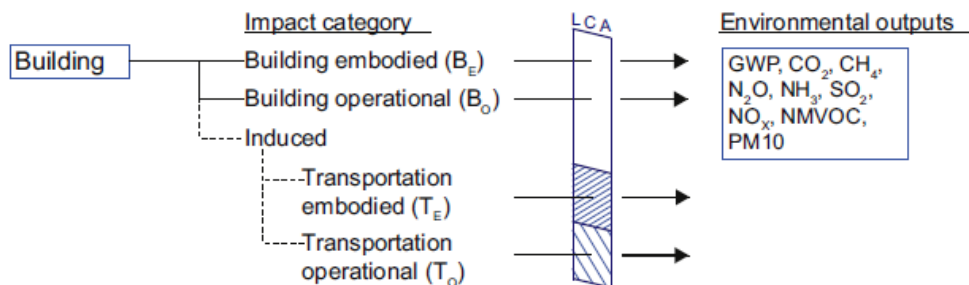
<sup>67</sup> Schiller, G (2007) *Urban infrastructure: challenges for resource efficiency of in the building stock*, *Building Research & Information*, 35(4), p.399-411

networks in the recast Energy Performance of Buildings Directive (see Section 2.1.2), with both new and existing buildings having the potential to benefit from existing high efficiency and low carbon energy infrastructure.

### 3.1.3.3 Location and connectivity

A range of studies reviewed from the EU and US demonstrate a strong correlation between location and accessibility, with evidence for reduced car use where buildings are well connected in relation to extensive, multi-node public transport networks.

Anderson et al (2015) described additional energy use associated with transport as an ‘induced’ effect of buildings, arguing for the environmental impacts resulting from the interaction between individual buildings and their urban context to be captured<sup>68</sup>. The methodology proposed to capture these impacts is illustrated in Figure 3.3. This methodology was further applied by Anderson et al (2015b) to a case study of the urban region of the German city Munich, using a streamlined life-cycle assessment based on Global Warming Potential (kg CO<sub>2</sub> equivalents)<sup>69</sup>. Steemers (2008) estimated there to be a ratio of 2:1 between building energy use in the use phase and urban transport energy use, citing estimates from London (UK) as well as international comparisons for major cities.



**Figure 3.3. Proposed methodology to capture ‘induced’ built environment impacts**

Source: Anderson et al (2015)

A strong relationship between population and employment density of urban areas and variations in transport energy use is identified in literature. For example, North American studies suggest that transport energy use can vary by 17-19% between high and low density locations, depending on location and public transport accessibility. This finding is supported by carbon footprint analyses for office buildings in the UK<sup>70</sup>. Some analysis in the US and Canada goes further, suggesting that transport related energy use has the potential, for some modern low energy buildings, to be greater than building energy consumption in the use phase<sup>71</sup>.

## 3.2 Bottom up LCA analysis of selected building typologies

### 3.2.1 Residential building typologies

Residential buildings are the most significant building typology in terms of resource use across the EU. A number of LCA studies have therefore been reviewed in order to identify macro-scale environmental impacts that may be predicted for generic new build housing and construction typologies and forms. Studies have primarily been selected on the basis that they take a sectoral perspective. They do this either by:

<sup>68</sup> Anderson.J.E, Wulfhorst.G and W.Lang, *Energy analysis of the built environment — A review and outlook*, Renewable and Sustainable Energy Reviews, 44(2015)149–158

<sup>69</sup> Anderson.J.E, Wulfhorst.G and W.Lang, *Expanding the use of life-cycle assessment to capture induced impacts in the built environment*, Building and Environment, 94(2015)403-416

<sup>70</sup> British Council for Offices, *Whole life carbon footprint measurement and offices*, March 2012, UK

<sup>71</sup> Victoria Transport Institute, *Recommendations for improving LEED transportation and parking credits*, January 2015, [http://www.vtpi.org/leed\\_rec.pdf](http://www.vtpi.org/leed_rec.pdf) and Wilson.A and R.Navaro, *Driving to Green Buildings: The Transportation Energy Intensity of Buildings*, Building Green, September 2007, <https://www2.buildinggreen.com/article/driving-green-buildings-transportation-energy-intensity-buildings>

- Modelling and comparing the performance of common EU residential building typologies and forms, or;
- Cross checking the performance of building typologies and forms that are typical in one Member State with those from other EU Member States with different climatic conditions and construction cultures.

With over 40% of the EU residential building stock pre-dating 1960 and with a replacement rate of 1-2%, the role of renovation is also considered important to analyse.

### **3.2.1.1 The environmental improvement potential for EU residential building typologies**

The Environmental Improvement Potentials of Residential Buildings (IMPRO Buildings) was carried out by JRC-IPTS<sup>72</sup>. A life cycle assessment was carried out encompassing 72 residential building typologies, 53 of which were existing stock and 19 new construction forms. The building form and typologies were selected and described in order to be representative of the forms of housing that typify the EU stock (single family houses, multi family houses, high rise apartments) and the variations in climate conditions (split into three zones – north, middle and south).

The system boundary, life cycle stages and impact categories selected reflected those specified in EN 15978, with the exception of the impact category for abiotic depletion, which was omitted. The resource parameter primary energy (renewable and non-renewable sources) was additionally modelled. A functional unit of 1m<sup>2</sup> of living space over one year was defined and analysed for each residential building typology. The service life of each individual building typology as a whole, ranging between 20 and 40 years, and the main building elements, ranging between 10 and 80 years, were taken into account in the modelling.

The key findings of the study were as follows:

- The use phase of buildings is the most important because of primary energy use for, in particular, space heating, hot water and lighting;
- For new buildings the construction phase becomes proportionally more important, with load bearing walls, basements and floors/ceilings the most significant modelled impacts;
- The effect of building form and geometry is reflected in a general trend for higher energy demand for larger, single family houses;

A ‘refurbishment factor’ was applied to take into account building elements that were forecast to require replacing during the building typology’s service life, but the relative contribution of the impacts associated with these building elements to the use phase was not clearly identified or captured by the impact categories used.

The most significant options for improvement identified were further design improvements to reduce the energy use of new buildings, the substitution of concrete and bricks by wood in new construction, and renovation measures to improve roofs, façades and air tightness. Moreover, the resource efficiency potential of more compact dwelling forms was also highlighted. The improvement potential of selecting wood as a construction material was highlighted but caveated because of the need for further investigation in order to fully take into account whether timber is taken from sustainable managed forestry. This identified methodological weaknesses which are discussed further in Section 3.3.3.

### **3.2.1.2 Selected LCA literature addressing residential building typologies**

Similarly to the IMPRO Buildings study described above, a study by Cuéllar-Franca and Azapagic (2012) was selected for review because it analysed common residential building forms with a view to extrapolate the findings across the building stock<sup>73</sup>. The study differed from IMPRO Buildings in that its starting point was the most common house forms in the UK – namely detached (130m<sup>2</sup>), semi-detached (90m<sup>2</sup>) and terraced (60m<sup>2</sup>) house forms. The functional unit was defined as occupation by 2.3 people of a whole house over a service life span of 50 years. The system boundary, life cycle stages and impact categories selected reflected those specified in EN 15978, with the addition of human, terrestrial, freshwater and marine aquatic toxicity

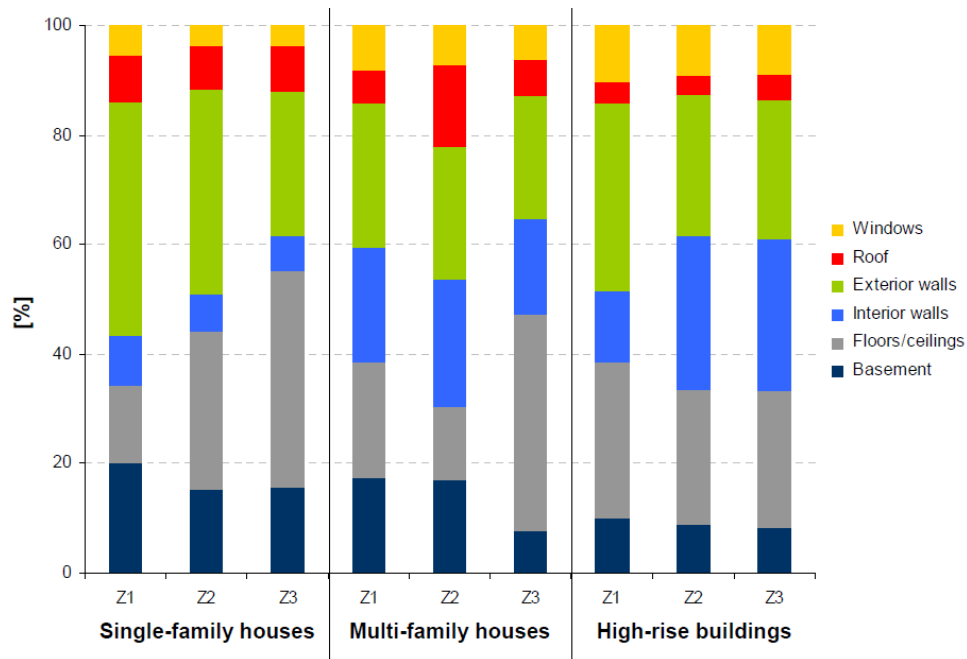
<sup>72</sup> *ibid* 65

<sup>73</sup> Cuéllar-Franca.R.M and A.Azapagic, *Environmental impacts of the UK residential sector: Life cycle assessment of houses*, Building and Environment 54 (2012) p.86-99*ibid*



potential. Importantly, the results of the study were also compared and contrasted with the results of similar analyses of house forms in France, Spain and the UK.

The results mirror those of IMPRO (2008), as well as a study of Italian residential building forms by Asdruballi et al (2013)<sup>74</sup> which similarly used a functional unit of 1m<sup>2</sup> per year, the environmental impact categories specified in EN 15978 and a service life span of 50 years. These studies indicate that energy use and associated impacts in the use phase are of the greatest significance followed by the production phase, which is modelled to account for 9-15% of the overall environmental impacts. The embodied energy associated with the main building elements is summarised for the house typologies analysed in Figure 3.4. A comparison of results is not possible for toxicity potential as this is not specified in all cases.



**Figure 3.4 Contribution of individual construction elements to the embodied energy of new residential properties according to climate zone and building typology**

Source: JRC-IPTS (2008)

Only for higher density and taller building forms do embodied impacts already appear to take on a greater significance, with the life cycle significance potentially rising to over 45%, and this may be understated if we assume further improvements in energy efficiency (Thomark 2002). However, it is important to note that the overall balance between energy consumption in the use phase (regulated by building permits) and embodied energy in construction materials is shifting towards embodied energy. This is because modern residential buildings have lower primary energy demand in the use phase and may have increased embodied energy associated with, amongst other factors, improvements in the thermal efficiency of the building fabric<sup>75</sup>.

In addition to further reductions in CO<sub>2</sub> emissions and therefore global warming potential (GWP), the importance of building more compact dwelling forms which share party walls has been highlighted. This finding is also supported by Norman et al (2006)<sup>76</sup> who analysed building construction, use and associated transport using an economic input-output life cycle assessment model. It is important to note that the improvement potential related to urban density can only be identified if a different functional unit is used, moving from m<sup>2</sup> of dwelling to the dwelling space per occupant or household. This point was also highlighted by Ekins and Spangenberg (2013) in Section 3.1.2 and by Cuéllar-Franca and Azapagic (2012).

<sup>74</sup> Asdruballi.F, Baldassarri.C and V.Fthenakis, *Life cycle analysis in the construction sector: guiding the optimisation of conventional Italian buildings*, Energy and Buildings, 64(2013), p.73-89

<sup>75</sup> Sartori.I and A.G.Hestnes, *Energy use in the life cycle of conventional and low energy buildings: a review article*, Energy Build, 2007, 39(3), p.249-257

<sup>76</sup> Norman.J, MacLean.H, and C.Kennedy, *Comparing High and Low Residential Density: Life-Cycle Analysis of Energy Use and Greenhouse Gas Emissions*, Journal of Urban Planning and Development, March 2006, Vol. 132, No. 1 : pp. 10-21

An important methodological note is that the studies reviewed did not clearly identify the relative contribution to impact categories of materials used in subsequent maintenance and refurbishment during the service life of a property. In particular, components such as paint, ceramic flooring and tiles, window frames and copper pipe and wiring have the potential to contribute to toxicity impact categories<sup>77</sup>, although identification of this contribution is dependent on these categories being included. Therefore they would not have been quantified by the IMPRO Buildings study and, moreover, it is worth noting that they are not currently included within the scope of EN 15978 or EN 15804.

So-called 'unregulated' electricity use associated with appliances and other plug loads within a home are difficult to estimate at the design stage. Unregulated in this context means that it is not regulated as part of local building permitting. The growth in household appliance and electrical equipment ownership across the EU has led to an increase in this portion of use phase energy use. EU product policies, such as Eco-design, address this electricity use, but home builders and landlords can also play a role in specifying or offering low energy appliances and fittings.

### 3.2.2 Office building typologies

#### 3.2.2.1 The environmental improvement potential for EU office building typologies

An LCA was carried out, supported by reference to LCA reviews such as Ortiz et al (2008)<sup>78</sup>, in support of development of the EU Green Public Procurement (GPP) criteria for office buildings<sup>79</sup>. The LCA was based on a functional unit of the use of 1m<sup>2</sup> of office space for one year, modelled based on a hypothetical air conditioned office building with an open plan layout and a total area of 4,620 m<sup>2</sup> in three floors. The assumed service life was 50 years. The system boundary, life cycle stages and environmental impact categories selected reflected those specified in EN 15978, together with the resource parameters of primary energy and water consumption. Sensitivity analysis was carried out for scenarios based on the three main EU climate zones, different building ages and for variations in specifications for specific building components.

The LCA and supporting LCA review indicated that for office buildings across the Europe's distinctive climatic zones, energy use during their occupation is responsible for the most significant impacts. Primary energy use during the occupation of a building - also referred to as the use phase - was highlighted as being associated with the most significant environmental impacts. These impacts were mainly attributed to greenhouse gas emissions from the consumption of electricity and natural gas for heating, cooling, ventilation, lighting and hot water.

The Energy Performance of Buildings Directive has led to the adoption of stricter regulations on energy use at Member State level (see Section 2.1.1.6). Office buildings have, as a result, become more energy efficient and the significance of space heating, particularly in northern Europe, has reduced. Space heating requirements are, however, still significant in older office buildings, which may therefore be candidates for major renovation. Intelligent lighting controls have allowed for lighting systems to become more responsive to occupancy and daylighting levels, thereby saving electricity. The thermal efficiency of the building fabric, building orientation and façade configurations, water use, together with a buildings depth and layout, all play a role in influencing heating, cooling, lighting and ventilation requirements in existing buildings<sup>80</sup>.

Cooling-related energy use has become more significant, particularly in warmer climates, because of the increased use of computers and the installation of larger IT servers which generate waste heat. The installation of more intensive HVAC systems is a choice that allows for greater flexibility of floor layouts as well as more cost efficient use of floor plates. This may however be false economy because it does not necessarily optimise the productivity of indoor work environments, as evidenced by building performance evaluations in the UK and other Member States<sup>81</sup>.

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<sup>77</sup> Allacker, K., *Sustainable building - the development of an evaluation method*, Dissertation presented in partial fulfilment of the requirements for the degree of Doctor of Engineering, KU Leuven, Belgium, September 2010

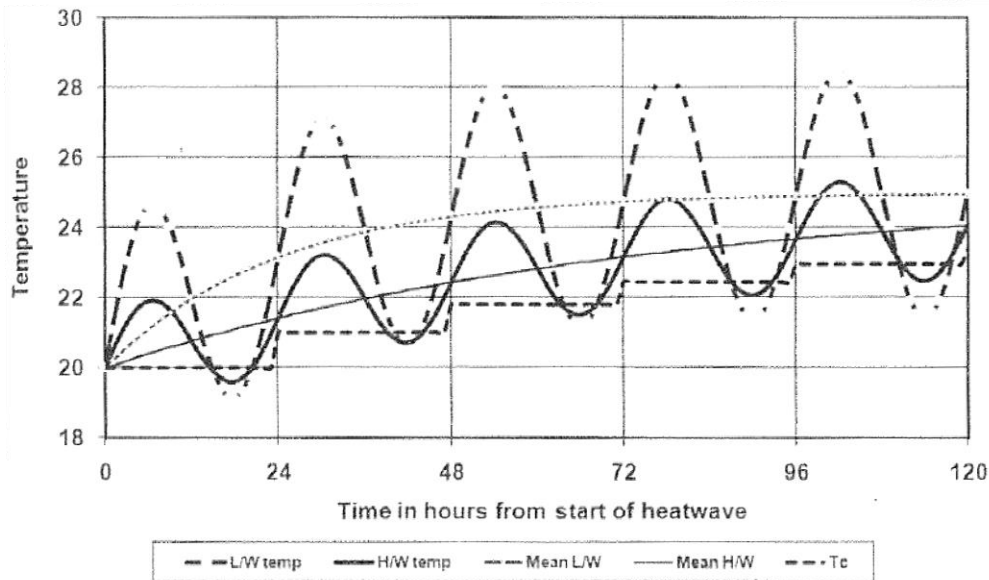
<sup>78</sup> Ortiz, O., Castells, F. and G. Sonnemann, *Sustainability in the construction industry: A review of recent developments based on LCA*, Construction and building materials, 23(2009), p-28-39

<sup>79</sup> European Commission, *GPP Office buildings: Technical Background report*, JRC-IPTS 2011 and 2014 revisions

<sup>80</sup> Baker, N. & K. Steemers (1999) *Energy and environment in design: A technical design guide*, Taylor and Francis.

<sup>81</sup> Innovation UK, *Building performance evaluation*, <https://connect.innovateuk.org/web/building-performance-evaluation>

As office buildings have become overall more energy efficient in terms of their regulated energy use, this has at the same time resulted in an increase in the importance of environmental impacts associated with their construction. The use of more energy intensive insulation materials, the beneficial use of increased thermal mass and façade systems in order to meet higher energy efficiency standards has, for example, tended to increase the overall environmental impact of the construction materials used<sup>82</sup>. These features cannot be seen in isolation as they have an important role to play in passive building design, as illustrated by the moderating effect of thermal mass on the interior temperature (L/W and H/W temp) and the accepted comfort temperature ( $T_c$ ) during a heatwave for a generic building in a temperate (mid European) climate zone, in Figure 3.5. The balance between production and use phase energy is explored further in the next Section 3.2.2.2.



**Figure 3.5 Comparison of indoor thermal variation of light weight (L/W) and heavy weight (H/W) buildings**

Source: Nicol et al (2012)

Just as was the case for residential building typologies reviewed in 3.2.1, the LCA study and review for office buildings did not clearly identify the relative contribution to impact categories of materials used in subsequent maintenance and refurbishment during the service life of a property. In particular, components such as paint, window frames and copper pipe and wiring have the potential to contribute to toxicity impact categories, although identification of this contribution is dependent on these categories being included. Therefore they would not have been quantified by the studies referred to and, moreover, it is worth noting that they are not currently included within the scope of EN 15978 or EN 15804. Related to this, it is notable that RICS recommends the inclusion of finishes to floors, walls and ceilings to be included in analyses of embodied energy or carbon emissions<sup>83</sup>.

### 3.2.2.2 Changes in the balance between production and use phase impacts

The balance between the significance of the production phase and the use phase is dynamic and has been changing as energy requirements for building permits have become stricter<sup>84</sup>. Taken from guidance published by RICS in the UK for calculating embodied carbon emissions<sup>85</sup> Figure 3.7. illustrates the current balance for a number of different building typologies and Figure 3.7 the indicative overall change that has occurred in the UK for office buildings between 2006 and as projected for 2016/19. In the Figure 3.6 the significance of both the production phase ('product') and use phase (including 'maintenance and repairs') are highlighted in all

<sup>82</sup> Rawlinson, S & D, Weight, *Embodied carbon*, Building Magazine, p-88-91, 12th October 2007

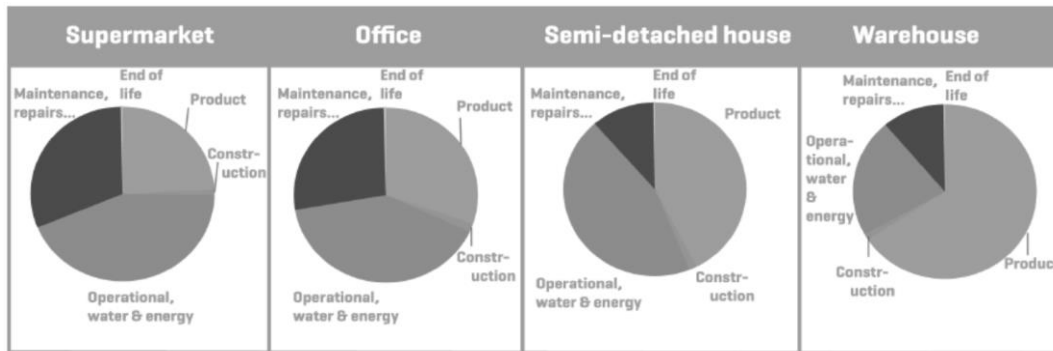
<sup>83</sup> Royal Institute of Chartered Surveyors (2014) *Methodology to calculate embodied carbon*, RICS guidance note

<sup>84</sup> Sartori, I and A.G. Hestnes. *Energy use in the life cycle of conventional and low-energy buildings: a review article*, Energy Build, 2007, 39(3):249-57.

<sup>85</sup> *ibid* 83

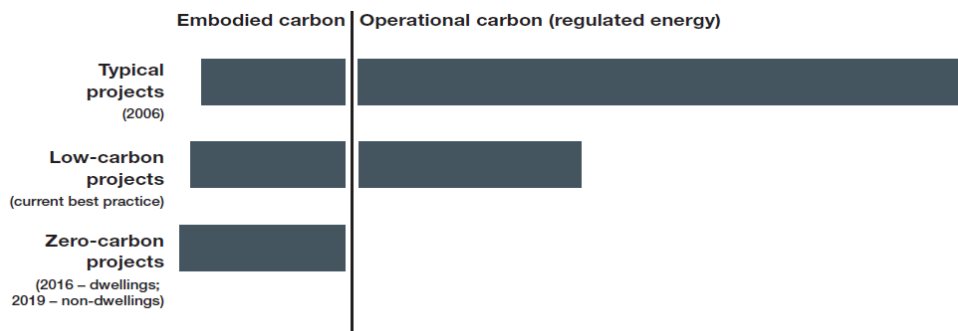
cases. In Figure 3.7 the production phase ('embodied carbon') can be seen to increase marginally as more energy intensive materials are specified whilst the energy use of a building ('operational carbon') decreases to a position of net zero carbon.

It is important at this point to distinguish between 'regulated' and 'unregulated' operational energy use and CO<sub>2</sub> emissions. The increased energy demands of IT equipment highlighted in section 3.2.2.1 are reflected in an increase in 'unregulated' electricity use i.e. plug loads connected to the electricity main within commercial buildings. Whilst some Member States have attempted to include estimates of this electricity use within their definitions of 'nearly zero energy' buildings, they are more difficult to estimate and control at design stage.



**Figure 3.6. Indicative balance of embodied CO<sub>2</sub> by life cycle phase for four building typologies**

Source: RICS (2014)



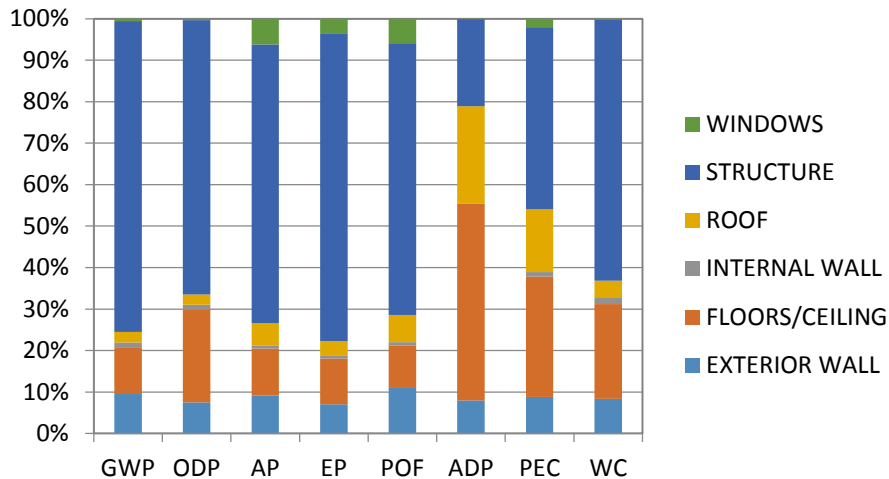
**Figure 3.7. The ratio of embodied to use phase CO<sub>2</sub> emissions in relation to building standards (2006-2019)**

Source: RICS (2014)

The production of construction materials and products used in the construction and use phases is responsible for the next most significant environmental impacts. These relate to the resources used to manufacture products, as well as emissions arising from material extraction and energy used in their processing, generally termed embodied energy. Resource use is also related to the amount of waste generated during product manufacturing, construction on-site and demolition processes, which can make up a significant proportion of the overall material flows on a construction site.

Taken together, these factors highlight the importance of designing and specifying for overall resource efficiency, with evidence from JRC-IPTS and other LCA studies<sup>86</sup> suggesting that the most significant building elements to address are, in the example of a mid-rise office building, the floors, roof, structure (including foundations) and external walls. The contributions of the different building elements to the modelled environmental impact of 1m<sup>2</sup> of office building located in London are reported in Figure 3.8.

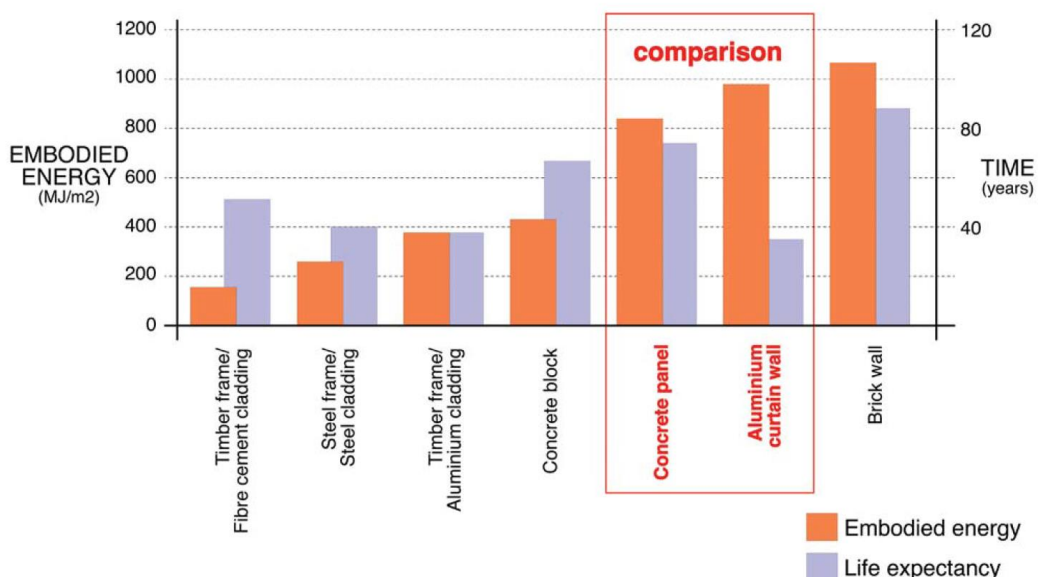
<sup>86</sup> ibid 79



**Figure 3.8. Contribution of building elements to the production stage environmental impacts of 1m<sup>2</sup> of a hypothetical office building located in London**  
 Source: JRC-IPTS (2011)

A further important consideration is time. The lifespan of the building, which is also sometimes referred to as its service life, and its components are important factors influencing construction and use phase impacts, as well as the need for replacement buildings. The longer the lifespan of the hot spot structural and enclosing elements of the building, the lower their associated life cycle environmental impacts. This assumes that the overall energy performance is also prioritised as part of the overall optimisation of performance during the building's service life.

The importance of considering the lifespan of components is illustrated by the example in Figure 3.9, which for the two comparison options highlights that although the embodied energy associated with each component is similar, one option has a longer anticipated life expectancy. There are, however, significant potential uncertainties associated with building and, albeit less so, product life spans, which make it difficult to factor this into considerations at the design stage.



**Figure 3.9. Indicative comparison of the embodied energy and life expectancy of curtain walling options**  
 Source: RICS (2010)

### **3.3 Bottom up LCA analysis for common building materials**

In this section a brief review is made of LCA analysis for the most common building materials, namely mineral-based, metallic and wood, and with a focus on load bearing structures, external walls and facades. The review of LCA evidence in sections 3.1 and 3.2 has highlighted the significance of load bearing structures and facade materials as hot spots for the environmental impacts of residential and commercial buildings. An initial review has therefore been made of LCA and other relevant scientific evidence that identify hot spots along their life cycle and the related potential for performance improvements.

The distinct environmental performance and resource efficient aspects associated with each load bearing structure and facade material, together with potential improvement options are identified. As was highlighted in relation to the choice of functional unit for overall resource use, consideration of the fundamental design and engineering parameters for structures has also been shown to be a key factor. This is because it is necessary to allow for a comparison of the overall resource efficiency of material use, for example with reference to per unit of load capacity per unit dimension<sup>87</sup>.

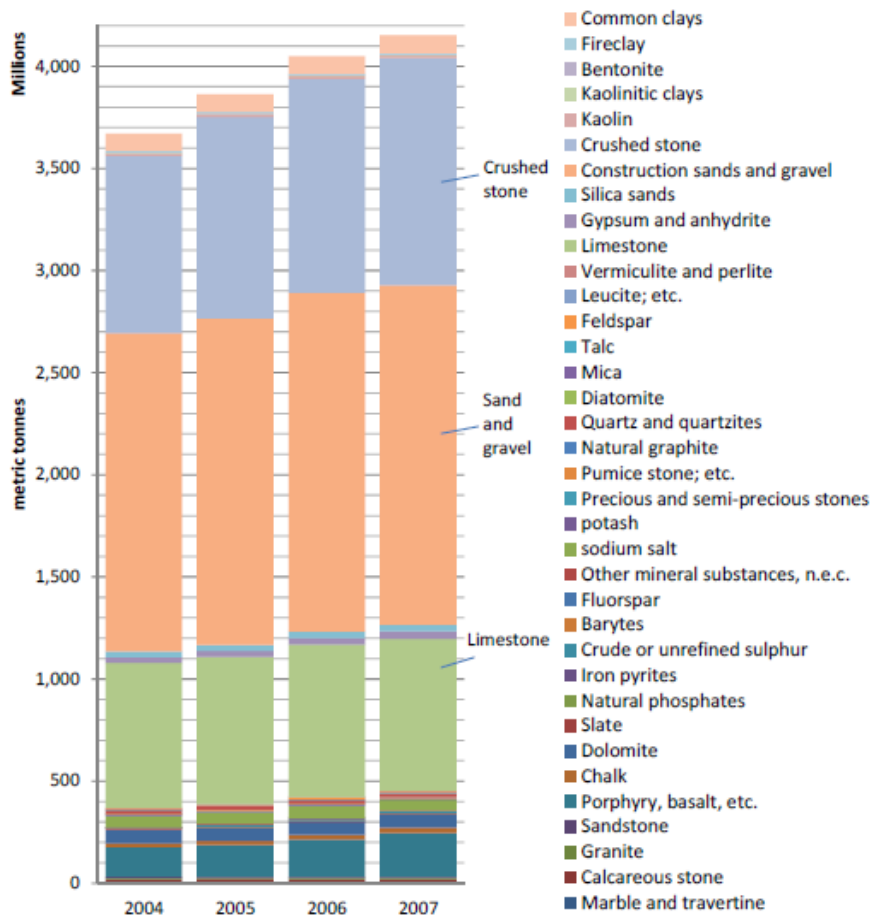
The construction materials used for buildings across the EU varies by Member State and also reflect sub-regional and regional construction cultures and traditions. This is reflected in choices of structural materials (e.g. concrete, steel, wood) as well as associated external cladding and facade materials (e.g. brick, block/render, metal, tile, wood). It is therefore considered important that, at a macro-objective level, the most common forms of raw materials are all possible to be addressed without forcing comparative judgements to be made of their environmental impacts which may not reflect their sub-regional or regional availability or cultural tendencies towards the use of specific construction materials.

#### **3.3.1 The improvement potential for non-metallic minerals**

As was described in Section 2.1.3.3, EU construction material flows are dominated by the use of non-metallic mineral resources, including limestone, clay, gravel and sand, which are used to produce, amongst other materials, concrete, bricks and tiles. Figure 3.10 provides an overall breakdown of non-metallic mineral extraction for the EU-27 (as was). Moreover, top down LCA evidence reviewed in section 3.1 suggested that the most significant environmental impacts are associated with the use of concrete and steel.

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<sup>87</sup> *ibid* 60



**Figure 3.10. Non-metallic mineral resource extraction of the EU-27 (2004-2007)**

Source: European Commission (2013)

Given the significance of concrete to the EU construction sector, relevant literature has been reviewed to identify production hot spots and key areas of focus for improvement. Marinkovic et al (2014) highlights that cement makes the largest contribution to the environmental impacts of concrete, with CO<sub>2</sub> emissions from the calcination of limestone and the burning of fossil fuels accounting for between 75% and 94% across the impact categories used – global warming, eutrophication, acidification and photochemical ozone creation - whereas aggregate production accounts for 0.8% and 5.4% across the impact categories.

Transport distances are also a significant consideration for concrete, with the contribution across the impact categories ranging indicatively from 3% to 20% depending on the mode and distances. The potential for CO<sub>2</sub> sequestration (removal) by the natural process of carbonation is also highlighted by Marinkovic et al (2014), with removal estimated to increase to up to 40% of manufacturing emissions if concrete from demolition sites is crushed for recycling as aggregate.

Much attention appears to have focussed on the use of recycled concrete aggregates (RCA) derived from construction and demolition waste, with associated resulting reductions in mineral extraction volumes and waste arisings. However, the potential for reduction in the Global Warming Potential of concrete is relatively small when compared to the improvement potential associated with addressing the production of portland cement, the concrete mix design and the design specification of structures<sup>88</sup>. It is also important to note that the benefit of a reduction in large volume construction material flows are not fully captured by the abiotic depletion impact category used in EN 15978, primarily because these flows are subject to local and regional constraints that are not picked up in the indicators calculation of resource criticality<sup>89</sup>.

<sup>88</sup> Marinkovic.S.B, Malesev.M and IIgnjatovic, *Life Cycle Assessment (LCA) of concrete made using recycled concrete or natural aggregates* published in *Eco-efficient construction and building materials* (2014), Woodhead Publishing Limited, p.239-266

<sup>89</sup> Work is ongoing at the University of Dundee in the UK to develop a new 'sustainable use of natural resources' indicator. This would take into account both abiotic and biotic resources, as well as the energy used to extract, transport and manufacture the related product.

At a fundamental level, significant reductions in the global warming potential of emissions from concrete can be achieved by the replacement of cement clinker or Portland cement. Habert (2014) summarises the state of the art in terms of addressing the impacts of producing the most common form of cement used – Portland cement based on limestone – as well as lower impact substitutes for clinker and cementitious binders, which can include industrial by-products (e.g. power station fly ash, blast furnace slag, copper slag) and alternative raw minerals (e.g. magnesium hydrates)<sup>90</sup>.

Structures research by Arup for the Institution of Structural Engineers<sup>91</sup> (2014) and international building performance benchmarking projects such as the Concrete Usage Index<sup>92</sup> (2012) have highlighted the potential to reduce CO<sub>2</sub> emissions by up to 50% through the optimised use of concrete. Options which have been implemented include better mix designs (e.g. the use of superplasticisers), light weighting (e.g. hollow pre-cast slabs or voids in formwork) and high strength concrete. Attention is being focussed on the improvement potential of concrete at a global level by the World Business Council on Sustainable Development's (WBCSD) Cement Sustainability Initiative and at an EU level by the Concrete Initiative.

### 3.3.2 The improvement potential for metals

Alongside concrete, steel is a predominant structural material and is associated with significant environmental impacts across the construction sector. Research by the University of Cambridge on resource flows associated with steel production has sought to identify both the most significant production-related environmental hot spots and macro-scale improvement opportunities<sup>93</sup>.

Reducing demand for new materials production has been identified as the most significant improvement opportunity, with light weight design, longer life spans for structural components and more intensive use of the space created by structures emerging from analysis as the most effective options. Attention to fundamental structural design parameters has also been highlighted for other major structural materials as being as important in minimising embodied energy<sup>94</sup>.

The re-use of steel and aluminium was identified as a further significant potential improvement opportunity, although the environmental benefits may be reduced because the diverted waste metal would need to be replaced by more primary production<sup>95</sup>. This is because the sector is 'scrap constrained' as a high proportion of recycled material is already used, meaning any reduction in supply could create demand for primary production.

### 3.3.3 The improvement potential for wood

Wood construction materials are renewable raw materials. As such their continued availability is dependent on the management of forests as biological systems and habitats. This factor is the subject of ongoing debate in the LCA community as the potential environmental effects of forestry are currently not claimed to be sufficiently well accounted for within the commonly used LCA methods and impact categories. This issue was recognised during preparation of the background study to the Commission's European Resource Efficiency Platform (EREP). Factors that are the focus for continued discussion and debate include land use, soil depletion, CO<sub>2</sub> sequestration, biogenic VOC emissions, ecosystem services and ecosystem damage<sup>96 97</sup>.

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<sup>90</sup> Habert.G, *Assessing the environmental impact of conventional and 'green' cement production in Eco-efficient construction and building materials* (2014) Woodhead publishing, p.199

<sup>91</sup> The Institution of Structural Engineers, *The value of structural engineering to sustainable construction*, Final report prepared by Arup, 6<sup>th</sup> March 2012.

<sup>92</sup> Centre for Sustainable Buildings and Construction and the Building and Construction Authority (2012) *Concrete usage index*, Singapore

<sup>93</sup> University of Cambridge, *WellMet2050*, <http://www.lcmp.eng.cam.ac.uk/wellmet2/introduction> and Allwood.J.M (2013) *Transitions to material efficiency in the UK and steel economy*, Philosophical transactions of the Royal Society, UK

<sup>94</sup> *ibid* 91

<sup>95</sup> Milford.R, *Re-use without melting: emissions savings from case studies*, University of Cambridge, September 2010

<sup>96</sup> Allacker.K, Maia de Souza.D and S,Serenella, *Land use impact assessment in the construction sector: an analysis of LCIA models and case study application*, International Journal of Life Cycle Assessment (2014) 19:1799–1809

<sup>97</sup> Päävinen.R, Lindner.M, Rosén.K and M.J.Lexer, *A concept for assessing sustainability impacts of forestry-wood chains*, European Journal of Forest Resources (2012), 131:7-19



The importance of ensuring that the wood and wood-based materials used in the construction and renovation of buildings are sourced from legal and sustainable sources is a policy objective at EU level. Moreover, there is significant experience in Member States and within the wood and construction industries in sourcing according to the sustainable forestry criteria of established private certification schemes such as the Forestry Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC). These certification schemes are based on the UNEP and FAO principles of Sustainable Forestry Management (SFM) established at the Rio Earth Summit in 1992<sup>98</sup>. These principles, although not defined in detail in UNEP or FAO literature, provide an internationally agreed reference point.

The use of timber as a structural frame for houses is largely based on high quality timber from forestry in alpine regions of the EU, although lower grade and waste material is used for products such as Orientated Strand Board (OSB) cladding. In order to construct taller buildings and structures with wider bay widths, for uses such as apartments, schools and offices, glued laminate, compressed fibre or hybrid wood products are required in order to achieve the necessary structural design parameters. These engineered timber products may, in some cases, be energy intensive to manufacture, although there may be savings on material use in foundations. A life cycle approach and consideration of structural design parameters is therefore required to make performance comparisons for these types of timber products.

### 3.3.4 The improvement potential from circular flows

Waste from the sector is generated at three key points in the life cycle of buildings – during the production stage, the construction stage and at the end of life. Waste can be reduced by minimisation strategies applied during the first two stages and by cycling materials, either by re-use or recycling for use as input materials. The European Resource Efficiency Platform (EREP) top down study cited in Section 3.1 highlighted the life cycle importance of:

- Recycling concrete instead of landfilling,
- The use of recycled construction and demolition waste, and
- A reduction in the amount of waste from construction.

Contractors and designers can make major improvements in materials efficiency, by minimising waste generation during production, construction and demolition, by maximising the recycling rate, reusing materials and selecting construction products with a higher recycled content and lower embodied impacts.

According to Osmani et al (2008), on average 33 % of waste generation from a construction site is the responsibility of a failure to implement waste prevention measures during both the design and preliminary construction phases<sup>99</sup>. Reporting on findings from a survey of projects in the Netherlands, Bossink and Brouwers (1996) found that on average 9% by weight of purchased construction materials leaves a site as waste<sup>100</sup>. Significant contributors by weight included stone cladding (29%), piles (17%), concrete (13%), mortar (8%), packaging (7%) and bricks (3%). Additional causal factors highlighted included ordering errors during procurement, damage during materials handling and on-site operational practices. A review of twenty-three published studies by Mália et al (2013) concluded that concrete and brick generally accounted for approximately 70% of the overall waste volume generated.

Analysis of the environmental improvement potential associated with the selective demolition and recovery of waste construction materials has highlighted the sectoral importance of replacing virgin raw materials with recycled and/or re-used materials or building elements<sup>101</sup>. Current practices such as 'soft strip outs' to recover fit-out materials, together with the down cycling of high volumes of recovered aggregates, ceramics and brick into fill material and non-structural construction products (e.g. road bases), have been modelled to only deliver improvements of less than 5% across selected environmental impact categories –in the cited study climate change, acidification, photochemical smog, eutrophication and ecotoxicity .

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<sup>98</sup> Castaneda, F. *Criteria and indicators for sustainable forestry management*. UN FAO, <http://www.fao.org/docrep/x8080e/x8080e06.htm#TopOfPage>

<sup>99</sup> Osmani, M., Glass, J., Price, A.D.F., 2008. *Architects' perspectives on construction waste reduction by design*. Waste Management 28, 1147-1158

<sup>100</sup> Bossink, B.A.G and H.J.H. Brouwers, *Construction waste: Quantification and source evaluation*, Journal of Construction Engineering and Management, March 1996

<sup>101</sup> A.Coelho and J de Brito, *Influence of construction and demolition waste management on the environmental impact of buildings*, Journal of waste management, 32(2012), p.532-541,

To make significant improvements, selective deconstruction would be required, with practices used that would enable the re-use of wooden, masonry and metal building elements. The processing of crushing and grading concrete to a quality sufficient for replacement of coarse natural aggregate in structural concrete would contribute towards reducing total building material flows<sup>102</sup>.

According to the European Commission's Reference Document on Best Environmental Management Practice in the building and construction sector<sup>103</sup>, the use of materials with high recycled content is one of the best practices with the potential for greatest influence on resource efficiency in construction. This finding is supported by extensive work with the construction sector by WRAP in the UK<sup>104</sup>. However, as was noted in Section 3.3.1, for bulk materials the environmental benefits of recycling can, to some extent, be outweighed by transport related emissions, so careful consideration of the overall system impacts is required.

### 3.4 Factors that may result in a gap between design and actual performance

The potential for gaps to emerge between the modelled energy performance of a building and its services at design stage and its performance upon occupation has become the focus of increasing attention. This is in part due to an expectation that investment in higher performance buildings delivers the expected benefits. Two of the most common cited factors are briefly discussed in the next two sub-sections. Other potential areas of focus include Building Energy Management Systems, lighting and on-site energy generation<sup>105</sup>.

In this section the main focus is on possible design versus actual performance variations in energy use, for which evidence already available. There appears, however, to be a gap in the evidence base for other resource efficiency aspects. A study has been commissioned by DG ENV to investigate this issue further, the findings of which will feed into this work.

#### 3.4.1 The quality and integrity of the building fabric

In order to guarantee a high performing low energy building, it is important to ensure that the completed building fabric has a low level of air infiltration (i.e. it is air tight and does not leak air) and minimal thermal bridges where heat can be conducted through the buildings structure from outside to inside (or vice versa). This should be addressed at the design stage by careful detailing of the external fabric and at the construction stage by ensuring quality and precision on-site, as demonstrated by the Passivhaus standard developed in Germany and now promoted across the EU, which also includes post-construction testing<sup>106</sup>.

In some Member States, such as the UK and Ireland, 'accredited details' are specified for designers and builders. These are examples of building elements and construction details that minimise thermal bridging. In general, however, limited guidance is provided across the EU<sup>107</sup>. In Italy there is understood to be a certification scheme for construction details. Only Denmark is understood to currently legally require thermal imaging to test construction quality<sup>108</sup>.

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<sup>102</sup> Hiete, M, *Waste management plants and technology for recycling construction and demolition (C&D) waste: state-of-the-art and future challenges* in Pacheco-Torgal.F, Tam.V, Labrincha.J, Ding.V & J.de Brito (Ed) (2013) *Handbook of recycled concrete & demolition waste*, Woodhead Publishing Limited

<sup>103</sup> European Commission, *Reference Document on Best Environmental Management Practice in the building and construction sector* (2012): <http://susproc.jrc.ec.europa.eu/activities/emas/documents/ConstructionSector.pdf>

<sup>104</sup> WRAP (2009) *Delivering higher recycled content in construction projects*, UK

<sup>105</sup> JRC-IPTS, *Green Public Procurement Criteria for the design, construction and management of Office buildings*, Draft technical report, December 2014

<sup>106</sup> Passipedia, *Thermal bridges*, *Passivhaus Institut*, [http://www.passipedia.org/passipedia\\_en/basics/building\\_physics\\_-\\_basics/heat\\_transfer/thermal\\_bridges#what\\_defines\\_thermal\\_bridge\\_free\\_design](http://www.passipedia.org/passipedia_en/basics/building_physics_-_basics/heat_transfer/thermal_bridges#what_defines_thermal_bridge_free_design)

<sup>107</sup> Asiepi (ASessment and Improvement of the EPBD Impact), *An effective Handling of Thermal Bridges in the EPBD Context*, Final Report of the IEE ASIEPI Work on Thermal Bridges, 31st March 2010

<sup>108</sup> Asiepi (ASessment and Improvement of the EPBD Impact), *Analysis of Execution Quality Related to Thermal Bridges*, 18th October 2009

The UK PROBE building post-occupancy project identified air tightness as a common problem in new-build completions<sup>109</sup> and it was identified by the IMPRO Buildings study as a major improvement option for renovations (see Section 3.2.1). Recognising the importance of air tightness, at least 11 Member States now require some form of testing of the integrity of the building fabric at national or regional level, with Denmark, Ireland, France and the UK setting minimum requirements in their building regulations<sup>110</sup>. The most common form of testing is the blower door test.

### 3.4.2 Heating, Ventilation and Cooling (HVAC) systems

Evidence from the monitoring of building projects from design through to handover and operation suggests that the performance of the building services – i.e. the Heating, Ventilation and Cooling (HVAC) systems – is an important factor to control in the overall management of energy use. The increasing complexity and energy intensity of these systems means that if they are not commissioned and operated correctly, they can contribute to higher energy use.

Evidence from surveys of buildings commissioned in the US suggests based on findings from a database of 643 buildings that energy-related commissioning problems can increase energy use by approximately 15%<sup>111</sup>. A study of low energy buildings by the UK's Carbon Trust revealed that 40% of the building developers involved did not meet their low energy goals because of problems that could have been addressed by better commissioning. Evidence has also emerged in relation to energy saving technologies such as heat pumps, as demonstrated by the findings from monitored projects in programmes such as EnOB in Germany<sup>112</sup>.

## 3.5 In-direct factors influencing the performance, service life and value of buildings

### 3.5.1 What are the links between health, wellbeing and building performance?

There is increasing attention being given to the importance of creating comfortable and healthy buildings for occupiers – whether they be office workers or home owners – as a means of differentiating 'green' buildings. This is in part because, alongside the financial benefit of lower running costs, this can influence the attractiveness of 'green' buildings.

Given that the link between improved financial value and 'green' buildings as a certified product appears not to have yet been conclusively made in the EU<sup>113</sup>, the increasing focus on health and comfort potentially allows a clearer link to be made between the upfront financial costs and long term benefits. There is also the potential for this to be reflected in the design and service life of 'green' buildings<sup>114</sup>. However, market research in some Member States suggests indicatively that whilst property industry professionals recognise the potential links between value and health & comfort, there is the need for more definition of what is meant in practice by concepts such as 'wellbeing'<sup>115</sup>.

In order to illustrate the potential linkages between health and wellbeing and levels of satisfaction with buildings in the property market, two indicative examples are described below, drawing upon cited evidence:

- *A healthy and attractive working environment* with good daylighting, ventilation, stable seasonal temperatures, user control and views of green/blue spaces can contribute to greater workforce satisfaction, less illness related absences and greater productivity<sup>116</sup>. The performance of the

<sup>109</sup> PROBE, *Final report 4: Strategic conclusions*, Report to DEFRA (UK Government), August 1999, <http://www.usablebuildings.co.uk/Probe/ProbePDFs/SR4.pdf>

<sup>110</sup> Heike.E-K, Erhorn.H, Lahmidi.H and R.Anderson, *Airtightness requirements for high performance building Envelopes*, Published by Asiepi, 2010 and ATTMA, *Measuring air permeability of building envelopes*, Technical standard L2, October 2010

<sup>111</sup> Lawrence Berkeley National Laboratory, *Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions*, Report prepared for the Californian Energy Commission, USA, July 21st 2009

<sup>112</sup> Research for Energy Optimised Building (EnOB),, *Research for energy optimised building*, Germany <http://www.enob.info/en/analysis/analysis/details/workplace-satisfaction-and-comfort/>

<sup>113</sup> Sustainable Building Alliance, *Green impact - Environmental assessment and financial performance*, Research carried out by Deloitte, ITB and EIREM, December 2012

<sup>114</sup> CIBSE Journal, *Taking the temperature – roundtable on health, wellbeing and productivity*, March 2015, UK, <http://portfolio.cpl.co.uk/CIBSE/201503/roundtable/>

<sup>115</sup> The Feeling Good Foundation, *Wellbeing Matters - assessing views on the impact of the built environment on wellbeing*, Analysis of the results from the Estates Gazette with Grosvenor Estates 'Property Industry Sentiment Survey', October 2014

<sup>116</sup> Useable Buildings Trust, *PROBE post occupancy study series*, Building Services Journal 1995-2002, <http://www.usablebuildings.co.uk/>

workforce is important because staff costs can account for up to 90% of operating costs. From a life cycle cost and market perspective, these factors may in turn translate into improved valuations (offset for occupiers by improved workforce productivity and lower running costs), a differentiator in the market and longer service lifespan.

- *Comfortable and healthy homes* with stable internal temperatures and humidity levels, as well as good ventilation and daylighting can contribute to less seasonal illnesses and respiratory problems (particularly in small children and the elderly), and an improved sense of wellbeing<sup>117</sup>. From a life cycle cost and market perspective, these factors may in turn translate into more attractive properties<sup>118</sup>, more stable valuations over time (offset by lower occupier running costs), differentiation in the market, a reduced burden on health services<sup>119</sup>, reduced public/private renovation costs and a longer service lifespan in the housing market.

The interplay between these linkages will depend on the nature of a buildings ownership and occupation. For example, a house builder will not benefit from lower running costs and more comfortable homes, but may be able to attribute greater value to them or use these factors to differentiate their product in the market. In contrast, pension funds and social landlords retain ownership of properties in the long-term. For a social landlord, lower running costs for tenants may in turn reduce rent arrears. In both cases lower life cycle costs and future resilience could reduce financing and insurance costs.

### 3.5.2 Evidence for the significance of health and wellbeing factors

There is increasing scientific and market evidence to support the linkages discussed in 3.5.1. This is evidenced by a selection of recently published standards, evidence reviews and market research:

- The launch in the US of the Well Building Standard<sup>120</sup>, which is the result of extensive research and consultation with medical professionals,
- The findings from a recent evidence collecting exercise by the World Green Building Council for office buildings<sup>121</sup> and
- The findings from surveys of citizens, such as the Healthy Homes Barometer<sup>122</sup>, and property professionals<sup>123</sup>.

In order to illustrate some of the possible areas of focus, those 'pre-conditions' for Well Building certification that are independent of occupier choices and therefore under the control of building design teams are listed in Table 3.1. Features relating to water, nourishment and fitness have been omitted.

**Table 3.1. New construction pre-conditions for Well Building standard certification**

Category	Required features
Air	<ul style="list-style-type: none"> <li>- Air quality standards</li> <li>- Ventilation effectiveness</li> <li>- VOC reduction</li> <li>- Air filtration</li> <li>- Microbe and mould control</li> <li>- Fundamental material safety</li> <li>- Moisture management</li> </ul>
Light	<ul style="list-style-type: none"> <li>- Visual lighting design</li> <li>- Circadian lighting design</li> <li>- Electric light glare control</li> <li>- Solar glare control</li> </ul>

<sup>117</sup> Building Performance Institute Europe, *Indoor air quality, thermal comfort and daylight*, March 2015

<sup>118</sup> Velux and Humboldt University, *Healthy homes barometer 2015*

<sup>119</sup> BRE Trust (2015) *The cost of poor housing to the NHS*, Research carried out for the BRE Trust, UK

<sup>120</sup> International Wellbeing Institute, *The Well Building standard*, <http://www.wellcertified.com/>

<sup>121</sup> World Green Building Council (2014) *Health, wellbeing & productivity in office – the next chapter for green buildings*.

<sup>122</sup> *ibid* 118

<sup>123</sup> *ibid* 115

Comfort	- Exterior noise intrusion - Internally generated noise - Thermal comfort
Mind	- Post-occupancy surveys - Biophilia (qualitative)

Adapted from International Well Building Institute (2014)

Research across the EU has also focussed on the existing housing stock, which in certain countries, regions and climate zones of the EU is of high concern because of the issues of fuel poverty, unhealthy conditions and related health impacts<sup>124 125</sup>. These may in turn be a factor for consideration by governments, as the direct and indirect costs of addressing these problems can be high, particularly in more deprived areas<sup>126</sup>. The extent of EU fuel poverty is illustrated in Figure 3.11.

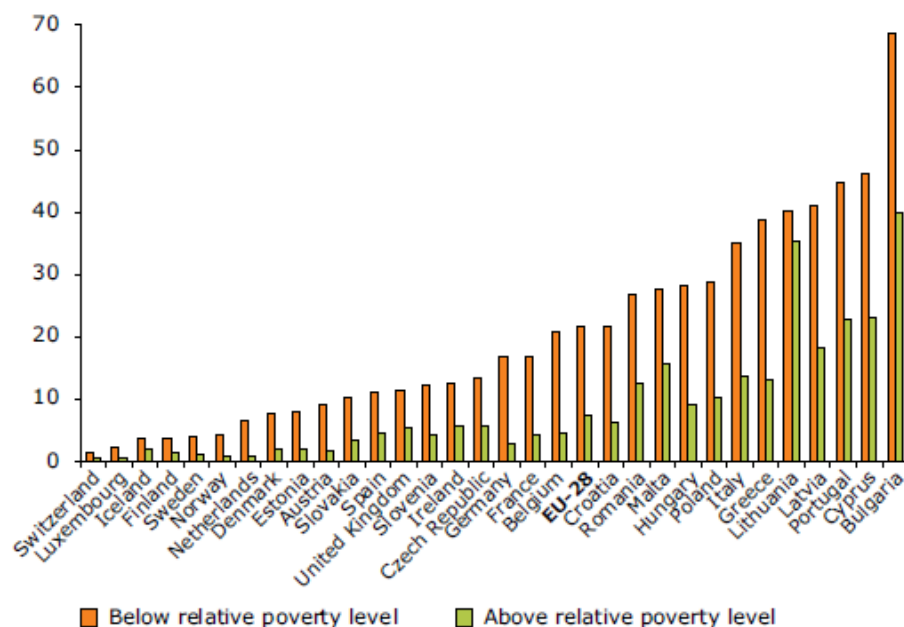


Figure 3.11 Percentage of EEA-33 population unable to keep their homes warm (2011)

Source: European Environment Agency (2013)

The following sub-sections briefly summarise, with reference mainly to evidence relating to office buildings, the four health and wellbeing factors most commonly cited in literature and addressed by existing reporting and assessment tools – namely thermal comfort, daylighting, indoor air quality, and acoustics and noise.

The Building Performance Institute Europe (BPiE) has highlighted that despite reference in the recast Energy Performance of Buildings Directive to the need to '...take account of general indoor climate conditions, in order to avoid possible negative effects such as inadequate ventilation' there are currently no common standards across the EU for three of these factors<sup>127</sup>.

### 3.5.2.1 Thermal comfort

In low energy or passive buildings, the control of thermal comfort and overheating is an important factor. This is because uncontrolled thermal gain from natural lighting and ventilation, as well as insufficient thermal mass within a building's structure, can lead to uncomfortable conditions that may require additional cooling energy. The recast EPD Directive 2010/31/EU specifically addresses overheating, stating that:

<sup>124</sup> Building Performance Institute Europe, *Alleviating fuel poverty in the EU*, May 2014

<sup>125</sup> EEA (European Environment Agency), *Environmental indicator report 2013 - Natural resources and human well-being in a green economy*, 20th November 2013

<sup>126</sup> *ibid* 119

<sup>127</sup> Building Performance Institute Europe, *Indoor air quality, thermal comfort and daylight – analysis of residential building regulations in eight EU member states*, March 2015

*'...there should be focus on measures which avoid overheating, such as shading and sufficient thermal capacity in the building construction, and further development and application of passive cooling techniques, primarily those that improve indoor climatic conditions and the micro- climate around buildings.'*

Literature based on post-occupancy surveys suggests that although occupants may have a greater tolerance for hot and cold conditions in a low energy building – following the 'adaptive' approach to comfort<sup>128</sup> - they also place a significance on being able to control their working conditions to within self-defined parameters<sup>129</sup>  
<sup>130</sup>.

As was also highlighted in Section 3.1.1, adverse climate change may also lead to problems with overheating at building and urban scale. Climate change resilience may necessitate adaptations to existing buildings as well as their surroundings, for example by adding solar control features, adjusting internal layouts and increasing/adding the presence vegetation and water features . The latter as a design feature has multiple benefits because there is strong evidence that so-called 'biophilia' – the fundamental human need to be in natural spaces – contributes to increased wellbeing.

### **3.5.2.2 Daylighting**

Natural light has been shown to contribute to more conducive and productive working environments and is preferred by office workers, who also tend to seek a window location. The plan depth of an office 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 level of 500 lux (lumens/m<sup>2</sup>) necessary for a working environment – equivalent to a Daylighting Factor of 2%<sup>131</sup>.

However, without careful design, natural light can make the internal environment uncomfortable and, potentially, result in more energy use than predicted. Whilst a design may achieve an ideal Daylighting Factor of 2% at a plan depth of 6 metres, this would result in unwanted glare and thermal gains near the windows. As a result, solar control strategies are required.

### **3.5.2.3 Indoor Air Quality**

Indoor air quality is an important measure of the health of a building. Studies suggest that healthy indoor air quality is a factor that can improve productivity. Conversely, the problem of so-called 'sick building syndrome' can lead to reduced productivity and even lost time due to work-related illness.

In an air tight modern home or office, the most significant direct emissions sources are understood to be paints and varnishes, textile furnishings, floor coverings and fit-out incorporating particle board<sup>132</sup>, although significant progress has been made by EU industry in reducing harmful emissions associated with products such as paints and particle board. For buildings with ventilation systems, indirect outdoor sources such as traffic have been identified as also being of significance to indoor air quality<sup>133</sup>.

In older residential buildings, humidity and draughts may be more important considerations and can have significant implications for the health of occupants. An extensive recent review of literature relating to homes suggested that around 16% of the EU population (approximately 80 million people) live in homes in which damp and associated mould growth may provoke respiratory or allergenic health effects<sup>134</sup>. The 'moisture

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<sup>128</sup> Nicol.F, Humphreys.M and S,Roaf (2012) *Adaptive thermal comfort: principles and practice*, Routledge

<sup>129</sup> Wagner.A et al, *Thermal comfort and workplace occupant satisfaction—Results of field studies in German low energy office buildings*, Energy and Buildings 39 (2007) 758–769

<sup>130</sup> Research for Energy Optimised Building (EnOB), *Workplace satisfaction and comfort*, Germany, Accessed December 2015, <http://www.enob.info/en/analysis/analysis/details/workplace-satisfaction-and-comfort/>

<sup>131</sup> Baker.N and K,Stemers (1999) *Energy and Environment in Architecture: A Technical Design Guide*, Taylor & Francis and European Commission (1994) *Daylighting in buildings*, THERMIE project

<sup>132</sup> Bluysen et al, *European Indoor Air Quality Audit in 56 office buildings*, Indoor Air: 1996, 6(4), p-221-228

<sup>133</sup> European Commission (2011) *Promoting actions for healthy indoor air*, DG Health & Consumers

<sup>134</sup> Fraunhofer IBP, *Towards an identification of European indoor environments' impact on health and performance*, Germany, 5th December 2014

and mould' programme initiated to tackle problems in Finland's housing stock is just one example from a Member State of the significance of this issue to wider public health <sup>135</sup>.

School buildings are understood to be affected by a tendency towards poor ventilation, which can lead to high CO<sub>2</sub> levels because of the generally high occupation of classrooms <sup>136</sup>. This in turn can affect performance and absence rates from classes.

As workers' salaries represent the majority of a business's expenditure (significantly greater than energy use), improvements in air quality can be attributed a value. Research suggests that by increasing ventilation rates from 2.5 l/s to 10 l/s per person, productivity can be increased by around 5% <sup>137</sup>. Ventilation rates are closely related to the control of CO<sub>2</sub> levels, which are the focus of attention in standards such as EN 15251. Related to this, productivity has been observed to increase by approximately 1% for every 10% reduction in dissatisfaction with indoor air quality.

WHO IAQ guidelines exist for the level of indoor exposure levels for a number of contaminants, including PM2.5 particulates, CO, NO<sub>2</sub>, formaldehyde, benzene and naphthalene. Of these contaminants, DG Health & Consumers identified fine particulate matter from outdoor air pollution and indoor combustion equipment as the most significant source of indoor exposure <sup>138</sup>. This finding is supported by the European Collaborative Action (ECA) on 'Urban air, indoor environment and human exposure' <sup>139</sup>, the EnVIE project <sup>140</sup> and EU monitoring projects such as Officair <sup>141</sup>.

The monitoring and control of emissions from priority chemicals, including Volatile Organic Compounds (VOC's), has been the focus of action at EU level. Work is ongoing to support the CE marking of products under the Construction Products Regulation with two relevant areas of focus - the harmonisation of health-based evaluations of emissions from construction products (based on Lowest Concentration of Interest values) and the development of an emissions performance class system for reporting to consumers. A number of Member States now have legislation and associated product labelling schemes for emissions from construction products, including France, Germany and Belgium.

#### **3.5.2.4 Acoustics and noise**

The potential for acoustic disturbance from both inside and outside a building is cited as an important aspect of occupant satisfaction. The potential for disturbance depends on the nature of the buildings use, servicing and internal layout. In offices, for example, it may relate to open plan environments as well as poor acoustic separation between cellular offices or meeting rooms <sup>142</sup>. Servicing such as air conditioning, as well as server rooms, can cause disturbance.

In apartments and terraces, acoustic insulation of party walls and floors is particularly important to ensure privacy, in terms of both impact and airborne transmission of sound. In both cases external sources such as traffic and street activity can be sources of disturbance. In commercial buildings this can lead to decisions to seal windows and mechanically ventilate spaces.

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<sup>135</sup> Ministry of the Environment, *Moisture and mould programme*, Finland, <http://uutiset.hometalkoot.fi/en/home.html>

<sup>136</sup> *ibid* 134

<sup>137</sup> Djukanovic et al, *Cost benefit analysis of improved air quality in an office building*, Proceedings: Indoor Air 2002

<sup>138</sup> *ibid* 103

<sup>139</sup> JRC-IHCP, <https://ec.europa.eu/jrc/en/research-topic/human-exposure>

<sup>140</sup> EnVIE, *Co-ordination Action on Indoor Air Quality and Health Effects*, FP6 project final activity report, 10th February 2009

<sup>141</sup> Officair project, <http://www.officair-project.eu/>

<sup>142</sup> *ibid* 121

### Summary of findings on macro-environmental 'hot spots'

- Whilst environmental impacts related to the use phase of buildings remain important, particularly for the existing building stock, the increased energy efficiency of new and renovated buildings is shifting the balance towards impacts associated with construction materials;
- Load bearing structures, external walls and facades appear as the main hot spot for material impacts across the majority of the impact categories used in the LCA literature reviewed. Addressing these impacts entails a focus on the life cycle impacts of the most significant mineral and metals flows, which comprise concrete, brick, ceramic, steel and timber;
- Significant impacts associated with building materials and elements may also arise during the use phase. This is because scheduled major repairs and maintenance may result in materials and elements being replaced (e.g. roofs, facades).
- Renovations may also result in the replacement of fit out materials and other major elements such as windows and facades. Distinct impacts associated with fit out materials, such as those captured toxicity categories, may not be identified and quantified if these indicators are not included in the impact categories selected.
- The environmental impacts associated with each of these materials and elements are distinct and cannot be addressed by a focus on one aspect alone, for example material flow. A composite approach is therefore needed that can address the distinct impacts associated with non-metallic mineral, metal and wood-based materials.
- The efficiency and intensity of use of structures, space and land is an important focus for improvement. For homes, more compact building forms are more land, material and energy efficient. Design for adaptability and extension of the life span of structures can reduce material impacts;
- The choice of functional unit is critical in defining how the intensity of resource use is measured at macro-objective and indicator level.
- Externalised, 'induced' effects beyond the conventional LCA boundary of a building can be as significant as those related to buildings themselves. For example, transport related emissions influenced by the accessibility of a building to public transport networks and amenities;
- Evidence from occupant surveys show that comfort, health and wellbeing aspects such as thermal comfort, natural light, indoor air quality and acoustics are critical to performance and occupant satisfaction with buildings, which in turn have the potential to influence productivity and property values.
- Specific hazards can be identified in relation to the living conditions in existing, energy inefficient housing across Europe. This relates to both the ease of heating these properties but also to the presence of damp and mould as a result of the poor quality and/or deterioration of the building fabric.



## 4. Priorities, scope and boundaries of existing assessment and reporting tools

In this Chapter two broad types of schemes and tools currently used in professional contexts to assess the performance of buildings are examined in order to compare and contrast their macro-objectives. The first type, building assessment schemes, tend to be used to carry out 'asset ratings' for new building designs. The second type, investor reporting tools, tend to be used to carry out 'operational ratings' for existing building stock and associated renovations.

For each scheme or tool, their macro-objectives as defined by broad categories or criteria areas (e.g. materials and resources, location and transportation), have been identified. Where a weighting or scoring system is used then this is examined in order to identify the relative importance assigned to each category or criteria area so that the different systems can be compared and contrasted.

### 4.1 The use of assessment and reporting tools in the property market

The demand for tools to evaluate and compare the environmental performance of buildings has led to the development of a range of building assessment schemes and reporting tools. The majority of these carry out evaluations that are an '*asset rating*' i.e. an assessment is made of the building *at the design stage*, which is then followed up in the construction and completion stages.

The outcome of such an assessment generally takes the form of an '*endorsement label*'. This indicates that a building is third party verified to comply with the schemes requirements, usually at a specific benchmark level of performance. Property investment reporting tools tend not to include this step. Instead they generally only report on an evaluation that has taken place, together with the outcome in the form of normalised data for specific categories of environmental performance.

An increasing trend can also be observed in the market for the '*operational rating*' of buildings i.e. an evaluation is made of the performance of an existing building or a stock of buildings *in use*. This form of rating is becoming more important with the increase in focus on building renovation to improve energy performance. A good example is the requirement for public buildings to have Display Energy Certificates (DEC) in the UK. Commissioning and post-occupancy assessment of new buildings is also on the increase as clients seek a narrowing of gaps between design and actual performance.

The outcome of such a rating generally takes the form of a '*comparative label*' which reports on a buildings level of performance either quantitatively or with reference to benchmark levels of performance. Energy Performance Certificates are the most common example that is currently used in the EU.

It is important to also note that many of the existing building assessment schemes that have, up until now, been providing asset ratings are now moving to also provide endorsed (i.e. third party verified) operational ratings. BREEAM, which originates in the UK, is the most relevant example in this respect as versions of the criteria set have been developed for the assessment of existing buildings.

### 4.2 The move towards standardised frameworks for assessment and reporting

#### 4.2.1 The harmonisation of product declarations and environmental performance assessments

The Construction Products Regulation (EU) No 305/2011 seeks to ensure that reliable information on the environmental performance of products is provided in the EU market. To this end, it seeks to harmonise Declarations of Performance for building products for which there exist EN standards. With the advent of the European single market for construction products, there was a concern that national Environmental Product Declaration (EPD) schemes and building level assessment schemes based on LCA principles would represent a barrier to trade across Europe. As a result, two standards were developed and published by CEN/TC 350:

- EN 15804<sup>143</sup> (2012) This standard provides the Product Category Rules for construction products and services, with the aim to ensure that EPDs for construction products, construction services and construction processes are derived, verified and presented in a harmonised way.
- EN 15978<sup>144</sup> (2011) This standard deals with the aggregation of the information at the building level, describing the rules for applying EPDs in a building assessment. The identification of boundary conditions and the setting up of scenarios are major parts of the standard.

These standards do not, as such, provide macro-objectives for the environmental performance of buildings. Instead they provide a harmonised set of environmental and resource use indicators for use in the assessment and reporting of performance.

The pilot phase of the European Commission's Product Environmental Footprint (PEF) method for life cycle assessment<sup>145</sup> includes a number of building products and uses as its starting point a more extensive set of environmental and resource use indicators. The potential influence of the PEF on future standards for building environmental assessment will, to an extent, depend on the outcomes from this pilot.

With the onset of the above referred to two EN standards, the major building assessment schemes are moving to harmonise their approach to environmental performance on a life cycle basis – both in terms of EPD schemes and LCA methodologies. The life cycle stages defined by EN 15804 and EN 15978 have therefore been used in Section 4.3 of this working paper to compare the scope of selected schemes – namely the product, construction, use and end of life stages.

## 4.2.2 Initiatives to harmonise environmental performance indicators

### 4.2.2.1 The Sustainable Building Alliance (SBA)

One of the most important industry-led initiatives is that of the Sustainable Building Alliance (SBA)<sup>146</sup>. The SBA has since 2009 convened certified bodies for the major building assessment schemes used in the EU - BREEAM, HQE, DGNB, SB Tool and LEED - with the aim of working towards a harmonised framework of core indicators for the environmental performance of buildings. An initial set of indicators (the 'Common Metrics') was selected based on a combination of expert judgement and reference to the aforementioned EN standards.

With the co-operation of the SB Alliance partners the common metrics identified have now been pilot tested in two phases on example buildings<sup>147</sup>. The common metrics pilots have focussed on four LCA-orientated indicators - non-renewable primary energy consumption, CO<sub>2</sub> equivalents, drinking water consumption and waste production – as well as measures of thermal comfort and indoor air quality.

### 4.2.2.2 The Common European Sustainable Built Environment (CESBA)

The CESBA (Common European Sustainable Built Environment Assessment) movement was established in 2011 and aims to respond to the perceived confusion caused by the proliferation of building assessment schemes across the EU<sup>148</sup>. The movement brings together a number of other projects and platforms led by public authorities that have been developing assessment systems, such as ENERBuild<sup>149</sup>.

#### *The 'Building signature' KPIs*

The CESBA partners have developed a set of Key Performance Indicators that form the basis for the CESBA 'building signature', which all building certifications must include in order to receive the CESBA signature. The KPIs comprise primary energy use, CO<sub>2</sub> emissions, reused/recycled materials, water consumption and solid

<sup>143</sup> EN 15804: 2012 + A1:2013. *Sustainability of construction works - Environmental product declarations – Core rules for the product category of construction products*

<sup>144</sup> EN 15978: 2011. *Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method*

<sup>145</sup> Commission recommendation of 9 April 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations (OJ L-124 4.5.2013 p-1)

<sup>146</sup> Sustainable Building Alliance, <http://www.sballiance.org/>

<sup>147</sup> Sustainable Building Alliance (2011) *Piloting SBA Common Metrics – Phase 1, Technical and operational feasibility of the SBA common metrics, and Sustainable Building Alliance (2011) Beyond research to operational application and comparability, Phase 2 summary, August 2014*

<sup>148</sup> Common European Sustainable Built Environment Assessment (CESBA), [http://wiki.cesba.eu/wiki/Main\\_Page](http://wiki.cesba.eu/wiki/Main_Page)

<sup>149</sup> Project ENERBUILD, *Energy Efficient and Renewable Energies in the Building sector*, <http://www.enerbuild.eu/>

waste, as well as building life cycle costs, health and wellbeing factors (IAQ and thermal comfort) and monitoring/optimisation in operation.

*The 'Generic tool indicator' assessment system*

A CESBA 'generic tool indicator' system is being tested in eight Member States using model building assessments. This system clusters indicators under five broad evaluation categories to which points are assigned (in brackets):

1. Quality of location and equipment (80 points)
2. Process and planning quality (240 points)
3. Energy demand and supply (450 points)
4. Health and Comfort (200 points)
5. Building materials and construction (200 points)

The tool is understood to be largely based on the outcomes from the ENERBuild project. A supporting analysis of the criteria and weightings of seven existing systems resulted in a composite weighting in table 4.1. The intention is that this composite weighting is used as a common basis but is then adapted by specific schemes to reflect macro regional priorities, which are identified as including local materials, urban environment and landscape, depletion of habitats and water use for irrigation.

**Table 4.1 Synthesis of the weightings of seven building assessment schemes**

Criteria area	Weighting
Energy	37%
Materials	20%
Water	9%
Site	9%
Comfort	6%
Process	6%
Servicing	5%
Waste	5%
Economy	3%

Source: CESBA (2015)

**4.2.2.3 Building Performance Indicators, Green Building Council Finland**

In order to shift the focus from overall building ratings to reporting on a smaller number of specific aspects of performance, a set of eight Building Performance Indicators have been developed, with reference to the CEN/TC 350 family of standards<sup>150</sup>. The indicators were identified and agreed on through a process of stakeholder engagement and have been made freely available. The design stage indicators are as follows<sup>151</sup>:

- E-Value: The design energy performance reported according to EN 15217;
- Life-cycle carbon footprint: Calculation for the phases described in EN 15804;
- Life Cycle Costs: Calculation according to EN 15643-4;
- Indoor air class: With reference to EN 15251 and Finnish guidelines;

<sup>150</sup> Virta.M, Hovorka.F and A.Lippo, *Building passports as a tool to evaluate the sustainability of a building*, December 2012, <http://www.worldgbc.org/>

<sup>151</sup> Green Building Council Finland, *Building Performance Indicators*, Accessed November 2015, <http://figbc.fi/en/building-performance-indicators/>

The remaining indicators cover measured energy consumption, operational carbon footprint, baseload energy demand and user satisfaction. The indicators can be used to create a 'building passport' that presents in a simple format key aspects of a building's design and operational performance.

### 4.3 Analysis of assessment and reporting tool macro-objectives

An important part of the initial study of macro-objectives is to identify those of the most common building assessment and reporting tools available in the market. These correspond to what the EU FP7 Superbuildings project refers to as the '*subjects of concern*' and '*protection goals*' for each scheme or tool <sup>152</sup>.

The most significant building assessment schemes and reporting tools were identified from literature and market research. These were split into 1) multi-criteria schemes that are verified by accredited assessors and 2) reporting tools used on both a verified and unverified basis by investors and building occupiers.

#### 4.3.1 Comparative framework used for the analysis of macro-objectives

For each tool, the *generic core criteria set* used as the starting point for the adaption or direct implementation of scheme criteria sets across the EU is identified. From this core criteria set, the scope, focus and prioritisation of the criteria areas is then identified. The scope and focus is sub-divided into the following three categories:

- 'Direct' impacts relating to the building life cycle stages defined by EN 15978
- Extension of the EN 15978 LCA boundary to capture 'induced' impacts in the wider urban environment
- Potential 'in-direct' human and economic influences on the performance, service life and value of a building

These categories reflect the broad areas of potential focus identified from the review of the life cycle evidence in Chapter 3. They also seek to capture the full range of potential influences and perspectives on life cycle performance and the holistic design of buildings so that they can form the basis for further discussion and evidence gathering.

The prioritisation of macro-objectives by each tool – taken to be equivalent in this case to 'categories' or 'criteria areas' - is then also examined in order to compare and contrast the relative importance assigned to them. Here only those aspects that *directly* influence the environmental performance of buildings, or which were flagged up in Chapter 3 of this paper, were checked for their contribution.

#### 4.3.2 Multi-criteria schemes verified by accredited assessors

In this section, the five building assessment schemes with the greatest uptake and broadest geographical reach in the EU market are each analysed using the proposed framework for comparison of macro-objectives. The schemes analysed are as follows:

- The Code for a Sustainable Build Environment, Building Research Establishment (Origin: UK)
- Haute Qualité Environnementale (HQE), Centre Scientifique et Technique du Bâtiment (Origin: France)
- Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), German Sustainable Building Council (Origin: Germany)
- Sustainable Building (SB) Tool, International Initiative for a Sustainable Built Environment (Origin: International)
- Leadership in Energy & Environmental Design (LEED), US Green Building Council (Origin: USA)

For each scheme analysed, the generic criteria set used as the basis for international adoption, together with underlying technical evidence for the prioritisation of the criteria (where available) is analysed.

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<sup>152</sup> VTT, *Sustainability and performance assessment and benchmarking of buildings*, Tarja Häkkinen (Ed.), Summary findings of the SuPerBuildings Project, Espoo 2012.

It should be noted that SB Tool forms the basis for a number of distinct national schemes, including the Czech Republic (SBTool CZ), Portugal (SBTool PT), Italy (Protocollo ITACA) and Spain (Verde). Only the generic SB Tool criteria set is analysed in this paper.

#### 4.3.2.1 Code for a Sustainable Built Environment, BRE

The UK-based Building Research Establishment (BRE) has developed and operates the BREEAM sustainability assessment scheme for buildings, which was first launched in the UK in 1990. Since then the scope of BREEAM has expanded to cover a full range of domestic and non-domestic building typologies and life cycle stages.

To support the use and adaptation of the BREEAM family of schemes across the EU and internationally, BRE has developed a Code for a Sustainable Built Environment (CSBE), which sets out a set of strategic principles and requirements for the assessment of the built environment. The CSBE is interpreted through core process and technical standards, which all scheme operators shall adhere to when adapting BREEAM to local conditions. The core technical standard for buildings, which currently covers the 'new construction', 'in-use' and 'refurbishment and fit-out' life cycle stages, has been analysed and categorised in table 4.2.

**Table 4.2. BRE CSBE: life cycle boundaries, scope and prioritisation**

Aspect of building	Assessment and reporting tool scope
<b>Building life cycle stages (as defined by EN 15978)</b>	
Product	<ul style="list-style-type: none"> <li>○ Low environmental impact materials</li> </ul>
Construction	<ul style="list-style-type: none"> <li>○ Design, construction and commissioning management</li> <li>○ Construction site emissions and impacts</li> <li>○ Construction waste management and monitoring</li> <li>○ Material life cycle efficiency</li> <li>○ Sustainable and efficient land use</li> </ul>
Use	<ul style="list-style-type: none"> <li>○ Post-handover aftercare</li> <li>○ Energy demand reduction and monitoring</li> <li>○ Low and zero carbon energy generation</li> <li>○ Water demand reduction and monitoring</li> <li>○ Alternative water sources</li> <li>○ Operational waste storage, management and monitoring</li> <li>○ Minimise operational chemical pollution</li> </ul>
End of life	<ul style="list-style-type: none"> <li>○ <i>Not currently addressed</i></li> </ul>
<b>Extended LCA boundary to capture 'induced' impacts</b>	
Transport	<ul style="list-style-type: none"> <li>○ Minimise transport related energy use, pollution and congestion</li> <li>○ Access to public transport networks and alternative modes of transport</li> </ul>
<b>In-direct influences on the performance, service life and value</b>	
Cost and value	<ul style="list-style-type: none"> <li>○ Service life planning and life cycle costing</li> </ul>
Functional quality	Visual comfort <ul style="list-style-type: none"> <li>○ Lighting controls</li> <li>○ Daylighting, glare control and flicker</li> <li>○ View out</li> </ul> Indoor Air Quality <ul style="list-style-type: none"> <li>○ Ventilation</li> <li>○ Building product emissions</li> </ul> Thermal comfort <ul style="list-style-type: none"> <li>○ Thermal performance and control</li> </ul> Acoustic comfort <ul style="list-style-type: none"> <li>○ Acoustic performance (internal and external sources)</li> </ul>
Building configuration	<ul style="list-style-type: none"> <li>○ Future functional adaptability</li> <li>○ Adaptability to climate change</li> </ul>

*Adapted from BRE Global (2015)*

The BREEAM scheme weightings follow a common methodology and are intended to be adjusted to suit the local context and building life cycle stage of each scheme e.g. based on climactic zones and rainfall. The category contributions of the BREEAM International New Construction 2013 scheme criteria are used in Table 4.3 to illustrate a possible weighting.

It is also important to note that a minimum score is required for certain criteria in order to achieve the higher benchmark levels of Excellent or Outstanding. The criterion '*Ene 1 - Reduction of CO<sub>2</sub> emissions*' has the most

significant minimum score requirement for BREEAM International New Construction 2013. 'Innovation' credits can also be awarded for exemplary scores for ten issues that include:

- Ene 01 Energy efficiency
- Tra 03a&b Alternative modes of transport
- Wat 01 Water consumption
- Mat 01 Life cycle impacts
- Mat 03 Responsible sourcing of materials
- Wst 01 Construction site waste management
- Wst 02 Recycled aggregates

This potential assignment of credits lends these issues an additional, cumulative weighting.

**Table 4.3. BREEAM International New Construction weightings: Contribution of each category**

Category	Credits achievable	Overall weighted contribution
Management	22	12%
Health & wellbeing	10	15%
Energy	30	19%
Transport	9	8%
Water	9	6%
Materials	12	12.5%
Waste	7	7.5%
Land use & ecology	10	10%
Pollution	13	10%
<i>Innovation</i>	10	10%

Source: BRE Global (2014)

#### 4.3.2.2 Buildings under construction, HQE International

HQE was launched in 2005. 'Buildings under construction' is a set of criteria designed to improve the environmental quality of residential and non-residential buildings. It lays down requirements to assess and monitor the environmental performance of buildings, as well as addressing the comfort and health of building end users.

The criteria are developed and updated by the Centre Scientifique et Technique du Bâtiment (CSTB) in France. The main certification body is Certivea, which is a subsidiary of CSTB<sup>153</sup>, although outside of France this is carried out by its subsidiary Cerway. Assessment and auditing is carried out at three stages during the progression of a construction or renovation project - programming, design and execution.

The HQE Buildings under construction criteria are analysed in Tables 4.4 and 4.5. In considering the contribution of requirements within each target area to the overall weighted scores in Table 4.5, it is important to note that pre-requisites are defined for each target area.

The HQE criteria have recently been subject to review, with a new overarching 'framework for sustainable development' having been published in May 2015<sup>154</sup>. It defines a sustainable building as one that, in interaction with its context, addresses quality of life, respect for the environment, economical performance and responsible management. This revised framework is now being used to inform a revision of the criteria.

<sup>153</sup> HQE Association, *La certification NF bâtiments tertiaires*, <http://assohqe.org/hqe/spip.php?rubrique62> and Certivea, 2012, <http://www.certivea.fr/>

<sup>154</sup> HQE Association, *Le bâtiment durable pour tous – cadre de référence du bâtiment durable de l'association HQE*, May 2015

**Table 4.4. HQE Buildings under construction: life cycle boundaries, scope and prioritisation**

Aspect of building	Assessment and reporting tool scope
<b>Building life cycle stages (as defined by EN 15978)</b>	
Product	<ul style="list-style-type: none"> <li>Choice of construction products to limit the environmental impact of the building</li> </ul>
Construction	<ul style="list-style-type: none"> <li>Optimisation of site waste management</li> </ul>
Use	<ul style="list-style-type: none"> <li>Reduction in energy use and CO<sub>2</sub> emissions through design, systems, services and renewable energy generation</li> <li>Reduction in drinking water consumption</li> <li>Optimisation of operational waste recycling</li> <li>Construction products, systems and processes that are easy/low impact to maintain</li> </ul>
End of life	<ul style="list-style-type: none"> <li>Removability/separability of construction products</li> </ul>
<b>Extended LCA boundary to capture 'induced' impacts</b>	
Transport	<ul style="list-style-type: none"> <li>Control of travel methods and encourage least polluting modes</li> <li>Promote public transport</li> </ul>
<b>In-direct influences on the design, service life and value</b>	
Cost and value	<ul style="list-style-type: none"> <li><i>Not specifically addressed</i></li> </ul>
Functional quality	Planning for sustainable development <ul style="list-style-type: none"> <li>Encouraging the greening of areas within the plot</li> </ul> Quality of outdoor spaces accessible for users <ul style="list-style-type: none"> <li>Outdoor climatic environment</li> </ul> Limiting health related impacts <ul style="list-style-type: none"> <li>Choice of construction products in order to limit health related impacts</li> </ul> Occupier comfort <ul style="list-style-type: none"> <li>Hygrothermal comfort</li> <li>Monitoring and control of comfort conditions</li> <li>Acoustic comfort</li> <li>Optimised natural and artificial light</li> <li>Effective ventilation and control of indoor air pollution</li> </ul>
Building configuration	<ul style="list-style-type: none"> <li>Adaptability over time based on forecast lifespan and useage</li> </ul>

*Adapted from Cerway (2014)*

**Table 4.5. HQE Buildings under construction weightings: Contribution of each target area**

Theme	Target area	Pre-requisites	Points available	Overall weighted contribution
Energy	Energy	<ul style="list-style-type: none"> <li>Calculation of CO<sub>2</sub> equivalent emissions</li> <li>Use of dynamic thermal simulation to reduce energy demand by &gt;10%</li> <li>Renewable energy feasibility study</li> </ul>	45	25.00%
Environment	Site	<ul style="list-style-type: none"> <li>Consistency with sustainable urban land use policies</li> <li>Control of polluting travel methods</li> </ul>	91	4.17%
	Components	<ul style="list-style-type: none"> <li>Adaptability of the building over time</li> </ul>	53	4.17%
	Work on the site		43	4.17%
	Water	<ul style="list-style-type: none"> <li>Determine overall consumption</li> <li>Limit water demand for sanitary use by comparison with a reference performance</li> <li>Manage rainwater in an alternative way</li> <li>Water metering</li> </ul>	40	4.17%
	Waste	<ul style="list-style-type: none"> <li>Identify and quantify site waste by type</li> </ul>	14	4.17%
	Maintenance	<ul style="list-style-type: none"> <li>Design to facilitate future maintenance and servicing</li> <li>Sub-metering of specified energy uses</li> </ul>	45	4.17%
Comfort	Hygrothermal comfort	<ul style="list-style-type: none"> <li>Specific measures to address hygrothermal comfort</li> <li>Define appropriate temperatures and minimum thermal comfort levels</li> </ul>	40	6.25%

	Acoustic comfort	- Optimised quality for a number of listed indicators	4	6.25%
	Visual comfort	- Minimum access to daylight and outdoor views	23	6.25%
	Olfactory comfort		5	6.25%
Health	Spaces quality		20	8.33%
	Air quality	- Identify and reduce the effects of internal and external sources of pollution	32	8.33%
	Water quality	- Choice of materials compatible with the nature of the water supply	24	8.33%

Source: Cerway (2014)

#### 4.3.2.3 Core 14 buildings, DGNB

The DGNB system was launched in 2009 and is run by the German Sustainable Building Council. The system is implemented internationally using the Core 14 catalogue criteria set. This consists of five core criteria groups, together with separate consideration of the siting of the building. Assessments are based on the whole life cycle of the building, with the environmental quality criteria including a requirement for an LCA and the economic quality criteria including a requirement for Life Cycle Costing. The generic DGNB Core 14 criteria are analysed in Table 4.6 and the Core 14 scoring for office buildings in Table 4.7.

The DGNB system informed the development of the German Federal Building Ministry's Assessment System for Sustainable Building (BNB)<sup>155</sup>. This system is used for the evaluation of offices and administrative buildings and has many similarities with the DGNB system. It is compulsory for federal buildings, so is therefore of significance in Germany for public procurement.

**Table 4.6. DGNB Core 14: life cycle boundaries, scope and prioritisation**

Aspect of building	Assessment and reporting tool scope
<b>Building life cycle stages (as defined by EN 15978)</b>	
Product	<ul style="list-style-type: none"> <li>○ Material production</li> <li>○ Sustainable timber sourcing</li> </ul>
Construction	<ul style="list-style-type: none"> <li>○ Land use (soil sealing)</li> <li>○ Building envelope quality</li> </ul>
Use	<ul style="list-style-type: none"> <li>○ Primary energy demand</li> <li>○ Water demand</li> </ul>
End of life	<ul style="list-style-type: none"> <li>○ Deconstruction and disassembly</li> </ul>
<b>Extended LCA boundary to capture 'induced' impacts</b>	
Transport	<ul style="list-style-type: none"> <li>○ Cycling convenience</li> <li>○ Public transport accessibility</li> </ul>
<b>In-direct influences on the design, service life and value</b>	
Cost and value	<ul style="list-style-type: none"> <li>○ Life cycle costs</li> <li>○ Value retention, suitability for third party use</li> </ul>
Functional quality	<ul style="list-style-type: none"> <li>○ Thermal comfort</li> <li>○ Acoustic comfort</li> <li>○ Visual comfort</li> <li>○ Indoor air quality</li> <li>○ Quality of outdoor spaces</li> </ul>
Building configuration	<ul style="list-style-type: none"> <li>○ Efficient use of floor area</li> <li>○ Suitability for conversion</li> </ul>

Adapted from DGNB (2015)

<sup>155</sup> Federal Ministry for the Environment, the Protection of Nature, Construction and Nuclear Safety, *Assessment system for sustainable building*, <http://www.nachhaltigesbauen.de/sustainable-building-english-speaking-information/assessment-system-for-sustainable-building.html>



**Table 4.7. DGNB Core 14 Offices: Contribution of selected criteria and criteria groups**

Criteria groups and selected relevant sub-criteria	% contribution achievable	Potential contribution to total score
Environmental quality - LCA - Local environmental impact - Responsible procurement - Primary energy demand - Drinking water demand and wastewater volume - Land use	7.9% 3.4% 1.1% 5.6% 2.3% 2.3%	22.6%
Economic quality - Life Cycle Cost - Flexibility and adaptability - Commercial viability	9.6% 9.6% 3.2%	22.4%
Sociocultural and functional quality - Occupier comfort - Indoor air quality - User control - Quality of outdoor spaces - Cyclist facilities - Design, layout and urban quality	7.8% 2.6% 1.7% 0.9% 0.9% 3.5%	22.5%
Technical quality - Sound insulation - Building envelope quality - Adaptability of technical systems - Deconstruction and disassembly	4.1% 4.1% 2.0% 4.1%	22.5%
Process quality - Construction quality assurance - Systematic commissioning	1.4% 1.4%	10%
Site quality - Transport access - Access to amenities	<i>n/a</i>	<i>Considered separately</i>

Source: DGNB (2014)

#### 4.3.2.4 SB Tool, iiSBE

The Sustainable Building (SB) Tool was developed by the International Initiative for a Sustainable Built Environment (iiSBE). The framework developed by iiSBE is designed to be adapted to local conditions and building types. It forms the basis for schemes in a number of EU countries, including the Czech Republic (SBTool CZ), Portugal (SBTool PT), Italy (Protocollo ITACA) and Spain (Verde).

The iiSBE framework consists of seven assessment categories. These categories address the pre-design, design, construction and operational phases of a building. The 'site assessment' criteria are applied as appropriate to the scale of a development at a separate pre-design stage. The 'building assessment' criteria are applied at the design, construction and operational stages.

Third party users of the criteria are able to choose the number of criteria and therefore the comprehensiveness of the building assessment. The design phase categories have a minimum number of criteria of 14 and a maximum of 103. Mandatory criteria are also established at each level of comprehensiveness. The scoring used by SB Tool is notable in that it is weighted to take into account the extent, duration and intensity of environmental impacts, as illustrated in Figure 4.1.

Adjustable		Pre-set values		
Potential effects of Loadings and Qualities	Extent of potential effect (1 to 5 points)	Duration of potential effect (1 to 5 points)	Intensity of Potential Effect (1 to 3 points)	Primary system directly affected (1 to 5 points)
1 Much less	1 Building	1 1 to 3 years	1 Minor	1 Servicability
2 Less	2 Site / project	2 3 to 10 years	2 Moderate	1 Cost & economics
3 OK	3 Neighborhood	3 10 to 30 years	3 Major	2 Human comfort & well-being
4 More	4 Urban / Region	4 30 to 75 years		2 Non-energy resources
5 Much more	5 Global	5 >75 years		3 Energy resources
				3 Water resources
				4 Human health
				4 Ecological systems
				5 Life safety
				5 Climate system

**Figure 4.1. Calculation of weighting factors and identification of end points for SB Tool**

Source: iiSBE (2012)

Benchmark levels are not set in SB Tool and instead can be set by the national schemes that adapt the basic criteria set. This intention is that the scoring is benchmarked relative to the performance of national or regional references for minimal of acceptable practices. Credits from the 'site assessment' contribute separately and in addition to building performance which is measured against the 'building assessment' criteria. The SB Tool criteria mid scope (53 criteria) are analysed in Tables 4.8 and 4.9.

**Table 4.8. SB Tool: life cycle boundaries, scope and prioritisation (mid scope)**

Aspect of building	Assessment and reporting tool scope
<b>Building life cycle stages (as defined by EN 15978)</b>	
Product	<ul style="list-style-type: none"> <li>○ Embodied non-renewable energy in construction materials</li> <li>○ Degree of re-use of suitable existing structure(s)</li> <li>○ Use of virgin non-renewable materials</li> </ul>
Construction	<i>Not specifically addressed</i>
Use	<ul style="list-style-type: none"> <li>○ Extent of on-site parking facilities</li> <li>○ Development density to ensure efficient land use</li> <li>○ Consumption of non-renewable energy               <ul style="list-style-type: none"> <li>- Passive solar orientation</li> <li>- Orientation for passive ventilation</li> <li>- GHG emissions from primary energy use</li> <li>- Use of vegetation to provide ambient cooling</li> </ul> </li> <li>○ Contribution to heat island effect</li> <li>○ Use of water by occupants</li> <li>○ Optimisation/maintenance of operating performance</li> </ul>
End of life	<i>Not specifically addressed</i>
<b>Extended LCA boundary to capture 'induced' impacts</b>	
Transport	<ul style="list-style-type: none"> <li>○ Impact of private cars on the capacity of local roads</li> </ul>
<b>In-direct influences on the design, service life and value</b>	
Cost and value	<ul style="list-style-type: none"> <li>○ Operational and maintenance costs</li> </ul>
Functional quality	<ul style="list-style-type: none"> <li>○ Controllability</li> <li>○ Air temperature and relative humidity</li> <li>○ Indoor air quality and ventilation</li> <li>○ Daylighting and illumination</li> </ul>

Adapted from iiSBE (2014)

**Table 4.9. SB Tool 2014: Contribution of categories and selected criteria (mid scope)**

Category headings and selected relevant sub-criteria	% contribution achievable	Potential contribution to total score
Site assessment		
Site regeneration and development, urban design and infrastructure	0.8%	9.3%
- Use of vegetation to provide ambient cooling	3.0%	
- Orientation for passive solar gain and ventilation	2.0%	
- Development density to ensure efficient land use (neighbourhood scale)	3.0%	
- Extent of on-site parking facilities	1.6%	
Building assessment		
Energy and resource consumption		35.4%
- Embodied non-renewable energy in construction materials	10.1%	
- <u>Mandatory</u> : Consumption of non-renewable energy	10.1%	
- <u>Mandatory</u> : Degree of re-use of suitable existing structures	3.0%	
- Use of virgin non-renewable materials	2.4%	
- <u>Mandatory</u> : Use of water for occupant needs	3.6%	
- Use of water for irrigation purposes and building systems	6.1%	
Environmental loadings		28.5%
- <u>Mandatory</u> : GHG emissions from primary energy use	12.6%	
- Impact of private cars on capacity of local roads	0.5%	
- Contribution to heat island effect	3.2%	
Indoor environmental quality		5.1%
- <u>Mandatory</u> : CO <sub>2</sub> concentrations in indoor air	0.6%	
- Effectiveness of natural ventilation	3.0%	
- Air temperature and relative humidity	1.2%	
- <u>Mandatory</u> : Daylighting and illumination	0.6%	
- Noise and acoustics	0.2%	
Service quality		4.9%
- Spatial efficiency	0.2%	
- Controllability	0.3%	
- Optimisation/maintenance of operating performance	1.4%	
Social, cultural and perceptual aspects		4.0%
- <u>Mandatory</u> : universal access on site and within the building	1.8%	
Cost and economic aspects		1.5%
- Operating and maintenance cost	0.6%	
- <u>Mandatory</u> : Affordability of residential rents and cost levels	0.3%	

Source: iiSBE (2014)

#### 4.3.2.5 Building design and construction, LEED

The Leadership in Energy and Environmental Design (LEED) system was developed by the US Green Building Council and launched in 2000. LEED 'Building design and construction' is targeted at new constructions and major renovations. It consists of five environmental categories and an innovation in design category<sup>156</sup>.

The credit requirements under each category are written for the USA context as it predominantly based on US standards developed by bodies such as ASHRAE and ASTM. 'Alternative Compliance Paths' are, however, described for projects seeking to become certified outside of the USA. The credits assigned are weighted according to their significance using LEED's weighting methodology. A number of criteria are set as pre-requisites within each category. The LEED criteria are analysed in Tables 4.10 and 4.11.

**Table 4.10. LEED Building design and construction, life cycle boundaries, scope and prioritisation**

Aspect of building	Assessment and reporting tool scope
<b>Building life cycle stages (as defined by EN 15978)</b>	
Product	<ul style="list-style-type: none"> <li>○ Building life cycle impact reduction</li> </ul>
Construction	<ul style="list-style-type: none"> <li>○ Construction pollution prevention</li> <li>○ Construction/demolition waste management planning</li> <li>○ Commissioning and verification</li> </ul>
Use	<ul style="list-style-type: none"> <li>○ Minimum or optimised energy performance</li> <li>○ Building-level energy metering</li> <li>○ Renewable energy production</li> <li>○ Water use reduction</li> <li>○ Rainwater management</li> <li>○ Heat island reduction</li> <li>○ Storage and collection of recyclables</li> </ul>
End of life	<ul style="list-style-type: none"> <li>○ Construction/demolition waste management planning</li> </ul>
<b>Extended LCA boundary to capture 'induced' impacts</b>	
Transport	<ul style="list-style-type: none"> <li>○ Surrounding density and diverse uses</li> <li>○ Access to quality transit</li> <li>○ Bicycle facilities</li> <li>○ Reduced parking footprint</li> </ul>
<b>In-direct influences on the design, service life and value</b>	
Cost and value	<i>Not specifically addressed</i>
Functional quality	<ul style="list-style-type: none"> <li>○ Indoor air quality performance and strategy</li> <li>○ Thermal comfort</li> <li>○ Interior lighting and daylight</li> <li>○ Quality views</li> <li>○ Acoustic performance</li> </ul>

*Adapted from US GBC (2014)*

**Table 4.11. LEED New Construction and Major Renovation: Contribution of categories and selected criteria**

Category	Credits achievable	Credits (out of 110)
<i>Location and transportation</i>		15%
- Surrounding density and diverse uses	4.6%	
- Access to quality transit	4.6%	
- Bicycle facilities	0.9%	
- Reduced parking footprint	0.9%	
<i>Sustainable sites</i>		9%
- Construction activity pollution prevention	<i>Pre-requisite</i>	
- Rainwater management	2.8%	
- Heat island reduction	1.8%	
<i>Water efficiency</i>		10%
- Outdoor and indoor water use reduction	<i>Pre-requisite</i>	
- Building-level water metering	<i>Pre-requisite</i>	
- Further water use reduction	7.3%	

<sup>156</sup> US Green Building Council, *LEED 2009 for new construction and major renovations*, Updated version November 2011.

<i>Energy and atmosphere</i>		30%
- Commissioning and verification	<i>Pre-requisite</i>	
- Minimum energy performance	<i>Pre-requisite</i>	
- Building-level energy metering	<i>Pre-requisite</i>	
- Enhanced commissioning	5.5%	
- Optimised energy performance	16.5%	
- Renewable energy production	2.8%	
<i>Materials and resources</i>		12%
- Storage and collection of recyclables	<i>Pre-requisite</i>	
- Construction/demolition waste management planning	<i>Pre-requisite</i>	
- Building life cycle impact reduction	4.6%	
- Environmental Product Declarations	1.8%	
- Sourcing of raw materials	1.8%	
- Material ingredients	1.8%	
<i>Indoor environmental quality</i>		15%
Minimum indoor air quality performance	<i>Pre-requisite</i>	
Enhanced IAQ strategies	1.8%	
Low-emitting materials	2.8%	
Indoor IAQ assessment	1.8%	
Thermal comfort	0.9%	
Interior lighting	1.8%	
Daylight	2.8%	
Quality views	0.9%	
Acoustic performance	0.9%	
<i>Innovation in design</i>	-	6%
<i>Regional priority</i>	-	4%

Source: US GBC (2014)

### 4.3.3 Investor and occupier reporting tools

In this section five tools that are currently used by property investors and occupiers at EU and international level to benchmark the performance of property portfolios are briefly analysed using the previously described framework for comparison of macro-objectives.

The tools have been selected as they are understood to be those most commonly used in the market, or are a commonly cited reference points for industry guidance or internal reporting. The selection is not intended to be exhaustive, but instead to provide an insight into the most common reporting priorities for some of the largest property investors in the EU market.

The main commonality between the tools analysed is a focus on the operation of commercial buildings such as offices. The increasing use of such tools reflects a shift by investors towards greater awareness of the long-term, life cycle costs, benefits and risks associated with ownership and occupancy<sup>157</sup>.

The five tools that have been selected for analysis are:

- The Environment Code, Investment Property Databank (IPD) (Origin: UK)
- Construction and Real Estate, the Global Reporting Initiative (Origin: International)
- Global Real Estate Sustainability Benchmark (GRESB), Green Building Certification Institute (Origin: USA/Netherlands)
- Green Rating, Green Rating Alliance (Origin: European)
- Real Estate Environmental Benchmark, Better Buildings Partnership (Origin: UK)

A feature of these tools is that they form part of wider company or fund reporting on Corporate Social Responsibility (CSR) and Socially Responsible Investment (SRI) policies. This means that their environmental criteria tend to be embedded within a broader reporting framework.

<sup>157</sup> Lutzkendorf.T and D.Lorenz (2005) *Sustainable property investment: valuing sustainable buildings through property performance assessment*, Building Research & Information, 33(3), p.212-234

For each tool the same macro-objective framework is used as in Section 4.3.1. When analysing the contribution of categories and criteria to the total potential score, only those sub-criteria of direct relevance are highlighted.

The policies and criteria of specialist property portfolios such as Aviva's igloo Regeneration Fund (UK) are also of relevance to this study, but leading examples of SRI policies such as igloo's Footprint policy<sup>158</sup> are not specifically analysed in this working paper.

#### 4.3.3.1 The Environment Code, Investment Property Databank

The Investment Property Databank (IPD) Environment Code is a framework for collecting property related environmental information. It was launched in 2008. The aim of the Code is to respond to investor and occupier demands for performance data that can be linked to financial performance and the management of property portfolios. The Code is supported by Barclays and Bureau Veritas in association with the Sustainable Building (SB) Alliance. The Code focusses attention on energy use, water usage and waste production, although the supporting 'health check' also covers travel, pollution and health. The Environment Code's criteria and credits and analysed in tables 4.12 and 4.13.

**Table 4.12. IPD Environment Code, life cycle boundaries, scope and prioritisation**

Aspect of building	Assessment and reporting tool scope
<b>Building life cycle stages (as defined by EN 15978)</b>	
Product	<i>Not specifically addressed</i>
Construction	<i>Not specifically addressed</i>
Use	<ul style="list-style-type: none"> <li>○ Energy use (total and sub-metered)               <ul style="list-style-type: none"> <li>- Electricity use (renewable and non-renewable)</li> <li>- Fuel use (fossil and renewable)</li> <li>- Other energy use (communal and renewable)</li> <li>- CO<sub>2</sub> equivalent emissions</li> </ul> </li> <li>○ Water use               <ul style="list-style-type: none"> <li>- Sourced water</li> <li>- Harvested and recycled water</li> </ul> </li> <li>○ Waste               <ul style="list-style-type: none"> <li>- Landfilled and incinerated</li> <li>- Recycled and composted</li> </ul> </li> </ul>
End of life	<i>Not specifically addressed</i>
<b>Extended LCA boundary to capture 'induced' impacts</b>	
Transport	<ul style="list-style-type: none"> <li>○ Public transport facilities</li> <li>○ Cycling, alternative vehicle and car pool facilities</li> </ul>
<b>In-direct influences on the design, service life and value</b>	
Cost and value	<i>Not specifically addressed</i>
Functional quality	<ul style="list-style-type: none"> <li>○ Frequency of checks made on HVAC, temperature and air quality</li> <li>○ % workstation access to daylight and outside view</li> <li>○ Personal control over indoor climate (temperature and lighting)</li> <li>○ Occupier surveys</li> </ul>

Source: IPD Environment Code (2010)

<sup>158</sup> igloo Regeneration Fund, Aviva Investors, UK <http://www.igloo.uk.net/>

**Table 4.13. IPD Code, Environmental Health Check weighting of sections**

Section	Selected credits	Total credits achievable	Weighting
Management - Energy, water and waste management plan - Health and wellbeing management plan - Travel and transport management plan	30 10 10	80	16%
Energy - Type of indoor climate system - Seasonal and occupancy linked heating, cooling and lighting - Type of lighting and glazing - Type of energy used for HVAC and hot water - Proportion of non-renewable energy offset - Extent of sub-metering	10 20 20 10 10 10	120	24%
Water - Extent of water efficient fittings	20	45	9%
Waste - Extent of general waste separation - Extent of other wastes collected separately	10 10	50	10%
Travel - Extent of 'green travel plan' for the building - Public transport facilities nearby - Extent of cyclist facilities - Alternative vehicle facilities - Car pooling facilities and parking	10 10 10 10 5	55	11%
Pollution	-	50	10%
Health - Frequency of checks made on HVAC, temperature and air quality - % workstation access to daylight and outside view - Personal control over indoor climate (temperature and lighting)	40 10 10	100	20%

Source: IPD Environment Code (2010)

#### 4.3.3.2 Construction and Real Estate Sector Supplement, Global Reporting Initiative

The Global Reporting Initiative (GRI) was established in the US by CERES and UNEP. It provides organisations in a range of sectors with sustainability reporting tools. The GRI Construction and Real Estate Sector Supplement (CRESS) was launched in 2011<sup>159</sup>.

The CRESS is targeted at companies that invest in, develop, construct or manage buildings. It includes a specific sub-section on the Environment, addressing the themes of materials; energy; water; biodiversity; emissions, effluents and waste; and transport. No weighting or credit system is understood to be applied to each environmental reporting aspect. Each is identified as a 'core' reporting aspect. The GRI CRESS reporting aspects are analysed in Table 4.14.

<sup>159</sup> Global Reporting Initiative, *Construction and Real Estate*, <https://www.globalreporting.org/reporting/sector-guidance/sector-guidance/construction-and-real-estate/Pages/default.aspx>

**Table 4.14. GRI CRESS, life cycle boundaries, scope and prioritisation**

Aspect of building	Assessment and reporting tool scope
<b>Building life cycle stages (as defined by EN 15978)</b>	
Product	<ul style="list-style-type: none"> <li>○ Materials               <ul style="list-style-type: none"> <li>- By weight, value of volume</li> <li>- Recycled and re-used input materials</li> </ul> </li> </ul>
Construction	<ul style="list-style-type: none"> <li>○ GHG emissions               <ul style="list-style-type: none"> <li>- GHG emissions intensity of construction activity</li> </ul> </li> </ul>
Use	<ul style="list-style-type: none"> <li>○ GHG emissions               <ul style="list-style-type: none"> <li>- Total direct and indirect emissions</li> <li>- GHG emissions intensity of buildings</li> </ul> </li> <li>○ Energy               <ul style="list-style-type: none"> <li>- Direct consumption by primary source</li> <li>- Indirect consumption by primary source</li> <li>- Building energy intensity</li> <li>- Savings due to conservation and efficiency</li> </ul> </li> <li>○ Water use               <ul style="list-style-type: none"> <li>- Total withdrawal by source</li> <li>- Water recycled and re-used</li> <li>- Building water intensity</li> </ul> </li> <li>○ Waste               <ul style="list-style-type: none"> <li>- Total weight of waste by type and disposal method</li> </ul> </li> </ul>
End of life	<i>Not specifically addressed</i>
<b>Extended LCA boundary to capture 'induced' impacts</b>	
Transport	<ul style="list-style-type: none"> <li>○ Significant impacts of transporting members of the workforce</li> </ul>
<b>In-direct influences on the design, service life and value</b>	
Cost and value	<i>Not specifically addressed</i>
Functional quality	<i>Not specifically addressed</i>

Source: GRI (2011)

#### 4.3.3.3 Global Real Estate Sustainability Benchmark (GRESB)

GRESB is an international tool developed to support benchmarking and reporting by institutional investors. It is based around an annual survey, the results of which are presented as a 'scorecard' and in an anonymised way in order to support benchmarking comparisons<sup>160</sup>. The survey includes environmental, social and governance issues.

Seven sustainability aspects are addressed, including a specific scoring for 'new constructions and major renovations'. No weighting or credit system is applied to each environmental reporting aspect. GRESB is aligned with GRI CRESS and a full range of building typologies are included within the survey, including residential assets, allowing for a combination of data collection on the performance of new and existing assets. The GRESS reporting aspects are analysed in Table 4.15.

<sup>160</sup> Global Real Estate Sustainability Benchmark, *GRESB participant guide 2015*, <https://gresb.com/survey>



**Table 4.15. GRESB, life cycle boundaries, scope and prioritisation**

Aspect of building	Assessment and reporting tool scope
<b>Building life cycle stages (as defined by EN 15978)</b>	
Production	<ul style="list-style-type: none"> <li>○ Policies on construction materials               <ul style="list-style-type: none"> <li>- Local extraction and recovery</li> <li>- Rapidly renewable, low embodied carbon and recycled materials</li> <li>- Ease of recycling</li> <li>- Low emitting materials</li> </ul> </li> </ul>
Construction	<ul style="list-style-type: none"> <li>○ Targets for waste reduction, re-use and recycling</li> </ul>
Use phase	<ul style="list-style-type: none"> <li>○ Energy consumption               <ul style="list-style-type: none"> <li>- Minimum energy efficiency requirements, including net-zero energy codes/standards</li> <li>- Generation from on-site renewable sources</li> <li>- Savings due to implemented measures</li> </ul> </li> <li>○ Water consumption               <ul style="list-style-type: none"> <li>- Minimum water efficiency requirements</li> <li>- Savings due to implemented measures</li> </ul> </li> <li>○ Metered and sub-metered data collection from operation               <ul style="list-style-type: none"> <li>- Energy, GHG emissions, water and waste</li> </ul> </li> </ul>
End of life	<i>Not specifically addressed</i>
<b>Extended LCA boundary to capture 'induced' impacts</b>	
Transport	<ul style="list-style-type: none"> <li>○ Site selection for connection multi-modal transit networks</li> <li>○ Location of projects within existing developed areas</li> <li>○ Employee travel and transportation</li> </ul>
<b>In-direct influences on the design, service life and value</b>	
Cost and value	<i>Not specifically addressed</i>
Functional quality	<ul style="list-style-type: none"> <li>○ Building measures focussed on occupant wellbeing               <ul style="list-style-type: none"> <li>- Daylight</li> <li>- Natural ventilation</li> <li>- Occupant controls</li> <li>- Indoor air quality monitoring</li> <li>- Provision of green/social spaces</li> </ul> </li> <li>○ Data collection               <ul style="list-style-type: none"> <li>- Indoor environmental quality</li> <li>- Occupier comfort and satisfaction</li> </ul> </li> </ul>

Source: GRESB (2015)

#### 4.3.3.4 Green Rating, the Green Rating Alliance

The Green Rating Alliance was founded in 2009 by a number of major real estate investors, including AEW, AXA, Allianz and Invesco<sup>161</sup>. Its assessment tool was launched in 2011 and aims to assess, monitor and improve the sustainability performance of existing buildings. Their tools seek to allow for the benchmarking of all buildings, in contrast to assessment schemes which only offer a pass or fail system. The assessment system comprises two elements, with six metrics which can be applied to office, retail and logistic buildings:

1. Quantitative based on bills: Energy use, carbon dioxide emissions and water use;
2. Qualitative based on interviews and audits: Transport, waste and wellbeing.

The quantitative metrics are intended to reflect service charges and total occupancy costs, while the qualitative metrics reflect on occupier locational decisions and loyalty. The Green Rating tool is analysed in Table 4.16.

<sup>161</sup> Green Rating Alliance, *Green rating tool*, <http://www.green-rating.com/index.php/methodology/green-rating-tool/>

Performance is third party assessed and submitted on an anonymised basis so as to allow comparisons to be made across the portfolios of the members. Benchmarking is made based on the intrinsic, actual and potential performance of a building.

**Table 4.16. Green Rating: life cycle boundaries, scope and prioritisation**

Aspect of building	Assessment and reporting tool scope
<b>Building life cycle stages (as defined by EN 15978)</b>	
Product	<i>Not specifically addressed</i>
Construction	<i>Not specifically addressed</i>
Use	<ul style="list-style-type: none"> <li>○ GHG emissions               <ul style="list-style-type: none"> <li>- Total direct and indirect emissions</li> </ul> </li> <li>○ Energy               <ul style="list-style-type: none"> <li>- Total consumption by primary source</li> </ul> </li> <li>○ Water use               <ul style="list-style-type: none"> <li>- Total consumption by primary source</li> </ul> </li> <li>○ Waste               <ul style="list-style-type: none"> <li>- Total weight of waste by type and disposal method</li> </ul> </li> </ul>
End of life	<i>Not specifically addressed</i>
<b>Extended LCA boundary to capture 'induced' impacts</b>	
Transport	<ul style="list-style-type: none"> <li>○ Transport modes used by occupiers</li> </ul>
<b>In-direct influences on the design, service life and value</b>	
Cost and value	<i>Not specifically addressed</i>
Functional quality	<ul style="list-style-type: none"> <li>○ Aspects of wellbeing relating to the building and location</li> </ul>

Source: Green Rating Alliance (2015)

#### 4.3.3.5 Real Estate Environmental Benchmark, the Better Buildings Partnership

The Real Estate Environmental Benchmark (REEB) is an operational benchmark of the performance of existing commercial properties in the UK that are owned by members of the London Better Buildings Partnership<sup>162</sup>. Members of the BBP include investors, fund managers and property owners, including Aviva, Deutsche Bank, Hammerson and Legal & General.

Data on energy, water and waste is collected, validated and reported on for three year periods. Based on the pool of data from the 'in-use' performance of properties benchmarks are derived which allow for performance comparisons to be made between similar property types. The BBP has also developed a 'sustainability benchmarking toolkit' to support the benchmarking of carbon emissions from assets<sup>163</sup>. The REEB is analysed in Table 4.17.

**Table 4.17. Real Estate Environmental Benchmark: life cycle boundaries, scope and prioritisation**

<sup>162</sup> Better Building Partnership, *Real Estate Environmental Benchmark*, <http://www.betterbuildingspartnership.co.uk/our-priorities/measuring-reporting/real-estate-environmental-benchmark> and <http://www.jll.co.uk/united-kingdom/en-gb/services/developers-and-investors/sustainability/real-estate-environmental-benchmark>

<sup>163</sup> Better Building Partnership (2010) *Sustainability Benchmarking Toolkit for Commercial Buildings - Principles for best practice*

Aspect of building	Assessment and reporting tool scope
<b>Building life cycle stages (as defined by EN 15978)</b>	
Product	<i>Not specifically addressed</i>
Construction	<i>Not specifically addressed</i>
Use	<ul style="list-style-type: none"> <li>○ Energy <ul style="list-style-type: none"> <li>- Consumption per m<sup>2</sup> of Net Lettable Area by primary source</li> </ul> </li> <li>○ Water use <ul style="list-style-type: none"> <li>- Consumption per person per working day and per m<sup>2</sup> of Net Lettable Area</li> </ul> </li> <li>○ Waste <ul style="list-style-type: none"> <li>- Proportion of waste diverted and segregate for recycling, re-use and composting</li> </ul> </li> </ul>
End of life	<i>Not specifically addressed</i>
<b>Extended LCA boundary to capture 'induced' impacts</b>	
Transport	<i>Not specifically addressed</i>
<b>In-direct influences on the design, service life and value</b>	
Cost and value	○ Operating costs per m <sup>2</sup> of Net Lettable Area per year
Functional quality	<i>Not specifically addressed</i>

Source: Better Buildings Partnership (2015)

### Summary of findings on assessment and reporting tools

- The assessment tools tend to focus on the design of new-build or renovation projects, whereas the reporting tools tend to focus on existing building performance.
- In general the multi-criteria schemes have mandatory criteria or pre-requisite criteria that must be complied with.
- Weightings applied to the remaining criteria use as their starting point a generic set of weightings which are then tailored to the national or regional context. The generic weighting therefore provides a starting point for the prioritisation of criteria.
- The scoring or weighted contribution of criteria areas within the majority of the tools analysed is determined by panels of experts, as well as wider stakeholder consultations. Only one appears to be directly shaped by LCA evidence.
- Primary energy use or CO<sub>2</sub> emissions in the use phase are weighted as the most significant in all tools followed by aggregated scores or combinations of criterion for construction material impacts.
- Water use and waste arisings (construction or use phase) are weighted less significantly in assessment tools but are commonly included in reporting tools.
- Location close to public transport connections is weighted significantly in two tools, reported on in three tools and is addressed to a lesser extent in three others.
- The aggregated scores for common combinations of occupant comfort and wellbeing criteria – typically IAQ, thermal comfort, daylighting and acoustics - are weighted significantly in all assessment tools, but are only weighted significantly in one reporting tool.
- Some tools address the areas of cost and value, with a focus on tools such as Life Cycle Costing and issues such as the future flexibility and adaptability of properties.

## 5. Outlook on the scope and macro-objectives based on the initial evidence and stakeholder consultation

In this section the findings from the analysis in Chapters 2, 3 and 4 are discussed and initial conclusions drawn on how they may influence the outlook on the selection of macro-objectives for EU buildings. A summary of the responses of stakeholders to questions posed during the stakeholder consultation during June and July 2015 is then presented for each section, together with thematic comments received, for each chapter. These summaries should be read in conjunction with the minutes of the 16<sup>th</sup> June 2015 main stakeholder working group meeting held in Brussels.

### 5.1 The scope of building typologies to be addressed

Of the estimated 233 million residential and commercial buildings in the EU in 2013, residential buildings account for approximately 75% of the total floor area (m<sup>2</sup>). This is followed by retail (7%), offices (6%), education (4%), hotels and restaurants (3%) and healthcare (2%). Other uses such as industrial and sports facilities account for approximately 4% of the total floor area. Residential buildings account for the largest proportion of the EU building stock and should therefore be a focus for attention.

The distinct variations in usage patterns, form, servicing and construction techniques between the predominant types of public and commercial buildings are potential distinguishing factors. For example, those designed for high intensity, day to day occupation by people – namely offices, education facilities and hotels – could be a further focus of attention. Retail, industrial and sports facilities tend to consist of large volume spaces with a very different construction form and servicing needs.

The age of the buildings is a major consideration in terms of environmental performance. The majority of the residential building stock pre-dates more stringent building standards to regulate energy use. With an estimated annual replacement rate of between 1-2% and a renovation rate of between 0.5% and 1.2%, the performance of the existing residential buildings is therefore significantly more important within the short to medium term than new buildings.

Europe's office building stock is also dated. For example, in Germany, 59% of the stock dates from between 1950 and 1990 and, in the UK, 22% dates from before 1960. The average annual rate of replacement of offices across Europe is cited as being between 1% and 2%, but can be closer to 3% in major centres such as London. With the economic crisis, the market has seen an increased focus on the better use of existing building assets.

#### **Questions posed to stakeholders on *the scope of building typologies to be addressed***

- *Should the focus be on residential and office buildings, or should other buildings intended for high intensity, day to day occupation be included? e.g. schools, hotels*

In general, stakeholders wanted the scope to be broad enough to cover all types of buildings but with priority given to residential buildings because they account for some 75% of building stock and to public office buildings and schools for their potential to act as benchmarks for public authorities.

It was pointed out that these questions are perhaps too early to consider in the project since Macro-objectives should apply to the entire building sector and that it is only when indicators are being discussed that building type becomes more relevant.

- *Should large volume retail, industrial and storage buildings be kept within the scope given that they have very different construction and servicing needs?*

These were not, in general, seen as an initial focus for attention.

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- *In addition to new buildings, should the scope encompass all existing buildings or only the potential for performance improvement at the point of renovation?*

Mixed opinions were expressed about whether these macro-objectives should apply to new, renovated or existing buildings. Although stakeholders wanted all three types of building included in the scope, there was a general view that for existing buildings, the focus should be on the point of renovation. Support was expressed by some stakeholders for the inclusion of historical buildings too.

An argument in favour of focussing on the point of renovation was that some 90% of all building stock in 2050 already exists today and will most likely be renovated before then and so both existing and renovated buildings should be included. However, caution was urged that assessment of existing buildings should not be used as an excuse to demolish and rebuild without considering renovation first.

## 5.2 Macro-objectives identified from EU and Member State policies

From the initial review in Chapter 2 of this working paper, the EU environmental policy frameworks, requirements and initiatives that are of more direct relevance to the identification of building resource efficiency macro-objectives have been identified as follows:

- Reduction of greenhouse gas emissions: The EU climate and energy package establishes legally binding greenhouse gas reduction targets. Consumption of primary energy by buildings in the use phase accounts for a significant proportion of the EU's CO<sub>2</sub> emissions. Legislation has therefore been put in place which requires the implementation of minimum standards and, in the medium to long term, a 'near zero energy' requirement for new buildings and the progressive energy efficient renovation of the existing building stock. Climate change adaptation is a related area of focus for the Commission because of the cost and risks it may pose.
- Resource use and its impact on natural capital: The Roadmap to a Resource Efficient Europe was followed-up by the development of resource efficiency indicators to define, monitor and guide progress towards a low carbon and resource efficient EU. Those indicators that can be directly related to the built environment consist of:
  - Resource use: Material flow intensity related to GDP, energy productivity, share of renewable energy, water use, urban land use;
  - Environmental pressures on 'natural capital': greenhouse gas emissions, water exploitation;
  - Thematic indicators: Urban air quality (PM<sub>10</sub> emissions).

Water use is the subject of a Blueprint for action at EU level. Greater efficiency is proposed in order to reduce stress but measures are to be set at local/regional level depending on water stress. Notably, mineral waste and construction waste recycling are specifically excluded from the indicators.

- Waste reduction and circular material flows: The Waste Framework Directive establishes a 2020 target for 70% of Construction and Demolition Waste to be re-used, recycled or recovered. Given the wide variation in the current performance of Member States, ranging from 10% to 90%, this represents a significant challenge. This target is complemented by resource efficiency objectives to reduce and transform material flows, with mineral flows associated with construction accounting for approximately 40% of EU material flows and, based on evidence from Germany, very significant material stocks. The new Circular Economy package has refocused attention on recycling and re-use, as well as newer concepts such as the future adaptability of buildings.
- Resource efficient urban development: A theme that recurs in the 7<sup>th</sup> EAP, the Roadmap to a Resource Efficient Europe, EU urban policy and in leading Member State resource efficiency strategies is the need to interrelate urban planning, infrastructure, and building form and location. The multiple resource efficiency benefits of compact, land efficient and public transport connected buildings are highlighted and cited as an objective.

Together these high level objectives provide a clear starting point for identifying macro-objectives. Several of these macro-objectives are legally binding but now require a drive for implementation at building level.

Others are more complex as they imply further investigation in order to relate them to buildings, or because they integrate several facets of building design and urban planning.

The high level resource efficiency objective of reducing domestic material flows requires further attention. This is because a simple focus on domestic material flow does not capture 'hidden' flows and impacts from imported materials. These may include environmental pollution from abiotic resource extraction, ecosystem damage from biotic resource extraction and relative abiotic resource scarcity.

#### **Questions posed to stakeholders on EU and Member State policies**

- *Which aspects of EU frameworks, regulations and initiatives should be the priority focus to identify macro-objectives for this study?*

Stakeholders specifically mentioned the Energy Performance of Buildings Directive (2010/31/EU), the Energy Efficiency Directive (2012/27/EU), the Construction Products Regulation (EU) No 305/2011, the Waste Framework Directive (2008/98/EU) and the Timber Regulation (EU) No 995/2010 as pieces of legislation that should be used as a focus to help identify macro-objectives for resource efficient buildings.

- *Do the current EU resource efficiency indicators provide a useful starting point for macro-objectives?*

Overall, it was considered that current EU resource efficiency indicators are too strongly based on mass and volumetric factors for materials and that a more holistic approach should be taken that accounts for factors such as health and wellbeing, waste reuse/recycling and hazardous substances.

- *Are evaluations of the relative success or impact of Member State resource efficiency policies available?*

No examples of the success or impact of Member State resource efficiency policies were put forward.

- *Are there examples of Member State policy frameworks and macro-objectives on resource efficiency that are linked to building performance indicators?*

Display Energy Certificates in Public buildings and the Carbon Reduction Commitment Energy Efficiency Scheme in the UK were cited as a useful drivers for behavioural change in building management. Building regulations in the UK also limit the design water consumption per person.

Reference was also made to the requirement for Abiotic Depletion Potential (ADP) and embodied energy to be calculated for all new buildings in the Netherlands, the Belgian Law of 21 December 1998 regarding sustainable product standards and the implementation of building performance indicators for energy efficiency and indoor climate in Denmark and France.

- *Thematic comments on EU and Member State policies*

It was suggested that it is perhaps better to ask 'What are meaningful macro-objectives for buildings that could link to EU policy?'. In general, stakeholders believe that most relevant macro-objectives for buildings are well defined already in EU policy. The problem is how to implement these at the building level.

In general, stakeholders found the review of relevant EU policies helpful but would also appreciate some information about the degrees of success of these policies and how their impact is measured or monitored and a 'gap-overlap' analysis showing how these policies fit together in relation to buildings. It was asked whether it would be appropriate to also include future policy proposals (namely the EU Building Observatory, the Revised Circular Economy Package and the Accessibility Act) and also the existing '*Communication on The Urban Dimension on EU Policies – Key Features of an EU Urban Agenda*'.

It was noted that whilst the Energy Performance of Buildings Directive lays out a path towards nearly zero energy buildings, it leaves the precise definition of what nearly zero energy means to regional or national authorities. Greater clarity was therefore felt by some stakeholders to be needed as to what is meant exactly by the term 'Near Zero Energy Buildings' as well as a better understanding of the potential cost implications for sustainable buildings if they are to be embraced by the market.

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A clearer definition overall of what is meant by the term 'resource efficiency' and the relationship between this definition and 'environmental performance' in the context of this study was requested so that it can be better linked to policy objectives.

To date in relation buildings, significantly more focus has been given to energy consumption during the use phase than to material resources and very little, to no focus has been made on land-use and biodiversity impacts of buildings. Possible areas to consider for macro-objectives could also therefore include accounting for the embodied energy of construction materials, the building structure service life and design suitability for local climate.

It was pointed out that the presence of Substances of Very High Concern (SVHCs) in materials used in buildings and their possible emissions could also be mentioned as provision for this is made in both the Construction Products Regulation and REACH Regulation Articles 31 and 33.

Other notable comments on Chapter 2 included:

- the potential conflict between using timber for low carbon building structures with the land use required to produce raw materials,
- a request to better link indicators from Member State policies to their macro-objectives, and
- a complaint about the apparent bias against downcycling which could potentially be the best environmental solution if site specific factors are taken into account on a per project basis.

### **5.3 Macro-objectives identified from 'hot spots' for improving resource efficiency**

#### **5.3.1 Environmental and resource efficiency 'hot spots'**

Environmental and resource efficiency 'hot spots' for the improved performance of buildings were identified in Chapter 3 of this working paper. These are based on the findings and results of technical studies of buildings and major construction materials from both sectoral and building typology perspectives. The use of normalisation and weighting in LCA studies is the subject of controversy and most of the studies reviewed do not carry out these steps, making it more difficult to clearly prioritise hot spot environmental impacts. Nevertheless, it is possible to identify those of significance and, with reference to Chapter 2 of this paper, make the link to EU policy priorities.

Overall the use phase of buildings is the most significant in the life cycle of buildings because of the Global Warming Potential of emissions related to primary energy use. But the balance is changing as the 'regulated' energy used by buildings reduces and more energy and resource intensive construction elements may be required to achieve higher performance. Increased cooling and auxiliary energy use, as well as 'unregulated' energy use associated with occupiers of buildings, are trends identified in some Member States.

From a top down sectoral perspective, the study carried out for the European Resource Efficiency Platform (EREP) provides the most comprehensive overall view of the sector. The findings recommend a focus on large flows of materials. This would entail a focus on life cycle impacts associated with mineral and metals flows, with concrete, brick, ceramic, steel, copper and aluminium having been identified. Notably, timber is not addressed because of difficulties evaluating the environmental impacts associated with forestry using current LCA methodologies.

As was noted in Section 5.1, material flow accounting using indicators such as DMC or TMC cannot reflect the distinct range of impacts associated with these construction materials. The most significant impacts associated with each of these major material flows should form the basis for macro-objectives. At a simple level, and as a starting point for discussion, this could focus on the following hot spots:

- Concrete: Greenhouse gas emissions from the production of cement production and, to a lesser extent, material flows and the transport of the mineral (abiotic) resources such as coarse aggregate.
- Steel, copper and aluminium: Greenhouse gas emissions from the production of steel, as well as 'hidden' (abiotic) resource flows, GHG emissions and toxicity arising from the extraction and processing of ore.

- Timber: Total biotic resource flows, as well as the greenhouse gas emissions and ecosystem damage that may be caused by the cultivation of the raw material. Engineered timber may also be energy intensive to manufacture.

At a building level, the importance of impacts related to the materials used for the load bearing structures, external walls and facades was clearly highlighted by all the studies reviewed. As well as macro-objectives relating to the distinct impacts of these materials, the potential to define macro-objectives from a design and engineering perspective could also be considered. For example, the comparative improvement potential of the re-use of existing concrete structures and the light weighting of new structures can be as significant as changes in mix design to reduce the cement content. The fundamental structural design parameters and intended lifespan should be used when evaluating the life cycle impacts of different material options. A further area of improvement relates to the efficiency and intensity of use of structures, space and land. There is significant evidence that for domestic buildings, more compact building forms such as apartments and terraces are more land, material and energy efficient. In contrast, taller building forms also require more material intensive structures in function of the number of floors. The choice of functional unit is therefore critical in defining how the intensity of resource use will be addressed.

Linked to these issues, the efficiency with which space is used within building designs – both on a temporal and spatial basis - and future flexibility in the ability to change layouts and uses can also have a significant influence on comparative LCA performances. For example, depth of floor plates and floor to ceiling heights have been identified as a factor influencing the future potential for changes of use.

An area that was found to be less well defined was the relative contribution of materials used for subsequent maintenance and refurbishment during the service life. Analyses of embodied energy and greenhouse gas emissions suggests that this component of the use phase may be significant enough to consider alongside the product phase. There is also evidence that the inclusion of toxicity impact categories within an LCA reveals impacts relating to the production phase, but also finishing and fit out materials replaced during the use phase.

Externalised, 'induced' effects beyond the conventional LCA boundary of a building could also be considered. Decisions relating to the location of buildings are identified as being of significance. This is because the accessibility of a home or commercial building to public transport networks and amenities, in combination with the overall urban density, tend to have a strong correlation with transport energy use.

#### **Questions posed to stakeholders on *macro-environmental 'hot spots'***

- *Which building uses/typologies should be prioritised at an EU level based on their environmental significance?*

A mixed reaction was received from stakeholders regarding what building typologies / uses to prioritise. Some commented that no use / typology should be prioritised since macro-objectives chosen should apply to all building uses and typologies.

Considering time constraints on the study, most stakeholders wanted residential properties to be prioritised due to the fact that they dominate current building stock and because they are currently the least monitored.

Some stakeholders wanted public office buildings to be prioritised too due to their potential to act as showcase exemplars and also due to the fact that public authorities are generally involved in all stages of the building lifecycle (development, ownership, occupation and renovation/demolition). Other stakeholders felt that public office buildings were already quite well covered by existing schemes and by the Energy Performance of Buildings Directive and so the potential for improvement in schools and hospitals should also be recognised.

- *How should the resource efficiency of the most common structural materials be addressed within the macro-objectives?*

Caution was urged by some stakeholders to try to avoid talking in too much detail about materials before any macro-objectives have been decided. The statement that '*structures appear as the main hot-spot for material impacts*' was questioned by some stakeholders. They considered that this may not always be the case in long life buildings that may be subject to several non-structural renovations and refits during their lifetime.



It was commented by several stakeholders that considering Abiotic Depletion Potential (ADP) for the most common structural materials would not be a useful approach because these materials or their feedstock(s) are generally widely available. Instead, it would be better to consider the Global Warming Potential (GWP) of materials based on emissions from their extraction and processing, and that this should be considered within the context of the overall life cycle greenhouse gas emissions.

The need to also account for non-structural materials was mentioned as well as the fact that many material choices are influenced by local traditions and material availability. In general, approaches to resource efficiency should not favour one material over another per se, but could perhaps try to reward lean construction and low waste production from construction works.

It was suggested that work by the University of Dundee on a new resource use indicator and the WRAP embodied carbon database could be helpful in discussion about LCA considerations.

- *Are there other aspects of building resource efficiency that justify consideration based on their environmental significance?*

There was general agreement amongst stakeholders that the embodied energy of construction materials as a whole (including structures) can become just as significant as or even more so than the energy consumption during the use phase, at least in low energy buildings. Even in normal buildings, other LCA impacts due to construction materials can overshadow impacts during the use phase.

A balance between embodied energy of materials, energy consumption during use, local climate and health and wellbeing factors must be aimed for. It is important to consider this balance in the light of the relationships between planning authorities, developers, owners and occupiers, which may have many conflicting interests.

Stakeholders mentioned the potential importance of land use and water use, which could be highly relevant depending on local conditions. Impacts on biodiversity and also emissions of hazardous substances directly from building materials were considered as factors that are not sufficiently addressed in existing building assessment schemes.

In relation to hazardous substances and materials, the concept of "product passports", which has been developed by the European Resource Efficiency Platform (EREP), could be useful both in terms of information for buyers and at the end-of-life stage in determining whether certain materials can be potentially reused or recycled.

Overall, it was considered that LCA indicators should be used that complement the EN 15804 framework for Environmental Product Declarations (EPDs) for construction materials. A new draft CEN TR on additional indicators (to be finalised in November) was also highlighted.

The architectural quality of a building was mentioned as an important factor influencing the overall lifetime of a building structure. Productivity of buildings was also mentioned as a potentially important factor.

- *To what extent should 'induced' impacts be included as macro-objectives?*

There were mixed views on 'induced' impacts such as commuting. On one hand although induced impacts were recognised as important, it was felt that these are outside the scope of most building projects and cannot be controlled by developers. The main focus of the macro-objectives should be on environmental pressures associated with individual buildings. These should be used to develop a 'common language' for sustainable buildings.

On the other hand, the balance of stakeholder opinion suggested that environmental pressures/interactions that can be influenced at an urban development scale should be considered within a wider (optional) scope. Issues to consider include the 'quality of location' (public transport connections being a key factor) as well as land use, 'green infrastructure' and the usability of the public realm. Even if action was being taken at only building level, this would allow design teams to still have these issues 'on the agenda' when dealing with clients.

Consideration of wider urban issues would avoid sustainable buildings being located in unsustainable locations but also enable a focus on distinct performance improvement opportunities achievable at scale (e.g. shared infrastructure, more efficient building forms).

○ *Thematic comments on resource efficiency 'hot spots'*

A number of doubts and questions were raised by stakeholders regarding the LCA findings presented. The rationale behind the selection of the studies compiled should be described. Hot spots should be contextualised by mentioning the functional unit, what LCA indicators were used, any weightings applied and the design lifespan to reach these conclusions. For example, conclusions about whether concrete or wood is a better material in building structures would really depend on whether land use was considered.

Stakeholders agreed that the choice of functional unit was critical, although any per capita based units, despite being the logical choice, would be considered difficult to accurately implement due to the complex nature of leasing of commercial buildings, and whether those buildings are open five, six or seven days a week. Another important consideration is time, i.e. impacts per year of building life, where impacts due to materials used would decrease the longer they remain in the building.

Some stakeholders questioned what was meant by the term 'performance' in the title of Section 3.5. The potential risk of low vapour permeability materials exacerbating or creating problems with damp and mould was mentioned and reference made to ISO 7330 as a potentially useful source for defining indoor comfort conditions in buildings.

Other notable comments on Chapter 3 included:

- The importance of the performance gap between design predictions and actual use was generally acknowledged by stakeholders and is especially important where design lifetime of buildings (either too short or too long) do not correspond to real life times.
- The importance of closed loop recycling was emphasised as it was considered that open loop recycling was less beneficial,
- A balance is needed between achieving high housing/office densities and health and wellbeing factors for occupants,
- With metals, it was stated that specific targets for recycled contents should not be given because recycling rates are already close to 100% and that specifying recycled metal content in one product simply means that less recycled metal is available for another product.
- Caution was urged to avoid any approaches that over emphasise the importance of recycled aggregates since whether or not this is part of the optimum solution will depend on site specific and project specific factors.
- Care needs to be taken when comparing the environmental impacts of wood with heavier materials. Further discussion on the LCA impacts of wood should not be avoided simply because of a lack of agreement, particularly if wood is to be highlighted as an advantageous material. Impacts relating to land use, biogenic VOC emissions and indoor VOC emissions from wood treatments were cited.

### **5.3.2 Health and wellbeing factors**

'Indirect' health & wellbeing factors that may influence the performance, service life and value of a building are increasing seen as a proxy for 'green buildings'. Whilst there is increasing evidence for the quantifiable benefits in terms of the satisfaction, productivity and health of building occupiers, in order to warrant their inclusion within the macro-objectives there should be a clear link between these factors and the resource efficiency of the building.

There is clear evidence from post occupancy studies of buildings that health & wellbeing aspects such as thermal comfort and natural lighting are critical to the performance and occupant satisfaction of low energy buildings. However, it is to be explored further with stakeholders whether this, together with potential health and productivity benefits, justify having specific macro-objectives.

### **Questions posed to stakeholders on health and wellbeing aspects**

- *Are the links between health and wellbeing aspects and the resource efficiency of buildings strong enough to justify their inclusion as macro-objectives?*

The link between health and wellbeing factors and the resource efficiency of buildings was questioned by some stakeholders and in general was seen as something that is difficult to quantify. Nonetheless, the overall response was that health and wellbeing impacts are extremely important from a social and economic perspective and should be somehow addressed in the macro-objectives.

In general, it was considered that health and wellbeing factors may under certain circumstances conflict with environmental factors, but in no way should detract from the overall sustainability of buildings. Some factors will be more important than others depending on the use of the building. For example, health and wellbeing factors were considered to be extremely important in office buildings where links to improved productivity could easily out-strip any cost savings due to reduced energy consumption.

- *Does a healthier building always equate to a building with better environmental performance?*

Stakeholders agreed that there is no guaranteed and proven link between healthy buildings and improved environmental performance but equally did provide some specific examples where links exist, either positive or negative.

Arguments in support of healthier buildings centred on the fact that residential and office buildings are designed principally for occupants, that healthy buildings are an important part of the social pillar of building sustainability and can result in improved productivity in offices and hospitals, with possible indirect environmental benefits.

A number of examples were cited of where environmental performance was affected negatively. A Danish survey was cited that revealed a tendency for homeowners in air-tight houses to experience more problems with over-heating during summer months than in older buildings. With improved daylighting, links may be complementary or conflicting - for example, improved daylighting will reduce energy consumption due to lighting but may increase the potential for heat loss from a building and require higher floor to ceiling heights.

- *What evidence exists that the associated improvements in occupier satisfaction and productivity translate into more resource efficient buildings?*

No specific evidence was cited. The importance of addressing widespread problems of damp and mould in the existing EU housing stock was emphasised by some stakeholders, with tackling the associated health problems having the linked potential benefit of improving the energy efficiency of this stock.

- *What evidence exists that health and wellbeing aspects can extend the design/service life of buildings?*

Often the choice to renovate is linked to user comfort issues and aesthetic issues rather than functional ones so buildings designed with user comfort in mind have a reduced probability of future renovation works being needed (and the consequent environmental impacts associated with renovation works). No specific supporting evidence was cited.

- *Thematic comments on health and wellbeing aspects*

It was generally felt that resource efficient buildings are predominantly focussed on the 'environmental' pillar of sustainability whereas economic and social factors should also be considered.

It was pointed out by some stakeholders that as demonstrable financial benefits for owners and/or tenants of more sustainable buildings are now understood to be achievable, then the market will naturally respond to these. Highly relevant work in this matter regarding "sustainability data gathering" was cited (eg. ECOPAS IPDs in the UK).

## 5.4 Macro-objectives identified from existing assessment and reporting tools

Two broad type of tools were analysed in Chapter 4 - five building assessment schemes used to carry out 'asset ratings' for new building designs and five investor reporting tools used to carry out 'operational ratings' for existing buildings and renovations.

In the majority of cases the scoring or weighted contribution of criteria areas within these tools is determined by panels of experts, as well as wider stakeholder consultations. Only one of the tools examined is directly informed by LCA evidence for building environmental hot spots and incorporates a weighting designed to reflect the spatial and temporal significance of environmental impacts.

Based on this initial comparison of a sample of the most commonly used assessment and reporting tools, the following priorities were identified on the basis of having been weighted as being significant. The weightings used to derive these priorities were taken from the generic scoring systems for each tool. Whilst there are differences in emphasis between the tools, the building assessment schemes in particular emphasise the importance of further adaptations of the scoring to reflect the national and regional context in which the tools are to be used.

### *Priorities identified for building assessment tools*

- Life cycle impacts within the building boundary: Primary energy use or CO<sub>2</sub> emissions in the use phase are weighted as the most significant in all tools followed by aggregated scores or combinations of criterion for construction material impacts (embodied energy, CO<sub>2</sub> footprint or a weighted aggregation of LCA indicator scores). Water can be included on the basis of resource scarcity in a country or location.
- 'Induced' impacts outside of the building's boundary: Location close to public transport connections is weighted significantly in one scheme and is addressed to a lesser extent in two others. Public transport linkages and proximity to amenities is a pre-design consideration in one tool.
- In-direct influences on the performance, service life and value: The aggregated scores for common combinations of occupant comfort and wellbeing criteria – typically IAQ, thermal comfort, daylighting and acoustics - are weighted significantly in all schemes, but in two examples is weighted close to or equal to what can be considered as 'hot spot' life cycle impacts.

### *Priorities identified for investor reporting tools*

- Life cycle impacts within the building boundary: Primary energy use, CO<sub>2</sub> emissions, water use, waste arisings are reported in all four tools with energy being the most highly weighted in one tool.
- 'Induced' impacts outside of the buildings boundary: Site selection for public transport connections and employee related journeys and impacts are reported in three tools and are weighted significantly by at least one tool.
- In-direct influences on the design, service life and value: Occupant wellbeing relating to lighting, ventilation, HVAC, occupant controls and outside views are weighted significantly in one tool and are a general consideration in another.

Whilst the harmonisation work of the SB Alliance and CESBA provides a valuable reference point for indicator development, as they are based on pilot work carried out jointly by building assessment schemes and public authorities, they do not provide as clear an outlook on how the overarching priorities (macro-objectives) should be determined. This may be because they are a synthesis of existing schemes so, as a result, they reflect a consensus on priorities that already exists in the property market.

Although there is an underlying move towards technical standardisation according to EN 15978 and EN 15804, these standards provide life cycle calculation methodologies and reporting frameworks and do not as such provide a clear and prioritised set of overarching macro-objectives. The extent to which their LCA indicator and parameter sets capture and allow for the measurement of performance for the distinct hot spots associated with common building typologies and construction systems will be analysed in the next stage of this study (Work Package B). For example, abiotic resource depletion is more appropriate for critical raw materials than high volume construction materials and, furthermore, an accepted indicator for biotic resources such as timber is not currently available or widely used.

### Questions posed to stakeholders on *assessment and reporting tools*

- *To what extent should the weightings and priorities of the tools analysed inform the macro-objectives?*

Many stakeholders raised the issue of weighting, both in LCAs and in existing assessment and reporting tools. The lack of an agreed weighting scheme for all LCA indicators was pointed out and the uncertainty surrounding factors for Abiotic Depletion Potential (ADP) and toxicity indicators mentioned. It was also pointed out that the CESBA scheme does not set a generic weighting scheme for its key performance indicators but let this be decided at the regional level.

Stakeholders generally felt that the weightings and priorities used in existing tools should not directly influence the development of macro-objectives but instead should form part of the underlying evidence behind the choice of indicators.

Caution was urged to make sure that the macro-objectives avoid encouraging or obliging the prescription of weighting factors and instead try to complement the progress made by existing schemes if they are to have a real impact on the market and not create confusion.

- *How might the findings from collaborative projects such as the SB Alliance, CESBA, SuperBuildings and OpenHouse inform the macro-objectives?*

Support was expressed for the relevance of the SB Alliance, CESBA, SuperBuildings and OpenHouse projects to the development of macro-objectives although caution was urged that they should inform and not lead the development of macro-objectives (and indicators). It was highlighted that some of these projects are not so close to market reality and that care should be taken to ensure that the macro-objectives are meaningful and robust.

- *Are there examples of tools where the criteria have been strongly informed by LCA and resource efficiency hot spots?*

Reported examples of tools whose criteria were considered to have been strongly influenced by LCA and hot spots for resource efficiency are EN 15804, EN 15978, the Active House calculation Tool, Elodie and HQE Performance (in France), BNB, eLCA and DGNB in Germany and IMPACT and BREEAM (in the UK).

- *Are there any other tools not analysed in this paper which have distinct criteria areas that should be considered further?*

In the UK the 'Bigger, Better Data Initiative' and the 'Real Estate Environmental Benchmark of the London Better Buildings Partnership' were highlighted as being of potential interest. One industry tool not yet analysed that may be worth considering in the future was that of Building Information Modelling (BIM).

- *Thematic comments on assessment and reporting tools*

Real experience from property portfolio managers has revealed how difficult it can be to try and obtain certification of the same building using different schemes because data sets are not comparable. One of the main benefits of this project should be to try and set a common baseline for such data (where this is linked to the agreed macro-objectives). The CESBA 'Building Signature' was cited as an attempt to improve the comparability of buildings between different systems.

Other notable comments on Chapter 4 included:

- The need to mention the ongoing work of CEN/TC 350 to identify additional environmental impact categories and the ongoing Product Environmental Footprint (PEF) pilots for construction works.
- Where weightings are specified by certain schemes, the reasoning behind the choice of those particular weightings should be explained by the schemes themselves.
- Other investor reporting tools to consider include the UK ECOPAS Survey, surveys by the Dow Jones SI and FTSE4Good, the fund manager guide published by the Institutional Investors Group on Climate Change and the very recently initiated Climate Bonds Initiative.

## 6. Prioritisation exercise to identify the macro-objectives based on the evidence collated

In this section a stepwise methodology is described which has been developed and applied in order to cluster and prioritise environmental issues of established importance at EU level. The methodology provides a structured basis for the prioritisation and definition of the macro-objectives, consisting of five steps:

1. Identification of a reference set of 20 priority environmental issues at EU level;
2. Association of building life cycle 'hot spots' with these 20 reference environmental issues;
3. Association of existing EU strategies and policy instruments with the identified building life cycle 'hot spots';
4. Prioritisation and categorisation of the 20 reference environmental issues based on their EU policy and building life cycle significance;
5. Clustering of the 20 reference environmental issues so that building-related macro-objectives can then be identified.

The methodology uses as its starting point the European Environment Agency's 'State and Outlook' reporting framework, life cycle evidence for 'hot spots' gathered in support of this study and existing EU policies and strategies.

### 6.1 Development of the prioritisation methodology

The stakeholder consultation, together with follow-up discussions with the project steering group (SG1) and technical sub group (SG2), highlighted the need to establish a clearer prioritisation of the environmental issues and the resources that should be addressed by the macro-objectives. A wide range of opinions, together with examples of macro-objective frameworks were put forward, but no clear methodological solutions to enable the integration of:

- the priorities set out within EU and MS policy frameworks;
- the most significant environmental impacts identified by Life Cycle Assessments;
- the minimum requirements and weighted issues within existing assessment and reporting tools.

It is considered that whilst such a prioritisation methodology would need to take into account of the relative significance of environmental issues as reflected in EU policy, as well as the policies of Member States that have lead initiatives, it would first and foremost need to reflect the significance of environmental issues along the life cycle of buildings. This may, in turn, imply the need to make reference to a weighting system for environmental issues of the kind developed by JRC-IES<sup>164</sup> or the US EPA<sup>165</sup>.

The potential to refer to the priorities of existing building assessment and reporting tools was emphasised by the wider stakeholder group (SG4) and in written feedback. There were, however, also strong views that the macro-objectives should be identified based on scientific evidence. It is therefore proposed that a cross-check of macro-objectives against the priorities of these tools is carried out, but only once a revised list of macro-objectives has been identified based on life cycle evidence and EU policy.

Based on literature references provided by stakeholders, a stepwise methodology has been developed in order to provide a filter for the policy and life cycle evidence gathered in chapters 2 and 3 of this working paper. The methodology aims to provide a more structured basis for the prioritisation and definition of the macro-objectives, and consists of the following five steps:

1. Identify priority environmental issues at EU level: Current priorities for reporting at EU level are reflected in the European Environment Agency's 'State and Outlook' reporting (SOER) framework which groups 20 environmental issues under the three thematic priorities of the 7<sup>th</sup> Environmental Action Programme.

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<sup>164</sup> European Commission (2012) *Life cycle indicators for resources, products and waste - framework*, Joint Research Centre

<sup>165</sup> EPA (Environmental Protection Agency) SBA (Science Advisory Board), *Reducing risk: setting priorities and strategies for environmental protection*, United States, 2000.

2. Associate building life cycle 'hot spots' with the SOER environmental issues: The most significant associated life cycle environmental impacts and resource flows along the life cycle of buildings, and their related LCIA indicators, shall be identified for the SOER environmental issues from step 1. For each environmental issue, the significance of the life cycle stages has been colour coded (see Appendix 1).
3. Associate existing EU policies with building life cycle hot spots: For each of the life cycle hot spots identified in step 2, EU policies are identified, categorised according to whether they are strategies (e.g. strategy, roadmap, blueprint) or policy instruments (e.g. regulation, directive). From these, the most relevant EU building-related policy responses are identified;

The findings from these first three steps are brought together in table 6.3 and in Appendix 1.

4. Prioritisation and categorisation of the SOER environmental issues and hot spots: Selection of the most significant SOER environmental issues, based on their associated building life cycle hot spots and EU policy responses, for clustering and further analysis in the next step;
5. Cluster analysis and identification of macro-objectives: The EEA's Drivers, Pressures, State, Impact, Responses (DPSIR) framework is used to analyse each cluster of SOER environmental issues and to then identify 'responses' for the building sector *i.e. macro-objectives*.

The findings from these last two steps are brought together in Table 6.4 and then in Appendix 2.

## 6.2 Application of the prioritisation methodology

The individual steps 1-5 are described and implemented in the following sections of this chapter.

### 6.2.1 Step 1: Identify priority environmental issues at EU level




The three thematic priority objectives of the 7<sup>th</sup> Environmental Action Programme have been selected as a starting point as they are intended to provide an overall frame for environmental policy making at EU level. They are:

- Protecting, preserving and enhancing the Union's natural capital
- Turning the Union into a resource efficient, green and competitive low-carbon economy
- Safeguarding the Union's citizens from environment-related pressures and risks to health and well-being

The 7<sup>th</sup> EAP is considered appropriate as a high level reference point because it establishes environmental policy priorities for the period up to 2020 and also forms the starting point for the EU's 2050 vision of living well '*...within the planet's ecological limits*'.

Reference to the SOER framework, as presented in Section 2.1.3.1 and summarised in Table 6.1, was also suggested as a holistic and suitably comprehensive starting point by some stakeholders, who considered it important not to rule out any specific environmental issue until a screening had been carried out. Whilst the SOER framework does not apply specifically to the building sector, its broad scope encompasses many environmental issues that are likely to be relevant – for example, material resource efficiency, greenhouse gas emissions and land use and soil functions – as well as allowing for the identification of interrelationships between issues.

**Table 6.1 EEA SOER reporting framework for the state and outlook for the EU environment**

	5-10 year trends	20+ years outlook	Progress to policy targets	Read more in Section ...
<b>Protecting, conserving and enhancing natural capital</b>				
Terrestrial and freshwater biodiversity			<input type="checkbox"/>	3.3
Land use and soil functions			No target	3.4
Ecological status of freshwater bodies			<input checked="" type="checkbox"/>	3.5
Water quality and nutrient loading			<input type="checkbox"/>	3.6
Air pollution and its ecosystem impacts			<input type="checkbox"/>	3.7
Marine and coastal biodiversity			<input checked="" type="checkbox"/>	3.8
Climate change impacts on ecosystems			No target	3.9
<b>Resource efficiency and the low-carbon economy</b>				
Material resource efficiency and material use			No target	4.3
Waste management			<input type="checkbox"/>	4.4
Greenhouse gas emissions and climate change mitigation			<input checked="" type="checkbox"/> / <input checked="" type="checkbox"/>	4.5
Energy consumption and fossil fuel use			<input checked="" type="checkbox"/>	4.6
Transport demand and related environmental impacts			<input type="checkbox"/>	4.7
Industrial pollution to air, soil and water			<input type="checkbox"/>	4.8
Water use and water quantity stress			<input checked="" type="checkbox"/>	4.9
<b>Safeguarding from environmental risks to health</b>				
Water pollution and related environmental health risks			<input checked="" type="checkbox"/> / <input type="checkbox"/>	5.4
Air pollution and related environmental health risks			<input type="checkbox"/>	5.5
Noise pollution (especially in urban areas)		N.A.	<input type="checkbox"/>	5.6
Urban systems and grey infrastructure			No target	5.7
Climate change and related environmental health risks			No target	5.8
Chemicals and related environmental health risks			<input type="checkbox"/> / <input checked="" type="checkbox"/>	5.9
<b>Indicative assessment of trends and outlook</b>		<b>Indicative assessment of progress to policy targets</b>		
	Deteriorating trends dominate	<input checked="" type="checkbox"/>	Largely not on track to achieving key policy targets	
	Trends show mixed picture	<input type="checkbox"/>	Partially on track to achieving key policy targets	
	Improving trends dominate	<input checked="" type="checkbox"/>	Largely on track to achieving key policy targets	

Source: European Environmental Agency (2015)

### 6.2.2 Step 2: Associated building life cycle 'hot spots' with the SOER environmental issues

Drawing upon the findings of the top down and bottom up LCA evidence examined in chapter 3, as well as building and construction sectoral analysis carried out by the EEA and Eurostat as examined in chapter 2<sup>166</sup>, the most significant life cycle environmental impacts and material flows associated with the construction of buildings have been mapped onto the 7<sup>th</sup> EAP thematic priorities and the 20 associated state and outlook environmental issues.

For each SOER environmental issue, the stages in the life cycle of a building has been indicatively colour coded according to their significance. A text summary of the relevant environmental pressures that drive the most significant impacts associated with the life cycle stages has also been added, together with related LCA impact categories and parameters identified from EN 15804 and Product Environmental Footprint<sup>167</sup>. The significance

<sup>166</sup> European Environment Agency, *Environmental indicator report 2013: Natural resources and human well-being in a green economy*

<sup>167</sup> *ibid* 145



of each issue is ranked according to the key in Table 6.2 and the rankings are integrated into the matrix, which can be found in Appendix 1.

It is to be noted that some significant gaps were identified in the life cycle evidence. For example, the JRC IMPRO study of EU housing<sup>168</sup> omitted toxicity and land use impact categories because, at the time, the available indicators were not considered robust enough. Similarly, the European Commission's EREP study<sup>169</sup> did not address land use impacts because of similar methodological shortcomings. It is also the case that some issues, such as water use, may only become significant at local level due to environmental stresses.

**Table 6.2 Key for the significance of building life cycle stages**

Life cycle stages according to EN 15978	Not applicable/no data	Low significance	Low to moderate significance	Moderate to high significance	High significance
<b>Production</b> The 'cradle to gate' processes for the materials and services used in the construction		Yellow	Orange	Red-Orange	Red
<b>Construction</b> The processes from the factory gate of the different construction products to the practical completion of the construction work.		Yellow	Orange	Red-Orange	Red
<b>Occupation</b> The period from the practical completion of the construction work to the point of time when the building is deconstructed/demolished.		Yellow	Orange	Red-Orange	Red
<b>Demolition</b> Starts when the building is decommissioned and is not intended to have any further use. Provides a source of materials, products and building elements that are to be discarded, recovered, recycled or reused.		Yellow	Orange	Red-Orange	Red
<b>Benefits and loads beyond the system boundary</b> The re-use, recovery and recycling potential of materials.		Yellow	Orange	Red-Orange	Red

### 6.2.3 Step 3: Associate existing EU policies with building life cycle hot spots

Having identified the most relevant building life cycle stages, pressures and LCA impact categories for each of the SOER environmental issues, EU strategies and policies that address these life cycle stages and pressures have then been mapped onto each SOER environmental issue. For each set of EU strategies and policy instruments, the most important building-related policy responses have been identified.

A summary of how these three different elements are linked together is provided in Table 6.3 and the full results of this exercise are presented in the matrix in Appendix 1. The matrix illustrates how, for each SOER environmental issue there may be a number of different related hot spots associated with the life cycle of buildings. It also illustrates how quantification of these hot spots in an LCA requires the selection of appropriate impact categories. These have been identified from the LCA studies referred to in Chapter 3. It is notable that in some cases where non-LCA evidence was referenced the hot spots identified would not be picked up by the EN 15804/15978 impact categories. In these cases relevant impact categories have been selected from the European Commission's PEF methodology.

The EU strategies and instruments listed in the matrix reflect the full spectrum of EU environmental policy areas, encompassing a range of hot spots along the life cycle for buildings as well as reflecting environmental pressures that have different receptors, which may occur at different scales and which will have different geographical extents e.g. local, regional, cross EU boundary, international.

<sup>168</sup> Nemry et al (2008) *Environmental improvement potentials of residential buildings (IMPRO-Buildings)*, Joint Research Centre IPTS, European Commission.

<sup>169</sup> European Commission, *Assessment of scenarios and options towards a resource efficient Europe – An analysis for the European built environment*, final report, March 2014

The EU strategies and instruments listed broadly relate to the supply chain for the production of construction materials (for example, industrial emissions), the occupation and use of buildings (for example, energy use and CO<sub>2</sub> emissions) and the end of life phase for buildings and related materials (for example, construction and demolition waste). The wider impacts of buildings and property development are also captured in the matrix. For example, transport and air pollution emissions limits, urban development pressures on land use, soil and habitats.

For some aspects related to health and comfort, for example noise policy, it is more difficult to relate the policies to environmental hot spots. Issues such as adaptation to climate change also require the identification of potential or anticipated hot spots, given that there was no specific dynamic LCA evidence to support this exercise

**Table 6.3. How SOER environmental issues, life cycle hot spots and EU strategies and policies are linked together in one matrix**

EEA environmental issues	Life cycle relevance to buildings				Summary of life cycle 'hot spots' and their related impact categories and parameters	Related EU strategies and policy instruments	EU building-related policy responses	
	Production	Construction	Occupation	Demolition				
<b>7<sup>th</sup> EAP thematic priority x</b>								
x. EEA SOER environmental issue					<ul style="list-style-type: none"> <li>Brief descriptions of the life cycle hot spots associated with the environmental issue, described in terms of environmental pressures that may arise along the life cycle of buildings.</li> </ul>	<p><i>Impact Categories</i></p> <ul style="list-style-type: none"> <li>Those that capture and quantify the impacts associated with the hot spots in the previous column have been identified from EN 15804/15978 and the EU's Product Environmental Footprint methodology</li> </ul> <p><i>Parameters</i></p> <ul style="list-style-type: none"> <li>Those parameters from EN 15804/15978 that quantify resource flows or pollutants associated with the hot spots identified in the previous column</li> </ul>	<p><i>Strategies:</i></p> <ul style="list-style-type: none"> <li>Programme, strategies and blueprints for action that address the environmental issues and hot spots identified</li> </ul> <p><i>Instruments:</i></p> <ul style="list-style-type: none"> <li>Regulations and Directives that require action to address specific environmental issues and hot spots of relevance to the built environment</li> </ul>	<ul style="list-style-type: none"> <li>Policy responses identified from EU strategies and policies that are relevant to the building sector</li> </ul>

The colour coding of the life cycle phases provides a simplified assessment of their relative significance for the specific environmental issue.

#### 6.2.4 Step 4: Prioritisation and categorisation of the EU environmental issues and hot spots

The SOER environmental issues have been analysed and then categorised in Table 6.4 based on the following criteria:

- Their *life cycle significance* based on the evidence from top-down studies and data on EU resource flows and urban development trends;
- Their *coverage by EU strategy and/or policy instruments*, with the implementation of strategy by policy instruments being given more weight;
- The potential for *environmental pressures to vary in their significances at a regional or local level* which may not be detected in top down LCA studies (e.g. water stress);
- The potential for the impact on human health to vary at a local level depending on factors such as the climate and the nature of the building stock (e.g. damp, overheating, poor IAQ) across distinct EU climate zones and/or where specific forms of construction are used.

The relationships identified between the SOER environmental issues, life cycle hot spots and EU policy are brought together in Table 6.4. The table is structured as follows:

- *Vertically* the environmental issues are categorised first according to their life cycle significance and then, additionally, according to their geographical extent as identified in EEA SOER reporting.
- *Horizontally* the environmental issues are categorised according to the weight of EU policies and strategies that were identified in Appendix 1 as addressing the environmental issue.

In some cases, for example, for waste management it can be seen that there are combination effects or strong links to several of the SOER environmental issues, e.g with material resource efficiency.

**Table 6.4. Relationship between the SOER environmental issues and their significance to the building life cycle significance and in EU strategies and policies**

Life cycle significance and geographical extent		EU policy significance		
		EU strategy implemented by policy instruments	EU strategy with proposed policy instruments <i>and/or lead MS instruments</i>	EU strategy with implied regional and local implementation
<b>Moderate to high life cycle significance</b>	Global or cross-boundary	- 1e. Air pollution and its ecosystem impacts - 2c. Greenhouse Gas emissions and climate change mitigation - 2d. Energy consumption and fossil fuel use		- 1g. Climate change - impacts on ecosystems
	National or regional	- 1a. Terrestrial and freshwater biodiversity - 2b. Waste management - 2e. Transport demand and related environmental impacts - 3b. Air pollution and related environmental health risks	- 2a. Material resource efficiency and material use	- 2g. Water use and water quantity stress
	Localised but extensive human health issues	- 3f. Chemicals and related environmental health risks		- 3e. Climate change and related environmental health risks - 3c. Noise pollution (especially urban areas)
<b>Low to moderate significance</b>	Combinations of regional and local effects	- 1c. Ecological status of freshwater bodies - 1d. Water quality and nutrient loading - 1f. Marine and coastal biodiversity - 3a. Water pollution and related environmental health risks		- 1b. Land use and soil functions with 2a, 2e and 3b

## 6.2.5 Step 5: Issue cluster analysis and identification of macro-objectives

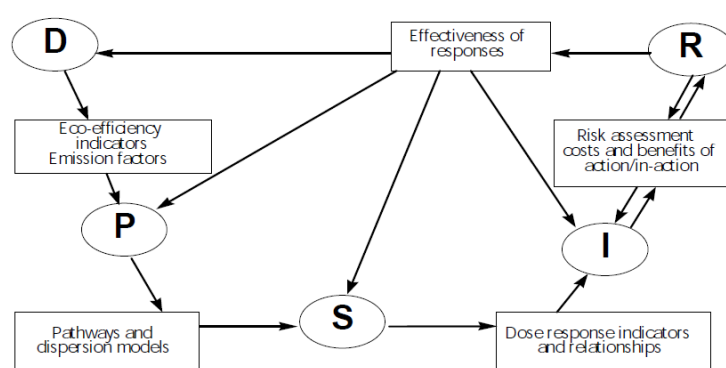
Based on the categorisation in table 6.4, the implied linkages and associations between the SOER environmental issues and the most significant hot spots for the environmental impact of buildings, have been used to cluster the SOER environmental issues. These clusters are presented in Appendix 2 under the following broad categories with each given a provisional heading that relate them to the building sector:

- Clusters identified based on life cycle significance and combined EU strategy and instrument coverage:
  - 'Building material flows and impacts'
  - 'Greenhouse gas emissions from energy use'
  - 'Greenhouse gas emissions from fuel use'
- Clusters identified based on EU strategy coverage and the potential for regional or locally extensive human health impacts:
  - 'Building related water use'
  - 'Urban pressures on land use and habitats'
- Clusters identified based on EU strategy coverage and the potential for regional or locally extensive human health impacts:
  - 'Health risks from hazardous substances'
  - 'Urban resilience to climate change'

These clusters of environmental issues identified were then analysed using the EEA's Drivers, Pressures, State, Impact and Response (DPSIR) framework<sup>170</sup> (see Figure 6.2). The aim was to achieve a clear definition of the 'response' to the cluster of environmental issues. The 'response' can be described in terms of 'actions' at building, neighbourhood and stock level which are then articulated as a 'macro-objective'. The results of this analysis are presented in Appendix 2.

Based on the balance of feedback from the stakeholder consultation, the general view was that the intent of the macro-objectives should be to describe strategic objectives for the building sector at EU level. However, in seeking to do this they should not be so high level and strategic that it becomes difficult to relate them to actions at building project level and associated indicators of performance that may be used at building, neighbourhood and stock level.

This results in seven clusters, now renamed macro-objectives, have been taken forward for further refinement into the final set of macro-objectives presented in Chapter 7



**Figure 6.2. The EEA DPSIR framework for reporting on environmental issues**

Source: European Environmental Agency (1999)

To aid understanding of how the DPSIR has been applied to this exercise, an example using an environmental issue is presented in Table 6.5.

<sup>170</sup> European Environment Agency, *Environmental indicators: typology and overview*, Technical report No 25, 1999

**Table 6.5. Example of DPSIR framework applied to CO<sub>2</sub> emissions**

<b>DPSIR framework</b>	<b>Contribution of CO<sub>2</sub> emissions from fossil fuel use to climate change</b>
<b>Drivers</b>	<ul style="list-style-type: none"> <li>○ Societal demand for fossil fuels to provide heating, electricity and transport</li> </ul>
<b>Pressures</b>	<ul style="list-style-type: none"> <li>○ Emissions of CO<sub>2</sub> from the burning of coal, gas and oil (= <i>LCA inventory and midpoint</i>)</li> </ul>
<b>State</b>	<ul style="list-style-type: none"> <li>○ Measured increases in atmospheric CO<sub>2</sub> levels</li> <li>○ Emerging evidence of global temperature change and climate change events</li> <li>○ Depletion of fossil fuel reserves (= <i>Resource parameter</i>)</li> </ul>
<b>Impact</b>	<ul style="list-style-type: none"> <li>○ Radiative forcing caused by Greenhouse Gas emissions</li> <li>○ Damage caused to the environment and human health (= <i>LCA endpoints</i>)</li> </ul>
<b>Response</b>	<ul style="list-style-type: none"> <li>○ International agreements to reduce CO<sub>2</sub> emissions</li> <li>○ EU 2020 climate and energy package with proposed action on building energy efficiency and renewable energy</li> <li>○ Sectoral specific responses at EU and MS level <i>e.g. EPB Directive</i></li> </ul>

## 7. The final set of macro-objectives

In section 7.1 a framework is presented as a means of unifying and presenting the complex interactions between:

- Resource use and environmental performance,
- The different scales at which action can be taken in the building sector, and
- The different perspectives and drivers for action of stakeholders in the building sector.

The final set of macro-objectives is then presented in section 7.2, split into those relating to 'life cycle environmental performance' and 'quality, performance and value creation'. The identification of these two types of macro-objectives emphasises that the focus for the common EU framework will not only be on environmental performance, but also other human and economic factors that may influence the service life and performance of buildings in the long term.

A cross-check of to what extent the final proposals are aligned with the criteria sets of the tools reviewed in Chapter 4 is also then provided in section 7.3.

### 7.1 Overall framework for building, neighbourhood and stock macro-objectives

A clear message to emerge from the consultation was the need for some form of unifying concept that can be used to communicate:

- how the macro-objectives and indicators relate to each other,
- the relationship between resource efficiency and environmental performance,
- how the common framework as a whole will address the human and economic issues that are of priority to potential adopters i.e. investors, constructors, landlords, occupiers.

The consultation highlighted the complexity of the subject when seeking to apply a common framework to the whole building sector. It also highlighted the many different perspectives and priorities of the stakeholders who may be the target for adoption of the framework.

A set of diagrams (Figures 7.1 and 7.2) have therefore been developed in order to provide a clear, logical communication of the interactions between the different elements of a common framework and to recognise the different priorities and entry points for potential adopters. The diagrams are based on the following assumptions:

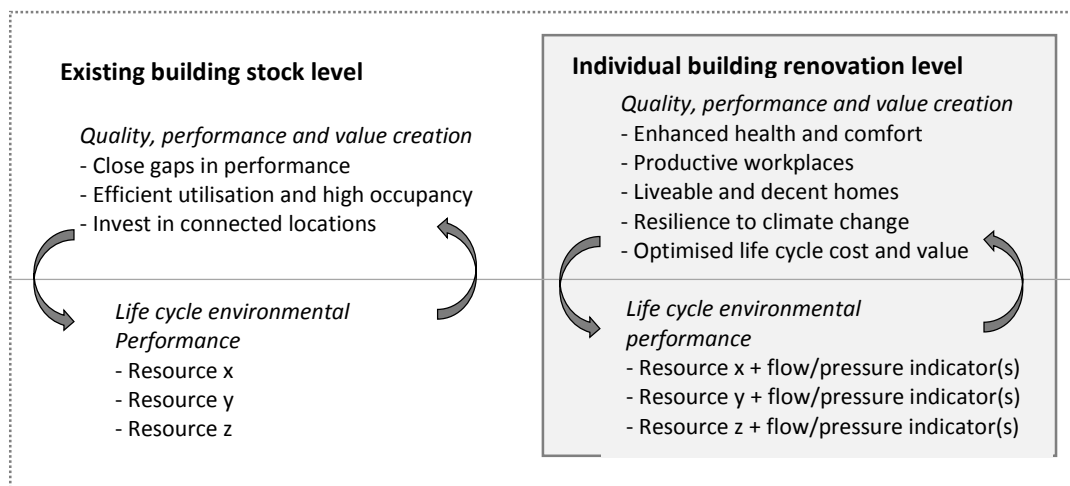
- *Resource efficiency is a component of environmental performance:* Environmental pressures are a function of both the flow of a resource and the environmental impacts related to that flow. These impacts are often distinct to the resource and how they is used. For example, the hot spots for concrete are cement and steel rebar production, because of the release of CO<sub>2</sub> and hazardous emissions during production, whereas bulk sand and aggregates generally accounts for a small proportion of the overall environmental impacts.
- *Human and economic factors should be at the heart of the framework:* Those factors identified as being critical to long-term value creation shall be established as distinct macro-objectives in their own right, but with a clear separation from the life cycle environmental performance macro-objectives because of the potential for trade-offs (see the next point). The aim should therefore be to achieve a win-win between the drivers for quality and value creation (socio-economic) and drivers for environmental performance.
- *Buildings should achieve more with less resources and environmental impacts:* Whilst certain design aspects of buildings are, based on evidence, important for the long-term health and comfort of occupants, and consequently also the functionality and value of buildings, these aspects may in some cases imply trade-offs in terms of resource use and environmental performance. These aspects shall therefore be identified as drivers, pre-requisites and macro-objectives for quality design and long-term value creation. They should be clearly

separated from environmental performance macro-objectives to ensure that any potential trade-offs are taken into account.

- *Human health impacts shall be addressed by 'quality and value' macro-objectives:* To ensure coherence, it is also proposed that the SOER environmental issues addressed by the '*life cycle environmental performance macro-objectives*' are always related to resource use and consequential environmental impacts associated with these resource flows, whereas EEA SOER environmental issues that suppose exposure pathways for building occupants shall be addressed by '*quality, performance and value macro-objectives*' (e.g. hazardous emissions from building materials).
- *Buildings shall be the focus but a neighbourhood and stock level perspective is important:* The main focus shall be on individual buildings, for which macro-objectives will be identified and then a core indicator set developed. The macro-objectives for buildings could then be complemented by a small number of further macro-objectives (but in the short-term no indicators) at two broader levels:
  - Existing building stock level (i.e. existing buildings with the same owner/landlord) to reflect the need for performance comparisons and reporting across stock, and
  - New-build neighbourhood masterplan level (designers: architect or urban designer-led masterplanning team) to reflect scenarios in which urban form, development layouts and infrastructure can be influenced.

A focus on the stock level was supported by many stakeholders. This would support the aggregation of data from building level indicators, as well as encouraging a focus on wider issues such as location. The stock renovation scenario is represented in Figure 7.1.

**Figure 7.1. Proposed framework for EU building life cycle environmental performance improvements: 'existing building stock renovation scenario'**

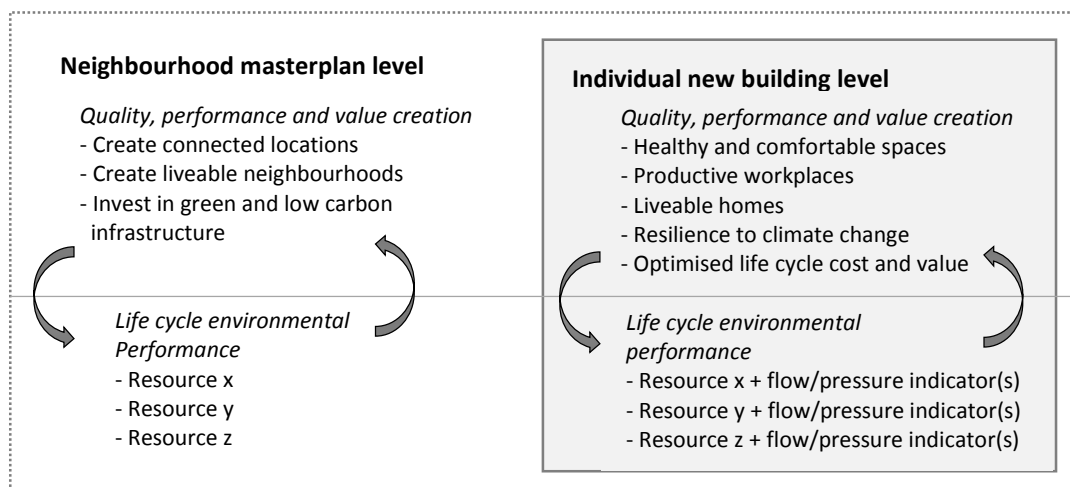




The neighbourhood level was, on balance, considered to be important, although it was the subject of widely opposing views from stakeholders. This level would support engagement with building professionals at the interface between planners, urban designers and architects.

Both the background research and stakeholder feedback highlighted the many potential benefits of addressing this scale e.g. well connected locations influence property value, shared energy infrastructure may be more cost effective, compact development forms tend to be more material and energy efficient. There may also be the potential for building performance indicators to be used by planners and urban designers to set rules for building plots in masterplans. The new-build neighbourhood scenario is represented in Figure 7.2.

**Figure 7.2. Proposed framework for EU building life cycle environmental performance improvements: 'new-build neighbourhoods and buildings scenario'**



Notes:

\* Building level macro-objectives and indicators could additionally be used at an early stage to set rules for building plots within a masterplan

+ Neighbourhood level macro-objectives could be used at an early pre-design stage to inform building location choices (if applicable) and the negotiation of 'planning gain' (contributions normally made to wider infrastructure improvements)

## 7.2 Thematic clustering of the selected macro-objectives

In this section, the final set of macro-objectives are brought together under two headings – '*life cycle environmental performance*' and '*quality, performance and value*'. For each of these headings there are macro-objectives that relate to the building scale and macro-objectives that relate to the neighbourhood and/or existing stock scale. These two headings and the three different levels to which they relate reflect the framework that was described in section 7.1.

The macro-objectives are further divided into those that, in the short term, are proposed to be taken forward for further analysis in order to identify performance indicators, and those that, in the medium to long term, may be considered for the potential identification of performance indicators. For each macro-objective that will be taken forward in the short term a narrative is provided to detail the intended scope and focus. The aim of this is to inform the follow-up work on indicator identification.

### 7.2.1 'Life cycle environmental performance' macro-objectives

In this section, the 'life cycle environmental performance' macro-objectives identified by the process in Chapter 6 and concluded on in Appendix 2 are brought together and described in more detail. Three macro-objectives are proposed to be taken forward for identification of indicators at building level, and two at the stock and neighbourhood level will be retained for potential later identification of indicators.

In Appendix 2.3, two further macro-objectives were identified that addressed *health risks from hazardous substances* and *urban resilience to climate change*, respectively. It is proposed to place these macro-objectives within the '*quality, performance and value*' cluster in section 7.2.2. This is for two main reasons:

- These macro-objectives have a stronger focus on occupier health than the environment, with a consequential influence on the long-term value of properties and risk minimisation.
- There are potential trade-offs between addressing these two macro-objectives and the performance of a building against, for example, macro-objective B1: *Greenhouse gas emissions from building life cycle energy use* (e.g. more cooling and ventilation may increase energy use and GHG emissions).

**Table 7.1 Building (B) level macro-objectives proposed for identification of indicators**

Macro-objectives	Intended scope and focus
<p><b>B1: Greenhouse gas emissions from building life cycle energy use</b></p> <p>Minimise the total GHG emissions along a buildings lifecycle, with a focus on building operational energy use emissions and embodied emissions.</p>	<p>Action at building level with a focus on 1) energy performance and low/zero emissions energy technologies and infrastructure during the use phase, 2) reductions in use phase emissions and embodied emissions along the buildings life cycle, such as those associated with the manufacturing of construction materials. This shall include a focus on the potential trade-offs between the two.</p>
<p><b>B2: Resource efficient material life cycles</b></p> <p>Optimise building design, engineering and form in order to support lean and circular flows, extend long-term material utility and reduce significant environmental impacts.</p>	<p>Action at building level with a focus on material efficiency and circular utility, from manufacturing, design, engineering and construction through to upgrading, adaptability and deconstruction. The overall objective shall be to reduce waste, optimise material use intensity and reduce the life cycle environmental impacts of designs and material choices.</p>
<p><b>B3: Efficient use of water resources</b></p> <p>Make efficient use of water resources, particularly in areas of identified long-term or projected water stress.</p>	<p>Action at building level in areas of long-term or projected water stress to minimise water resource use. This could combine efficiency measures, as well as supply-side measures such as water recycling and rainwater harvesting.</p>

**Table 7.2 Stock and neighbourhood (SN) level macro-objectives for later potential identification of indicators**

Macro-objectives	Intended scope and focus
<p><b>N1: Urban pressures on land and habitats</b></p> <p>Efficient use of land in order to minimise urban sprawl, habitat fragmentation and the loss of fertile soils.</p>	<p>Action at neighbourhood level to use land more efficiently through a combination of development on brownfield sites, more compact development forms, the integration of green infrastructure and the minimisation of soil sealing.</p>
<p><b>SN1: Greenhouse gas emissions from building occupier's travel patterns</b></p> <p>Minimise GHG emissions and urban air pollution associated with the travel patterns and transport modes used during the occupation of buildings and neighbourhoods.</p>	<p>Action at stock and neighbourhood level to promote sustainable modes of transport, to avoid urban sprawl, minimise private car parking provision and to promote well connected sites and mixed use development forms.</p> <p><i>It is proposed that this macro-objective is linked to value creation by addressing it as a 'quality, performance and value' macro-objective (see N2: Connected locations).</i></p>

### 7.2.2 'Quality, performance and value creation' macro-objectives

As described in section 7.1 a series of 'quality, performance and value' macro-objectives have been identified that reflect those additional areas of importance identified in Chapter 5 and from the stakeholder consultation.

Health and comfort has been identified as important focus for macro-objectives. It is proposed that this area is addressed by two macro-objectives:

- *B4a: Healthy and comfortable spaces* will focus on the specific environmental and health issues identified in Appendices 1 and 2. These relate to the risk of exposure to chemicals and air pollution, to which the additional hazards of damp and mould are to be added, having been identified as a risk to health in older residential buildings;
- B4a could potentially later be complemented by B4b, which is presented in table 7.4, which would allow for inclusion of a broader set of health and comfort issues, which could include ventilation, daylight and thermal comfort;
- *B5: Resilience to climate change* will consider the tolerance of buildings to projected future climatic conditions, with an initial focus on thermal comfort..

Value creation and, in particular, Life Cycle Costing (LCC) were also identified as important areas of focus by stakeholders. It is therefore proposed that a specific macro-objective (B6: Optimised life cycle cost and value) is included that focusses on LCC and long-term value, with the aim of promoting a life cycle perspective on investment in buildings.

**Table 7.3 Building (B) level macro-objectives proposed for identification of indicators**

Macro-objectives	Intended scope and focus
<p><b>B4a: Healthy and comfortable spaces</b></p> <p>Design, construction and renovation of buildings that protect human health by minimising the potential for occupier and worker exposure to health risks.</p>	<p>Action at building level in response to the linkages between EU health, construction and chemicals policies and strategy. This should minimise risks to future property values and reduce cost burdens on health systems – particularly in cases where old buildings are to be renovated as there may be hazards relating to materials used, as well as damp and mould.</p> <p>A focus is proposed on exposure to hazardous substances, which can relate to ventilation intake air (where controlled ventilation is installed) or, in general, to emissions from materials and surface treatments used in the internal fit-out. For renovations of domestic properties, damp and mould have additionally been identified as significant health issues (biological hazards), and should be considered within the scope.</p> <p>The potential for the exposure of workers installing or dismantling building materials should also be taken into account.</p>
<p><b>B5: Resilience to climate change</b></p> <p>The futureproofing of building thermal performance to projected changes in the urban microclimate, in order to protect occupier health and comfort.</p>	<p>Action at building level to design-in resilience to projected climate change. This would minimise risks to future property values and make properties more attractive and comfortable for occupiers.</p> <p>The focus is proposed on thermal comfort, with EU strategy highlighting the need to integrate the consideration of overheating into building standards. The tolerances of building designs to overheating is therefore likely to be the main focus.</p> <p>The scope could also consider the potential for ‘green infrastructure’ at the building level, for which there is evidence that certain features can improve the thermal tolerance of buildings and their surrounding microclimate.</p>
<p><b>B6: Optimised life cycle cost and value</b></p> <p>Optimisation of the life cycle cost and value of buildings, inclusive of acquisition, operation, maintenance and disposal.</p>	<p>Life Cycle Costing (LCC) is particularly relevant to achieving an improved environmental performance because higher initial capital costs may be required to achieve lower life-cycle running costs, higher residual property values and improved workforce productivity. It therefore represents a method for making effective, long-term investment decisions.</p> <p>LCC is an important tool during the project definition, concept design and detailed design stages, where it can be used to select and value engineer the design that will provide the lowest overall cost (and highest residual value) along the life cycle of the asset. It may also take into account so-called 'intangible' benefits, which may include factors that influence the users' comfort, amenity and productivity.</p>

### 7.2.1.1 Building, neighbourhood and stock: macro-objectives for later potential indicator identification

A broader set of ‘quality, performance and value’ macro-objectives were identified in section 7.1, including those that are relevant to:

- Buildings – B4b and B7a/b;
- New-build neighbourhoods masterplans – N2, N3 and N4;
- The management of existing stocks of buildings – S1 and S2;
- Both new-build neighbourhood masterplans and the renovation of existing building stock – SN1;

The macro-objectives are outlined in table 7.4. It is proposed that their intended scope and focus will be developed in more detail if they are taken forward.

**Table 7.4. Additional macro-objectives for later potential identification of indicators**

Macro-objectives	Intended scope and focus
<p><b>B4b: Healthy and comfortable spaces</b></p> <p>Provide a healthy and comfortable indoor environment with good air quality, ventilation, natural light and temperature.</p>	<i>To be further defined</i>
<p><b>B7a: Productive workplaces</b></p> <p>Configure spaces to provide productive and space efficient working environments which meet modern standards.</p>	<i>To be further defined</i>
<p><b>B7b: Liveable and decent homes</b></p> <p>Ensure that homes meet modern space, privacy and acoustic standards.</p>	<i>To be further defined</i>
<p><b>N2: Connected locations</b></p> <p>Create neighbourhoods which have good public transport, cycling and walking accessibility.</p>	<i>To be further defined</i>
<p><b>N3: Liveable neighbourhoods</b></p> <p>Create neighbourhoods that provide a range of facilities and amenities within walking distance.</p>	<i>To be further defined</i>
<p><b>N4: Developing green and low carbon infrastructure</b></p> <p>Use economies of scale to integrate new forms of infrastructure that reduce CO<sub>2</sub> emissions and provide multiple benefits.</p>	<i>To be further defined</i>
<p><b>S1: Close gaps in performance</b></p> <p>Close gaps in performance between the best and worst performing properties and raise the overall stock performance.</p>	<i>To be further defined</i>

<p><b>S2: Efficient utilisation and high occupancy</b></p> <p>Maximise the utilisation efficiency of space and minimise void rates across the stock.</p>	<p><i>To be further defined</i></p>
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### 7.3 Cross-check of alignment with existing assessment and reporting tools

In order to cross-check for the alignment of the intended scope of the six macro-objectives to be taken forward with those of the assessment and reporting tools previously analysed in Chapter 4, an initial cross-check has been carried out. The results are presented in Table 7.

The highest level of alignment can be seen for B3, where all tools address this macro-objective, followed by B1, where it can be seen that some tools only partially address embodied emissions. B2 is partially addressed by the majority of the tools, reflecting a general focus on only some potential aspects of this macro-objective – namely waste management and recycled/re-used content.

B4a is addressed by three tools, but the specific proposed focus on hazards is not addressed by four tools. B5 and B6 are not addressed by six and seven tools respectively, which may in part be due to their scope being somewhat broader than traditional environmental macro-objectives. Whilst the proposed focus of B5 could to some extent be addressed by criteria on thermal comfort, their focus is currently not on tolerance to projected climate change.

**Table 7.5 Cross-check of macro-objective coverage by existing assessment and reporting tools**

Macro-objectives identified	Multi-criteria assessment schemes					Investor and occupier reporting tools				
	CSBE (BREEAM)	HQE	DGNB	SB Tool	LEED	IPD	GRI	GRESB	Green Rating	REEB
B1 Low carbon building life cycle	+	✓	✓	✓	✓	-	+	+	+	+
B2 Resource efficient material flows	✓	+	+	+	+	-	+	+	-	-
B3 Efficient use of water resources	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
B4a Healthy and comfortable spaces	+	✓	✓	-	✓	-	-	+	-	-
B5 Resilience to climate change	✓	-	-	+	+	-	-	-	-	-
B6 Optimised life cycle cost and value	✓	-	✓	+	-	-	-	-	-	-

Key

✓ Fully addressed

+ Partially addressed

- Not currently addressed

#### **7.4 Proposed 'rules' for translating macro-objectives into building level indicators**

The review of LCA evidence and the work of the European Resource Efficiency Platform (EREP) highlighted the importance of several factors that are critical when seeking to analyse intensity of resource use. These mainly relate to the specification of the object of assessment, as described by EN 15978. It is therefore proposed that some rules are set when translating macro-objectives into measurable indicators of building performance.

From the technical literature reviewed to date, three initial rules can be identified:

- Unit of consumption: The functional unit shall reflect as far as possible the unit of consumption for the building *e.g. household (homes), workstation or employee (offices), pupil or class (school)*;
- Building form: Where possible, a performance comparison should be made between options for the building form in order to benchmark resource use intensity *e.g. factors such as form, density and height may influence the energy performance and the construction materials used*.
- Design parameters: For building structures, performance comparisons of material options shall be related to the design lifespan and shall additionally take into account fundamental engineering design parameters and safety factors, some of which will be specific to the location and form of the building *e.g. wind loads, earthquake resistance*;

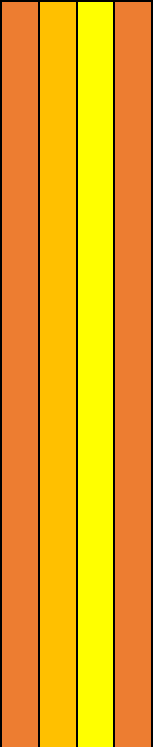
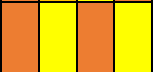
## Appendix 1. Matrix associating EEA state of the environment issues, building life cycle relevance and EU policy responses

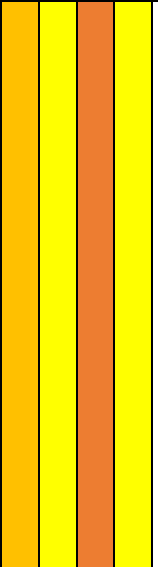
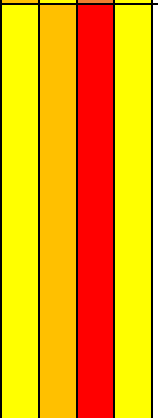
EEA SOER environmental issues	Life cycle relevance to buildings				Summary of life cycle 'hot spots' and their related impact categories and parameters	Related EU strategies and policy instruments	EU building-related policy responses	
	Production	Construction	Occupation	Demolition				
<b>7<sup>th</sup> EAP thematic priority 1: Protecting , preserving and enhancing the Union's natural capital</b>								
1a. Terrestrial and freshwater biodiversity					<ul style="list-style-type: none"> <li>Habitat damage caused by biotic and abiotic resource exploitation, extraction and consumption to manufacture products, in particular: <ul style="list-style-type: none"> <li><i>Metallic mineral extraction and forestry products</i></li> </ul> </li> <li>Habitat fragmentation resulting from greenfield development</li> <li>See also 1 d and g</li> </ul>	<p><i>Impact Categories</i></p> <ul style="list-style-type: none"> <li>Land transformation (PEF default)</li> <li>Impacts on habitats or ecosystem services are not calculated (<i>see other issues for pollution proxies</i>)</li> </ul>	<p><i>Strategies:</i></p> <ul style="list-style-type: none"> <li>Raw Materials Initiative (2008)</li> <li>Biodiversity strategy to 2020 (2011)</li> <li>Green Infrastructure SWD (2013)</li> <li>Forest Strategy (2013)</li> <li>Blueprint for forest based industries (2013)</li> </ul> <p><i>Instruments:</i></p> <ul style="list-style-type: none"> <li>Habitat Directive 92/43/EEC</li> <li>Timber Regulation (EC) No 995/2010</li> </ul>	<ul style="list-style-type: none"> <li>Protection of habitat types and designated sites, with reference to Natura 2000</li> <li>Maintenance and enhancement of ecosystems and their services</li> <li>'No-net-loss' of ecosystems and their services</li> <li>Maintenance of the biodiversity and productivity of forests</li> <li>Legal harvesting of timber within and outside of the EU</li> </ul>
1b. Land use and soil functions					<ul style="list-style-type: none"> <li>Biotic material consumption (primarily wood)</li> <li>Construction on and the sealing of greenfield land</li> <li>Contamination of brownfield land</li> <li>Landfilling of construction and demolition waste</li> </ul>	<p><i>Impact Categories</i></p> <ul style="list-style-type: none"> <li>Land transformation (PEF default)</li> </ul>	<p><i>Strategies:</i></p> <ul style="list-style-type: none"> <li>Thematic strategy for soil protection (2006)</li> <li>Thematic strategy for the urban environment (2005)</li> <li>7<sup>th</sup> Environmental Action Programme (2013)</li> </ul>	<ul style="list-style-type: none"> <li>Reduction in the loss and degradation of soils</li> <li>Reduction in urban soil sealing</li> <li>The integration of land use and transport planning with the objective to resource efficiency e.g. compact urban development to avoid urban sprawl, re-use of brownfield sites</li> </ul>
1c. Ecological status of freshwater bodies					<ul style="list-style-type: none"> <li>Material extraction and product manufacturing</li> <li>Thermal pollution from electricity</li> </ul>	<p><i>Impact Categories</i></p> <ul style="list-style-type: none"> <li>Eutrophication</li> <li>Ecotoxicity for</li> </ul>	<p><i>Instruments:</i></p> <ul style="list-style-type: none"> <li>Water Framework Directive 2000/60/EC</li> </ul>	<ul style="list-style-type: none"> <li>Protection of water resources from urban wastewater and industrial pollution.</li> </ul>



1d. Water quality and nutrient loading			<ul style="list-style-type: none"> <li>○ generation</li> <li>○ Wastewater treatment and discharge</li> <li>○ Urban run-off from hard surfaces</li> </ul>	<p>aquatic freshwater (PEF default)</p> <p><i>Parameters:</i></p> <ul style="list-style-type: none"> <li>○ Hazardous waste disposed</li> </ul>	<ul style="list-style-type: none"> <li>- Urban Wastewater Directive 91/271/EEC</li> <li>- Industrial Emissions Directive 2010/75/EU</li> </ul>	<ul style="list-style-type: none"> <li>○ Regulation of priority substances that may pollute surface waters</li> <li>○ Minimise pollution from industrial sources by reference to sectoral performance standards and BAT techniques</li> </ul>
1e. Air pollution and its ecosystem impacts			<ul style="list-style-type: none"> <li>○ Material extraction, processing and product manufacturing</li> <li>- Emissions from power generation and heating plant (including building scale, particularly domestic emissions)</li> <li>- Vehicle emissions from private and public transport</li> <li>○ Changes in land use to forestry result in biogenic VOC emissions.</li> </ul>	<p><i>Impact Categories</i></p> <ul style="list-style-type: none"> <li>○ Acidification for soil and water</li> <li>○ Ozone depletion</li> <li>○ Photochemical ozone creation</li> <li>○ Particulate matter (PEF default)</li> </ul>	<p><i>Instruments:</i></p> <ul style="list-style-type: none"> <li>- Clean Air policy package (2013)</li> <li>- Industrial Emissions Directive 2010/75/EU</li> <li>- Clean Air Directive 2008/50/EC</li> <li>- National Emissions Ceiling Directive 2001/81/EC</li> </ul>	<ul style="list-style-type: none"> <li>○ Local emissions ceilings for total SO<sub>2</sub>, NO<sub>x</sub>, VOC, NH<sub>3</sub> and PM pollution from industrial, power generation and transport sources</li> </ul>
1f. Marine and coastal biodiversity			<ul style="list-style-type: none"> <li>○ Dredging in order to extract aggregate resources (to meet local and regionally specific demand)</li> <li>○ Wastewater treatment and discharge (e.g. regionally specific conditions for eutrophication)</li> <li>○ Urban run-off from hard surfaces</li> </ul>	<p><i>Impact Categories</i></p> <ul style="list-style-type: none"> <li>○ Eutrophication</li> <li>○ Impacts on habitats or ecosystem services are not calculated (<i>see other issues for pollution proxies</i>)</li> </ul>	<p><i>Strategies:</i></p> <ul style="list-style-type: none"> <li>- Raw Materials Initiative (2008)</li> </ul> <p><i>Instruments:</i></p> <ul style="list-style-type: none"> <li>- Water Framework Directive 2000/60/EC</li> <li>- Urban Wastewater Directive 91/271/EEC</li> </ul>	<ul style="list-style-type: none"> <li>○ Protection of water resources from industrial urban wastewater pollution</li> <li>○ Regulation of priority substances that may pollute waters</li> </ul>
1g. Climate change impacts on ecosystems			<ul style="list-style-type: none"> <li>○ Habitat damage and climatic shifts indirectly caused by GHG emissions from energy production to supply industry and buildings</li> <li>○ Urban heat island effect creates localised microclimates</li> </ul>	<p><i>Impact Categories</i></p> <ul style="list-style-type: none"> <li>○ Impacts on habitats or ecosystem services are not calculated (<i>end point damage more appropriate</i>)</li> </ul>	<p><i>Strategies:</i></p> <ul style="list-style-type: none"> <li>- EU strategy on adaptation to climate change (2013)</li> <li>- Biodiversity strategy to 2020 (2011)</li> <li>- Green Infrastructure SWD (2013)</li> <li>- 2020 Climate and Energy package (2009)</li> </ul>	<ul style="list-style-type: none"> <li>○ Establishment of greenhouse gas emissions reduction targets, with sectoral contributions relating to buildings, industry and transport.</li> <li>○ Promotion of the role of Green Infrastructure in mitigation and adaptation</li> </ul>

7 <sup>th</sup> EAP thematic priority 2: Turning the Union into a resource efficient, green and competitive low-carbon economy						
2a. Material resource efficiency and material use				<ul style="list-style-type: none"> <li>○ Material flows (use and dissipation) associated with extraction, processing, production and construction processes</li> <li>○ Changes in patterns of urban development which suppose more materials per dwelling unit.</li> <li>○ Rapid turnover and short lifespans for material intensive buildings in some high value locations</li> <li>○ Waste arisings sent to landfill from construction and demolition sites.</li> </ul> <p><i>Impact Categories</i></p> <ul style="list-style-type: none"> <li>○ Depletion of abiotic resources: elements, fossil fuels</li> </ul> <p><i>Parameters:</i></p> <ul style="list-style-type: none"> <li>○ Use of non-renewable and renewable primary energy resources as raw materials</li> <li>○ Use of secondary material</li> <li>○ Output flows: components for re-use and materials for recycling</li> <li>○ Input flow substitution (<i>see PEF recommendations</i>)</li> </ul>	<p><i>Strategies:</i></p> <ul style="list-style-type: none"> <li>- (Revised) circular economy package (2015-16)</li> <li>- Resource efficiency opportunities in the building sector (2014)</li> <li>- Roadmap to a resource efficient Europe (2011)</li> <li>- Raw Materials Initiative (2008)</li> </ul> <p><i>Instruments:</i></p> <ul style="list-style-type: none"> <li>- Construction Products Regulation (EU) No 305/2011</li> <li>- Industrial Emissions Directive 2010/75/EU</li> </ul>	<ul style="list-style-type: none"> <li>○ Maximise the re-use and recycling of materials and construction waste</li> <li>○ Support the market for the incorporation of waste into construction products</li> <li>○ Improved durability and lifespan for buildings, structures and products</li> <li>○ Prudent management of natural resources at EU and global scale</li> </ul>

2b. Waste management		<ul style="list-style-type: none"> <li>○ Waste arising from material extraction, processing and production (so-called 'hidden flows')</li> <li>○ Waste arising sent to landfill from construction and demolition sites</li> <li>○ Potential for hazardous waste arisings</li> </ul>	<p><i>Impact Categories</i></p> <ul style="list-style-type: none"> <li>○ Human toxicity (PEF default)</li> <li>○ Particulate matter/respiratory inorganics (PEF default)</li> <li>○ Depletion of abiotic resources: elements, fossil fuels</li> </ul> <p><i>Parameters:</i></p> <ul style="list-style-type: none"> <li>○ Use of non-renewable and renewable primary energy resources as raw materials</li> <li>○ Use of secondary material</li> <li>○ Hazardous and non hazardous waste disposed</li> <li>○ Output flows: components for re-use and materials for recycling</li> </ul>	<p><i>Instruments:</i></p> <ul style="list-style-type: none"> <li>- Landfill Directive 1999/31/EC</li> <li>- Waste Framework Directive 2008/98/EC</li> <li>- Industrial Emissions Directive 2010/75/EU</li> </ul>	<ul style="list-style-type: none"> <li>○ Reduction by a minimum of 70% in non-hazardous construction &amp; demolition waste going to landfill</li> <li>○ Minimise pollution from industrial sources by reference to sectoral performance standards and BAT techniques</li> </ul>
2c. Greenhouse gas emissions and climate change mitigation		<ul style="list-style-type: none"> <li>○ Material processing and product manufacturing (metals and non-</li> </ul>	<p><i>Impact Categories</i></p> <ul style="list-style-type: none"> <li>○ Global warming</li> </ul>	<p><i>Strategies:</i></p> <ul style="list-style-type: none"> <li>- The Energy Union package (2015)</li> </ul>	<ul style="list-style-type: none"> <li>○ Establishment of greenhouse gas emissions reduction targets, with</li> </ul>

<p>2d. Energy consumption and fossil fuel use</p>		<p>metallic minerals)</p> <ul style="list-style-type: none"> <li>○ Fossil fuel used to supply heat, cooling and electricity to buildings during occupation</li> </ul> <p><i>Note:</i> significance rating reflects new construction (as of 2015/16). For renovations the production phase would tend to be 'low' and the use phase 'moderate to high' or 'high'</p>	<ul style="list-style-type: none"> <li>○ Acidification for soil and water</li> <li>○ Photochemical ozone creation</li> <li>○ Human toxicity (PEF default)</li> <li>○ Particulate matter/respiratory inorganics (PEF default)</li> <li>○ Ionising radiation (PEF default)</li> <li>○ Eutrophication – aquatic (PEF default)</li> </ul> <p><i>Parameters:</i></p> <ul style="list-style-type: none"> <li>○ Use of non-renewable and renewable primary energy</li> </ul>	<ul style="list-style-type: none"> <li>- 2020 Climate and Energy package (2009)</li> </ul> <p><i>Instruments:</i></p> <ul style="list-style-type: none"> <li>- Energy Efficiency Directive 2012/27/EU</li> <li>- Energy Performance of Buildings Directive 2010/31/EC</li> <li>- Renewable Energy Directive 2009/28/EC</li> </ul>	<p>sectoral contributions relating to buildings, industry and transport.</p> <ul style="list-style-type: none"> <li>○ Establishment of minimum, cost optimal performance requirements for new buildings and major renovations</li> <li>○ Future requirement for new buildings to be 'nearly zero energy'</li> <li>○ Increased use of decentralised renewable and/or high efficiency energy systems</li> <li>○ Increased attention over time on embodied GHG emissions for new, high performance buildings</li> </ul>
<p>2e. Transport demand and related environmental impacts</p>		<ul style="list-style-type: none"> <li>○ Bulk material and product transportation to production and construction sites</li> <li>○ Private and public transport journeys to and from building locations</li> </ul>	<p><i>Impact Categories</i></p> <ul style="list-style-type: none"> <li>○ Global warming</li> <li>○ Photochemical ozone creation</li> <li>○ Human toxicity (PEF default)</li> <li>○ Particulate matter/respiratory inorganics (PEF default)</li> </ul> <p><i>Parameters:</i></p> <ul style="list-style-type: none"> <li>○ Use of non-renewable and renewable primary energy</li> </ul>	<p><i>Strategies:</i></p> <ul style="list-style-type: none"> <li>- 7<sup>th</sup> Environmental Action Programme (2014)</li> <li>- Thematic strategy for the urban environment (2005)</li> </ul> <p><i>Instruments:</i></p> <ul style="list-style-type: none"> <li>- Clean Air policy package (2013)</li> <li>- National Emissions Ceiling Directive 2001/81/EC</li> </ul>	<ul style="list-style-type: none"> <li>○ Local emissions ceilings for total SO<sub>2</sub>, NO<sub>x</sub>, VOC, NH<sub>3</sub> and PM pollution from industrial and transport sources</li> <li>○ Urban planning to avoid urban sprawl, promote sustainable transport and mixed use development</li> </ul>

2f. Industrial pollution to air, soil and water				<ul style="list-style-type: none"> <li>○ Material extraction, processing and product manufacturing <ul style="list-style-type: none"> <li>- <i>Steel, copper, concrete and glass are the most significant contributors</i></li> </ul> </li> </ul>	<p><i>Impact Categories</i></p> <ul style="list-style-type: none"> <li>○ Acidification for soil and water</li> <li>○ Photochemical ozone creation</li> <li>○ Human toxicity (PEF default)</li> <li>○ Particulate matter/respiratory inorganics (PEF default)</li> <li>○ Ecotoxicity for aquatic freshwater (PEF default)</li> </ul> <p><i>Parameters:</i></p> <ul style="list-style-type: none"> <li>○ Hazardous and non hazardous waste disposed</li> </ul>	<p><i>Instruments:</i></p> <ul style="list-style-type: none"> <li>- Clean Air policy package (2013)</li> <li>- Industrial Emissions Directive 2010/75/EU</li> <li>- Construction Products Regulation (EU) No 305/2011</li> <li>- Water Framework Directive 2000/60/EC</li> </ul>	<ul style="list-style-type: none"> <li>○ Protection of water resources from industrial pollution</li> <li>○ Regulation of priority substances that may pollute surface waters</li> <li>○ Minimise pollution from industrial sources by reference to sectoral performance standards and BAT techniques</li> </ul>
2g. Water use and water quantity stress				<ul style="list-style-type: none"> <li>○ Material extraction, processing and product manufacturing</li> <li>○ Extraction to facilitate construction</li> <li>○ Water use by building occupiers</li> <li>○ Dust suppression during demolition</li> </ul> <p><i>Note:</i> Limited data is available to assess the relative significance of 'embodied' water use</p>	<p><i>Impact Categories</i></p> <ul style="list-style-type: none"> <li>○ Resource depletion (PEF default)</li> </ul> <p><i>Parameters:</i></p> <ul style="list-style-type: none"> <li>○ Net use of fresh water</li> </ul>	<p><i>Strategies:</i></p> <ul style="list-style-type: none"> <li>- Blueprint to safeguard Europe's water resources (2012)</li> </ul> <p><i>Instruments:</i></p> <ul style="list-style-type: none"> <li>- Water Framework Directive 2000/60/EC</li> </ul>	<ul style="list-style-type: none"> <li>○ Improve the water efficiency of industrial activities and buildings</li> <li>○ Counter water stress and set efficiency targets at river basin level</li> </ul>

7 <sup>th</sup> EAP thematic priority 3: Safeguarding the Union's citizens from environment-related pressures and risks to health and well-being							
3a. Water pollution and related environmental health risks				<ul style="list-style-type: none"> <li>Material extraction and product manufacturing</li> <li>Wastewater treatment and discharge</li> <li>Urban run-off from hard surfaces</li> </ul>	<p><i>Impact Categories</i></p> <ul style="list-style-type: none"> <li>Resource depletion (PEF default)</li> </ul> <p><i>Parameters:</i></p> <ul style="list-style-type: none"> <li>Net use of fresh water</li> </ul>	<p><i>Instruments:</i></p> <ul style="list-style-type: none"> <li>Water Framework Directive 2000/60/EC</li> <li>Urban Wastewater Directive 91/271/EEC</li> <li>Industrial Emissions Directive 2010/75/EU</li> </ul>	<ul style="list-style-type: none"> <li>Protection of water resources from industrial and urban wastewater pollution</li> <li>Regulation of priority substances that may pollute surface waters</li> <li>Minimise pollution from industrial sources by reference to sectoral performance standards and BAT techniques</li> </ul>
3b. Air pollution and related environmental health risks				<ul style="list-style-type: none"> <li>Material extraction, processing and product manufacturing</li> <li>Emissions from power generation and heating plant</li> <li>Vehicle emissions from private and public transport</li> <li>Intake and infiltration of emissions into buildings</li> </ul>	<p><i>Impact Categories</i></p> <ul style="list-style-type: none"> <li>Photochemical ozone creation</li> <li>Human toxicity (PEF default)</li> <li>Particulate matter/respiratory inorganics (PEF default)</li> </ul>	<p><i>Strategies</i></p> <ul style="list-style-type: none"> <li>EU Environment and health strategy (2013)</li> </ul> <p><i>Instruments:</i></p> <ul style="list-style-type: none"> <li>Clean Air policy package (2013)</li> <li>Industrial Emissions Directive 2010/75/EU</li> <li>Clean Air Directive 2008/50/EC</li> <li>National Emissions Ceiling Directive 2001/81/EC</li> <li>Montreal Protocol (1987)</li> </ul>	<ul style="list-style-type: none"> <li>Local emissions ceilings for pollutants responsible for acidification, eutrophication and ground-level ozone pollution - CH<sub>4</sub>, SO<sub>2</sub>, NO<sub>x</sub>, VOC, NH<sub>3</sub> and PM pollution from industrial, power generation and transport sources</li> <li>Continued control of emissions of ozone depleting substances</li> </ul>
3c. Noise pollution (especially urban areas)				<ul style="list-style-type: none"> <li>Manufacturing sites</li> <li>Construction site activities</li> <li>Traffic in urban streets</li> <li>Street and building cohabitation</li> </ul> <p><i>Note:</i> No evidence base is available to identify 'hot spots'</p>	<p><i>None applicable</i></p>	<p><i>Instruments:</i></p> <ul style="list-style-type: none"> <li>Environmental Noise Directive (2002)</li> </ul>	<ul style="list-style-type: none"> <li>Prevention of residential environmental noise exposure</li> <li>Preservation of areas with good environmental noise quality</li> </ul>
3d. Urban systems and grey infrastructure				<ul style="list-style-type: none"> <li>Material extraction, processing and product manufacturing</li> <li>Maintenance and upgrading of infrastructure</li> </ul>	<p><i>See 2a, 2c/d, 2f</i></p>	<p><i>See energy, water and transport infrastructure as addressed under environmental issues 1c/d, 2c/d and 2e</i></p>	<p><i>See objectives identified in relation to energy, water and transport infrastructure</i></p>

3e. Climate change and related environmental health risks				<ul style="list-style-type: none"> <li>○ Overheating of the built environment</li> <li>○ Exposure of buildings and infrastructure to extreme weather events</li> <li>○ Increased risk of flood events</li> </ul>	<p>Additional heating or cooling – see 2c/d.</p> <p><i>No impact categories associated with other effects.</i></p>	<p><i>Strategies:</i></p> <ul style="list-style-type: none"> <li>○ EU strategy on adaptation to climate change (2013)</li> <li>○ Biodiversity strategy to 2020 (2011)</li> <li>○ Green Infrastructure (2013)</li> </ul>	<ul style="list-style-type: none"> <li>○ Climate proof cities, buildings and infrastructure according to regional and local impacts</li> <li>○ Mitigation of flooding, urban heat islands and building overheating</li> <li>○ Inclusion of climate change considerations in construction standards</li> </ul>
3f. Chemicals and related environmental health risks				<ul style="list-style-type: none"> <li>○ Exposure of workers to potential hazards during product manufacturing</li> <li>○ Exposure of building occupiers to hazardous emissions from construction products/finishes</li> <li>○ Exposure of workers to potential hazards during building renovation or demolition</li> </ul>	<p><i>Impact Categories</i></p> <ul style="list-style-type: none"> <li>○ Photochemical ozone creation</li> <li>○ Human toxicity (PEF default)</li> <li>○ Particulate matter/respiratory inorganics (PEF default)</li> </ul> <p><i>Parameters:</i></p> <ul style="list-style-type: none"> <li>○ Hazardous and non hazardous waste disposed</li> </ul>	<p><i>Strategies</i></p> <ul style="list-style-type: none"> <li>○ 7<sup>th</sup> Environmental Action Programme (2014)</li> <li>○ EU Occupational Safety and Health (OSH) Strategic Framework (2014)</li> <li>○ EU Environment and health strategy (2013)</li> </ul> <p><i>Instruments</i></p> <ul style="list-style-type: none"> <li>○ Construction Products Regulation (EU) No 305/2011</li> <li>○ Industrial Emissions Directive 2010/75/EU</li> <li>○ Waste Framework Directive 2008/98/EC</li> <li>○ CLP Regulation (EC) No 1272/2008</li> <li>○ REACH Regulation (EC) No 1907/2006</li> <li>○ Safety and health of workers Directive 89/391/EEC</li> </ul>	<ul style="list-style-type: none"> <li>○ Minimise occupational and environmental exposure risks associated with hazardous chemicals and materials during handling and disposal</li> <li>○ Minimise risks of exposure associated with living environments and indoor and outdoor air quality, with a specific focus on children</li> <li>○ Minimise consumer and environmental exposure from construction products and finishes</li> </ul>

## Appendix 2. Drivers, Pressures, State, Impact and Response (DPSIR) analysis of environmental issues clusters and identification of 'responses'

### 2.1 Macro-objectives identified based on life cycle significance and combined EU strategy and instrument coverage

Clustering of EEA SOER environmental issues	'Building material flows and impacts' 2b. Waste management 2a. Material resource efficiency and material use	'Contribution of energy use to climate change' 2c. Greenhouse Gas emissions and climate change mitigation	
	<i>Associated environmental issues:</i> 1b. Land use and soil functions 2c. Greenhouse Gas emissions and climate change mitigation 2f. Industrial pollution to air, soil and water	'Greenhouse gas emissions from energy use' 1e. Air pollution and its ecosystem impacts 2d. Energy consumption and fossil fuel use 3b. Air pollution and related environmental health risks	'Greenhouse gas emissions from fuel use' 1e. Air pollution and its ecosystem impacts 2e. Transport demand and related environmental impacts 3b. Air pollution and related environmental health risks
<b>Drivers</b>	<ul style="list-style-type: none"> <li>○ Demand for construction materials manufactured from fossil fuels, metals, non-metallic minerals and timber</li> <li>○ Construction and demolition waste arisings that are sent to landfill or down cycled</li> </ul>	<ul style="list-style-type: none"> <li>○ Energy use to extract, process and manufacture products</li> <li>○ Production of cement</li> <li>○ Energy use during the occupation of buildings with majority of emissions from aging building stock</li> <li>○ Private transport associated with building occupants</li> </ul>	<ul style="list-style-type: none"> <li>○ Private and public transport journeys and urban congestion</li> <li>○ <i>Potential for longer distance transport of high mass/large flow construction materials</i></li> </ul>
<b>Pressures</b>	<ul style="list-style-type: none"> <li>○ Increased extraction and 'hidden flows' associated with fossil fuel, metal, non-metallic mineral and timber resources</li> <li>○ Emissions to the environment arising from extraction and manufacturing processes and associated transport</li> <li>○ Changes in land use as a result of primary resource extraction</li> </ul>	<ul style="list-style-type: none"> <li>○ Increased extraction and depletion of fossil fuel resources</li> <li>○ Emissions of CO<sub>2</sub> associated with building energy use</li> <li>○ Emissions of GHG from vehicles</li> </ul>	<ul style="list-style-type: none"> <li>○ Increased extraction and depletion of fossil fuel resources</li> <li>○ Emissions of GHG from vehicles</li> <li>○ Localised NO<sub>x</sub>, VOC and PM pollution</li> </ul>
<b>State</b>	<ul style="list-style-type: none"> <li>○ Abiotic raw material reserves that have criticality status</li> <li>○ Increased material stocks in landfill</li> <li>○ Sustainability of forestry (biotic) resources</li> <li>○ Changes in productivity and biodiversity of land and forestry</li> <li>○ Air, soil and water quality</li> </ul>	<ul style="list-style-type: none"> <li>○ Short to medium term stabilisation/reduction of building related GHG emissions</li> <li>○ Increasing GHG emissions from transport</li> <li>○ Measured climatic changes at regional and international level</li> </ul>	<ul style="list-style-type: none"> <li>○ Transport related emissions are the only sector in which CO<sub>2</sub> emissions and local air pollution has risen</li> </ul>



<b>Impact</b>	<ul style="list-style-type: none"> <li>○ Variable damage to soil resources and ecosystem services</li> <li>○ Damage arising from climate change as a result of GHG and other industrial emissions associated with material production</li> </ul>	<ul style="list-style-type: none"> <li>○ Damage arising from climate change as a result of GHG emissions associated with primary fossil energy use</li> <li>○ Damage arising from climate change as a result of GHG and other industrial emissions associated with material production</li> </ul>	<ul style="list-style-type: none"> <li>○ Damage arising from GHG emissions associated with primary fossil energy use</li> <li>○ Damage arising from localised NO<sub>x</sub>, VOC and PM pollution</li> </ul>
<b>Response</b> <i>(within the scope of stock, neighbourhood and building level)</i>	<p>Action at <i>building level</i> with a focus on material efficiency and circular utility, from manufacturing, design, engineering and construction through to upgrading, adaptation and deconstruction. The overall objective shall be to reduce the life cycle environmental impacts of designs and material choices.</p>	<p>Action at <i>stock, neighbourhood and building level</i> with a focus on 1) energy performance and low/zero emissions energy technologies and infrastructure during the use phase, 2) the potential trade-offs with the embodied energy of materials along the buildings life cycle.</p>	<p>Action at <i>stock and neighbourhood level</i> to promote sustainable modes of transport, at <i>neighbourhood level</i> to avoid urban sprawl and promote well connected, mixed use development forms, and at <i>building level</i> to select well connected sites and minimise private car parking provision.</p>
	<p><i>Macro-objective:</i> Optimise building design and form in order to maximise circular and sustainable material flows, extend material utility and reduce environmental impacts.</p>	<p><i>Macro-objective:</i> Minimise the total GHG emissions along a buildings lifecycle, avoiding trade-offs between embodied emissions and building energy use emissions.</p>	<p><i>Macro-objective:</i> Minimise GHG emissions and urban air pollution associated with the travel patterns and transport modes used during the occupation of buildings and neighbourhoods.</p>

## 2.2 Macro-objectives identified based on EU strategy coverage, regional/local environmental pressures and/or combinations of environmental effects

<b>Clustering of EEA environmental issues</b>	<b>'Building related water use'</b> 2g. Water use and water quantity stress 3a. Water pollution and related environmental health risks 1d. Water quality and nutrient loading	<b>'Urban pressures on land use and habitats'</b> 1b. Land use and soil functions 1a. Terrestrial and freshwater biodiversity 1e. Air pollution and its ecosystem impacts 3b. Air pollution and related environmental health risks
<b>Drivers</b>	<ul style="list-style-type: none"> <li>Greater per capita use of water in the home.</li> <li>Pressure from urban development and the related increase in demand in river basins under water stress.</li> </ul>	<ul style="list-style-type: none"> <li>Increased urban sprawl and the use of greenfield development sites with agricultural or biodiversity value</li> <li>Increased use of material obtained from biotic sources</li> </ul>
<b>Pressures</b>	<ul style="list-style-type: none"> <li>Increased abstraction from available sources</li> <li>Competing demand with agriculture and industry</li> <li>More energy intensive water treatment may be required</li> <li>Reduced soil infiltration as a result of hard surfaces and urban drainage systems.</li> <li>Wastewater may need to be recycled</li> </ul>	<ul style="list-style-type: none"> <li>Loss and degradation of fertile land</li> <li>Extension into greenfields of urban development and infrastructure</li> <li>Contamination of brownfield land</li> </ul>
<b>State</b>	<ul style="list-style-type: none"> <li>Reduced reservoir reserves</li> <li>Soil and groundwater depletion</li> <li>Rivers with low flow</li> </ul>	<ul style="list-style-type: none"> <li>Increase in extent of urban areas</li> <li>Reduction in stock of fertile greenfield land</li> <li>Increase in habitat fragmentation on urban fringes</li> </ul>
<b>Impact</b>	<ul style="list-style-type: none"> <li>Damage associated with increased GHG emissions from water extraction/treatment</li> <li>Depleted soil moisture levels</li> </ul>	<ul style="list-style-type: none"> <li>Reduction in productive land assets</li> <li>Sealing of soil with associated reduction in infiltration and increase in run-off</li> <li>Habitat fragmentation and changes in the biodiversity of land and forestry Shift to monoculture to produce biotic materials</li> </ul>
<b>Response</b> <i>(within the scope of stock, neighbourhood and building level)</i>	Action in areas of long-term or projected water stress at <i>building level</i> to minimise water use through efficiency measures, water recycling and rainwater harvesting; and at <i>stock and neighbourhood level</i> to use landscape and infrastructure to support more efficient management of water resources.	Action at <i>neighbourhood level</i> to use land more efficiently through a combination of development on brownfield sites, more compact development forms, the integration of green infrastructure and the minimisation of soil sealing.
	<i>Macro-objective:</i> Efficient use of water resources, particularly in areas of identified long-term or projected water stress.	<i>Macro-objective:</i> Efficient use of land in order to minimise urban sprawl, habitat fragmentation and the loss of fertile soils.

## 2.3 Macro-objectives identified based on EU strategy coverage and the potential for regional or locally extensive human health impacts

Clustering of EEA environmental issues	'Health risks from hazardous substances'	'Urban resilience to climate change'
<b>Drivers</b>	<ul style="list-style-type: none"> <li>3a. Water pollution and related environmental health risks</li> <li>3b. Air pollution and related environmental health risks</li> <li>3f. Chemicals and related environmental health risks</li> </ul>	<ul style="list-style-type: none"> <li>1b. Land use and soil functions</li> <li>1g. Climate change impacts on ecosystems</li> <li>2d. Energy consumption and fossil fuel use</li> <li>2g. Water use and water quantity stress</li> <li>3e. Climate change and related environmental health risks</li> </ul>
<b>Pressures</b>	<ul style="list-style-type: none"> <li>○ Increased extraction of fossil fuel, metal, non-metallic mineral and timber resources</li> <li>○ Associated impacts relating to energy use, industrial pollution, transport and land use change</li> <li>○ Hazardous emissions from construction materials and finishings</li> </ul>	<ul style="list-style-type: none"> <li>○ Increased urban heat island effect</li> <li>○ More frequent flood and extreme weather events</li> <li>○ Unstable conditions influence habitats and biodiversity</li> <li>○ Depletion of surface water resources</li> </ul>
<b>State</b>	<ul style="list-style-type: none"> <li>○ Air, soil and water quality (EU and international locations)</li> <li>○ Hazardous waste arisings</li> <li>○ Measurements of building Indoor Air Quality (IAQ)</li> </ul>	<ul style="list-style-type: none"> <li>○ <i>Increased frequency and extremes of events identified under 'pressures'</i></li> </ul>
<b>Impact</b>	<ul style="list-style-type: none"> <li>○ GHG emissions (metallic and non-metallic minerals and engineered timber)</li> <li>○ Variable impacts on land use and ecosystems services (biotic materials)</li> <li>○ Health of building occupants (damage resulting from ventilation intake from outside and emissions from inside)</li> </ul>	<ul style="list-style-type: none"> <li>○ Damage associated with increased GHG emissions from cooling</li> <li>○ Changes in habitats and biodiversity</li> <li>○ Increased extent of areas affected by flood events</li> </ul>
<b>Response</b> <i>(within the scope of stock, neighbourhood and building level)</i>	Action at <i>building level</i> in response to the linkages implied by EU health, construction and chemicals policy and strategy.	Action at <i>stock and neighbourhood level</i> to build the capacity of the urban environment, and in particular green infrastructure, to moderate change; and at <i>building level</i> to design-in resilience to predicted conditions.
	<i>Macro-objective:</i> Design and construction of buildings that protect human health by minimising the use of and exposure to hazardous substances along their life cycle.	<i>Macro-objective:</i> Future proofing of the urban environment through adaptive and resilient design and renovation of the built environment and by protecting and enhancing ecosystem services.

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