Study on measuring the application of circular approaches in the construction industry ecosystem

Final study

Written by Chloé Brincat, Indira de Graaf, Cleónice León Vargas, Andreas Mitsios and Nina Neubauer (Deloitte) and Katherine Adams and Gilli Hobbs (Reusefully)
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GLOSSARY

Term	Definition
BIM	Building Information Modelling
BoQ	Bill of Quantities
BPIE	Building Performance Institute Europe
BREEAM	Building Research Establishment Environmental Assessment Methodology
C&D	Construction and demolition
CE	Circular Economy
CEAP	Circular Economy Action Plan
CEW	Civil engineering works
CSR	Corporate Social Responsibility
DDC	Danish Design Center
DGNB	German Sustainable Building Council (Deutsche Gesellschaft für Nachhaltiges Bauen)
DMA	Dynamic mechanical analysis
EDA	European Demolition Association
EoL	End of Life
EPD	Environmental Product Declaration
ESG	Environmental Social Governance
GDP	Gross domestic product
GJ	Gigajoules
GLA	Greater London Authority
GRI	Global Reporting Initiative
GSI	Global Solutions Initiative
Institute NEN	Royal Netherlands Standardization Institute
ISO	International Organization for Standardization
IT	Italy
ITACA	Italian Institute for Innovation and Transparency in Public Procurement and Environmental Compatibility
KPIs	Key Performance Indicators
LCA	Lifecycle analysis
LCC	Life Cycle Costing
LCI	Life Cycle Inventory
LEED	Leadership in Energy and Environmental Design
MCI	Material Circularity Indicator
MEAT	Most Economically Advantageous Tender
MFA	Material Flow Accounts
NMD	Nationale Milieudatabase (Dutch Environmental Database)
PDA	Project Development Assistance
PEMD	Produits, équipements, matériaux et déchets issus du bâtiment (products, equipment, materials and waste related to demolition of buildings)
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (EU Regulation)
REN	Dutch Real Estate Norm
SDG	Sustainable Development Goals
SME	Small and medium-sized enterprise
WLC	Whole Life-Cycle Carbon

ABSTRACT

The construction ecosystem contributes some 11.5% of the EU's Gross Value Added and employs almost 25 million people in over 5 million firms, most of which are SMEs[1]. In line with the Circular Economy Action Plan[2], the transition to a circular economy in construction has the potential to enable more value to be retained within the industry's value chains and offer new opportunities for innovation, as well as reducing environmental impacts.

This study presents new insights on the uptake of circularity approaches, obtained from 300+ stakeholders from across the EU construction ecosystem. The work found that while the vast majority of construction ecosystem stakeholders consider the transition to a circular economy to be a priority, only a minority of them (below 25% on average) actively measure their own circular approaches.

To facilitate this transition, barriers need to be overcome, including the lack of standardisation and interoperability of data and measurement approaches, as well as data availability issues across value chains. Drivers can be explored to counteract these barriers, including harmonising data formats across the EU/industry, encouraging circular business opportunities, and regulating in support of the circular transition.

To support future measurement of the uptake of circular approaches in construction, the report recommends indicators that construction ecosystem actors could use at four different levels: product/material; building/infrastructure; organisation/process; and urban.

[1] European Commission (2023), Transition Pathway for Construction. https://ec.europa.eu/docsroom/documents/53854
[2] COM(2020) 98 final

EXECUTIVE SUMMARY

The need to boost the uptake of circular approaches in construction

Transitioning to a circular economy is particularly important for the construction industry ecosystem, which is currently responsible for over one-third of total waste generation in the EU[3]. Currently, the largely linear economic model puts significant pressure on the extraction of raw materials, with buildings alone in the EU accounting for two-thirds of cement use, more than a third of steel, a quarter of aluminium, and almost 20% of plastics[4]. Producing these materials results in about 250 million tonnes of CO_2 emissions annually, which could be reduced if more resources were reused and recycled[5].

On the other hand, the construction ecosystem is very important to the EU economy, as it employs 24.9 million people and provides a value added of EUR 1 158 billion (9.6% of the EU total)[6]. It also drives economic growth by creating new jobs, while it provides solutions for social, climate and energy challenges.

The EU has developed a number of industry-specific measures and proposals to support the uptake of circular approaches for construction. This includes the Renovation Wave strategy[7] and Construction Products Regulation revision proposal[8], as well as more recent developments such as the Transition Pathway for construction[9] and the EU Taxonomy's environment Delegated Act (expected 2023), which sets out criteria for economic activities, including construction and real estate, that constitute significant contributions to the transition to a circular economy.

To ensure the success of these initiatives and the overall ambition to make the construction industry ecosystem more circular, it is important to understand levels of uptake of circular approaches and the barriers and drivers faced by the value chain in making this transition. Given limitations in current reporting and data availability, this study assessed and consulted 300+ stakeholders to collect new data from across the value chain to assess activities, challenges, and future intentions.

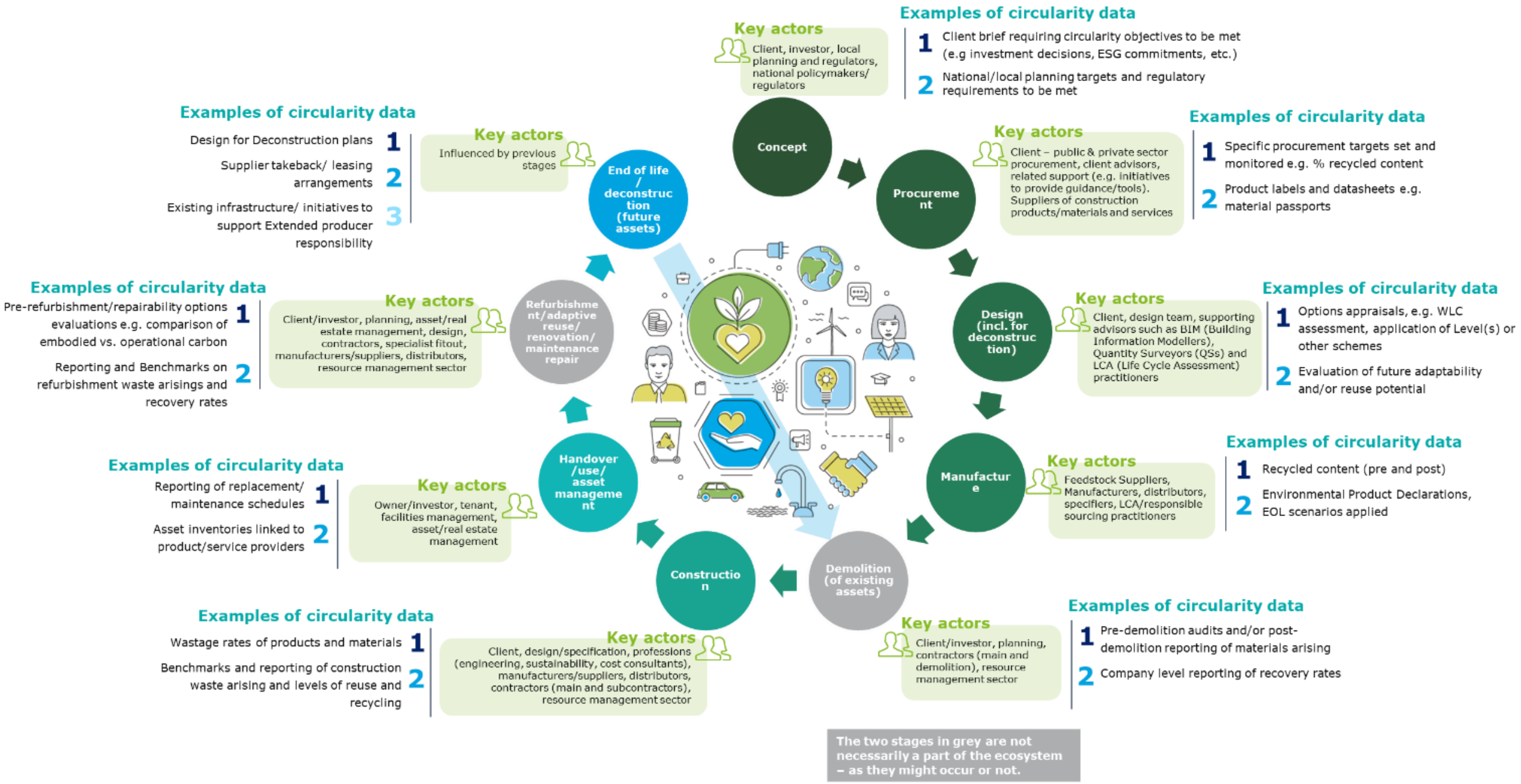
Understanding the current uptake of circular approaches in the construction industry ecosystem

As demonstrated by the levels of waste and raw material extraction associated with construction, the industry could do better when it comes to adopting circular approaches. Whilst voluntary frameworks such as Level(s)[10] are playing an important role in facilitating and harmonising circularity performance measurements, the scarcity of legal obligations to report across the value chain, as well as the lack of available data, is likely holding back large-scale uptake.

This study collected additional data from stakeholders primarily through consultations, including surveys, workshops and interviews. To do this, the study team first mapped out the different sections of the construction industry value chain, including identifying key actors and relevant data to support the measurement of the uptake of circular approaches. This is illustrated in the figure below.

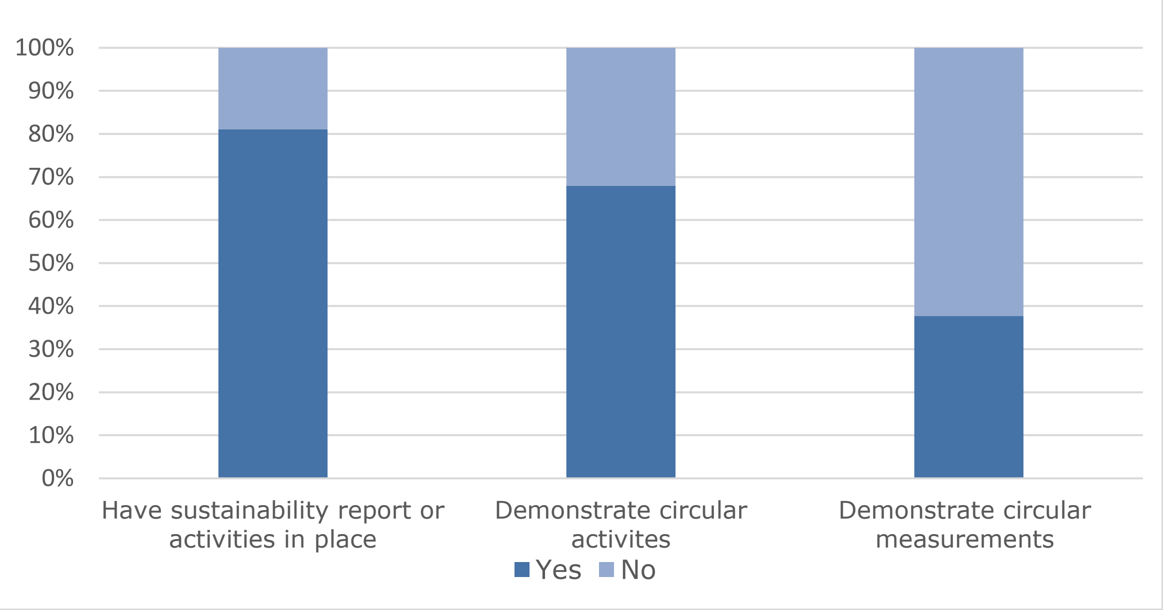
3 Eurostat, 2018. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics
4 Ibid.
5 Ibid.
6 European Commission (2023), Transition Pathway for Construction. https://ec.europa.eu/docsroom/documents/53854
7 COM(2020) 662 final
8 COM(2022) 144 final
9 European Commission (2023), Transition Pathway for Construction. https://ec.europa.eu/docsroom/documents/53854
10 Level(s): European framework for sustainable buildings. https://environment.ec.europa.eu/topics/circular-economy/levels_en

Figure 1: Infographic of the EU construction industry ecosystem value chain



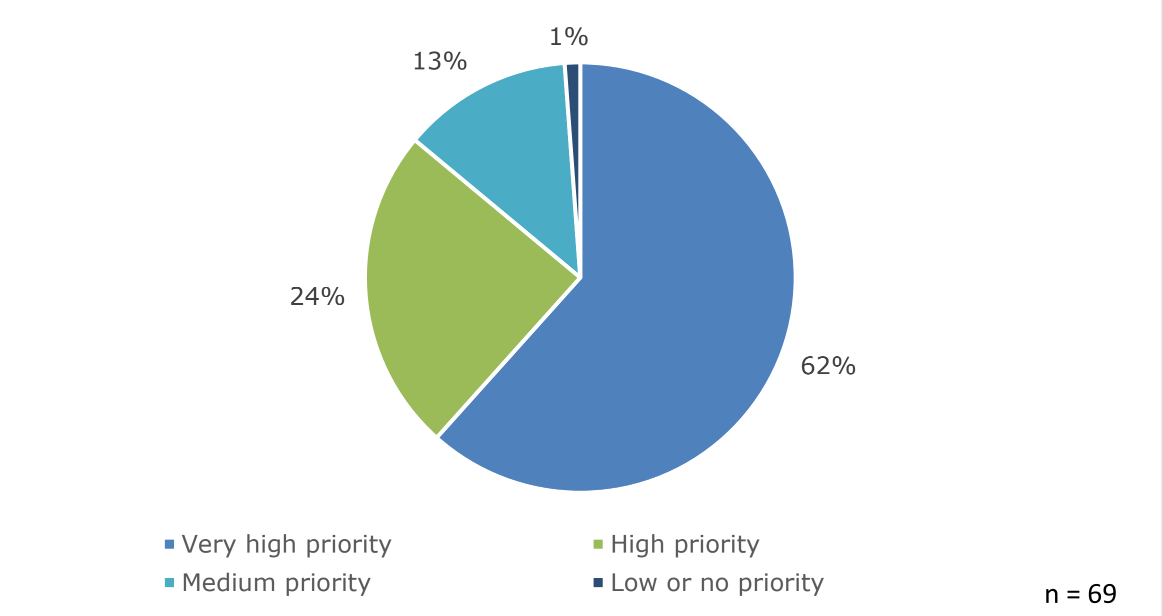
The data collected from across the construction industry value chain as part of this study found a strong level of engagement and interest in sustainability issues – including circularity – even if specific circular approaches have not always been adopted. For example, out of publicly available data analysed for 174 construction companies (summarised in Figure 2), 68% mentioned circularity activities as part of wider sustainability strategies. Regarding reporting, only 38% of these companies had published reports covering their circularity performance.

Figure 2: Summary of desk research carried out on 174 construction companies



In terms of levels of engagement in the circular transition, the study's first survey of construction industry stakeholders (summarised in Figure 3) showed that the vast majority (86% respondents) see implementing circular approaches as either a high or very high priority, and only 1% said it was low/no priority.

Figure 3: Level of priority placed on implementing circularity approaches

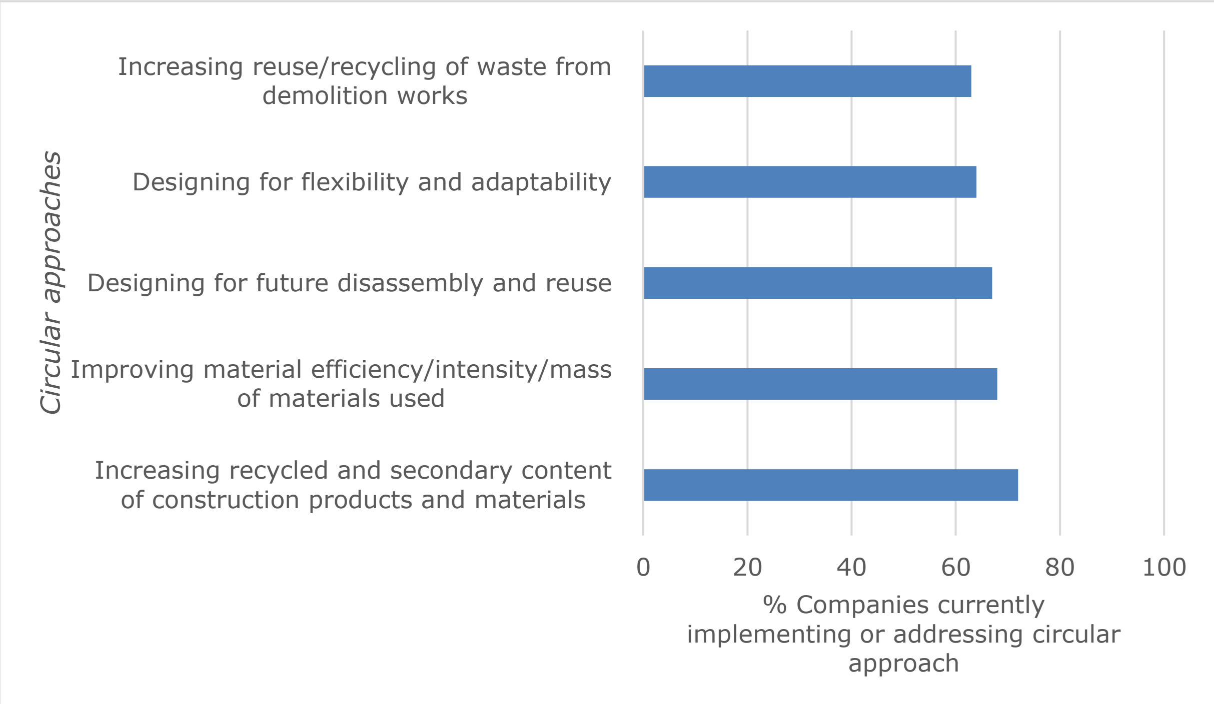


Consultation activities carried out across the study reinforced the fact that while the level of industry engagement in circular approaches is relatively high, only a minority of stakeholders are currently actively measuring circularity performance, with the highest share of surveyed stakeholders (29%) actively measuring reuse/recycling of waste from demolition activities. Responses were higher when respondents were asked about upcoming/future measurement ambitions. The reasons for low levels of current reporting are set out in the barriers section of the report below and include lack of availability of data and reporting obligations.

In terms of current activities – which may not yet be reported in a systematic way by companies – the second survey showed that the majority of companies are currently implementing and addressing circular approaches within their organisations. The top five approaches reported were:

1. Increasing recycled and secondary content of construction products and materials
2. Improving material efficiency/intensity/mass of materials used
3. Designing for future disassembly and reuse
4. Designing for flexibility and adaptability
5. Increasing reuse/recycling of waste from demolition works

Figure 4: Top 5 circular approaches currently implemented



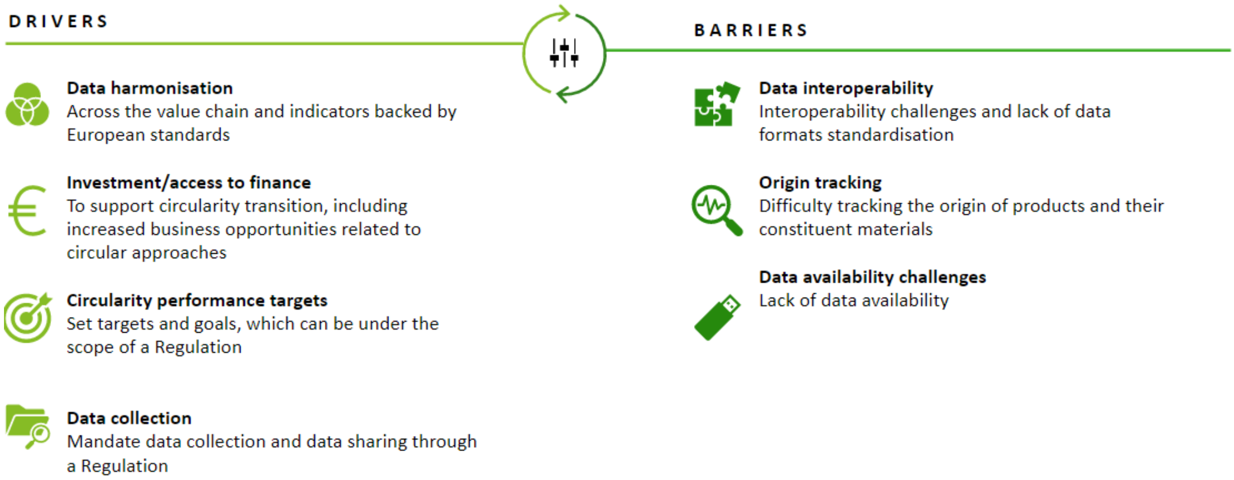
Drivers and barriers influencing the uptake of circularity approaches

To understand the underlying factors influencing the uptake of circularity approaches, the study assessed the existence of drivers that facilitate the implementation of circular approaches, as well as barriers that hinder it.

Data collected throughout the study highlighted a number of general drivers and barriers that span multiple stakeholder types and value chain stages, which are summarised in

Figure 5.

Figure 5: Overview of general drivers and barriers to measuring circularity performance



The study also includes further insights on drivers and barriers provided by stakeholders related to different value chain levels, for example highlighting that the Digital Product Passport initiative will drive increased reporting and data sharing at the product level.

Recommended indicators to measure the uptake of circularity approaches

To measure the future uptake of circular approaches in the construction industry ecosystem, the study proposes a series of indicators (set out in Table 1) that can be applied to the following four levels:

- Product or material level – concerning the materials and products that are used within construction
- Building or infrastructure level – at the whole asset level, for construction works e.g. road, bridge etc
- Organisational level - across a construction-related company's body of work, usually with data aggregated from the organisation's activities
- Urban level – this is at a municipality/city level

These indicators were shortlisted from a long-list of indicators according to the following criteria:

1. **Data**, including data availability, accuracy and timeliness;
2. **Availability of standard measurement methodology;**
3. **Current measurement**, taking into account voluntary or mandatory measuring;
4. **Ease of measurement,** now and in the future;
5. **Relevance** assessed with the link between the indicator and broader circularity goals;
6. **Drivers and barriers** (including willingness of target groups to record data).

Mind-mapping exercises and expert interviews were then used to map connections between potential indicators and prioritise 'core' indicators from 'supplementary' indicators (some of which are sub-sets of the core indicators). The table below summarises the recommended 21 core indicators and the typical units used to measure them (5 at product level, 9 at building level, 5 at organisational level, 2 at urban level). The report also contains 19 supplementary indicators (5 at product level, 7 at building level, 4 at organisational level and 3 at urban level).

Table 1: Summary of recommended core indicators for each level of activity

Core indicators (units)
Product or material level
P1: Reused product (yes/no)
P3: Recycled/secondary content (% by mass)
P6: Predicted service life (years)
P7: Hazardous waste (% by mass)
P8: Realistic end-of-life scenarios developed (yes/no)
Building or infrastructure level
B2: At concept stage: comparison of asset life cycle assessment (Depends on impact categories, e.g. $kgCO_2$ eq/ m^2/yr)
B3: At design stage: Material intensity/ dematerialisation (kg/m^2/yr)
B4: At design stage: reused content (% by mass)
B5: At design stage: recycled content (% by mass)
B7: Designed for disassembly/ deconstruction (% reuse potential by mass)
B8: Construction waste generated on and off site (tonnes/100k EUR)
B10: Construction waste reused, recycled, recovered, landfilled (% by mass)
B14 : Demolition waste generated (tonnes)
B16: Demolition waste reused, recycled, recovered, landfilled (% by mass)
Organisation or process level
O2: Predicted service life of buildings/infrastructure portfolio (average number of years)
O3: Average reused and recycled content in new buildings/infrastructure (circular inputs) (% by mass)
O4: Reused and secondary content input (% by mass)
O5: Non-hazardous waste arisings (tonnes/100k EUR)
O7 : Waste management routes (% by mass/year)
Urban level

U1: Construction and Demolition waste generated in a defined urban area (tonnes per capita)
U2: Recycling/recovery rate of construction and demolition waste (% by mass)

By identifying data requirements and synergies between indicators, as well as linking indicators to specific circular approaches and value chain stages, the report provides industry and policy makers with a tool box that can be used to develop circularity performance measurement systems. In particular, this toolbox can be used to reduce administrative burdens by aggregating data at different project levels to give different insights on circularity performance. Looking forward, the use of these indicators and systems will give the policy makers and industry a clearer view on the uptake of circular approaches and remaining barriers to be overcome.

INTRODUCTION

Study objectives

Despite wide-ranging policy efforts across the EU to increase the uptake of circularity approaches in the construction industry eco-system, the lack of publicly available and standardised data makes it difficult to assess the effectiveness of these policies. This study aims to address this by:

1. Providing an overview of the current status of the uptake of circular approaches in the EU construction industry ecosystem

2. Identifying and prioritising indicators that can be used to measure the uptake of circular approaches in the EU construction industry ecosystem

3. Assessing drivers and barriers that influence, facilitate or prevent the reporting of data to measure the update of circular approaches

To achieve these key objectives, the study followed the following methodological steps:

Methodology

Desktop research was used to collect and analyse publicly available information about stakeholders in the EU construction industry. This research included mapping out key actors across the construction industry ecosystem value chain and analysing public available data related to their activities. This includes an analysis of the sustainability and circularity activities of 174 companies from across the construction industry ecosystem.

The study team **consulted over 300 stakeholders** including by conducting two surveys and two workshops with stakeholders from the construction industry to:

- Collect data on current activities, including the extent to which stakeholders are currently measuring circularity performance
- Gain broader insights into the status of circularity across different sections of the value chain, including through selecting case studies
- Test preliminary findings on indicators to refine the final recommendations of this study

These insights and data were supplemented with expert interviews which were carried out at the end of the study to develop a range of case studies, linked to recommended indicators and required data, and to further refine the study recommendations.

Finally, on the basis of the data collected through desktop research and stakeholder consultation, the **shortlisted indicators** were further assessed against a set of criteria to select 'core indicators' to be recommended. This analysis also identified synergies between indicators where the same or similar data can be collected to measure performance against more than one indicator.

Structure of this report

The study is split into three sections:

- The first section set out the **current status of the uptake of circularity in the EU construction industry ecosystem**. This includes the mapping of relevant data and stakeholders across the full value chain.

- The second section **identifies indicators that can be used to measure the uptake of circular approaches in the EU construction industry ecosystem.**

- The third section sets out the **drivers and barriers** that are influencing, facilitating or preventing the measurement of circular approaches in the EU construction industry ecosystem. These are also broken down as far as possible into the four levels set out above.

Finally, the **findings and conclusions** evaluate the shortlisted indicators using all the data collected throughout the study in order to propose a final set of core indicators in the **recommendations.**

The reports Annexes provide further background on the study:

- Annex A includes the indicator profiles for all shortlisted indicators
- Annex B includes 8 case studies showing good practices in the uptake and measurement of circular approaches
- Annex C includes the list of 174 companies that were used for the desktop research on current industry uptake of circular approaches
- Annex D gives an overview of the research undertaken on data collected across the construction industry ecosystem value chains
- Annex E provides the scoring given to shortlisted circularity indicators
- Annex F gives further details on drivers and barriers related to the uptake of circular approaches
- Annex g includes the references and sources of information used for this study

ASSESSING THE UPTAKE OF CIRCULAR APPROACHES IN THE CONSTRUCTION INDUSTRY ECOSYSTEM

This section presents the study's assessment of the current uptake of circular approaches in the EU construction industry ecosystem, bringing together data collected through desktop research and stakeholder consultations. This starts with a mapping of the construction industry ecosystem value chain and relevant circular approaches to be assessed; we then present our analysis of the current uptake and measurement of circular approaches. Finally, this section includes an overview of the data collected for each value chain stage.

Mapping the construction industry ecosystem value chain and circular approaches

Circular approaches can be applied across all the stages of the construction industry value chain, whether it is at the design, use or end-of-life phase. This is why it is relevant to understand what the common stages in the construction industry value chain are, as each stage allows for the possibility to apply circularity approaches in a different way. Based on our data collection activities, i.e. interviews with stakeholders and consultation survey, we have identified nine different value chain stages that form part of the value chain and where circular approaches can take place (illustrated in Figure 1):

- **Concept:** during this stage it is possible to lay out the first steps of a project. It is where initial ideas are outlined regarding the building design, the durability of the project, the resilience of the materials to be used; the different use scenarios in mind and the suitability of the different solutions, parts and construction products. All these initial concepts/ideas will be further set down in the design phase.

- **Procurement:** this stage is relevant for the acquisition of goods and services prior to the construction phase. It is where the project's environmental impact can be assessed. The main actors involved in this phase are able to specify sustainable building approaches that should be used in tenders/proposals.

- **Design (including design for deconstruction):** in this stage the ideas of the concept stage are made more concrete. Plans, schematics and details regarding the construction project are developed. This stage is relevant for implementing circular economy principles in the design requirements and strategies and for considering aspects such as the use of recycled materials, the future reuse potential and recyclability capacity of both the building and the materials to be used, as well as the building's/infrastructure's transformation capacity.

- **Manufacture:** during this stage the creation of goods takes place. This stage is relevant as it is possible to ensure the product durability, and the products' recycling and recovery potential. It is also a relevant stage to reduce the use of hazardous substances that hamper the reuse/recyclability and thus curb the products' use in buildings due to these reuse/recyclability challenges.

- **Demolition (of existing assets)[11]:** this stage consists of the dismantling of existing assets (e.g. buildings/infrastructure or parts thereof), which occurs through pre-planned and controlled methods. In this stage, the reduction of waste and a high-quality waste management plan are relevant to separate materials resulting from the demolition into batches with an appropriate place of destination/treatment. During this stage it is also possible to do a preliminary on-site sorting of all waste, where hazardous and non-hazardous waste is separated accordingly.

- **Construction:** this stage consists of the assembly and erection of the structure(s) designed previously. Construction techniques are relevant as these may promote the durability of buildings and the resilience of the materials, and also promote the

11 Demolition of existing assets is marked in grey in the Figure 1, since this stage is not always present in the lifecycle of the building.

adaptability of buildings/infrastructure. Appropriate construction techniques also contribute to an easy and clean building deconstruction in the future.

- **Handover, use, asset management:** during this stage, the formal finalisation of the project takes place. The end-users of the project begin to use the building/infrastructure. Asset management maximises the usability due to the collection of critical asset performance data in real-time, which leads to an understanding of the asset's complete life cycle. Asset management is relevant because it adopts life cycle thinking in realising full value from the assets and allows for decision making in terms of e.g. greener investment in production systems; investments/practices to increase energy and material efficiency; using, maintaining and remanufacturing production systems which can be reused and recycled at the end of their first life; etc.

- **Refurbishment, adaptive reuse, renovation, maintenance and repair**[12]: this stage ensures the building/infrastructure is remodelled, refashioned, renovated, adapted or improved. This stage is relevant since adoption of circular economy principles can reduce the use of materials in existing buildings and minimise emissions embedded in building materials. Moreover, existing buildings/infrastructure can be extended in their lifespan and the intensity of building use can be increased. Overall, this stage reduced the demand for new construction, which consumes more materials than renovating, repairing, maintaining and refurbishing existing buildings.

- **End of life and deconstruction of future assets:** during this stage the selective dismantling of building/infrastructure components occurs for the purposes of reusing, repurposing, recycling and managing waste. Deconstruction represents value for the circular economy goals since it is possible to extract high-value materials for resale or reuse. These materials include steel, wood, aluminium, furnishings and finishes, which all can be reused and/or repurposed for future use. Within each stage, the stakeholders identified (such as government/regulators/local authorities and those within the financing and planning/design stages) have key roles to play for the uptake of circular approaches. In addition to this, stakeholders are also relevant for data creation which facilitates the measurement of circularity.

The study identified a list of circular approaches to be used for the measurement of activities, which are listed below:

- Product as service, new business models
- Designing for future disassembly and reuse
- Designing for flexibility and adaptability
- Improving material efficiency/intensity/mass of materials used
- Improving durability, lifespan, repairability of construction works
- Increasing recycled and secondary content of construction products and materials
- Increasing direct reuse of products and materials
- Increasing reuse/recycling of waste from construction works
- Increasing reuse/recycling of waste from demolition works

12 The stage of refurbishment, adaptive reuse, renovation, maintenance and repair is marked in grey in figure 1, since this stage is not always present in the building's lifecycle.

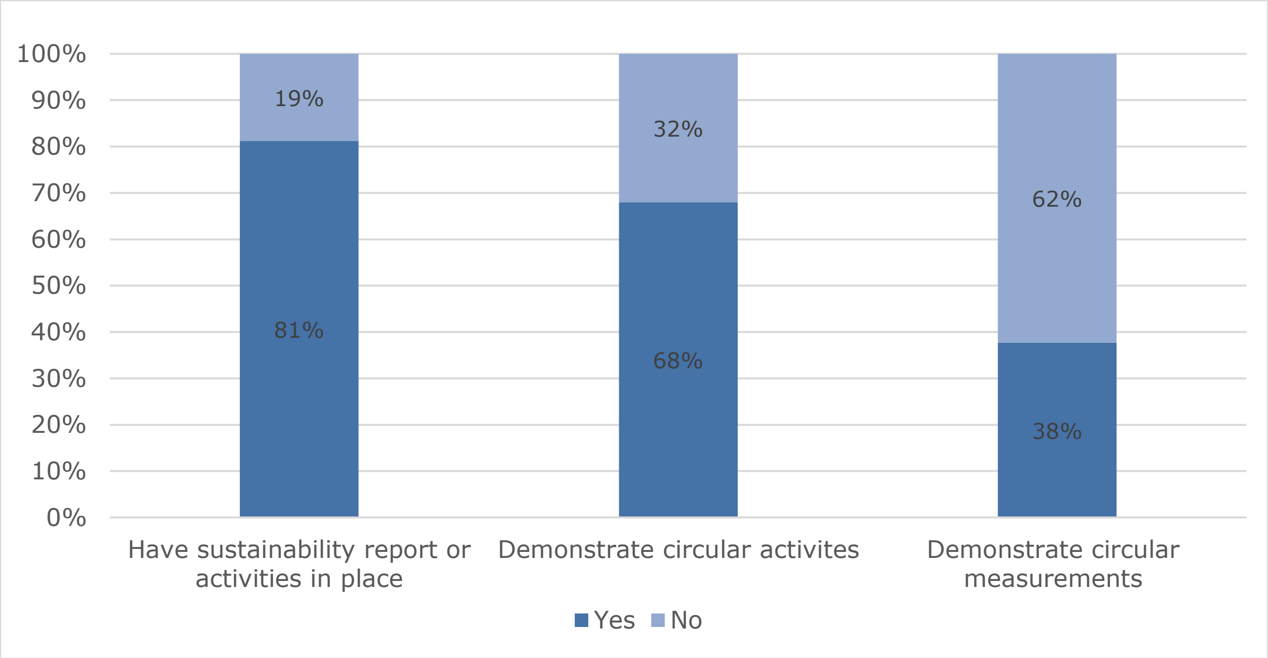
- Reducing waste/wastage rates/waste generation from construction activities
- Lifetime extension e.g. through retaining and refurbishing

Analysis of data collected on the uptake of circularity

As a first step to understanding the current state of play, the study team analysed the websites of 174 stakeholders[13] in the construction industry ecosystem. The purpose was to identify whether these companies have sustainability reports in place or mention circularity, before assessing approaches to circularity in more detail.

This research showed that 81% of these stakeholders had a sustainability report in place or were carrying out activities to improve their sustainability. 68% of the stakeholders scanned also mentioned circularity as part of these activities, while only 38% were reporting their circularity performance.

Figure 6: Share of companies that have sustainability or circularity activities in place today



To understand how these results vary by stakeholder type, the study team divided the stakeholders into the following groups:

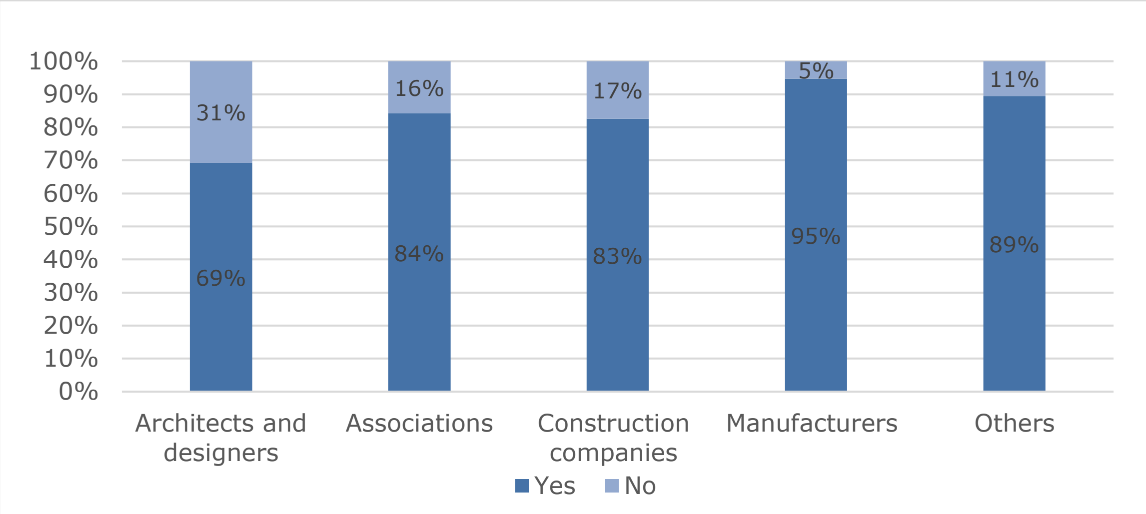
- Architects and designers (incl. engineers)
- Associations (incl. asset management, building control, demolition contractors, distributers and logistics, facility manager, feedstock suppliers)
- Construction companies
- Manufacturers
- Other (including real estate companies, insurers, consultants)

Based on the companies we have looked into, manufacturers appear to be the stakeholder group that have the highest share of sustainability report or activities in place (95%)

[13] See Annex C for the total list of companies analysed

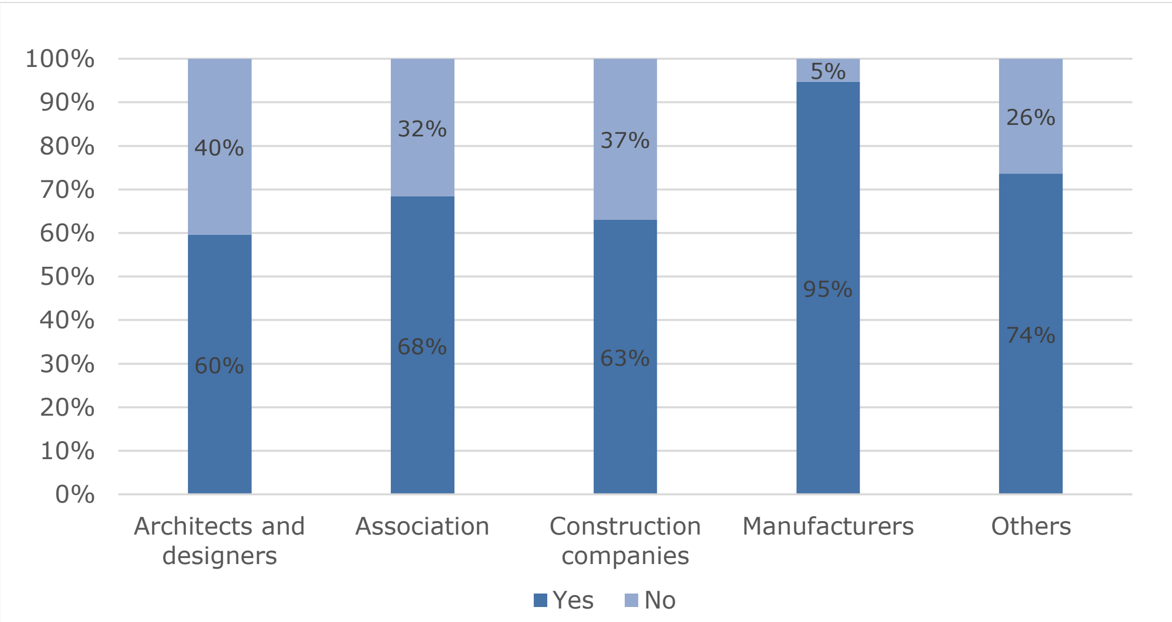
whereas only 69% of the architects and designers surveyed had sustainability reports/reported activities in place.

Figure 7: Share of companies that have a sustainability report or activities in place – by company type



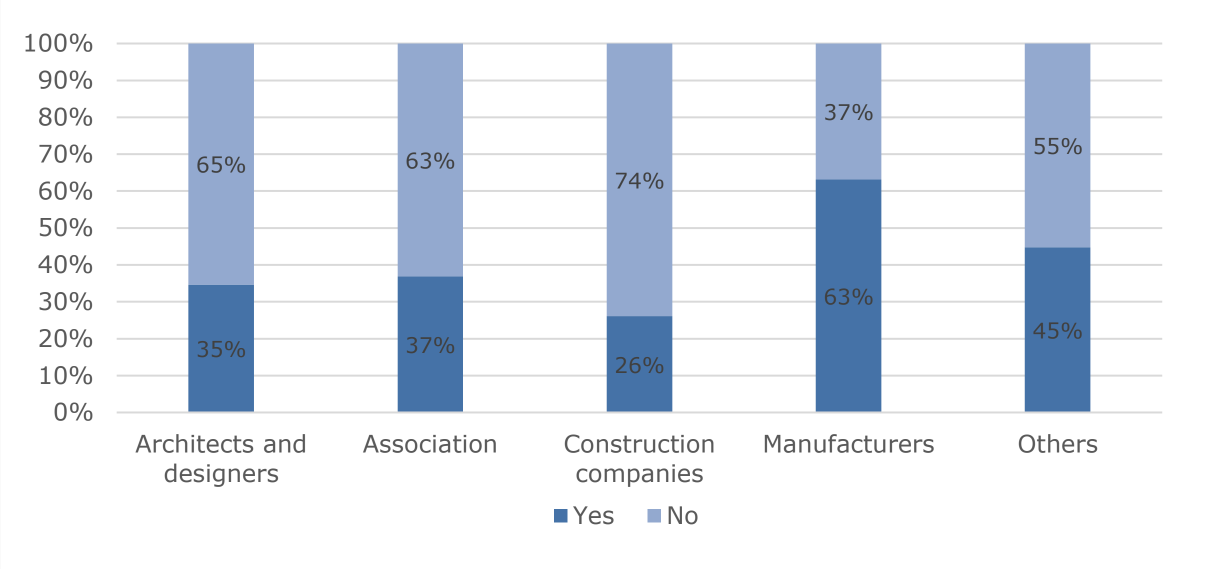
When it comes to demonstrating circular activities, manufacturers have again the highest share at 95%. This is compared with 68% of associations, 63 % of construction companies and 60% of architects and designers reviewed publishing evidence that they were applying circular approaches.

Figure 8: Share of demonstrated circular activities by stakeholder type



Finally, when it comes to measuring circularity, the study team found again that manufacturers had the highest share (63% of the manufacturers reviewed have circular measurements in their reports). On the lower end, 37% of the manufacturers and 35% of the architects and designers reviewed demonstrated circular measurements.

Figure 9: Share of demonstrated circular measurements by stakeholder type



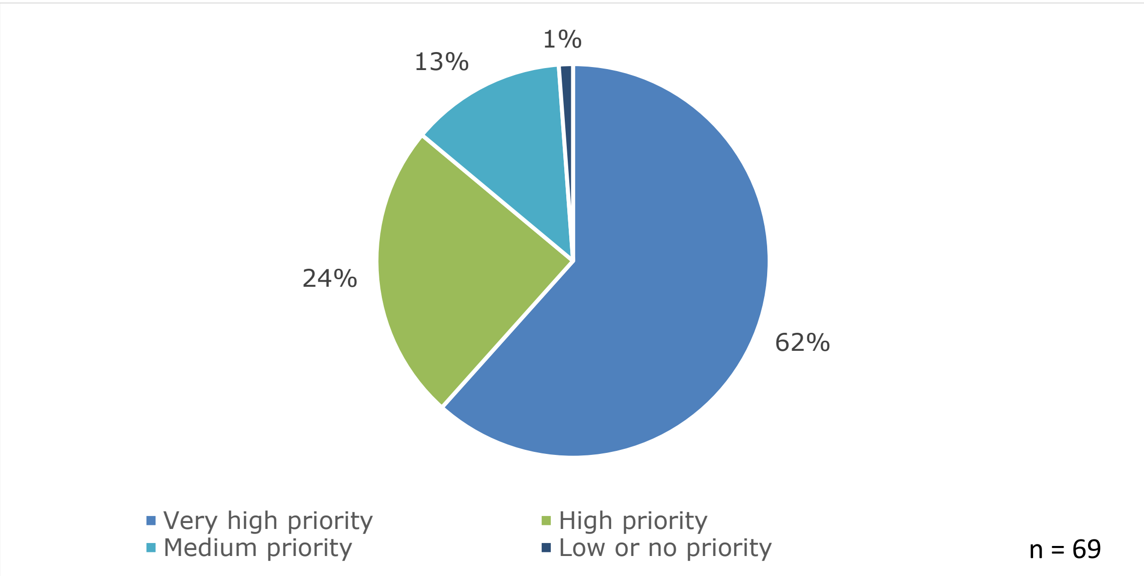
Level of uptake of the different circular approaches

To understand the level of uptake of the different circularity approaches, we collected data during two surveys, two workshops, and one registration survey for the second workshop, which also served us as means to ask about the implementation of the circularity approaches.

While these findings show limited active measurement of performance related to different circular approaches, it also shows that the majority of stakeholders are prioritising circularity and are interested in or planning to measure performance (if they are not already).

The sampling size of the first survey was 69 respondents. Of these, when asked about the level of priority place on implementing circularity approaches, the vast majority of respondents (63%) mentioned that this is a very high priority, and 24% a high priority. For 13% of the respondents, the implementation of circularity approaches is medium priority. For only 1% of the respondents, this is low or no priority at all.

Figure 10: First survey - Level of priority placed on implementing circularity approaches



During the second survey, our sampling size was 120 respondents. This survey gave further details on respondents' current activities in relation to specific circular approaches. As illustrated in the figure below, the majority of respondents reported that they currently implementing or addressing the following five approaches:

1. Increasing recycled and secondary content of construction products and materials (86 of 120 respondents)

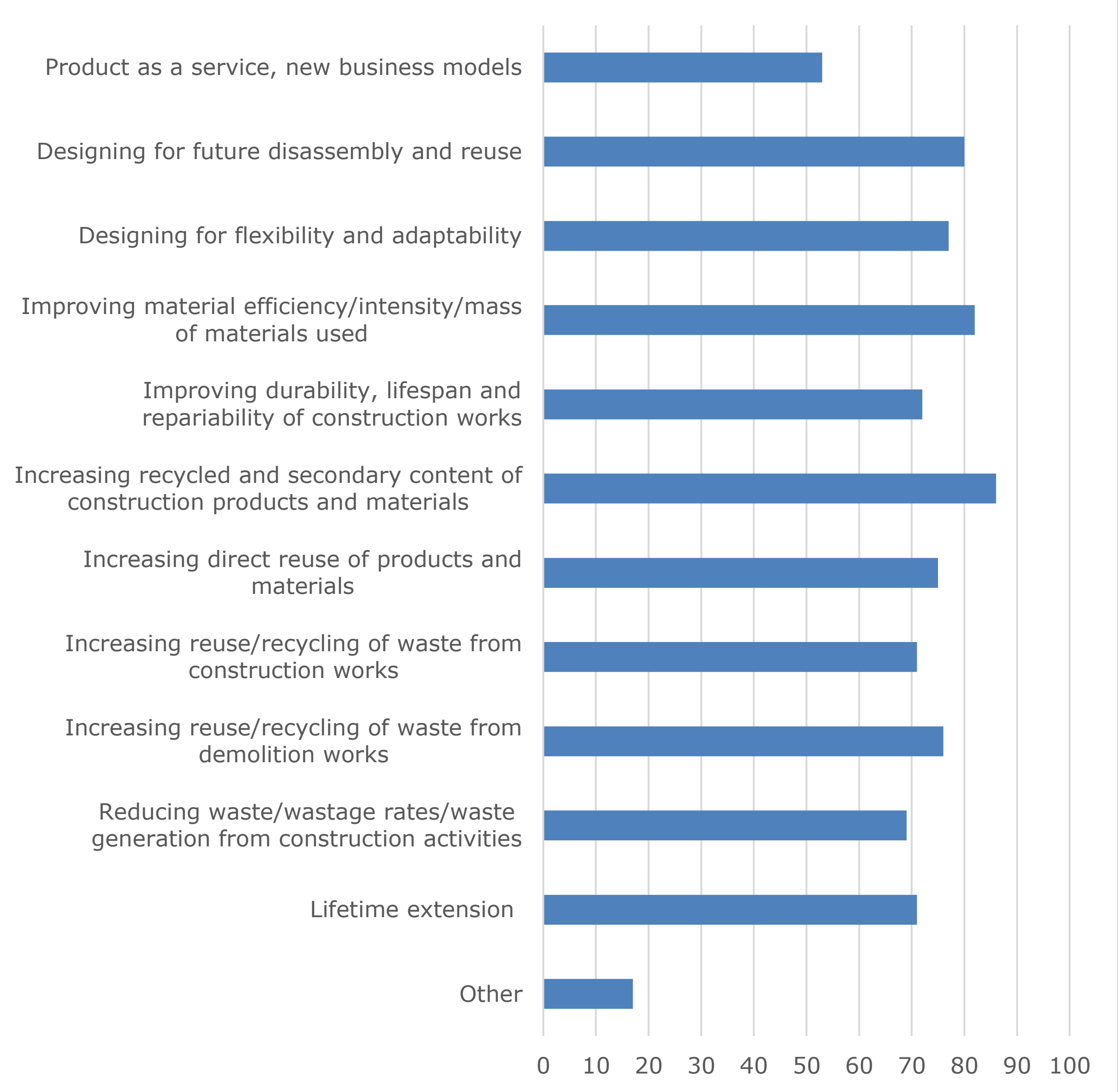
2. Improving material efficiency/intensity/mass of materials used (82 of 120 respondents)

3. Designing for future disassembly and reuse (80 out of 120 respondents)

4. Designing for flexibility and adaptability (77 out of 120 respondents)

5. Increasing reuse/recycling of waste from demolition works (76 out of 120 respondents)

Figure 11: Second survey results – Number of stakeholders that are currently implementing circular approaches (out of 120)



During the first survey, the study team also asked about the regularity with which organisations carry out the circularity approaches presented, the results of which are presented in

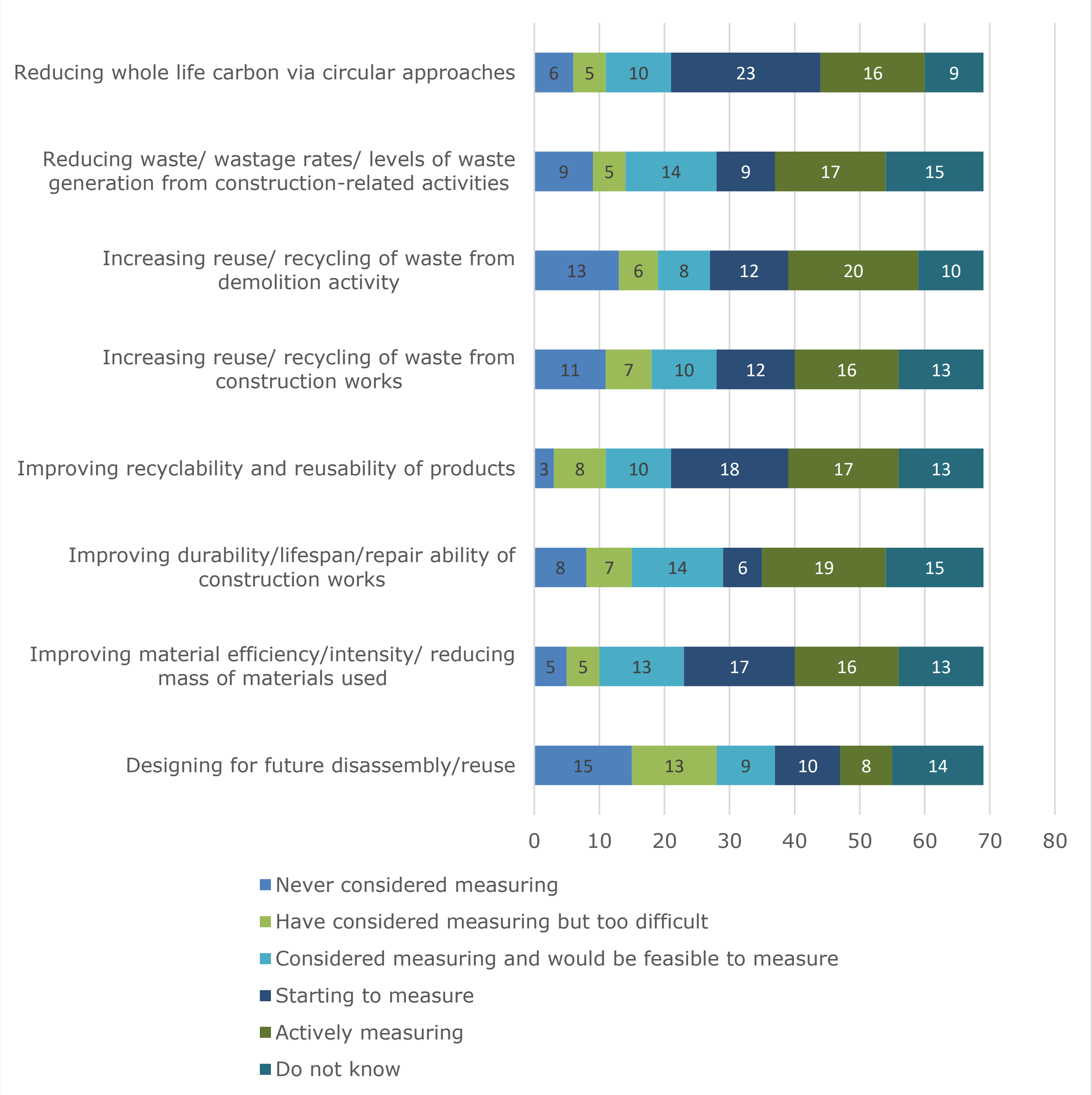
Figure 12. The three most frequent circularity approaches applied consistently by the organisations that responded this survey are:

- Improving durability/lifespan/repairability of construction works (52% of respondents)
- Improving material efficiency/intensity/mass of materials used (48% of respondents)
- Increasing recycled/secondary content of construction materials/products; and (designing for) flexibility and adaptability (38% of respondents)

The circular approaches that are rarely or never carried out by the respondents are:

- Product as a Service (PaaS), new circular business models (27% of respondents)
- Increasing reuse/recycling waste from demolition activities (17% of respondents)
- Increasing reuse/recycling waste from construction works (17% of respondents)

Figure 12: First survey results - frequency in which organisations carry out circularity approaches



Besides asking the stakeholders whether they implement circular approaches and the frequency of the implementation, we also asked during the first survey, whether stakeholders are measuring the implementation of the circularity approaches they are implementing.

We found through this survey question that the overall share of active measurement is low (around 1 in 4 respondents responded positively for the most common approaches). The top three circularity approaches that organisations are currently actively measuring are:

1. Increasing reuse/recycling waste from demolition activities (29% of respondents)

2. Improving durability/lifespan/repairability of construction works (27% of respondents)

3. Reducing waste/wastage rates/ levels of waste generation from construction-related activities; and improving recyclability and reusability of products (25% of respondents)

A circular approach that the highest number of stakeholders reported as "starting to measure" is reducing whole life carbon via circular approaches (33% of respondents). This is followed by improving recyclability and reusability of products (26% of respondents).

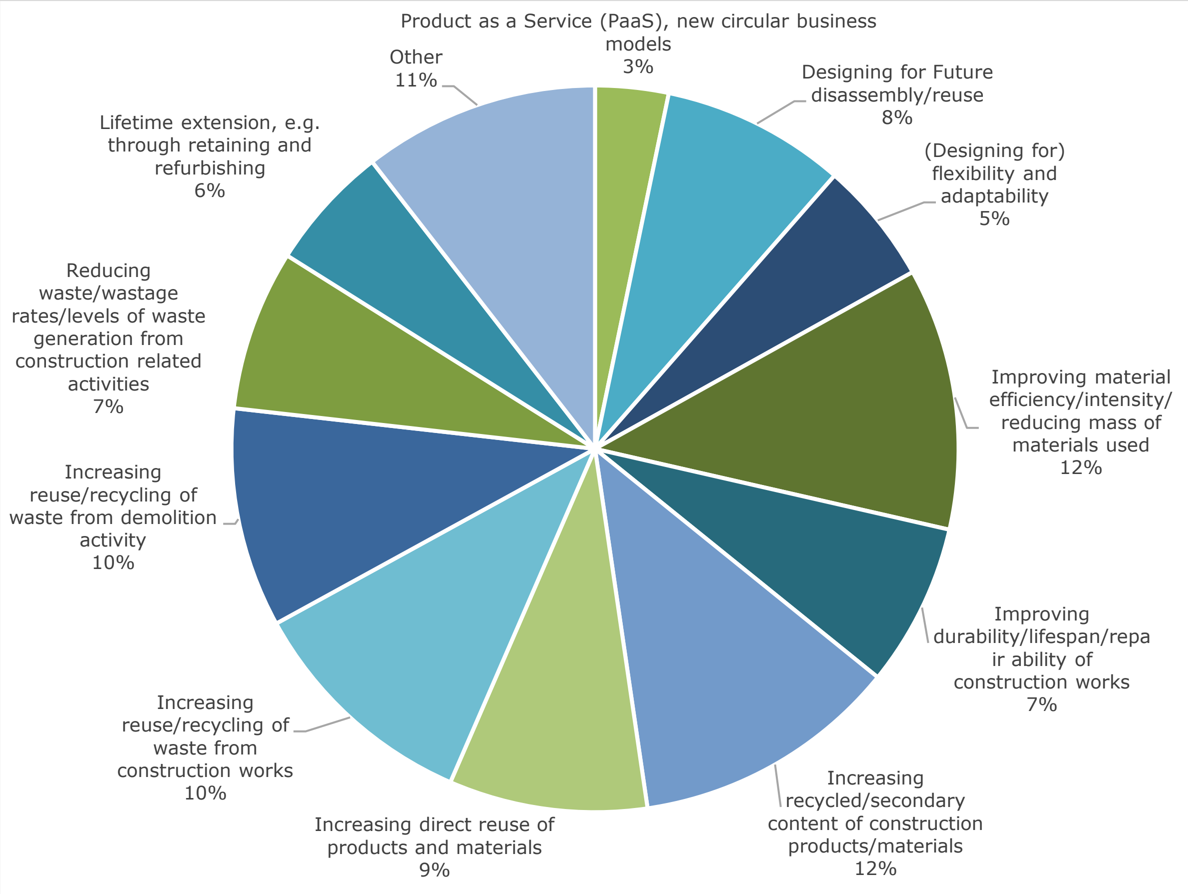
Reducing waste/wastage rates/levels of waste generation from construction-related activities is a circular approach that stakeholders mentioned as having been considered for measurement, as well as improving durability/lifespan/repairability of construction works (20% of respondents).

Finally, as part of the registration for the second workshop, we launched a survey for which we received 341 responses. Of those that are currently measuring performance related to circular approaches, the two most common approaches were:

1. Increasing recycled/secondary content of construction products/materials; and improving material efficiency/intensity/reducing mass of materials used (12% of responses)

2. Increasing reuse/recycling of waste from demolition activity and/or from construction works (10% of responses)

Figure 13: Figure 13: Workshop 2 survey results – measurement of circular approaches


Product as a Service (PaaS), new circular business models
3%
Designing for Future disassembly/reuse
8%
(Designing for) flexibility and adaptability
5%
Improving material efficiency/intensity/ reducing mass of materials used
12%
Improving durability/lifespan/repair ability of construction works
7%
Increasing recycled/secondary content of construction products/materials
12%
Increasing direct reuse of products and materials
9%
Increasing reuse/recycling of waste from construction works
10%
Increasing reuse/recycling of waste from demolition activity
10%
Reducing waste/wastage rates/levels of waste generation from construction related activities
7%
Lifetime extension, e.g. through retaining and refurbishing
6%
Other
11%

Availability of data to measure performance related to circular approaches

Having assessed the uptake of circular approaches, and the levels of current measurement, the study also assessed the availability of data across the value chain that can be used to measure performance.

Annex D provides examples of data currently being collected by companies, which was collected through desktop research and the stakeholder consultations. The data is categorised per value chain stage as well as per level (i.e. product, process/organisational, buildings/asset, urban, regional/national).

Within the main findings regarding data, it can be seen that the data is mostly available for the construction stage. Moreover, data that are often collected throughout the lifecycle stages and by several actors are the following:

Data on materials, including for example:

- Amount of material available for reuse/recycling in the next life cycle in kilograms
- Total materials purchased (m^3)
    - % of recycled (materials) aggregate mix
    - Reuse/recycled rates of building materials
    - Recycled rates of materials
- Bill of quantities: total mass of materials and products, split by reused, recycled, primary origin to calculate intensity (especially if weighting is being used) divided by predicted lifespan

Data on waste, including for example:

- National/local planning targets and regulatory requirements to be met:
    - Amount of waste produced from demolition and construction activities per year. Data can be aggregated from development projects or obtained from resource management site reporting.
- Construction, refurbishment, and demolition waste:
    - Generation and recycling rate: type of recycling (e.g. downcycling), breakdown of waste production, % of non-recovered and recovered waste, % reduction of the amount of waste going directly to a rubbish tip, % of sanitary waste used for energy reclamation, quantity of unsorted waste, % of waste recycled, % waste valorisation, % waste elimination, % of materials/waste recovered by type of recovery; % of materials from reuse in new constructions
    - Management of refurbishment, construction and demolition waste generated:
        - Waste processing costs (in case of loss of materials) in euros, % by weight to reuse, recycling, (energy) recovery, or landfill (disposal). Data can be aggregated from development projects or obtained from resource management site reporting.
        - Waste for disposal per operation (non-) hazardous waste: (t) waste for incineration with energy recovery, (t) waste incineration without energy recovery, (t) waste landfill, (t) other disposal operations, amounts and types of waste split by construction, refurbishment, demolitions.
        - Amounts and types of waste with predicted/ actual management routes split by options.

- Amounts (kg/empl) of waste per employee, % of waste reduction per employee since 2019

Case studies

To get a more in-depth understanding of how some companies have adopted and implemented circular approaches, and started to collect data on performance, the study team developed a series of case studies. These cover different levels and sections of the construction industry ecosystem value chain, as well as different European countries.

These case studies highlight good practice examples of companies applying and measuring circular approaches, with links to the related indicators recommended in this study. The aim is for that these case studies can support companies to put measurement into practice, through exploring similar case studies and systems that have been developed.

The full set of case studies – listed below - is included in Annex B.

Italy: ITACA Protocol (products and building level) - a multicriteria building environmental sustainability assessment tool that is used to assess the environmental sustainability of buildings, including circular aspects.

Belgium: BE Circular – Reuse in circular building sites (urban level) – a project including a competition to apply circularity, mainly linked to the renovation of buildings.

France: Demolition waste and products Diagnostic (PEMD) platform (building level) – a digital platform that supports compliance with PEMD audits and also supports collaboration and data sharing related to demolitions.

Netherlands: Circular procurement based upon Environmental Cost Indicator (Infrastructure case study) (urban level) – an example of integrating circularity requirements into public procurement.

EU: Circular Construction in Regenerative Cities - Circuit project (urban level) – an EU-wider project demonstrating how circular construction approaches can be scaled and replicated.

France: Level(s) implementation for office renovation project (building level) – the use of Level(s) to measure the circularity performance of an office renovation

UK: GLA CE statement (urban level) – Circular Economy statements required as part of planning applications in the City of London

UK: British land CE KPIs (organisation level) - a sustainability brief for development projects (including circularity aspects), in line with British Land's broader sustainability strategy.

INDICATORS FOR THE UPTAKE OF CIRCULAR APPROACHES IN THE CONSTRUCTION INDUSTRY ECOSYSTEM

Shortlisting criteria

To better understand the future uptake of circularity approaches in the construction industry ecosystem, the study team have identified a series of circularity indicators. These indicators can be used to measure the uptake of approaches at different levels of the construction industry.

To do this we first identified a longlist of potential indicators from the data sources used over the course of the study. This included a review of non-sector specific indicators, reports and academic papers. From the long list of indicators generated, a shorter list was developed.

To prioritise indicators from this list, the study team analysed each indicator against the following criteria, where scores were given out of 3 (1 being low, 2 being medium and 3 being high), adding up to a maximum total of 24 possible points:

1. **Data (6 points)**, including data availability (3 points), accuracy and timeliness (3 points);
2. **Availability of standard measurement methodology (3 points);**
3. **Current measurement (3 points)**, taking into account voluntary or mandatory measuring;
4. **Ease of measurement (3 points),** now and in the future;
5. **Relevance (3 points)** assessed with the link between the indicator and broader circularity goals;
6. **Drivers (3 points) and barriers (3 points),** including willingness of target groups to record data.

The scoring of these indicators can be found in Annex E. As part of this scoring, the use within Level(s) was an important reference point, particularly, 2.1 Bill of quantities, materials and lifespans; 2.2 Construction & Demolition waste and materials; 2.3 Design for adaptability and renovation; 2.4 Design for deconstruction, reuse and recycling.

Considering the need to ensure a sufficient spread of indicators for each level (product/material, building/infrastructure, organisational, urban) and circular approach, this shortlisting process resulted in a list of 40 indicators.

The shortlisted indicators

The following table provides an overview of the shortlisted indicators by level, including short definitions.

Table 2: Overview of shortlisted indicators

Product or material level	Building or infrastructure level	Organisation or process level	Urban level (city/region/national)
P1: Reused product i.e. used again for same or different purpose without altering the form of it. Measured as Yes/No	**B1: At Concept stage comparison of asset life cycle costs** Costs of asset over life cycle. E.g. euro/m^2/yr	**O1: Refurbishment/Transformation rate of buildings/assets portfolio** For example, % of buildings/infrastructure refurbished/year	**U1: Demolition waste generated** Resulting from the installation of products/materials, refurbishment and deconstruction/demolition of buildings/ assets; Measured in tonnes/capita
P2: Remanufactured/reused content i.e. % by mass which has been remanufactured or from a reused source	**B2: At Concept stage comparison of asset life cycle assessment** Assessment of the whole life carbon of the asset e.g. $kgCO_2$ eq/ m^2/yr	**O2: Predicted service life of buildings/assets** More relevant to those who have multiple assets; for example, average service life remaining (measured in years)	**U2: Recycling/recovery rate of Construction and Demolition Waste** Resulting from the installation of products/materials, refurbishment and deconstruction/demolition of buildings/assets; Measured in % by mass for recycling/recovery of materials
P3: Recycled/secondary content i.e. % by mass of product that is from a recycled or secondary (other industrial processes) content	**B3: At Design stage - Material intensity/ dematerialisation** The relative amount of material used e.g. kg/m^2/yr	**O3: Average reused and recycled content in new buildings/assets (circular inputs)** The average proportion of a reused and recycled content in new assets/ measured as % by mass	**U3: Refurbishment and transformation rate relative to new construction** The amount of buildings/assets refurbished versus the number built new over a given timeframe (measured in % of buildings/infrastructure refurbished/year)
P4: Design for disassembly and circularity i.e Product is design to be disassembled to aid future use; measured using an index/checklist	**B4: At Design stage - reused content** The proportion of the asset that is designed with reused products /materials (% by mass)	**O4: Reused and secondary content input** % by mass of recycled and secondary (from industrial processes) used within products	**U4: Demolition rate** The amount of buildings demolished over a given timeframe (measured as % by area - demolished/built environment)

P5: Wastage rate i.e. the amount of product/material delivered but not used (measured as % by mass	**B5: At Design stage - recycled content** The proportion of the asset that is designed with recycled content (% by mass)	**O5: Non-hazardous waste arisings** Resulting from the installation of products/materials, refurbishment and deconstruction/demolition of buildings/assets; Measured in tonnes /100K Euros (overall project value)	**U5: Average age at demolition** The average age of assets/buildings when demolished (in years)
P6: Predicted service life Estimated period of service in use, measured in years	**B6: Designed for adaptability and flexibility** Measurement of the adaptability/flexibility of the asset in use (measured as a score)	**O6: Hazardous Waste** Resulting from the installation of products/materials, refurbishment and deconstruction/demolition of buildings/ assets; Tonnes /100K Euros (overall project value)	
P7: Hazardous waste % by mass hazardous waste the product may generate	**B7: Designed for disassembly/ deconstruction** e.g. proportion of the asset that can be disassembled at end of life (% reuse potential by mass)	**O7: Waste management routes** Resulting from the installation of products/materials, refurbishment and deconstruction/demolition of building/ assets; Measured in % by mass/year for reuse, recycling, recovery and disposal	
P8: Realistic end of life scenarios developed i.e. the reuse, recycling, recovery and disposal routes at end of life identified (measured as Yes/No)	**B8: Construction waste generated on and off site** Resulting from the installation of products and materials; Measured in tonnes/100K Euros (project value)	**O8: Requirements set for specification of circular economy approaches including recycled + reused products and materials** The amount of projects/assets that have these type of requirements/initiatives (measured by % of projects/year)	
P9: Residual value per unit product/material at end-of-life i.e. the financial value of the product at the end of life (in Euros per functional unit)	**B9: Hazardous Waste generated during construction** Resulting from the installation of products and materials; Measured in % by mass	**O9: Requirements set for pre-demolition audits and subsequent implementation** The amount of projects/assets where pre-demolition audits are	

		required/implemented (measured by % of projects/year)	
P10: Part of an Extended Producer Responsibility system i.e. take-back system (measured as Yes/No)	**B10: Construction Waste reused, recycled, recovered, landfilled** Resulting from the installation of products and materials; Measured in % by mass reused, recycled, recovered and landfilled		
	B11: Construction related waste generated through in-use/ refurbishment cycles Amount of waste (tonnes/100K Euros (project value)) generated from the installation and removal of products/materials during maintenance, repair and refurbishment etc.		
	B12: Effective utilisation of building (e.g. levels of occupancy) or asset; Intensiveness of use For example how much the asset is in productive use/ how much of the asset is being used (e.g. hours of utilisation/m^2)		
	B13: At end of use of building/asset - Proportion of building/asset retained (mass) for further use e.g. % by mass of the asset retained for future reuse (adaptive reuse)		
	B14: Demolition waste generated		

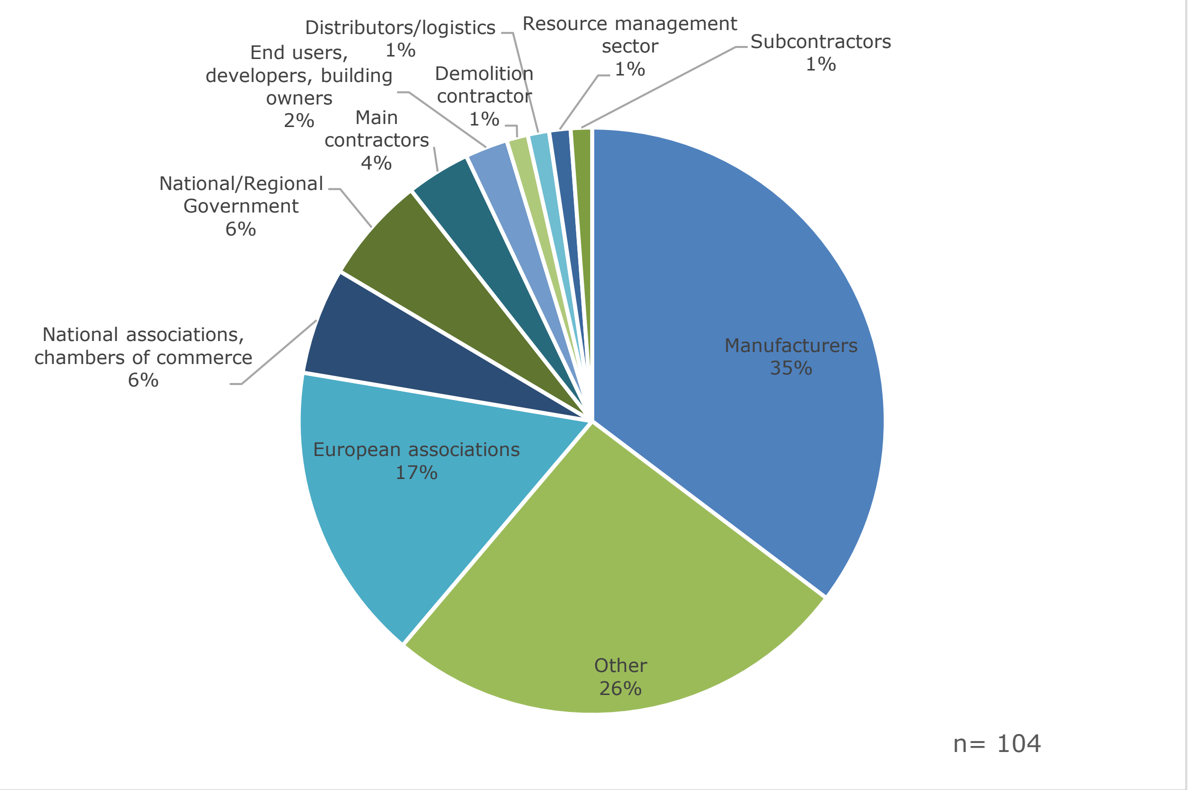
	Resulting from the deconstruction/demolition of the asset Measured in tonnes		
	B15: Hazardous waste generated at Demolition Resulting from the deconstruction/demolition of the asset Measured in % by mass		
	B16: Demolition Waste reused, recycled, recovered, landfilled Resulting from the deconstruction/demolition of the asset. Measured in % by mass reused, recycled, recovered, landfilled.		

Feedback from stakeholder consultations

During the second workshop, the shortlisted indicators were presented and tested. More than 100 participants joined this workshop and answered interactive questions on the shortlisted indicators[14].

As illustrated in Figure 14, the attendees presented a good share between key stakeholder groups. The largest stakeholder groups present during the workshop were manufacturers and European associations but more specific stakeholder groups, such as distributors/logistics professionals, were also present.

Figure 14: Share of stakeholder groups represented in the 2nd workshop



During the workshop, the attendees were given the opportunity to rate the 40 shortlisted indicators using a web-based rating tool. The rating scale was between 1 and 5: 5 being very important and 1 being not important at all. An overview of the rating is shown in Figure 15.

On **product/material level**, one indicator was clearly assessed as being the most important one: design for disassembly and circularity. Further indicators that were given a high rating include: reused product, predicted service life, hazardous waste. Part of an Extended Producer Responsibility system (i.e. take-back system) was ranked as being the least importance by the participants.

Looking into **building/ infrastructure level**, the stakeholders assessed the indicators related to designed for disassembly/deconstruction as the most important. Further; seven indicators reached a rating above 4, mainly related to waste.

Regarding **organisation/ process level**, all indicators seem to have a similar rating between 3.4 and 4.1. Nevertheless, Refurbishment/Transformation rate of buildings/assets

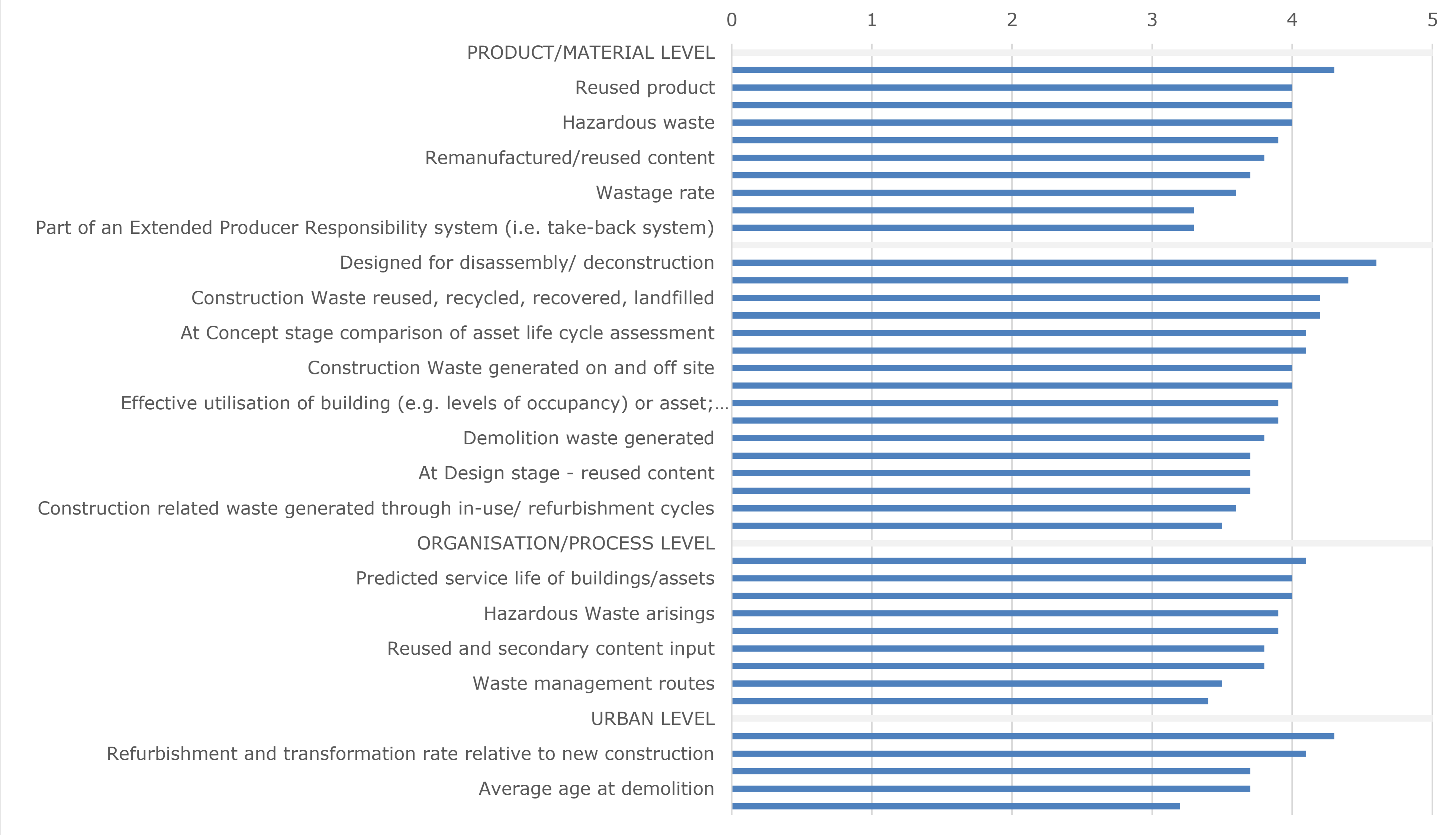
[14] Note: Although over 100 participants joined the call, this number fluctuated throughout the call, impacting the sample size that decreased to 14 for the last questions.

portfolio was assessed as the most important. Average reused and recycled content in new buildings/assets (circular inputs) seems to be less important.

On **urban level**, recycling/recovery rate of construction and demolition waste was rated the most important, followed by refurbishment and transformation rate relative to new construction. Demolition rate seems to be the indicator with the least importance on the urban level.

Finally, looking at the overall scores, indicators on building/infrastructure level were assessed to have the highest importance on average.

Figure 15: Rating of shortlisted indicators (5 being very important and 1 being not important at all)



DRIVERS AND BARRIERS

Methodology

For the identification of drivers and barriers that influence, facilitate, or prevent the implementation of the shortlisted indicators and their measurement, as well as the uptake of circular approaches in general, the project team carried out the following activities:

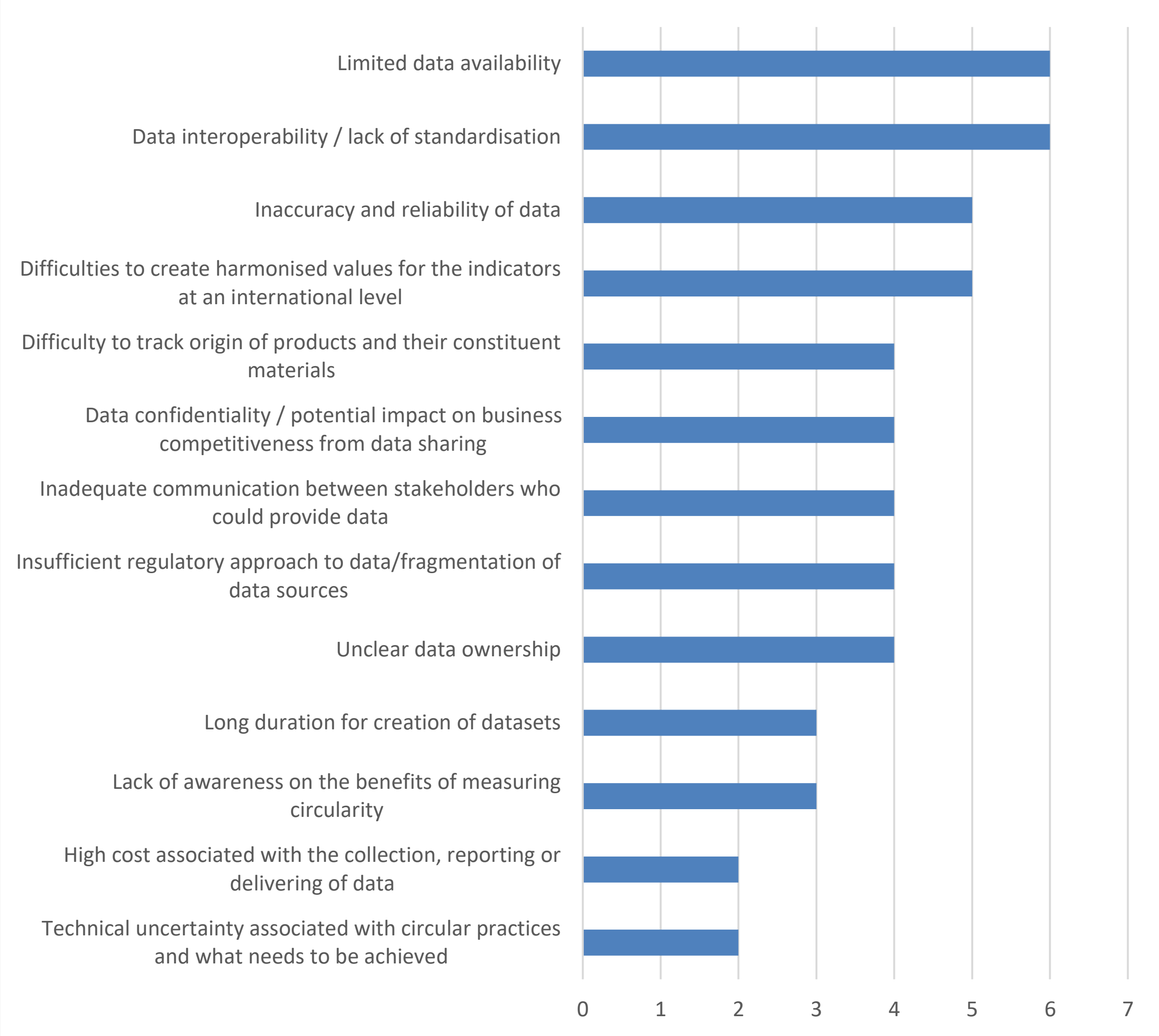
- **Preliminary definition of drivers and barriers:** included the preliminary definition of barriers and drivers, the analytical framework and methodology used to carry out the detailed analysis.
- **(Stakeholder consultation) and analysis:** the views of stakeholders were collected through the study's surveys workshops, surveys and targeted interviews.

Identified drivers and barriers

The first activity performed included the preliminary definition of barriers and drivers based on desktop research, as well as through the first consultation survey and the first workshop. The result of this analysis resulted in the identification of general drivers and barriers that apply to the definition, implementation of indicators to measure circularity, as well as in the relevant collection of the required data.

The paragraphs below provide the results of the assessment of drivers and barriers for four different types of stakeholders (manufacturers and suppliers, non-profit and academic organisations, public sector and private sector). These results were gathered through the first workshop where participants were able to score the drivers and barriers as very significant, medium or no significance. Figure 16 presents the results on the barriers that were voted as very significant.

Figure 16: First workshop results – Barriers that were voted to be 'very significant'

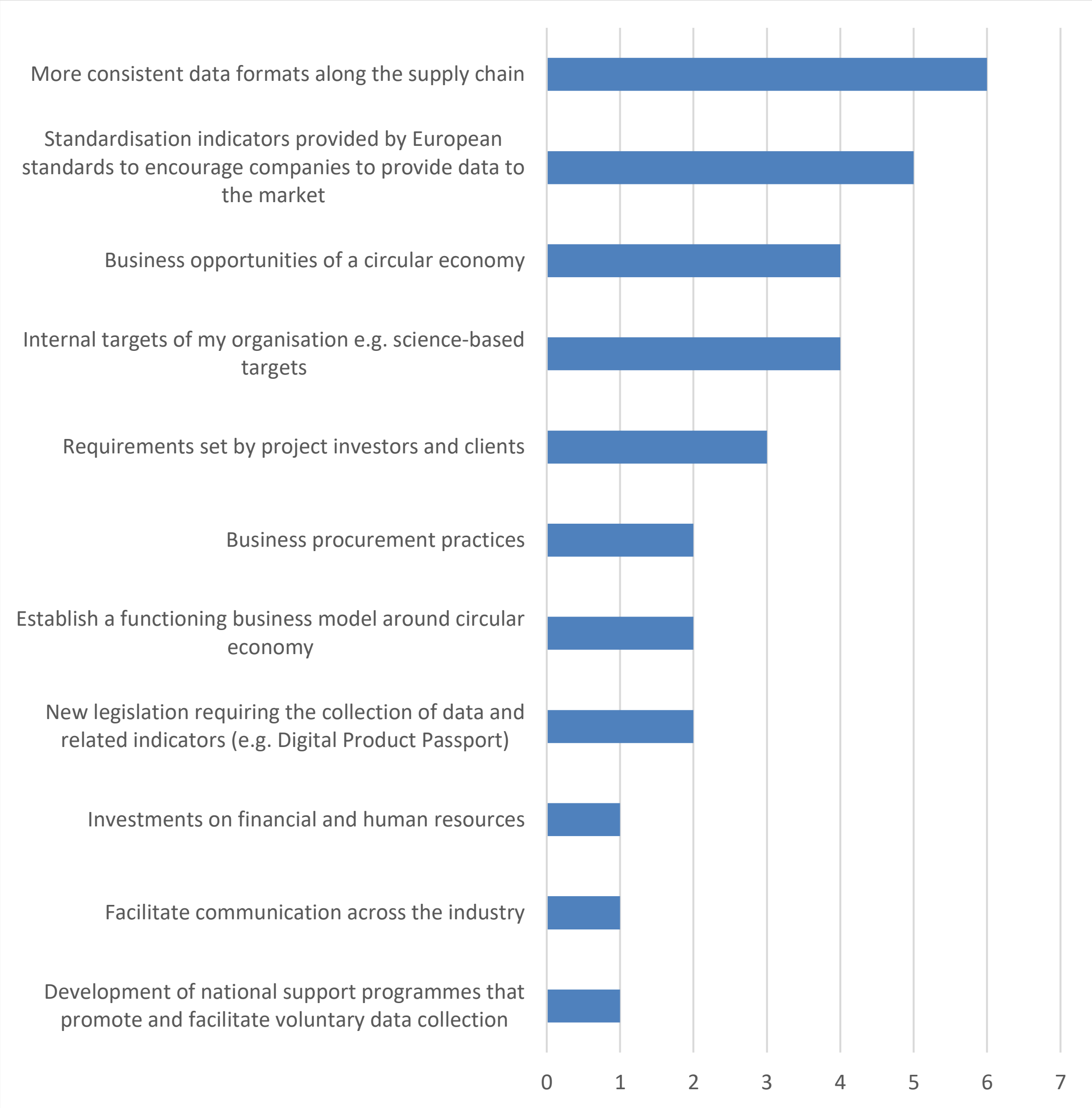


As it can be seen from the figure, the lack of standardisation, origin tracking, and overall data information is the main issue for all 4 types of stakeholders.

Nevertheless, there were some differences on the scoring by the different types of stakeholders. The difficulties in creating harmonised values for the indicators at an international level and limited data availability are seen as the most significant barriers for manufacturers. For non-profit and academic organisations, the difficulty in tracking the origin of products and their constituent materials is the most significant barrier. For the private and public sector, the data interoperability and lack of standardisation is regarded comparatively as a particularly significant barrier.

Figure 17 presents the results of drivers that were voted as very significant.

Figure 17: First workshop results – Drivers that were voted to be 'very significant'



Legislation, business opportunities and data consistency/standardisation appear to be common drivers for all types of stakeholders.

As in the case of barriers, there were some differences on the scoring of drivers by the different types of stakeholders. Having more consistent data formats along the supply chain and standardised indicators provided by European standards to encourage companies to provide data to the market is comparatively a more significant driver for manufacturers. For non-profit and academic organisations, an increase on investments on financial and human resources as well as setting environmental performance requirements to drive adoption are regarded as more significant drivers to increase the measurement of circularity performance. Finally, the establishment of business opportunities of a circular economy is regarded as the most significant driver, both for the private and public sectors. The private sectors also considers the setting of new legislation requiring the collection of data and related indicators as a particularly important driver.

Indicator-specific drivers and barriers

Annex F presents the results of the analysis of the drivers and barriers for the shortlisted indicators. These have been identified based on the results of the second survey and workshop of the study, as well as targeted interviews with stakeholders. It must be noted that while the project team endeavoured to collect feedback from the stakeholder consultation activities that linked drivers and barriers to specific indicators, the insights here are limited. This is due to the fact that to a large extent the drivers and barriers are common to all indicators and horizontal by nature. For this reason the linking of drivers and barriers with specific indicators is based mainly on their theme and content (e.g. reusability, recyclability, adaptability etc) and the expert judgement of the project team.

FINDINGS AND CONCLUSIONS

General conclusions

The new data and insights collected from over 300 stakeholders over the course of the study suggest a relatively high level of engagement in the circular transition. That said, the share of stakeholders who have reported that they are actively implementing and measuring circular approaches remains low.

A key barrier that is holding back a more widespread uptake of circular approaches is interoperability challenges related to differences in data formats used. This issue can be exacerbated if new reporting requirements are released at EU, national and industry levels that add further administrative burdens on organisations without reducing or aligning with existing requirements.

To better understand the links between different indicators, and the potential for harmonisation, they study have carried out an ‘indicator profiling’ exercise, which summarises the findings and conclusions for each of the shortlisted indicators.

Indicator profiling

In order to further refine and target the recommendations from this study, the study team took all data collected throughout the course of the study to create ‘profiles’ for each indicator. An example of one of these profiles (P1: Reused product) is included below and the other profiles are included in Annex A. One of the key aims here is to draw connections and synergies between different indicators and their data requirements.

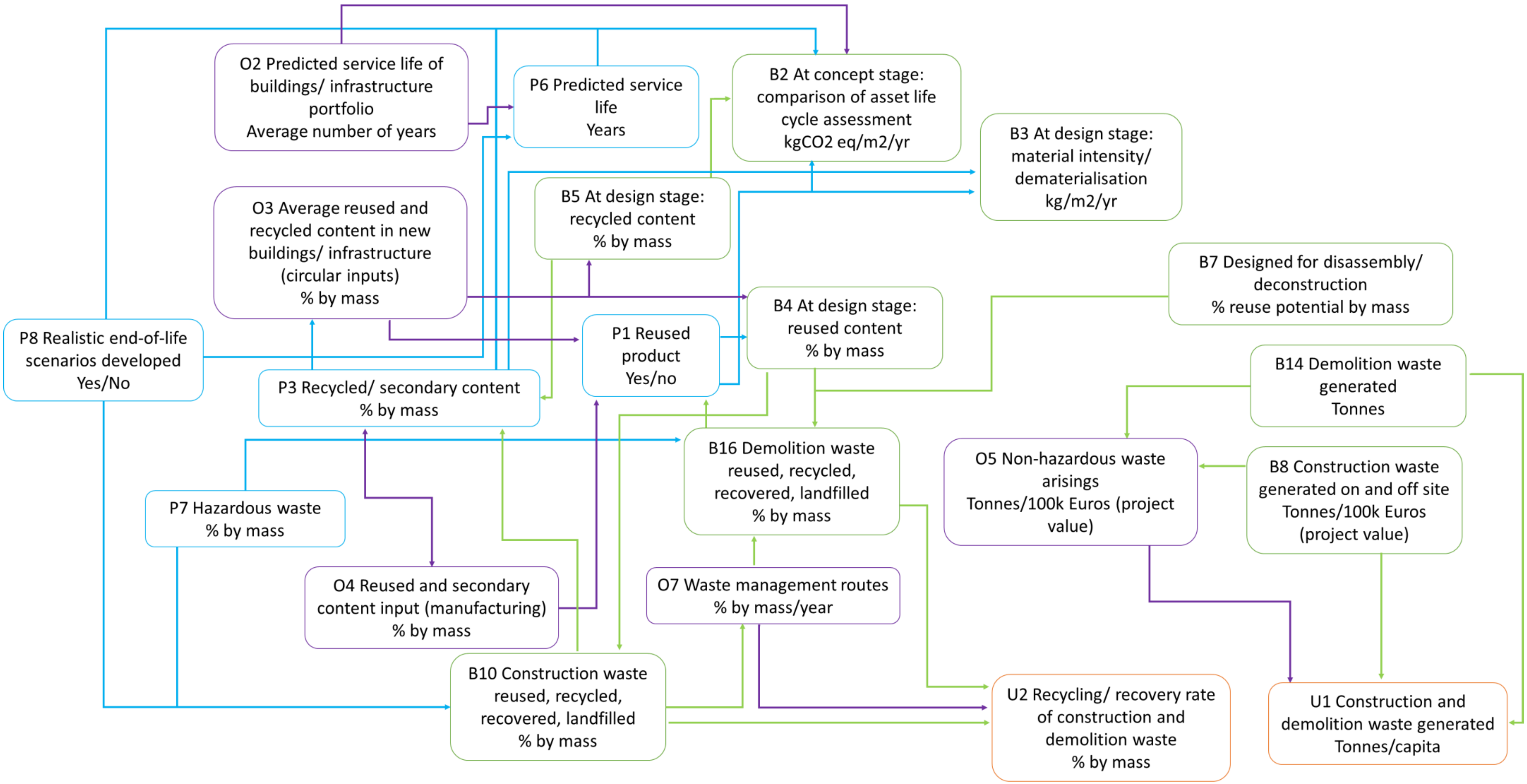
Table 3: Example indicator profile: P1 'Reused Product'

P1 Reused product		
Description: The product or material has been used before (arising from demolition/ strip out) or delivered to a construction site but not installed (e.g. surplus). Could be in a similar or different application with minimal processing.		**Units:** Yes/No (it is a reused product)
Data requirements: - Simple to assess - Some traceability from previous application may be required e.g. pre-demolition audit	**Shortlisting score:** 83 % (20/24)	**Stakeholder score/feedback:** Workshop 2 - Average ranking 4 out of 5 Survey 2 – 27% actively measuring and 33% considering measuring (72/120)
Circularity Approach(es) - Increasing direct reuse of products and materials - Increasing reuse/recycling of waste from construction works - Increasing reuse/recycling of waste from demolition works	**Key Life cycle stages** Manufacture, Construction, End of Life **Key Actors:** Manufacturers, Contractors, Resource Management Industry	**Link to other indicators:** P2 Remanufactured/reused content B2 At concept stage: comparison of asset life cycle assessment B3 At design stage: Material intensity/ dematerialisation B4 At design stage: reused content B16 Demolition waste reused, recycled, recovered, landfilled O3 Average reused and recycled content in new buildings/infrastructure (circular inputs) O4 Reused and secondary content input
Evidence of industry uptake / case studies: Measured in C2C Product Standard as: Increasing Demand: Incorporating Cycled and/or Renewable Content. Examples of data collection include the FCBRE project and Brussels Environment (see Annex B)	**Specific Drivers & Barriers:** Easy to assess Within EU Taxonomy Proposed Technical Criteria Embodied carbon calculations Lack of Traceability upstream	**Recommendation:** **Core** indicator (link to P2 indicator)

Mind-mapping

As part of this indicator profiling, the study team carried out a mind-mapping exercise to identify links and synergies between different indicators. This is important to identify indicators that can be grouped – where the same or similar data can be collected to measure performance against multiple indicators. For example, data for certain indicator, may be provided at the product level, aggregated at the building/asset level and aggregated again at the organisational level. These may also then be used at the urban level. The snapshot of the mind-map below demonstrates visually how all the shortlisted indicators are linked to one another.

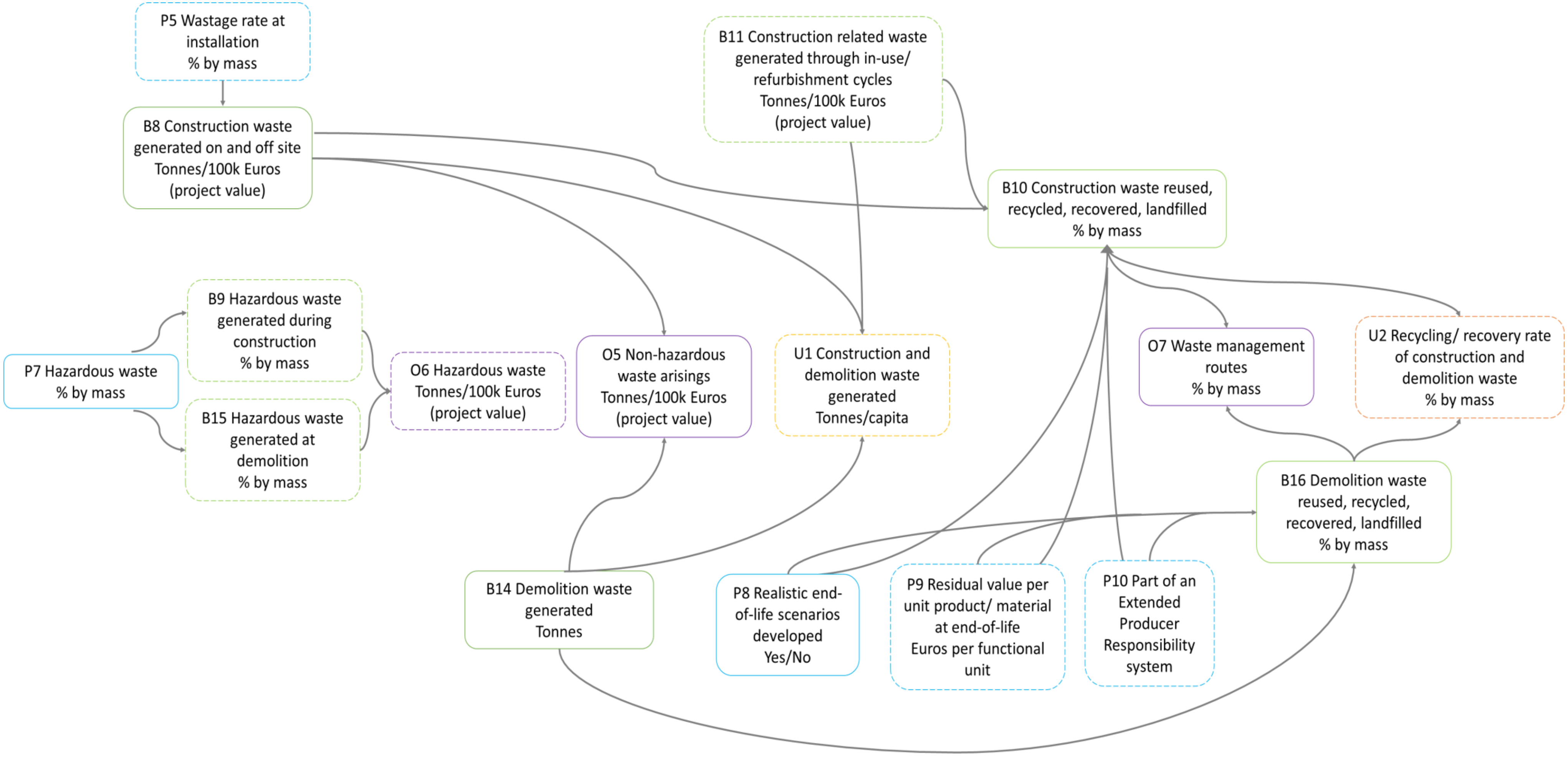
Figure 18: Snapshot of the overall mind-map showing data connections between all shortlisted indicators (note: blue is product level, green is building level, purple is organisational level and orange is urban level)



As can be seen from Figure 19, there are many inter-linkages and dependencies, so further mind-mapping was undertaken for different themes and subsets of indicators, to better understand the measurement systems that can be established to measure uptake at different levels. This enables a systems-thinking approach to be used when selecting the best indicators for a specific project or organisation.

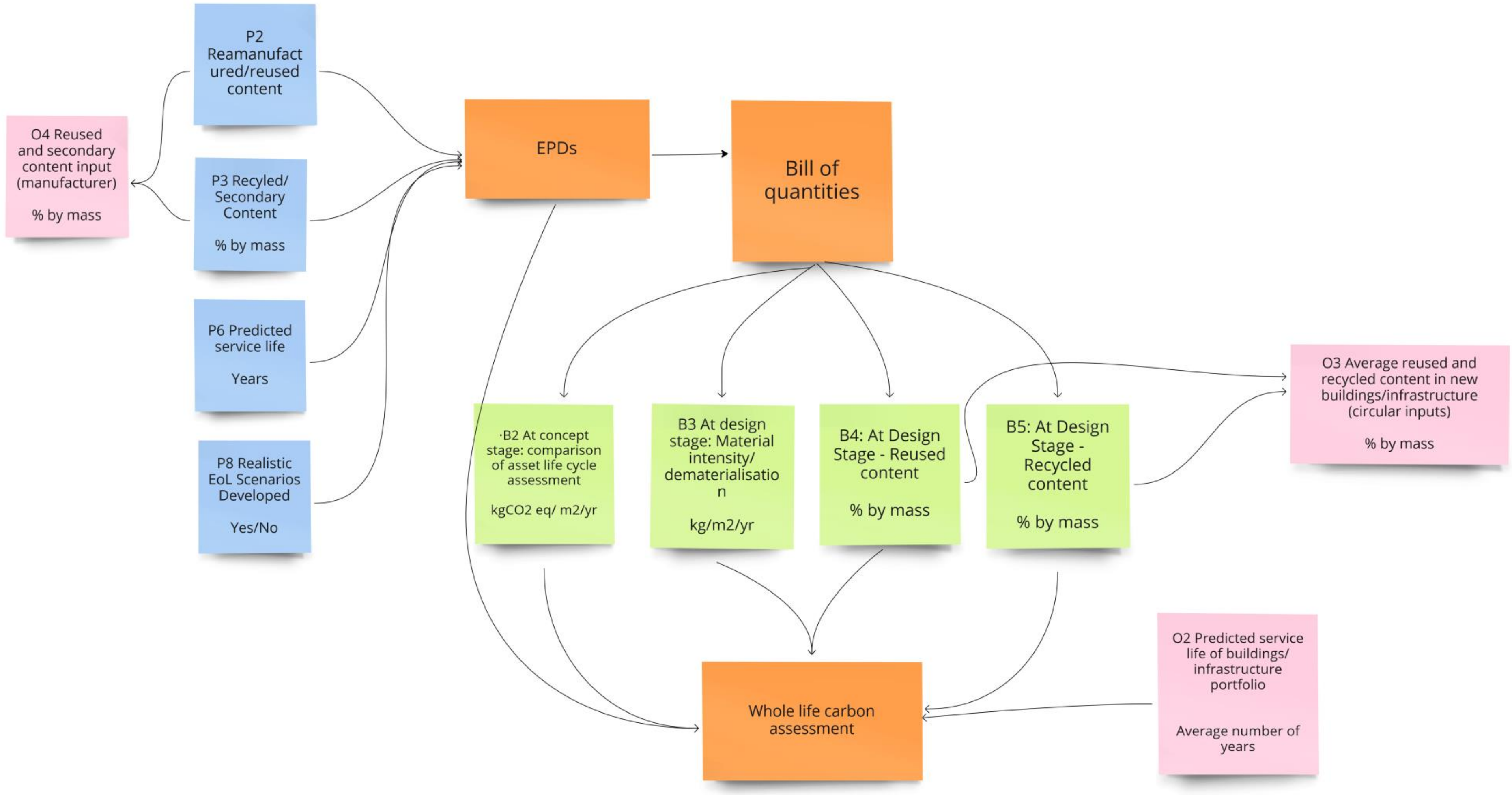
The figure below shows the relationships for the indicators that address waste generation and recovery (at the asset/building level, organisation and urban level) which are split by construction and demolition activities and non-hazardous and hazardous waste. Also shown are some of the activities that may affect this such as if the product is deemed to be hazardous at end of life (P7), and if realistic end of life scenarios are developed (P8), the residual value at end of life (P9) and if there is an Extended Producer Responsibility in place (P10).

Figure 19: Mind-map for waste generation and recovery (note: dotted lines have been used for indicators that are judged to be 'supplementary' (explained in the recommendations section); blue is product level, green is building level, purple is organisational level and orange is urban level)



Finally, the mind-map below shows that data collected for Environmental Product Declarations (EPDs) at the product level can then feed into a whole life carbon assessment, where a number of building level indicators are relevant. As such, if manufacturers are producing EPDs, then data collection mechanism should be in place to measure the relevant indicators. This is also relevant for building and infrastructure owners, designers, contractors when involved in whole life carbon assessments.

Figure 20: Mind-map for data collected for Environmental Performance Declarations (EPDs)



RECOMMENDATIONS

Using the inputs from the indicator profiles and mind-mapping exercises presented above, we have proposed a final set of recommended **21** core indicators that can be used to measure the uptake of circularity approaches in the construction industry ecosystem (5 at product level, 9 at building level, 5 at organisational level, 2 at urban level). The remaining **19** are suggested as supplementary (5 at product level, 7 at building level, 4 at organisational level and 3 at urban level)

These recommended indicators are listed in the tables below for each level, with the synergies to other indicators also set out (as established in the mind-mapping exercises). These synergies represent the fact that the same/similar data is needed or that the indicators relate to similar issues.

In terms of next steps for the Commission and other policy makers in taking forward these recommendations, the intention is that the linkages established between different indicators can support the harmonisation and streamlining requirements. The proposed indicators are also grouped according to circular approaches to enable policy makers to isolate indicators that are relevant for different objectives.

There are several key standards and/or data sources referenced throughout the profiles of the recommended indicators, which are noted here as being highly relevant in the further development of measurement of circularity at one or more of the four levels. These include:

- **EN15804** - the Environmental Product Declaration standard for the sustainability of construction works and services. This standard harmonises the structure for EPDs in the construction sector, making the information transparent and comparable. A second version of the standard called EN 15804+A2 was published in 2019, with the main goal to align with Product Environmental Footprint (PEF). Many relevant data types (to the recommended circularity indicators) are used to prepare an EPD, although not all the data is readily extractable in the desired format e.g. % recycled content of a product by mass.

- **ISO 14021 Environmental Labels and Declarations –** this specifies requirements for self-declared environmental claims, including statements, symbols and graphics, regarding products. It provides a definition for what is recycled content for products: 'the proportion, by mass, of recycled material in a product'. Only pre-consumer and post-consumer material shall be considered as recycled content. Definitions are also provided for pre and post-consumer materials.

- **Bill of Quantities (BoQ) –** detailed inventory of a building or infrastructure, split by mass and by product/material. It is recommended that Level(s) is used as the reference point for a suitable BoQ to support measurement of circularity. The overall cost is also used to determine project cost and value.

- **Pre- and post- demolition audits** - fundamental to having data on number, age, type and tonnage related to demolition projects. Additional information relating to resource management routes and having central databases for reporting data will be highly supportive in urban level reporting. It is recommended that the templates and approach being developed in France (as set out in the PEMD case study) forms the reference point for these audits in the absence of an EU accepted standard.

- **Predicted service life definitions -** this is a multi-part standard which provided a framework for assessing service life, definitions for a lifecycle and reference service data and how to estimate remaining service life of buildings.

Product or material level recommended indicators

The recommendations for the core product level indicators are shown in the table below.

Table 4: Recommendations for the short-listed product/material level indicators

Product level CORE INDICATORS and unit	Main Data required	Input from other indicators	Input to other (CORE) indicators	Synergy with CORE indicators
P1 Reused product Yes or No	Product/material category Origin/ source	B16 Demolition waste reused, recycled, recovered, landfilled	B2 At concept stage: comparison of asset life cycle assessment B3 At design stage: Material intensity/ dematerialisation B4 At design stage: reused content O4 Reused and secondary content input	P7 Hazardous waste O3 Average reused and recycled content in new buildings/infrastructure (circular inputs)
P3 Recycled/secondary content % by mass	Total mass of materials and products {**EPD data** (EN15804)} split by recycled and secondary origin. Split recycled content by pre and post-consumer.		B2 At concept stage: comparison of asset life cycle assessment B3 At design stage: Material intensity/ dematerialisation B5 At design stage: recycled content O4 Reused and secondary content input	O3 Average reused and recycled content in new buildings/infrastructure (circular inputs)

P6 Predicted service life Years	Standard service lives maybe published by various Countries e.g. Germany. Within **EPD**s and some Product Standards Service life planning is within ISO 15686-8:2008		B2 At concept stage: comparison of asset life cycle assessment	P8 Realistic end of life scenarios developed O2 Predicted service life of buildings/infrastructure portfolio
P7 Hazardous waste % by mass List of substances	Need to understand if the product or any of its constituent parts are hazardous at end of life – list under CPR Amount of product and proportion which is hazardous (%)		P8 Realistic end of life scenarios developed	P3: Recycled/secondary content B10 Construction waste reused, recycled, recovered, landfilled B16 Demolition waste reused, recycled, recovered, landfilled O7 Waste management routes
P8 Realistic end of life scenarios developed Yes or No	Include reuse, recycling, recovery and landfill (as %) Should be based on current practices. **EPDs**, defined in EN 15804 (Module C and D now mandated)	P7 Hazardous Waste	B2 At concept stage: comparison of asset life cycle assessment	B10 Construction waste reused, recycled, recovered, landfilled B16 Demolition waste reused, recycled, recovered, landfilled O7 Waste management routes

Assessment of data availability and drivers for core indicators:

A key driver at the product level is the need for data for EPDs: end of life scenarios (Module C and D), predicted service life, and recycled/secondary content, which are included as indicators. Other datasets underpinning the Core indicators, such as hazardous waste and service life predictions are commonly collected for various purposes (i.e. service life planning and CPR and REACH obligations). Finally, drivers and means of measurement are largely in place for selected core indicators (including standards e.g. ISO 14021 Environmental Labels and Declarations, and ISO 15686-8:2008)

Supplementary indicators:

- P4 Design for disassembly and circularity
- P2 Reused/remanufactured content
- P5 Wastage rate at installation
- P9 Residual value per unit product/material at end-of-life
- P10 Part of an Extended Producer Responsibility system

Building or infrastructure level recommended indicators

The recommendations for the short listed building/infrastructure level indicators are shown in the table below.

Table 5: Recommendations for the short listed building/infrastructure level indicators

Building level CORE INDICATORS and unit	Main data required	Input from other indicators	Input to other (CORE) indicators	Synergy with CORE indicators
B2 At concept stage: comparison of asset life cycle assessment kgCO2 eq/ m2/yr	EN15978 (currently under revision) Building life cycle assessment (Civil Engineering Works = EN 17472). Data includes: **Bill of Quantities** for products/materials to be installed, to be matched with LCA data – either generic or proprietary **EPDs** (Environmental Product Declarations (EN15804). Civil Engineering = EN 17472:2022. Extracts global warming potential data (CO_2 eq.).	P1: Reused content P2: Remanufactured or reused content P3: Recycled/secondary content P8 Realistic end of life scenarios developed P6 Predicted service life B3/B4/B5 in terms of Total mass of materials and products (split by reused, recycled, primary origin) B10/B16 also provides input data for EoL allocation	N/A	B3 At design stage: Material Intensity/ dematerialisation B4 At design stage reused content O2 Predicted service life of buildings/infrastructure portfolio
B3 At design stage: Material intensity/ dematerialisation kg/m^2/yr	Total mass of materials and products (**Bill of Quantities BoQ)**, split by reused, recycled, primary origin to calculate intensity (especially if weighting is being used) divided by predicted lifespan	B4/B5 in terms of Total mass of materials and products (split by reused, recycled, primary origin)	B2 At concept stage: comparison of asset life cycle assessment	B4/B5 in terms of Total mass of materials and products (split by reused, recycled, primary origin)

B4 At design stage: reused content % by mass	Total mass of materials and products **(BoQ)**, split by reused, recycled, primary origin to calculate % by weight that is reused.	P1 Reused product	O3 Average reused and recycled content in new buildings/infrastructure (circular inputs)	B3/B5 in terms of Total mass of materials and products (split by reused, recycled, primary origin) O4 Reused and secondary content input
B5 At design stage: recycled content % by mass	Total mass of materials and products (**BoQ**), split by reused, recycled (post consumer - raw form or as part of a product), primary origin to calculate % by weight that is recycled	P3 Recycled, secondary content	O3 Average reused and recycled content in new buildings/infrastructure (circular inputs)	B3/B4 in terms of Total mass of materials and products (split by reused, recycled, primary origin) O4 Reused and secondary content input
B7 Designed for disassembly/ deconstruction % reuse potential by mass	Percentage by weight of able to be disassembled materials compared to those in **BoQ** Aligned with specific design aspects that contribute to reversibility and future reuse such as independence of elements, connection type, standardised components etc.	N/A	B2 At concept stage: comparison of asset life cycle assessment	B16 Demolition waste reused, recycled, recovered, landfilled
B8 Construction waste generated on and off site tonnes/100K Euros (project value)	Amounts (by mass) and types of waste predicted/produced and project value. Ideally reported according to key (standardised) material streams	N/A	O5 Non hazardous waste arisings U1 Construction & Demolition waste generated	B10 Construction waste reused, recycled, recovered, landfilled B9 Hazardous waste generated during construction should be reported as sub-set

B10 Construction waste reused, recycled, recovered, landfilled % by mass	Amounts (by mass) and types of waste with predicted/ actual management routes split by options, such as reuse, recycle, recover, landfill.	P7 Hazardous Waste B8 Construction waste generated on and off site	P8 Realistic end of life scenarios developed O7 Waste management routes U2 Recycling/recovery rate of construction and demolition waste	O5 Non hazardous waste arisings
B14 Demolition waste generated Tonnes	Typically provided through pre-demolition audit **PDA** – types and amounts (by mass) of key demolition products. Ideally linked to targets for reuse, recycling etc. (B16)	O9 Requirements set for pre-demolition audits and subsequent implementation	O5 Non hazardous waste arisings U1 Demolition waste generated	B15 Hazardous waste generated at demolition should be reported as subset
B16 Demolition waste reused, recycled, recovered, landfilled % by mass	Amounts (by mass) and types of waste with predicted/ actual management routes split by options, such as reuse, recycle, recover, landfill. (Post-demolition reconciliation linked to **PDA**)	B14 Demolition waste generated O9 Requirements set for pre-demolition audits and subsequent implementation	P8 Realistic end of life scenarios developed O7 Waste management routes U2 Recycling/recovery rate of construction and demolition waste	N/A

Assessment of data availability and drivers for core indicators:

From the table summary, it is clear that there are a number of core data sets that can already be used as a basis to report the circularity indicators listed here. These include:

- Bill of Quantities – it is fundamental to have a detailed breakdown of the type and quantities of products and materials that are required to construct building and civil engineering works (CEW). At concept stage, this is often linked to optioneering of early design options, including the potential to retain buildings or infrastructure, rather than full demolition and new build. For certain projects, e.g. infrastructure to deal with flooding risk, it can also be used to evaluate alternatives such as nature based solutions, i.e. the best option can be to not build anything. Substitution at element or component level can also be assessed more effectively when the benefit of reused and recycled content is quantifiable in the context of the whole building or civil engineering works. For existing buildings/ CEW, this BoQ information is typically not readily available, so the alternative is often linked to carrying out a full pre-demolition audit.

- Pre-demolition audits are becoming more commonplace, as illustrated by the French Government's recent national policy requiring these for all demolitions over 1000 m2 from this year. The audits effectively develop a Bill of Quantities for existing structures, usually combined with an assessment of what can be reused, recycled or otherwise recovered; set against quantities (weight) and product (reuse)/ material (recycling) categories. The post-demolition reporting of what actually happened will add further data accuracy over time as assumptions are revised and results are challenged where there is variance from benchmarks. The fact that there are different methodologies and data templates across the EU is not helpful to arriving at comparable benchmarks and reporting of levels of reuse, recycling and recovery of waste arising from demolition.

- Construction site environmental reporting is also quite common, especially in terms of monitoring performance against company targets to reduce avoidable waste and divert other waste from landfill. Similarly, all the voluntary sustainability standards, such as BREEAM, DGNB and Level(s) promote such reporting. Therefore, data relating to waste generation and subsequent management is commonly available.

- Environmental Product Declarations and other generic LCA data, especially for embodied carbon, is also readily accessible across the construction supply chain in recent years. When combined together (using Bill of Quantities), this can offer insights into likely replacement cycles and end of life scenarios to allocate the related impacts across the asset life cycle. However, this data is not always easy to extract from the EPDs to report building/CEW level indicators such as recycled content as % by weight.

The main indicator that has consistently been judged to be high priority but does not have an existing source of data to build upon, relates to Design for Disassembly/ Deconstruction. A key barrier is the lack of standardised methodologies to measure the extent to which this has been delivered. There are checklists and tools that are currently being used at the moment, such as Italy's ITACA which requires a percentage by weight of disassembled materials equal to at least 50%, and by weight of components and materials, and Level (s) 2.4 Design for Deconstruction, and other checklists based upon ISO 20887.

There are strong dependencies between the data captured at building/CEW level and the ability to report against indicators at both Urban and Organisational levels. Accordingly, the accessibility and upward reporting of 'development' level performance is also important to note. It could be thought that is unnecessary to aggregate at these higher levels (urban/organisation) but these are often the mandates that have created the current activity at building/CEW level. For example, planning requirements driving pre-demolition audits, or clients having carbon reporting and reduction targets that necessitate having a detailed BoQ.

Supplementary indicators:

- B1 At concept stage: comparison of asset life cycle costs
- B6 Designed for adaptability and flexibility
- B9 Hazardous waste generated during construction (note but could be measured with B8)
- B11 Construction related waste generated through in-use/ refurbishment cycles
- B12 Effective utilisation of building (e.g. levels of occupancy) or asset; Intensiveness of use B13 At end of use of building/asset: proportion of building/asset retained (mass) for further use
- B15 Hazardous waste generated at demolition

Organisation or process level recommended indicators

The recommendations for the short listed organisational indicators are shown in the Table below.

Table 6: Recommendations for the short listed organisational/process level indicators

Organisational/process level CORE INDICATORS and unit	Main data required	Input from other indicators	Input to other (CORE) indicators	Synergy with CORE indicators
O2 Predicted service life of buildings/infrastructure portfolio Average number of years	The predicted service life definitions in ISO 15686-1:2011 The overall number of buildings/assets	B1 At concept stage: comparison of asset life cycle costs	B2 At concept stage: comparison of asset life cycle assessment	U5 Average age at demolition
O3 Average reused and recycled content in new buildings/infrastructure (circular inputs) % by mass	Total mass of materials and products, split by reused, recycled, primary origin to calculate % by weight that is reused and recycled Aggregate data for all relevant new build assets	B4 At design stage: reused content B5 At design stage: recycled content	N/A	P1 Reused product P2 Remanufactured/reused content P3 Recycled/secondary content
O4 Reused and secondary content input (manufacturer) % by mass	Total mass of materials and products, split by reused, recycled and secondary origin and primary materials Definitions within ISO 14021 Environmental Labels and Declarations	P1 Reused product P2 Remanufactured/reused content P3 Recycled/secondary content	N/A	N/A
O5 Non hazardous waste arisings Tonnes /100K Euros (overall project value)	Amounts and types of waste. Produced. Ideally reported according to key material streams (EWCs); Split by construction, refurbishment	B8 Construction waste generated on and off site	U1 Demolition waste generated O7 Waste management routes	B10 Construction waste reused, recycled, recovered, landfilled B16 Demolition waste reused, recycled, recovered, landfilled

	and demolition activities; project value/spend.	B11 Construction related waste generated through in-use/ refurbishment cycles B14 Demolition waste generated		U2 Recycling/recovery rate of construction and demolition waste
O7 Waste management routes % by mass/year	Amounts and types (EWCs) of waste with actual management routes split by options, such as reuse, recycle, recover, landfill. Split by construction, refurbishment and demolition activities; Split by onsite and offsite; Split by non-hazardous and hazardous waste	B10 Construction waste reused, recycled, recovered, landfilled B16 Demolition waste reused, recycled, recovered, landfilled	U2 Recycling/recovery rate of construction and demolition waste	B8 Construction waste generated on and off site B9 Hazardous waste generated during construction B14 Demolition waste generated B15 Hazardous waste generated at demolition (as a subset of B14) O5 Non hazardous waste arisings O6 Hazardous waste

Assessment of data availability and drivers for core indicators:

The organisational indicators mainly follow the recommendations at the product and building/asset level, as the data is aggregated at these levels to report at an organisational level. The indicators are relevant for those that have a portfolio of assets/buildings. The two Core indicators which have the most drivers in place are for non-hazardous waste arisings and waste management routes, largely because this is included in companies ESG and CSR/sustainability reporting and may also be part of sustainability indexes e.g. GRESB and GSI. Hazardous waste may also be part of company reporting systems, but there is less evidence of it being measured.

For the Core indicator of measuring average reuse and recycled/secondary in new buildings/infrastructure, it is recognised that asset owners can start to aggregate this data from their projects, linked to the increasing drivers for measurement e.g. whole life carbon assessments. Also included as a Core indicator is for manufacturers to record their recycled/secondary content across their relevant product ranges, again due to increasing drivers including company reporting. The Core indicator of Predicted service life is already commonly measured as part of asset management processes, though not often linked to circularity. Supplementary indicators include those that would enable circularity through the setting of processes/requirements (e.g. pre-demolition audits). The refurbishment/transformation of assets, whilst useful, has limited measurement currently and drivers (especially for commercial developments).

Supplementary indicators:

- O1 Refurbishment/transformation rate of buildings/infrastructure portfolio
- O6 Hazardous waste
- O8 Requirements set for specification of circular economy approaches including recycled + reused products and materials
- O9 Requirements set for pre-demolition audits and subsequent implementation

Urban level recommended indicators

The recommendations for the short listed urban indicators are shown in the table below.

Table 7: Recommendations for the short listed urban level indicators

Urban level CORE INDICATORS and unit	Main Data required	Input from other indicators	Input to other (CORE) indicators	Synergy with CORE indicators
U1 Construction & Demolition waste generated Tonnes/ capita	The amount of waste produced from construction and demolition activities per year. Data can be aggregated from development projects or obtained from resource management site reporting.	B8 Construction waste generated on and off site B14 Demolition waste generated	N/A	O5 Non hazardous waste arisings O6 Hazardous waste (as a subset of O5)
U2 Recycling/recovery rate of construction and demolition waste % by mass	Management of construction, refurbishment and demolition waste generated, % by weight to reuse, recycling, (energy) recovery, or landfill (disposal). Data can be aggregated from development projects or obtained from resource management site reporting.	B10 Construction waste reused, recycled, recovered, landfilled B16 Demolition waste reused, recycled, recovered, landfilled	N/A	O7 Waste management routes

Assessment of data availability and drivers for core indicators:

The current availability of data that is required for the circularity indicators at Urban scale is somewhat limited currently, mainly since this is essentially an aggregation exercise (from a specified geographic region with various construction activities within). As discussed in preceding levels, there are significant barriers to wholesale and standardised reporting at these levels, with the exception of EPD related information. However, there are good examples of municipalities who have, or are developing, robust systems of reporting, often linked to the planning process. The CIRCuIT project has explored the urban level indicator options in great detail and concluded that they should focus on 5 indicators at city level. However, when considering the application of these indicators across all urban areas, which is currently very limited, it would be unrealistic as a starting point to have all 5. Therefore, two Core indicators were selected that would be straightforward to report against, ideally based upon aggregated building/CEW data, with supporting organisational data and drivers.

Supplementary indicators:

- U3 Refurbishment and transformation rate relative to new construction
- U4 Demolition rate
- U5 Average age at demolition

Re-grouping recommended indicators Table 8

Given the large number of recommended indicators, the study team recognises that it may be helpful in future policy applications to narrow down this list by focusing on the indicators which are relevant for different circular approaches or themes. To support with this further categorisation, Table 8 (below) shows the relevant indicators (core and supplementary) for each circular economy approach. Some approaches have many relevant indicators such as increasing direct reuse of products and materials, increasing reuse/recycling of waste from construction works, and increasing reuse/recycling of waste from demolition works.

Table 8: Overview or regrouping of recommended indicators by circular economy approach

Circular economy approach	Relevant indicators (Core)	Relevant indicators (Supplementary)
Product as service, new business models		- P10 Part of an Extended Producer Responsibility system (Yes/No) - B1 At concept stage: comparison of asset life cycle costs (euro/m^2/yr) - O8 Requirements set for specification of circular economy approaches (% of projects/yr)
Designing for future disassembly and reuse	- B7 Designed for disassembly/ deconstruction (% reuse potential by mass)	- P4 Design for disassembly and circularity (Index/checklist) - O8 Requirements set for specification of circular economy approaches (% of projects/yr)
Designing for flexibility and adaptability		- B6 Designed for adaptability and flexibility (Score) - O1 Refurbishment/transformation rate of buildings/infrastructure portfolio (% of buildings/infrastructure refurbished/yr) - O8 Requirements set for specification of circular economy approaches (% of projects/yr) - U3 Refurbishment and transformation rate relative to new construction (% of buildings/infrastructure refurbished/yr)
Improving material efficiency/intensity/mass of materials used	- B3 At design stage: Material intensity/ dematerialisation (kg/m2/yr)	- O8 Requirements set for specification of circular economy approaches (% of projects/yr)
Improving durability, lifespan, repairability of construction works	- P6 Predicted service life (years)	- B1 At concept stage: comparison of asset life cycle costs (euro/^{m2}/yr)

Circular economy approach	Relevant indicators (Core)	Relevant indicators (Supplementary)
	- B2 At concept stage: comparison of asset life cycle assessment (kgCO2 eq/ m^2/yr) - B3 At design stage: Material intensity/ dematerialisation (kg/ m^2/yr) - O2 Predicted service life of buildings/infrastructure portfolio (Ave number of years)	- B11 Construction related waste generated through in-use/ refurbishment cycles (tonnes/100K Euros project value) - O8 Requirements set for specification of circular economy approaches (% of projects/yr)
Increasing recycled and secondary content of construction products and materials	- P3 Recycled and Secondary Content (% by mass) - P8 Realistic end of life scenarios developed (Yes/No) - B5: At Design Stage - Recycled content (% by mass) - O3 Average reused and recycled content in new buildings/infrastructure (circular inputs) (% by mass) - O4 Reused, recycled and secondary content input (manufacturer level) (% by mass)	- P9 Residual value per unit product/material at end-of-life (Euros per functional unit) - P10 Part of an Extended Producer Responsibility system (Yes/No) - O8 Requirements set for specification of circular economy approaches (% of projects/yr)

Circular economy approach	Relevant indicators (Core)	Relevant indicators (Supplementary)
Increasing direct reuse of products and materials	- P1 Reused product (Yes/No) - P8 Realistic end of life scenarios developed (Yes/No) - B2 At concept stage: comparison of asset life cycle assessment (kgCO2 eq/ m^2/yr) - B4 At Design Stage - Reused content (% by mass) - B16 Demolition waste reused, recycled, recovered, landfilled (% by mass) - O3 Average reused and recycled content in new buildings/infrastructure (circular inputs) (% by mass) - O4 Reused, recycled and secondary content input (manufacturer level) (% by mass) - O7 Waste management routes (% by mass/yr)	- P2 Remanufactured/reused content (% by mass) - P9 Residual value per unit product/material at end-of-life (Euros per functional unit) - P10 Part of an Extended Producer Responsibility system (Yes/No) - O8 Requirements set for specification of circular economy approaches (% of projects/yr) - O9 Requirements set for pre-demolition audits and subsequent implementation (% of projects/yr)
Increasing reuse/recycling of waste from construction works	- P1 Reused product (Yes/No) - P7 Hazardous waste (% by mass) - P8 Realistic end of life scenarios developed (Yes/No)	- P9 Residual value per unit product/material at end-of-life (Euros per functional unit) - P10 Part of an Extended Producer Responsibility system (Yes/No) - O6 Hazardous waste arisings (tonnes/100K Euros project value)

Circular economy approach	Relevant indicators (Core)	Relevant indicators (Supplementary)
	- P3 Recycled and Secondary Content (% by mass) - B4 At Design Stage - Reused content (% by mass) - B5 At Design Stage - Recycled content (% by mass) - B10 Construction waste reused, recycled, recovered, landfilled (% by mass) - O3 Average reused and recycled content in new buildings/infrastructure (circular inputs) (% by mass) - O4 Reused, recycled and secondary content input (manufacturer level) (% by mass) - O7 Waste management routes (% by mass/yr) - U2 Recycling/recovery rate of construction and demolition waste (% by mass)	- O8 Requirements set for specification of circular economy approaches (% of projects/yr)

Circular economy approach	Relevant indicators (Core)	Relevant indicators (Supplementary)
Increasing reuse/recycling of waste from demolition works	- P1 Reused product (Yes/No) - P3 Recycled and Secondary Content (% by mass) - P7 Hazardous waste (% by mass) - P8 Realistic end of life scenarios developed (Yes/No) - B4 At Design Stage - Reused content (% by mass) - B5 At Design Stage - Recycled content (% by mass) - B7 Designed for disassembly/ deconstruction (% reuse potential by mass) - B14 Demolition waste generated (Tonnes) - B16 Demolition waste reused, recycled, recovered, landfilled (% by mass) - O3 Average reused and recycled content in new buildings/infrastructure (circular inputs) (% by mass)	- P2 Remanufactured/reused content (% by mass) - P4 Design for disassembly and circularity (Index/checklist) - P9 Residual value per unit product/material at end-of-life (Euros per functional unit) - P10 Part of an Extended Producer Responsibility system (Yes/No) - B15 Hazardous waste generated at demolition (% by mass) - O6 Hazardous waste arisings (tonnes/100K Euros project value) - O8 Requirements set for specification of circular economy approaches (% of projects/yr) - O9 Requirements set for pre-demolition audits and subsequent implementation (% of projects/yr)

Circular economy approach	Relevant indicators (Core)	Relevant indicators (Supplementary)
	- O4 Reused, recycled and secondary content input (manufacturer level) (% by mass) - O7 Waste management routes (% by mass/yr) - U2 Recycling/recovery rate of construction and demolition waste (% by mass)	
Reducing waste/wastage rates/waste generation from construction activities	- P7 Hazardous waste (% by mass) - B2 At concept stage: comparison of asset life cycle assessment (kgCO2 eq/ m^2/yr) - B8 Construction waste generated on and off site (tonnes/100K Euros project value) - B14 Demolition waste generated (Tonnes) - O5 Non hazardous waste arisings (tonnes/100K Euros project value)	- P5 Wastage rate at installation (% by mass) - B9 Hazardous waste generated during construction (% by mass) - B11 Construction related waste generated through in-use/ refurbishment cycles (tonnes/100K Euros project value) - B13 At end of use of building/infrastructure: proportion retained (mass) for further use (% by mass retained) - O6 Hazardous waste arisings (tonnes/100K Euros project value) - O8 Requirements set for specification of circular economy approaches (% of projects/yr) - U4 Demolition Rate (% by area (demolished/built environment))

Circular economy approach	Relevant indicators (Core)	Relevant indicators (Supplementary)
	- U1 Construction and Demolition waste generated (tonnes/ capita)	- U5 Average age at demolition (Years)
Life time extension e.g. through retaining and refurbishing	- P6 Predicted service life (Years) - B2 At concept stage: comparison of asset life cycle assessment (kgCO2 eq/ m^2/yr) - O2 Predicted service life of buildings/infrastructure portfolio (Ave. number of years) - O5 Non hazardous waste arisings (tonnes/100K Euros project value) - U1 Construction and Demolition waste generated (tonnes/ capita)	- P2 Remanufactured/reused content (% by mass) - B6 Designed for adaptability and flexibility (score) - B12 Effective utilisation of building (e.g. levels of occupancy) or asset; Intensiveness of use (hours of utilisation/m2) - B13 At end of use of building/infrastructure: proportion retained (mass) for further use (% by mass retained) - O1 Refurbishment/transformation rate of buildings/infrastructure portfolio (% of buildings/infrastructure refurbished/yr) - O8 Requirements set for specification of circular economy approaches (% of projects/yr) - U3 Refurbishment and transformation rate relative to new construction (% of buildings/infrastructure refurbished/yr) - U4 Demolition Rate (% by area (demolished/built environment)) - U5 Average age at demolition (Years)

In summary, this report provides policy makers and stakeholders from across the construction industry ecosystem with a toolbox that can be used to boost the uptake and measurement of circular approaches. In particular, indicator profiles can be used to identify indicators that are most relevant for measuring performance at specific levels and elements of the value chain, and also to identify data requirements. The tables included in this section can also help organisations to identify synergies between possible indicators and to work together

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