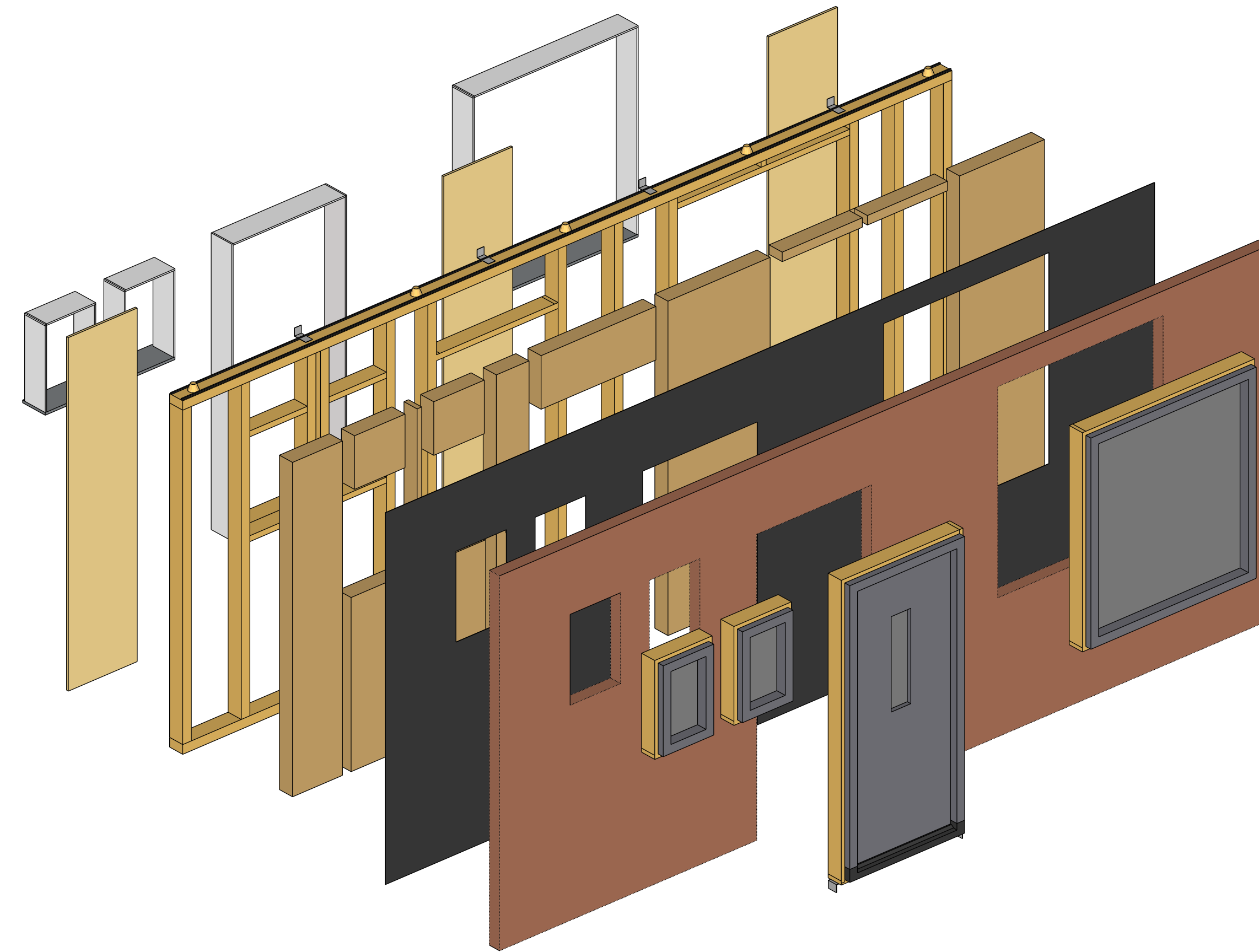


CIRCULAR ADAPTABLE INDUSTRIALISED FAÇADE SYSTEM

For building renovations



Introduction

Problem statement & objective

The construction sector significantly impacts the environment, responsible for 11% of national CO₂ emissions and half of primary material use. With 33% of these emissions coming from residential renovations by 2030, the Netherlands targets a fully circular construction economy by 2050. However, barriers such as material availability, storage, lack of digital infrastructure, quality assurance and high costs hinder reuse. Modern façades, with their complex, non-reversible designs, further complicate recycling.

Industrialised renovation offers an efficient, scalable solution using digital tools and standardised, adaptable components. This research aims to develop a modular facade renovation system that incorporates reusable materials while maintaining affordability and meeting building codes. Focused on row houses, which make up 42% of Dutch homes, this approach supports standardisation while allowing adaptability for non-uniform facade layouts. The strategy involves replacing façades while retaining load-bearing structures and openings. Bio-based and recycled materials will be prioritised for their potential to support CO₂ neutrality, with biodegradability and reusability serving as key criteria. This ensures materials remain within either the biological or technical cycle of the circular economy, helping to close the loop and reduce resource loss.

Case study façades

The design of the renovation system will be tested on two different facade layouts. The selected buildings are row houses that no longer meet current regulations and standards. The chosen row house are representative of the average row house in the Netherlands, meaning they have a masonry wall and do not exceed three stories in height.

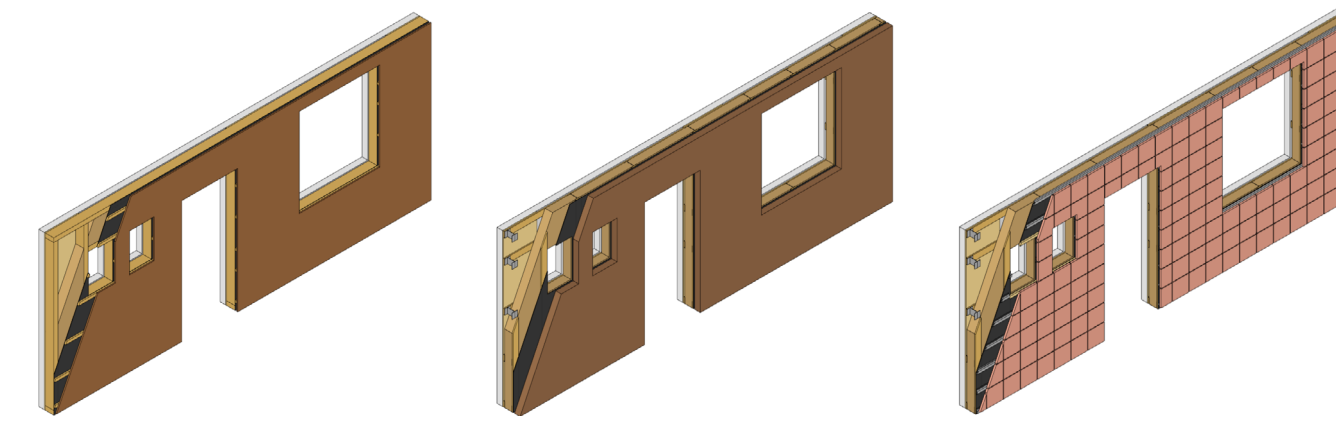


Material selection

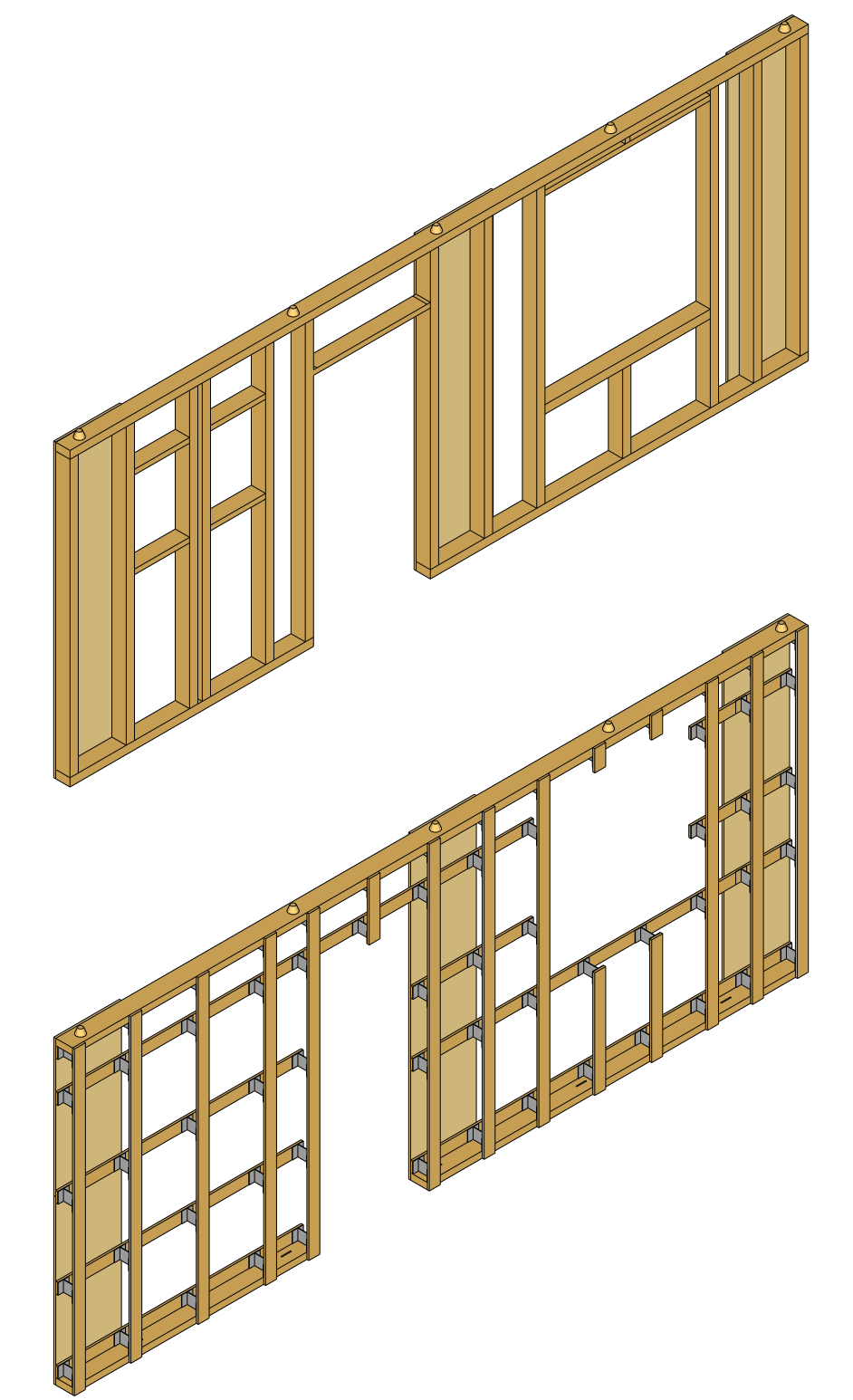
Preliminary facade designs were made based on adaptability, environmental impact, reuse possibilities and reducing materials. Each one of these designs used materials that were researched in the literature review. They all contribute to a circular economy.

Design concept

The insights from the different design approaches and the reusability study were combined into new preliminary designs. Various cladding options such as ClickBricks, Pretty Plastic or wooden cladding can be fitted to the structure of the facade system.



The structure consists of either a plywood frame with aluminium brackets or a timber frame construction with demountable steel connections hidden in the timber. It is not necessary to cover the entire back of the structure with OSB panels. Instead, both structures are reinforced with smaller OSB panels to keep the structure rigid. Timber cone connections allow easy assembly without precise alignment, as upper facade units slide onto lower ones, creating a secure, self-locking fit with a 1 cm gap that is filled with compressible tape. These connections require no screws or chemical anchors and allow for easy disassembly.



Evaluation

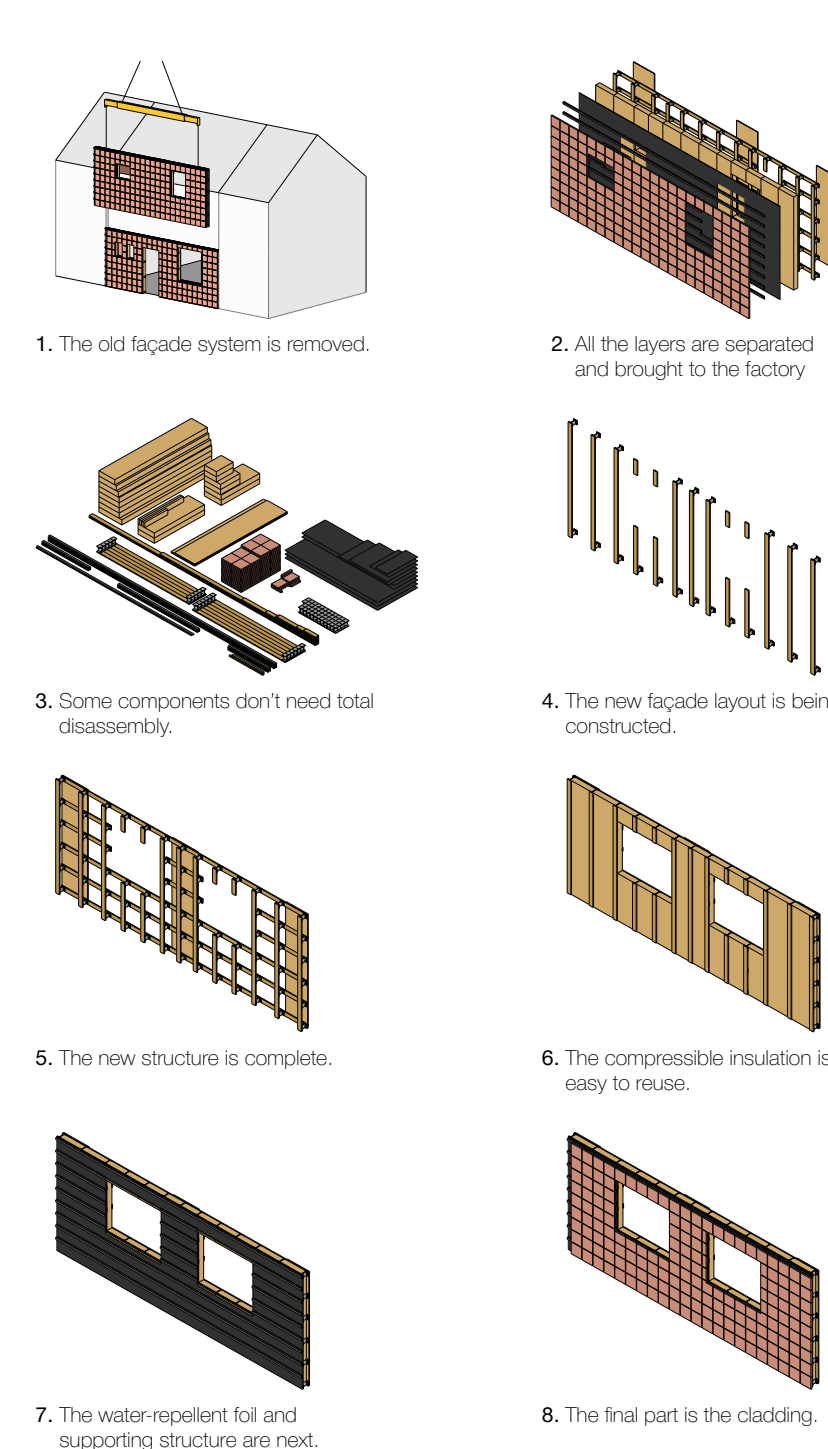
Test the reuse possibilities

The facade system is designed for disassembly and reuse, enabling adaptation to new layouts with minimal material loss. Each layer (cladding, structure and insulation) must be separated before reassembly.

The reuse process involves removing the existing facade system, separating its layers in a factory or warehouse and reconstructing a new design based on the retained elements. One facade can be used directly for another facade or materials from multiple facade can be stored and later be used for multiple façades, this will limit the use of virgin material. Materials were selected for durability and all connections were designed for easy disassembly, facilitating this cycle. The aluminium-plywood structure with Pretty Plastic cladding serves as an example of this process on the right.

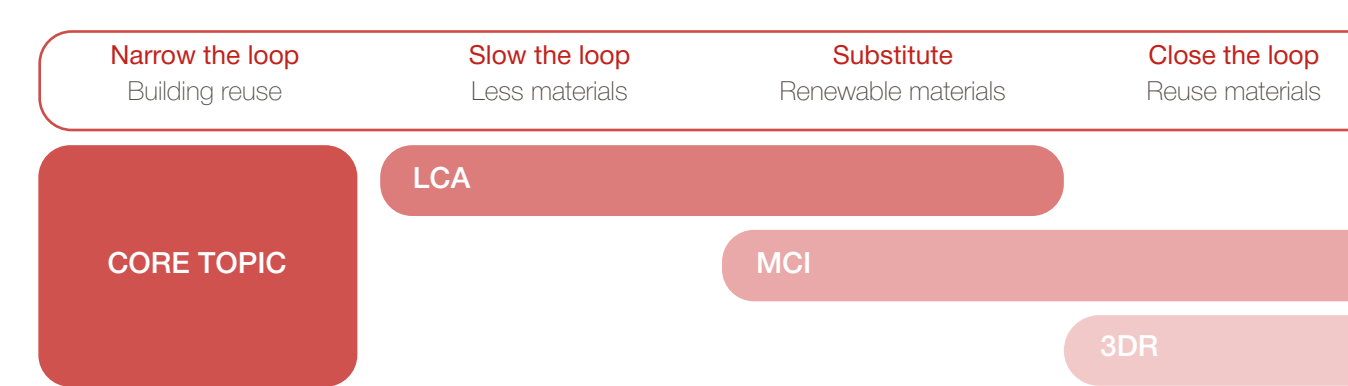
Among the options, the plywood-aluminium structure with ClickBrick cladding requires the fewest new materials when being remanufactured into a new facade system. ClickBrick's modularity reduces waste, though its weight and dry connections limit factory pre-installation. Accoya and Pretty Plastic use similar support systems, where Accoya uses a timber frame and Pretty Plastic uses an aluminium one.

Reuse sequence



Test the reuse possibilities

A circular construction economy is guided by four key principles: narrowing the loop (building less and reusing more), slowing the loop (using materials more efficiently), substitution (using renewable, low-impact materials) and closing the loop (promoting high-quality reuse). Façade renovation (which is the core topic of this report) embodies the first principle. To evaluate the preliminary designs, three methods were used to reflect the other principles: Life Cycle Assessment (LCA) for environmental impact, Material Circularity Indicator (MCI) for circular material use and 3DR for assessing disassembly, durability and reuse.



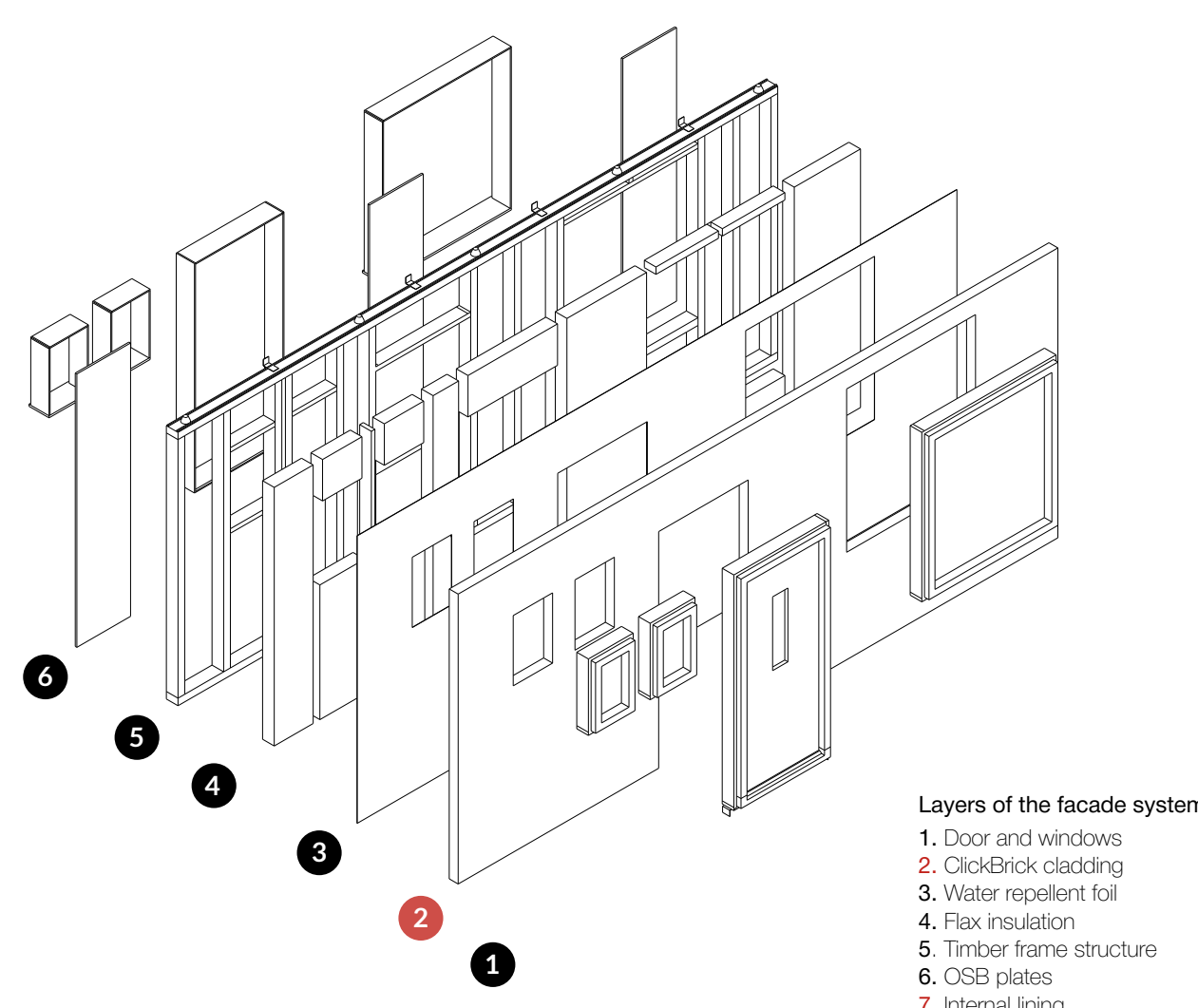
	Structures			Cladding			Conventional
	Timber	Plywood-aluminium	Accoya	Pretty Plastic	ClickBrick	Brick cavity facade	
Feedstock	Mass	0.95	0.95	0.95	0.95	0.95	0.95
	Regenerative	0.05	0.05	0.05	0.05	0.05	0.05
	Recycled	0%	0.1%	0%	0.5%	10%	5%
End-of-life	Cycle of use	2	2	2	2	2	1
	Recycled	0%	0.1%	0%	0.5%	10%	5%
	Increase	0.1%	0.5%	0.0%	0%	0%	0%
Compost	0.1%	0.5%	0%	0%	0%	0%	
	0%	0%	0%	0%	0%	0%	
Evaluation	LCA (kgCO ₂ -eq)	0.22	0.32	0.78	0.58	0.74	0.93
	MCI	0.89	0.92	0.8	0.85	0.78	0.12
	3DR	0.9	0.75	0.75	0.85	0.95	0.2

The outcomes of the evaluation can be seen on the right. No single design excelled in all areas; instead, different systems performed best in different categories. Timber frames excelled in carbon storage (LCA), Pretty Plastic led in recycled content (MCI) and ClickBrick scored highest for reuse potential (3DR). Overall, the timber frame with Pretty Plastic cladding delivered the most balanced performance.

Design proposal

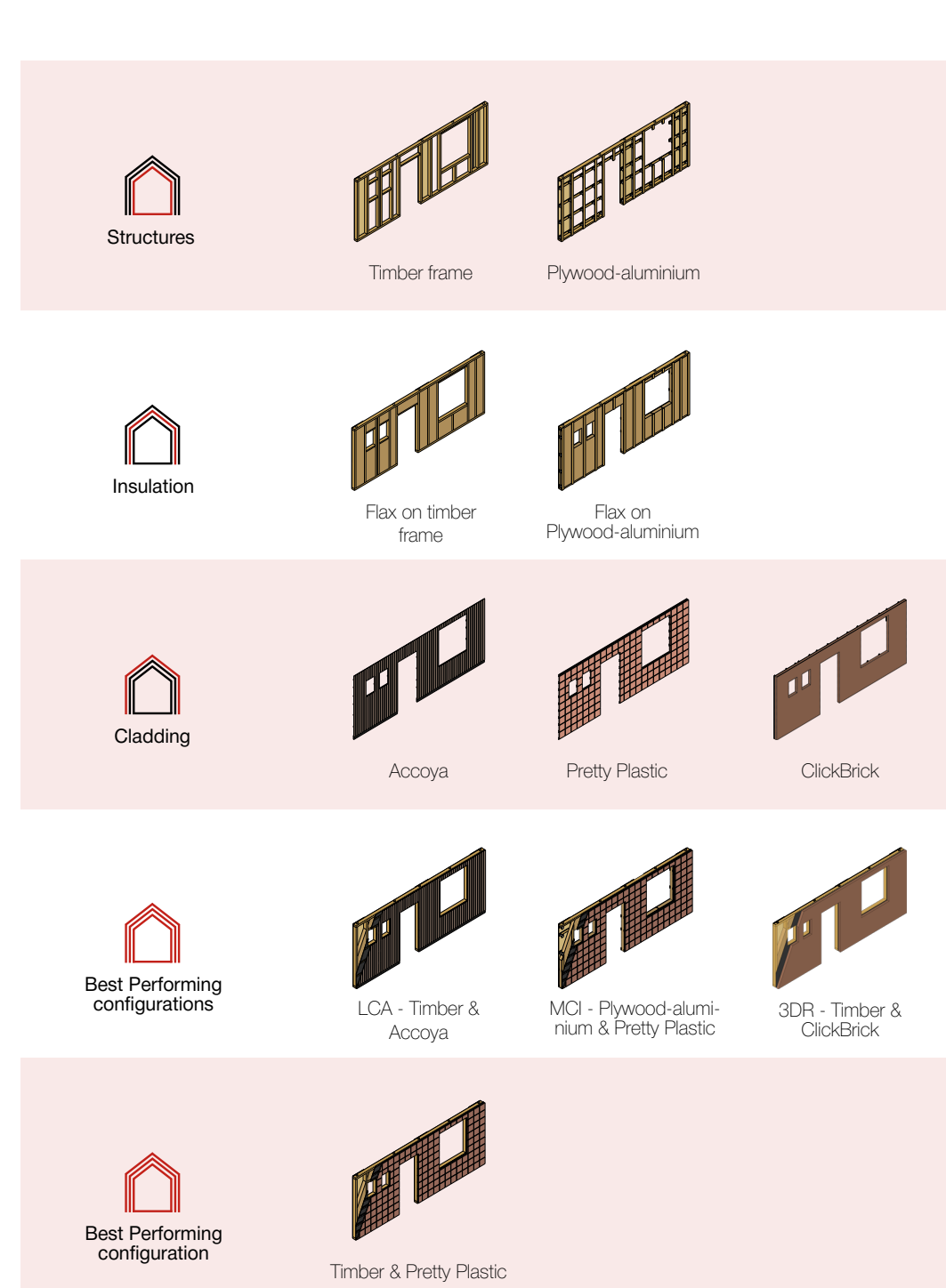
Facade system build-up

First the facade system can be designed using the configuration on the right and then the door and windows can be added. In addition, detailed technical drawings must be produced, including clear views and precise dimensions, to ensure accurate implementation. All the layers are shown down below in an exploded view. The layers with the red numbers will be added later on site.



- Layers of the facade system
1. Door and windows
 2. ClickBrick cladding
 3. Water repellent foil
 4. Flax insulation
 5. Timber frame structure
 6. OSB plates
 7. Internal lining

Facade system configuration

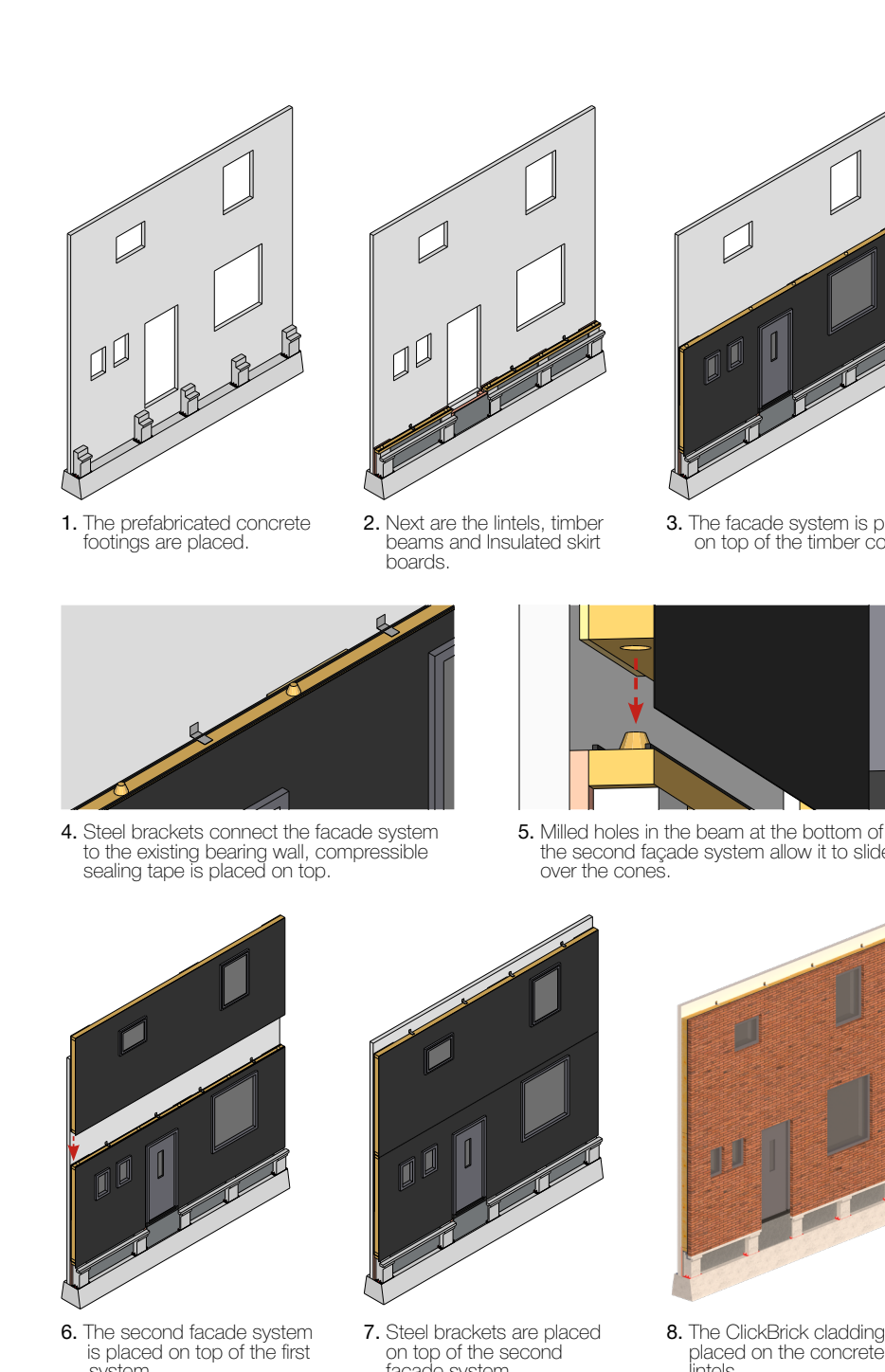


Connections

Timber cone connections lock the top and bottoms system to each other. These can be seen in the bottom detail and in the mounting sequence on the right. Steel brackets anchor the facade systems to the existing wall, maintaining spacing and preventing horizontal movement. Compressible sealing tapes ensure airtightness and reduce thermal bridging.

The facade rests on timber beams supported by prefabricated concrete footings bolted to the existing foundation. ClickBrick cladding is installed afterward, supported by the footings and a concrete lintel.

Mounting sequence cones



Vertical details

