Circular Economy in the Built Environment

Architects Climate Action Network

January 2024

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Architects Climate Action Network

Architects Climate Action Network (ACAN) is a voluntary network of individuals from within architecture and its related built environment professions taking critical action to transform our industry in the face of the climate and ecological crises.

Our Mission

ACAN exists to address the way our built environment is made, operated and renewed in response to the climate emergency. As a network of individuals, we channel personal energy, expertise and action towards a common goal - the systemic change of our profession and the construction industry as a whole. We see this as a matter of urgency. Our mission is to mobilise a new movement of professional activists towards this goal by building an open, supportive and inclusive organisation. ACAN empowers individuals to proactively seek change and facilitates collective effort through a shared platform built on collaboration.

ACAN is driven by three aims:

- Rapid decarbonisation of the built environment
- Ecological regeneration, through the immediate adoption of regenerative & ecological principles
- Cultural transformation of the profession

Content

Executive summary

How to use this guide

The ACAN Circular Economy group have been focusing on how circular economy principles can be applied within the context of the UK construction industry. In 2021, the Circular Economy group ran the Circular Series, a 9-part event series addressing the key challenges and opportunities of realising CE approaches at each of the RIBA stages, from strategic definition at Stage 0 to the building in use at Stage 7. To close the circle, ACAN proposes to extend RIBA Stage 7 to address the building's end of life. The Circular Series featured presentations from experts from across the industry, to discuss in detail how to incorporate circularity within UK construction in a meaningful way.

At the end of the series, having learnt from the insights of the speakers, the Circular Economy group decided that translating the presentations into a practical design guide would be highly valuable.

This guide is structured in three chapters based on the circular economy principles of Maximise Reuse, Design for Optimisation and Minimise waste. Each chapter is grouped into Early Considerations (RIBA Stages 0-1), Project Planning and Design (RIBA Stages 2-4), Construction and Handover (RIBA Stages 5-6) and In-Use and End of Life (RIBA Stage 7).

The aim of the guide is to give design teams a current overview of the process to design for a circular economy.

Introduction

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1. Client Engagement

Explain risks

Organise a kick-off meeting or a workshop with the client and relevant stakeholders to set the scene. Explain the context within which a building or development will be situated at the start of project discussions. Explain the risks of climate change, mitigation and adaptation strategies, changing material resource availability, future heating costs, decarbonisation of grid and property market expectations. Understanding the context will help guide future discussions of appropriate circular strategy and material choice (amongst other things) by bringing it back to the 'why' the project is moving away from 'business-as-usual'. Refer to the UKGBC circular economy guidance to set the context[1].

To achieve client buy-in

Utilise the client's ESG policies (environmental, social, governance) and assess council and client aspirations and targets.

Emphasise potential embodied carbon reduction, minimised demolition waste, a potentially easier planning route, reduced disruption to the neighbourhood, potential of phased refurbishment (which could allow parts of the asset to remain functional).

Use whole life cost modelling, totalling the cost of ownership over the life of the asset to explain how higher initial investments pay back over time.

2. Setting Out Overall Project Aims

Initial considerations should include laying out project strategy options (See section 6) to the client to help determine the correct ones (more than one strategy may be suitable). Suitability should be explored in terms of the client aims, project type, site, timescale and local availability.

Scenario planning

Use scenario planning during the development of the strategic brief to determine the client's main vision to apply circular economy principles. For instance, in some cases the client may want to focus on maximising future adaptability, while minimising material use might be the primary focus in other cases. An initial strategic briefing workshop could incorporate broader scenario planning tools.

During the development of the strategic brief, scenario planning is a useful tool to collect information from the client about possible future use changes that inform flexible and adaptable design decisions later. Future adaptation requirements can range from small-scale changes to larger scale reconfigurations. Smaller changes in use may include potential space for a ground floor bedroom and wet room for an elderly or infirm resident. Medium scale functional changes can include converting open plan offices to cellular offices. Larger changes can be mono-functional, trans-functional or multidimensional[2] (See Design for optimisation chapter).

3. Decision Tree

To develop the business case, it is crucial to allow sufficient time and budget for site appraisal, condition surveys, existing user surveys, pre-deconstruction audit and feasibility studies to determine the following (site/project related):

A, Is a new building required or can the existing building (if any) be adapted or reused?

B, Can it be deconstructed into smaller components and reused on site / resold to second-hand materials retailers?

C, Is the site the best available option? Are there other brownfield sites available?

Figure 1: Decision tree, A tool for evaluating the site and project in its initial phase

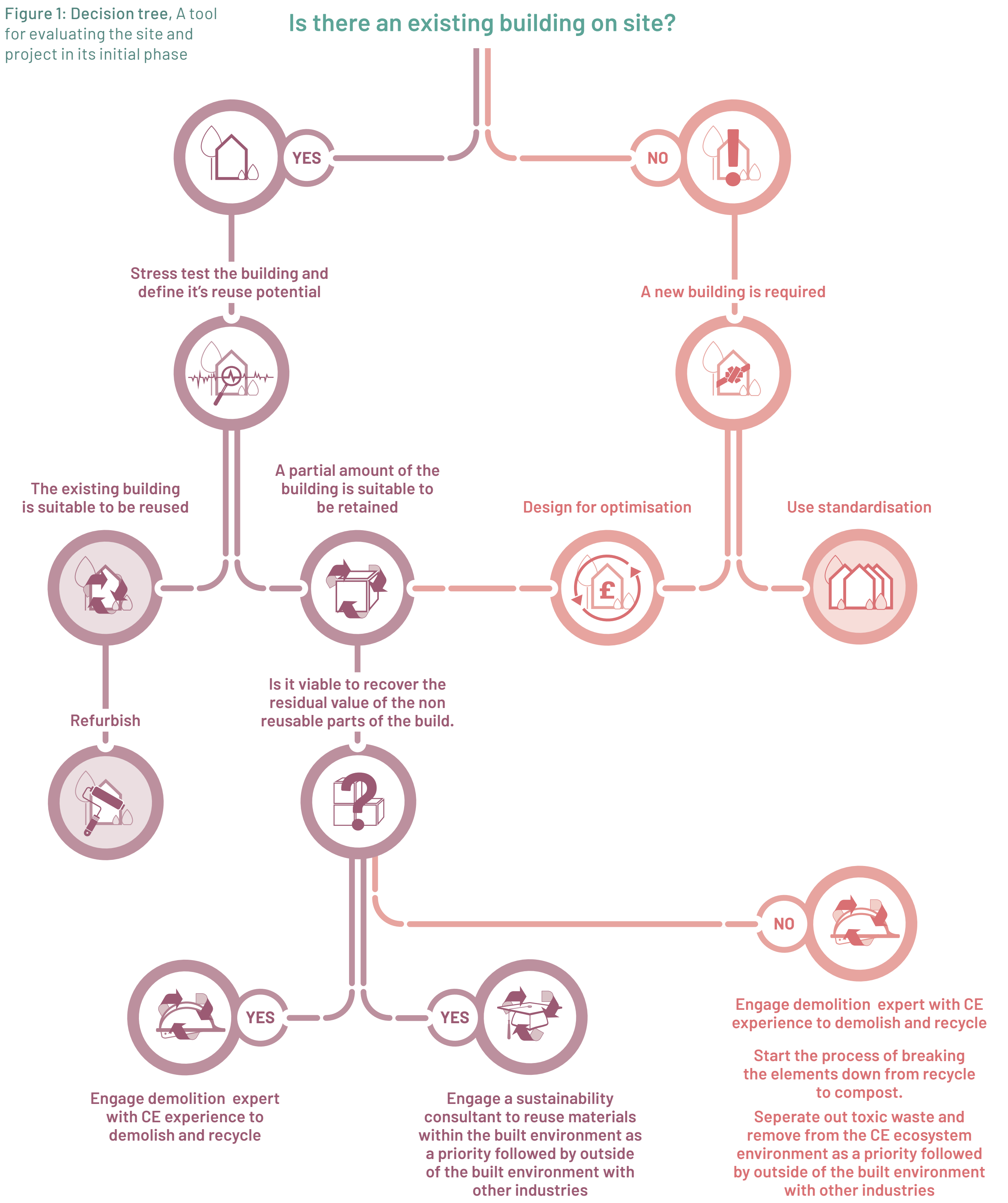
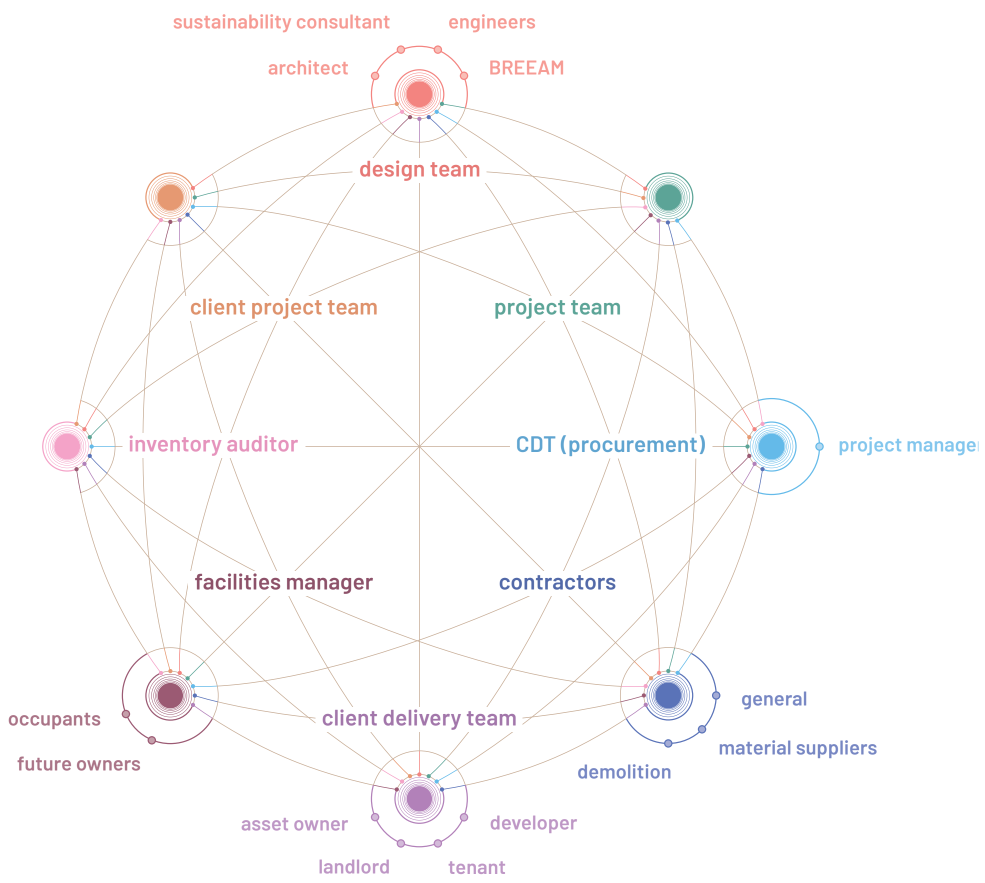


Figure 2: Stakeholder mapping, Map out relevant stakeholders and relationships between them throughout the project phrases to determine communication channels and collaboration opportunities



4. Stakeholders

Map out the stakeholders and consultants to participate in the project at different stages and determine programming needs. Stakeholders include the client, the design team of architects and engineers, sustainability consultants, quantity surveyors, contractor, facilities manager, property team and planning authorities. Use the soft landings framework to set the responsibilities and establish systems of communications (e.g. schedule of workshops) between the stakeholders. The soft landings framework aims to bridge the gap between design intent and operational use and provide a useful guide to establish collaboration between the different stakeholders and should be used throughout the different stages[3].

5. Metrics

Identify and outline metrics that will be used and write a method statement to achieve them. Agree amongst the project team and stakeholders. For example:

- Embodied carbon target,
- Operational energy target,
- Potable water use target,
- Material recycled content target,
- Circularity targets,
- Reclaimed/reused materials target.

Determine if a circular statement is to be included in the project brief. In London for instance, a GLA Circular Economy Statement[4] is to be included for planning if a project is of potential strategic importance (PSI).

*Note, while there is currently no standard metric to measure circularity, several projects are currently working on developing future circular economy benchmarks.

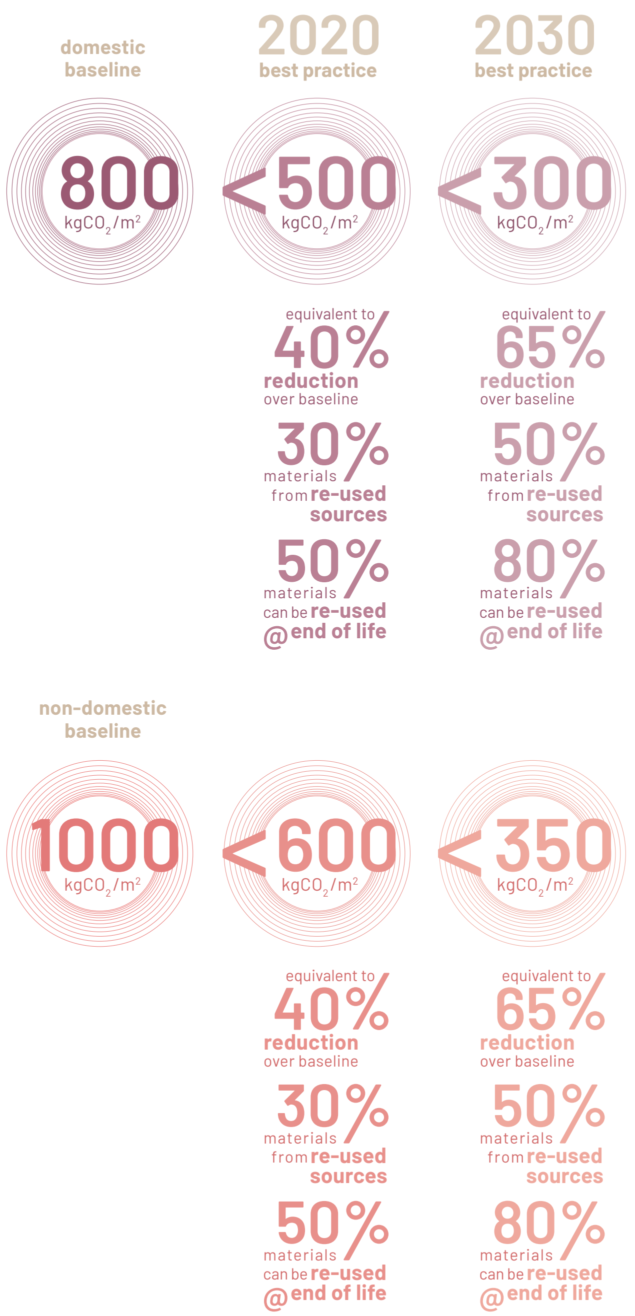


Figure 3: Setting out project targets (source: metrics adapted from LETI)

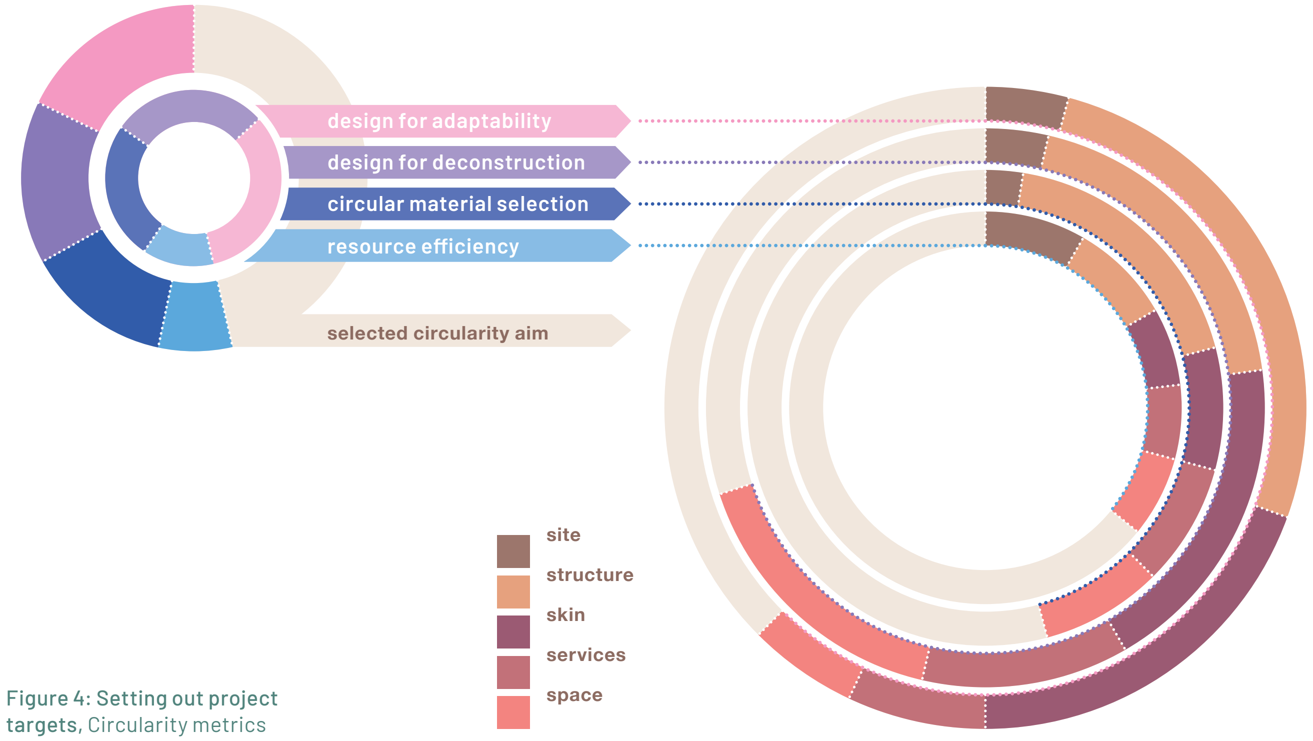
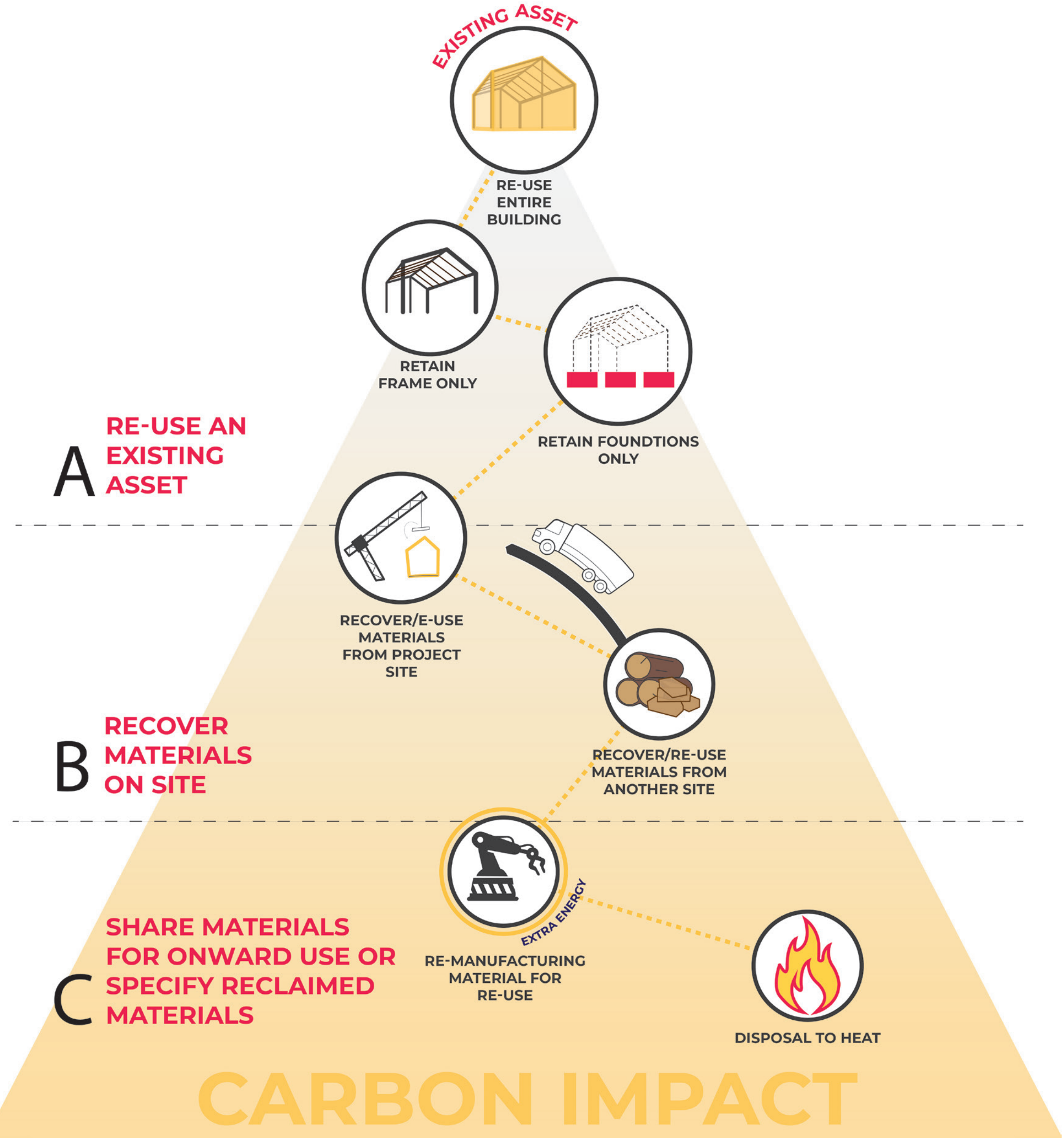


Figure 4: Setting out project targets, Circularity metrics

6. Project Strategies

Identify key strategies to prioritise in the project. More than one strategy may be suitable.

Figure 5: Hierarchy of reuse strategies



Maximise reuse
Introduction

Maximising reuse means that the design prioritises retaining existing assets, building components and materials at their highest value and maximising opportunities for their future reuse[5].

A, Reuse an existing asset

Definition, Resusing an existing asset ranges from reusing the entire building without major modifications to retaining the structural frame only.

B, Recover materials on site

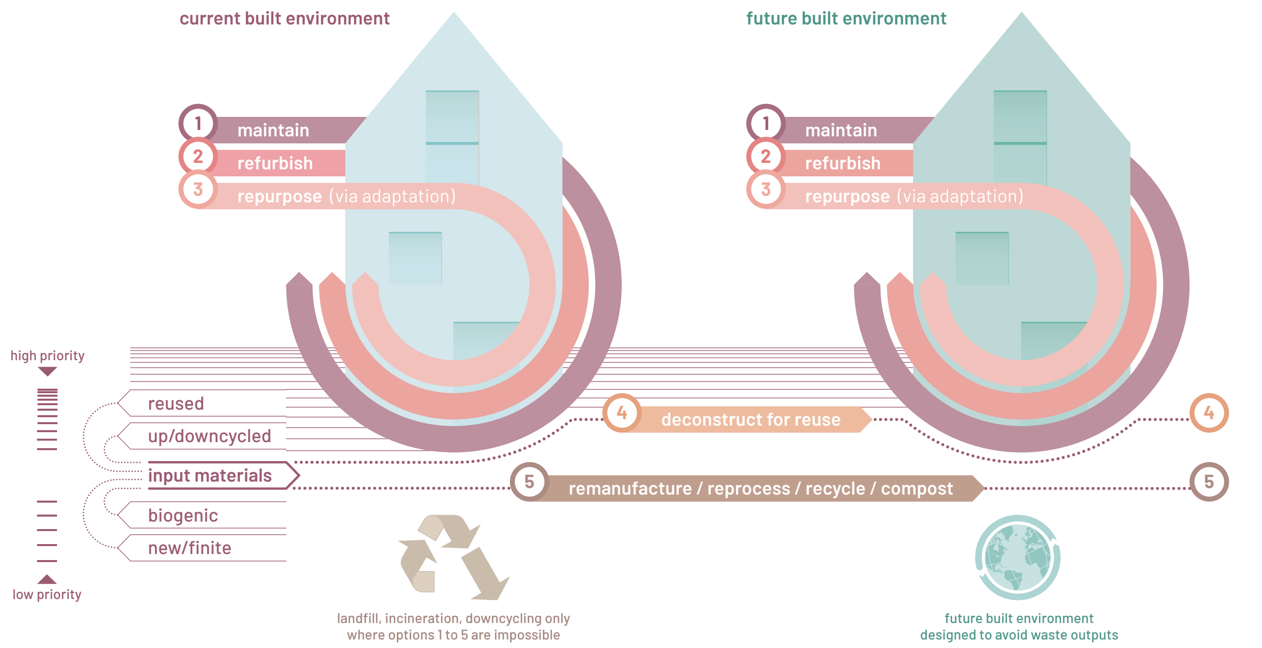
Definition, Reusing or recovering materials means using materials or components that were either recovered from the project site or sourced from another site or material retailer. Reuse elements range from structural (brick, steel) to fittings and finishes.

C, Share materials for onward use or specify reclaimed materials

Definition, If the materials cannot be reused on site, they will be sent for onward reuse via a sharing platform, which can be a reclaimed material broker or the original material supplier. Similarly, a project can specify reclaimed materials from a broker or material supplier.

There is a hierarchy between different types of material reuse based on how much carbon impact each option has. Retaining an existing asset in its entirety will almost always have the most minimised carbon impact. Reusing materials and components without major remanufacturing is the second best option, while remanufacturing and recycling are further down the reuse hierarchy, since these processes require additional energy input. Disposal and waste to heat should be last resource solutions. The R-frameworks are useful tools to understand the reuse hierarchy (See Minimise impact and waste).

Figure 6: Reuse strategies adapted from LETI (source: LETI Circular Economy One Pager)



Maximise reuse
Early considerations (RIBA Stages 0-1)

When there is an existing asset on site

Reusing an existing asset with the appropriate future tenets will have the most minimised carbon impact. 80% of the building stock required by 2050 exists today. A key goal should be to identify already existing assets that are suitable and evaluate their potential to be reused.

When there is an existing building on site, the first step should always be to evaluate whether this asset is suitable for retrofit, considering both current and future needs of the occupiers. Ultimately, the more intrusion to an existing asset, the more parameters come into play, which will result in higher embodied carbon. Retrofit almost always offers the most carbon saving potential, as it requires less virgin materials than new build and generates less waste.

If the asset is not suitable to be reused entirely, its materials and components should be deconstructed (instead of demolished) ensuring their reuse is possible in another project. To achieve this, it is important to engage specialists in deconstruction and salvaging as early in the design process as possible.

Sourcing building products from virgin materials contribute to resource depletion and carbon intensive activities to manufacture. Many of the most common building materials are possible to reuse without major remanufacturing (e.g. bricks). The FCRBE Reuse Toolkit: Material sheets provide information on commonly reused materials[6]. Keeping materials and components within existing material flows in construction will help reduce demand on new materials.

Aim: Retrofit an existing asset in its entirety to extend the lifetime of the asset.

Project strategies

Asset audit: Conduct an initial audit of the asset considering the current building fabric and layout and the needs of the client.

Hold an initial workshop with the client to determine current and future use scenarios. This will inform the basis of the decision as to whether the existing building will satisfy the requirements. These workshops should include the client team and sustainability specialists to assess the extent of the alterations necessary.

Conduct an initial assessment of building fabric, airtightness, ventilation, and energy use of the existing building to determine whether retrofitting is the most efficient solution. For specific performance targets, refer to the LETI Climate Emergency Retrofit Guide[7], the AECB Level 1 or Level 2 retrofit targets[8] or Enerphit[9].

Aim: Reuse materials and components of the building. Enter materials and components of the existing building to the market of reused products.

Project strategies

Prepare for a reclamation audit. Conduct an initial material assessment of the material stock embedded within the existing building.

Carry out a reclamation audit for buildings scheduled for demolition or strip out and refurbishment, identifying building components and materials with high reuse potential. Determine the correct approach from the start of the project with the client. This will then inform the design team of the goal and help to align interests. For instance, is the reclamation audit conducted for environmental/economic/policy-led/certification or qualification reasons?

The final product of a reclamation audit is an inventory consisting of the materials' details: dimensions, quantity, condition, environmental impact, technical characteristics and disassembly details.

The FCRBE Reuse Toolkit: Reclamation Audit provides an Excel template for the inventory as well as guidance on how to set the scope of the audit[10].

In the early stages, it may be enough to to do a brief visual scan identifying the main reuse opportunities. Starting as early as possible will increase your chances of maximising reuse.

Stakeholders involved in a reclamation audit can be the building owners, architects, surveyors, demolition contractors, construction contractors, reuse experts and reclamation dealers. For instance, architects may be able to asses the value of the building materials based on technical, economic, environmental and design aspects, but they might not be very familiar with the reuse market. Therefore, they might be best suited to conduct the audit in case the purpose is on-site reuse. On the contrary, salvage dealers will have a good understanding of the reuse market, but they might only focus on salvaging products with an already established market for reselling. Therefore, they are most suitable when the scope of the audit is finding products that are easily resold. Building owners may be best placed to conduct a quick initial audit due to their potential proximity and access to the site, but they might lack the technical expertise to determine reuse value. Demolition and deconstruction contractors have an understanding of the technical and legal aspects of material reuse, but they may be faced with conflicts of interest to achieve their own targets. It is therefore crucial to identify the required scope and aim of the reclamation audit before conducting it[11].

When there is no existing asset on site

Products from virgin materials contribute to resource depletion and carbon intensive activities to manufacture. When sourcing new materials for a project, the priority is to look into reusing materials instead of sourcing virgin materials. Set reuse objectives with the client. Designers and specifiers often struggle to use reclaimed construction materials, so it is important to engage with purchasing advisors with specialist knowledge in sourcing used materials. The FCRBE Reuse Toolkit: Procurement Strategies document provides guidance on setting up reclaimed material procurement strategies[12].

Aim: Reuse materials and components. Source used materials for the project instead of using virgin materials.

Project strategies

Start by resource mapping suppliers of reclaimed materials and other sources of used material flows. The mapping can also extend to natural resources, ground conditions (potential resource for aggregates) and human capital available within close vicinity of the site.

In this stage the focus is on getting familiar with the reuse markets and the options available. Moving on to the next stage, the focus will be to set up the strategy for procurement of reused materials. Note that materials suitable for reuse may be located in waste streams. For instance, sub soils (clays, grits, sands, gravels) excavated during the foundation works could be upcycled into rammed earth structures.

Hold a workshop with the key stakeholders to assess the viability of the most easily reusable materials to suit the concept design and to familiarise them with materials available for reuse and their specific performance and aesthetic characteristics

Formulate the reuse objective with the client and the design team by the end of this stage.

Hold a workshop with the client to establish specific reuse objectives alongside environmental and circularity ambitions. This serves as a clear communication of the reuse expectations to external providers. This should identify any additional stakeholders, such as reclamation dealers, local social enterprises that deal with salvaging materials and any additional expertise needed in the design team (e.g. reuse consultant, buying adviser etc).

Maximise reuse
Project planning & design (RIBA Stages 2-4)

When there is an existing asset on site

If retrofit is deemed feasible, the next step is to set out the required changes and performance targets. In this stage of works, the focus is on balancing maximum carbon savings (retaining the maximum of the existing structure) whilst achieving the desired building performance and function for the client's use (current and future). Striking this balance is only possible through well implemented retrofit projects, which follow a whole-building strategy[13].

For secondary materials sent onward for reuse, this stage of works is about rigorous data and logistics management. The perceived obstacles associated with material reuse (e.g. lack of deconstruction expertise, lack of time for additional tasks, lack of knowledge on reuse markets) often outweigh the benefits perceived by the client and design team. It is important to evaluate these obstacles early in the process and appoint the right experts to help the team overcome them. This saves significant carbon emissions in addition to having financial value to the client.

Aim: Reusing an existing asset in its entirety. Map out the needs of the client and desired performance targets.

Project strategies

After the initial building assessment, break down the building into layers to set out the key works along with the strategies, details and performance targets.

In the technical design phase, the sequence of works should be planned along with the details of the interventions.

Material passports & Data collection

Material passports ensure the future reuse of materials. Their production should begin as early as possible by surveying and logging the existing asset and new components.

At a minimum, a material passport contains information on material quantities, where each material is located in the building (based on the building layers) and their residual financial value. In case of a retrofit project, the material or building passports will consist of a mix between the components and materials of the existing structure and the newly built elements.

Initially, it is likely that there will be limited or no information on the existing asset (e.g. no 3D models or CAD drawings) about the existing structure. In this case the asset audit will form the basis of the data collection. This may have been done in a simple Excel spreadsheet or a more dynamic collaborative software such as Morta or Air table.

This data can then be transformed into a detailed 3D design model as early as the concept design stage, containing basic information on product specification (materials and material types used), classification coding (where they are used) and the quantities of materials used.

Towards the end of this stage, the basis of the materials passports likely shifts from design models to production and construction models. In general, construction models will be used by the installers and therefore will represent the as-built asset better than design models. Effective BIM management is therefore crucial throughout the technical design phase and construction phases, to make sure that the models that form the basis of the passports will reflect the real life asset accurately.

In the technical design phase, the design team will have a more detailed understanding of the materials used in the project, so the material passport production can progress into its next phase. The next step is to enrich the data collected during the concept design with information on the degree of reuse, recycled content and disassembly potential of the products used.

Aim: Reuse materials and components. Enter materials and components of the existing building to the market of reused products.

Project strategies

Conduct the reclamation audit

As outlined in the previous chapter, reclamation audits have different scopes. While an early stage audit can be as simple as walking around the building and physically tagging high reuse value components, the level of detail will become more granular as more data is collected throughout the project. Materials should be carefully documented in the inventory, including quantities and any marks on the component. Data can also include performance characteristics, connection and disassembly details and any changes during the first life of the component. As previously mentioned, there are free templates available for logging the data[14].

Once the data is documented in a spreadsheet, a unique identifier (such as QR code) can be created for each identified component. The materials on-site should be labelled with these physically when possible, so the contractors have the documented data available to them during the deconstruction of the components. The reclamation audit is also the basis for the creation of material passports.

The process of inventory and logging of data is a labour intensive process. There are currently no truly efficient ways that would allow for a dynamic editing of data as it develops (e.g. links to Revit). Appoint one or two people from the design team or hire an external 'reuse expert'. They should become the single point of call to work with the contractor throughout the design.

Organising ownership and logistics of the materials

Evaluate whether the materials identified can be reused on site or sent to another site or material broker. Discuss options with the client to use the materials in one of their other upcoming projects and explain the incentives to building their own material inventory. Benefits are wide ranging and include increased stability on fluctuating prices of materials due to economic uncertainties and time efficiency due to shortened material order times.

This practice is currently gaining popularity among industry professionals.

In the case of off-site reuse, the team should begin to search for buyers and set up a material storage policy. Contact salvage dealers and reach out to networks to see if there is any party interested in taking on the materials. Advertise on material exchange platforms or set up an internal material exchange platform. There are more and more examples of this practice recently[15]. It is also good practice to contact the manufacturer of the materials to see if they have a take-back scheme.

Organise the logistics of the material handling with the contractor to manage the storage, packaging and transportation of the materials. The appointed contractor should be willing and able to work with the reuse scenarios. The requirements should be clearly specified in their appointment contract.

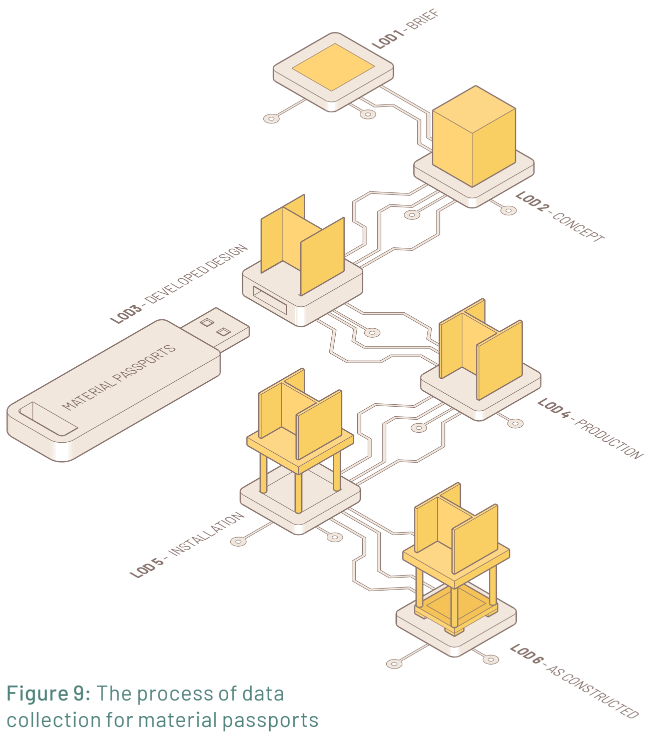


Figure 9: The process of data collection for material passports

When there is no existing asset on site

Working with a pool of existing materials requires flexibility from the design team, who should be equipped to deal with the added uncertainties. Setting up a flexible procurement schedule is a useful way to allow a level of flexibly. The client and design team should be open to working with unique aesthetic features that may arise from using a variety of reclaimed materials.

Aim: Reuse materials and components. Source used materials for the project instead of using virgin materials. Set the Reuse objective and develop a Supply strategy.

Project strategies

Reuse objectives, either in a quantitative or qualitative form should be included in the contract documents of contractors and used as a basis for the tender.

Objective / Qualitative / Specific: Integrate this or that reclaimed material for this or that part of the project.

Objective / Quantitative / Specific: Integrate an agreed percentage of this or that reclaimed material for this or that part of the project.

Objective / Qualitative / Open: Favour reusing building materials wherever possible.

Objective / Quantitative / Open: Integrate an agreed percentage of reclaimed materials.

Once the objectives are set, engage with the contractors through workshops. Designate time to evaluate the technical and economic feasibility of the objective. The design team, engineers and contractors will need to negotiate through this process, so allow for flexibility and ensure there is a platform for regular communication[16].

Start developing a supply strategy to source the reclaimed materials and work alongside the contractors iteratively to develop the construction details and ensure there are no buildability issues.

Standard specification clauses are not written with reuse being considered. It is likely you will need to edit and adapt the clauses, making them tailored towards reuse.

Maximise reuse
Construction & handover (RIBA Stage 5-6)

When there is an existing asset on site

During the construction process, the construction team will likely be faced with unexpected challenges on site which can only be solved through deviation from the original construction details. Develop strategies to address the uncertainties arising from using reclaimed materials (e.g. flexible procurement). If the construction works involve the deconstruction of an existing asset, the deconstruction and salvaging of high reuse value components start in this stage, led by the contractor or other suitable professionals, with the active participation of the design and engineering teams. Once the construction works are completed, the design team should hold a series of handover workshops with the client and building users to ensure the complex documentation produced over the design and construction of the asset is understood by the client.

Aim: Reusing an existing asset in its entirety.

Project strategies

Material passports production:

Enrich the existing material data with exact specification information, including but not limited to type, quantities, material composition, and assembly details. This is an iterative process and can be done parallel to construction.

Ensuring effective BIM and risk management. The design and construction teams should collaborate to find solutions to onsite problems without compromising circular strategies. Any deviation from the original construction plans should be accurately reflected in the material passports documentation. Hold regular workshops during the construction phase to maintain collaborative problem solving and information flow between the design and construction team.

Data from material passports can be used to indicate overall circularity of the project. With the collated data on the materials, the project team can calculate the ratio of virgin versus recycled/remanufactured/reused products, the expected functional lifecycle of the products specified and the end of life options (disassembly and reuse potential) compared to other industry averages. This data should be used to benchmark future projects and as the basis for improvement. During construction, the design, engineering and construction team should continuously evaluate the building performance (e.g. airtightness, ventilation) and monetary progress of the project.

Handover documentation for material passports:

Hold workshops with the client explaining the format and information included in the material passports produced. Ensure the client or building management can monitor and modify the information contained in the passports so that the documentation can be updated in case of maintenance works during the asset's life.

Aim: Reuse materials and components. Enter materials and components of the existing building to the market of reused products.

Project strategies

Deconstruction of high-reuse potential components:

Prepare a method statement for the disassembly of elements together with the contractor, before the start of deconstruction. At the start of this stage, carry out trials of deconstructing certain components to understand barriers and sensibly allocate time for deconstruction activities. Make sure there is scope to update the method statement, as it will be an iterative process with opportunities and barriers presenting themselves during the deconstruction.

Evaluate the hierarchy of materials based on reuse value in the deconstruction plan. Deconstructing building components is a complex process - especially ones that were not designed for disassembly. It is likely that there will be sacrificial elements in the process. Consider which materials are the most valuable based on environmental, economic and practical criteria so that the construction team can make informed decisions during the process.

Storage of disassembled materials:

Set up a storage and logistics plan for the salvaged materials before the works begin. This should consider whether or not there is enough space on site to safely store the materials. If not, look for alternative storage options. Consider the specific packaging requirements of the materials. It is good practice to contact a manufacturer of similar components to ask for specialist packaging advice. Consider whether one of the stakeholders is interested in building their own stock of reclaimed materials for future use.

Documentation of materials:

The documentation of the materials will be a dynamic process during deconstruction, as material quantities and qualities will likely be different from what is indicated on the original material inventory. Hold regular workshops between the deconstruction and the design team and appoint a person in the team who is in charge of logging material details. The materials deconstructed on site should be physically tagged with identifiers. During handover, make sure that the information contained in the documents is thoroughly explained to the client and the building operator.

When there is no existing asset on site

Aim: Reuse materials and components. Integrate the used materials in the construction plan.

Project strategies

Building with second-hand materials comes with its own set of unique challenges. There are still numerous regulatory barriers (safety, warranties etc.) preventing the large-scale uptake of using reclaimed materials. Generally, it is the suppliers' responsibility to provide the reclaimed materials in a clean and ready-to-use condition. Special installation requirements for commonly reused materials can be found in the FCRBE Material Sheets[17]. As a general rule of thumb, working with reclaimed materials requires more flexibility from the construction team in terms of the timing and installation and from the client to allow for aesthetic variations.

Maximise reuse

In use & end of life (RIBA Stage 7)

Once the building is handed over to the client, it is the clients' and the building occupants' responsibility to operate and maintain the asset so that the building remains circular and suitable for deconstruction and reuse at the end of its life. There is often a gap between design intent and operational use. The handover process should ensure that the users receive all the necessary information to operate the building in a circular manner. Ideally, the design team should stay engaged to carry out post-occupancy performance evaluation and aftercare reviews. Decisions made post-handover about modifying the asset should follow a circularity plan, which should be guided by the adaptability details outlined in the handover documentation (e.g. the existing structural grid enables converting an office space into educational space). Any maintenance works or replacement carried out during the asset's life should be recorded in the system. Any maintenance work should be carried out without major intrusions and in the most resource efficient way, to minimise waste. At the end of the building's life, the deconstruction plan should be followed. In case of a circular asset, modular deconstruction into post-fabrication assemblies can also be considered to maximise material and time efficiency.

*While the previous chapters were divided into Retrofit, Partial Reuse and New Build chapters, by the time the building is in its operational and end-of-life stage, it will generally make no difference whether the starting point for the works was an existing building or not (with a few exceptions that are detailed below). Therefore, the strategies and actions of this stage are discussed together.

Project strategies

Engage early with product manufacturers

Collaborate with manufacturers when procuring the materials, so that an end-of-life strategy is already in place from the beginning. This can include service agreements (e.g. façade leasing) or pre-agreed take-back programmes. This approach to working with suppliers is becoming more popular, but there is still big scope for improvement. Encourage suppliers to provide alternative solutions during procurement. Incentivise them with the tender process. If there was no agreement during procurement, re-engage with them during the in-use phase and develop the end-of-life strategy together, emphasising the value of material reuse to them.

Improve the quality of pre-redevelopment and deconstruction audits

At the building's (or component's) end of life, prepare the pre-redevelopment and deconstruction audit to the same standard as required for material passports, including as much detail as possible. This will have a cost and time implication for the deconstruction contractor, however, to incentivise the client to agree to this, pitch to them the value of material passports. Having a building portfolio with high quality material passports will enable them to spare time and costs in the future - plus their assets will become a pool of materials that they can rely on in the future, more resilient to fluctuating new material prices and availability.

Factor in additional time in the case of buildings that started as a retrofit project, since the identification of suppliers, age of the components etc. might be more difficult on the 'old' parts of the building.

Advertise materials to be passed on for reuse as early as possible, be proactive

Reports and statements are sometimes prepared by sustainability consultants without any responsibility assigned to project team members to action the recommendations. To avoid missed opportunities,

assign clear responsibilities to project team members. The responsibility to pass on materials for future reuse can fall on the deconstruction contractor, the sustainability consultant or the design team. It takes proactive approach to find buyers for materials.

Take photos and record the details of the materials to be passed on early in the deconstruction audit process and start joining material reuse forums and share the material information as early as possible.

This will ensure the shorter time between deconstruction and finding a new buyer, limiting the cost implications of storage and logistics.

Share information on materials that are not usually reused as well. If not sold, these materials will often find new owners as donations.

Work closely together with the deconstruction contractor. Establish which materials are high value to them, and which ones they will prioritise reselling to understand which materials will be likely left over.

As the process of joining forums and engaging with material buyers can be very time consuming, make sure you collect data on what platforms worked best and what was the most efficient and effective way to do it. This will save considerable amount of time on future projects.

Focus on digital data management during in-use (BIM, Material passports)

Ensure that there's a long-term strategy in place for material passporting, including assigning responsibilities for data ownership and maintenance.

It is especially important to model retrofitted parts of the building in detail. Retrofitted parts may be more difficult to find information on, since they are varied in dates, so to enable future reuse, particular attention must be paid to these elements.

Ideally, in the future, essential material information will be available in centralised sources. As it stands today, information may be stored in various locations.

Do not miss out on the opportunity to implement reuse on shorter lifespan material (fit-out)

Fit-out and Retrofit projects offer a good opportunity to maximise reuse of the shorter lifespan assets. While reusing finishes and interior elements might not be as significant in carbon savings as reusing structural elements, they provide a good opportunity to test out principles. Since these components have shorter lifespans, it is easier to design them with deconstruction in mind, controlling the process of the material at the end of its life.

Design for optimisation
Introduction

Design for optimisation includes a set of design principles: designing for longevity, flexibility, adaptability, disassembly, standardisation and modularity[18].

A, Longevity

Definition, Designing for longevity means the asset is designed to be:

durable and resilient to withstand environmental conditions (now and in the future)

capable of responding to current and long-term needs of the client and society

easily maintained and adapted without major disruption to the building.

B, Flexibility

Definition, A flexible built asset is capable of adapting to the changing use of building occupants through the reconfigurability of its parts. This may include short periodical changes (e.g. different daytime or evening use, seasonal changes) or long-term changes (e.g. change of ownership).

C, Adaptability

Definition, An adaptable asset is designed to suit the present needs of building users while considering and accommodating possible future changes. This involves scenario planning and optimising the structural and non-structural elements of the building to best respond to the scenarios.

D, Design for assembly, disassembly and recoverability

Definition, An asset designed for disassembly and recoverability enables non-disruptive deconstruction and reuse or recycling of its components individually or in clusters.

E, Use standardisation and modularity

Definition, A modular design with standardised elements uses clusters of components as the basis of construction with standardised dimensions, enabling maximum waste reduction and reuse.

Design for optimisation
Early considerations (RIBA Stages 0-1)

Buildings components have varying service lives, which means they will need to be maintained and replaced at different points in time. Building design should respond to these varieties through a strategy that is flexible and can accommodate for change throughout the building's life through adaptability and reversibility.

Structurally, a building can be transformed if independence between the elements and systems is achieved and where the interfaces between these parts are designed for exchangability. Spatial transformation potential is highest when the least amount of effort is required to accommodate different functions - in turn avoiding any major reconstruction work, demolition and material loss.

A reversible circular building is defined as one that supports processes of transformation or dismantling of its components without significant damage. In a reversible building, components can be added, substituted, relocated and separated from one another without intrusion to the fabric. The long term value of a building depends on the transformation and reuse potential on three levels: structural, spatial and material[19].

Aim: Look at buildings as dynamic - not static - structures that suit user needs now and in the future.

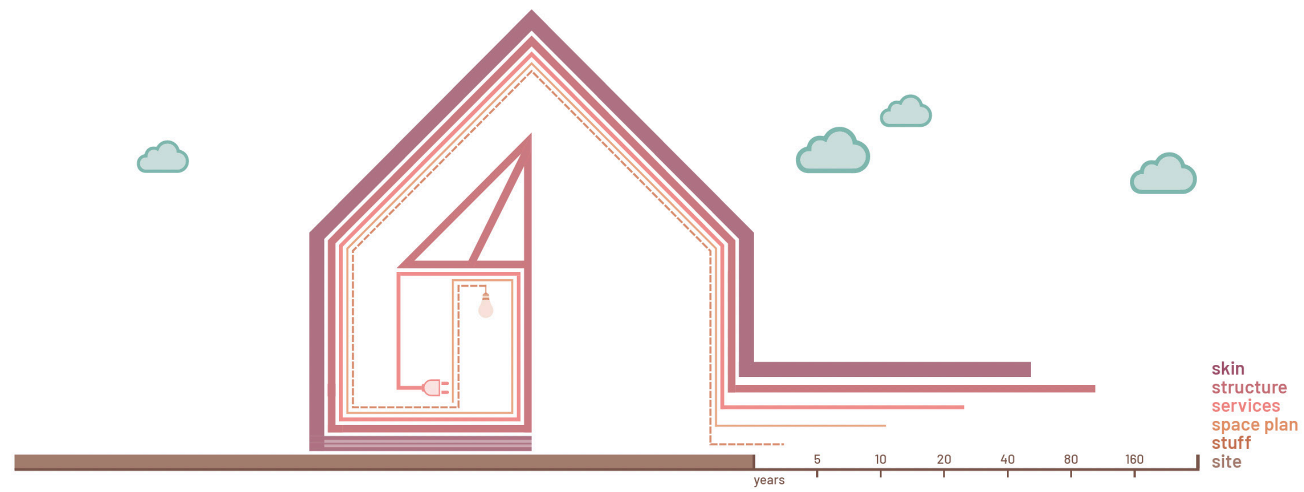
Project strategies

Adaptability: Hold a workshop with stakeholders to develop future scenario modelling and explore how the building users' needs might change over time.

A circular building design adds a time factor in the design brief, which means that the design isn't just focused on the initial program, but considers multiple use scenarios for the building and its components as well as future occupants and owners.

In case of commercial buildings, these workshops should include the local authorities as well as the

Figure 10: Building layers with different life cycles



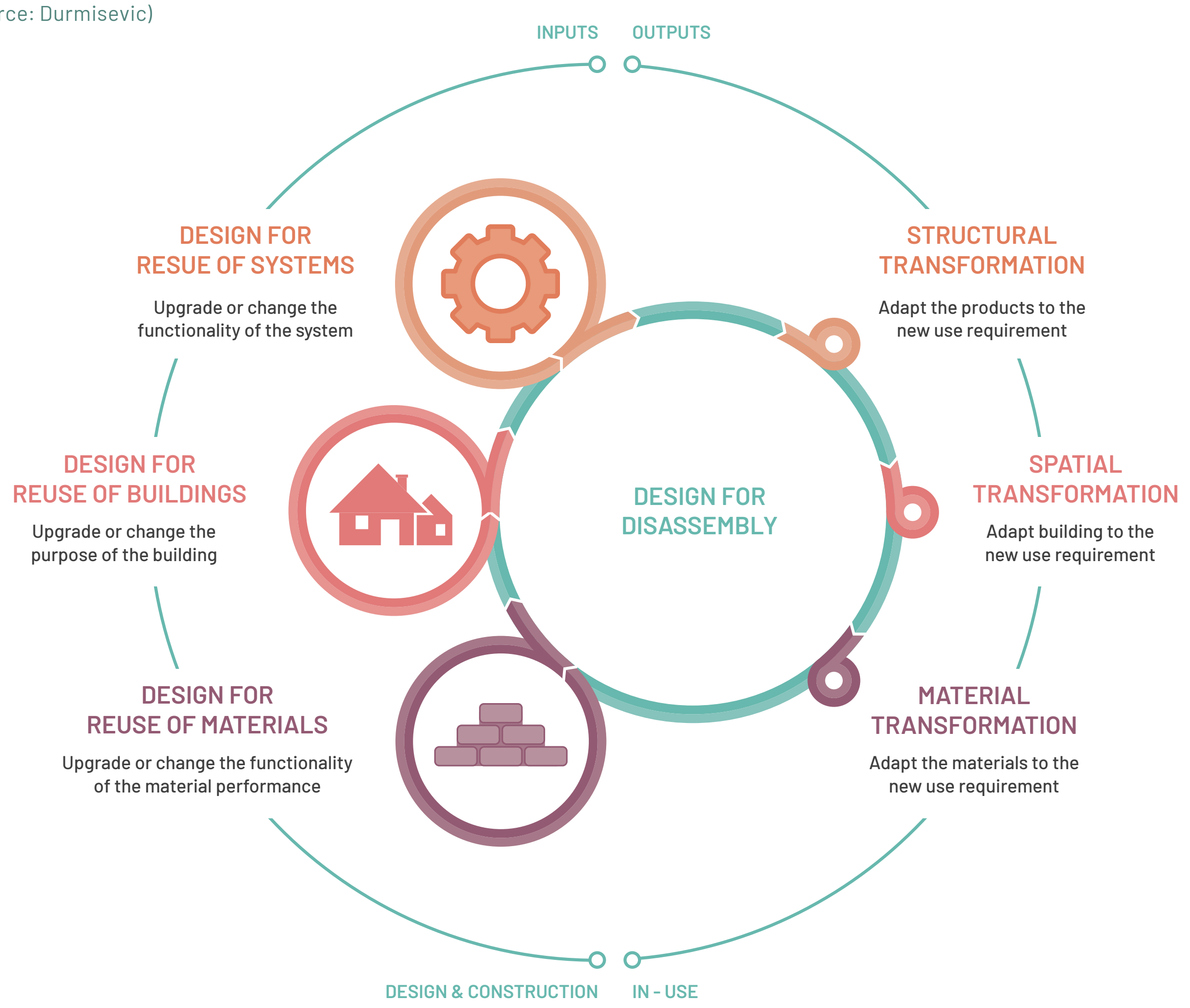
client, to explore possible future transformation opportunities based on the plans of the local authority (e.g. urban planning, future uses of the neighbourhood, projected business growth, future trends in work/living spaces). Future scenarios should address changes in building size due to changing number or typology of users.

Establish high level strategies for adaptability based on the different scenarios identified (both short and long-term). Specify different life cycle phases with the client and the requirements for each use phase.

Exchangeability: Apply a layered approach, where each building layer is independent from each other.

The building layers need to be clearly separated to ensure the replacement of shorter lifespan components do not result in damaging other layers.

Figure 11: Principles of designing for disassembly (Source: Durmisevic)



Design for optimisation
Project planning & design (RIBA Stages 2-4)

Traditional, linear building design is characterised by complex and closed hierarchy of building components, where the replacement of one component significantly impacts other building parts. In an optimised, circular built asset, the components are independent and exchangeable. Independency means that the assembly, transformation and disassembly of components within a building layer can be carried out without affecting others. Exchangeability means the systems and components can be disassembled without damaging surrounding parts of the structure and providing potential for their reuse. Independence and exchangeability depend on the physical relations between building layers and components (e.g. interface design)[20].

In this stage of works, the focus is on optimising these relationships. Work on the design to maximise the non-disruptive adaptability, maintainability and exchangeability of the layers.

Aim: Look at buildings as dynamic structures

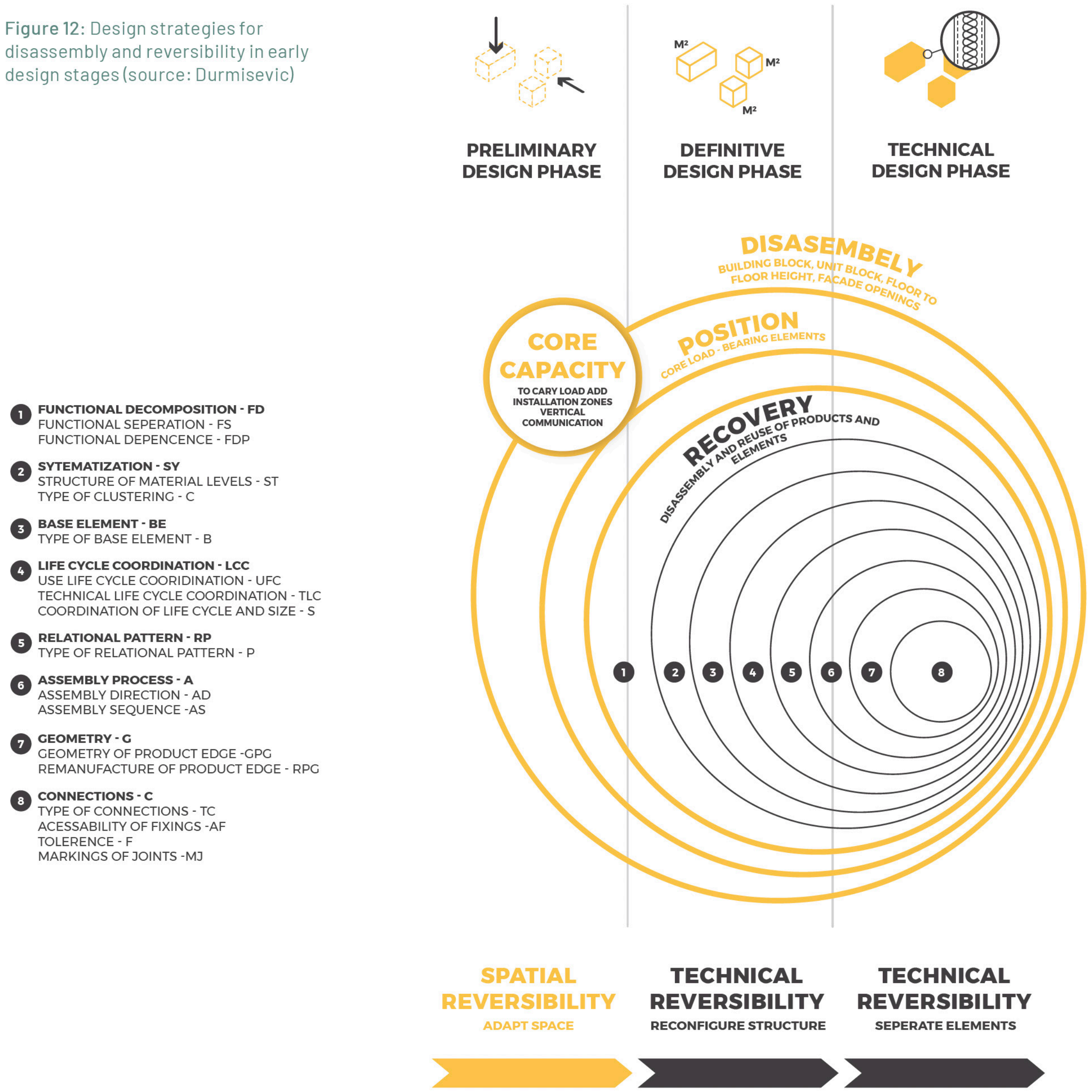
Project strategies

Develop an adaptability plan:

- Focus on developing optimal dimensions, positioning of core elements, core capacity and building level disassembly. This determines the spatial reversibility and upgradeability of a building (See Figure 14).
- Choose a regular approach to the building grid, as a regular grid allows for easier future adaptability.
- Break down the proposal into layers: site, structure, skin, services, space plan, stuff. Each layer should be able to accommodate future needs whilst serving the current needs. Layers should be independent of each other and accessible for change in the future. The clustering and systematisation of elements should be developed throughout concept design and technical design.
- Standardise dimensions across the layers and position circulations and access that do not inhibit the future alterations[21].
- Correct dimensions should demonstrate an understanding of spatial capacities required in the current brief and in the future for different building typologies. Consider the spatial capacities of different building typologies along three parameters: natural light, floor-to-ceiling and floor-to-floor height. For instance, a 2.5 m high window would reflect natural light in the room within 5 metres from the facade, so the spaces used by occupants should be within this range while service areas can be beyond this distance. To optimise the transformation potential across functions (e.g. school, office, residential), allow for higher floor-to-ceiling and floor-to-floor heights. Make sure service zones are adequately sized and have the capacity to adapt to future needs.
- Core capacity and positioning: Cores are typically interior elements that are used to connect spaces from one part of the building to the other. This can include but is not limited to MEP equipment, staircases and elevator shafts. Cores typically have a high performance criteria attached to them[22]. Design for a minimum amount of fixed elements that allow to maximise the future transformations. The scenario modelling in the early stages identified possible future use typologies. Consider the specific requirements outlined in building regulations for the different scenarios and optimise the core so that the future adaptation of the building can be carried out with the least intrusive works.
- Position the core as shown in Figure 14. A post and beam system would open up to different scenarios than a cross wall construction method.

- To enable higher transformation capacity, cluster core elements. Generally speaking, unclustered elements create barriers for future scenarios.
- Load bearing elements can be adapted based on scenario modelling conclusions in the earlier design stage.
- Develop vertical communication of the proposal if multistory.
- Assess the future disassembly potential of the building. The handover documentation should include a disassembly plan of the building. Start outlining this alongside developing the adaptability plan.

Figure 12: Design strategies for disassembly and reversibility in early design stages (source: Durmisevic)



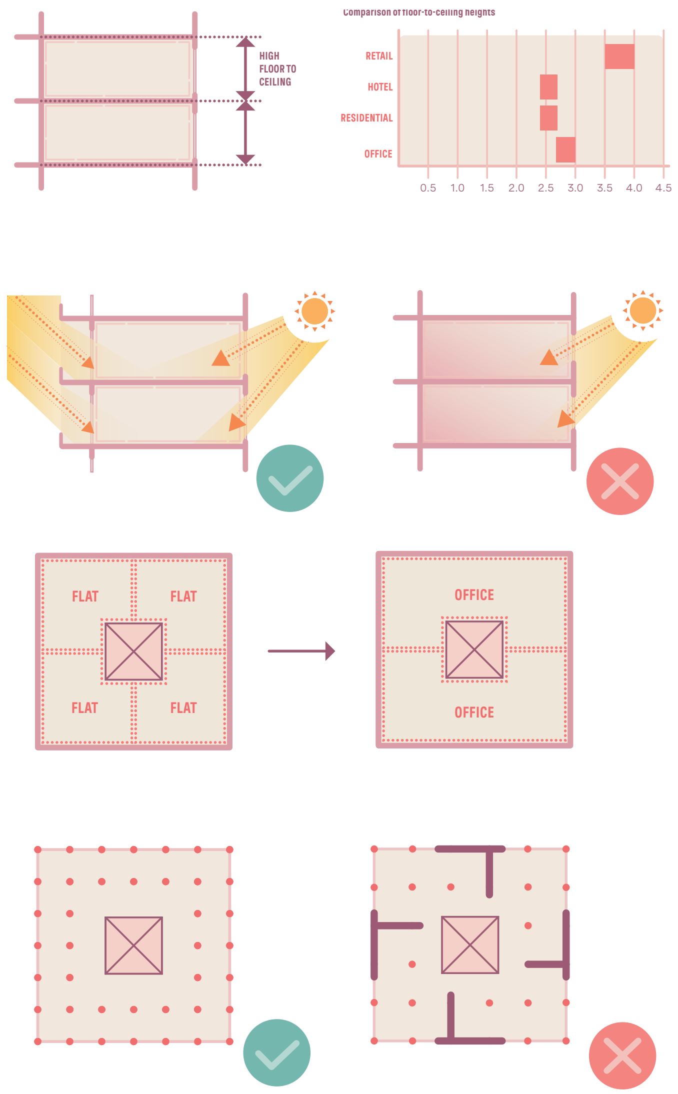


Figure 14: Key strategies for reversibility: ceiling height, natural light, core design (Source: Cheshire, Durmisevic)

Develop a construction plan:

- In the technical design phase, focus on the physical reversibility of elements, which will be determined by the their placement within the layers, the assembly sequencing - which should be based on life-cycle coordination between the components -, interface geometry and connection types.
- Break down the building proposal into shearing layers. An alternative and complementary approach to the shearing layers is to cluster components based on building functions: supporting, enclosing, servicing and partitioning. These are further divided into subsystems: foundation, frame, floor, facade, roof, inner walls, ventilation, heating system, water system and electrical system[23]. Whichever clustering approach is followed, the design should aim to keep components independent from each other. Maximise the independence between layers through modular zoning and planned interpenetrations (e.g. planned voids for services).
- Life cycle coordination of material components. Evaluate elements and components on their expected life. Materials with similar life spans should be clustered together to allow replacement and refurbishment of them without major disturbance to the adjacent building fabric.

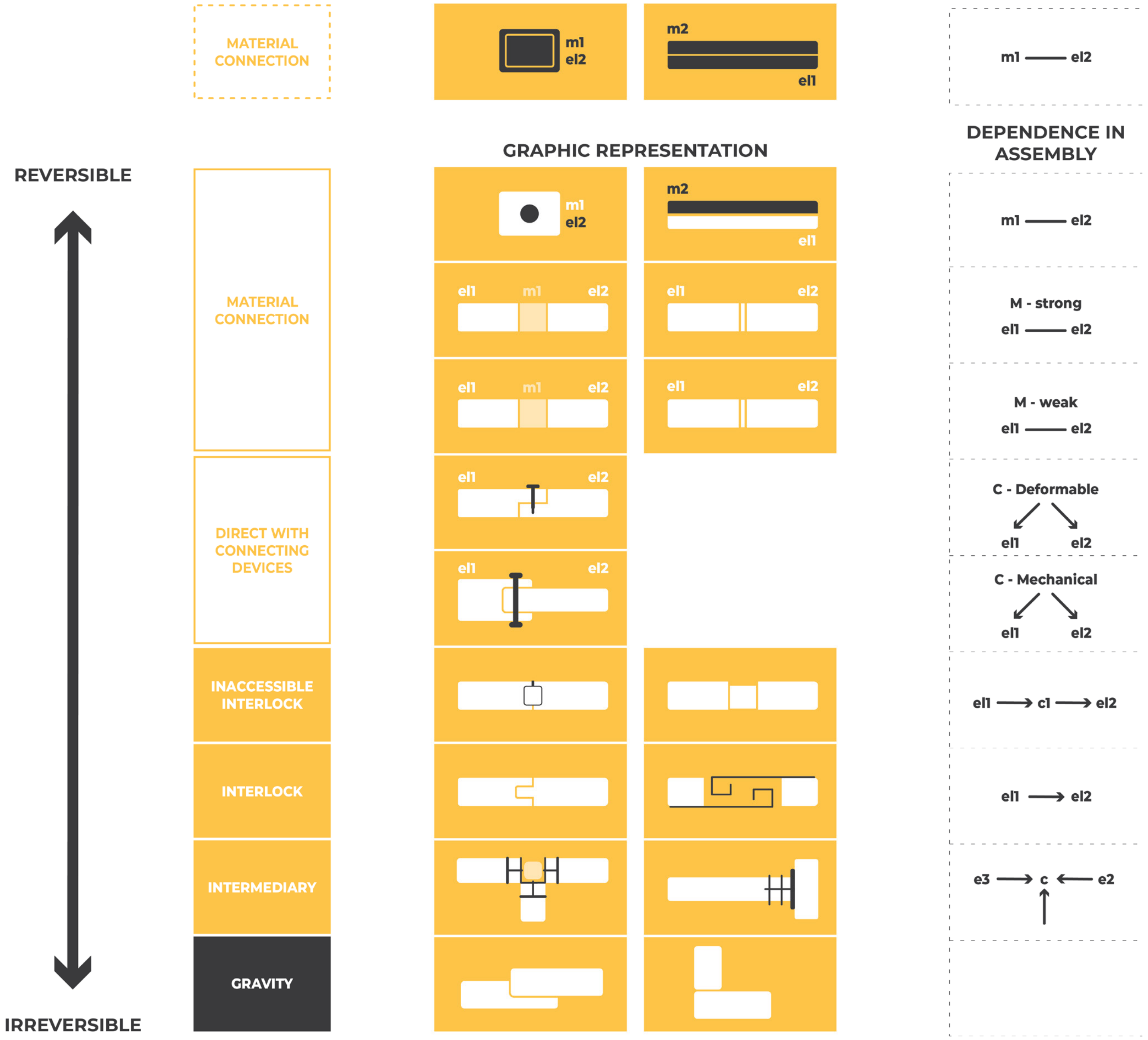
- Develop interface design and physical connections:

There are three distinct types of connections to consider: integral, accessory or filled[24].

Integral connections include open, overlapping or interlocked connections.

Prioritise open or overlapping geometries in the design, as these are the easiest to disassemble. For instance, overlapped connections are used between vertical, external facade elements or to join vertical and horizontal components.

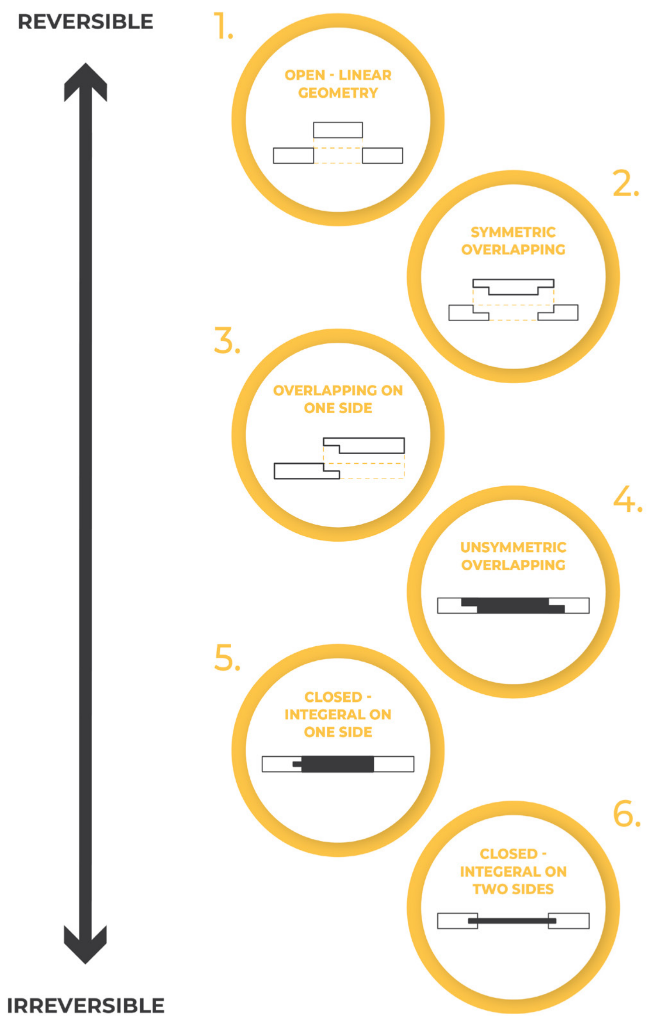
Figure 15: Material connection details (source: Durmisevic)



Accessory connections mean that additional parts are used to connect the elements. The additional accessory can be either internal or external to the joined components. Prioritise external joints where possible, as they provide an easier opportunity for dismantling.

Avoid filled connections, where two components are joined together through a bonding chemical (glue, mortar, welding etc), as these make disassembly difficult. Dry-joining techniques should always be preferred to chemical bonding[25].

Figure 16: Material connection details (source: Durmisevic)



- Work towards <5% 'special components' across standardised and modular designs.
- Hold workshops with the team of architects, engineering team and manufacturers focusing on the feasibility of different interface design and life cycle coordination to determine correct assembly sequences.
- Consider assembly and disassembly sequences. When designing for disassembly, the way we assemble a building sets a mirror image of the building during its disassembly phase. Assembly sequences are either sequential or parallel. Designing for parallel assembly and will in turn speed up the process of disassembly as multiple components can be worked on at a single time. Make sure as built and construction record data is captured and recorded to go into the final handover documentation.
- Before moving on to construction, prepare the final building layering and set out the construction and assembly sequences. The development of these should be collective between the design and construction teams. Incorporate a degree of flexibility in the design to be able to respond to site specific challenges arising during construction.

See more details on reversibility in the BAMB research project[26].

Design for optimisation
Construction & handover (RIBA Stage 5-6)

The process of construction should be dynamic and all details should be carefully documented for future traceability. Continue to collaborate, monitor and document decisions about the strategies established in the earlier phases regarding functional and life cycle clustering of building components, interface designs and connection types. Develop the documentation alongside construction. The construction and assembly sequencing of a building will ultimately determine the building's potential to be adapted for a future use scenario and the potential of its components to be successfully disassembled and reused. Keep the engagement between the design and construction teams so that specific site challenges are addressed and resulting changes to the design details are documented. Without accurate documentation, the building's transformation and reuse potential is significantly reduced in reality.

The aim is to look at the building design and construction as a dynamic process.

Project strategies

Data collection

Continue to enrich the data on your chosen platform (e.g. 3D digital twins) during the construction phase. By this stage, detailed information on building components will be available and can be fully captured. Include supplier details, material constituents, quantities and characteristics (e.g. embodied carbon figures, end of life opportunities), and design and connection details in the documentation. Refer to ISO 20887:2020 for detailed information[27].

Handover documentation

The handover documentation will ultimately determine the building's potential to be adapted in the future and the potential of its components to be successfully disassembled and reused. The building maintenance team should undertake any maintenance work or replacement of components in alignment with the handover documentation and record any resulting changes. This is only possible if they have a full understanding of what is included in the documents. Engage with the client, building maintenance team and the end users through a series of workshops in the handover stage. A physical walk-around tour of the building may be useful to explain the details, operation and maintenance[28].

Design for optimisation
In use & end of life (RIBA Stage 7)

Once the building is handed over to the client, it is the clients' and the building occupants' responsibility to operate and maintain the asset so that the building remains circular and suitable for deconstruction and reuse at the end of its life. There is often a gap between design intent and operational use. The handover process should ensure that the users receive all the necessary information to operate the building in a circular manner.

Ideally, the design team should stay engaged to carry out post-occupancy performance evaluation and aftercare reviews.

Decisions made post-handover about modifying the asset should follow a circularity plan, which should be guided by the adaptability details outlined in the handover documentation (e.g. the existing structural grid enables converting an office space into educational space).

Any maintenance works or replacement carried out during the asset's life should be recorded in the system.

Any maintenance work should be carried out without major intrusions and in the most resource efficient way, to minimise waste.

At the end of the built asset's life, the deconstruction plan should be followed. In case of a circular asset, modular deconstruction into post-fabrication assemblies can also be considered to maximise material and time efficiency.

Project strategies

Asset maintenance during operation and information management

During the in-use stage, the best strategy is to prolong and preserve the building's and its components' useful life through maintenance, so that end-of-life can be 'avoided' for as long as possible. As seen in many cases, maintenance and replacement guidance in O&M documents are prepared but often not followed through. It is important to have a circular building management strategy in place, including an outline of necessary future upgrades and adaptability instructions detailing the least intrusive way to execute those. The design team have to work closely with the client and future occupants to develop a maintenance and replacement strategy.

The circular operation and deconstruction strategy of the building should be updated multiple times: at first once the construction is completed, to respond to differences between design intent and as-built state, and then, on an annual basis. In this way, the client and maintenance team can develop a roadmap towards the end-of-life. It is also recommended to have a 'mid-term review' of the building, re-evaluating the maintenance and end-of-life strategy of its components.

Minimise impact & waste
Introduction

Waste generation and construction impact can be minimised in multiple ways, including[29]:

A, Minimising material input and waste by design

Optimise the design to use the minimum amount of materials to still meet the needs and provide high quality. Achieved by designing out unnecessary finishes or optimising the structural grid. Waste production should be considered for the whole life cycle of the asset, including construction, in-use and deconstruction.

B, Specify low impact materials

Considerations on material impact include environmental impact and any adverse impact on human health. Avoid non-renewable, toxic, hazardous materials.

C, Specify reclaimed materials and materials with recycled content

Reclaimed materials and recycled content materials reduce the demand for virgin materials and optimise material efficiency.

D, Reduce construction impact

Reduce the waste during construction through optimising the process (e.g. off-site or lean manufacturing).

Minimise impact & waste
Early considerations (RIBA Stages 0-1)

The construction industry is the biggest source of waste generation in the EU, generating almost one billion tonnes of construction and demolition waste per year[30]. Selecting low-impact, quickly renewable and biodegradable materials, specifying remanufactured and recycled materials and designing out waste and excess material use should be integral to the early stage design considerations.

Project strategies

Hold an initial workshop with the client and relevant stakeholders to introduce key concepts of minimising waste and impact, such as the R-frameworks[31] and material cascades.

The R-frameworks for the waste hierarchy are useful visual tools to demonstrate the decision-making hierarchy. First, refuse unnecessary construction and prioritise retaining existing assets. Second, think about reducing total material inputs. Third, reuse materials from existing material flows. Fourth, select materials with recycled and remanufactured content. Fifth, choose biodegradable materials that can rot at the end of life. Lastly, reject non-recyclable materials going into waste streams.

Explain the idea of material cascades, which considers the possibilities of extending a material's lifecycle by transforming it into different products.

Minimise the total input of materials while ensuring the quality of the design.

Total material input can be reduced through optimising the design - for instance through standardisation. To enable this, engineers and other relevant stakeholders should participate in the early conversations about optimising material input.

By reducing the material palette, that is, reducing the diversity of specified materials, will reduce the risk of cross-contamination between material types which often complicates end-of-life reuse or recycling.

Promote greener and cleaner building chemistry.

Prioritise natural, renewable and biodegradable materials whenever possible and engage with relevant stakeholders early.

Always consider local resources first through resource mapping.

Set targets to specify high percentages of remanufactured and recycled products. Using recycled or remanufactured products reduces impact through the preservation of scarce virgin materials.

Avoid mixing technical and biological materials together to preserve clean and non toxic material cycles.

Minimise impact & waste
Project planning & design (RIBA Stages 2-4)

The planning and design stage is crucial to minimise impact and design out waste. The strategies considered earlier will take a concrete shape through the specification documents and bill of materials. The overarching aim here should be dematerialisation (to minimise total material input to the building while making sure quality and durability is not compromised) and maximising the efficiency of construction to minimise waste leaving the site during the next stage.

Project strategies

Develop the strategy of dematerialisation.

Make sure the design is optimised in terms of the structure (See Design for optimisation chapter).

Specification should aim to include a high percentage of:

- Standarised and modular components and off-site manufactured products, as these reduce construction waste significantly,
- Products with high remanufactured and recycled content,
- Natural, renewable and bio-degradable products.

Details should avoid:

- Glues, and aim to use mechanical and accessible fixings where possible, while making sure fabric efficiency is not compromised,
- Avoid toxic materials that compromise future recyclability,
- Avoid unnecessary finishes and keep surfaces exposed where possible,
- Minimise the diversity of material types.

Develop a strategy for future end-of-life.

In this stage, the design team should consider the end-of-life scenarios of the specified materials. Documenting the building components through material passports and BIM is essential to preserve future material value (See Maximise reuse chapter).

Specify products from manufacturers with established take-back schemes.

Consider products as a service approach.

To maximise the lifecycle of the materials specified, we need to rethink ownership structures. The products as a service approach promotes a shift from selling products to selling services.

Some building components (e.g. lighting, lifts, ventilation, heating and cooling) can be leased by the product manufacturers. A performance contract is signed between the client and the supplier so that the client only pays for the actual usage of the service. In this case there is a continuity of ownership given that the manufacturer owns the material throughout its life in the asset and the product will be taken back and reused by the supplier at the end of its useful life.

This approach is often avoided by clients due to perceived risks (e.g. warranties). To mitigate these risks, ensure the supplier provides a transparent pricing policy and that there are contract clauses protecting the client. Leverage potential financial gains for the client through a comparison of capital expenditure and operational budget.

Develop a waste management strategy for construction.

Hold a workshop with the contractors and discuss in detail how materials will be managed on site.

Minimise impact & waste
Construction & handover (RIBA Stage 5-6)

The construction stage is one of the most significant sources of waste generation so its important that the waste management plan that is in place aspires towards 0 % waste and stringent targets for the lead contractor and sub-contractors are set. This should be discussed and developed in the project planning stage.

Project strategies

Make sure a detailed waste management plan and a reuse mandate - if the project includes demolition - are part of the tender documents of the contractor.

Lean manufacturing, off-site and modular manufacturing and distributed manufacturing are construction methods that lead to significantly less waste produced on site.

To ensure future reusability, make sure the components are physically tagged with product information during the construction process.

The design team should closely collaborate with the construction team during this stage and ensure a continuous flow of information. Hold regular workshops between the construction and design team.

Minimise impact & waste

In use & end of life (RIBA Stage 7)

Once the building is handed over to the client, it is the clients' and the building occupants' responsibility to operate and maintain the asset so that the building remains circular and suitable for deconstruction and reuse at the end of its life. There is often a gap between design intent and operational use. The handover process should ensure that the users receive all the necessary information to operate the building in a circular manner.

Ideally, the design team should stay engaged to carry out post-occupancy performance evaluation and aftercare reviews.

Decisions made post handover about modifying the asset should follow a circularity plan, which should be guided by the adaptability details outlined in the handover documentation (e.g. the existing structural grid enables converting an office space into educational space).

Any maintenance works or replacement carried out during the asset's life should be recorded in the systems.

Any maintenance work should be carried out without major intrusions and in the most resource efficient way, to minimise waste.

At the end of the built asset's life, the deconstruction plan should be followed. In case of a circular asset, modular deconstruction into post-fabrication assemblies can also be considered to maximise material and time efficiency.

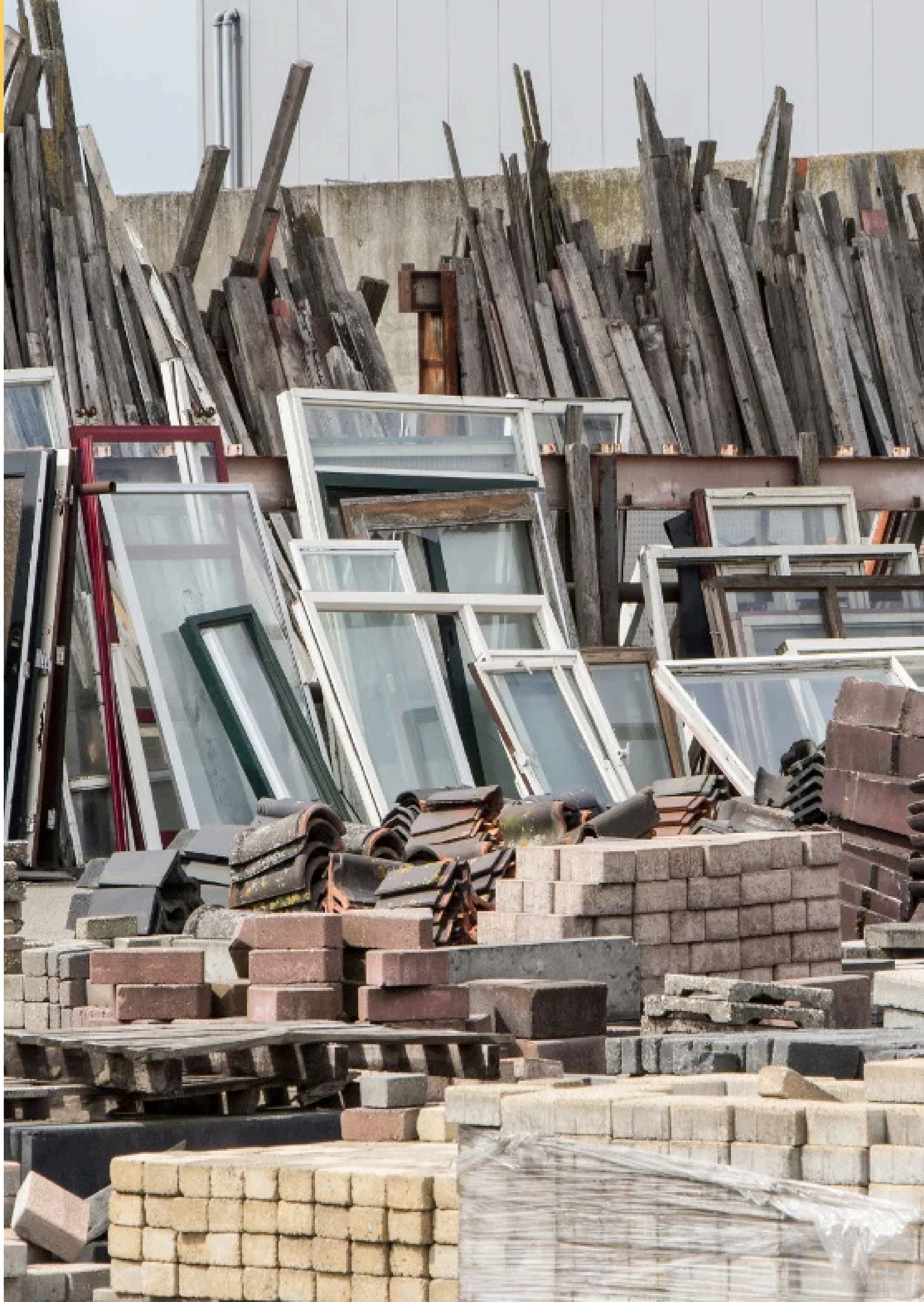
Project strategies

Follow maintenance strategy & deconstruction plans

The circular management plan should have detailed information on the adaptability of the building. Following this plan will result in the least amount of waste during the building's life. Similarly, the deconstruction plans and material passports include details about the reusability and recyclability of each material. It's important to appoint a project team member with sufficient time allocated to evaluate the feasibility of these recommendations.

Incentivise the client and the deconstruction contractor to avoid sending materials to landfill

The first objective is to explain to the client the benefit of selling or keeping materials for future reuse – emphasising the business case might be the most effective argument. The deconstruction contractor's team must also be incentivised to consider which materials are fit for reuse, even just as a donation (see maximise reuse chapter). Especially in the case of commercial refit projects, the pace of deconstruction works often hinders the possibility of meaningful evaluation of reuse opportunities. Work with the client and the contractor together to come up with a reuse strategy of materials and minimise waste at deconstruction.



		Early Considerations RIBA Stages 0-1	**Project Planning & Design** RIBA Stages 2-4	**Construction & Handover** RIBA Stages 5-6	**In Use & End of Life** RIBA Stage 7
Retrofit	**Maximise reuse**	**1.** Evaluate whether this asset is suitable for retrofit **2.** Conduct an initial audit of the asset considering the current building fabric and layout and the needs of the client. **3.** Hold an initial workshop with the client to determine current and future use scenarios. This will inform the basis of the decision as to whether the existing building will satisfy the requirements. **4.** Conduct initial building assessment of building fabric, airtightness, ventilation, and energy use of the existing building to determine whether retrofitting is the most efficient solution.	**1.** Set out the required changes and performance targets. In this stage of works, the focus is on balancing maximum carbon savings (retaining the maximum within the existing structure) whilst achieving the desired building performance and function for the client's use (current and future). **2.** In the technical design phase, the sequence of works should be planned along with the details of the interventions. **3.** Create an inventory of materials sent onward for reuse. Material passports ensure the future reuse of materials. Their production should begin as early as possible by surveying and logging the existing asset and new components.	**1.** To deal with any construction problems that might change a design detail, develop strategies to address the uncertainties arising from using reclaimed materials (e.g. flexible procurement). **2.** The design and construction teams should collaborate to find solutions to onsite problems without compromising circular strategies. Hold regular workshops during the construction phase to maintain collaborative problem solving and information flow between the design and construction team. **3.** Enrich the existing material passport data with exact specification information, including but not limited to type, quantities, material composition, and assembly details. **4.** At Handover, hold workshops with the client explaining the format and information included in the material passports produced. Ensure the client or building management can monitor and modify the information contained in the passports so that the documentation can be updated in case of maintenance works during the asset's life.	**1.** At this stage of works, ideally, an end-of-life strategy is already in place (e.g. leasing agreements, pre-agreed take back programmes). For building components with no end-of-life agreements. If for certain elements there was no agreement during procurement, re-engage with the product manufacturer during the use phase of the building to develop and end-of-life strategy for the building element together. **2.** During the use phase of the building, ensure that there is a digital data management strategy that assigns responsibilities for data ownership and maintenance long-term. **3.** Ensure retrofitted parts are modelled in detail to enable future reuse. **4.** Improve the detail of pre-deconstruction audits to be material passport quality. 5. Do not overlook the carbon savings that smaller reuse opportunities (e.g. finishes or interior elements) offer.
	Design for optimisation	**1.** Hold a workshop with stakeholders to do future scenario modelling and explore how the building users' needs might change over time. **2.** Include a time factor within the design brief, which means that the design isn't just focused on the initial program, but considers multiple use scenarios for the building and its components, considering future occupants and owners. **3.** The building should be designed for exchangeability. Apply a layered approach, where each building layer is independent from each other. Layers should depend on element type and lifespan.	**1.** Building the components should be independent and exchangeable. Independency means that the assembly, transformation and disassembly of components within a building layer can be carried out without affecting others. **2.** Develop an adaptability plan. **3.** Break down the proposal into layers, dividing the building into the different elements. **4.** When adding new elements into the building, standardise dimensions across the layers and position circulations and access that do not inhibit the future alterations. **5.** Assess the future disassembly potential of the building. **6.** Develop a construction plan, focus on the physical reversibility of the elements. Break down the building proposal into shearing layers and cluster components based on building functions. 7. Cluster elements and components together based on their life cycle where possible. **8.** Interface design and physical connections. There are three distinct types of connections to consider: integral, accessory or filled. **9.** When possible, prioritise open or overlapping geometries in the design, as these are the easiest to disassemble. **10.** For all new elements, prioritise external joints where possible, as they provide an easier opportunity for dismantling. Hold workshops with all the relevant stakeholders to design all new joints. **11.** For all new elements, consider assembly and disassembly sequences.	**1.** Data collection: Continue to enrich the data on your chosen platform. **2.** Handover documentation: Engage with the client, building maintenance team and the end users through a series of workshops in the handover stage.	**1.** Ideally avoid end of life by continuously refurbishing and keeping the building in use for as long as possible. **2.** Include a circular management strategy in the O&M manuals, which outlines the necessary future upgrades and adaptability instructions detailins the least intrusive ways to execute it. **3.** Encourage an annual review of material end of life strategies by clients and maintance teams. **4.** Encourage a mid-term improvement plan.
	Minimise impact and waste	**1.** Hold an initial workshop with the client and relevant stakeholders to introduce key concepts of minimising waste and impact, such as the R-frameworks and material cascades. **2.** Explain the idea of material cascades, which considers the possibilities of extending a material's lifecycle by transforming it into different products. **3.** Minimise the total input of materials while ensuring the quality of the design. **4.** Prioritise natural, renewable and biodegradable materials whenever possible and engage with relevant stakeholders early. **5.** Consider local resources **6.** Set targets to specify high percentages of remanufactured and recycled products. **7.** Avoid mixing technical and biological materials together to preserve clean and non toxic material cycles.	**1.** Develop the strategy of dematerialisation. Make sure the design is optimised in terms of the structure. **2.** Specify whenever possible, natural, renewable and bio-degradable products. Products with high remanufactured and recycled content. **3.** Design with standardised and modular components and off-site manufactured products as these reduce construction waste significantly. **4.** Avoid the use of glues and aim to use mechanical and accessible fixings where possible, while making sure fabric efficiency is not compromised. **5.** Avoid unnecessary finishes and keep surfaces exposed where possible. **6.** Develop strategy for future end-of-life. **7.** Documenting the building components through material passports and BIM **8.** Whenever possible, specify products from manufacturers with established take-back schemes. **9.** Consider products as a service approach. **10.** Develop a waste management strategy during construction.	**1.** Make sure a detailed waste management plan and reuse mandate are part of the tender documents for the contractor. **2.** The waste management plan that is in place aspires towards 0% waste and stringent targets for the lead contractor and sub-contractors are set. **3.** To ensure future reusability, make sure the components are physically tagged with product information during the construction process. **4.** The design team should closely collaborate with the construction team during this stage and ensure a continuous flow of information.	**1.** The handover process should ensure that the user receives all the necessary information to operate the building in a circular manner. **2.** The design team should stay engaged to carry out post-occupancy performance evaluation and aftercare reviews. **3.** Decisions made post-handover about modifying the asset should follow a circularity plan, which should be guided by the adaptability details outlined in the handover documentation. **4.** Consider extended design life for primary building elements. **5.** Include documentation to let users know how to recycle / reuse materials when it reaches its end of life and its service life. **6.** Make sure the material/building passports are specific e.g. some products look similar but have very different recycling options due to age/composition. e.g. mineral ceiling tiles. therefore it's important to have labelling and traceability data access. **7.** At the end of the built asset's life, the deconstruction plan should be followed.

A!	Early Considerations RIBA Stages 0-1	Project Planning & Design RIBA Stages 2-4	Construction & Handover RIBA Stages 5-6	In Use & End of Life RIBA Stage 7
Partial Reuse — **Maximise reuse**	**1.** If the asset is not suitable to be reused entirely, its materials and components should be deconstructed (instead of demolished), ensuring their reuse is possible in another project **2.** Carry out a reclamation audit for buildings scheduled for demolition or strip out and refurbishment, identifying building components and materials with high reuse potential. **3.** Produce a inventory consisting of the materials' details: dimensions, quantity, condition, environmental impact, technical characteristics and disassembly.	**1.** Conduct a reclamation audit - materials should be carefully documented in the inventory. **2.** Following the audit, procede to make material passports for all the items that can be reused. **3.** Evaluate whether the materials identified can be reused on site or sent to another site or material broker. **4.** With respect to materials that would be reused off-site, the team should begin to search for buyers and set up a material storage policy. **5.** Organise the logistics of the material handling with the contractor; to manage the storage, packaging and transportation of the materials.	**1.** Prepare a method statement for the disassembly of elements with the contractor, before the start of deconstruction. **2.** At the start of this stage, carry out trials of deconstructing certain components to understand barriers and sensibly allocate time for deconstruction activities. **3.** Evaluate the hierarchy of materials based on reuse value in the deconstruction plan. **4.** Consider which materials are the most valuable based on environmental, economic and practical criteria. **5.** As a general rule of thumb, working with reclaimed materials requires more flexibility from the construction team in terms of the timing and installation and from the client to allow for aesthetic variations. **6.** Set up a storage and logistics plan for the materials salvaged before the works begin. **7.** Hold regular workshops between the deconstruction and the design team and appoint a person in the team who is in charge of logging material details.	**1.** At this stage of works, ideally, an end-of-life strategy is already in place (e.g. leasing agreements, pre-agreed take back programmes). For building components with no end-of-life agreements. If for certain elements there was no agreement during procurement, re-engage with the product manufacturer during the use phase of the building to develop and end-of-life strategy for the building element together. **2.** During the use phase of the building, ensure that there is a digital data management strategy that assigns responsibilities for data ownership and maintenance long-term. **3.**Ensure retrofitted parts are modelled in detail to enable future reuse. **4.** Improve the detail of pre-deconstruction audits to be material passport quality. **5.** Do not overlook the carbon savings that smaller reuse opportunities (e.g. finishes or interior elements) offer.
Partial Reuse — **Design for optimisation**	**1.** Hold a workshop with stakeholders to do future scenario modelling and explore how the building users' needs might change over time. **2.** Include a time factor in the design brief; this means that the design isn't just focused on the initial program, but considers multiple use scenarios for the building and its components, considering future occupants and owners. **3.** The building should be designed for exchangeability. Apply a layered approach, where each building layer is independent from each other. Layers should depend on element type and lifespan.	**1.** Building the components should be independent and exchangeable. Independency means that the assembly, transformation and disassembly of components within a building layer can be carried out without affecting others. **2.** Develop an adaptability plan. **3.** Choose a regular approach to the building grid. **4.** Break down the proposal into layers, dividing the building into the different elements. **5.** When adding new elements into the building, standardise dimensions across the layers and position circulations and access that do not inhibit the future alterations. **6.** Clustering core elements such as load bearing, installation and communication, enables buildings to be designed with higher transformation capacity. **7.** Assess the future disassembly potential of the building. **8.** Develop a construction plan, focusing on the physical reversibility of the elements. Break down the building proposal into shearing layers and cluster components based on building functions. **9.** Cluster elements and components together based on their life cycle where possible. **10.** Interface design and physical connections. There are three distinct types of connections to consider: integral, accessory or filled. **11.** Prioritise open or overlapping geometries in the design, as these are the easiest to disassemble. **12.** Prioritise external joints where possible, as they provide an easier opportunity for dismantling. Hold workshops with all the relevant stakeholders to design all new joints. **13.** Consider assembly and disassembly sequences.	**1.** Data collection: Continue to enrich the data on your chosen platform. **2.** Handover documentation: Engage with the client, building maintenance team and the end users through a series of workshops in the handover stage.	**1.** Ideally avoid end of life by continuously refurbishing and keeping the building in use for as long as possible. **2.** Include a circular management strategy in the O&M manuals, which outlines the necessary future upgrades and adaptability instructions detailins the least intrusive ways to execute it. **3.** Encourage an annual review of material end of life strategies by clients and maintance teams. **4.** Encourage a mid-term improvement plan. **5.** Test out principles of deconstruction and material reuse on shorter lifespan assets that are more easily controlled to learn and then apply to long lifespan assets.
Partial Reuse — **Minimise impact and waste**	**1.** Hold an initial workshop with the client and relevant stakeholders to introduce key concepts of minimising waste and impact, such as the R-frameworks and material cascades. **2.** Explain the idea of material cascades, which considers the possibilities of extending a material's lifecycle by transforming it into different products. **3.** Minimise the total input of materials while ensuring the quality of the design. **4.** Prioritise natural, renewable and biodegradable materials whenever possible and engage with relevant stakeholders early. **5.** Consider local resources **6.** Set targets to specify high percentages of remanufactured and recycled products. **7.** Avoid mixing technical and biological materials together to preserve clean and non toxic material cycles.	**1.** Develop the strategy of dematerialisation. Make sure the design is optimised in terms of the structure. **2.** Specify wherever possible, natural, renewable and biodegradable products and products with high remanufactured and recycled content. **3.** Design with standardised and modular components and off-site manufactured products as these reduce construction waste significantly. **4.** Avoid the use of glues and aim to use mechanical and accessible fixings where possible, while making sure fabric efficiency is not compromised. **5.** Avoid unnecessary finishes and keep surfaces exposed where possible. **6.** Develop strategy for future end-of-life. **7.** Documenting the building components through material passports and BIM **8.** Wherever possible, specify products from manufacturers with established take-back schemes. **9.** Consider products as a service approach. **10.** Develop a waste management strategy during construction.	**1.** Make sure a detailed waste management plan and a reuse mandate are part of the contractor's tender documentation. **2.** The waste management plan that is in place aspires towards 0% waste and stringent targets for the lead contractor and sub-contractors are set. **3.** To ensure future reusability, make sure the components are physically tagged with product information during the construction process. **4.** The design team should closely collaborate with the construction team during this stage and ensure a continuous flow of information.	**1.** The handover process should ensure that the user receive all the necessary information to operate the building in a circular manner. **2.** The design team should stay engaged to carry out post-occupancy performance evaluation and aftercare reviews. **3.** Decisions made post handover about modifying the asset should follow a circularity plan, which should be guided by the adaptability details outlined in the handover documentation. **4.** Ensure that there's a long term strategy in place for material passporting, including assigning responsibilities for data ownership and maintenance. **5.** At the building's end of life, prepare the deconstruction audit to the quality of material passports, to spare time and costs.

		Early Considerations RIBA Stages 0-1	**Project Planning & Design** RIBA Stages 2-4	**Construction & Handover** RIBA Stages 5-6	**In Use & End of Life** RIBA Stage 7
New Build	**Maximise reuse**	**1.** When sourcing new materials for a project, the priority is to look into reusing materials instead of sourcing virgin materials. Set reuse objectives with the client. **2.** Hold a workshop with the key stakeholders to assess the viability of the most easily reusable materials to suit the concept design and to familiarise them with materials available for reuse and their specific performance and aesthetic characteristics **3.** Formulate the reuse objective with the client and the design team by the end of this stage. **4.** Hold a workshop with the client to establish specific reuse objectives alongside environmental and circularity ambitions	**1.** Agree with the client on reuse objectives or targets. Reuse objectives, either in a quantitative or qualitative form should be included in the contractor's contract documents and used as a basis for the tender. **2.** Once the objectives are set; engage with the contractors via workshops. **3.** Start developing a supply strategy to source the reclaimed materials and work alongside the contractors iteratively to develop the construction details and ensure there aren't any buildability issues. **4.** Standard specification clauses are not written with reuse being considered. It is likely you will need to edit and adapt the clauses, tailoring them towards reuse.	**1.** Prepare a method statement for the disassembly of elements together with the contractor, before the start of deconstruction.Carry out trials of deconstructing certain components to understand barriers and sensibly allocate time for deconstruction activities. **2.** Hold regular workshops with manufacturers and the design and construction team to allow for more collaboration. **3.** Engage the facilities/management team as early as possible into the built process, for them to contribute and have a good understanding of the new build. **4.** Encourage the contractor to start collating the O&M manual early, and provide a comprehensive document that captures specific information on building elements, including deconstruction or any existing end of life interest from suppliers or customers. **5.** At handover, hold workshops with the client explaining the format and information included in the material passports and other documentation produced. Ensure the client / building management can monitor and modify the information contained in the passports so that the documentation can be updated in case of maintenance works during the asset's life.	**1.** At this stage of works, ideally, an end-of-life strategy is already in place (e.g. leasing agreements, pre-agreed take back programmes). For building components with no end-of-life agreements. If for certain elements there was no agreement during procurement, re-engage with the product manufacturer during the use phase of the building to develop and end-of-life strategy for the building element together. **2.** During the use phase of the building, ensure that there is a digital data management strategy that assigns responsibilities for data ownership and maintenance long-term. **3.** Ensure retrofitted parts are modelled in detail to enable future reuse. **4.** Improve the detail of pre-deconstruction audits to be material passport quality. **5.** Do not overlook the carbon savings that smaller reuse opportunities (e.g. finishes or interior elements) offer. **6.** Re-evaluate any existing storage plan for future reuse scenarios.
	Design for optimisation	**1.** Hold a workshop with stakeholders to do future scenario modelling and explore how the building users' needs might change over time. **2.** Include a time factor in the design brief, which means that the design isn't just focused on the initial program, but considers multiple use scenarios for the building and its components, considering future occupants and owners. **3.** The building should be design for exchangeability. Apply a layered approach, where each building layer is independent from each other. Layers should depend on element type and lifespan.	**1.** Building the components should be independent and exchangeable. Independency means that the assembly, transformation and disassembly of components within a building layer can be carried out without affecting others. **2.** Develop an adaptability plan. **3.** Choose a regular approach to the building grid. **4.** Break down the proposal into layers, dividing the building into the different elements. **5.** Standardise dimensions across the layers and position circulations and access that do not inhibit future alterations. **6.** Clustering core elements such as load bearing, installation and communication, enables buildings to be designed with higher transformation capacity. **7.** Assess the future disassembly potential of the building. **8.** Develop a construction plan, focus on the physical reversibility of elements. Break down the building proposal into shearing layers and cluster components based on building functions. **9.** Cluster elements and components together based on their life cycle where possible. **10.** Interface design and physical connections. There are three distinct types of connections to consider: integral, accessory or filled. **11.** Prioritise open or overlapping geometries in the design, as these are the easiest to disassemble. **12.** Prioritise external joints where possible, as they provide an easier opportunity for dismantling. Hold workshops with all the relevant stakeholders to design all new joints. **13.** Consider assembly and disassembly sequences.	**1.** During construction run a checklist in order to ensure any on site changes retain the measures and flexibility noted in the adaptability plan. **2.** Data collection: Continue to enrich the data on your chosen platform. **3.** Ensure handover documentation contains along all other documentation the future scenario modelling, adaptability plan and assembly and disassembly sequences identified within the design process. **4.** Engage with the client, building maintenance team and the end users through a series of workshops in the handover stage.	**1.** Decisions made post-handover about modifying the asset should follow a circularity plan, which should be guided by the adaptability details outlined in the handover documentation. **2.** Any individuals and companies undertaking maintenance, replacement or additional works should be provided with material passports and assembly and disassembly sequences for assets where relevant. **3.** The building owner/manager should ensure that individuals and companies undertaking works are competent and skilled with regard to the asset. **4.** Where the user/occupier of the building is changed, identify if existing assets to be removed can be stored on site for future re-use on site. e.g. acoustic panels, kit and FF&E within offices.
	Minimise impact and waste	**1.** Hold an initial workshop with the client and relevant stakeholders to introduce key concepts of minimising waste and impact, such as the R-frameworks and material cascades. **2.** Explain the idea of material cascades, which considers the possibilities of extending a material's lifecycle by transforming it into different products. **3.** Minimise the total input of materials while ensuring the quality of the design. **4.** Prioritise natural, renewable and biodegradable materials wherever possible and engage with relevant stakeholders early. **5.** Consider local resources **6.** Set targets to specify high percentages of remanufactured and recycled products. **7.** Avoid mixing technical and biological materials together to preserve clean and non-toxic material cycles.	**1.** Develop the strategy of dematerialisation. Ensure that the design is optimised in terms of the structure. **2.** Specify wherever possible, natural, renewable and biodegradable products and products with high remanufactured and recycled content. **3.** Design with standarised and modular components and off-site manufactured products, as these reduce construction waste significantly. **4.** Avoid the use of glues and aim to use mechanical and accessible fixings where possible, while making sure fabric efficiency is not compromised. **5.** Avoid unnecessary finishes and keep surfaces exposed where possible. **6.** Develop strategy for future end-of-life. **7.** Document the building components through material passports and BIM **8.** Wherever possible, specify products from manufacturers with established take-back schemes. **9.** Consider products as a service approach. **10.** Develop waste management strategy during construction.	**1.** Consider multiple locations for information on building elements and systems to be retained, from material passports, material tags, O&M manual etc. **2.** Make sure a detailed waste management plan and a reuse mandate are part of the tender documents of the contractor. **3.** The waste management plan that is in place aspires towards 0 % waste and stringent targets for the lead contractor and sub-contractors are set. **4.** To ensure future reusability, make sure the components are physically tagged with product information during the construction process. **5.** The design team should closely collaborate with the construction team during this stage and ensure a continuous fl ow of information.	**1.** The handover process should ensure that the user receive all the necessary information to operate the building in a circular manner. **2.** The design team should stay engaged to carry out post-occupancy performance evaluation and aftercare reviews. **3.** At the end of the built asset's life, the deconstruction plan should be followed.

Next steps

The intent of this design guide was to provide practical guidance to design teams about actions that can be practiced at present and are within the control of design teams to move towards a circular built environment. We recognise that there are significant opportunities for improvement which are currently hindered by barriers outside the scope of the design team. Pushing the industry to overcome these obstacles by implementing standards, best practice and legislation will be crucial in the years to come if we want to realise a circular built environment.

The ACAN Circular Economy group is committed to supporting and campaigning to overcome the following barriers.

Continuity of ownership – the need for central databases

The long lifespan of buildings in itself often proves to be a barrier to circularity. It is hard to predict use changes in the building over long periods of time. The building might change owner who is not aware or willing to manage the information package that comes with the building or the manufacturer of the building's components doesn't operate anymore when the time comes to make an intervention.

Private companies taking on the role of recording building component data is a risk. This data should be stored in two places. First, the client owning the asset should hold responsibility to produce, maintain and store this information.

Second, the information should be stored in a centrally sourced database.

While documenting material data on long life span assets proves challenging due to current industry barriers, shorter life span assets are more easily manageable in current market conditions. Fit out and retrofit projects are good opportunities to trial out concepts that can then be applied elsewhere. However, the barrier in this case tends to be the fast-pace of the project. Deconstruction contractors see value in certain items, but often avoid a full evaluation due to time constraints. The industry must come up with a system to incentivise stakeholders involved in the deconstruction audit to minimise materials going to waste instead of being donated or sold.

Material passports

Material passports are effective to ensure there is a concrete strategy in place about the future reuse of materials. However, their preparation and maintenance is costly and time consuming. In the case of an existing building, to maximise efficiency, the deconstruction contractor's team should be allowed sufficient time to prepare the deconstruction audit to the standard and detail required for material passports. As more and more developers see the value of material passporting – as their building portfolio turns into a pool of materials – the design team should always advocate for time allowance throughout the project to prepare the passports to the highest possible standard. The responsibility of maintaining the material passports should be explicitly assigned to someone on the project team and stored centrally.

Reuse reports and circular statements

Reuse reports, deconstruction audits and circular economy statements are often prepared by external consultants, without explicit responsibility assigned to project stakeholders to action the findings and recommendations of these reports. As such, whether or not these will be implemented depend on the proactivity and time availability of project team members. While informal networks can be effective, the industry needs more formal and statutory systems, so that circular strategies become standard practice.

Storage facilities

Without affordable and accessible storage facilities to store materials until a future buyer is found, the material reuse system remains unfeasible in many cases. Whether it is local authorities providing land and warehouse facilities or groups of private companies and manufacturers building up these networks together remain a question for the industry, but they are crucial to enable material reuse networks to scale up.

Warranties

Similar to the lack of storage facilities, another industry-wide barrier to material reuse is the lack of standard testing procedures to ensure materials are safe and suitable for reuse.

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