Circular Economy Metrics for Buildings

A deep dive into best practice approaches for measuring circular economy principles in the built environment by the Circular Economy Forum

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UKGBC Circular Economy Forum

This deep dive has been created by members of the Circular Economy Forum, a group of industry experts convened by the UK Green Building Council to facilitate peer-to-peer knowledge exchange. The findings and insight enclosed within this report represent the views of the report authors.

Contributors

The development of the Circular Economy Metrics for Buildings was led by an industry task group as part of the Circular Economy Forum, namely Working Group 2: Circular Economy performance criteria, monitoring metrics and benchmarks. UKGBC would like to sincerely thank all task group participants, alongside all involved stakeholders and consultation respondents for their feedback, assistance and contributions over the course of the project.

The task group participants included representatives from the following organisations:

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1. Introduction

Circular Economy and the use of circular economy design principles are becoming an increasingly important topic in the built environment. The benefits of a circular economy, including its impacts on carbon and value (in relation to financial and other value metrics), have been explored with case studies evidencing this[1]. The current UKGBC publication on System Enablers for a Circular Economy, published in January 2023, identified metrics, benchmarks and indicators as crucial to enable the system-level change required to deliver a circular economy in the built environment. However, the development of metrics to measure the circular economy is still an emerging topic with a lack of consensus in the industry currently. A working group as part of the UKGBC Circular Economy Forum has come together to collate their thoughts and investigated current metrics. This paper brings together a suggested set of metrics to start the conversation on how we should measure circular economy approaches within the built environment sector.

1.1 Context and scope

This report has been created by members of the Circular Economy Forum, a group of industry convened by the UK Green Building Council to facilitate peer-to-peer knowledge exchange. Members of this forum are from varied backgrounds across the value chain of the built environment, actively championing the circular economy in their respective roles. They come together regularly to discuss challenges and solutions and share experiences. As part of that, the group identified a lack of circularity metrics for built assets a barrier to widespread adoption of circular economy principles. A working group formed around this topic, collating their views on the matter, which resulted in this paper, intended as a thought piece in a rapidly developing topic area.

This paper collates existing circular economy metrics for buildings into one place to trigger industry discussion on the challenges and opportunities arising through consistent industry measurement and reporting. The recommended circular economy metrics are not intended to be a definitive list but very much a conversation starter to crowd-source the opportunities and constraints to collating meaningful data to drive change.

1.2 Why should we measure circularity?

The benefits and urgent need to move away from a linear economy to a circular economy are well documented in the UKGBC Circular Economy Guidance for Construction Clients (2019) as well as System Enablers for a Circular Economy (2023), with the key benefits being:

- Minimised resource extraction
- Reduced carbon emissions and environmental impacts
- Long-term thinking to avoid displacing negative impacts into the future and enable more adaptability

As awareness and adoption of circular economy principles and the systemic shift needed becomes more widespread, attention naturally turns to the question of what 'good' looks like. Similar to the embodied carbon conversation, defining common metrics helps focus the conversation and establish targets and goals that the industry can follow. It also enables coordinated data collection for insights and benchmarking. Benefits of measuring and benchmarking circularity include:

- Adding definition to what the circular economy means for the built environment
- Helping clients and project teams understand what success looks like, which in turn can feed into ESG reporting and brand enhancement
- Driving change through informing policy
- Creating healthy competition amongst manufacturers
- Identifying potential benefits to different stakeholders along the value chain
- Capturing the material value locked up in a building asset

1 UKGBC (2022) Insights into how circular economy principles impact carbon and value. Available at: https://www.ukgbc.org/ukgbc-work/how-circular-economy-principles-can-impact-carbon-and-value/

Scale of measurement

With circularity opportunities occurring at every life cycle stage, it is important to encourage consistent measurement at different scales to allow data flow for meaningful decision making. For example, in order to measure the recycled content of a building, it is necessary to understand the quantities and recycled content of the products in the building.

Figure 1 shows the three scales, with a summary of responsibilities and drivers. Collective and collaborative industry action is therefore key to transitioning towards a circular economy.

Figure 1: Scales of the built environment

	Product	Building	Cities
Responsibility	• Material suppliers and manufacturers	• Design and construction teams • Demolition contractors	• Planners and policy makers • Centralised public or private organisations
Why measure?	• Transparency for product accountability and comparison • Data to inform building scale measurement	• Drives resource efficiency and whole life embodied carbon reduction in building design and construction • Data to inform city scale monitoring	• Facilitates urban mining for efficient resource redistribution across the value chain • Data to inform target setting in policy and identifying the market value to catalyse innovation and new start-ups

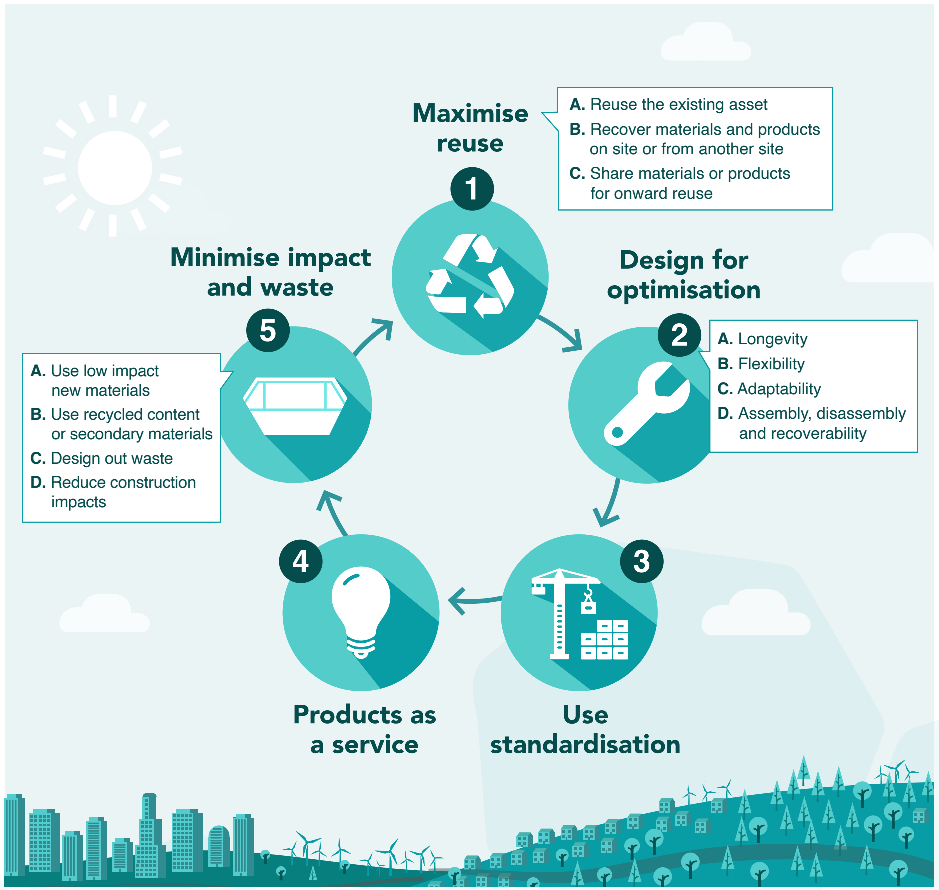
At the building level

Influencing circularity at the building scale is an important leverage point for change:

- It is a critical decision point for re-use rather than re-build, minimising new material demand in the first instance;
- It creates the right demand in the supply chain for more circular products; and
- It is the source of future resources for development, rethinking our buildings as material banks.

As such, this paper is focused on circularity indicators at the building scale.

Figure 2: Circular economy principles for construction



2. Building circularity metrics

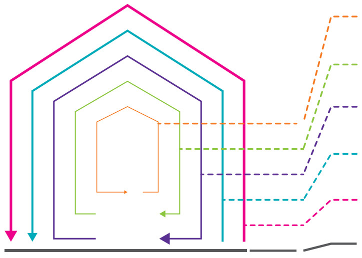
2.1 Approach

Over the past 2 years, members of the UKGBC Circular Economy Forum have formed a working group to investigate current circular economy metrics and collate their thoughts on how they could practically be used on built projects. This deep dive is the result of an industry review of best practice guidance, tools and indicators, which has formed the basis for the building circularity metrics discussed in this paper. This included research done by CIRCuiT (research report D3.3 Recommendations on circularity indicators for WP8, January 2021) and the GLA Circular Economy Statement Guidance (March 2022). These were narrowed into a concise list of seven metrics:

1. Dematerialisation (Upfront), kg/m² GIA
2. Dematerialisation (Life Cycle), kg/m² GIA
3. Design for Disassembly & Re-use, % (tonnes)
4. Material:
    a. Re-used % (tonnes)
    b. Remanufactured % (tonnes)
    c. Recycled % (tonnes)
5. Material Database and Passport % (tonnes)
6. Design for adaptability % (Area)
7. Embodied Carbon (kgCO_2e/m² GIA)

The metrics have been selected by the Forum with the view that they could reasonably be adopted and used by any project team for any archetype and at any project stage, to measure the incremental and absolute circularity of projects. This also supports forming the evidence base to incentivise circular design practices across the industry.

Figure 3 – Building in layers[2]



2 Brand, S. (1995). How Buildings Learn; What Happens After They're Built. Viking Press

2.2 Breakdown of indicators

It is proposed that the metrics are voluntarily reported by building layers, as defined by Stuart Brand's model in his book, How Buildings Learn (Brand, 1994). Benefits of this are:

- There is an obvious lead discipline for each layer, therefore visibility of metrics by layer empowers disciplines and their related supply chains, industry groups and members to take ownership of driving innovation and best practice.
- Each layer can be aligned with the elemental scope within the RICS guidance on Whole Life Carbon Assessment for the Built Environment (RICS, 2017), ensuring consistency of reporting for fair comparison.
- Layers have different design life, guiding the prioritisation of metrics in more detail than prioritising at a whole building level.
- Aligns with the London Plan Guidance for Circular Economy Statements (March 2022)

The seven metrics are unpacked within the following tables to collate current industry thinking as a starting point for wider debate and catalyst for voluntary pilot studies:

Definitions	Clear definition to ensure common understanding of the scope of the metric and proposed units
Actions	Guidance on actions, level of detail and data sources at different RIBA Stages to enable the metric to be estimated and measured
Benefits	A summary of the driver for different actions proposed at each RIBA stage, encouraging early consideration at the right level of detail to drive meaningful conversations before decisions are locked in and opportunities locked out.
Case Studies	Examples of where a metric has been measured and resulted in an increase in circular outcomes
Additional Considerations	Summary of the interplay between different metrics and project drivers to mitigate against unintended consequences and maximise the sustainable outcome for a project.

1. Dematerialisation – Upfront (kg/m^2 GIA)
2. Dematerialisation – Life Cycle (kg/m^2 GIA)

Definition/ Metric	Definition: Delivering the same product using a lower percentage of mass or material types in the product. This is achieved by optimisation – maximising resource effectiveness by reducing the mass or material types in the product. Metric: Total mass of building interventions by building layer normalised by the Gross Internal Area.			
RIBA Stages	**RIBA 0/1** **Brief Development**	**RIBA 2-4** **Design**	**RIBA 5-6** **Construction and Handover**	**RIBA 7** **In-use – end of life**
Actions	Explore opportunities for refurbishment and re-use. Establish dematerialisation target.	LCA - module A for kg mass for upfront. Include Module B for 60-year life cycle. Can be carried out as part of GLA WLC Assessment and/or BREEAM Mat 01. Update each design stage.		BIM/Digital Twin – in-use. Update LCA model.
Benefits	• By setting a challenging dematerialisation target across a portfolio or at building level clients will have to promote refurbishment over new build. This will provide economic savings in terms of cost of demolition and new construction.	• Designing out waste. • Retain existing building elements.	• Programme savings. • Reduced material costs.	• Minimising intervention and refurbishments.
Additional Considerations	• To be measured over a given time period as per embodied carbon calculations including upfront and in-use interventions. • Projects should be targeting the lowest possible kg/m^2, however the designers and building operators should be considering the impact of dematerialisation against other factors including embodied and operational carbon. • Dematerialisation is not an indicator on carbon intensity and should be considered in balance with other metrics. E.g. Less carbon intensive construction types such as 70% GGBS concrete frame may have a higher kg/m^2 but lower $kgCO_2e/m^2$ than a virgin steel frame for the same application. • Dematerialisation should be reported for upfront and 60 year building life cycles as per whole life carbon. This is to encourage designing for longevity as well as adaptability, by considering the impact of replacement cycles. • Dematerialisation can be monitored during operation, through the use of BIM and updated LCA calculations throughout the whole life of the building.			

3. Design for Disassembly & Re-use (% Tonnes)

Definition/ Metric	Definition: The design of materials, products and components or systems to allow ease of disassembly at end of use/life for reuse, repurpose or remanufacture. Metric: The percent of total mass of materials, products and components or systems for the new build/refurbishment/fit-out that have been designed for disassembly.			
RIBA Stages	**RIBA 0/1** **Brief Development**	**RIBA 2-4** **Design**	**RIBA 5-6** **Construction and Handover**	**RIBA 7** **In-use – end of life**
Actions	Include design for disassembly as key part of project brief.	Calculate percentage of total mass/area designed for disassembly vs target. Early supply chain engagement to identify disassembly opportunities and constraints. Inclusion of a Disassembly & Re-use Intent Guide within the Contractor Requirements to ensure design assumptions are safeguarded and developed further with the supply chain.	Calculate percentage of total mass/area installed designed for disassembly vs target. Inclusion of a Disassembly & Re-use Guide within the Operation & Maintenance manual handed over to the building owner.	Consult and update the Disassembly & Re-use Guide with each physical change to the building (e.g. repair, replacement, refurbishment).
Benefits	• If an owner occupier, costs of refurbishment in the future will be lower as ability to disassemble and reuse/repurpose/remanufacture materials/products components/ systems will be cheaper than demolition and waste disposal/ downcycling. Will also be inherent value in materials/products components/systems as second-hand construction materials market develops and matures. • If not an owner occupier, building should be more valuable as value associated with materials components/ products/systems that can be disassembled is recognised by new owner. • Less adhesives etc reduces VOCs.	• Ability to meet client brief. • Design out demolition.	• Meet client requirement. • Design out demolition. • Case study material for future work winning. • Clear documentation to facilitate future disassembly and reuse during the building's multiple life cycles.	• Ease of disassembly to allow reuse/ repurpose/remanufacture. • Realise monetary value associated with materials, products and components/ systems. • Lower embodied carbon calculation as part of demolition, refurbishment or fit-out.
Additional Considerations	• Relies on information denoting disassembly of materials/products/components/systems to be readily available and the client/design team/contractor/facilities contractor/ strip-out/demolition contractor knowing that this information exists and is accessible. It is also crucial that this information is updated as changes are made to the building over its lifetime. • CDM also plays a role. Sequence of installation may mean that disassembly not possible due to safe access issues. Disassembly therefore needs to be thought of as part of the design and installation process.			

4. Material Reused, Remanufactured or Recycled (% Tonnes)

Definition/ Metric	Definitions: Reused: Materials, products and components/systems that are reused in their current form. Remanufactured: Materials, products and components/systems which are an upgraded version of the original or manufactured into something new. Recycled: Materials, products or components/systems which are reprocessed into substances which can be used in the production process of the original material, product or component/system or for other production purposes. Metric: The percent of total mass of materials, products and components/systems for the new build/refurbishment/fit-out that have been reused, repurposed or remanufactured, either from the building undergoing demolition, refurbishment, fit-out or from other buildings, third parties etc.			
RIBA Stages	**RIBA 0/1** **Brief Development**	**RIBA 2-4** **Design**	**RIBA 5-6** **Construction and Handover**	**RIBA 7** **In-use – end of life**
Actions	Commission a pre-redevelopment audit and materials inventory. Identify materials available for reuse either as part of the design or via third parties. Set a target as part of their brief on a) mass/area of materials from existing building to be reused within the new build/refurbishment/fit-out b) mass/area of materials from existing building to be reused on alternative projects/via third parties c) mass/area of reused materials available from other projects/third parties incorporated into the design.	Brief design team on strategy for incorporation of reused/repurposed/remanufactured materials, products and/or components/systems. Percent of total mass of materials products or components/systems that have been incorporated into the design that are reused, repurposed or remanufactured vs target.	Percent of total mass of materials products or components/systems incorporated into the building that are reused, repurposed or remanufactured vs target.	Percent of total mass of materials products or components/systems that have been reused, repurposed or remanufactured at end of use/life vs target. Materials inventory/pre-demolition/refurbishment audit to be updated for the building.
Benefits	• Lower embodied carbon footprint of new build/refurbishment/fit-out. • Potential for lower build costs if materials, products and components/systems are reused, particularly taking into consideration price increases for materials in 2021.	• Ability to meet client brief. • Lower embodied carbon footprint of new build/refurbishment/fit-out.	• Meet client requirement. • Case study material for future work winning.	• Lower waste disposal costs as materials, products and components/systems are identified for reuse at end of use/life.
Additional Considerations	• An enlightened client that is willing to specify reused, repurposed or remanufactured materials is key. • Materials can be reused from the existing building into the new design, reused as part of the design of another building, sent for reuse via specialist third parties or sent to third parties that specialise in reusing a wide range of materials. • Where warranties and testing certificates can be supplied plus aesthetics are not an issue, adoption should be straightforward and easy to measure. It should also be straightforward for materials where warranty is not an issue e.g. bricks, roof tiles, paving slabs etc. • Where warranty is an issue, ask the question of the original manufacturer. Are they willing and able to re-test and re-warranty their product? • Embodied carbon reduction strategies and cost of raw materials will be drivers to allow adoption. • Materials reuse market needs to mature beyond sporadic, individual project case studies to encourage adoption. • Logistics and storage also a barrier which would need to be overcome before the materials reuse market can mature.			

5. Material Database and Passports (% Tonnes)				
Definition/ Metric	Definition: The collation of materials properties digitally, that when accessed in the future, will provide the information required to increase the likelihood of materials being reused, repurposed or remanufactured at end of use/life. Metric: The percent of total mass of materials that have been tagged to allow access to the materials database.			
RIBA Stages	**RIBA 0/1 Brief Development**	**RIBA 2-4 Design**	**RIBA 5-6 Construction and Handover**	**RIBA 7 In-use – end of life**
Actions	Client team to identify scope of passports within a project, as appropriate for the project brief. Are all components and systems to be included? Only new? Only those likely to be removed? Client team to identify deliverables. Material database/passports and physical tagging recommended as a minimum. BIM optional. Madaster optional. Team to start developing data requirements for each element, within defined scope. Early surveys to be carried out, to gather information about existing building materials (if applicable).	Team to develop data deliverables. Identify data to be collected for each element or system, for each workstage. Recommend using BAMB material passport best practice guide as starting point. https://tinyurl.com/smxakx75 Set up and populate material database as required by client brief. Measurement should be against percentage completed. If BIM project, ensure client requirements are included within BIM deliverables, and are being captured at the appropriate workstage. Set up link between material database and BIM model, if required. Be selective about what is imported to model, don't overload it.	Material database to be updated with as built information. Physical tags to be installed to elements during construction, ensuring the data can be easily accessed during operation and end of life. Material passport interface to be developed for building in operation. This is the record contained within the database for each item.	Verification survey to be carried out, particularly if the material database has not been updated during building operation. Material Passport can be exported for each item sent for onward reuse/recycling. Manufacturer information especially relevant, as we aspire for better manufacturer take back schemes and more robust second hand/refurbished marketplace.
Benefits	• Enables early discussion of feasibility and viability of implementing material passporting. • Early surveys enable existing materials to be considered as design options are being developed.	• Enables database to be developed and utilised as design tool.	• Captures specification information and links it to the built element.	• Maximum reuse potential, ability to utilise manufacturer takeback scheme and demonstrate maintenance history, to help assess condition and suitability for reuse. Ultimately will keep products and materials in use for longer, reducing demand for virgin materials.
Additional Considerations	• Data should be collated within a Materials Database, and can be sourced either from survey information or manufacturers. The CPA/CIA template for digitisation of information for products will likely be a future input (https://constructioninnovationhub.org.uk/wp-content/uploads/2022/05/LEXiCON_FinalReport.pdf). The Material Passport is the record contained within the database, and there should be a physical identification tag on the built asset to locate the information within the database. A Material Database can be linked to a BIM model if desired. • This approach is in its infancy, originally pioneered by the BAMB research project, and Madaster platform. • During design stages, the Orms Material Passport approach could be implemented which utilises a materials database. This can be connected to BIM models, which in turn can be used as an input for the Madaster platform. • Further information can be found here: https://www.orms.co.uk/insights/materialpassports/			

6. Design for adaptability (transformation capacity) (% Area)				
Definition/ Metric	Definition: The ability to be changed or modified to make suitable for a particular purpose (ISO 20887). Metric: The percentage area of total building that has been designed for adaptability.			
RIBA Stages	**RIBA 0/1** **Brief Development**	**RIBA 2-4** **Design**	**RIBA 5-6** **Construction and Handover**	**RIBA 7** **In-use – end of life**
Actions	Include adaptability as part of client brief with reference to versatility, convertibility & expandability (ISO 20887).	Ensure design for ability is clearly communicated during tender phase, so contractor value engineering options support rather than prevent this. For example, offsite prefabrication often offers cost savings, but may rely on binding layers of the building which will limit future adaptability.	Ensure contractor fully understands the approach, so that adaptability remains. Particularly relevant for D&B projects, and projects with offsite prefabrication. Encourage adaptability options from contractor, who may be able to spot areas of opportunity.	Versatility has the most relevance in use and could be considered a form of utilisation rate. Convertibility & expandability are relevant for refurbishment potential.
Benefits	• Reduced risk of building redundancy.	• More cost effective to incorporate adaptability strategies earlier into the design thinking.	• Convertibility and expandability, will enable projects to be tweaked for the expected market at building launch, maximising value at completion. This is particularly relevant for projects with long construction periods.	• Increased utilisation of asset. • Contribution to resale value as asset can be expanded/ easily have a use change.
Additional Considerations	• In relation to metrics, it is the spatial and technical aspects of building design which allow for adaptation to another function. This indicator is measured using ISO 20887 which identifies 3 design measurements for adaptability: – Versatility can be measured by the percentage of usable space that has multiple uses on a daily, weekly, or monthly basis, without requiring changes to the main features of the space. – Convertibility can be measured by the percentage of usable space that has been designed to be converted easily to multiple uses. – Expandability can be assessed in terms of the number of additional floors or percentage of additional floor space possible without major alteration to the foundation and structural system. The percentage of reserve load bearing capacity can also be used to assess expandability. A "yes or no" assessment of vertical expandability can be made if the structural design of the designated roof area allows for supported loads of at least one additional floor-level of a similar use-type. Horizontal expandability can be assessed in terms of the amount or percentage of additional lot area not covered by the building area which is permitted to be built on. NOTE Expandability can be constrained by structural design limits or municipal planning regulations. • Finding the appropriate level of design for adaptability can be difficult. When setting the brief, financial cost and embodied carbon impacts should be considered against the likelihood of these adaptations being required. • Refer to deconstruction plan for guidance. The approach to design for adaptability is project specific, and this should be reflected in the final design. However, even if future adaptation isn't expected, it should be considered and high-level approaches implemented.			

7. Embodied Carbon ($kgCO_2e/m^2$ GIA)				
Definition/ Metric	Definition: Total greenhouse gas emissions associated with the materials incorporated into a building from cradle to grave. This includes emissions associated with the product stage (raw material extraction, transport and material processing), construction stage (transport and installation processes), in-use stage (use, maintenance, repair, replacement, refurbishment) and end of life (de-construction, transport, waste processing and disposal). Metric: Mass of carbon dioxide equivalent per meter squared of gross internal floor area.			
RIBA Stages	**RIBA 0/1 Brief Development**	**RIBA 2-4 Design**	**RIBA 5-6 Construction and Handover**	**RIBA 7 In-use – end of life**
Actions	Target setting within the brief. Prediction based on generic values.	Prediction based on specific values.	Calculate based on actual material specifications, as-installed quantities and Environmental Product Declarations where available.	Calculated on actual values.
Benefits	• How to value potential future benefit today? $kgCO_2e$ value. NB see GLA WLC Policy SI2 for carbon valuing of circularity.	• Identifying the actual carbon/ environmental impacts of the use of recycled/reused content and the potential benefits of future disassembly and reuse/recycling.	• Assessing the actual circular carbon emissions benefits incorporated by practical completion. In addition, using this data to predict the expected circular benefits during the 'In Use' phase of the built asset.	• Assessing the actual circular impacts that have occurred during the 'In Use' phase of the built asset. In addition, assisting with planning to optimise the future potential of redundant existing material.
Additional Considerations	• Reuse or recycling of existing structures, products and materials. Factoring in future discounting to reuse potential.	• Detailed examination of recycled products and materials. Designing for disassembly and reuse.	• Consolidating previous decisions.	• End of Life disassembly and preparation for future reuse.

3. Reflections and next steps

Whilst the proposed metrics within this report focus on materials as a starting point, the most sustainable outcomes will be unveiled when considered alongside other metrics such as social value and embodied carbon. By collating these in one place, it is hoped that more projects are empowered to voluntarily start measuring circularity, enabling data and experiences to be shared for building up a clearer picture on the approach and interpretation of metrics for adopting as standard.

From this initial baselining exercise, a number of queries arose. A summary of these for potential future research are as follows:

3.1 Metrics

- Do metrics always have to be quantified? Lack of data can sometimes be a barrier to action and simply 'doing the right thing'.
- Is tonnage the right measure for Design for Disassembly & Re-use, Material Re-used, Remanufactured, Recycled and Material Database and Passport? If not, what would be a better measure?
- Is an overall building circularity index useful? A consolidated metric does not give visibility to how a building is performing under different circular economy principles and may not empower different players in the value chain to improve performance.
- What does good look like? Providing target benchmarks drives improvement and competition.

3.2 Processes

- Development of a standard reporting template.
- Development of an overarching scorecard so that circularity performance is quickly visible.

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