Chapter 6
Standards and Frameworks Supporting Circular Construction

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Abstract Circular Economy is a crucial factor in addressing sustainability. It is also on top of the agenda of the European Union and at a global scale. For Circular Economy to be successful in the construction industry, however, standardisation is a vital requirement. This document refers to an overview on the need for standardisation in Circular Economy. It further refers to national level standards and standardisation, together with a review of European and International level standards. To this effect, following a review of the state of the art in standardisation, key components were identified, and a questionnaire was designed and conducted across 19 countries with experts and practitioners in Circular Economy in Construction. The objective of the questionnaire was to assess and understand the level of implementation and standardization of Circular Economy across different countries. The assessment conducted was intended as a review of the perception of standards and their implementation across Europe by the participants of the survey as practitioners in Circular Economy. A review of standards in Circular Economy at a European and International level was carried out to define gaps to be addressed, together with opportunities in standardisation, to support Circularity in the Construction Industry. Case studies in implementation of standardisation are presented with respect to Deconstruction, Recycled Aggregate and Reuse of products.

Keywords Circular economy · Standardisation · Sustainability · Construction · Demolition waste

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L. Bragança et al. (eds.), *Shaping Circular Transitions in the Built Environment*,
Springer Tracts in Civil Engineering, https://doi.org/10.1007/978-3-032-02834-1_6

6.1 Overview of the Need for Standardization

The transition to a circular economy is crucial for the European Union's sustainable, efficient, and competitive economy. The value of materials and resources must be kept in the economy for as long as possible, in order for this to be achieved. Recent studies show wider benefits of circular economy, including reducing carbon dioxide emissions. This aligns with the key EU priorities, including jobs, investments, climate and energy, the social and industrial innovation, and global drive on sustainable development [1]. In the context of the built environment, standardisation plays a crucial role in promoting and operationalising circular economy practices. By establishing common frameworks, guidelines, and protocols, standardisation ensures consistency, interoperability, scalability, and efficiency in the implementation of circular practices. It provides a structured approach to adopting circular economy principles in various aspects of the built environment, including in the construction of new buildings, building refurbishment and the building end of life. For instance, key aspects of circular economy refer to standardisation at product level (e.g. standardised approach for the use of recycled aggregates in concrete), or at the building level (e.g. standardised approach for design for disassembly and adaptability).

The widespread adoption of circular economy practices in the construction sector has become a global priority to address environmental challenges and promote long-term sustainability. In this context, standardisation emerges as a key element that can catalyse this transition towards more circular and resource-efficient models. Standardisation can be essential in driving the conversion towards to a low-carbon, sustainable, resource-efficient, and competitive economy. By establishing common frameworks, guidelines, and protocols, standardisation enables the consistent and efficient implementation of circular practices in the built environment. This contributes to the achievement of EU priorities, global sustainable development goals, and the development of a more sustainable and environmentally friendly future.

A number of studies and analyses have shed light on the importance of standardisation in different aspects of sustainable construction, providing valuable insights into how it can drive the adoption of circular practices across the industry. A few of these studies are discussed below:

The framework proposed in "A New Framework for Circular Refurbishment of Buildings to Operationalize Circular Economy Policies" provides detailed guidance for the implementation of circular economy policies in building refurbishment. This structured approach ranges from the initial mapping of buildings to the monitoring of their operation to ensure circularity, highlighting the importance of standardising processes to achieve consistent and sustainable results [2].

On the other hand, the study on the "Implementation Stage for Circular Economy in the Danish Building and Construction Sector" highlights the potential of circular economy practices in the Danish construction industry to improve sustainability. It proposes three key approaches for the implementation of circular practices: the use of waste as building materials, the reuse of building materials and design for

disassembly. These strategies, supported by standardised standards and processes, can contribute significantly to reducing resource consumption and minimising waste in construction [3].

In addition, the review on the "Application of circular economy principles in buildings" offers a wide range of strategies to maximise the reuse of materials and components, optimise building design and promote a product-as-a-service model. These recommendations, supported by standardised standards and processes, can serve as a solid framework for the effective implementation of circular economy principles in the built environment [4].

Furthermore, the study on "Drivers and barriers towards circular economy in the building sector: Stakeholder interviews and analysis of five European countries policies and practices" provides a comprehensive overview of the challenges and opportunities related to the adoption of the circular economy in the building sector. Through field interviews with stakeholders in five European countries, the study highlights the need for common standards and regulations that can facilitate the shift towards more circular practices [5].

Finally, the publication on "Use of Recycled Aggregates in Concrete: Opportunities for Upscaling in Europe" highlights the crucial role of standardisation in promoting the use of recycled aggregates in concrete. By addressing challenges and opportunities throughout the supply chain, this analysis highlights how standards can facilitate the integration of recycled materials into conventional construction practices, thus promoting greater circularity in the construction industry [6].

The references provided, along with others, add to our understanding of the significance of standardization in circular economy practices within the built environment. By establishing common frameworks, guidelines, and protocols, standardization ensures consistency, interoperability, scalability, quality and efficiency in the application of circular practices, leading to a more sustainable and resource-efficient built environment. It also gives a clearer picture that standardisation can play a crucial role in promoting and implementing circular economy practices within the built environment. As outlined in the scope of ISO TC323 for Circular Economy [7], standardization in the field of Circular Economy contributes towards the development of frameworks, provide supporting tools and addresses requirements for the implementation of activities to maximize the contribution to Sustainable Development. Standardization is an important process in advancing the Circular Economy, by providing a framework to assess the quality and sustainability of materials, products and processes. Standards are a requirement in building trust in the market where good quality is recognised. This will lay the foundation for a smooth transition to the circular model. It should also be noted that the quality of the circular product is assessed based on material composition or properties of input materials (e.g., EN 206 for concrete). However, this does not reflect the suitability of a circular product for its final use, so its performance for intended function should be analysed.

In conclusion, standardisation plays a vital role in promoting and implementing circular economy practices in the built environment. These efforts contribute to the shift towards a more sustainable and resource-efficient built environment.

6.1.1 Adoption of Performance-Based Analysis

As outlined above to ensure quality of a circular product to build trust in the market where good quality is recognised, performance-based analysis (PBA) should be implemented as a key perspective ensuring consumer´s satisfaction. The level of implementation of PBA differs among regions and is affected by local authorities or local standardization bodies. This highlights the importance of having standards and uniformity on an international level which then translates to local level.

The main organizations contributing to development of Performance-Based Analysis approach in Civil Engineering include [8]:

1. ATC: Applied Technology Council.
2. BSI: British Standards Institute.
3. Caltrans: California Department of Transportation.
4. CSA: Canadian Standards Association.
5. CEN/CENELEC: European Standards Organizations.
6. FEMA: Federal Emergency Management Agency.
7. UNEP: United Nations Environment Programme.
8. USEPA: United States Environmental Protection Agency.
9. TAC: Transportation Association of Canada.

According to Easa et al. the level of implementation of standards varies across different countries and regions [8]. Their paper highlights that North American countries, particularly the United States and Canada, are leading in promoting and creating specifications and codes for the use of Performance-Based Analysis (PBA). These countries have made significant progress in implementing PBA in various civil engineering fields [8].

On the other hand, Asian countries like China, Japan, Iran, and India are also showing an emerging focus on PBA, although to a lesser extent compared to North America. Australia and European countries such as France, Greece, and the United Kingdom have comparatively fewer publications in the PBA areas, indicating a potentially lower level of implementation in these regions [8].

The paper also emphasizes the need for formal PBA procedures in transportation and environmental engineering, following the example of structural engineering, suggesting that the level of implementation may vary across different civil engineering disciplines [8].

Overall, the level of implementation for standards related to Performance-Based Analysis in civil engineering, as discussed in the paper, appears to be more advanced in North America compared to other regions, with varying degrees of progress in different countries and fields within the discipline [8].

6.1.2 Good Practice for the Adoption of Standards: Lessons Learnt from Electronic Industry

The electronics industry presents an opportunity for an understanding of the application of circular economy and can be referred to in a review to assess approaches in that sector; it is referred to as an example of good practice for considerations in the field of the built environment and a circular building industry. Regulations and standards play a vital role in promoting sustainability in the power electronics industry by setting guidelines and requirements that support the growth of environmentally friendly products. This can be used as an example of good practice also for built environment and circular building industry. Here are some ways in which regulations and standards contribute to promoting sustainability in the power electronics industry [9]:

- **Environmental Performance Requirements**: Regulations and standards can impose requirements on the environmental performance of power electronics beyond just energy efficiency levels. By considering factors such as material efficiency, lifecycle impacts, and end-of-life performance, regulations can push manufacturers to design products that reduce negative environmental impacts throughout the lifespan of the product.
- **Mitigating Pollution**: Regulations and directives aim to limit or forbid the use of toxic materials in the manufacturing progress of power electronics. By restricting the use of hazardous materials, regulations contribute to reducing pollution and promoting a cleaner production process.
- **Guiding Sustainable Design**: Regulations and standards provide guidance to designers and manufacturers on developing power electronics products that are durable, energy-efficient, repairable, recyclable, and incorporate recycled materials. By outlining specific criteria for sustainable product development, regulations help drive innovation towards more sustainable practices.
- **Circular Economy Perspective**: Standards in the circular economy perspective offer best practices for designing products that comply with material efficiency requirements. By aligning with circular economy principles, power electronics manufacturers can adopt sustainable practices that encourage resource efficiency and waste reduction.
- **Compliance and Implementation**: Understanding and complying with regulations and standards is essential for implementing sustainable product development in the power electronics industry. By adhering to specific criteria and adopting relevant standards, designers can ensure that their products meet sustainability requirements and contribute to a more environmentally friendly industry.

The progress of implementation of standards and policies can be depicted in the level of development of energy efficiency, which became an important pillar of the EU´s climate and energy policy. In the beginning, the initial product policies of the EU were established during the late 1970s and have since developed into a cohesive array of measures within framework directives, aimed at standardizing

and enhancing the regulatory framework. Following years of insufficient execution, significant strides have been made in terms of both scope and ambition over the past decade. By 2020, mandatory product measures encompassed 50% of the EU's total final energy consumption, resulting in energy savings of 46 Mtoe [10].

6.1.3 Barriers to Implementation of Standards

As discussed above the implementation of Standards at a National and International level are important as they create a framework to assess the quality and sustainability of materials, products and processes. They also lay the foundations for a smooth transition to the circular model on a National and International level and rise up the level of trust in the purchasing and use of these materials. Below are some barriers which can be faced when implementing standards:

- **Cost of Compliance**: Adhering to standards often involves costs related to training, certification, testing, and documentation. Companies may view these costs as barriers to full compliance with standards, especially if they perceive limited benefits in return.
- **Lack of Resources**: Small and medium-sized enterprises (SMEs) may lack the resources, expertise, and dedicated staff needed to implement and comply with standards effectively. Limited resources can hinder the adoption of standards in smaller companies.
- **Resistance to Change**: Resistance from employees, management, or stakeholders within an organization can impede the implementation of standards. Resistance to change and unwillingness to integrate new practices can be significant barriers to compliance.
- **Inconsistency in Interpretation**: Different stakeholders may interpret standards differently, leading to inconsistencies in implementation across the industry. Lack of clarity and uniformity in interpreting standards can hinder effective compliance.
- **Regulatory Uncertainty**: Rapid changes in regulations and standards can create uncertainty for companies, making it challenging to keep up with evolving requirements. Uncertainty about future standards can delay or complicate implementation efforts.
- **Compatibility Issues**: Standards from different organizations or regions may conflict or overlap, creating compatibility issues for companies operating in multiple markets. Ensuring alignment and consistency across various standards can be a barrier to implementation.
- **Training and Capacity Building**: Companies may lack the necessary training and capacity to understand, implement, and monitor compliance with standards effectively. Investing in training programs and building internal capacity can help overcome this barrier.

- **Supply Chain Challenges**: Ensuring that suppliers and partners also comply with relevant standards can be a challenge. Lack of visibility and control over the entire supply chain can hinder efforts to implement standards consistently.
- **Monitoring and Enforcement**: Monitoring and enforcing compliance with standards can be resource-intensive and require robust systems for tracking and reporting. Without effective monitoring mechanisms in place, companies may struggle to ensure ongoing compliance.

6.2 National Level Standards and Standardisation

6.2.1 National Level Standards

National standards play a crucial role in implementing circular economy principles in specific contexts and regions. These standards provide guidelines and requirements tailored to local conditions, industries and regulations, facilitating the implementation of sustainable practices and promoting resource efficiency.

In the construction sector, for example, national standards transposing European Standards, such as EN 206 on concrete production and conformity, ensure that materials meet certain quality and performance criteria. However, as the circular economy gains traction, there's a growing recognition of the need to go beyond traditional quality assessments and consider the suitability of circular products for their intended use.

In this context, in the case of construction materials, national standards play a crucial role with reference to the local and regional context and scenario, key products used and building typologies, and in setting up characterisation and classification frameworks, which are essential in transforming industrial byproducts into recycled products for construction.

National standards can address this by incorporating criteria that evaluate not only the material composition, but also the performance of circular products in real-world applications, and with reference to an intend use. By setting clear benchmarks for performance and durability, these standards help to build confidence in circular products and technologies, thereby accelerating their uptake in the market.

In addition, national standards can address specific challenges and opportunities within different sectors and industries. For example, in the construction sector, standards may focus on promoting the use of recycled materials, designing for disassembly, or optimising resource efficiency throughout a building's lifecycle.

By aligning with international frameworks and guidelines, national standards also ensure consistency and compatibility across borders, facilitating trade and cooperation on circular economy initiatives. This harmonisation of standards not only improves market access for circular products, but also promotes innovation and knowledge sharing on a global scale.

6.2.2 National Level Standardisation

At a national level, standardization is overseen by organizations like the British Standards Institution (BSI) [11], German Institute of Standardization ("Deutsches Institut für Normung", DIN), the Bureau of Indian Standards (BIS) [12] and others in respective countries. These groups create and release national standards covering various construction aspects, including design codes, safety regulations, material usage, and quality control.

National standardization involves various steps, beginning with identifying standardization requirements in response to industry needs, technological advancements, and regulatory demands [13]. Technical committees or working groups are then formed to develop standards for specific areas of interest. These committees comprise experts from industry, academia, government, and other relevant stakeholders who work together to create guidelines, specifications, and best practices.

Consensus building is a vital step in the development of national standards. Stakeholders review and provide input on draft standards to ensure that different perspectives are considered and the standards reflect the industry's collective expertise and interests [8]. Once the standards are finalized, they are published and made available to the public through various channels, such as online platforms, libraries, and specialized publications.

National governments adopt and integrate these standards into their legal frameworks, making compliance mandatory for construction activities. Enforcement mechanisms are implemented to ensure adherence to these standards.

6.2.3 Research Methodology

A study was conducted with the objective of assessing the understanding and perception of standardisation in Circular Economy in different countries, among practitioners and stakeholders active in the field. The assessment refers to an overview on the need for standardisation in Circular Economy. It further refers to national level standards and standardisation, together with a review of European and International level standards.

To this effect, following a review of the state of the art in standardisation, key components were identified, and a questionnaire was designed and conducted across 19 countries with experts and practitioners in circular Economy in Construction. The objective of the questionnaire was to assess and understand the level of implementation and standardization of Circular Economy across different countries. The assessment conducted was intended as a review of the perception of standards and their implementation across Europe by the participants of the survey as practitioners in Circular Economy.

The methodology selected to address the review of standards and policies at national and international level across EU, based on a questionnaire with practitioners and stakeholders in different countries, allowed for information to be gathered addressing the objectives outlined. The survey was structured in different sections to address key aspects related to standardisation. These sections included an introduction to each country, information related to the National standards body, as well as the mechanism and standards developed in each country. The standards identified for each country were also addressed, identifying which of them are implemented and to what extent, along with any corresponding guidelines and recommendations.

In addition, reference was made to European and International standard, including how they are applied, the national parameters set, an overview of the standards and objectives, whether their adoption is mandatory or voluntary, the level/extent of implementation, how each standard is referenced at the national level (partially or fully), as well as any regulations to promote their implementation. The effectiveness, limitations and target audience of these standards were also assessed, as well as any gaps, revisions or references to implementation.

Reference was also made to each National standard/guideline, including the language in which it is written, the key objectives, how it is adopted, publishing entity, the level/extent of implementation, its efficiency and merits, how it is referenced in national regulations (partially or fully), the reference data sets, boundaries and justification, target audience, gaps, revisions and reference to its implementation.

Further the survey identified two areas of focus as key example, specifically: the dismantling of buildings and the use of recycled aggregates. For each of these areas, the relevant standards, reference data sets, the limits set in the guidelines and their justification, how they are implemented and to what extent, and any gaps were identified.

6.2.4 Survey of Standards

The objective of the survey was to address key aspects pertaining to standardisation, specifically to address critical aspects, including reviewing the need for standardisation, identifying national level standards and standardisation, and identifying International and European standards adopted in each country. The questionnaire was structured in various sections as follows:

1. Introduction to country, national standards entity and link, and mechanism and standards developed per country,
2. Standards referred to in each country—and which of them are implemented, along with guidelines and recommendations,

3. Reference to each international European standard mentioned—and how these are enforced, parameters set, overview, objectives, mandatory or voluntary adoption, the level/extent of implementation, how each standard is referenced nationally and whether partially or fully, along with any regulation to enact such standards, the effectiveness, limits, and to whom standards are addressed, as well as any gaps, revisions and references to implementation,
4. Reference to each national standard/guideline—including the language in which it is written, key objectives, how it is adopted, by whom it is published, the level/extend to which it is implemented, its efficiency and merits, how it is references in national regulations and whether partially or fully, its efficiency and merits, referenced data sets, limits and justification, to whom it is addressed, gaps, revisions, and reference to its implementation,
5. Focus area: building disassembly—relevant standards, reference data sets, limits set in the guidelines and their justification, how it is implemented and to what extent, and any gaps,
6. Focus area: recycled aggregate—relevant standards, reference data sets, limits set in the guidelines and their justification, how it is implemented and to what extent, and any gaps.

The countries participating in the survey for which responses where obtained are the following:

1.	2.
3.	4.
5.	6.
7.	8.
9.	10.
11.	12.
13.	14.
15.	16.
17.	18.
19.	

1. Belgium
2. Croatia
3. Czech Republic
4. Cyprus
5. Georgia
6. Ireland
7. Italy
8. Kosovo

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9. Latvia
10. Malta
11. North Macedonia
12. Poland
13. Portugal
14. Romania
15. Serbia
16. Spain
17. The Netherlands
18. Turkey
19. UK

The survey referred to primarily European Union members states but also other countries and territories in Europe and beyond. The survey was presented in the English language for all countries.

The Questionnaire. The survey was divided into 6 sections of different interest for standardization at the national and international level in each country. Table 6.1 outlined the different section and, includes the areas covered in the survey.

The data gathered through the questionnaire was clustered for each country, edited and organised in a structured template whilst taking into account all the information provided including key references and links to standard platforms and associated documents. The key challenge in this process referred to national standards which were published in languages other than English as is the case for non-English speaking regions, which required translation of key components to identify the objectives of respective documents. This was not the case for International Standards which are generally in English and some National Standards in specific countries. The structure used for clustering and analysis is presented in Table 6.2.

Standard Language Adopted in different Countries. When it comes to national standards/guidelines, the default language for most countries is English. Those countries where standards are presented fully in English are the UK, Ireland, North Macedonia (only few standards are translated to national language), Republic of Serbia and Malta. The countries whose standards are mostly in English are: Croatia (Croatian is also used), Cyprus (the decision is taken by the stakeholders, otherwise Greek is used as the national language), Kosovo (Albanian and Serbian are also used) and Latvia (English and translated also into Latvian. Occasionally German is used). Countries that do not use English include Brazil and Portugal (Portuguese), Czech Republic (Czech), Georgia (Georgian), Italy (Italian), Spain (Spanish), and Turkey (Turkish). Respondents for Belgium, Poland, Romania and the Netherlands did not provide clear information on the standard language adopted.

Table 6.1 Questions used in the survey

Section 1: General information
• Where are you from?
• Reference link to the National Standards Entity
• Through which mechanisms are standard developed in your country?
Section 2: List standards referred to in your country
• Which International Standards in Circular Economy are referred to and/or implemented in your country? (List the Standards)
• Which International Standards in Circular Economy are referred to and/or implemented in your country? (List the reference links)
• Which European Standards in Circular Economy are referred to and/or implemented in your country? (List the Standards)
• Which European Standards in Circular Economy are referred to and/or implemented in your country? (List the reference links)
• Which National Standards in Circular Economy are referred to and/or implemented in your country? (List the Standards)
• Which National Standards in Circular Economy are referred to and/or implemented in your country? (List the References links)
• Which Guidelines in Circular Economy are referred to and/or implemented in your country?
• Which Recommendations in Circular Economy are referred to and/or implemented in your country?
Section 3: With reference to each international European standards mentioned
• How is the standard referenced or enforced at National Level? Is it through a regulation or a policy framework? Does it cover the entire standard or parts/specific clauses only?
• How are the National Determined parameters set in the standard? (Example percentage limits on the use of recycled aggregate in structural concrete set at national level through national regulation)
• Provide a short overview of the different sections of the standard
• List the key objectives of the Standard
• How is the standard adopted in your country? Is it mandatory or voluntary?
• How is the Standards implemented and to which level/extent?
• How is each standard referenced in national regulations? Does it cover the entire standard or parts of it/specific clauses? Which Regulation if any enacts the standard? Provide link to regulation
• How effective is the standard and which are its merits in the National territory?
• Which are the limits set in the guidelines—what is their justification?
• Which Regulation if any enacts the standard?
• For whom is the standard addressed?
• Are there gaps which are not covered by the standard?
• Are there any revisions required?
• Provide Reference to the Implementation of the standard in your country

(continued)

Table 6.1 (continued)

Section 4: With reference to each national standard/guidelines listed
• What is the Standard Language?
• List the key objectives of the Standard
• How is the standard adopted in your country (voluntary or business case through incentives and disincentives, or regulation enforcing a standard or part of it)? Is it mandatory or voluntary?
• Who published the document: industry or ministry or standards entity or other stakeholders?
• How is the Standards implemented and to which level/extent?
• How effective is the standard and which are its merits in the National territory?
• How is each standard referenced in national regulations? Does it cover the entire standard or parts of it/specific clauses? Which Regulation if any enacts the standard? Provide link to regulation
• How effective is the standard and which are its merits ?
• What is the reference data set used for the standard?
• Which are the limits set in the guidelines—what is their justification?
• For whom is the standard addressed?
• Are there gaps which are not covered by the standard?
• Are there any revisions required?
• Provide Reference to the Implementation of the standard in your country
Section 5: Focus area—building disassembly
• List relevant standard covering this area
• What is the reference data set used for the standard?
• Which are the limits set in the guidelines—what is their justification?
• How is it implemented and to which extent?
• Which are the gaps in the standard?
Section 6: Focus area—recycled aggregate
• List relevant standards covering this area
• What is the reference data set used for the standard?
• Which are the limits set in the guidelines—what is their justification?
• How is it implemented and to which extent?
• Which are the gaps in the standard?

6.2.5 Country Factsheets

This section gives a summary of the information given by each respondent from each country via the survey above. The questionnaire in the survey is not exhaustive and may contain gaps. The purpose of the questionnaire was to assess the perception of practitioners on standards at national, European and International level, and how Standards are implemented in the country, from their perception.

Standards generally aim to define terminology, methodologies, and certification bases, providing technical measurements and supporting new technologies. They

Table 6.2 Structure used to cluster and analyze national survey responses

1. National standard entities and mechanism/s
a. Summary of national standard entities and mechanism through which standards are developed per country
2. Standards referred to
a. National, International, and European Standards referred to and/or implemented
b. Guidelines and recommendations in Circular Economy referred to and/or implemented
3. Reference to international European standards
a. Key objectives of the Standard
b. Overview of different sections of the standard
c. Standard reference or enforcement
d. How National Determined parameters in the standard are set
e. How the standard is adopted and implemented, and to what level/extent
f. How each standard is referenced in national regulations, and which Regulation (if any) enacts the standard
g. Effectiveness of the standard and its merits in the National territory
h. Which are the limits set in the guidelines - what is their justification?
i. Regulation (if any) which enacts the standard
j. For whom is the standard addressed?
k. Are there gaps which are not covered by the standard?
l. Are there any revisions required?
m. Provide Reference to the Implementation of the standard in your country
4. Reference to national standard guidelines
a. Objectives of the Standard
b. Publisher
c. Adoption
d. Effectiveness and Merits
e. Implementation
f. How is each standard referenced in national regulations? Does it cover the entire standard or parts of it/specific clauses? Which Regulation, if any enacts the standard? Provide links to regulation
g. Standard's effectiveness and merits
h. Standard's reference data set
i. Limits and justification
j. For whom is the standard addressed?
k. Are there gaps which are not covered by the standard?
l. Are there any revisions required?
m. Provide references to the implementation of the standard in your country
5. Focus area building disassembly
6. Focus area recycled aggregate

include sections on scope, normative references, terms and definitions, and specific clauses relevant to the standard's title and scope.

The stages of the development process are the: proposal, committee formation, drafting, public consultation, approval, publication, and periodic review. Committees and technical groups comprising industry, academia, government, and other stakeholders collaborate to create and revise standards based on technological advancements, regulatory changes, and market needs.

Belgium. The Belgian Bureau for Standardisation (NBN) [14] is the central entity responsible for developing standards in Belgium. NBN collaborates with various stakeholders, including industry experts, government bodies, and academic institutions. The development process involves consultation, drafting, and consensus-building to ensure that standards are comprehensive, practical, and aligned with national and international objectives.

Croatia. The key body responsible for developing and maintaining standards is the Croatian Standards Institute (CSI/HZN) [15]. HZN's involvement in international and European standardization organizations ensures that such standards are accessible on a national level, allowing representatives to participate in the development of national standards at international and European levels.

Croatia refers to and implements various national, international, and European standards. The assessment of the sustainability of construction works using the framework provided by HRN EN 15643:2021 [16] is one such example. Other standards relevant to circular economy include EN 303 808 V1.1.1:2023 [17] and EN 17861:2023 [18]. National standards are accessible through HZN's repository [19]. The development of a program for circular management of space and buildings for 2021–2030 has provided guidelines [20] to promote CE principles in urban planning and construction. This aims at extending buildings' life cycles, encouraging the reuse of spaces, and reducing construction waste.

Standards may be either mandatory or voluntary and are designed for a broad audience, including industry professionals, businesses, government agencies, and consumers. These standards provide technical specifications and best practices for various stakeholders to ensure compliance and promote sustainability. While some standards, particularly those regulated at the EU level, are obligatory, others, especially those related to sustainability in construction, are not mandatory. Implementation typically occurs at the project design, material level, and through testing. Such standards that contribute to sustainable development do so by promoting circularity in construction and urban planning. However, information on the effectiveness and specific merits of these standards in the national territory is limited.

Croatia currently has no specific standard for building disassembly. However, the Development Program for Circular Management of Space and Buildings [20] includes principles relevant to this area. Similarly, while no specific standard is available solely for recycled aggregates, standard HR 1128 [21] addresses concrete requirements, incorporating elements relevant to the use of recycled materials in construction.

Cyprus. In Cyprus, standards development is managed by the national standardisation body and technical committees. The country currently lacks published international standards related to the CE, although the first ones are expected from ISO/TC 323 [16] in early 2024 and respective complimentary European standards are currently being developed by CEN/TC 473. National standards are limited, with one in progress for certifying circular plastic products. CE guidelines in Cyprus are mainly driven by private initiatives, such as assessments for specific industries like hotels, conducted by private companies and associations. The Ministries of Energy, Commerce and Industry, and Agriculture, Rural Development and Environment, and Deputy Ministry of Research, Innovation and Digital Policy are coordinating the national action plan on CE and supporting funding schemes CE transition.

The effectiveness of standards is monitored through market surveillance and conformity reports from random checks. National regulations usually refer to entire standards, as seen in the regulation on fuel specifications (Κ.Δ.Π. 252/2015 [22]).

All standards are voluntary unless they are harmonized European standards, which become de facto mandatory and provide CE marking. These harmonized standards are referenced in national regulations and tenders. National regulations often directly reference standards or develop national annexes to supplement European standards. Adoption of standards in Cyprus is voluntary by default, with European standards adopted nationally by law and published in the Official Journal of the Cyprus Government. Implementation varies, with harmonized standards becoming mandatory if they support EU Directives or Regulations.

For building disassembly, the relevant standard ISO 20887:2020 [23] is not yet implemented in Cyprus. There are no existing standards for recycled aggregates, though studies are ongoing to evaluate their inclusion in future standards.

Czech Republic. In the Czech Republic, the national standards are developed by the Czech Office for Standards, Metrology, and Testing (UNMZ) [24] in collaboration with the Czech Standardization Agency. This process begins with a government request for a standard, followed by public procurement for document preparation. The country utilizes various international and European standards, including ISO 14044 [25], EN 17861 [26], ETSI EN 303 808 V1.1.1 [27], EN 17410 [28], EN 15804 [29], EN 15978 [30], EN 13108-8 [31], and EN 15342-7 [32]. However, there are no specific national standards for Circular Economy at present. Guidelines are based on the European CD Waste protocol and national guidelines for asbestos management, while recommendations include the State Health Institute's methodology for ensuring the safety of children and young people in public facilities.

Standards on Life Cycle Assessment are adopted, too. These standards are comprehensive in describing LCA and related tools, but still voluntary, with limited actual application. They are primarily referenced in national regulations, impacting environmental consultants. The effectiveness of these standards is generally assessed through voluntary market implementation, with a noted lack of enforceable regulations. They are aimed at various stakeholders but have limited effectiveness due to their non-mandatory nature.

For building disassembly, no specific standards are mentioned. Regarding recycled aggregates, relevant standards include ČSN EN 1744-6 [33], ČSN EN 1097-6 [34], ČSN EN 1367-4 [35], ČSN EN 1744-5 [36], ČSN EN 1744-1+A1 [37], and ČSN EN 933-11 [38]. These standards cover various testing methods for chemical, mechanical, and physical properties of aggregates. However, the extent of their implementation and any existing gaps are not detailed.

Georgia. In Georgia, standards are primarily developed through laws or strategic documents under the Ministry of Economy and Sustainable Development. The Waste Management Code, adopted in accordance with EU directives, serves as a key international standard for waste management, aiming to prevent waste, increase re-use, and ensure environmentally safe treatment.

The Waste Management Code's objectives include waste prevention, environmentally safe treatment, and efficient resource use, covering various types of waste except for specific exclusions like radioactive waste. The code aims to protect the environment and human health through effective waste management mechanisms. Enforcement of the Waste Management Code is through the law and by-laws, addressing business and state entities. The code's effectiveness and merits are ensured through legal enforcement, although specific limits and justifications are not outlined. The English version of the code is available for reference [39].

There is limited information available regarding national standard guidelines in Georgia, with no details on objectives, publisher, adoption, effectiveness, or implementation. The code primarily targets waste management but lacks specific information on building disassembly or recycled aggregate standards.

Ireland. The National Standards Authority of Ireland (NSAI) [40] is the body that oversees the development and implementation of standards [41], including those related to the circular economy. The NSAI National Committee on Circular Economy, along with its subcommittees and working groups, plays a crucial role in developing standards in this area. These standards include those developed under ISO and CEN committees, addressing various aspects of circular economy principles and frameworks.

Internationally, Ireland is engaged in developing standards under ISO/TC323 and CEN/TC350, focusing on circular economy principles, business models, and circularity measurement frameworks. The Circular Economy and Miscellaneous Provisions Act 2022, signed into law, underpins Ireland's transition towards a more sustainable production and consumption model, aiming to reduce greenhouse gas emissions and promote resource efficiency.

The key objectives of the Circular Economy Act include shifting Ireland away from a linear economy, incentivizing the use of reusable and recyclable alternatives, tackling illegal dumping and littering, and promoting waste prevention and recycling. The Act introduces various measures, including a mandatory segregation regime for commercial waste, support for environmental and circular economy projects, and the establishment of circular economy policies.

Implementation of the Circular Economy Act is to be enforced, with measures such as mandatory segregation and incentivized charging for commercial waste.

The Act also establishes legal requirements for the Circular Economy Strategy and National Food Loss Prevention Roadmap. While details about national standard guidelines are limited, the Act signifies a significant step towards promoting circular economy practices in Ireland.

Italy. The development of technical standards in Italy is overseen by the National Standards Body (UNI) [42], which has been actively involved in creating voluntary technical standards for over a century. These standards codify the state of the art of products, services, processes, and professions, often in collaboration with thousands of experts across various sectors. Additionally, emerging themes at a European level are addressed through CEN Workshop Agreements, with pre-standardization documents processed by restricted author tables.

Internationally, Italian technical standards are developed with consideration for the work of ISO/TC 323 "Circular economy" working groups, resulting in standards like ISO 59004 [43], ISO 59010 [44], and ISO 59020 [45]. Nationally, standards such as UNI/TS 11820:2022 [46] and UNI/TR 11821:2023 [47] provide methods, indicators, and best practices for measuring circularity and analyzing circular economy applications.

Guidelines and recommendations in the circular economy are provided by entities like the Ministry of Ecological Transition [48] and the CAM (Minimum Environmental Criteria) [49]. These resources offer strategic guidance and criteria for implementing circular practices.

The key objectives of standards such as UNI/TS 11820:2022 [46] and UNI/TR 11821:2023 [47] include evaluating the circularity of organizations and analyzing good practices of circular economy applications. These standards outline criteria for measurement, evaluation, and analysis, addressing different aspects of circular economy principles and methodologies.

Adoption of these standards is voluntary, with implementation primarily at the company and organization level. While details regarding enforcement, effectiveness, and regulatory references are limited due to the recent nature of these standards, their adoption by 37 companies and organizations during the experimental phase indicates growing interest and participation in circular economy initiatives in Italy.

The standards and guidelines serve as valuable resources for companies and organizations seeking to adopt circular economy practices, providing frameworks, indicators, and best practices for evaluating and implementing circularity in various contexts.

Kosovo. The standardization process is facilitated by the Kosovo Standardization Agency (KSA) and operates within the framework of European integration, particularly through the Stabilization and Association Process Tracking Mechanism (STM) [50]. International [51, 52], European [53], and national [54] standards are referenced and implemented, with the adoption of construction codes equivalent to European standards being a key objective. However, Kosovo is not a member of international standardization bodies like ISO and is working towards cooperation with these organizations.

The Law on Standardization in Kosovo mirrors European and international systems, providing procedural rules for drafting, approving, and applying standards. While adoption of Kosovar standards is voluntary, they can become mandatory through legislation. The KSA oversees standardization activities, with any entity eligible to propose standards. Despite effective implementation, there are ongoing efforts to develop national annexes and revise existing standards, particularly in civil engineering.

The KSA, under the Ministry of Industry, oversees the approval and harmonization of standards, contributing to economic development and regional competition. The effectiveness of standards is supervised by the Ministry of Trade, with Kosovo standards identified as "SK" and harmonized with European counterparts. The country is striving to align its laws and regulations with EU standards, promoting regional integration and economic growth.

In specific focus areas like building disassembly and recycled aggregate, relevant standards and legal frameworks exist, but implementation challenges persist. These challenges include an underdeveloped market for repurposed goods, inefficient waste management practices, and gaps in record-keeping and operational procedures. Addressing these gaps is crucial for Kosovo's transition towards a more circular economy and sustainable waste management practices.

Latvia. In Latvia, national standardization is facilitated by the National Standardization Institution "Latvijas Standarts" (LVS) [55] which operates through standardization technical committees composed of stakeholders in specific areas. Latvia, as a member state of the European Union and the European Standardization Organization, adopts international and European standards, such as EN 50614 [56] and EN 50625 [57]. However, national standards specific to the circular economy have not yet been developed or approved.

The adoption of European and international standards is initiated by the industry or the relevant industry ministry, with "Latvijas Standards" taking them over after recommendation by standardization technical committees. While the application of standards is generally voluntary, their fulfilment becomes mandatory if referenced in regulatory acts. Latvian regulatory acts may refer to standards or specific clauses, with mandatory application determined by law or Cabinet of Ministers regulations.

Efforts to translate standards referenced in regulatory acts into Latvian are underway, with the objective of ensuring compliance. The application of standards typically applies to the applicator of the relevant normative act, with mandatory application not extending to other persons. Although specific information regarding the effectiveness and merits of standards in Latvia is not provided, the adoption and implementation process aligns with European and international practices.

In focus areas such as building disassembly and recycled aggregate, relevant standards and guidelines are not explicitly mentioned, indicating potential gaps in standardization efforts in these domains. Overall, while Latvia actively adopts international and European standards, there is room for further development and implementation of standards tailored to specific national priorities, such as the circular economy.

Malta. Malta is active in Standardisation through the MCCAA (Malta Communication and Consumer Affairs Authority) [58] and participates in Technical Committees for standards on Circular Economy, including CEN TC350/SC1 Circular Economy in the Construction sector [59]. In Malta, the transition to circular economy is an ongoing development.

The main government institutions in charge of implementing the circular economy in Malta is the Ministry for the Environment, Energy and Enterprise [60]. The Circular Economy Malta (CEMalta) [61] is the unit set up by Government to administer Circular Economy in Malta under the Environment Protection Act, Malta CAP 549: Circular Economy Malta [62]. CEMalta was established through Subsidiary Legislation SL.595.28 [61].

SL. 623.08 Construction Site Management Regulations [63] refer to the standard SM810 for Recycling oriented Deconstruction and Classification of Waste [64] 65, therefore incorporating the standard within the regulatory framework. Compliance with the standards is considered as an essential requirement before an executable Development Permit is issued. Any deconstruction or excavation works which is carried out on a site will need address sections five (5), seven (7) and eight (8) of the national standard SM 810:2022 'Recycling-oriented Deconstruction, Controlled Excavation Works and Classification of Waste' [65].

Furthermore, apertures in a residential building are required to follow the standardisation of dimensions of internal and external apertures as specified in the Technical Document titled 'standardisation of Apertures for Residential Buildings in Malta'.

The objectives of the standards SM810 [65] in Malta was to:

- establish best practice for (de)construction, aimed at reducing the generation of construction and demolition waste and purifying the resulting waste streams;
- establish a classification for construction and demolition waste by type, material, composition and weight to encourage on-site separation as well as improve the quality of waste streams for subsequent reuse or recycling;
- establish standards for appropriate excavation work, with the aim of reusing excavated rock for the purposes of construction.
- establish standards for the dimensions of internal and external apertures of residential dwellings aimed at encouraging the re-use of fittings as well as reducing diversity, bringing about economies of scale.

These standards are merged within the regulatory framework. It is an essential requirement to comply with these standards before an executable Development Permit is issued. In order to improve the quality of the waste, the above standards aim to classify construction and demolition waste according to the material type and composition. The standards were organized into: two standards for C&D Waste (SM810: Recycling-oriented Deconstruction, Controlled Excavation Works and Classification of Waste [65]; SM820 Classification of Recycled Aggregate (In consultation phase) [66]); and a technical guideline for apertures.

The Recycling Oriented Deconstruction of Buildings Standard SM810:2022 (The Recycling-oriented Deconstruction, Controlled Excavation Works and Classification of Waste) was published in 2022 by MCCAA as an important and fundamental

National Standard, following a public Consultation [65]. The standard is incorporated within the regulatory framework through SL. 623.08 Construction Site Management Regulations. Compliance [67] with the standards is considered as an essential requirement prior to the issuance of an executable Development Permit.

North Macedonia. The Standardization Institute of the Republic of North Macedonia (ISRSM) is the official organization responsible for standardization in North Macedonia [68]. ISRSM is key to creating, promoting, and spreading national standards. To address specific standardization areas, ISRSM sets up technical committees. These committees consist of experts from various sectors, including industry, government, academia, and other relevant fields.

The country has a system of implementation where either European Standards are adopted or local standards are created. In both cases, the standards need to pass a public hearing before implementation. North Macedonia follows a number of standards related to sustainable development, waste management and energy efficiency. Their national guidelines are available in English. No information was given regarding standards related to Circular Economy and Building Disassembly. With reference to the focus area of Recycled Aggregate, two standards were mentioned, namely: MKC EN 1744-6:2010/AC:2010 [69] and MKC EN 933-11:2010 [70]. Standard "MKC EN 197-6:2024—Cement—Part 6: Cement with recycled building materials" was adopted to control the production of cement from recycled materials.

Poland. Significant detailed information on Circular Economy and Standardisation was not provided by the Polish respondents. The key information provided refers to the national standardisation entity platform and standardisation which is in Polish [71].

Portugal. Portugal also has a website in Portuguese regarding national standard entities and mechanisms through which standards are developed [72]. It was also explained that they have technical committees which mirror the ISO and CEN committees.

With regards to Circular Economy, they use a number of guidelines and standards. They refer to the *Circular Economy Action Plan: The European Green Deal* [73] from the international level, while *A new Circular Economy Action Plan: For a cleaner and more competitive Europe* [73] is implemented from the European level and at a national level they have the standard *Plano de Ação para a Economia Circular* [74]. A number of key objectives used for the standards were outlined. These are: to decouple economic growth from resource consumption, extract and consume resources more efficiently, improve waste management, share goods and services, reduce GHG emissions and other environmental impacts, from the perspective of analyzing the energy cycle life and close product life cycles.

Portugal has a circular economy policy framework which is implemented on a voluntary basis and they also have a circular economy action plan which is reflected in the National Standards.

Romania. Romania's only information provided was the national standard entity—ASRO [75]. This is the national platform for the development and adoption of European and International standards. At European level, the standardization activity is regulated by Regulation 1025_2012 [76].

Serbia. The Serbian Standards Institute (ISS) [77] is the national body responsible for standardization in Serbia. ISS plays a central role in the development, promotion, and dissemination of national standards. Technical committees are established by the Serbian Standards Institute to focus on specific areas of standardization.

These committees are composed of experts from relevant industries, government agencies, academia, and other stakeholders. They work together to develop and update standards in their respective fields. Serbian standards (and related documents) may be original or may be developed based on international, European, and other regional standards and related documents, as well as national standards and related documents of other countries in accordance with agreements signed with the national standardization bodies of those countries. Standards are developed and defined through a process of knowledge sharing and best practices, and they are built upon a consensus reached among experts representing stakeholders in standardization committees. Serbian standards are created and published while adhering to the principles and rules established by international and European standardization organizations. Draft standards or revisions are typically subject to public consultation, allowing stakeholders, including the public, to provide feedback and input on proposed standards. This inclusive process helps ensure that standards reflect the needs and perspectives of various sectors. Involving all stakeholders in the process of adopting Serbian standards is possible in Step 1—Submitting proposals for a new project to the relevant standards committee and in Step 4—Public consultation on the draft Serbian standard. In the other stages of development, the standard is only accessible to members of the standards committee until its publication. The Serbian respondent gave very detailed answers to the survey.

Serbia has a number of standards they refer to and implement which are ISO/DIS standards for Circular Economy, CE standards which are in the consideration and adoption phase and National standards which seem to be identical to the ISO and EN standards. It should be noted that the standards listed for the National and International section are the same links. Serbia has a website which is used for guidelines and recommendations for circular economy [78].

With reference to the two areas of focus which are Building Disassembly and Implementation and extent of implementation, one will notice that according to the Serbian respondent, *ISO 20887: Sustainability in building and civil engineering works* [79] is mentioned which for implementation, there is a low level of implementation and although the standard is published (but not mentioned in the survey) it is not generally applied.

With reference to another focus area mentioned in the survey—Recycled Aggregate, the Serbian respondent mentioned a number of standards, namely:

- SRPS EN 206 Concrete—Specification, performance, production and conformity [80].

- SRPS EN 12620 Aggregates for concrete [81].
- SRPS EN 13055 Lightweight aggregates [82].
- SRPS EN 933 series of standards "Tests for geometrical properties of aggregates" [83].
- SRPS EN 197-6 Cement—Part 6: Cement with recycled building materials—only draft version, still not in application. Identical to corresponding EU standards.

The respondent also outlines that the application of fine recycled aggregates is still being researched. The implementation requirements are outlined in the guidelines Rulebook on Technical Requirements for the composition of concrete determined by the standards SRPS EN 206 [78] and SRPS U.M1.206 [84] and the application of aggregates in accordance with SRPS EN 12620 [81] or SRPS EN 13055 [82].

Spain. Spain has a national entity called the UNE [85] and implements standards from an International, European and National level. Spain has guidelines and recommendations for Circular Economy and is referred to in the document Estrategia Española de Economía Circular, España [86]. The Spanish Circular Economy Action plan for 2021–2021 includes 116 measures proposed by eleven ministries aimed at achieving the objectives for the year 2030, while also maintaining coherence with initiatives and policies undertaken at the community level.

The main objectives in Spain for International standards are the following: Protection and improvement of the environment, preventive action, decarbonisation of economy, "Polluter pays" principle, health protection, rationalization and efficiency, cooperation and coordination between public entities, public participation, sustainable development, solidarity between people and territories, integration of environmental conscience in decision making, increasingly competitive economy, generation of quality employment.

On a national level, the objectives for standards differ to the international ones. Here are the objectives:

- Production: the production of a product from conception to manufacture keeping in mind it's lifespan, repair and repurpose to create less waste.
- Consumption: promote sustainable consumption and promote recycling where possible.
- Waste management: when facing the reality that raw materials worldwide are becoming expensive and scarce, it is imperative for action to be taken to reuse, recover and recycle
- Secondary raw materials: the implementation of secondary raw materials gives the possibility of better usage of natural resources
- Water reuse and purification: Water is an important resource in the Iberian Peninsula. It has an important contribution to the Spanish economy and work is done to address obtaining second raw materials.

The Spanish also have a Spanish Strategy for Circular Economy called, España Circular 2030 [86]. España Circular 2030 created a production and consumption model platform for the reduction of waste and better usage of resources within

the economy. In this way, waste is recycled and reused as long as possible before becoming unavoidable waste.

Although España Circular 2030 has a long-term vision, it is to be implemented in the short and medium term by means of successive action plans. The regulation which enacts the standard is Directive 2018/851/UE. Such standards are addressed to construction, farming, fishing and forestry, industry in general, consumption goods, tourism, and textile and garment sector.

The Netherlands. The Dutch respondent had very little information to share in the survey. NEN [87] is the standard entity through which standards are developed. More information (in Dutch) on how standards are developed is available on the site [88]. Guidelines for circular economy are in development. For four years there are progress studies by the Planbureau voor de Leefomgeving (PBL) which will be developed into Guidelines and Standards. To date all guidelines and standards are on a voluntary basis. There are also policy frameworks, strictly in the building industry for new buildings. This is not yet applicable for existing buildings and the circular economy as most is energy-driven.

Turkey. The national standard entities and mechanism to develop standards are carried out by the Ministry for Environment, Urbanism and Climate Change via ISO 59000 (under publication). A number of standards at National, European and International level are implemented in Turkey. The adoption of international European standards is mandatory, with implementation being required at national and company levels. All implemented actions/projects are available in guidelines called *Technical Assistance for Assessment of Turkey's Potential on Transition to Circular Economy*.

United Kingdom. The Department for the Environment, Food and Rural Affairs provides information regarding the national standard entities and mechanism [89]. The implementation of standards at European and international level refer to: BS EN 18177 Circular Economy in the construction sector—framework, principles and definitions; BS ISO 59040:2025 Circular Economy—Product circularity Data Sheet; BS ISO 59014:2024 Environmental management and circular economy. Sustainability and traceability of the recovery of secondary materials. Principles, requirements and guidance; BS ISO 59004:2024—Circular Economy. Vocabulary, principles and guidance for implementation; BS ISO 59020:2024 Circular Economy. Measuring and assessing circularity performance; BS ISO 59010:2024 Circular economy. Guidance on the transition of business models and value networks. Standards and guidelines at national level primarily include the BS8001 Circular Economy standards [90] as well as recommendations through the IStructE guideline for reuse [91].

In the UK, the key objectives of international European standards are for circular economy for new buildings, where reference/enforcement, along with adoption and how national determined parameters in the standard are set, are voluntary. The same can be said for how each standard is references in national regulations at this stage, where no regulations enact the standard. As for implementation of the standard however, it follows BS 8001 environmental benefits through improved resource use.

The UK also as yet does not have any measurements for the effectiveness of the standard so far. However, the goal for net zero has been changed.

The standard requires revisions and is currently addressed to building construction, with gaps not covered by the standard including existing building stocks, and various applications. When it comes to implementing the standard, the UK references BS 8001 environmental benefits through improved resource use.

In the national standard guidelines, which are in English, the objectives of the standard are determined from BS 8001 [90] environmental benefits through improved resource use. At this level, standards are published by the standards entity, with adoption on a voluntary basis. The current effectiveness of the standard is stated as being good. As for implementation, this is carried out for large construction projects and is addressed to construction in general.

6.2.6 Country Factsheets: Discussion

The review of CE standards and standardisation across Europe and beyond, and the perception of their implementation, provides some key insights in the current state of standardisation in Circular Economy. The survey outcomes suggest that there is an understanding of the need for standardisation across most countries, to support policy and regulations. The level of implementation of European standards and International Standards, however varies across States, as does the perception of standardisation as identified through the questionnaire. While generally there is a voluntary framework of standards, these are not necessarily covering all aspects of the industry. However, there is a degree of implementation in various countries, through policy, regulations frameworks and legislation which refer to the standards. The survey conducted suggests that the level of implementation varies, with different recent and current developments, and with a perception of key ongoing actions towards standardisation to further support policy and implementation.

6.3 International and European Level Standards and Standardisation

Standardization refers to the creation, publishing, and implementation of standards in different sectors, including the construction industry. This process occurs at both national and international levels. Two prominent organizations that play a crucial role in standardization efforts are the International Organization for Standardization (ISO) [92] and the European Committee for Standardization (CEN) [93].

6.3.1 International Level Standardisation

In today's globalized world, standardization has become crucial in numerous industries, including the construction sector. At the international level, standardization is facilitated by organizations such as the International Organization for Standardization (ISO) [92] and the European Committee for Standardization (CEN) [93]. These organizations combine national standardization bodies from various countries to develop and publish international standards [13]. The primary objective is to promote harmonization, interoperability, and compatibility across borders.

The process of international standardization involves the formation of technical committees that address specific areas of standardization. Experts from participating countries collaborate to develop global standards. The draft standards are reviewed to ensure accuracy, clarity, and relevance. They are then circulated among participating countries for voting and approval. The standards are approved if a significant majority of the participating countries support them. Once approved, the international standards are published and made available to the public. National standardization bodies adopt these standards and incorporate them into their national frameworks.

The implementation of standards involves various aspects, including the acceptance of international standards as national ones and their referencing through laws and regulations. In this way, compliance with the standards becomes mandatory. Authorized bodies often verify compliance through inspections, audits, and certifications. Educational initiatives and training programs are conducted to raise awareness and build the capacity of professionals in the construction industry. This ensures they have the necessary information and skills to implement and conform with the standards.

The construction industry, including contractors, engineers, architects, and suppliers, plays a vital role in implementing standards. They incorporate the standards into their processes, designs, and specifications to ensure compliance and quality. Standards are periodically reviewed and updated to reflect advancements in technology, changes in regulations, and emerging industry practices. Monitoring and feedback mechanisms are established to gather information on the effectiveness and relevance of the standards, leading to continuous improvement.

6.3.2 Key Players in European Standardisation

The process of European standardization involves numerous parties and aims to reach a consensus. Standards development is mainly driven by market demands, with the industry playing a crucial role in initiating it. Three European Standards Organizations, namely the European Committee for Standardization (CEN) [93], the European Committee for Electrotechnical Standardization (CENELEC) [94], and the European Telecommunications Standards Institute (ETSI) [95], are responsible for the development of European standards [96].

ESOs—The European Standardization Organizations. The European Standardization Organizations, namely CEN, CENELEC, and ETSI, are officially recognized as providers of European standards by Regulation (EU) No 1025/2012. These organizations have cooperated with the European Commission since 1984, when the first agreement was signed. The agreement was later revised in 2003 and provides general guidelines for collaboration between the parties involved [97].

CEN. The European Committee for Standardization, also known as CEN, is an organization that brings together the national standardization bodies of 33 European countries. Its primary purpose is to create a space for developing European standards and other technical documents related to a wide range of products, materials, services, and processes, including air, space, chemicals, construction, and more [93].

CENELEC. CENELEC, the European Committee for Electrotechnical Standardization, is in charge for standardization in electro-technical engineering. The voluntary standards developed by CENELEC help to enable trade between different countries, access new markets, reduce compliance costs, and encourages the growth of the EU single market. In addition, CENELEC collaborates closely with the International Electrotechnical Commission (IEC) to create market opportunities at the international level [94].

ETSI. The European Telecommunications Standards Institute (ETSI) creates international applicable standards for information and communications technology (ICT). This covers fixed, mobile, radio, converged, broadcast, and internet technologies. ETSI's primary aim is to develop and preserve the technical standards required by its members. With ETSI, the industry can directly participate in standards development. However, to access CEN and CENELEC, the sector can only involve themselves through their respective national standardization bodies [95].

Other stakeholders involved in European standardization [97]: EU and EFTA countries' National Standardization Bodies (NSBs) are responsible for developing a European consensus. Small and medium-sized enterprises (SMEs) are represented by the non-profit organization Small Business Standards, which reinforces their representation. Consumer, trade union, and environmental interests are represented by ANEC, ETUC, and ECOS, respectively. They are essential for accountability. Public authorities develop standards-receptive regulation, issue standardization directives and public procurement, and provide funding to the European Standardization Organizations (ESOs) and the NSBs.

6.3.3 Review of International Standardization Bodies

Procedures for the reporting, quantification, assessment and guarantee of sustainable buildings have been established in many countries. There was, however, the need to develop systems and standards for the assessment of better insertion of life cycle analysis methodologies with regards to environmental, social and economic aspects

[59]. Standardization is crucial in facilitating the transition to a circular economy, where the goal is to move from a linear throwaway society to a circular model. This transition involves using raw materials as long and frequently as possible and managing natural resources within a closed circle without consuming new resources [98].

In this section a brief overview will be given of the main International and European standardisation bodies which are working towards creating common standards in the Circular Economy for buildings and construction. These standardisation bodies are namely CEN/TC 350, ASTM International, ISO Technical Committee 323 and CEN-CLC/JTC 10.

European Committee for Standardization (CEN). CEN, the European Committee for Standardization, holds a distinguished position as one of the three European Standardization Organizations officially recognized by the European Union as well as the European Free Trade Association. Its primary function is to develop and define voluntary standards at the European level. Boasting a membership of national standardization bodies from 33 European countries, CEN plays a crucial role in promoting the creation of European standards across various sectors, such as construction [99].

CEN has established standards in the circular economy realm designed to encourage sustainable practices, enhance resource efficiency, and embrace circular construction principles. These criteria offer direction and specifications for utilizing recycled materials, assessing circularity, and carrying out circular economy strategies within the construction industry [93].

CEN/TC350 provides a framework of coordinated European standards for the analysis of environmental, social and economic performance of structures. These are based on a life cycle method as a contribution to applying sustainable construction. The aim of these standards is to grow and implement a mechanism of sustainability assessment tools for buildings that address the assessment of the environmental, social and economic performance as well as the technical quality and functionality/serviceability of the building. In this European standard, the building including its foundations and the external environment footprint of the building site, is the area of assessments and the basis of impacts over the life cycle of the property. It is important to note, that in order to assess the environmental, economic and social performance of the building, the footprint of the site does not take into consideration the impacts of non-building appliances [59].

When assessing the results and carrying out comparisons between alternative design options at design stage or when comparing finished buildings, a “fair basis” must always be considered. For this reason, the concept of “functional equivalent” was introduced. The functional performance of buildings should form the basis of the comparison. These requirements effect the results of the assessment. For this reason, they need to be considered during any assessment. It is clear that the functional equivalent must always be communicated together with the results of the assessment. Should the National, Regional or Local entity prefer, it is allowed to communicate the results with more collected groups of information and/or indications after the

valuation. The results, however, must be reported separately from the standardised assessment results making it clear that this is additional information [59].

This European system of assessments strives to have truly transparent performance-based standards and for this reason, CEN/TC 350 only considers performance aspects and impacts that are reported with the quantitative indicators. In the framework level standards, these indicators establish the requirements for the building and product level being use. At the building level, the assessment communicates that the descriptive model of the building is defined by the requirements for technical and functional performance of the building [59].

In CEN/TC 350 the sustainability assessment of buildings as a player in the implementation process of sustainability of construction works is a multi-level process. The framework for the assessment of social and economic performance has working groups developing these processes. The descriptive and assessment of sustainability aspects consider the economic, environmental and social performance. This performance creates a relationship between the technical performance and functionality aspects and thus one can say that the two concepts, performance-based buildings and sustainability in the building construction are emerging as a complementary tool. The addition of economic and social performance has encouraged to transition from an assessment of environmental impacts to a wider assessment of sustainability characteristics. This assessment is significant in the discussion of the quality of the building and the built environment [59].

CEN has formed specialized working groups, including CEN/TC 350/SC 1, dedicated to promoting circular economy principles within the construction industry. These groups strive to create standards that encourage the adoption of circular construction practices, focusing on certifications for products containing recycled materials and guidelines for future life cycles [100]. CEN ensures coordination and alignment with existing construction committees supporting the circular economy, such as ISO/TC 323 and CEN-CLC/JTC 10 [100].

ASTM International. ASTM International is a well-known organization that has been actively developing standards for the circular economy. The organization has been mainly focused on sustainability and circularity and has created specialized technical committees and workgroups to define frameworks, principles, and sector-specific applications. These efforts have led to the development of various methods to measure sustainability and circularity, making ASTM International a pivotal contributor to the development of circular economy standards worldwide.

ASTM International has formed technical committees and workgroups to promote the circular economy concept. The workgroups comprise experts from diverse industries collaborating to create standards that facilitate circular practices. For instance, Subcommittee E60.13 on Sustainable Manufacturing concentrates on devising design principles for the circular economy [101].

ASTM International has developed a roadmap for technical standards to improve production efficiencies and reduce waste materials. The roadmap identifies openings for new and existing standards in relation to circular economy in manufacturing [101].

ASTM International actively partners with key players in the manufacturing industry to pinpoint the necessary standards for prolonging the lifespan and improving the recovery of materials and goods through repair, reuse, remanufacturing, and recycling. Moreover, the organization spearheads roundtables and workshops to cultivate circular economy principles and establish standards that bolster circularity. By spearheading the creation of circular economy standards, ASTM International emphasizes its dedication to promoting sustainable initiatives, optimizing resource utilization, and mitigating waste across diverse sectors.

International Organization for Standardization (ISO). Another organisation and technical committee to consider is ISO Technical Committee 323—Circular Economy. ISO/TC 323 is a committee of experts from several countries, including industry, academia, and government representatives. ISO TC 323 was set up to standardize the field of CE by proposing a number of international texts, guidelines and tools for all public and private organizations with the aim of contributing to the field of circular economy and sustainable development. TC 323 aims to propose some transversal texts but not targeted towards a specific activity. If specific activities need some personalised text, then these will be written baked on the TC 323 experience. The scope is to develop frameworks, guidelines, supporting tools and requirements for the application of activities of all organisations involved in this sector, to amplify the contribution to Sustainable Development [7].

The purpose of ISO TC 323 is to contribute to an answer of the collective emergencies by proposing an alternative environmental emergency. These are mainly, resource depletion, water generation, climate change and biodiversity losses. There are also social emergencies to consider which are closely linked to the environmental ones, such as resource access and social inequalities. By promoting a new mindset, one can initiate more collaborative partnerships and create more value networks, to develop concrete, operational texts for all user types, including small and medium enterprises from all over the world [7].

This committee is tasked with developing frameworks, guidance, supporting tools, and requirements to promote implementing circular economy practices that contribute to sustainable development [102]. ISO plans to introduce new international standards for the circular economy in 2024, providing guidance and requirements for transitioning to a circular economy model [92]. The scope of the standards is to cover principles, terminology, frameworks, and implementation guidance for the circular economy, ensuring consistent practices [103]. For that purpose, the committee collaborates with other ISO technical committees responsible for developing standards related to the circular economy, such as sustainable procurement, quality management, and environmental management [103].

The primary goal of ISO/TC 323 is to address the pressing need to shift to a circular economy. This is in response to resource depletion, climate change, and growing inequalities. ISO aims to develop standards that provide organizations with a global vision and a framework for adopting circular economy practices [92].

Some of the opportunities considered as part of the circular economy mindset are:

- integrated systematic eco design to manage one's products/services/solutions

- consider waste as a resource as far as possible to reinforce material valorisation
- promote collaboration and partnership
- integrate long term vision by balancing the economic/financial results/indicators with the environmental and social indicators to better change the mindset [7].

TC323 decided to propose a package to better understand the implementation of Circular Economy. Four main International Standards are under development, namely:

- ISO 59004—to give definitions/principles/framework for implementation and areas of action.
- ISO 59010—to shift from linear to circular business models to help organizations implement a new business model.
- ISO 59020—to measure if a business is really circular. This standard identifies which set of indicators to use and which data framework is required.
- ISO 59040—to focus on a product along the value chain and provide circularity at this level [7].

A standard on secondary material is also under development to propose guidelines to manage the material and include recommendations for traceability mainly for waste.

CEN-CENELEC Joint Technical Committee 10 on Energy-related products—Material Efficiency Aspects for Eco-design. The last technical committee highlighted for discussion is CEN-CENELEC [59] Joint Technical Committee 10 on Energy-related products—Material Efficiency Aspects for Eco-design (CEN-CLC/JTC 10). This was created after the publication of the Circular Economy Action Plan in 2015. The European Commission asked the three European Standardization Organizations—CEN, CENELEC and ETSI to create standards on material efficiency to establish future eco-design requirements on durability, reparability and recyclability of products as well as other things. This introduced a new focus on material efficiency during the design phase [102].

The CEN-CLC/JTC 10 created a group of eight standards with principles to consider when dealing the material efficiency of energy-related products. Some of the factors considered were extending the product lifetime, the ability to reuse components or recycle material from products at end-of-life and use of reused components and/or recycled materials in products. The standards developed by CEN-CLC/JTC 10 were used by Technical Committees to process product-specific or product group standards addressing material efficiency features [102].

International Standardisation: General Conclusions

Circular Economy is a complex challenge that needs to consider not only the environmental question but also the social one. The question one needs to ask has to deal with more than the value chain with the value network and also consider the holistic/systemic/life cycle thinking perspective relationship. One needs to rethink the long-term vision to balance economic/financial indicators with environmental/

social ones. Thus, one needs to change the mode of production and consumption at individual/organisational/country level [7].

For products or materials to be designed intelligently, one has to also consider the efficient use of the resources in the production processes as inefficiency can reduce business opportunities and substantial waste generation. One of the problems experienced by operators showing interest in using secondary raw materials is the vagueness of the quality of the materials in hand. Due to the lack of EU-wide standards, it will be hard to assess the impurity levels or suitability of high-grade recycled products. By creating quality standards, the overall trust in secondary raw materials and in recycled materials will increase. This ensures better support and take-up of this market [102].

The facilitation of cross-border circulation of secondary raw materials ensures that trading of these materials can be facilitated across the EU. With the use of electronic data exchange, the cross-border process can be simplified. By enhancing the accessibility of data on secondary raw materials, the EU will further grow the Raw Materials Information Systems and support the research on raw material flows across the European Union [102].

The biggest sources of waste across Europe are construction and demolition surplus. Most of the materials generated in this sector are recyclable and can be reused. There is however a barrier in this process since the rates to reuse and recycling vary widely across the EU. The construction industry plays an essential role in the environmental performance and infrastructure, throughout the lifespan of the building. Considering buildings are permanent structures that last for decades, it is imperative to promote design improvements that will mitigate and reduce the negative environmental footprint of buildings and enhance the durability and recyclability of their materials [102].

Innovation and creativity will play an important role in this systemic change. Europe and the world need to rethink the way of production and consumption. To transition material waste into products that have a high value-added quality, new technologies, processes, frameworks, services and business models are needed to determine the future of our economy and society. Research and innovation are major contributors in encouraging this shift as they provide knowledge which leads to trust in the investment. Research and innovation will also shift the EU industry towards competitiveness and modernisation. Reliable indicators will be important to understand the progress of this transition towards a more circular economy and the impact of these actions at EU and National level [102].

6.3.4 Identification of Challenges at International, European and Regional Levels

In considering the discussion on standards and standardisation above, different challenges and gaps are identified.

In the working groups of ISO/TC 323, a critical evaluation of the standards was evaluated and the following was drawn up [7]:

- the ambition level is very low,
- no holistic interpretation in definition of principles. points such as service life extension, design, upstream innovation were not considered,
- no guidance for circularity,
- the concepts were in part only of little help when transferred to company and product level.

The possible negative effects were also identified:

- Discrepancy with goals of Green Deal and CEAP due to carrying interpretation of circular economy concepts;
- Increasing fragmentation of the EU internal market in Circular Economy standardization;
- Linear concepts were declared as Circular Economy without the necessary transformation process;
- Problem of availability of critical raw material in the EU was insufficiently addressed;
- In particular, the principles of established environmental management systems such as ISO 14001 et al. were insufficiently used for evaluation of options for action.

The negative effects regarded in ISO/TC 323 Circular Economy can be absorbed by mirroring at European level. The option of European annexes would make it possible to adapt the forthcoming international standards to the needs of the European internal markets. The call for the European mirroring of ISO/TC 323 is for the following reasons [7]:

- Fundamental issues of the Circular Economy are defined which implications for all industries and elementary components of the transformation;
- In the legislative projects, relevant to the industry such as the Eco-design regulations, the Green Claims Directive, the Critical Raw Materials Acts and the Digital Product Passport, ISO/TC323 standards, especially in the area of definitions risk not being compatible with the main objectives of the legislative projects unless they undergo European adaptation [7].

In CEN/TC350, the standards address just the analytical part of the building assessment system but does not address the valuation part. It should also be noted that the standards do not offer valuation methods, nor do they set levels, classes or benchmarks to understand the performance of the building when they are used. Thus CEN/TC 350 standards assume that the assessment and weighting factors in the performance of buildings have to be addressed by other assessment systems, or as part of national assessment systems. It should be noted however, that initiatives like LEnSE and UNEP = SBCI discuss these assessments and approach to weighting and benchmarking, both on an international level as well as on a European level [102].

The CEN/TC350 *Final Gap analysis Consultation report and findings*, drawn up to summarize the gap analysis work carried out by CEN/TC 350 work groups and the feedback received from National Standards Bodies and other key stakeholders. Nine focus areas were developed in this document. Each area outlines the feedback given by the National Standard Bodies and other stakeholders and the feedback was drawn up in a table for each focus area. Below is a list of the nine areas, a description of what the area encompasses and a concluding summary of the gaps and action required as outlined in the document [104].

6.3.5 Framework and Definitions

Framework and definitions are required to guide and document the standard development process in the field of circular economy in the construction sector [104]. In this way, a common language for all stakeholders involved is established which addresses and encourages stakeholders to define what they need in the standardization process [104]. The framework will establish the boundaries of standardization work and the required interfaces to regulatory systems.

This focus area is addressed by the activities of WG1. This means that this WG will be addressing the feedback as part of their work.

6.3.6 Circular Indicators, Measurements and Assessment

Circularity criteria can be measured using indicators which give quantitative and qualitative insights on how well a product can perform in the context of a circular economy. These indicators were developed by "Ellen MacArthur Foundation" and the European Commission is actively supporting the circular economy in EU States. Towards this goal, an online monitoring tool launched by Eurostat gives users an overview of different circular indicators across EU countries.

From the feedback received it was clear that this is an area which is not aligned and consensus was not given from the stakeholders concerned. There was not any great agreement on the measurement and assessment needed to support circularity, where the gaps are and what methods and data would therefore deliver the requirements. Given the lack of agreement on what should be measured and how, it is clear that more work needs to be done in this area and a dedicated working group should be created to address these requirements. Although one would not ignore the current assessment methods, there is no agreement that the existing approaches and methods are yielding the results needed to assess circularity in relation to costs and benefits [104].

6.3.7 Circular Data, Data Storage and Maintenance and Product/Building Passports

Circular data documentation is an important means to achieve more circular construction in the construction sector. It promotes the reuse of materials, products and elements at a project level while also reducing waste, consumption of raw materials and reduction in the negative environmental impact. The objective for additional documentation on a product and on a project is to "support sustainable production, to enable the transition to a circular economy, to provide new business opportunities to economic actors, to support consumers in making sustainable choices and to allow authorities to verify compliance with legal obligations." (The Circular Economy Action Plan's Sustainable Product Initiative).

By developing a standardization product passport, it is felt that the knowledge of the product content used in the building can be tracked and facilitate the maintenance of the building, as well as the repair and renovation. The passport can also increase the worth of the materials and products when it comes to reuse and recycling. The product passport would also support the goal of the Green Deal and in particular the Circular Economy Action Plan's Sustainable Product Initiative, the EU's Digital Europe Programme and the EU Data strategy. This can be achieved by improving product sustainability and digitalization, boosting material and energy efficiency, enabling new business models and circular value extraction based on data sharing.

In the circular construction world, having the ability to compare and exchange digital representations of objects in construction is essential. Thus, it is imperative that developers of the passports make agreements in this respect, as otherwise, the desired outcome will not be achieved. To facilitate this, harmonized development of digital passports in the EU is essential by defining the format, scope, digitalization, data generation and access for product passports.

It should be noted that the Circularity requirements for EU Taxonomy request digital tools to support enhancing and extending the service life and future adaptations and reuse of materials or buildings. No existing standards to support implementation exist to date.

From the feedback received it seems there is a general agreement that product and building data should be available in digital form to facilitate circularity in construction. Currently there are a lot of activities being carried out at EU level which needs to be considered in this context especially in relation to CPR AQUIS revision, EU taxonomy, Digital Building logbook. There is also a need to further define the data needs in order to then standardise such templates [104].

6.3.8 Planning and Design and Regulations for Circularity (Product/Building/CEW)

The main objective of Circular Economy is to keep materials in a closed loop and extend their lives through the reuse, repair, remanufacture and recycle approaches. Buildings are like material banks in which the ease and ability to deconstruct and reconstruct a building plays a key role in the Circular Economy. Construction waste from one building should be considered as building material for another building.

There needs to be a focus on design building components that include at least the 5 "design for R options". This means: design for reduce, design for reuse, design for repair, design for remanufacture and design for recycling. This means that the using, managing, operation and renovation of a building needs to be rethought.

To avoid gaps and misunderstandings between researchers and industry, Standardization is essential. By having standardized parts for buildings together with standardized systems, will ease the disassembly and repair activities. If buildings are built modular, it will facilitate the repair/replacement/change/upgrade of components without the need to demolish the whole building. To achieve Circular Economy, the technical based obstacles as well as the hurdles in business models and social embracement need to be addressed.

This section outlines a number of gaps which most stakeholders agreed on overall. There are, however, many comments related to the scope and nature of standardization which need to be addressed. It was also highlighted that there are needs for better assessment and pre-demolition auditing to facilitate better use of structure and resources. Having design rules, guidance and indicators related to future disassembly, adaptability and reusability were also highlighted as priorities. From the comments presented in the document, the gap in this area could be split into 2 with one area focused on reuse and the other designing circularity [104].

6.3.9 Construction Site and Resources and Regulations in Context of Circular Economy

Construction and demolition waste is known to make-up for more than a third of all waste which is generated in the EU. Thus Reuse of construction products is an important part of the circular economy process. The waste is made up of a wide variety of materials such as concrete, bricks, wood, glass, minerals, wool, metals and plastics. To reap the full potential of this waste one needs to consider the following steps:

- construction site management of waste,
- resume of residual and cut-off materials,
- take-back for reuse on other sites,
- take-back to reintroduce into the production process,

- planning phase,
- circularity assessment as designed.

Despite the potential of REUSE of construction waste, the level of recycling and material recovery varies greatly across Europe, ranging from less than 10% to over 90% reuse. Since different EU countries apply different definitions of waste, it makes cross-country comparisons difficult. This could be addressed through standardization.

In the document there was a medium to high recognition that further clarification and guidance to support the optimal reuse of structures and products is essential. It also highlighted the importance of supporting recycling and end of waste criteria. References were made to the need to develop technical details related to both reuse and recycling. It was however made clear that issues to address the resume were more urgent than the issues of recycling. Recycling is dealing with materials while reuse is more relevant as an asset, product or component level. Ways to address the concerns of the insurance sector like carrying out non-destructive tests were also highlighted [104].

6.3.10 Operation and Maintenance/Repair/Refurbishment and Regulations in the Context of Circular Economy

Three methods to extend the lifespan of a building or material is maintenance, repair and refurbishment. Maintenance and repair of constructions are effective for extending the technical lifespan and reducing the need of reconstruction. Refurbishment of used construction products on the other hand led to extended lifespan of a product. For effective maintenance, repair and the consecutive use of construction materials in more than one construction-cycle, one needs to design these construction products and elements for this purpose.

Circular CPR AQUIS needs harmonized technical standards to function in such design aspects as intended lifespan, maintainability, reparability and deconstruction ability. Testing is also essential to ensure functionality, health and safety of the products in the next life cycle.

A number of stakeholders referred to draft standard *EN 17680 Sustainability of construction work—Evaluation of the potential for sustainable refurbishment of buildings.* Thus, this standard should be considered before any further gaps related to refurbishment are addressed [104].

6.3.11 Built Environment End-of-Life and Maximizing Resource Retention (Building Product, Material)

This area considered the end-of-life aspects of products and structures in the built environment. The aspects to be considered include process and data needed to support maximizing the value of assets and materials. In the London Circular Economy Statement guidance policy document, a 'waste hierarchy' is illustrated and this can be adapted to convey the relative priority. Another approach is to consider buildings as Material banks and should be used to the highest value possible thus reducing environmental impacts of construction through displacing primary products and materials. This method helps reduce the impact of managing the demolition waste, avoid landfill/disposal and can yield economic benefits.

Dealing with end-of-life materials arising from demolition has been the emphasis for many years. There has been a change with the introduction of pre-demolition/redevelopment auditing and retention of existing assets before demolition commences. Considering the better management of demolition waste has been a property in a number of Member States national policy and EU policy, there is substantial guidance, standards, protocol, tools and policies to consider.

The feedback from the stakeholders had many comments and proposals for additional gaps relating to the End-of-life phase. There is a need for further clarification and refinement of standards especially for pre-demolition audits/appraisals and decision to maximise retention. There were also many gaps raised from previous focus areas, namely in aspects of definitions, decisions relating to refurbish vs demolition, reuse and recycling. The focus should thus be on standardisation related to pre-demolition audit, selective demotion and end-of-waste criteria [104].

6.3.12 Circular Business Models

In order to achieve a circular economy, one needs to develop circular business models to drive it. In linear economy models, the mindset is to 'take, make, use, dispose/recycle'. In a circular economy, however, one needs to shift away from this mindset. The alternative approach for a better alignment with the circular economy is related to the way construction products and materials are supplied.

The first shift in mindset is to see buildings as material banks which need to be 'mined' instead of the reliance on new products (including recycled materials). These banks could be from deconstruction of existing assets or acquiring from digital marketplaces often called material exchanges. As already mentioned in previous areas above, the reuse of existing materials has its multiple benefits as well as issues to consider. Suppliers could also consider a shift from supplying products to services or at least offer to retrieve the product back for reuse, remanufacturing or other recovery. If a supplier is permanently tied to its product, it will be in the supplier's interest to design products which are easily modified and maintain their value.

The stakeholders did not support the gaps in this focus area mainly due to national policy and markets dictating the activities discussed in this area. Reference was also made to other focus areas like circular procurement and standardization gaps for promoting reuse and recycling of products and materials [104].

6.3.13 Circular Procurement

This area deals with different procurement processes within the European Commission such as the Green Public Procurement (GPP), The Socially Responsible Public Procurement (SRPP) and the ISO 20400: 2017 Sustainable Procurement. The procurement process is a key component meant for Organisations to interact with their supply chain. This can drive change in the product ecosystem. The procurement process and collaboration therein are essential to achieve change from linear to circular economy.

The following documents are considered important in relation to circular procurement in Europe. There are namely:

1. The Level(s) framework—this document focuses on life cycle environmental performance, health and comfort, cost, value and risk.
2. The EU GPP—this document aims to create a good balance between environmental performance, cost consideration, market availability and ease of verification.
3. Planform CB '23 Guide "Measuring Circularity in the Construction Sector 2.0"—this document proposes three goals for circular construction which are:

    - environmental protection,
    - to protect stocks of material,
    - value retention.

The guide also addresses social fairness. This area scored low for all the preliminary gaps. It was uncertain if this was something that should be done outside of the national boundaries. Since certain areas are still evolving at EU level with Level(s) and EU Taxonomy, this area is not considered a priority to date. It was felt that Standardization would be needed prior to specifying the context of circular procurement [104].

6.4 Case Studies in Standardisation

6.4.1 Recycled Aggregate

An extensive overview of standards describing the use of recycled aggregate in concrete is presented in the study by Pacheco et al. [105]. According to this study, the requirements can be divided into two groups based on the aggregate use. The first group is addressed by standard, EN 12620 which defines the quality of the recycled aggregate [106]. The second group is described in EN 206 [107] and deals with the incorporation ratio of RA in concrete. Both of these standards have their specifications at national levels. Therefore, RA's maximum allowed incorporation ratios for structural use differ among European countries. For example, in Denmark, for use in low to moderate exposure requirements, fine aggregates can be used up to 30% of the incorporation ratio ($\leq$ C30/37) and coarse aggregate up to 100% ($\leq$ C40/50) [108].

In France, the standard NF EN 206-1/CN describes different conditions based on recycled aggregate size and allows use of up to 30% of RA for low-demanding exposure classes. In Italy, the use of RA is described based on Ministry Decree NTC:2018, and its incorporation rate depends on the origin of the RA and the strength class (e.g. 60% for non-demanding structural concrete (C20/25) and moderate quality RA; 30% for C30/37 and high-quality RA). Requirements are implemented using national specification LNEC E471 in Portugal, where high-quality coarse aggregate from waste can be used up to 25% of total aggregates (fine + coarse) ($\leq$ C40/50) and even in most environmental exposure classes.

Recycled aggregate was standardised in Malta using the SM820—Classification of Recycled Aggregate, which describes technical parameters for the classification of waste aggregate [64].

The Czech version of the European Standard (CSN EN 206, 2014) outlines the exposure classes for various environmental actions along with the recommended technical limits for concrete composition and strength classes [109]. Within the X0 environmental classes, there are sub-classes that specify the humidity levels in different environments. Each class must adhere to the requirements for a minimum amount of cement, a maximum water-cement ratio, and a minimum compressive strength class. Recycled aggregate in concrete must comply with the geometrical, physical, and chemical properties outlined in (EN 12620, 2002; CSN EN 12620+A1, 2008) [106, 110]. Some crucial properties are detailed in (CSN EN 206-1/Z3, 2008) and the updated Czech European Standard (CSN EN 206, 2014) [111].

6.4.2 Deconstruction and Reuse of Elements

A key element for proper waste management of construction materials is sorting Construction Demolition Waste (CDW) at a deconstruction site. Therefore, multiple

documents tend to standardise this approach. Historically, the example of good practice is Austrian standard ÖNORM B 3151 Dismantling of buildings as a standard method for demolition, which describes the standardised approach for each deconstruction where more than 100 t of CDW will be produced and the scope of information depends on the volume of the building (greater or smaller than 3500 m^3) [112]. Nevertheless, pre-demolition audits are mandatory in projects where waste production is estimated to be higher than 750 t. It describes the pre-demolition audit and prescribes an assessment of dangerous compounds and materials interfering with the future recycling process in the demolished construction and how to eliminate their occurrence in the waste flows. Furthermore, prescribed forms for the declaration of materials are presented in the document appendix. It also suggests what material flows should be declared in the pre-demolition audit and recommends waste management scenarios. The standard, however, is focused on main materials such as asphalt, concrete, excavated soil, wood, and metals.

At European standardisation level, the key document is the EU Construction and Demolition Waste Protocol and Guidelines 2018 [113], which is currently under revision. In the revised version, renovation is recommended as a preferred option of how to deal with a building after its end of life. To support this, the guideline stressed the importance of digital building logbooks (DBL), which provide building data in a more interoperable manner. This approach opens space for the implementation of standards related to building renovation passports, building material passports, and digital product passports, which should support the user in better maintaining products and services and thus prolong the service life of building products and buildings. Furthermore, this guideline standardises the steps of a pre-demolition audit, such as the definition of the scope of the audit, study before inspection, field survey, inventory of materials, resource and waste management recommendations, reporting, and further traceability. In addition, it describes the requirements for auditors. This guideline also standardises the procedure for selective deconstruction, which should be performed in the following steps: interruption of supply and drainage lines, removal of furniture, removal of hazardous substances and materials, removal/dismantling of non-load bearing structures (ceilings, floor coverings, doors, windows etc.), demolition of load-bearing structures, demolition/removal of foundations and ground covers.

In relation to waste management, JRC's Best Environmental Management Practices provides guidelines and recommendations in relation to CDW management and suggests the use of a life cycle perspective in consideration of waste management scenarios [114].

For instance, in the Czech Republic, there is a guideline for pre-demolition audits, which is not mandatory. The EU CDW protocol focuses mainly on the separation of dangerous waste and, similarly to Austrian standards, suggests protocols that can help auditors identify the main material flows. Currently, a new standard is being prepared, which also focuses on recommended reuse and recycling approaches and combines information among the circular value chain from pre-demolition audit to selective deconstruction and waste management.

In Malta, the procedure of selective deconstruction is standardised by SM810 for recycling-oriented Deconstruction and Classification of Waste [64], 65. Together with SM820, standards were developed to cover deconstruction and use of aggregates with focus on proper classification to support the implementation of circular principles and minimize consumption of primary resources [64]. SM810 covers information related to planning, classification of waste and conducting demolition operations. SM810 mentions also practice based on BS 6187:2011, which prescribes demolition practice in Great Britain [115].

In other European countries, the threshold for performing a pre-demolition audit differs. For example, in Sweden, pre-demolition audits are always required [116]. In some countries, such as Germany, the pre-demolition audit is mandatory with a focus on the identification of dangerous materials, also considering the possible risks for workers at building sites [117]. At least an inventory of materials present in the buildings is mandatory in Flanders for non-residential buildings with volumes higher than 1000 m^3 [116]. Inventory and intended waste management scenarios are mandatory in the Netherlands for each building demolition, where more than 10 m^3 is produced [117]. Among other construction and demolition waste flows, asbestos waste is a dangerous type of waste that must be audited in most of the countries in the European Union [118].

6.4.3 Reuse of Products

Besides the implementation of standards for deconstruction, there is a growing emphasis on the concept of re-utilisation or reuse of products. This circular strategy is, according to the hierarchy of waste management, the most prioritised one as it results in the keeping of the value of the product. According to the ISO standard focusing on design for disassembly, reuse is defined as the use of products or components more than once for the same or other purposes without reprocessing [119]. Therefore, efforts are being made to establish and broaden markets for re-utilisation and to devise structures that support it. This includes defining the status of reused products, setting responsibility guidelines, and adopting quality standards and certificates for construction products. In addition, standards should be implemented to reduce legislative hurdles.

Furthermore, to make reuse more accessible, new physical and digital platforms and networks are being developed to link the providers and consumers of materials from deconstruction. These platforms can play a role in all stages of a project, from planning to execution [120, 121]. For instance, reclaimed materials from the regions of France, Belgium, and the Netherlands are well described at Project Opalis, which provides technical documentation on the most common construction products [121].

In addition, Finland has introduced Materialitori, a waste information platform that also serves as a marketplace for reusable products, waste by-products, and recyclable materials [122]. Similarly, the Netherlands is promoting re-utilisation in the

construction sector through the use of material passports and the Concrete Agreement. This agreement brings stakeholders together to collaborate on enhancing the sustainability of concrete, including the re-utilisation of concrete [123].

Reuse is generally used as a term for any activity that leads to the re-utilisation of products and prolongs their service life. However, based on the final use, two types of reuses can be identified: (1) reuse for the same purpose and (2) reuse for different purposes (re-purposing). The second option leads to finding a new place in new construction, where the product will have a different function. The advantage of this approach can be that the product does not need to fulfil technical requirements for the original function, and its new function is, for example, rather aesthetical. On the other hand, this approach can result in just time-limited use, where the product is exposed to conditions that it is not intended to use. Thus, it can lead to a shorter service life and may be considered in some situations as only the scenario expanding the time before landfilling. To maximise the reuse of products and find the proper function, several standards have been implemented. The important perspective on the assessment of the quality of reclaimed materials is described in the guideline, which focuses on best practices in France, Belgium, and the Netherlands [124].

Acknowledgements The authors of this chapter would like to thank the European Union and COST (European Cooperation in Science and Technology) for supporting the COST Action CircularB CA21103. www.circularb.eu.

This chapter was developed with the support of, and within the framework of the CircularB research project. The following Circular Economy experts and practitioners are also acknowledged for their participation in the questionnaire. Their responses to our survey provided key insights into the implementation of circular economy standards across Europe and beyond: Daniel-Viorel Ungureanu (Romania), Jan Pešta (Czech Republic), Vanessa Tavares (Portugal), Ivana Carevic and Ivan Lukačević (Croatia), Mercedes del Rio (Spain), Meri Cvetkovska (North Macedonia), Marilena de Simone (Italy), Olivera Bukvić (Serbia), Visar Krelani (Kosovo), Bengü Güngör (Turkey), Ekaterine Kardava (Georgia), Simon Duindam (The Netherlands), Sandra Gusta (Latvia), Haitham AbuGhaida (Belgium), Ruben Paul Borg (Malta), Paul Archbold (Ireland), Jan Kazak (Poland), and Peter Griffiths (United Kingdom).

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