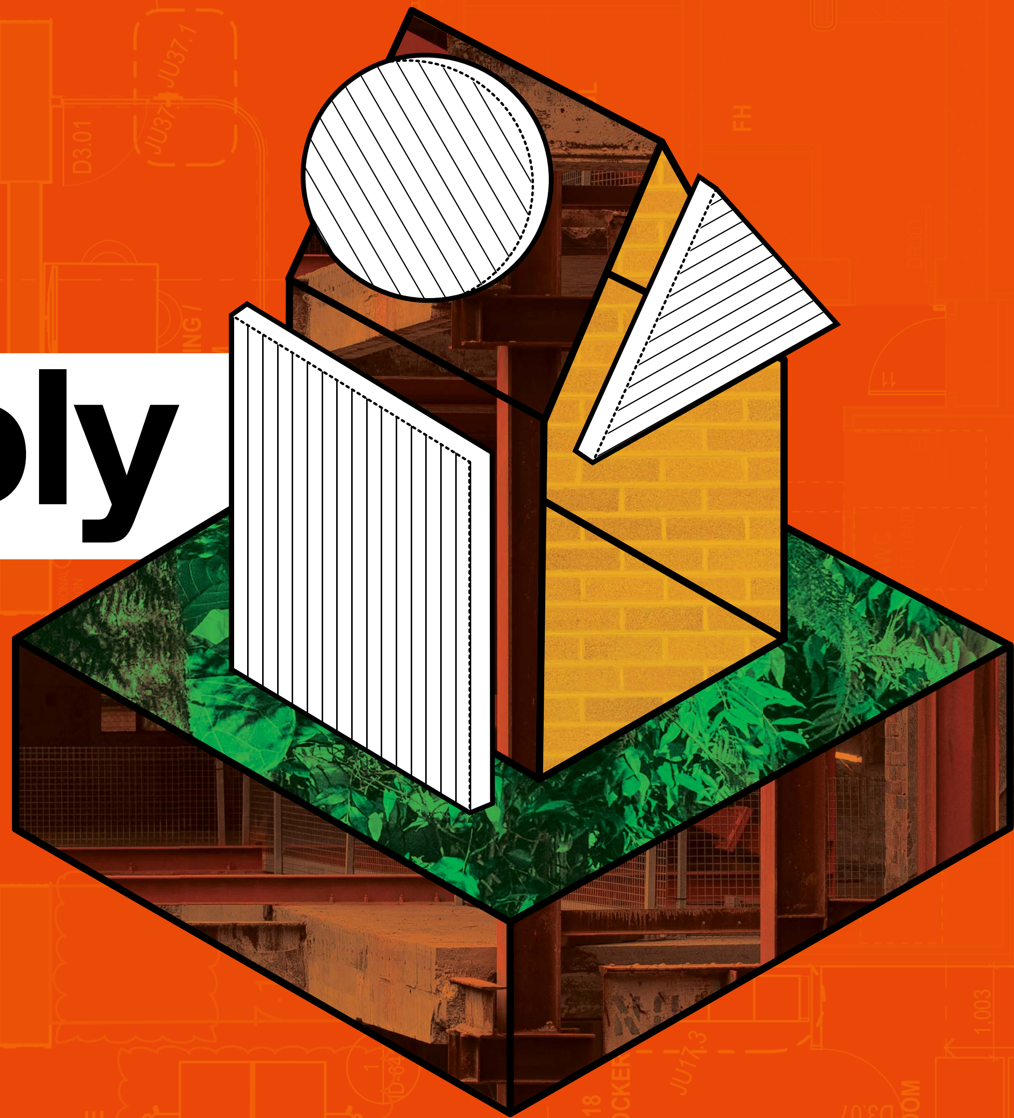
How to write a

Building Disassembly Plan



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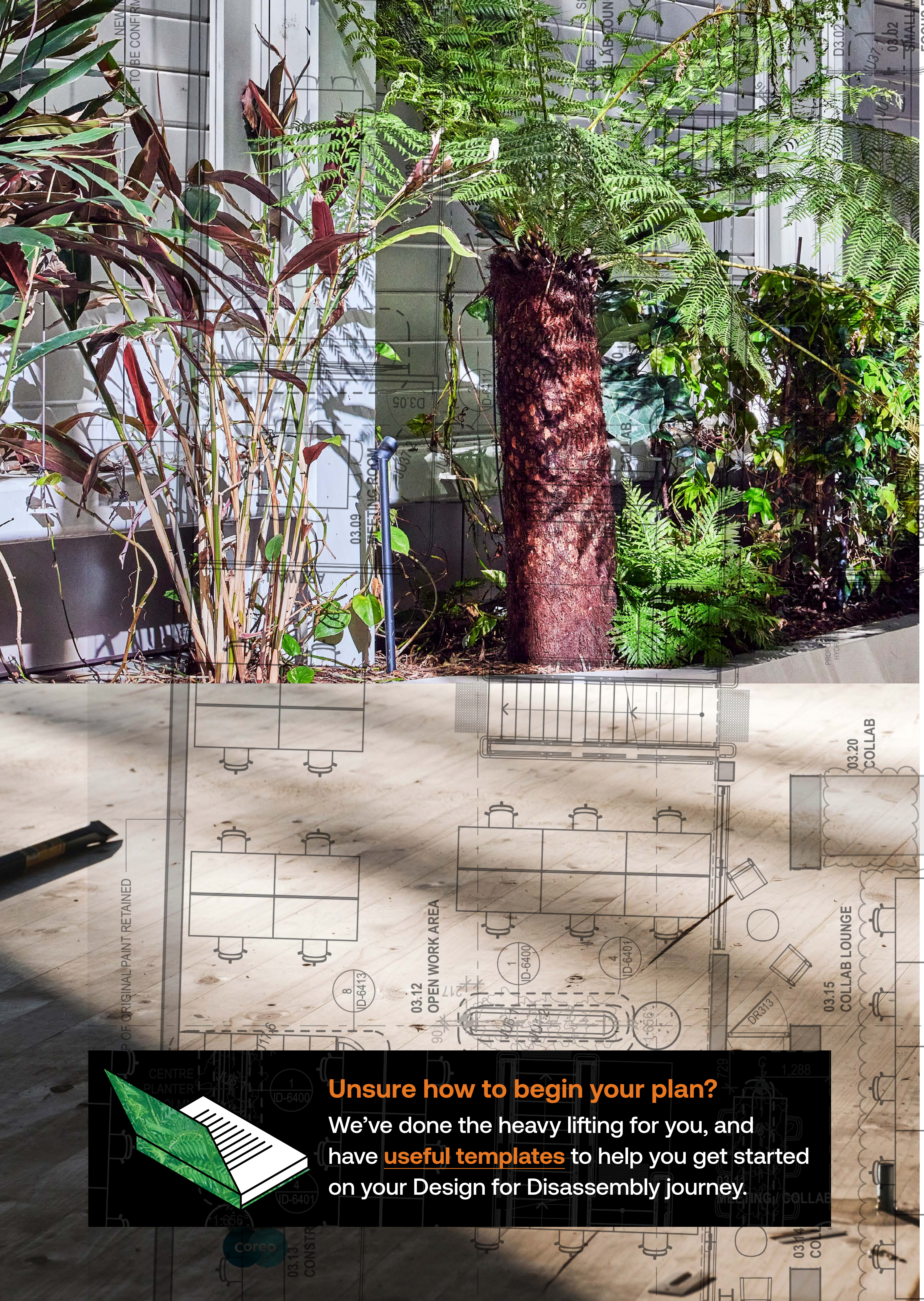

Unsure how to begin your plan?

We've done the heavy lifting for you, and have **useful templates** to help you get started on your Design for Disassembly journey.

The built environment plays a significant role in protecting and enhancing people, places, and the natural environment. To achieve national sustainability targets and create a regenerative future, modern building practices require a paradigm shift that considers disassembly with the same engineering, innovation and thoughtfulness as their construction.

This guide has been developed by Built with Coreo to enable a meaningful shift in how we prioritise Design for Disassembly. When applied to projects of any scale, we are able to fully realise the financial, environmental, and productivity benefits of reusability.

Design for Disassembly (DfD) offers a compelling solution to several critical challenges:

- **Carbon emissions:** Reusing structural elements and materials drastically reduces the carbon footprint associated with manufacturing new construction products.
- **Nature impacts:** By minimising the need for virgin materials, we protect ecosystems, biodiversity, and finite resources.
- **Productivity:** By realising the benefits of greater floor area per tonne of materials and labour-hour input, we can enhance overall industry productivity.

The increasing awareness of the urgent need to transition to a global circular economy necessitates widespread adoption of DfD. By transforming the way we construct buildings, we tap into the vast potential of existing materials and create a more sustainable, resource-efficient future for our built environment.

The purpose of this document is to give practical guidance around authoring a building disassembly plan where elements of buildings are disassemblable. This document also has **useful templates** that can be used on DfD projects.

A contractor's ability to influence DfD can be limited by the stage they become involved with a project, so this guide outlines how contractors can influence change downstream with subcontractors. When the design team is proactively planning for disassembly from concept stage, comprehensive disassembly strategies can be embedded. Additionally, there are opportunities to integrate DfD as design and fastening solutions evolve.

Importantly, a building disassembly plan is crucial to track and record the future removal and reuse of products and materials in the building. Built and Coreo are committed to providing expert guidance and practical templates to promote and enrich current and future DfD projects.

In 2022, Built invited Dr Jacqueline Cramer to speak at an event held promoting circular economy solutions for the property sector. Dr Cramer is a renowned expert on circular economy and one of the driving forces behind The Netherlands' commitment to achieving a fully circular economy by 2050. View Dr Cramer's lecture here.

Following that event, Built authored a paper called Demystifying the circular economy: A practical guide for moving towards a circular economy in the built environment.

As proactive advocates for a sustainable future, we understand that we all play a part in creating culture and helping society define what is good. So, when we gathered to consider how we could continue to drive change in this fast-paced area, we drew knowledge from our experience delivering projects from a kit of parts. These projects mirror the principles of what circular economy considers important; they were designed as "material banks," by using building components that could be disassembled and re-assembled elsewhere at the end of their first life, with very little loss in value.

However, building components can only be taken apart economically if they are designed for easy disassembly and if a building disassembly guide on how to do so is produced. When we sought out examples of building disassembly plans, we found very few relevant resources. So we decided to create our own.

> "We'd like to see Australia use lessons learned in the Netherlands to bypass barriers and constraints identified in its own journey towards a circular economy, so we can accelerate the adoption of a circular economy domestically. Industry collaboration and alignment is critical to the structural changes needed to get there."

We have distilled our findings into this guide to give all projects a head start when considering disassembly, from the earliest stages of design through to handover, and for use in the future disassembly and reuse of the building's components.

Joe Karten, Head of Sustainability & Social Impact

Today, buildings' embodied impacts are responsible for 22% of total global carbon emissions. According to the National Waste Report, the Australian building industry produces 25.2 million tonnes of waste each year - that's 33% of all waste generated throughout the country. Of that building waste, 6 million tonnes end up in landfills every single year. In Europe, natural resources are scarce and construction accounts for around 40% of the material and energy consumption which is why a switch to a circular future is necessary.

When I look at a building, I see not just its entirety, but also the multitude of components and materials that comprise it. I envision endless possibilities for these elements to be repurposed across multiple life cycles. Perhaps it's the child in me, the one who revelled in the joy of building with blocks, but I believe that the property industry shares this innate desire to create, innovate, and reimagine.

> "We must rethink what we take, how and when we make, and what we do with materials we no longer need - this is in fact a question of our survival. With under six years of CO_2 budget left in the world to limit global warming to 1.5°C, the need to act is more important than ever."

Scaling up from the individual building to the broader context of an entire city, I see a world brimming with potential. It's a world where waste is designed out, and we create more from what we already have. This is the essence of a circular economy – one that serves both people and nature.

To achieve this vision, we must revolutionise the built environment, property, and infrastructure sectors. We need to embrace a design philosophy that looks beyond the present and envisions a future where buildings stand tall today yet hold the promise of being recreated tomorrow. This is the power of DfD—a concept that not only preserves the integrity of our structures, but also fosters a sustainable and resilient built environment for generations to come.

Ashleigh Morris, CEO of Coreo

What is Design for Disassembly?

Today, we often demolish structures before many of the components have reached their end-of-life. Most existing buildings were built with little consideration of their end-of-life. Demolition and disposal is the result of not embedding DfD in design.

DfD turns buildings into ‘material banks’ to be harvested for reuse.

DfD is a design technique that takes into account the life span of building layers and the building as a whole (see image below). It involves designing structures so that each of its layers and the materials, products, and components they are made up of, may be easily dismantled for reuse, resale, donation, or recycling.

Buildings designed for disassembly require disassembly plans*. These plans are essential for two key reasons:

- **Ownership changes and time lapses:** Buildings often change hands, and considerable time may pass before disassembly.
- **Preserving knowledge:** A disassembly plan ensures knowledge about optimal element recovery is not lost over time.

Disassembling and reusing building materials, enabled by both DfD and a clear disassembly plan, is critical to achieving global circularity goals including SDG 12. However, we are conscious that one or two buildings will not drive change at the pace required to achieve the government’s target. That is why Built and Coreo are sharing this guide, to enable more projects to adopt a DfD approach ithat s intended to accelerate progress towards a circular transformation.

Skin	20-100 years
Structure	60-200 years
Fittings	5-10 years
Interior	3-30 years
Services	5-20 years
Site	

Adapted from: Brand, S. *How buildings learn: What happens after they’re built.* (1994). New York: Viking.

*

An optimal disassembly plan will act like an assembly plan in reverse, calling out each design element (finishes, services, façade, etc.) and describing both how the element can be disassembled, as well as current best second life options for its component parts.

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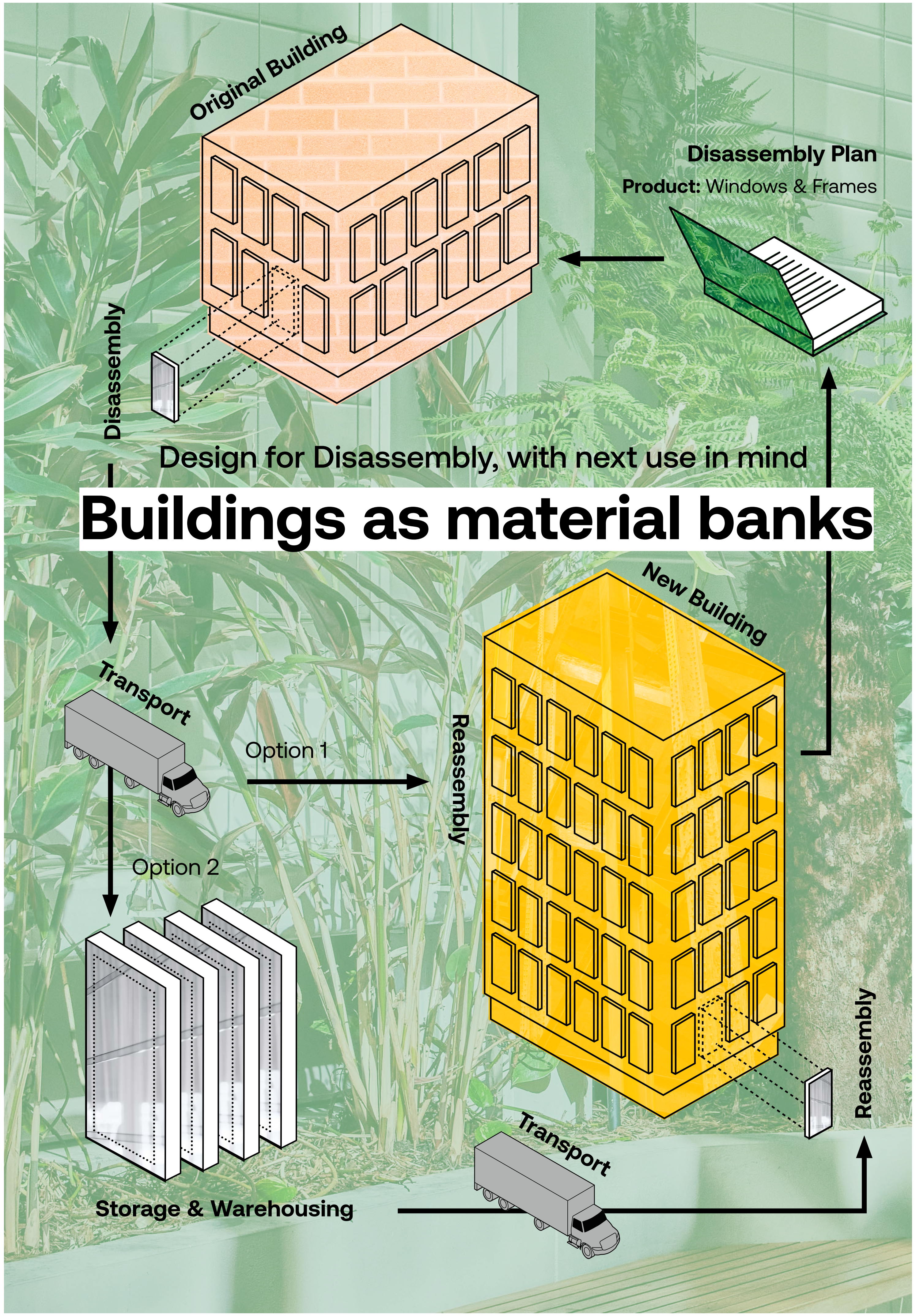


Frequently asked questions

How do I start designing for disassembly?

There are multiple free resources to help you get started on your journey to DfD. Here are a few:

Circular Buildings toolkit – Arup

Demystifying the circular economy – Built

Creating a circular economy for interior fitout design, construction & defit – Forward Thinking Design

What is the value of DfD?

- Life cycle carbon and nature impacts reduction in new build upon materials reuse
- Faster and safer construction, leveraging modular and prefabricated products
- Residual value of building materials at building's end-of-life, decreasing future procurement spend as ownership of materials is retained
- Ability to implement innovative ownership structures, such as Community Land Trusts
- Savings from avoided waste management costs
- Supply chain and regulatory risk mitigation

What are enabling factors of DfD?

To ensure that a building is designed for disassembly, include the requirement for DfD in the project specifications. By doing so, contractors will be able to flag any issues and modify the design early on in the process.

Include the contractual requirement for your contractor to submit a DfD plan at project completion, at the same time as all other project documentation is submitted.

Another potential enabling factor is determined by whether a project is pursuing BREEAM certification. Within BREEAM, measures to accommodate for future changes and adaptations would be awarded one credit under Waste Wst 06 Functional Adaptability category. The DfD philosophy is perfectly aligned with the requirements of Wst 06 as it considers measures for future adaptations of the asset during design phase.

For Developers: Developers with multiple assets should consider DfD as an opportunity to develop an internal inventory of products that can be used and reused across their properties, making them their own offtake partner. Assets can be taken apart, with their components used elsewhere within their portfolio, leading to considerable cost savings through avoided new materials procurement.

For Builders: Several state and local governments are pursuing improved circularity outcomes on large-scale projects. Examples include the City of Ballarat's pursuit to become a circular economy precinct, and the Brisbane 2032 Olympics, which aim to become Australia's first net zero circular economy region. Therefore, there is a competitive advantage for builders in becoming skilled about circularity initiatives such as DfD.

Does DfD cost more?

DfD doesn't necessarily cost more nor does it usually increase the project timeline, as long as the requirement is communicated early to the design team. On the contrary, elements that favour future disassembly are often modular and allow for quicker installation. While there may be administrative costs associated with compiling the DfD plan and a full inventory, be sure to discuss program implications and logistics with your contractor.

Other associated costs include the disassembly costs at time of disassembly (in lieu of demolition costs). Storage costs may also need to be considered should there be a delay in product reuse.

See **appendix** for what we have learnt from implementing DfD in our practice.

Photography © Petra Appelhof

CASE STUDY:

Brummen Town Hall, Netherlands

The Town Hall in the Dutch city of Brummen is a shining example of DfD. Concerned about potential redundancy due to shifting district boundaries, the municipality commissioned a building with a fixed 20-year service life. Architect Thomas Rau responded by designing a building block-like structure, enabling 90% of materials to be dismantled and reused after the designated period. This was achieved by favouring high-quality, prefabricated timber over difficult-to-recycle concrete. The building's design prioritised future reuse and modular assembly, supported by a comprehensive material passport.

The circular design resulted in significant benefits. First it ensured a 20% residual value for building materials at the end of its life, according to contractor BAM. Additionally, the modular construction method reduced construction time, leading to cost savings. By consciously integrating end-of-life considerations into the design phase, the Brummen Town Hall serves as a model for circular construction, demonstrating the potential for buildings to become material banks for the future.

Learn more about the project **here**

How to develop a disassembly plan

Section 1. About this plan

This introduction section to the disassembly plan should include a clear table of contents, indicate what is in the plan and advise readers on how to interpret. This section will be different for every project, depending on the client's needs and the building's expected lifespan.

Section 2. Important considerations

Address the disassembly plan's limitations such as:

- *It remains the responsibility of the contractor conducting the disassembly work to produce their disassembly strategy in line with the safety requirements that are valid at the time of disassembly;*
- *All Building Regulations compliance-related matters will need to be revisited based on the code at the time of disassembly and re-installation of elements;*
- *Elements that may need repair, repurposing, refurbishment, remanufacturing;*
- *Elements that might need to be re-certified prior to using them in a new location (eg. weatherproofing, fire rating);*
- *Elements that will need warranties to be re-certified because of disassembly;*
- *Elements that have not been designed for disassembly (e.g. foundations).*

Section 3. Steps for disassembly

The disassembly process is sequential, logical and measured in the reverse order of a traditional installation. For instance, a sequence could look like:

Step 1: loose furniture

Step 2: joinery and finishes

Step 3: services

Step 4: roofing and façade

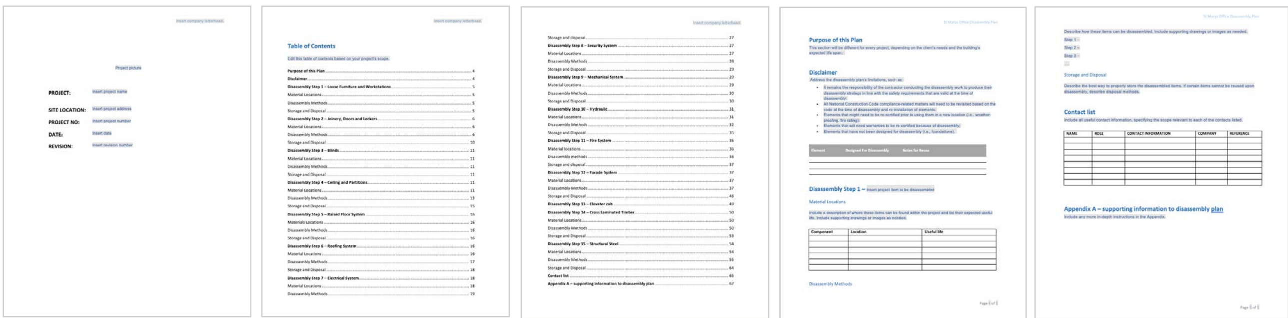
Step 5: superstructure

This section can be viewed like an installation manual, but in reverse. The sequence and number of steps will depend on the project.

Collecting the right information

Critical information to be incorporated into the disassembly plan is to be collected from subcontractors. Engaging these experts provides invaluable insight that will guide the DfD plan to ensure the full scope of opportunities and limitations are explored. It is important to include DfD in their scope of work to incentivise trade contractors to detail the methods of disassembly as economically as possible.

To collect the relevant information, we recommend issuing a questionnaire (template linked opposite) to all subcontractors as early in the design process as possible. Using a questionnaire is a way to gather consistent information across trades. Contractor feedback can be drawn upon to inform the disassembly plan.



Section 4. Contacts list

Include all useful contact information in the disassembly plan, specifying the scope relevant to each of the contacts listed.

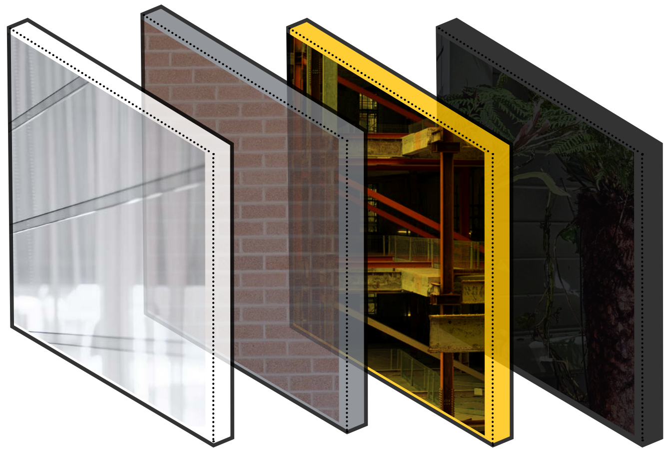
Section 5. Appendix

Additional in depth instructions in the Appendix.

Resources:

[Disassembly Plan Template]

[Disassembly Plan Questionnaire]



> "Anyone who believes in infinite growth on a physically finite planet, is either mad, or an economist"
> Sir David Attenborough

CASE STUDY:

FTD Circular

FTD Circular saw a clear need to create an efficient way for organisations to take a circular economy approach to fitout design, construction, and de-fit. To do this, the FTD Circular asset management platform (available in Australia), powered by Hardcat Lebosi, was designed to capture, track/trace and manage a detailed inventory of all assets within a building or project. Each asset entered into the register can be accompanied by extensive data, including Environmental Product Declarations, supply chain, warranties, reuse, takeback, sale, donation or recycling pathways, and precise instructions for maintenance and eventual disassembly.

This streamlined data repository allows stakeholders to effortlessly access and manage crucial information on the materials and products within a building, facilitating informed decision-making and value extension throughout its life cycle.

By emphasising the detailed tracking, verification and documentation within the asset register, the platform empowers organisations to enact responsible end-of-life strategies for their assets, seamlessly aligning with the principles of a circular economy.

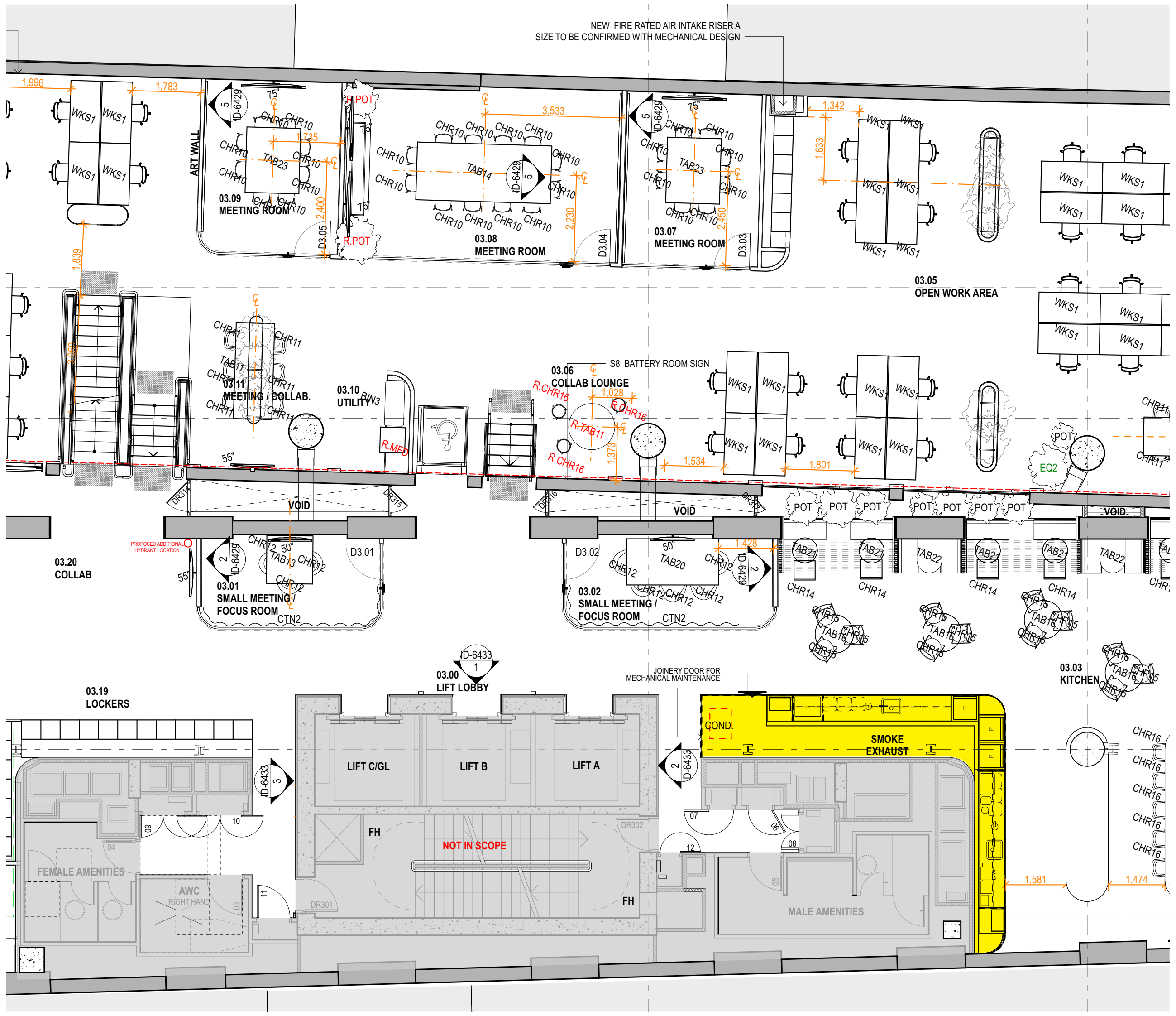
Sample of a building disassembly plan

An example DfD guide for joinery is provided below.

1. Materials location

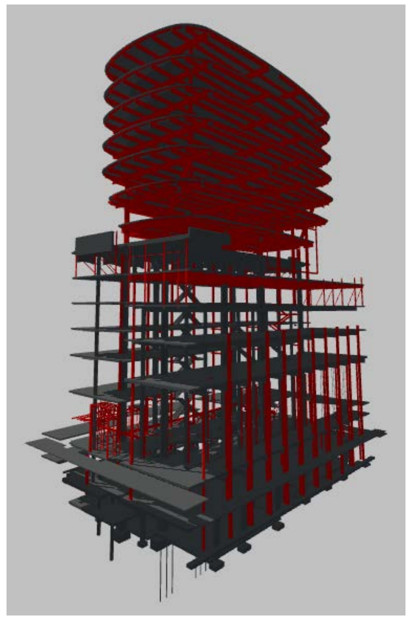
Items relevant to this section of the disassembly plan are listed below.

Component	Location	Quantity	Useful life
Kitchen cabinets	*Level 3*	*10 LM*	*10 years*

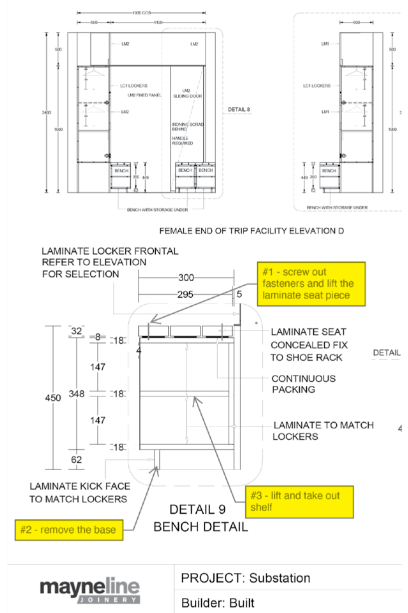


2. Disassembly methods

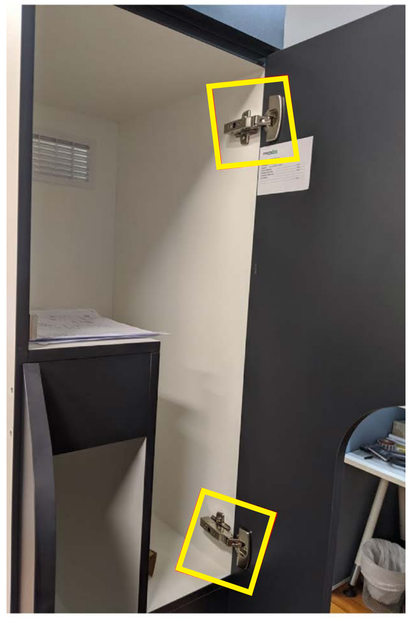
There are several ways trades can show how to disassemble elements from their scope of work. These include:



Screenshots from a BIM model



Shop drawings and markups



Photography and video

3. Storage and notes for recovery

Include any notes around the recovery of the materials covered in this section.

While joinery carcasses are reusable, the reusability of finished elements will depend on the condition post disassembly.

Infill panels may need to be replaced if wall dimensions differ when partitions are reassembled.

For maximum value retention, ensure that once removed, products are stacked on top of one another and kept in a dry, secure location during storage.

Items that cannot be reused are listed below.

Item	Recovery mechanism
Kitchen cabinets	*De-fit and resale / donation with FTD Circular*
Infill panels	Recycling

Glossary of circular design terms

Deconstruction: Unlike demolition where buildings are knocked down and materials are downcycled, deconstruction involves carefully taking apart portions of buildings or removing their contents with the primary goal of reuse in mind. Distinct from disassembly which is considered in the design stage, deconstruction applies to buildings that were not designed for disassembly.

Design for Disassembly: Designing products and assets in a way that the materials within may be dismantled and recovered for reuse, resale, recycling, or donation.

Disassemblable: Able to be separated into different parts.

Digital Twins: A dynamic model that mirrors the real-world building, continuously updated with data collected from sensors, IoT devices, and other sources. It enables simulations, analysis, and monitoring of the building's performance throughout its life cycle, from design and construction to operation and maintenance.

Disassembly Plan: A document showing the sequence of processing steps, the type of disassembly action, the part or fastener worked on in each step, the tools used, and the resulting material and part outputs (with its potential limitations) from fully disassembling a building.

Downcycling/Upcycling: Downcycling is a form of recycling that involves the destruction of waste in order to create something new (typically of less value than the original), whereas upcycling takes waste and creates something new that is of greater value than the original, without destruction of waste.

Material Intensity: A measure of the resources (e.g. water, energy, materials) needed for the production, processing, and disposal of a product or process. Refers to both volumes and types of materials (the lower the diversity of materials, the easier to manage).

Material Passport: A set of data describing defined characteristics of materials in products that give them value for recovery and reuse.

Modularity: The degree to which a system's components may be separated, repaired or replaced, and recombined, often with the benefit of flexibility and resilience.

Multifunctionality: Having several different uses, often to the benefit of lower material intensity.

Recovered Resources: Products or materials created from reused, repurposed, restored, or recycled products or materials.

Renewable Resources: Sustainably and naturally replenishable resources such as timber, fungi, or food.

Restorable Resources: Technologically or professionally returning a product or material to its former condition, place, or position.

Resources & links:

Disassembly Plan Template

Disassembly Plan Questionnaire

Circular Buildings toolkit – Arup

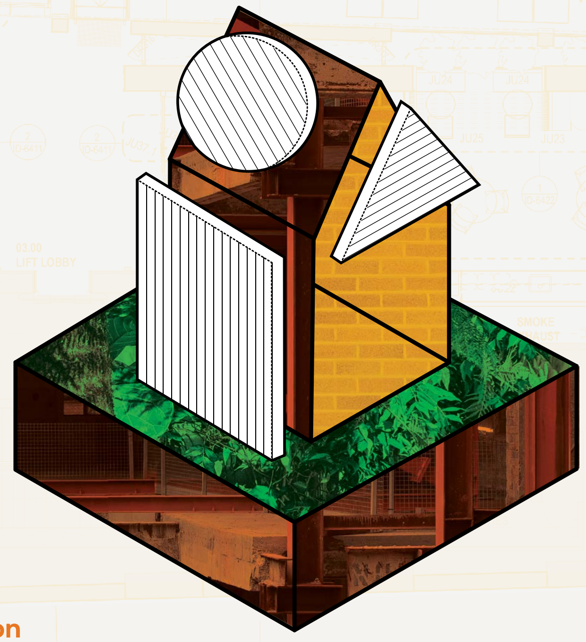
Demystifying the circular economy – Built

Creating a circular economy for interior fitout design, construction & deft – Forward Thinking Design

Circular Economy – UKGBC

Design for a Circular Economy – City of London

Guide to Circular economy – European Commision



About the authors:

Filomena Beshara is a Sustainability Manager at Built. Her career has focused on creating change in the built environment – working towards healthier buildings that use fewer resources and drive positive social and environmental outcomes. She works with clients, integrating their values to inspire change and action on projects, and delivering leading sustainability results.

Cameron Kaufman is a Circular Economy Specialist at Coreo. She drives circular innovation in projects, methodologies, and organisational capabilities through systems-based analysis, reimagined strategies, and collaborative initiatives. Her work spans across all key economic sectors and has a deep specialisation in the built environment and the resources sector.

If you would like to work with us towards a circular economy, or if you have any feedback, please contact Joe Karten at joekarten@built.com.au or Cameron Kaufman at cameron@coreo.com.au.

Appendix: What we have learnt about DfD

- **Planning ahead is crucial** when designing for disassembly. Project teams should start by categorising the most common building materials and products, and decide where they fit along the 10R Model of the circularity continuum (from completely reusable to destined for recycling and/or waste-to-energy).
- **Questions about DfD** should be asked of the subcontractors very early into the project, to allow for any design modifications required to accommodate disassembly. Once the head contractor receives the completed questionnaires from the subcontractors, they should carefully review the answers and drill down into the details with the respondents.
- Make sure to clarify with materials suppliers if there are any **limitations to their product warranties** if they are reused elsewhere.
- Make sure that the **sequence of disassembly** among trades is logical, and highlight any potential overlaps between trade scopes, or instances where trades need to work together to disassemble certain elements within the project.
- **Foundations** are hard to reuse as they are usually made of steel piles and concrete which cannot be disassembled and are difficult to access. We have yet to find a solution to effectively design foundations for disassembly and reuse. However, capturing full details of foundations may facilatate their reuse insitu under a new building scheme in the future.
- **Carpets tiles, resilient floor tiles, and wood flooring** can be easily installed for disassembly. If the tiles are installed with glue or a strong adhesive, damage may occur when they are stripped off, and re-installation may be more difficult. A better solution entails a floating floor (i.e. resilient floor planks, timber planks), glue-free adhesives, or loose lay, so that the tiles and planks can be removed and re-installed elsewhere as needed.

Different levels of circularity (10R Model)

More Circular

Refuse: Prevent raw materials' use
Reduce: Decrease raw materials' use
Redesign: Reshape product with a view to circularity principles
Reuse: Use product again (as secondhand)
Repair: Maintain and repair product
Refurbish: Revive product
Remanufacture: Make new from secondhand product
Repurpose: Reuse product but with other function
Recycle: Salvage material streams with highest possible value
Recover: Incinerate waste with energy recovery

Less Circular

Source: Cramer, J., The Raw Materials Transition in the Amsterdam Metropolitan Area: Added Value for the Economy, Well-Being and the Environment, Environment, 2017, 59, 3, 14-21. tandfonline.com

- **Ceramic/porcelain tiles** cannot be designed for disassembly. However, if you are planning to use them for bathrooms, you may consider bathroom pods and/or removable tile modules/panels that already have tiles in place and can be removed in their entirety after project completion, and installed elsewhere.
- **Joinery** can be easily designed for disassembly. Screw connections and bolted plates should be preferenced over the use of adhesives, for a cleaner and easier disassembly.
- Within the category of **building services**, the majority of equipment can be disconnected and used elsewhere. Cables, conduits, and pipes can also be reused, but it is important to verify that no surface damage or major bends have occurred. Cables and conduits should be running through an area that is easy to access (raised floor, ceiling cavity) as pulling on them can cause damage.
- **Façade systems** can be designed for disassembly by using modular systems with accessible connections and joints.
- **Interior framing and ceilings** mostly involve light gauge steel framing and plasterboard/mineral fibre or metal pan ceiling tiles. Light gauge steel framing is hard to reuse, as it gets damaged during disassembly (especially the bottom and top tracks). Discuss with your ceilings and partitions contractors whether there is an opportunity to fasten steel framing in a way that allows for disassembly. Enquire if alternate paneling systems are available as an alternative to plasterboard, as plasterboard is very hard to reuse once it has been fastened to steel tracks. Finally, it is worth mentioning that there are several systems on the Australian market that are designed to be assembled and disassembled in a non-destructive way over many life cycles (e.g. **Klikwood** and **X-Frame**).
- **Roofing systems** cannot be reused as they need to be laid down on a specific surface to be truly waterproof. However, roofing system components can be designed for disassembly, so elements such as corrugated steel roofing panels and tiles can be taken for reuse elsewhere. Air and vapour barriers are unlikely to be reusable after first use.
- **Structure and superstructure** can be designed for disassembly through modular solutions such as bolted precast panels, CLT and GLT, and steel members. Poured-in-place concrete cannot be disassembled and should not be considered a circular solution, but rather a permanent installation whose life cycle should be maximised.

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Working closely with international brands and the UK's biggest businesses, we transform new and heritage buildings, uplift sustainability standards, deliver complex live-sites, and roll-outs.

Committed to growing and servicing long-term relationships with global brands and the UK's best businesses, works range from luxury high-end hotel and retail, to the next generation of workplaces, across sectors to help accelerate our clients' priorities.

builtuk.co

Coreo

Coreo is Australia's most awarded circular economy consultancy, renowned for its expertise in successfully implementing circular practices at scale across all major economic sectors.

Coreo exists to tackle the root problem — our unsustainable, linear take-make-waste economy, which propels nature loss, climate change, growing inequality, and pollution at an alarming pace. As the trusted team of specialists for high-profile organisations, Coreo works to harness their collective power to disrupt the outdated 300-year-old linear economic paradigm, challenging the notion of infinite growth on our finite planet.

Our goal is to increase the circular maturity of individual organisations, catalysing broader economic transformation from today's linear economy to a circular model that emphasises eliminate-circulate-regenerate principles.

coreo.com.au