ARUP

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The Reuse Playbook

Reference:

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Job number

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Contents

1. Introduction

1.1 This Edition

This first edition is made available so you can benefit from the research and use for your projects, but please provide feedback. You can add your feedback here.

1.2 From a linear economy to a circular economy

Take, make, waste. We do it, but it's wrong!

In our current economy, as an industry, we tear up mountains to recover raw materials, use huge quantities of energy to form these materials into useful products like steel beams and glass, to build a building. At the end of the building life, we tear it down and often lose those valuable materials. Would we find it easier to build a building from an existing building, or from a mountain? Our economy favours the mountain approach, and it is costing the earth!

In a circular economy, by contrast, we stop waste being produced in the first place. The circular economy is based on three principles, driven by design:

- Eliminate waste and pollution
- Circulate products and materials (at their highest value)
- Regenerate nature

A circular economy could reduce global carbon dioxide emissions from building materials by 38% in 2050. It could also make the sector more resilient to supply chain disruptions and price volatility of raw materials. A circular economy decouples economic activity from the consumption of finite resources. It is a resilient system that is good for business, people, and the environment.

The built environment significantly contributes to greenhouse gas emissions and uses almost 50% of the materials extracted every year. During the construction process, 15% of these materials are wasted. Resources are finite. If we don't learn how to normalise the reuse of materials, we will exhaust our supplies and the implications of this on humanity could be disastrous. We must look for ways to build better.

Current projections estimate that by 2060, the equivalent of the city of Paris will be built each week. Cement manufacturing alone is responsible for 8% of all carbon dioxide emissions. When a building is demolished, the majority of its materials end up in landfill or losing significant value through downcycling. We need to rethink our built environment to tackle climate change. Some solutions have looked at ways to upgrade our buildings so that they are energy efficient and powered by renewable energy. While crucial, these solutions need to be complemented by a revision of how we design, make, and use products and materials.

There are many ways to incorporate circular strategies into your project and a great place to start is with the Circular Buildings Toolkit. The Toolkit outlines four main circular economy strategies that directly address emissions from the built environment:

1. Build nothing - make better use of existing buildings through sharing, flexibility and refurbishment so fewer new buildings need to be erected.
2. Build for long term value – increase building utilisation and design for durability, adaptability and deconstructability
3. Build efficiently – Use fewer new materials through lean design, reducing waste and recycling and reusing existing materials and components.
4. Build with the right resources – select materials which are renewable, recyclable, non-hazardous and promote biodiversity.

The framework sets out metrics and actions for each strategy, each of which can have a huge impact on our built environment designs. Together, these circular economy strategies could reduce global carbon dioxide emissions from construction and demolition of buildings by 2.1 billion tonnes, by 2050, making them vital to tackling climate change.

1.3 Reusing materials

Across the built environment we continue to specify materials without consideration for the provenance of those materials. We must normalise and streamline the material reuse process for the built environment sector by creating a plan of work that outlines the key personas involved, the tasks and the deliverables required. The Reuse Playbook also signposts to the great work already done in this space.

To do this will take bold action, stepping out of our usual role, stepping into procurement, maybe even stepping over our scope lines. It will take collaboration across the project team, and a willingness to do things differently, for the good of future generations.

Strategy 8 of the Circular Buildings Toolkit is focussed on reducing the use of virgin materials. Action 8.1 seeks to maximise the use of reclaimed components for all building layers: when reusing components from existing, soon to be demolished, or already deconstructed structures, the need for manufacturing new components is reduced. The main structure and envelope account for more than 50% of total material use and therefore are areas of focus. But where are these materials, and how can we incorporate them into our projects. This document seeks to support this activity, and to build a better knowledge base for future projects.

1.4 The Reuse Playbook

The roles we play and the tasks we do in the linear economy need to be rewritten to be suitable for a circular process. We need to establish what needs doing and which personas are best placed to do it to avoid confusion, knowledge gaps and inefficiencies. Figure 2: Chapters of the Reuse Playbook highlights the current lack of cross-party collaboration and the absence of a pragmatic analysis that looks at what each stakeholder can gift the process of material reuse.

This is where the Reuse Playbook comes in.

The Reuse Playbook takes a step back from current practices and critically establishes the core tasks and interactions needed to effectively reuse materials and maps which stakeholders are best placed to complete each of these tasks, and how they might be incentivised to do this. To capture this, the Playbook has been created and informed by key stakeholders in the circular construction value chain – manufacturers, engineers, architects, quantity surveyors, contractors, stockholders, insurance companies, property developers and policy makers.

The Reuse Playbook is not designed to provide a complete guide to reuse in all contexts and for all materials. Instead, it focuses on the process of reuse and signposts readers towards valuable resources for more specific information.

Figure 1: Extract from 'From Principles to Practices: First Steps towards a Circular Built Environment' (Ellen MacArthur Foundation, 2022)

1.5 How to use The Reuse Playbook

The Reuse Playbook is arranged into nine chapters, each focusing on a key topic essential to reusing materials and components. A broad sequence of when we expect each topic to be approached in the process is shown in Figure 2. In reality, the reuse process may involve jumping from one to another, and iterative circles between different stages. The chapters are written so that readers can start at any point in the cycle, with links between chapters added where topics are relevant to more than one chapter.

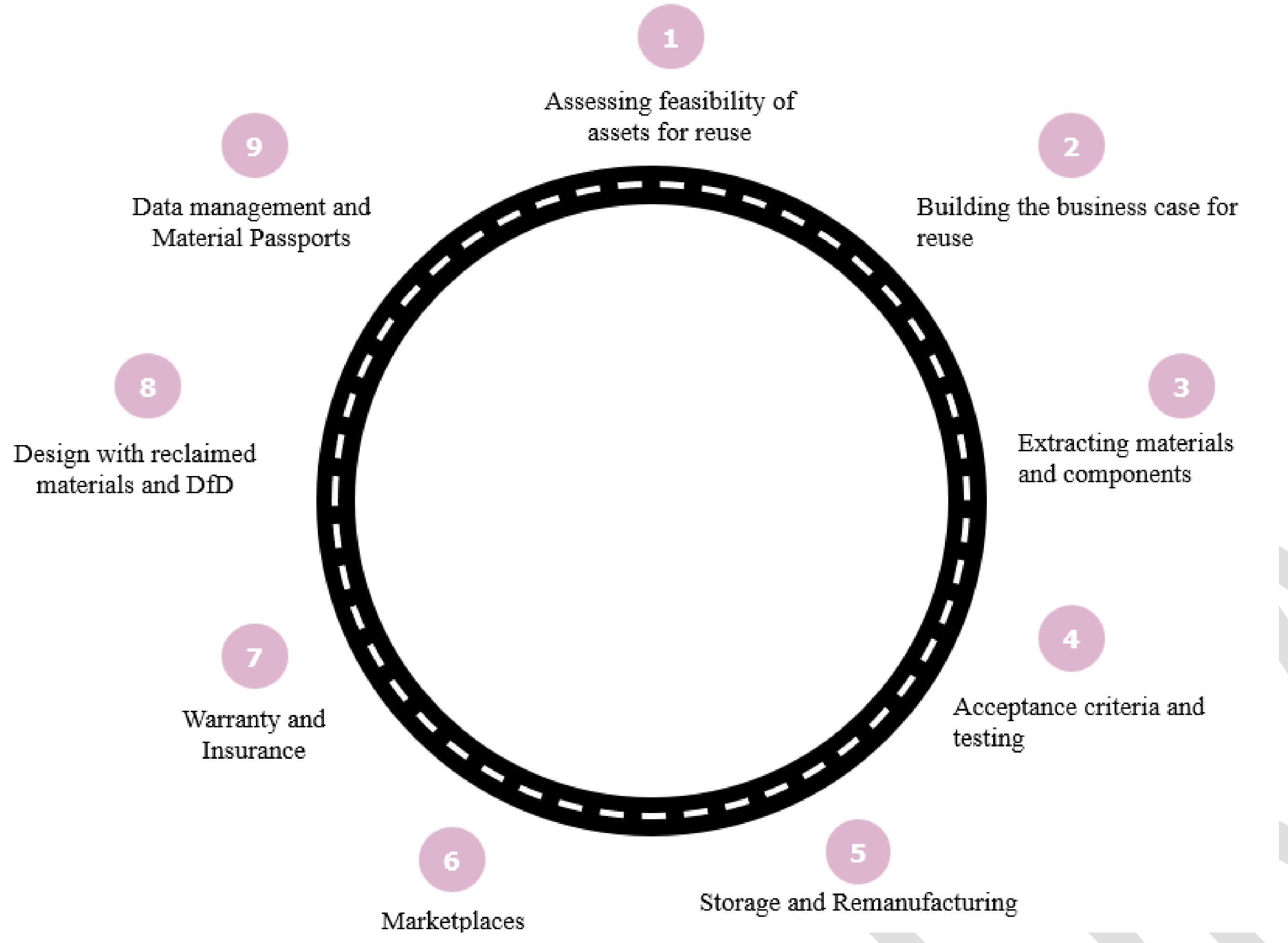
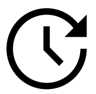


Figure 2: Chapters of the Reuse Playbook

When considering the timeline of impacts, it's important to distinguish between immediate and potential future impacts. Immediate impacts involve working with existing materials, while future impacts include practices like material passporting, which facilitate the circulation of materials into reusable future building stock. The playbook differentiates between actions which facilitate current reuse to those which enable future reuse using the following symbols:

 Action enables reuse today

 Action enables potential future reuse

1.6 Who is the Reuse Playbook for?

While material reuse will happen on a local level, many of the barriers to reuse require systems in place which will work equally as well in whichever location the material originates or is used. For example, how to tag a material for reuse, what information is required, how to database this so it can be imported into a BIM model, etc. For this reason, the Playbook is about the global barriers. You might see the system as follows:

- Global Level, solutions that work regardless of locality
- Regional / Country Level, solutions specific to a country or jurisdiction, policy governing options
- Local / Geography Level, solutions valid for a locality, origination and transport of the item for reuse

A key assumption we have made when writing this chapter is that the readers are operating in a context where circularity in construction is yet to be realised, and as such we address the challenges associated with working with assets that have not been designed with future uses in mind.

1.7 When to reuse?

This playbook is applicable from the point of where complete in-situ reuse or refurbishment has been thoroughly explored and deemed not to be feasible. This may be because the existing asset is not suited to the proposed use due to spatial shortcomings or degradation and the level of intervention required is costly and carbon intensive.

Prior to this point, it is important to complete not only a desk study but also on the ground research to understand the assets full context. This includes its context within the existing and proposed local area, the local community, how they currently engage with it, what would benefit them moving forwards and any cultural impacts of a change, existing heritage of the building itself and of the area it's in. It is also important to consider how a change in the assets use and size might affect local amenities, the existing transport systems and local infrastructure.

When completing the desk study; local policy, legislation and governmental targets must be examined, as these steer the creation of assets and what they are used for. The next level of considerations is the client's ESG, Social Value and Financial goals.

- Framework follows CE hierarchy (Figure 3): GLA guidance (best practise and region agnostic)
- Decreasing returns obtained outwards, from retention/retrofit to material recycling (Figure 4)
- Deconstruction/material reuse pathway specifically (follow key steps below)

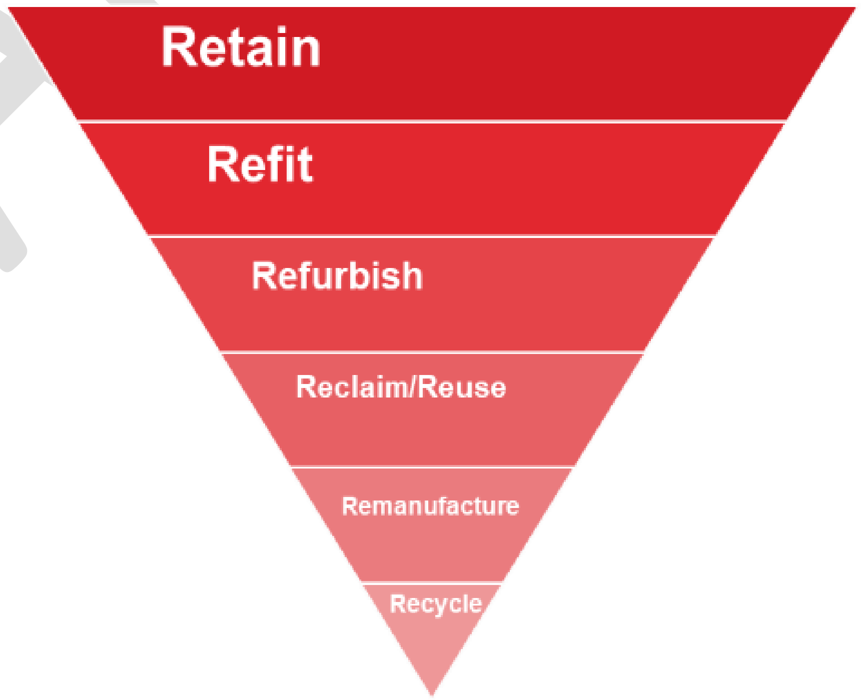


Figure 3 CE hierarchy for building approaches (Arup, adapted from London Plan Policy D3 Fig 3.2)

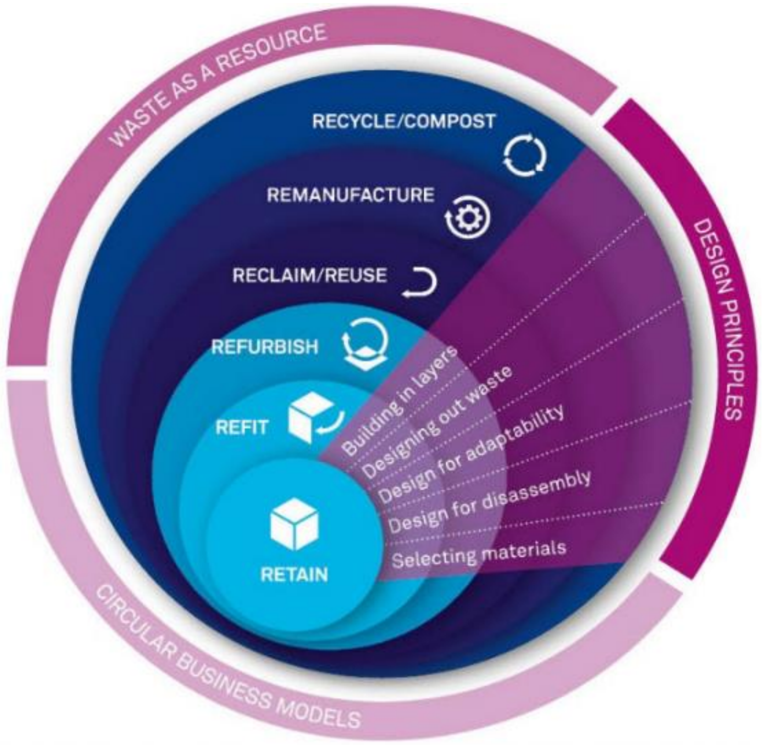


Figure 4 Circular economy hierarchy for building approaches (GLA, 2022)

1.8 Feedback Please!

This is a first draft. We encourage you to use it to take your own material reuse projects forward. Please test the document and see how it helps to normalise the process. We anticipate an update and would very much welcome your feedback, to help improve the playbook.

You can add your feedback here.

2. Assessing the feasibility of assets for reuse

In this chapter, we explore the steps to take once a project has been designated for deconstruction and reuse. What should happen next? How can you assess the contents of your existing building and identify the opportunities to harness the energy and carbon embedded in the existing materials and components on the site to create new assets?

This chapter structured into three main sections:

1. auditing and cataloguing assets to ascertain the quantity and quality of materials and components
2. identifying suitable reuse pathways for the identified materials
3. understanding how audit information can support the wider process of reuse

2.1 Auditing and cataloguing

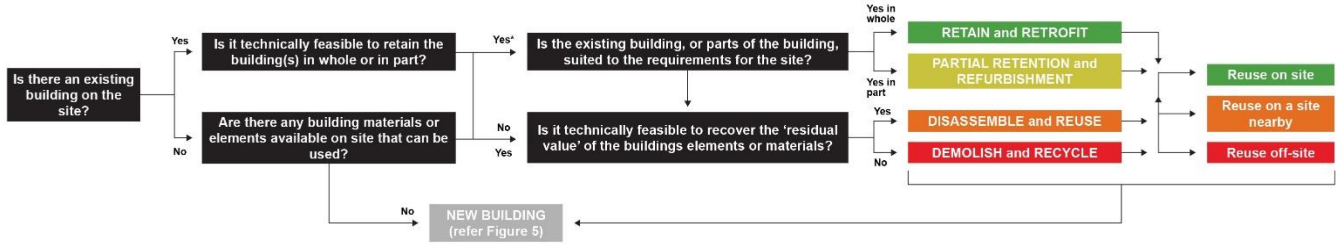
2.1.1 Pre-redevelopment Audits

The first audit that should be completed before different redevelopment options are considered, is a tool for understanding whether any existing buildings, structures and materials can be retained, refurbished or incorporated into the new development. It takes a strategic view of the existing building and development options and should be carried out early and inform the design. It explores the opportunities for reuse at feasibility stage and compares them with the benefits of building new. It is in essence an existing building condition survey and optioneering study.

The optioneering follows a hierarchy of; refit/refurbish/substantial refurbishment and extension/reclaim and reuse.

This initial audit contains a range of social, environmental and economic aspects of each option for site redevelopment. Site survey results, including a summary of the existing assets; ages, key materials, photos and site plans.

The audit occurs alongside an early-stage design optioneering exercise and whole life carbon assessment: the aim of which is to understand the impacts of different design options, that vary in scale of redevelopment, with the WLCA showing options' carbon footprint (Figure 3 shows decision tree to inform optimal reuse approach): Carbon Benchmarking (LETI/Ramboll Danish report/NBZCD)



2.1.2 Existing asset audits

Once a pathway for the asset has been determined, it is essential to conduct an audit of the existing asset to create an inventory of materials and components in an existing building. This audit can be used to ascertain what elements/materials are available for reuse and if it is feasible to recover materials for reuse purposes. The main factors that need to be included in an audit that influence high-quality reutilisation are existing use, technical characteristics, condition, exposure to pollutants and the possibility of non-destructive dismantling. The party who undertakes the existing building audit can differ per project, this can be the demolition contractor, a dedicated circular economy service, a structural engineering firm or a sustainability consulting service.

In the UK this is known as a pre-demolition audit and it can be a condition to receive planning permission in some boroughs and counties. Historically, the primary aim of these audits was to identify the volume of materials to be demolished, categorise them into waste groups and establish waste processing routes to fulfil waste reporting requirements.

Similar audits are now mandatory in some European countries buildings over 1000m2 in floor area (Titre principal de la présentation Anti-waste and circular economy (AGEC) law – France (2020) - effective July 2023). In other countries, sustainability certifications require audits of existing buildings as part of their criteria.

DIN SPEC 91484 was created in Germany in 2023 to describe a procedure to record building materials, as a base to evaluate the potential for high-quality reutilisation prior to demolition and refurbishment. It is split into two auditing stages, an initial audit and a detailed audit and it standardises the types of data that are collected for each material or component within each stage.

Before undertaking an existing building audit, the design/project team needs to systematically gather all existing building records in an orderly way, explaining the current understanding of the existing building elements to the auditing team. Table 1 lists examples of the documents to gather and surveys to undertake to develop an understanding of the key building information. Technology such as 3D cameras, Matterport scans and Open Space, can be utilised to more efficiently undertake surveys. Once the audit has been completed, a relevant member of the design team should review the audit to check the quantities reported and ensure that it is reasonable.

Currently, information collected as part of the audit is communicated in either PDFs, excel based systems or on digital platforms. The client owns the data in this audit, which shows what is in their existing buildings. Unfortunately, existing building audits often don't include the level of detail needed to facilitate the future reuse of items. The DIN SPECs two-pass approach reduces the amount of data that needs to be collected by the initial audit, with further information being collected about the items that are deemed to be reusable.

Once the audit has been completed, further specialist surveys such as intrusive structural surveys and façade surveys should be appointed to assess the feasibility of technical reuse strategies.

Table 1: Idealised Information to collect in an existing building audit, based on DIN SPEC 91484

Data Type	Source
Location within the asset	Archive drawings or on-site survey
Ease of dismantlability	Connection type information, archive information, on-site survey through visual inspection, accessibility.
Geometry of item (dimensions & weight)	Archive drawings / on-site measurement
Current use of item	Archive drawings / on-site visual assessment
Age of item	Archive information / O&M manuals
Existing documentation	Archive information / O&M manuals
Floor to ceiling heights	Archive Drawings or On-site survey
Item Location	On-site survey
Images	On-site survey
Condition	On-site survey
Pollutants	Visual Inspection / More invasive tests if suspected
Financial Value (both as-is and refurbished)	Cost database for reclaimed items needs to be produced and be universally available.
Carbon Value	Appropriate carbon databases alongside geometry information
Material Identification and Quantification	Visual on-site survey / Archive Information / European Waste Codes / UniClass Codes / BCIS
Detailed Technical Survey Components (Structural intrusive investigations, MEP existing survey, façade existing survey)	
Potential for high-value reuse (as defined above)	Technical, logistical and market understanding
Targets for reuse/recycling (%)	
Local reclamation and remanufacturing centre network	Knowledge of the local market and services

2.2 Next Life Options

There are different opportunities for items that are being removed from an existing site, summarised in Figure 5. Reuse within the client portfolio is generally preferred as it gives the client a project carbon benefit within current carbon reporting system boundaries. While reuse off-site doesn't reduce carbon for the donor client, it does give the client storytelling opportunities and social value stories. To determine the appropriate next life for a material component, each option should be compared with consideration of the factors in Figure 6.

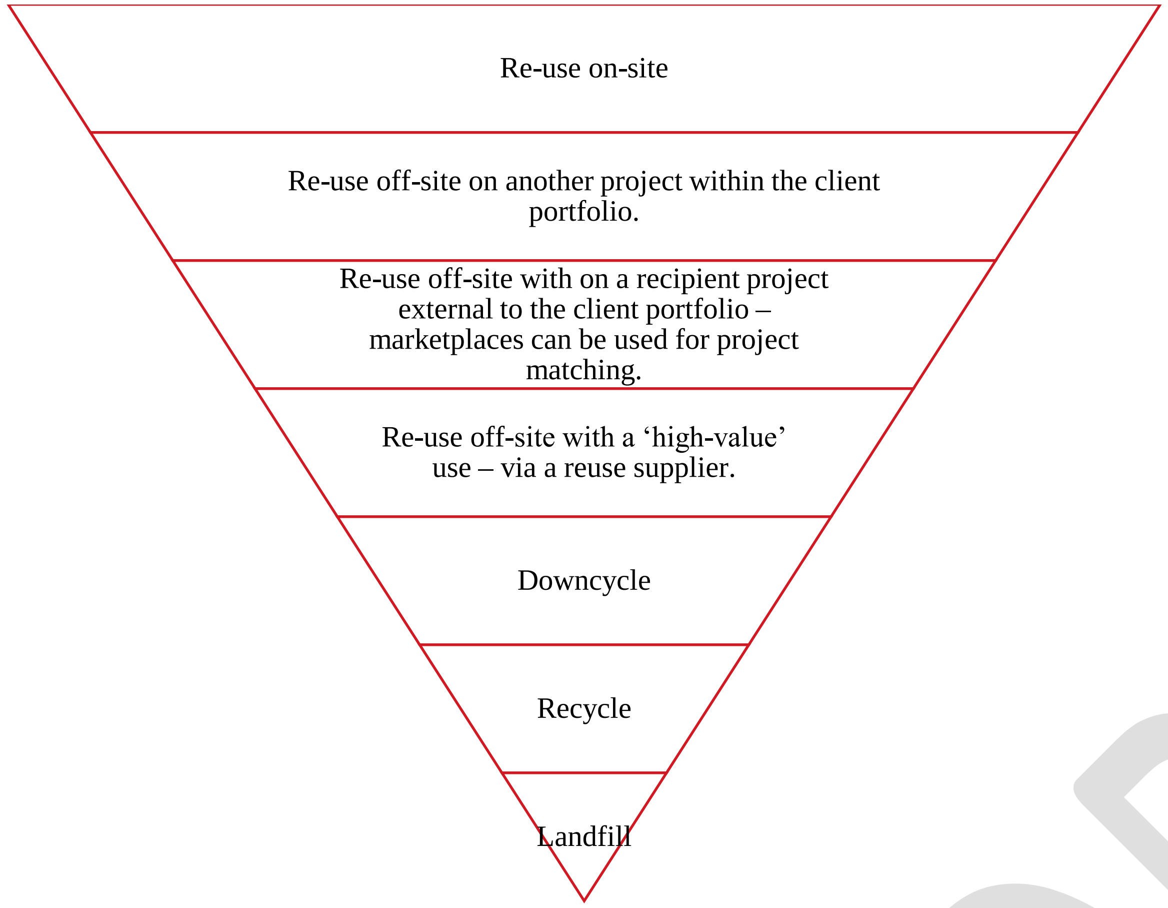


Figure 5: Next life options for reclaimed materials

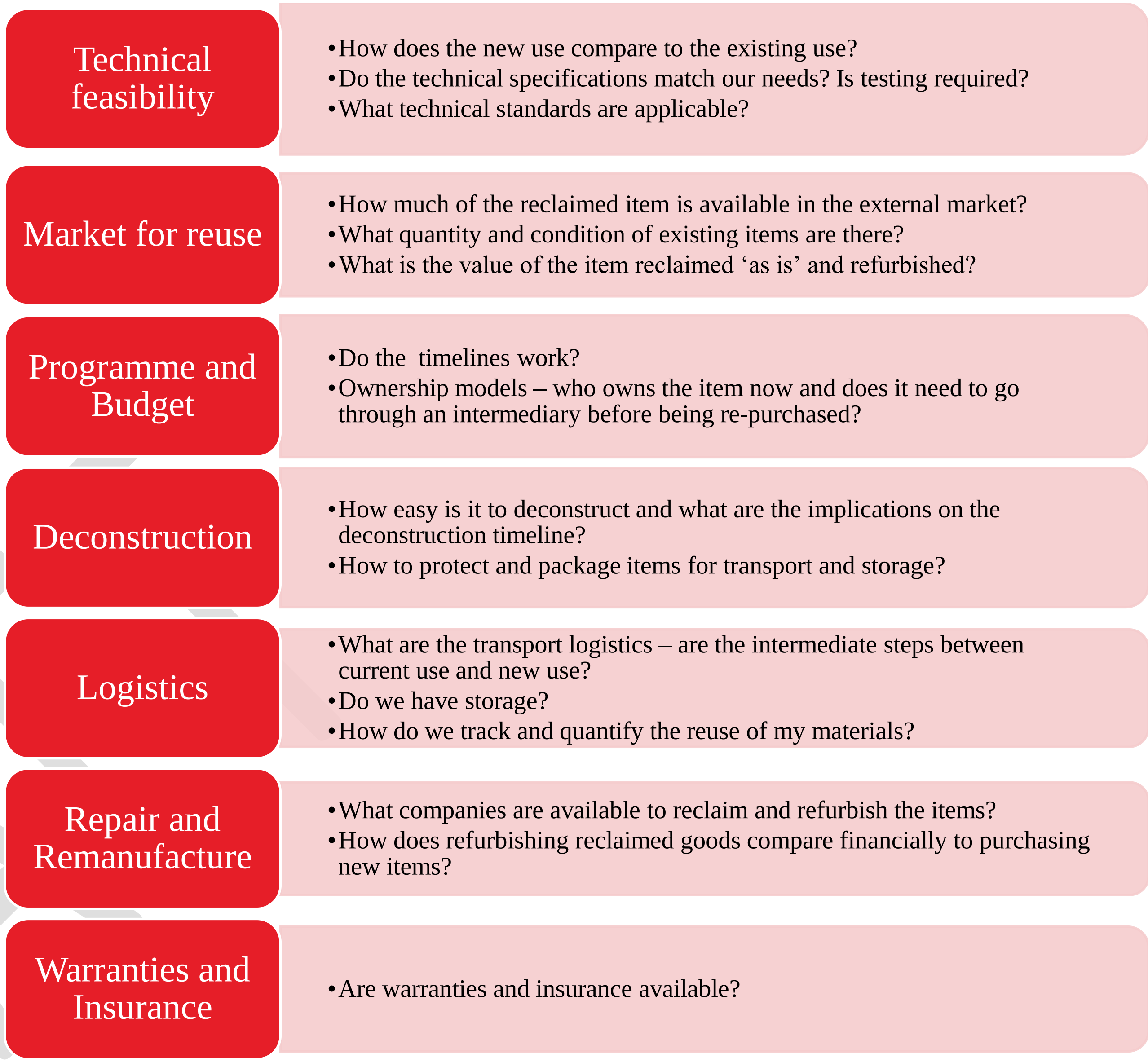


Figure 6: Considerations for determining next life pathway

Discussion point: Building Services Reuse

Building services reuse has typically been allocated to the 'too difficult' box given the often-short lifetimes of equipment and the potential trade-off with operational efficiency. However, components such as ductwork, piping, cable trays, fans, chillers and lighting offer good potential for reuse.

Figure 7 provides a workflow to start conversations around opportunities for building services reuse.

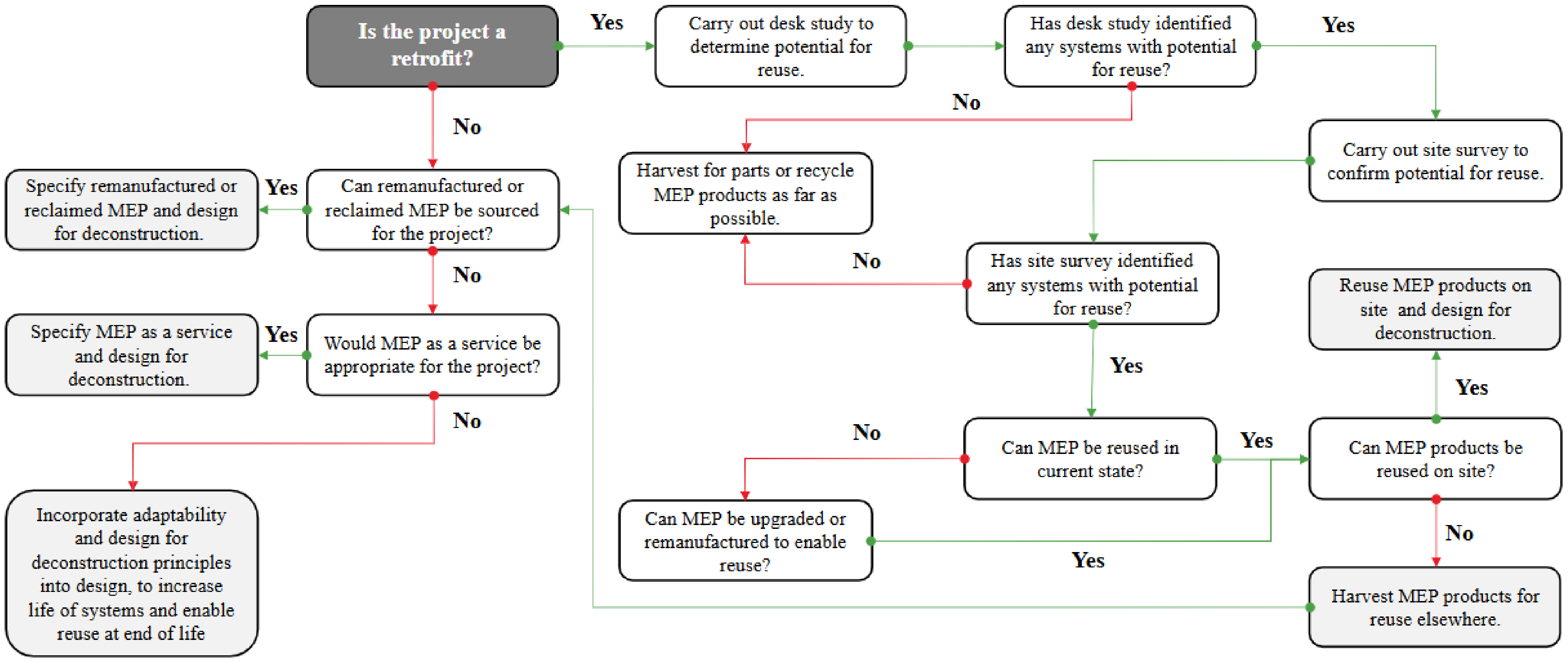


Figure 7: Workflow to determine opportunities for MEP Reuse

2.3 Contributors

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2.4 Action Plan

Key Action	DesignStage taking place	Required skills and knowledge to complete action	Responsible persona	Output	Receiving persona(s)
Desk Study – Holistic understanding of the existing asset and its surroundings, the client's sustainability aspirations and certification targets, policy. Create a project specific timeline for the circular economy process.	Predesign	Community engagement, historical context of area and asset, client goals, policy requirements.	Design Team and Client representative	Desk study report	Client
Undertake **an early-stage condition audit** of the asset (decision tree) to inform the extent of refurbishment.	Conceptual Design	Knowledge of building audits and how condition affects design options, and WLCAs.	Design team & Sustainability Consultant (WLC/CE).	Costed options for the optioneering study. Both carbon and capital.	DT and WLC consultant doing the optioneering.
Existing asset audit to know the condition/quantity of materials, structure and contents on site for reuse. Treat the building as a material bank.	Conceptual Design	Knowledge of building auditing.	Specialist pre-demolition audit contractor. or Structural Engineer, Sustainability consultant, Demolition contractor.	Pre-demolition or pre-refurbishment audit.	Sustainability consultant, design team. Material manufacturer/stockists.
Extract useful audit information and translate it into material reuse/CE design opportunities, ensuring the tracker/format used optimises future information usefulness.	Conceptual Design	CE design and material reuse opportunity knowledge. (Arup CBT + CE strategies).	Sustainability (CE) Consultant & Design team.	Circular Economy Strategy Tracker.	Client, Design team.
Deconstruction (demolition) contractor or sustainability consultant to **contact remanufacturer** for on-site and off-site reuse of the project's components and materials. **Item specific assessment** to take place.	Schematic Design	Knowledge of services landscape.	Demolition contractor, Sustainability Consultant.	CE Tracker Update – Assigned.	Client, Sustainability Consultant.
If no on-site reuse, examine **cross-portfolio sharing** options (reusing within client's portfolio). Currently this is more rewarded by policy than off-site reuse, due to carbon accounting gap.	Schematic Design	Knowledge of current client portfolio, inc. potentially relevant projects.	Client representative.	CE Tracker Update.	Client, Sustainability Consultant.
Find **donor projects** for off-site reuse. Some clients prefer these to be of community value to create social value stories. For heavier materials, may be easier to match with other corporate projects.	Schematic Design	Knowledge of current projects which could be interested in this salvaged material.	Demolition Contractor, Sustainability Consultant. Material Broker.	CE Tracker Update.	Client, Sustainability Consultant.
Explore **manufacturers with take-back schemes** for items that can't be reused on-site, across the portfolio or donated off-site. Take-back schemes vary and can involve the manufacturer recycling the existing product or remanufacturing and re-selling it.	Schematic Design	Knowledge of take-back scheme process and potential companies to contact.	Sustainability Consultant.	CE Tracker Update.	Client, Sustainability Consultant.
On-board a **marketplace** and agree cataloguing/upload process (and project social value goals). Upload items with sufficient uptake window and then a collection window prior to site strip-out.	Schematic Design	Knowledge of marketplace industry and process of listing materials.	Sustainability Consultant.	CE Tracker Update.	Client, Sustainability Consultant.

3. Building the business case for reuse

- To be completed in Phase 2

4. Extracting materials and components

4.1 Introduction

At this stage, we extract materials, components and whole structures from the donor building, allowing them to be reused in other developments. While the goal of this stage is straightforward, a key challenge is balancing ease of deconstruction with maximizing material recovery. The time and cost of deconstruction often exceeds the value of the salvaged materials, making it essential to set expectations early in the project.

This trade-off should be clearly defined in the tender process, ensuring that program and budget considerations account for material recovery efforts. In practice, achieving 100% recovery is unrealistic—for instance, sections of steel may need to be cut off, or inner glass panes may break during removal. A realistic yield value should be targeted based on the material, available storage and market. For example, in office buildings, about 60% of modular partitions and ceilings can be reused without reconditioning, while the remaining 40% are typically damaged by holes for electrical wiring or lamps meaning that they have limited opportunities for reuse.

Deciding whether to deconstruct entire assemblies/components or their constituent elements depends on the reuse potential. Reusing or re-warranting whole assemblies minimizes contamination and reduces processing effort. Alternatively, off-site mixed-material facilities can help separate materials efficiently.

Understanding the logistics of dismantling, handling, and storage is essential to maintaining quality and minimizing costs. By integrating these considerations above into a well-planned extraction strategy not only supports circular economy principles, but also ensures compliance with health, safety, and environmental regulations, ultimately enabling more efficient and responsible reuse in construction projects.

4.2 Barriers

- **Safety Risks & Hazardous Materials:** Identifying risks like asbestos, lead paint, or unknown materials is crucial before deconstruction. Material testing and mitigation strategies are needed to ensure worker safety and compliance with current regulations for reuse components and materials.
- The distinction and classification between reusable components and materials and waste can inhibit certain players from handling materials due to policy and regulations e.g. waste handling licences.
- **Challenges in Disassembly:** Existing buildings were not designed for reuse, making extraction complex. For example, composite materials with the use of adhesives, and large embedded MEP components require specialized removal techniques.
- **Labour & Cost Constraints:** Deconstruction is more time-consuming and costly than demolition in part due to the bespoke nature of each project and non-standardised processes. Cleaning, sorting, and testing add further expenses.
- **Handling & Damage Risks:** Poor handling by third parties can reduce material reuse potential. Project specifications should include a dismantling plan that aligns with the acceptance criteria with clear guidelines for careful material management.

4.3 Enablers

- **Strategic Planning & Early Engagement:** As discussed in chapter 2, an Existing Building Audit will help to identify materials, their second-use applications and can help to assess demand, quantities, and logistics during the demolition tender. Involve contractors to conduct deconstruction trials to identify challenges early so they can establish safe and efficient extraction methods.
- **Logistical Coordination:** Defining ownership, financial responsibilities, and transportation logistics prior to deconstruction allows for the smooth transition from the donor building and recipient building.
- **Collaboration Across the Value Chain:** Leverage expertise from specialist contractors, manufacturers, and demolition teams. Utilising existing information from previous stages like pre-demolition audits and testing during the deconstruction process will help plan for deconstruction costs, time, material storage and passporting.
- **Provide training and workshops** to align with reuse acceptance criteria and ensure careful handling to maximise material recovery rates. It also provides opportunities for trials and any non-standardised training and PPE for safe disassembly.
- **Incentives:** Use financial incentives to promote responsible material recovery. By ensuring value retention of the deconstructed materials (e.g., through a Futures Trading model), will encourage deconstruction with care.
- **Methodologies and tooling:** For components and materials that are currently not designed for disassembly, more efficient methodologies need to be developed which may include design and implementation of specialised tooling. These may be developed by a single player but often will involve the subject matter experts, demolition contractors and machinery companies.

<u>Discussion Point: Brick Reuse</u>

There is a mature industry for reclamation of used bricks. While reuse is technically feasible, by either reusing from the existing building, site to site reuse, or from the market, this practice does not come without its challenges. The value of bricks is currently dependent on the visual desirability of the bricks themselves, as the process of chipping mortar off individual bricks is a lengthy, laborious, and difficult task done by hand.

The industry recovery rate is typically 5 – 20% without any specialist approach. This is dependent on the mortar used, brick construction and brick type and condition. However, when bricks reuse is desirable and feasible, using specialist brick and stone contractors can increase the yield significantly to upwards of 60%.

Technology companies such as Brique Recyc, who have developed a machine to cleaning the bricks can also decrease the amount of time needed to individually clean the brick by up to 5x. This makes the process more efficient and could also prevent reuse yield losses from additional transport and handling during typical approaches.

Find out more: https://briquerecyc.com/en

4.4 Assessing ease and value of extraction

To determine the feasibility and viability of material extraction we recommend taking a systematic approach, using a grading or traffic light system against the considerations defined in **Table 1**. This should be completed by or with the demolition contractor.

Additionally, sites are often constrained by the physical space and timings. Therefore, the importance of knowing the next link in the value chain, whether that is a marketplace, short- or long- term storage with a known or unknown owner is essential. Having an agreed approach on the deconstruction method, storage conditions and the chain of ownership will ultimately allow for the movement of reuseable components and materials. This approach requires early engagement from the building owner, subject matter experts like material specialists and manufacturers to contractors and second owners and stockists.

Table 1: Considerations for component extraction

Item	Description	Examples of Easy/higher yield	Examples of Difficult/ lower yield
Connections	The ease/yield of separating components may depend on the type of connections used	e.g. Modular partition systems	e.g. Welded structural frames
Access to component	The location and integration of a component within the structure affect how easily it can be removed.	e.g. Exposed ceiling beams	e.g. deeply embedded foundation elements
Robustness	More durable materials are able to withstand the forces applied during the extraction process	e.g. Solid timber beams	e.g. plasterboard, thin aluminium cladding
Logistics: Protection	Components must be safeguarded from damage during extraction and transport.	E.g. Prefabricated façade panels with edge protection	e.g. Glass panes (without frames)
Logistics: Ground access	Site constraints can impact the ease of removal and transportation of components.	e.g. Open-access sites	e.g. confined urban areas with limited movement
Logistics: Storage	Available space for temporary storage affects reuse feasibility.	e.g. Large on-site storage space	e.g. no storage availability requiring immediate offsite transport
Logistics: Crane lifts/ lifting	Heavy or high-positioned components require specialized lifting equipment.	e.g. Small prefabricated panels	e.g. large concrete slabs requiring heavy cranes
Logistics: Collection	The ability to gather and transport components efficiently impacts reuse viability.	e.g. Modular units loaded onto trucks e.g. roll on- off skips	e.g. Fragmented masonry requiring multiple handling steps - pallets
Condition	Surface / high level condition the same as condition seen across the site The physical state of materials determines whether they can be reused without significant refurbishment.	e.g. Well-maintained steel beams	e.g. water-damaged drywall
Regulation compliance	Components must meet current building codes and safety standards to be reused. I.e. Material composition (REACH, Asbestos)	e.g. Certified fire-rated doors	e.g. outdated electrical wiring E.g.2 Operational carbon
Cost uplift	The financial investment required to extract and prepare components for reuse varies.	e.g. Simple disassembly of prefabricated elements	e.g. costly deconstruction of reinforced structures
Labour	Skilled labour is necessary for careful dismantling, affecting feasibility.	e.g. Saw steel structures	e.g. Bricks
Landfill cost vs Rebate	Savings from diverting waste from landfills versus the potential revenue from reused materials can influence decisions.	e.g. Reclaimed bricks with resale value e.g. metals	e.g. mixed demolition waste with high disposal costs e.g. glass, low landfill cost (UK)
Market demand	The availability of buyers or users for reclaimed materials affects their reuse potential.	e.g. High demand for reclaimed timber flooring	e.g. limited market for outdated HVAC components

4.5 Signposts

Reference	Short description
The Institute of Demolition Engineers and National Federation of Demolition Contractors	UK industry bodies for demolition contractors and practitioners https://demolition-nfdc.com/wp-content/uploads/2022/07/DRG116_Demolition_and_Refurbishment_Resource_Protocol_2019-1.pdf
Alliance for Sustainable Building Products: DISRUPT I and II.	Industry wide collaboration research for the reuse of steel. Includes guidance on the reuse of steel, including the acceptance criteria, equipment and logistical considerations. https://asbp.org.uk/toolkit/disrupt-2-steel-reuse-project-toolkit
Reuse Engineers Collective	A not-for-profit group of practising engineers championing, accelerating and delivering reuse in the built environment to support the transition of the UK's built environment to Net Zero Carbon.
European Demolition Association – Circular Economy Working Group	A platform for national demolition associations and demolition related contractors and suppliers. https://www.europeandemolition.org/information/construction-and-circular-economy
Environmental Protection Agency (US): Best Practices for Reducing, Reusing, and Recycling Construction and Demolition Materials	https://www.epa.gov/smm/best-practices-reducing-reusing-and-recycling-construction-and-demolition-materials Includes guidance on the design and disassembly for reuse
Opalis	The Opalis website provides a wealth of detailed information on how to extract timber, steel, bricks, insulation, facades and other building elements: https://opalis.eu/en/materials
Institute of Structural Engineers: 2012 Olympic stadium case study	Refer to this video (from 32:00) for a discussion of how the roof of the London 2012 Olympic stadium was deconstructed.

4.6 Case Study 1: 2 Aldermanbury Square

Year of Construction: 2025

Location: London

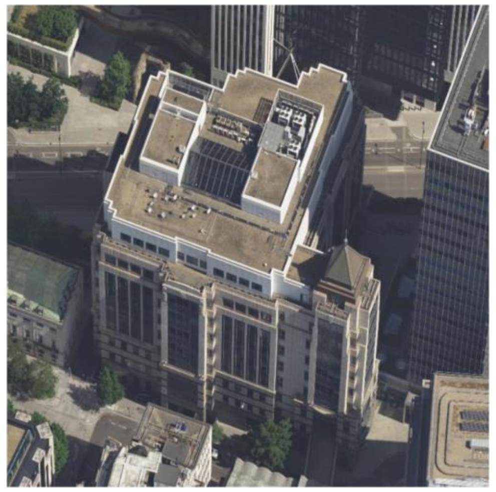


Figure 8: Donor building - City Place House

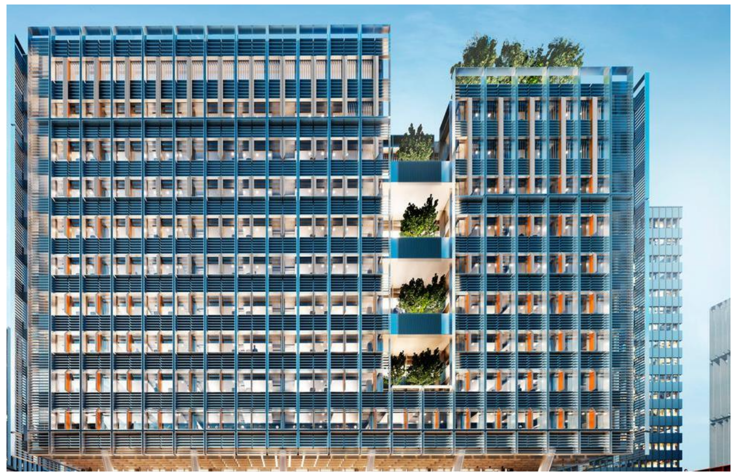


Figure 9: Recipient building on same site - 2 Aldermanbury Square

To reduce the structural carbon intensity of a new office scheme, steel beams were deconstructed and reused from the existing building on the site – City Place House (Figure 8), a steel framed, concrete composite building constructed in 1990. The structural engineering team (Arup) started the process by auditing the steelwork to understand if it aligned with archive the drawings and identify areas of corrosion and other damage. Each steelwork member was given a unique identifier and its properties catalogued (Figure 10). This ID followed the beam right the way through the process.

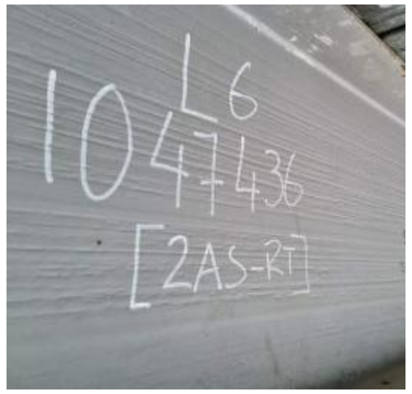


Figure 10: Steelwork IDs

Due to locked-in stresses in the structure, it wasn't possible to simply unbolt the connections. Instead, the deconstruction involved cutting beams and columns as close to their nodes as possible (Figure 11), which was a laborious process. Members are transported to, EMR (European Metals Recycling)) in Erith for documenting and testing. At this point the steel wase-fabricated, cut to length, blasted and sent to the steelwork fabricator.

Figure 11: Steelwork extraction

Several challenges were experienced by the project team in this process, and consequently most steelwork was reused on another site, where the programme aligned more favourably with the deconstruction process. Challenges included:

- Strip-out coincided with detailed design – this made it difficult to know whether the as-built sections sizes matched the archive drawings
- There were many unknowns in the properties of the steelwork as the design team didn't know close to the node the contractor would be able to cut, whether individual beams have service penetrations, fittings and stiffeners and what damage members might see as the composite slab is ripped off, the beams are being prised apart from the frame and loaded onto the truck.
- The programme did not allow for these unknowns to be resolved, the material to be tested, defabricated and cleaned. Only when this point is reached is it possible to design with confidence using the existing steelwork.
- Smaller sections less than 50kg/m were more susceptible to damage

However this was a valuable learning experience, and key lessons learnt including the following:

- Composite slab came away fairly easily – this should not be a barrier to deconstruction and reuse, particularly for larger, more robust elements
- Same site reuse is challenging – easier to work with a different site on an aligned programme, or better yet, a stockholder
- Crane time is a key barrier – for efficient reuse a second tower crane can help to decouple the deconstruction from other works happening on site.

4.7 Case Study 2: Sound circularity Reuse – Saint-Gobain Ecophon

Saint-Gobain Ecophon has been offering a Reuse take-back service in Sweden since June 2024. This service includes guidelines for dismantling ceiling tiles and a first on-site sorting by customers, an inventory with product and quantity identification, as well as the provision of reusable boxes and bags for both reuse and recycling. It also covers the collection of these boxes and bags, along with payment and an EPD based climate savings certificate. Once received at Ecophon, the tiles are inspected to ensure they meet acceptance criteria before being made available for resale the reminder being recycled.

The take-back process involves building owners, contractors and demolition companies, as well as Ecophon's Innovation, Marketing, internal Operations and Sales teams. The key success factors to initiate and enable the service have been a long term commitment and clear ownership by the Innovation team together with a cross functional way of working to get ambassadors and stakeholders involved early in the process. The key driver of this initiative is customer demand for reused products, while the main challenge lies in establishing large-scale connections with deconstruction companies and building owners to integrate this new practice.

Various take-back services and business models for the reuse of partitions and ceilings in office buildings are currently being tested by SG Clipper Cormaine and Eurocoustic in Paris, in addition to environmental and cost assessment, as part of the European project DRASTIC (www.drasticproject.eu). In France, with the implementation of Extended Producer Responsibility (EPR) in May 2023, the ecosystem has evolved. Ongoing collaborations with deconstruction companies and eco-organizations aim to address these changes.

The main challenges to scaling up include time, costs, and the specialized skills required for selective deconstruction, as well as effective information sharing between manufacturers, building owners, and contractors to facilitate material extraction and planning. Additionally, ensuring economic balance and insurability remains a key challenge for the long-term viability of these initiatives.

Find out more about Ecophon here.

4.8 Contributors

Florence Wu, Materials Engineer, Arup

Marie Lamblet, Deputy Innovation on Circularity, Saint Gobain

4.9 Action Plan

Key Action	Required skills and knowledge to complete this action	Responsible persona (collaborators in brackets)	Output	Receiving persona(s)
Agree acceptance criteria	Elemental level data, yield targets, acceptable contamination/damage level	If reuse project is established: Engineer/Architect that will design with the material If marketplace/other third party will receive the item: Material Specialist or specifications set by third party	Images/illustrations showing acceptable and unacceptable damage.	Deconstruction contractor
Define method statement for extraction and realistic yields	High level approach to achieve reuse aspirations. Opportunity to pushback on acceptance criteria.	Principal contractor	Completed as part of the tender documentation	Developer / sustainability consultant
Confirm stakeholder to take material	Awareness of upcoming projects or marketplaces Understanding of logistics and programme requirements Understanding of legal and commercial implications of change in ownership	Principal contractor / material broker	Written agreement with receiving stakeholder	Developer / Principal Contractor
Deconstruction investigations e.g. understand access points and attachment points	As-built drawings Understanding of loading bays and access prior to soft strip	Principal contractor (FM team)	Will form part of Deconstruction Methodology document	Developer / sustainability consultant
Full deconstruction methodology with cost, carbon, benefit analysis	Material/ component specific criteria (Liaise with Material specialist including manufacturers)	Principal contractor	Deconstruction Methodology document	Developer / sustainability consultant
Removal or cleaning of materials/ components not covered in principal contractor scope.	Methodologies to deconstruct and storage criteria	Developer/ tenants	Increased quantity of material meeting acceptance criteria	Principal contractor / receiving stakeholder
Update pre-demolition audit and confirm acceptance criteria and condition	Types of materials and conditions	Principal contractor	Pre-demolition audit	Stakeholder receiving material/ component
Principal contractor to provide full tender to include labour, programme and sequencing and cost uplift	Logistics, methodologies and programme Calculated realistic yields and costs	Principal contractor	Decision to proceed	Developer / sustainability consultant
Enabling works, soft strip / hard demolition	Break out components for access Label components/ materials for reuse Protect elements / careful dismantle of materials/ component	Principal contractor	Site prepared for deconstruction	Principal Contractor
Store components for collection	Storage conditions (Material specialist including manufacturers)	Principal contractor	Components segregated from recycling/ waste materials and moved to ground floor for easy collection	Transport contractor / stakeholder receiving material/ component
Organise collection	Minimum quantities and containers for easy transfer (Liaise with Stakeholder receiving material/ component)	Principal contractor	Components collected from site (stakeholder agreed in previous step)	Transport contractor / stakeholder receiving material/ component

5. Acceptance criteria and testing

5.1 Introduction

Each project will have its own set of acceptance criteria that needs to be well-defined to facilitate reliable material repurposing, these can be set from standards and specifications in addition to, project specific criteria. For the donor building, the acceptance criteria focuses on the feasibility of extracting quality materials, while the receiving building's criteria ensure suitability for reuse in its new application.

Key to this topic is understanding which tests are necessary by balancing technical feasibility, risk reduction, and cost-effectiveness. The tests will help to assess whether reused components meet structural, durability, and performance standards, thereby reducing the risk of failure, increasing confidence and ensuring compliance with regulations.

5.2 Barriers

Several key obstacles can hinder the development and implementation of acceptance criteria for reused materials in construction projects. These challenges must be addressed to ensure the feasibility, safety, and reliability of reclaimed materials.

- **Lack of Identified End-Users:** Without understanding the future application, materials may not undergo appropriate testing. Risk of reclaimed materials not being used efficiently, leading to waste.
- **Risk Tolerance & Perceived Safety Concerns:** Varying risk tolerance among stakeholders can deter acceptance, especially for structural applications, which can lead to inefficient application of reuse. Without understanding the possible applications, a risk assessment and appropriate testing criteria cannot be realised, leading to many unknowns.
- **Limited Data & Material History:** Lack of records on prior use, modifications, and conditions makes assessment difficult, increasing the risk for reuse. To decrease the risk, testing can be used to mitigate some of these however, the cost of this is often placed on the asset owner which can reduce appetite.
- **Absence of Standardized Testing Methods:** Materials that do not have universally accepted testing criteria lead to inconsistent evaluations, increasing the risk to the end user.
- **Challenges in Offering Warranties:** Balancing the risk and performance is difficult without full history and testing leads to liability concerns from manufacturers and contractors which hinders the ability for warranties to be provided.
- **Logistical & Cost Barriers:** Dismantling, repair, and testing add costs compared to using new materials and demolition processes that have economies of scale. Currently the need for bespoke removal techniques and testing for certain materials and projects (i.e. steel vs modular components like carpet tiles) will increase cost.

5.3 Enablers

Achieving efficient material reuse requires clear acceptance criteria and standardised testing methods to ensure materials meet safety, performance, and quality standards. This involves comprehensive data collection, expert evaluation, and policy support to establish reliable assessment frameworks for reclaimed materials.

- **Access to Comprehensive Material Data:** Detailed information on material properties, historical use, and performance is essential for assessing reuse potential. Collaborating with material specialists including manufacturers to help specify the appropriate level of testing and risk assessments.
- **Technical Expertise & Testing:** Collaborating with both material specialists and demolition contractors to provide insights on potential applications, the testing required for those and the safe disassembly and storage to achieve the highest yield accounting for commercial and logistical considerations.
    - Standardized testing ensures compliance with safety and quality standards, reducing the need for bespoke testing and therefore the risk which may allow for warranties on reused materials.
- **Driving Demand & Market Development:** Increased industry demand fosters innovation and strengthens supply chains for reclaimed materials. Designing and optimising testing procedures, in particular non-destructive methods, both on-site and off-site, need to be studied and developed further to allow testing at scale.
- **Pilot Projects & Demonstration:** Feasibility trials showcase performance and build confidence in reused materials, which will help to establish clear guidelines for warranties and liability. This will influence the perception of what is acceptable (visually and technically), providing flexibility in design and balancing the risk level.
- **Incorporating Reuse into Project Planning:** Early integration of data collection, testing, and trials into planning stages. Without collaboration of understanding the existing asset and its condition, we cannot unlock the full reuse potential to allow efficient use of these components and materials.

5.4 Finding the right risk level

Identifying the potential application of reused materials is a critical first step, as it dictates the level of risk and the extent of testing required.

Different applications have varying performance, safety, and regulatory requirements. For example, structural elements like beams and columns demand more rigorous assessment than non-structural components such as cladding or interior finishes. For MEP equipment, operational performance testing is needed in addition to physical condition to comply with energy efficiency regulations.

Understanding the intended use allows for a risk-based approach, ensuring that testing is proportionate to the demands of the new application while avoiding unnecessary costs and delays. By aligning testing protocols with the specific functional and safety requirements of a material's next life cycle, stakeholders can make informed decisions that optimize reuse opportunities while maintaining compliance and reliability. Intended uses include:

- Retention (extending life)
- Like-for-like reuse (onsite)
- Like -for-like- reuse (offsite)
- Reuse (unknown application)*
- Reuse (secondary, lower risk application)
- Closed loop recycling

It should be noted that this identification process can be iterative and can occur further down the reuse cycle. For example, information from testing may inhibit certain use cases, and therefore change the level of risk and testing required. It is also likely that the end application is unknown. For example, when components are treated as stock, and therefore testing may be done once the component is selected for its intended use. Equally the material or component can be reused in a complete different or hybrid solution, using a mixture of old and new components which require testing as a full unit. For example, feasibility studies have shown it is possible to remanufacture double glazed units reusing the existing glass whilst replacing gaskets and spacer bars.

Potential risks include:

- Structural, risk to life.
- Structural, risk to injury/ discomfort including operational efficiency
- Non-structural, risk to injury/ discomfort including operational efficiency
- Non-structural, aesthetics.

In addition to the above, meeting current and upcoming regulation also needs to be considered with a need to balance operational and embodied carbon with safety and functional requirements.

Figure 12 provides one way of classifying risk and effort. High effort items typically come with a significant carbon reward but also onerous testing requirements and high cost.

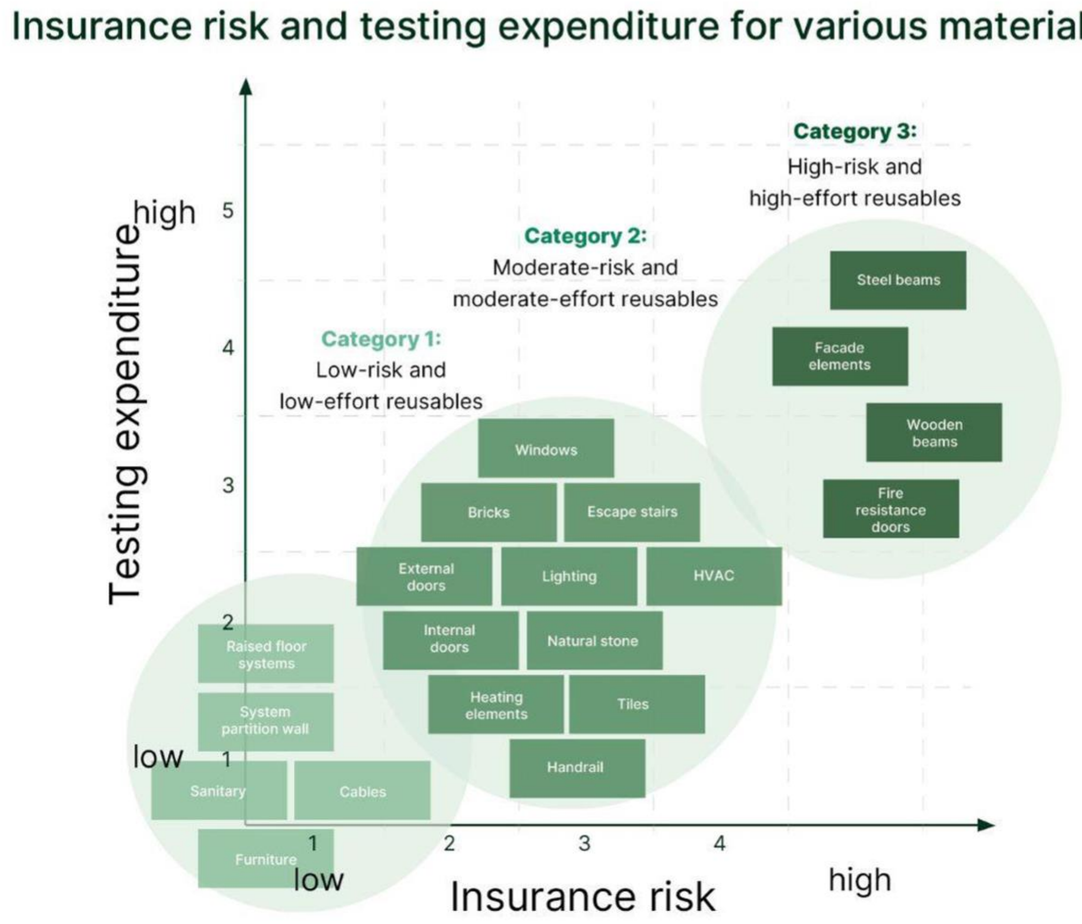


Figure 12: Insurance risk and testing expenditure for various materials (Concular)

5.5 Workflow

A project workflow in and described in the following pages, provides a high-level overview to ensure the successful integration of materials for re-use. This is material and application agnostic and therefore may differ in the level of detail required. Case studies are provided throughout as examples of material or application specific testing criteria.

The following sections provides key questions or mini case studies for the steps highlighted in the workflow.

Steps 1 – 3 is significant to define the intended use of the material which is a key decision in choosing the acceptance criteria and the right level of testing. The more data that can be collected, the more informed decisions can be made by subject matter experts. This ultimately helps to mitigate risk and if data is more readily available in the future, can lead to providing warranties and insurance of these components and materials.

5.5.1 Step 1: Building level data collection

Information can not only help identify key stakeholders such as the original manufacturer and contractors that might be able to provide insight into the feasibility to reuse and also highlight changes, failures and performance.

Data	Questions and information
Building age and location	Do the materials/component still comply with current regulations. Are there external impact that influence performance (e.g. seismic area)
Exposure condition	Are there external impact that influence performance (e.g. highly corrosive environment)
Maintenance records	Has equipment/ material been regularly maintained. Do we know the manufacturer/ operator – do they do take-back schemes
Previous surveys	Has there been any changes to the 'as-built' drawings. Were there any failures and why Can we see how it was constructed without doing intrusive surveys
Form of construction	Do we know how to dismantle the components
Quantity and location of materials	Can we get a meaningful yield for reuse. Is the equipment/ material accessible
Specification	What was the performance criteria and service life

5.5.2 Step 2: Visual Inspection

A visual inspection should be completed by a competent person such as a subject matter expert. In the future this may be assisted by the role of AI/ robotics to help identify materials, components and any visible defects.

For example, if the window is unknown, a visual inspection would indicate material component and build-up. For example, a double glazed unit, a visual inspection would identify:

- The glazing type e.g laminate/ monolithic/ bronze,
- Any coatings and films,
- Frame materials,
- Internally or externally beaded (for extraction).

It could also indicate the condition for reuse, are the double-glazed units starting to fog up typically indicating that the gaskets are at the end of its service life, or if the coating/ laminate layer is starting to fail due to moisture or UV exposure and therefore may have reduced performance (structural and/or operational).

5.5.3 Step 3: Preliminary testing

The level of the preliminary testing is dependent on the second use application, however, may also feed into whether it is feasible or if the application use be reduced to allow for a lower risk.

Data	Questions and information
Physical testing	What is its current performance (operation or physical)

Data	Questions and information
Material composition	Do the materials/component still comply with current regulations. Are there any contaminants
Condition survey/ NDT	What is its current performance (operation or physical) Where are element/ defect locations Has this degraded over time
Dismantling survey	Can we remove it from site safely?
Modelling	Where physical testing is not possible or can be used in conjunction with modelling – can we confirm its current performance and performance in its second application.

For example, preliminary tests may be required to understand how the stone is fixed to a façade (e.g. adhesive, mechanical) which will provide insight into the feasibility for removal without damaging the stone for reuse. This stone can then be sent for physical testing like petrographic examination, which will provide the stone's geological name (commercial and geological naming convention is not the same) and therefore it's inherent properties. If the stone properties are known, it can help determine its potential reuse application. Stone used for facades will require more stringent impact load resistance, compared to that for landscaping and furniture.

5.5.4 Step 4: Grouping

Depending on the application and risk on failure, the level of testing can be determined. In some instances, a representative sample can be used to provide confidence for a group components and materials. Some of these are provided by standards and regulations, whilst others are determined by risk appetite and the liable party and their processes.

It should be noted that there may be different subsets within groups, for example if the material is being used on the same site or a site within the same portfolio or being sent to a third-party. The level of testing and when the testing occurs may differ, for example testing may occur in-situ vs. off-site before or after installation.

5.5.5 Step 5: Classification of testing

As noted above, by determining the second-use application the acceptance criteria can be defined. This will vary both from a performance perspective, does this meet regulation in terms of function and safety, and does it still enable the balance of operational and embodied carbon in addition to comfort and other trade-offs. There is also an opportunity to enhance and improve performance and resilience for future use. This could be explored by combining new and reused components (add new coatings, allowing for design for disassembly to continue reuse).

Additionally, there is a visual acceptance criterion which can be categorised as:

- 'As new',
- Small imperfections not visible from viewing distance,
- Visible defects
- 'New aesthetic' – not traditionally accepted

Some marketplaces, such as CCBuild in Sweden, include the possibility to rate their products and materials based on the conditions (Figure 13). This added information enablers buyers or recipients to filter according to the level of visual acceptance criteria they desire for each of the products.

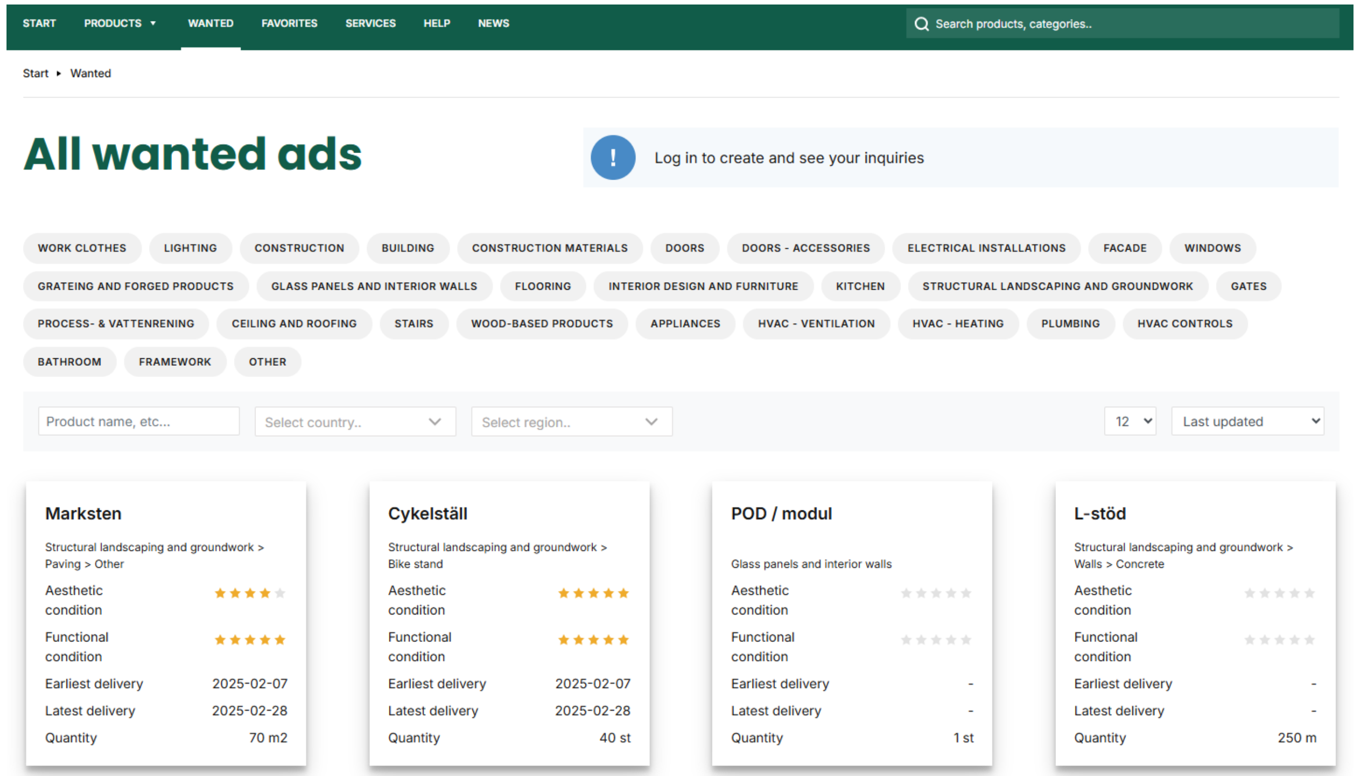
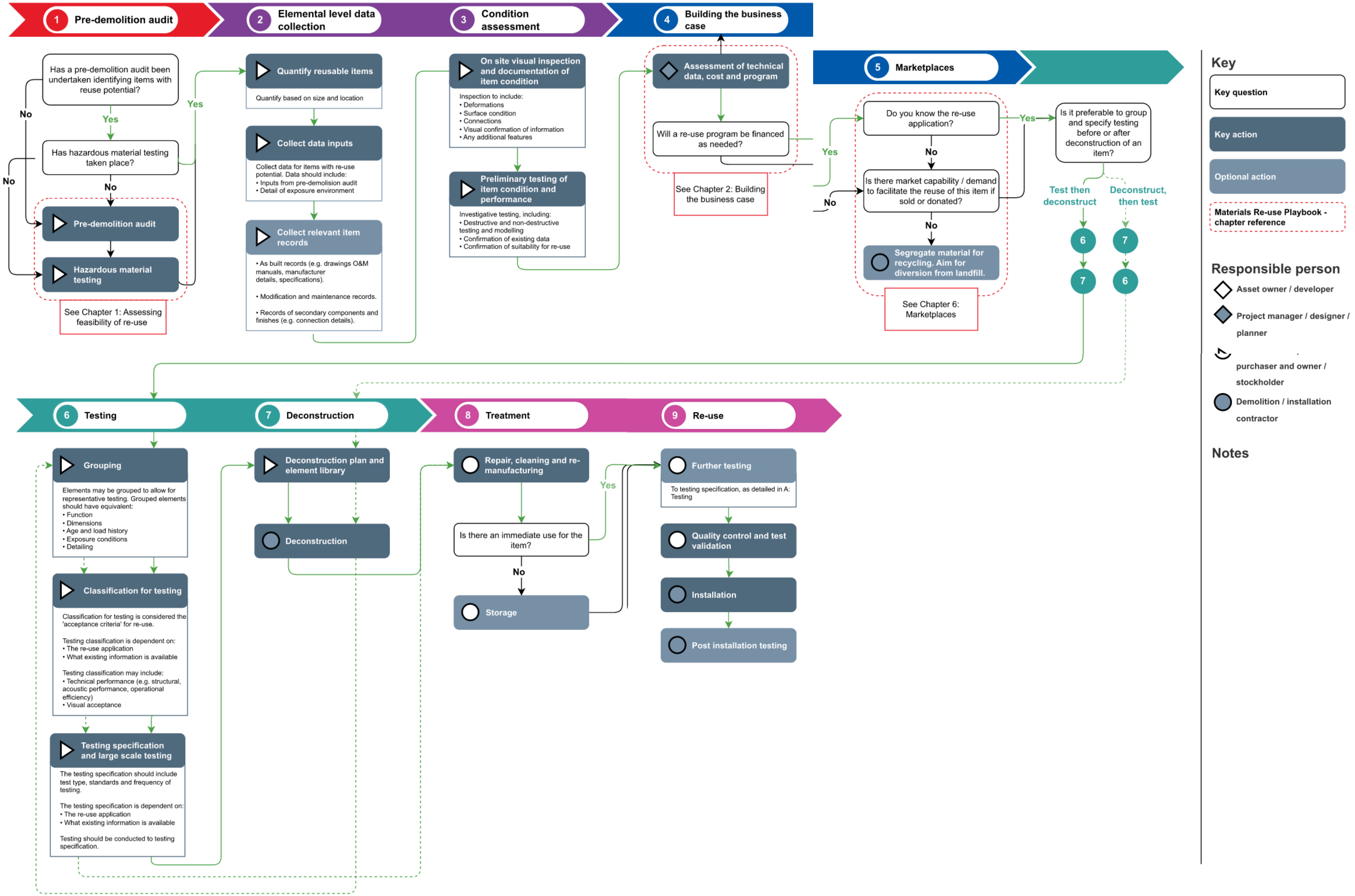


Figure 13: CCBuild Marketplace allows the donor to rate the aesthetic condition of the product they sell based on 5 stars rating system embedded in the marketplace platform

5.5.6 Step 6: Testing specification

As noted above, by determining the second-use application the testing specification can be determined. Some of these are provided by existing standards and regulations whilst others are determined by risk appetite and the liable party and their processes.

Process flow for acceptance criteria and testing of re-use items and materials



5.6 Signposts

Material	Documents
General	IiA 36192 – Investigating practical feasibility for the reuse of steel IiA 37076 Specifying construction materials for re-use https://cdn.prod.website-files.com/6540cf880126ab97b2f349fc/65d3cb3524ced419a5361368_240215-Whitepaper-Concular-Reclaimed_Construction%20_Material_Insurance.pdf Evaluating re-use potential: Material profiles and vision for project workflow - Arup DIN SPEC 91484 Table 3 Reuse toolkit Elliot Wood: Full Circle to Reuse guidehttps://online.flippingbook.com/view/915371497/40/ IStructE Circular economy and reuse: guidance for designers: https://www.istructe.org/resources/guidance/circular-economy/
Concrete	Cement, concrete & the circular economy, CEMBUREAU, 2016 NS 3682:2022 Hollow Core Slabs for Reuse, Standard Norge EN 1168:2005+A3:201 Precast concrete products – Hollow core slabs EN 206:2013 Concrete - specification, performance, production and conformity (+A1:2016) Structural reuse, Enabling business by reuse of basic building components, Lendager, April 2023 Circular economy and reuse: guidance for designers, Institution of Structural Engineers, July 2023 Appraisal of existing structures, 3 edition, Institution of Structural Engineers, 2010 Reusability assessment of reinforced concrete components prior to deconstruction from obsolete buildings. Journal of Building Engineering. 2024
Masonry	BS EN 1996-1 Eurocode 6 - Design of masonry structures, British Standards Institution Climate action: we can put a block on brick, Rosie Mounsey and Steve Webb, RIBA Journal Intelligence Structures, 2021 BS EN 771-1:2011 Specification for masonry units. Clay masonry units (+A1:2015), British Standards Institution EAD 170005-00-0305, Re-cycled clay masonry units, European Organisation for Technical Assessment, 2017 Cleaning of Clay Brickwork, Brick Development Association, 2022 Reuse of Clay Brickwork, Brick Development Association, 2022 Reuse toolkit: Materials sheet – Reclaimed solid terracotta brick, Interreg North-West Europe FCRBE, 2021 Structures Notes 2006 NST 09, Reuse of bricks, Deborah Lazarus, Arup, 2006 PAS 70:2003 HD clay bricks - guide to appearance and site measured dimensions and tolerance, British Standards Institution BS EN 1745:2020 Masonry and masonry products. Methods for determining thermal properties, British Standards Institution BS EN 772-13:2000 Methods of test for masonry units - Determination of net and gross dry density of masonry units (except for natural stone) PD 6697:2019 Recommendations for the design of masonry structures to BS EN 1996-1-1 and BS EN 1996-2, British Standards Institution
Steel	CEN/TS 1090-201:2025 - Execution of steel structures and aluminium structures - Reuse of structural steel CEN/TC 135/WG 2 "Technical requirements for the execution of steel structures" Alliance for Sustainable Building Products. Business considerations for steel reuse - DISRUPT Toolkit. 2023 Arup IiA 34063. Exploring steel reuse from cyclically loaded structures. Investigating a methodology for reuse steel subjected to fatigue. 2023. Alliance for Sustainable Building Products. DISRUPT PROJECT ON STEEL REUSE. Delivering Innovative Steel ReUse ProjecT literature review. 2023. IStructE. Circular economy and reuse: guidance for designers. Steel Construction Institute (SCI) – P427 Protocol for reusing structural steel Steel Construction Institute (SCI) – P440 Reuse of pre-1970 steelwork PROGRESS - European recommendations for reuse of steel products in single-storey buildings. 2020
MEP	datocms-assets.com/74636/1664543791-aterbruksguiden-for-installationer-bd-2022-04-22.pdf re-certification (fire doors/ equipment etc.)

5.7 Case Study 1: Brick Reuse for Arkadia Apartments

Status: Completed 2019
Location: Sydney, Australia
Project owner: Defence Housing Australia
Collaborators: DKO, Breathe Architecture, Icon Co, Oculus, LOHAS

Arkadia comprises the development of 152 new dwellings composed so that each of the buildings house micro communities with only 7-8 apartments on each level. Acknowledging the historic narrative and heritage of this site was the starting point for the design team, where salvaged brick procurement from LOHAS references the site's brickworks history dating back to the 1870s. LOHAS is one of the largest salvaged brick suppliers in New South Wales, Australia.

Process

LOHAS did careful deconstruction to extract reusable bricks with minimal damage. Grading, filtering and asbestos / lime testing of salvaged bricks took place at LOHAS facilities. 20% of bricks used in Arkadia were from ongoing LOHAS stock and the remaining 80% required were sourced from the demolition of residential and industrial buildings local to the site.

What worked well

The reuse of the bricks was a strategy driven by the architects from the concept design stage. The choice of reused bricks was factored into the project's ambitious carbon reduction and circularity ambitions.

Every reused brick saved 0.5 kg of CO_2 emissions compared to manufacturing a new brick. This project used approximately 480,000 recycled bricks equivalent to 240,000 kg of CO_2 emissions avoided. Virgin material extraction for the brickwork was also avoided. Each second-hand brick LOHAS provide is at a minimum 20% cheaper than standard virgin bricks.

How can it be replicated?

Availability of bricks – working with salvaged brick providers from the earliest design stages is crucial to ensure sufficient lead time to source the required number of bricks.

Wide acceptance in brick aesthetic – this project embraced a facade with varying colours and grades of brick. If consistency is desired, sourcing may be more challenging.

Mortar selection – refer to iStructE circular economy and reuse guidance for designers 'brick' section. The choice of mortar (lime vs cement) will pose barriers to brick reclaim in the future. Some construction codes demand a minimum proportion of cement in mortar which is more difficult to chip off at end of life.

5.8 Case Study 2: DISRUPT 2 (Steel)

Delivering Innovative Steel ReUse ProjecT (DISRUPT) initiative, led by the Alliance for Sustainable Building Products (ASBP), aims to promote and facilitate the reuse of structural steel in construction.

The main objectives were to:

1. Collaborate with the demolition industry to increase the availability of reusable steel components.
2. Create resources to assist stakeholders in identifying, recovering, and integrating reclaimed steel into new projects.
3. Encourage the adoption of business practices that prioritize material reuse over traditional recycling or disposal methods.

Who was involved

Collaboration across the value chain include industry bodies including ASBP, Institute of Demolition Engineers (IDE) and steel suppliers and stockists like Cleveland Steel.

What worked well?

Understanding the acceptance criteria from the material manufacturers early on the projects which is clearly communicated to the client through to contractors onsite. This enabled understanding and common objective across the value chain. For example, defining the acceptable steel types and section sizes and dimensions to the impact of deconstruction methods like cutting in-situ and reducing heat affected zones to increase the yield of reusable steel.

How can it be replicated?

The toolkit developed in collaboration with the industry helps lower the barrier to the initial surveying steps during the early strategic stages of the project which enables contingency and flexibility for the rest of the project for successful reuse.

5.9 Contributors

Florence Wu, Materials Engineer, Arup

Amy Smith, Sustainability Consultant, Arup

Sarah Onsang, Graduate Engineer, Arup

5.10 Action Plan

Key Action	Required skills and knowledge to complete this action	Responsible person (collaborators in brackets)	Output	Receiving person(s)
Identify future application	Chain of custody (storage). Market capability / demand for item.	Material broker (material expert)	Proposed re-use and chain of custody plan.	Asset owner/developer, stockholder
Review pre-demolition audit and hazardous material testing with reuse potential elements identified.	Completed pre-demolition audit and hazard materials testing.	Materials/waste expert	Understanding of quantity of salvageable items/materials.	Project manager, planner, designer, asset owner/developer
Determine aesthetic and functional requirements of materials for salvage	Material and product requirements and properties	Material expert (material broker)	Rating of product conditions both at high level (star system) and detailed (qualitative description).	Stockholder
Undertake on site visual inspection and documentation of condition for reusable items and undertake on site preliminary testing (or sample testing)	Item records, details of exposure environment, completed pre-demolition audit. Asset/ materials condition assessment capability.	Materials expert	Report or register detailing technical detail and condition of items/materials. This may be inputted into existing audit.	Project manager, planner, designer, asset owner/developer
Assess **cost and program** feasibility for reuse of elements	Understanding of the quantity, condition and application of re-useable items/materials. Assign items and materials to specialised material experts that can test and assess the quality of each of the products. This should ideally occur prior to transporting all quantities of the product into the storage space.	Project manager (planner, designer, materials expert)	Proposed re-use and chain of custody plan. List of products assigned to each of the different material experts and a template for each of the product category to be filled in by the expert	Asset owner/developer, stockholder
Determine grouping, number of samples and classification of items/materials for testing	Data on item / material: • Function • Intended re-use application • Dimensions • Age and load history • Exposure conditions • Detailing Assess consequences risk of failure (future application must be assumed/known) to help inform number of samples required.	Materials expert	Grouping and classification input to tracking system.	Asset owner/developer, stockholder
Testing	Knowledge of relevant testing standards Testing equipment	Material specific: Testing house / Manufacturer /stockholder	Update material passports with test results	End purchaser/ stockholder

6. Stockholders, storage and remanufacturing

6.1 Introduction

Storage is essential in the reuse of building materials to bridge the gap between the deconstruction of buildings and the subsequent reuse of materials. The need for storage arises due to the timing mismatch between the availability of recovered materials and the demand for them in new construction projects. This timing is key when it comes to actioning recovery, as it affects the efficiency and quality of the materials recovered. Additionally, the length of time in storage is crucial, considering the time it takes for interest to be generated and demand to be realized. Proper storage can ensure that the quality of materials is maintained and should prevent damage from environmental factors such as moisture, temperature fluctuations, or exposure to sunlight. Different types of materials and elements will have varying needs and requirements for proper storage, e.g., timber will require storage in temperature and moisture-controlled spaces. See Opalis' Reuse Toolkit Material Sheets[1] for detailed information on proper storage of different reused materials. A key difference to building with virgin materials, is considerations of waste classification of recovered building materials. Waste directives classify materials as waste based on their storage duration, hence it is essential to plan and ensure that the materials will be reused within a reasonable timeframe.

Remanufacturing might be required as products need to be taken back to product specification stage before they are allowed to be used again, to ensure that the materials requalify and demonstrate fit for new use. This may be required when materials have been damaged or when they need to be adapted to meet the specifications of a new project. including removal of finishes, cleaning, and reshaping (e.g., concrete carving). Remanufacturing may also be necessary to meet updated regulatory requirements. Particularly MEP systems should be ensured to meet continuously increasing requirements of energy efficiency.

Remanufacturing should occur post deconstruction at a manufacturing or storage facility, once classifications and specifications for testing have been established, determined by the future application of the materials. Some remanufacturing can be carried out on-site, such as cleaning and repairs, while more comprehensive adaptations require access to specialised facilities. See chapter 4 for more details on acceptance criteria and testing. Although remanufacturing may contribute to the embodied carbon of reclaimed products, there are environmental benefits such as avoiding use of virgin materials and waste reduction, as well as subsequential optimisation of energy efficiency.

The business model of stockholders typically revolves around the acquisition, storage, and resale of reclaimed materials, often working closely with contractors, developers, and material specialists. They may operate on a short-term or long-term storage basis, depending on the type and nature of the materials and market demand. Stockholders can charge fees for storage and handling, and they may also offer additional services such as quality testing, certification, and remanufacturing.

The best approach to storage depends on the type of materials, level of technical specification, scale of the project, project types, etc.

Summary table of different storage models:

<table>
<tr><th colspan="2"></th><th>Temporary storage</th><th colspan="3">Long term storage</th></tr>
<tr><th colspan="2">Use case</th><th>Site-to-site & same site re-use</th><th>Closed loop take-back and Product-as-a-Service</th><th>Physical marketplaces*</th><th>Virtual marketplace*</th></tr>
<tr><td colspan="2">Material source (location)</td><td>Single location</td><td>Multiple locations</td><td>Multiple locations</td><td>Multiple locations</td></tr>
<tr><td colspan="2">Material destination</td><td>Known</td><td>Known</td><td>Unknown</td><td>Unknown</td></tr>
<tr><td colspan="2">Storage space location</td><td>On-site or rented from 3rd party in proximity to new site - depends on destination of materials/ products.</td><td>Manufacturers own storage spaces</td><td>Physical marketplace owner or business owner (if different)</td><td>Dispersed multiple locations</td></tr>
<tr><td colspan="2">Timeline/time in storage</td><td>Known</td><td>Unknown</td><td>Unknown</td><td>Unknown</td></tr>
<tr><td colspan="2">Supply (volumes and timings)</td><td>Known</td><td>High degree of certainty and possible to forecast</td><td>Low degree of certainty and less possible to forecast</td><td>Low degree of certainty and less possible to forecast</td></tr>
<tr><td colspan="2">Demand</td><td>Known</td><td>Possibility to forecast</td><td>Difficult to forecast</td><td>Difficult to forecast</td></tr>
<tr><td colspan="2">Point of testing **</td><td>Prior to storage</td><td colspan="3" rowspan="2">Prior and post storage, depending on length of time in storage</td></tr>
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<tr><td colspan="2">Ownership while in storage</td><td>Donor or recipient developer/asset owner</td><td rowspan="5">Manufacturer</td><td rowspan="5">Stockist / marketplace</td><td rowspan="4">Local resellers. Can include small scale manufacturers and contractors</td></tr>
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<tr><td>Transport</td><td>Local resellers and/or recipient buyers</td></tr>
</table>

*See chapter 6 for further information on marketplaces
**See chapter 4 for further information on acceptance criteria and testing

[1] opalis.eu/sites/default/files/2022-02/FCRBE-all_sheets_merged-EN.pdf

6.2 Types of Storage

6.2.1 Temporary storage - site-to-site or same site reuse:

In this use case, the reused material and products are either sourced from the donor site and eventually implemented at the recipient site, or the materials remains onsite to use in renovation or new built post deconstruction of existing building. The origins, destination, demand, and timelines for the materials and products are typically known. The developer/asset owner is the key responsible actor, although the contractor is responsible for carrying out the deconstruction, refurbishments, and sometimes testing and storage. The developer/asset owner could also take the role of the stockholder of the physical on-site temporary storage, while the contractor would be responsible for managing and securing it. In the case of limited on-site space, storage location can be rented from a third party in proximity to donor and recipient site. This model requires complex coordination between the donor and recipient project developers and contractors, particularly regarding the timing and availability of materials. This approach is appropriate for both large and small-scale reuse, though small-scale reuse might not be financially feasible. In regard to insurance, this model is generally considered less risky, as it requires shorter transportation routes directly from donor site to recipient site, thus minimising the risks of transport damage[2]. Quality testing and assurance should be done prior to storage to ensure materials meet necessary capabilities for future use and to avoid spending unnecessary efforts on materials that cannot be reused.

Case study 1: Off-site temporary storage: BCCC (Brussels Construction Consolidation Centre), Brussels, Belgium

The BCCC is a logistics platform offering consolidated material deliveries. As a part of their service offerings, the BCCC rents temporary storage space for reused materials from deconstruction sites, to fill the gap between projects. It also offers cleaning, refurbishment, and quality checks of the materials at their location as well as logistics management. The BCCC stored 650 pallets of recovered flint tiles to be reused in the complete renovation of the WTC towers – now known as ZIN located in Brussels.[3]

6.2.2 Long term storage - takeback schemes and Product-as-a-Service (PaaS)

Takeback schemes involve manufacturers or suppliers accepting returned products at the end of their life cycle for reuse, refurbishment, or recycling. Product-as-a-Service (PaaS) is a model where customers subscribe to use products and receive services like maintenance and upgrades, thus instead of buying the product, customers pay recurring fees. The main difference between the two models is that the ownership remains with the manufacturer/supplier in the PaaS model, whereas take-back schemes often transfer ownership to the customer. These schemes are common for products with high reuse potential, such as steel, timber, insulation, and certain fixtures and fittings.

The storage space is owned by the manufacturer themselves. Manufacturers are the key responsible actors in the closed loop system, which results in high levels of transparency and traceability for, ensuring accountability. Recovering and reselling materials and products can in some cases result in financial savings, if the scale of operations is at a sufficient size – in other cases with limited material and product recovery, reverse logistics, remanufacturing, and storage can prove costlier than business-as-usual. This approach works best for large-scale operations, as it may not be financially feasible at a small-scale.

Case study 3: Take-back: Saint-Gobain Glass

To achieve closed-loop recycling, Saint-Gobain Glass France created a network of around 50 recycling companies who collect and dismantle the glass products at end-of-use. The process involves excluding non-recyclable glazing, carefully dismantling and storing end-of-life glazed products, and collecting and processing them at recycling sites. The treated glass cullet is then reintroduced into float plants for new glass production.[4]

Case Study 4: Space-as-a-service: Adapteo

Adapteo emphasise the reuse and flexibility of their modular buildings. After the initial use, Adapteo takes back the modules, refurbishes, and prepares them for new projects. These processes happen across their several hubs across Europe, involving thorough inspection, maintenance, and any necessary upgrades to ensure the modules meet quality standards for future use.[5]

[2] Huuhka, Satu, et al. Re-Use of Structural Elements; Environmentally Efficient Recovery of Building Components. VTT Technical Research Centre of Finland.

[3] https://bccc.brussels/nl/homepage/

[4] https://www.saint-gobain-glass.fr/fr/saint-gobain-glass-recycling-vers-une-production-durable-du-verre#enjeux

[5] https://adapteo.com/

6.2.3 Long term storage/ physical yard marketplaces

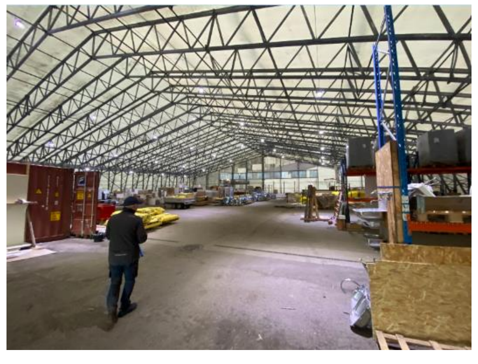
This model involves open-loop recovery of products and materials, where marketplaces buy used materials and resell them for profit or recover materials as a free service offering and resell them. It is typically used for small-scale reuse, as matching demand and supply for large-scale projects is challenging. For steel stockists like Cleveland Steel, there is uncertainty regarding the time it takes to sell steel due to inconsistent demand. For the buyer (i.e. contractor) and planners (i.e. architects), acquiring materials from this model requires good knowledge of the available materials and location. Material costs will include costs of preparation for reuse and the deconstruction contractor cover costs by reselling materials to stockholders.

Case Study 5: Cleveland steel

Cleveland Steel provides on-site storage, eliminating the need for customers to store materials themselves. Safe and timely transportation of steel is ensured by their global delivery network. Testing is conducted by UKAS-approved independent laboratories, with third-party inspection and validation available upon request. Flexibility and cost-effectiveness are ensured, as customers only pay for the level of testing specified.[6]

Case Study 6: Ombygg, Oslo, Norway

Ombygg is a public-private partnership for clean construction, owned by Resirqel and operated by Sirkulær Ressurssentral. Ombygg provides SMEs with access to secondary materials and offers deconstruction service providers opportunities to store or sell recovered products. Supported by the City of Oslo with a temporary reduced lease rate on a municipal plot, Ombygg provides a 4,500 m² warehouse facility that serves as interim storage and sales of various recovered construction materials, aiming to make them as appealing as new materials to public, commercial, and private clients. Public partners include Oslobygg and Statsbygg, while private partners involve OBOS, Mustad Eiendom, Høegh Eiendom, Entra, Gjensidige Forsikring, and EBA.[7] [8]



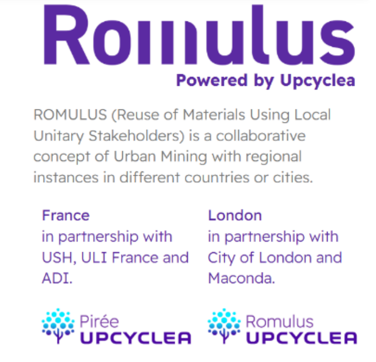
6.2.4 Long term storage - Virtual marketplace

Virtual marketplaces facilitate the reuse of materials such as bricks, roof tiles, stone, wood panels, windows, doors, staircase banisters, and balconies. These platforms connect physical inventory to online visibility and procurement through inventory apps that combine photos, location tags, and database tools. The marketplace buys used materials and resells them for profit or recovers materials as a free service offering and resells them. Storage space is either provided by the marketplace or the individual and small-scale local businesses and manufacturers. A big challenge in this model is ensuring warranty for the reused materials, as well as ensuring that the sold materials are traceable during future use.

Reuse markets for used bricks, roof tiles, and stone and wood panels are well-established, as well as markets for windows, doors, staircase banisters, balconies, and alike.

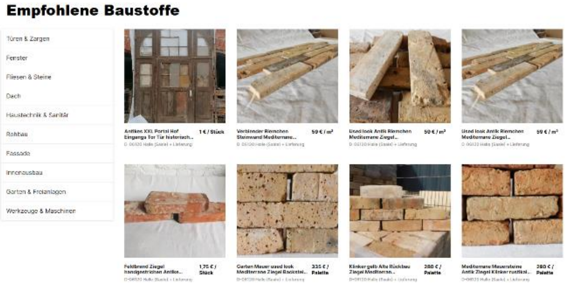
Case study 7: Romulus, London, UK

The Romulus project is a collaborative initiative aimed at promoting the circular economy within London's built environment. It seeks to maximize the reuse of building materials by creating a marketplace for reclaimed products, reducing waste, and lowering carbon emissions. The project involves partnerships between the City of London Corporation, Maconda Solutions, and Upcyclea, among others. Utilizing the Upcyclea platform, Romulus digitizes inventories and creates material passports to track reusable materials.



Case Study 8: Restado, Germany

restado.de is a marketplace for reclaimed construction materials, offering items from deconstruction, oversupply, or leftover projects for both professional and private buyers. The platform provides detailed product information and building instructions, supporting the sourcing of materials locally. Professional dealers post their available materials on the platform, maintaining the materials in their own storage spaces.



[6] https://cleveland-steel.com/

[7] https://www.ombygg.no/

[8] https://www.ressurssentral.no/sras

6.3 Barriers and considerations

- **Physical environmental protection**: Ensuring that materials are protected from moisture, temperature fluctuations, contamination, physical damage, and theft. For example, timber must be stored in temperature-controlled storage. Specific storage requirements must be clarified for different materials to prevent degradation.

- **Quality assurance**: Quality testing and assurance should be conducted before storage, and in some cases prior to deconstruction, to confirm that materials have the necessary capabilities for future use. Depending on the length of time spent in storage, materials and products should be tested before use, to ensure that they have not degraded due to poor quality storage.

- **Storage space and accessibility**: Accessibility to the materials should be assessed, for example if it will be needed in the short term or required suddenly. For each deconstruction project, it must be decided whether to use on-site storage, third-party rented storage, or manufacturer-owned storage facilities. Construction sites often have limited space for storage, making it difficult to store large quantities of materials on-site without causing congestion. Off-site storage also faces space constraints, as local storage space within proximity to customers is limited. In densely populated areas, high costs and space constraints create a disparity between the location of reclaimed item stocks and their market.

  Estimation of maximum transport distance [9]

Reclaimed materials	Transport distance (km)
Aggregates	150
Bricks	400
Timber	1600
Steel	4000
Aluminium	12000

- **Sufficient volume:** Unpredictable market demands and access to sufficient volume present challenges. Large projects may hesitate to supply all materials due to uncertainty about market demand, while limited availability of materials is not appealing to large projects. To accommodate the demands of large volumes, it is essential for the stockholder to maintain a substantial inventory. This approach poses challenges related to storage space availability and introduces uncertainties concerning divesting the stock and financial feasibility, if future reuse is unplanned or uncertain.

- **Cost-effectiveness**: Stockholders and contractors must carefully evaluate the financial feasibility of various storage options, particularly when dealing with smaller projects. The process of reuse inherently involves additional labour costs associated with deconstruction, sorting, and the actual reuse of materials. Furthermore, there are typically supplementary storage costs incurred when the timing of projects is not perfectly aligned. Project delays, which may arise from the acquisition of reused materials, can further escalate storage costs, and these increased expenses are generally incurred by the stockholder. The financial viability of storing materials is also constrained by the duration for which they can be stored without degradation.

- **Stakeholder and project coordination:** Effectively managing the timing and logistics of deconstruction and new construction projects to ensure materials are available when needed is a multifaceted and complex task. This process involves addressing various logistical challenges, such as coordinating deliveries, managing inventory, and balancing supply and demand. The coordination required is highly dependent on the type of material or product involved. For instance, facades are typically designed for specific projects, and their reuse is contingent upon a new project requiring a similar design. In contrast, structural elements like steel beams are less dependent on visual elements and can be more readily repurposed. Additionally, the costs associated with labour, equipment, and time for storage, cleaning, repair, and remanufacturing are typically covered by either the deconstruction contractor and reseller or the developer.

- **Skills**: Improper on-site storage and deconstruction practices often lead to material degradation, making a significant portion of materials unsuitable for reuse (See chapter 3 for more information on handling and extraction of materials).

- **Transparency:** It is crucial to ensure transparency on how materials and products are handled and stored of and material performance in each step, from deconstruction to storage to new use and by whom. This is particularly key information for insurers, relying on contractor and stockholder assurance due to lack of historical data.

- **Waste classifications:** Waste directives regulate the categorization of materials as waste depending on the time spent in storage. To avoid regulatory implications, it should be planned and preferably certain that the elements will be reused. However, if the material is considered waste due to abandonment, error, or logistical processes before reuse is certain, it is categorized as "preparation for reuse" and it can reclaim the classification as a product when reuse is guaranteed. The categorization of materials as either waste, products, or preparation for reuse determines which regulations apply for transportation and storage.

6.4 Enablers

- **Early contractor engagement:** Involving contractors early in the project to plan for material reuse and storage that includes costs and programme.

- **Access to material databases and demolition plans:** Utilising databases that provide information on available reclaimed materials and their properties. Having knowledge of planned demolition projects can enable stockists and resellers to salvage materials, while developers, planners, and contractors can plan for integration of reused materials in future projects, and better predict availability, and potentially design new projects accordingly.

- **Quality assurance:** Ensuring that materials are tested and meet the required standards before and after storage (See chapter 4 for more information on acceptance criteria and testing).

- **Material passports:** Enabler of quality assurance, as it gives insights into how materials are processed, handled, refurbished, and stored (See chapter 9 for more information on Material Passports).

[9] Anderson, J. & Howard, N. The Green Guide to Housing Specification, BRE Report 390. UK: BRE, 2000 ; Huuhka, Satu, et al. Re-Use of Structural Elements; Environmentally Efficient Recovery of Building Components. VTT Technical Research Centre of Finland.

- **Assurance of future use:** Apply a Futures trading approach, which in a nutshell means to create contracts to buy or sell a specific product or materials at a future date. In futures trading both asset owners and design firms can forward both risks and costs. This is an approach that is already used in other industries such as in agriculture. Futures trading will enable the future buyer to purchase the product in advance, at a set price and with an estimated timeline when the product will become available

6.5 Signposts

- FCRBE Reuse Toolkit: https://vb.nweurope.eu/projects/project-search/fcrbe-facilitating-the-circulation-of-reclaimed-building-elements-in-northwestern-europe/#tab-3
- project-manager-guide-building-material-reuse.pdf
- how-to-guide-reuse.pdf

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6.7 Action Plan

RIBA Stage	Key Action	Required Skills and Knowledge	Responsible Persona	Output	Receiving Persona(s)
Strategic Definition, Preparation and Brief	Engage early with contractors for cost, logistics, and program certainty, ideally pre-tender.	Project management, stakeholder engagement, knowledge of circular economy opportunities	Project Manager	Detailed engagement plans and schedules for material reuse	Contractors, developers
Strategic Definition, Preparation and Brief	Include storage requirements in tenders for awareness and planning.	Tender writing, knowledge of storage criteria	Owner/developer (incl. public bodies like municipalities), architects/planners	Tender documents specifying storage requirements	Stockholder, planner/designer, contractor
Strategic Definition, Preparation and Brief	Plan regular meetings to align stockholders and contractors on key issues to foster cooperation, ensuring that supply and demand, skills, equipment, and storage needs, are met.	Meeting facilitation, stakeholder engagement, understanding of reuse market needs	Stockholder	Comprehensive demand and supply plans for reused materials	Contractor
Strategic Definition, Preparation and Brief	Develop a site-specific storage plan considering the timeline for application and future use. This plan should evaluate site conditions, outline the proper storage requirements for various materials, and include earliest and latest delivery times as well as quantities.	Evaluation skills of site conditions, knowledge of material storage requirements	Short term stockholder (e.g., developer)	Detailed storage location plans for various materials	Developers, contractors, architects
Strategic Definition, Preparation and Brief	Include requirements for sorting and categorization of materials on-site, transportation, and storage based on local regulations in contracts, including outlining of responsibilities and selection criteria.	Knowledge of material handling, waste classification, logistical management, regulatory compliance	Asset owner/developer, planner	Clear sorting and selection criteria and comprehensive transport and storage plans	Deconstruction contractor, stockholder
Strategic Definition, Preparation and Brief, Deconstruction	Document how materials should be handled and stored to maintain quality, ensuring that information is available to all relevant parties.	Documentation skills, knowledge of material handling	Material expert, planner/designer, contractor	Detailed documentation of storage processes and quality	Deconstruction contractor, stockholder
Strategic Definition, Preparation and Brief, Deconstruction	Establish contracts for reserving materials and agreeing on process routes.	Contract management, negotiation skills	Developer, contractor	Contracts detailing material reservation and process routes	Stockholder
Preparation and Brief	Train deconstruction contractors and storage personnel on best practices for handling materials.	Training development, knowledge of deconstruction and storage practices	Material and logistics experts.	Well-trained personnel in deconstruction and storage practices	Deconstruction teams, site management, storage management
Preparation and Brief, Concept Design	Plan and allocate space for on-site storage to ensure the quality and quantity of stock as well as on-site safety.	Logistics expertise, technical material knowledge, environmental protection	Asset owner/developer, planner	Quality storage plans ensuring material integrity	Deconstruction contractor
Depends on use case	Develop and utilize material databases to track and manage inventory effectively, with individual labels/markings for each reclaimed material to ensure provenance.	Database management, knowledge of material properties, urban mining experts	Stockholder	Updated and accurate material databases	Planner/designer, contractor
Depends on use case	Keep and update inventory to measure material quantities and establish reuse availability. Signal availability of material to potential buyers in a timely manner.	Inventory management, data entry, material assessment	Stockholder, developer/planner	Comprehensive digital inventory and material passports	Contractor, planner/designer, stockholder
N/A	Initiate public-private partnerships to align stakeholders on material reuse. These partnerships should involve local authorities, developers, contractors, and stockholders.	Partnership development, stakeholder engagement	Local authorities/municipalities	Coordinated plans for material stock, demolition, and storage	Developers, contractors, stockholders, planners

7. Marketplaces

7.1 Introduction

“There is no such thing as waste, only materials in the wrong place.”

The purpose of material marketplaces is to facilitate the matching of (broker) the supply of secondary materials with projects and stakeholders that have a demand for such materials. As such, marketplaces play an important role to ensure that the (residual) value of materials is preserved and captured. Marketplaces provide a platform (both digital and physical) to broker this exchange in value between suppliers and buyers.

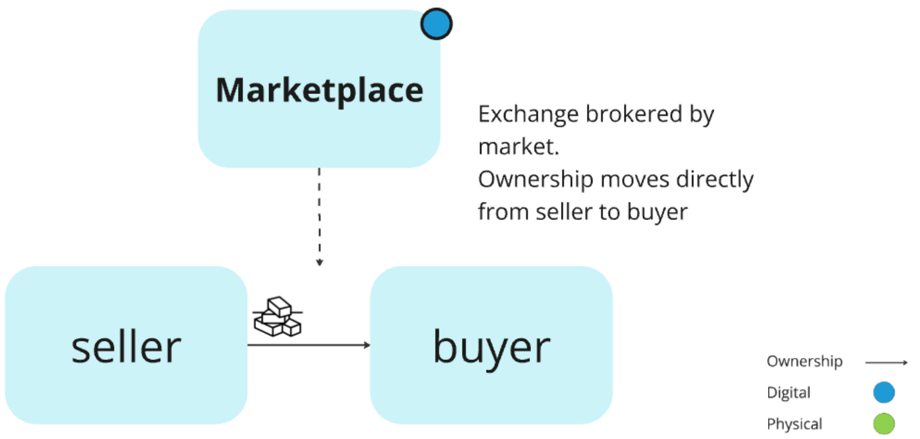
Typically, marketplaces for secondary construction materials foster the material exchange between different organisations and building projects. However, marketplaces can also support the cycling of materials across industry, e.g. the recycling of PVC window frames into post-consumer recycled plastics for other consumer goods.

7.2 Types of Marketplaces

There is a diversity of marketplaces that enable the exchange of secondary materials, and range in their focus, form and function.

As the exchange of ownership of secondary materials a key function of marketplaces, we can use this to categorise several main types of marketplaces:

- **Matchmaker**: In this type of marketplace, the ownership of the materials exchanges directly between seller and buyer. The marketplace brokers this exchange but does not directly obtain ownership of the materials. The functionality of the marketplace can include the listing of materials and dynamic matchmaking between buyers and sellers.
  - The functionality and interaction with this marketplace include both the listing/selling as well as the sourcing/buying of materials.
  - Typically, the marketplace itself does not include infrastructure to store and transport materials. This is usually arranged through the buyers and sellers.



Examples of Matchmakers:

Circotrade is a French company that captures buildings’ unrealised value by listing, gauging and trading their components via an innovative futures contract. In this way, Circotrade overcomes the financial and logistical barriers facing reuse and boosts the uptake of secondary construction materials and products. [10]

Excess Materials Exchange (EME) is a digital platform that matches waste or excess materials with partners who can repurpose them efficiently and creatively. It uses product passports, AI, and secured transactions to simplify the journey from waste to resource.[11]

Rheaply is a technology company that connects organisations with surplus or needed resources. Rheaply's platform facilitates the exchange and reuse of items.[12]

Eiffel Trading is an online marketplace for construction companies involved in heavy civil and marine projects. The online marketplace is a platform for companies to procure and liquidate new/used/surplus equipment and material.[13]

- **Market**: In these types of marketplaces, the marketplace sources and directly owns the secondary materials directly. The secondary materials are subsequently sold to prospective buyers and projects.
  - With the marketplace subsuming ownership of the secondary materials, often, the marketplace has sites for the (intermediate) storage of secondary materials, and sometimes include logistics and transportation services such as Takeback schemes.

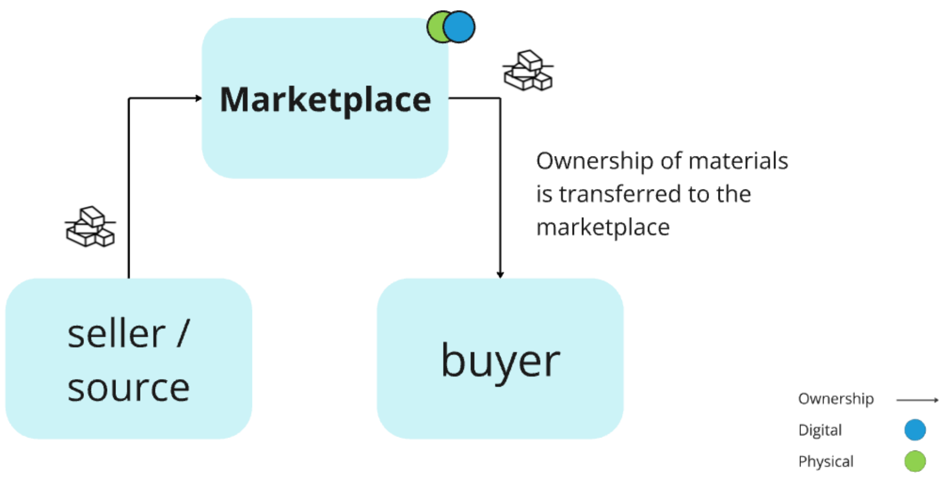
[10] https://www.circotrade.com/

[11] https://excessmaterialsexchange.com/

[12] https://rheaply.com/

[13] https://www.eiffeltrading.com/

- There are a range of examples of these marketplaces, spanning a range of materials, and can include both online sites, as well as offline/physical locations.
- The interaction of stakeholders within these types of marketplaces can vary in their offering to indicate two sub-categorises:
  - **Trader**: Where stakeholders can both directly sell to, *and* buy from the marketplace.
  - **Stockist**: Where stakeholders interact with the marketplace through only the buying of secondary materials.



Examples of Markets, Traders, and Stockists:

Greendozer[14] is a Danish platform that sells new, surplus, and recycled building materials to promote sustainable construction

Reclamation Centres (e.g. the Rebuild Site in Carlisle, UK), which host physical locations where secondary materials can be stored and obtained.

Rotor DC is an employee-owned cooperative based in Brussels that organises the reuse of construction materials. They also dismantle, process and trade salvaged building components (from hardware and chairs to ceramic tiles and doors).

Material Suppliers offering secondary products (e.g. Reused steel). The matching of stock and requirements can be facilitated through digital tools, such as Heyne Tillet Steel's HTS Stockmatcher.[15]

[14] https://greendozer.com/

[15] https://stockmatcher.co.uk/

Doors Unhinged is a U.S.-based company that specializes in selling reclaimed commercial doors, frames, and hardware.[16] Doors Unhinged supports the integration of reclaimed materials into new designs, supporting building professionals to adopt eco-friendly practices.

Other characteristics of marketplaces: There are several important distinctive characteristics that differentiate the variety of marketplaces.

- **Material selection:**
  - **Material specific** - Certain marketplaces are specialised in the sourcing and sale of a specific product or material (e.g. steel, doors, etc.)
  - **Material agnostic** - Some marketplaces can accommodate (the majority of) all types of secondary construction materials.
- **Cost Structure**:
  - **Free to list and browse**: Some marketplaces allow anyone to freely list items for offtake. Typically, a commission for the platform is paid at the point of sale between the materials.
  - **Subscription**: Some platforms offer a premium subscription or regular fee. The offerings of such subscriptions vary from the ability to list and browse all materials, to added value services such as matchmaking.

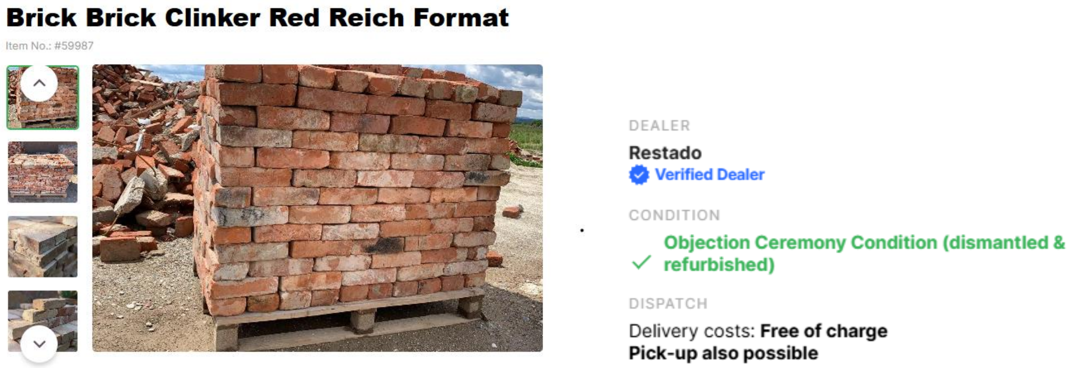
7.3 Barriers & Key Considerations

There are several important considerations and potential challenges that in the use of material marketplaces. These include:

- **Material quality and assurance**: Secondary materials often hold a greater perceived risk. While the actual performance risk of secondary materials is explained further in Chapter 4, at the point of procurement, it is often important to provide assurances with regards to the material quality. This information is critical to reduce the perceived risk of secondary materials in the procurement process. For example, some platforms such as 'Restado' indicate the material quality, as well as highlight any assurances/insurance that may be included.[17]

[16] https://doorsunhinged.com/

[17] https://restado.de/



- **Time**: The purpose of marketplaces is to match the supply and demand of secondary materials. There is an important moment to bridge the time from when materials are needed within a construction project and the time from when they are released from situ. If materials are released too early, the need for temporary storage is likely to increase costs. While if the materials are released too late, then this could impact the construction programme. Optimising the supply and demand of materials (that consider both spatial and temporal considerations) is an important factor to minimise costs associated with secondary materials.
- **Quantity of supply:** Certain materials may have an inconsistent supply. While a secondary material may suit a new project well, limited quantities may reduce its attractiveness.
- **Storage and logistics**: The transportation of secondary materials from, and to, buildings and projects. As mentioned above, the temporary storage of secondary construction materials can be costly. While, if projects are too distant, then transportation costs may increase. (See Chapter 5)
- **Pricing**: As with most marketplaces, pricing is dynamic and can fluctuate based on the overarching economic and pricing environment of construction materials. It is important to consider whether the material price includes storage and transportation, the cost of deconstruction and obtaining the materials, as well as any insurance.
- **Verification**: Through the buying and selling of materials, it is difficult to verify and certify the actual (re-)use and/or disposal of such materials by the purchaser. It can be important for organisations that supply secondary materials to ensure that such materials are being responsibly used/disposed at the end of their life, ensuring alignment with growing ESG reporting requirements and regulations.

7.4 Enablers

There are a range of enablers that can facilitate marketplaces.

- **Material information** – Access to detailed and up-to-date information on the materials, including condition, quantities and locations. This can be greatly facilitated with the wide-scale adoption and integration of digital technologies, such as material passports (Chapter 9).
- **Digitally-enabled platforms** – The use of digital (and AI-powered) technologies can support the matchmaking of materials across various uses. Digital platforms, that can integrate with digital material information (e.g. material passports) can bring together a critical mass of information across larger spatial scales.
- **De-risking** – Providing greater surety on the quality of secondary materials (e.g. through testing (Chapter 4) and insurance (Chapter 7) can help to reduce the perceived risks of material reuse. Clearly presenting this information within marketplaces is important to support procurement processes.
- **(Reverse) Logistics** - To optimise costs of transportation and storage, reverse logistics services can support the physical connection of secondary materials between project sites. Such services can help to reduce the complexity with reuse. For example, an integrated service can be offered by suppliers of secondary materials for specific materials (e.g. Doors Unhinged's service for reused doors).
- **Early engagement –** It is important for contractors and project teams to have early engagement with marketplaces. Pre-purchasing of secondary materials can provide increased certainty to design teams.

7.5 Signposts

City Loops – Material Banks and Marketplaces	The CityLoops website provides resources on establishing and running physical material banks and digital marketplaces for construction and demolition waste (CDW). These platforms connect materials from demolition sites with construction projects, promoting circularity. The site includes replication packages detailing experiences from CityLoops cities, highlighting the importance of storage solutions and digital platforms for tracking and matching materials. It also discusses various business models for material banks and the role of local authorities in facilitating reuse and recycling. [18]
Arup's Material Reuse Directory	Arup has developed a directory to bring together the current landscape of secondary material exchange platforms in a single searchable database. The aim of the directory is to help Arup teams to platforms that may be appropriate for a given project, engage with clients, and assist bid writing, to support the reuse of construction materials. [19] Link here (Arup internal only)

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[18] https://cityloops.eu/construction-demolition-waste/material-banks-and-marketplaces

[19] https://arup.sharepoint.com/:x:/r/sites/IiA44147ReusePlatformDirectory/Shared Documents/General/02. Working folder/20250901 Material Exchange Platform Directory.xlsx?d=wa689d9a724854f83b01b02cfbaa510f1&csf=1&web=1&e=LVCB7z

Joe McGranahan - Consultant, Arup

Action Plan

Key Action	Required skills and knowledge to complete this action	Responsible persona (collaborators in brackets)	Output	Receiving persona(s)
Integrate information on materials into the marketplace	Technical knowledge to assess, categorise and store detailed information of materials (quantities, quality, ease of disassembly, etc.) Access to building information (BIM, schemes & drawings). Detailed information from PDA and/or material passports. See Chapters 1, 4 & 9 for more information. This stage can be done early in the lifecycle of a building, as soon as potential re-development is known.	Consultant engineers and/or reuse specialists: Pre-redevelopment/deconstruction auditor.	Detailed and catalogued information for all materials (quantity, quality, availability date)	Building (materials) owner
List materials on marketplace	Detailed and documented information on materials.	Supplier (marketplace) Material Owner (Building Owner, or Contractor)	Detailed material information clearly listed on marketplace.	Marketplace
Indicate and publicise demand	Detailed information of (new) development material requirements. Engagement with marketplaces and suppliers.	Material recipients (including Developer, design team, main contractor)	Material demand documentation Advertisement and/or notification of available materials to perceiving personas.	Material receives (including main contractor, suppliers, designers) (Potential new role as a Material Hunter). Marketplace
Promote and matchmake availability of materials	Detailed knowledge of supply and demand. Tools to enable matching of supply and demand. List of required quantities for recipient building or project.	Marketplace	Identified potential material demand.	Material donors (owner, supported by general contractor) Recipient building design teams
Pre-purchasing of materials	List of required quantities for recipient building or project. Pre-purchasing of materials to reserve materials prior to materials being released from the donor building.	Owner and/or Developer Procurement specialist (informed via Design team)	Pre-purchased secondary materials for donor project.	Owner and/or Developer Procurement specialist
Transportation of materials	Equipment and expertise to disassemble materials. Material transportation equipment. Storage facility. (See Chapters 3 & 5)	Material supplier, or recipient (such as material contractor) Owner (in cases of owner furnished)	Transported materials	Project site (main contractor for recipient building)

8. Insurance

8.1 Introduction

The successful development of reclaimed materials in the construction industry hinges significantly on securing adequate insurance coverage. However, insurance companies traditionally depend on historical data to evaluate risk and determine policy pricing. Given the innovative nature of these new approaches, there is a lack of historical data regarding the frequency and severity of claims. As a result, insurers are tasked with enhancing their comprehension of the unique risks associated with these emerging business models and practices in order to facilitate their insurability.

This chapter aims to provide a comprehensive overview of the insurance landscape for reclaimed materials.

8.2 Understanding the difference between warranties and insurance

Although they both provide protection against certain risks, insurance and warranty are two different concepts. **Insurance** is a contract between an individual or entity (the policyholder) and an insurance company, in which the insurer agrees to provide financial compensation for specific losses or damages that occur during a specified period of time. The policyholder pays a premium to the insurance company in exchange for this coverage. Insurance policies can cover a wide range of risks, such as property damage, liability, health, life, and more. When it comes to reclaimed materials, the most relevant ones are **Construction All Risks, Property Insurance, Product Liability Insurance** (see details below).

Warranty, on the other hand, is a guarantee provided by the manufacturer or seller of a product that it will function properly for a certain period of time or meet certain specifications. If the product fails to meet these expectations within the warranty period, the manufacturer or seller will repair or replace it at no cost to the consumer.

The main difference between insurance and warranty is that insurance provides protection against uncertain events, while warranty provides protection against defects or malfunctions in a product. Additionally, insurance is typically a voluntary purchase, while warranty is often included in the price of the product.

8.3 Insurance for reclaimed materials

Despite the momentum behind the use of reclaimed, the built environment is facing difficulties to find adapted insurance cover. Indeed, materials salvaged from previous structures can vary in quality and structural integrity. Insurers should thus closely collaborate with the various stakeholders of the sector to improve risk understanding and drive insurability and unlock the potential of those construction practices.

To grasp the specific needs driven using reclaimed materials and the challenges for insurance industry, here are the main types of guarantees impacted:

Product Liability Insurance provides coverage for damages caused to third parties, by the (reclaimed) product.

- Policyholder = product manufacturer or distributor
- Claim scenarios can include third-party damage resulting from collapse due to insufficient load-bearing capacity, or the costs of demolishing and rebuilding third-party property due to quality defects.

Construction insurance and Property Insurance provide coverage for damages to the reclaimed product and the rest of the whole building, during the construction phase (Construction Insurance) or after delivery (Property Insurance). Those guarantees can be selected on top of the product liability insurance. For Construction Insurance, the policyholder is typically the building owner, but often also the contractors and subcontractors can have their own policies. Claim scenarios can include damage due to collapse, fire or water.

Since reclaimed materials may come from various sources and have a history that is not easily traceable, there is a higher risk of potential defects compared to new materials. This uncertainty around quality and risk levels can potentially lead to higher premiums or even lack of coverage under traditional Statutory Warranty and Product Liability Insurance policies.

8.4 Barriers and Enablers

Few insurance products covering reclaimed materials exist, partly due to risks needing to be better defined to make such coverage mainstream.

To this extent, AXA is working on developing a risk framework to better equip underwriters when considering construction projects involving reclaimed materials. Working with ARUP, AXA has identified, for each stage of the reclaiming process (e.g., product removal, transport and storage) various types of risks:

- Risk arising from conditions during initial operation like change in loading conditions over time, or performance deficiency due to severe weather conditions
- Risks related to difficulties during the disassembly of reclaimed products, like unproper removal of coating, or disassembly errors of cutting location

The extent of these risks varies by product; for instance, the risks associated with removing steel beams are moderate due to the precision of manual cutting, whereas the risks are higher for windows due to potential glass breakage during dismantling.

Additionally, the severity of these risks is influenced by several key factors including building characterization to assess the risk associated with potential collapse, the provenance of materials (whether sourced from on-site reuse or reclaimed platforms), the time of primary manufacturing in relation to evolving building codes and standards.

Currently, insurance companies primarily rely on third-party technical consulting firms to assess these risks.

To improve the insurability of reclaimed materials moving forward, it is essential to establish clear norms or “common techniques” standards. These standards would help streamline the evaluation process and reduce the need for extensive case-by-case analyses.

This is for example the case in France, where the CTICM (an organization that supports professionals in steel construction) has developed a guide of professional recommendations for reuse. These professional recommendations have been deemed compliant with the insurance concept of “common technique” by the insurers who are members of the C2P commission (Product Prevention Commission).

8.5 Signposts

Insurance products that cover reclaimed materials do exist, but their availability is limited and often dependent on third-party certification.

8.5.1 Concular RCMI

Concular and VHV Versicherungen have codeveloped the “Reclaimed Construction Material Insurance” (RCMI) module. This add-on module can be selected by customers (usually building owners) as an extension to their Property Insurance to cover reclaimed construction materials.

8.5.2 AXA France

The AXA France’s “Batissur” insurance product provides coverage both during the construction phase (“Construction All Risks” Insurance) and after the delivery of the project Decennial Liability.

Reclaimed materials are covered when their use is certified by third parties technical consulting firms (“Bureau d’études techniques” i.e., providers of testing, inspection and compliance services like Setec or Egis). The different types of consulting firms in the field of construction include structural engineering firms, which focus on the design of structures and foundations, thermal engineering firms, specializing in aspects related to the energy performance of buildings, fluid engineering firms, dealing with plumbing, heating, ventilation, and air conditioning systems, and, environmental engineering firms, which assess the environmental impact of construction projects.

8.6 Contributors

Anne-Sophie Duret, AXA

8.7 Action Plan

Key Action	Required skills and knowledge to complete this action	Responsible persona	Output	Receiving persona(s)
Obtain **third-party certifications** from third-party technical consulting firms or testing houses for reclaimed products.	The third-party firm that assesses the project would have the required skills and knowledge for reclaimed materials per product, building / engineering specialisms	Technical consulting firms/ testing houses	Third-party certifications	Insurance company
Establish clear norms or standards on reusing materials. The sectors should therefore develop **professional recommendations for reuse** (or equivalent)	In-depth materials knowledge and industry influence. Note.	Professional sectors and industry bodies (eg. IStructE, IMechE) The professional recommendations should be validated by relevant authorities.	A set of professional recommendations specifying the conditions for reuse (describing the processes for removal, transport, storage, reinstallation …)	Construction industry, insurance companies
Develop knowledge of reclaimed materials in the insurance industry	Underwriters and risk engineers should develop their knowledge around reclaimed materials and establish internal data bases	Underwriters and risk engineers	Improved understanding of risks, more insurance policies applicable to reclaimed materials	Underwriters and risk engineers

9. Designing with reclaimed products and designing for reuse

Note: Architecture perspective to be added in Phase 2

9.1 Introduction

This chapter explores the process of designing with reclaimed materials and designing to enable reuse. The decision to do this may occur at different points within the project, and it may be before or after a supply of reclaimed products has been identified (this identification process is explored in more detail in chapter 8). The question is then, is there any difference in how we design with reclaimed materials? Other than some minor adjustments to calculations that are covered in material specific guidance such as SCI P427[1] for structural steel, the analytical process of designing an element will be very similar. However, designers have a key role to play in enabling and unlocking material reuse through:

1. Advocating for material reuse
2. Maximising opportunities to use reclaimed elements through flexible design processes and a “kit of parts” design approach.
3. Design to extend the life of building components through durability and easy maintenance and repairs, to ensure they are in a good condition for reuse.
4. Designing for future reuse, by using “design for deconstruction” principles and specifying standardised elements/sizes to maximise the market for reuse.

The process for designing with reclaimed materials may differ depending on whether the project is a refurbishment or new build. For example, if the project is a refurbishment, then initially the focus should be on how to maximise the reuse of materials on site. Alternatively, if the project is a new build, then the focus should be on establishing a flexible design process that enables adaptation to the available reclaimed materials on the market.

<u>Sidebar: First steps for introducing reuse into a project in 2025</u>

1. **Carry out a sustainability workshop with the client and design team**. As early as possible in the design process, discussions should be had around the possibility of reuse. At high level, impacts such as programme, cost, and (likely) carbon, biodiversity and societal benefits should be explored.

2. **Set project targets and establish a champion within the client organisation**. Once an agreement has been reached about the desire to use reclaimed materials, targets should be set and a client champion identified to ensure implementation on the project.

3. **Understand the resource pool**.

- **Refurbishment:** If the project is a retrofit the design team should make best efforts to establish supply from the existing site. A pre-redevelopment audit should be carried out to gain a better insight into the available building elements and their condition (refer to chapter 2). For active building services systems, it may also be valuable to reach out to manufacturers to understand the expected operational performance of elements, and if there are any opportunities for refurbishing/remanufacturing.

- **New build**: If the project is a new build, early engagement with suppliers is encouraged to understand the available resource pool. The maturity of the market for reclaimed products will vary depending on the building element. Structural elements such as reclaimed steel sections may be held by stockists, whereas building services products may need to be sought through a more bespoke arrangement. Even for those items held by stockists, there can be challenges in securing resources as the demand for some elements is greater than the available supply.

4. **Explore discipline specific opportunities**. As the project progresses, the design team should work together to establish the opportunities for reuse.

    - **Structures:** Set up a sustainability workshop with the architect. In 2025, this workshop will likely be about identifying the structural components most suitable for substitution with reused elements. Agreement needs to be established across the design team that reuse is desirable; this will require some thought about programme, cost, and (likely) carbon benefits. There is precedent for this workshop occurring across the RIBA stages, including after stage 4. It’s always worth having a conversation.

    - **MEP:** Carry out feasibility studies to understand requirements/impacts of retaining equipment on site or specifying reclaimed products, such as impact on operational performance, compliance with latest building regulations, spatial coordination and aesthetic impacts.

5. **Small wins are still wins.** Getting designers, clients and contractors comfortable with material reuse and establishing precedent is valuable in itself, even if the scale of reuse is small.

9.2 Advocating for material reuse

The design phase dictates the demand for reclaimed materials and therefore provides the impetus for all previous stages in the material reuse circle to take place. Engineers and designers should therefore be armed with a thorough knowledge of reuse in order to provide clients and other project stakeholders with a holistic view of the benefits and challenges. Table 2 summarises some of these arguments for reuse along with wider considerations and risks. For greater detail refer to the IStructE Circular Economy and Reuse guide[2] or CIBSE’s TM56: Resource efficiency of building services[14].

Table 2: Making the case for designing with reclaimed materials

Driver	Benefits of reuse	Holistic considerations
Embodied Carbon	Reclaimed materials can enable a step change reduction in embodied carbon that would otherwise be challenging and expensive to achieve through low-carbon specification (i.e. novel concrete mixes, high recycled contents, bio-based materials etc.). In the case of building services equipment, it seems unlikely that embodied carbon targets could be met without the use of reclaimed materials.	Use of reclaimed materials could inadvertently increase embodied carbon, for instance where heavier materials lead to increased foundations, or additional transport outweighs the benefit (as can be the case for bricks).
Waste	Reuse diverts materials from downcycling and landfill and helps to meet LEED and BREEAM requirements (MAT 01, MAT 06, WST01).	Discuss with the contractor how damage of reclaimed elements during the deconstruction process can be minimised, and agree with the client who is responsible for safely storing items.
Reducing the ecological and social impact of extracting non-renewable resources	Along with reducing embodied carbon and energy, reuse also minimises water use, pollution, biodiversity impacts, land use and impacts on communities local to the sites of extraction.	Material quantities should always be optimised, even when using reclaimed materials. Refer to the Discussion point below for more context on utilisation and reclaimed steel.
Local Economy	Research has shown that new business models focused on reuse offer significant opportunities for innovation and job creation local to the construction site[3].	While we transition to a more circular economy, lack of labour skilled in material reuse may act as a barrier.
Establishing demand and precedent	While circular construction is in its infancy, there is a benefit to the industry demonstrating demand	If establishing precedent is the main driver (for instance in demonstrator projects), it is nevertheless vital to be transparent and share the

Driver	Benefits of reuse	Holistic considerations
	for reuse and sharing precedent to lower barriers of entry for others.	carbon and financial cost to help move the industry forward.
Meet local planning requirements	Appendix A provides a summary of global policies that mandate implementation of circular principles or can help to strengthen the case for reuse.	
Cost	Refer to chapter 3 for a discussion on cost impacts of reuse. Case Study A provides an example of where the project team reduced risk of unstable virgin steel costs by opting for reused elements.	Procurement challenges (discussed in Chapter 7) can present a risk to budget and programme and a contingency plan should be in place where sourcing is not guaranteed.

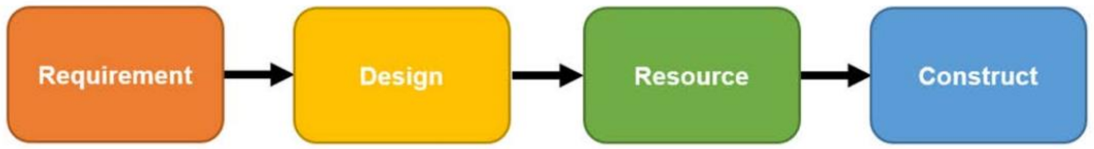
Discussion point: Reclaimed steel utilisation

It is generally understood that scrap steel is a resource-constrained material[4] and that redirecting reclaimed steel sections away from being recycled in an electric arc furnace will result in increased production of high carbon intensity BOF steel somewhere else in the world. It is important therefore that the reclaimed steel be used efficiently on site such that the contingent shift in production methods results in less carbon than if a new efficient beam had been used. Current advice[2] is to only use reclaimed steel where utilisation rates greater than 60-70% can be met, otherwise the carbon benefit compared to recycling and using a highly utilised new section is likely marginal.

In regions where the demand for reclaimed steel is greater than the supply, the onus to use reclaimed sections as efficiently as possible, is even more important to ensure we are making the best of use of these resources. Conversely, in regions where steel reuse is still in its infancy, it is justifiable to have moderately utilised reclaimed steel in order to advance demand and create precedent.

9.3 Maximising reuse opportunities with flexible design processes and resource-led design

Current design practice is typically detached from resource availability, with procurement happening after the design is complete (Figure 15). This has not always been the case. Historically, design has been constrained by available material, and it has been advantageous to make use of already processed material, such as the practice of using ‘spolia’ (stone taken from an existing structure and reused elsewhere) in Roman and Byzantine architecture. More recently, this material constraint has led designers to create highly efficient and innovative forms, such as Pier-Luigi Nervi’s isostatic slabs which were driven by steel shortages in post-World War II Italy.



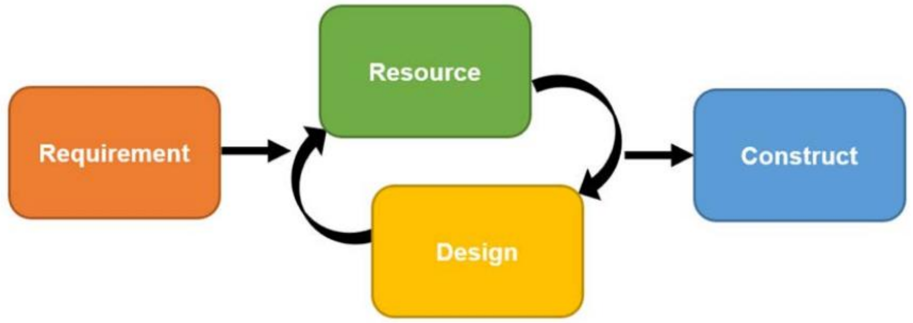


Figure 15: Traditional and resource-led design approaches [Error! Bookmark not defined.]

Today, we can maximise the use and demand for reclaimed materials by using similar thinking, where we let our pool of available reclaimed materials dictate the solution space for the design (Figure 2). This process is known as a ‘kit of parts’ or ‘resource-led’ design. While appropriate technology and the market for reclaimed materials develops, it is likely most feasible to use a hybrid approach, wherein only a portion of the structure (for instance a roof or a plant enclosure) is the subject of a kit of parts design process.

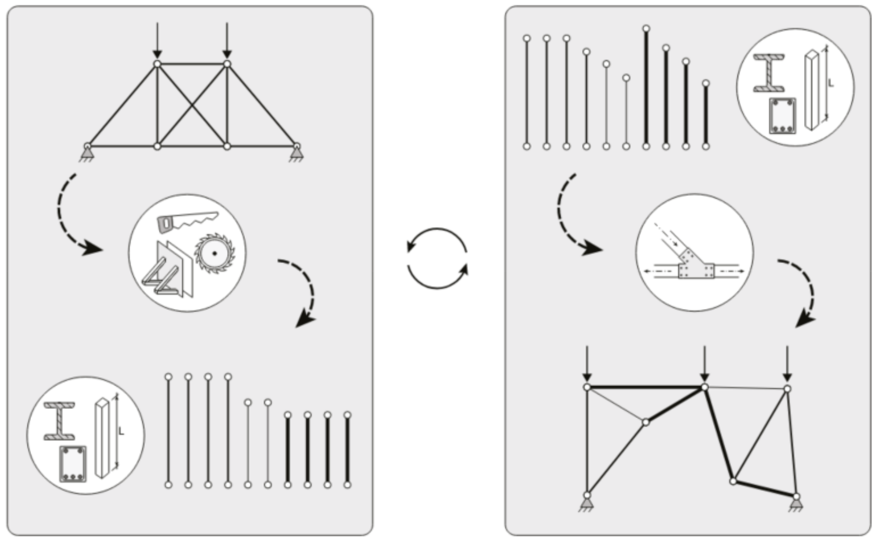


Figure 16: Structural example of how the resource-led design process (right) switches the inputs and outputs in the design process[5]

A resource-led design approach, is most suitable where reclaimed materials can be sourced from stockists, or if the reclaimed materials are coming from the project site, or a donor project. The following key steps are involved, as demonstrated using the example of a heating/cooling emitters:

1. **Understand the available pool of resources**

   Create a schedule of heating/cooling emitters suitable for reuse, including key characteristics such as heating/cooling capacity, acoustic performance, physical dimensions.

2. **Understand the design requirements**

   Carry out heating/cooling load calculations to determine the requirements of different building spaces, also noting additional requirements such as spatial constraints or acoustic requirements.

3. **Pair resources with design requirements**

   Assign heating/cooling emitters to spaces. Compare the requirements of building spaces with available heating/cooling emitters to find the best match for each area.

4. **Repeat steps 2 and 3 adjusting design requirements to maximise use of resource pool**

   Where there isn't a good match for a space, see if any adjustments can be made to the building requirements to enable the reuse of emitters. For example, in an open plan space could the area served by the emitters be adjusted to suit the available resources. Or, if the difficulty is with limited ceiling voids, could the ceiling be lowered in some back of house spaces.

Where a resource-led design process is unsuitable, or if the drive for reuse happens after the design is established, it may be more appropriate to build a **flexibility allowance** into the design. For example, structural reuse is often compromised by the need to find reclaimed elements that match the exact dimensions specified. By including a 'flexibility allowance' in the cross-sectional dimensions, length or weight we can increase the likelihood of finding a matching component, while also creating contingencies where supply changes and the optimal element becomes unavailable. This flexibility can be achieved through more generous structural zones or connections that adjust an element to the correct length.

Flexibility allowances should be defined in collaboration with the whole design team to get buy-in and avoid confusion. The level of flexibility will depend on the boundaries of reasonable efficiency, on interfaces with other elements and allowable weights. For coordination purposes it is advisable that the most conservative sizing is modelled to avoid clashes. While building-in flexibility may seem daunting to achieve for all elements in a project, it is recommended that designers start small, focusing on just those components which would offset the most embodied carbon through their reuse.

Discussion point: MEP Reuse and floor to ceiling heights

Reusing heating and cooling emitters on a project is a great way to reduce the environmental impact of your design. However, it may have other impacts which need to be considered. For example, discussions should be had with the architects about the aesthetic impact for exposed emitters, or the requirements for ceiling or floor voids for concealed emitters. Working with a *kit of parts* limits our opportunities to optimise designs in the way that has become expected, and means that accommodations may need to be made elsewhere to achieve the same floor to ceiling height. However, even if the building height increases in order to accommodate a larger service zone, it is likely that the decision to reuse emitters would still reduce the buildings embodied carbon (WLC Office Heating and Cooling Systems).

Sidebar: Prioritising MEP products for reuse

When prioritising MEP items for reuse, it may be best to target, products with a high environmental impact, passive products (items without moving parts) and products that are not visible to the building user. Based on these guidelines, the following MEP items should be prioritised for reuse[16]:

- Equipment cabinet/electricity cabinet
- Ventilation ducts and passive devices
- Space heating and cooling emitters (radiators, fan coil units, fan air heater/cooler)
- Lighting
- Cable ladders

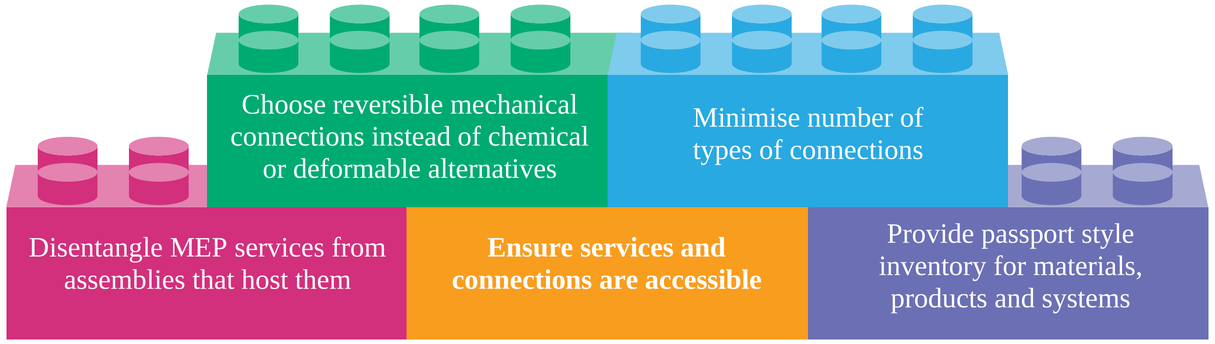
9.4 Design to extend the life of building components

As well as maximising the use of reclaimed products during design, it is crucial that we design to enable reuse at end of life. It is important to ensure the practicalities of maintenance and repair are considered during the design process, so that building components can be kept in the best possible condition for reuse, and can be easily removed from the building at end of life. Early discussions around space planning, should consider access requirements for maintenance, and opportunities for condition-based maintenance should be explored, particularly for MEP equipment. For example, vibration monitoring can be used to detect early signs of problems with pumps such as an unbalanced load, or bearing wear. Detecting and attending to problems early can prevent premature wear and tear and equipment breakdowns, as well as extending the life of equipment. This ongoing monitoring and condition-based maintenance is offered as a service by some MEP manufacturers for equipment such as chillers and lifts[14]. Further guidance on providing condition-based maintenance, using non-destructive testing, for building services can be found in BSRIA Application Guide 1/2003 (Pearson and Seaman, 2003). The agreed approach for the project should be captured in an access and maintenance plan.

Active building systems, such as heating and cooling, should be carefully designed to ensure that they work efficiently. The oversizing of heating and cooling equipment is a common issue, with the heat load of most buildings being less than 15% for the majority of the heating season[18]. Dynamic simulations can be used to more accurately determine building demands, and equipment should be selected based on performance at full and part load. Designing only for the maximum demands of a building can mean that equipment does not operate effectively. For example, equipment such as heat pumps and chillers may cycle on and off more frequently or work outside of their optimum range, leading to reduced equipment life. Once the equipment has been installed it is also recommended that soft landings, seasonal commissioning and building tuning are considered. These processes can optimise system performance, closing the performance gap and ensuring the facilities management team understand how the building has been designed to operate so they can maintain and run it more effectively.

9.5 Designing for future reuse

Designing for future reuse involves designing for 'disassembly, transport and eventual reassembly'[6] ISO 20887:2020[7]. Guidance on the principles of designing for adaption and deconstruction can be found in the IStructE Circular Economy Guidance (Table 20.1) and *CIBSE TM56: Resource Efficiency of Building Services* [14]. An example of the design for deconstruction principles, as they relate to MEP, can be seen below.



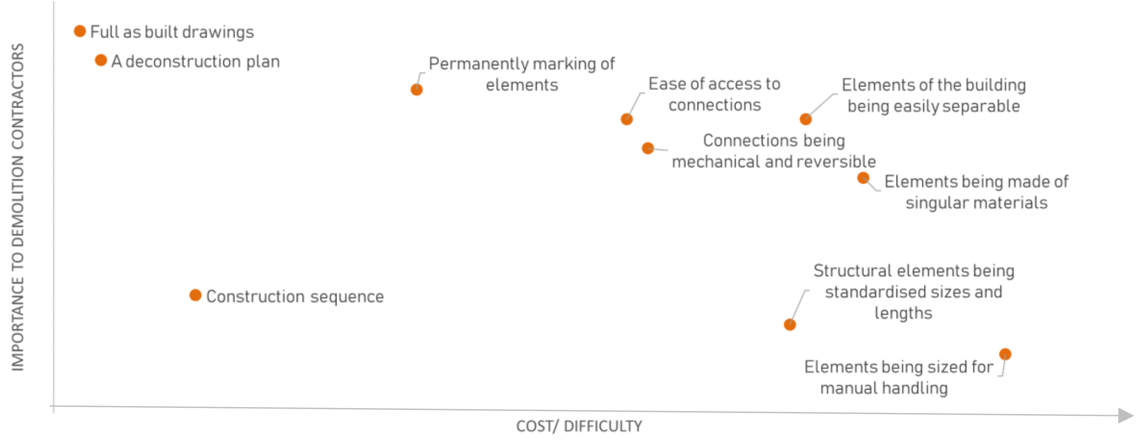
(*2021 Design for Deconstruction Guide for Building Services (WIP).docx*)

These principles aim to aid deconstruction through planning and design, allowing components to be taken apart more easily. This facilitates reuse at the end of life and increases the adaptability throughout the building's life. Materials which are 'locked in' at end-of-life cannot be extracted and reintroduced into the manufacturing process to offset raw material consumption. Designing for deconstruction facilitates the extraction of materials, allowing them to be retained at their highest possible value for as long as possible.

To ensure the details designed for deconstruction are communicated to future stakeholders, it is essential to create a **deconstruction plan**. This document provides guidance to future contractors on how deconstruction can be achieved safely, efficiently, and with optimal reuse yield. It should define the deconstruction sequence based on structural stability, outline key temporary works requirements and explain the form of material passporting used.[8] Where possible, this should be developed with a contractor or construction expert.

At the detailed design stage, designers should also include clauses in their specifications to mandate as-built drawings, material passports and physical tagging of elements. The UK National Structural Steelwork Specification for Building Construction (7th edition), Annex J provides useful clauses to cover these topics as well as the treatment of existing paint or corrosion coatings for reclaimed elements.

Many DfD principles can be provided at no/low additional cost. Figure 1 shows that the actions, related to structural elements, which are most meaningful to demolition contractors are in fact the easiest or cheapest for engineers to implement. 'Easy wins' include documentation (in the UK, key information is already required as part of the H&S file), buildability and easy maintenance. These principles are also applicable to other building elements.

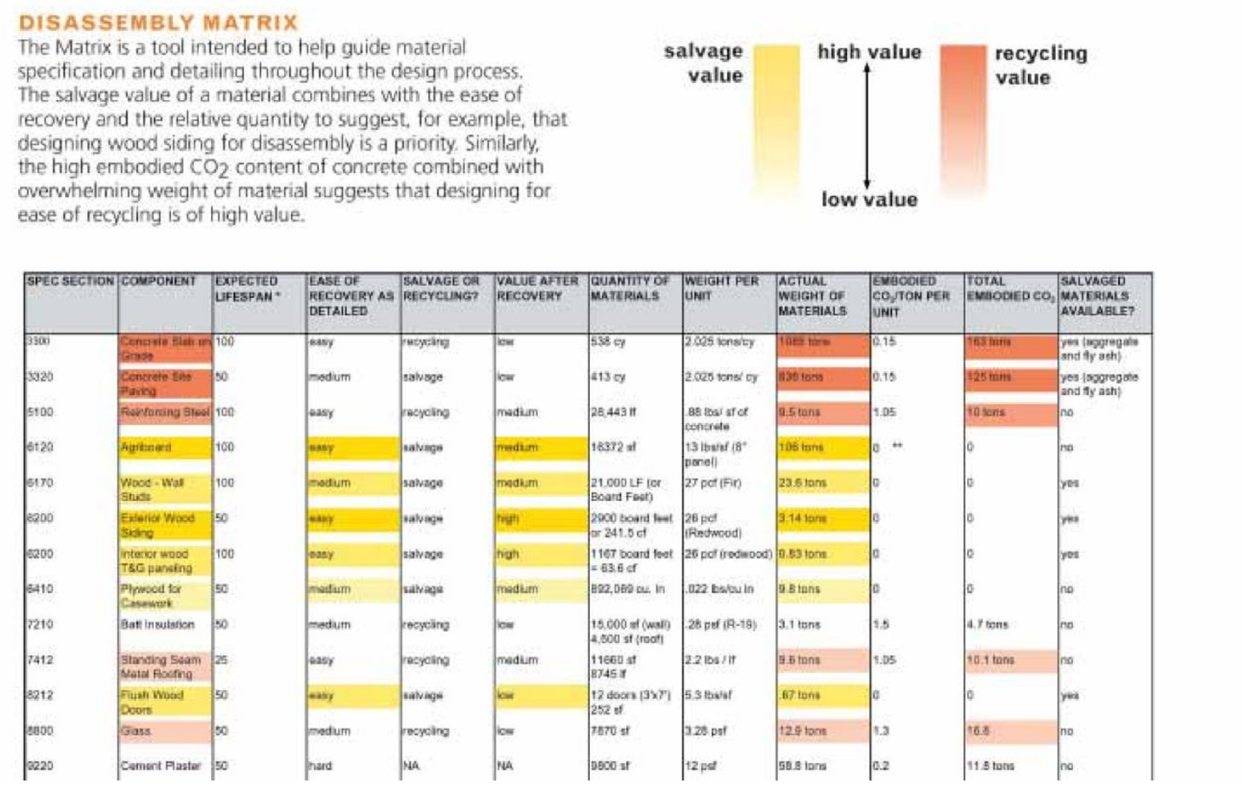


Plot showing importance of specific DfD actions to demolition contractors v. the perceived ease of implementation to structural engineers (based on survey of 30 structural engineers)

DfD is not suitable for every building. Standardisation, redundancy and other DfD principles will usually involve increasing embodied carbon (See case study 2) – to justify this, project teams should assess the likelihood of a premature end-of-life, ideally in the early design stages. Factors to consider include:

- Building location – locations with high land values may be prompted to demolish and rebuild to deliver the highest value for the land. A Finnish study9 found that the more urban the location of the building the more likely it would be demolished, primarily motivated by needing to make way for new construction. Only 5% of buildings were demolished due to structural/technical issues.
- Building sector – offices are more likely to be demolished for aesthetic reasons or changing needs whereas social infrastructure such as hospitals, schools and arts buildings tend to be maintained to extend design life. On average, commercial buildings in the UK are demolished after 35 years, with similar statistics echoed in Japan and the US.
- Building element – designing for deconstruction may be more appropriate for certain systems or building elements such as those with high embodied carbon, or high salvage value. It may also be more appropriate for elements such as building services systems, where design for deconstruction principles can also improve building adaptability, enable products to be reused if the building changes use14. A disassembly matrix can be used to assess the opportunities for different elements, see example below19

As well as designing for disassembly, consideration should be given to selecting standardised products and systems for the building. Not only can this help to reduce wastage when maintaining and upgrading equipment, but it enables easier redistribution of products for reuse elsewhere[14]. It may also be possible to specify products where circularity has been explicitly designed for, to enable replacements and upgrades of components. For example, the Zhaga Consortium, is an industry initiative focused on standardising LED components. This will enable interchangeability of LED light sources made by different manufacturers, without any change in the luminaire[15].



SPEC SECTION	COMPONENT	EXPECTED LIFESPAN *	EASE OF RECOVERY AS DETAILED	SALVAGE OR RECYCLING?	VALUE AFTER RECOVERY	QUANTITY OF MATERIALS	WEIGHT PER UNIT	ACTUAL WEIGHT OF MATERIALS	EMBODIED CO_2/TON PER UNIT	TOTAL EMBODIED CO_2	SALVAGED MATERIALS AVAILABLE?
3300	Concrete Slab on Grade	100	easy	recycling	low	538 cy	2.025 tons/cy	1089 tons	0.15	163 tons	yes (aggregate and fly ash)
3320	Concrete Site Paving	50	medium	salvage	low	413 cy	2.025 tons/ cy	839 tons	0.15	125 tons	yes (aggregate and fly ash)
5100	Reinforcing Steel	100	easy	recycling	medium	28,443 lf	.88 lbs/ sf of concrete	9.5 tons	1.05	10 tons	no
6120	Agriboard	100	easy	salvage	medium	16372 sf	13 lbs/sf (8" panel)	106 tons	0 **	0	no
6170	Wood - Wall Studs	100	medium	salvage	medium	21,000 LF (or Board Feet)	27 pcf (Fir)	23.6 tons	0	0	yes
6200	Exterior Wood Siding	50	easy	salvage	high	2900 board feet or 241.5 cf	26 pcf (Redwood)	3.14 tons	0	0	yes
6200	Interior wood T&G paneling	100	easy	salvage	high	1167 board feet = 63.6 cf	26 pcf (redwood)	0.83 tons	0	0	yes
6410	Plywood for Casework	50	medium	salvage	medium	892,089 cu. in	.022 lbs/cu in	9.8 tons	0	0	no
7210	Batt Insulation	50	medium	recycling	low	15,000 sf (wall) 4,500 sf (roof)	.28 psf (R-19)	3.1 tons	1.5	4.7 tons	no
7412	Standing Seam Metal Roofing	25	easy	recycling	medium	11660 sf 8745 lf	2.2 lbs / lf	9.6 tons	1.05	10.1 tons	no
8212	Flush Wood Doors	50	easy	salvage	low	12 doors (3'x7') 252 sf	5.3 lbs/sf	.67 tons	0	0	yes
8800	Glass	50	medium	recycling	low	7870 sf	3.28 psf	12.9 tons	1.3	16.8	no
9220	Cement Plaster	50	hard	NA	NA	9800 sf	12 psf	58.8 tons	0.2	11.8 tons	no

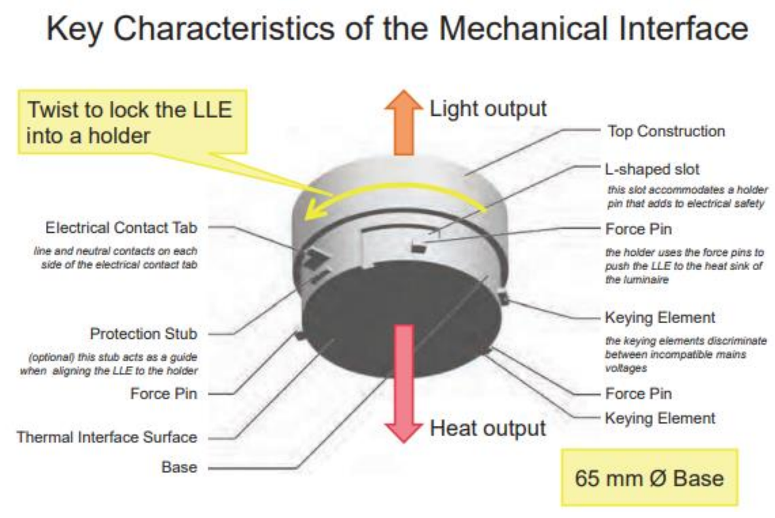


Figure 20 Example of product standardisation: Zhaga Consortium's approach to making LED light sources interchangeable (Zhaga, 2014)

(image from TM56[14])

9.6 Barriers

- **Supply**: In many cases, the supply of reclaimed structural elements and buildings services equipment is less than what is needed for a single major project. Where supply does exist, it may not be local, and transport adds carbon, cost and logistical complexity.
- **Risk:** Concerns about liability and the lack of warranties can be significant barriers. Contractors and owners are often unwilling to take on the risk of reusing products without clear warranties. Other risks or a perception of risk stem from the higher number of unknowns in reclaimed components.
- **Lack of guidance and precedent:** Industry guidance and precedent act to mitigate the perception of risk. Guidance such as SCI P428 has helped push steel reuse into the mainstream, but guidance for other materials is severely lacking. For instance, there is no definitive guide on how to design different buildings services with reclaimed products. CIBSE TM56[14] provides some principles and insights, but more detailed guidance is required.
- **Timing**: The timespan between design and construction can be 2-3 years for medium-sized commercial projects, and decades for infrastructure projects. Where a source of reclaimed components is identified in the process, how can this be assured to be available when it is needed for construction? Where components are mined from an existing building on the site, how can these components be deconstructed, remanufactured and tested in time for the new construction?
- **Condition:** Where components are identified for reuse from an existing building on a site, it may be difficult to establish the condition at design stage, if they are inaccessible or concealed behind other building layers.
- **Bias toward new: T**he preferences of clients and contractors can play a role, with some preferring new products over reused ones due to concerns about reliability and performance.
- **Logistics:** Practical, logistical challenges arise from dismantling, storing, and reassembling products that have the potential to increase costs and affect the programme. For buildings services, the practical ability to clean, re-seal and re-insulate ductwork and piping can make or break reuse goals.

9.7 Enablers

- **Legislation and Policy Support:** Government mandates for reused/recycled content percentages or carbon-based taxes can drive market behaviour and incentivise reuse
- **Design team buy in**: Willingness of clients and the wider design team to accept reused products.
- **Audits**: As discussed in Chapter 2, conducting thorough audits before redevelopment or demolition projects helps identify reusable products, provenance and condition. This is key to establishing the 'kit of parts' the designer can work with.
- **Plug and play components:** Reusing components is most feasible where existing materials and systems can be evaluated and integrated into new designs without extensive modifications.
- **Collaboration with Deconstruction Contractors:** Early-stage engagement with deconstruction specialists helps design buildings for disassembly and supports the cost-effective recovery of valuable components
- **Same owner, different site:** Arguably the easiest form of reuse is where the owner of the material doesn't change hands, but the material is used on *different* site within the portfolio, giving a greater window of time between deconstruction and rebuild.

9.8 Signposts - General

- UK Green Building Council. Design for Deconstruction: Practical Guide. UK Green Building Council, 2024. <https://ukgbc.org/wp-content/uploads/2024/07/Design-for-Deconstruction.pdf>
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- UK Green Building Council. Circular Economy Innovation Insights. UK Green Building Council, 2020. <https://www.ukgbc.org/wp-content/uploads/2020/03/Circular-Economy-Innovation-Insights.pdf>
- Lifecycle Building Center. Design for Deconstruction. Lifecycle Building Center, 2020. https://www.lifecyclebuilding.org/docs/DFD.pdf

9.9 Signposts - Structural

- ISO 20887: Sustainability in buildings and civil engineering works – Design for disassembly and adaptability - Principles, requirements and guidance, 2019
- SCI P428 – design for demountable composite construction systems UK practice
- SCI P427 – Reuse of steelwork
- SCI P440 – Reuse of steelwork pre-1971
- Circular economy and reuse (IStructE) - Guidance for designers
- British Land report on reusing in-situ concrete (pending publication)
- Reuse of hollowcore Norwegian Standard
- Reuse of precast (Dutch standard) CROW -
- European research project "PROGRESS"
- PrEN 1090-X: 2022 – Excecution of steel structures and aluminium structures – Steel structures part X – Reuse of structural steel
- Technische Komission Stahlbauzentrum Schweiz (2022) Re-use – Wiederverwendung von Stahlbauteilen
- Design of Truss Structures Through Reuse (Brütting et al. 2019)[10]
- Reuse of concrete components in new construction projects: Critical review of 77 circular precedents (Küpfer et al. 2023) [4]
- HTS Stockmatcher – a freely accessible tool that can be used to match designed steel sections with those available in a stockholder catalogue.[11]

9.10 Signposts – MEP

Ruddell, Tom, et al. *Justification for Remanufacture in the Lighting Industry*. EGG Lighting, 2021. <https://egglighting.com/wp-content/uploads/2021/02/Justification-for-remanufacture-in-the-lighting-industry-2021.pdf>

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Arup. *Guideline for Building Services Design Inspired by the Cradle to Cradle Concept*. Arup, 2019. <https://build360.ie/wp-content/uploads/2023/01/Guideline-for-Building-Services-Design-inspired-by-the-Cradle-to-Cradle-Concept-1.pdf>

Chartered Institution of Building Services Engineers. *TM56: Resource Efficiency of Building Services*. London: Chartered Institution of Building Services Engineers, 2014.

Chartered Institution of Building Services Engineers. TM66: Creating a Circular Economy in the Lighting Industry. London: Chartered Institution of Building Services Engineers, 2021.

Chartered Institution of Building Services Engineers and Arup. *Circular Economy Principles for Building Services*. London: Chartered Institution of Building Services Engineers, 2020

Remanufacturing Industries Council. *Remanufacturing Sectors: Electrical Apparatus*. Remanufacturing Industries Council, 2021. <https://remancouncil.org/webinars/remanufacturing-sectors-electrical-apparatus-2/>

Alliance for Sustainable Building Products. *Reusing MEP Systems in Construction*. Alliance for Sustainable Building Products, 2024. <https://asbp.org.uk/webinar-recording/reusing-mep-systems-in-construction#:~:text=Summary,costs%2C%20and%20promote%20environmental%20responsibility>

American Society of Heating, Refrigerating and Air-Conditioning Engineers. *Sustainability Roadmap*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2006.

Recolight. *Reuse Hub*. Recolight, 2025. https://www.recolight.co.uk/reuse-hub/

Bengt Dahlgren. *Återbruksguiden för Installationer*. Bengt Dahlgren, 2022. <https://bengtdahlgren.se/resource/aterbruksguiden-for-installationer>

9.11 Case studies - Structural

9.11.1 Case Study 1: Steel reuse at Brent Cross Substation

Year of Construction: 2020

Location: London

When Brent Cross Substation was designed, there was little precedent for including reclaimed steelwork in new construction. The team successfully substituted 57% of the proposed steel with reclaimed, saving 95 tCO2e. At the time, the cost of reclaimed steelwork was 25% less than prime steel, including the additional testing and remanufacturing.

The following factors were considered instrumental to the successful implementation.

- **Aspirational client:** linking steel reuse with the client aspiration for net-zero meant that it became an essential part of the project that stood up to challenges by the contractor.
- **Champions:** The project director identified individuals within the project team who would champion the plan for steel reuse
- **Buy-in:** Early-stage sustainability workshops established that steel reuse was key in meeting the aspirations for a net-zero carbon asset and the idea got buy-in from the whole project team.
- **Early engagement with suppliers:** The stockholder (Cleveland Steel) was contacted even before concept design. This connection helped obtain valuable details on costs and programme impact of using reclaimed steel early on, reducing the perceived risk. While the design did not work directly out of the stockholder's catalogue of sections, the structural engineer based the design on knowing that the stock was predominantly large circular hollow sections, and the final utilisations were >70%.
- **Starting small:** The engineers did not attempt to substitute all of the steel with reclaimed, instead focusing on larger sections where the carbon benefit was greatest.

9.11.2 Case Study 2: Design for deconstruction on Soho Place, London

The trade-off between design for deconstruction and cost and carbon impacts has been investigated in a study on the design for deconstruction potential of Soho Place (London, UK).

The 10 superstructure levels of this mixed-use building typically comprise of concrete filled columns and post-tensioned (PT) concrete floorplates. This structural scheme was chosen to maximise lettable area, provide the best mechanical/structural combination (PT allowed a low energy ventilation system) and satisfy the architectural vision (exposed soffits); however, it would pose significant challenges for deconstruction. The study investigated the cost and carbon impact of a more DfD-friendly alternative, involving steel-only, standard section columns and a demountable composite steel-concrete floorplate.

The study showed that the DfD alternative would result in an increase in both upfront cost and whole-life carbon (Figure 3). However, using the PROGRESS calculation method for accounting for the potential benefit of reuse[12], which assigns the potential benefits of steel reuse to Module D, the DfD alternative provides a net reduction in embodied carbon (Figure 4). The DfD alternative would also result in a lighter frame with standard sections in this instance, which would speed up procurement, reduce crane operations and reduce foundations (although these savings were not included in the comparison).

While quantifying the benefits of DfD is useful for decision-making, it is worth noting that for many projects, any assumption around future reuse is purely speculative, and module D is typically excluded from whole-life carbon assessment reporting.

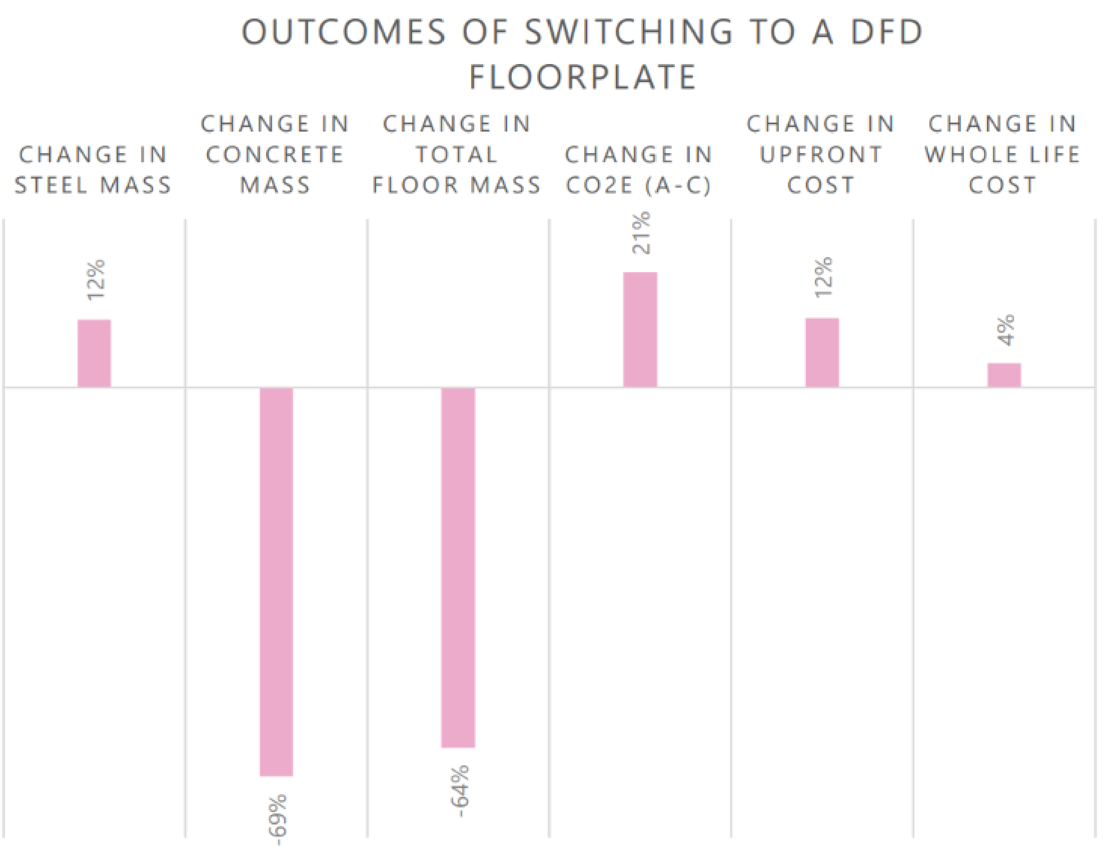

Figure 17: Comparison of the case study floorplate to an alternative designed for deconstruction against key parameters

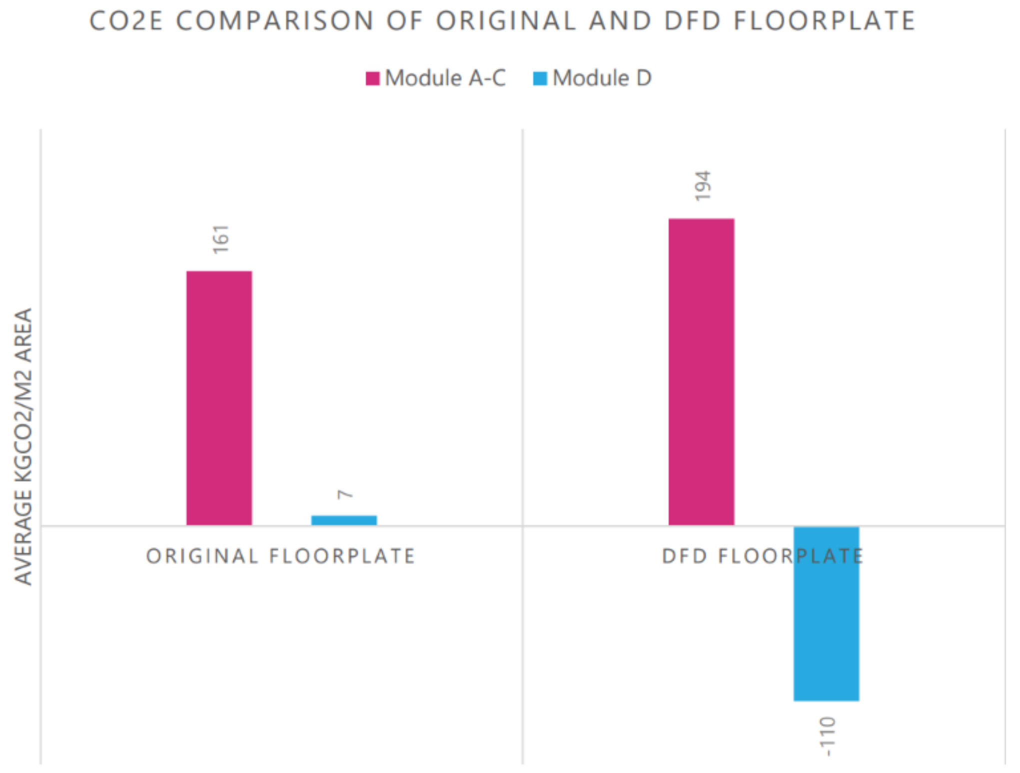

Figure 18: Comparison of the original and DfD floorplates, including the potential benefits of steel reuse

9.11.3 Case Study 3: Euston Tower

Year of Construction: ~2030

Location: London

Euston Tower is an existing office building constructed in the mid-1960s. It is a reinforced concrete frame of 32 floors and stands at 125m tall. Extensive feasibility studies have demonstrated that the tight floor-to-ceiling heights and floorplate designed for cellular offices could not reasonably provide modern spec office space, and indeed the existing building has not been fully occupied in more than 30 years. However, the concrete is in excellent condition and still has significant value as primary structure.

The concept for material reuse at Euston Tower is to ‘harvest’ panels of existing reinforced concrete which can serve as new ‘precast’ panels in the new building. This has arisen out of a desire from the client and design team to make best use of the existing tower while providing a best-in-class commercial offering. The existing foundations and central stability core are to be retained in-situ.

While reuse of steel is beginning to gain mainstream traction, reuse of cast in situ reinforced concrete is still in its infancy.

Our structural typology is ribbed slab (see Figure 5), which is an advantageous form of construction for reuse because the arrangement of reinforcing bars in the slab is clear by inspection. This might not be the case in flat slab construction where bars may be designed for a specific task and their location not immediately evident when viewed externally. Original reinforcement drawings at Euston Tower have been lost, so reuse is limited to simple components of the structure .

Cutting the panel such that the plank would span a shorter distance than the current condition was felt to be not such a great leap into the unknown, provided sufficient anchorage for bars could be redeveloped through the connection detailing. In order to gain confidence in the suitability of extracted panels and investigate the practicalities of the process, a test panel was extracted and sent to the University of Surrey for testing.

The slab exhibited excellent structural behaviour. Tests were arranged so as to simulate the use of the panel in a new floorplate. The panel was subject to four-point-bend testing and subject to 110kNm of applied bending and 120kN of applied shear. This is equivalent to 43kPa of applied area load which is about 8 times typical characteristic high end office loads.

Key to the success of this project to date has been a client who has supported and pushed for innovation, and a design team who was unified in support of reuse.

Figure 19: Extraction of in-situ slab at Euston Tower

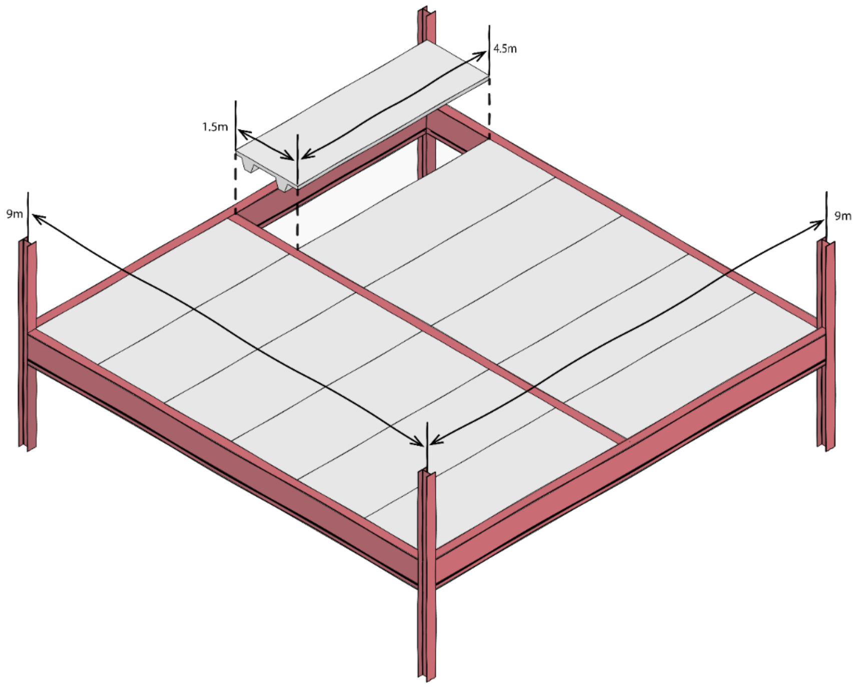

Figure 20: Isometric drawing demonstrating the intended use case for the extracted concrete element

9.12 Case studies – Building Services Reuse

9.12.1 Case Study 4: Commercial Fit-Out (Raine Square, Perth, Australia), overcoming issues with warranties.

A commercial retrofit was undertaken to upgrade tenant space for a renewed lease of 5 years. The project team proposed the reuse of the 28 existing boiling chilled water units, which were either towards the end or at the end of the manufacturer's warranty period. When consulted, the manufacturer recommended replacement of all units instead of reuse. The sub-contractor also refused to warrant the installation. To overcome this issue, a servicing plan was set up between the client and manufacturer which included the manufacturer attending site during commissioning to service the BCWUs in lieu of a sub-contractor warranty. This was pursued by the client due to the cost saving associated (approx. $300k AUD) and the client's own sustainability initiatives. It was

9.12.2 Case Study 5: Office refurbishment (1 Finsbury Avenue, London, UK), MEP reuse

1 Finsbury Avenue, originally built in 1984, underwent a £60m retrofit to transform it from a high-tech and high-end finance office into a modern space for London's tech sector. The project focused on reusing and refurbishing existing mechanical, electrical, and public health systems to minimise waste and embodied energy. This innovative approach preserved the building's iconic features while adapting it to meet contemporary needs.The process of ‘test, appraise, use or abandon’ was applied rigorously to all existing plant, to ensure it was capable of functioning for the 15-year tenant lease period to meet the team’s ambition for reuse. This included getting the original equipment manufacturers on site to survey the plant and provide a report and recommendations on the work needed to extend its life.

90% of the mechanical central plant was reused, including AHUs, cooling towers, and chillers. The cooling towers were refurbished, while the chillers were capacity tested and found to be in good condition. The building's distinctive heated façade system was retained.

The existing public health water systems, including chilled water and hot water systems, were reused. New calorifiers had to be installed but the load profile was optimised to accommodate the mixed-use nature of the building.

https://www.cibsejournal.com/case-studies/case-study-the-challenge-of-reusing-central-plant-at-the-60m-retrofit-of-1-finsbury-avenue/

9.12.3 Case Study 6: Lighting refurbishment Manchester Town Hall (Manchester, UK), Whitecroft Lighting

Manchester City Council has begun a six year programme of activity to decarbonise its estate of buildings, which includes refurbishing the Town Hall. Whitecroft was selected to supply the lighting and had the brief of balancing environmental targets with high quality lighting and the aesthetics of the building. Through their Vitality Relight service, Whitecroft undertook building surveys, to determine which luminaires could be regenerated and which should be replaced. Whitecroft upgraded the building’s Raft T5 Fluorescent lighting system, fitting 2,350 modular LED Gear Trays into the Raft and improved lighting controls to support energy reduction. As part of the Vitality Relight service, a 5-year warranty is provided for refurbished lighting. The upgraded lighting is projected to:

- Make energy savings in excess of 44%
- Reduce carbon emissions by 38 tCO_2e/year
- Extend the lifecycle of the luminaires

https://www.whitecroftlighting.com/case-studies/manchester-town-hall/

https://www.whitecroftlighting.com/sustainability/vitality-relight/

9.13 Contributors

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9.14 Action Plan

Key Action	Required skills and knowledge to complete this action	Responsible persona (collaborators in brackets)	Output	Receiving persona(s)
Establish whether it is possible or appropriate to construct structure using reclaimed components	Diplomacy Find champions within the client organisation Communicate potential risks and design and construction costs	Engineer (client, architect, sustainability consultant)	Project team buy-in Early-stage sustainability deliverables Any fee for additional design work	N/A
Begin discussions with wider design team around access requirements and ensure this is accounted for in early space planning. Discuss proposed maintenance regimes with the client and make them aware of the benefits of things like preventative maintenance.	Knowledge of maintenance required for different building elements.	Engineer (client, design team)	Access and maintenance plan.	Client, contractor, FM team
Create a plan ensure active building elements perform optimally, increasing operational efficiency and extending equipment life.	Knowledge of building optimisation measures, soft landing, seasonal commissioning, building tuning.	Design team, building optimisation expert		Client, contractor, FM team
Structures: Consider whether a resource-led/kit of parts design approach is feasible for all or part of the design	Establish link between structural design tools and supply pool	Structural engineer	Preliminary design drawings	Design team
MEP: Consider whether a resource-led/kit of parts design approach is feasible for all or part of the design	As building loads/requirements are confirmed investigate feasibility of reusing equipment on site. Carry out studies to understand requirements/impacts of retaining equipment, such as impact on operational performance, remanufacturing /refurbishment requirements to bring up to latest building regs.	MEP engineer (manufacturer, architects)	Feasibility study detailing options for using reclaimed materials, for client sign off	Client, design team
Define reuse target and optimal elements for designing with reclaimed materials	Understanding of requirement for high utilisation Understanding of the market for reclaimed materials and which quantities are feasibly procured within the timeframe	Structural engineer (Sustainability consultant, client)	GAs and specifications showing allowable elements to be made with reclaimed materials	Main Contractor Client
Early engagement to locate supply of reclaimed materials	**Existing or donor building:** Obtain pre-demolition audit, condition assessment, test certificates (refer to Chapter X) **3rd Party marketplace:** Initial discussions with suppliers on likely supply and timescales	Design team / 'Material broker'	Design reports and/or tender documentation should outline findings from discussions with suppliers	Client Contractor Cost consultant
Define flexibility allowance	Determine the amount that a section size/weight can increase or decrease by before it is not either efficient or feasibly coordinated	Structural Engineer (Architect)	Specification providing flexibility allowance for elements targeted for reclaimed materials	Main Contractor
Secure source of materials if using a 3rd party marketplace	Knowledge of marketplaces / reclaimed material suppliers	Main Contractor or relevant subcontractor i.e. steel fabricator, precast	Materials supplier Availability timeframes	Structural Engineer Project Manager

Key Action	Required skills and knowledge to complete this action	Responsible persona (collaborators in brackets)	Output	Receiving persona(s)
	Final verification that materials are suitable	manufacturer (Structural engineer, architect)		Cost Consultant Asset insurer
Plan for retention of building elements (where reclaimed elements are to be sourced from site on refurbishment projects)	Understanding of existing building elements, and design requirements of project. Specific knowledge of performance and testing requirements of building elements to be retained.	Design team (contractor, manufacturer)	Design documents (e.g. drawings)detailing items to be retained in place, deconstructed to be stored for reuse on site. Specification detailing any tests required to confirm building elements can be reused as expected.	contractor
Define design for deconstruction strategy for asset	Understanding the balance between upfront carbon and likely lifespan	Client (Sustainability Consultant)	Sustainability report, referencing multi-discipline deconstruction plan	Design team
Determine elements that should be designed for deconstruction	Depending on deconstruction strategy, only certain elements should be targeted i.e. floor beams, MEP distribution	Design team	Design drawings with deconstructable elements clearly highlighted, or specification detailing connections/fixings	Client Contractor
Design for deconstruction	Structural engineering principles Knowledge of deconstruction techniques	Design team (Demolition contractor)	Deconstruction Plan Design drawings with deconstructable elements clearly highlighted, or specification detailing connections/fixings	Client Contractor Sustainability Consultant
Provide good set of as built drawings /model/ digital twin (contractors) to enable easy understanding of what is present in the building at end of life. Create detailed equipment documentation/O&M/ material passports which are set up to enable the documentation of maintenance/repair work.	Understanding of building design and installation	Contractor (design team)	Set of as built data, O&M/ material passports	Owner, facilities management team
Update above documents as building changes over life.	Knowledge of building, ongoing maintenance, repairs and replacement	Facilities management, owner	Up to date record of building elements	Varies, will be useful for pre-redevelopment audit

10. Data management and material passports

10.1 Introduction

Data management is a key enabler for many of the actions described in the cycle of reuse. Valuable data to collect for the reuse of existing materials could include quantities, geometries, build-ups, location, condition, manufacturer, certifications and more… which can quickly appear overwhelming and unmanageable.

Enter material passports. A material passport (MP) is a digital instrument that is used to store qualitative and quantitative data on a material's condition and specification in an accessible way (during asset life and at end of life) to retain the material's value and enable its reuse. Just like a normal passport, it gives material an identity, thereby preventing it from becoming waste.

MPs can be created at various scales, such as material, product, or building and can take various formats, ranging from simple data templates in Excel, to detailed digital systems, such as a passporting platform (see 'Material Passporting Platforms') or a BIM-based MP tool. Guidance on format exists (see 'Signposts') however there are currently no standards or requirements.

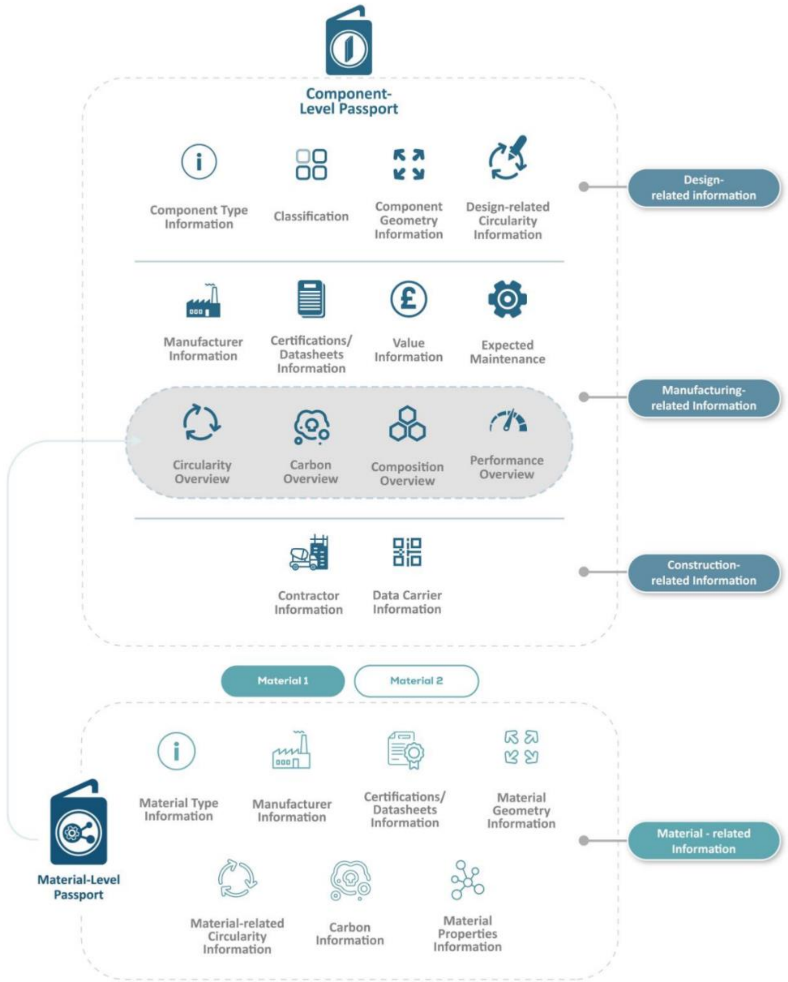

Figure 21 - Information to be included within a material- and component-level passports (the most granular levels of material passporting as defined by Waterman framework (Waterman Group, 2023)).

MPs aim to solve the uncertainty associated with the specification and performance of used materials that leads to a lack of warranties for reused materials, which is one of the main barriers to reuse. Storing information such as material certifications can also bring cost and benefits in other steps to reuse by reducing the representative sample size for testing and verification, as there is more confidence in the material properties from the outset.

Adoption of MPs will have a snow-ball effect on reuse, as assembling lower-level MPs (material/product/component) into a higher-level MP (building/city/country) is greater than the sum of its parts. MPs at a building level can provide building circularity metrics and, at a city and country level, can create a national level materials stock database and allow urban mining and materials exchange at a much wider level, creating a larger and more centralised pool of reused materials.

The lack of MP standardisation and of interoperability between BIM and MP platforms present the main blockers to the widespread creation and use of MPs. However, it is expected that, as passporting practices are more widely adopted and an industry standard is developed, the use of BIM in conjunction with specialised MP software could unlock a more comprehensive and streamlined approach to managing the information needed to create up-to-date and accurate project material databases through automation.

The most important thing to remember when embarking on this step is that passporting is still in its infancy and there is much to be learnt as the construction industry gains experience in it. Therefore, every opportunity to pilot MPs, no matter how small, should be taken to support this industry development.

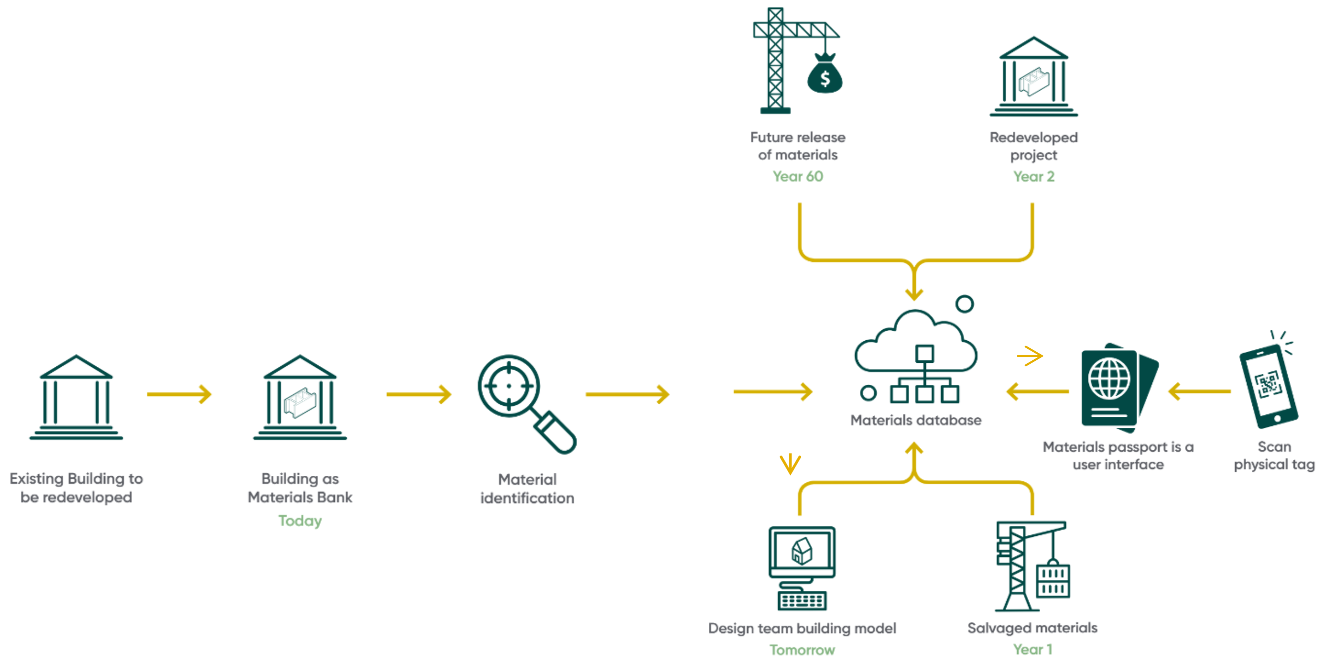

Figure 22 – Data flows enabled by MPs and BIM, adapted from Orms Material Passports policy paper.

10.2 Assumptions

Material passporting terminology used in this chapter aligns with that used in Waterman framework. The framework aims to establish a comprehensive and standardised protocol for the production and management of MPs in the construction industry to address the lack of consistency that poses a significant barrier to material data management to enable material reuse. This chapter focuses mainly on material and component passports (and their product counterparts). Higher-level passports are built-up from these.

MP for Reuse Now: We assume that comprehensive surveys as part of a pre-demolition audit have been conducted to obtain database of materials most valuable for reuse.

MP for Future Reuse: We assume that an as-built model of the asset exists with verified BIM LOD 350 (min) - 500 (ideal, as includes connection/interface details that inform circularity). This means the following is available as a minimum for each element: geometry, material and location defined, with each element having a unique ID and associated asset data

How can I implement material passporting on my project now?

To enable future reuse of materials:

Introduce contractual clauses to cover material passporting by Contractor and FM team. This can be included in Structural Specifications for the Contractor, as exemplified by the National Structural Steelwork Specification, Annex J – Sustainability Specification (Table J.1, presented in Figure 23 below).

Set up material database and populate – liaise with manufacturers for product-specific MPs

Establish naming standard (in future, this should be industry-standardised) and shared parameters file to correctly set up BIM for database interoperability

Connect the MP database to BIM model via a bidirectional link

Contractor and FM team use MPs as a user interface to access and update information during construction and use

To reuse materials on my project now:

Identify materials for reuse – this doesn't have to be the entire building, focus efforts on what's most valuable

Set up material database and populate using existing database or comprehensive, targeted surveys

Establish naming standard and shared parameters file to correctly set up new BIM for database interoperability

Tag physical objects with digital datasets held as MPs using data carriers (stickers with QR codes or NFC tags)

Disassemble elements and store without damaging. Some elements may need reprocessing/reconditioning for reuse. All changes in properties and condition to be reflected in MPs.

Refer to Orms policy paper for more information.

Table J.1 Sustainability Specification – Checklist

Information required by the Steelwork Contractor:
(i) Any part of the steelwork that is to incorporate reclaimed steel products, see J.3.3;
(ii) Any part of the steelwork that is to be left untreated, see J.3.5.1;
(iii) Any details of the fire design, namely the design utilisation per section size in the fire condition;
(iv) Any workshop waste targets;
(v) A Life Cycle Assessment of the whole building, see J.2.2;
(vi) Any specific material sourcing requirements, e.g. products to be sourced from within 500 miles of the project site, see also J.3.2.1.
Information provided by the Steelwork Contractor:
(i) All relevant EPDs for the steel and other products, see J.3.2.3;
(ii) The embodied carbon of the fabricated steelwork;
(iii) Digital records of the "As erected" structure, which should include all environmental, material quality and quantity data, including batch traceability for main structural members, to facilitate future reuse (to be included in the Operation and Maintenance (O+M) manual, see Clause **3.8.4** of NSSS and J.3.2.2);
(iv) Evidence of having in place an Environmental Management System, see J.3.6.2.

Note: The specification of a minimum recycled content for steel products is not recommended. For metals, where there is a limited supply of recycled feedstocks, market stimulation is ineffective and may result in inefficient processing and unnecessary transportation, see the declaration on recycling principles by the metals industry (Atherton 2007).

Figure 23 – Example of clauses specifying information required by the steelwork contractor upon completion of works. While material passports are not explicitly mentioned, they could be easily specified as the material data storage method. (Taken from NSSS 7th edition – Annex J)

10.3 Barriers

- Lack of standardisation meaning there is no widely agreed terminology, definition, scope, or process making it hard to compare data across projects as well as regulatory frameworks that enable common bases for MPs. For example, while the EU has introduced Digital Product Passports and Digital Building Logbooks, it is unclear if these will be adopted for MPs or if a new regulation for the built environment will be established. The Waterman MP framework represents the first important step to a standardised MP protocol, but this is not yet a requirement and must be developed further.
    - A consequence of this is a currently limited catalogue of manufacturer-specific digital product passports. This forces reliance on more generic material passports.
- Unclear responsibility structure for creation and maintenance of MPs. Waterman MP framework proposes (as shown in Figure 24):
    - Manufacturers to be responsible for the creation of material/product MPs in the manufacturing stage containing material-related and manufacturing-related information
    - Principal contractor to be responsible for the addition of design-related and construction-related information at construction stage, based on as-built BIM model. Currently, there is rarely an onus on contractors to provide as-built models. To counter this, as-built model submission and MPs should be inbuilt into the Employer's Requirements at Stage 3, along with the implementation of BIM to ISO 19650 – 1/2.
    - Sustainability consultant to be responsible for providing third-party verification of manufacturer and contractor's information to ensure data validity and robustness, and producing material database with MPs (can choose third-party platform or Excel). Upskilling will be required as sustainability consultant may not currently have the knowledge to undertake this step.
    - Facilities management to be responsible for updating MPs to reflect condition in use
- There is a lack of information for existing building stock, which represents a substantial source of materials for future construction. However, this can be retrospectively obtained via pre-demolition audits and surveys.
- Lack of situation-specific information. This granularity of information facilitates recovery and reuse – knowing how a component is built up informs how it can/should be deconstructed without damage (disassembly manuals).

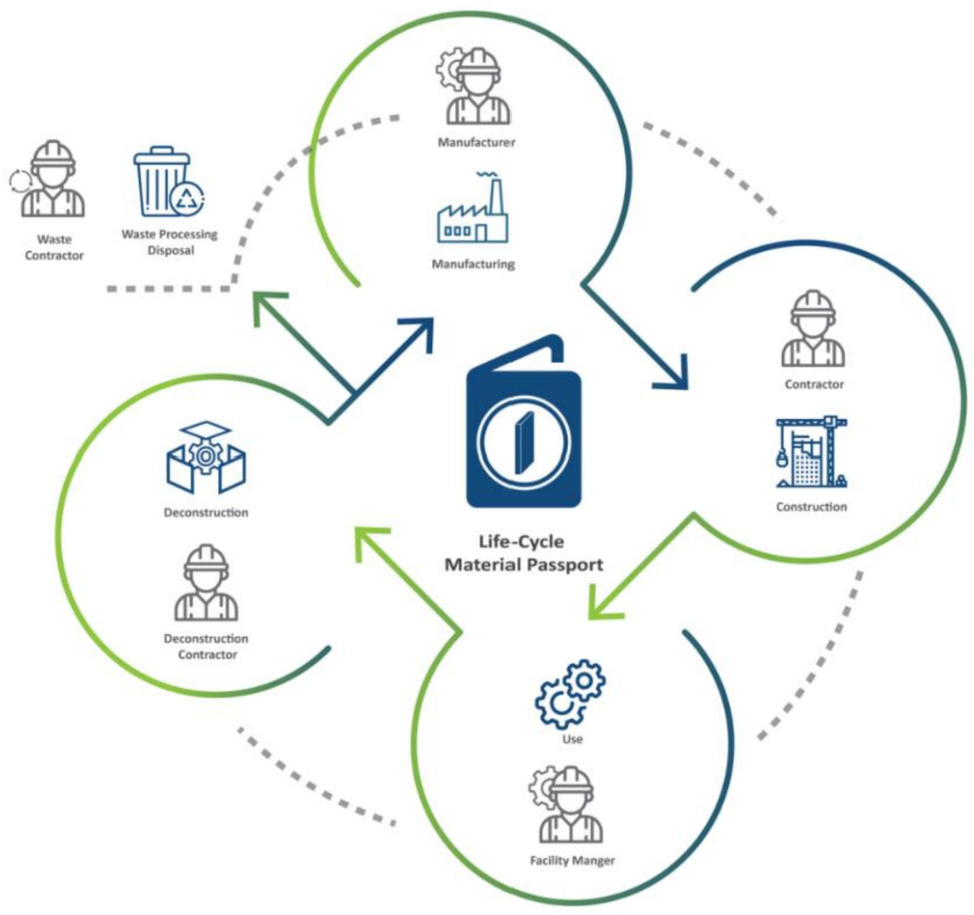

Figure 24 - Responsibility for MPs at different stages of an asset's life (taken from Waterman's Material Passport Framework).

- Lack of a common, streamlined approach to the MP-to-element matching step: BIM models interact with existing material passporting platforms in different ways. Some platform offerings automate the MP-to-element matching step by drawing information on geometry, material type and location from the existing BIM model. These use UniClass codes to map the data.
    - Populating consistent Uniclass/COBie asset data relies on the model being set up correctly for interoperability to the material passport platform.
    - If this cannot be achieved, matching material/product data to (modelled) building elements manually is time intensive, makes the process prone to inconsistencies and leads to a requirement for more rigorous data quality checks of this process
- Material passports not kept up to date as condition changes (through maintenance, repair, refurbishment, etc) during the life of the asset, rendering what was initially a digital twin obsolete.
    - Introduce contractual clause for FM to update material passports throughout the asset's use phase

10.4 Enablers

- At its most basic level, a material passport can be as simple as an Excel spreadsheet.

- Regulation or policy mandating and standardising material passporting: while this does not yet exist, there have been promising policy signals. The European Union's Circular Economy Action Plan is a regulation that falls under the European Green Deal - ensuring Europe reaches net zero emissions by 2050. As part of this, Digital product passport legislation (entered into force in 2024) was introduced to include information on "*product's origins, materials, environmental impacts and disposal recommendations*".
- Modelled elements are assigned a unique ID and provide information on geometry (section size, length), material (grade) and location. Situation-specific info can and should be added as notes on the material passport platform, i.e. whether the material has been subject to fatigue (typically based on use type)
- Comprehensive catalogues of manufacturer specific digital products (with all material/product data) rather than reliance on generic materials/products
- Automated matching step – relies on IFC classification being part of deliverable and requires budget for design/construction team
- Access to a Project Information Model (PIM) - A federated as-built and verified LOD500 3D Model.
- APIs to connect to marketplaces or link to manufacturers to unlock take-back schemes, to close the material loop. Refer to 'Closing the material loop' sidebar and 'Marketplaces' chapter for more on take-back schemes.

Discussion Point: Closing the material loop

Currently, owing to the lack of top-down mandated material passporting, warranties and a formalised framework, the business case for marketplaces is weak. This is leading some MP platforms to seek alternative routes to close the material loop. Madaster, for example, is liaising with manufacturers to explore take-back schemes, where the passporting platform would track and trace materal/product use and signal to manufacturers when these are ready to be fed back into their system for reconditioning.

10.5 Material Passporting Platforms

Company	Material Passporting	Circularity Metrics	Demountability Scores	Environmental Impact Calculations	Functionality Revit/Excel	Bolt-on Capabilities
Maconda	Material Passporting: 10,000 on the platform, mix of generic and manufacturer specific.	Circularity Metrics for both buildings and portfolio	Demountability Measures	Environmental Impact Indicators: Embodied carbon, material health and toxicity.	Excel based input, uploaded to site manually from a bill of materials. To link information to location, need to manually add tags to the BIM model. Or can add generic information like floor level on the site.	Cross portfolio metrics and reuse opportunities; Carbon tracker; report on material flows; Logistics support; Financial valuation.
Madaster	Material Passporting: 400+ Generic Passports & 62,000 verified product level passports.	Circularity Metrics: Metric based on the MCI developed by EMF.	Demountability Measures	Environmental Impact Indicators	Revit Integration & Excel-based Input	Aggregated KPIs across portfolios and geographies; Identifies stranded assets; Urban mining screener; Financial valuation; Compatibility with RICS.
Circuland	Material Passporting: Product Passports - 500 generic passports – looking to grow to 25,000 manufacturer passports by February.	Circularity Metrics	Demountability Measures: Both product demountability and in-situ demountability.	Environmental Impact Indicators	Revit Integration & Excel-based Input	Portfolio Level Passports; External marketplace connection; Building material stocks database (BOQs); Consultancy on data QA; 3D visualisations; Employer's Requirements

10.6 Signposts

EU Buildings as Material Banks (BAMB) 2020 - Buildings as Material Banks – Material Passports Best Practice

Watermans – Material Passports Framework Waterman-Materials-Passports-Framework

Orms and Lancaster University - Material Passports: Accelerating Material Reuse in Construction

Orms Material Passport User Interface Template – Material Passport Template

EU Digital Product Passport Legislation

Arup Sustainability Team Material Passporting Scope Document – Material Passporting Scope.docx

10.7 Case studies

10.7.1 Case Study 1: Schiphol Airport (2020)

The future of a 10-year old cargo building owned by Schiphol Real Estate (SRE) was called into question to make space for a new taxiway sought by Schiphol airport. Recognising the building as a material bank, SRE decided to prioritise circularity in the tender for demolition. To facilitate this, SRE material passported all the structure (using construction record drawings and maintenance records) in Madaster. By well-documenting the existing material, SRE managed to find a single buyer, Lek Demolition (a circular demolition company), for the 2,000 tonnes of steel construction, approximately 82,000 manually removed screws, 15 concrete stairs, 11,000 m² of roof insulation and 11,000 m² of roofing. The structure was dismantled in 6 months and reconstructed 4km away, only requiring new foundations.

10.7.2 Case Study 2: Edenica Building (2024)

The Edenica building is a recently completed new-build 12-storey office building in Fetter Lane, City of London. Waterman was the multidisciplinary consultant for this scheme, covering SMEP design, sustainability and environmental specialist roles, in close collaboration with Fletcher Priest Architects, and Mace as main contractor.

Despite its 120-year design life, the design team recognised that the Edenica building is likely to change use over the course of its life. To facilitate and favour adaption or deconstruction for reuse over demolition, the team decided to implement material passporting for substructure (piles, retaining walls and basement slab) and superstructure elements (steel frame, precast concrete floor planks), external precast concrete façade panels and the raised access floor. Mace provided the material passport information.

This project acted as Waterman's pilot for material passporting on a building scale and has formed the basis for the methodology outlined in their Materials Passports Framework.

10.8 Contributors

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Action Plan

The following table breaks down the actions required by a project team seeking to implement material passporting on their project. It assumes the material database is being built from scratch. Process for reused elements will be largely similar to that above, but the material database is to be created by Obtain material database from existing database OR comprehensive, targeted survey.

Key Action	Required skills and knowledge to complete this action	Responsible persona	Output	Receiving persona(s)
Standardisation of MP format and content	Expertise in data management, CE and regulatory framework	Industry bodies	Unified standard for MP data including terminologies, data formats, aggregation levels	Project teams, including Architects, Engineers, Contractors, Client and FM
Development of data collection methods for existing buildings	Expertise in scanning technologies (Lidar, photogrammetry), AI and machine learning, and building material identification.	Research institutions, technology providers (AI and scanning technologies), demolition/ deconstruction contractors	Protocols and technologies for efficient and accurate data collection on material composition, hazardous substances, and condition assessments in existing buildings	Architects, Consultants (Engineers), Social Housing Organisations, Material Suppliers
Definition of MP scope on project	Knowledge of project scope, identification of elements to be provided with MPs	Project team, Client	Type and scope of MPs to be recorded, BIM model requirements, MP ownership strategy	Client
Creation of Employer's Requirements Specification Document	Knowledge of contracts and MP standards	Sustainability Consultant	Employer's Requirements Specification Document	Client
Creation of product passports	Knowledge of product information and manufacturing process	Manufacturers	Product passports for manufacturers' product range	Principal Contractor
Creation of naming standard for material passports model/database	Expertise in data management, knowledge of MP format, proficient user of material database software (platform/excel)	Sustainability Consultant	Material passports model/database naming standard	Principal Contractor, Sustainability Consultant
Production of as-built model	BIM capabilities in software that can export IFC	Principal Contractor	As-built model with all data (geometry, material, location + unique ID) following material database naming standard (to allow automation of MP-BIM matching step)	Building Owner
Matching of MP to each modelled element, connecting material database to BIM model (ideally via bidirectional link)	Programming skills, knowledge of both BIM and MP software	Principal Contractor, Sustainability Consultant (upskilling required)	Populated material passport model/database, with each element uniquely identified and passported.	Sustainability Consultant
Quality assurance and verification of material passports database	Knowledge of MP standardised format	Sustainability Consultant (with optional third-party verification for further robustness)		Insurers
Development of a MP user interface, to access information from material database	Programming skills, knowledge of material database and user experience	Programmer	MP user interface platform	Client
Contractual clauses to integrate MPs in use	Knowledge of contracts	Client (supported by Sustainability Consultant)	FM team contractually bound to update MPs in use	FM team
Update MPs throughout life of building	Access to and training on MP interface	Facilities Management	Up-to-date MPs at building end-of-life	Client

Appendix A

Relevant European policies

Table 3 describes regulatory frameworks concerning construction materials and sustainability in the EU.

Table 3: Examples of policy encouraging material reuse and design for deconstruction

Policy	Geography
Greater London Authority (GLA) London Plan Policies SI2 and SI7 addressing whole life carbon policy and circular economy	London
Energy Performance of Buildings Directive (EPBD) requires the calculation of whole life-cycle carbon for new-builds, with limits to be introduced from 2030	EU
Corporate Sustainability Reporting Directive (CSRD) applies to large companies or listed companies and mandates reporting on resource consumption, use of reused materials and share of waste reused, recycled and landfilled.	EU
RE2020 Regulation and Anti-waste and Circular Economy Law	France
AGEC Law: The AGEC Law (2020) establishes an extended producer responsibility (REP) system for managing construction waste in France, enhancing waste collection and valorization. Stakeholders must affiliate with eco-organizations and pay an eco-contribution on construction products. The law also revises waste diagnosis to promote awareness of waste recovery and reuse during major demolition or renovation projects.	France
Building Regulations – Chapter 11, Clause 297-298: mandatory embodied carbon limit of 12kg CO2-eq/m2/year (over a 50-year lifespan) for new buildings >1000m² area	Denmark
Building Regulations – new-builds must meet the energy limits set within the 'Nearly Energy-Neutral Buildings' (BENG) to obtain the environment and planning permit	Netherlands
Construction Products Regulation (CPR): The CPR currently doesn't address reusable or bio-sourced construction materials, but the European Parliament supports ambitious revisions aligned with the circular economy, indicating future regulatory changes.	Europe

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