European Commission

JRC SCIENCE FOR POLICY REPORT

Background research for the revision of EU Green Public Procurement criteria for Buildings

Tasks 1 to 4: Version 1.0

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February 2022

Joint Research Centre

EUR XXXXX XX

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JRCXXXXXX

EUR XXXXX XX

PDF	ISBN XXX-XX-XX-XXXXX-X	ISSN XXXX-XXXX	doi:XX.XXXX/XXXXXX
Print	ISBN XXX-XX-XX-XXXXX-X	ISSN XXXX-XXXX	doi:XX.XXXX/XXXXXX

Luxembourg: Publications Office of the European Union, 20XX [if no identifiers, please use Brussels: European Commission, 20XX or Ispra: European Commission, 20XX or Geel: European Commission, 20XX or Karlsruhe: European Commission, 20XX or Petten: European Commission, 20XX or Seville: European Commission, 20XX depending on your unit]

How to cite this report: Author(s), *Title*, EUR (where available), Publisher, Publisher City, Year of Publication, ISBN 978-92-79-XXXXX-X (where available), doi:10.2760/XXXXX (where available), JRCXXXXXX.

Contents

Abstract

In 2016, the Commission published EU GPP criteria for office buildings. Since then, many developments in EU policy have occurred (and still are occurring) that directly affect investments in buildings.

The EU Taxonomy is defining how complying with certain criteria for buildings can demonstrate a substantial contribution to climate change mitigation or climate change adaptation (more criteria on other contributions soon to follow). The Energy Efficiency Directive requires public authorities to play an exemplary role in the procurement of energy efficient products, systems and services while the Renovation Wave and the Energy Performance of Buildings Directive (EPBD) are driving building renovation. While the EPBD sets an overarching methodology for assessing the energy performance of buildings and the Level(s) common framework sets a total of 16 indicators that can be applied to assess the sustainability of buildings. The New European Bauhaus goes even further by looking at aesthetics and inclusivity in addition to sustainability.

These myriad policy developments have been briefly reviewed, together with relevant market analysis of EU building stock, environmental impacts of buildings in the academic literature and a review of the improvement potential for a limited number of building fittings (only taps and showers in this first draft).

Taking inspiration from the Level(s) framework and the EU Taxonomy, it is proposed to update the EU GPP criteria for office buildings and group theme into seven themes. Furthermore, in order to reach a greater number of EU buildings, it is proposed to expand the scope to also include educational buildings and social housing.

Acknowledgements

This report has been developed in the context of the Adminstrative Arrangement *(to be completed)* between DG Environment (ENV) and DG Joint Research Centre (JRC).

The authors wish to thank the co-ordinating policy officer from DG Environment (Enrico Degiorgis) and other Commission colleagues for their valuable discussions, inputs and reactions to the report (special mention to Josefina Lindblom, Manfred Fuchs….*(to be completed as project progresses)*.

The authors also wish all the stakeholders who have participated in the criteria revision process and contributed valuable insights and experiences that have helped shape these criteria proposals ….*(to be completed as project progresses)*..

Executive summary

The science for policy report sets the policy context for the revision of EU Green Public Procurement (GPP) criteria for buildings. In addition to the identification and summary of relevant policies, background research is provided on: (i) the EU building stock and key economic indicators of the building construction sector; trends in Green Building Rating Systems; (iii) a short review of the main environmental impacts associated with buildings and (iv) a technical analysis of the main technical systems used in buildings. This last point in particular is used to assess the potential for improvement in building performance. Significant future updates to the content of this report are foreseen after further research and consultation with stakeholders.

Policy context

Buildings play an important role in many cross-cutting EU policies and are the sole subject of high-profile, dedicated building policies – all of which have been created or updated only very recently. Particularly for this resaon, it was considered relevant to revise the existing EU GPP criteria that were set for buildings back in 2016.

The main cross-cutting policies are the European Green Deal (EGD), the EU Taxonomy for environmentally sustainable economic activities, the Circular Economy Action Plan (CEAP), the recovery plan for Europe and the Energy Efficiency Directive (EED). The main building-specific policies are the Renovation Wave, the Level(s) framework, the New European Bauhaus and the Energy Performance of Buildings Directive (EPBD).

Key conclusions

The key conclusions from this report are that:

- The revised EU GPP criteria for buildings must be strongly based on the Level(s) framework and find synergies with the EU Taxonomy, the EED and the EPBD.
- The potential impact of EU GPP criteria could be increased by a factor of four by expanding the scope to include educational buildings and social housing in addition to public offices.
- The two highest profile environmental impacts associated with buildings today are operational energy use and life cycle carbon, but care needs to be taken in order not to reduce occupant health and wellbeing in order to lower those impacts.

Main findings

The use of the Level(s) framework represents a logical evolution for the existing EU GPP criteria for buildings. By comparing the six macro-objectives of Level(s) with the six environmental goals of the EU Taxonomy on environmentally sustainable economic activities, EU GPP criteria for buildings should be centred around the following seven themes:

1. Energy consumption and life cycle greenhouse gas emissions
2. Material efficiency and circularity
3. Efficient use of water resources
4. Occupant comfort and wellbeing
5. Vulnerability and resilience to climate hazards
6. Life cycle costing
7. Biodiversity

In terms of building stock in the EU, approximately 75% of total floor area is associated with residential buildings (varying from 60% to 89% in individual countries). Of the remaining 25%,

The often cited figure of 75% of EU building stock having poor energy performance is in no small part due to the age profile of EU buildings, with around half of total residential stock being built before 1970 and generally less than 10% having been built in the last 10-12 years.

The current level of impact of EU GPP criteria on public office buildings is limited by the fact that these types of buildings account for anywhere between 3 and 32% of non-residential building area (average around 10%)

and this, coupled with the fact that non-residential buildings only account for 25% of total EU building stock, means that EU GPP criteria for public offices is only targeting around 2-3% of EU building area.

By also including social housing and educational buildings within the scope, the potential impact of EU GPP criteria could be increased by targeting 11-12% of building stock instead of 2-3%.

In terms of environmental impacts, most assessments have focussed on energy consumption and carbon emissions (operational and/or embodied). There are literally thousands of research papers published on the subject of life cycle assessment of buildings. The general concensus is that results from studies are difficult to compare due to the many degrees of freedom that can be applied, even when following international standard methodologies. It is for this reason that anyone setting any benchmark for life cycle carbon emissions must also clearly fix a number of methodological variables, such as: scope of building elements, scope of operational energy, use of generic data etc.

Despite the many variables that exist in building LCA methods, a general conclusion is that impacts due to operational energy use have been (and will be) greatly reduced due to new building standards and particular focus on better thermal performance of building envelopes and more efficient building technical systems. As energy performance has improved, efforts are turning to the other main source of carbon emissions, embodied carbon.

Efforts to reduce embodied carbon can focus on different areas, such as using lower carbon materials, using prefabricated elements to reduce waste and to maximize reuse opportunities at end-of-life or to design buildings and elements that are more durable and easy to repair.

Efforts to improve water efficiency, daylighting, acoustics and indoor air quality have not received the same attention in building standards but significant progress has been made. Indoor air quality is becoming more of an issue for designers now, since one of the trade-offs with energy efficient buildings is a more air-tight building. One of the major limitations on improving the envronmental performance of any newly constructed or renovated building is the lack of appropriately skilled and experienced staff in the construction sector.

The research to identify improvement potentials for building environmental performance is incomplete in this first draft, but for the taps and showers components that were analysed, there is major room for improvement, especially with renovation, to reduce water consumption by a factor of 2 to 3.

Related and future JRC work

The JRC is active in a number of areas that are directly or indirectly relevant to EU GPP criteria for buildings. Consultation is foreseen with the following parts of JRC, as a minimum, to ensure that in-house knowledge can play a major role in improving the quality and relevance of EU GPP criteria proposals and supporting rationale:

- JRC Directorate C on Energy, Transport & Climate (especially units: C1-Energy storage; C2-Energy efficiency and renewables; C3: Energy security, distribution and markets and C5-Air and climate).
- JRC Directorate D on Sustainable Resources (especially units: D2-Water and marine resources and D6-Knowledge for sustainable development & food security).
- JRC Directorate E on Space, Security and Migration (especially units: E1-Disaster risk management and E4-Safety & security of buildings).

Background

Since the publication of EU GPP criteria for office buildings in 2016, many policy developments have taken place that have an influence on the revision process of this EU GPP criteria-set. Before entering into details that are purely focussed on buildings, it is worth highlighting some key, cross-cutting and high level policies in Europe.

High level, cross-sectorial policy context

The European Green Deal

As set out in [Communication (2019) 640](), the European Green Deal is the Commission's new growth strategy to transform the EU into a fair and prosperous society. This enormously complex task has been structured into 11 key elements, which are illustrated below.

Figure 1. The European Green Deal (EGD)

From the 11 key elements of the European Green Deal (EGD), buildings can be considered to have the following degrees of relevance and potential influence:

- "*Building and renovating in an energy and resource efficient way*": complete relevance and direct relationship in potential GPP criteria for buildings by looking at their energy performance, design for deconstruction and management of construction and demolition waste (CDW).
- "Increasing the EU's Climate ambition for 2030 and 2050": directly relevant to buildings in terms of operational CO_2 emissions from energy consumption in buildings and embodied CO_2 in construction products, materials and waste.
- "*Supplying clean, affordable and secure energy*": partially relevant and direct relationship in potential GPP criteria if referring to renewable energy installed in-situ or nearby, including district heating.
- "*Preserving and restoring ecosystems and biodiversity*": partially relevant and indirect relationship in GPP criteria if referring to green roofs or green walls.
- "*A zero pollution ambition for a toxic-free environment*": partially relevant and indirect relationship in GPP criteria if referring to emissions of Volatile Organic Compounds, ventilation performance class and indoor supply air classes delivered by ventilation systems.

- “Financing the transition”: GPP criteria, by its very nature, can act as a key instrument to specify the purchasing of goods or contracting of services that are in line with the goals of the EGD. The construction of new buildings and the renovation of existing ones, at the European level, involves considerable sums of money – thus representing a major opportunity for driving change.

This last point links to another cross-cutting and highly relevant policy, the EU Taxonomy.

The EU Taxonomy for sustainable economic activities

The aim of the taxonomy is to provide a common language and clear definition of what economic activities can be considered as “environmentally sustainable”. The taxonomy works within the existing classification of economic activities and sets rules for companies to report according to common rules and principles.

The taxonomy thus enables investors to better understand how environmentally sustainable the companies and activities they are investing in actually are. The taxonomy is focussed on the following 6 environmental objectives:

1. Climate change mitigation
2. Climate change adaptation
3. The sustainable use and protection of water and marine resources
4. The transition to a circular economy
5. Pollution prevention and control
6. The protection and restoration of biodiversity and ecosystems

The basic framework for the EU Taxonomy is set out in Regulation (EU) 2020/852. The framework makes general reference to the conditions that an economic activity must comply with in order to be considered as environmentally sustainable. Specific requirements for technical screening criteria and do no significant harm criteria for relevant economic activities will be provided in a total of six Annexes to Regulation (EU) 2020/852, one per environmental objective. As of January 2022, Annex I (on climate change mitigation) and Annex II (on climate change adaptation) had been prepared.

For each Annex, criteria are set for economic activities that are considered to have the potential to make a significant contribution to the corresponding environmental objective. The contribution can be made in different ways, namely by a direct contribution based on the performance of the economic activity or an indirect contribution due to one economic activity enabling the direct contribution of another economic activity.

EU Taxonomy economic activities of direct relevance to the EU GPP criteria for buildings for the different environmental objectives are summarised below.

Table 1. Cross-check of building-related economic activities in the EU Taxonomy against environmental objectives

Economic activity (within the construction and real estate sector)	**Significant contribution to**		**(still to be finalised)**			
	1. Climate change mitigation	**2. Climate change adaptation**	**3.Water and marine resources**	**4. Circular economy**	**Pollution**	**Biodiversity**
The construction of new buildings	X	X	?	?	?	?
The renovation of existing buildings	X	X	?	?	?	?
The installation, maintenance and repair of energy efficiency equipment	X	X	?	?	?	?
The installation, maintenance and repair of charging stations for electric vehicles in buildings (and parking spaces attached to	X	X	?	?	?	?

Economic activity (within the construction and real estate sector)	Significant contribution to		(still to be finalised)			
	1. Climate change mitigation	2. Climate change adaptation	3.Water and marine resources	4. Circular economy	Pollution	Biodiversity
buildings)						
The installation, maintenance and repair of instruments and devices for measuring, regulation and controlling energy performance of buildings	X	X	?	?	?	?
The installation, maintenance and repair of renewable energy technologies	X	X	?	?	?	?
The acquisition and ownership of buildings	X	X	?	?	?	?

It is clear that the EU Taxonomy covers potential procurement criteria for buildings in both a broad sense (i.e. new construction activity, renovation activity and acquisition activity) and in more focussed activities (e.g. energy efficiency equipment or onsite renewable energy technologies).

Circular Economy Action Plan

The shift to a circular economy is regarded as an opportunity to establish new job-intensive activities within Europe's industry and bring more manufacturing back to the EU in some sectors, while minimizing environmental and climate impacts. The EU Circular Economy Action Plan 1.0 from 2015[1] required changes to EU legislation to encourage a more circular economy.

This included amendments to the Waste Framework Directive, which makes several additional references to construction and demolition waste (CDW). Some of the most relevant updates in the revised Waste Framework Directive for CDW are:

- Article 3: Setting a definition of CDW.
- Article 9d): To encourage the re-use of and repair of construction materials and products.
- Article 9f): To take into account best available techniques to reduce CDW generation.
- Article 11b): To promote selective demolition for the removal and safe handling of hazardous CDW.
- Article 11b): To establish sorting systems for CDW at least for wood, mineral fractions, metal, glass, plastic and plaster
- Article 11(6): To consider, by 31 December 2024, the setting of preparing for reuse and recycling targets for CDW and its specific material fractions.

More recently, the European Commission introduced a new Circular Economy Action Plan (CEAP)[2] as one of the key elements of the European Green Deal.[3] The aim of the new CEAP is to reduce the EU's consumption footprint and double the EU's circular material use rate in the coming decade, while boosting economic growth.

Construction and buildings are highlighted as one of the key product value chains in the new CEAP – with construction and demolition activities being considered responsible for around 35% of all EU waste generated. The CEAP highlights two key principles to be applied to buildings: design for durability and design for

[1] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Closing the loop - An EU action plan for the Circular Economy

[2] Communication from the Commission to the European parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A new Circular Economy Action Plan, For a cleaner and more competitive Europe. Brussels, 11.3.2020 (COM 2020) 98 final)

[3] Communication from the Commission to the European parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. The European Green Deal. Brussels, 11.12.2019 (COM(2019) 640 final)

adaptability. The safe, sustainable and circular use of excavated soils is specifically mentioned, as are initiatives to reduce soil sealing and to consider revising CDW material recovery targets.

Recovery Plan for Europe

The announcement of the COVID-19 pandemic and the ensuing lockdowns and restrictions implemented by governments across the EU have had severe economic consequences. In an effort to repair and recover from these impacts, the EU has agreed to create "Next Generation EU", which also forms part of the new long-term EU budget for 2021 to 2027.

The Next Generation EU programme effectively borrows 750€ billion from financial markets, which will be repaid over a long period of time in future EU budgets (not before 2028 or after 2058). The majority of this new finance (560€ billion) is being attributed to what is termed the "Recovery and Resilience Facility", whose aim is to support investments and reforms to deliver green and digital transitions that improve the resilience of national economies in a way that also links to EU priorities.

Member States were required to draw up national recovery and resilience plans and a recurring theme in many of them was the renovation of building stock to improve energy efficiency. Renovating existing building stock has clear resource efficiency benefits compared to demolishing and building new, and improving energy performance can help societies move towards climate neutrality whilst also limiting the risk of energy poverty. To maximise the benefits of such investments, it is important to make sure that investments are targeted to the most vulnerable members of society and to the buildings where the most cost-effective improvements can be made.

Building specific policy

Renovation Wave

In October 2020, the European Commission published a communication titled: "A Renovation Wave for Europe – greening our buildings, creating jobs, improving lives". The need for such a strategy is underpinned by the relatively old age of Europe's building stock (with 85% of existing buildings today being more than 20 years old) and the fact that around 85 to 95% of buildings existing today will still be there in 2050. Consequently, there is (i) significant room for improvement in existing building stock and (ii) to meet any climate neutrality or building energy efficiency targets in 2050, renovation of existing building stock will play a major role.

The current rate of energy renovation in buildings is very low (around 1%, and just 0.2% for "deep" energy renovations). The EU strategy aims to double annual energy renovation rates in the next 10 years with a particular focus on:

- Tackling energy poverty and the worst-performing buildings.
- Public buildings and social infrastructure.
- Decarbonising heating and cooling.

Especially the first bullet point listed above makes a direct link to the need to deliver improved building energy performance via GPP for new and renovated buildings. The Renovation Wave initiative aims to build upon national long-term climate strategies and national energy and climate plans as well as dovetailing with Energy Performance Certificates and reporting under the Level(s) framework. Some of the key Renovation Wave actions are listed below.

Table 2. Key actions related to the Renovation Wave

Stengthening information, legal certainty and incentives for renovation	
Revision of Energy Performance Certificates and proposal to introduce mandatory minimum energy performance standards for all types of buildings in the EPBD	2021
Revision of requirements on energy audits in the EED	2021
Proposal on Building Renovation Passports and introduction of a single digital tool unifying them with Digital Building Logbooks	2023

Developing a 2050 whole life-cycle performance roadmap to reduce carbon emissions form buildings and advancing national benchmarking with Member States	2023
Reinforced, accessible and more targeted funding supported by technical assistance.	2021
Proposed strengthened financing for the ELENA facility from the InvestEU advisory hub and possibly from other European programmes	
Consider the introduction of a 'deep renovation' standard as part of the EPBD revision	2021
Revising the climate-proofing guidelines for projects supported by the EU	2021
Supporting de-risking energy efficiency investments, and proposing to incorporate environmental, social and governance (ESG) risks into the Capital Requirements law and the Solvency II Directive	2021
Reviewing the General Block Exemption Regulation and Energy and Environmental Aid Guidelines	2021
Creating green jobs, upskilling workers and attracting new talent	
Supporting Member States to update their national roadmaps for the training of the construction workforce through the Build Up Skills Initiative and helping implement the 2020 European Skills Agenda	2020
Sustainable built environment	
Reviewing material recovery targets and supporting the internal market for secondary raw materials	2024
Presenting a unified EU Framework for digital permitting and recommending Building Information Modelling in public procurement	2021
Supporting digitalisation in the construction sector through Horizon Europe, Digital Innovation Hubs and Testing and Experimentation Facilities	2021
Placing an integrated participatory and neighbourhood based approach at the heart of renovation	
Setting up a creative European Bauhaus platform to combine sustainability with art and design	2020
Supporting sustainable and decarbonised energy solutions through Horizon Europe and the R&I co-creation space	2020
Facilitating the development of energy communities and local action through the European Smart Cities Marketplace	2020
Supporting the development of climate-resilient building standards	2020
Tackling energy poverty and worst-performing buildings	
Launching the Affordable Housing Initiative piloting 100 renovation districts	2021
Public buildings and social infrastructure showing the way	
Proposing to extend the requirements for renovation to buildings in the EED to all public administration levels	2021
Based on Level(s), developing green public procurement criteria related to life cycle and climate resilience for certain public buildings	2022
Decarbonising heating and cooling	
Developing ecodesign and energy labelling measures	2020
Assessing the extension of the use of emission trading to emissions from buildings	2021
Revising the RED and the EED and considering strengthening the renewable heating and cooling target and introducing a requirement for minimum proportions of renewable energy in buildings. Also facilitating access of waste and renewable heat and cool into energy systems	2021

Source: (To be confirmed)

Clearly there are many ongoing policy actions relating to the Renovation Wave and this, coupled with the turmoil associated with the COVID restrictions and new recovery funding, means that more time may be needed to implement and assess progress in these action points.

The Level(s) framework

Level(s) is a European framework for sustainability that aims to provide a common language for assessing and reporting on the sustainability performance of buildings. After testing a beta version of Level(s) in 80 different projects in 16 different countries, the first public version was published on the same day as the Renovation Wave initiative (14th October 2020).

While the framework has been developed very much with residential and office buildings in mind, it can be applied in principle to any type of building. It is built upon a series of 6 "macro-objectives" that cover different environment, social and economic aspects of building performance:

1. Greenhouse gas and air pollutant emissions along a buildings life cycle
2. Resource efficient and circular material life cycles
3. Efficient use of water resources
4. Healthy and comfortable spaces
5. Adaptation and resilience to climate change
6. Optimised life cycle cost and value

The first three macro-objectives are clear environmental goals, macro-objectives 4 and 5 have both social and environmental aspects while the last macro-objective is purely economical. There is actually a close overlap between Level(s) macro-objectives and the EU taxonomy for environmentally sustainable economic activities, which is illustrated below.

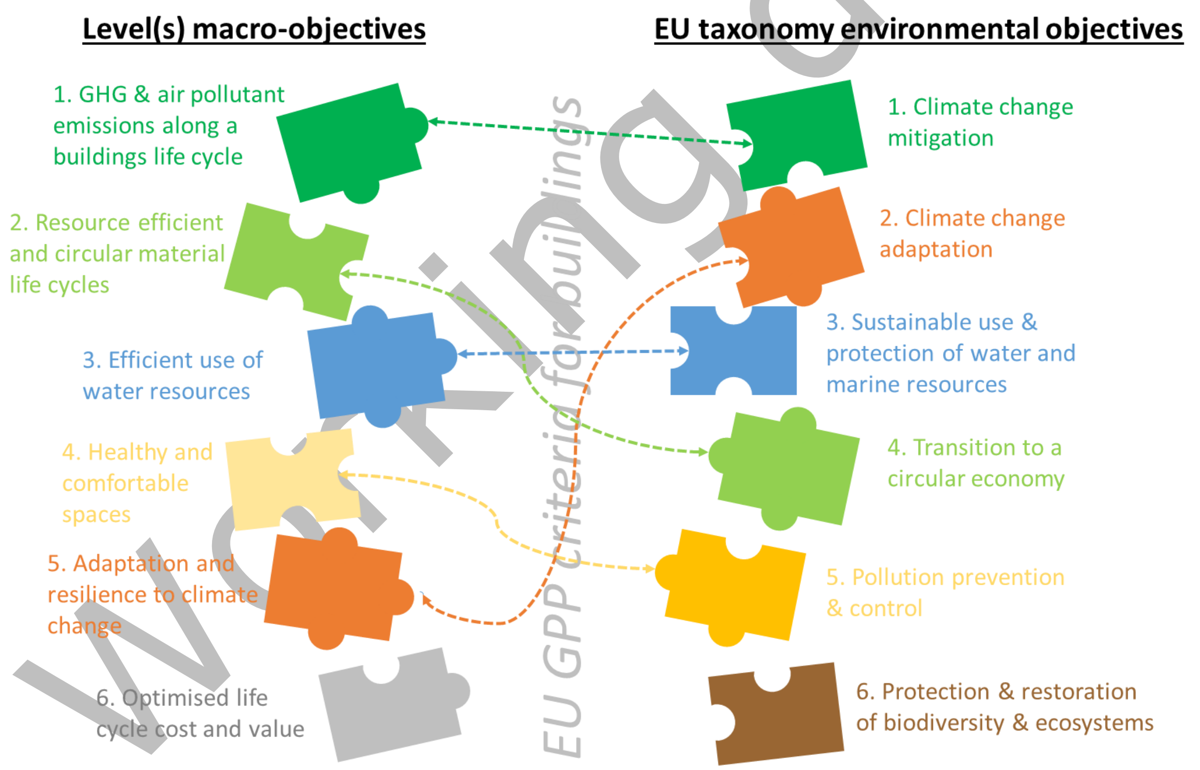

Figure 2. Commonalities between Level(s) and the EU taxonomy.

The illustration above shows that 5 of the 6 macro-objectives of the Level(s) framework line up completely (macro-objectives 1, 2, 3 and 5) or partially (macro-objective 4) with the environmental objectives of the EU taxonomy. The main difference between these two policies is that Level(s) looks at life cycle cost and value while the EU taxonomy looks at biodiversity.

EU GPP criteria should take inspiration from both of these important policy initiatives and so a total of 7 themes should be considered when drafting criteria proposals. These themes are as follows:

1. Energy consumption and life cycle greenhouse gas emissions

2. Material efficiency and circularity
3. Efficient use of water resources
4. Occupant comfort and wellbeing
5. Vulnerability and resilience to climate hazards
6. Life cycle costing
7. Biodiversity

Now that the areas for potential EU GPP criteria for buildings have been framed by relevant policy developments, it is time to present the normal background JRC research that accompanies proposals for EU GPP criteria. This research consists of 4 main background tasks, as follows:

- Task 1: scope and definition, including any relevant policy, legislation and technical standards.
- Task 2: market research, typically the value and volume of the market across the EU.
- Task 3: identification of main environmental impacts associated with buildings.
- Task 4: technical analysis to identify the improvement potentials.

The research for these 4 tasks will evolve during the project and the project process is explained in more detail in the next section.

Criteria development and stakeholder consultation process

In order to update the EU GPP criteria, the Joint Research Centre (JRC) of the European Commission, together with DG Environment (ENV) aim to conduct the necessary research and stakeholder consultation following the process illustrated below.

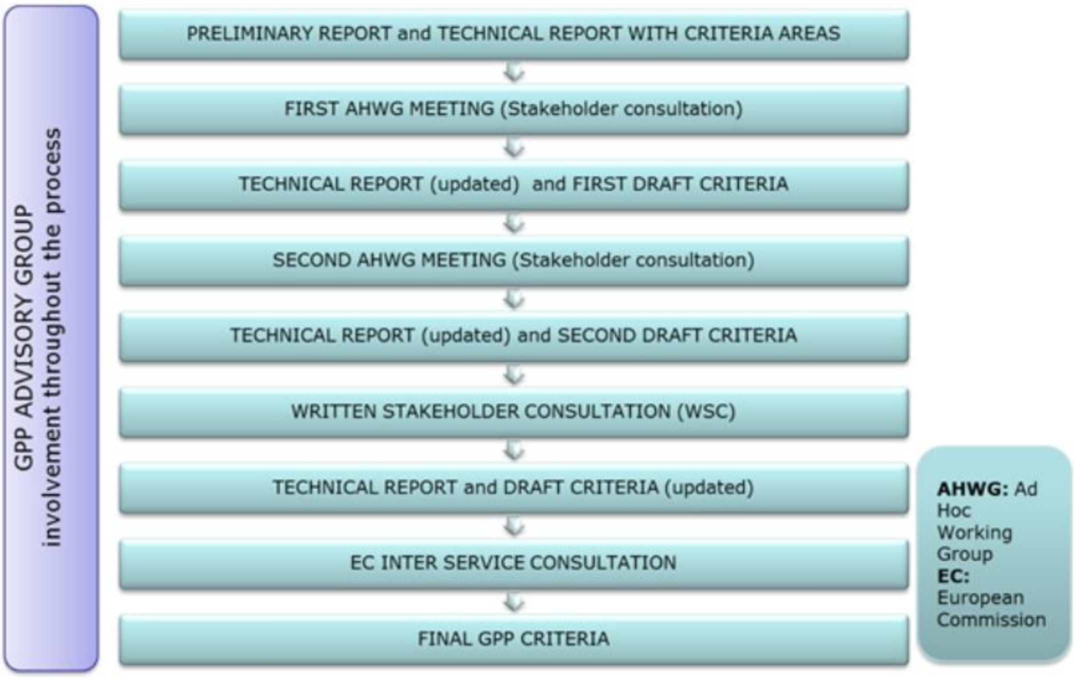

Figure 3. Illustration of the EU GPP criteria development/revision process

The process begins with research being conducted by the JRC for the background report. The first 4 tasks for the preliminary background report will, for buildings, generally involve the following:

- **Task 1 (scope and definition)**: This task starts with the scope of the "product group", which in this case would refer to the types of buildings covered and the types of construction activity and building management that is covered. Depending on the scope, relevant definitions, policy, technical standards and legislation are identified.
- **Task 2 (market analysis)**: This task focuses on market analysis. In the case of buildings, there are many different types of service or activity that are relevant, for example architectural services, demolition works, site preparation works, construction works, installation of services and management/maintenance services. Any interesting trends in the market should also be flagged here – for example developments with Green Building Certification schemes.
- **Task 3 (main environmental impacts)**: The aim of this task is to identify the main environmental impacts associated with buildings. This process begins by reviewing relevant life cycle assessments available in the literature so that environmental impacts and trade-offs can be identified across the entire building life cycle. However, it is also necessary to consider other environmental impacts that are not well captured by LCA methodologies, such as adverse effects on human health or biodiversity.
- **Task 4 (technical analysis and improvement potential)**: This task aims to assess the building from a technical perspective, looking at the different building elements, components, systems and controls that determine how a building functions and performs. Opportunities for improvement of particular systems or designs, and how they could reduce environmental impacts or bring other benefits, is explored in this task wherever possible.

The criteria proposals from task 5 are presented in a separate, and more concise, technical report (with criteria areas). Tasks 1 to 5 are all part of the first row in the diagram above.

The content of the tasks 1 to 5 (especially the criteria proposals from task 5) are subjected to stakeholder consultation. Following reactions and input from stakeholders, a revised set of criteria proposals are produced and subjected to a second round of stakeholder consultation. Depending on how the reactions are at the second meeting, it may be considered necessary to have a third (written) stakeholder consultation, but this step can be skipped to save time if the criteria are sufficiently well developed and no new issues have been flagged in the second consultation that could realistically be resolved within a third round of consultation.

Task 1: Scope and definition

The scope of the EU GPP criteria for buildings can be considered in terms of:

- building function (i.e. the main purpose of the building, which could be residential, office, educational, commercial activity, industrial activity, civic buildings, sports-related buildings, social services, healthcare, religious, emergency services, military or combinations of these),
- building typology (e.g. prefabricated buildings, high-rise buildings, apartment blocks, detached houses, semi-detached houses, terraced houses, warehouses etc. further distinctions may be made based on the choice of structural materials or other factors).
- economic activities related to the physical building asset (e.g. architectural services, engineering design services, demolition activities, site preparation works, construction works, renovation works, installation works, building management services, maintenance works etc.).
- time (i.e. of the project and of the building lifecycle, from design, through construction, completion, occupancy and end of life).
- physical boundaries (i.e. whether to include the surrounding land on the building plot area, any parking areas and any installed energy systems that are not physically inside the building.

Comparison to existing scope

As will be shown later in the market analysis section, public office buildings generally count for less than 15% of the non-residential building floor area. Considering that the EU average floor area split between residential and non-residential buildings is 75% to 25%, this means that around 3 to 4% of total EU building area is public offices. In order to increase the potential impact of EU GPP criteria for buildings, it was considered relevant to expand the scope to educational buildings and to social housing. Making the approximate assumptions from the task 2 data presented later that around 20% of non-residential buildings are educational buildings (mostly public) and around 5% of all residential building floor area is social housing, expanding the scope would therefore increase the coverage of EU GPP criteria from around 3-4% of EU building floor area to around 11-12%.

A comparison of the scope of the proposed EU GPP criteria for buildings and those from 2016 (Dodd et al., 2016) is provided below.

Table 3. Comparison of scope of proposed EU GPP criteria for buildings with those from 2016

	Proposed scope	2016 criteria
Building functionality	Office, residential and educational	Office
Building typology	Not specified	Not specified
Economic activity	Same	(i) preliminary scoping and feasibility; (ii) detailed design and applications for permits; (iii) strip-out, demolition and site preparation works; (iv) construction or major renovation works; (v) installation of energy systems and supply of energy services; (vi) completion and handover; (vii) facilities management and (viii) post-occupancy evaluation.
Time	Same	From design up until end of occupancy.
Physical boundary	Includes parking and areas beyond building curtilage but still within building plot area.	Does not cover parking and areas beyond building curtilage but still within building plot area.

The major differences in scope are that the new criteria will also be designed to consider residential and educational buildings and will also consider criteria that could apply to the surrounding plot area of the building. The main reasons for including the building plot area is that it may be crucial in ensuring that onsite or nearby renewable energy systems are included within the scope.

Consideration of relevant Common Procurement Vocabulary (CPV) codes

In order to provide a harmonised system for public procurement, to help identify related tenders and classify public expenditure, Regulation (EC) No 213/2008[4] sets out a hierarchy of Common Procurement Vocabulary codes. A bewildering array of entries are identified when searching for terms like "buildings" or "construction" and these are compiled in Annex I for reference. When viewed in a more hierarchical form, as shown in the figure below, it becomes easier to understand.

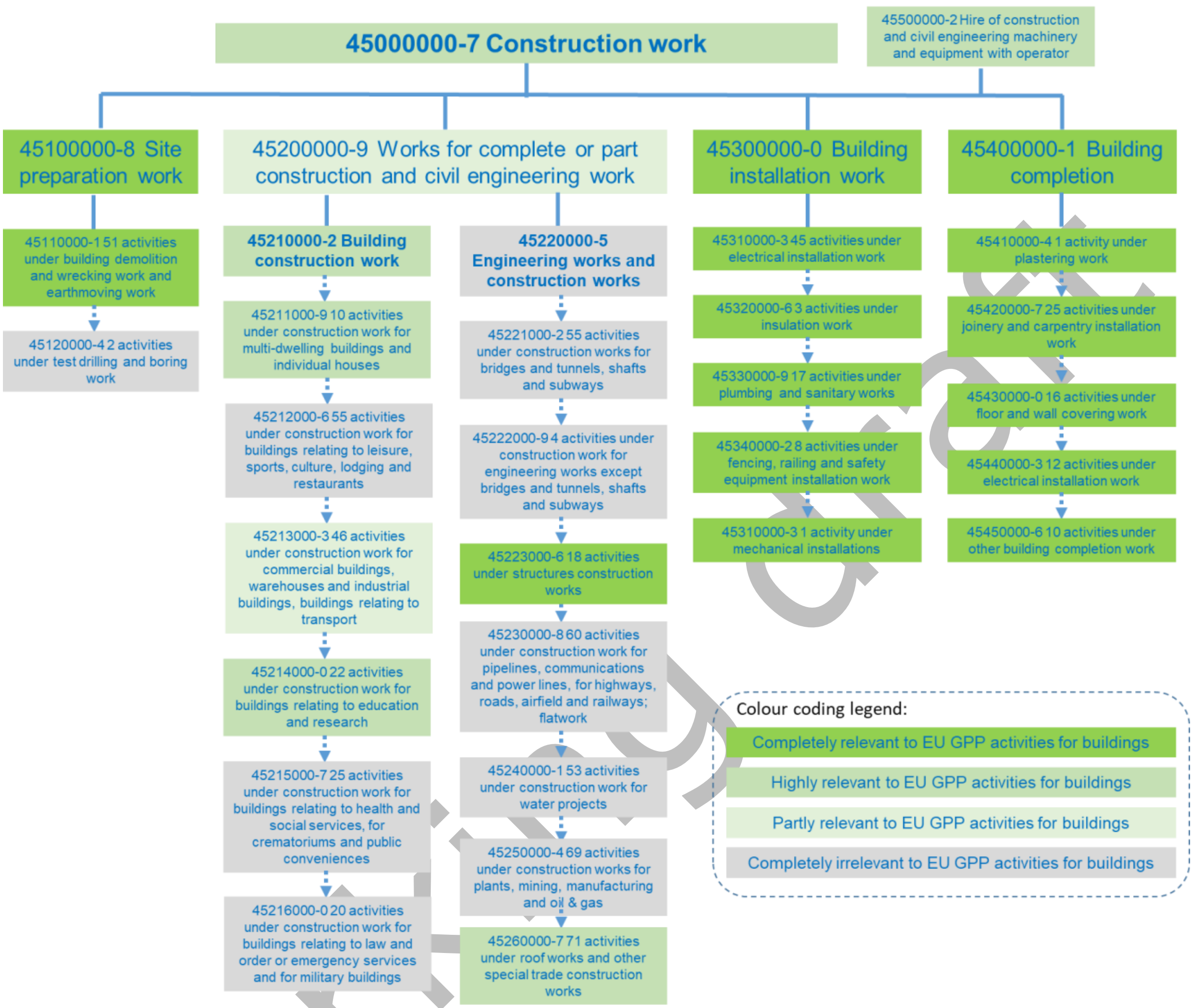

Figure 4. Overview of Common Procurement Vocabulary (CPV) codes for works activities in the construction sector

The CPV hierarchy does generally follow the order in which different works would take place as time progresses in a building project, i.e. generally reading the hierarchy from left to right and ignoring most of the activities in the 3rd column that are to do with civil engineering works and are not building-orientated.

Looking at the hierarchy above, any of the activities within the 1st, 2nd, 4th and 5th columns could be relevant in the public procurement of a new building. Some entries are in grey in the 2nd column due to the limitation of the proposed scope of public buildings.

The importance of each activity in the 3rd, 4th and 5th columns will of course depend on the nature of the building and the site where it will be constructed. Some of the grey civil engineering activities in the 3rd column could also become relevant if the construction project is especially large (e.g. a housing development) and/or remote from existing sewerage networks or roads and if onsite or nearby energy generation is to be included (e.g. district heating or renewable installations). However, it should be considered whether these civil engineering works are part of the same subject matter or should be subject to a separate procurement exercise, especially considered the different economic operators that would typically be involved.

[4] Commission Regulation (EC) No 213/2008, amending Regulation (EC) No 2195/2002 of the European Parliament and of the Council on the Common Procurement Vocabulary (CPV) and Directives 2004/17/EC and 2004/18/EC of the European Parliament and of the Council on public procurement procedures, as regards the revision of the CPV

In addition to works, there are also a number of services that are relevant to a building project. These services also have CPV codes listed in Regulation (EC) No 213/2008. Some of the more relevant and general services (and works) that could apply to different stages of a building project are shown below.

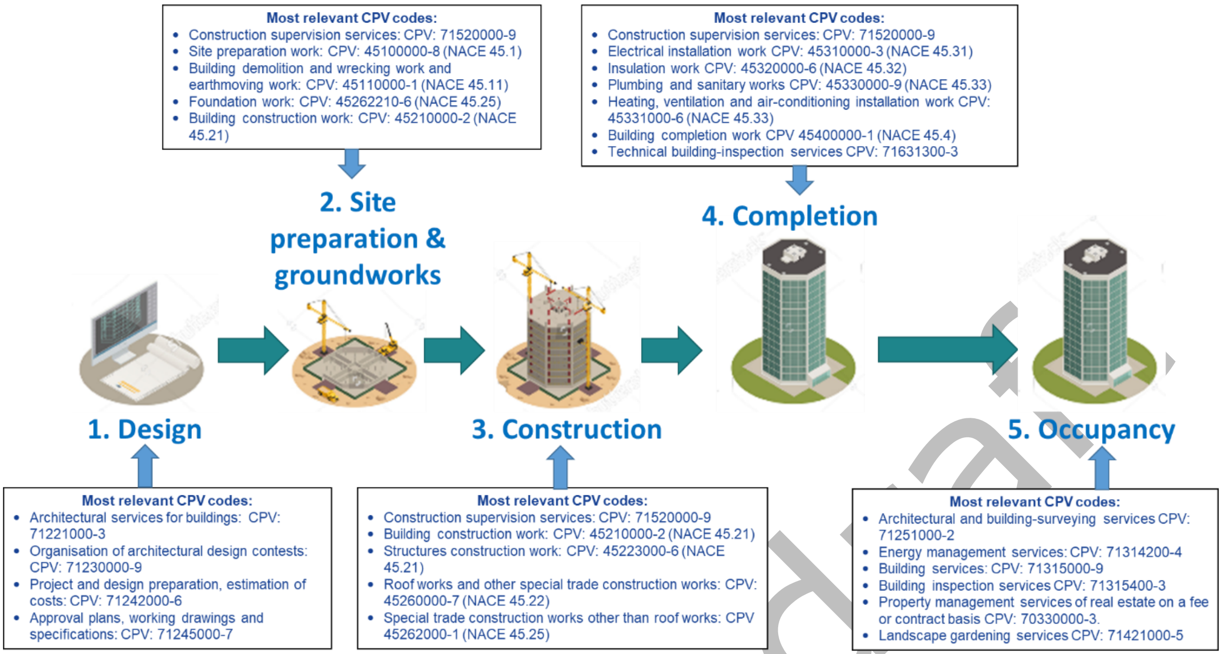

Figure 5. Illustration of different CPV codes (works and services) that can apply at different stages of a building's life cycle.

There are many other works and services with specific CPV codes that could be considered relevant. However, in order to be concise, only some of the higher level works and services have been mentioned in the illustration above.

At the design stage, the importance of architectural services cannot be overestimated. Depending on the available budget and the novelty of the building, architectural design contests may be relevant. Once a conceptual design is agreed, it is important to then carry out a more detailed design that can be approved by planning authorities and that can allow for a more accurate estimation of costs. If a building is more standardised, then a lot less work will be required at this stage.

The extent of site preparation work required and the degree of supervision necessary will depend on site specific factors. Much greater control and supervision will be needed in sites located in densely populated urban areas, where demolition may be required and the proximity of existing services or even metro lines need to be considered, compared to a rural greenfield site. Groundworks will also vary greatly depending on the underlying soil and water table. If any underground floors are planned and foundations need to go deeper, this will affect the quantity of soil to be excavated. Depending on the history of the site, there may be a risk that excavated soil is contaminated and may need to be treated as hazardous waste or be treated.

Construction activities will be influenced by the building form and structure (e.g. cross-laminated timber, steel or reinforced concrete) and shell used in the building and the extent of prefabricated elements that are used. The structure will also influence the type and specification of foundations needed.

Building completion refers to electrical installations such as wiring, alarms, antennae, aerials, lightning-protection, lifts, escalators, telecommunications equipment, cabling, electricity supply and transformer stations, lighting and other electrical equipment. It also refers to the installation of thermal and sound insulation, and to the installation of plumbing and sanitary equipment such as central-heating systems, boilers, ventilation systems, air conditioners, water plumbing, drains, fitting of taps, sinks, toilets and showers, gas piping and related fittings. There are existing EU GPP criteria on the DG Environment website for the following building components:

- Sanitary tapware (2013)
- Flushing toilets and urinals (2013)

Although the EU GPP criteria for the products listed above are quite old, there may be useful references to standards and methodologies. Where relevant, data and preparatory research conducted for ecodesign impact assessments for products and technical systems that are used in buildings will be considered in more detail, when assessing the improvement potential for water consumption in Task 4.

Relevant services for an occupied building that could fall within EU GPP criteria would generally refer to the regular management of the building, the operation and maintenance of its technical systems (e.g. heating, cooling, ventilation and lighting) and routine maintenance of building elements. Other services such as cleaning, security or tenant management or leasing and the maintenance of landscaped areas should be considered as subject matter for different tenders. In fact, the Commission has already published EU GPP criteria on the DG Environment website for:

- Public space maintenance, see staff working document (2019) 404.
- Indoor cleaning services, see staff working document (2018) 443.

Since the scope for the new EU GPP criteria for buildings is expanding from just office buildings to now also include residential and educational buildings, it is worth explaining how the CPV codes distinguishes between construction work for different building functions as well.

Table 4. Different types of building considered in CPV codes

Building group type	Specific categories and codes
Construction work for multi-dwelling buildings and individual houses (45211000-9)	Construction work for houses (45211100-0); Sheltered housing construction work (45211200-1); Houses construction work (45211300-2); Bathrooms construction work (45211310-5); Porches construction work (45211320-8); Multi-dwelling buildings construction work (45211340-4); Flats construction work (45211341-1); Multi-functional buildings construction work (45211350-7); Urban development construction work (45211360-0); Construction works for saunas (45211370-3).
Construction work for buildings relating to leisure, sports, culture, lodging and restaurants (45212000-6);	Construction work of leisure facilities (45212100-7);…. Construction work for sports facilities (45212200-8);… Construction work for art and cultural buildings (45212300-9);… Library construction work (45212330-8);… Accommodation and restaurant buildings (45212400-0);… Kitchen or restaurant conversion (45212500-1); Pavilion construction work (45212600-2).
Construction work for commercial buildings, warehouses and industrial buildings, buildings relating to transport (45213000-3)	Construction work for commercial buildings (45213100-4);…. Office block construction work (45213150-9); Construction work for warehouses and industrial buildings (45213200-5); Buildings associated with transport (45213300-6).
Construction work for buildings relating to education and research (45214000-0)	Construction work for kindergarten buildings (45214100-1); Construction work for school buildings (45214200-2); Primary school construction work (45214210-5); Secondary school construction work (45214220-8); Special school construction work (45214230-1); Construction work for college buildings (45214300-3); Vocational college construction work (45214310-6); Technical college construction work (45214320-9); Construction work for university buildings (45214400-4); Polytechnic construction work (45214410-7); Lecture theatre construction work (45214420-0); Language laboratory construction work (45214430-3); Construction work for buildings of further education (45214500-5); Construction work for research buildings (45214600-6); Laboratory building construction work (45214610-9); Research and testing facilities construction work (45214620-2); Scientific installations (45214630-5); Installation works of cleanrooms (45214631-2); Meteorological stations construction work (45214640-8); Construction work for halls of residence (45214700-7); Entrance hall construction work (45214710-0); Training facilities building (45214800-8).
Construction work for buildings relating to health and social services, for crematoriums and public conveniences (45215000-7)	Construction work for buildings relating to health (45215100-8); Spa construction work (45215110-1); Special medical building construction work (45215120-4); Clinic construction work (45215130-7); Hospital facilities construction work (45215140-0); Construction work for social services buildings (45215200-9); Construction work for subsidised residential accommodation (45215210-2); Retirement home construction

	work (45215212-6); Nursing home construction work (45215213-3); Residential homes construction work (45215214-0); Children's home construction work (45215215-7); Construction work for social facilities other than subsidised residential accommodation (45215220-5); Daycare centre construction work (45215221-2); Civic centre construction work (45215222-9); Construction work for crematoriums (45215300-0); Cemetery works (45215400-1); Public conveniences (45215500-2)
Construction work for buildings relating to law and order or emergency services and for military buildings (45216000-4)	Construction work for buildings relating to law and order or emergency services (45216100-5); Construction work for buildings relating to law and order (45216110-8); Police station construction work (45216111-5); Court building construction work (45216112-2); Prison building construction work (45216113-9); Parliament and public assembly buildings (45216114-6); Construction work for buildings relating to emergency services (45216120-1); Fire station construction work (45216121-8); Ambulance station construction work (45216122-5); Mountain-rescue building construction work (45216123-2); Lifeboat station construction work (45216124-9); Emergency-services building construction work (45216125-6); Coastguard building construction work (45216126-3); Rescue-service station construction work (45216127-0); Lighthouse construction work (45216128-7); Protective shelters (45216129-4) Construction work for military buildings and installations (45216200-6); Military bunker construction work (45216220-2); Military shelter construction work (45216230-5); Trench defences construction work (45216250-1);
Inflatable buildings construction work (45217000-1)	

The terms used to describe buildings in the table above should be used as far as possible when defining the scope of the EU GPP criteria for buildings. It is clear from the table that a general term such as "buildings relating to education" covers a wide range of buildings that can be expected to have different uses and occupational patterns.

Scope proposal and definitions

The initial proposal for the scope of buildings to be covered is implied by the green text in the table above, corresponding to:

> *"The procurement of any works or services for the design, site-preparation, construction, completion, renovation or management of social housing, office buildings and buildings relating to educational and any multi-functional buildings where one of the aforementioned functions accounts for at least 50% of the gross internal floor area."*

For the purposes of these EU GPP criteria proposals, the following definitions apply:

- "***Buildings relating educational services***" means buildings whose primary function is the teaching of students and includes kindergardens, primary schools, secondary schools, special needs schools, vocational colleges, technical colleges and university buildings.
- "***Buildings related to social services***" means buildings whose primary function is the provision of social services and includes retirement homes, nursing homes, children's homes, daycare centres and civic centres.
- "***Completion***", in the context of a building project, means works or services relating to the installation of electrical infrastructure, lifts, escalators, telecommunications equipment, illumination equipment, thermal insulation, sound insulation, plumbing, sanitary works, heating, ventilation, air-conditioning, drains, gas fittings, railings, fencing, fire-prevention features, doors, windows and related components, suspended ceilings, partition walls, fitted kitchens, internal floor and wall

coverings, outdoor cladding and paving as well as any other works relating to plastering, joinery & carpentry, painting, surface protection or façade.

- "***Construction***", in the context of a building project, means works or services relating to building foundations, structure, structural shell, parking lot (if within the building plot area), roof works, scaffolding, concrete work, structural steel erection work and masonry and bricklaying work.
- "***Design***", in the context of a building project, covers architectural, feasibility study, engineering, planning, specifications drafting, surveying, working drawings, approval planning and cost estimation services relating to conceptual and detailed designs for a new or renovated building.
- "***Management***", in the context of a currently occupied building, means the routine maintenance of building facilities, including sanitary fittings, security features and technical systems, as well as the operation and optimisation of energy systems, reporting on building performance to occupants about factors such as specific energy consumption, CO_2 emissions, specific water consumption or indoor air quality and periodically evaluating occupant satisfaction with the building performance.
- "***Office buildings***", means buildings whose primary function is to provide space for administrative financial, professional or customer services. The office area must make up a significant majority of the total building's gross area. The building may also comprise other type of spaces, like meeting rooms, training classrooms, staff facilities, or technical rooms.
- "***Renovation***", in the context of a building project, means construction and/or demolition works to improve aspects of a building. Renovation activities can vary in terms of their depth (% of e.g. floor area affected by the renovation activity) and their primary focus (e.g. replacement/upgrading of building energy systems, façade replacement, new windows, floor and wall coverings etc.).
- "***Residential buildings***" means buildings whose primary function is to provide private living spaces for people and includes multi-dwelling buildings, individual houses or sheltered housing.
- "***Site preparation***", in the context of a building project, means works or services relating to demolition, excavation, earthmoving and land-reclamation.

<u>*Rationale for scope proposal and definitions*</u>

Before justifying the choice of scope, the caveat that EU GPP criteria are voluntary and that public authorities can decide to apply only one or any number of them to suit their needs must be mentioned. This flexibility means that the criteria could be potentially applied to almost any type of building procurement.

However, since the scope will influence the type of criteria that are proposed and will direct the focus of the background research, it is important to decide on a particular scope at the beginning.

The general expansion of the scope is to increase the potential impact that EU GPP criteria can have on the building sector. Office buildings remain in the scope as was the case with the 2016 EU GPP criteria. By including residential buildings and buildings related to educational and social services, the scope now covers those public-owned buildings where citizens tend to spend the majority of their time.

The suggestion to consider including parliament and public assembly buildings in the scope is more related to the aim to lead by example in what are generally high-profile public buildings.

The suggestion for libraries to be included is made because it falls somewhere between educational and social services but is neither one nor the other in the strictest sense, being considered more as a public amenity.

The definitions relating to building project stages and building types are broadly aligned with the structure and hierarchy of Common Procurement Vocabulary (CPV) codes. The definition of office buildings remains the same as the 2016 EU GPP criteria.

The definition of the term "renovation" will be subject to further debate as there is not yet agreement on definitions for terms such as "energy renovation" or "deep renovation" or "major renovation".

The EU taxonomy would be one possible way forward with a definition of "energy renovation" being "*a renovation activity that achieves at least 30% energy savings, complies with minimum energy performance requirements for major renovation of existing buildings, or consists of individual measures related to the* *energy performance of buildings, such as the installation, maintenance or repair of energy efficiency equipment or of instruments and devices for measuring, regulating and controlling the energy performance of buildings, where such individual measures comply with the criteria set out*."

Another important source for a future definition is the Commission proposal for a recast EPBD, where "deep renovation" is proposed to be considered as: *"a renovation that transforms buildings into zero-emission buildings; in a first step, as a renovation that transforms buildings into nearly zero-energy buildings."*

Relevant policy, legislation and technical standards by theme

With the general themes for EU GPP criteria for buildings having been defined by the Level(s) framework and the EU Taxonomy for sustainable economic activities, and the scope of buildings having been defined, it is now worth reviewing the most relevant policy, legislation and technical standards for each theme.

Theme 1: Energy consumption and life cycle greenhouse gas emissions

Commission Communications: The importance of improving energy consumption of buildings to not only achieve energy savings but also to reduce carbon emissions at EU level. The Communication on Europe's 2030 climate ambition, where a 55% reduction in net CO_2 emissions compared to 1990 levels is to be aimed for by 2030, emphasises the importance of the role of energy renovation of buildings when it says:

"The building sector, currently responsible for 40% of final energy and 36% of greenhouse gas emissions in the EU, has a large cost-effective potential to reduce emissions. Today, 75% of the EU's building stock is energy inefficient[5]. Many homes are still heated with outdated systems that use polluting fossil fuels such as coal and oil. To fully tap into this potential for improvement would require the renovation rate, which is around 1% today, to double and more in the period up to 2030. In particular, deep renovations addressing building shells, smart digitalisation and the integration of renewable energy together need to increase strongly."

The urgent need for building renovation activities to meet the ambitious 2030 net carbon emission targets is well captured in the Renovation Wave Communication COM(2020)662, when it says:

"To achieve the 55% emission reduction target, by 2030 the EU should reduce buildings' greenhouse gas emissions by 60%, their final energy consumption by 14% and energy consumption for heating and cooling by 18% (compared to 2015 levels). It is therefore urgent for the EU to focus on how to make our buildings more energy-efficient, less carbon-intensive over their full life-cycle and more sustainable. Applying circularity principles to building renovation will reduce materials-related greenhouse gas emissions for buildings.

Today, only 11% of the EU existing building stock undergoes some level of renovation each year. However, very rarely, renovation works address energy performance of buildings. The weighted annual energy renovation rate is low at some 1%. Across the EU, deep renovations that reduce energy consumption by at least 60% are carried out only in 0.2% of the building stock per year and in some regions, energy renovation rates are virtually absent. At this pace, cutting carbon emissions from the building sector to net-zero would require centuries. It is time to act."

It is worth noting how the Renovation Wave communication also highlights the importance of embodied carbon in construction materials. A special focus on heating and cooling systems is stated in Commission Recommendation (EU) 2019/786 on building renovation, which states in recital 3: "*The 2015 Paris Agreement on climate change following the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 21) boosts the Union's efforts to decarbonise its building stock. Given that almost 50 % of the Union's final energy consumption is for heating and cooling, of which 80 % is used in buildings, the Union's achievement of its energy and climate goals is linked to its efforts to renovate building stocks by giving priority to energy efficiency, applying the 'energy efficiency first' principle and considering the deployment of renewables.*"

Energy Performance of Buildings Directive (EPBD) No 2010/31/EU: The EPBD is the key legislative instrument for implementing and monitoring the evolution of the energy performance of the EU's building stock. Due to differences in national or regional approaches to energy performance assessment and differences in climate, culture and associated building forms and materials, the EPBD sets out an overarching methodology with various points of freedom for Member States.

5 The same communication states here that: "New buildings today consume only half as much as typical buildings from the 1980s. About 35% of the EU's buildings are over 50 years old.

These freedoms extend also to the definition of Nearly Zero Energy Buildings (NZEBs), the scope of assessment (e.g. heating only or other energy consuming building technical systems) and the setting of thresholds for different classes in Energy Performance Certificates.

A recent (December 2021) proposal from the Commission to recast the EPBD now refers to Zero Emission Buildings (ZEBs), thus recognising the link between energy and carbon emissions and acknowledging that zero emission is a broader objective (i.e. accounting for the quantity AND carbon factor(s) of energy needed). So long as zero emission efforts are underpinned by energy efficiency first principles, the synergy between energy efficiency and reduced carbon emissions can be ensured. In article 7, the proposed EPBD recast sets provisions on all new buildings to be zero emission and have a life cycle Global Warming Potential (GWP) assessment by 2030 (by 2027 for new buildings with a useful floor area >2000m^2).

Energy Efficiency Directive (EED) 2012/27/EU: was recently consolidated in January 2021. Article 5 of this Directive obliges public bodies to lead the way in energy renovation, specifically requiring that at least 3% of the heated/cooled total floor area of central government buildings with floor areas >250m^2 is renovated to at least cost optimal energy performance levels (as defined in Articles 4 and 5 of the EPBD). Article 6 of the EED obliges central governments to purchase only those products, services or buildings that have high energy-efficiency performance. What exactly is meant by this term is not clarified in the EED, but there is room for interpretation as it allows for factors relating to cost-effectiveness, economical feasibility, wider sustainability, technical suitability and sufficient competition to be considered.

A recent (July 2021) proposal from the Commission to recast the EED would broaden the scope of requirements on exemplary practice in energy renovation from central government to all public bodies (article 6) In line with the proposals for a recast EPBD, the proposals for the EED also state that contracting authorities may request life cycle GWP in tenders, in line with the methodology referred to in Level(s) indicator 1.2 and especially for buildings with >2000m^2 floor area.

EN standards: In terms of technical standards, there are two separate CEN Technical Committees working on energy performance methods (CEN/TC 371) and on life cycle carbon emissions from buildings (CEN/TC 350). Some of the main standards are presented below.

- CEN/TC 350: the main standard of reference here is EN 15978, setting out a calculation method for a buildings environmental performance over its entire life cycle. This method at building level is complimented by a related standard (EN 15804) that applies at the level of construction products.
- CEN/TC 371: the overarching series of EN ISO 52000 standards (see more details in Annex II for a framework of how EN standards are structured into modules and sub-modules).

As indicated in Figure 2, theme 1 is very well aligned with macro-objective 1 of Level(s) and the climate change mitigation environmental objective of the EU Taxonomy.

Level(s): Level(s) has two relevant indicators. The first one is indicator 1.1 on use stage energy consumption, where results should be reported in units of kWh/m^2/yr of primary energy in accordance with applicable national or regional methods. This result may be split into non-renewable and renewable and into "self-used" or "balance", where the latter allows for subtracted any exported energy produced onsite.

The second indicator is 1.2 on life cycle carbon emissions, where results are to be reported in terms of fossil Global Warming Potential (GWP), biogenic GWP and land use & land use change GWP across the modules A to D of a building life cycle as defined in EN 15978. The details of the Level(s) method, which is explicitly referred to in the EPBD recast proposal for life cycle GWP calculations, is in line with EN 15978 but defines a minimum scope for building elements to be covered in embodied carbon calculations.

EU Taxonomy: The EU Taxonomy, as part of defining a significant contribution to climate change mitigation, requires that the construction of new buildings have a calculate primary energy demand that is 10% lower than the threshold set for NZEB buildings in the same country and that energy performance is reported on an EPC. Furthermore, for any new buildings >5000m^2, a life cycle GWP assessment shall be carried out in line with Level(s) indicator 1.2. For building renovation, the renovation activity must meet the relevant national definition of "major renovation" defined in line with the EPBD or deliver a reduction of primary energy demand of at least 30%.

Theme 2: Material efficiency and circularity

Material efficiency is a broad concept whose main facets are:

- Using less materials in the first place to meet a given need or function,
- Construction or demolition processes that produce less waste and/or site waste management procedures that segregate CDW to maximise its potential for recycling and recovery.
- Building elements that last longer, either because they are more durable or easy to adapt and repair,
- Building designs that facilitate the disassembly and reuse of building elements at the end of life.

Commission Communications: Greater material efficiency can not only deliver significant reductions in total EU waste generation, but also make a significant contribution to reducing greenhouse gas emissions, thus working in tandem with theme 1. To have a rough idea of the potential impacts, a Commission Communication on the new CEAP (COM(2020)98) states:

"The construction sector is responsible for over 35% of the EU's total waste generation (Eurostat, 2016). Greenhouse gas emissions from material extraction, manufacturing of construction products, construction and renovation of buildings are estimated at 5-12% of total national GHG emissions[6]. Greater material efficiency could save 80% of those emissions[7]."

Level(s), EN and ISO standards: The different facets of material efficiency are covered in the Level(s) framework under the following indicators:

- Indicator 2.1: bill of quantities, materials and lifespans.
- Indicator 2.2: construction and demolition waste (CDW) and materials.
- Indicator 2.3: design for adaptability and renovation.
- Indicator 2.4: design for deconstruction.

Material footprint: When estimating the bill of quantities, because this has a direct relationship to the cost of a building project, the International Cost Management Standard is a highly relevant standard to cite (the third edition of this standard was published recently, in November 2021). This facet of material efficiency also has a clear link to life cycle costing in theme 6, and in particular when lifespans of building elements and components are considered. Likewise, when embodied carbon is associated with material quantities, a link to theme 1 is established.

Waste management: The Waste Framework Directive (WFD) is the single most important piece of EU legislation with relation to CDW. The WFD defines a waste hierarchy of: prevention > preparing for re-use > recycling > other recovery > disposal and had set a target of 70% of CDW being prepared for reuse, recycled or materially recovered (including backfilling) by 2020 for each Member State. New targets for CDW will be considered by 31 December 2024 and these new targets may also be applied to specific fractions of CDW.

At the present moment, the EU Taxonomy is also considering targets for CDW from new construction, demolition and renovation activities for demonstrating a significant contribution to a circular economy. No doubt these taxonomy targets will be more ambitious than the legal target set out in the WFD.

Design for adaptability: One of the aspects of social performance framework for a building set out in EN 15643-3 is adaptability. The four main features of adaptability described therein are: (i) ability to accommodate individual user requirements (e.g. need for private working spaces and group working spaces); (ii) ability to accommodate changes in user requirements (e.g. need bathroom on ground floor of a house, need an extra bedroom in a flat, merging classrooms for large events etc.); (iii) ability to accommodate technical changes (e.g. change of heating system) and (iv) the ability to accommodate changes of use (e.g. office to residential).

EN 16309 is linked to EN 15643-3 and provides more details about how to assess and communicate the adaptability of a building against different scenarios within the EN 15978 life cycle framework. Other social performance aspects that are mentioned in EN 16309 such as indoor air quality and thermal comfort can be argued as being part of the concept of "adaptability", but these are treated separately in the EU GPP criteria

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6 See: https://www.boverket.se/sv/byggande/hallbart-byggande-och-forvaltning/miljoindikatorer---aktuell-status/vaxthusgaser/

7 See: Hertwich, E., Lifset, R., Pauliuk, S., Heeren, N., IRP, (2020), Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future.

structure, under theme 4. A similar case applies to the social performance of buildings in terms of resistance to climate hazards, which is covered separately under theme 5.

The ISO 20887 standard addresses design for adaptability concepts using the following terms: (i) versatility (i.e. how to accommodate different use needs simultaneously); (ii) convertibility (i.e. how to accommodate intermittent changes of use) and (iii) expandability (i.e. how to increase available space or functionalities of the building).

The Level(s) methodology already defines a scoring matrix for quantifying the adaptability of office buildings (in the indicator 2.3 user manual) and similar calculations can be made in the ECO 2.1 criterion published by DGNB or the calculator provided by BREEAM Netherlands and the Dutch Real Estate Norm.

Design for deconstruction: The adequate design of buildings for deconstruction can make a major contribution to the circular economy in the medium to long-term future, when buildings under renovation or reach the end of their lives. Such design principles are in line with the Buildings As Material Banks (BAMB) concept. The BAMB research group have promoted the idea of material passports, which manufacturers would provide to their customers and which informs about how the product can be disassembled and what options are available for its reuse, recycling or recover at the end of life. While material passports are of clear value in improving the circularity of material flows in the building sector, the ultimate goal is to put this all together to drive reversible building design.

ISO 20887 refers to some key underlying disassembly principles, namely: ease of access to connections of components and services; independence of connections; reversibility of connections; avoidance of unnecessary treatments and finishes; simplicity of design; standardisation and safety of disassembly.

The Level(s) methodology already defines a scoring method for quantifying the design for deconstruction of buildings and the TEC 1.6 criterion published by DGNB does so too.

Theme 3: Efficient use of water resources

Legislation: The overarching EU policy that covers the efficient use of water resources is the EU Water Framework Directive[8]. The principle aim of the Directive is to protect and enhance the status of aquatic ecosystems. Such an aim goes hand in hand with the efficient use of water resources, since excessive water abstraction will place more pressure on aquatic ecosystems and any abstracted water returning to the same natural watercourse will be coming via wastewater plant discharges or agricultural runoff, thus bringing pollutants and having an adverse effect on water quality in that natural watercourse.

Commission Communications: COM(2008)414 on addressing the challenge of water scarcity and droughts in the European Union proposed the setting up of a European Drought Observatory, which was later set up and which provides a wealth of drought data that could potentially be used by relevant authorities to take actions in real-time that could reduce water demand (e.g. water pricing control for customers or setting limits on abstraction limits).

The same Communication also proposed including a "Water Performance of Buildings Directive", whose function would be broadly similar to the "Energy Performance of Buildings Directive", except that the focus would be on use stage water consumption instead of use stage energy consumption. Such a legal instrument would in principle cover taps, showers, toilets, rainwater harvesting systems and greywater recycling systems. Since 2007, no such Directive has materialised.

Another initiative proposed by the Communication was to explore the possibility of expanding existing EU labelling schemes for water-consuming devices and fittings. Today, there are two main voluntary labelling schemes operating at the European level: the European Water Label and related the Unified Water Label. These labelling schemes offer searchable databases of products for consumers to compare and select tap, shower, and toilet-related products with a known water efficiency.

EN standards: In terms of technical standards, there are two separate CEN Technical Committees working on sanitary appliances (CEN/TC 163), on water supply (CEN/TC 164) and, as far as rainwater and greywater are concerned, part of CEN/TC 165 (wastewater engineering). Some of the main standards are presented below.

[8] Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy"

- CEN/TC 163: Performance requirements and test methods for different types of WC pans with integral traps (EN 997), wall-hung urinals (EN 13407), WC and urinal flushing cisterns (EN 14055) and wash basins (EN 14688).
- CEN/TC 164: Technical specifications for sanitary tapware of various types and fittings (EN 200, EN 246, EN 816, EN 817, EN 1111, EN 1112, EN 1113, EN 1286, EN 1287).
- CEN/TC 165: Onsite non-potable water systems for rainwater (EN 16941-1) and for treated greywater (EN 16941-2).

Because of the potential benefits of linking rainwater harvesting and greywater reuse to irrigation, it is proposed to explore further standards relating to irrigation and the different types of systems available. Irrigation will generally be more important with buildings with large plot areas (e.g. schools) but could also apply even to buildings in dense urban environments if green roof and/or green walls are used.

Level(s): Indicator 3.1 in the Level(s) framework is specifically about water consumption and provides a bespoke calculator that allows users to adjust usage factors and specific water consumption rates of taps, showers, bath-tubs, toilets and urinals as well as estimating potential inputs from rainwater harvesting or greywater recycling systems. Results are calculated in units of m^3/occupant/year and can be split into potable water (mains) and non-potable fractions.

EU Taxonomy: Although the Annex for significant contributions to the environmental objective of "protection and sustainable use of water resources" has not yet been finalised, the do no significant harm criteria for climate change mitigation set upper limits for the specific water consumption of different sanitary fittings.

Theme 4: Occupant comfort and wellbeing

Occupant comfort and wellbeing is a complex and often subjective quality that architects, designers and engineers have made a great deal of effort to understand and optimise. Many of the different facets of occupant comfort and wellbeing are inter-related as well and trade-offs exist. For example, indoor air quality, in terms of the concentration of pollutants present in the air, is influenced both by the sources of those pollutants (indoors and outdoors) and can indoor-sourced pollutants can be reduced by ventilating. However, ventilating affects the indoor temperature and thus thermal comfort of occupants and can generate more noise, either by allowing outdoor noise in via open windows or by the running of ventilation equipment. So a balance needs to be struck both between different facets of occupant comfort and between occupant comfort and energy consumption (link to theme 1).

Legislation: Many of the building technical systems used in buildings to maintain occupant comfort are covered by the Ecodesign Directive[9] and the Energy Labelling Framework Regulation[10]. Some of the most relevant product groups and associated energy labelling Regulations include:

- Water heaters: Commission Delegated Regulation (EU) No 812/2013.
- Air-based heat pumps: Commission Delegated Regulation (EU) No 626/2011.
- Local space heating appliances: Commission Delegated Regulation (EU) No 2015/1186.
- Light sources: Commission Delegated Regulation (EU) No 2019/2015.
- Residential ventilation units: Commission Delegated Regulation (EU) No 1254/2014.

Most of the energy-related product groups that have energy labels have recently undergone or are undergoing a rescaling of energy classes. This means that a current range of, for example, A+++ to E, will now become A to G. Article 12 of the Energy Labelling Framework Regulation makes provision for the establishment of a European Product Registry for Energy Labelling (EPREL).

Although the EPREL database is not yet publically available, it will greatly help procurers decide on the appropriate ambition level when setting procurement criteria for defined energy-related products.

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9 Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (Text with EEA relevance) OJ L 285, 31.10.2009, p.10.

10 Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling and repealing Directive 2010/30/EU (Text with EEA relevance) OJ L 198, 28.7.2017, p.1.

In combination at building level, the energy-related products used to maintain occupant comfort fall within the scope of the Energy Performance of Buildings Directive (2010/31/EU) and the Energy Efficiency Directive (2012/27/EU), which have been referenced earlier with theme 1.

The quality of an environment inside a building is to some extent influenced by the quality of the environment immediately outside the building. In this sense, it is worth mentioning the Environmental Noise Directive (2002/49/EC) that provides a methodological approach for mapping noise in urban areas and the Air Quality Directive (2008/50/EC) for the monitoring and control of fine particulate matter, ozone, sulphur oxides, nitrogen oxides carbon monoxide and benzene in ambient air.

EN standards: The EN 15643 standard considers the concept of "health and comfort" as a key part of the social performance framework for buildings. Within this concept, EN 15643-3 refers to:

- Acoustics,
- indoor air quality,
- visual comfort,
- water quality,
- electromagnetic fields,
- spatial characteristics and
- thermal characteristics.

The present (2014) version of EN 16309 provides information on assessing all of these aforementioned characteristics except for water quality and electromagnetic fields. It splits these aspects into: (i) those that are determined by the building-fabric and (ii) those that are determined by user and control system interactions.

The main Technical Committees involved in EN standards regarding occupant comfort are:

- CEN/TC 122 for ergonomics of the physical environment, specifically standards that relate to the thermal environment, for example EN ISO 11399 on basic principles, EN ISO 10551 for subjective judgements, EN ISO 7243 and 7933 for heat stress, and EN ISO 15265 on stress prevention EN ISO 7730 on the analytical determination of thermal comfort, EN ISO 7726 on instrumentation to measure physical quantities
- CEN/TC 156 for ventilation for buildings, which includes standards relating to naturally and mechanically powered residential ventilation, ductwork, air terminal devices, air handling units, fans, louvres, cowls and roof outlets for ventilation and cooling systems. Of particular relevance are the EN 16798 series of standards and the restructuring of other EN standards into this series: EN 15251 → EN 16798-1; EN 13779 → EN 16798-3; EN 15241 → EN 16798-5-1+EN 16798-5-2; EN 15242 → EN 16798-7; EN 15243 → EN 16798-9 and EN 15239+EN15240 → EN 16798-17.
- CEN/TC 169 for lighting applications, especially EN 12464-1 for lighting of workplaces indoors, EN 15193-1 on energy requirements for lighting and EN 17037 on daylight in buildings.
- CEN/TC 195 for air filters for general air cleaning, with specifications for particulate removal (especially the EN 16890 series of standards).
- CEN/TC 228 for heating systems in buildings, for example the EN 12381 series of standards for calculating design heat load, EN 15316 series of standards on methods for calculating system energy requirements and system efficiencies and the EN 15378 series of standards on heating systems and Domestic Hot Water systems.
- CEN/TC 264 for air quality, especially the ISO 16000 series of standards on emission test chamber methods.
- CEN/TC 351 for construction products – assessment of release of dangerous substances, and especially EN 16516.

Many of these standards fit into the modular framework for the Energy Performance of Buildings assessment (see Annex II), which stems from the overarching EN ISO 52000 series of standards.

Level(s): Given that occupant comfort is a complex issue, Level(s) presents four indicators, the latter two of which are not yet fully developed:

- Indicator 4.1: Indoor air quality.
- Indicator 4.2: Time outside of thermal comfort range.
- Indicator 4.3: Lighting and visual comfort.
- Indicator 4.4: Acoustics and protection against noise.

EU Taxonomy: The Taxonomy is focussed on environmental objectives whereas the concept of occupant health and comfort is more social. Nevertheless, there is a partial overlap with Level(s) indicator 4.1 on indoor air quality, where the taxonomy refers to the specification of construction products and materials that have low formaldehyde emissions. The Level(s) indicator on indoor air quality looks to not only limit formaldehyde emissions from construction materials, but other volatile organic compounds (VOCs) as well.

Theme 5: Vulnerability and resilience to climate change

Commission: The EU strategy on adaptation to climate change set out in Staff Working Document (2018) 461 made very limited reference to buildings, instead focussing climate-proofing actions mainly on agriculture, aquaculture and infrastructure.

In a more recent Commission Communication (COM(2021)82) on the new EU strategy on adaptation to climate change, a more specific reference is made to buildings in the following text:

"We need to do more to prepare Europe's building stock to withstand the impacts of climate change. Extreme weather and long-lasting climatic changes can damage buildings and their mitigation potential e.g. solar panels or thermal insulation after hailstorms. However, buildings can also contribute to large-scale adaptation, for example through local water retention that reduces the urban heat island effect with green roofs and walls. The Renovation Wave and the Circular Economy Action Plan identify climate resilience as a key principle. The Commission will explore options to better predict climate-induced stress on buildings and to integrate climate resilience considerations into the construction and renovation of buildings through Green Public Procurement criteria for public buildings, the Digital Building Logbook, and as part of the process to revise the Energy Performance of Buildings Directive and the Construction Products Regulation."

Of particular relevance in the above text is the intention to explore using EU GPP criteria as a tool for specifying how new buildings can be designed, or existing buildings renovated, in such a way as to reduce risks associated with climate hazards.

Legislation: One of the best known and concerning climate hazards is flooding. The EU Floods Directive (2007/60/EC) sets requirements for Member States to conduct a preliminary flood risk assessment of their river basins and coastal areas by 2011 and, where real risks of flood damage exist, they must develop flood hazard maps and flood risk maps by 2013. These maps will identify areas with a medium likely hood of flooding (at least a 1 in 100 year event) and extreme events or low likelihood events, in which expected water depths should be indicated. In the areas identified as being at risk the number of inhabitants potentially at risk, the economic activity and the environmental damage potential shall be indicated. By 2015, flood risk management plans should be developed for areas of identified flood risk and measures to take to reduce flood risk. However, the general risk management approach does not focus at all on adaptation measures that could be applied to buildings to reduce the extent of damage caused to existing buildings in a flood event, but instead looks at broader interventions at the urban or catchment level.

Level(s): The Level(s) framework sets out three separate indicators relating to vulnerability and resilience to climate hazards, under macro-objective 5:

- 5.1: Protection of occupier health and thermal comfort.
- 5.2: Increased risk of extreme weather events.
- 5.3: Sustainable drainage.

With indicator 5.1, the focus is on future thermal comfort of the occupants and the methodology and relevant EN standards are effectively the same as for assessing thermal comfort today (e.g. EN 16798 etc.). The main difference is that a projected future climate data file is used for dynamic energy simulation instead of a present-time climate data file based on historical data.

Indicators 5.2 and 5.3 are still to be fully developed and only offer guidance for conceptual design discussions in the latest versions (January 2022) of the Level(s) user manuals. Developments in the new versions of Eurocode standards for building structures will most likely have an influence on indicator 5.2 in the future.

EU Taxonomy: With climate change adaptation being one of the main environmental objectives of the Taxonomy, it is worth explaining further here the types of climate hazards that are identified in the Taxonomy.

Table 5. Climate hazards in the EU Taxonomy

	Temperature-related	Wind-related	Water-related	Solid mass-related
Chronic	Changing temperature (air, freshwater, marine water)	Changing wind patterns	Changing precipitation patterns and types (rain, hail, snow/ice)	Coastal erosion
	Heat stress		Precipitation or hydrological variability	Soil degradation
	Temperature variability		Ocean acidification	Soil erosion
	Permanent thawing		Saline intrusion	Solifluction
			Sea level rise	
			Water stress	
Acute	Heat wave	Cyclone, hurricane, typhoon	Drought	Avalanche
	Cold wave / frost	Storm (including blizzards, dust and sandstorms)	Heavy precipitation (rain, hail, snow/ice)	Landslide
	Wildfire	Tornado	Flood (coastal, fluvial, pluvial, ground water)	Subsidence
			Glacial lake outburst	

Part of the requirements for the construction of new buildings or renovation of new buildings making a substantial contribution to climate change adaptation is to screen the climate hazards listed above for the projected lifetime of the building, to conduct a climate risk and vulnerability assessment for identified physical climate risks, to assess possible “adaptation solutions” to reduce the physical climate risk and finally to implement adaptation solutions. As a rule, such solutions should not transfer the climate risk elsewhere, should favour nature-based solutions as much as possible and should be monitored and measured against pre-defined indicators.

Theme 6: Life cycle costing

EU initiatives: Life Cycle Costing is being promoted by the Commission especially in the context of Green Public Procurement, in line with the provisions made under the 2014 public procurement Directive 2014/24/EU for awarding contracts on the basis of the Most Economically Advantageous Tender (MEAT).

Life Cycle Costing makes good sense regardless of a public authority’s environmental objectives. By applying LCC public purchasers take into account the costs of resource use, maintenance and disposal which are not reflected in the purchase price. Often this will lead to ‘win-win’ situations whereby a greener product, work or service is also cheaper overall. The main potential for savings over the life-cycle of a good, work or service are:

- Savings on use of energy and water.
- Savings on maintenance and replacement costs.
- Savings on disposal costs (or revenues for reusable or recyclable parts).

Especially for public procurement, the Commission has developed LCC tools for the following product groups: (i) vending machines; (ii) imaging equipment; (iii) computers and monitors; (iv) indoor lighting and (v) outdoor lighting.

However, buildings are a much more complicated subject matter for procurement and the market value of a building is also influenced highly by site-specific factors and subjective and architectural factors that relate to the quality of living, working and amenity spaces provided in and around the building.

EU Legislation: The most relevant references to life cycle costing are Article 68 of Directive 2014/24/EU and Article 83 of Directive 2014/25/EU, which both basically say that life cycle costs must cover the costs of acquisition, of use, of maintenance and of end of life. External costs such as greenhouse gas emissions can also be counted if a monetary value can be determined, is objectively verifiable, non-discriminatory, is accessible to all interested parties and can be provided with reasonable effort by normally diligent economic operators.

EN standards: EN 15643-4 concerns the framework rules and methods for cash flow calculations over a buildings life cycle, as part of the broader sustainability performance assessment framework of construction works that the EN 15643 standards cover. Many of the terms and principles used are common with the ISO 15686 series of standards. EN 16627 details the calculation method (processes, tasks and actions) and boundaries at the level of a building project and within the EN 15798 modules for a building life cycle.

The fact that renewable energy systems and energy storage systems are also being installed on and around buildings to a greater extent will also have a significant influence on life cycle costing calculations and there is a separate EN standard (EN 15459-1) dedicated to the economic evaluation of energy systems used in buildings, which also falls within standardisation work related to the Energy Performance of Buildings Directive.

Because a life cycle costing exercise is very complex for buildings, due to the long lifetime and large number of building elements, components, materials and technical systems of which it is composed, it is crucial for any contracting authority to clearly specify any functional requirements and use scenarios for the building, which all tenderers or designers must adhere to. Since building structure lifetime is a clear limit to the likely lifetime of a building, the Eurocodes (EN 1990 series of standards) may be used to determine upper limits for the required service life of a building.

Outside of the EN standard framework, it is worth mentioning here the 3rd edition of the International Cost Management Standard (ICMS) that was published in November 2021. The standard sets out a clear hierarchy of costs, that are broad split into: acquisition costs, operational costs and end-of-life costs and external (carbon) costs. Although the standard is designed for use beyond the EU, it also includes a mapping of the carbon costs from different parts of the ICMS3 hierarchy onto the life cycle stages of the EN 15978 life cycle framework.

Theme 7: Biodiversity

EU initiatives: The EU Biodiversity Strategy for 2030, as set out in Communication COM(2020)380 aims, amongst other things, to increase "greening" of urban and peri-urban areas. European cities with populations greater than 20,000 inhabitants are called to develop ambitious "Urban Greening Plans". While there is pressure to develop urban spaces for their inherent real estate value, there are options to improve greening of existing developments, for example by installing green roofs and green walls and making use of hedges instead of walls or fencing to delimit urban spaces.

EN standards: The authors are not aware of an EN or ISO standards for the construction of green roofs or green walls. However, standards have been in place in Germany for decades via the German Landscape Research, Development and Construction Society (FLL) and, more recently a UK Green Roof Code of Practice.

Task 2: Market analysis and considerations

Eurostat data

According to the Eurostat database for structural business statistics, the “EU construction of buildings” sector (corresponding to NACE Division 41, and further sub-divided into “41.1: development of building projects” and “41.2: construction of residential and non-residential buildings”), accounted for:

- 821,400 enterprises (3.6% of all enterprises in the non-financial business economy[11] of the EU).
- Around 95.1% of these enterprises where micro-enterprises (<10 employees) and accounting for 33.1% of employment and 43.6% of value added.
- Only 450 enterprises employed more than 250 people in this sector, but they accounted for 12.8% of employment and 20.5% of value added.
- 3.1 million employees (2.4% of all employment in the non-financial business economy and 25.7% of the total number of people employed in construction).
- By comparing total employees with value added for the two sub-sectors in this activity, the apparent labour productivity for “41.1 development of building projects” was 96,000 EUR/person while that of “41.2 construction of residential and non-residential buildings” was much lower, at 38,000 EUR/person).

The % shares of value added and employment at Member State level are presented below, in order of value added.

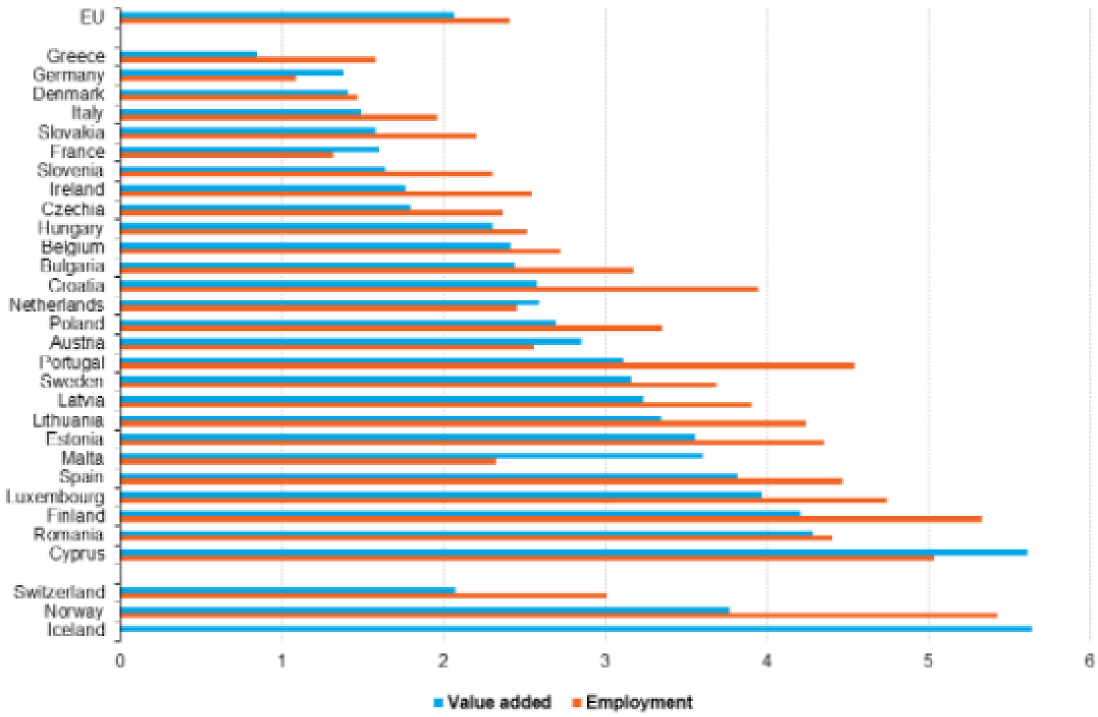

Figure 6. Relative importance (%) of construction of buildings (NACE Division 41) at Member State level and the EU, 2018.

Source: Eurostat (online data code sbs_na_sca_r2)

[11] The non-financial business economy includes the sectors of industry, construction, distributive trades and services. This refers to economic activities covered by Sections B to J and L to N and Division 95 of NACE Rev. 2 and the enterprises or its legal units that carry out those activities. (B: Mining and quarrying; C: Manufacturing; D: Electricity, gas, steam and air-conditioning supply; E: Water supply; sewerage, waste management and remediation activities; **F: Construction;** G: Wholesale and retail trade; repair of motor vehicles and motorcycles; H: Transportation and storage; I: Accommodation and food service activities; J: Information and communication; L: Real estate activities; M: Professional, scientific and technical activities; N: Administrative and support service activities; 95: Repair of computers and personal and household goods).

The data for "construction of buildings" includes the construction of complete buildings for sale or ownership and includes remodelling or renovation of existing structures but does not include architectural, engineering, technical testing and analytical services (NACE Division 71). At national level, it must be noted that the construction of buildings sectors displays a strongly cyclical pattern that is influenced by business and consumer confidence, interest rates and government programs. It remains to be seen how the COVID pandemic and the injection of public finance into the building construction sector, coupled with major losses in other sectors related to tourism, will influence data for 2020 onwards.

The range of relative contributions of the construction of buildings to national economies shown in Figure 6 varied by a factor of around 4-5 when considering the all countries. The majority of countries had relative contributions within a factor of 2 when compared with each other. The building construction sectors in Cyprus and Romania were the most significant. While Germany had the least significant sector at Member State level in relative terms, it is worth noting that it is by far the largest country in terms of absolute numbers.

Further analysis of construction and renovation activity in terms of Euros and, if possible, in term of m2 of building area will be attempted in the next draft of the background report. To obtain an idea of the relevance of public contracts, a detailed search history of public authority contracts published in eTED since 2016 will also be prepared, with a focus on the following sectors as a minimum:

- 45100000 – site preparation work
- 45210000 – building construction work
- 45260000 – Roof works and other special trade construction works
- 45300000 – Building installation work
- 45400000 – Building completion work
- 71221000 – Architectural services for buildings
- 71500000 – Construction-related services

The analysis will focus on the number of contracts and be structured by the minimum value ranges of those contracts and the country it is advertised.

The European Construction Sector Observatory (ECSO)

The ECSO offers a wealth of information and analyses about the European construction sector, with particular focus on the five areas that were identified as part of an EU strategy for the sustainable competitiveness of the construction sector and its enterprises (see (COM 2012)433).

1. Financing and digitalisation
2. Skills and qualifications
3. Resource efficiency
4. Regulatory framework
5. International competition

In the next draft of the background report, the different ECSO country profile reports and data mapper to provide a better and more up to date analysis than the structural business statistics report from Eurostat presented above.

European Building Stock Observatory

The EU Building Stock Observatory (BSO) was established in 2016 with the aim to provide a better understanding of the energy performance of the building sector through reliable, consistent and comparable data.

The BSO contains a database, a data mapper and factsheets for monitoring the energy performance of buildings across Europe. Proposals for the recast of the Energy Performance of Buildings Directive make direct reference to the requirement for Member States to provide data to the BSO in a standardised format each year.

Today, the BSO covers a broad range of energy related topics and provide information on the building stock, energy consumption, building elements and technical building systems installed, energy performance certificates, nearly zero-energy buildings and renovation rates, but also areas like energy poverty and financing aspects.

A total of 250 indicators feed into the BSO database that cover the following 10 thematic areas:

- building stock characteristics
- building shell performance
- technical building systems
- nearly Zero-Energy Buildings
- building renovation
- energy consumption
- certification
- financing
- energy poverty
- energy market

More specific aspects of the data from the BSO will be considered when investigating the technical improvement potential (Task 4) of energy efficiency via renovation activities and to place any concrete proposals for EU GPP criteria in the context of the existing building stock (in Task 5). For the sake of a general market overview, building stock characteristics from BSO factsheets are considered here in Task 2.

Building stock characteristics

Residential vs non-residential: the BSO splits residential buildings into the following categories:

- Residential: single family (detached, semi-detached) or multi-family;
- Non-residential: offices (private or public); wholesale and retail trade; hotels and restaurants; health care or educational buildings.

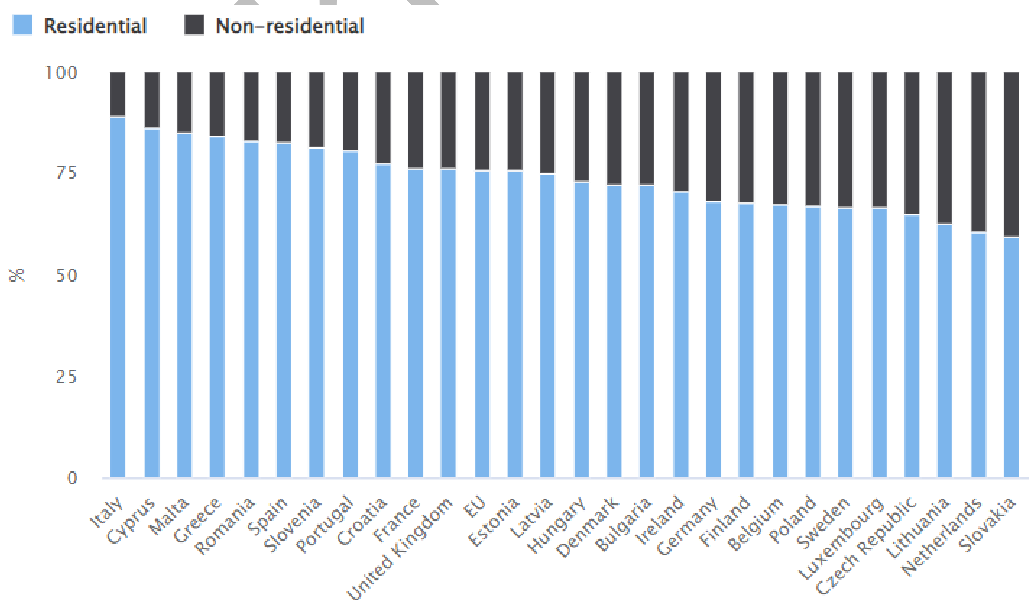

Figure 7. Split of residential and non-residential building floor areas

Source: Building Stock Observatory factsheets, https://ec.europa.eu/energy/eu-buildings-factsheets_en?redir=1

The total floor area of buildings in the EU is dominated by residential buildings (ca. 76%), varying from as high as 89% in Italy to just under 60% in Slovakia.

Age-profiles of residential buildings: The age-profile of residential building stock in different European countries is shown below.

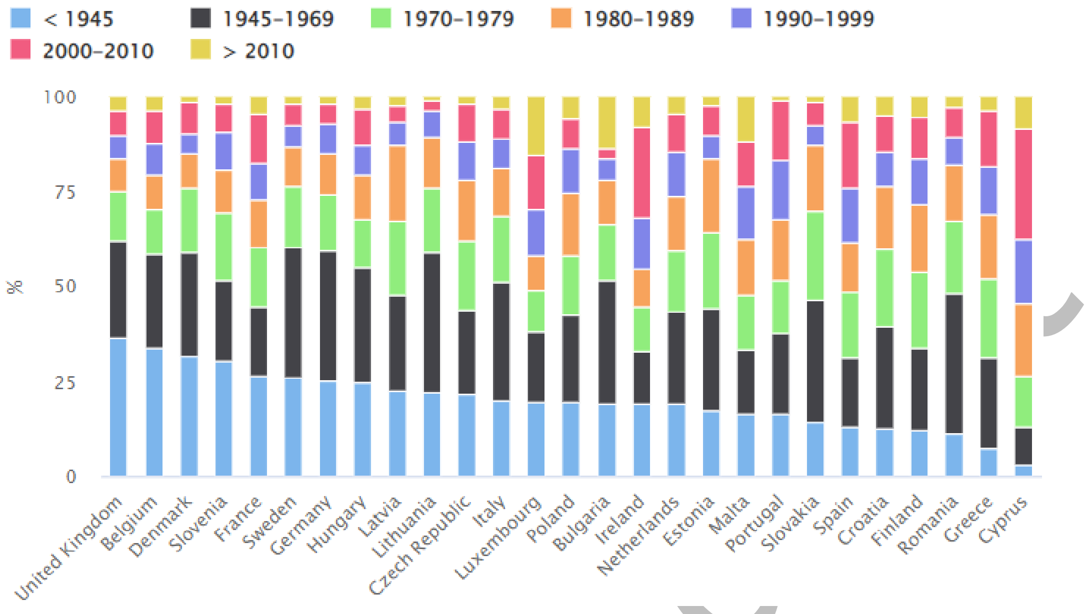

Figure 8. Age profiles of residential buildings in different countries

Source: Building Stock Observatory factsheets, https://ec.europa.eu/energy/eu-buildings-factsheets_en?redir=1

The data are ordered from left to right in order of the largest share of oldest buildings (<1945). With the notable exception of Cyprus, somewhere between 30 and 60% of all residential buildings currently standing, were built before the first thermal regulations for buildings came into force in 1970.

The countries with the most modern buildings (i.e. from the year 2000 onwards) are Cyprus, Luxembourg and Ireland with around 30% of buildings in this age category. Some countries only have very small shares of modern residential buildings in their stock (e.g. Lithuania at 3.5%; Latvia at 6.6%; Germany at 7.1%; Sweden at 7.2% and Slovakia at 7.3%).

Share of social housing: Social housing can be considered as housing that is provided at prices below normal market rates to target groups of disadvantaged people, socially less advantaged people or key workers.

Although residential buildings are mostly privately owned, it is worth paying attention to the share of residential buildings that are social housing in different countries, since it is likely that public finance will be directly or indirectly involved in construction, renovation and management of such buildings.

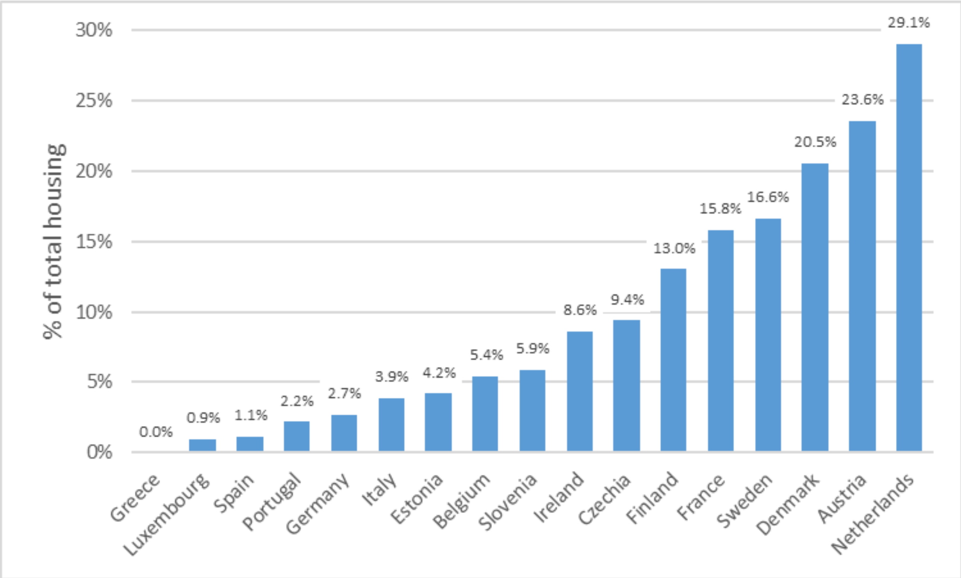

Figure 9. Share of social housing in national housing building stocks

Source: Housing Europe Observatory. [The State of Housing in Europe 2021]

The data from the Housing Europe report shows a major difference in the proportions of housing stock that are considered as "social housing". There is a factor of 29 difference between the highest and lowest shares and there is a gradual spread of social housing shares for different countries in between. Generally speaking, the Nordic countries tend towards the higher shares of social housing and the southern European countries towards the lower shares of social housing.

In terms of new construction and renovation of social housing units, the following data is presented in the Housing Europe report.

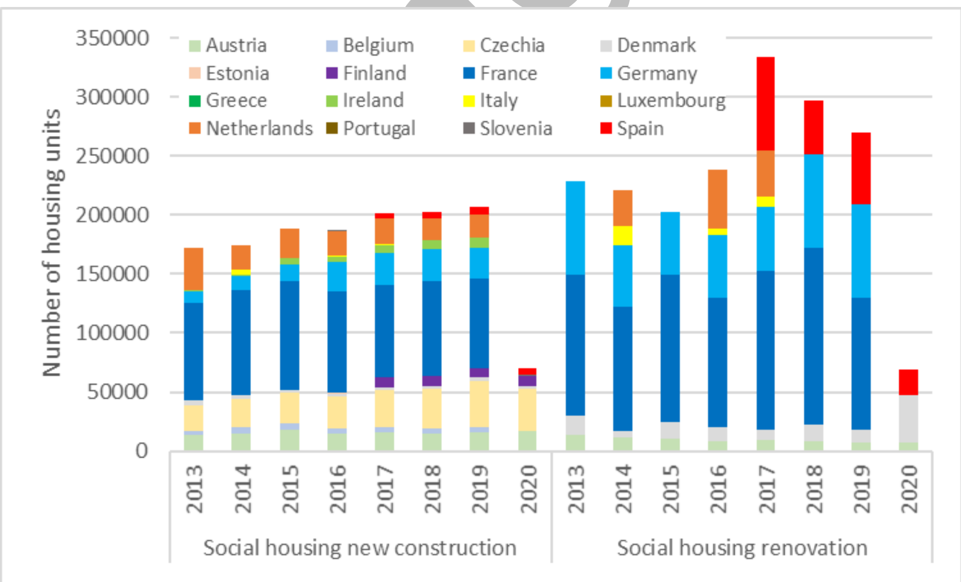

Figure 10. Trends in social housing construction and renovation in Europe (2013 to 2020)

Source: Housing Europe Observatory. [The State of Housing in Europe 2021]

The data above show that construction and renovation activity for social housing varies significantly in different Member States. Part of the different may stem from different policies and definitions used at national level. For example, whether housing is owned by public authorities, by not-for-profit housing associations or is made available for purchase and lower-than-market prices rather than rent. Another clear trend is how the restrictions implemented in response to the COVID outbreak have had a clear effect on new construction and renovation activity across all Member States, with the notable exceptions of Austria, Denmark and, to some extent, Spain.

Up until 2020, France was by far the leading Member State both in terms of new construction and renovation of social housing. Germany (renovation and construction) and Spain (renovation) have significant shares of social housing activities, however, it should be borne in mind that these are also large Member States in terms of population. Those Member States showing a proportionally high degree of activity in social housing construction and/or renovation during 2013 to 2020 are: Austria, Czechia and the Netherlands.

Non-residential building types by floor area: The main building types of relevance to the EU GPP criteria are public offices and educational buildings.

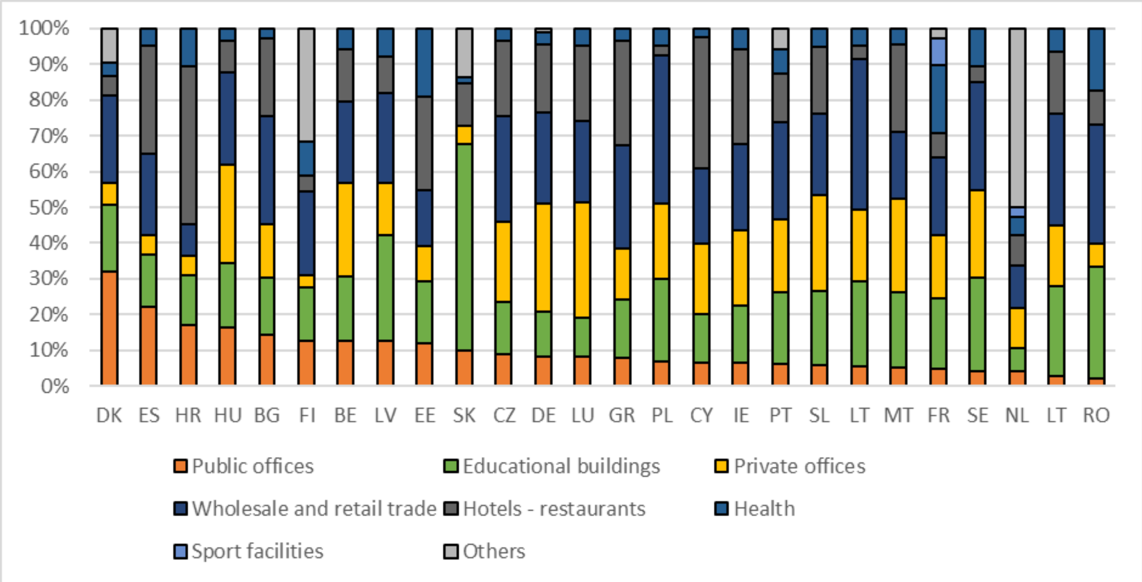

Figure 11. Split of floor area by non-residential building type

Source: Building Stock Observatory factsheets, https://ec.europa.eu/energy/eu-buildings-factsheets_en?redir=1

The share of public offices varies significantly between different countries, with Denmark being the highest (ca. 32%) and Spain (22%), Croatia (17%) and Hungary (16%) being the next most significant. Most of the other countries had public office spaces between 5 and 10% and Romania and Italy (note "LT" typo in x-axis of graph above) having the lowest shares, at less than 3%.

In terms of educational buildings, Slovakia had by far the largest share at around 57% of total non-residential building floor area. Most countries had a share of between 15 and 30%, with the lowest countries being Germany (12%), Luxembourg (11%) and the Netherlands (7%).

Green Building Rating Systems (GBRSs)

Another important market development in the building sector which is considered of relevance in the revision of EU GPP criteria is the rise and rise of Green Building Rating Systems (GBRSs). The idea of these systems is to score the "greenness" of a building design and/or a finally constructed building using a combination of mandatory and optional criteria. While the focus is normally on environmental aspects, it is also possible that criteria relate to social, economic and management aspects as well (directly or indirectly).

There are dozens of GBRSs worldwide (Sanchez Cordero et al., 2020), with the most significant ones in Europe being:

- BREEAM (Building Research Establishment's Environmental Assessment Method, since 1990).
- DGNB (Deutsche Gesellschaft Fur Nachhaltiges Bauen / The German Sustainable Building Council, since 2008).
- HQE (Haute Qualite Environment, since 1997).
- HQM (Home Quality Mark, since 2015).
- LEED (Leadership in Energy and Environmental Design).

- BEAT (Building Evaluation Assessment Tool, in Denmark).
- PromisE (The Finnish Environmental Performance Assessment Criteria).
- SBTool (IISBE, International Initiative for a Sustainable Built Environment)

The potential of GBRSs to drive market demand for "green" buildings is based on the availability of clearly defined technical criteria and associated scoring rules, together with benchmark scores that would be needed to certify a building as, for example, a bronze, silver or gold certified building.

Clients would tend to specify a desired final certification outcome as part of their brief to the design team, together with all the usual technical and functional requirements for the building. Then it would be up to the design team to work with a GBRS assessor to determine how they can achieve sufficient points to meet the rating. Because there are many different ways to achieve the certification, the GBRSs do not necessarily impact on the design freedoms to the point of compromising the original client brief.

Each GBRS has its own style, content and structure. According to Sanchez Cordero et al., (2019), there are more than 500 different indicators across dozens of GBRSs that can be applied to buildings in the EU. To ensure that GBRSs used in the EU can find, maintain or increase common ground, Level(s), a common EU framework for the assessment of sustainability of buildings was developed by the European Commission. The first public version of Level(s) was released in October 2020, after a 2 year test phase.

A comparison of the Level(s) macro-objectives with selected GBRSs carried out by Sanchez Cordero et al., (2019) and showed the following high-level overlaps with Level(s):

Table 6. Level(s) macro-objective coverage by 4 Green Building Rating Systems

Level(s) macro-objective	Green Building Rating System (% of total rating available)			
	BREEAM	DGNB	HQE	LEED
1. Greenhouse gas emissions along a buildings life cycle	Yes (20.0%)	Yes (3.6%)	Yes (5.03%)	Yes (33.0%)
2. Resource efficient and circular material life cycles	Yes (8.9%)	Yes (11.3%)	Yes (5.77%)	Yes (13.0%)
3. Efficient use of water resources	Yes (7.0%)	Yes (0.64%)	Yes (7.14%)	Yes (11.0%)
4. Healthy and comfortable spaces	Yes (6.1%)	Yes (4.35%)	Yes (16.1%)	Yes (9.0%)
5. Adaptation and resilience to climate change	Yes (0.6%)	Yes (0.86%)	No	No
6. Optimised life cycle cost and value	No	Yes (0.36%)	No	No
TOTAL	**42.6%**	**21.1%**	**39.2%**	**66.0%**

Source: Sanchez Cordero et al., 2019

Now that the Level(s) framework has been published and GBRSs have had time to start thinking about how to find common approaches with Level(s), it would be worth repeating such an analysis, but in more detail, comparing to the 16 Level(s) indicators with specific criteria in the GBRSs. An ongoing EU project is currently looking at selected Level(s) indicators to assess to what extent they currently match with a number of European GBRSs.

In terms of certified buildings in the EU, Sanchez Cordero et al., (2020) indicate that BREEAM is by far the most commonly used, accounting for around 65% of the 11,000+ certified buildings in Europe considered in their study. The next most common GBRS was HQE (13.5%) then DGNB (6.5%).

Task 3: Identification of main environmental impacts associated with buildings

Many of the environmental impacts of buildings can, and have been, assessed by life cycle assessment methodologies. These methods can quantify a significant number of different midpoint environmental impacts, the most commonly assessed of which is Global Warming Potential.

However, because a number of environmental impacts are not well covered by LCA methods, in addition to a review of the LCA literature, other environmental impacts will also be considered.

Site selection

The first strategic decision taken when deciding on client needs for a new building is the choice of building site. This could be a greenfield site, an urban site or the site of an existing building (including the further choice about whether to demolish and rebuild or to renovate). Some of the potential environmental impacts and benefits for these four different scenarios are as follows:

Table 7. Potential environmental impacts and benefits based on building project type

Project type	Negative impacts	Positive impacts
New building on greenfield site	• Significant disruption to topsoil and any flora and fauna on site and in immediate surroundings during construction and during building lifetime. • Will normally increase storm water runoff rates → increased flood risks downstream. • Additional materials and resources used to connect to services and other infrastructure. • If very remote, need to discharge wastewater locally. • Possible need for building users to travel further or by private car to access building.	• Less space/access restrictions. • Less interference from existing services and infrastructure. • Reincorporation of topsoil and excavation waste onsite or nearby. • Incorporate sustainable drainage features for the plot area. • Well-designed landscaping and introduction of green roof/walls, nesting boxes and water features.
New building on empty urban plot	• Disruption to any topsoil and any flora or fauna on the plot area during construction and during building lifetime. • Depending on site history, possibility of contaminated soil to be treated.	• Potential mitigation via landscaping and introduction of green roof/walls, nesting boxes and water features. • Cleaning of any contaminated soil. • Can expect good existing public transport links and amenities for building users.
Demolition of existing building and later construction on same plot	• Production of large quantities of Demolition Waste (DW), including hazardous waste. • More materials needed for new building than if choosing to renovate instead. • Space and access restrictions → safety concerns and need to transport/store waste offsite. • Care needed not to disrupt existing services and infrastructure.	• Opportunities for reusing, recycling and recovering materials and components. • Greater design freedom for new building than if choosing to renovate.
Major renovation of existing building.	• Space and access restrictions → safety concerns and need to transport/store waste offsite. • Limited scope for new building features, functionality and performance.	• Saving of large quantities of materials by reusing the existing structure and any other building elements.

There are many factors that can influence the choice of site for a public building project, these decisions could have already been taken as part of much broader urban planning strategies, or be due to economic factors, or be due to the preference of the future occupants of the building or be due to other sites being ruled out due to conflicts with surrounding land owners.

Whatever the reasoning behind the choice of the site, in cases where a new building is to be constructed on a greenfield site, some mandatory requirements relating to biodiversity mitigation should apply – with the aim of restoring or, even better, enhancing the biodiversity of the site after the new building has been constructed.

Life Cycle Assessment of buildings

General methodology and related issues

Of all the LCA indicators, by far the most widely used and reported on is Global Warming Potential (GWP) and for this reason, the main focus of this chapter is on GWP assessments of buildings. It is widely reported that European buildings are associated with around 36% of total CO_2 emissions in Europe. With policy targeting a climate neutral Europe by 2050 and buildings being responsible for such a significant share of greenhouse gas emissions, a lot of focus has been placed on life cycle carbon emissions in the academic literature and in real life building projects.

In Europe, the EN 15978 standard, published back in 2011, provides the common definition for the different life cycle stages of a building.

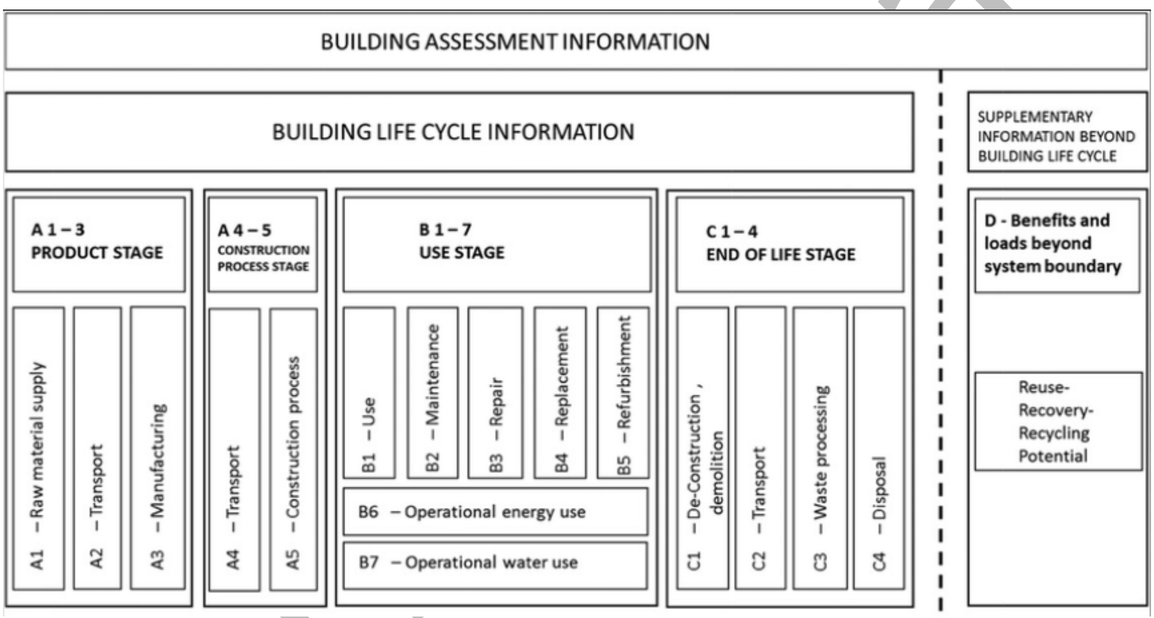

Figure 12. Display of modular information for the different stages of the building assessment.

Source: EN 15978.2011. Sustainability of Construction Works – Assessment of environmental performance of buildings – Calculation method

The framework does not include site preparation (essentially module A0). While the EN 15978 standard forms the basis for the LCA of buildings in Europe, there are areas of freedom for LCA practitioners, necessary to one extent or another, that thus present sources of major variations in results can occur and that would need to be harmonised in order for results of different buildings to be truly comparable. For example, Nwodo and Anumba (2019)[12] identified the following sources of variation:

- Data intensity and quality.
- Definition of functional units.
- Assumptions for building life span and building element service lives.
- Lack of procedures for defining system boundaries.
- Lack of uncertainty analysis.

[12] Nwodo M.N. and Anumba C.J. A review of life cycle assessment of buildings using a systematic approach, Building and Environment, 162, 2019, 106290, doi.org/10.1016/j.buildenv.2019.106290

There are a number of different types of uncertainty with LCA studies, eleven to be precise, that are presented and discussed by Bjorklund (2002). The lack of uncertainty analysis in building LCA studies was also cited as a concern by Pomponi et al., (2017) who cited the potential of Monte Carlo algorithms as a relatively simple way to incorporate uncertainty analysis in building LCA studies.

Variability in studies due to different scopes for operational energy (module B6)

Results from different studies are not easy to compare for a number of reasons, one of which is differences in the precise scope of operational energy consumption in module B6, which can differ as follows:

- Including some or all of five main building technical systems covered by the Energy Performance of Buildings Directive (heating, ventilation, cooling, hot water and lighting systems);
- Including other building (e.g. lifts and escalators);
- Including non-building related uses (e.g. plug-in devices, appliances or even vehicle charging);
- Including (i.e. subtracting) exporting energy from onsite renewable energy systems.

Variability in studies due to different scopes for embodied carbon (modules A1-A5 and B2 to B4)

While building designers will have a much clearer idea of the quantities of materials involved in the sub-structure and superstructure (because these need to be accurately specified and because relatively few materials and components are involved) gathering data for “interior fittings” and “building services” is a much more onerous task.

A recent study by the Concrete Centre (CC, 2021) found that building services accounted for around one third of embodied carbon in a concrete apartment block (with the structure accounting for another third and cladding and internal floors and walls accounting for the final third).

A design guide published by the London Energy Transition Initiative (LETI) estimated that mechanical, electrical and public health services (MEP) and internal finishes accounted for up to 35% for office buildings (19%), residential buildings (20%) and school buildings (35%).

Therefore it can be reasonably assumed that failing to report on building services and interior finishes can lead to significant underestimates of embodied carbon.

Variability caused by type of LCA method

Just looking at the pre-use phase (i.e. modules A1-A5), Saynajoki et al., (2017) found that embodied carbon footprints varied by a factor of almost 70 (from 30 to 2000 kgCO$_2$.eq./m^2). Such a large range of variation is a concern given that many of the other sources of variation, such as assumed service lives of building elements, assumed life of the entire building and operational energy performance, were not even considered. The full distribution of results from the 116 studies reviewed by the authors is shown below.

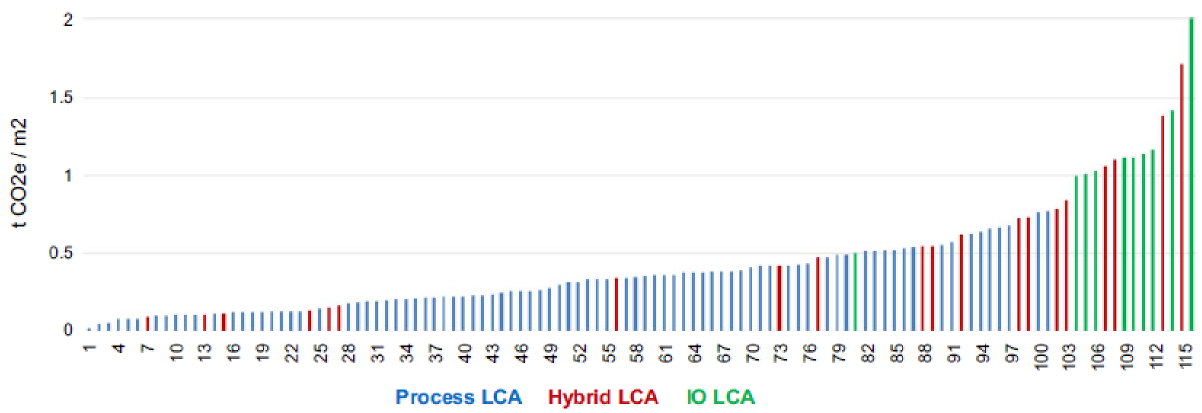

Figure 13. Greenhouse gas emissions per gross m^2 of building LCA studies

Source: Saynajoki et al., 2017

The distribution of results shows some clear association between the nature of the LCA method and the final result, with “process LCA” studies dominating the lower range of results and “IO LCA” (Input-Output) studies dominating the higher range of results. Saynojoki et al., (2017) explain that:

- Process LCA methods are the most common and are based on energy and mass flows for all of the processes involved in making the building but can lead to underestimates when applying cut-off criteria at the level of each individual process.
- Input-Output LCA methods are based on monetary transactions that follow causal relationships between different industry sectors. These economic relationships are established in input-output tables for entire national or regional economies and provide overall relationships such as, "X million EUR of steel is associated with Y tonnes of CO2 emissions". However, this method also suffers from the limitation that the same economic relationship is assumed for all activities within a given sector, when this will often not be the case (e.g. not all steel is equal in terms of specific CO2 emissions). This type of inaccuracy is known as an aggregation error.
- Hybrid LCAs attempt to combine the useful features of both types of LCA method.

The tendency for high values being generated by IO LCA methods was also commented by Rock et al., (2020), who highlighted it as being more commonly applied in LCAs for office building studies in the US and Japan.

Variability caused by use of different cut-off rules

The effect of applying different cut-off rules on the results of a whole building LCA for (i) a standard design Brazilian public school building; (ii) a living laboratory and (iii) a passive office building showed that the choice of cut-off rules could significantly affect the total amounts of materials remaining in the LCA study and thus the results for different impact categories (Gomes and Pulgrossi, 2020). The cut-off scenarios in question were:

- Scenario 1: excluding items that represent less than 1% of total mass input or less than 1% of energy usage in unit processes (so long as all combined this does not exceed 5% of the total mass or energy (EN 15804:2012).
- Scenario 2: excluding all building elements except for the structure and envelope (LEED approach).

The authors found that the EN 15804 cut-off rule removed between 2 and 8% of total masses to be assessed while the LEED cut-off rule removed increased these mass removals to between 29 and 32%. The effect on individual impact categories was often disproportionately higher than the mass removal (compare changes between blue, orange and grey columns for "Mass" with changes in the equivalent columns for other indicators in the figure below)..

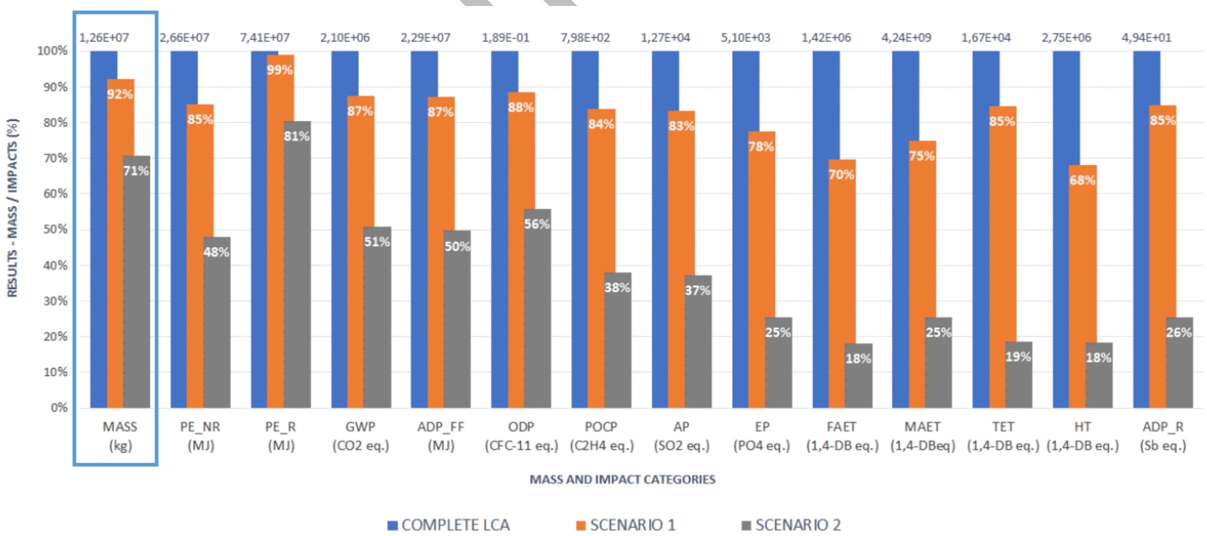

Figure 14. Comparative results for full assessment and 2 cut-off scenarios for a public school

Source: Gomes and Pulgrossi, 2020.

Some examples of disproportionate differences caused by the cut-off scenarios include:

- 8% of mass cut-off translating to 13% drop in GWP and a 32% drop in Human Toxicity.
- 29% of mass cut-off translating to just a 19% drop in renewable primary energy but a 75% drop in Eutrophication Potential.

To help set greater commonality between assessments, the Level(s) framework defines a minimum scope of building elements to be covered in life cycle carbon assessments in Level(s) user manual 1.2 that is much more comprehensive than just the building structure and envelope as specified in LEED. Furthermore, Level(s) also defines default service lives to be used for many building elements, which users should use in the absence of better estimations.

Table 8. Minimum scope for Level(s) building elements for life cycle GWP analysis

Building parts	Related building elements	Expected lifespan
Shell (substructure and superstructure)		
Load bearing structural frame	– Frame (beams, columns and slabs) – Upper floors – External walls – Balconies	60 years
Non-load bearing elements	– Ground floor slab – Internal walls, partitions and doors – Stairs and ramps	30 years
Facades	– External wall systems, cladding and shading devices	30 years (35 years glazed)
	– Façade openings (including windows and external doors)	30 years
	– External paints, coatings and renders	10 years (paint), 30 years (render)
Roof	– Structure – Weatherproofing	30 years
Parking facilities	– Above ground and underground (within the curtilage of the building and servicing the building occupiers) [13]	60 years
Core (fittings, furnishings and services)		
Fittings and furnishings	– Sanitary fittings	20 years
	– Cupboards, wardrobes and worktops	10 years
	– Floor finishes, coverings and coatings	30 years (finishes), 10 years (coatings)
	– Skirting and trimming	30 years
	– Sockets and switches	30 years
	– Wall and ceiling finishes and coatings	20 years (finishes), 10 years (coatings)
In-built lighting system	– Light fittings – Control systems and sensors	15 years
Energy system	– Heating plant and distribution	20 years
	– Radiators	30 years
	– Cooling plant and distribution	15 years
	– Electricity generation	15 years
	– Electricity distribution	30 years
Ventilation system	– Air handling units	20 years
	– Ductwork and distribution	30 years
Sanitary systems	– Cold water distribution – Hot water distribution – Water treatment systems – Drainage system	25 years
Other systems	– Lifts and escalators	20 years
	– Firefighting installations	30 years
	– Communication and security installations	15 years
	– Telecoms and data installations	15 years
External works		
Utilities	– Connections and diversions	30 years

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

Building parts	Related building elements	Expected lifespan
	– Substations and equipment	
Landscaping	– Paving and other hard surfacing	25 years
	– Fencing, railings and walls	20 years
	– Drainage systems	30 years

Source: Level(s) user manual 1.2, available on the JRC website.

The need for better harmonisation between Product Environmental Footprint (PEF) and EN 15978

An analysis conducted by Mirzaie et al., (2020) with the main goal to compare PEF and EN 15978 methods for end-of-life modelling and results for an office building also showed nicely in one graph how the different impact categories compared over the Module A to D life cycle stages of a building.

One important point of the paper was to emphasize the differences in Module C and D results for the two methods. The authors identified the need to better harmonize the EN 15978 and PEF methods in terms of end-of-life formulas by (i) to report on module D like EN 15978 does and (ii) to report burdens and benefits separately for each life cycle stage like PEF does. Without a harmonization on this approach, any LCA database is going to compatible with one methodology or the other, which limits the scope for analysis of LCA practitioners in a given project. The need for harmonization is especially pressing with the general shift that is happening from “zero-energy” buildings to “zero-emission” buildings.

As of early 2022, the European Commission has a new Recommendation in place (Recommendation 2021/2279, repealing the original PEF Recommendation 2013/179). A total of 4 annexes come together with the new PEF Recommendation that provide details on the life cycle assessment methodology, modelling requirements, data provision and data quality requirements. The EN 15978 standard was originally published in 2011 and it is not clear if and when the standard might be revised.

The data presented by Mirzaie et al. (2020) also gives a good indication of when the main life cycle impacts occur for a building, both in relative terms per impact category and in weighted and normalised terms.

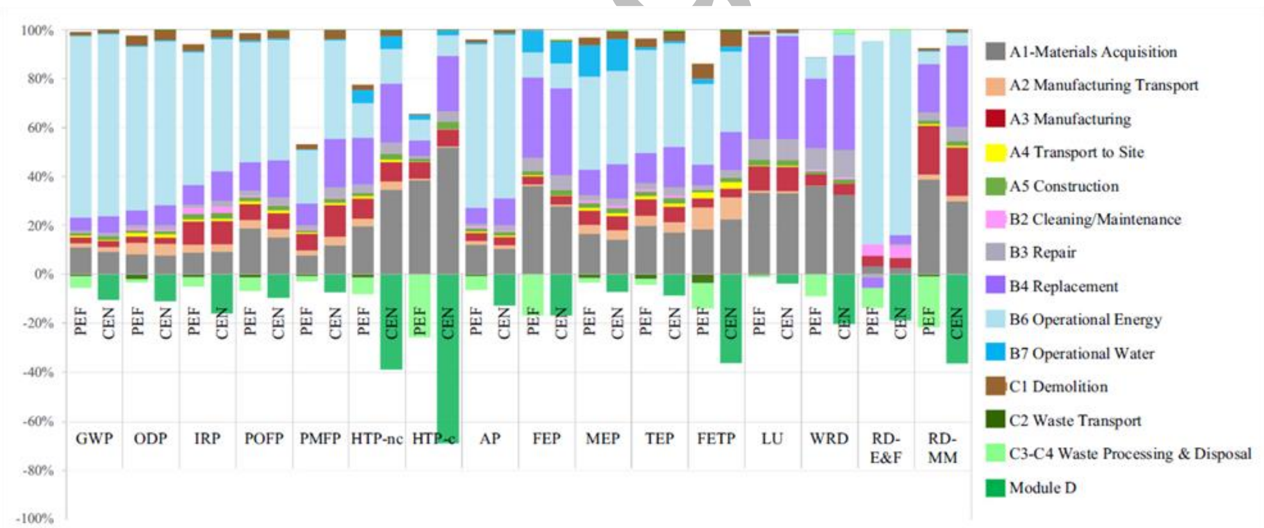

Figure 15. Relative comparison of life cycle impacts according to PEF and CEN (EN 15978) standards.

Source: Mirzaie et al., 2020.

The data in Figure 15 show how, for example, impacts like Global Warming Potential (GWP), Ozone Depletion Potential (ODP) and Acidification Potential (AP) and Resource Depletion of energy carriers and fossil fuels (RD-E&F) are dominated by operational energy. It also shows how the operational energy stage of the building life cycle had little to no influence at all on impacts such as Land Use (LU), Water Resource Depletion (WRD) and Resource Depletion of non-fossil minerals and metals (RD-MM).

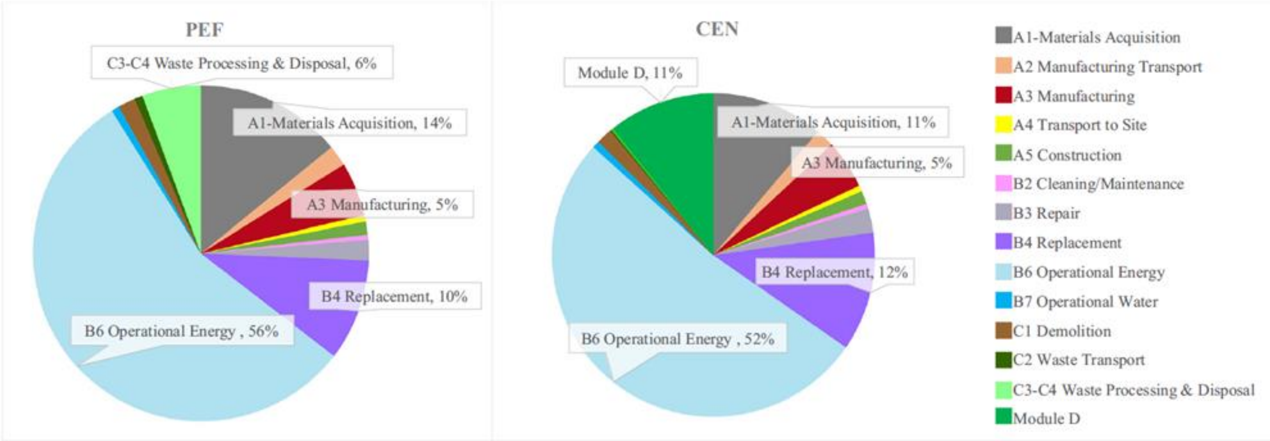

Figure 16. Relative contributions of office building life cycle modules to the single score impact

Source: Mirzaie et al., 2020.

From Figure 16 it is clear that after applying weighting factors to the results of the different impact categories shown in Figure 15 to achieve a single score, operational energy is the most significant life cycle stage. Overall, the split between total impacts due to operational energy (i.e. B6) and total impacts due to materials (i.e. A1 to C4, excluding B6 and B7) were split almost 50:50. A major influence on the total impacts associated with materials is the actual scope and assumptions made for different building elements.

The same authors also provided a comparative breakdown of the five categories of buildings elements that could be expected to account for the vast majority of materials used and that are under the control of building designers.

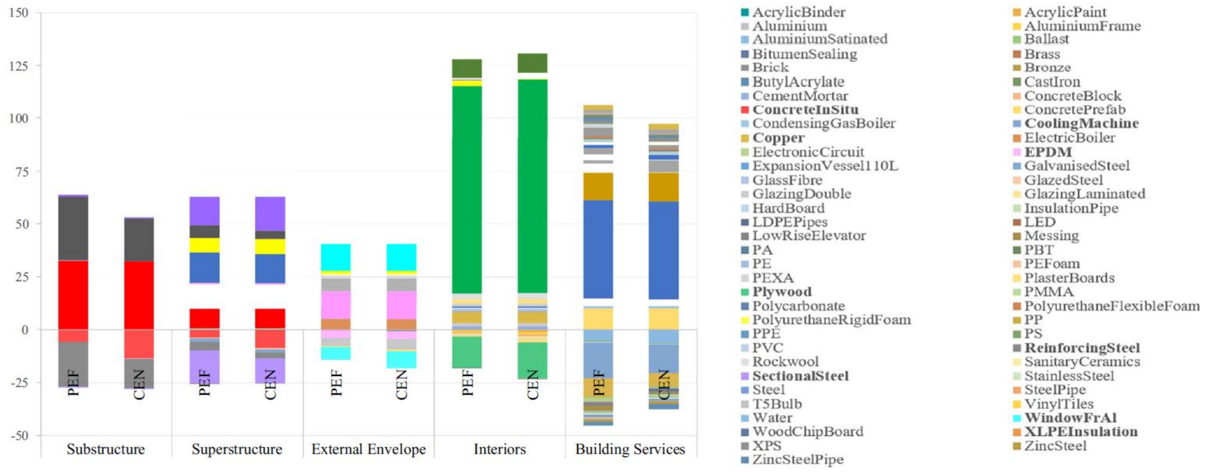

Figure 17. Normalised and weighted life cycle embodied impact: contribution of building elements and materials, according to PEF and EN 15978 methods.

Source: Mirzaie et al., 2020.

While building designers will have a much clearer idea of the quantities of materials involved in the sub-structure and superstructure (because these need to be accurately specified and because relatively few materials and components are involved) gathering data for “interior fittings” and “building services” is a much more onerous task.

The complexity of predicting quantities and embodied carbon of interior fittings and building services is due to the large number of components involved, the large number of suppliers and specialised construction staff carrying out the installation work and the fact that replacement cycles need to be estimated and will be more frequent than, for example, the external envelope. As per Figure 17 above, these difficult-to-foresee parts of the embodied carbon of a building can actually account for highly significant shares (i.e. >50%) of normalised life cycle impacts in office buildings.

Trends and relationships between operational and embodied carbon

With older buildings, operational carbon emissions would typically dominate the total carbon emissions over the full life cycle of a building. However, as designers chase zero-energy targets, which involves making buildings more energy efficient and using lower carbon energy sources, the contribution of embodied carbon to whole life cycle carbon emissions becomes more and more significant. In terms of future scenarios, this trend is well illustrated in the Climate Emergency Design Guide (CEDG) published by the London Energy Transformation Initiative (LETI).

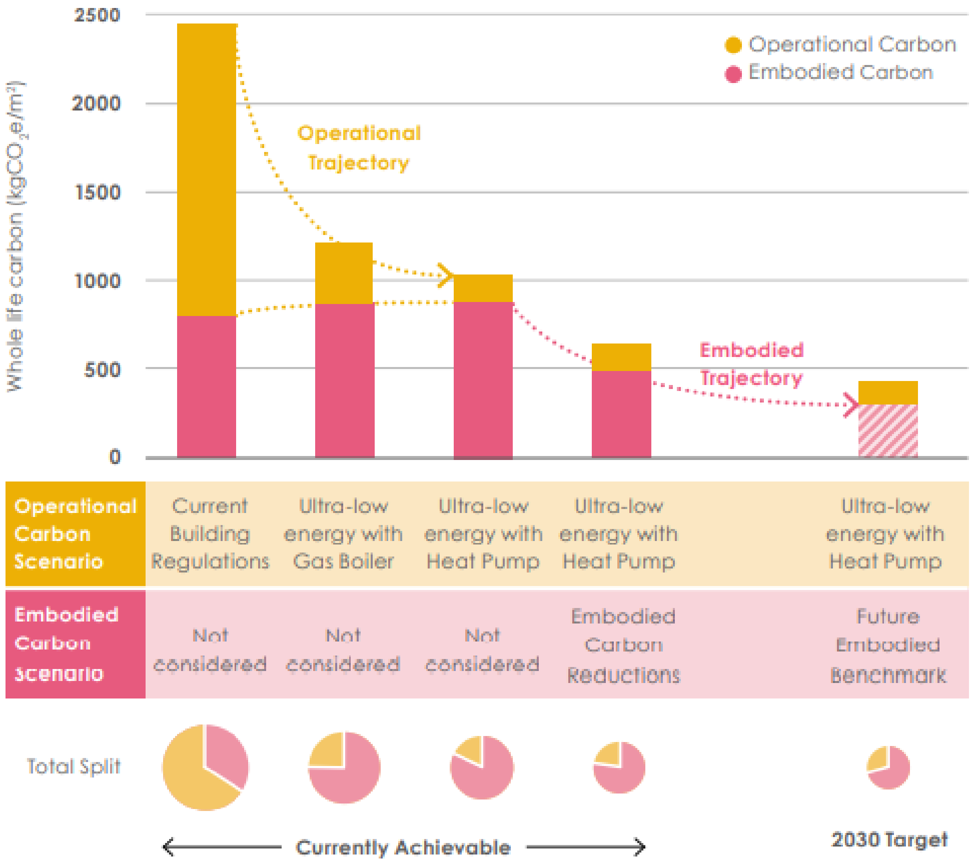

Figure 18. Projected operational and embodied carbon trajectories

Source: LETI, CEDG (2020)

The trends shown in the figure above indicate a dramatic reduction in operational carbon being brought about by a shift to much more efficient heating technologies and a very modest increase in embodied carbon occurring (e.g. via more insulation materials). Efforts to reduce embodied carbon, which would by then be the dominant source of overall carbon, could involve building using less materials, more durable materials and systems that are easier to repair, specifying low carbon materials, the increased use of prefabricated elements and building spaces that are easy to adapt.

A similar trend of major reductions in operational carbon coupled with more modest reductions, or even increases, in embodied carbon was found by Röck et al., (2020) in a broad study of over 650 case studies.

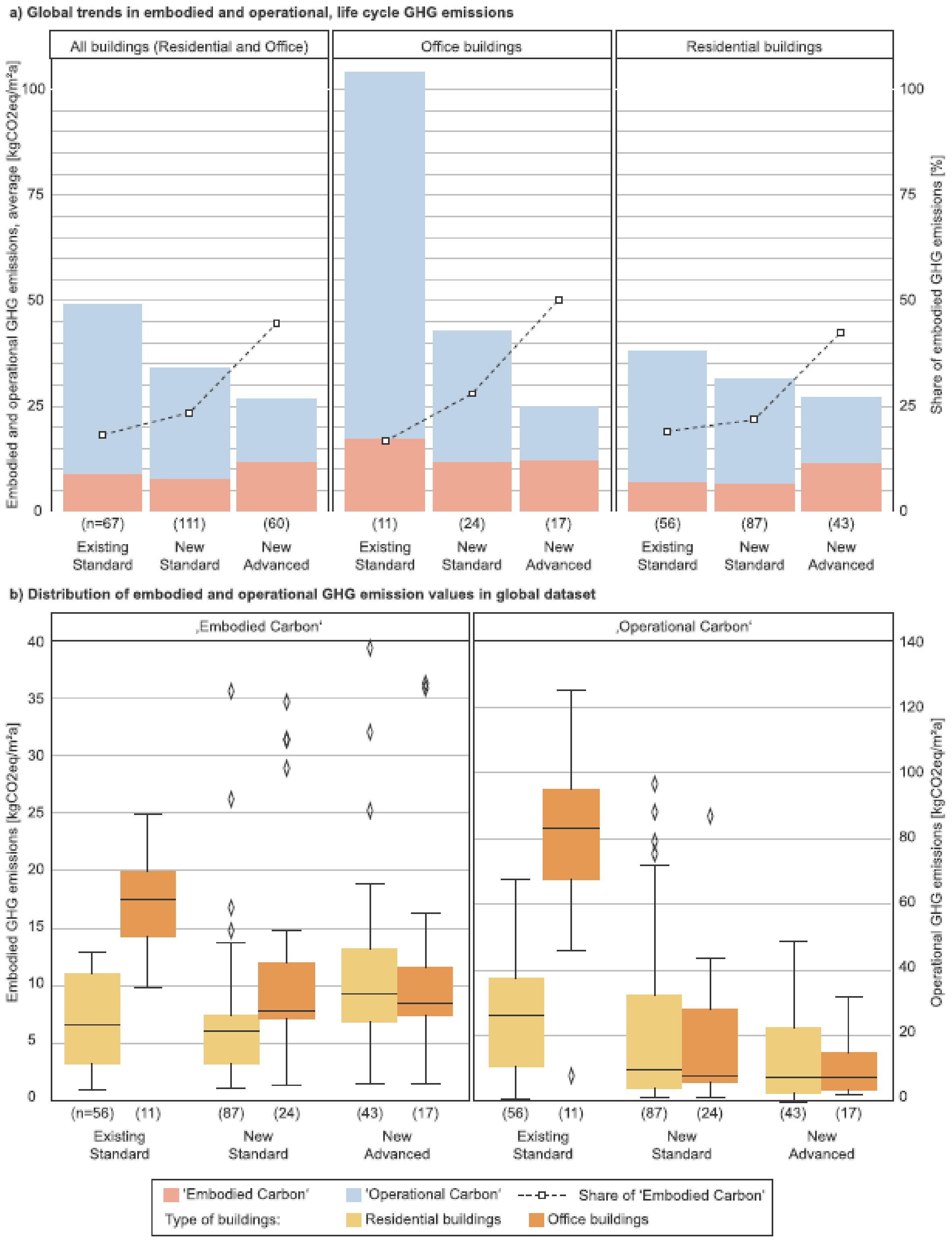

Figure 19. (a) Average trends and (b) spread of individual values for life cycle carbon for residential and office buildings of different energy classes

Source: Röck et al., (2020)

A wealth of information is contained in the Figure above. Results are split into three levels of energy performance category as follows:

- “Existing standard”: i.e. buildings constructed before the tightening of standards for energy performance.

- "New standard": i.e. buildings constructed in line with recent or current building standards for energy performance.
- "New advanced": i.e. passive houses or near or net zero energy buildings.

In part (a) at the top of the graph, the average embodied and operational carbon impacts are stacked together. The first observation is that the combined trend for residential and office buildings is dominated by the trends for residential buildings, because the number of residential buildings making it through to the final analysis was 3-4 times higher than office buildings. What can be seen from part (a) of Figure 19 is that there are highly significant reductions in operational carbon for both office and residential buildings (especially office buildings) as the energy performance standard applied to the building improves. Moving from "existing standard" to "new standard", embodied carbon did not increase in absolute terms, but it did increase significantly for residential buildings and slightly for office buildings when moving from "new standard" to "new advanced". These changes effectively meant the share of embodied carbon increasing from 17% to 28% to 50% for office buildings and from 19% to 22% to 43% for residential building when going from "existing standard" to "new standard" to "new advanced" type buildings.

In terms of the distribution of individual operational carbon and embodied carbon results, part (b) of Figure 19 shows box plots with the 1^{st} quartile and 3^{rd} quartile values (line in between being the 2^{nd} quartile value) and the ends of the whiskers representing maximum and minimum values. While the spread of results for each dataset was significant, focussing on median values shows clear trends and the boxplots showed that "new advanced" residential buildings suffered from a much greater increase in embodied carbon than office buildings.

A typical scenario for how embodied and operational carbon emissions occur over a new building life cycle, also from the LETI design guide, is provided below.

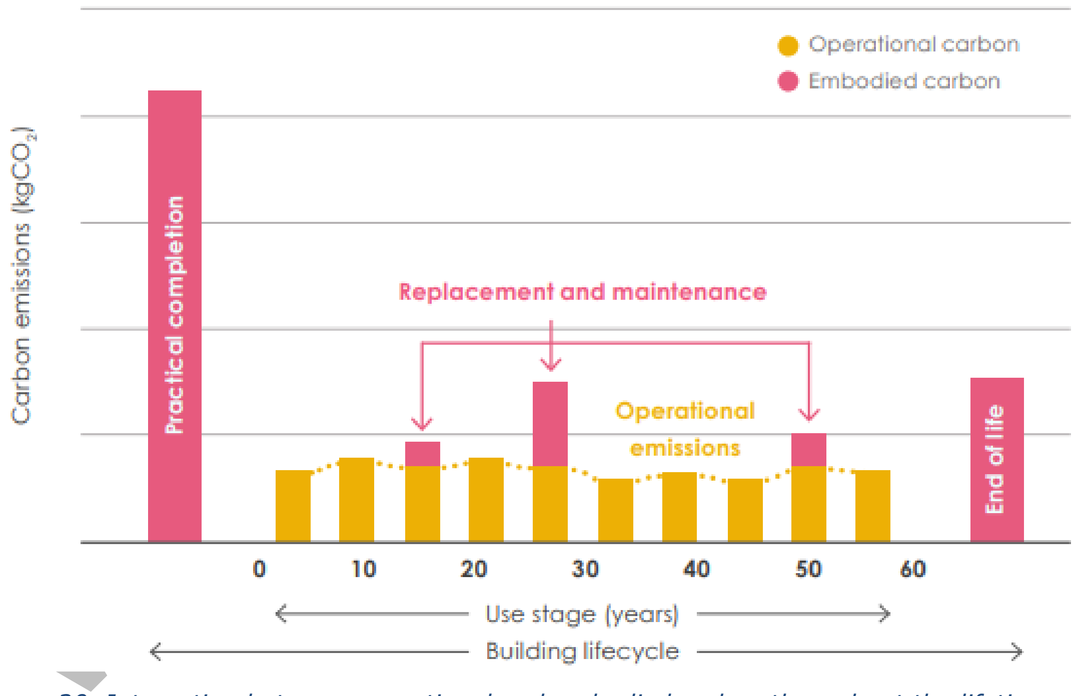

Figure 20. Interaction between operational and embodied carbon throughout the lifetime of a building

Source: LETI, CEDG (2020)

The LETI design guide actually promotes a separate reporting of embodied carbon because of the external influence on operational carbon of carbon factors of energy sources (e.g. Rasmussen et al. (2013), or simply buying 100% renewable electricity from the grid would improve building results without any actions necessarily being taken by the building designer. So they promote targets for "Energy Use Intensity" (EUI) for all normal use phase energy consumption (except vehicle charging) in lieu of operational carbon and separate targets for embodied carbon. The targets they set are as follows:

- Small scale housing: 35 non-renewable kWh/m^2.yr (15 due to space heating) and **500 kgCO_2/m^2**

- Medium and large scale housing: 35 non-renewable kWh/m^2.yr (15 due to space heating) and **500 kgCO_2/m^2**
- Commercial offices: 55 non-renewable kWh/m^2.yr (15 due to space heating) and **600 kgCO_2/m^2**
- Schools: 65 non-renewable kWh/m^2.yr (15 due to space heating) and **600 kgCO_2/m^2**

These embodied energy targets represent a 40% reduction compared to baseline scenarios. Ignoring any major design innovations, meeting these targets would generally require the greater incorporation of significant shares of reused materials in the building and a much greater reuse potential of building elements at end of life.

The RIBA 2030 Climate Challenge

In a similar manner to the LETI design guide (LETI, 2020), the RIBA 2030 Climate Challenge sets separate thresholds for operational energy (in kWh/m^2/yr) and embodied carbon (in addition to a potable water use limit in terms of l/person/day and wellbeing requirements (overheating, daylighting, CO_2 levels, VOCs and formaldehyde), they set requirements for **embodied carbon** as follows:

- New build offices: **< 970 kgCO_2.eq./m^2** by 2025 and **< 750 kgCO_2.eq./m^2** by 2030.
- New build schools: **< 675 kgCO_2.eq./m^2** by 2025 and **< 540 kgCO_2.eq.m^2** by 2030.
- New residential buildings: **< 800 kgCO_2.eq./m^2** by 2025 and **< 625 kgCO_2.eq./m^2** by 2030.

These thresholds include emissions from life cycle modules A1 to C4, excluding B6 and B7 for operational energy and water consumption. Furthermore, the analysis must include at least 95% of the substructure, superstructure, finishes, fixed furniture, fitting and equipment and building services by cost and also include estimated refrigerant leakage. More details on the method are presumably aligned with the embodied carbon calculations detailed in the RICS professional statement (RICS, 2017).

Embodied and operational carbon results reported in the literature

The study referred to earlier about the sensitivity of 116 as-constructed embodied carbon results for buildings (Saynajoki et al., 2017) also compared results by building type, main structural material, building size and climate zone.

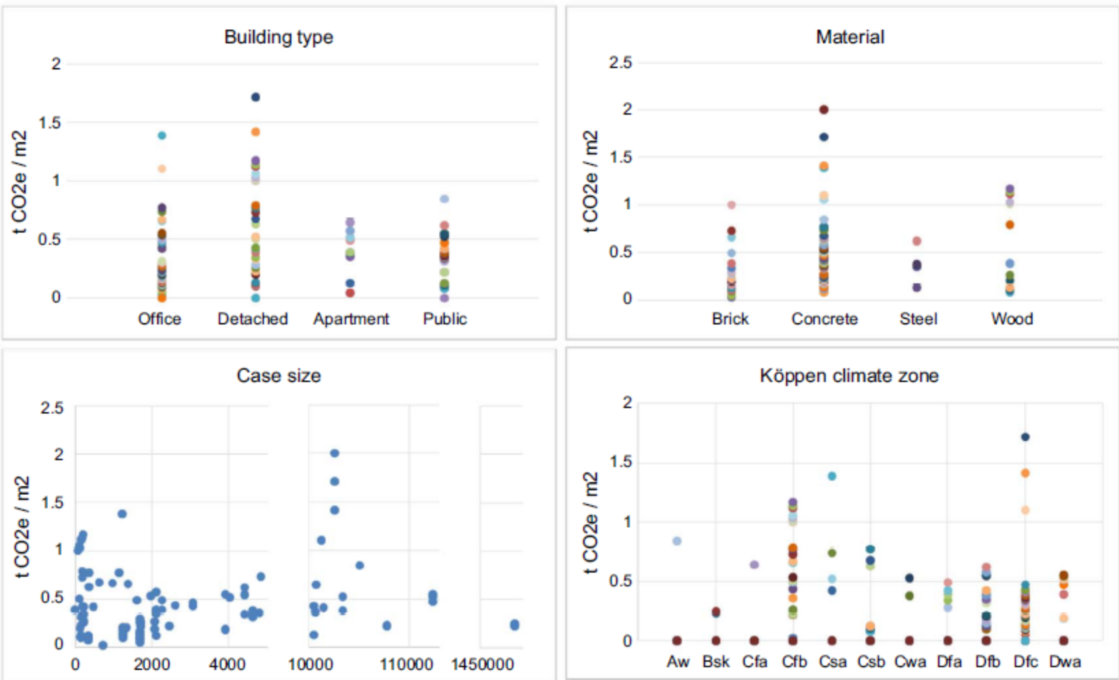

Figure 21. Plots of results of 116 case studies according to building type, materials, size and climate zone.

Source: Saynajoki et al., 2017

From the results shown above, these factors still showed significant variability within each variable. Although no clear relationship could be established, it is interesting to see the following:

- that detached residential buildings tended towards higher embodied carbon results than apartment buildings,
- that the public buildings (mainly educational buildings) had a similar spread of embodied carbon results as office buildings (ignoring some higher outliers for office buildings),
- that order of magnitude differences could be seen within the data sets for each building type,
- that wood materials did not show any clear benefits on embodied carbon compared to other materials,
- that there is no correlation between total building floor area and specific CO_2/m^2

The dominant sources of variations in results between different studies appear to be method-based and data source-based. Consequently, before any policy might consider setting voluntary or mandatory targets for buildings, freedoms on the methodology must be tightened and the choice of generic data be more limited.

A lot of research has been published for life cycle GWP of residential buildings, which is well justified since they account for around 75% of total EU building stock.

Chastas et al., (2018) reviewed a total of 95 LCA studies of residential buildings. They tried to make the results more comparable by normalising the reference study periods all to 50 years (71 of the 95 studies had used 50 years already) and then filtering out studies that (i) did not clearly define the floor area; or (ii) did not clearly show that A4+A5 life cycle stages were included or (iii) did not cover all of the main sources of operational energy consumption (i.e. heating, ventilation, cooling, domestic hot water, lighting and appliances). The authors found that the share of embodied carbon increases as the energy performance of the building increases, more specifically, shares of embodied carbon were from 9 to 22% for conventional residential buildings, from 32 to 38% for passive houses and from 21 to 57% for low energy residential buildings. An nZEB building that did not pass the filtering criteria had embodied carbon accounting for 71% of total life cycle carbon.

In a review of case studies of single family houses, Soust-Verdaguer et al., (2016) reported that there was significant heterogeneity in LCA studies for residential buildings in the literature. Some of the main differences were:

- Different goals for the studies (e.g. to compare different building designs, to optimise a single design, a sensitivity analysis for specific features, such as the energy mix).
- Different scopes for the studies (e.g. different life cycle stages included/excluded, different functional units used, including/excluding interior fittings and services in embodied carbon analysis).
- Different assumptions for building reference lifetime, different assumptions for service lives of building elements and different end-of-life assumptions.

Schools and many educational buildings are typically low-rise buildings within a significant plot area and thus have quite a high specific envelope area: interior volume ratio. This can make these buildings more susceptible to heat loss, or excessive solar gain in cases of poor envelope thermal performance. However, at the same time, these types of buildings have significant opportunities for energy efficiency, especially via the installation of combined heat and power units and the installation of onsite renewable energy systems.

An interesting study by Odell et al., (2020), which focussed purely on real energy consumption (electricity and gas) and real water consumption in 13 different schools in Western Australia over a 3 year period (2015 to 2017). They converted electricity, gas and water consumption into carbon emissions and then normalised the data to a per student basis. Just the knowledge that the school performance was being audited led to user behaviour changes that improved the performance in 12 of the 13 schools and an average reduction in per student operational carbon of 20%. These savings also have a direct translation into operational cost reductions.

Task 4: Technical analysis and improvement potential

Buildings are complex systems composed of multiple and inter-related technical systems, all of which have some degree of influence on the overall life cycle impacts of the building.

The purpose of this section is to analyse some of the most relevant building technical systems, explaining how they work, the different configurations and systems that are available today and their performance ranges. By comparing the performances of different types of system, some estimation of the improvement potential that can be made via technical specifications in EU GPP criteria can be presented.

Due to the fact that this section will require input from experts in very well defined fields, this task is far from complete in this 1st version of the background report. An example section is provided for some of the systems related to theme 3, on the efficient use of water resources in order to give stakeholders an idea of what type and level of information would be needed.

Systems related to theme 3: efficient use of water resources

Scope of water systems covered

The technical performance of individual sanitary tapware and showers, *(flushing toilets, urinals, greywater recycling systems, rainwater harvesting systems and irrigation systems will also be considered here in the next draft)*. It does not extend to water heating systems or hot water storage tanks, which are considered as relevant to theme 1.

Water use patterns in different building types

Investments in water efficiency are encouraged throughout the building but in cases where limited resources are available, investments should be targeted to those sanitary fittings and appliances where most water is consumed. At a general level, the split of water consumption varies with building type, although each individual building will have its own very specific use patterns. A comparison of some of the main building types that could be owned by public procurement are compared with each other.

Table 9. Splits of water consumption in showers, toilets, washbasin and kitchen taps by building type

Building type	Toilets & urinals	Showers / baths	Washbasin taps	Kitchen taps	Other
Residential	25%	33%	7%	7%	28%
Public office	63%	0%	2%	4%	31%
Educational	28%	1%	3%	4%	64%
Health & social	45%	0%	8%	4%	43%
Recreation, culture, sport	74%	0%	4%	0%	22%

Source: Cordella et al., 2014.

Toilets and urinals consistently represent important shares of water consumption for all building types, while showers and baths are only really significant in residential buildings. Office buildings, if they provide changing rooms for staff who cycle to work, or fitness areas for staff to carry out lunchtime exercise activities could have much more significant shares of water consumption due to showers than the 0% stated above. For other public buildings, targeted investments in public buildings like sports centres changing facilities could deliver major water savings.

Basic technical description of sanitary tapware and showers

Taps and showers are essentially products of the valve industry that consist of several functional and design features. Some of the main distinctions between the different types of taps are illustrated below.

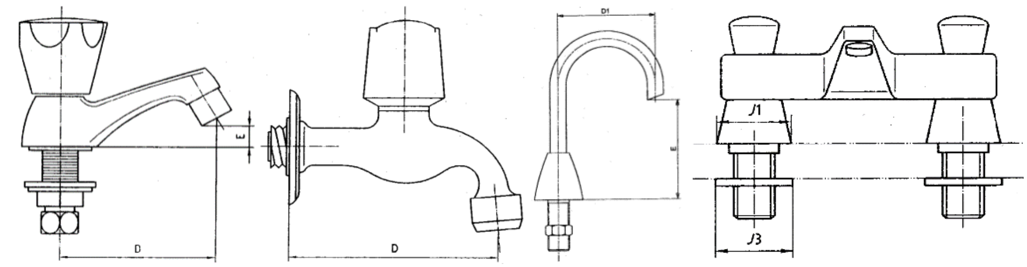

Figure 22. Types of taps according to EN 200:2008 (left to right: pillar tap, bib tap, single-hole combination tap, two-hole combination tap).

Source: EN 200:2008, as reproduced in Cordella et al., 2014

The main EN standard for tap specifications is EN 200, and for shower outlets, it is EN 1112. Products are broadly split into two types (1 & 2) and are assigned product classes based on their flowrate (and some other qualities, such as acoustics).

The release of water from taps is controlled by either spindles (the original mechanism) or ceramic discs (a more modern mechanism).

Spindle taps: Spindle taps were, in the past, the only type of mechanism available for supplying water. They are still used across the EU since they can be used in both high- and low-pressure systems. The principle on which they operate is simple, the flow rate being controlled by turning the tap head.

Spindle taps are typically composed of several components, as shown in Figure 23. The tap consists of a spindle with a valve seat placed at the bottom of the spindle. A washer is attached to the end of the spindle and it is positioned over the hole through which water flows. As the handle is turned it moves the washer up or down to adjust the flow.

The various parts of the tap are generally robust and hard-wearing. During the lifetime of a spindle tap, the key components likely to require replacing are tap washers, O-rings or regrinding of the valve seat where this has been eroded[14].

This mechanism is typically used in pillar taps, which are mainly used in the UK. According to some stakeholders, in the UK the "traditional" look of pillar taps in the bathroom is still desirable. However, other European countries also have a significant pillar tap market.

[14] See: http://www.diydoctor.org.uk/projects/dripping_tap.html

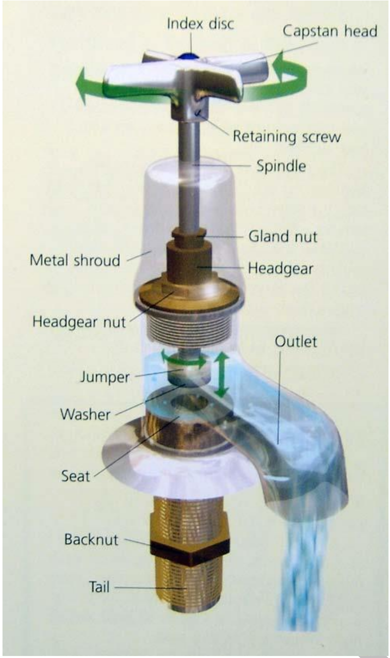

Figure 23. Spindle tap mechanism and components

Source: See: http://www.upperplumbers.co.uk/plumbing/Plumbing_principles/taps.html

Ceramic disc taps: Taps based on ceramic discs operate differently to spindle taps. In this case, water flow is controlled through two ceramic discs in the tap body that are separated when the handle is turned or lifted. As illustrated in Figure 24 for a single-lever mixer tap, some components of a ceramic disc tap are the same as those of a spindle tap but the mechanism differs.

The main components of a ceramic disc tap are (see photo 1 in Figure 24):

- spout (A);
- tap cartridge (B);
- handle (C);
- retaining screw (D);
- screw cover / hot-cold indicator (E).

The main element of this type of tap is the cartridge, which consists of a number of parts itself (see photo 2 in Figure 24):

- disc-retaining washer (A);
- ceramic discs (B);
- O-ring which stops any water seepage up to the head of the tap (C);
- valve retaining nut (D);
- spindle on which the handle sits (E).

As with spindle taps, ceramic disc taps are designed to be hard-wearing. Ceramic discs are the key component and they are designed to be durable and it is unusual for them to wear out completely. However, if new discs are needed, the whole tap cartridge is usually replaced.

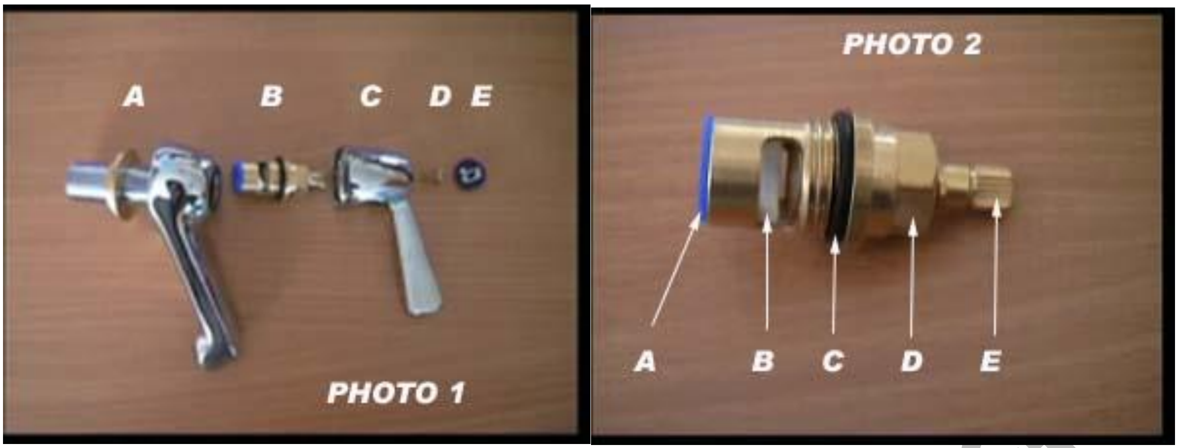

Figure 24. Components of a ceramic disc tap (Photo 1) and of the tap cartridge (Photo 2).

Source: See: http://www.diydoctor.org.uk/projects/ceramic_disc_taps.htm

In general, ceramic disc taps require a certain pressure at which to operate in order to provide an acceptable flow rate. However, the design of the tap (e.g. the size and alignment of the discs, the diameter of the opening which water can pass through and the resistance provided) can be adapted to the pressure at which they will operate, from 0.1 bar to higher pressures (e.g. 0.5 bar, 1.0 bar and above). However, given the fact that low-pressure systems in Europe are only found in the UK, Ireland and some Eastern countries, the majority of ceramic disc taps on the EU market are designed for higher pressure systems. In order to ensure that an acceptable flow rate is achieved, it is important that taps are properly designed for the pressure system with which they are intended to be used and that the minimum/maximum pressure of use are clearly communicated.

Evolution of the control technology: In terms of technology evolution, the first taps/valves had two handles. These are still used mainly for high-end decorative products and for thermostatic mixers.

Single-lever taps/valves were invented in 1937 and became popular in the 1990s thanks to ceramic disc cartridge improvement in terms of performance and reliability. This gave increased possibilities to manufacturers for researching and developing product design lines. The market for this type of products is very mature and many tap manufacturers produce their own cartridges.

In the late 1980s-1990's, the market saw the introduction of thermostatic valves. The reliability of components has improved since the 1990s for the benefit of comfort and security. The trend is now towards downsizing, inclusion of water-saving features and further penetration of thermostatic valves, at least in the shower valve sector for the domestic market.

Showers: Showers are systems composed of one or more outlets (e.g. showerheads and/or a hand showers) and interrelated control valves and/or devices for regulating water flow and temperature (e.g. through a mixer/thermostatic element).

The shower outlet delivers water to the end-user and it is usually connected to the valve via a hose or, if it is wall-mounted, via a shower arm. The showerhead is a typical outlet and its design and components can vary depending on the type and complexity of the product. For instance, some showerheads have aerators or built-in flow regulators. Some examples of outlets are provided in together with an indication of the main components. Shower outlets can consist of:

- a body;
- a spray disc/plate;
- seals (e.g. nitrile rubber seals);
- a flow regulator / aerator mechanisms (depending on the product design).

A built-in water heater is present in electric instantaneous showers. Safety aspects are of key importance for this specific product group, which was included in the preparatory study for "Eco-design of Water Heaters"[15].

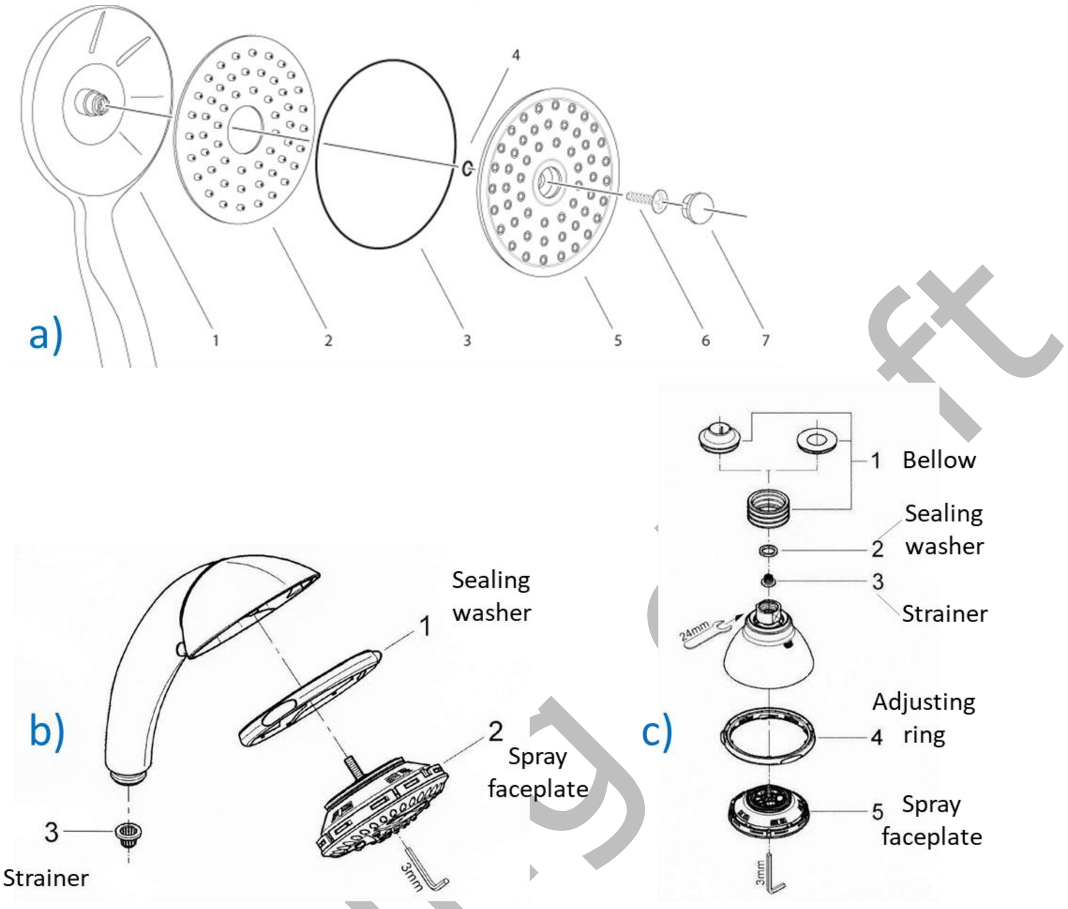

Figure 25. Examples of shower outlets: a) single spray showerhead; b) "Champagne" showerhead and c) massage hand shower.

Sources: Cordella et al., 2014 and, specifically for image a) http://www.wayneansell.com/portfolio/hh-336n_diagram_lrg.png; for image b) http://www.showerdoc.com/shower-spares/grohe/GROHE-PARENT-37-Grohe- movario-Head-Shower-Champagne-1-2in-28-396 and for image c) http://www.showerdoc.com/shower-spares/grohe/GROHE-PARENT-32-Grohe-Movario-Handshower-Massage-28-391

Tap and shower performance

Each tap or shower product needs to have a defined class, based on the mains water pressures it can operate satisfactorily under and the specific flow rate of the fitting under standard conditions.

Table 10. Classification of taps and shower outlets based on their flow rates according to EN 200:2008 and to EN 1112:2008.

Water supply system	Class	Flow rate in L/min	
		Taps	Shower outlets
Type 1	ZZ	-	1.5-7.2
	Z	≤ 9	7.2-12
	A	≤ 15.0	12-15
	S	≤ 20	15-20

[15] See: http://www.ecohotwater.org/

Water supply system	Class	Flow rate in L/min	
		Taps	Shower outlets
Type 1	ZZ	-	1.5-7.2
	B	≤ 25	20-25
	C	≤ 30	25-30
	D	≤ 38	30-38
Type 2	X	≤ 7.5	-
	Y	≤ 15	-
	R	≤ 7.5 hot and ≤ 4.2 cold	-
	E	-	3.6-8.4
	H	-	> 8.4

Source: Cordella et al., 2014

Such performance classes could potentially be used as a means to verify compliance with any EU GPP criteria since the letters for the performance class should be imprinted on the products.

Another way to potentially verify performance is to look at any voluntary water label available on the packaging on new products. A number of different national water labelling schemes have agreed to come together under the Unified Water Label, which still links to the European water label catalogue and which lists thousands of different tap and shower products.

An example of what the European Water Label looks like is provided below.

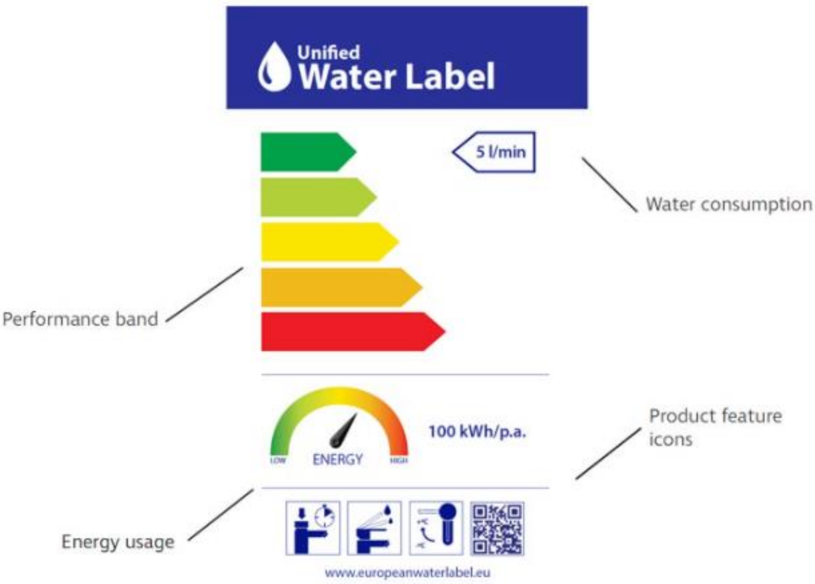

Figure 26. Unified water label for water using (bathroom) products

Source: https://www.ciphe.org.uk/newsroom/media-centre/latest-blogs/its-streamline-time-for-the-european-water-label-scheme/

A review of the products on the catalogue showed performance ranges varying as follows:

- From 3.7 to 106.4 L/min (mostly from 4.0 to 12.0 L/min) for kitchen taps.
- From 1.3 to 150.5 L/min (mostly from 4.0 to 12.0 L/min) for washbasin taps.
- From 4.0 to 120.4 L/min (mostly from 6.0 to 18.0 L/min) for shower controls.
- From 4.0 to 50.0 L/min (mostly from 6.0 to 12.0 L/min) for shower handsets.

There are clearly large potentials for improvement when renovating tap and shower fittings in existing buildings. However, savings estimated due to water efficient fittings may also be partially offset by changes to user behaviour (e.g. users may shower for longer) and certain users will not because less due to their nature (e.g. vessel filling).

Water saving technologies and tap/shower product features

In the last 10-20 years, tap and shower technologies have shown a shift towards more water efficient designs. The main drivers behind this shift include:

- The cost of supplying water is increasing and these costs are passed on to consumers in the form of higher water bills. In response to this, consumers and businesses are keen to identify and implement measures that enable them to reduce their water bills.
- Other utility costs are also increasing, for example gas and electricity. The energy consumption associated to heating water is recognised by both businesses and consumers as a potential area for cost savings.
- Consumer awareness of the environment and the impact they have on it, including their water use, is increasing. This has resulted in many consumers sourcing products that help them to achieve a more sustainable lifestyle.
- Businesses are increasingly aware of their environmental impacts and profile and the commercial benefits from improved reputation through increased Corporate Social Responsibility.
- Businesses are increasingly recognising the risk posed by water scarcity to their operations, especially those that utilise large volumes or where water is integral to or the limiting factor in their processes. More sustainable water use will help reduce overall water consumption and minimise exposure to such risks.
- Regulations, government policies and public support to promote product innovation and development in the area of water efficiency.
- Increased provision of water efficiency labelling increases awareness and consumer/business understanding of the differences in products.

The main water saving technologies (which also save energy when hot water is involved) are briefly presented below.

Flow and spray design patterns: One of the first actions to improve the efficiency of taps and showers was to add a flow restrictor, to increase the speed of water, and to design improved spray patterns. Already in the 1970s, this allowed the introduction of showerheads delivering 16% less water than "conventional" models and performing the same (15-16 L/minute versus 18.5 L/minute at 2 bar). New models were designed in the 1990s that delivered 27% less water (13.5 L/minute against 18.5 L/minute at the same pressure).

Conventional showerhead sprays emit water in many (often more than 20) small continuous jets producing a narrow needle-like spray. The water jets are usually set in a circular pattern to balance coverage area and comfort. Showerhead designs can employ different spray types which can result in greater consumer satisfaction and water savings. However, it must be observed that this is an area characterised by a significant level of subjectivity.

For example, the Methven Satinjet showers[16] use twin jets of water that collide and turn the water stream into thousands of tiny droplets. These are also fitted with a flow restrictor, with flow rates of 9 and 14 L/minute, and can also be retrofitted easily. The manufacturer website indicates that assuming a conventional shower flows at 20 L/minute and that four showers of 10 minutes are on average taken in a household every day, a reduction of the water flow to 14 L/minute could allow savings of up to 27% in hot water energy costs and up to 30% in the water costs. Cost savings would be 50% for energy and 55% for water with a further reduction of the water flow to 9 L/minute. Considering 12 L/minute as the updated reference, the revised savings in case of 9 L/minute would be about 25%. Relatively short payback times (a few months) are reported for this product by the manufacturer.

[16] See: http://www.methven.com/nz/innovations/satinjet/

Another design concept developed by Nordic ECO[17] is based on a screw-like turbine device. When the water reaches the showerhead it rebounds from the underside of the "screw" and is retained in an expansion chamber, where pressure increases. Once a certain level of pressure is reached, the water bounces back and out of the chamber many times per second. This pattern uniquely manipulates the surface tension of water. Without choking the water flow, this action maximises the effect of every drop, maintaining pressure and temperature whilst consuming much less water but achieving the performance of a much greater flow. There is no attempt to give the feeling of having more water by filling water droplets with air but to deliver fuller droplets with propulsion and impact. Nordic ECO's showers can deliver a flow rate of 6-9 L/minute, depending on the model. It is declared that the 9 L/minute model is considered as effective as a conventional shower with a flow of 19 L/minute. The showerheads are available at about EUR 60 (June 2013). No information on the payback period has been gathered but the website of the manufacturer provides a tool to calculate the savings associated with individual circumstances[18].

Aerators: An aerator is a device that entrains air into the water stream through the Venturi effect. This breaks the water stream into many small droplets providing an effective cleansing function with less water. The resulting water stream is softer to touch and non-splashing.

Standard aerators do not allow the flow rate to be controlled independently from the pressure: the flow will increase as the pressure increases. However, aerators are commonly combined with a flow regulator producing a constant flow rate regardless of pressure fluctuations (see Figure 27 and the flow regulator section below).

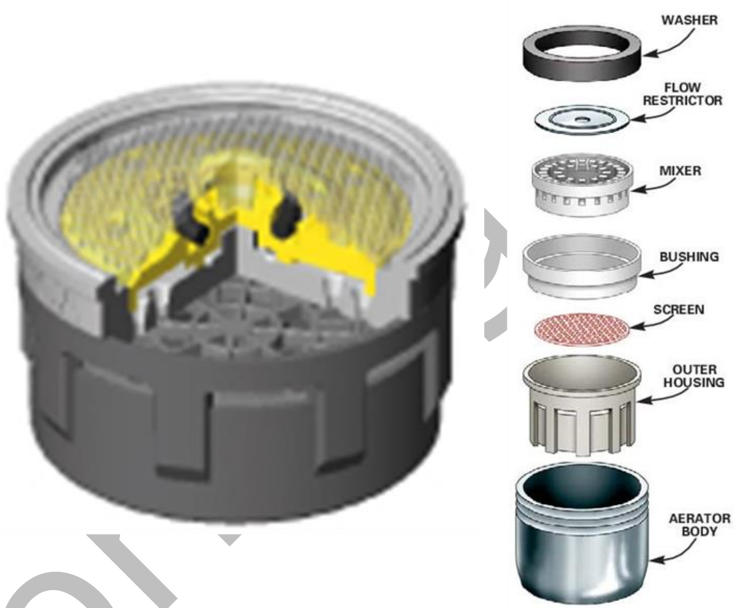

Figure 27. Example of an aerator with an integrated flow regulator (left) and a restricted aerator for taps (right).

Sources: Cordella et al., 2014 and, specifically for image on left (see: http://www.neoperl.net/en/oem/products/flowregulators/design.html) and for image on right (see: http://www.askmehelpdesk.com/plumbing/there-no-water-coming-out-hot-water-tap-what-can-431402.html)

Aerators are integrated into the tap spout or into the shower outlet (with or without a flow regulator) and when used in low-pressure water supply systems they allow an increase in the perceived water pressure and provide a flow-straightening function. In Europe they can be found in most of the products designed for domestic and non-domestic applications. Aerating shower handsets often need a minimum maintained pressure of 1.0 bar to allow them to actually aerate. This is thus not a technology that is suitable for all installations.

With respect to the reference flows of 12 L/minute for showers and 9 L/minute for taps, the water-saving potential of aerators is considered to vary between 5% and 50%, depending on whether a flow regulator for the reduction of the water flow rate is installed, or less. There is no particular obstacle to the diffusion of this technology. The typical cost of aerators could be up to EUR 10. However, consumers must be informed that

[17] See: http://www.nordiceco.com/index.php?option=com_content&view=article&id=90&Itemid=24
[18] See: http://www.nordiceco.com/index.php?option=com_content&view=article&id=105&Itemid=30

the flow indicated by the manufacturers depends on the pressure of the system and may have consequences for the comfort. As aerators are a technology commonly implemented in taps and showers, the advantages due to this technology must be considered to be generally exploited.

Flow regulators: Aerators are often used in conjunction with a flow regulator to compensate pressure variations. Flow regulators maintain a constant flow rate regardless of pressure ensuring comfort for the end-user at low pressures and water saving at high pressures.

The flow regulator is composed of a specifically designed profiled body and a dynamic O-ring. The O-ring reacts to the pressure changes and adjusts its shape to decrease the amount of water going through while the flow rate remains constant (see Figure 28). In the event of no flow or low pressure, the elastomer is relaxed (position 1 in Figure 28). As the pressure increases the elastomer is compressed into the seating area reducing the water passage (positions 2 and 3 in Figure 28). As the pressure decreases the elastomer relaxes and reopens the water passage (returning to positions 2 and 1).

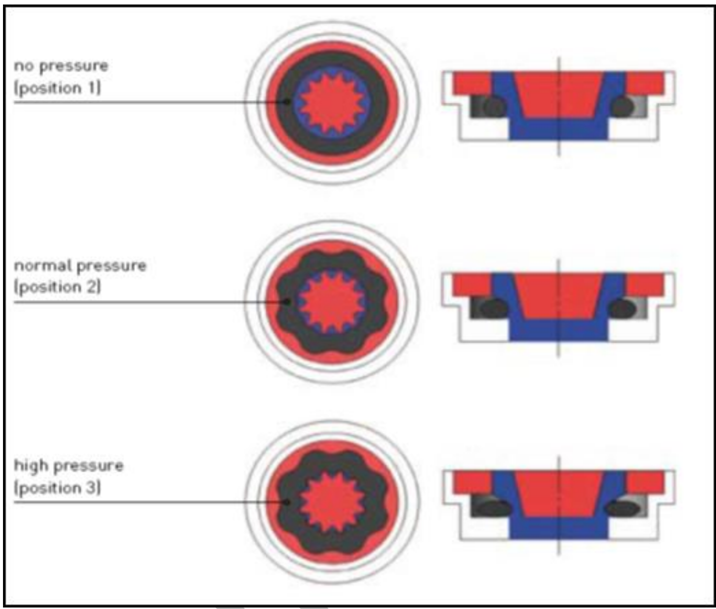

Figure 28. Flow regulator mechanism

Sources: Cordella et al., 2014 and Neoperl products brochure – flow regulators (supplied by manufacturer)

Flow regulators are designed and manufactured to operate at different flow rates and to provide control over a range of pressure conditions (see Figure 29). They are available in standardised dimensions and designs to meet different water-saving specifications. Installers and end-users must select the most suitable product for the intended used (e.g. high- or low-pressure system). Standard regulators control the flow rate between 0.8 and 10 bar.

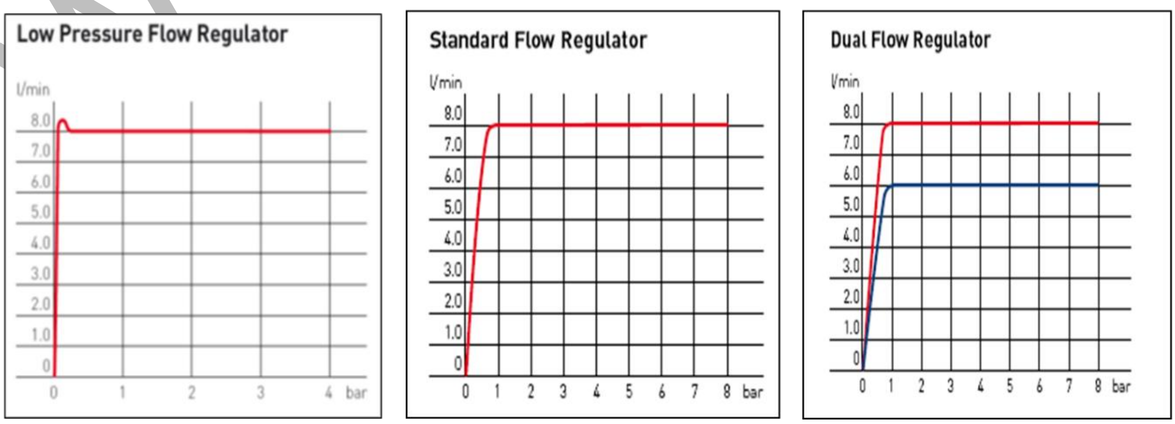

Figure 29. Performance of different flow regulator types for up to 8 bar pressure

Sources: Cordella et al., 2014 and Neoperl products brochure – flow regulators (supplied by manufacturer)

Special models developed for low-pressure installations are typical for the UK and Ireland. The flow control function of these special regulators can be initiated significantly earlier, for instance when pressure is about 0.25 bar.

Dual-flow regulators are also available which allow the users to select between two possible flow rates or between two different pressure modes (e.g. requiring maximum flow at low pressures or compensating flow rate at standard pressure ranges).

Flow regulators are technologically different from flow restrictors. Flow restrictors are mechanical restrictions which reduce the water flow. These can be, for instance, orifice discs or limited cross-section areas, and they are designed to provide a certain flow rate at a given pressure. However, restrictor-driven flows depend on the pressure: if the pressure rises or drops, the flow rate increases or decreases as well. Ensuring a minimum flow rate is critical in terms of hygiene, safety and comfort. It was also reported that flow restrictors are usually not applied or are removed from products used in low-pressure systems since they restrict the size of the water pathways thus simply reducing the efficiency of the product while not regulating flow rate.

Compared to flow restrictors, flow regulators represent a superior solution since they can provide a constant flow, independently from the pressure. In addition, flow regulators can even provide more water at low pressure. This adds more comfort and user satisfaction in parallel to saving water.

Combinations of aerators and flow restrictors: The design of taps and shower outlets can have an influence on water consumption by controlling the flow and spray pattern and therefore the amount of water used. The water flow can be further reduced by entraining air into the water and including a flow regulator (see Figure 30 for a showerhead). This has for instance allowed a reduction of the water flow of some showerhead models from 18.5 to 8 L/minute (56% decrease), which also results in energy savings due to reduced hot water use. Retrofitting a tap with an aerator and a flow regulator could cost from less than EUR 5.5 to EUR 20, thus representing a minor contribution to the overall product cost.

Figure 30. Example of a showerhead with an aerator and a flow regulator.

Sources: Cordella et al., 2014 and https://pro.hansgrohe-int.com/assets/global/ecosmart_en.pdf

This design strategy has been implemented in both taps and showers, as done in the Ecosmart product line. To use water in showerheads more efficiently, about 3 L of air per L of water is drawn in through the entire spray disc and mixed together with inflowing water, which results in the water drops becoming more voluminous, lighter and softer. The combination of the flow limitation, special spray jets and the mixing of water with air can reduce water consumption down to 6-9 L/minute.

Low-flow showers however are not always suitable for low-pressure water supply systems because they may not fulfil the expectations of users and for electric showers because of the risk of scalding. A lower flow rate means the water will stay in contact with the heating element for longer, resulting in overheating. Some products include safety features to prevent this by switching off the heating elements when the flow is too low or the water gets too hot.

Flow boosters: Flow boosters are features that allow users to select the desired water flow mode. They have been introduced over the last couple of years and their use could spread significantly onto the market.

Flow boosters must not be confused with diverters, often used as indicating devices for switching the water flow between bathtub taps and shower outlets, and with flow switchers, for instance often used as indicating devices for switching from rain to massage modes in showerheads.

Flow boosters can be implemented in taps and showers as "eco-buttons". These allow the user to intentionally override default flow limitation(s) or water-saving position(s) to get full flow on demand for a specific purpose.

The flow rate is controlled by an integrated flow regulator. The water-saving position is usually set as the default mode. By pressing the button, the user can switch from water- saving to boost modes and vice versa (see Figure 31). This provides flexibility of use, for instance when sinks or vessels must be filled.

Figure 31. Examples of applications for flow boosters in taps and showers

Sources: Cordella et al., 2014 and http://www.neoperl.ch/en/retail/products/watersavers/linesfeatures/ECOBOOSTER.html

These control devices are easy to install and could decrease water use by 10-50%, with respect to the reference flows of 12 L/minute for showers and 9 L/minute for taps, depending on the conditions of use and on the default water flows. Thus, it is important to inform users about the different modes they can operate in order to gain maximum benefits.

An example of a product on the market is the Neoperl Ecobooster[19]. Flow rates of showers and taps can be switched from 11 to 20 L/minute and from 7 to 17 L/minute, respectively. The Ecobooster costs approximately EUR 25. The payback period will depend on how much the default water saving position is used.

The average increase in cost associated to this technology is considered to be about EUR 20.

Two-stage cartridge taps: Two-stage cartridge taps are increasingly included by manufacturers in their product ranges as an incentive to operate with reduced flow rates and/or cold water.

Two main design concepts can be used:

- devices for the automatic return to a "middle" position;
- brakes (commonly known as a "click" cartridge) for limiting movements from a "middle" position.

[19] http://www.neoperl.ch/en/retail/products/watersavers/linesfeatures/ECOBOOSTER.html

Setting cold water in the middle position is an emerging feature installed on single-lever taps. During "normal" conditions, these taps deliver cold water. Hot water flows only when the lever is intentionally moved to the left, in some cases requiring an additional pressure from the user. The mixer lever can be easily turned back to the water- and energy-saving position.

With respect to the reference flows of 12 L/minute for showers and 9 L/minute for taps, the energy saving achievable with this system can be 5-30%. However, the actual saving potential strongly depends on the user behaviour. The benefits of having such a system installed in bath taps for instance could be offset for users who prefer to use warm water. Additionally, it must be noted that not all taps permit the implementation of this feature.

In the case of brakes, full flow rates and/or consumption of hot water are only possible after the user overcomes a mechanical resistance. In theory, water brakes can be fitted to all taps though they are typically fitted to single-lever mixer taps. For instance, the lever can be easily raised until the "middle" flow position. This is usually set at 50% of maximum flow; however the break could also be set to a different point. At this point the user will feel a resistance to movement, and opening the tap any further requires additional force to overcome the brake. Once overcome, the lever will move as easily as before towards full flow, as shown in Figure 32. As for flow boosters, the performance of the product may vary depending on the default water flow rate.

Figure 32. Example of tap with a water brake installed

Sources: Cordella et al., 2014

With respect to the reference flows of 12 L/minute for showers and 9 L/minute for taps, the water-saving potential of brakes is estimated to be between 5% and 30%. The average increase in cost associated to this technology could be estimated to be about EUR 15. However, the payback period will depend on the conditions of use of the product.

Some taps directly integrate both water- and energy-saving features into their designs. An example is the Ceramix Blue taps[20]. The manufacturer's suggested retail price for this model is approximately EUR 235. In addition, the manufacturer has estimated that for a family of four people, the installation of this model of taps could lead up to a saving of up to EUR 207 per year (considering an exchange rate of 1.19 between GBP and EUR), including both water and energy savings. A breakdown of water and energy savings are shown in Figure 4.11. The average water and energy (by gas) prices have been considered as EUR 2.1 per m^3 and EUR 0.08 per kWh, respectively. Based on the above data, the payback time for this product would be about one year.

[20] See: http://www.reuter-shop.com/ideal-standard-ceramix-blue-basin-mixer-with-flow-rate-limiter-p308504.php

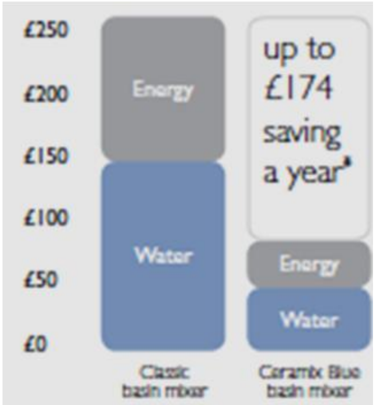

Figure 33. Potential savings from CeraMix Blue Eco

Sources: Cordella et al., 2014 and http://www.ideal-standard.co.uk/fileadmin/templates/main/res/material/gb/help_support/brochures/IS_Multisuite_Multiproduct_Bro_GB_Taps-Mixers-2012.pdf

A similar system for saving water and energy is to force the lever to return automatically to a position with lower water temperature and flow when unnecessary. Conventional mixers could be cheaper to buy but more expensive when costs for use are considered, as shown in Figure 34.

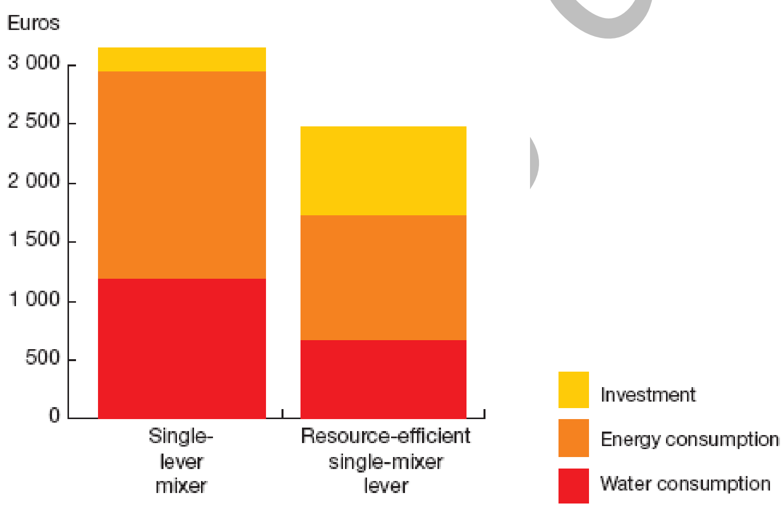

Figure 34. Estimated savings from a mixer tap with automatic repositioning of the single level [21]

Sources: Cordella et al., 2014 and Swedish Energy Agency Informs: Save Energy with efficient tapware (article supplied by stakeholder)

Three conventional mixers for kitchen sinks, washbasins and showers together could cost between EUR 170 and EUR 280, including VAT. The overall cost for purchasing and using these three conventional taps for 15 years could be estimated to be EUR 3225. In contrast, the more efficient mixers could cost between EUR 450 and EUR 550, including VAT, and could allow a saving of EUR 725 over 15 years. The price difference is thus earned back in a few years (1-3) via reduced energy and water costs.

Automatic taps (push taps): Push taps, or automatic shut-off taps, are valves that deliver water after a mechanical operation from the user and that then stop by themselves. As with sensor taps, automatic shut-off/push taps are typically used in the non-domestic sector, which is why they are often designed to be tamper-proof and vandal-resistant. They typically do not allow user-adjustable flow control. As well as being water-efficient (up to 50-60% of water with respect to the reference flows of 12 L/minute for showers and 9

21Swedish Energy Agency Informs: Save Energy with efficient tapware (article supplied by stakeholder)

L/minute for taps), push taps offer a good level of hygiene. The average increase in cost associated to this technology could be about EUR 20. Retrofitting to this type of taps is also possible

Automatic shut-off taps can be designed to be activated with hands, elbows, knees or feet, depending on the end-users' requirements. Once activated, they cannot be left running indefinitely but they are set to automatically stop flowing after a certain time (e.g. 1-30 seconds). In order to maximise the potential water saving offered by push taps, the use of the tap needs to be considered carefully in order to optimise the settings, in particular the flow rate and the run time.

Automatic taps (sensor taps): Sensor taps are devices that start delivering water when a movement is detected and that terminate with a set delay time.

These are typically used in non-domestic applications even though they are also suitable for households. Sensor taps are well suited for use within public washrooms since they operate without the user having to touch a button, tap or handle. They are also suitable for use within kitchens, restaurants, schools, hospitals and offices and have been available on the market for a number of years. It is possible that their use could be expanded in the domestic market in the future, depending on the application.

Sensor taps generally consist of four key components: an electromechanically operated valve (also known as a solenoid valve), an infrared sensor, a power source, and a tap unit (see Figure 35).

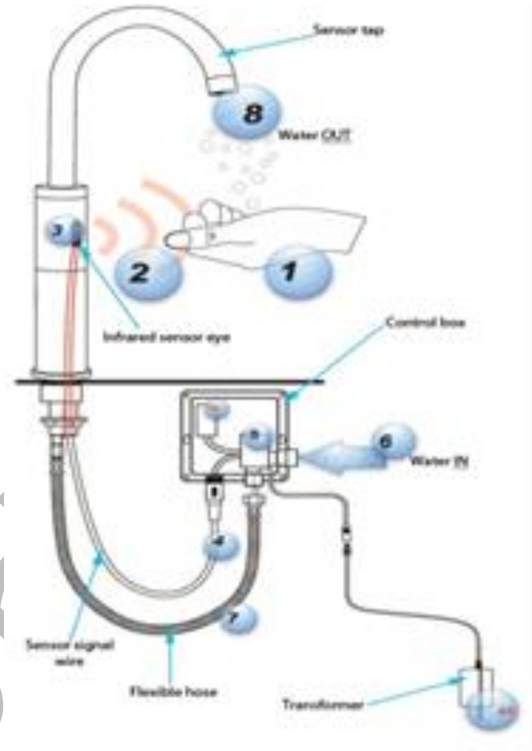

Figure 35. Sensor tap operation

Sources: Cordella et al., 2014 and http://www.autotaps.com/how-automatic-tap-work.html

Looking at the figure above, when the infrared sensor (2) detects the presence of the user's hands in front of the tap (1) it sends an electronic signal to the solenoid valve (5) inside the control box. This initiates the flow of water (6), which is fed to the user (8) via the flexible hose (7) connected to the tap. When the detected object is no longer present, the infrared unit sends a new signal to the solenoid valve to terminate the flow of water. This usually occurs after a few seconds. The solenoid valve transforms electrical energy into motion, and physically starts and stops the water flow.

The power consumption of these taps is minimal, for example from 0.5 mW (DC) in static conditions to 2 W (AC) in dynamic conditions[22]. Some models are able to operate with AA batteries, which could last up to two years depending on the level of use[23]. The trend is to improve the battery life up to 10 years.

It is estimated that 15-20% of new commercial buildings adopt this technology. With respect to the reference flows of 12 L/minute for showers and 9 L/minute for taps, the water-saving potential of sensor taps is considered to be up to 50-60%, depending on the conditions of use and set delay time. Since taps are activated or deactivated within a few seconds they do not drip (a common problem with manual taps). Sensor taps require specific knowledge in design, manufacturing, installation and maintenance. The average cost increase associated to this technology is considered to be EUR 150.

Thermostatic mixing valves: These are mixers that, if properly designed, allow the delivery of water at a stable and controllable temperature and flow. Two cartridges are currently included in the design of this product, one for regulating the water flow and another one for temperature control, as shown in Figure 4.14. The time to find and reach a desired temperature is much shorter than in single-lever and double-handle mixers, with direct implications for water and energy savings, estimated being up to 10-15%.

Mechanical stop positions can be applied even to the thermostatic valves of showers, as in the case of Ecostop[24]. Full flow and hot temperatures can be set only after pushing a safety button. According to the producer, water consumption can be reduced by up to 50% with this function, with respect to the reference flows of 12 L/minute for showers and 9 L/minute for taps.

Figure 36. Example of thermostatic mixing valve for showers

Sources: Cordella et al., 2014 and http://www.houzz.com/photos/423099/Bathroom-Thermostatic-Mixer-Valve-Shower-Tap-5592-contemporary-showers-

The use in Europe typically concerns showering, for which they could represent up to half of the market with an increasing sales trend, but further applications could be foreseen in the future (e.g. in kitchens).

The key component of this technology is the thermostatic element, which regulates and controls the outlet temperature in the event of variations in the hot and cold water input conditions. This can also limit the risk of scalding in case of low flow rates. Different mechanical and electronic systems have been developed but the most cost-effective ones at the moment are the wax thermostats.

The average cost of cartridges for thermostatic valves can be the double that for single-lever valves. Thermostatic mixers are more expensive than other mixers. A high quality one could cost between EUR 60 and EUR 200 and up to EUR 2000. The average cost increase associated to this technology is considered to be about EUR 70.

The product is designed to mix hot and cold water entering the system from the correct sides (conventionally hot water from the cartridge controlling the temperature and cold water from the opposite side). The installation of the product is extremely important for the correct functioning of the device. In terms of functionality, the thermostatic element can lose some precision with time, but this can be easily compensated by selecting a different temperature of use. Some elements could also need to be replaced after some time if

[22] http://cmr.org.in/sensor_tap.html
[23] http://www.autotaps.com/atx-8205-technical-details.html
[24] http://www.hansgrohe.com.sg/assets/global/hg_thermostats_en.pdf

they are not properly designed or installed. There are no particular difficulties for changing cartridges when necessary and the main maintenance intervention against limescale is to flow water at the maximum and minimum temperatures once per week.

Technical problems and possible issues that could be potentially associated to the use of thermostatic mixing valves have been identified by stakeholders and have been reported in Cordella et al., 2014. This highlights the importance of the quality of the thermostatic valve and correct installation for the satisfactory functioning of the product.

Cost ranges for different tap types, hand showers and showerheads

An analysis of costs is also important so that procurers can have an idea of how much certain specifications for taps of showers may affect the prices in different offers.

According to data provided by stakeholders during the MEErP preparatory study for taps and showers (Cordella et al., 2014), the following price ranges were considered for the tap and shower products listed below.

Table 11. Indications for the prices of kitchen taps, bathroom taps, shower valves and shower outlets

Design feature	Cost range in EUR for one unit of product (median)			
	Kitchen taps	**Bathroom taps**	**Shower valves**	**Shower outlets**
Single control mixer	10-500 (35-100)	15–500 (35-65)	15–300 (35-65)	
Double-handle mixer • Spindle • Ceramic discs	10–500 (35-50) 10-500 (35-100)	20–150 (35-50) 15-500 (35-65)	20–150 (35-50) 15-300 (35-65)	
Pillar taps (pair)		10-150 (20-50)		
Thermostatic mixer	25-800 (60-200) Not common feature	25-800 (60-200)	25-800 (60-200)	
Self-closing tap (mechanical)	30–300 (50-120) Not common feature	30–300 (50-120)	30–700 (50-120), varying from valve to complete shower column	
Infra-red sensor tap	100–600 (185-250)	100–600 (185-250)	100–600 (185-250)	
Industrial kitchen tap	150-300 (150)			
Hand shower				5-150 (40)
Showerhead				20-200 (100)

Source: Cordella et al., 2014

Although these costs are exclusive of any installation costs, it is clear that if tenderers want, for example, a thermostatic mixer in their taps or showers, it would be best to directly specify this in the call for tender because they add a significant upfront cost to the system.

Conclusions

Policy and scope: Buildings are a major source of environmental impacts and are targeted in a number of cross-cutting policies (e.g. the European Green Deal, Circular Economy Action Plan, the Energy Efficiency Directive and the EU Taxonomy) and building-specific policies (e.g. the Energy Performance of Buildings Directive, the Renovation Wave and the Level(s) framework).

Taking all of these policies into consideration, EU GPP criteria for buildings will be centred on the following seven themes listed below.

- Theme 1: energy consumption and life cycle greenhouse gas emissions
- Theme 2: Material efficiency and circularity
- Theme 3: Efficient use of water resources
- Theme 4: Occupant comfort and wellbeing
- Theme 5: Vulnerability and resilience to climate change
- Theme 6: Life cycle costing
- Theme 7: Biodiversity

In order to increase the potential impact of EU GPP criteria for buildings, the scope is proposed to be increased from just office buildings to also include social housing and educational buildings. However, it should be borne in mind that individual criteria can potentially be applied to most buildings.

Market analysis: Europe's building stock is dominated by residential buildings (around 75% of total) of which only a small fraction is social housing. However, the share of social housing varies significantly from Member State to Member State (e.g. for virtually 0% of rented accommodation in Greece to around 29% in the Netherlands). In terms of non-residential buildings, public offices and educational buildings typically accounted for 20 to 40% of total non-residential buildings at Member State level.

Environmental impacts: A review of literature on the Life Cycle Assessment (LCA) of buildings shows a general focus on Global Warming Potential (GWP) and highlighted the importance of operational energy consumption on overall impacts. As the energy efficiency of buildings improves, the share of impacts embodied in construction materials becomes more important to overall results and policies are shifting this way too. However, concerns have been raised about the lack of data available to accurately quantify embodied impacts and certain methodological differences between the Product Environmental Footprint (PEF) and EN 15978.

Impacts that are not so well captured by LCA methods relate to biodiversity, and human health. The latter aspect extends to different features of building design, such as indoor air quality, thermal comfort, daylighting, noise levels and potential contribution to flood risk.

Technical analysis: The analysis of the main technical systems used in buildings that relate to energy and water efficiency are reviewed with a view to explaining how they work and the scope for further improvement. In the first draft of this report, the analysis of taps and showers reveals a high range of specific consumption rates and different designs that can deliver potentially large improvement potentials (factor of 2 or 3 ranges in performance are not uncommon). Since taps and showers are CE marked with performance classes, this could be used in EU GPP specifications. Another interesting option for specifying would be to refer to voluntary water labels, which have thousands of examples of tap and shower products on the EU market.

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List of abbreviations and definitions

TBC To be completed (in next version of document)

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Annexes

Annex I. List of most relevant Common Procurement Vocabulary codes

Table 12. Particularly relevant CPC and CPV codes for works and services related to building design, construction, demolition and management

Service or work description	NACE code / CPC code	CPV code
Construction work	45 /	45000000-7
Site preparation work	45.1 /	45100000-8
Building demolition and wrecking work and earthmoving work	45.11 /	45110000-1
Demolition, site preparation and clearance work	45.11 /	45111000-8
Demolition work	45.11 /	45111100-9
Site preparation and clearance work	45.11 /	45111200-0
Blasting and associated rock-removal work		45111210-3
Blasting work		45111211-0
Rock-removal work		45111212-7
Site-clearance work		45111213-4
Blast-clearing work		45111214-1
Scrub-removal work		45111220-6
Ground-stabilisation work		45111230-9
Ground-drainage work		45111240-2
Ground investigation work		45111250-5
Site-preparation work for mining		45111260-8
Primary works for services		45111290-7
Site-development work		45111291-4
Dismantling works		45111300-1
Dismantling works for military installations		45111310-4
Dismantling works for security installations		45111320-7
Excavating and earthmoving work		45112000-5
Trench-digging work		45112100-6
Soil-stripping work		45112200-7
Topsoil-stripping work		45112210-0
Infill and land-reclamation work		45112300-8
Infill work		45112310-1
Land-reclamation work		45112320-4
Site-reclamation work		45112330-7
Soil-decontamination work		45112340-0
Reclamation of waste land		45112350-3
Land rehabilitation work		45112360-6
Excavating work		45112400-9

Grave-digging work		45112410-2
Basement excavation work		45112420-5
Terracing of hillsides		45112440-1
Terracing work		45112441-8
Excavation work at archaeological sites		45112450-4
Earthmoving work		45112500-0
Cut and fill		45112600-1
Landscaping work		45112700-2
Landscaping work for green areas	45.11 /	45112710-5
Landscaping work for parks		45112711-2
Landscaping work for gardens		45112712-9
Landscaping work for roof gardens	45.11 /	45112713-6
Landscaping work for cemeteries		45112714-3
Landscaping work for sports grounds and recreational areas		45112720-8
Landscaping work for golf courses		45112721-5
Landscaping work for riding areas		45112722-2
Landscaping work for playgrounds		45112723-9
Landscaping work for roads and motorways		45112730-1
Landscaping work for airports		45112740-4
Siteworks		45113000-2
Test drilling and boring work		45120000-4
Test drilling work		45121000-1
Test boring work		45122000-8
Works for complete or part construction and civil engineering work		45200000-9
Building construction work		45210000-2
Construction work for multi-dwelling buildings and individual houses		45211000-9
Construction work for houses		45211100-0
Sheltered housing construction work		45211200-1
Houses construction work		45211300-2
Bathrooms construction work		45211310-5
Porches construction work		45211320-8
Multi-dwelling buildings construction work		45211340-4
Flats construction work	45.21 /	45211341-1
Multi-functional buildings construction work	45.21 /	45211350-7
Urban development construction work		45211360-0
Construction works for saunas		45211370-3
Construction work for buildings relating to leisure, sports, culture, lodging and restaurants		45212000-6

Construction work of leisure facilities		45212100-7
Leisure centre construction work		45212110-0
Theme park construction work		45212120-3
Amusement park construction work		45212130-6
Recreation installation		45212140-9
Cinema construction work		45212150-2
Casino construction work		45212160-5
Entertainment building construction work		45212170-8
Entertainment centre construction work		45212171-5
Recreation centre construction work		45212172-2
Ticket offices construction work		45212180-1
Sun-protection works		45212190-4
Construction work for sports facilities		45212200-8
Single-purpose sports facilities construction work		45212210-1
Ice rink construction work		45212211-8
Construction work for swimming pool		45212212-5
Sport markings works		45212213-2
Multi-purpose sports facilities construction work		45212220-4
Construction work in connection with structures for sports ground		45212221-1
Gymnasium construction work		45212222-8
Winter-sports facilities construction work		45212223-5
Stadium construction work		45212224-2
Sports hall construction work		45212225-9
Installation of changing rooms		45212230-7
Repair and maintenance work in connection with sports facilities		45212290-5
Construction work for art and cultural buildings		45212300-9
Construction work for buildings relating to exhibitions		45212310-2
Art gallery construction work		45212311-9
Exhibition centre construction work		45212312-6
Museum construction work		45212313-3
Historical monument or memorial construction work		45212314-0
Construction work for buildings relating to artistic performances		45212320-5
Auditorium construction work		45212321-2
Theatre construction work		45212322-9
Library construction work		45212330-8

Multimedia library construction work		45212331-5
Lecture hall construction work		45212340-1
Buildings of particular historical or architectural interest		45212350-4
Prehistoric monument construction work		45212351-1
Industrial monument construction work		45212352-8
Palace construction work		45212353-5
Castle construction work		45212354-2
Religious buildings construction work		45212360-7
Church construction work		45212361-4
Accommodation and restaurant buildings		45212400-0
Construction work for lodging buildings		45212410-3
Hotel construction work		45212411-0
Hostel construction work		45212412-7
Short-stay accommodation construction work		45212413-4
Construction work for restaurants and similar facilities		45212420-6
Restaurant construction work		45212421-3
Canteen construction work		45212422-0
Cafeteria construction work		45212423-7
Kitchen or restaurant conversion		45212500-1
Pavilion construction work		45212600-2
Construction work for commercial buildings, warehouses and industrial buildings, buildings relating to transport		45213000-3
Shop buildings construction work		45213110-7
Shopping centre construction work		45213111-4
Shop units construction work		45213112-1
Post office construction work		45213120-0
Bank construction work		45213130-3
Market construction work		45213140-6
Covered market construction work		45213141-3
Open-air market construction work		45213142-0
Office block construction work	45.21 /	45213150-9
Construction work for warehouses and industrial buildings		45213200-5
Cold-storage installations		45213210-8
Construction work for warehouses		45213220-1
Warehouse stores construction work		45213221-8
Abattoir construction work		45213230-4
Agricultural buildings construction work		45213240-7
Barn construction work		45213241-4

Cowsheds construction work		45213242-1
Construction work for industrial buildings		45213250-0
Industrial units construction work		45213251-7
Workshops construction work		45213252-4
Stores depot construction work		45213260-3
Construction works for recycling station		45213270-6
Construction works for compost facility		45213280-9
Buildings associated with transport		45213300-6
Construction work for buildings relating to road transport		45213310-9
Bus station construction work		45213311-6
Car park building construction work	45.21 /	45213312-3
Service-area building construction work		45213313-0
Bus garage construction work		45213314-7
Bus-stop shelter construction work		45213315-4
Installation works of walkways		45213316-1
Construction work for buildings relating to railway transport		45213320-2
Railway station construction work		45213321-9
Rail terminal building construction work		45213322-6
Construction work for buildings relating to air transport		45213330-5
Airport buildings construction work		45213331-2
Airport control tower construction work		45213332-9
Installation works of airport check-in counters		45213333-6
Construction work for buildings relating to water transport		45213340-8
Ferry terminal building construction work		45213341-5
Ro-ro terminal construction work		45213342-2
Construction work for buildings relating to various means of transport		45213350-1
Maintenance hangar construction work		45213351-8
Service depot construction work		45213352-5
Installation works of passenger boarding bridges		45213353-2
Installation of staff rooms		45213400-7
Construction work for buildings relating to education and research	45.21 /	45214000-0
Construction work for kindergarten buildings	45.21 /	45214100-1
Construction work for school buildings	45.21 /	45214200-2
Primary school construction work	45.21 /	45214210-5
Secondary school construction work	45.21 /	45214220-8
Special school construction work	45.21 /	45214230-1

Construction work for college buildings	45.21 /	45214300-3
Vocational college construction work	45.21 /	45214310-6
Technical college construction work	45.21 /	45214320-9
Construction work for university buildings	45.21 /	45214400-4
Polytechnic construction work		45214410-7
Lecture theatre construction work		45214420-0
Language laboratory construction work		45214430-3
Construction work for buildings of further education		45214500-5
Construction work for research buildings	45.21 /	45214600-6
Laboratory building construction work		45214610-9
Research and testing facilities construction work		
Scientific installations		
Installation works of cleanrooms		
Meteorological stations construction work		
Construction work for halls of residence	45.21 /	45214700-7
Entrance hall construction work		45214710-0
Training facilities building		45214800-8
Construction work for buildings relating to health and social services, for crematoriums and public conveniences		45215000-7
Construction work for buildings relating to health		45215100-8
Spa construction work		45215110-1
Special medical building construction work		45215120-4
Clinic construction work		45215130-7
Hospital facilities construction work		45215140-0
Operating theatre construction work		45215141-7
Intensive-care unit construction work		45215142-4
Diagnostic screening room construction work		45215143-1
Screening rooms construction work		45215144-8
Fluoroscopy room construction work		45215145-5
Pathology room construction work		45215146-2
Forensic room construction work		45215147-9
Catheter room construction work		45215148-6
Construction work for social services buildings		45215200-9
Construction work for subsidised residential accommodation	45.21 /	45215210-2
Retirement home construction work	45.21 /	45215212-6
Nursing home construction work	45.21 /	45215213-3
Residential homes construction work		45215214-0
Children's home construction work		45215215-7

Construction work for social facilities other than subsidised residential accommodation		45215220-5
Daycare centre construction work		45215221-2
Civic centre construction work		45215222-9
Construction work for crematoriums		45215300-0
Cemetery works		45215400-1
Public conveniences		45215500-2
Construction work for buildings relating to law and order or emergency services and for military buildings		45216000-4
Construction work for buildings relating to law and order or emergency services		45216100-5
Construction work for buildings relating to law and order		45216110-8
Police station construction work		45216111-5
Court building construction work	45.21 /	45216112-2
Prison building construction work		45216113-9
Parliament and public assembly buildings	45.21 /	45216114-6
Construction work for buildings relating to emergency services		45216120-1
Fire station construction work		45216121-8
Ambulance station construction work		45216122-5
Structures construction work	45.21 /	45223000-6
Assembly of metal structures	45.21 /	45223100-7
Installation of metal structures	45.21 /	45223110-0
Structural works	45.21 /	45223200-8
Structural steelworks	45.21 /	45223210-1
Structural shell work	45.21 /	45223220-4
Parking lot construction work	45.21 /	45223300-9
Underground car park construction work	45.21 /	45223310-2
Reinforced-concrete structures	45.21 /	45223500-1
Assembly and erection of prefabricated structures	45.21 /	45223800-4
Prefabricated constructions	45.21 /	45223810-7
Prefabricated components	45.21 /	45223822-4
Ancillary works for pipelines and cables	45.21 /	45232000-2
Ancillary works for water pipelines	45.21 /	45232100-3
Irrigation works	45.21 /	45232120-9
Irrigation piping construction work	45.21 /	45232121-6
Storm-water piping construction work	45.21 /	45232130-2
District-heating mains construction work	45.21 /	45232140-5
Heating works	45.21 /	45232141-2

Works related to water-distribution pipelines	45.21 /	45232150-8
Transformer substation	45.21 /	45232221-7
Construction and ancillary works for telephone and communication lines	45.21 /	45232300-5
Foul-water piping construction work	45.21 /	45232411-6
Drainage construction works	45.21 /	45232450-1
Drainage and surface works	45.21 /	45232451-8
Drainage works	45.21 /	45232452-5
Drains construction work	45.21 /	45232453-2
Rain-water basin construction work	45.21 /	45232454-9
Sanitary works	45.21 /	45232460-4
Roof works and other special trade construction works	45.22 /	45260000-7
Erection and related works of roof frames and coverings	45.22 /	45261000-4
Heating plant construction work	45.25 /	45251200-3
Cogeneration plant construction work	45.25 /	45251220-9
District-heating plant construction work	45.25 /	45251250-8
Special trade construction works other than roof works	45.25 /	45262000-1
Foundation work	45.25 /	45262210-6
Concrete work	45.25 /	45262300-4
Structural steel erection work for buildings	45.25 /	45262410-8
Bricklaying work	45.25 /	45262520-2
Facing brickwork	45.25 /	45262521-9
Masonry work	45.25 /	45262522-6
Miscellaneous special-trade construction work	45.25 /	45262600-7
Cladding works	45.25 /	45262650-2
Refurbishment of run-down buildings	45.25 /	45262690-4
Building alteration work	45.25 /	45262700-8
Building extension work	45.25 /	45262800-9
Balcony work	45.25 /	45262900-0
Electrical installation work	45.31 /	45310000-3
Lightning-protection works	45.31 /	45312310-3
Lift and escalator installation work	45.31 /	45313000-4
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XX-NA-XXXXX-EN-N

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of the European Union

doi:XX.XXXX/XXXXXX

ISBN XXX-XX-XX-XXXXX-X