Circular opportunities of aluminium systems

Practical guide for architects and building professionals

Reynaers Aluminium

Windows.
Doors.
Curtain walls.

Together for better

www.reynaers.be

About Reynaers Aluminium

"Together we are improving the living and working environment for people now and future generations."

As part of the Reynaers Group, Reynaers Aluminium is a leading specialist in the development and marketing of innovative, sustainable aluminium solutions for windows, doors, and façades. Together with our partners, we focus on creating energy-efficient, responsibly-made products that make a difference for homes, buildings, and the people they serve.

Reynaers Group was founded in 1965, currently employs over 2,800 people in more than 40 countries and exports its products to more than 70 countries across five continents.

In 2021, the Reynaers Group posted a turnover of 638 million euros. The company also owes its success to its close collaboration with 5,000 partner manufacturers, architects and project developers worldwide. We have summed up this unique collaboration in our motto: Together for better.

At the Reynaers Campus we share our knowledge and experience with architects, manufacturers, contractors, and other partners from the construction sector. This is where we also inspire them with new technologies. In addition to the Technology, Training, and Automation Centre, the Reynaers Campus is also home to an Experience Centre, where you can discover future buildings in our virtual reality space, Avalon.

Contents

WiCO : Window of Circular Opportunity

Various studies have shown that, of all the industries, the construction industry has one of the greatest impacts on the environment and the climate of our planet. This major impact also brings with it a certain responsibility – or in our eyes, an opportunity. The construction industry is the ideal sector to focus on methods and products that can benefit the environment. **Circularity is a central concept in this respect.**

Circular business and circular products are omnipresent in specialist literature, at trade fairs and at seminars. Every professional has heard of it, and some have already formed a clear opinion of it. However, there is still a long way to go before we see circular products being used on a large scale in construction projects. Even the definition of the term "circularity" is currently part of the discussion, but it is clear that it goes beyond mere recycling.

For decades, Reynaers Aluminium has incorporated topics such as **innovation and sustainability into its mission and values, and circularity** is part of that. We keep our partners and consumers informed of how we are developing sustainable, high-quality products every day.

This guide falls within the scope of the research project "Window of Circular Opportunity" (WiCO). The project aims to provide valuable guidelines and joinery solutions for circular buildings. It is an ambitious project that came about in cooperation with the Flemish Institute for Technological Research (VITO) and the Vrije Universiteit Brussel (VUB), with the support of Circular Flanders. When Reynaers Aluminium signed the Green Deal on Circular Construction in 2019, the seeds of the WiCO project were sown.

The purpose of this guide is to provide architects, fabricators and building owners with practical guidance on how to use our products in circular construction projects.

VUB VRIJE UNIVERSITEIT BRUSSEL

vito vision on technology

Reynaers Aluminium

Vision on circularity within our industry

Reynaers Aluminium wants to present itself as a company that embraces circularity in all its facets and in all our departments. We contribute to sustainable construction by providing efficient solutions that meet the expectations and quality of life of current and future users, throughout the lifetime of our products. Paying attention to circularity is one of the many ways we add value to construction projects.

The different layers of circularity are discussed extensively in other literature, but we would like to add our own key points that we want to focus on with our aluminium products. In our opinion, the greatest potential for our products lies in their value retention, owing this to:

- **Long life** – aluminium is a durable and high-quality material, thanks in part to a long-lasting surface treatment
- **Adaptability** – aluminium components can easily be replaced
- **Detachability** – components of aluminium systems are easy to dismantle for reuse or recycling
- **Recyclability** – aluminium can be reused endlessly, without downcycling

Within this guide, we split our findings into several levels. From the material level to the project and product level, we discuss where we see circular opportunities or can improve existing practices. Let us start with the basics: the material.

Circularity at material level

As we strive to minimise our environmental impact in all aspects of the production process, we want to present a broader and as accurate an account as possible. As an example of this balanced approach, let us take a closer look at our most commonly used material: aluminium. What makes aluminium attractive for use in circular products?

- **High quality** – aluminium has a long lifespan, is lightweight yet very strong, and requires only limited maintenance
- **High recycling rate** – more than 90% of all aluminium from buildings is recycled (source: European Aluminium, Circular Aluminium Action Plan 2020)
- **Excellent value retention** – aluminium has a high intrinsic value due to the longevity of the element
- **Limited environmental impact of recycled aluminium** – energy consumption in the production of recycled aluminium is 20 times less than in the production of standard primary aluminium

This last point may be less obvious, and therefore requires a little more explanation.

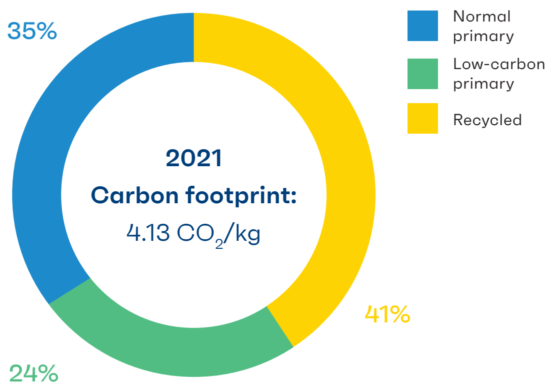
Recycled versus low-carbon aluminium

Within the global construction sector, 36% (European market average for 2019) of aluminium production is from recycled aluminium (source: International Aluminium Institute – base year 2019). By guaranteeing the purity of scrap, among other things, the market can make maximum use of recycled materials. Nevertheless, the supply of recycled material is insufficient to meet market demand.

We have noted that in the case of aluminium systems, the focus is on recycled content, which is why many system suppliers end up bidding for recycled aluminium. Our ambition is to find the right balance in our aluminium purchasing policy between recycled materials (our "fair share") and low-carbon primary aluminium. Low-carbon aluminium is primary aluminium that has been produced using renewable energy, mainly from hydroelectric power plants.

We look at how much recycled aluminium is available on the market and then purchase material in a responsible manner.

How can we, as a company, reduce our CO2 impact? By using a mix of recycled and low-carbon aluminium, as shown in the graphic below.



Graphic 1.1: Purchase ratio of types of aluminium (billets) by Reynaers Group in 2021.

Reynaers Aluminium wants to present an honest and accurate image. The inclusion of high percentages of recycled material in certain products has no impact on the total amount of recycled content in the chain, precisely because of its limited availability. Striving for a maximum amount of recycled aluminium on a project basis therefore only increases the cost, without any impact on the industry as a whole.

However, our solutions do not consist solely of aluminium. An average system also contains the following components.

Composition of standard window system

	Window (per m²)	Sliding window (per m²)
Aluminium	34%	24%
Thermal break	7%	2%
Seals	3%	1%
Glass	53%	68%
Hardware and other	4%	5%
Total	**100%**	**100%**

Table 1.1 - Source: EPD MasterLine 8 and ConceptPatio 130

As you can see, next to aluminium, glass accounts for the largest share. However, as an aluminium processing company, we have no impact on the circularity of the glazing in our systems. In addition, compared with aluminium, the average proportion of the other components is not so high. Therefore, glass and the other components do not feature prominently in this WiCO guide. It is sufficient to say that when systems do show a significant proportion of these materials, we make extensive use of recycled materials.

However, circularity is more than recycling. In this guide, we want to show that there are other possible scenarios by pointing out both the pros and cons of circular processing. Through several practical cases, we examine circularity at building and product level. Finally, we take a look at the future as we see it for circularity in the construction sector.

Conclusions

Circularity at material level

The most important materials in joinery are aluminium and glass. Aluminium offers the advantage of having a high recycling rate at the end of its life. In terms of aluminium, Reynaers Aluminium therefore applies a purchasing policy aimed at a “fair share” of recycled aluminium. *Recycled content* greatly reduces the environmental impact of aluminium, but its availability is limited. However, the high durability of aluminium means that it takes a long time for the building material to come back into the cycle. Therefore, it does not make sense to aim for a maximum amount of recycled aluminium in a single project. Nevertheless, to reduce the environmental impact, the recycled aluminium is combined with the purchase of low-carbon aluminium, which is produced with the help of renewable energy. This allows us to process aluminium well below the European average for *embodied carbon*.

Circularity at building level

Circular construction can be part of sustainable construction – the one concept does not preclude the other. To define the sustainability of buildings, several internationally recognised certificates are currently issued, such as the well-known BREEAM or LEED labels. Value labels that refer to circular aspects within sustainable building are much less common. That is why it is useful to examine on a micro-level, project by project, how circularity is applied in practice and what the benefits are.

Using a number of interesting projects, we would like to explain the various aspects of circularity at building level. We explain some of the key concepts in detail, discuss where the circular possibilities exist for each project and show why Reynaers Aluminium is a suitable sustainable building partner.

Circularity refers to the extension of the lifetime, reuse and recycling of construction components in order to keep the cycle of materials completely closed. The number of projects in which the circularity principle has been included from the start and continued through to completion is currently fairly limited. We selected three Belgian projects in which circularity forms the basis for obtaining a sustainable result.

- **’t Centrum** – the first circular office building in Flanders (Westerlo)
- **Victoria Regina** – a multifunctional high-rise renovation (Brussels)
- **Circular Retrofit Lab** – a cluster of student residences converted into a VUB living lab (Brussels)

Standardisation

Standardisation, modularity and compatibility allow building components to be combined and used over and over again. Thanks to the standardised shape and size of the components, (spare) parts can always be found quickly and repairs are easier to carry out.

Case study: ’t Centrum

‘t Centrum is a sustainable office building in Westerlo that was designed at the request of Kamp C. The building design by West Architectuur is completely detachable and, after disassembly, can even be rebuilt at a different location. Reynaers Aluminium ConceptWall 50 systems were used to construct the building shell and offer a façade solution that is easy to install and disassemble. It is the ideal project for getting acquainted with the world of circular tendering and circular construction techniques.

A unique feature of this project is that a circular tender procedure was held in which performance criteria were defined on the basis of a fixed construction budget. Construction teams were able to submit their proposal and demonstrate the circular nature of their plan through performance calculations. After an intensive assessment process, a winner was chosen: the consortium including contractor Beneens and architectural firm West Architectuur.

Focus points for this project

- Prepare a circular tender down to the last detail
- Guarantee the detachability of elements
- Offer standardisation in dimensioning

Figure 2.1

Figure 2.2: ‘t Centrum Kamp C - Visualisations

Design for disassembly as an asset

The possibility to dismantle ‘t Centrum was a key performance statement that Kamp C wanted to demonstrate as a case study, since the design of the building allows for total dismantling and reconstruction at a new location, fully in accordance with the rules of circular building. The basis of this design is a grid structure in CLT, with fixed dimensions of 5 x 5 metres.

To guarantee the detachability of the building even more, the architects opted for the Reynaers Aluminium ConceptWall 50 façade system. This solution consists of dry connections (i.e. a construction with screws and EPDM seals) that can be dismantled and reused perfectly. ConceptWall 50 also allows filling elements to be changed according to the use of the building. Glass, panels or opening elements can be swapped without difficulty.

Compatibility

Compatible building components are materials that can be interchanged and recombined.

Detachability

The detachability of a building is the extent to which objects can be dismantled without affecting the existing value.

Façade-as-a-service

The tender required that at least 50% of the building be offered as a service. But offering a façade as a service for 20 years entails maintenance costs, among other things. Our high-quality surface treatment coupled with periodic maintenance allow this period to be bridged. The excellent thermal values of our façade systems also help to cover the energy costs of this service – which is decisive for the circular nature of the project.

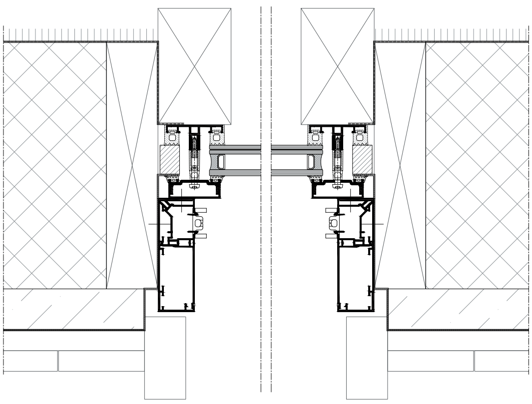


Figure 2.3: Horizontal section of the façade of ‘t Centrum

Because there is no conclusive legal framework for the ownership of a leasing façade, financing the façade of ‘t Centrum was a challenge. You could also ask yourself what the value of this façade is when considered separately from the building. After all, it is not a straightforward matter to fit it into the dimensions of another building.

“We see this case as a pilot project, but in order to make ‘façade-as-a-service’ scalable, the government will have to adapt the legal framework.”

Joeri Beneens
CEO Beneens Bouw en Interieur

Solution used: Reynaers Aluminium ConceptWall 50 - Alu on Wood

Circular criteria in tender documents

The tender process for ’t Centrum is not a standard procedure, that much is clear. But in terms of joinery, this case provides a lot of inspiration. An overview of criteria that the designer can include in **future tender documents**:

Thermal performance

To make a building truly future-proof, we can aim to make its thermal performance 10% better than the current EPB requirements. Meticulous insulation helps to dramatically reduce your energy consumption, which is good for the planet and your wallet.

Acoustic performance

Some projects may experience noise from their surroundings in the future. To preserve the value of these buildings, architects can specify acoustic performances for the shell components from the very first sketches, taking into account possible future changes in function:

- Windows: Rw + Ctr = 42 dB
- Sliding windows: Rw + Ctr = 40 dB
- Doors: Rw + Ctr = 38 dB

With such high demands, it is best to pay attention to the building connection as well. The width of the joints must remain limited, while the joints themselves must have sufficient mass. Working with a pre-frame can offer an advantage here (cf. detachable building connection, page 25).

Flexibility of the joinery

Flexible aluminium profiles allow for many circular interventions. Thus, with adaptable joinery, you can easily replace filling elements, change opening and fixed elements or add an insulation upgrade to your project.

The building as materials depot

Choose joinery that is reusable, detachable, and recyclable. The use of standardisation in dimensions can also add value.

A dismantling plan

The speed and efficiency of dismantling is also extremely important to enable reuse and selective demolition. Further on in this document, we quote the “detachability index”, a concept that measures the ease of dismantling.

The material or product passport

A passport for materials or components to facilitate maintenance and urban mining. The construction industry is still looking for a total solution here, but further on in this guide (page 32) we elaborate on our vision.

The EPD (Environmental Product Declaration)

The EPD indicates the environmental impact of a product in a transparent, objective and externally verified way. The EPD is based on a life cycle analysis (LCA), which assesses the environmental impact of a product from material extraction to finished product, installation, use and end of life. An EPD is a voluntary declaration, and does not judge how good or bad a product is, nor whether it is environmentally better than alternatives.

Product Circularity Data Sheets (PCDS)

These files provide consumers and professionals within the construction industry with an internationally standardised and reliable overview of the circularity aspects of a material or product. The following aspects are addressed: composition, maintenance, dismantling and recycling. Reynaers Aluminium uses PCDS data to help its customers and partners make a responsible product choice.

Case study: Victoria Regina

With its 24 floors and view over the Botanical Garden of Brussels, the Victoria Regina Tower is a landmark in the capital. However, the building, which was inaugurated in 1974, was in need of a thorough update. The architectural firm 51N4E was responsible for the design of the renovation, and we helped to find a solution.

Focus points for this project

- Enable smart use and reuse of materials
- Create a future-proof, multifunctional building

Figure 2.4: Victoria Regina - Visualisation © 51N4E

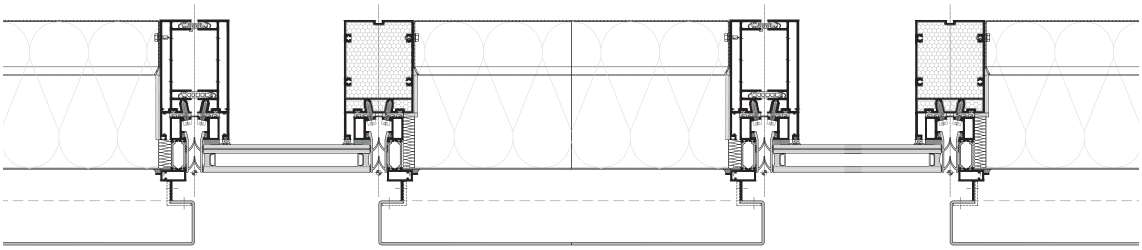


Figure 2.5: Horizontal section of the façade of Victoria Regina

The designers of 51N4E embarked upon the project with the motto: “The most sustainable building is the one that is not demolished.” In other words, do not demolish, but renovate. The original vertical concrete structure was retained, while the purpose of the building was transformed from a single-function to a multifunctional model. A hotel, modern office spaces and a stylish co-working space all come together under one roof. A design focused on efficient change.

Figure 2.6: Victoria Regina - Visualisation © 51N4E

Change-oriented building

A change-oriented building contains high-quality spaces that are both accessible and versatile. These spaces prevent the building from becoming obsolete and make expensive renovations unnecessary. This way, the lifespan of buildings and their components is extended.

In circular construction, a balance must always be sought between the interests and expectations of the various parties involved. Finding a balance between costs, lead times and possibilities makes **working in a building team an added value in any circular project**. In consultation with our project team, the construction team behind the Victoria Regina Tower ultimately opted for a modified Reynaers Aluminium solution with minimal consumption of materials and more future-proof components.

It is therefore not self-evident, and in the course of the project a number of other circular ideas were explored, which were not retained for several reasons.

An element façade with cassettes would make it possible to replace fixed elements in the façade with new opening systems. This added freedom would also make the building suitable as a residential tower, for example. For the construction team, this proposal did not prove to be the ideal solution due to the higher material costs compared with a framework façade with only fixed parts.

In addition, 51N4E proposed reusing the sheet metal from the old façade in the new one. But after a thorough analysis, stripping and then repainting the elements proved to be a process too environmentally unfriendly. The lack of companies carrying out this process on a large scale also meant that this idea was not the best option for the tower.

The lower storey height was also a challenge for the design. For this reason, architects and designers should look to greater storey heights in the future in order to combine our future-proof technology with optimum light conditions. **This also makes it easier for buildings with a greater storey height to qualify for sustainable renovation.** In this way, sustainability and liveability can be combined in a clear concept.

Solution used: Reynaers Aluminium modular façade system (project solution).

Figure 2.7: Victoria Regina - Visualisation © 51N4E

Case study: Circular Retrofit Lab (Campus VUB)

As part of the BAMB (Buildings as Material Banks) project, between 2016 and 2019 a cluster of student residences at the VUB was converted into a Living Lab, an exemplary laboratory of circular building techniques. The interchangeable shell components, consisting of Reynaers Aluminium ConceptWall 50 façade systems, perfectly met user needs.

Focus points for this project

- Create a change-oriented building
- Optimise interchangeability

Figure 2.8: © VUB Architectural Engineering. Photos: Simone Valerio, Kaderstudio

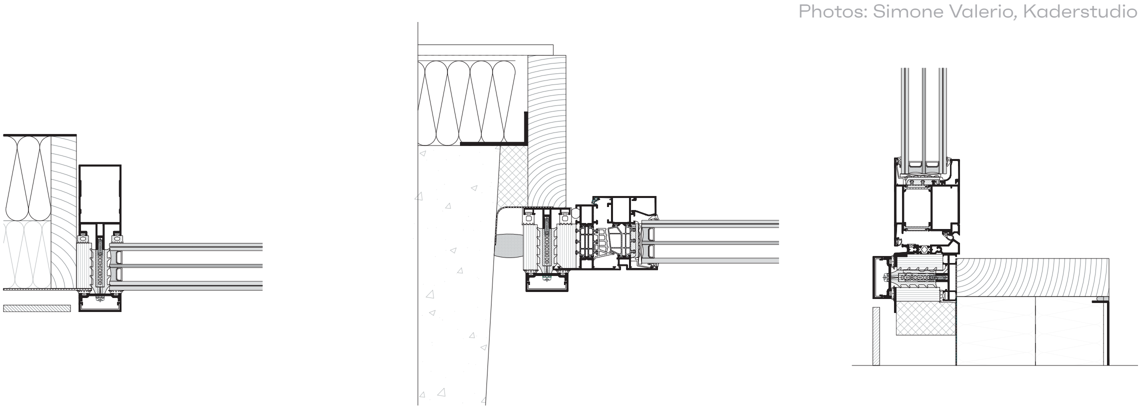


Figure 2.9: Various sections of the façade of Circular Retrofit Lab © VUB Architectural Engineering. Photos: Simone Valerio, Kaderstudio

Figure 2.10: © VUB architectural engineering

The concept of the Retrofit Lab states that the space of the building changes its function every 6 months, in order to indicate the circular benefits. Possible functions are a seminar and office space or a studio for VUB guests. The adaptability of the building structure is therefore crucial. Interchangeable ConceptWall 50 façade elements allow for easy, aesthetic and functional renovation in the use phase.

The building envelope has a fixed modulation, which allows fixed components to be swapped with opening parts. The opaque shell in the side wall can be partially or fully dismantled. Elements with opaque panels, fixed glazing and opening windows were finished and installed as an easy-to-manage unit. As the project has the same openings everywhere, you can interchange the elements at any time. The location of doors, windows and fixed elements can thus be rearranged at any time.

Solution used: Reynaers Aluminium ConceptWall 50 - Alu on Wood

Manageability

Manageable components are easy to handle and move. They facilitate building modifications and increase the feasibility of collection and return transport. This helps make component reuse financially competitive, while facilitating easy replacements.

Conclusions

Circularity at building level

Circularity can be implemented in projects in various ways: by focusing on detachability, the reuse of materials, standardisation, a change-oriented building design, and so on. It is precisely this diversity of solutions that ensures that circularity is not a self-evident concept, which makes working in a construction team advisable. It definitely makes the search for circular solutions very interesting.

However, we can also see challenges for our industry, such as further optimising the possibilities for reusing materials.

When the sheet metal from the Victoria Regina Tower was reused, it transpired that there was not enough capacity to repaint sustainably on a large scale. When reusing aluminium systems, it is important that the thermal performance of the profiles meets current expectations. Offering a façade “as a service” also often runs up against limits on its financing.

Despite these challenges, the examples show that it is possible to build in a change-oriented way. This is already possible with existing joinery options.

Circularity at product level

In the introduction, we touched upon the fact that the aluminium industry needs to achieve a **minimum impact on the environment** in several areas. Each building, and consequently each construction product, must strive to have as the lowest ecological footprint possible, taking into account the macroscopic issue of availability. As a system house, Reynaers Aluminium and its suppliers have a major impact on the products we design ourselves. However, we can also influence the production processes of our suppliers and customers to a certain extent.

1 Aluminium, a sustainable metal

Choice of material is therefore an important first step. Aluminium is the most commonly used raw material in our products, and therefore has the greatest potential to reduce our environmental impact. It is a material that lends itself very well to recycling, for example. As we have already mentioned, we have a policy that focuses on the fair and sustainable purchase of both recycled and low-carbon aluminium. In this context, it is crucial to know that the production of recycled aluminium uses only 5% of the energy required to produce primary aluminium.

2 Optimal use of material

A second important factor concerns the **optimisation of material use and the choice of sustainable components** in the development of our systems. In the context of circularity, this includes the replaceability of wear-sensitive parts and ways of matching the choice of material to the function of the system.

3 High insulation, low consumption

A third essential pillar is the **optimisation of the thermal performance of our systems.** This allows us to reduce energy consumption in buildings. We research and develop solutions around topics such as ventilation and thermal design to make our systems ready for the requirements and regulations of tomorrow.

4 We look beyond our own product

Fourthly, we also look at the link between our products and the building in which they are placed. Building components rarely stand alone, but form a coherent whole. Reynaers Aluminium must therefore **look beyond the confines of its own product**. Thus, in this guide, we also present a concept of a new building connection that meets the needs of our partners and the consumer (see below).

5 The bar has to be raised

Finally, we want to raise the bar by focusing even more on **circular aspects in the construction sector, and more specifically in the area of joinery**. As a starting point, we used the circularity scan in the WiCO project, carried out by VITO.

Circularity scan of Reynaers Aluminium products

At the start of the WiCO project, the independent research institute VITO examined a number of Reynaers Aluminium products. A circularity scan is a qualitative assessment of circularity on different levels of scale, at material, sub-element and element levels. As a basis for the assessment, the production and assembly steps, the material and element properties as well as the different connections are mapped.

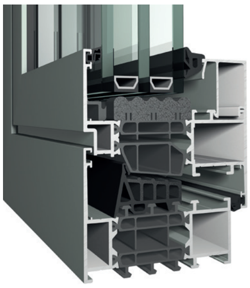


Figure 3.1: MasterLine 8 windows/doors

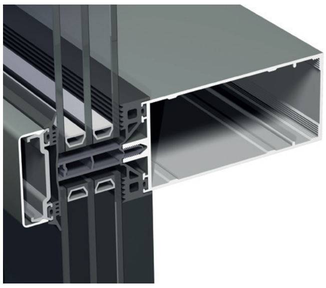


Figure 3.2: ConceptWall 50 curtain wall

Figure 3.3: MasterPatio sliding window

The test object for windows and doors was our MasterLine 8 series, for curtain walls ConceptWall 50 and for sliding windows our MasterPatio sliding system. The study came to the following conclusions for the above products.

Strengths of aluminium systems in terms of circularity

- **High recycling rate** – more than 90% of all aluminium used is recycled (source: European Aluminium, Circular Aluminium Action Plan 2020)
- **Easy replacement of glass** – using glazing beads or clip-on strips
- **Modularity and interchangeability of components** – especially for curtain walls
- **Long component life** – aluminium systems last up to 60 years (source: Michael Stacey, 2014[1]) and the average home in Flanders, Belgium also has a lifespan of 60 years (Circular Flanders)

So our current products already embody various circular aspects.

Weaknesses of aluminium systems in terms of circularity

- **Difficult reuse** – it is very difficult to bring used profiles back into the cycle as components for new windows. The dimensions are decisive, additional machining and logistics are needed. Furthermore, stripping profiles is time-consuming and polluting
- **Separating materials** – pressed and bonded corner cleats cannot be selectively processed for recycling
- **Separating elements** – windows are difficult to dismantle undamaged as a whole

[1] From study: Aluminium and Durability - Towards Sustainable Cities, edited by Michael Stacey, published by Cwningen Press, November 2014.

How to assess the potential for circularity?

As a system supplier, we will continue to build on the current strengths and address the weaknesses where possible. In the short term, we want to improve the disassembly of joinery in particular. Improving the detachability of components, such as corner cleats, requires a longer research process, which we are working on within R&D. Today, stripping and repainting individual profiles is bad for the environment, but it is possible to repaint installed elements (see below).

Using the Reuse Potential Diagram (also known as the Butterfly model), products can be analysed for their circular potential. To minimise the end-of-life waste stream, a waterfall system is used, in which, among other things, remanufacturing and refurbishing are given preference over recycling. In this way, the circularity scan can identify the opportunities for our systems, and where things could be improved.

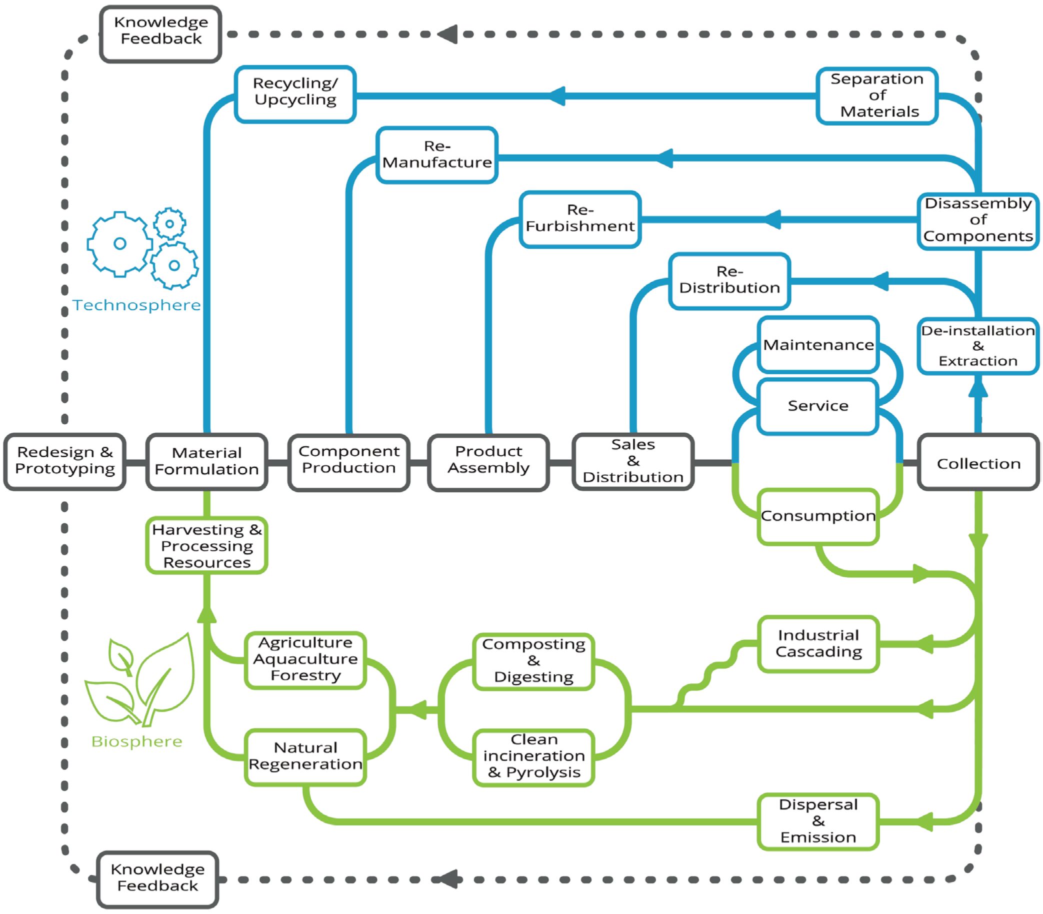


Figure 3.4: Reuse Potential Diagram, ©EPEA BV

Circular design through existing adaptable systems

Reynaers Aluminium already applies many circular techniques to its current product range. In this way, we increase the lifespan of our systems and minimise the ecological impact for our customers and partners. In the paragraphs that follow, we discuss how circularity is incorporated into the design of our current windows, doors, sliding windows and façades.

Windows, doors and sliding windows

Aluminium joinery has several interesting properties that make adaptability possible. For residential products – that is: windows, doors and sliding windows – we can very easily replace components such as glass, seals, locks and hinges with new ones. The design engineer can bring the system's performance back into line with user expectations (for example, by increasing the level of insulation) without replacing all the components. Even a fixed window could in principle be transformed into an opening window, but this currently requires considerable effort and cannot therefore be regarded as a standard solution.

Replace glass

After removing the seal, the glazing bead can be unclipped to allow for an easy upgrade to higher-performance glass. Only a new glazing bead and seal have to be provided, adapted to the thickness of the glass.

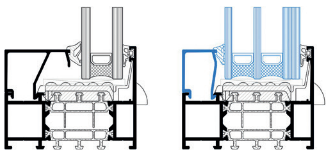


Figure 3.5

Improve thermal insulation

The thermal insulation of our current systems can be improved by fitting additional and better seals. Of course, for the seal under the glass, the glass itself has to be removed. This upgrade is therefore usually done at the same time as fitting higher-performance glass.

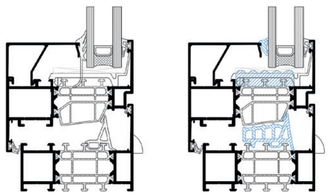


Figure 3.6

Add an opening element

It is also possible to change the type of opening. By removing the glass and making other adjustments, a fixed window can be turned into an opening window.

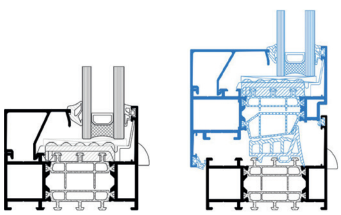


Figure 3.7

Replace hinges and hardware

Universal hardware groove: hinges and operating hardware are pushed or clamped into this standard groove. This allows them to be replaced. This groove is also standard for the different hardware suppliers, which provides additional freedom.

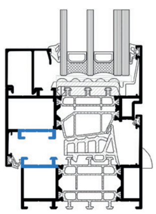


Figure 3.8

Façades

Reynaers Aluminium curtain wall and element façade systems have even more circular benefits than our range of reliable residential systems. Here are a few of their most sustainable properties in a nutshell.

Curtain walls

Replace glass

In curtain wall systems such as ConceptWall 50 and ConceptWall 60, both the anchoring and the assembly of the system are done using reversible screw connections. Glazing is clamped between the clamping rail, which is then finished off by a durable and aesthetic covering profile. The unit can also be completely dismantled, making it easy to recycle or replace.

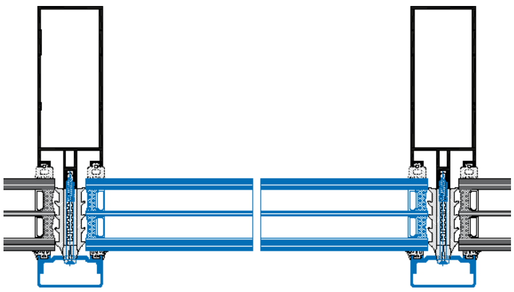


Figure 3.9: Horizontal section of the ConceptWall 50 curtain wall system with fixed glazing

Add an opening element

Easy disassembly allows installers to change glass quickly or completely refresh the covering profile during renovation projects. In addition, there is also the possibility of adding new (inward- or outward-)opening elements such as a top-hung window, a parallel-opening window or a door. The clean, uniform character of the façade is preserved, while user-friendly opening options make life easier for visitors and residents alike.

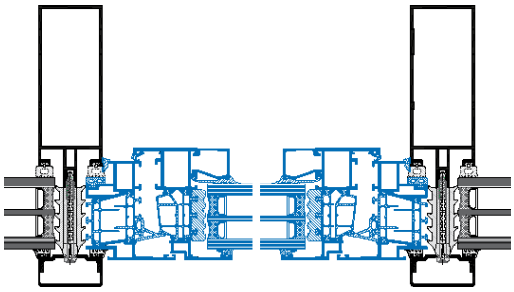


Figure 3.10: Horizontal section of the ConceptWall 50 curtain wall system with inward-opening window

Add structural glazing for a more subtle effect

Adding opening elements in a building has a visual impact, but structurally bonded glazing in the opening element can reduce this impact. In that case, no extra aluminium is visible on the outside.

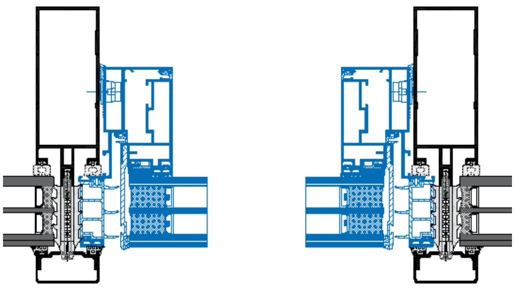


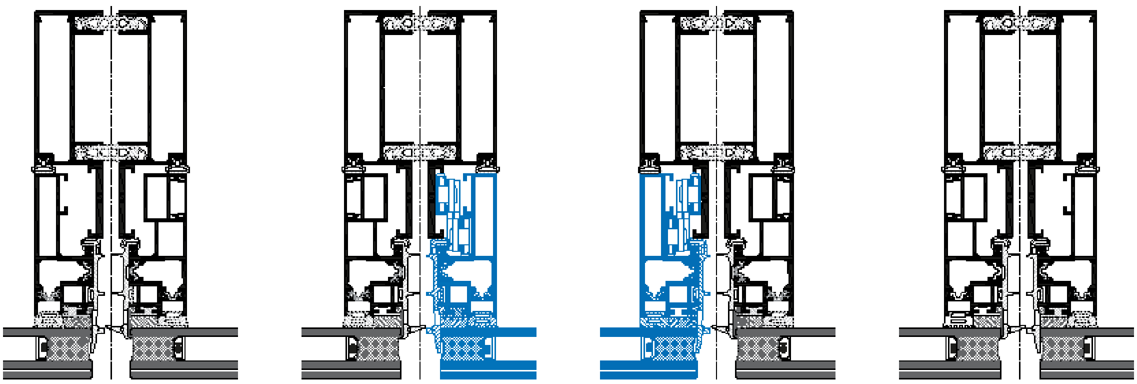
Figure 3.11: Horizontal section of the ConceptWall 50 curtain wall system with outward-opening structurally bonded window

Some buildings can change function over the years, and our façade systems offer possibilities for taking this into account even at the design stage. In this way, the system can easily be adapted to extend the life of a project. For example, when converting an office tower into a residential building, it is important to provide sufficient opening elements. A well-thought-out, future-oriented design, in which the dimensions of the joinery are coordinated and allow for possible interchange, should make the daily life of future residents easier and worry-free.

Element façades

Add opening part

Another type of façade is the **element façade**, in which both fixed and opening elements consist of individual cassettes. Visually, there is no difference between the two types, and when it comes to repurposing, fixed cassettes can easily be replaced by opening elements, which are usually parallel-opening or top-hung windows, but elements that open outwards can also be integrated.



igure 3.12: Section of the ConceptWall 86 element wall system, with structural glazing.
Left and right without and centre with opening part

Replace entire element

The element façade also makes it easier to dismantle and replace the glass plate during structural bonding. However, for safety reasons, it is recommended that bonding takes place in the controlled environment of the workshop and not on the building site. Replacement also means that the entire cassette and glass assembly must be dismantled and replaced. The amount of material used and the price of this solution are higher, but because of the added flexibility, the life of the façade – and therefore the entire project – is longer and more sustainable.

In conclusion, our current products can already fulfil certain circular aspects: a long life, adaptability according to user expectations, and dismantling (especially for façades).

Circularity across the product life cycle

We have extensively reviewed the role of existing systems in the circular construction process. Now it is time to shift the focus onto circularity across the product life cycle. Circularity plays an important role in the **design phase**, the **use phase** and the **end-of-life phase**. Based on these different phases, we discuss the specific circular possibilities that an architect and/or building owner can apply to joinery.

1

Design phase

In the design phase, we search for **an adapted building connection** that makes it easy to dismantle or replace elements. Next, we address the **detachability index**, which is an objective measuring method that indicates how easily products and their components can be separated. Finally, we discuss the **product passport**, which can be a vital link on the road to a circular construction industry.

Figure 3.13: Design phase

2

Use phase

During the use phase, **proper cleaning, lubrication and adjustment** can help products achieve their intended lifespan. These are strategies that can normally be found in an operating or maintenance manual, but are often forgotten.

Other measures with a larger impact, both in terms of time and cost, can extend the life of a product beyond its standard period of use. **Refurbishment, on-site repainting or the replacement of façade components** can – depending on the situation and the project requirements – be used to keep products in use for many years and avoid complete replacement. Concepts such as residual value determination, recycling value and reuse value play a crucial role here.

Figure 3.14: Refurbishment by repainting elements on site.
© Resporepair

3

End-of-life phase

If other strategies no longer allow the product to be preserved, it must be broken down and processed in a responsible manner. This end-of-life phase focuses on issues such as **demolition, waste separation and recycling**.

Figure 3.15: Sorted aluminium scrap for recycling process

Circularity during the design phase

Circular construction starts as early as in the design phase of a project by paying attention to the assembly and disassembly of joinery through, for example, detachable building connections that contribute to the adaptability of the project. In addition, consideration must be given to materials today and for the future, which can be achieved, for example, through a material or product passport. These principles and tools are discussed in detail in this chapter.

Standard building connection

One of the focus points in our WiCO project is to simplify the separation of elements, which is made possible with an adapted Reynaers Aluminium building connection. In Belgium today, most contractors and fabricators work with **a typical building connection** where the edges are closed off with PU foam to ensure wind and water tightness. Below we give an overview of the main components of this system.

1. Plate sill + anti-vibration sheet
2. Frame profile
3. Drip cap
4. Support anchor
5. PUR foam or other flexible insulation material
6. Foil
7. Infill for interior finishing
8. Interior finishing

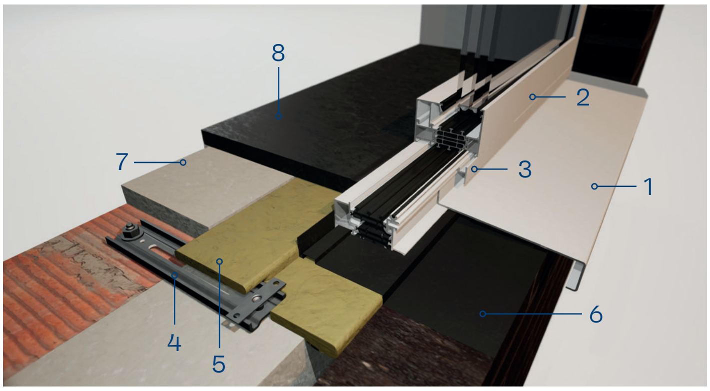


Figure 3.16: 3D visualisation of standard building connection

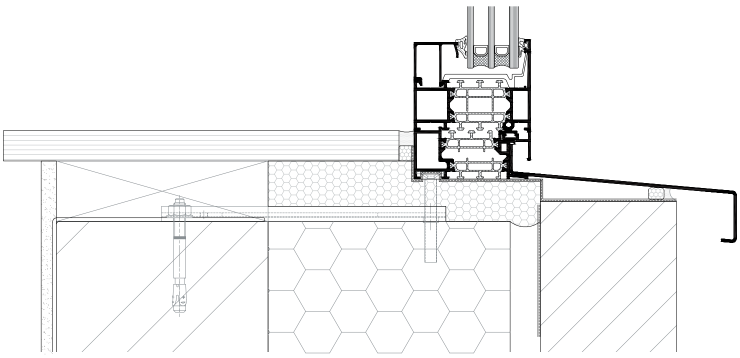


Figure 3.17: Standard building connection

One advantage of the standard building connection is that every professional knows and uses this traditional method. Universal mounting using screw-in anchors is also possible across systems.

However, this standard solution also has one or two **points of attention**. Because of the low level of detachability of this system, it is virtually impossible to remove the joinery from the building shell without damaging the interior finishing. In addition, the reveals often have to be filled in when you want to install the interior finishing.

Reynaers Aluminium concept: detachable building connection

In response, Reynaers Aluminium has developed a concept for a new detachable building connection. **After dismantling, this innovative system leaves less damage to the interior finishing and the thermal shell.** The elements are wider than those of a standard building shell, which has an impact on transport. However, because a support for the interior finishing is included, installation is made easier. This concept also takes into account the installation tolerances on the interior finishing.

1. Plate sill
2. Frame profile
3. Drip cap
4. Seal
5. Mounting frame
6. Expanding rubber strip (or other insulation material)
7. Adjusting block
8. Foil
9. L-shaped finishing profile

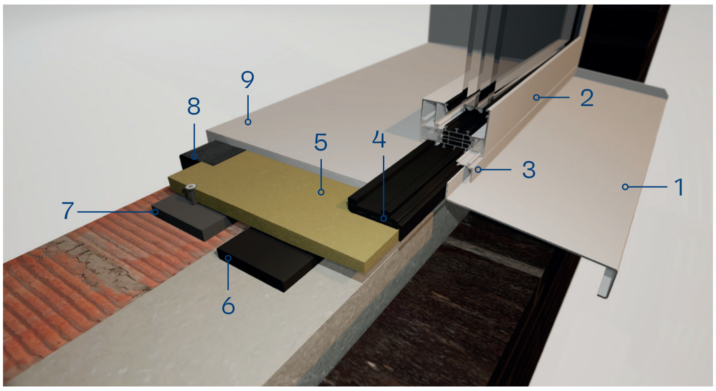


Figure 3.18: 3D visualisation of detachable building connection concept

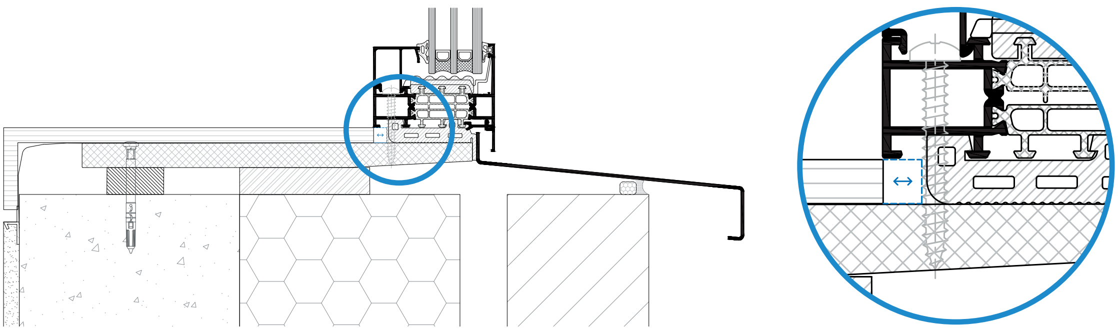


Figure 3.19: Detachable building connection concept with finishing profile (patent pending)

We explain this concept and the research behind it in more detail on the following pages.

Reynaers Aluminium concept: detachable building connection

The concept of the new detachable building connection can be used in various building constructions, such as a timber frame, an ETICS system, a traditional cavity wall and more. But how is the system fitted correctly? And is it easy to remove? We explain it step by step.

1

Connect element to mounting frame
A seal is first applied around the joinery. This ensures that the element is sealed, but also provides the space between the system and the mounting frame that is required for the subsequent installation of the interior finishing (principle patented by Reynaers Aluminium). The mounting frame is then screwed to the joinery.

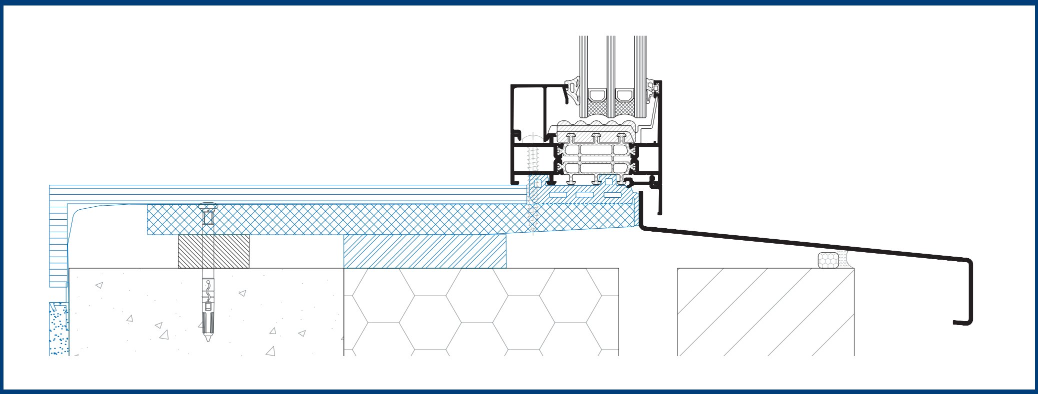


Figure 3.20: Vertical section of detachable building connection concept with finishing profile

2

Install unit with expansion seal
The on-site design engineer applies an expansion seal around the mounting frame and places the unit in the window opening. The mounting frame is then anchored to the building shell with adjusting blocks and a screw fastening. A vapour-tight foil is laid on the inside, from the mounting frame to the inside wall.

3

Fit finishing profile
The next step is to fit the interior finishing. This is usually an L-shaped finishing profile that slides under the joinery, but a gypsum board angle or wooden finishing are also possible. Ideally, this creates a shadow joint so that you do not have to damage the plaster when you want to remove the joinery again.

You can also plaster directly onto the mounting frame, but then it is no longer possible to dismantle without causing damage. The advantage os that you do not have to use PUR to fill up the gaps between the window frame and insulation. Also, everything is ready for finishing after the joinery has been installed. This detachable building connection is perfect for use around windows, but can also come in handy for doors and sliding doors.

Comparing building connections

To illustrate the strength of this detachable concept, we compare it with another, more standard building connection, and a compromise of detachable with plaster. Below is a comparison of these three methods during different construction phases.

Dismantling

Detachable building connection concept with finishing profile R

1. Remove L-shaped finishing profile (reusable)
2. Remove glazing bead and glass
3. Remove window frame by means of screws

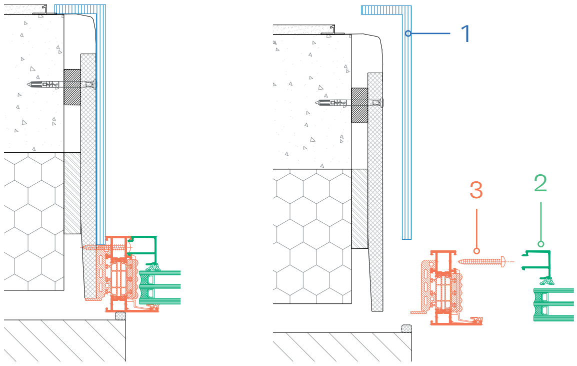


Figure 3.21

Detachable building connection concept with plaster R

1. Remove plaster (non-reusable)
2. Remove glazing bead and glass
3. Remove window frame by means of screws

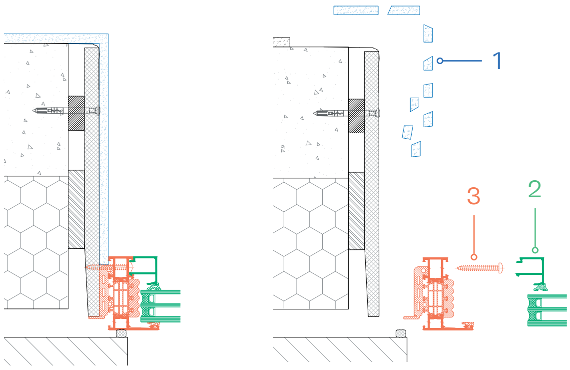


Figure 3.22

Standard building connection with plaster

1. Remove plaster (non-reusable)
2. Remove glazing bead and glass
3. Cut sealing foil loose and remove coating filling (non-reusable)
4. Remove the window frame: loosen dowels and cut PUR foam loose (non-reusable)

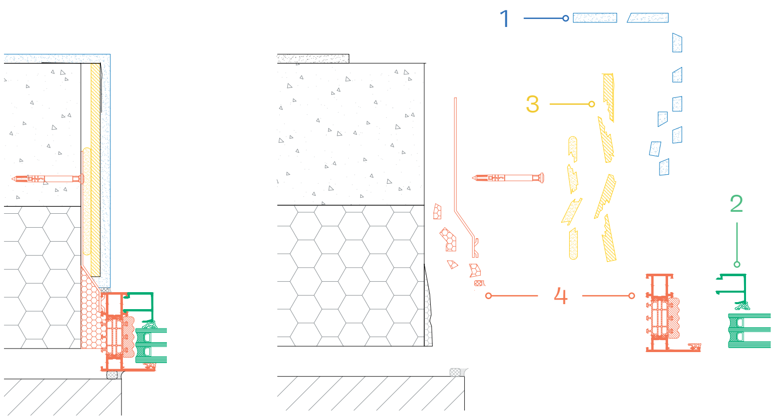


Figure 3.23

The detachable building connection makes for easy dismantling and allows all aluminium components to be reused. The other two options require more time and allow only partial reuse. This makes our new building connection the perfect circular construction partner for your new building or renovation project.

Reassembly

When reassembling, we follow the reverse procedure. The materials that were damaged during dismantling must be added again in the second and third option.

Detachable building connection concept with finishing profile

R

1. Fit window frame using screws
2. Fit glass and glazing bead
3. Fit L-shaped finishing profile

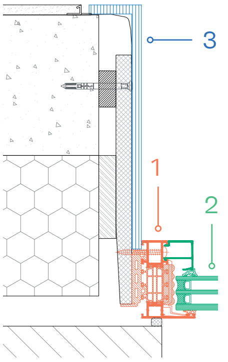


Figure 3.24

Detachable building connection concept with plaster

R

1. Fit window frame using screws
2. Fit glass and glazing bead
3. Apply plaster (new)

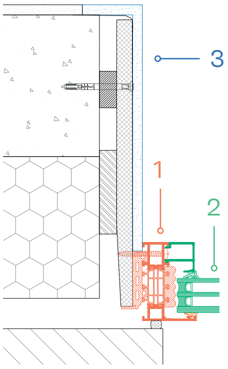


Figure 3.25

Standard building connection with plaster

1. Fit window frame using dowels and PUR foam (new)
2. Install filling and foil (new)
3. Fit glass and glazing bead
4. Apply plaster (new)

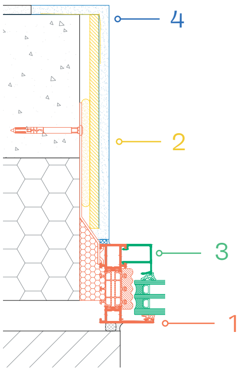


Figure 3.26

If you install our **detachable building connection concept** after a previous extension, you can perfectly reposition all components. Our innovative proposal also makes it possible to **reuse the entire building connection** in the event of a renovation. The standard and circular connection with coating present difficulties in reusing the interior finishing, thermal shell and fixings of the joinery.

Evaluation of building connections based on determination of residual value and construction cost

You can also compare the different building connections on the basis of residual value calculations and a price calculation. Here we notice a certain cost shift.

The mounting frame of the new building connection increases the price of the joinery, but this additional cost is offset by faster, cheaper and simpler interior finishing.

Together with the Dutch consulting firm Alba Concepts, a **residual value calculation** was also made for the reuse scenario. Due to the amount of labour and damage that can occur to the joinery when using the standard building connection with dowels, this results in a loss of value. Consequently, a recycling scenario may be chosen more quickly. (See explanation of residual value determination on page 30).

Determination of residual value after 30 years

	Relative to initial material costs	Relative to initial total construction cost	Total construction cost (opening dimensions: 1230 x 1480 mm)
Detachable building connection concept with finishing profile R	**41 %**	**29 %**	**102 %**
Detachable building connection concept with plaster R	29 %	21 %	101 %
Standard building connection with plaster	-16 %	-11 %	100 %

Table 3.1: Determination of residual value for the 3 methods after 30 years

The negative value indicates a loss of value. -16% means that the value of the scrap is negated by the labour costs involved in breaking down, separating and recycling the materials, as reuse is not an option here.

From this comparison, we can conclude that a standard building connection leads more quickly to recycling, while the Reynaers Aluminium detachable connection concept facilitates a reuse scenario. Detachability and practical residual values are clearly influential factors when it comes to circularity.

However, to compare the circularity of systems easily, you need data. This is where the terms **disassembly potential and residual value determination** come in. We summarise these crucial concepts in the paragraphs below.

Disassembly potential

Disassembly potential, or detachability, what does it mean, exactly? The Dutch consulting firm Alba Concepts uses the following definition:

"The detachability of a construction element is the extent to which an object can be dismantled at all levels of scale without damaging the object or surrounding objects and thus protecting the existing value."

The more detachable a building is, the easier it is to harvest products and systems, and the more natural it is to do so. Detachability is therefore a crucial concept in a circular building economy. To calculate this index, you need to analyse both the connections in the product itself and the installation method. The type of connection, accessibility, possible intersections and shape inclusions are considered. A score of 0.1 to 1 is calculated for each component, where 1 means completely detachable and 0.1 means not detachable at all.

The exact formula to determine the disassembly potential of a product or element (DPn) is:

$$DP_n = \frac{4}{\frac{1}{CT_n} + \frac{1}{CA_n} + \frac{1}{ID_n} + \frac{1}{GPE_n}}$$

Where:

- **Connection type (CT)** – for example, a dry joint (1.0), bolt-nut joint (0.8) or a hard chemical joint (0.1)
- **Connection accessibility (CA)** – a score of 1.0 indicates that a component is freely accessible, without the need for additional actions. An inaccessible component, for example due to irreparable damage to a product or surrounding products, receives a score of 0.1
- **Independency (ID)** – such as electric cables running through a product. This scale runs from no intersections (score of 1.0) to the full integration of products and elements from different layers (score of 0.1)
- **Geometry of product edge (GPE)** – which determines the obstruction to removal. With a score of 0.1 there is complete obstruction, with 1.0 there is none

For further information on this topic, please refer to the annex of this guide (page 50).

Residual value determination

Besides the detachability index we also look at the residual values to assess the relative circularity of systems.
A residual value is determined on the basis of two scenarios: the scenario for **the reuse value** and the scenario for the **recycling value**.

The reuse value assumes that the product can be reused – in parallel with what Ellen McArthur calls 'reuse' (source: ellenmacarthurfoundation.org/circular-economy-diagram).

This value is defined as follows:

$$\textit{Reuse value} = PV_P - RP - QR - DC - IC - TC - SC$$

In this formula:

- **Product purchase value (PV_p)** – the gross purchase cost of the product
- **Reuse potential (RP)** – the proportion of material that does not leave the site freely and is lost
- **Quality reduction (QR)** – the impact of wear and tear and use on depreciation.
- **Dismantling costs (DC)** – the cost of selectively removing the product from the site
- **Inspection costs (IC)** – the costs of approving the product for reuse
- **Transport costs (TC)** – the logistics costs, based on an average number of kilometres and on the mass and volume of the product
- **Storage costs (SC)** – the costs of temporary storing reused products before reinstalling them on site

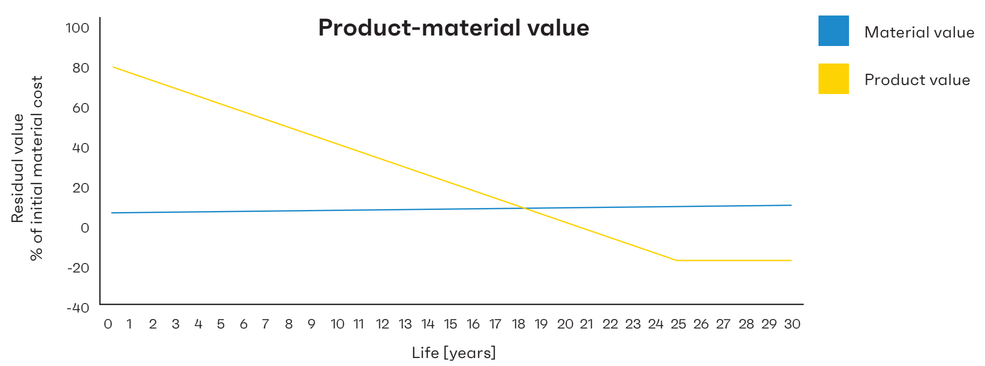
The recycling value considers the product as a raw material and is calculated as follows:

$$\textit{Recycling value} = PV_m - RP - DC - PC - TC - SC$$

In this formula:

- **Purchase value of material (PV_m)** – the estimated raw material price
- **Recycling potential (RP)** – this indicates the percentage of building materials that can be recycled on release
- **Demolition costs (DC)** – estimate of the costs for the labour to demolish
- **Processing costs (PC)** – the costs of processing and recycling the products
- **Transport costs (TC)** – the logistics costs, based on an average number of kilometres and on the mass and volume of the raw material
- **Storage costs (SC)** – the cost of temporary storage of the recycled raw material before it is reincorporated into the production process

There is a unique moment in time when the recycling value exceeds the reuse value (see tipping point Graphic 3.1). We prefer to postpone this moment for as long as possible for a circular product. Reuse is in fact a more interesting scenario with a lower environmental impact and a considerably longer lifespan than recycling. A glance at the formula shows that in the design it is best to aim for a minimum loss of quality and the lowest possible dismantling costs. All these costs are estimated on the basis of reference figures that the consulting firm Alba Concepts has determined together with cost experts. These figures are documented in the Dutch Financial Valuation Standard.[1]



Graphic 3.1

[1] Financial Valuation Standard - Alba Concepts. Drawn up by Alba Concepts on behalf of Metaalunie and FME, in association with the Dutch Ministry of Economic Affairs and Climate Policy.

Circular design – the product passport

We have already shown in this chapter how you can determine the circular nature of systems and buildings with the help of a new building connection, the detachability index and determinations of residual value. Another tool is the product passport.

A product passport is a document that contains information on the building materials and components of a system. Combine the different product passports from all the systems in a project and you get a building passport. This document is at least as important as the product passport, as the connections at element and building level determine circular possibilities in the end-of-life phase (e.g. identify connections that do or do not allow for damage-free dismantling). The information should preferably be both quantitative, such as environmental performance, and qualitative, such as dismantling guidelines. In addition, the passport should ideally contain information about the various life phases of the materials, the building elements and the building itself. This allows users, designers and other stakeholders to look up how to install, maintain or dismantle the material at any stage of its life.

Figure 3.27: © Philippe Piraux, Jaspers-Eyers Architects

For Reynaers Aluminium, the following information is indispensable in a product passport:

- System used
- Dimensions
- Colour code
- References list
- Glass or filler – as well as type, dimensions, and weight
- Weight and volume of material
- Energy and environmental performance
- Fabricator and Installer
- Production and installation date
- Maintenance guidelines
- Dismantling plan

Why use a product passport?

We would like to share some examples that demonstrate the need for a product passport.

In the case of a detachable building connection, it is important that every stakeholder in the chain is aware of this added value. A detailed product passport can provide clear information to installers, users and demolishers alike. In a renovation, for example, everyone who is familiar with the product passport knows that a non-standard method must be used to remove the window easily and without causing damage.

The product passport can also make reuse possible in the *end-of-life* phase (see below). Technical details in particular can be an important indicator here, such as the U-value: does the window still achieve current basic thermal values?

If the product passport defines the various materials and quantities, you can summarise this information at building level in the building passport. And based on the building passport, you can draw up a demolition inventory and a demolition follow-up plan. In this way, waste streams may be identified more often or more correctly and collected more selectively if appropriate.

Creating a product passport requires a lot of information and is therefore not always realistic in practice. The lack of a standardised process makes it very difficult to implement. More harmonisation and clarity are expected within the construction industry in the coming years, but at present there are no industry-wide guidelines or a unified passport. Reynaers Aluminium wants to work on this with its partners in the future.

Conclusions

Circularity in the design phase

One important aspect to consider when designing circular joinery is detachability. Joinery offers the possibility of being dismantled as efficiently as possible so as to promote reuse scenarios and a greater residual value. There are already detachable aspects in our systems, but the building connection remains a major challenge. Reynaers Aluminium therefore developed a concept for a detachable building connection. The various stakeholders must of course be aware of the more efficient method of dismantling. A product passport can help here.

Circularity during the use phase

From circularity in the design phase we are now shifting our focus to circularity in the use phase. It is every architect's dream to build a project that can provide generation after generation of users with a safe home, work or living environment. From a circular point of view, it is therefore important to guarantee the quality of each building element so that the life of the entire project is as long as possible. There are several strategies that can be applied in the use phase of a building - we will review each of them in this guide.

Lifespan and extension of lifespan

One of the aims of circular construction is to maximise the life of the building elements used. The product must continue to meet user expectations, both aesthetically and in terms of performance. A basic indicator of value here is that the maximum dimensions and weights of opening parts, as specified per system by the system supplier, are respected.

Another important parameter that can have a positive influence on lifespan is maintenance. Clean the windows with neutral cleaning products and always observe the maintenance instructions of the system supplier. From adjusting fittings to checking seals and cleaning drainage holes, your design engineer knows what is best for your systems.

Whereas maintenance ensures that your product achieves its intended lifespan, the aim with lifespan extension is to give products a second life. Think of a renovation. This is a point in a building's life cycle when the decision is usually made to replace the joinery. Reasons for replacing profiles include altered dimensions or the fact that the existing system is not compatible with a new type of glazing.

The thermal performance of joinery in older buildings is often hopelessly outdated. Fortunately, the thermal performance of aluminium systems has been improved significantly over the years. Current elements not only offer perfect insulation, they are also usually designed in such a way that double or triple glazing can be used and good airtightness is ensured.

Replacing elements completely is one thing, but there are also techniques for giving your current systems a longer life. Here are a few ways to guarantee a longer lifespan for aluminium joinery:

- **Refurbish** – replace the glass, hardware and seals
- **Repaint in situ** – apply a new coat of paint to withstand the elements
- **Partially replace façades** – install a new element only where necessary

Replacing only part of a façade offers clear advantages in terms of time and cost savings. But refurbishing elements or repainting on site could use some clarification.

Refurbishing joinery

Refurbishing means replacing or adding components – such as panes of glass, hardware, or seals – to existing elements to give the joinery a second life. One example of replaceable components is hinges, which, after frequent use, exhibit reduced performance due to mechanical wear and tear.

Causes of component ageing

- Joinery standing in the same position for a long period of time
- UV rays
- No or inadequate maintenance
- Large variations in temperature
- High frequency of use
- Incorrect use of opening parts

Examples of refurbishing

Replace seals
Properly functioning seals are important for the air- and watertightness of the system, as well as for the acoustic performance of the joinery. If they are not replaced in time, you run the risk of water damage, noise pollution and poor thermal performance in the long run.

Replace hardware components
In case of frequent use it may be necessary to replace the hardware parts even sooner if the frequency of use is significantly above the tested frequencies. For sliding windows and windows, the test frequency is 20,000 cycles, while for doors it ranges from 50,000 to 1,000,000 test cycles (see overview below).

Resistance to repeated opening and closing in accordance with EN 12400

EN 12400: 2002 Windows and pedestrian doors – Mechanical durability – Requirements and classifications			
Cycles	Windows	Doors	Class
			0
5,000	moderate	limited	1
10,000	normal	light	2
20,000	intensive	infrequent	3
50,000		moderate	4
100,000		normal	5
200,000		frequent	6
500,000		intensive	7
1,000,000		extreme	8

Table 3.2: Resistance to repeated opening and closing in accordance with EN 12400

The right choice of materials can limit or even eliminate the need for refurbishing. For example, the selection of the right hardware depending on the application.

During refurbishment, it is important also to check whether the joinery still meets requirements other than smooth opening, such as thermal performance. To assess the effect of such interventions on performance, we launched a test case.

Test case: Mariahof, Leuven

The joinery of one of the cloister buildings of the Mariahof in Leuven was in urgent need of an update. The design engineer suggested replacing only the glass, the seals and the hardware where the joinery was still in good condition. The other elements, mostly entrance doors, were completely replaced. The owner of the project accepted the proposal because it allowed residents to remain in the building and disruption was reduced to a minimum. This also meant that no new interior finishing was required.

Focus points for this project

- Residents remain in situ during the renovation
- Interior finishing remains intact
- Significant improvement in airtightness and acoustics

Figure 3.28: Mariahof façade

Figure 3.29: Smoke test

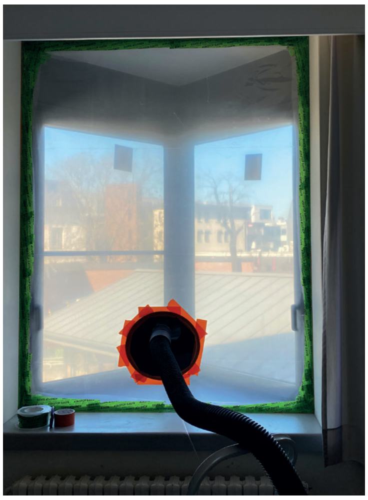


Figure 3.30: Blower door

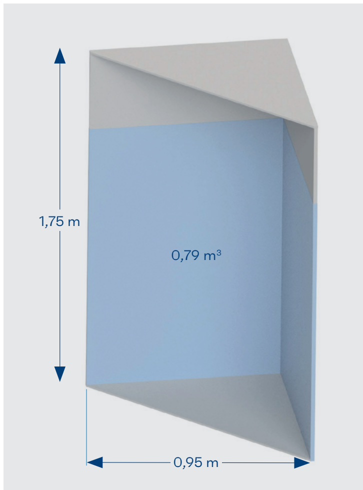


Figure 3.31: Volume simulation

To calculate the impact of this intervention on the performance of the building, a “blower door test” was carried out before and after the works. A smoke test on one of the windows to be removed showed clear leaks, as can be seen in the photos below. During the refurbishment of the Mariahof, the hardware and acoustic seals of the windows were replaced. The elements were fitted with thermally insulated glass that was glazed with silicone.

By comparing the results before and after refurbishing, we see a considerable improvement. The low pressure measurement showed an average improvement of 68%; the excess pressure measurement showed an improvement of 42%. The measured leakage flow rates after refurbishment are approximately equal between low and excess pressure, which is a real improvement compared with the original situation. Below is a brief overview of the measured results:

Improvement in air loss before and after refurbishment

	Negative pressure			Positive pressure		
	10Pa	25Pa	35Pa	10Pa	25Pa	35Pa
% improvement	66%	69%	-	51%	33%	41%
% average improvement		68%			42%	

Table 3.3: Comparison of air loss before and after refurbishment - Mariahof test case

Glass or other fillers can always be easily replaced or adjusted, as can the paintwork, seals and in some systems the insulation (using special seals and foams). Hardware, too, can be fully or partially replaced. Despite the possibilities for refurbishment, the original elements must have a decent production quality. It is not always possible to obtain a functional element through refurbishing when there are quality issues from the original fabrication onwards.

We can conclude that it is only possible to refurbish joinery if you take the above points into account. We notice that contemporary systems are better suited to being refurbished in a later phase of life. With older elements, the maximum glass thickness and the limited Uf-value can be an obstacle in the renovation and refurbishing process.

Verifying quality and compatibility of base material

Based on this practical case, we have formulated some points for attention that you should review before considering refurbishing joinery:

- **Check in advance whether spare parts are still available,**
  or look for alternatives that can be integrated into the profiles.
- **Check whether the profiles still meet the thermal expectations**
  This way you avoid the risk of condensation, for example.
- **Test whether the elements are still in good condition**
  Check for deformations, the condition of the mitres in the profile corners, etc.
- **Check whether the envisaged type of glass fits into the existing profiles**

Repainting joinery in situ

Aluminium window profiles are always finished with a coat of paint and/or anodised coating. This surface treatment, together with the design of the joinery, has a great influence on the look of the building.

It may be that after a while the look of the building no longer meets the expectations of the user. In that case you can suggest a new surface treatment for the joinery in order not having to replace the entire joinery. By repainting the windows you give your window profiles a second life, without disassembling or dismantling them. We will illustrate how this coating process works with a case involving Resporepair, an expert in repairs and renovations.

How they proceed:

1. **Preparing for primer**
In the first step, the work surface is thoroughly cleaned, sanded and degreased, to allow the primer to adhere properly. To avoid overspray on areas that are not to be repainted, the entire work area is masked off as much as possible.

2. **Priming and preparation for final coat**
After priming, the work area can optionally be heated to allow the varnish to harden. The work area is sanded and degreased again to ensure that the final coat adheres properly.

Figure 3.32: Protecting parts that are not being painted at the same time. © Resporepair

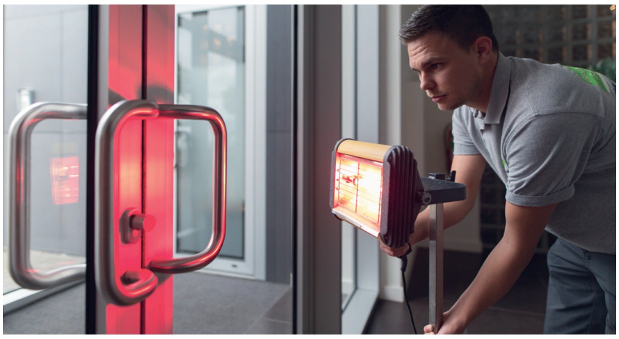


Figure 3.33: Hardening of paint. © Resporepair

3. **Optional: colour matching**
If the joinery to be repainted has to match another colour, a final colour determination is carried out on site. The paint specialist uses colour samples or a digital colour scanner for this.

4. **Painting and drying**
The entire area is then sprayed in the correct colour. Afterwards, the surface must dry sufficiently before the masking tape and the masking paper can be removed. The joinery looks reborn!

Today, there are numerous specialised firms who can easily carry out this work. Therefore, for many people the step to repainting has become more natural than the total replacement of elements. In addition, these painting professionals offer the necessary guarantees so that the owner can enjoy the renovated aluminium joinery without any worries.

Figure 3.34: Manual spraying of the surfaces to be treated. © Resporepair

Pay attention to temperature and humidity

- More substantial work should preferably take place between March and October, when the **outside temperature does not exceed 30° Celsius or fall below 10° Celsius**. Minor repairs can still be carried out in colder temperatures if you preheat the profiles. At higher temperatures, other thinners may be added to the paint so that it dries more slowly. **However, avoid direct sunlight** with dark colours.
- **Rainy or foggy weather should definitely be avoided during the painting process.** In such conditions, the humidity is far too high to allow the surface to dry properly.

Partially replacing façades

You can replace (refurbish) parts of aluminium elements, you can have your window profiles repainted on site, but **you can also choose to partially replace a façade**. This is a circular technique with the aim of extending the lifespan of a building as well. But how does this method work exactly?

To determine the impact and added value of partially replacing façades, we developed a case in association with the independent research institute VITO. Three scenarios were examined on a wing of the Reynaers Aluminium office building in Duffel. For these cases, the LCA and LCC were determined and compared. Based on the results of this comparison, you can choose the direction in which you want to steer your renovation.

Case study: Reynaers Campus, Duffel

The life cycle analysis (LCA) was carried out to determine the environmental impact of a selection of façade solutions. We quantified the environmental profile from the extraction of their raw materials to final disposal and/or recycling. The results of an LCA analysis can be used during the design phase to keep the environmental impact as low as possible, but also to compare different designs or scenarios. In this study, the latter aspect is used to **compare three possible replacement scenarios with each other**. In each of the three cases, we assume the same façade construction over a total period of 60 years. In each of the scenarios shown here, after 30 years the choice is made to either fully or partially replace the façade, for example to meet the expectations of the new user. In the first case, we replaced the entire façade with a new façade construction with a new layout. In the second case, only part of the façade was replaced with a modified layout. And in the third scenario, only the glazing, insulators, seals and hardware were replaced – the design remained unchanged.

Figure 3.35: Visualisation of the façade for cases 1 and 2 (same layout)

Case 1: Complete replacement with new layout

Most significant change. Functionality and appearance in line with the expectations of the new user.

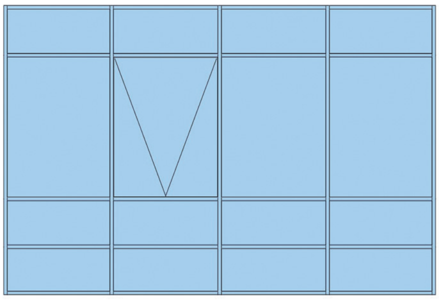


Figure 3.36: Front view of façade, case 1

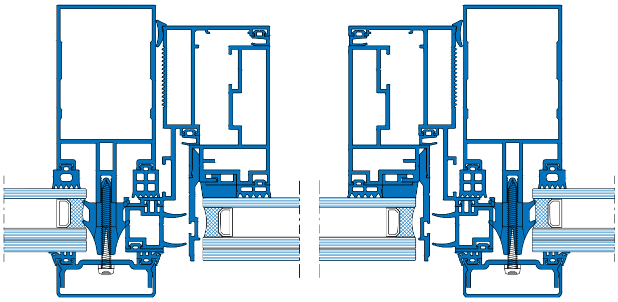


Figure 3.37: Horizontal section of façade, case 1

Case 2: Partial retention with new layout

Compromise in which functionality and appearance are still in line with the expectations of the new user.

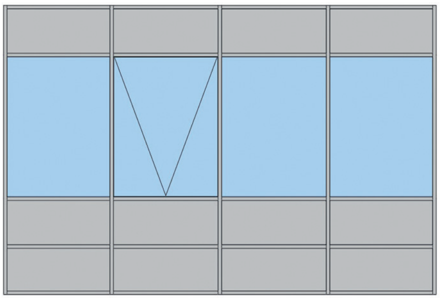


Figure 3.38: Front view of façade, case 2

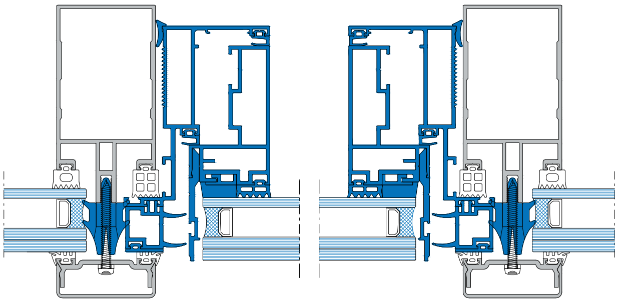


Figure 3.39: Horizontal section of façade, case 2

Case 3: Replacement of glazing, seals and hardware

Least intrusive adjustments with focus on retaining the materials and design, but less in line with expectations of the new user.

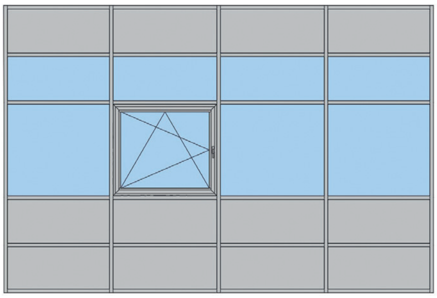


Figure 3.40: Front view of façade, case 3

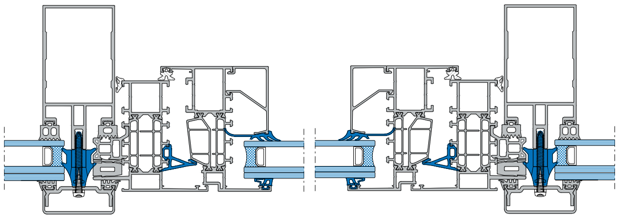
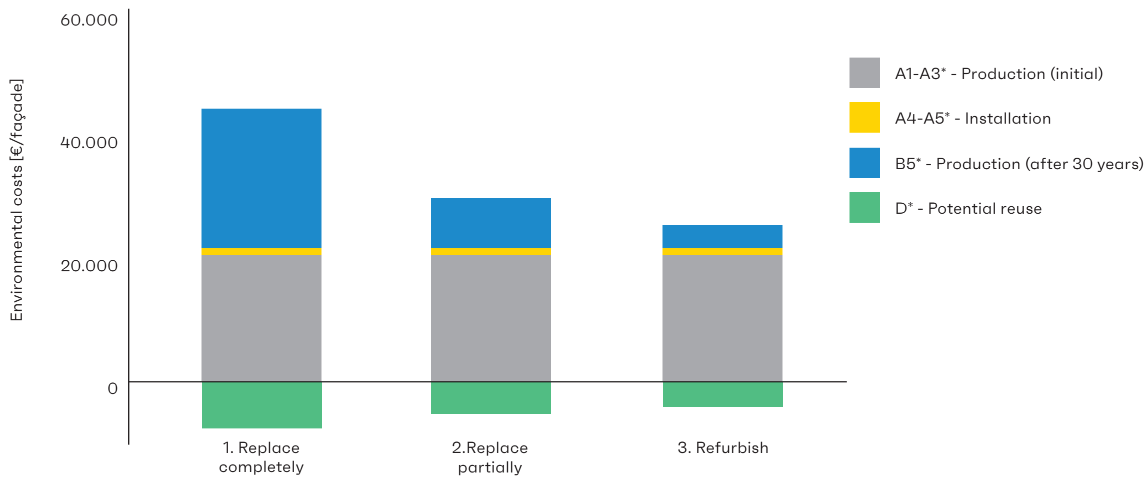


Figure 3.41: Horizontal section of façade, case 3

Explanation of the comparisons of the cases

Graphic 3.2 shows the results and comparison of the three scenarios for each main module (life cycle modules according to EN 15804). The results are expressed in environmental costs per façade. In Case 1, the result is determined by the impact of the original façade and the complete renovation after 30 years. By opting for more circular solutions in Case 2 and Case 3, the environmental impact can be greatly reduced by 33% and 42% respectively.

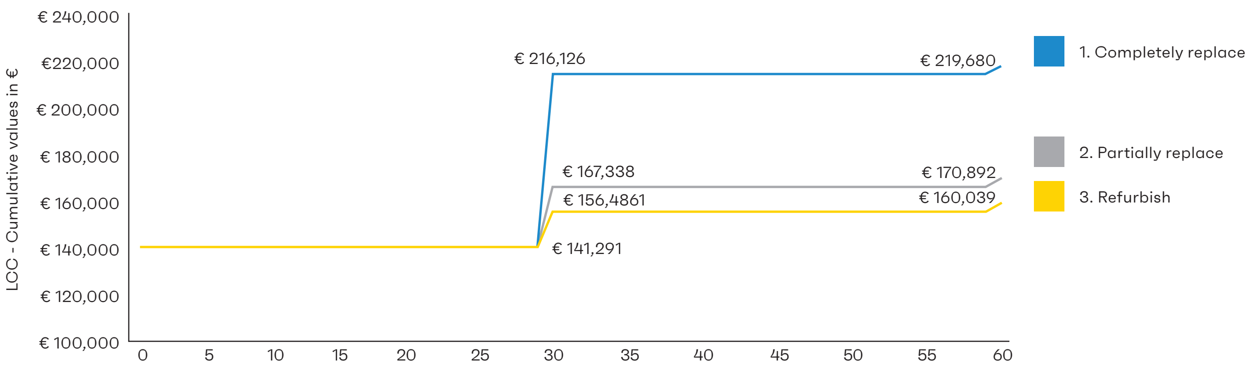


Graphic 3.2: Environmental costs per life phase for cases 1 to 3 (*source: European standard EN 15804)

The differences in environmental costs are entirely due to the amount of material that was replaced (module B5). Therefore, when renovating, it is certainly worth retaining existing materials as much as possible. As Case 2 shows, you can also apply a limited renovation – i.e. change the layout – with only a slightly higher environmental impact than in Case 3.

This can be clearly seen in the life cycle costing analysis (LCC, calculation based on material and labour costs over the entire life cycle). Until year 30, the year of the renovation, all cases score the same and the total cost is the same for all cases. For the renovation, we see that Case 1 in particular requires a large investment; after all, a completely new façade is being installed.

From an investment point of view, Cases 2 and 3 are therefore better choices, provided the façade to be renovated is sufficiently thermally efficient, watertight and airtight to continue to meet the user's expectations.



Graphic 3.3: Cumulative costs over 60 years for cases 1 to 3

Figure 3.42: SlimLine 38 Classic

The concept of residual value after 60 years was also applied to these cases. Please note that, depending on the case, either a recycling value or a reuse value or a combination of both was chosen. Cases 2 and 3 have a lower impact on the environment and costs. Here it becomes clear that these options are worthy alternatives to a full façade replacement, potentially providing the same performance and appearance as a full replacement.

Residual value determination after 60 years

Scenarios	% residual value in relation to the investment
Case 1 – Replacement of the entire façade after 30 years	40% - reuse value of new façade + recycling value of old façade
Case 2 – Remanufacturing of the façade after 30 years	10% - recycling value
Case 3 – Retention of the façade with refurbishment after 30 years	12% - recycling value

Table 3.4: Residual value determination of a façade after 60 years for cases 1 to 3

Conclusions

Circularity at product level - Use phase

Circular joinery retains its value as best it can throughout its lifetime. Dismantlability is an important criterion in this respect, as it allows for reuse. Where detachability is already very much present in façade systems, we can achieve this in windows by relying on an adapted building connection – as discussed earlier in this chapter. In addition, metrics such as residual value and detachability index make it easier to quantify dismantling.

The joinery has a very long lifespan, provided attention is paid to maintenance and use is made of the refurbishment options. If you choose to refurbish the joinery, then you must consider whether the thermal performance is still sufficient and whether there is any serious damage that could compromise performance in terms of air-, wind- and watertightness.

Circularity at end of life

When we can no longer reuse or renew aluminium systems, their life cycle ends. **The elements are dismantled, the material is sorted and recycling can begin.** But this process is not as self-evident as it seems. How does the end-of-life phase of products work out in practice? What are the benefits? And how can we avoid downcycling, or the depreciation of the recycled material?

Demolition

Every year, 15 million tonnes or 8.3 million m^3 of construction and demolition waste is produced in Flanders, Belgium (source: Circular Flanders). More than 90% of this waste consists of stony materials. In practice, these waste streams are selectively demolished by demolition contractors only when pure fractions yield more than mixed waste debris. However, selective demolition requires more space and time than non-selective processing, and this entails higher costs. Moreover, **the reuse of construction products is currently still a niche activity**.

The "Proeftuin circulair bouwen" ["Living Lab for Circular Construction"] research project of Circular Flanders studied how **urban mining – that is, the extraction of raw materials from urban sites** – is carried out in practice for different material streams.

- In **minimal selective demolition**, the standard practice, four streams are separated: mixed residual waste, B-wood, soil and stones, and mixed stone rubble
- In **selective demolition**, the following streams are added: plasterboard, hard plastics, roofing and glass waste

The size of the site can have a major impact on disposal and processing costs – and these costs in turn influence the choices made in relation to selective demolition.

Different material streams – including PVC and aluminium windows – are often disposed of separately before a building is completely demolished. However, flat glass waste often ends up largely in mixed waste (about 73% of post-consumer flat glass waste), which makes high-quality recycling difficult. Also, the distance to the nearest glass processing plant is usually much greater than the distance to the nearest rubble processing plant. Due to the additional transport costs, this step in the demolition process is therefore often skipped.

Demolishers usually smash the flat glass of buildings before they remove the aluminium joinery with a gripper. Carefully separating glass from aluminium costs significantly more than the absolute scrap value and is therefore not financially attractive. Studies are under way to recycle sheet glass efficiently, but every type of contamination is an obstacle. Therefore, the selective scrapping of flat glass is not yet being carried out on a large scale.

Sorting

Some demolishers carefully separate rubber seals and similar components from the aluminium in window profiles. After all, the price the demolisher gets for the aluminium depends on the purity of the waste, which makes the economic advantages of selective demolition more important, especially for large sites. In practice, however, we find that all joinery usually ends up in the same container.

After the selective or non-selective demolition of the construction material, the recycling plant continues to work with the waste. The first step is manual sorting. Sorters separate aluminium window frames from other aluminium waste because this alloy is of higher quality than, for example, sheet material.

Next, the aluminium is processed through a shredder, a large machine that tears the material into smaller pieces. This step can take place either at the scrapyard or at the foundry. Smelters usually use some of the waste, such as insulation bars and other plastics, as fuel during the smelting process. They also do not distinguish between painted or bare profiles, which recycling companies usually do.

1 **Shredding into small pieces**
During the shredding process, seals, and other high-caloric materials – waste that gives off a lot of energy during incineration – are separated.

2 **Removing the ferrous fraction**
A magnet then removes the iron from the metal fraction.

3 **Further separation of non-ferrous metals**
The next step is the further separation of non-ferrous fractions, using various techniques, including flotation. In this process, depending on the density, different fractions are separated in a liquid. At this point in the process, the remaining plastic material is also removed from the fraction.

In this way, the recycler can distinguish around 30 different aluminium fractions. This enables us to use the right alloys for extrusion and avoid downcycling. And to keep the environmental impact as low as possible, it is essential that extrusion alloys are not downcycled into casting alloys (these are alloys containing larger amounts of alloying elements such as silicon, copper and zinc). However, this process will only be carried out if it is also sufficiently attractive in financial terms to make this distinction during sorting.

Aluminium from demolition waste also contains a lot of zinc residues, from the hardware components and casting angles that hold the extruded profiles together. To form a pure extrusion alloy (6060), it is important to remove the zinc from the fraction, which can only be done by spectral analysis. This step is also relatively expensive and is therefore not always carried out. Only if the market price for the purer form of material is high enough, the procedure is applied.

Figure 3.43: Roughly sorted aluminium scrap

Recycling

After the sorting process, the fractions are sold to foundries, mainly in Europe but also further afield. They revalue the fractions by, for example, adding a pure primary alloy, i.e. alloys from the 1000 series with a minimum of 99% of the chemical element aluminium, to the scrap to obtain a high-quality extrusion alloy (6060 or 6063). The amount of pure primary material that needs to be added depends on the purity of the recycled aluminium. New billets (aluminium cylinders as base material for extrusion) are made and sent again to the extruder, who makes brand new window profiles from them.

Smelters can also provide base material for casting parts. Less pure scrap is used, which may lead to downcycling.

At present, the demand for aluminium is so high that almost all aluminium scrap is recycled. 99% of aluminium is collected at the end of its useful life (source: TU Delft study ‘Collection of aluminium from buildings in Europe’), while 91% returns to the circuit via demolishers, recyclers and smelters. However, these quantities are nowhere near sufficient to satisfy the global demand for aluminium, so primary aluminium still has to be produced.

Window recycling loop

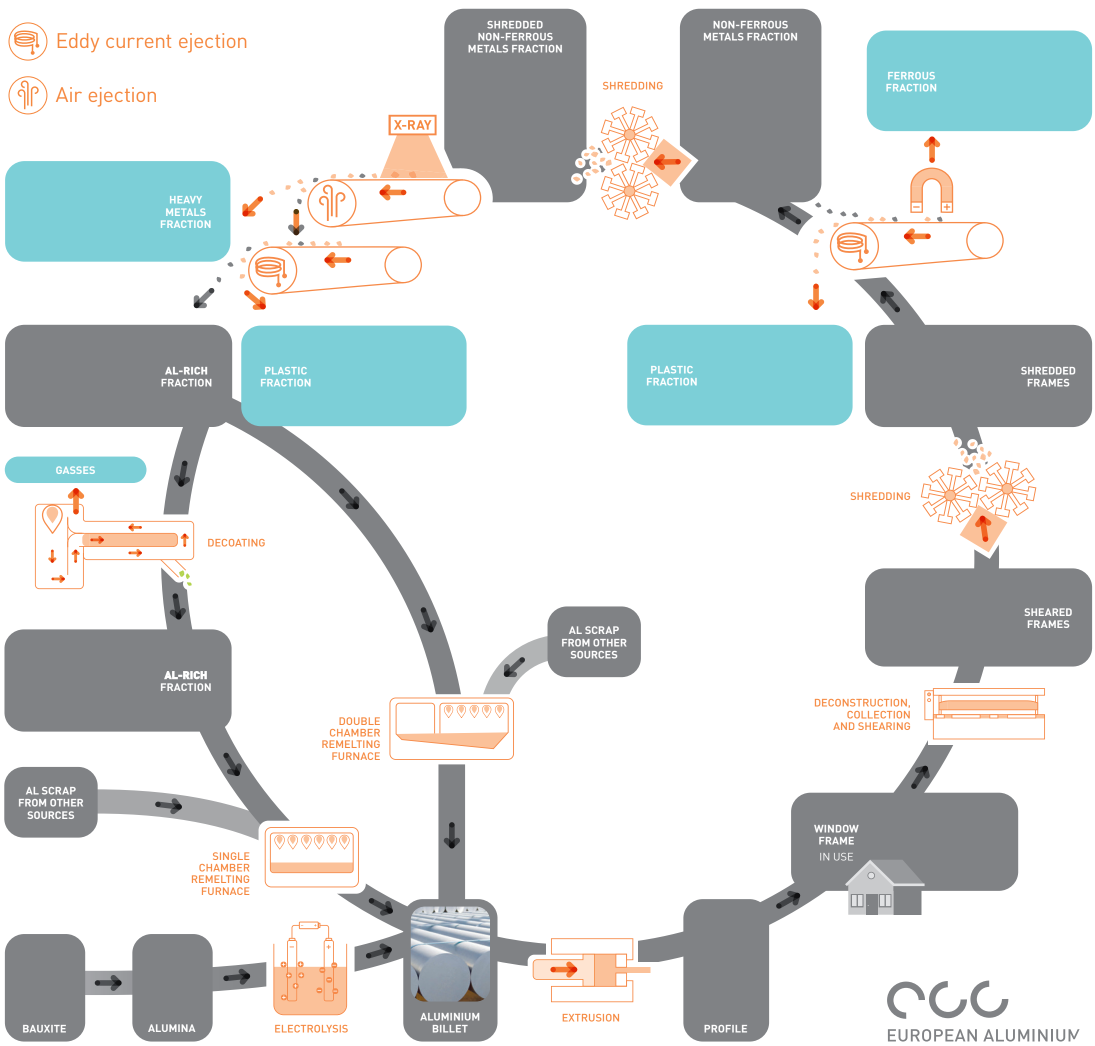


Figure3.44: Sorting process for optimal recovery of aluminium from demolition waste. Source: European Aluminium

Incoming material – after the demolition process, both the pure aluminium and the window frames are kept separate.

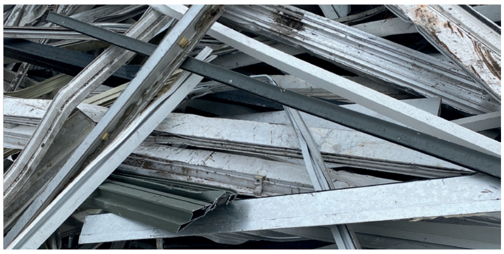


Figure 3.45

Sawn frames – the window frames are sawn into medium-sized pieces.

Figure 3.46

Shredded frames – a shredding machine shreds the aluminium into smaller pieces. In addition to aluminium, the waste also contains other fractions that need to be removed.

Figure 3.47

Non-ferrous fraction – a magnet is used to remove the ferrous components, while the plastic fractions are blown away.

Figure 3.48

Plastic fraction – other plastic components are also removed. This collection includes pieces of insulators and seals.

Figure 3.49

Aluminium fraction – the coating layers are removed from the remaining aluminium. This fraction is ready to be re-smelted into new billets.

Figure 3.50

Conclusions

Circularity at product level - End of life

Aluminium is recycled on a large scale. There are industrial processes that do this thoroughly and efficiently, but care must still be taken to avoid downcycling. For scrap processors, it is financially attractive to deliver less pure fractions for other applications, such as aluminium castings, since chemical elements such as copper, zinc, iron and silicon are present in greater quantities in these alloys. Due to the rising price of primary aluminium, demand for pure scrap fractions is increasing and we are seeing more and more investments in separating aluminium as purely as possible. In this way, aluminium profiles return to the cycle as full aluminium profiles.

Conclusion

The main purpose of this guide is to introduce architects and other stakeholders of the construction process to the world of circular building with aluminium joinery. This guide discusses circularity in all its facets, at material, project and product level. Today, the circularity aspect in buildings and products is a crucial factor to take into account – especially within our own area of expertise, aluminium. The demand for this user-friendly material is high, which only increases the importance of circularity in the entire aluminium life cycle.

With this guide, we have tried to highlight the various possibilities – these being both the strengths and the weaknesses of aluminium systems in terms of circularity. It is up to the architect to make proposals according to the client's expectations and the possibilities of the renovation project. In this respect, the guide can serve as a reference.

Currently, there are therefore many possibilities for circularity in the aluminium industry.

We showed the concept of a new Reynaers Aluminium building connection that allows for problem-free dismantling. The disassembly potential and residual value determination of products can facilitate a well-considered choice of materials and systems, although this is only done to a limited extent at present. Awareness and adaptation of circular thinking in companies is growing in the construction industry, but here too we are only talking about individual initiatives that are of limited application.

We therefore consider the harmonisation of these many ideas to be one of the most important areas to work on as regards circularity. Standardisation of circular techniques, such as a product passport, can ensure that more companies include circularity in their day-to-day operations. Bringing ideas together in a central database or creating an (online) hub around circular building can also provide a solution and increase support.

Figure 4.1: © Philippe Piraux, Jaspers-Eyers Architects

The lack of a legal framework for certain new circular concepts – think of installing a façade as a service, as in the case of ‘t Centrum – is still an obstacle. Incentives such as a legislative framework or low material costs can ensure that individual initiatives are more quickly incorporated into the whole sector.

But the limited return on investment of circular building is still the biggest stumbling block for many companies today. Reusing materials and cleanly separating building components during renovations takes time, and thus has financial implications. Research and storage also require resources, and it is not always clear how these costs are accounted for.

In addition, the introduction of new methods often requires a shift in mentality within an industry. Is the construction sector open to new solutions which are designed for disassembly? And what role do the other stakeholders in the construction process play in the modernisation and circular optimisation of the construction industry?

This guide therefore primarily shows the possibilities of circular building. We have learned from the past that it is vital to build up sufficient knowledge if we want to see innovations applied broadly and correctly in the implementation phase. Regular dialogue with stakeholders gives us an up-to-date picture of how and to what extent circularity is being embraced by the sector. New developments and initiatives are evolving every day, and only through open dialogue can we give these ideas a fair chance of growth.

Reynaers Aluminium also sees circularity as a cornerstone concept in its own operations for the future. Aluminium is easy to recycle, but only half of the material offered in our industry is recycled content. We are committed to better understanding and optimising the life cycle of aluminium. How can we process aluminium responsibly so that the environmental impact of our products remains low? And what possibilities can be explored to extend the lifespan of our profiles? Fascinating questions with equally fascinating answers.

Acknowledgements

We would like to thank everyone who contributed to the completion of this guide. Without the input of our partners, this project would not have been a success. Thanks to VITO for their scientific input during the project. We also thank the Department of Architectural Engineering of the Vrije Universiteit Brussel for their expertise and for the successful collaboration during the Circular Retrofit Lab project case. Their input during the research was also invaluable. Finally, we thank Ovam and Circular Flanders for their financial support.

In addition to government agencies and official organisations, we also worked closely with a number of professionals from the construction sector itself. Therefore, we thank all the firms of architects, design engineers, demolition firms and suppliers for their professional help. You can find these parties on the project website (windowsforcircularbuildings.com). Finally, we thank you, the reader, for joining us in discussing the world of circular building and exploring its endless possibilities.

Annex

Circular tools

Because of the urgency of integrating circularity into the construction sector, many tools have already been developed to help stakeholders design buildings and building elements in a circular way. Two main categories can be distinguished: design tools and evaluation tools.

Design tools provide design guidelines, while evaluation tools help to compare different design choices. The industry is not yet clear on how to apply such an evaluation of circularity in buildings – each tool uses different indicators. Nevertheless, it is worthwhile getting to know and use these tools better.

Design tools

The design tools developed for the (Belgian) construction sector are:

- **"Bouwen voor een circulaire economie" (VUB Architectural Engineering**) contains design strategies, qualities and concepts that designers and building owners can use to make informed design choices. For each design quality, a practical example is given and targeted actions are proposed.
- **"Bouwcatalogus veranderingsgericht bouwen" (VIBE)** provides additional information on change-oriented building, specifically aimed at real-life situations, in order to accelerate the transition to dismantlable construction.
- **"CE Kompas" (Circular Flanders)** is a checklist containing concrete steps for the various product life cycles with the aim of closing the (material) cycles.

International design tools include:

- **"The Circular Design Guide" (Ellen MacArthur Foundation)** is a guide that, depending on background knowledge, guides users in applying circular methods during the design process. For each method, a step-by-step plan or workshop is provided.
- **"The Sustainability Guide" (Interreg Baltic Sea Region)** is a comprehensive guide to eco-design and the circular economy. The guide offers companies, designers and researchers in higher education inspiration and tools to get started with sustainability. Circular business models, principles of eco-design and cases of pioneers in the circular economy are discussed.

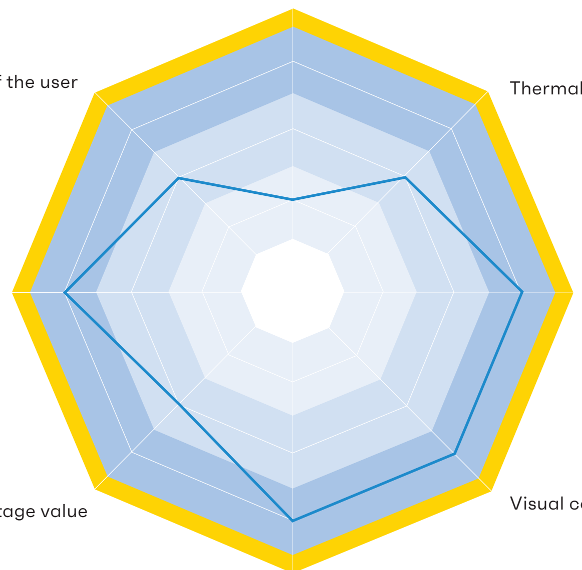
Figure 5.1: ©BAO Architecten

Evaluation tools
“GRO” (Norwegian for Growth, GRO: Op weg naar toekomstgerichte bouwprojecten | Vlaanderen.be) is a manual developed by the Facilitair Bedrijf, an organisation that supports governments and local authorities in Flanders with facilities services. The manual discusses various sustainability themes, including circularity.

The GRO seeks to provide an integrated design process to create future-proof buildings. Its principles can be applied to buildings of different functions (office, residential) and of all sizes. The GRO is strongly committed to raising awareness among relevant stakeholders to look at the entire building life cycle and integrate circular principles into their design. The GRO evaluates different criteria within three categories: People, Planet and Profit. The full list of criteria for the 2020 edition can be found in the GRO guide. The criteria are not weighted among themselves, but are shown in radar charts (Graphic 5.1 on the next page). This graphical representation allows you to evaluate very quickly how well the design scores against the various criteria. There are no criteria specific to joinery, but several factors are influenced by the choice of profiles. These are listed in Table 5.1 on the next page.

Category	Criterion	Aspect
People	Acoustics	Façade sound insulation, sound radiation (Vlarem)
	Thermal comfort	U-value, choice of glass, night ventilation
	Indoor air quality	Opening parts, grilles
	Visual comfort	Daylight penetration, glare, view, colour rendering of glass, direct sunlight
	Heritage value	Choice of joinery according to heritage
	Socially safe design	Social control, wayfinding, attractiveness, transparency
Planet	Energy performance	Performance of external joinery (U-value, g-value, etc.), airtightness (design)
	Preservation of raw materials	Inventory of materials present on site (potential reuse/recycling)
	Choice of materials (TOTEM)	Part of a TOTEM calculation
Profit	Maintenance-friendly design	Accessibility of glass surfaces, replacement of joinery, choice of materials for frames, hardware adapted to use
	Cleanliness-conscious design	Choice of frame material, avoid subdivisions, clean glazing
	Circular and future-oriented design	Modularity, staggered daylighting, standardisation, reuse potential, recycling potential

Table 5.1: GRO criteria linked to joinery (2020 version)



Graphic 5.1: Example of a GRO radar chart (2020 version)

In addition to the GRO, there are other evaluation tools that are used in the construction sector:

- **"Level(s)" (European Commission)** is an assessment framework that provides a common language for the sustainability performance of buildings – primarily through key sustainability indicators. It provides a robust approach to measuring and supporting improvements from design to end of life.
- **"C-Calc" (Cenergie)** measures the circularity of buildings based on the use of materials, the degree of adaptability of the building and the construction process.
- **"The Building Circularity Index" (Alba Concepts)**

Figure 5.2: MasterLine 8 panel door

Detachability index (Alba Concepts)

The determination of the detachability index of a product follows the following step-by-step plan: **All four detachability factors are first assessed by means of fixed category values**. These values are linked to scores ranging from 1.00 (no obstacle to detachability) to 0.10 (complete obstacle to detachability).

Objects are connected by various types of connections. With respect to detachability, dry connections, connections with added elements and direct integral connections are more important than soft and hard chemical connections.

1. Connection type (CT)

The scores of the different types of connections (CT) are shown in a table below.

Connection type (CT)		Score
Dry connection	Loose (no fasteners) Snap connection Velcro connection Magnetic connection	1.00
Connection with added elements	Nut and bolt connection Spring connection Corner connections Screw connection Connections with added connecting elements	0.80
Direct integral connection	Pin connections Nailed connection	0.60
Soft chemical connection	Cemented connection Foam connection (PUR)	0.20
Hard chemical connection	Glued connection Concreted connection Welded connection Cement-bonded connection Chemical anchors Hard chemical connection	0.10

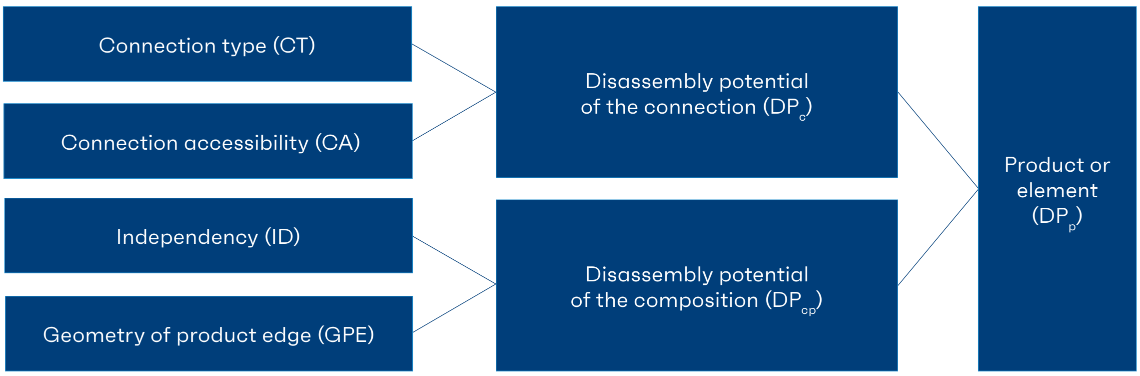


Table 5.2: Step-by-step plan for assessing the disassembly potential of a product or element

2. Connection accessibility (CA)
Can you (physically) get to the connection elements and to what extent is damage caused to the surrounding objects? This is the crux of the "connection accessibility" (CA) factor.

Connection accessibility (CA)	Score
Freely accessible without additional actions	1.00
Accessible with additional actions that do not cause damage	0.80
Accessible with additional actions with fully repairable damage	0.60
Accessible with additional actions with partially repairable damage (more than 20% of the value)	0.40
Not accessible – irreparable damage to the product or surrounding products	0.10

Table 5.23

3. Independency (ID)
A building contains intersections when products or elements run through each other or are even fully integrated with each other. As a consequence, more actions are needed to dismantle a product or element at the end of its life. Especially when the lifespans of the products in question differ greatly, you will have to replace them in the interim, while surrounding products or elements have to be preserved.

Independency (ID)	Score
No intersections - modular zoning of products or elements from different layers	1.00
Incidental intersections of products or elements from different layers	0.40
Full integration of products or elements from different layers	0.10

Table 5.24

4. Geometry of product edge (GPE)
The geometry of product edges determines how products are placed in a configuration, either open or closed. As the name suggests, this has to do with the physical edges of the product or element. When a product is "locked in" by surrounding products in this situation, it is called edging.

Geometry of product edge (GPE)	Score
Open, no obstacle to (intermediate) removal of products or elements	1.00
Overlap, partial obstacle to the (intermediate) removal of products or elements	0.40
Closed, complete obstacle to the (intermediate) removal of products or elements	0.10

Table 5.25

Detachability index

The exact formula to determine the disassembly potential of a product or element is:

$$DP_n = \frac{4}{\frac{1}{CT_n} + \frac{1}{CA_n} + \frac{1}{ID_n} + \frac{1}{GPE_n}}$$

Where:

- **DP_n** = disassembly potential of product or element n
- **CT_n** = connection type of product or element n
- **CA_n** = connection accessibility of product or element n
- **ID_n** = independency of product or element n
- **GPE_n** = geometry of product edge of product or element n

The detachability or disassembly potential index is a one-point score that indicates how detachable a specific product or element is from a building. Detailed drawings are an excellent source for determining the detachability of specific products. A relationship diagram can indicate which products are connected to each other and allows the detachability index of each product in the diagram to be determined. It is important to note that the measurement method is limited to products and elements: it does not usually assess the detachability index of seals or fasteners.

Explaining the method behind determining the residual value

With regard to financial residual value, a distinction can be made between reuse value and recycling value. Here, the financial residual value of the archetype to be reused (reuse value) is higher than the financial residual value of the elements and products to be recycled or downcycled (recycling value). However, a product must be detachably connected in order for the reuse value to be capitalised.

Reuse value

The following steps are taken to determine the reuse value of a product.

The starting point of the reuse value is the **purchase price** of the archetypes (PV_p), as recorded in an open budget. This budget includes the direct construction costs of the archetypes, which are further broken down into material and assembly costs. Only the material component is taken into account to determine the purchase price. The purchase price of all archetypes, sub-products and elements is provided by Reynaers Aluminium.

Secondly, the **reuse potential (RP)** of the archetype is determined. This value indicates what percentage of the archetype can be reused at the time of release. Next, an assumption is made about the degree to which the archetype degrades or declines in quality over time. To include **quality reduction (QR)** in the reuse value of the archetype, a percentage of the purchase value is used. As the quality reduction depends on the age of the archetype, the reuse value for the products and elements of the archetype was determined at 30 and 60 years. The quality reduction and reuse potential were determined based on reference numbers from Alba Concepts and together with cost experts.

The costs for dismantling the archetype are then determined. For the archetype, an estimate of the hours required for dismantling was made together with cost experts and using the calculated detachability. Dismantling time is the time between starting "dismantling" and placing on pallets. An average hourly rate was then used to arrive at the total **dismantling costs (DC) for labour**. The **dismantling costs of the material** were also determined.

Due to the quality reduction, it is often necessary for the archetype to be overhauled and repaired. These are the **overhaul or inspection costs (IC)**, which are determined as a percentage of the quality reduction. A relatively large quality reduction results in relatively high overhaul costs. The overhaul costs were determined using reference figures from Alba Concepts and together with cost experts.

In order for the archetype (and its elements) to be reused, costs for transporting the archetype to the storage location must be provided. The **transport costs (TC)** are determined on the basis of an average distance in kilometres and the costs for transport per m^3 or kg/tonne. Reference figures from Alba Concepts were used to determine the transport costs.

Finally, there are also costs for the temporary storage of the archetype. These costs are determined based on the average **storage costs (SC)** per kilogram and the average storage time. The storage costs were determined on the basis of reference figures from Alba Concepts.

The above steps result in the following calculation:

$$\textit{Reuse value} = PV_p - RP - QR - DC - IC - TC - SC$$

The above formula does not take into account price developments due to the effects of time (indexation). The reuse value is expressed exclusive of VAT.

Recycling value

The recycling value or material value represents the recycling scenario. In the hierarchy of building, element, product, material and raw material, this scenario focuses on the raw material and material level. It thus represents the most low-grade level of circularity, namely recycling. This means that a steel guard rail, for example, is melted down to the material steel or a plastic bench is reduced to granulated plastic.

The following steps are taken to determine the recycling value of a product.

The starting point of the recycling value is the **raw material price of the element or product (PV_m)**, as recorded in an open budget. Only the raw material of the element or product of the archetype is considered when determining the purchase price. The raw material prices are based on the London Metal Exchange or comparable commodity trading institutions (price level June 2021).

Secondly, the **recycling potential (RP)** of the product or element is determined. This value indicates what percentage of the building materials can be recycled at the time of release. The recycling potential was determined on the basis of reference figures from Alba Concepts and together with cost experts.

Then there are the costs for removing the product and/or element from the archetypes. For each building material, an estimate of the hours required for demolition was made together with cost experts. Based on an average hourly rate, the total **demolition costs (labour)** were then calculated. In addition, the **material demolition costs (DC)** were also determined.

The next step is to determine the **processing costs (PC)**. These are costs linked to the actual processing and recycling of the products and elements. The processing costs were determined on the basis of reference figures from Alba Concepts and together with cost experts.

In order to recycle a product or element, there are also costs for transport to the storage location. The **transport costs (TC)** are determined on the basis of an average distance in kilometres and the costs for transport per m^3 or kg/tonne. Reference figures from Alba Concepts were consulted to determine the transport costs.

Finally, there are also costs for the temporary storage of the element or product. These costs are determined on the basis of the average **storage costs (SC)** per m^3 and the average storage time. The storage costs were determined on the basis of reference figures from Alba Concepts.

The above steps result in the following calculation:

$$\textit{Recycling value} = PV_m - RP - DC - PC - TC - SC$$

The above formula does not take into account price developments due to the effects of time (indexation). The recycling value is expressed exclusive of VAT.

More information regarding the method and the determination of costs can be found in the Financial Valuation Standard - Alba Concepts (www.albaconcepts.nl). This document was drawn up by Alba Concepts on behalf of Metaalunie and FME, in association with the Dutch Ministry of Economic Affairs and Climate Policy.

Reynaers Aluminium environmental commitment

Reynaers Aluminium is aware that companies play an important role in caring for the environment. This is why we are constantly looking for new ways to become 'greener' and why we are pioneers in the field of energy savings and sustainable products.

This approach starts with the **material** we use for our profiles: aluminium. Thanks to its high durability and 100% recyclability without any loss of quality, this material has long enjoyed a solid reputation as an environmentally friendly metal. Its remarkable strength, anti-corrosion properties and ease of maintenance make it the ultimate building material for an industry that is constantly looking for lighter, stronger, more durable and environmentally friendly alternatives. Its sustainable character has already been confirmed by the **C2C (Cradle to Cradle®) certificate** for a number of advanced window, door and façade solutions.

In brief, this certificate guarantees that:

- no hazardous materials are used;
- our systems are manufactured with respect for raw materials, energy and water use;
- these systems can easily be recycled.

C2C-certified systems therefore offer a guarantee of environmentally friendly building according to the recycling concept.

However, sustainability is not limited to the use of materials: Reynaers Aluminium also pays a lot of attention to energy efficiency. Continuous investment in research and development has earned many of our systems the **Passive House Certified component** label and the Swiss **Minergi**e label.

These energy-efficient solutions can be used in low- and zero-energy houses and thus contribute to a sustainable environment, which makes it attractive for architects to work with such certified systems. The principles of these certificates are closely aligned with **BREEAM** (Building Research Establishment Environmental Assessment Method) and **LEED** (Leadership in Energy and Environmental Design), the internationally recognised labels that determine the sustainability levels of buildings. These certificates prove that environmental issues, such as the building's energy needs, the recycling of materials, the use of water, the comfort of people in the building, the use of renewable energy sources, the location of the building, etc. were taken into account in the construction of the buildings. The growing interest in these certificates is proof of the importance of sustainability. With innovative products, continuous research and a focus on knowledge exchange, Reynaers Aluminium is making a real contribution to this way of building.

However, our focus is not only on making our products greener, but also on **making ourselves as sustainable as possible as a company**. Over the last 20 years, we have always been a pioneer with initiatives such as the large-scale application of solar panels on our roofs and a programme of bicycle commuting, but now we thought it was time to go one step further.

Therefore, in 2021 we decided to dramatically reduce our carbon footprint. **The Science Based Target** initiative helps us and other companies around the world to use science to fight climate change and halve our emissions by 2030.

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Reynaers Aluminium

Oude Liersebaan 266
B-2570 Duffel

T +32 (0)15 30 88 10
info@reynaers.be
www.reynaers.be