D3.3 Recommendations on circularity indicators for WP8

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Abstract	Effective circular economy indicators allow actors to measure the circularity of their activities, target opportunities for improvement, and communicate their circular economy actions in a consistent and comparable way. This report presents the results of a research programme, which intended to develop indicators at the level of materials, buildings and cities. An initial review identified around 510 existing indicators within the extant literature, representing sources from the four CIRCuIT cities and internationally. A process of indicator development and prioritisation was then conducted, resulting in a list of recommended indicators including 10 at city-level, 13 at building-level and 11 at material-/product-/component-level. In addition, a number of enablers were identified as being useful to drive the circular economy process. These indicators will assist, at the municipal level in supporting evidence-based policy and planning development, and decision-making to support circularity of material flows within buildings and throughout material lifecycles. They can be used to inform measurement of the environmental, economic and social impact of circular economy decisions and validate their benefits (or not) using LCA (Life Cycle Assessment), LCC (Life Cycle Costing) and social approaches.

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Executive Summary

Overview

This report summarises the work done in CIRCuIT Task 3.2 “Development of circularity indicators”. It provides an overview of the methodology carried out to establish a set of indicators based upon a comprehensive literature review, incorporating the needs of the CIRCuIT project, the findings of D3.2, and stakeholder engagement. A list of recommended indicators is then provided, designed for use by a range of actor groups with influence over the circularity of built environment material flows. These are to be considered for eventual inclusion in the City Circularity Dashboard (CIRCuIT Task 8.5), as well as certain other tasks within CIRCuIT via integration into the Data Templates (Task 3.3) and Data Frameworks (Task 3.4).

Methodology

The list of recommended list includes indicators developed to measure circularity at the level of city, building and materials/products/components. The final list was compiled following a process in four steps:

- Step 1: Literature review - A literature review was carried out covering the UK, Denmark, Germany, Finland, the EU and, to some extent, beyond the EU to identify indicators linked to the CIRCuIT focus areas or indices (urban mining index, lifespan index and circular design index).

- Step 2: Initial selection, grouping and refinement of indicators - Using the literature review described in Step 1 a desk-based study was carried out to develop a rationalised list of indicators grouped according to lifecycle stage categories from cradle to grave.

- Step 3: Stakeholder engagement – Following the rationalisation and grouping of indicators, the refined set were used as the basis for discussions with invited stakeholders in a series of workshops within each CIRCuIT city cluster.

- Step 4: Prioritisation and recommendations for indicators – Following Steps 1 to 3, final prioritisation exercise was carried out to develop a shortlist of recommended indicators. This activity took into account the findings from the initial definition of useful indicators identified through the literature review, the initial grouping and refinement process, and a review of feedback from the stakeholder workshops. The Step 4 prioritisation also took into account the potential for indicators to contribute towards a set of ‘use cases’ for circular economy action developed concurrently within CIRCuIT Task 3.1.

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Finally, the prioritisation also classified indicators as either 'Core' or 'Aspirational'. Core indicators were those for which there exists a known methodology through which to calculate performance against the indicator, and the data necessary for the indicator is available.

The resulting shortlist of recommended indicators also presented information on the attributes of the indicators, including:

- A description of the indicator
- The measurement (where possible) and units of the indicator
- Relevant stakeholder/user of the indicator

Findings

Approximately 510 indicators were identified, emerging from all geographic areas and covering many lifecycle stages and focal aspects of materials, products, buildings and cities with regard to the circular economy.

Through the process of prioritisation described above the list was consolidated and refined. The final recommended list of indicators included 10 circular economy indicators at city level, 13 at building level and 11 at material/product/component level. Through the process of identification of these indicators, it also became apparent that some enabling factors would be necessary to drive the circular economy process, which were separately recommended as "enablers".

These indicators will be recommended for further evaluation to enable possible integration in the Circularity Dashboard.

Next steps

The main next task will involve further refinement of the recommended list of indicators in order to define the set of indicators to include in the Circularity Dashboard (Task 8.5). While the dashboard is aimed to be used at city level, a review of the building- and material-/product-/component-level indicators will be reviewed as they enable the calculation of city level indicators when aiding with the capture of data to be aggregated. Additionally, the recommendations presented in this report will be combined with the recommendations from Deliverable D3.2 to determine the data to be captured via CIRCuIT Tasks 3.3 (Data Templates) and 3.4 (Data frameworks) to support and monitor the circularity of activities across the CIRCuIT project; this will involve close collaboration with partners across CIRCuIT.

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1 Introduction

1.1 The purpose and structure of this report

The aim of this report is to summarise the work done in Task 3.2 “Development of circularity indicators”. It provides an overview of the methodology carried out to establish a set of indicators based upon a comprehensive literature review, incorporating the needs of the CIRCuIT project, the findings of D3.2, and stakeholder engagement. A list of recommended indicators at city, building and materials/products level is then provided, presenting a mix of impact metrics (e.g. recycled content, material use), productivity metrics (e.g. per value, area) and enabler metrics (e.g. number of projects with circular economy requirements) for inclusion in the Dashboard for Circularity Indicators (Task 8.5). Each indicator in the final recommended list is further described in a form that can be easily used by stakeholders and will provide guidance on the type of indicators that can be used depending on the data availability, their purpose, how they can be measured, monitored and reported and whom by and the benefits of using them.

1.2 General introduction

While substantial social and economic gains are made possible by urban lifestyles and economies, the enormous degree of material consumption currently required to do so contributes to the unsustainable degradation of the Earth’s natural systems, limiting their capacity to deliver essential ecosystem services that support society. In the long term, this trend will counteract any social and economic achievements. Moreover, there are large inefficiencies inherent to the existing delivery of societal benefits, presenting great potential to unlock additional benefits.

It is now widely understood that a key factor limiting or promoting the efficient and sustainable extraction of value is the structure of the economy. In a linear economy, the current standard model, the material resources that are used in a city or region’s built environments are generally extracted from a remote hinterland before travelling via the supply chain to where they serve their purpose as material stocks within built assets, before being removed and disposed of when the asset or product that contains the material comes to the end of its useful life.

The concept of the circular economy seeks to mitigate these issues by ensuring that maximal social and economic value is extracted from each unit of resource used by a society and by reducing the overall demand for resources, whilst minimising the negative impacts (e.g. on the environment) of those resources that are used.

CIRCuIT is a Horizon 2020 funded project which aims to support the creation of regenerative cities by promoting and implementing circular construction approaches. Running from 2019-

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2023, it brings together 29 ambitious partners from Copenhagen, London, Hamburg, and the Helsinki region working across the entire built environment value chain who will work collaboratively to enhance knowledge-and resource-sharing and uptake of the results. To bridge the gap between theory, practice, and policy, the consortium will deliver a series of demonstrations, case studies, events, training sessions, and other dissemination activities that showcase the possibilities of circular, regenerative built environments. Overarching objectives are: to increase the regenerative capacity in the four cities; to reduce the yearly consumption of virgin raw materials by 20% in new built environments; and to show cost savings of 15%. The project will implement innovative solutions focussed on the following areas:

- Urban mining and reverse cycles (dismantling buildings to re-use and recycling of materials);
- Extending building life through transformation and refurbishment;
- Designing for disassembly and flexible construction.

The overall objective of WP3 is to develop a consistent and comprehensive approach to data collection, analysis and management in order to support the demonstrators and to enable the aim for moving the concept of buildings as material banks into a city scale understanding and implementation. Task 3.2 focuses on the development of circularity indicators based on the findings of Task 3.1. The robust and concise list of indicators will provide an overview of circularity at a city, building and material level. The indicators are to be a mix of impact metrics (e.g. recycled content, material use), productivity metrics (e.g. per value, area) and enabler metrics (e.g. number of projects with circular economy requirements). Additionally, reflecting the CIRCuIT focus areas listed above, they are categorised into three indices: the urban mining index, lifespan index and circular design index (see Methodology – Step 2 for definition).

These indicators will assist, at the municipal level in supporting evidence-based policy and planning development, and decision-making to support circularity of material flows within buildings and throughout material lifecycles. In addition, these indicators can be used to inform measurement of the environmental, economic and social impact of circular economy decisions and validate their benefits (or not) using LCA (Life Cycle Assessment), LCC (Life Cycle Costing) and social approaches.

1.3 The role of indicators

An indicator is considered within this research to be a piece of information that an actor (for definition, see footnotes in Methodology Step 2) can use to measure performance and guide their decision-making to enable a circular economy.

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Effective indicators allow such actors to know what they should measure and how and should enable the industry to communicate their circular economy actions in a consistent way. Indicators can support tools used by organisations in identifying additional and circular value from their products; they can enable manufacturers to mitigate risks from material price volatility and material supply when combined with other actions; and, they can allow policymakers to design optimal interventions to promote circularity of built environment material flows. Indicators, sometimes also referred to as metrics, have a key role in enabling the supply chain to understand levels of performance that are achievable and to set targets/benchmark to drive and track improvements. An example is the dashboard created by the Construction Leadership Council in the UK[1], which provides the industry baseline for comparisons of their performances.

[1] New CLC Smart Construction Dashboard Published » Construction Leadership Council

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2 Methodology for the development of circular economy indicators

<u>Step 1:</u> Literature review

A literature review was carried out covering the UK, Denmark, Germany, Finland, the EU and, to some extent, beyond the EU to identify indicators linked to the CIRCuIT focus areas or indices (urban mining index, lifespan index and circular design index).

A semi-systematic approach was taken to the literature review, since the disaggregated and multi-disciplinary nature of the literature on indicators, as well as the need for overly broad eligibility criteria, were judged to prohibit a systematic protocol. Partners from each CIRCuIT city cluster (led by: DTU, TUHH, BRE and HSY) were instructed to conduct a review of the literature on indicators for the circularity of materials, products, buildings, cities and regions/economies[2].

The sources to be included within the literature review included:

1. Known sources (i.e. that the researchers were aware of already)
2. Academic publications
3. Government resources (whether municipal, national or international)
4. Standards and guidance
5. Grey literature (including research reports, think pieces etc.)

As well as literature, it was also recommended that the researchers consult relevant stakeholders in, for example, local government or academic institutions.

Additionally, any identified indicators were to be classed according to whether they would fit into one (or more) of three indices:

- **Urban Mining Index** – Indicators that allow measurement of the degree of secondary resource use through reuse/recycling in existing materials, products, buildings and cities.
- **Lifespan Index** – Indicators that allow measurement of the lifespans, efficiency of use and potential for lifespan extension of existing materials, products, buildings and cities.
- **Circular Design Index** – Indicators that allow measurement of how cities, buildings, and products have incorporated designs and principles in new construction, that facilitate the lifespan extension and reclamation of materials after their use cycle within buildings and products.

[2] NB the rationale for including indicators that covered regions and economies was that they would follow similar organisational principles to those of cities.

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For each indicator identified through the research process, the information shown in Table 1, below, was provided.

Table 1 Structure of the data collection template sent to the partners

Indicator	Provide a name for the indicator. This can be the original name given by the authors or, if the original is unclear, you can create your own. It should be as succinct and accurate as possible.	
Level of mandate	*Level 3*	Recommendations from academic papers, white papers and other research/conceptual work;
	Level 2	Voluntary industry reporting + initiatives, government and industry ambitions (including proposed policies);
	Level 1	Mandatory policies and regulations.
Description	Describe the indicator in more detail. This may be direct quotes from the original source describing the indicator, or it may be your own description.	
Source details	Where possible, provide the author, date and country of the relevant source. If possible, hyperlink a URL to the cell.	
Calculation method	How is performance on the indicator calculated? For example, what methodology is being used, what are the equations? Alternatively, provide a brief description.	
Data requirements	What data is required to perform the calculations for the indicator?	
Metric	What units are used to report performance on the indicator?	
Benchmarks/targets	Indicate whether there are either benchmarks (baselines for performance against this particular indicator) and/or targets (threshold levels to reach for the indicator). In case of 'yes', please provide brief details if possible.	
Comments box	Please briefly provide rationale for why the indicator has been classified as the type	
Index (urban mining index, lifespan index and circular design index)	Demonstrate which Index the indicator is relevant to. Some indicators will cut across more than one of the indices, for example use of reclaimed bricks in a new building could indicate urban mining and circular design. Tick more than one if it makes sense to do so. In other cases, an indicator will not fit neatly into any of the indices. (See the three 'index' descriptions below for more detail)	
Scale:	This is the scale that the indicator's authors intended it to be applied to. In reality, an indicator could theoretically be applied at multiple scales	
Regional/national/international	Check this box if the indicator measures some aspect of circularity at a level larger than a city (i.e. if it demonstrates circular attributes of a region, country, or multiple countries).	
City	Check this box if the indicator measures some aspect of circularity at the level of a town or city.	

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Asset [building]	Check this box if the indicator measures some aspect of circularity at the level of a building or other built asset.
Component/Product	Check this box if the indicator measures some aspect of circularity at the level of a building component/product.
Material	Check this box if the indicator measures some aspect of circularity at the level of a single material.
Organisation	Check this box if the indicator measures some aspect of circularity at the level of an organisation.
Other	Any additional comments

<u>Step 2:</u> Initial selection, grouping and refinement of indicators

Using the literature review described in Step 1 as a basis, work (including desk-based research as well as internal workshops between CIRCuIT partners) was carried out to develop a longlist of indicators that were applicable to CIRCuIT as well as to relevant stakeholders more generally. Some of these were directly pulled from sources in the literature, while others were developed to reflect the specific requirements within the CIRCuIT project.

This rationalisation was also based in part upon an "actor-based approach", whereby indicators were selected or developed according to their utility to the decision-making of key actors[3]. Actors from all points in the lifecycles of materials, products, buildings and building stocks were thus considered as potential users of the indicators, including but not limited to:

- Product manufacturers and distributors
- Building design teams and consultants
- Project clients (private and public)
- Building / asset / facilities managers and owners
- Demolition contractors
- Waste management organisations
- Reused product brokers
- Planning officers

[3] The term 'actor' is used in the present research to refer to any stakeholder with influence over the built environment of a city, and in particular the material stocks and flows associated with the built environment. Actors may be at any level of organisation from product manufacturers to city government.

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- City policymakers.

Evidently, each of the listed actor groups has a differing remit according to the scale of their influence (i.e. processes at the levels of materials/waste, products, buildings or cities) and lifecycle stage they are responsible for. The rationalised indicators were thus classified into product-, building- and city-level indicators, and under each of these classifications, indicators were also grouped according to lifecycle stage:

- **Cradle to gate:** including the extraction/provenance of raw materials, any manufacturing process (either to manufacture new products, remanufacture/recycle/reuse existing ones),
- **Installation and construction:** including transport, installation design and materials input
- **Use:** including maintenance, materials health, service life, use capacity, transformation capacity
- **End of life:** including reuse potential, transformation capacity (to avoid end of life)

To be maximally useful for the identified actors, the lifecycle stage-based groupings were further subdivided into the following categories:

- **Materials input:** this category describes any indicators that will influence the cradle to gate stage buildings and products/materials/components
- **Design:** this category describes any indicators that will influence the way the building is designed – building and products/materials/components levels only
- **Lifespan and in-use performance:** indicators of how efficiently value is extracted and waste is avoided from materials in their in-use phase in products, buildings or building stocks (cities)
- **Circular potential:** indicators that demonstrate the potential for in-use products or buildings to achieve value retention of materials, and minimise waste
- **Material outflows and recirculation:** indicators of the actual quantities and fates of materials emerging at end-of-life within a building
- **Circularity enablers:** indicators of the presence or absence of factors that could enable the acceleration of the uptake of circular decisions.

The refined list of indicators was then used as the basis for discussions in stakeholder engagement workshops, and are presented in section 3.3.

<u>Step 3:</u> Stakeholder engagement

Following the rationalisation and grouping of indicators, the refined set were used as the basis for discussions with invited stakeholders in a series of workshops within each CIRCuIT city cluster.

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During the workshops, the summarised indicators at product/materials, building and city level and the inter-connectivity of those three levels were discussed. Questions included:

- Do the indicators properly measure circular economy at the relevant level (city, building, product/material)?
- Which indicators are most important?
- How could circular economy indicators help to guide circular decision-making in different sectors?
- How should indicators be presented and communicated for highest impact?
- What is the feasibility of the relevant stakeholders implementing indicators such as the ones suggested?

A briefing paper with the refined set of indicators was sent to the participants prior to the event to give them more time to reflect on the indicators' list and come prepared. MIRO was used as a platform to run the workshops, which, due to COVID-19 restrictions, had to be held remotely. A MIRO board was created to capture participants feedback (see Figure 1 below). All the indicators provided in the briefing paper were listed on the board (blue = city level; pale yellow = building level; dark yellow = materials/product level).

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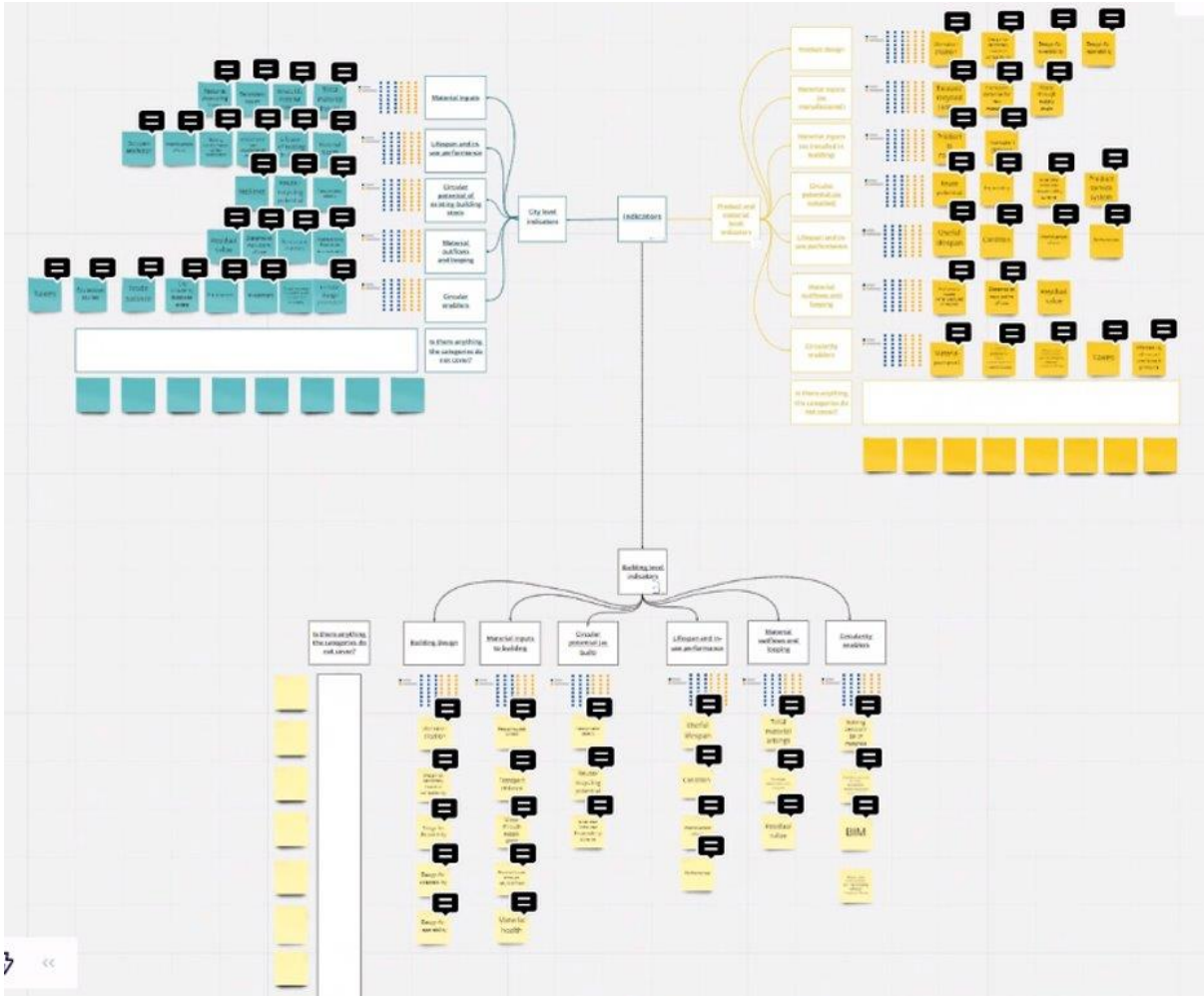

Figure 1: MIRO board used for the indicators' workshops

Each section of the board was constructed in the same way:

- Indicators were listed in the blue post-its and grouped per category – as per the briefing paper
- The little black comment box provided the definition of the indicators as per the briefing paper – as a reminder
- The delegates were given "dots" to vote for the indicators they decided were a priority (blue dots) or non-priority (yellow dots)
- Additional indicators deemed to be "missing" could also be added in the "white box" at the bottom of the MIRO board.

Figure 2, below, shows the building level MIRO board in more detail.

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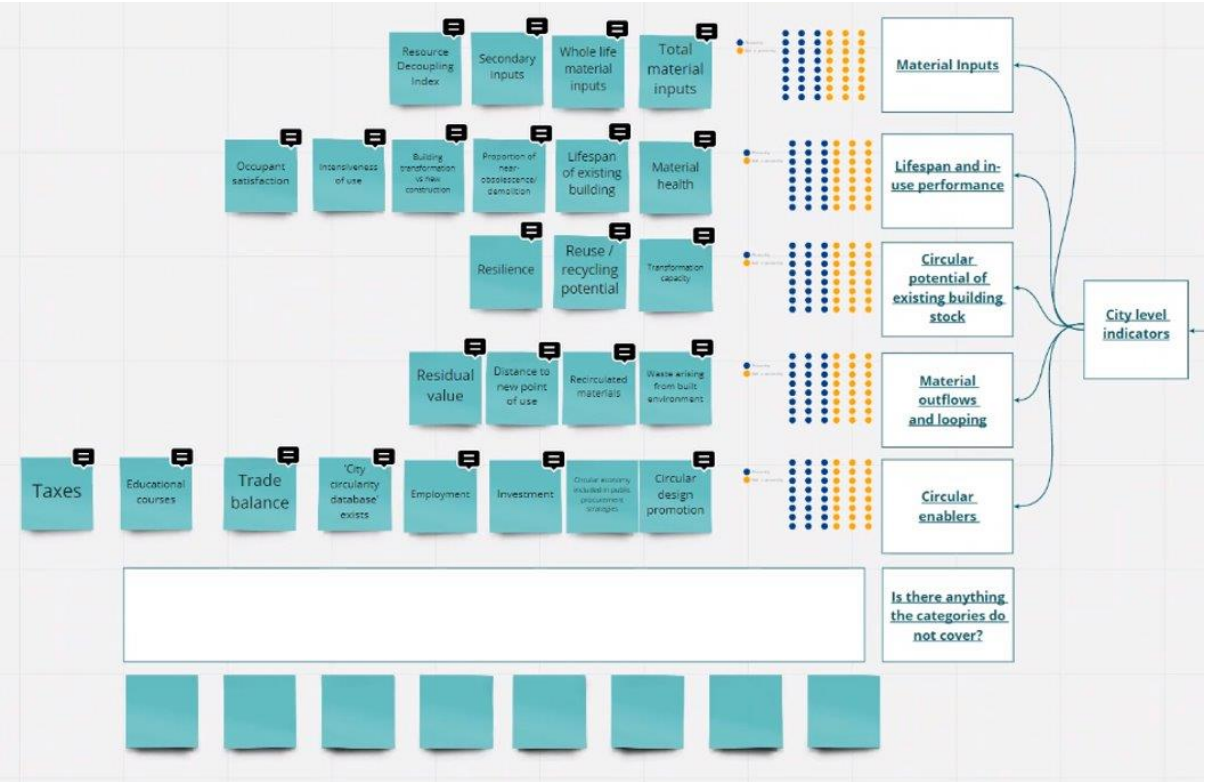

Figure 2: Building level indicators board in MIRO

Delegates were also able to provide comments for each indicator using the “comment” function or additional post-its.

The final task of the workshop was to gather any further feedback or suggestions. That was done via discussions over the board presented in Figure 3, below:

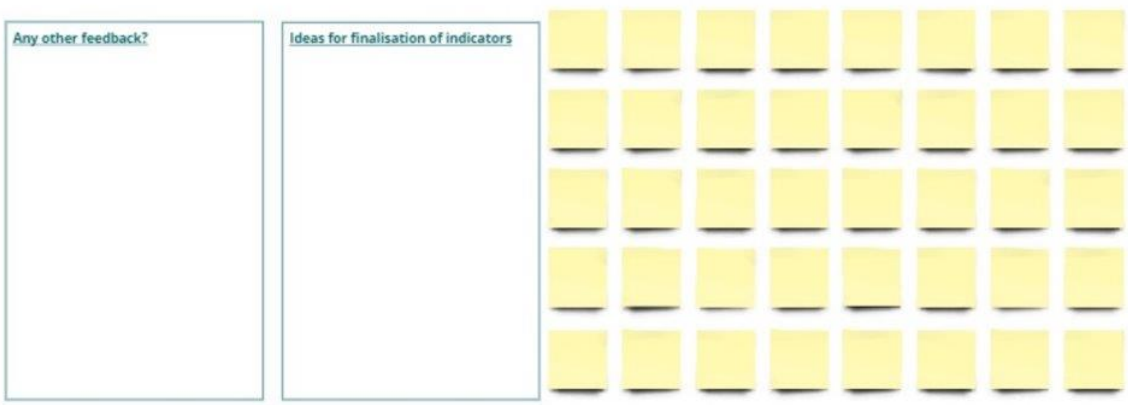

Figure 3: Further feedback and suggestions board in MIRO

Overall, over 80 stakeholders were consulted covering a range of professions: architects, designers, contractors, manufacturers, urban planners, etc. during more than 12 workshops across the 4 cities to represent the actors identified in section 3.1.1**Fejl! Henvisningskilde**

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ikke fundet.. Existing groups interested in circular economy indicators were specifically targets to ensure the right stakeholders were present. For example, the London workshops involved consultation of the UK Green Building Council circular economy forum, and the Finnish Association of Building Owners and Construction Clients (RAKLI).

Step 4: Prioritisation and recommendations for indicators

Following Steps 1 to 3, final prioritisation exercise was carried out to develop a shortlist of recommended indicators. This activity took into account the findings from the initial definition of useful indicators identified through the literature review (Methodology Step 1), the initial grouping and refinement process (Methodology Step 2), and a review of feedback from the stakeholder workshops (Methodology Step 3).

The Step 4 prioritisation also took into account the potential for indicators to contribute towards a set of 'use cases' for circular economy action developed concurrently within CIRCuIT Task 3.1 (these are presented within Table 2 of CIRCuIT deliverable report D3.1).

Finally, the prioritisation also classified indicators as either 'Core' or 'Aspirational'. Core indicators were those for which there exists a known methodology through which to calculate performance against the indicator, and the data necessary for the indicator is available.

The resulting shortlist of recommended indicators also presented information on the attributes of the indicators, including:

- A description of the indicator
- The measurement (where possible) and units of the indicator
- Relevant stakeholder/user of the indicator

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3 Findings

3.1 Key findings from Step 1: Literature review

3.1.1 General information

Approximately 510 of indicators were identified, emerging from all geographic areas and covering many lifecycle stages and focal aspects of materials, products, buildings and cities with regard to the circular economy.

3.1.2 Scale and scope

The scales covered by indicators ranged from the single units of materials or products to buildings and other built assets to city-level.

One notable trend was in terms of the lifecycle stages of products or buildings that the identified indicators covered: mostly, they were geared towards actors in the early stages (manufacture for products, and design/construction for buildings), whereas very few had the functionality of being continuously updated by stakeholder groups throughout a product or building's lifecycle. This is despite an understanding that many indicators of circularity may be influenced distinctly at all lifecycle stages. For example, a product may have good potential for reuse or recycling at design stage (e.g. due to being composed of easily recyclable materials or having design features that allow for high-value deinstallation), but its circularity at end-of-use within a building may be far lower if it was irreversibly bonded to surrounding components or combined with hazardous or non-recyclable materials upon installation.

3.1.3 Sources

Based on the broad scope of sources considered, indicators identified in the review were drawn from a range of stakeholder groups including, but not limited to, international governance bodies (i.e. the European Union), international development organisations (e.g. the Organisation for Economic Cooperation and Development), city authorities (e.g. Amsterdam Circular Strategy), research and technology organisations (e.g. Dutch Green Building Council, Ellen McArthur Foundation), sustainability assessment scheme operators (e.g. BREEAM) and various others. Most sources were organisations based within the European Union.

3.1.4 Content

While there was broad agreement over some aspects of the circular economy, such as the fact that it involved resources efficiency and minimisation of waste, there were also

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numerous heterogeneities between indicator sets in terms of content. This likely reflects the fact that the precise parameters, boundaries and terminologies of the circular economy concept is yet to be universally agreed upon (European Commission 2020[4]). Within the existing knowledge base on the circular economy, there are many overlapping concepts and principles, with different ones adopted by different stakeholder groups depending on their utility and applicability in context.

There were, understandably, variations in content between indicator sets that dealt with different scales (e.g. product indicators vs. city indicators), owing to the differing processes and challenges specific to each, though the general 'material input-output' metrics tended to be represented well throughout.

There was also variation in terms of the type of variables covered. In some cases, indicators were strictly focused on quantification of material flows and related impacts or externalities. In other cases, 'enabler' type metrics were used to indicate, for example, the level of investment in circular business models within cities.

Throughout the indicators identified there tended to be limited links made between resource use and sustainability-related externalities other than in very explicit cases such as product or building lifecycle assessment (LCA) indicators. The circularity of material flows tended to be taken as the final subject of indicators, rather than any positive or negative outcomes, though there were occasionally those such as 'decoupling index'[5] which sought to measure how strongly economic growth was linked with material consumption. The social dimensions of sustainability were poorly represented at all scales, owing in part to the relatively underdeveloped field of quantifying social value/development as related to the built environment. At city level, limited links with key built environment concepts such as transformation capacity – unclear exactly how to implement these.

3.1.5 Structure and data application

There was a high degree of variability in terms of how the identified indicators were structured. For example, some presented single observed data points while others presented the result of complex calculations; some presented binary 'yes/no' answers while others presented categorical or continuous variables; some relied on qualitative information analysis while others were strictly quantitative. The structure of indicators developed and adopted generally depended, at least in part, on the available data. In a great number of cases, and as validated through stakeholder workshops, the data that would be required to support the optimal indicators to measure circular economy was simply not available.

[4] https://op.europa.eu/en/publication-detail/-/publication/ca9846a8-6289-11ea-b735-01aa75ed71a1
[5] UNEP (2011) Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel.

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3.1.6 Standardisation and comparability

While, as mentioned, the indicators identified through the literature review did demonstrate some commonalities in terms of overarching focal areas, the otherwise high variability meant that there was little ability to make direct comparisons between systems that were measured using different indicator sets. For example, a building being measured using the Regenerate tool could not be compared against one measured using relevant BREEAM Materials and Waste metrics due to differences in the subjects of the data, measurement approaches, and types of variable.

Another point to note was that there was often no explicit consideration of whether the indicators would be useable by different stakeholder groups, especially those at different levels of organisations. No indicator developers created indicator sets wherein material-/product-level indicators could be aggregated to building-level indicators and then to city-level indicators, despite the fact that material flows span and may be indicated at these three levels.

3.2 Key findings from Step 2: Initial selection, grouping and refinement

Following the literature review (Step 1) and the development of a longlist of candidate indicators, a grouped and refined list of indicators was developed according to their relevance to CIRCuIT and their applicability for the defined actor groups and use cases as referred to in Deliverable D3.2. The resulting lists of indicators emerging from this grouping and refinement process are presented in Tables 2 to 4, commencing overleaf.

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Table 2: Grouped and refined list of selected city-level indicators

Category	Suggested indicator	Definition	CD/L/UM[6]	D3.2 use cases	Reference
Material inputs	Total material inputs to building stock	Total materials (virgin and secondary) added to the building stock via new construction, refurbishment, retrofit, repairs and maintenance.	UM	21, 23, 26, 27, 28, 29	Circular Flanders (2018)[7] EU Circular Economy Monitoring Framework
	Average whole life material inputs per building	Amount of material required for a typical building in the building stock, across its whole life.	UM	21, 28, 29	Schiller et al 2020[8]
	Secondary inputs to building stock – local/non-local (split into reuse and recycling)	Proportion of material inputs to building stock that are reused or recycled following a previous use within/outside the city/region.	UM	21, 22, 24, 26, 28, 29	CIRCuIT Task 4.1 EOL-RIR indicator from EU Circular Economy Monitoring Framework
	Resource Decoupling Index – economic/social/environmental	The amount of material input per unit of economic/ social/environmental value added by construction & buildings	CD	21, 29	UNEP 2011[9]; Sanye-Mengual et al 2019[10]

[6] Urban mining index (UM), circular design index (CD) or lifespan index (L)
[7] https://vlaanderen-circulair.be/en/summa-ce-centre/publications/indicators-for-a-circular-economy
[8] Schiller G, Lutzkendorf T, Lehmann I, Mormann K, Gruhler K & Knappe F (2020). Management system for building materials as a basis for closed loop material flow analysis considering material efficiency and climate change mitigation. *IOP Conf. Ser.: Earth Environ. Sci.* **588**, 022010
[9] UNEP (2011) Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel.
[10] Sanyé-Mengual E, Secchi M, Corrado S, Beylot S & Sala S (2019). Assessing the decoupling of economic growth from environmental impacts in the European Union: A consumption-based approach. *Journal of Cleaner Production* **236**, 117535.

Lifespan and in-use performance	Average/predicted lifespan of existing building stock	The average/predicted length of time the current buildings are expected to function for	L	21, 28, 29	CIRCuIT Tasks 4.1 and 5.1; Bradley & Kohler 2007[11]; Hu et al 2010[12]
	Near-obsolescence/demolition floorspace	Proportion of building stock that is at high relative risk of demolition within given timeframe	L	21, 28, 29	CIRCuIT Task 5.1; Bradley & Kohler 2007; Zhou et al 2019[13]
	Ratio of building transformation to new construction	Ratio of refurbishment/transformation to new construction	CD	21, 25, 28, 29	CIRCuIT Task 5.1 and discussions with partners
	Actual vs potential intensiveness of use	What is the average intensiveness of use of the building stock relative to the average potential intensiveness of use?	L	21, 25, 28, 29	CIRCuIT Task 5.1 and discussions with partners
	Average user satisfaction	What is the average user satisfaction of building users across building stock?	L	21, 25, 28, 29	CIRCuIT Task 5.1 and discussions with partners
	Material health	Average healthy life years lost due to material health impacts in building stock	L	21, 22, 25, 28, 29	Cradle to cradle certification scheme CIRCuIT Task 5.1 and discussions with partners

[11] Bradley PE & Kohler N (2007). Methodology for the survival analysis of urban building stocks (2007). *Building Research & Information* **35**(5), 529-542.
[12] Hu M, van der Voet E & Huppes G (2010). Dynamic material flow analysis for strategic construction and demolition waste management in Beijing. *Journal of Industrial Ecology* **14**, 440-456.
[13] Zhou W, Moncaster A, Reiner DM & Guthrie P (2019). Estimating lifetimes and stock turnover dynamics of urban residential buildings in China. *Sustainability* **11**, 3720.

Circular potential of existing building stock	Transformable floorspace	The proportion of a city's floorspace that is suitable to be adapted for a different function	CD	21, 25, 28, 29	CIRCuIT Task 5.1 and discussions with partners
	Reuse/recycling potential of existing building stock	The amount of materials which are available for reuse/recycling in the building stock	UM	21, 22, 23, 24, 26, 28, 29	Stephan & Athanassiadis 2018[14]; Hu et al 2010 GLA circular economy statement Materiaalitkiertoon[15]
	Resilience of building stock	Predicted material losses under most likely climate scenarios	L	21, 26, 28, 29	Kohler (2017)[16]
Material outflows and recirculation	Total material arisings from construction and buildings sector	The total amount of materials emerging from the construction and buildings sector	UM	21, 22, 24, 26, 28, 29	Eurostat Economy-Wide Material Flow Accounts[17] EU Circular Economy Monitoring Framework SDG indikatoren[18]
	Recirculated materials – local/non-local	The proportion of total material arisings (see above) that enter new use cycles within/outside the city/region	UM	21, 24, 26, 28, 29	EU Circular Economy Monitoring Framework Eurostat Economy-Wide Material Flow Accounts

[14] Stephan A & Athanassiadis A (2018). Towards a more circular construction sector: Estimating and spatialising current and future non-structural material replacement flows to maintain urban building stocks. *Resources, Conservation & Recycling* **129**, 248-262.
[15] https://materiaalitkiertoon.fi/fi-FI/Seuranta/Rakennusjatteet
[16] Kohler N (2017). From the design of green buildings to resilience management of building stocks. *Building Research & Information* **46**(5), 578-593.
[17] https://ec.europa.eu/eurostat/cache/metadata/en/env_ac_cur_esms.htm
[18] http://sdg-indikatoren.de/12-5-1/

	Average distance to new point of use by products/materials	The distance travelled between recirculated materials' original use and their next use	CD	21, 22, 23, 24, 26, 28, 29	BREEAM UK[19]
	Total residual value of recirculated materials	The total value obtained by recirculation of materials and products	CD	22, 23, 24, 26, 28, 29	BAMB[20]
Circularity enablers	Regulations and (dis)incentives promoting circular design (e.g. lean principles, design for disassembly and adaptability)/ building lifespan extension over replacement/ looping at building end of life	Promotion of circular design incentives	CD/L/UM	None	Aggregate levy[21] MI-ROG[22]
	Circular economy included in public procurement strategies	Circular economy is included in public procurement strategies	CD/L/UM	None	EU Circular Economy Monitoring Framework CIRCTER Project Final report[23]
	Investment in circular sectors and infrastructure	Investment into sectors and infrastructure using circular economy practices	CD/L/UM	None	EU Circular Economy Monitoring Framework Circular Flanders[24]

[19] BREEAM UK New Construction 2018
[20] www.bamb2020.eu
[21] Environmental taxes, reliefs and schemes for businesses: Aggregates Levy - GOV.UK (www.gov.uk)
[22] Major Infrastructure – Resources Optimisation Group (MI-ROG) (aecom.com)
[23] CIRCTER (Circular Economy and Territorial Consequences) https://www.espon.eu/circular-economy
[24] Vercalsteren A, Maarten C & Van Hoof V (2018). Indicators for a circular economy. SUMMA. Available at: https://circulareconomy.europa.eu/platform/sites/default/files/summa_-_indicators_for_a_circular_economy.pdf

	Number of people employed in circularity parts of construction sector	Employment in circular practices within the construction sector.	N/A	None	London Circular Economy Routemap[25] EU Circular Economy Monitoring Framework[26]
	'City circularity database' exists for aggregation and analysis of data on building stocks and material flows	A database is present in the city to analysis the circular economy practices in buildings	UM	21-29	CIRCuIT WP8
	Trade balance	Extent to which material consumption within city/region is based on resources extracted from outside the city/region	UM	None	EASAC indicators[27]
	Educational courses	Number of participants enrolled in University courses on the topic of circular economy	CD/L/UM	None	SDG indikatoren
	Taxes	Taxes on new products	UM	None	UK Aggregate Levy[28]

[25] LWARB. London Circular Economy Routemap. Available at: https://www.isb-global.com/lwarb-londons-circular-economy-routemap/
[26] Amsterdam Circle City Scan
[27] EASAC; European Academies Science Advisory Council (2016). Indicators for a circular economy. Available at: https://www.interacademies.org/publication/easac-indicators-circular-economy
[28] Rates and allowances: Aggregates Levy - GOV.UK (www.gov.uk)

Table 3: Grouped and refined list of selected building-level indicators

Category	Suggested indicator	Definitions	CD/L/UM[29]	D3.2 Use cases	Reference
Building design	Dematerialisation	Material savings achieved through design measures addressing dematerialisation while achieving the same whole life functionality and without compromising on durability, resilience, other technical requirements or health and safety.	CD	8	BREEAM UK[30] CEEQUAL MI-ROG Dutch GBC
	Design for secondary/ renewable material compatibility (i.e. secondary materials are available for design features)	Proportion of a building that can be assembled from secondary/renewable materials and components.	CD	8	CEEQUAL SCREEN indicators
	Design for disassembly	Proportion of building components that are reversible from the wider building without significant damage to either the removed component or its wider assembly	CD	10	ISO20887[31] BAMB DGNB London Circular Economy Statement Guidance; GLA (2020)

[29] Urban mining index (UM), circular design index (CD) or lifespan index (L)
[30] BREEAM UK New Construction 2018
[31] ISO 20887:2020. Sustainability in buildings and civil engineering works — Design for disassembly and adaptability — Principles, requirements and guidance. https://www.iso.org/standard/69370.html

	Design for adaptability (transformation capacity)	The spatial and technical aspects of building design allow for adaptation to another function (as designed)	CD	11	ISO20887 BAMB DGNB Regenerate tool[32]
	Design for repairability	Proportion of building components specified that are designed to be repairable	CD	9, 10	DGNB DGBC BREEAM indicators[33]
Material inputs to building	Reused/ recycled content (split by onsite and offsite reuse)	Proportion of the building that is formed of reused/recycled/upcycled products and product components	UM	12	London Circular Economy Statement[34]
	Average transport distance for raw materials (split by virgin and secondary)	The average distance each unit of material travelled to site. Both virgin and secondary.	CD	None	CEEQUAL BREEAM Voluntary sustainability class for new buildings[35]
	Material losses (waste) through supply chain and construction stage	The amount of materials lost as waste through the processing, transport, storage and configuration/ assembly of materials and	CD	12	Resource wisdom indicator[36] Ellen MacArthur Foundation[37]

[32] Regenerate Guidance Document.pdf - Google Drive
[33] Dutch Green Building Council 2018 - A Framework for Circular Buildings: Indicators for possible inclusion in BREEAM
[34] Circular Economy Statement Guidance consultation draft | London City Hall
[35] https://www.trafikstyrelsen.dk/da/Byggeri/Baeredygtigt-byggeri/Om-baeredygtigt-byggeri#hvad-er-baeredygtigt-byggeri
[36] https://www.sitra.fi/en/articles/resource-wisdom-indicators/
[37] Ellen MacArthur Foundation. Circularity indicators: An approach to measuring circularity. Available at: https://www.ellenmacarthurfoundation.org/resources/apply/material-circularity-indicator

		products prior to specification, plus construction site waste.			
	Material inputs through refurbishment	The quantity and profile of materials required for refurbishments of the building up to the date of measurement	CD	17, 18	London Circular Economy Statement[38] SCREEN indicators
	Material health	Overall health risks of materials and products in building, quantified as impact on healthy life years of building occupants	L	17, 18, 19, 20	Nordic Swan Ecolabel[39] BREEAM
Circular potential (as built)	Transformation capacity	The spatial and technical aspects of building design allow for adaptation to another function (as built)	CD	15, 16, 19, 20	BAMB (Durmesevic 2016[40])
	Reuse/recycling potential	The percentage (by mass) of products which can be reused/recycled	UM	17, 18, 19, 20, 27	Reuse Potential[41] Cradle to Cradle Certified™ Product[42]
	Repairability	The percentage (by mass) of products which can be repaired	L	15, 19, 20	London Circular Economy Statement DGNB

[38] Circular Economy Statement Guidance consultation draft | London City Hall
[39] https://www.nordic-ecolabel.org/
[40] https://www.bamb2020.eu/wp-content/uploads/2016/11/Elma-sustainable-innovation-paper.pdf
[41] Durmisevic 2019 - Reversible Building Design Strategies
[42] https://www.c2ccertified.org/get-certified/product-certification

	% building products covered by Extended Producer Responsibility scheme (e.g. a take-back scheme)	The percentage of buildings which are part of an Extended Producer Responsibility scheme	CD	17, 18, 19, 20	EPR[43]
Lifespan & in-use performance	Useful lifespan	The years the building can be used for its intended purpose	L	15, 16, 19, 20	CIRCuIT WP5 and discussions with partners
	Condition	The condition of the building relative to the industry average	L	15, 16, 19, 20, 27	MI-ROG RTS Environmental Classification?[44]
	Intensiveness of use	The intensity of building use compared to the industry average	L	15, 16, 17, 19, 20, 27	Ellen MacArthur Foundation
	Performance	How well the building performs its function (subjective or objective measurement depending on building function)	L	15, 16, 19, 20	CIRCuIT workshop November 2019
Material outflows and recirculation	Total material arisings (whole life)	The amount of material arisings from the building across its lifetime	UM	21, 24, 26, 28, 29	Part of the concept of EN 15978[45]
	% reused, remanufactured, recycled	The percentage of materials which were reused, remanufactured or recycled	CD	21, 24, 26, 28, 29	London Circular Economy Statement MI-ROG CITYkeys indicators

[43] https://www.wastepackgroup.co.uk/2020/08/26/defra-publishes-waste-plan-confirms-epr-date/
[44] https://cer.rts.fi/en/rts-environmental-classification/
[45] EN 15978: 2011 Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method

					SCREEN indicators Dutch GBC indicators[46]
	Residual value (all materials in building)	The total value obtained from material recirculation of materials within the building	L		MI-ROG
Circularity enablers	Building passport / Bill of Materials	The data set that describes the characteristics of the products in the building which give them value for recovery, recycling and reuse	CD/UM/L	8-20, 27	Dutch GBC indicators BAMB
	Guidelines available for repair, maintenance, transformation and material looping	Data is available for the repair, maintenance, transformation and material looping of the building	CD/UM/L	15-19	Renovation barometer[47] “Guidelines for Sustainable Building” (“Leitfaden Nachhaltiges Bauen”
	BIM	Has a Building Information Model with relevant circularity data	CD/UM/L	8-20, 27	UK industrial strategy[48]
	Relevant data routinely shared with a ‘city circularity database’ throughout lifetime	As described	CD/UM/L	21-29	CIRCuIT WP8 and discussions with partners

[46] Dutch Green Building Council 2018 - A Framework for Circular Buildings: Indicators for possible inclusion in BREEAM
[47] https://www.kiinteistoliitto.fi/palvelut/tutkimus/saannolliset/korjausrakentamisbarometri/
[48] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/210099/bis-13-955-construction-2025-industrial-strategy.pdf

Table 4: Grouped and refined list of selected product-level indicators

Category	Suggested indicator	Definitions	CD/L/UM[49]	D3.2 use cases	Reference
Product design	Dematerialisation	Product has been designed so that the minimum material inputs are required to achieve the same whole life functionality, without compromising on durability, resilience or health and safety.	CD	8, 9	BREEAM UK[50] CEEQUAL MI-ROG
	Design for secondary/renewable material compatibility (i.e. secondary materials are available for design features)	% by mass of product that can be assembled from secondary/renewable materials and components.	CD	9	CEEQUAL
	Design for reversibility	Product can be removed from the building without significant damage to either the removed product or other parts of the building.	CD	9, 10, 11, 27	BAMB DGNB
	Design for repairability	% by mass of components of the product that can be easily removed and repaired or replaced.	CD	9, 10, 27	DGNB
	Reused/recycled content	% by mass of the product that consists of components that have been reused/recycled	UM	9, 27	London Circular Economy Statement[51]

[49] Urban mining index (UM), circular design index (CD) or lifespan index (L)
[50] BREEAM UK New Construction 2018
[51] Circular Economy Statement Guidance consultation draft | London City Hall

Material inputs (as manufactured)	Material health	Overall health risks of materials and products in building, quantified as impact on healthy life years of building occupants	L	27, 28, 29	Nordic Swan Ecolabel[52] Cradle to Cradle Certified product[53]
	Average transport distance for raw materials (split by virgin and secondary)	The average distance the virgin and secondary materials have travelled before incorporation into the product	CD	9, 27	CEEQUAL BREEAM Voluntary sustainability class for new buildings[54]
	Material losses (waste) through supply chain	Quantity of materials wasted in processing, transport, storage and configuration/assembly of materials for final product	CD	8, 9, 27	Resource wisdom indicator[55] Ellen MacArthur Foundation
Material inputs (as installed in building)	Product is reused	The product has previously been used for the same function in another building	CD	9	DGBC indicators[56]
	Transport distance from point of extraction to point of installation	The distance the material travels between extraction and installation	UM	9	BREEAM Voluntary sustainability class for new buildings[57]

[52] https://www.nordic-ecolabel.org/
[53] https://www.c2ccertified.org/get-certified/product-certification
[54] https://www.trafikstyrelsen.dk/da/Byggeri/Baeredygtigt-byggeri/Om-baeredygtigt-byggeri#hvad-er-baeredygtigt-byggeri
[55] https://www.sitra.fi/en/articles/resource-wisdom-indicators/
[56] Dutch Green Building Council 2018 - A Framework for Circular Buildings: Indicators for possible inclusion in BREEAM
[57] https://www.trafikstyrelsen.dk/da/Byggeri/Baeredygtigt-byggeri/Om-baeredygtigt-byggeri#hvad-er-baeredygtigt-byggeri

Circular potential (as installed)	Reuse potential	Product is designed and installed so that it can be easily demounted from the wider assembly with no loss of value to itself or the assembly	UM	9, 10, 11, 15, 16, 17, 18, 27	Reuse Potential[58] Cradle to Cradle Certified product
	Repairability	The number of components of the product that can be easily removed and replaced (once installed)	L	9, 15	London Circular Economy Statement DGNB
	Part of an extended producer responsibility scheme	The product is covered by an Extended Producer Responsibility scheme by the manufacturer (e.g. a take-back scheme)	CD	9, 17, 18	EPR[59]
	Part of a product-service system	The product is used as part of a product-service system	CD	9, 17, 18	BAMB Ellen McArthur Foundation
Lifespan and in-use performance	Service life	The number of years the material or product can be used for its intended function	L	9, 15, 17, 18, 27	Ellen McArthur Foundation
	Condition	Condition of product compared with industry average, taking into account its time in-use and usage patterns	L	9, 15, 17, 18, 19, 27	MI-ROG BREEAM RTS Environmental Classification[60]
	Intensiveness of use	The intensity of product use compared to the industry average	L	9, 15, 17, 18	Ellen MacArthur Foundation

[58] Durmisevic 2019 - Reversible Building Design Strategies
[59] https://www.wastepackgroup.co.uk/2020/08/26/defra-publishes-waste-plan-confirms-epr-date/
[60] https://cer.rts.fi/en/rts-environmental-classification/

	Performance	How well the product or material performs its function	L	9, 15, 17, 18, 27	CIRCuIT workshop November 2019
Material outflows and recirculation	% of product actually reused, remanufactured or recycled	The percentage of materials in the product which actually sent for reused, remanufactured or recycled following the refurbishment/demolition of a building. NB this indicator would be useful where it feeds into a database compiling the stocks and flows of materials and products, for aggregation and analysis to understand typical whole life performance against circularity-related variables for common products / product groups.	CD	21-26, 28, 29	CIRCuIT Task 4.1 and discussions with partners
	Average distance to new point of use	Distance travelled by materials from original use to next use. NB this indicator would be useful where it feeds into a database compiling the stocks and flows of materials and products, for aggregation and analysis to understand typical whole life performance against circularity-related variables for common products / product groups	UM	21-26, 28, 29	Voluntary sustainability class for new buildings
	Residual value	Financial value obtained by actor with duty of care of product at building end of life. NB this indicator would be useful where it feeds into a database compiling the stocks and flows of materials and products, for aggregation and analysis to understand typical whole life performance against circularity-related variables for common products / product groups.	L	21-26, 28, 27, 29	CIRCuIT Tasks 4.1 and 7.5 and discussions with partners BAMB D15

Circularity enablers	Material passport	The data set that describes the characteristics of the products in the building which give them value for recovery, recycling and reuse	CD/UM/L	8-18	DGBC indicators BAMB
	Guidelines available for repair, maintenance and material looping	Data is available for the repair, maintenance, transformation and material looping of the building	CD/UM/L	9, 15, 17, 18	Renovation barometer[61] “Guidelines for Sustainable Building” (“Leitfaden Nachhaltiges Bauen) Cradle to Cradle Certified
	Relevant data routinely shared with ‘city circularity database’ throughout lifetime	As described; allows for material traceability throughout lifecycle	CD/UM/L	21-29	WP8
	Taxes	Taxes on new products	CD/UM/L	22	Aggregate Levy UK
	Affordability of reused and leased products	Price of reused and leased products compared to linear products	CD/UM/L	28, 29	Discussions with partners

[61] https://www.kiinteistoliitto.fi/palvelut/tutkimus/saannolliset/korjausrakentamisbarometri/

3.3 Key findings from Step 3: Stakeholder engagement

As described in section 2 (Step 2: Stakeholder engagement), a number of workshops were run in each city to discuss to gather the level of interest generated by the indicators.

The workshops did not focus on indicators that would be calculated using LCA, LCC or social impact, rather they focused on the more circularity-related indicators that would feed into these type of assessments (for example the mass of materials and distance transported, as opposed to the carbon footprint of these actions). However, the importance of including LCA-related metrics, in particular the carbon footprint in terms of $kgCO_2eq$ was mentioned in several workshops. Whatever the results provided by the indicators, the results should be validated by an environmental, economic and social impact assessment. In particular, the reference to LCA was made several times and, at the very least, a measure of the decisions taken expressed in terms of $kgCO_2eq$ was identified as being of high importance.

The outcomes of the workshop are presented at city, building and product/components in Annex 1. A summary of the findings is summarised in the sections below.

3.3.1 City-level workshop summary

The following indicators generated much interest from the stakeholders at city level:

- Total material inputs to building stock
- Secondary inputs to building stock – reused/recycled materials with more focus on reuse
- Ratio of building transformation to new construction
- Average/predicted lifespan of existing building stock
- Intensiveness of use
- Reuse/recycling potential of existing building stock
- Total waste arisings from construction and buildings sector and end of life reporting
- Recirculated materials

In addition, two indicators classified as enablers could be quantifiable and added to the list:

- Quantity of materials that is reused/recycled through dedicated centres
- Proportion of building stock mapped (i.e.: % of buildings for which material content has been calculated and mapped)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201

3.3.2 Building-level workshop summary

The following indicators generated the most interest from the stakeholders:

- Total materials input to building stock
- Design for disassembly
- Design for adaptability
- Renewable/recycled/reused content
- Reuse/recycling potential
- Transformation capacity
- Total material arisings (whole life)
- % reused, remanufactured, recycled
- End of Life scenario (additional)
- Intensiveness of use

Some of the indicators generated a lot of discussions and there is a range of opinions from the different cities, such as residual value.

3.3.3 Materials/products/components-level workshop summary

The following indicators generated the most interest from the stakeholders:

- Dematerialisation
- Design for reversibility and repairability
- Reused, recycled and renewable content
- Reused or recycled products
- Reuse potential
- Part of an extended producer responsibility scheme
- Service life
- % of product actually reused, remanufactured or recycled
- Residual value

Overall, there was a broad agreement on the indicators that should be taken forward. The main point of difference is around the reuse potential. Some stakeholders think it is more important to focus on the actual performances, others think that designing products with the potential for reuse will avoid the displacement of the impact to the future. Materials passports and guidelines on the product were discussed as important enabler to ensure that if a product is designed to be reused, that information is communicated throughout its use phase.

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4 Key findings from Step 4: Finalised list of indicators

The shortlist of recommended indicators, presented in Table 4 below, is the result of the final prioritisation exercise (Methodology Step 4), taking into account the findings from the initial definition of useful indicators identified through the literature review (Methodology Step 1), the initial grouping and refinement process (Methodology Step 2), and a review of feedback from the stakeholder workshops (Methodology Step 3).

These indicators will be recommended as part of the final identification of indicators for WP8 Dashboard for Circularity Indicators and will, where applicable, support the data collection process during the demonstrators.

Note that while enablers were considered less directly important for monitoring and benchmarking circular economy than more quantitative indicators, they are still included as recommendations (see Table 6) due to their ability to support evidence-based policy development and decision-making, as detailed in task 7.1 and 7.5. Note that only enablers as high or medium interest were selected for the final list.

Table 5 below provides a summary of the final list of indicators together with a definition, the measurement unit and stakeholder mapping.

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Table 4: Shortlist of indicators at city, building and materials/products/components level

City level indicators					
Category	**Indicator name (index)**	**Indicator description**	**Suggested unit**	**Stakeholder relevance/benefit**	**Core or Aspirational**
Material inputs Existing stock	Total material inputs to building stock (UM)	Indicates the quantity of material inputs (virgin and secondary) to the city's built environment. Calculated as an absolute quantity of materials used.	Tonnes of materials	Urban planners will be able to set targets on how much materials is needed and what type	Aspirational
	Secondary inputs to building stock – recycled materials (UM)	Indicates the proportion of raw material inputs to the city's built environment that are recycled (excluding downcycling) following a previous use cycle. Calculated as a percentage of recycled materials compared to virgin materials used.	% of recycled materials versus virgin materials	Planning officers will be able to set targets for amount of recycled materials to be used in future buildings	Aspirational
	Secondary inputs to building stock – reused materials (UM)	Indicates the proportion of raw material inputs to the city's built environment that are reused) following a previous use cycle. Calculated as a percentage of reused compared to virgin materials used.	% of reused materials versus virgin materials	Planning officers will be able to set targets for amount of reused materials to be used in future buildings	Aspirational
Lifespan and in-use performance	Ratio of building transformation to new construction (CD)	Ratio of refurbishment/transformation to new construction	% of buildings that are refurbished rather than demolished	Urban planners will be able to set targets for buildings to be refurbished rather than demolished	Core
	Intensiveness of use (L)	The average intensiveness of use of the building stock relative to the average potential intensiveness of use. This indicator is only suitable for buildings such as schools, offices or community centres.	% hours actually occupied versus potential	Planning officers will be able to validate the need for new buildings to be added or if they could more efficiently use existing ones	Aspirational

		Number of hours the building is occupied versus the amount of hours it has the capacity to be occupied in average			
	Proportion of different materials in building stock mapped (additional one) (UM)	Map of materials available in the current building stock Tonnes of materials of different types in different building types. This will be calculated using pre-demolition audits	Tonnes of materials	Demolition industry/contractors will be able to evaluate faster what material is available where for more efficient reuse	Aspirational
Circular potential of existing building stock	Reuse/recycling potential of existing building stock (UM)	The amount of materials which are available for reuse/recycling in the building stock.	Tonnes of materials that has the potential for reuse/recycling	Policy makers will be able to set targets for recycling and reuse	Aspirational
Material outflows and recirculation – based on actual current activities	Total materials/wastes arising from construction and buildings sector and end of life reporting (UM)	The total amount of materials and wastes emerging from the construction and buildings sector.	Tonnes of wastes generated	Policy makers will be able to understand quantities of wastes generated	Core
	Recirculated materials (UM)	The proportion of total materials arisings at end-of-use in buildings within the city/region (see above), that enter new use cycles within the city/region (reuse/recycle) % per tonnes of the city's construction and demolition waste that is recycled or reused	% per tonnes of the city's solid waste that is recycled or reused	Policy makers will be able to validate their targets for recycling and reuse against those numbers	Aspirational
	Quantity of materials that is reused/recycled through dedicated centres (UM)	Quantity of materials that is reused/recycled through as a material outflow Tonnes of materials reused/recycled in the city	Tonnes of materials reused/recycled	Policy makers will be able to understand the efficiency of reuse/recycling ability at city level	Core

Building level indicators					
Category	**Indicator name**	**Indicator description**	**Suggested unit**	**Stakeholder relevance/benefit**	**Core or aspirational**
Building design	Dematerialisation (linked to total material inputs to building stock) (CD)	Building has been designed so that the minimum material inputs are required to achieve the same whole life functionality, without compromising on durability, resilience, other technical performance requirements or health and safety. % of material that has not been used as a result of redesigning and as a function of the total amount of material used	% of material not used	Designers demonstrate that they have designed the asset with material optimisation. This will support building level assessments, such as BREEAM. This information will also inform LCA and LCC studies	Aspirational
	Design for disassembly (CD)	Proportion of building components that are reversible from the wider building without significant damage to either the removed component or its wider assembly. This indicator should be linked to BIM and guidelines to ensure stakeholder down the supply chain can optimise the building end of life. This indicator is measured using ISO20887. % of the building that can be disassembled at end of life	% of the building that can be disassembled	Designers can demonstrate to urban planners that the building can be disassembled at the end of its life. This will support building level assessments, such as DGNB. This information will also inform LCA and LCC studies	Core
	Design for adaptability (transformation capacity) (CD	The spatial and technical aspects of building design allow for adaptation to another function (as designed). This indicator is measured using ISO20887.	% of the building that can be adapted at end of life	Designers can demonstrate to urban planners that the building can be disassembled at the end of its life. This will support building	Core

		% of the building that can be adapted at end of life		level assessments, such as DGNB. This information will also inform LCA and LCC studies	
Material inputs to building	Reused content (UM)	Proportion of the building that is formed of reused products and product components % reused content	% reused content	These will enable contractors to demonstrate compliance with local requirements, such as the GLA circular economy statement. This indicator will also inform policy makers to set future targets. This information will also inform LCA studies	Core
	Recycled content (UM)	Proportion of the building that is formed of recycled/upcycled products and product components (exclude downcycling). % recycled content	% recycled content		Core
Circular potential (as built)	Transformation capacity (CD)	The spatial and technical aspects of building design allow for adaptation to another function (for existing buildings)	Monofunctional (score 3-6) Transfunctional (score 6-8) Fully transformable (score >8)[62]	This enables building owners/ managers or developers to understand the potential to transform their building to deliver greater value and function with lower resource inputs.	Aspirational
	Reuse potential (UM)	The percentage (by mass) of products which can be reused at the end of the life of the building	% by mass of products that can be reused	These will enable contractors to demonstrate compliance with	Core

[62] See Durmisevic, E. (2016). Dynamic and Circular Buildings by High Transformation and Reuse Capacity https://www.bamb2020.eu/wp-content/uploads/2016/11/Elma-sustainable-innovation-paper.pdf

	Recycling potential (UM)	The percentage (by mass) of products which can be recycled at the end of the life of the building	% by mass of products that can be recycled	local requirements, such as the GLA circular economy statement.	Core
Lifespan & in-use performance	Intensiveness of use (L)	The average intensiveness of use of the building stock relative to the average potential intensiveness of use. This indicator is only suitable for buildings such as schools, offices or community centres. Number of hours the building is occupied versus the amount of hours it has the capacity to be occupied in average	% hours actually occupied versus potential	Clients will be able to understand whether the use of their asset is optimised. Planning officers will also be able to validate the need for new buildings to be added or if they could more efficiently use existing ones	Aspirational
Material outflows and recirculati on	Residual value (all materials in building) (L)	The forecasted total value obtained from material recirculation of materials within the building	£ or euro that can be extracted from the reuse of components in the building	Demolition companies and contractors will be able to quantify the benefits of maximising reuse and recycling. Investors will understand the value of their portfolio	Aspirational
	Total material arisings (whole life) (UM)	The amount of waste materials from the building across its lifetime, including during future refurbishment, repair phases.	Tonnes of waste arising	Policy makers will be able to understand quantities of wastes generated. This information will also inform LCA and LCC studies	Core
	% reused, remanufactured, recycled (CD)	The percentage of materials which were reused, remanufactured or recycled at the end of the life of the building	% reused, remanufactured, recycled	Policy makers will be able to validate their targets for recycling and reuse against those numbers. This information will also inform LCA studies	Core

	End of Life reference scenario (UM)	Mapping of material history and recycling potential, before it reaches a material bank/storing site.	Typical % recycled or reused at end of life	Policy makers will be able to validate their targets for recycling and reuse against those numbers. This information will also inform LCA studies	Aspirational
Materials/product/components level indicators					
Category	**Indicator name (index)**	**Indicator description**	**Suggested unit**	**Stakeholder relevance/benefit**	**Core or aspirational**
Product design	Dematerialisation (linked to total material inputs to building stock) (CD)	Product has been designed so that the minimum material inputs are required to achieve the same whole life functionality, without compromising on durability, resilience, other technical performance requirements or health and safety. % of material that has not been used as a result of redesigning the product and as a function of the total amount of material used	% of material not used	Product manufacturers demonstrate that they have designed the product with material optimisation. This will support scheme such as the cradle to cradle certification scheme. This information will also inform LCA and LCC studies	Core
	Design for repairability (CD)	Product has been designed to enable future repair of key components of the product. This is not applicable to all products. % by mass of components of the product that can be easily removed and repaired or replaced.	% by mass of components of the product that can be easily removed and repaired or replaced.	Product manufacturers demonstrate that they have designed the product for future repairability. This will support scheme such as the cradle to cradle certification scheme. This information will also inform LCA and LCC studies	Core
Material inputs (as	Reused content (UM)	Proportion of the product/component that is formed of reused materials/products	% reused content	These will enable products manufacturers to demonstrate to	Core

manufactured)		% by mass of the product that consists of components that have been reused		contractors' compliance with local requirements, such as the GLA circular economy statement. This indicator will also inform policy makers to set future targets. This will also support product certification schemes like EPD or cradle to cradle This will support schemes such as the cradle to cradle certification scheme. This information will also inform LCA and LCC studies	
	Recycled content (UM)	Proportion of the product/component that is formed of recycled materials/products (exclude downcycling). % by mass of the product that consists of components that have been recycled	% recycled content		Core
Material inputs (as installed in building)	Product is reused after it has been used in a building (CD)	The product has previously been used for the same function in another building % of similar products/components that are reused at the end of their life based on actual waste analysis.	% reuse	This informs the product manufacturers on the end of life potential of their product/component. This can also inform policy makers on whether there is a further need for recycling facilities. This will support scheme such as the cradle to cradle certification scheme. This information will also inform LCA and LCC studies	Core
	Product is recycled after it has been used in a building (CD)	The product has previously been used for the same value function in another building and has been through some processing. % of similar products/components that are recycled at the end of their life based on actual waste analysis. Excludes downcycling	% recycled		Core
Circular potential (as installed)	Reuse potential (UM)	Product is designed and installed so that it can be easily demounted from the wider assembly with no loss of value to itself or the assembly	% potential reuse	This will support scheme such as the cradle to cradle certification scheme. This information will also inform LCA and LCC studies	Core

		% of the product/component that has the potential to be reused			
	Part of an extended producer responsibility scheme (CD)	The product is covered by an Extended Producer Responsibility scheme by the manufacturer (e.g. a take-back scheme) This is a yes/no answer	Yes/no	This will enable policy makers to identify where more EPR schemes may need to be implemented. This will affect product manufacturers & suppliers	Core
	Repairability potential (L)	The amount of components of the product that can be easily removed and replaced (once installed)	% of the essential components of the product that can be repaired	This will enable the replacement of core components of units without the need to replace whole units. This will enable facility managers to manage better the buildings	Aspirational
Lifespan and in-use performance	Service life (L)	The number of years the material or product has been used for its intended function.	Number of years	This will enable the demolition industry to understand whether the product/component can be reused. It will also inform contractors on when the product needs to be considered for further testing to ensure it is fit for purpose	Core
Material outflows and recirculati on	Residual value (L)	Financial value obtained by actor with duty of care of product at building end of life	£ or euro that can be made from the reuse of a product	Demolition companies and contractors will be able to quantify the benefits of maximising reuse and recycling. Investors will understand the value of their portfolio	Aspirational

Table 6: Short list of enablers at city, building and materials/products/components level

City level enablers		
Indicator	**Description**	**Stakeholder**
Promotion of circular design incentives	Number of initiatives, regulations, taxes for new materials and incentives promoting circular design (e.g. lean principles, design for disassembly and adaptability)/ building lifespan extension over replacement/ looping at building end of life	Policy makers need to develop the right incentives to the whole construction industry to enable more circular decisions to be made. Those could be at planning stage for example.
Circular economy included in public procurement strategies	Proportion of value procurement in which Circular economy requirements are included in public procurement strategies	Government department, local authorities, public bodies need to set procurement rules to enable more circular economy decisions to be made
'City circularity database' exists for aggregation and analysis of data on building stocks and material flows	A database is present in the city to analyse the circular economy practices in buildings	The database would be populated and used by contractors and demolition companies (demand/supply), facility managers (during refurbishment and repair cycles). It would also be useful to policy makers to establish targets for reuse/repair and recycling.
Educational courses/skills	Number of participants enrolled in University courses/ apprenticeship/ upskilling on the topic of circular economy	Universities and professional bodies can set up course to upskill professionals and students to make them aware of the importance of circular economy
Proportion of building stock mapped (ie: materials with building known)	Amount of material required for a typical building in the building stock, across its whole life.	A better understanding of the building stock in a given city will support planning officers in their decision to award permission to build as they would understand the building stock better.
Building level enablers		
Indicator	**Description**	**Comment**

Building passport / Bill of Materials	The data set that describes the characteristics of the products in the building which give them value for recovery, recycling and reuse	Building on materials passport this enable information on the building to be passed on to facility managers, landlords.
Guidelines available for repair, maintenance, transformation and material looping	Data is available for the repair, maintenance, transformation and material looping of the building	Information on the efficient repair/maintenance/replacement schedule of components will enable facility managers/ landlords to manage their facility more efficiently. It will also ensure the end of life of components/products is optimised. Product manufacturers could therefore benefit from materials/products re-entering the manufacturing loop
BIM	Has a Building Information Model with relevant circularity data.	The BIM model should be used by the whole building supply chain from designers to facility managers and need to be kept up to date throughout the building life
'City circularity database'	Relevant data routinely shared with a 'city circularity database' throughout lifetime	A database that enables communication across the whole supply chain and support the supply/demand of recycled/reused materials
Screening of existing buildings (added)	Resource and environmental pre-demolition audit	Contracted by the client or contractor, this will enable the policy makers to inform recycling/reuse targets
Logistic centre	Logistic centre to store and transport recycled/reuse materials in an efficient way. Linked to "number of reuse/recycling centres created" at city level/	Client with large portfolio would benefits for setting hubs to support a better supply/demand approach. Those could also be set up at city level.
Material/product/component enablers		
Indicator	**Description**	**Comment**
Material passport	The data set that describes the characteristics of the products in the building which give them value for recovery, recycling and reuse	This must be in place to support any re-use or potential re-use in future life cycles. Really important to know what is going into buildings today to avoid the same issues we currently face with

		existing building stock i.e. don't know what's in them so how do we reuse? Screening/mappings of the potential hazardous substances in buildings should be part of the materials passport. Long use of buildings, components and materials can be promoted by equipping buildings with a deconstruction/disassembly/adaptability plan
Guidelines available for repair, maintenance and material looping	Data is available for the repair, maintenance, transformation and material looping of the building	This is not always the right incentive for all products. Could be part of material passport
Taxes	Taxes on new products	Important to ensure that the tax will drive the right incentive and not promote the wrong behaviour. Tax relief on high recycling/reuse rate could be an option
Affordability of reused and leased products (additional)	Price of reused and leased products compared to linear products	This is calculated as part of a whole life costing approach

5 Summary and next steps

Summary of finding

Task 3.2 focused on the development of circularity indicators based on the findings of Task 3.1 to create a robust and concise list of indicators to recommend for inclusion in the Circularity Dashboard (WP8). The indicators identified provide an overview of circularity at a city, building and material level and a mix of impact metrics (e.g. recycled content, material use), productivity metrics (e.g. per value, area) and enabler metrics (e.g. number of projects with circular economy requirements). Those indicators will feed into the lifespan, urban mining and circular design indices and will assist, at the municipal level in supporting evidence-based policy and planning development and decision making, as well as at the project level, in terms of the availability and use of reclaimed and recycled materials. In addition, these indicators can be used to inform measurement of the environmental, economic and social impact of circular economy decisions and validate their benefits (or not) using LCA (Life Cycle Assessment), LCC (Life Cycle Costing) and social impact approaches.

Approximately 510 indicators were identified through the literature review and a process of prioritisation then enabled the categorisation of these indicators in categories following life cycle stages. A process of prioritisation taking into account the findings from the initial definition of useful indicators identified through the literature review, the initial grouping and refinement process, and a review of feedback from the stakeholder workshops. The final list of indicators was informed by the D3.2 use cases.

The final recommended list of indicators included 10 circular economy indicators at city level, 13 at building level and 11 at material/product/component level. Through the process of identification of these indicators, it also became apparent that some enabling factors would be necessary to drive the circular economy process. Those have been labelled “enablers”.

These indicators will be recommended for further evaluation to enable possible integration in the WP8 circularity dashboard.

Next steps

1) Refining and finalisation of the list of indicators to include in the WP8 Circularity Dashboard based on recommendations from D3.3. and wider input from the four cities, which might include the review of the initial list of indicators. While the dashboard is aimed to be used at city level, a review of the building and materials/products/components level indicators will be reviewed as they enable the calculation of city level ones.

2) Rationalisation of the indicators to feed into the measurement of the three indices: urban mining index, lifespan index and circular design index.

3) Clear and specific definition of the final indicators boundaries and applicability in each city

4) The results of this report will feed into the remaining WP3 tasks, specifically 3.3 and 3.4., WP8 and WP7.

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Annex 1: Feedback from stakeholder workshops

City level indicators

Table 7 below summarises the workshops findings at City level and highlights whether the indicators generated a high, medium or low level of interest. Based on the ease of calculation with the current data available, those indicators have been classified as suitable for CIRCuIT (core) or aspirational (ie: the data and/or the methodology to calculate the indicator are not available). It is important to note that not all indicators were given a rating as the workshop attendees were only given a number of votes each. The indicators were also classified as “impact” (eg: recycled content or materials use) or “productivity” (eg: per value, area).

Table 7: City level indicators identified as relevant to the sector

Category	Indicator name	Indicator description and suggested units	Priority (H/M/L)				Impact/ productivity	Core or aspirational
			Lon[63]	Cop[64]	Ham[65]	Van[66]		
Material inputs	Total material inputs to building stock	Indicates the quantity of material inputs (virgin and secondary) to the city's built environment Calculated as an absolute quantity of materials used materials used.	H	M	H	-	Impact	Core
	Secondary inputs to building stock – recycled materials	Indicates the proportion of raw material inputs to the city's built environment that are recycled (excluding downcycling) following a previous use cycle. Calculated as a percentage of recycled materials compared to virgin materials used.	H	L	-	-	Impact	Core
	Secondary inputs to building stock – reused materials	Indicates the proportion of raw material inputs to the city's built environment that are reused) following a previous use cycle. Calculated as a percentage of reused compared to virgin materials used.	H	L	H	-	Impact	Core
	Resource Decoupling Index –	The amount of material input per unit of economic/ social/environmental value added by construction & buildings	L	M	-		Productivity	Aspirational

[63] London
[64] Copenhagen
[65] Hamburg
[66] Vantaa

	economic/social/environmental							
Lifespan and in-use performance	Ratio of building transformation to new construction	Ratio of refurbishment/transformation to new construction	M	H	H		Productivity	Core
	Intensiveness of use	The average intensiveness of use of the building stock relative to the average potential intensiveness of use. This indicator is only suitable for buildings such as schools, offices or community centres.	M	-	-	-	Productivity	Core
	Average/predicted lifespan of existing building stock	The average/predicted length of time remaining in the current buildings are expected to function for. This could be defined as either the average life-span of the specific building type based on reference buildings OR the potential life-span, as a measure of possible future use cases - prolonging the lifespan.	H	H	-	L	Impact	Aspirational
Circular potential of existing building stock	Reuse/recycling potential of existing building stock	The amount of materials which are available for reuse/recycling in the building stock	H	H	H	Remove[67]	Impact	Core
Material outflows and recirculation	Total waste arisings from construction and buildings sector and end of life reporting	The total amount of materials wastes (which may be recycled/reused or downcycled/landfilled/incinerated) emerging from the construction and buildings sector	H	-	-	L	Impact	Core

[67] The Vantaa stakeholders felt that it was not really an indicator, but more like a material flow analysis or potential measure

	Recirculated materials	The proportion of total material arisings (see above) that enter new use cycles within the city/region (reuse/recycle) % per tonne of the city's construction and demolition waste that is recycled	H	-	-	-	Impact	Core

The indicators listed below were discussed during the workshops and it was decided that they should not be selected for the WP8 dashboard either because they were not seen as a priority or because they were seen as a priority, but not at city level. Table 8, below, summarises the rationales for not selecting them.

Table 8: City level indicators not selected

Category	Indicator name	Indicator description and suggested units	Reason this indicator was not selected			
			London	Vantaa	Hamburg	Copenhagen
Material inputs	Average whole life material inputs per building	Amount of material required for a typical building in the building stock, across its whole life.	Suggested remove			Medium interest
Lifespan and in-use performance	Near-obsolescence/demolition floorspace	Proportion of building stock that is at high relative risk of demolition within given timeframe	This indicator was seen as lower priority compared to others selected	Need better definition - remove	-	-
	Average user satisfaction	What is the average user satisfaction of building	This indicator was seen as difficult to measure, especially for residential developments. There is	Important but hard to measure - remove	-	Perhaps this could be building owner

		users across building stock?	opposing interest in performance and use versus cost and ease of delivery.			satisfaction? Suggest removing
	Material health	Average healthy life years lost due to material health impacts in building stock	This indicator was seen as difficult to measure. The connection between the average healthy life years and materials health can be difficult to establish, even though there are increasing number of studies.	Unclear what it means at city level – remove	Very important but more relevant at building or product level	Perhaps link to hazardous wastes? Suggest removing
Circular potential of existing building stock	Transformation capacity	The proportion of a city's floorspace that is suitable to be adapted for a different function	This indicator is important but best measured at building level.	Difficult to calculate – remove At city level, it would be best to include shared space	-	High priority – perhaps change to transformation potential? More appropriate at building level
	Resilience of building stock	Predicted material losses under most likely climate scenarios	-	Mixed review of this indicator. Suggest it is out of scope	-	Copenhagen has created scenarios of most likely climate change scenarios (e.g. urban heat islands, precipitation, floods etc) which could be used to predict most exposed materials/components. But out of scope
Material outflows and	Average distance to new point of use by products/materials	The distance travelled between recirculated	Distance is not the only issue, the type of transport is what is transported	-	It should not just be a consideration	-

recirculation		materials' original use and their next use	needs to be considered. Overall, this should be covered in a whole life environmental impact assessment		of the distance, but also of the haulier as there are limitations on the possibility to transport recycled materials	
	Total residual value of recirculated materials	The total value obtained by recirculation of materials and products	High - it would provide incentives to enable change at building level. Remove this indicator at city level and include at building level	-	Low priority – best applied at building level	-
Circularity enablers	Trade balance	The balance of trade is the difference between the monetary value of a nation's exports and imports over a certain time period	-	-	-	-
	Taxes	Impact of taxes incentives to promote the use of recycled (excluding down cycling) and reused activities on new products	Included in circular design incentives	-	-	-
Additional ones	Capture data being collected by other organisations, eg: GLA	Added by London	Merge with circular design incentives	N/A	N/A	N/A

	waste targets, CE statement					
Additional ones	Planning/how does the planning system encourage CE. It currently does not flex enough to promote radical thinking solutions	Added by London	Merge with circular design incentives	N/A	N/A	N/A

Table 9, below, presents the summary of the enablers that were discussed at the workshop. There was a consensus that those were not indicators but would be useful initiatives that would support a circular economy approach. The review of the four cities is summarise in this table.

Table 9: City level enablers review

Indicator	Description	Priority	Comment
Promotion of circular design incentives	Number of initiatives, regulations, taxes for new materials and incentives promoting circular design (e.g. lean principles, design for disassembly and adaptability)/ building lifespan extension over replacement/ looping at building end of life	High in London, Copenhagen and Hamburg	Great success in Denmark on energy efficiency In the UK, example of Aggregate Levy
Circular economy included in public procurement strategies	Proportion of value procurement in which Circular economy requirements are included in public procurement strategies	Medium in London	
Investment in circular sectors and infrastructure	Investment into sectors and infrastructure that demonstrate they are using circular economy practices, ie: that they apply some of the principles laid out in the building level section	Low in London and Copenhagen	Investors tend to be too much in business as usual thinking
Number of jobs created in circularity parts of construction sector	Number of jobs created in circular economy activities, such as repair, reuse, high recycling value	Low in London, and in Hamburg; medium in Copenhagen	Suggestion to separate jobs for low skills/unemployed workers
'City circularity database' exists for aggregation and analysis of data on building stocks and material flows	A database is present in the city to analyse the circular economy practices in buildings	High in London and Hamburg	
Educational courses/skills	Number of participants enrolled in University courses/ apprenticeship/ upskilling on the topic of circular economy	Low in London Medium in Copenhagen	Difficult to enforce, but could be attractive proposition for economic recovery
Quantity of materials that is reused/recycled through dedicated	Number of reuse/recycling centres created in the city	High in London	Heathrow expansion was considering the use of hubs to store products. This is essential to support logistic

centres (Additional one)			
Proportion of building stock mapped with materials content	Percentage of total floor area for which material content has been quantified using materials flow analysis.	High	Link to material flow analysis and supports understanding of what material might become available in the future if linked to

Building level indicators

Table 10, overleaf, summarises the workshops findings at building level and highlights whether the indicators generated a high, medium or low level of interest. Based on the ease of calculation with the current data available, those indicators have been classified as suitable for CIRCuIT (core) or aspirational (ie: the data and/or the methodology to calculate the indicator are not available). It is important to note that not all indicators were given a rating as the workshop attendees were only given a number of votes each. The indicators were also classified as “impact” (eg: recycled content or materials use) or “productivity” (eg: per value, area).

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 821201

Table 10: Building level indicators identified as relevant to the sector

Category	Indicator name	Indicator description and suggested units	Priority (H/M/L)				Impact/ productivity	Core or aspirational
			Lon[68]	Cop[69]	Ham[70]	Van[71]		
Building design	Dematerialisation (linked to total material inputs to building stock)	Building has been designed so that the minimum material inputs are required to achieve the same whole life functionality, without compromising on durability, resilience or health and safety.	H	L	-	-	Productivity	Core
	Design for disassembly (to enable increase reused and recycling potential)	Proportion of building components that are reversible from the wider building without significant damage to either the removed component or its wider assembly	H	M	H	-	Productivity	Core
	Design for adaptability (transformation capacity)	The spatial and technical aspects of building design allow for adaptation to another function (as designed)	H	L	-	-	Productivity	Core
	Design for repairability	Proportion of building components specified that are designed to be repairable	H	L	-	-	Productivity	Aspirational
Material inputs to building	Renewable content	Proportion of the building that is formed of renewable products and product components	L	-	-	M	Impact	Core
	Reused content	Proportion of the building that is formed of reused products and product components	M	-	-	M	Impact	Core

[68] London
[69] Copenhagen
[70] Hamburg
[71] Vantaa

Category	Indicator name	Indicator description and suggested units	Priority (H/M/L)				Impact/ productivity	Core or aspirational
			Lon[68]	Cop[69]	Ham[70]	Van[71]		
	Recycled content	Proportion of the building that is formed of recycled/upcycled products and product components (exclude downcycling)	L	-	-	M	Impact	Core
Circular potential (as built)	Transformation capacity	The spatial and technical aspects of building design allow for adaptation to another function (for existing buildings)	H	L	-	H	Productivity	Aspirational
	Reuse potential	The percentage (by mass) of products which can be reused	H	-	-	-	Impact	Core
	Recycling potential	The percentage (by mass) of products which can be recycled	M	-	-	-	Impact	Core
Lifespan & in-use performance	Useful lifespan	The years the building can be used for its intended purpose	H	L	-	-	Productivity	Core
	Intensiveness of use	The intensity of building use compared to the industry average	M	L	-	H	Productivity	Aspirational
Material outflows and recirculati on	Total material arisings (whole life)	The forecasted amount of waste materials from the building across its lifetime.	M	L	-	-	Impact	Core
	% reused, remanufactured, recycled	The actual percentage of materials which were reused, remanufactured or recycled at the end of the life of the building	H	L	H	-	Impact	Core

Category	Indicator name	Indicator description and suggested units	Priority (H/M/L)				Impact/ productivity	Core or aspirational
			Lon[68]	Cop[69]	Ham[70]	Van[71]		
	Residual value (all materials in building)	The forecasted total value obtained from material recirculation of materials within the building	H	L	X	H	Productivity	Aspirational
Additional indicator	End of Life scenario (additional discussed in Copenhagen)	Mapping of the typical end of life scenarios of materials (reuse/recycling), before it reaches a material bank/storing site.	N/A	L	N/A	N/A	Impact	Core

While the dashboard will be reporting city level indicators, the building level indicators are necessary to feed into the city level ones. The indicators listed below were discussed during the workshops and did not generate interest because they were not seen as a priority or because they were seen as a priority, but not at building level. Table 11, below, summarises the rationale for not selecting them.

Table 11: Building level indicators not selected

Category	Indicator name	Indicator description and suggested units	Reason this indicator was not selected			
			London	Vantaa	Hamburg	Copenhagen
Building design	Design for secondary material compatibility	Proportion of a building that can be assembled from secondary materials and components.	Medium interest			Low
Material inputs to building	Average transport distance for raw materials (split by virgin and secondary)	The average distance each unit of material travelled to site. Both virgin and secondary.	Should be calculated as part of WLC	Hard to measure	-	High interest

	Material inputs through refurbishment	The quantity and profile of materials required for refurbishments of the building up to the date of measurement	No	-	-	Low interest, hard to define
	Material health	Overall health risks of materials and products in building, quantified as impact on healthy life years of building occupants	No – materials level	-	-	Medium, but best measured at product level
	Material losses (waste) through supply chain and construction stage	The amount of materials lost as waste through the processing, transport, storage and configuration/ assembly of materials and products prior to specification, plus construction site waste.	Interesting – but not relevant to CIRCuIT	-	-	Low
Circular potential (as built)	Repairability	The percentage (by mass) of products which can be repaired	No – materials level	-	-	Low – difficult to measure
	% building products covered by Extended Producer Responsibility scheme (e.g. a take-back scheme)	The percentage of building products/components which are part of an Extended Producer Responsibility scheme	Not relevant at building level	-	Low	Low
Lifespan & in-use performance	Condition	The condition of the building relative to the industry average	No – the condition of the building does not always dictate what happens to the building	-	-	No

	Performance	How well the building performs its function (subjective or objective measurement depending on building function)	Medium – unsure how to quantify	Low	Not relevant	

Table 12, below, provide the summary of the enablers that were discussed at the workshop. There was a consensus that those were not indicators but would be useful initiatives that would support a circular economy approach. The review of the four cities is summarised in that table.

Table 12: Building level enablers review

Indicator	Description	Priority	Comment
Building passport / Bill of Materials	The data set that describes the characteristics of the products in the building which give them value for recovery, recycling and reuse	High in London and Hamburg but needs to be defined Low in Copenhagen	Needs to be clearly defined
Guidelines available for repair, maintenance, transformation and material looping	Data is available for the repair, maintenance, transformation and material looping of the building	High in London Low in Copenhagen	This is important to ensure the buildings designed for adaptability or disassembly reach their potential when reaching the end of their purposed life
BIM	Has a Building Information Model with relevant circularity data.	High in Vantaa, London and Hamburg Low in Copenhagen	BIM is seen as a mean to communicate information throughout the life stages of a building. It is important that the model is continuously updated
'City circularity database'	Relevant data routinely shared with a 'city circularity database' throughout lifetime	High in London Low in Copenhagen	
Screening of existing buildings (added)	Resource and environmental pre-demolition audit	Medium in Copenhagen	Pre-demolition audits enable the calculation of the reuse and recycling potential
Logistic centre	Logistic centre to store and transport recycled/reuse materials in an efficient way	High in Hamburg High in London	These hubs are key to enable the management of resources from buildings being demolished. This indicator cannot be implemented at building level, so will be moved to city level

Materials/products/components level indicators

Table 13, overleaf, summarises the workshops findings at materials/products/components level and highlight whether the indicators generated a high, medium or low level of interest. Based on the ease of calculation with the current data available, those indicators have been classified as suitable for CIRCuIT (core) or aspirational (ie: the data and/or the methodology to calculate the indicator are not available). It is important to note that not all indicators were given a rating as the workshop attendees were only given a number of votes each. The indicators were also classified as “impact” (eg: recycled content or materials use) or “productivity” (eg: per value, area).

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Table 13: Materials/product/component level indicators identified as relevant to the sector

Category	Indicator name	Indicator description and suggested units	Priority (H/M/L)				Impact/ productivity	Core or aspirational
			Lon[72]	Cop[73]	Ham[74]	Van[75]		
Product design	Dematerialisation (linked to total material inputs to building stock)	Product has been designed so that the minimum material inputs are required to achieve the same whole life functionality, without compromising on durability, resilience, other required technical performance or health and safety.	H	-	-	-	Productivity	Core
	Design for reversibility	Potential for a product to be removed from the building without significant damage to either the removed product or other parts of the building.	H	-	-	-	Productivity	Aspirational
	Design for repairability	% by mass of components of the product that can be easily removed and repaired or replaced.	H	-	-	-	Productivity	Core
Material inputs (as manufactured)	Reused content	% by mass of the product that consists of components that have been reused	H	H	-	-	Impact	Core
	Recycled content	% by mass of the product that consists of components that have been recycled	M	-	-	-	Impact	Core

[72] London
[73] Copenhagen
[74] Hamburg
[75] Vantaa

Category	Indicator name	Indicator description and suggested units	Priority (H/M/L)				Impact/ productivity	Core or aspirational
			Lon[72]	Cop[73]	Ham[74]	Van[75]		
	Environmental impact, waste, resource scarcity (additional indicator)	Circular economy should measure how it responds to the "resource challenge" according to UN i.e. how it responds to resource scarcity, environmental impacts and waste associated with resource consumption and production	N/A	H	N/A	N/A	Impact	Aspirational
Material inputs (as installed in building)	Product is reused after it has been used in a building	The product has previously been used for the same function in another building	H	M	-	-	Productivity	Core
	Product is recycled after it has been used in a building	The product has previously been used for the same value function in another building and has been through some processing	M	M	-	-	Productivity	Core
Circular potential (as installed)	Reuse potential	Product is designed and installed so that it can be easily demounted from the wider assembly with no loss of value to itself or the assembly	H	L	-	-	Impact	Core
	Repairability potential	The amount of components of the product that can be easily removed and replaced (once installed)	H	L	-	-	Impact	Aspirational
	Part of an extended producer responsibility scheme	The product is covered by an Extended Producer Responsibility scheme by the manufacturer (e.g. a take-back scheme)	H	-	-	-	Impact	Core

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Category	Indicator name	Indicator description and suggested units	Priority (H/M/L)				Impact/ productivity	Core or aspirational
			Lon[72]	Cop[73]	Ham[74]	Van[75]		
	Part of a product-service system	The product is used as part of a product-service system	L	-	-	-	Productivity	Aspirational
Lifespan and in-use performance	Service life	The number of years the material or product could be used for its intended function	H	H	-	-	Productivity	Core
Material outflows and recirculation	Residual value	Financial value obtained by actor with duty of care of product at building end of life	M	-	H	-	Productivity	Aspirational

While the dashboard will be reporting city level indicators, the materials/product/component level indicators are necessary to feed into the building level and thereafter into city level ones. The indicators listed below were discussed during the workshops and did not generate interest because they were not seen as a priority or because they were seen as a priority, but not at building level. Table **Fejl! Henvisningskilde ikke fundet.**14, below, summarises the rationale for not selecting them.

Table 14: Materials/product/component level indicators not selected

Category	Indicator name	Indicator description and suggested units	Reason why indicator was not selected			
			Lon[76]	Cop[77]	Ham[78]	Van[79]

[76] London
[77] Copenhagen
[78] Hamburg
[79] Vantaa

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Product design	Design for secondary/renewable material compatibility (i.e. secondary materials are available for design features)	% by mass of product that can be assembled from secondary/renewable materials and components.	There is a possibility that this disassembly does not happen	L	-	-
Material inputs (as manufactured)	Average transport distance for raw materials (split by virgin and secondary)	The average distance the virgin and secondary materials have travelled before incorporation into the product	This indicator may lead to the wrong approach. It needs to be considered as part of a whole life environmental impact	L transport should be included in whole life environmental impact	-	-
	Renewable content	% by mass of the product that consists of components from renewable source	Interesting indicator, but out of CIRCuIT scope	Interesting indicator, but out of CIRCuIT scope	-	-
	Material losses (waste) through supply chain	Quantity of materials wasted in processing, transport, storage and configuration/assembly of materials for final product	Low interest	Medium interest, but out of CIRCuIT scope		
Material inputs (as installed in building	Transport distance from point of extraction to point of installation	The distance the material travels between extraction and installation	-	-		
Lifespan and in-use performance	Condition	Condition of product compared with industry average, taking into account its time in-use and usage patterns	Difficult to measure	Low interest - Difficult to measure for some materials	-	-

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	Intensiveness of use	The intensity of product use compared to the industry average	Hard to measure at product level as it is out of manufacturer's control	-	-	-
	Performance	How the product or material performs its function	High interest but unsure how to quantify			
Material outflows and recirculation	Average distance to new point of use	Distance travelled by materials from original use to next use	Same as above	-	-	-
	% of product actually reused, remanufactured or recycled	The percentage of materials in the product which actually sent for reused, remanufactured or recycled following the refurbishment/demolition of a building	High interest but not suitable at product level	High interest but not suitable at product level	High interest but not suitable at product level	-

Table 15 below provide the summary of the enablers that were discussed at the workshop. There was a consensus that those were not indicators but would be useful initiatives that would support a circular economy approach. The review of the four cities is summarised in that table.

Table 15: Materials/product/component level enablers review

Indicator	Description	Priority	Comment
Material passport	The data set that describes the characteristics of the products in the building which give them	High for London, Hamburg and Copenhagen	This must be in place to support any re-use or potential re-use in future life cycles. Really important to know what we're putting into buildings today to avoid the same issues we currently face with existing building stock i.e. don't know what's in them so how do we

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	value for recovery, recycling and reuse		reuse? Screening/mappings of the potential hazardous substances in buildings should be part of the materials passport. Long use of buildings, components and materials can be promoted by equipping buildings with a deconstruction/disassembly/adaptability plan
Guidelines available for repair, maintenance and material looping	Data is available for the repair, maintenance, transformation and material looping of the building	High for London Low in Copenhagen	This is not always the right incentive for all products. Could be part of material passport
Relevant data routinely shared with 'city circularity database' throughout lifetime	As described; allows for material traceability throughout lifecycle	Not relevant for London or Copenhagen	Materials passport is seen as more relevant
Taxes	Taxes on new products	Low for London High in Copenhagen	Important to ensure that the tax will drive the right incentive and not promote the wrong behaviour. Tax relief on high recycling/reuse rate could be an option
Affordability of reused and leased products (additional)	Price of reused and leased products compared to linear products	Medium for London	This is calculated as part of a whole life costing approach

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