Circular Façade Systems and Construction: Design for Remanufacturing Window Systems

P5 | MSc 4
07.02.2019

Tania Cecilia Cortés Vargas
4747720

Mentors:

Tillmann Klein (1st mentor)
David Peck (2nd mentor)
Wijnand van Manen (Guest supervisor)
Peter Koorstra (BoE delegate)

KAWNEER
AN ARCONIC COMPANY

TU Delft
BK Bouwkunde

Problem Statement

Problem Statement



TAKE

Resource Extraction

Problem Statement



Problem Statement



Problem Statement



40%

of the materials that enter the global economy

40-50%

of the global output of GHG emissions & acid rain agents





TAKE

Resource Extraction







MAKE

Manufacturing · Distribution · Use



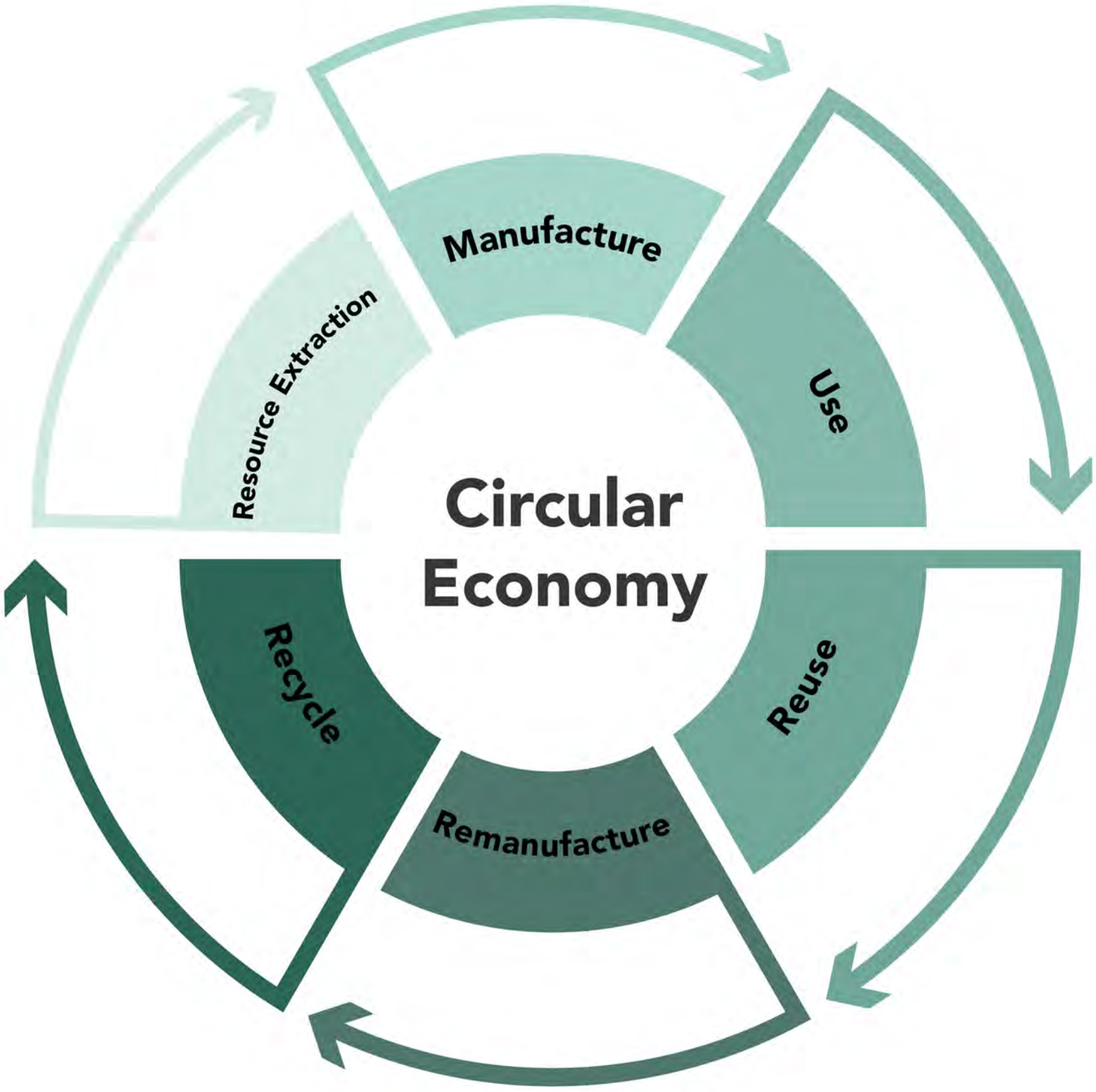
DISPOSE

Waste

Problem Statement



Problem Statement



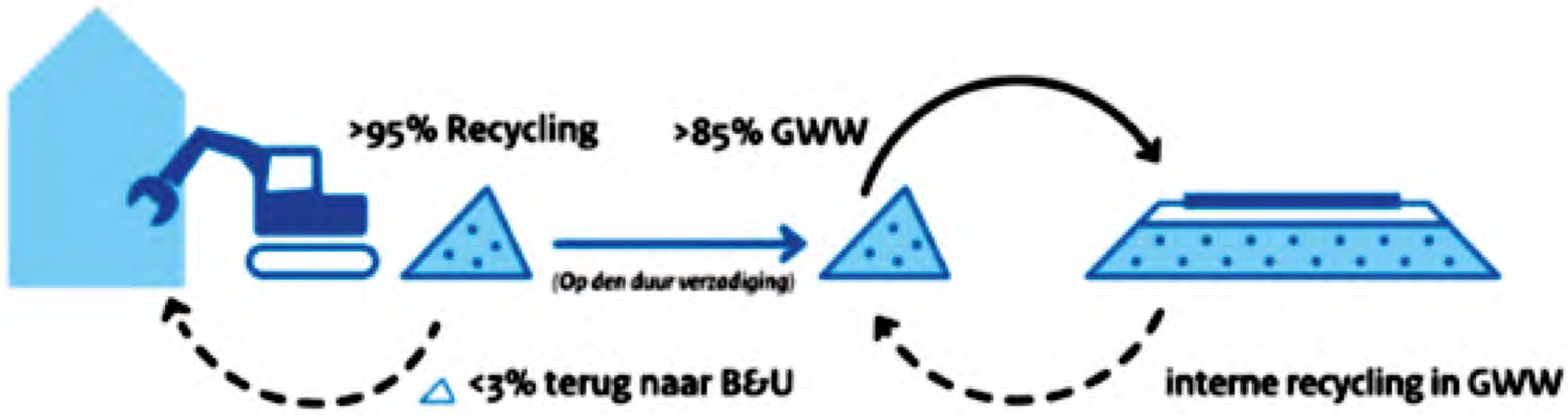
Concept diagram of a CE. Image by author.

Why?

Nederland circulair in 2050

Rijksbreed programma Circulaire Economie

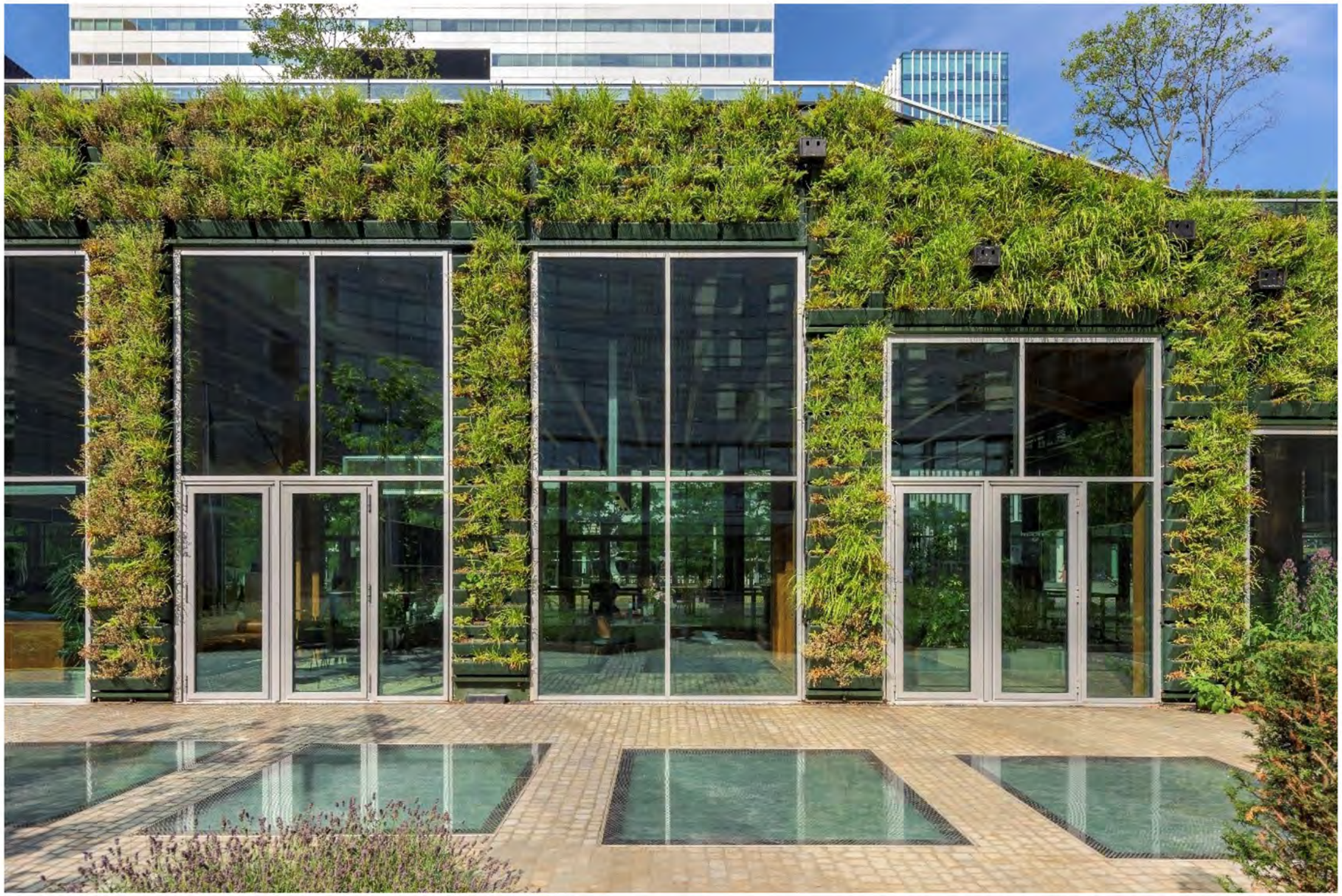
Circulaire Economie in de bouw



Problem Statement

A demand for a design strategy for façade systems taking into account **circularity** can contribute to **product life extension scenarios**, and is an alternative to demolition.

Kawneer Nederland B.V.



CIRCL Pavilion Amsterdam. Image bykawneer.com/bcs/architectuursystemen/nl/info_page/circulair.asp

AR 90 & AR 100 Programmes - Recylcing Aluminium

Main Research Question

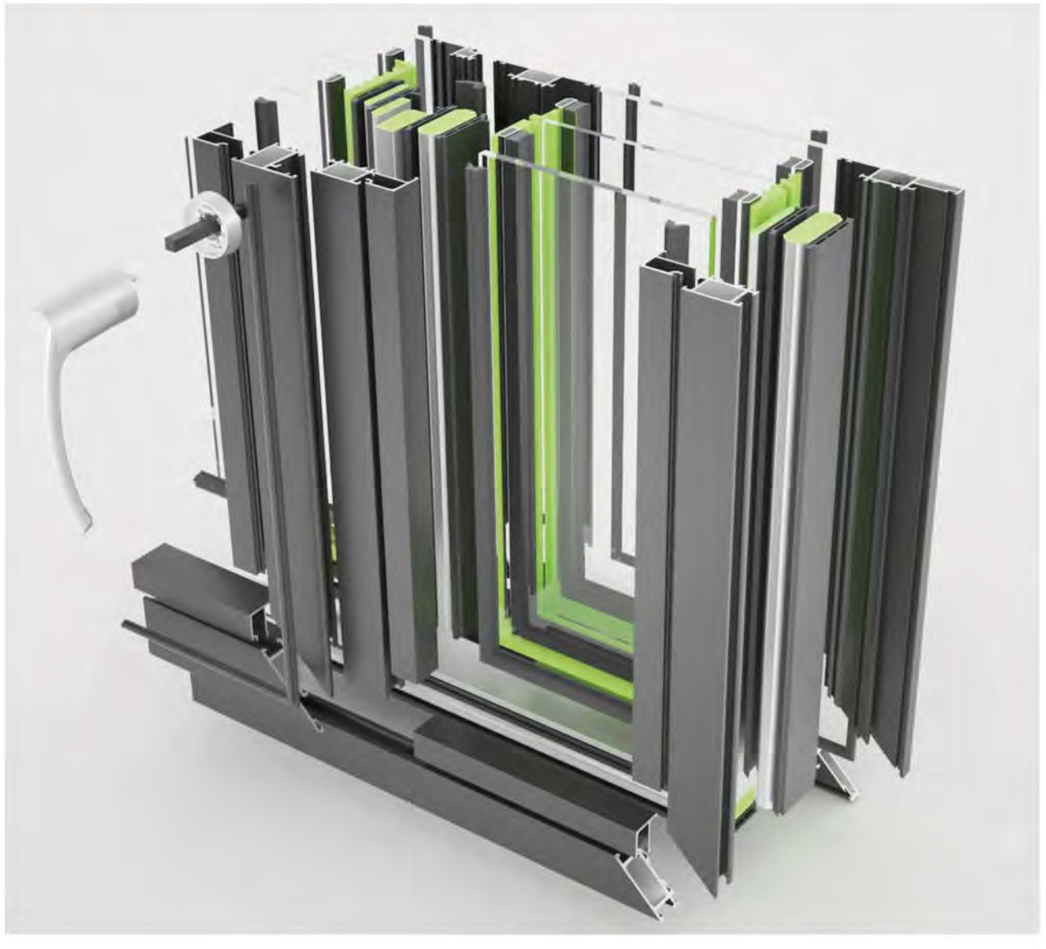
?

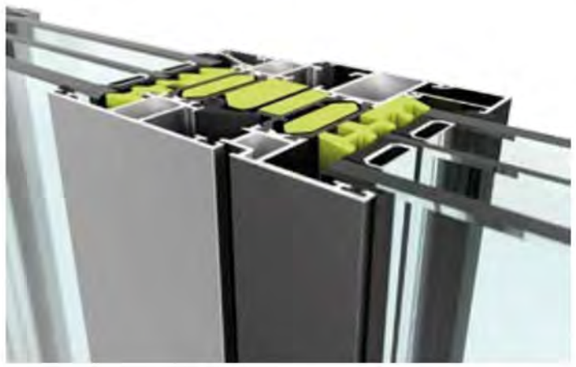
How can Kawneer's façade window systems be improved in terms of **circularity**, as a **long-term sustainable strategy**?

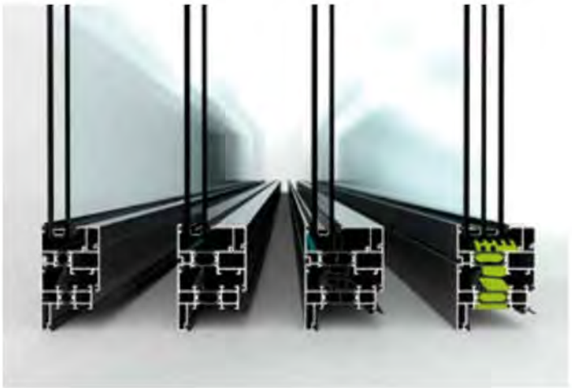
Focus and Restrictions

RT 82 HI + Window System
High Insulating Passive House window

KAWNEER
AN ARCONIC COMPANY



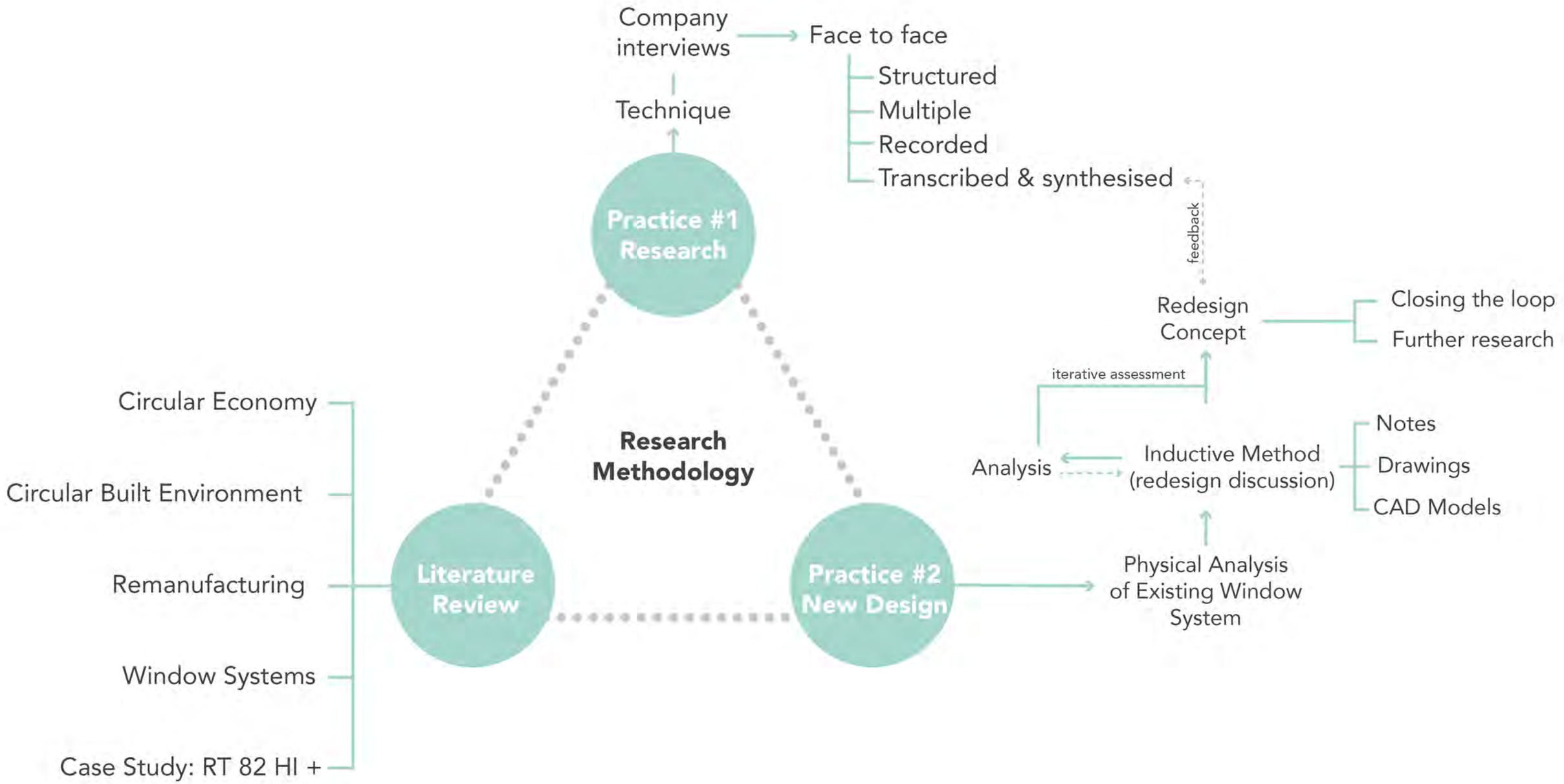






RT 82 HI + System exploded. Image by kawneer.com

Methodology



Literature Review

What is a Circular Economy?

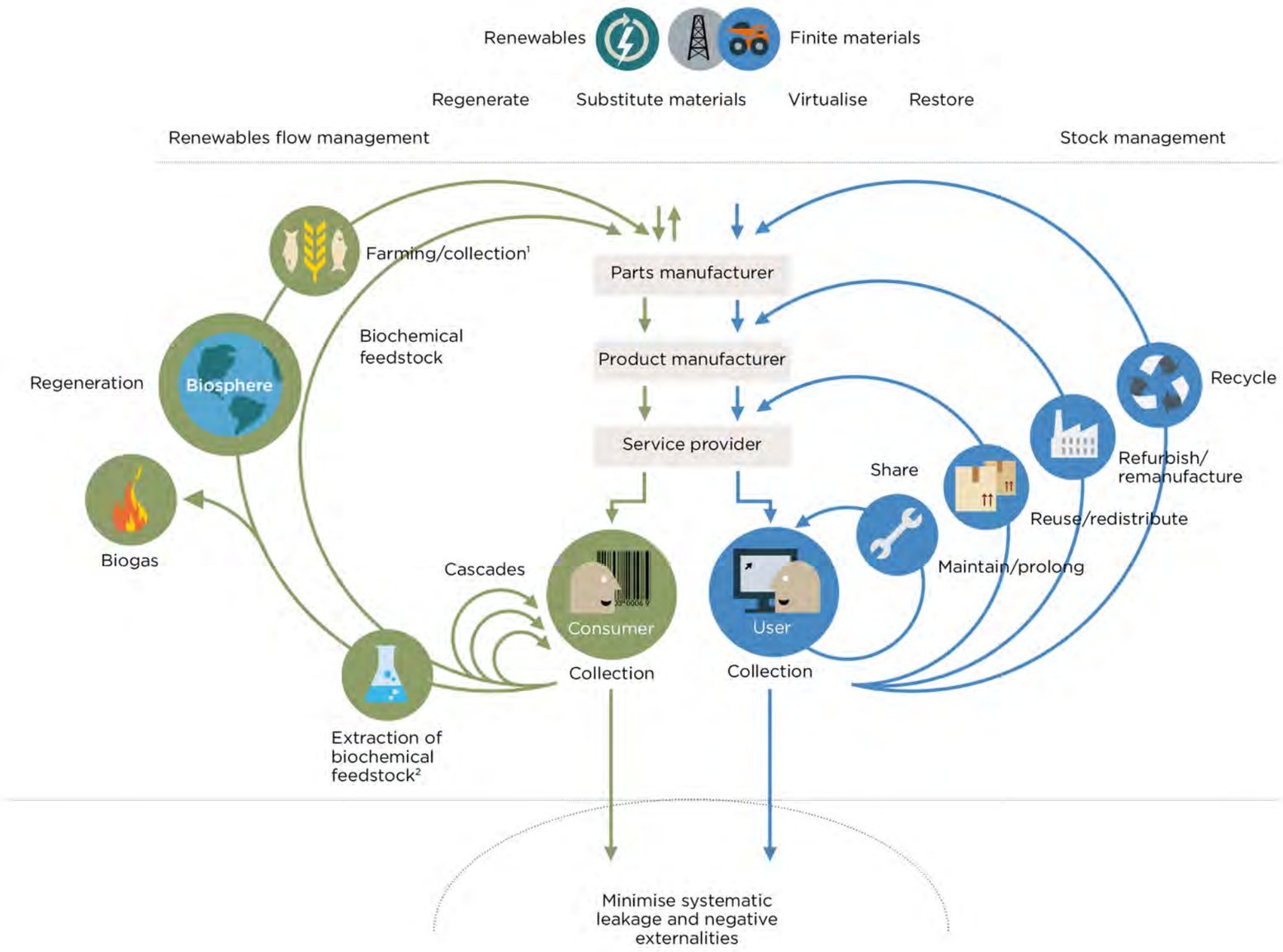
1. Design out of waste

2. Build resilience through diversity

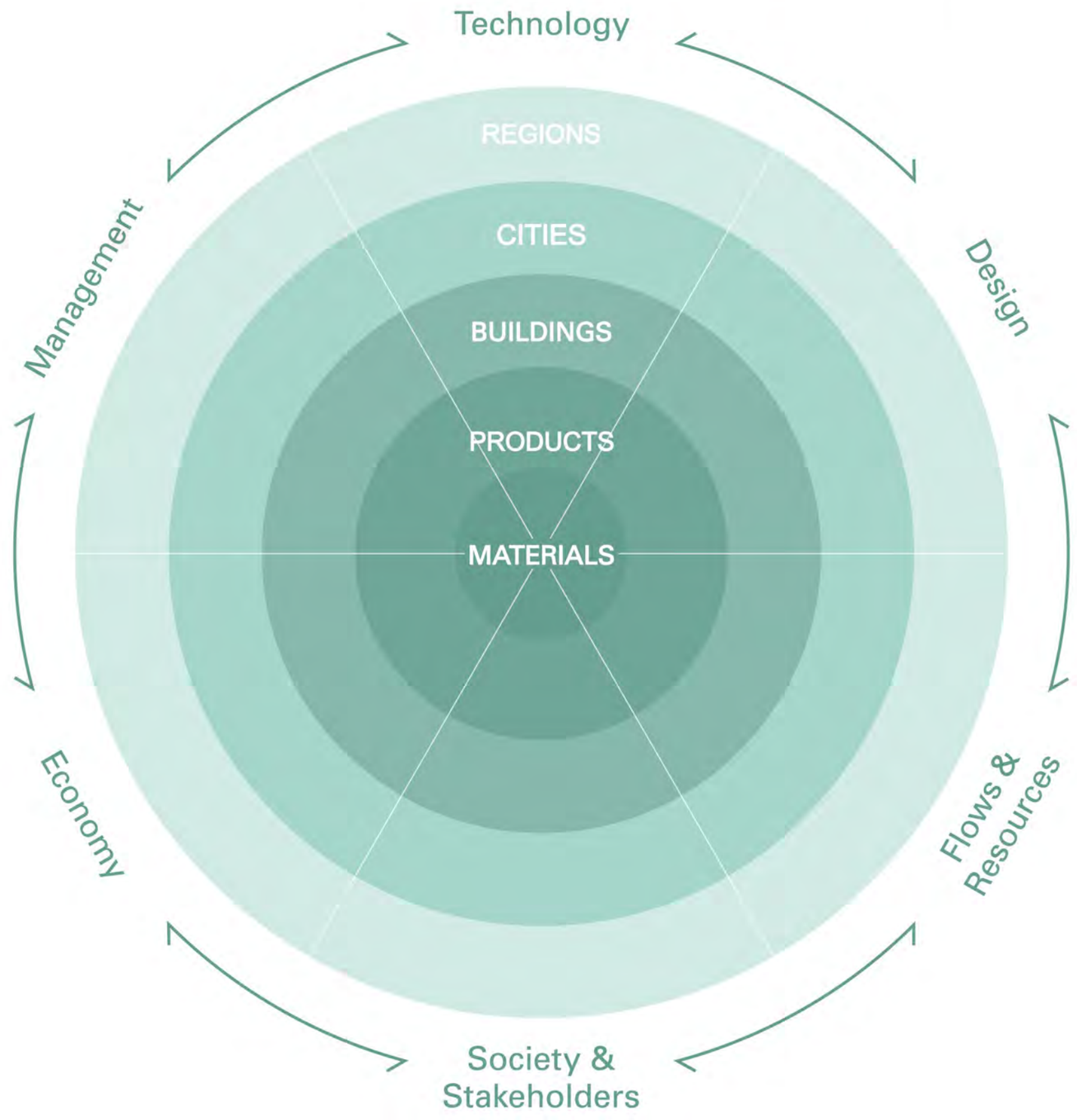
3. Shift to renewable energy sources

4. Think in systems

5. Think in cascades



Circular Built Environment



Circular Built Environment

"Time is the essence of the real design problem"



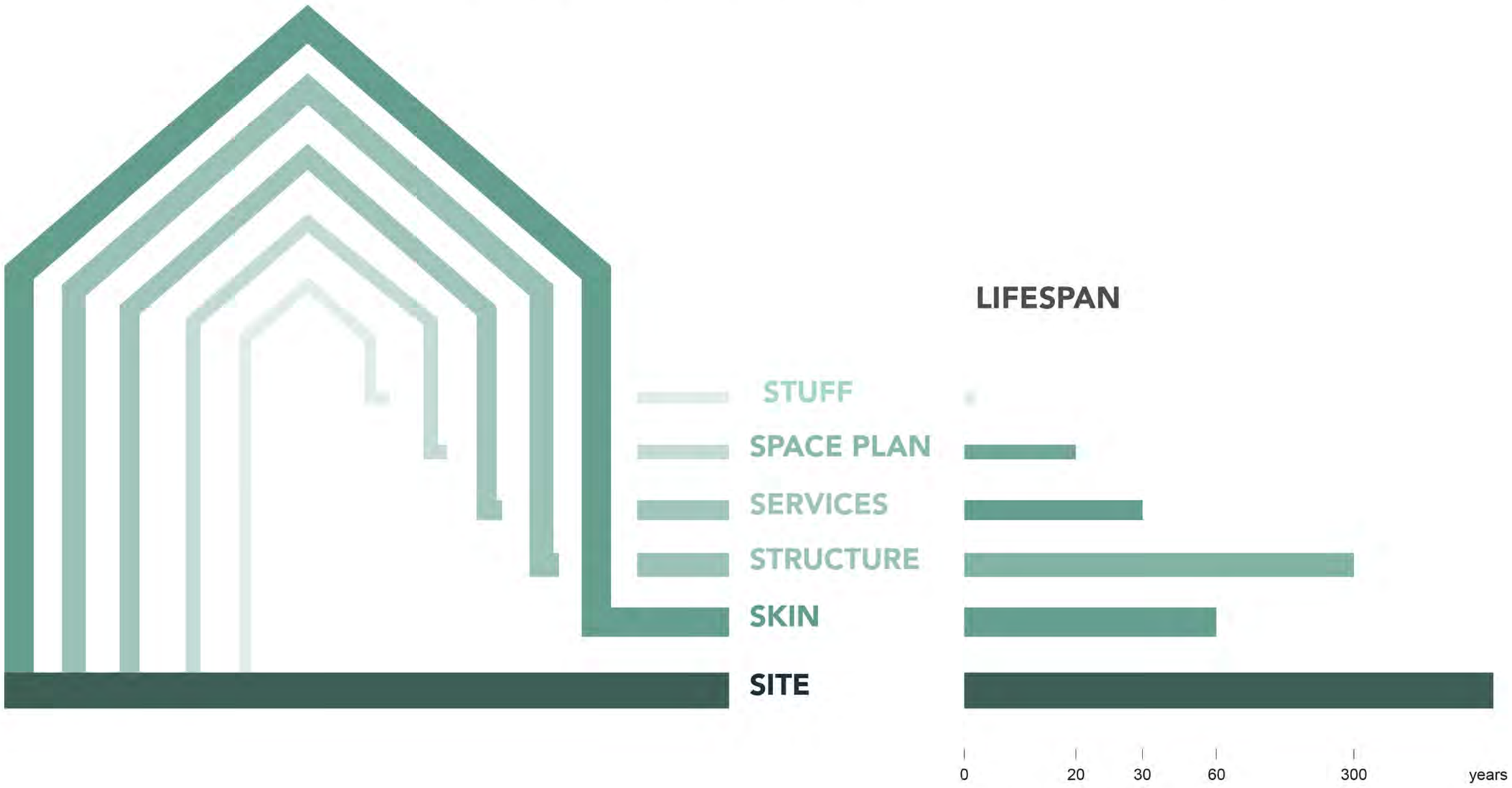
Circular Built Environment

Buildings are not static entities



Circular Built Environment

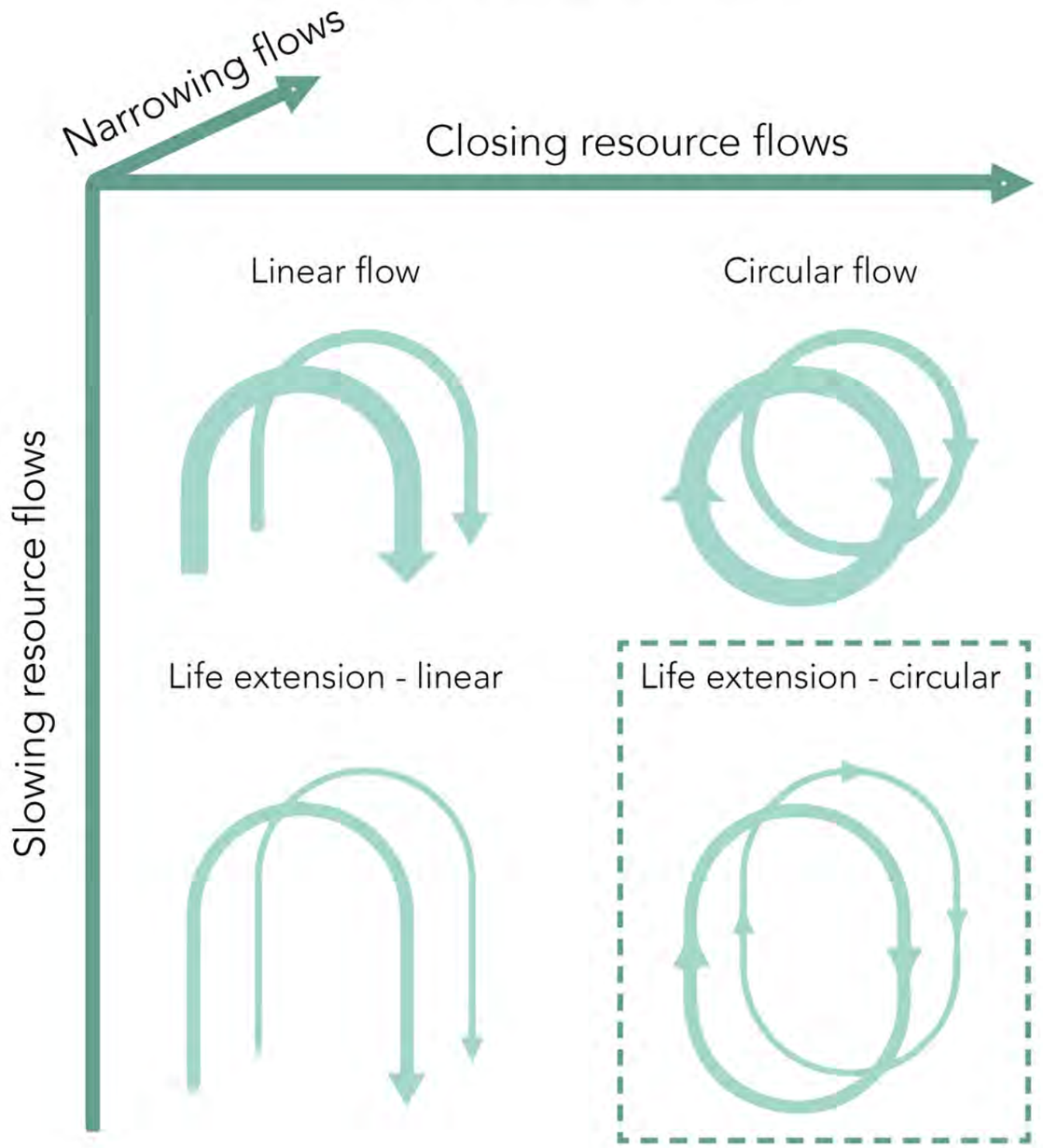
Shearing Layers of Change (Brand, 1994)



Circular Built Environment

Slowing Resource Loops

Based on (Bocken et al., 2015)



Circular Built Environment

Design strategies for slowing resource loops

Based on (Bocken et al., 2015)

How to design long-lasting products?



Designing long-life products



Reliability



Durability



Design for product life extension



Maintenance



Repair



Upgrade



Remanufacture

Circular Built Environment

Design strategies for slowing resource loops

Based on (Bocken et al., 2015)

How to design long-lasting products?



Designing long-life products



Reliability



Durability



Design for product life extension



Maintenance



Repair



Upgrade



Remanufacture

What is Remanufacturing?

Based on (Boorsma, 2016)

What is Remanufacturing?

Based on (Boorsma, 2016)

- Returning a used product to at least **OEM original performance specification** from the customers' perspective

What is Remanufacturing?

Based on (Boorsma, 2016)

- Returning a used product to at least **OEM original performance specification** from the customers' perspective

- Through a series of manufacturing steps acting on an **end-of-life part or product** .

What is Remanufacturing?

Based on (Boorsma, 2016)

- Returning a used product to at least **OEM original performance specification** from the customers' perspective

- Through a series of manufacturing steps acting on an **end-of-life part or product** .

- This gives the resultant product a warranty that is **at least equal or better** to that of a newly manufactured equivalent

What is Remanufacturing?

Based on (Boorsma, 2016)

- Returning a used product to at least **OEM original performance specification** from the customers' perspective

- Through a series of manufacturing steps acting on an **end-of-life part or product** .

- This gives the resultant product a warranty that is **at least equal or better** to that of a newly manufactured equivalent

- After this, the product receives a **serial number.**

What is Remanufacturing?

What is the difference?

Interview to Dr. Nabil Nsar by Dr. David Peck

Rebuilding, and refurbishment, are basically bringing the product back to a working condition and ensuring that it will function.
But it is not like a new condition, like what we do with remanufacturing.

Remanufacturing requires to bring the product back to like new condition. **Basically, you have a rebirth of the product.**



How are products Remanufactured?

Process

Based on (ERN, 2016), (Steinhilper, 1999)



Remanufacturing process. Image by author. Icons source: flaticon.com

Design for Remanufacturing (DfRem)

Based on (Nasr and Thurston, 2006), (Charter and Gray, 2008), (Hatcher et al, 2011)

Steps Involved

Detail Engineering



Product Strategy

Design for Remanufacturing (DfRem)

Based on (Nasr and Thurston, 2006), (Charter and Gray, 2008), (Hatcher et al, 2011)

ENTIRE REMANUFACTURING PROCESS

Steps Involved

Detail Engineering



Product Strategy

How to Design for Remanufacturing?

DfRem

Based on (Sundin, 2004), (Hatcher, 2011), (Ijomah et al., 2014), (Vogtländer et al., 2017)

RemPro Matrix

Product Property \ Remanufacturing Step	Inspection	Cleaning	Disassembly	Storage	Reprocess	Reassembly	Testing
Ease of Identification	x		x	x			
Ease of Verification	x						
Ease of Access	x	x	x		x		x
Ease of Handling			x	x	x	x	
Ease of Separation			x		x		
Ease of Securing						x	
Ease of Alignment						x	
Ease of Stacking				x			
Wear Resistance		x	x		x	x	

Figure 4.4 RemPro-matrix based on Sundin (2004). Image by author.

Product Properties

- **Durable** materials
- Identify components that require **similar assembly/disassembly** tools and techniques
- Disassemble should **not damage** the components
- **Standardization, Modularity, and interchangeability**
- The product is designed to **recover its functionality.**
- Selection of **materials that can survive** cleaning processes (i.e. the material melting point of the selected material is higher than clean process temperature)

...etc

Why should we Remanufacture products?

Benefits

Based on CRR (Centre for remanufacturing & Reuse, 2018)



Remanufacturer

- Local & skilled jobs
- Higher profit margins
- New manufacturing techniques
- Better customer relationships



Environment

Reduction in:

- Raw material consumption
- Energy consumption
- CO_2 emissions
- Materials sent to landfill



Customer

- Lower prices
- Availability
- Purchasing flexibility
- Longer lasting products

Analysing Kawneer Nederland B.V.

Kawneer Nederland B.V.

Modular Façade Systems

Windows and doors



Sliding windows and doors



Curtain Walls



Custom Made



Accessories



Façade Supply Chain

Relationship of Stakeholders

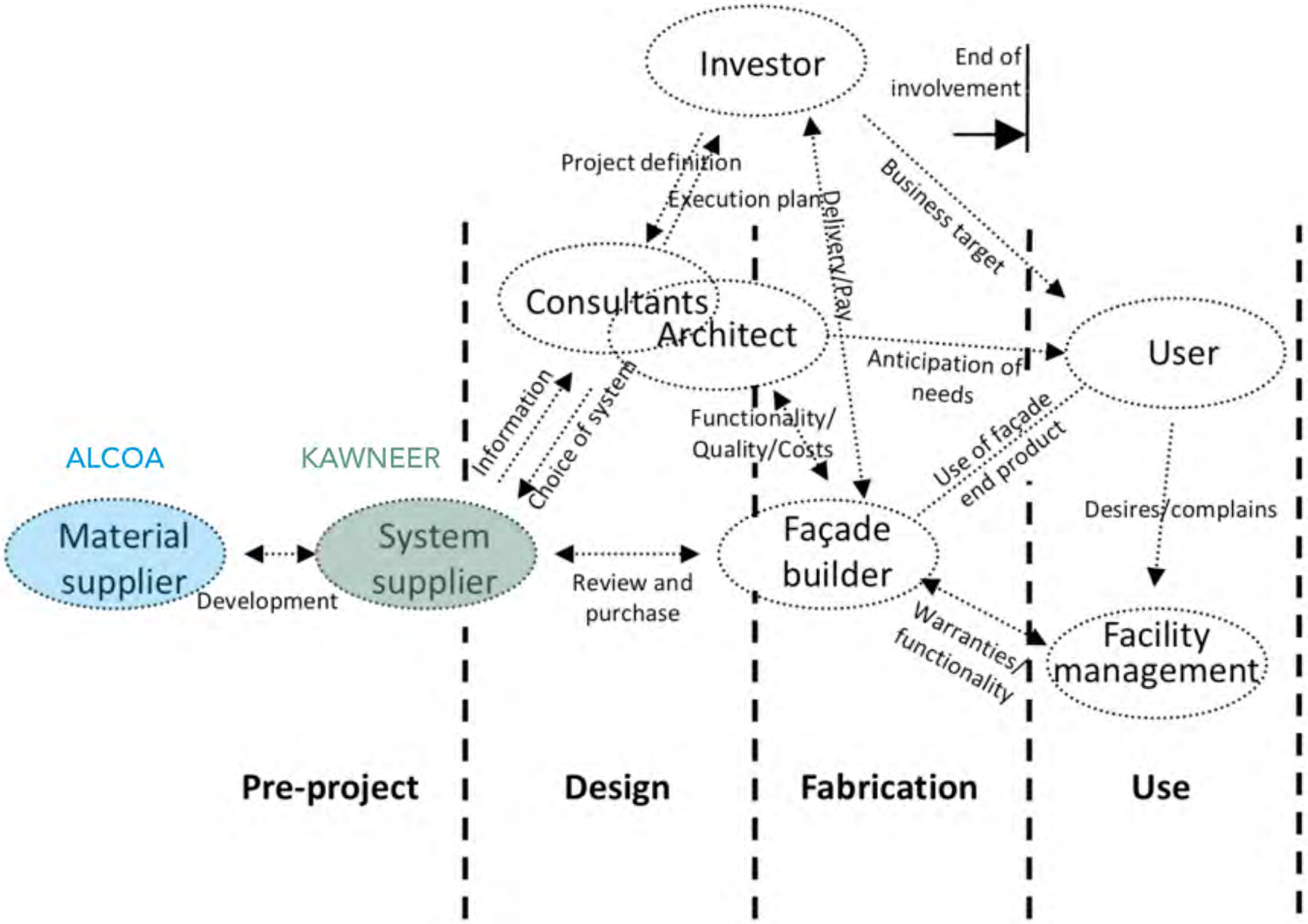


Figure 5.1 Scheme of the relationship of stakeholders. Image by Klein (2013).

Business Model Canvas

Key partners

Who are your most important partners?
Which key resources do you acquire from partners?
Which key activities do your partners perform?

1. Suppliers (hardware, insulation, etc)
2. Alcoa (parent company)
3. Façade builders
4. TU Delft BK, etc.

Key activities

1. Product Design
2. Product integrator
3. Purchasing hardware and other key accessories
4. Assemblying elements into products
5. Products are tested
6. Products are packed and sent to the client

Key resources

What are the resources you need to create & deliver your value proposition?

1. Technical and product design knowledge
2. Distribution network
3. Storage facility
4. Testing facility
5. Softwares, website

Value propositions

What is the value you delivery to your customer?
Which of your customer's problems are you helping to solve?
What is the customer need that your value proposition addresses?
What is your promise to your customers?
What are the products and services you create for your customers?

(a) Product: reliable aluminium systems with high thermal insulation and performance.

(b, c) Service: Technical support, advice during project development, and technical guidance.

Customer relationships

What relationship does each customer segment expect you to establish and maintain?

Long term relationships built through dedicated personal assistance.

Channels

How does your value proposition reach your customer? Where can your customer buy or use your products or services?

- Trade fairs
- Office Sales
- e-commerce
- Advertisement

Customer segments

For whom are you creating value?
What are the customer segments that either pay, receive or decide on your value proposition?

(a) Façade Manufacturers

(b) Architectural Firms

(c) Consultants

Cost structure

What are the important costs you make to create & delivery your value proposition?

- Fixed costs (overhead)
- Variable costs (procurement)

Revenue streams

How do customers reward you for the value you provide to them?
What are the different revenue models?

Business Model Canvas

Key partners

Who are your most important partners?
Which key resources do you acquire from partners?
Which key activities do your partners perform?

1. Suppliers (hardware, insulation, etc)
2. Alcoa (parent company)
3. Façade builders
4. TU Delft BK, etc.

Key activities

1. Product Design
2. Product integrator
3. Purchasing hardware and other key accessories
4. Assemblying elements into products
5. Products are tested
6. Products are packed and sent to the client

Key resources

What are the resources you need to create & deliver your value proposition?

1. Technical and product design knowledge
2. Distribution network
3. Storage facility
4. Testing facility
5. Softwares, website

Value propositions

What is the value you delivery to your customer?
Which of your customer's problems are you helping to solve?
What is the customer need that your value proposition addresses?
What is your promise to your customers?
What are the products and services you create for your customers?

(a) Product: reliable aluminium systems with high thermal insulation and performance.

(b, c) Service: Technical support, advice during project development, and technical guidance.

Customer relationships

What relationship does each customer segment expect you to establish and maintain?

Long term relationships built through dedicated personal assistance.

Channels

How does your value proposition reach your customer? Where can your customer buy or use your products or services?

- Trade fairs
- Office Sales
- e-commerce
- Advertisement

Customer segments

For whom are you creating value?
What are the customer segments that either pay, receive or decide on your value proposition?

(a) Façade Manufacturers

(b) Architectural Firms

(c) Consultants

Cost structure

What are the important costs you make to create & delivery your value proposition?

- Fixed costs (overhead)
- Variable costs (procurement)

Revenue streams

How do customers reward you for the value you provide to them?
What are the different revenue models?

One time value creation through products' sales.

Product's Lifecycle

Product's Lifecycle

SOURCING

ALCOA
Extraction of
virgin feedstock

Aluminium 6060
Origin:
- America
- Colombia
- Brazil
- Suriname

+ Recycled Aluminium

· Rubber
· Glass

Product's Lifecycle

SOURCING

ALCOA
Extraction of virgin feedstock

Aluminium 6060
Origin:
- America
- Colombia
- Brazil
- Suriname

+ Recycled Aluminium

· Rubber
· Glass

PRODUCTION

Material Manufacturer

Processed Materials
· Extruded profiles from aluminium billets

Kawneer

Manufacturing of Components
· Aluminium profiles with thermal breaks
· Hardware pieces
· Accessories

Facade Builders

Manufacturing of Products
· Assembly of components into complete façade systems

Product's Lifecycle

SOURCING

ALCOA
Extraction of virgin feedstock

Aluminium 6060
Origin:
- America
- Colombia
- Brazil
- Suriname

+ Recycled Aluminium

· Rubber
· Glass

PRODUCTION

Material Manufacturer

Processed Materials
· Extruded profiles from aluminium billets

Kawneer

Manufacturing of Components
· Aluminium profiles with thermal breaks
· Hardware pieces
· Accessories

Facade Builders

Manufacturing of Products
· Assembly of components into complete façade systems

USE

User/Owner

Final Products
· Maintenance

Product's Lifecycle

SOURCING

ALCOA
Extraction of virgin feedstock

Aluminium 6060
Origin:
- America
- Colombia
- Brazil
- Suriname

+ Recycled Aluminium

· Rubber
· Glass

PRODUCTION

Material Manufacturer

Processed Materials
· Extruded profiles from aluminium billets

Kawneer

Manufacturing of Components
· Aluminium profiles with thermal breaks
· Hardware pieces
· Accessories

Facade Builders

Manufacturing of Products
· Assembly of components into complete façade systems

USE

User/Owner

Final Products
· Maintenance

END-OF-LIFE

Demolition Company

Waste Manager

Recycled Material
· Collection & separation

Product's Lifecycle

SOURCING

ALCOA
Extraction of virgin feedstock

Aluminium 6060
Origin:
- America
- Colombia
- Brazil
- Suriname

+ Recycled Aluminium

· Rubber
· Glass

PRODUCTION

Material Manufacturer

Processed Materials
· Extruded profiles from aluminium billets

Kawneer

Manufacturing of Components
· Aluminium profiles with thermal breaks
· Hardware pieces
· Accessories

Facade Builders

Manufacturing of Products
· Assembly of components into complete façade systems

USE

User/Owner

Final Products
· Maintenance

END-OF-LIFE

Demolition Company

Waste Manager

Recycled Material
· Collection & separation

HKS
Recycling Company

6060 Aluminium
· Collection of the components with potential for recycling

Product's Lifecycle

SOURCING

ALCOA
Extraction of virgin feedstock

Aluminium 6060
Origin:
- America
- Colombia
- Brazil
- Suriname

+ Recycled Aluminium

· Rubber
· Glass

PRODUCTION

Material Manufacturer

Processed Materials
· Extruded profiles from aluminium billets

Kawneer

Manufacturing of Components
· Aluminium profiles with thermal breaks
· Hardware pieces
· Accessories

Facade Builders

Manufacturing of Products
· Assembly of components into complete façade systems

USE

User/Owner

Final Products
· Maintenance

END-OF-LIFE

Demolition Company

Waste Manager

Recycled Material
· Collection & separation

HKS
Recycling Company

6060 Aluminium
· Collection of the components with potential for recycling

RECYCLING

Emax
Melting Company

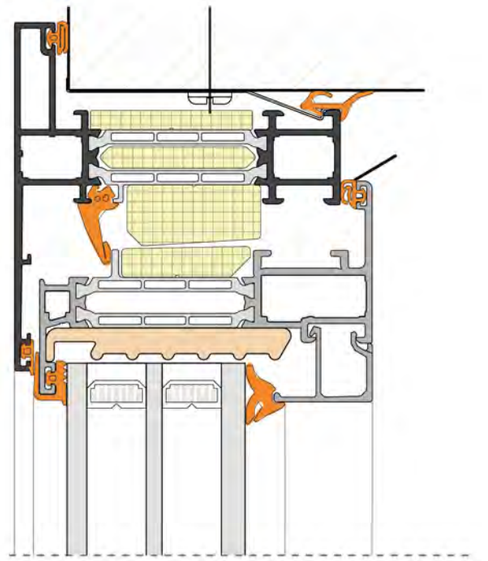
Melting collected 6060 aluminium into billets
· Process done in the Netherlands

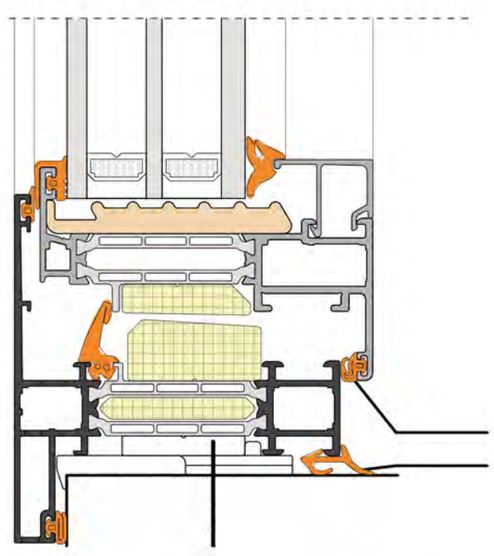
Extrusion of profiles from recycled aluminium
· Process done in Belgium

Case Study Analysis

RT 82 HI +

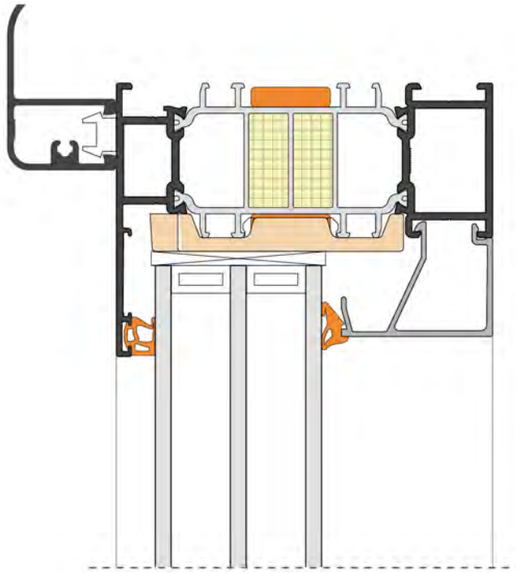
Product's Benchmark

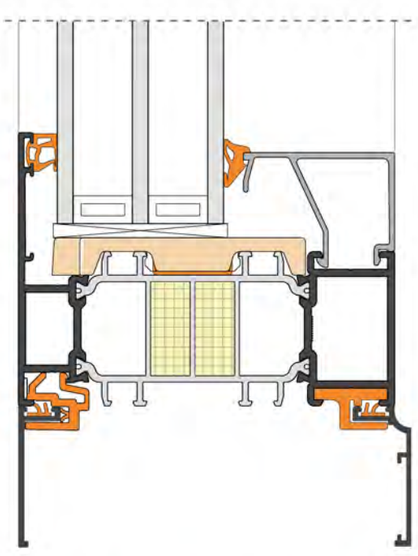




RT 82 HI + Aluminium Triple Glazed Window Frame

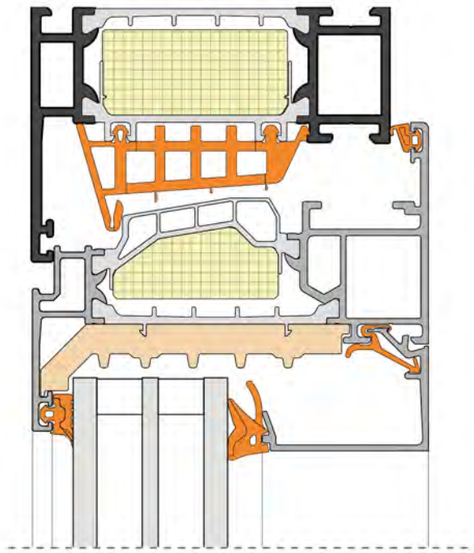
Kawneer

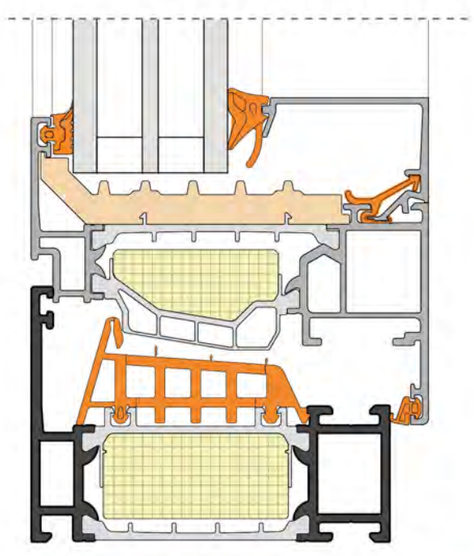




CS 104 HI Aluminium Triple Glazed Window Frame

Reynaers





AWS 90 SI + Aluminium Triple Glazed Window Frame

Schüco

Window Systems: State of the Art

Selected Systems & Materials

Aluminium

RT 82 HI + Aluminium Triple Glazed Window Frame - Kawneer

CS 104 HI Aluminium Triple Glazed Window Frame - Reynaers

AWS 90 SI + Aluminium Triple Glazed Window Frame - Schüco

U-PVC

PVC Triple Glazed Prestige Window Frame - Inoutic

GRP

GRP Triple Glazed Window Frame - Ecliptica

Hybrids

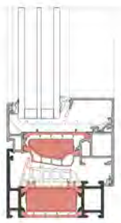
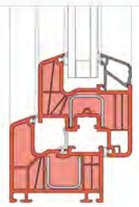
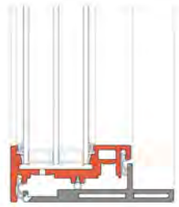
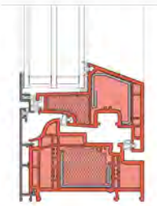
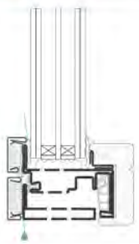
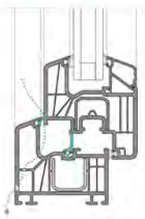
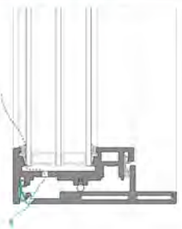
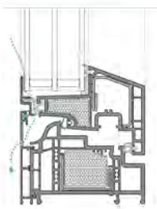
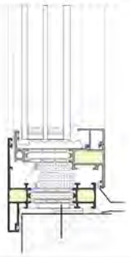
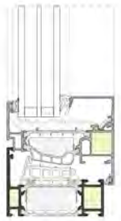
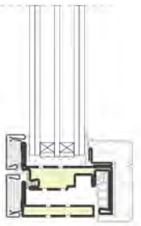
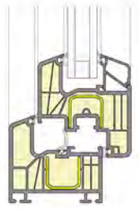
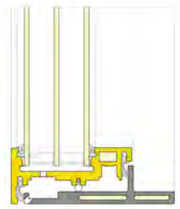
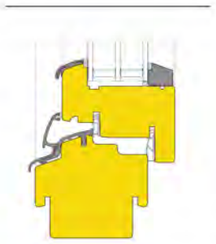
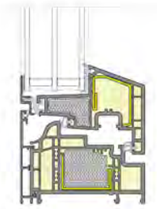
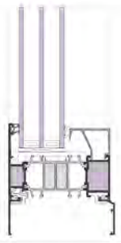
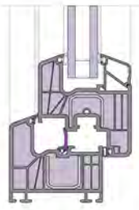
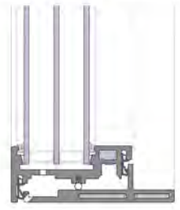
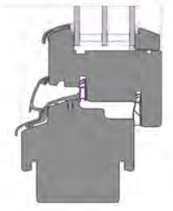
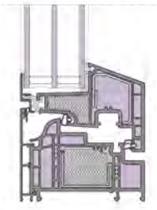
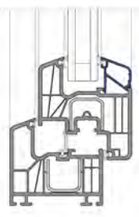
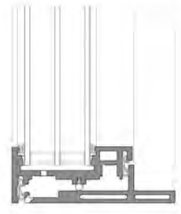
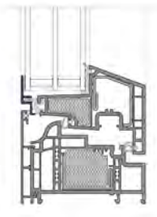
Platin Passiv Timber/Alum. triple Glazed Window Frame - Josko

Safir Plus PVC/Alum./GRP Triple Glazed Window Frame - Josko

Steel

Opificium TABS Steel triple glazed window frame Palladio

Window Systems: State of the Art

	RT 82 HI + Aluminium - Kawneer	CS 104 HI Aluminium - Reynaers	AWS 90 SI + Aluminium - Shüco	Opificium TABS Steel Triple Glazed Window Frame	PVC Triple Glazed Prestige Window Frame - Inoutic	Triple glazed frame GRP - Ecliptica	Triple glazed frame Timber/Aluminium - Josko	Safir Plus PVC/Al./GRP window frame - Josko
Thermal insulation								
Drainage								
Stiffness								
Sound insulation								
Adjustable glazing width								

Harris Profiles by Window System

Material	Weight	Aluminium	Steel	Timber	uPVC	GRP	Al/Wood	Al/PVC
Lightness	3	6	1	4	6	7	5	6
Durability	3	7	7	6	3	7	7	7
Cyclability	5	7	7	5	2	1	7	4
High strenght	2	6	7	6	2	7	6	7
Low maintenance	4	7	6	3	6	7	7	7
Low thermal conductivity	3	1	2	7	5	7	7	4
Low initial cost	3	6	3	7	7	1	5	4
Complex shapes	1	7	5	3	7	4	3	6
Low primary embodied energy	4	1	6	7	3	5	5	4
Reusable	5	7	7	7	4	1	7	4
Ease of repairness	5	7	7	5	4	1	6	4
No need for a thermal break	x	x	x	○	○	○	○	○
Total		**5.68**	**5.60**	**5.47**	**4.27**	**4.37**	**5.96**	**5.17**

Façade's Function Analysis

Outside

Context-Specific Conditions
· Solar radiation
· Temperature
· Humidity
· Precipitation
· Wind
· Surrounding noises
· Amount of gas and dust
· Mechanical loads
· Electromagnetic radiation
· Urban surroundings
· Local resources
· Socio-cultural context

Supplementary functions with a direct effect
· Thermal insulation
· Sunshading
· Measures influencing the microclimate (i.e. vegetation)

Supplementary building services
· External collectors
· PV/PVT
· Heatpipes
...etc

Façade

Protective Functions

· Insulation/Attenuation
· Seals & barriers
· Fitters
· Storage
· Redirection
· Physical barriers

Regulatory Functions

· Controlling/regulating
· Responding / Changing

Façades w. Integral Services

· Integral air/water collection
· Solar walls
· Media transport distribution
· Heat recovery systems

Inside

· Comfortable temperature/humidity range
· Amount & quality of light
· Air exchange rate
· Comfortable air velocity
· Comfortable sound level

· Visual relationship with external
· Differentiation of private & public areas
· Mechanical damage protection
· Fire protection
· Limitation of toxic loads

Supplementary functions with a direct effect
· Glare protection
· Privacy provision
· Redirection of daylight
·Storing/releasing energy for heating & cooling

Supplementary building services
· Convectors/radiators
· Artificial lighting
· Air conditioning (centralised/decentralised)

Reference Project

Brick cavity wall with RT 82 HI +

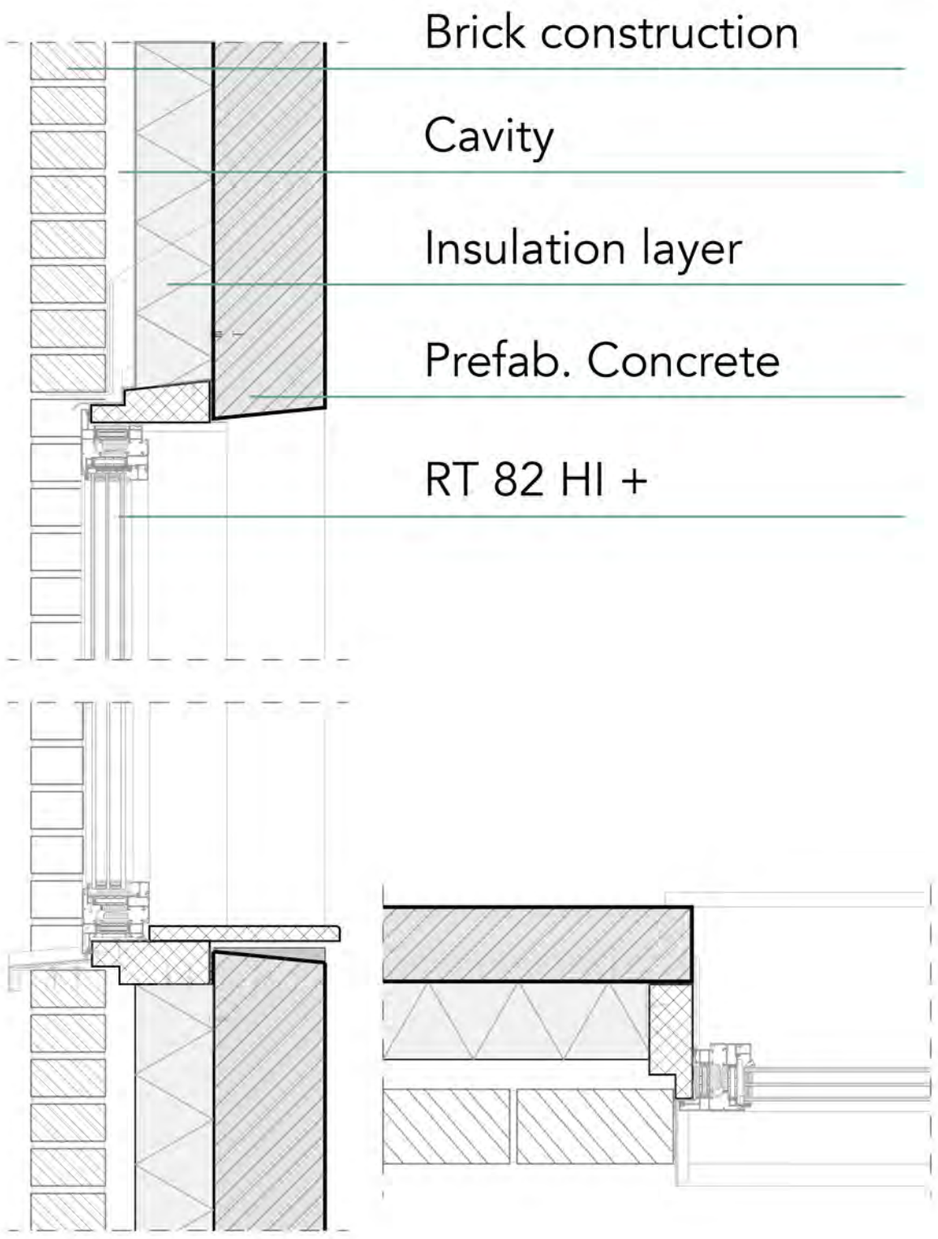
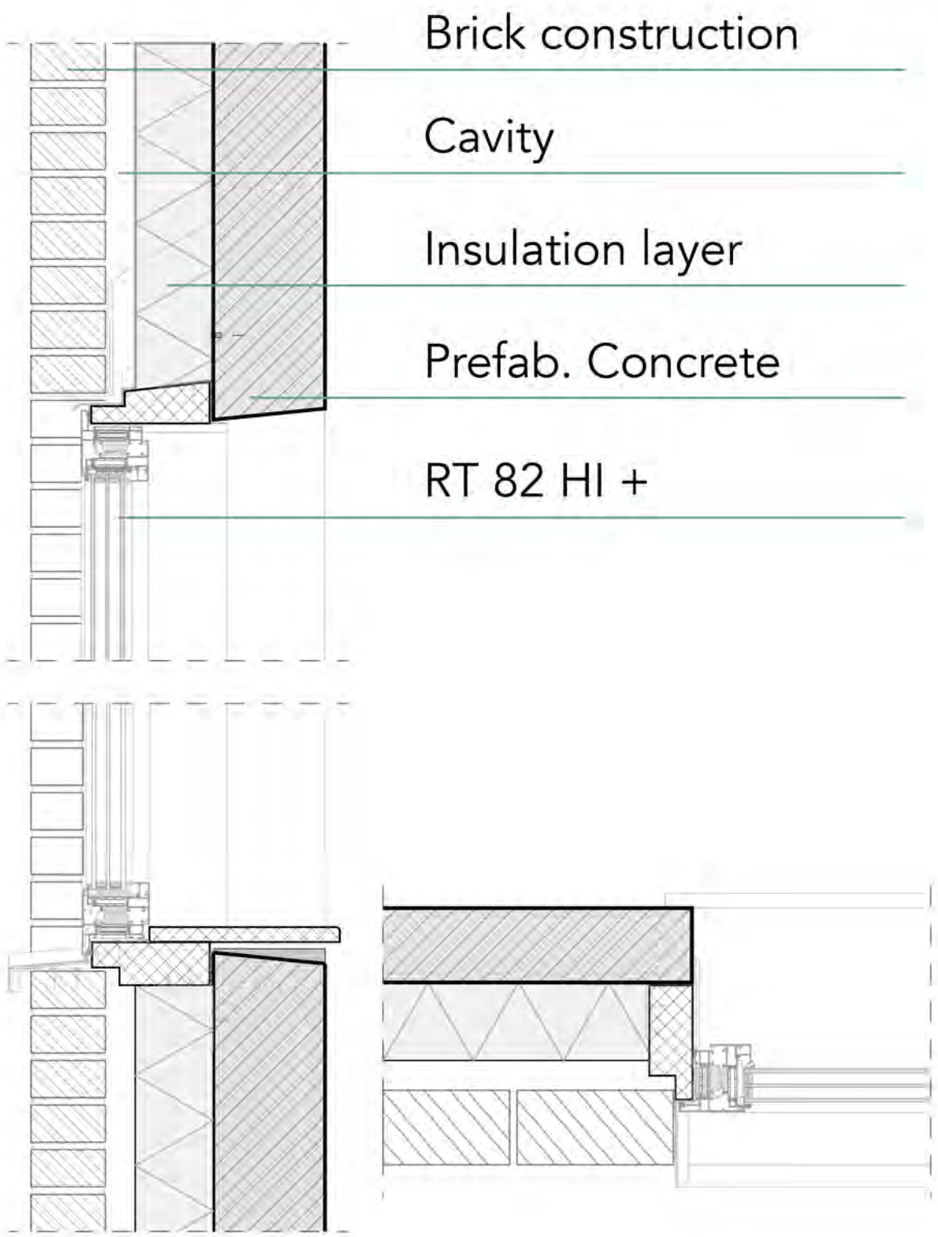


Figure 7.1 Detail of the reference project, brick cavity wall with the RT 82 HI +. Image by author.

Reference Project

Brick cavity wall with RT 82 HI +



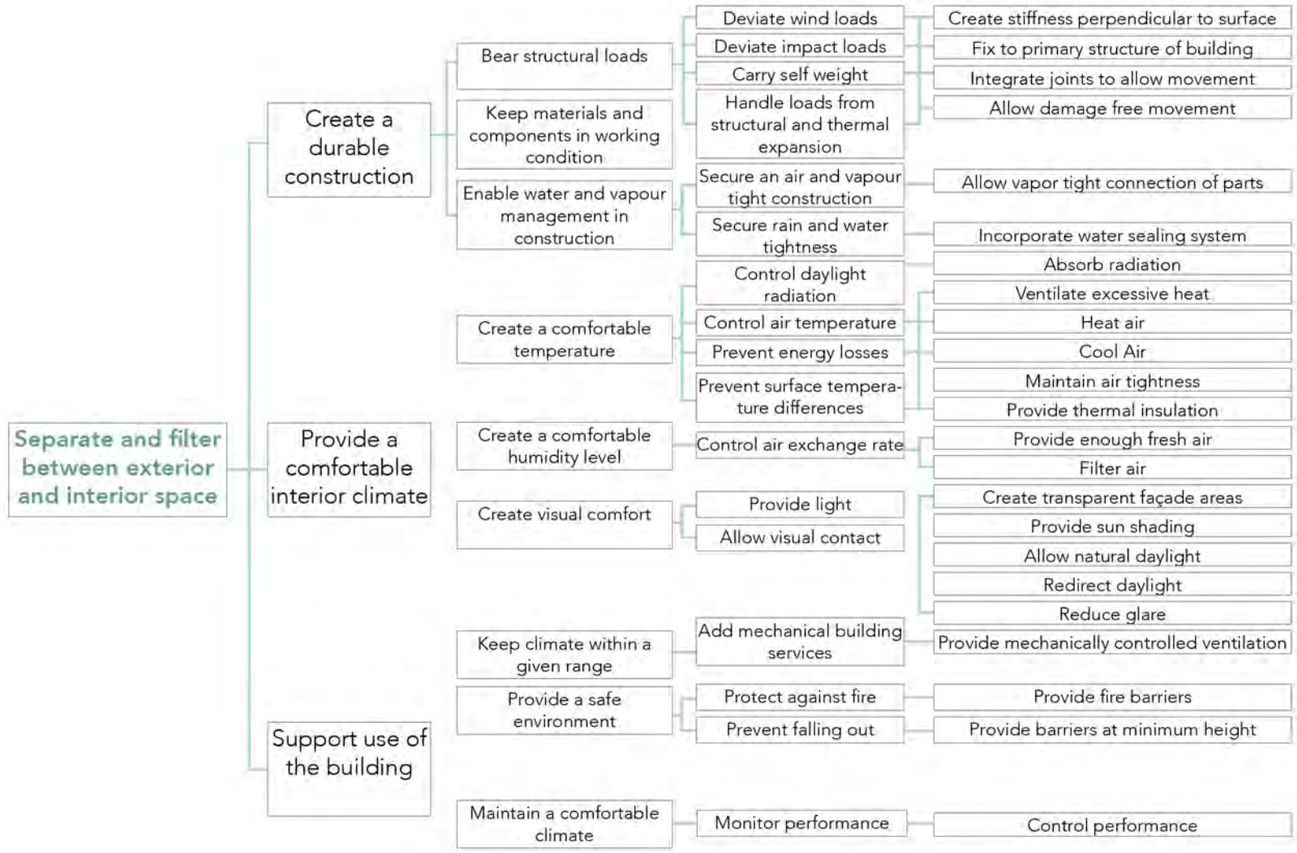
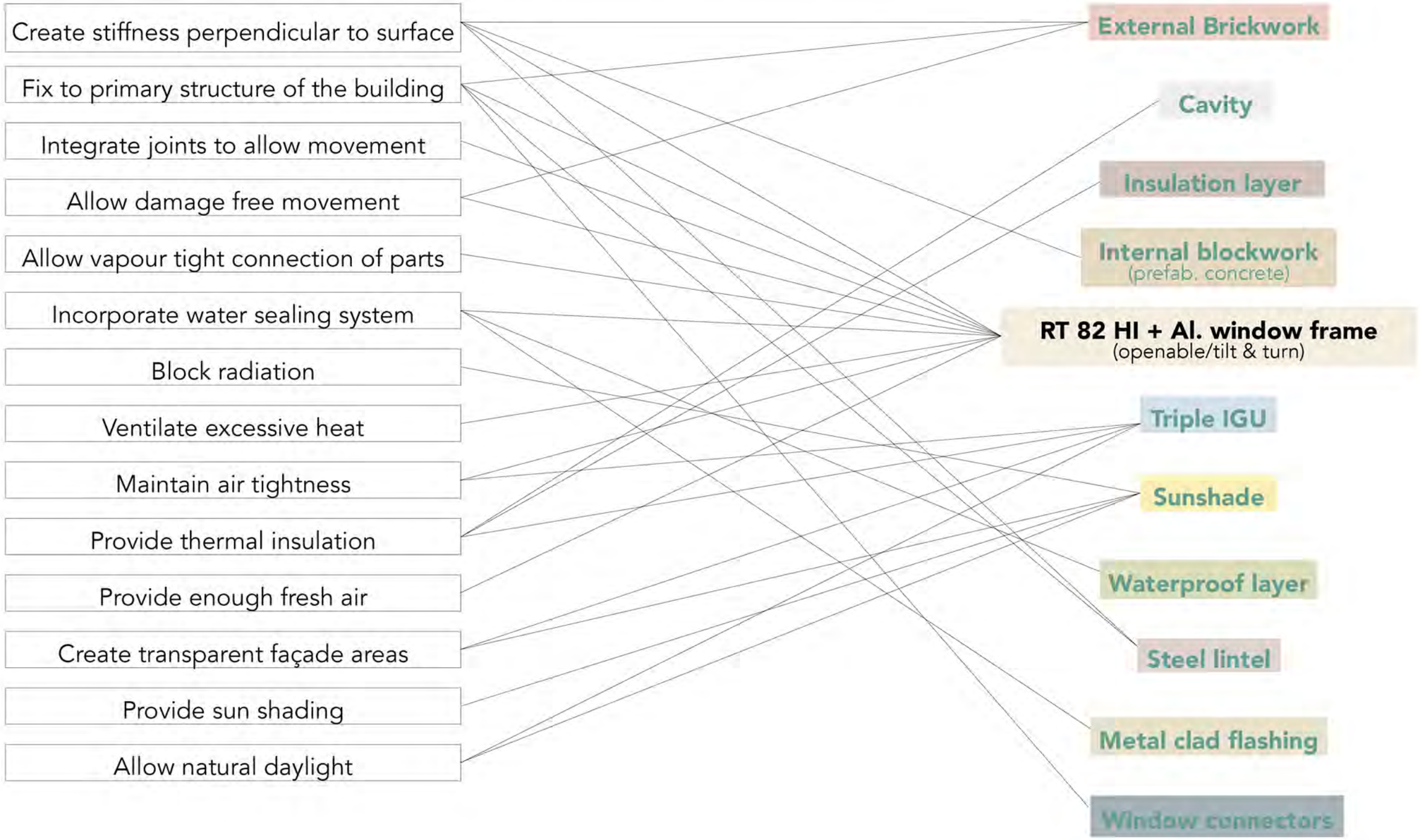


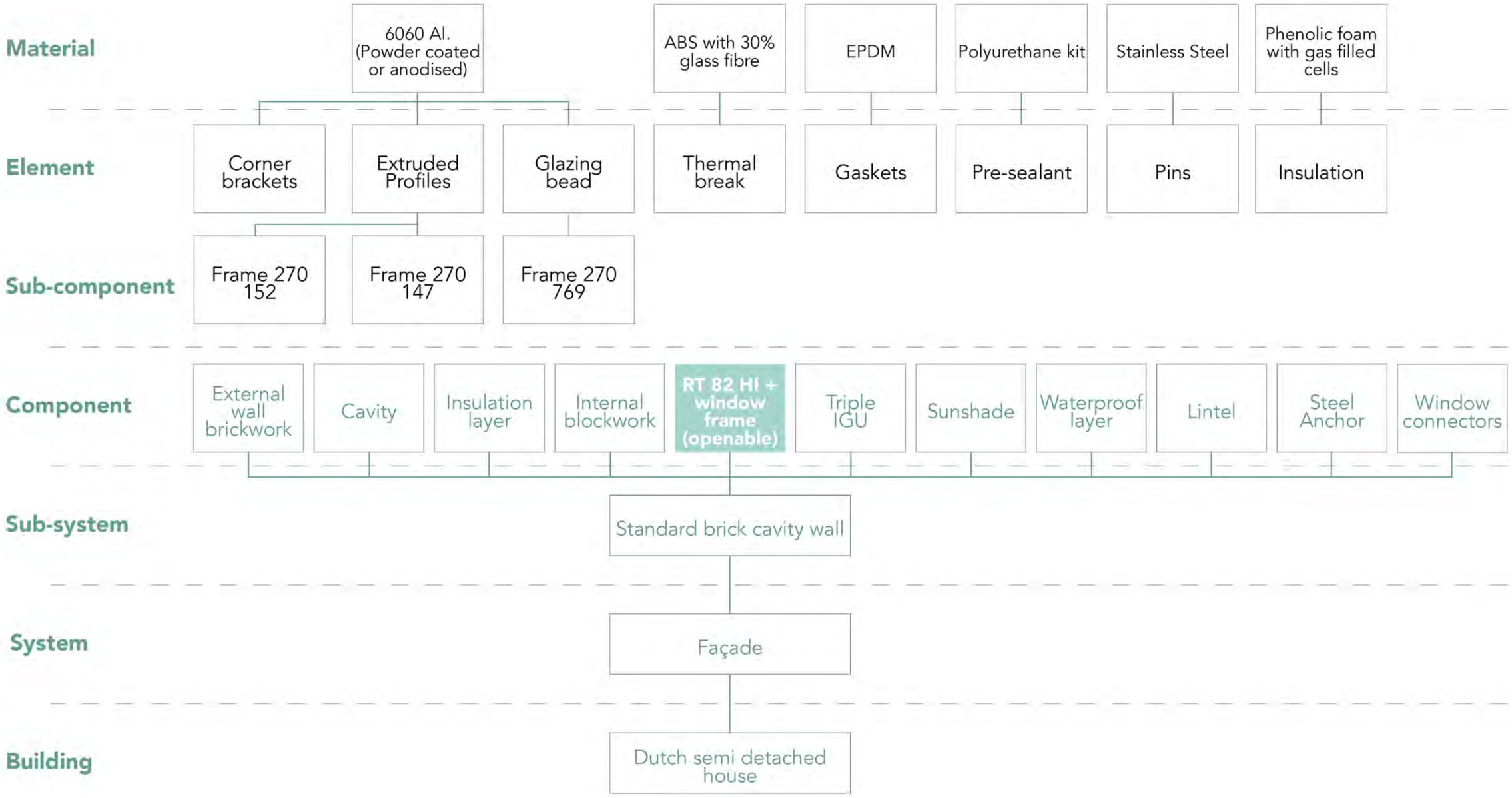
Figure 7.1 Detail of the reference project, brick cavity wall with the RT 82 HI +. Image by author.

Detailed Function Analysis

Functions & Components



Hierarchy Definition



Assessments

RT 82 HI + Circular Analysis

(1)

DfD
Design for Disassembly

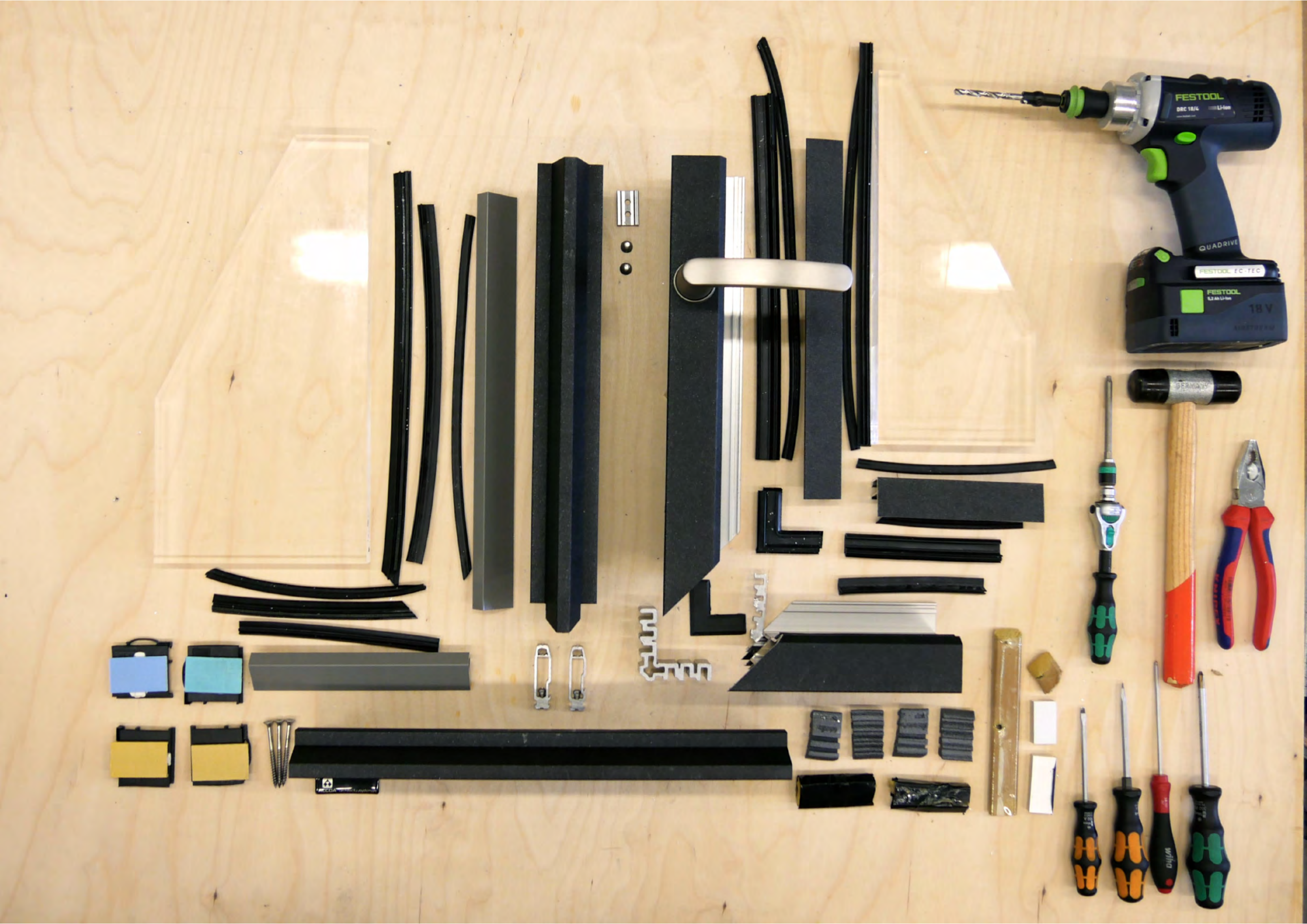
(2)

DfA
Design for Adaptability

(3)

DfRem
Design for Remanufacturing

Video by M.Bilow (2019)


FESTOOL
DRC 18/4
QUADRIVE
FESTOOL EC·TEC
FESTOOL
18 V
GERMANY
Wiha

Assessment on Design for Disassembly

DfD

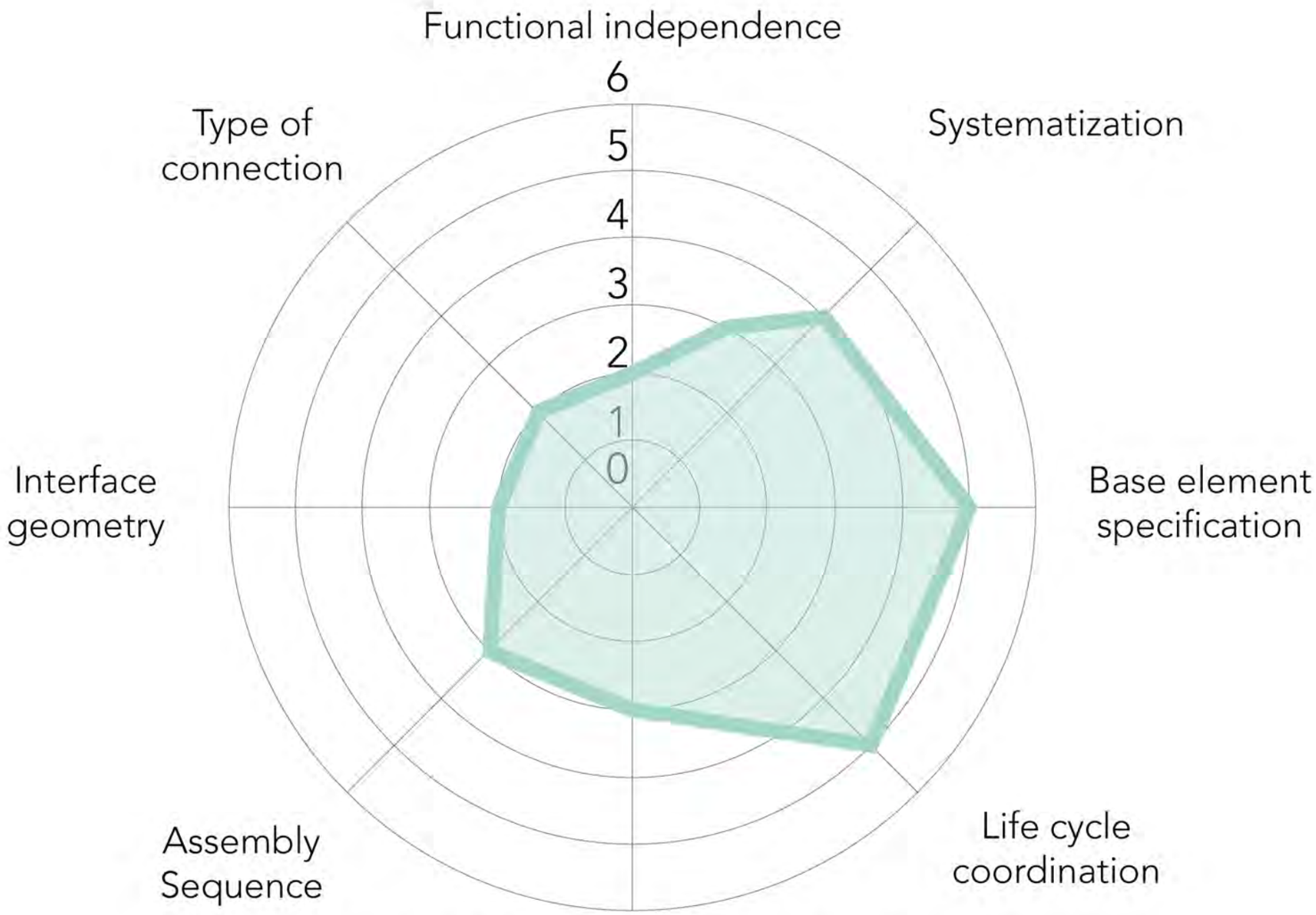
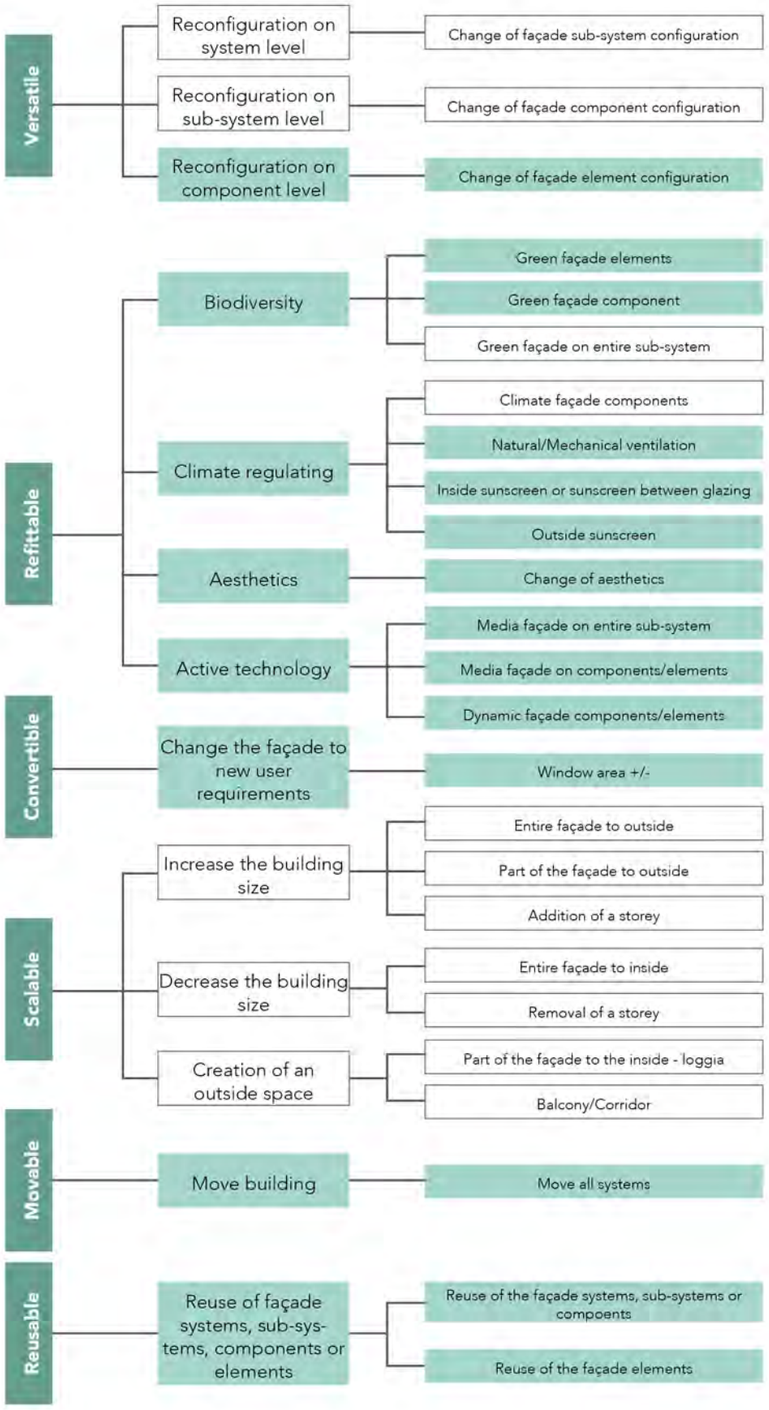


Figure 7.12 Results of the DfD assessment of the RT 82 HI +. Image by author.

54%

Assessment on Design for Adaptability (DfA)



Methodology

(1) Versatile: Possible to reconfigure

(2) Refittable: Biodiversity, climate regulating, aesthetics, active technology

(3) Convertible: Window Area (+/-)

(4) Scalable: Increase/Decrease building size

(5) Movable: Move all systems

(6) Reusable: Reuse of elements or subsystems/components

Assessment on Design for Adaptability (DfA)

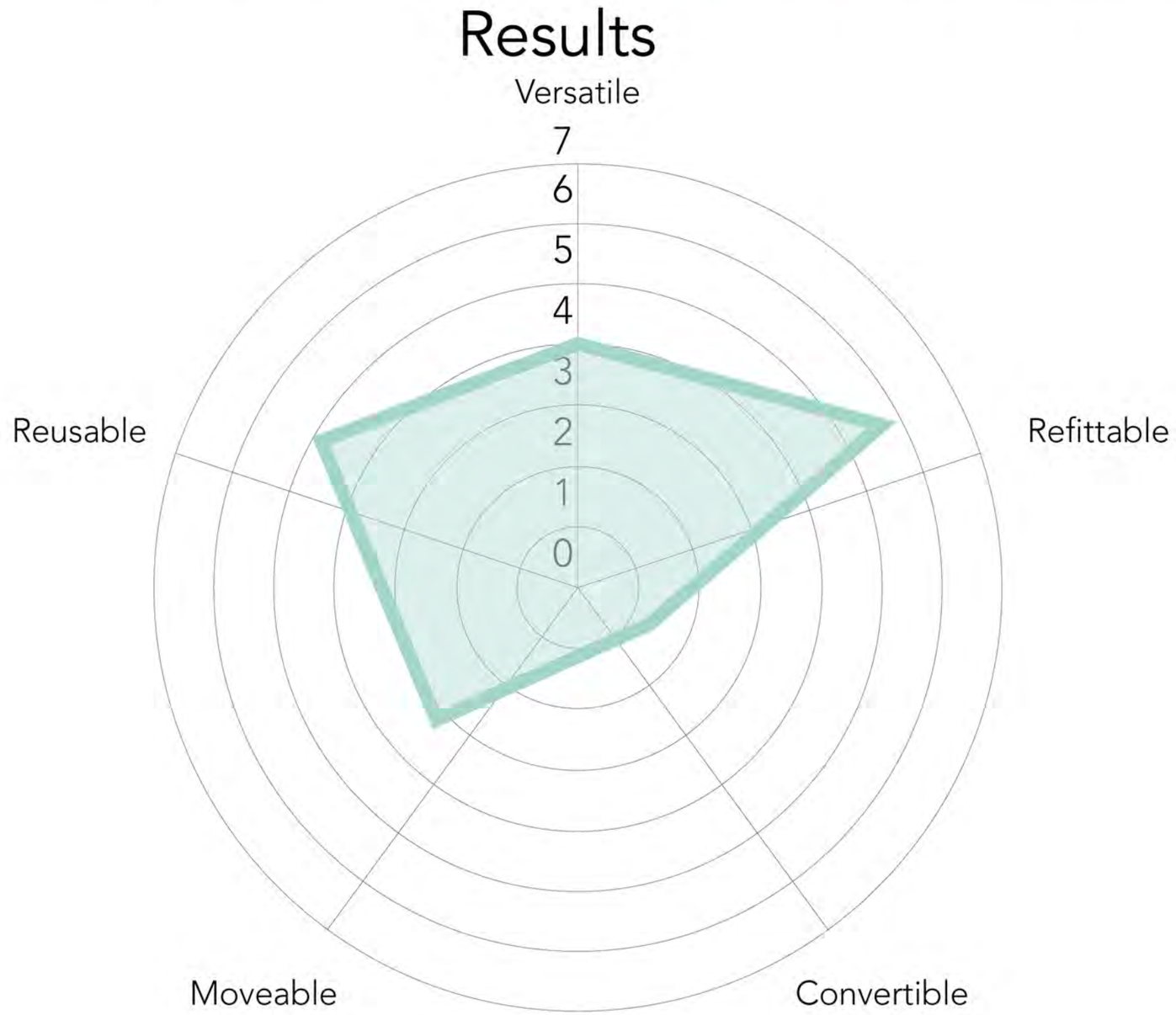


Figure 7.17 Results on the DfA assessment for the RT 82 HI +. Image by author.

69.52%

Assessment on Design for Remanufacturing (DfRem)

Methodology



Durable product



Recovery of product functionality



Standarization & Modularity



High remaining value



Affordable cores



Stable Technology



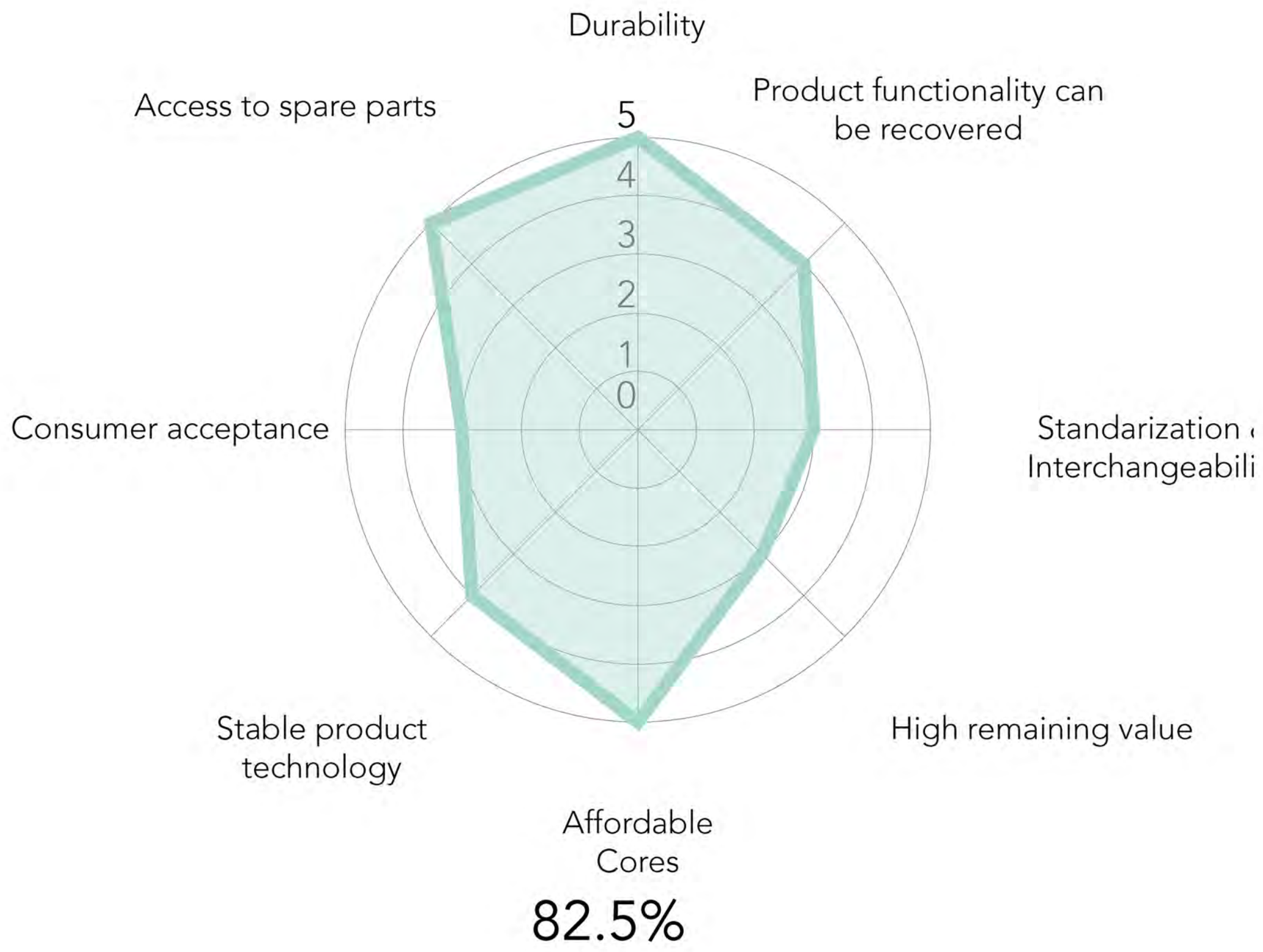
Core availability (5-7 years)



Designed for Disassembly

Assessment on Design for Adaptability (DfA)

Results



82.5%

Conclusions on the Assessments

(1) Complex **Geometry of Product Edge**

(2) **Type of connection** is not optimal for circularity

(3) There is no clear guidance on **how to disassmble**

(4) Too many elements = **Too many connections!**

Conclusions on the Assessments

(1) Complex **Geometry of Product Edge**

(2) **Type of connection** is not optimal for circularity

(3) There is no clear guidance on **how to disassmble**

(4) Too many elements = **Too many connections!**

(5) Ease of Assembly = Ease of Disassembly = Reuse

Design

Design Requirements

Functional

Separate and filter between exterior and interior space

1. Create a durable construction
- Bear structural loads
- Keep materials and components in working condition
- Enable water and vapor management in construction

2. Provide a comfortable interior climate
- Create a comfortable temperature
- Create a comfortable humidity level
- Create visual comfort

3. Support use of the building
- Keep climate within a given range
- Provide a safe environment
- Maintain comfortable climate

Circular

1. Is able to circulate hierarchically between the technical cycles of re-use, remanufacture, and recycling.

2. Is designed for disassembly, for adaptability

3. It reduces natural resources input and uses sustainable materials.

4. It measures the reduction of emission levels.

5. It measures the reduction of valuable material losses.

Aesthetical

1. Provides ease of change in finishings

2. Provides ease of change in frame form

3. Allows for slender construction

4. The aesthetic quality is not inferior to a non-circular product

Starting Point

Based on Harris Profiles Results

Material	Weight	Aluminium	Steel	Timber	uPVC	GRP	Al/Wood	Al/PVC
Lightness	3	6	1	4	6	7	5	6
Durability	3	7	7	6	3	7	7	7
Cyclability	5	7	7	5	2	1	7	4
High strenght	2	6	7	6	2	7	6	7
Low maintenance	4	7	6	3	6	7	7	7
Low thermal conductivity	3	1	2	7	5	7	7	4
Low initial cost	3	6	3	7	7	1	5	4
Complex shapes	1	7	5	3	7	4	3	6
Low primary embodied energy	4	1	6	7	3	5	5	4
Reusable	5	7	7	7	4	1	7	4
Ease of repairness	5	7	7	5	4	1	6	4
No need for a thermal break	x	x	x	o	o	o	o	o
Total		5.68	5.60	5.47	4.27	4.37	5.96	5.17

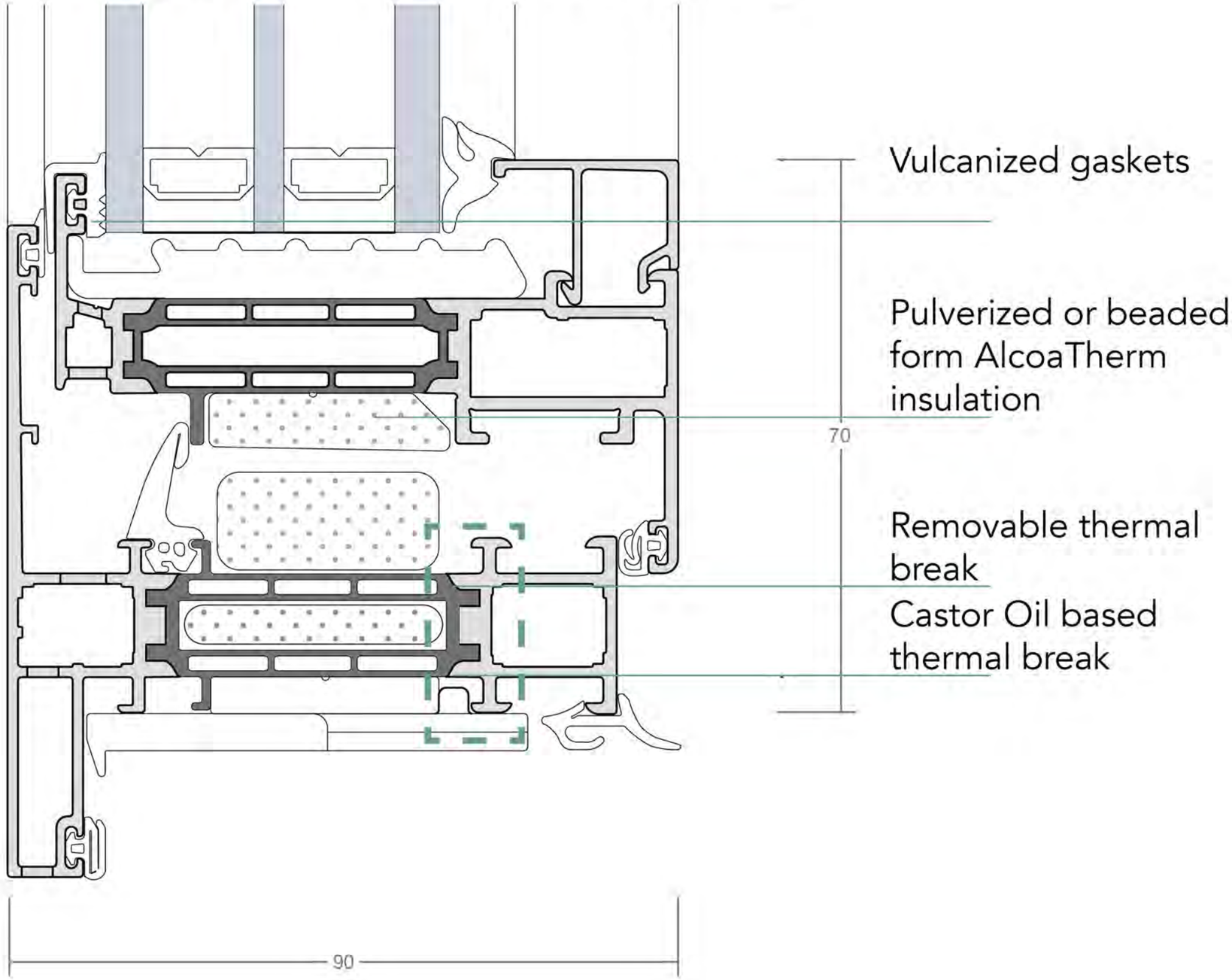
(1) **RT 82 HI + Optimization**

(2) **Hybrid System Variant A**

(3) **Hybrid System Variant B**

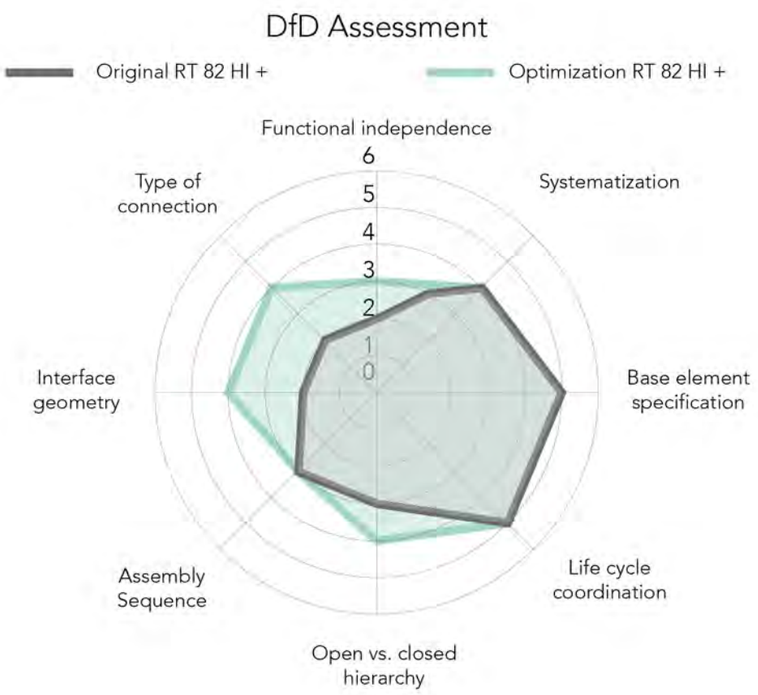
(1) RT 82 HI + Optimization

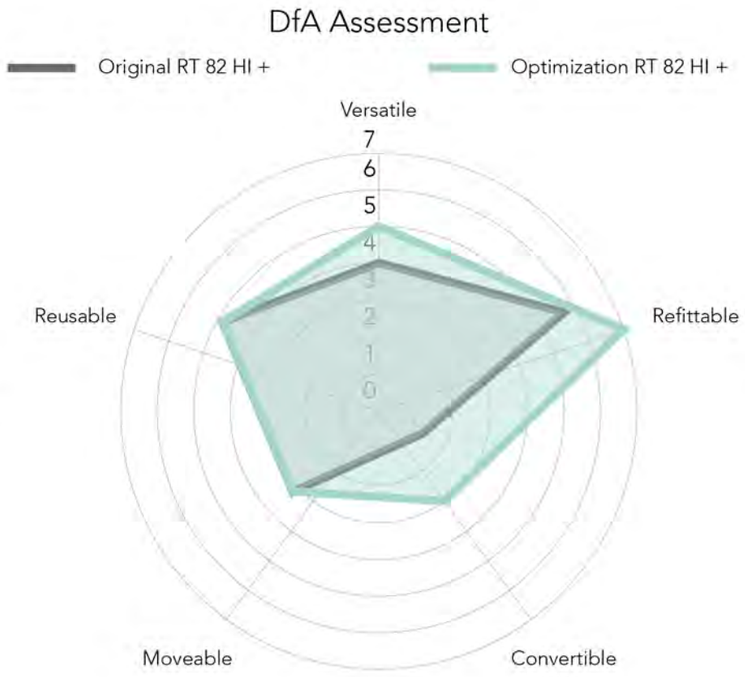
Small improvements for circularity

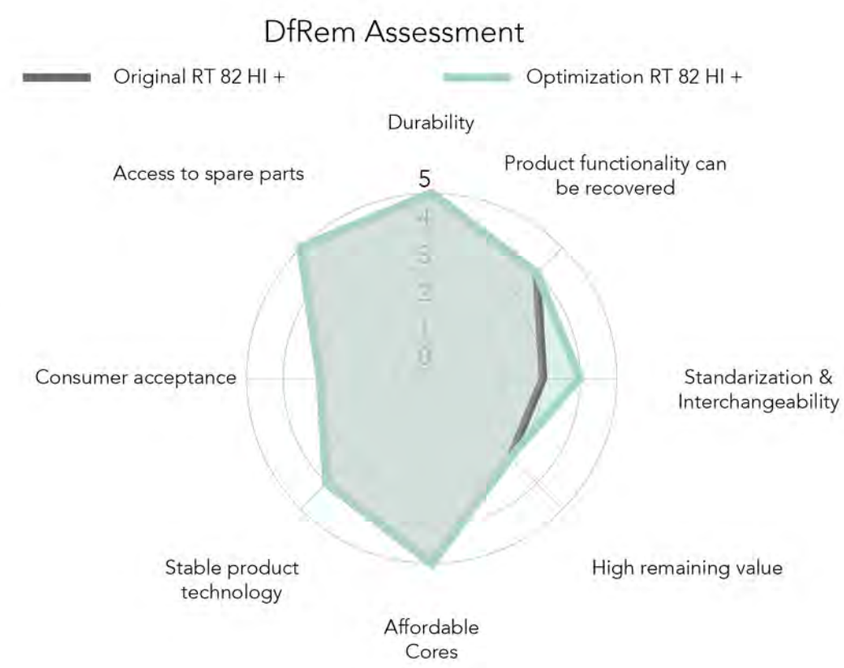


(1) RT 82 HI + Optimization

Assessment Results Comparison







NEW ARCHITECTURE?

Video derived from footage by Anderson (2019)

(2) Hybrid Variant A

Side View

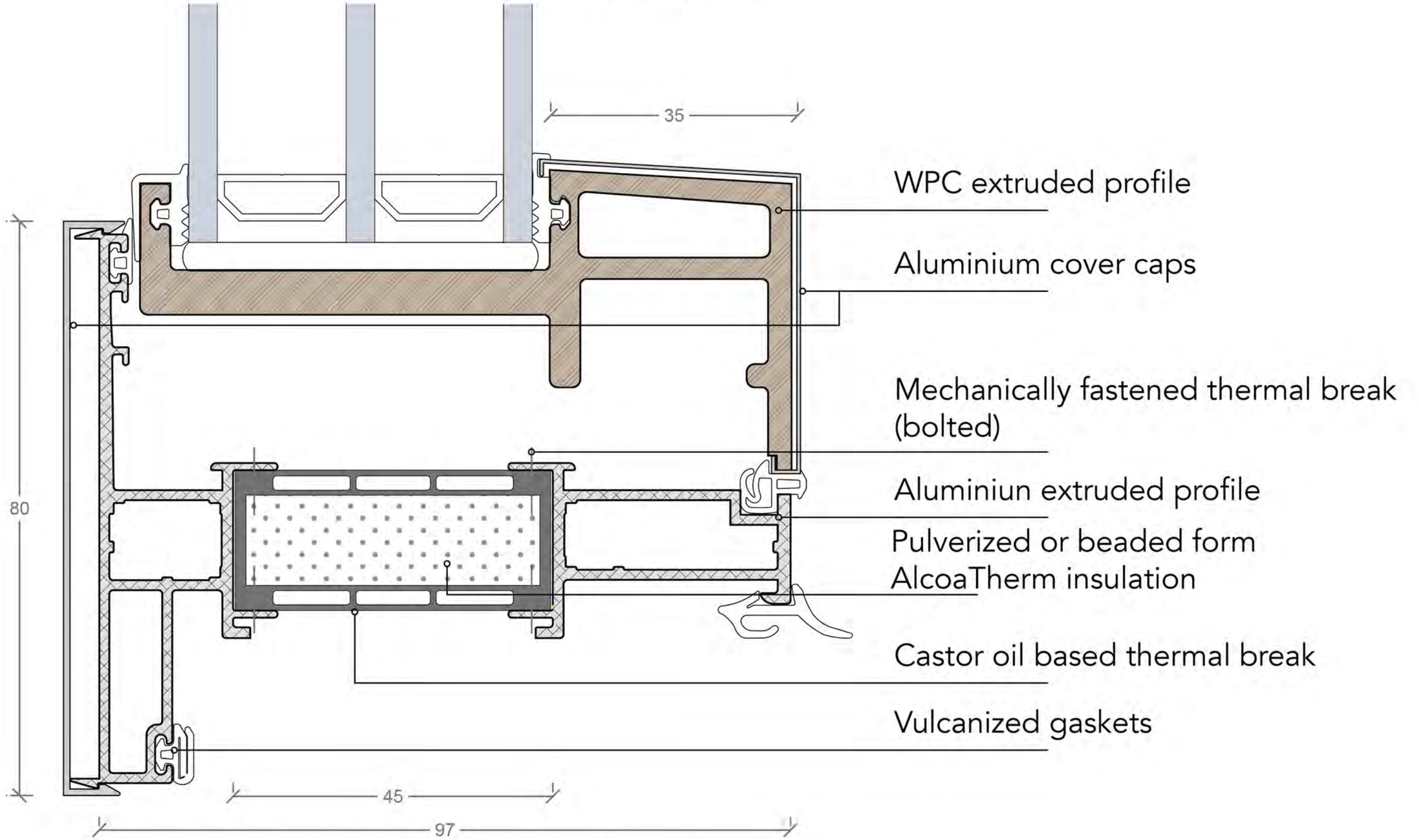
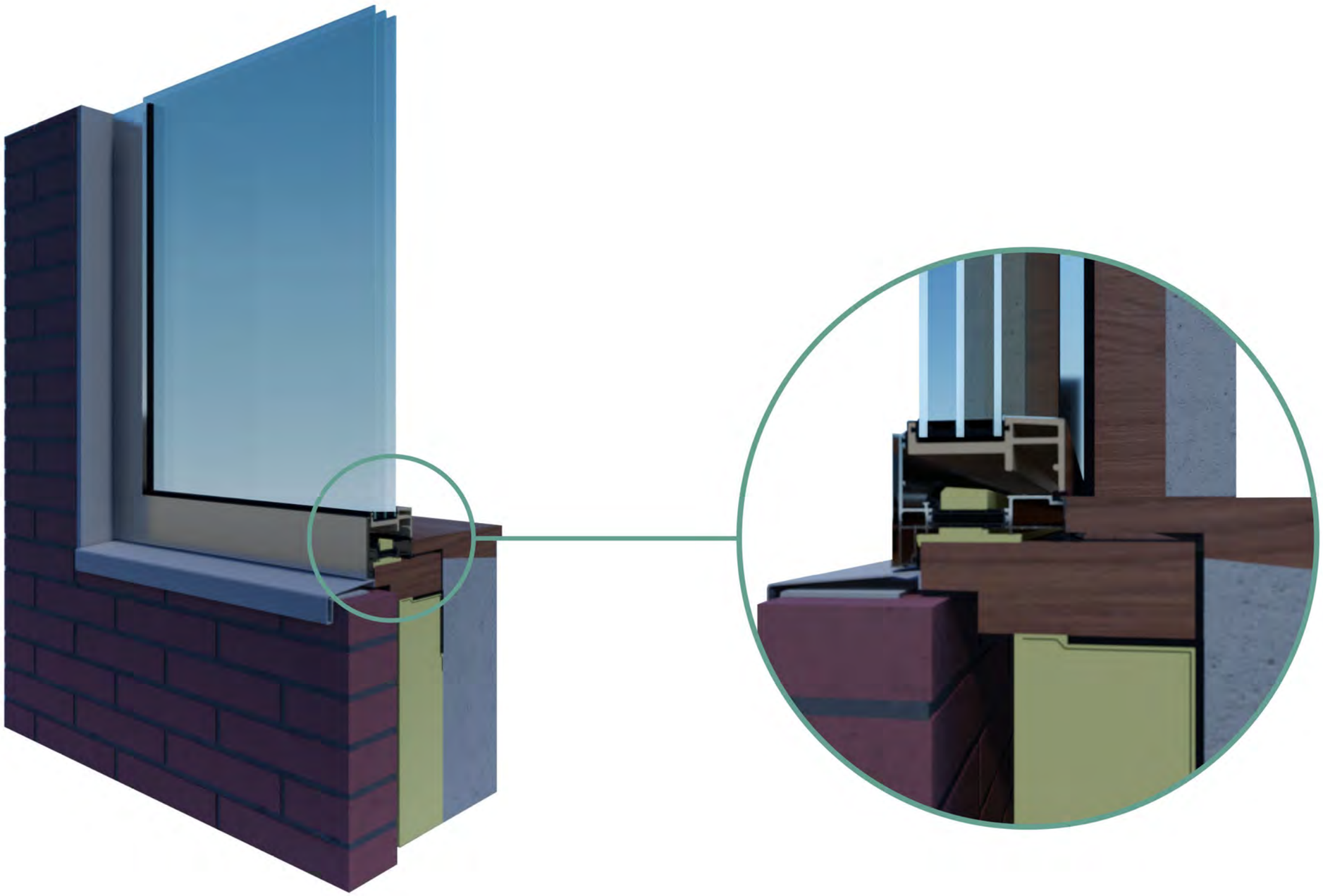


Figure 8.8 Side view of the profile for Hybrid System Variant A. Image by author.

(2) Hybrid Variant A

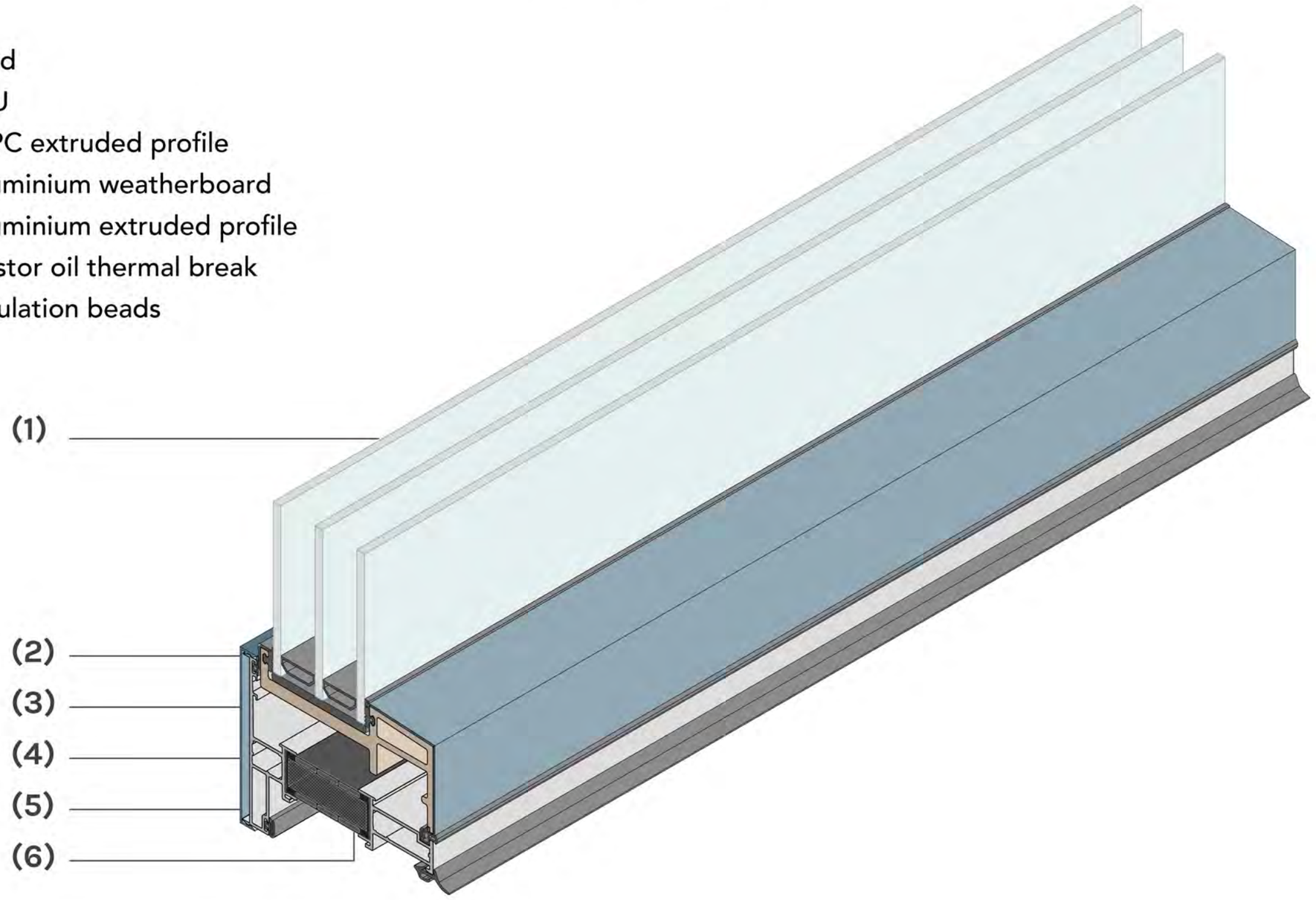
Side View in Brick Cavity Wall Construction



(2) Hybrid Variant A

Isometric View

Legend
(1) IGU
(2) WPC extruded profile
(3) Aluminium weatherboard
(4) Aluminium extruded profile
(5) Castor oil thermal break
(6) Insulation beads



(2) Hybrid Variant A

Exploded Isometric View

Legend
(1) IGU
(2) WPC extruded profile
(3) Aluminium weatherboard
(4) Aluminium extruded profile
(5) Castor oil thermal break
(6) Insulation beads

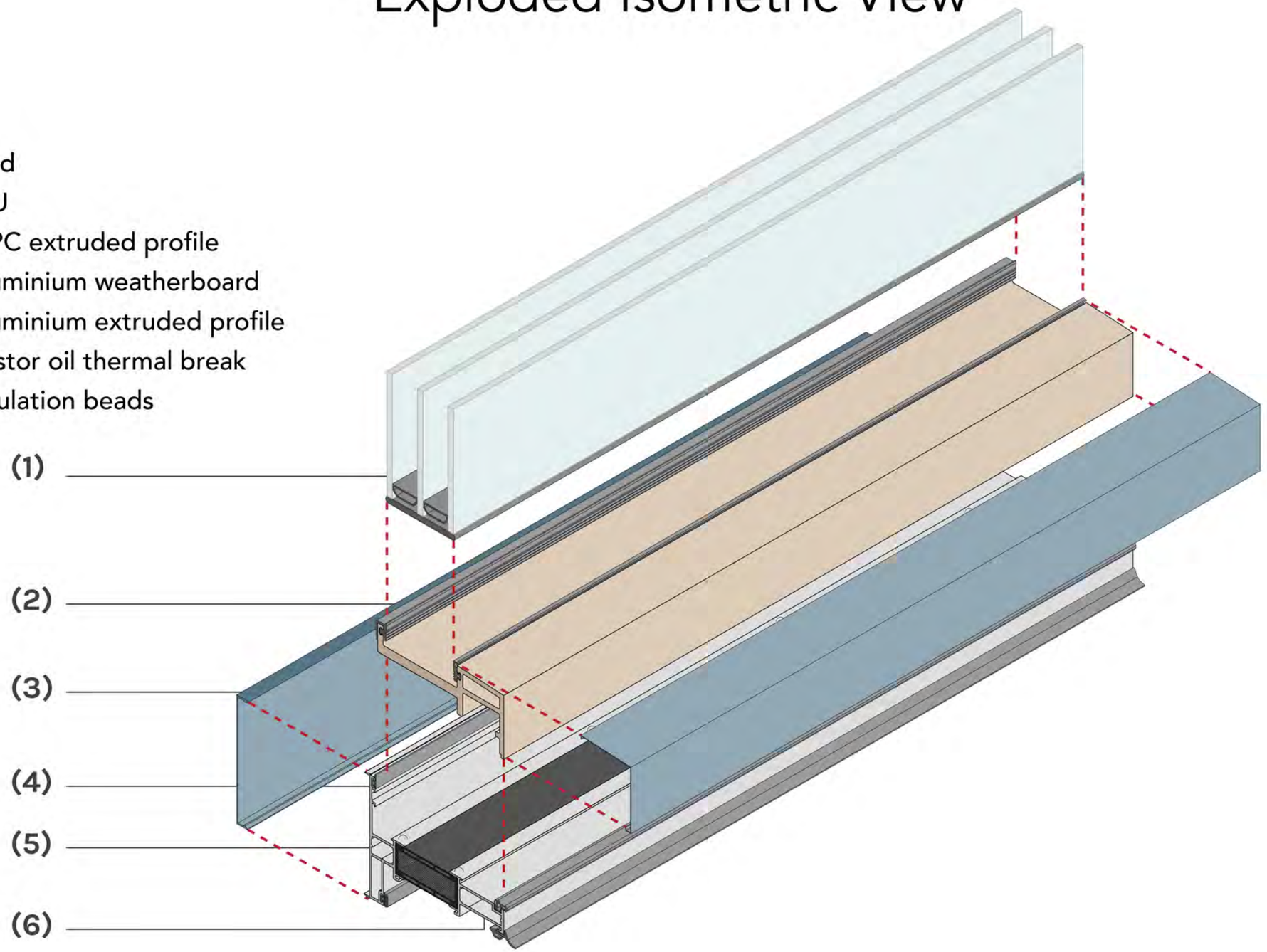
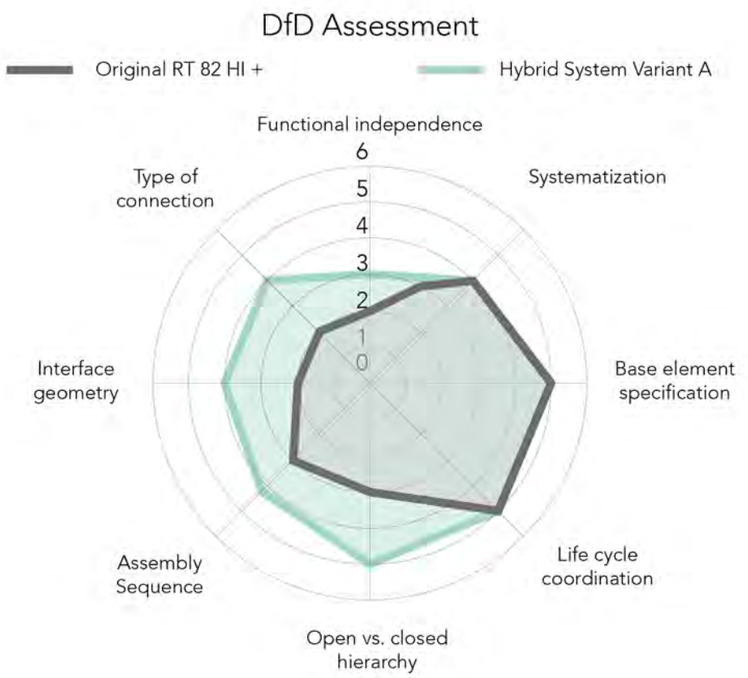
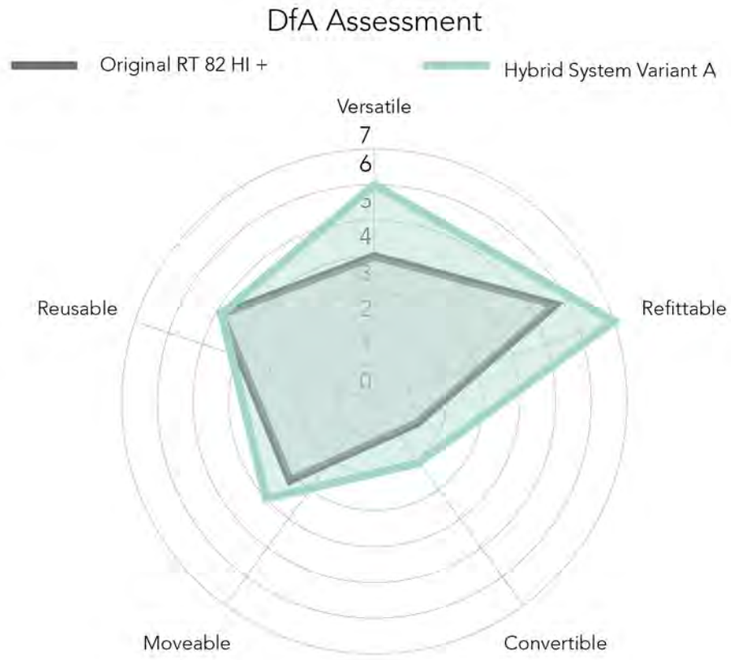


Figure 8.10 Exploded isometric view of the Hybrid System Variant A. Image by author.

(2) Hybrid Variant A

Assessment Results Comparison

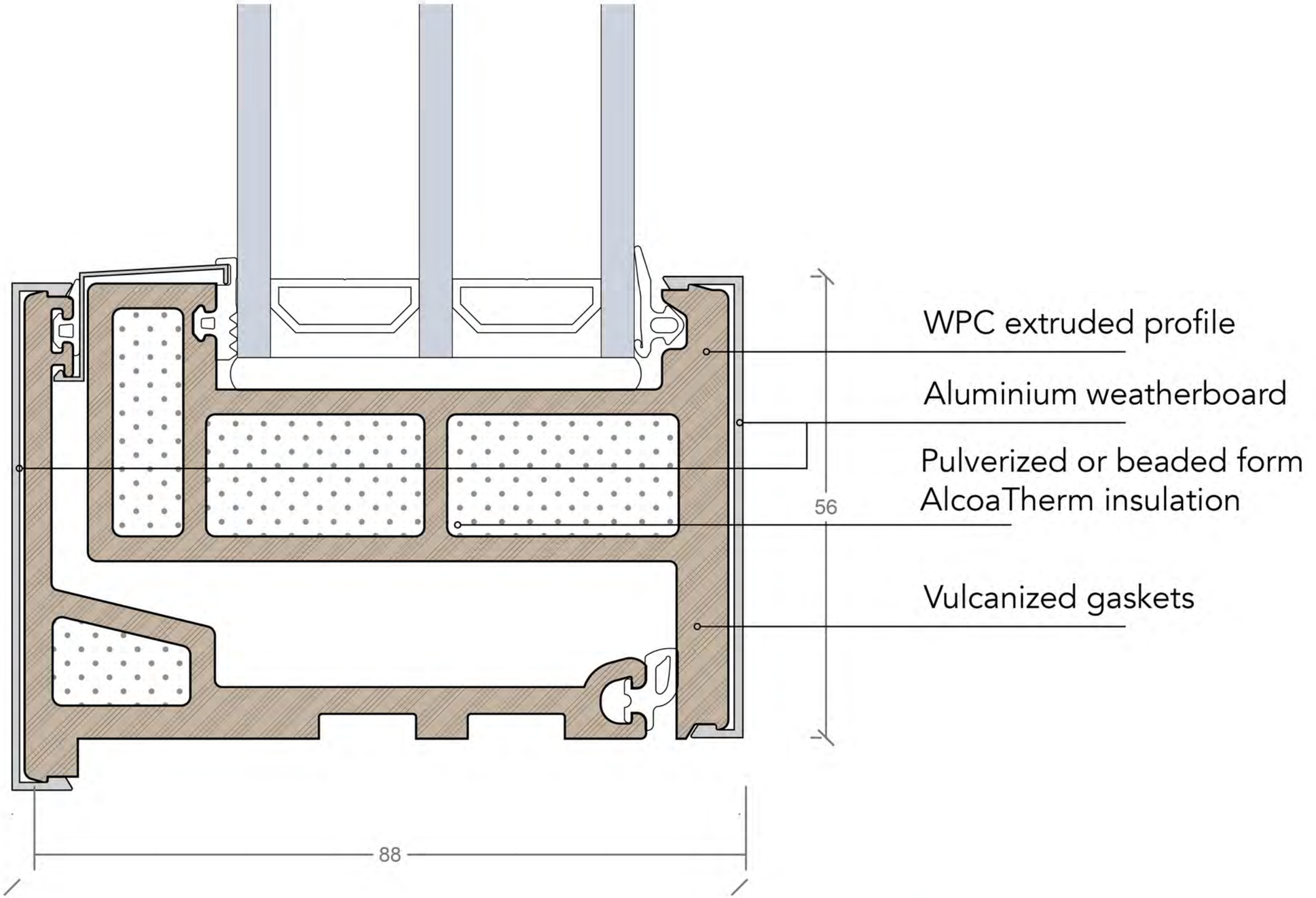






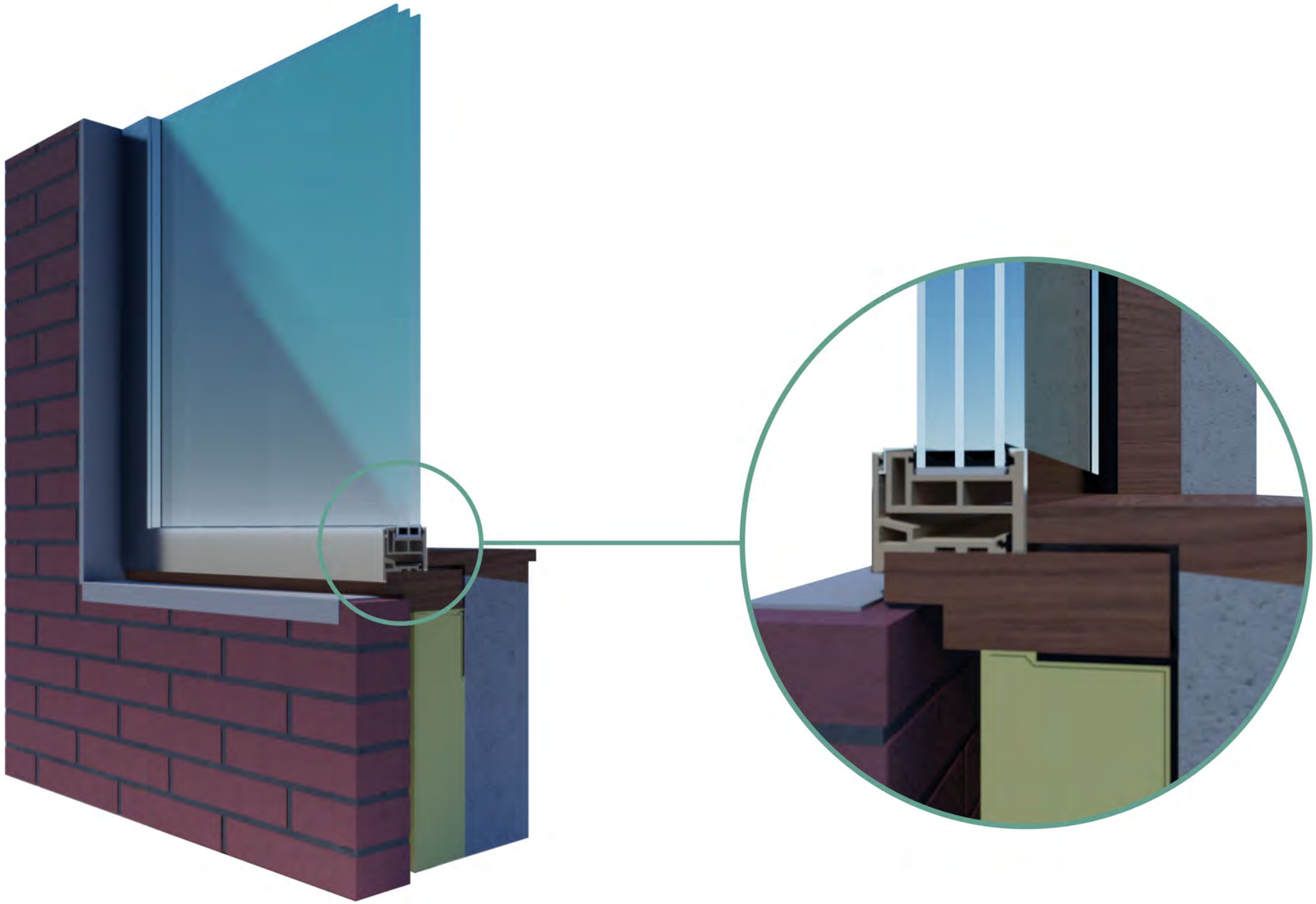
(3) Hybrid Variant B

Side View



(3) Hybrid Variant B

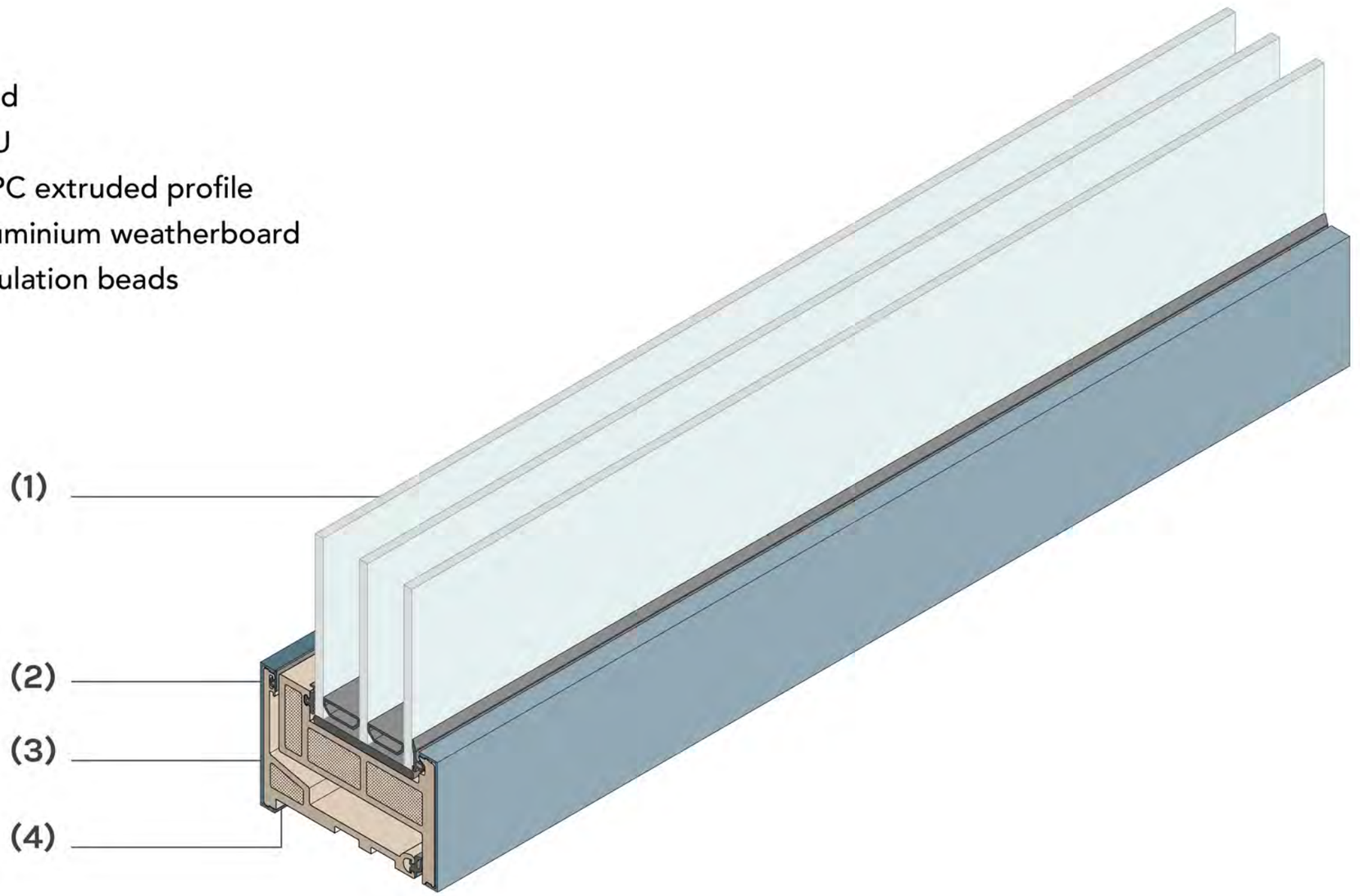
Side View in Brick Cavity Wall Construction



(3) Hybrid Variant B

Isometric View

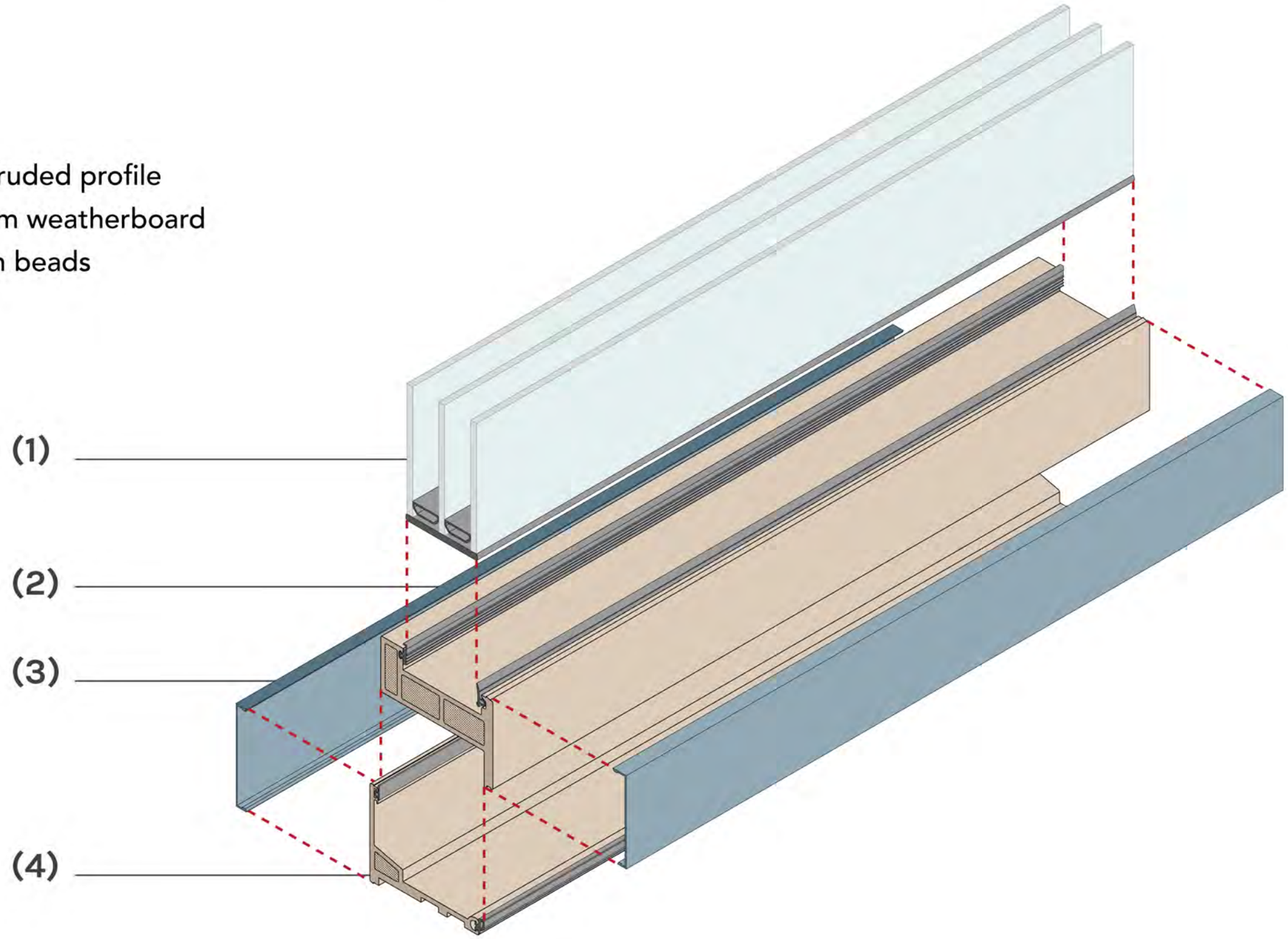
Legend
(1) IGU
(2) WPC extruded profile
(3) Aluminium weatherboard
(4) Insulation beads



(3) Hybrid Variant B

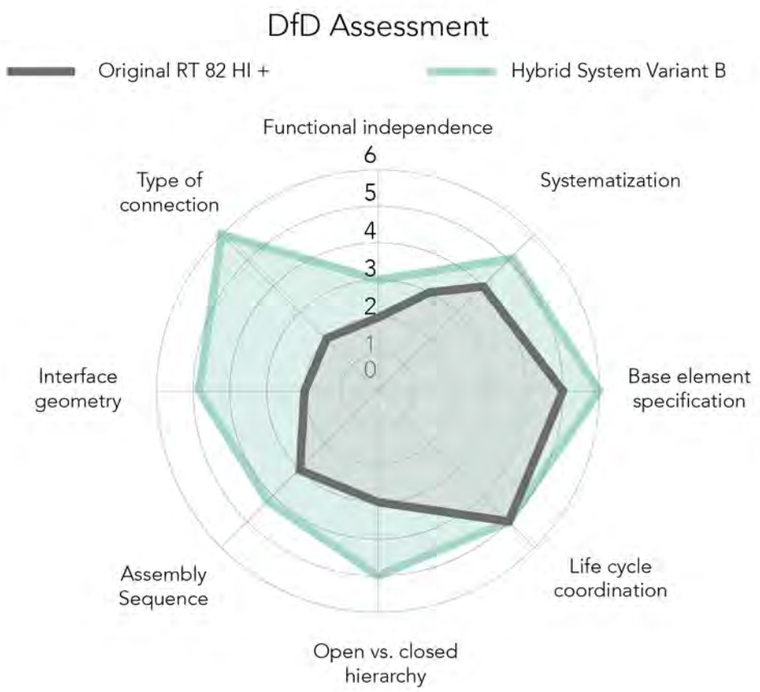
Exploded Isometric View

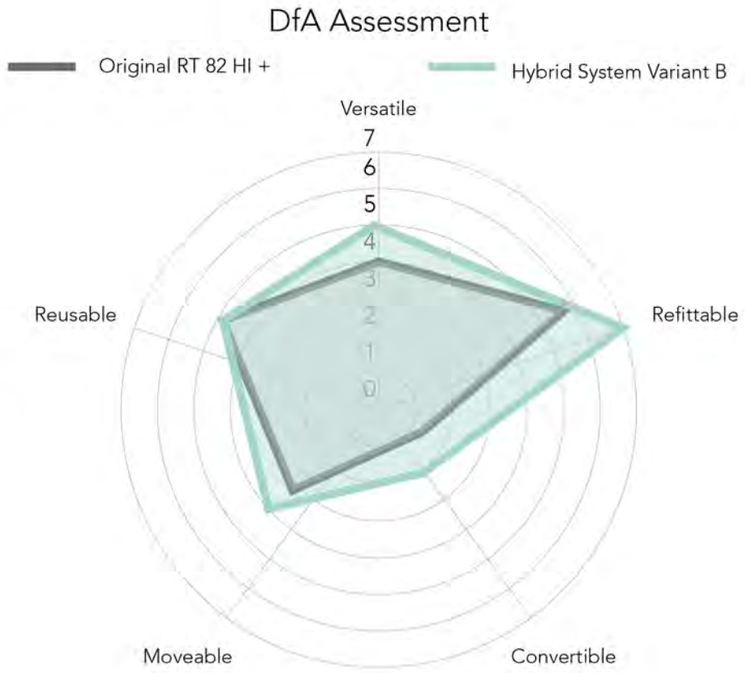
Legend
(1) IGU
(2) WPC extruded profile
(3) Aluminium weatherboard
(4) Insulation beads

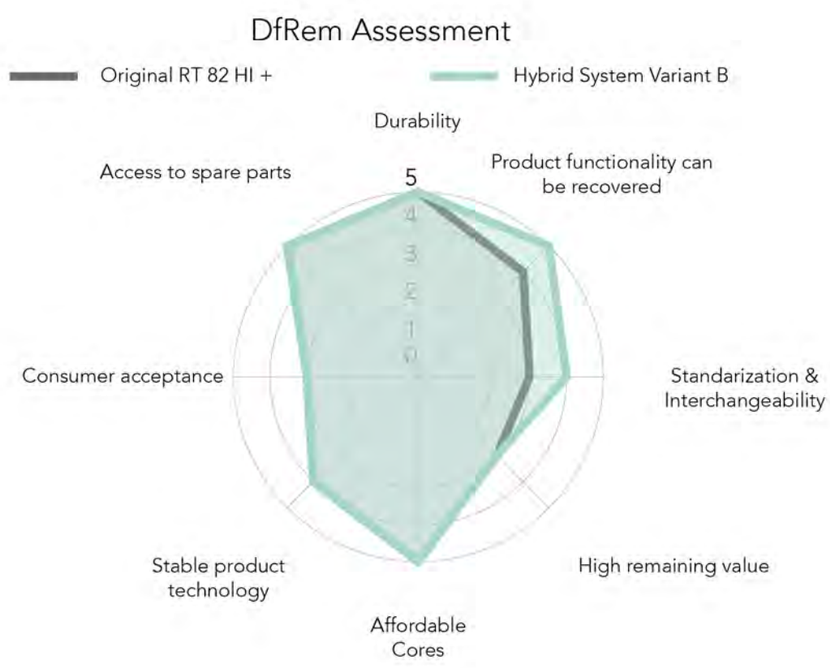


(3) Hybrid Variant B

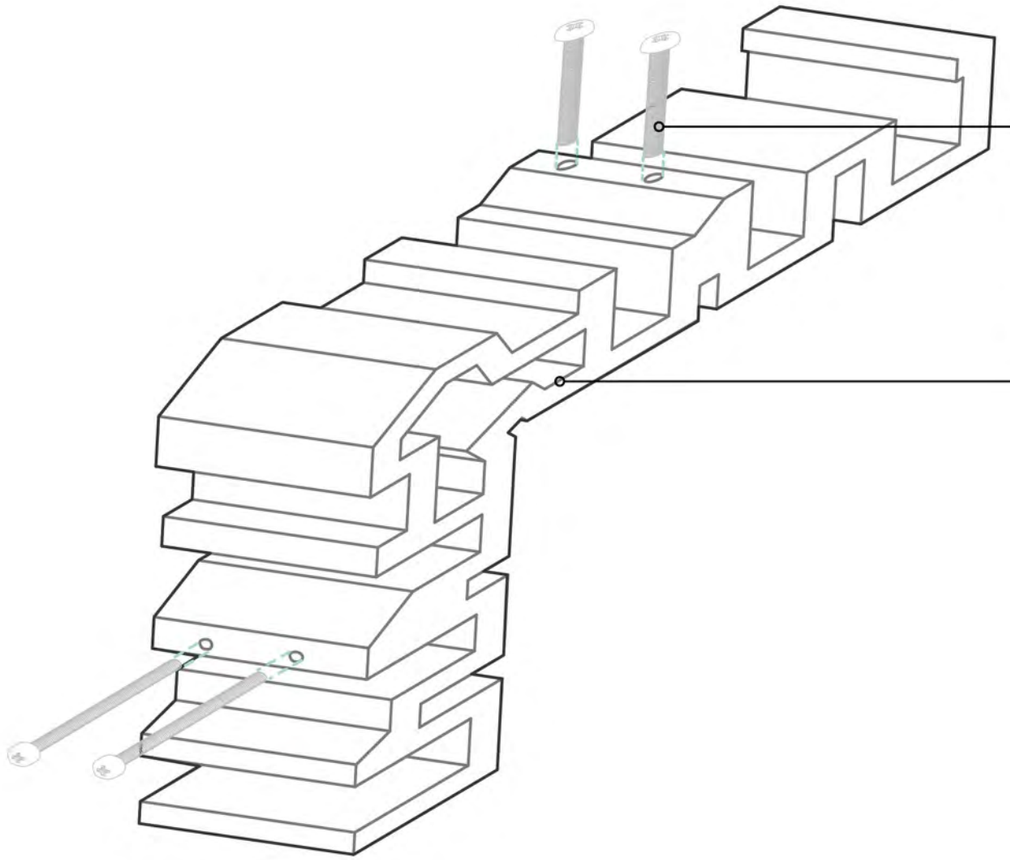
Assessment Results Comparison



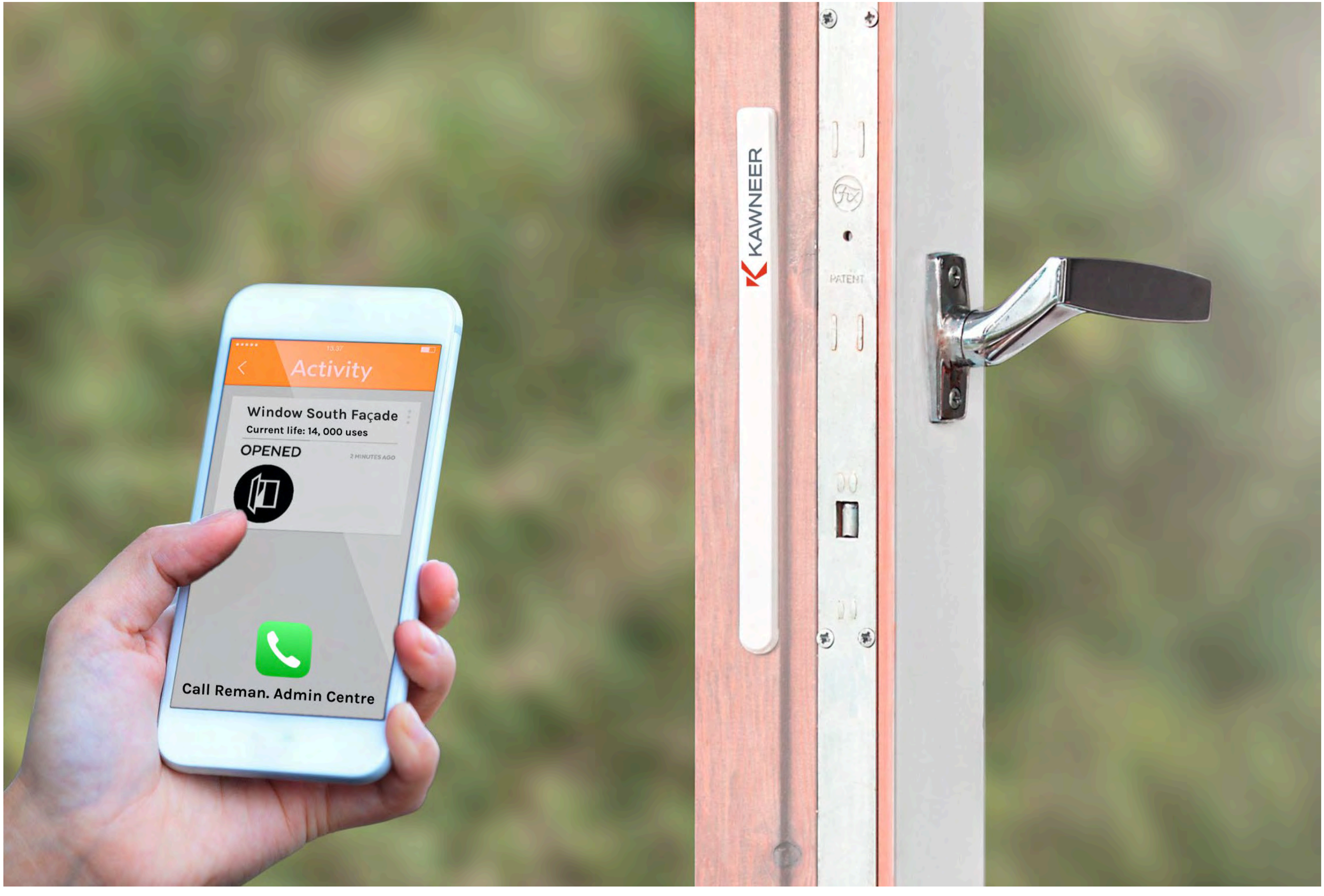




Improvements in Hardware & Connections



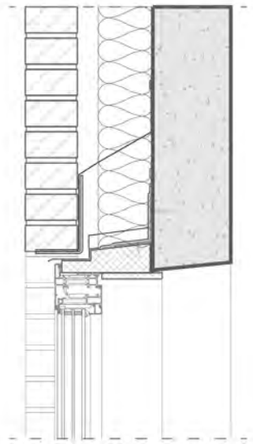


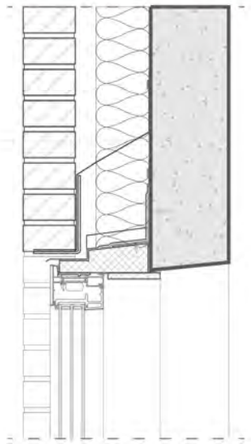

Activity
Window South Façade
Current life: 14, 000 uses
OPENED
2 MINUTES AGO
Call Reman. Admin Centre
KAWNEER
PATENT

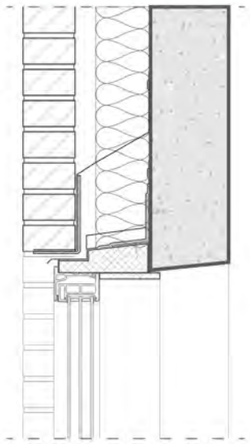
Reuse Scenarios

Attachment to four different types of façade systems

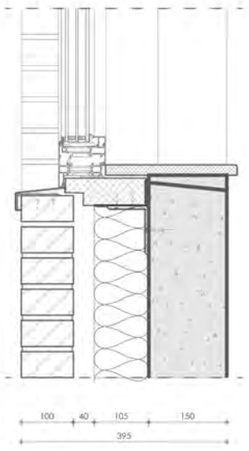
Brick Cavity Wall Construction

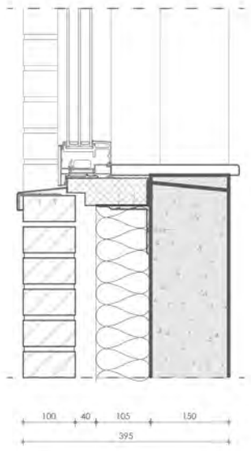


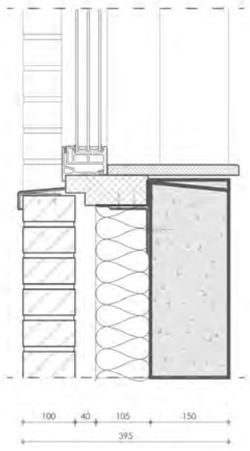




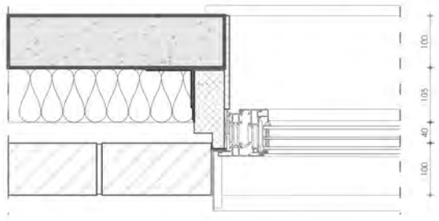
Vertical details



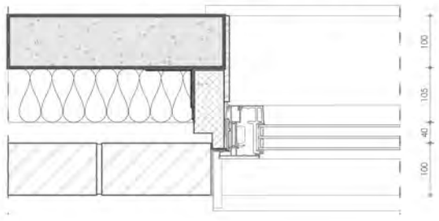




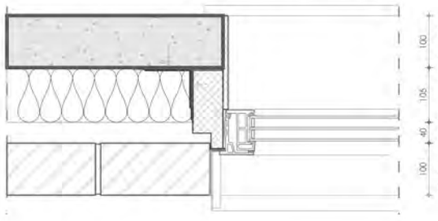
Optimization RT 82 HI +



Hybrid System Variant A



Hybrid System Variant B



Horizontal details

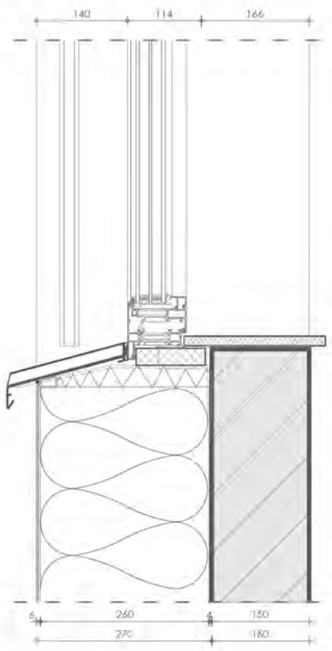


Reuse Scenarios

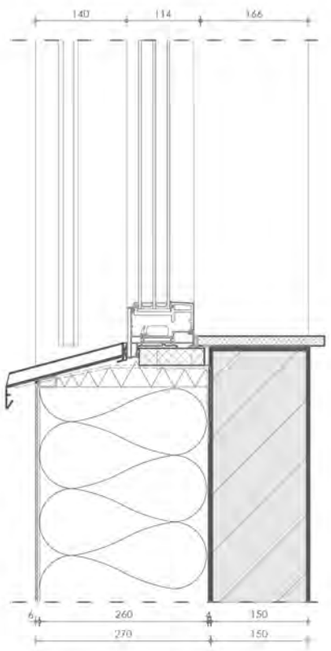
Attachment to four different types of façade systems

Passive House Façade System and Construction

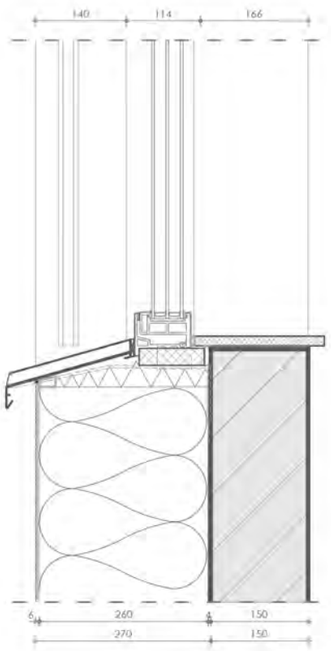
Optimization RT 82 HI +



Hybrid System Variant A



Hybrid System Variant B

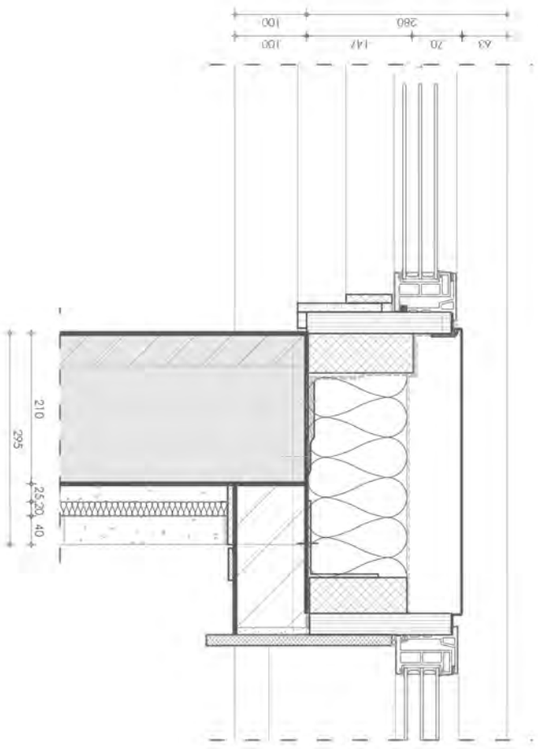


Reuse Scenarios

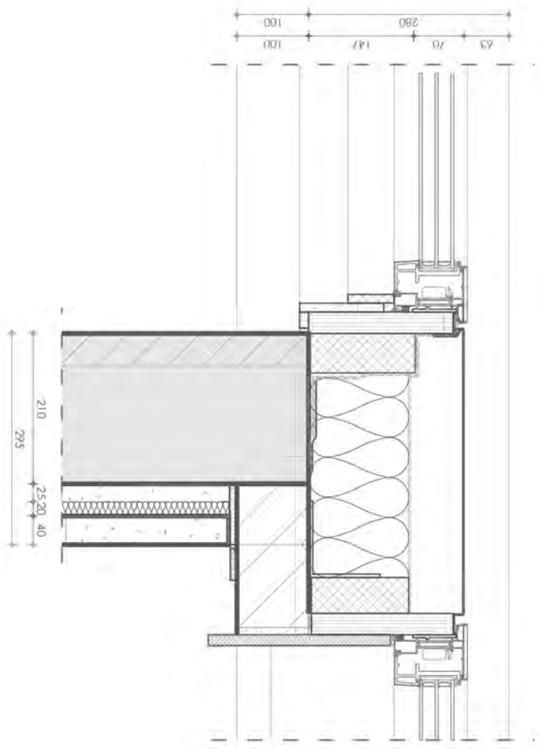
Attachment to four different types of façade systems

Residential Storey Floor Longitudinal Façade System and Construction

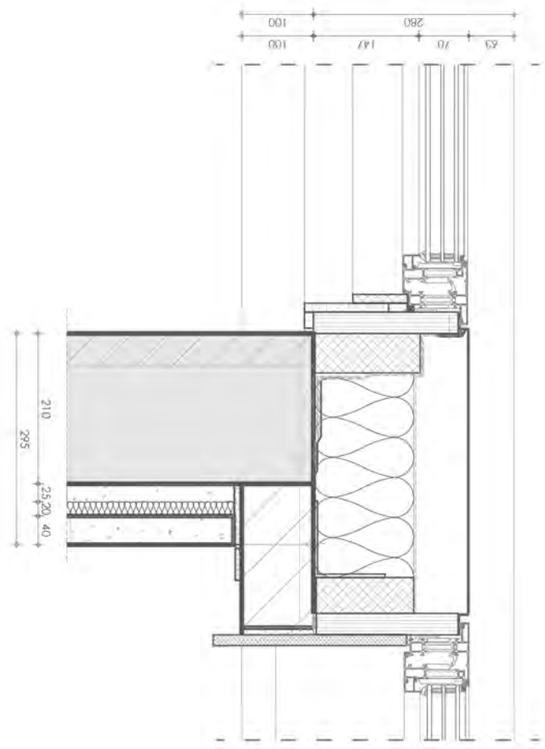
Hybrid System Variant B



Hybrid System Variant A



Optimization RT 82 HI +

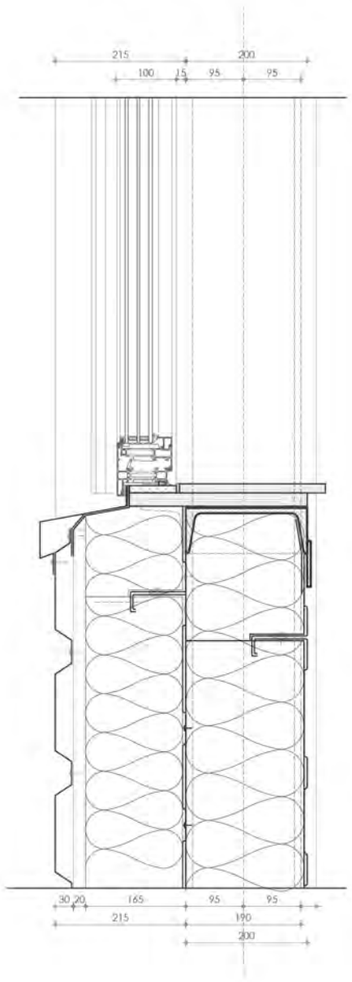


Reuse Scenarios

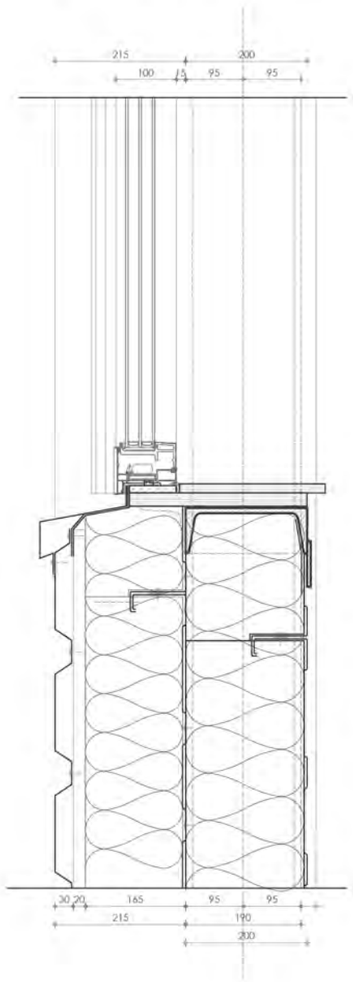
Attachment to four different types of façade systems

Non-Residential Building with Metal Cladding Façade System and Construction

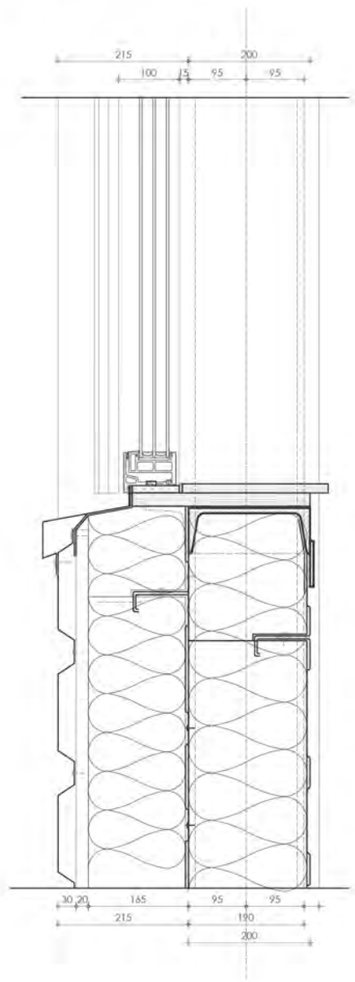
Optimization RT 82 HI +



Hybrid System Variant A



Hybrid System Variant B



Adaptability Scenarios

Change of Window Area

Change of aesthetics

Change of Function

Adaptability Scenarios

Change of Window Area (+/-)

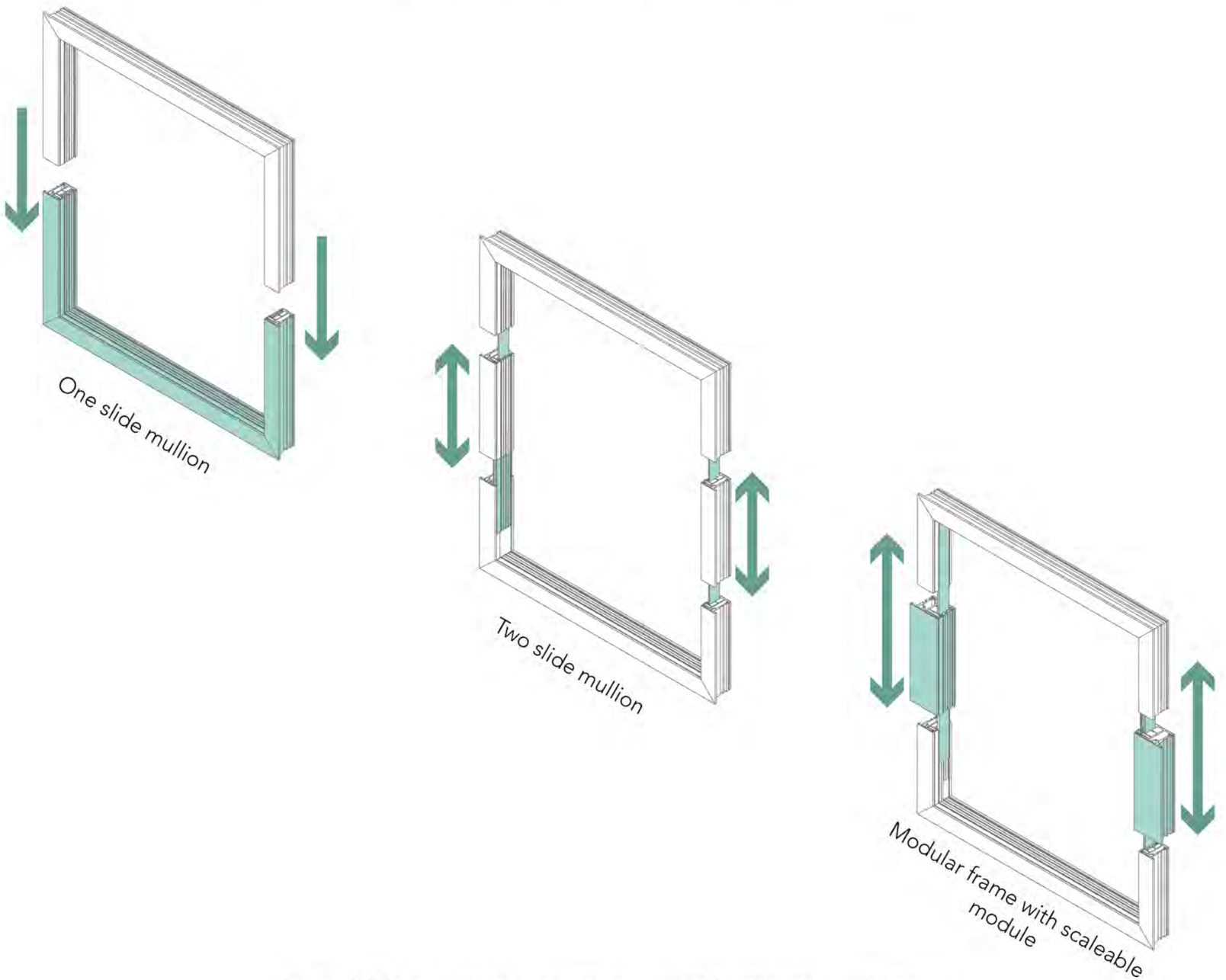
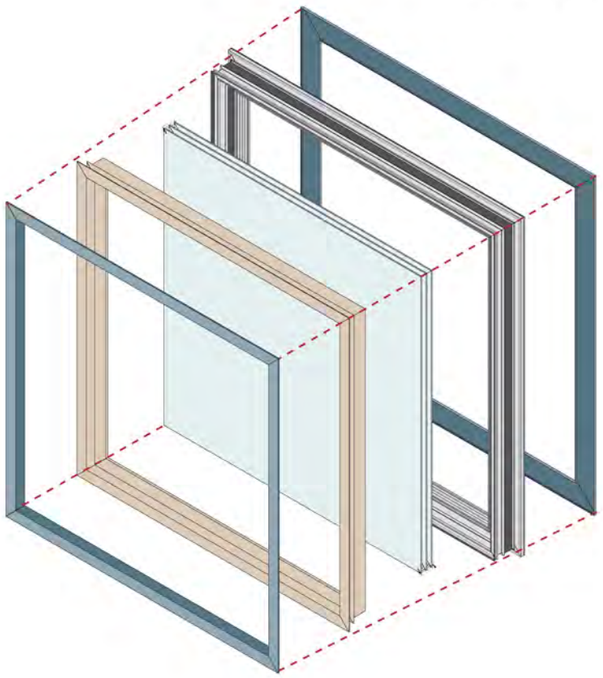
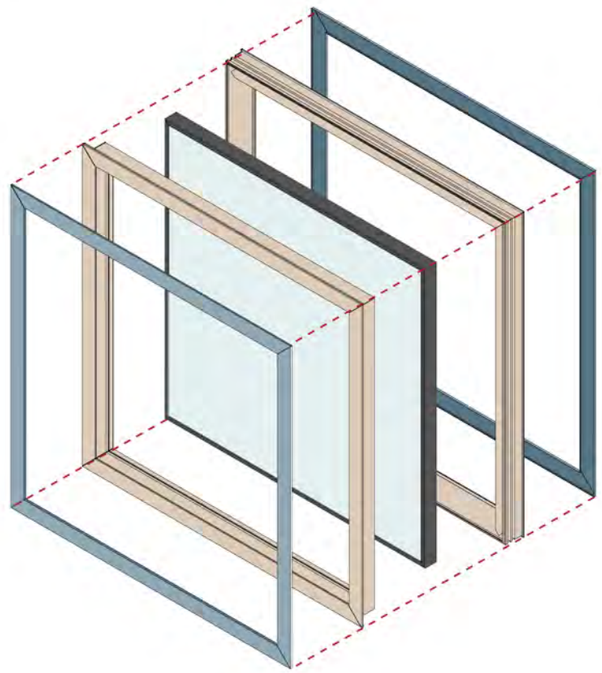


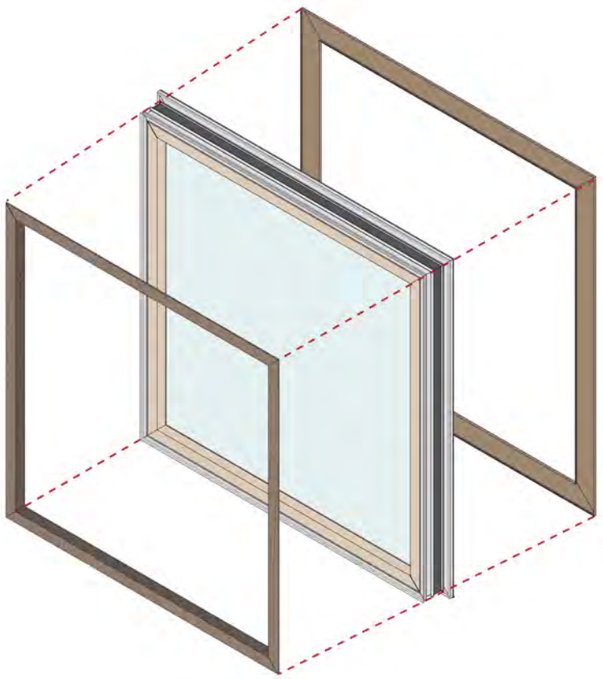
Figure 8.33 Convertible conceptual designs for the window systems.

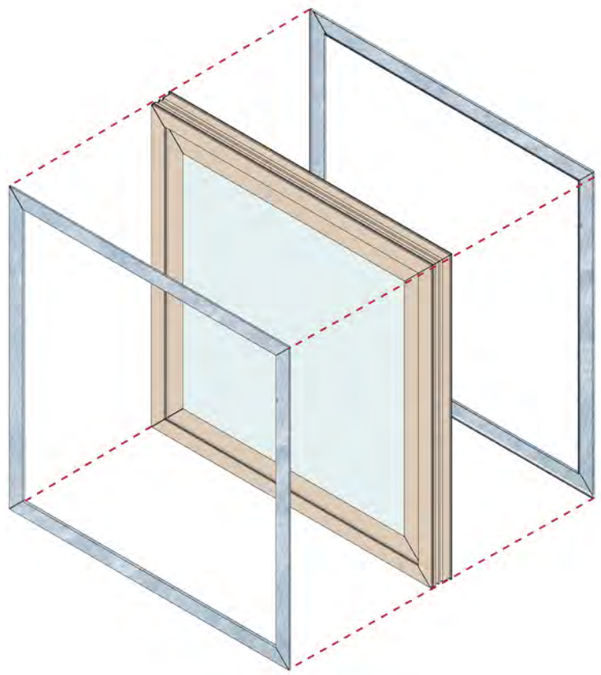
Adaptability Scenarios

Change of Aesthetics



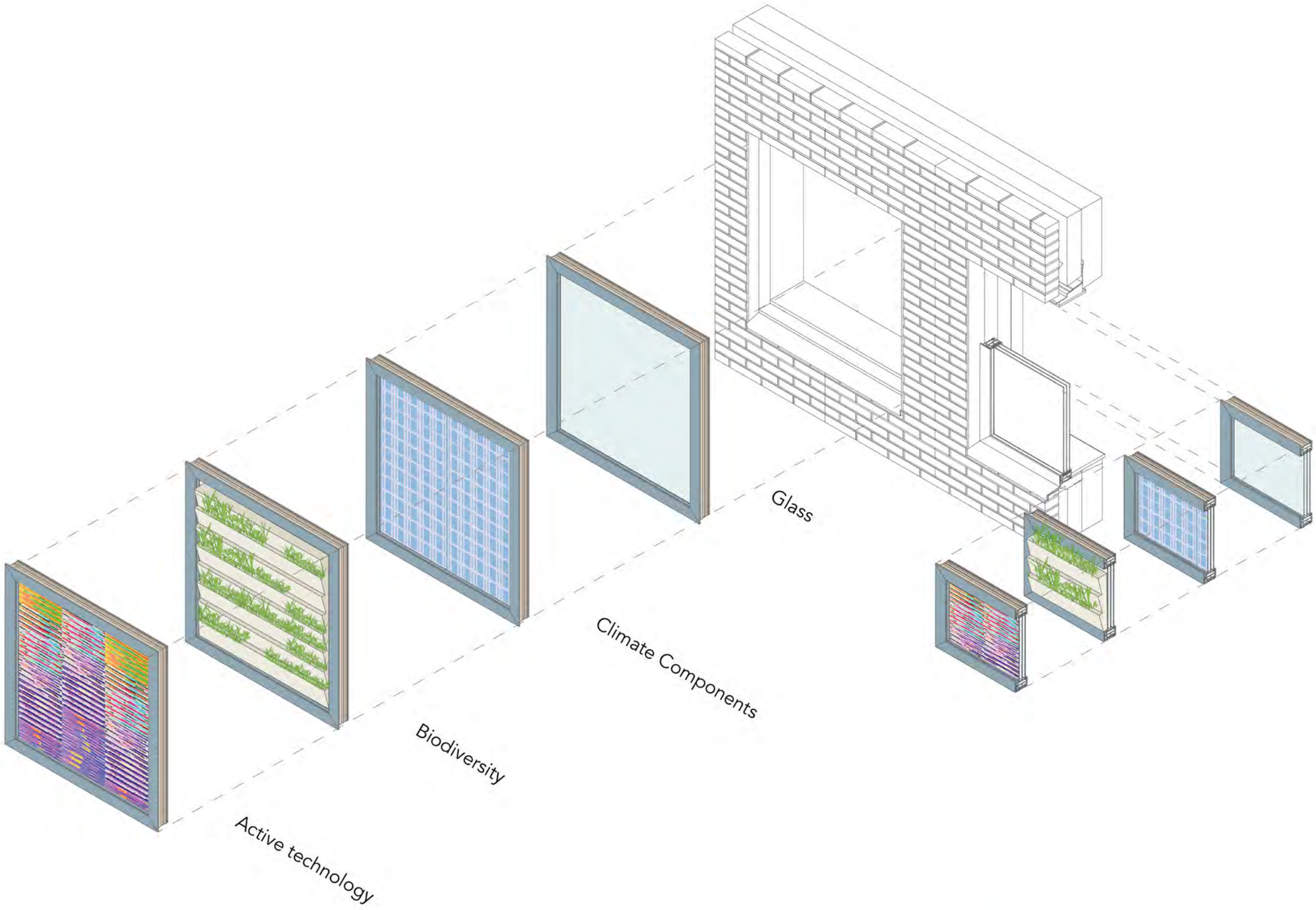






Adaptability Scenarios

Change of Function

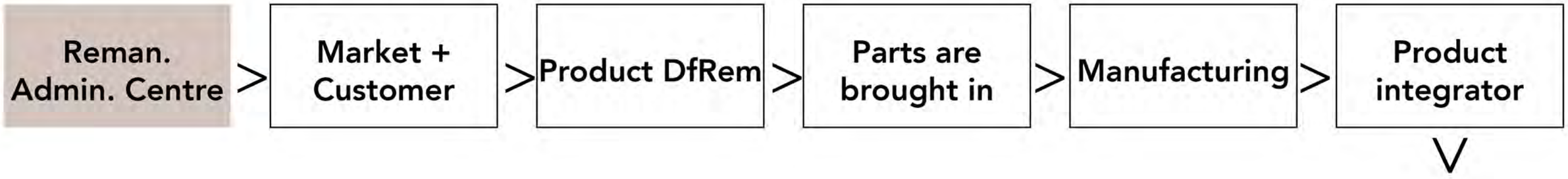


Remanufacturing Scenarios

(5) Key Activities

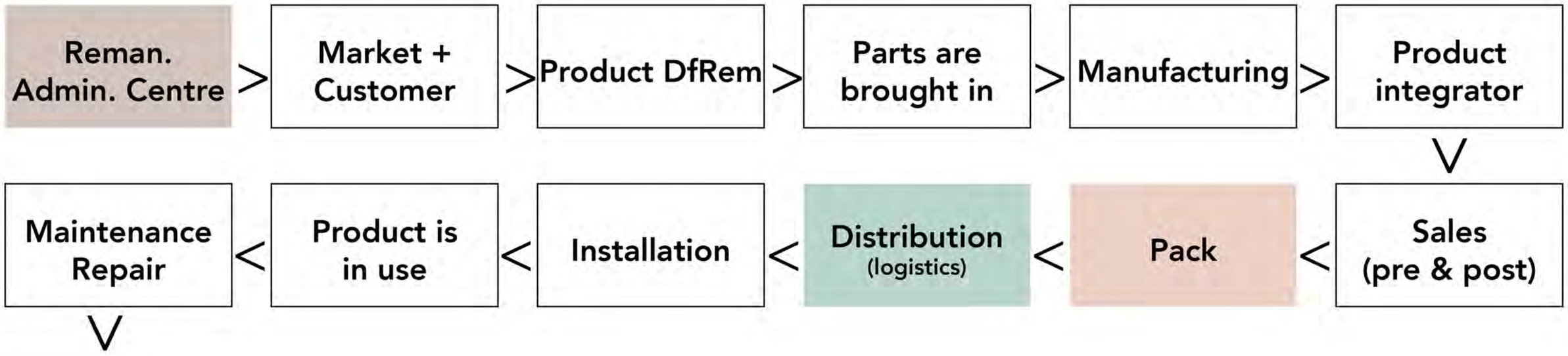
Remanufacturing Scenarios

(5) Key Activities



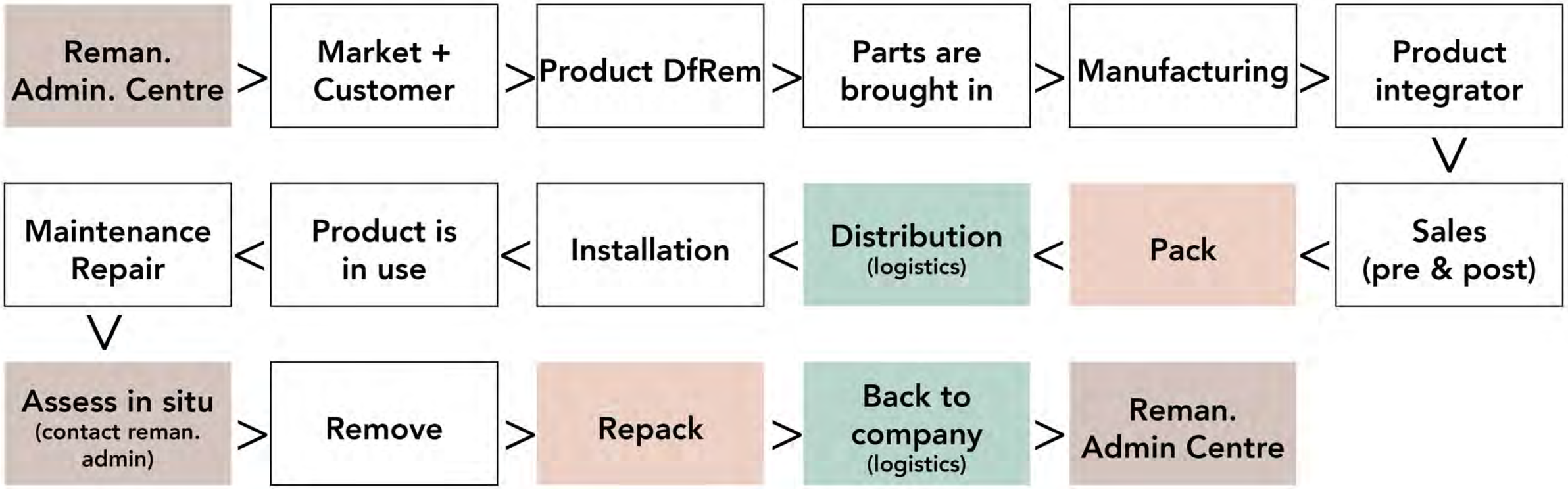
Remanufacturing Scenarios

(5) Key Activities



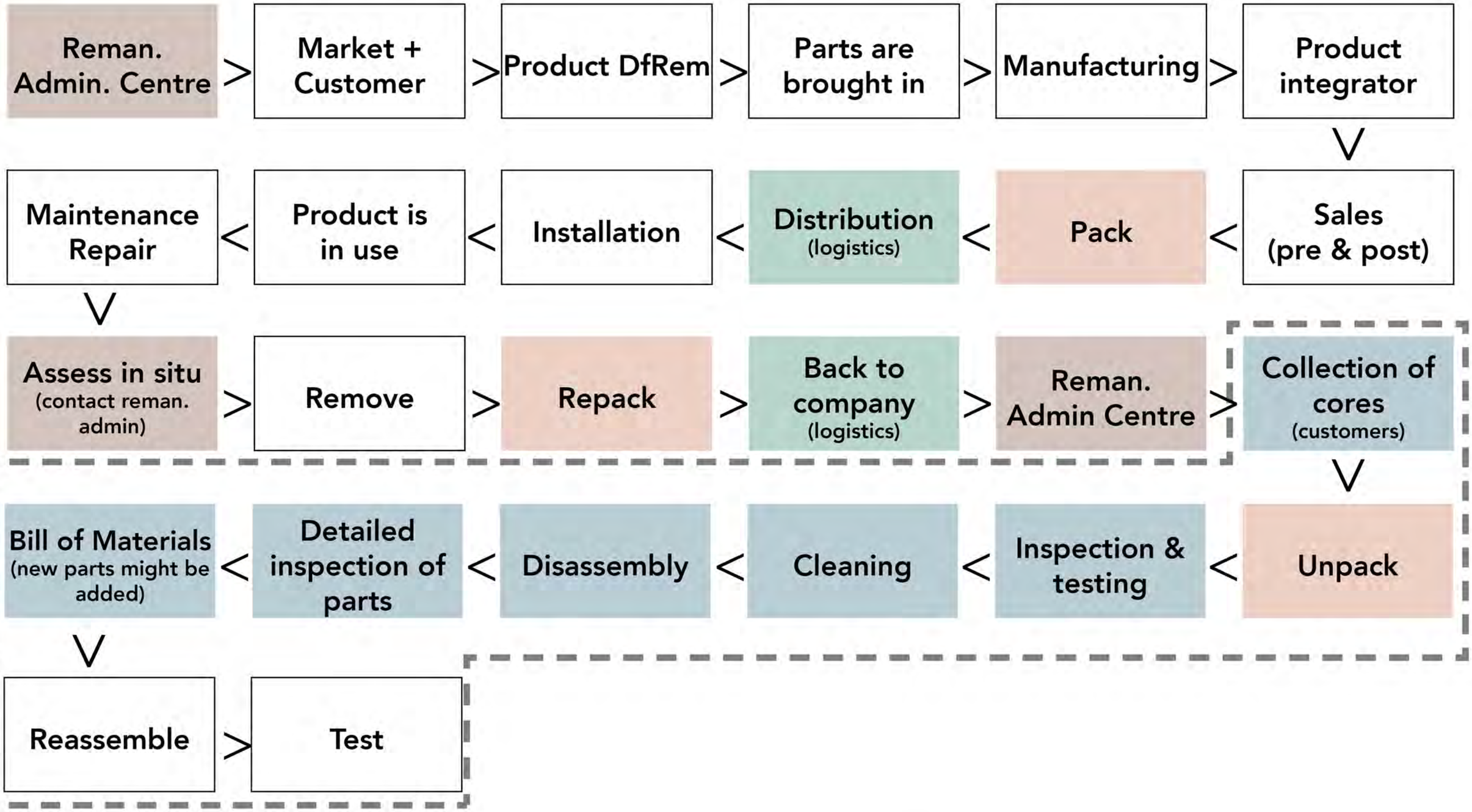
Remanufacturing Scenarios

(5) Key Activities



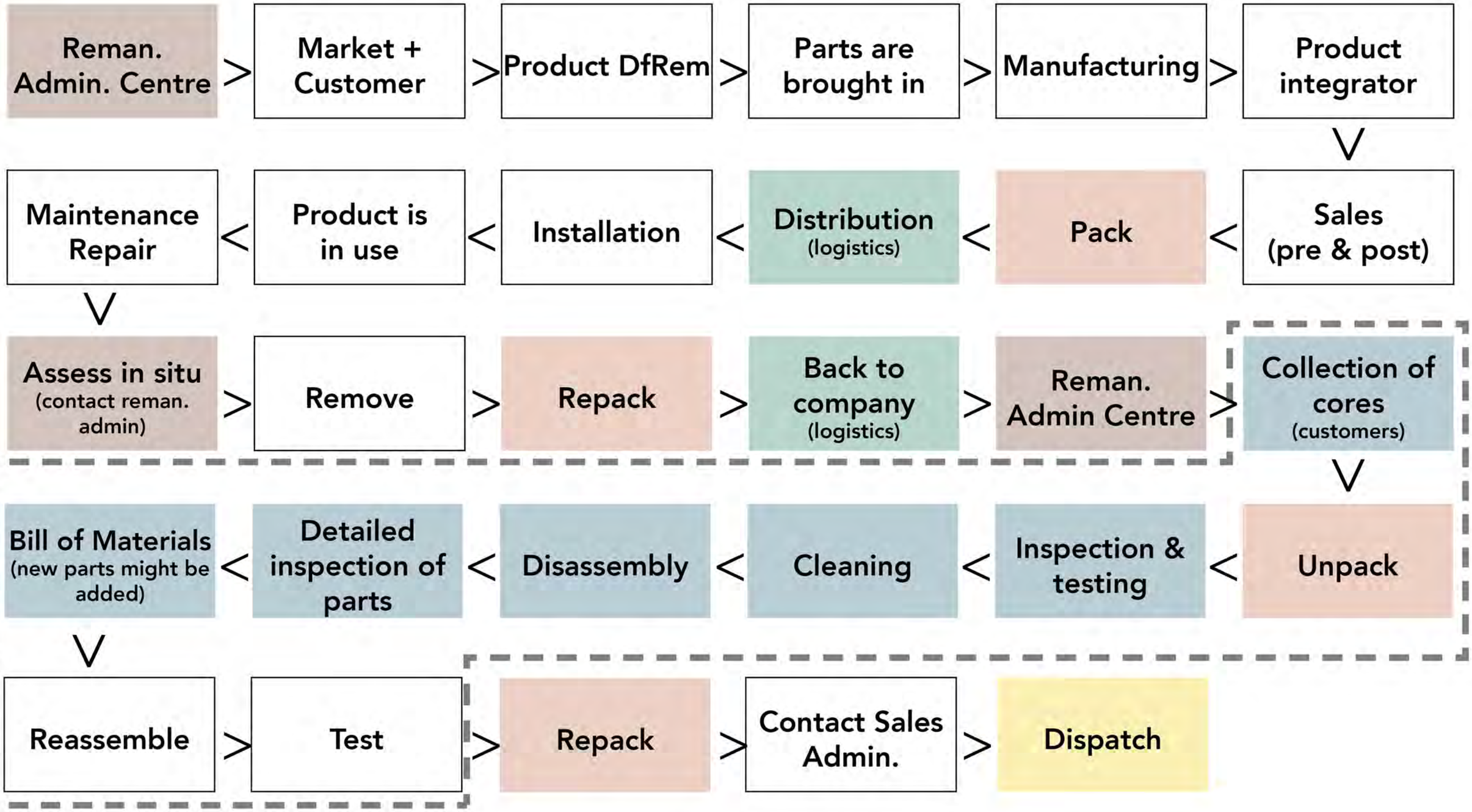
Remanufacturing Scenarios

(5) Key Activities



Remanufacturing Scenarios

(5) Key Activities



Conclusions

Closing the Loop

Closing the Loop

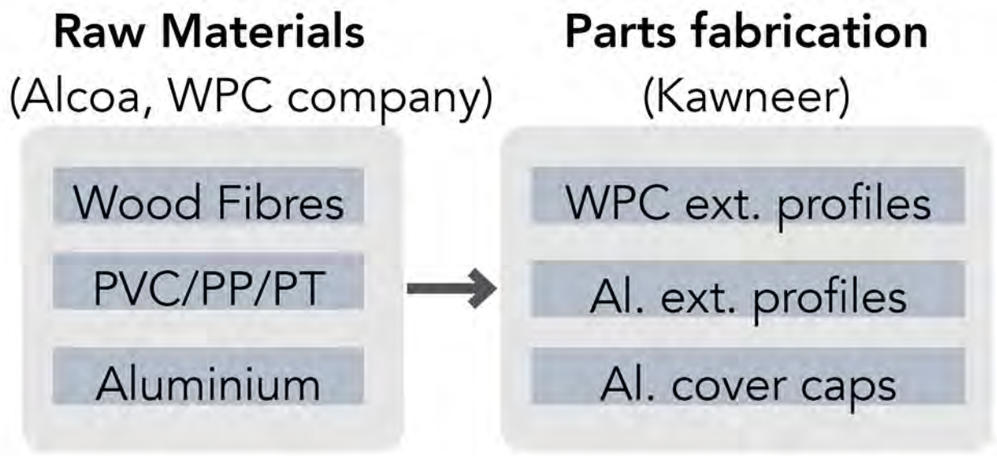
Raw Materials
(Alcoa, WPC company)

Wood Fibres

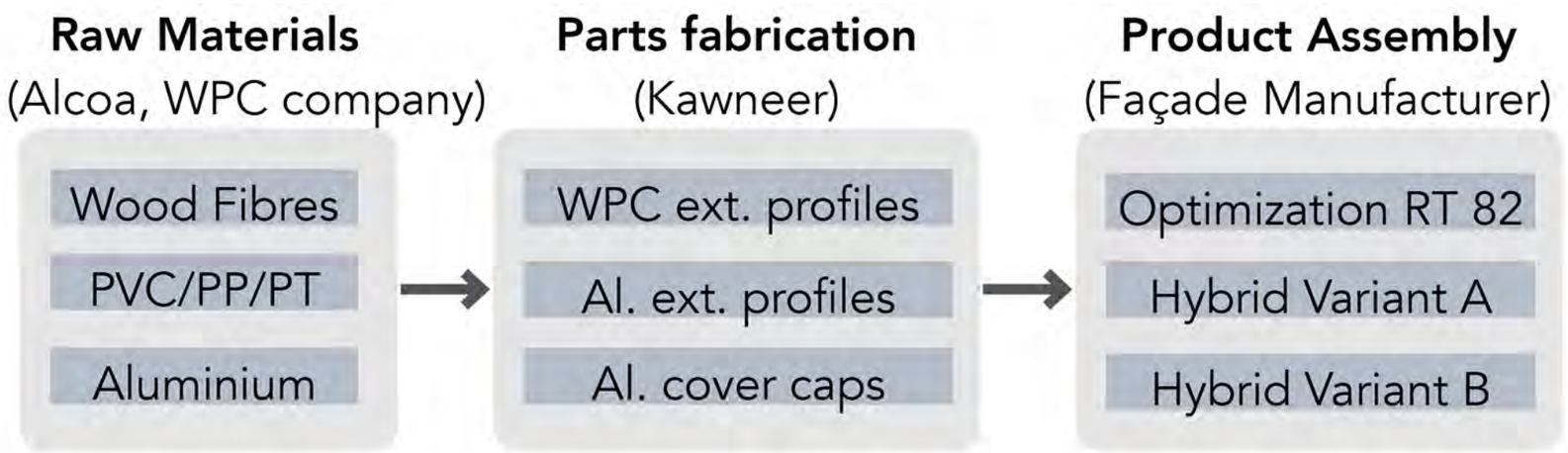
PVC/PP/PT

Aluminium

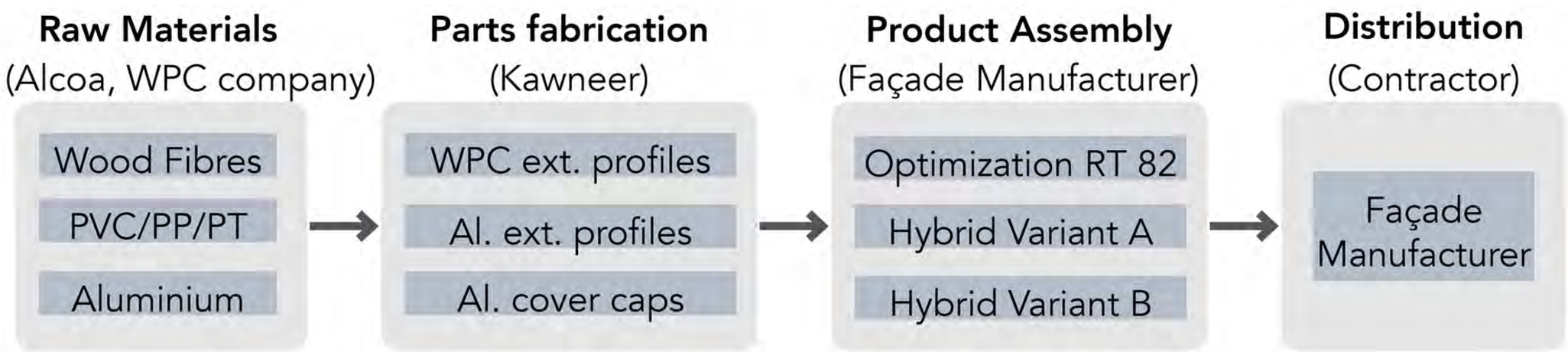
Closing the Loop



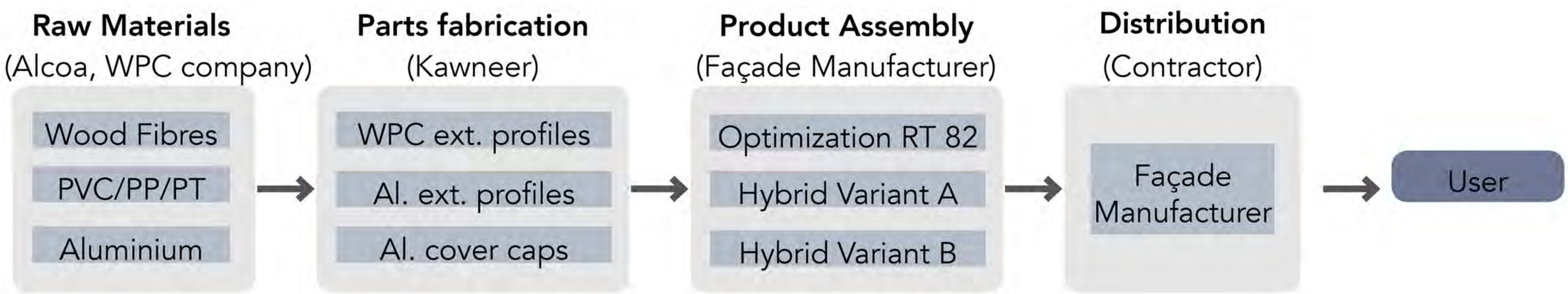
Closing the Loop



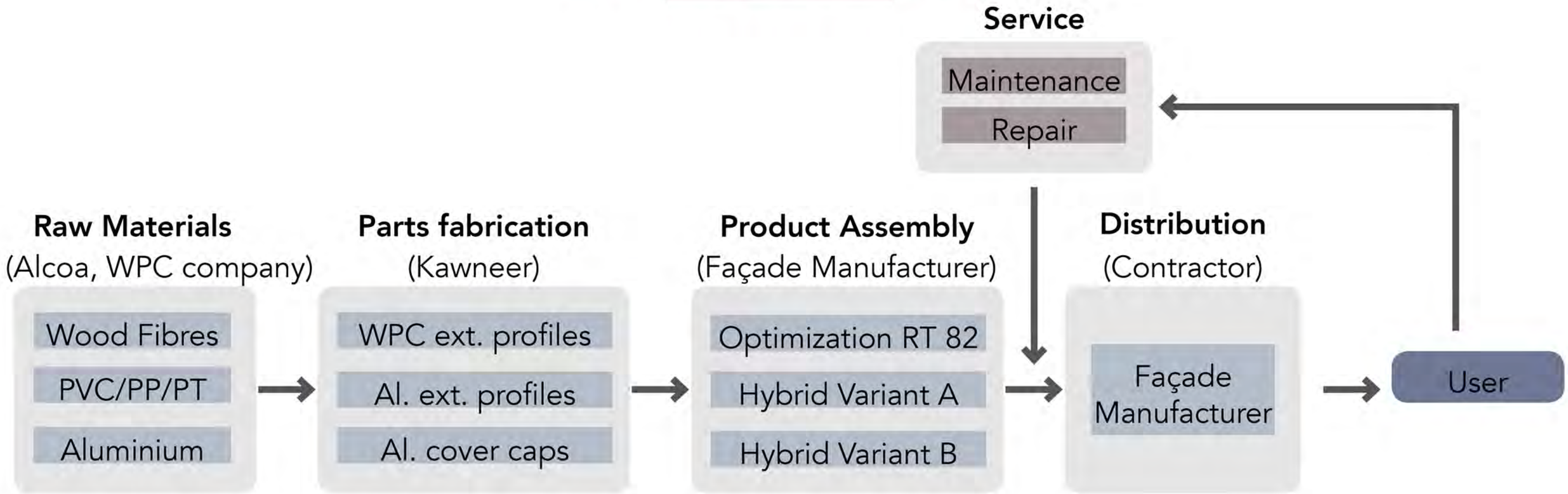
Closing the Loop



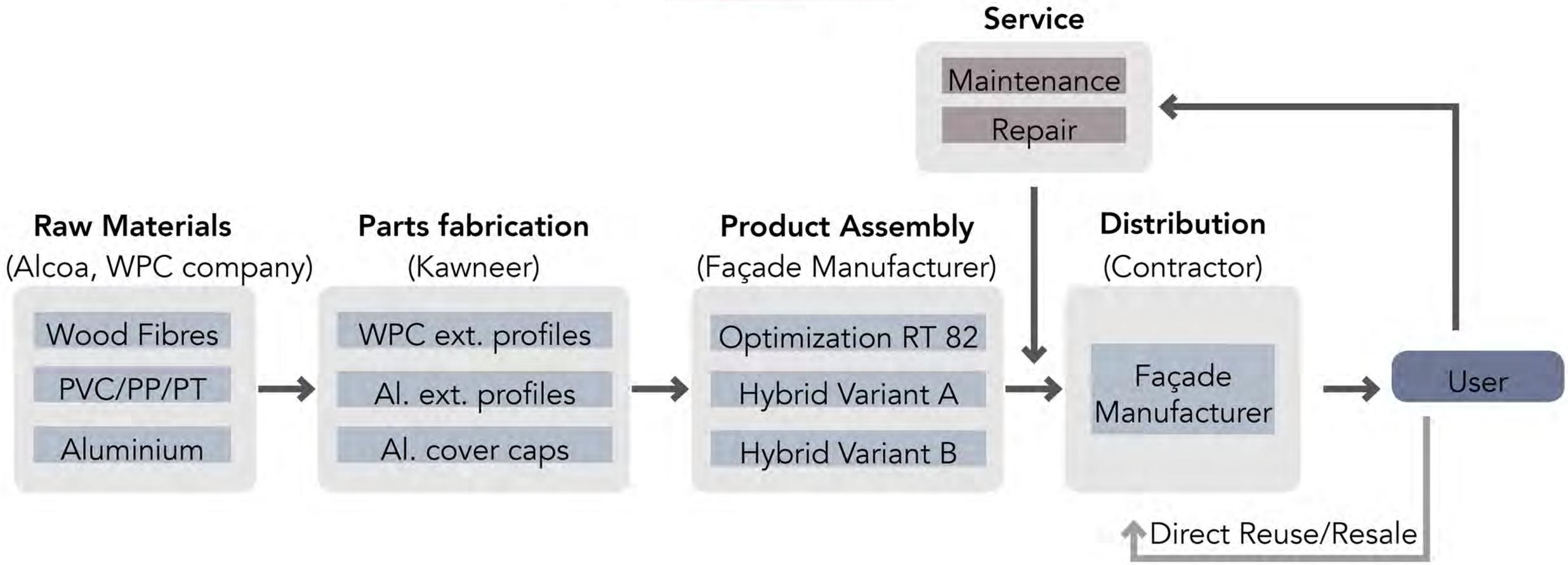
Closing the Loop



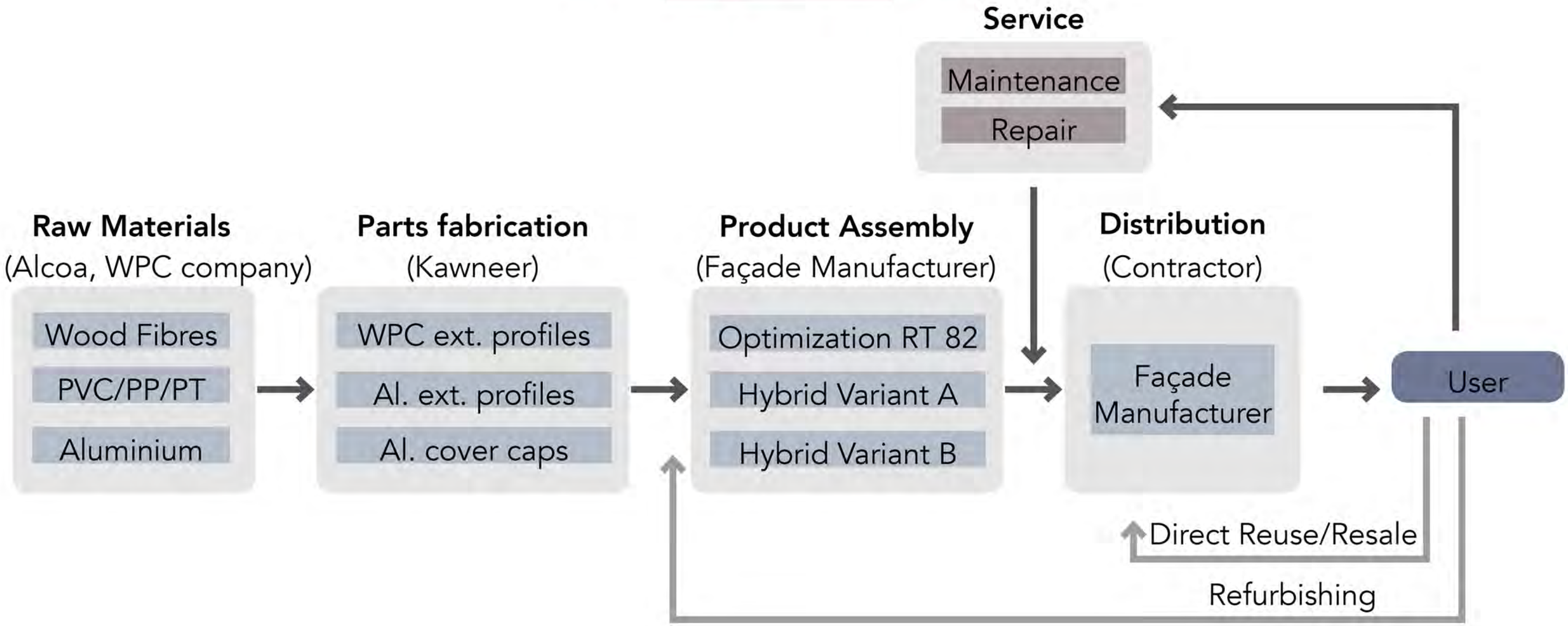
Closing the Loop



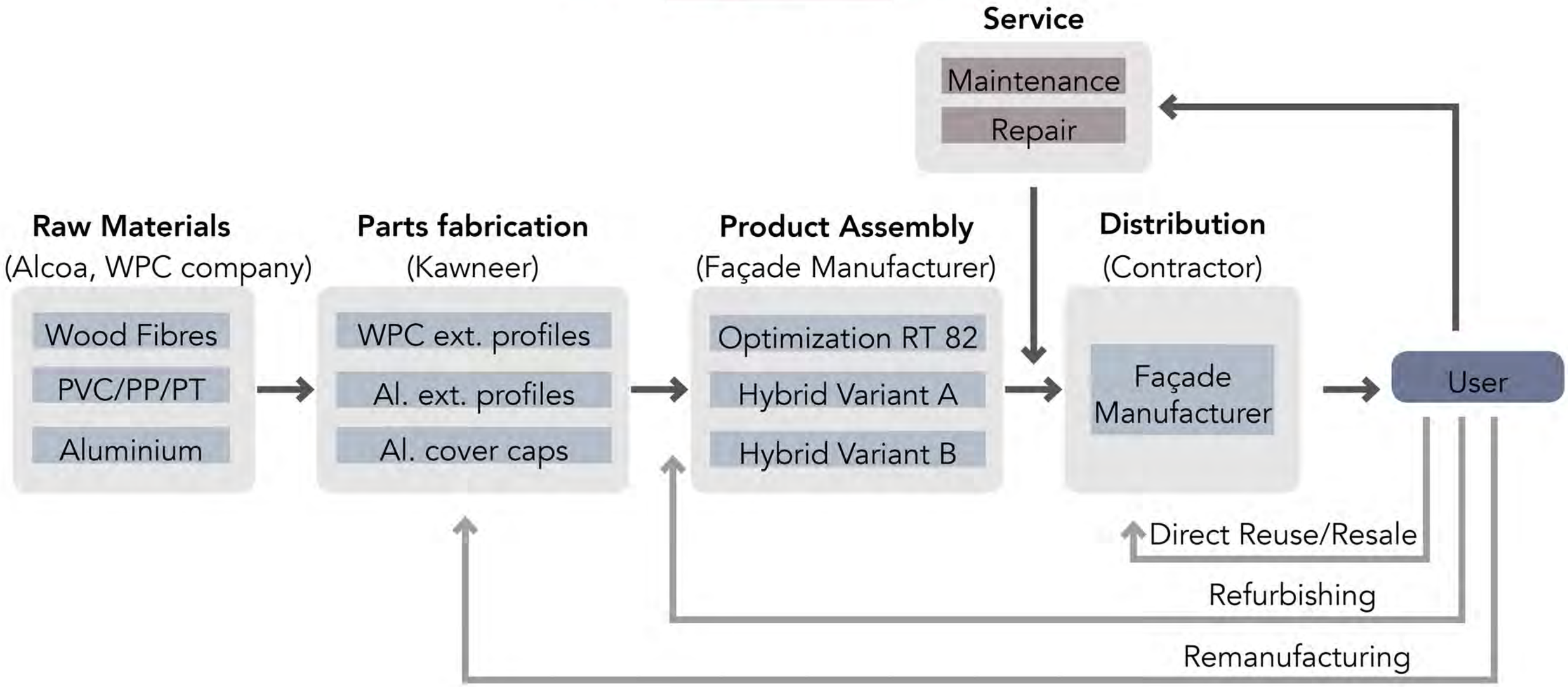
Closing the Loop



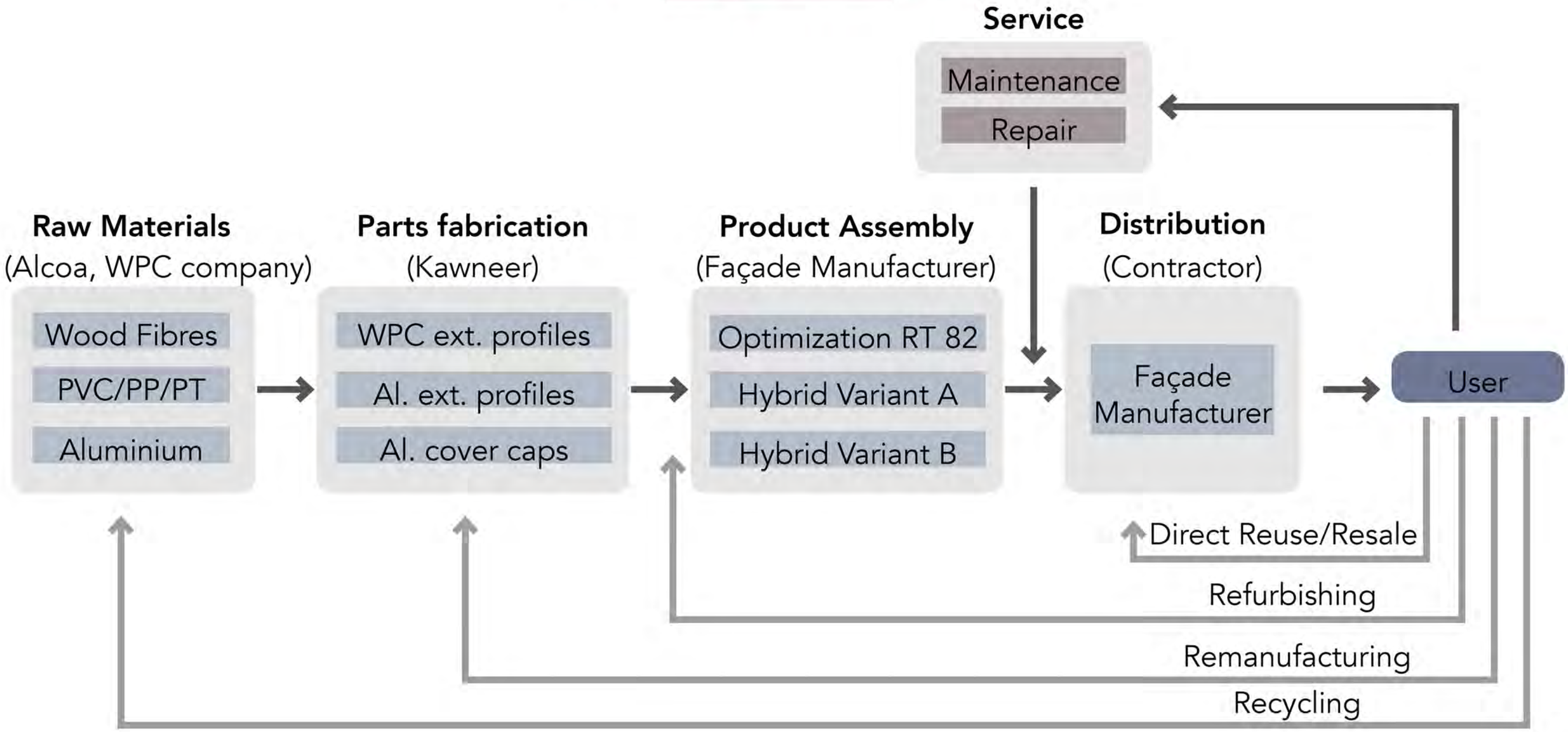
Closing the Loop



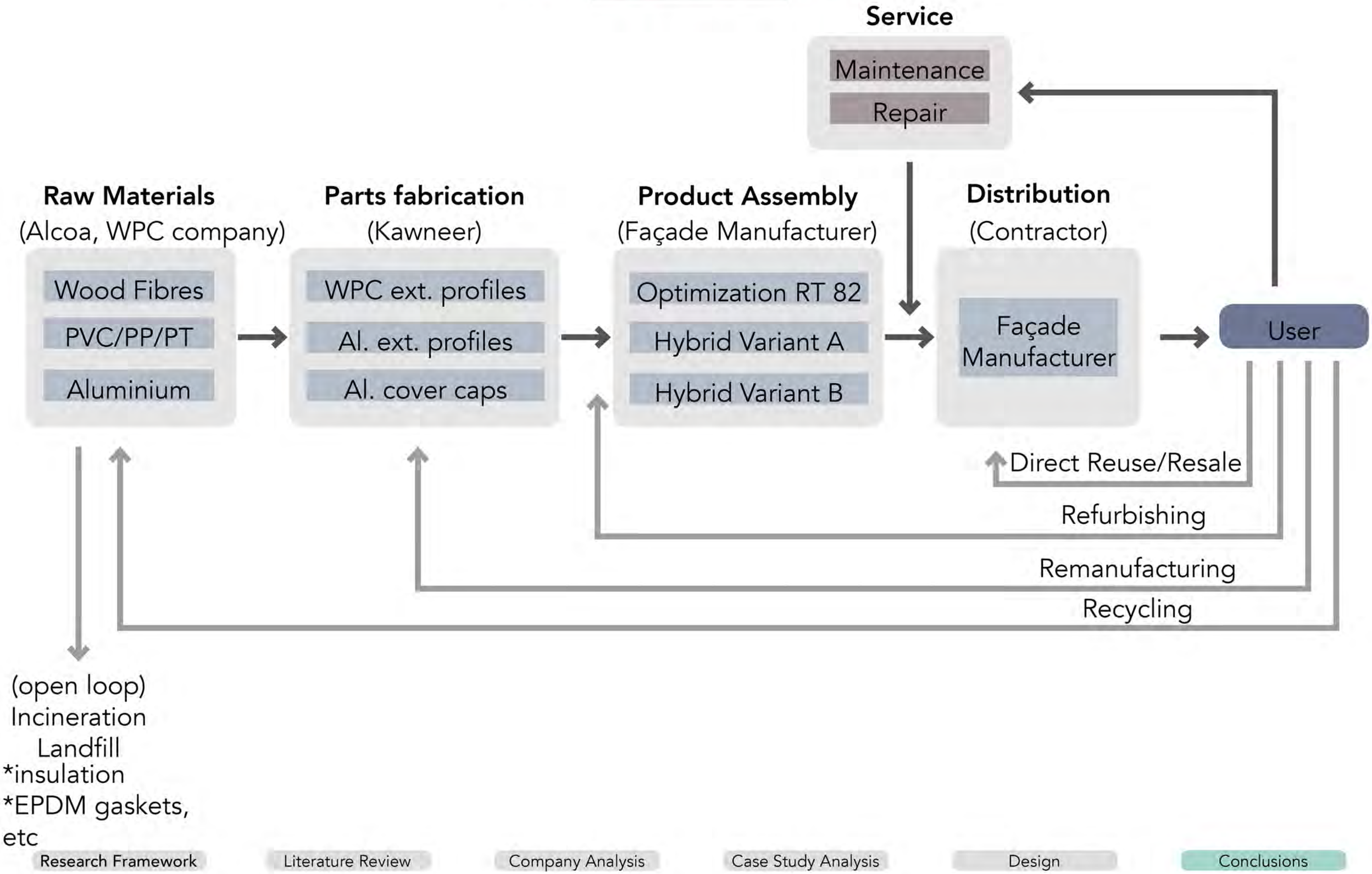
Closing the Loop



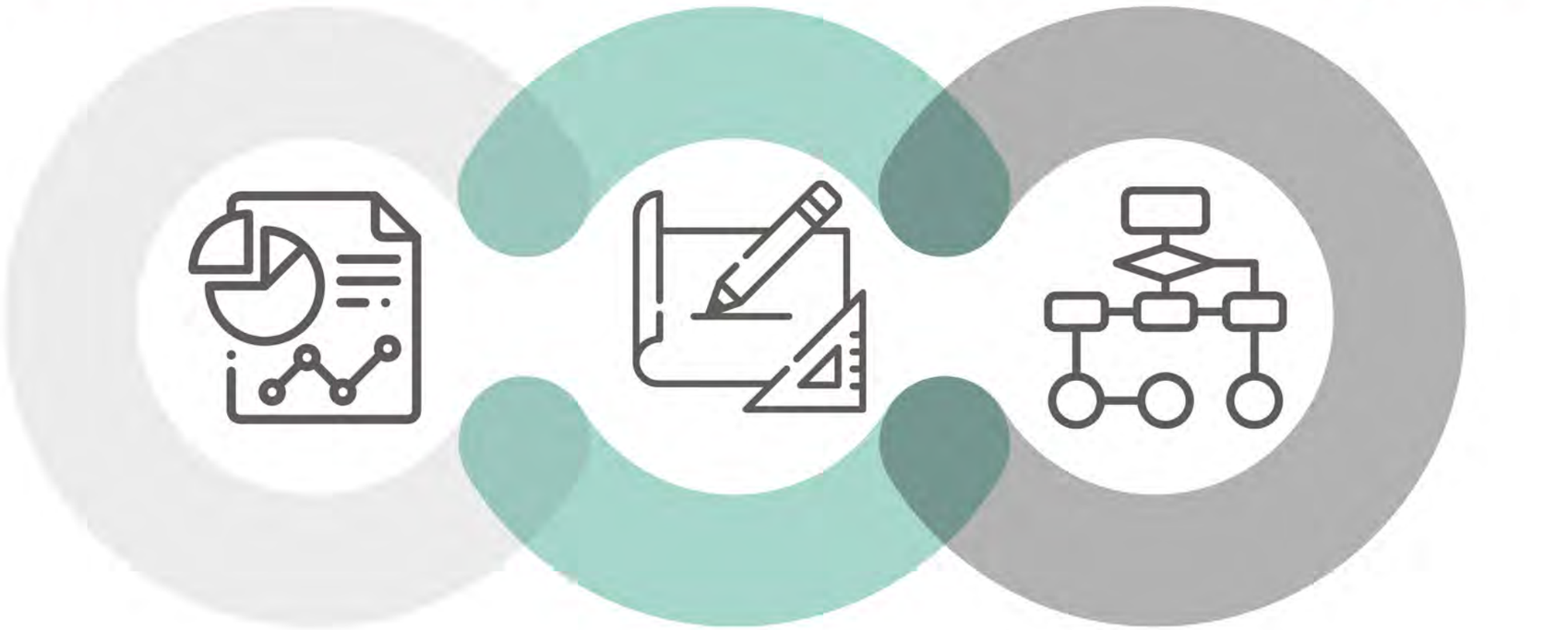
Closing the Loop



Closing the Loop



Is the System Ready?



DfD
DfA
DfRem

Is the System Ready?

MARKET DEMAND

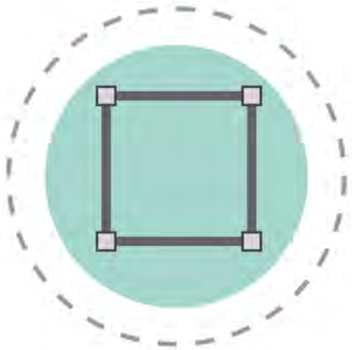
Business Models

Reverse Logistics



DfD
DfA
DfRem

Possible Circularity Scenarios



Direct reuse of window as a full component



Breakdown of elements for new/reman. windows



Change of location



Change of aesthetics



Change of infill



Disassembly



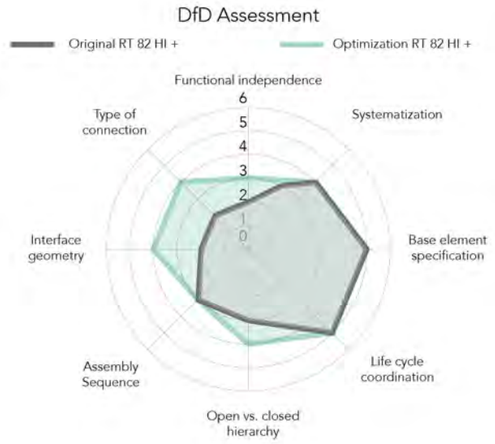
Remanufacture (elements are cores)

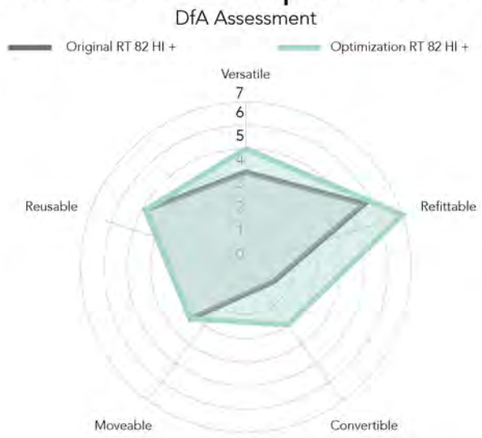


New Product

Assessments

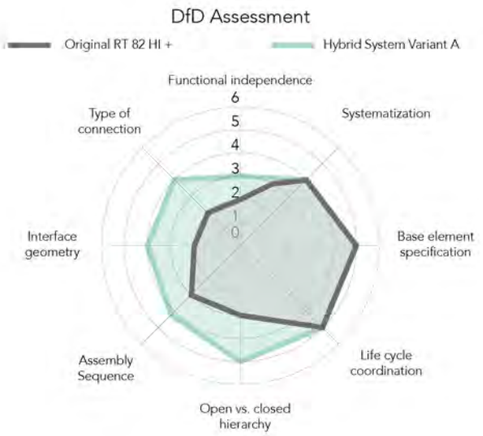
RT 82 HI + Optimization

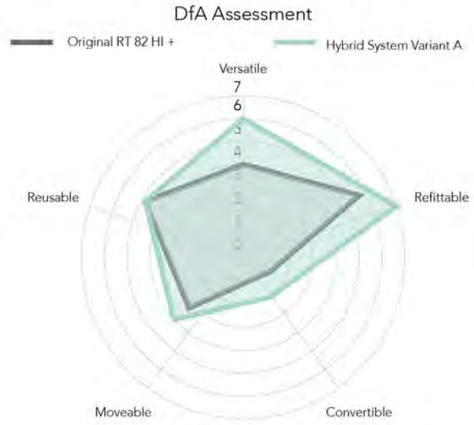






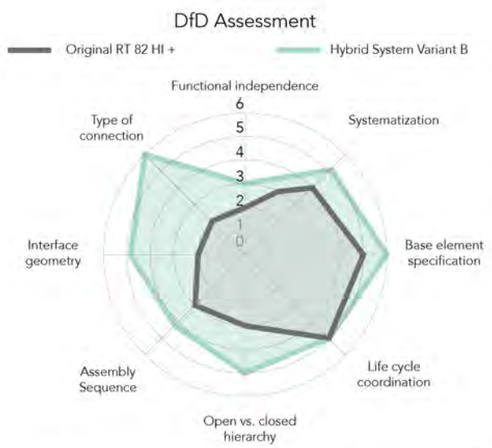
Hybrid Variant A

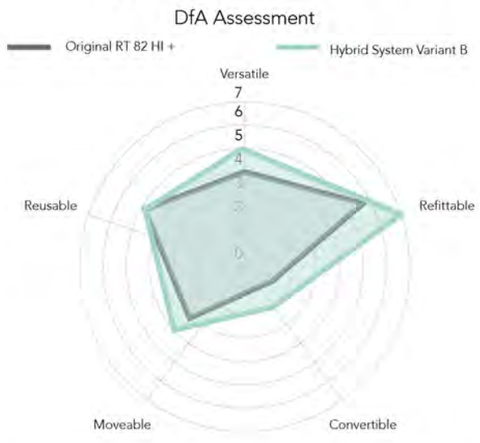






Hybrid Variant B







Limitations

Design focus on **frames product arch.**

Focus on **DfD, DfA, DfRem**

Material flows **briefly analysed**

Testing through **physical prototypes**

Limited research **warranties & serv.**

Analysis on **thermal transmittance**

Limitations

Design focus on **frames product arch.**

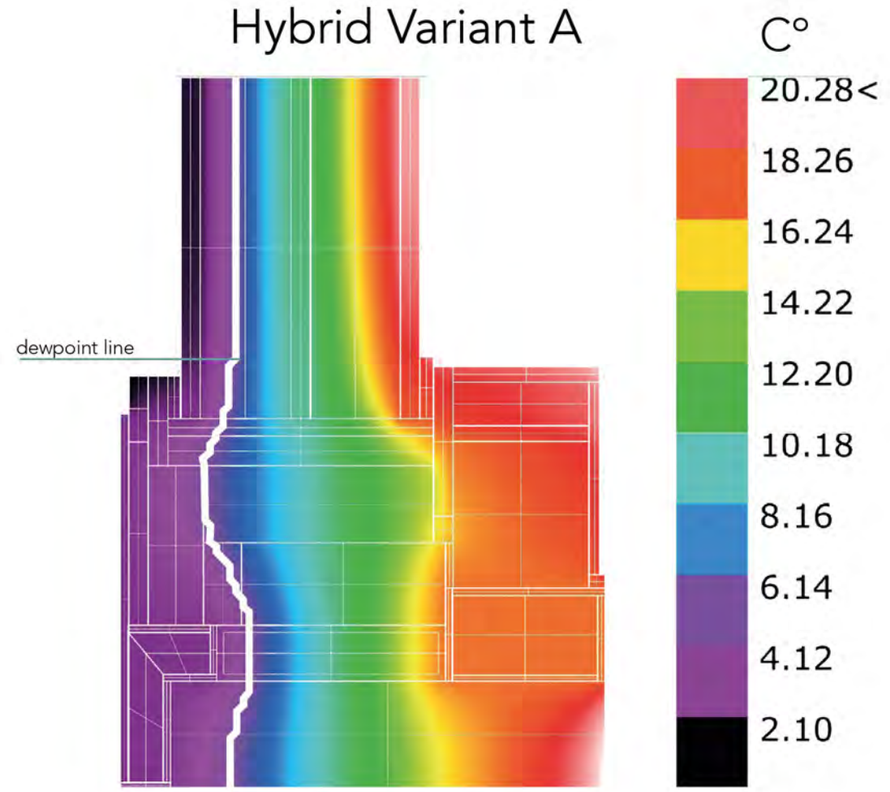
Focus on **DfD, DfA, DfRem**

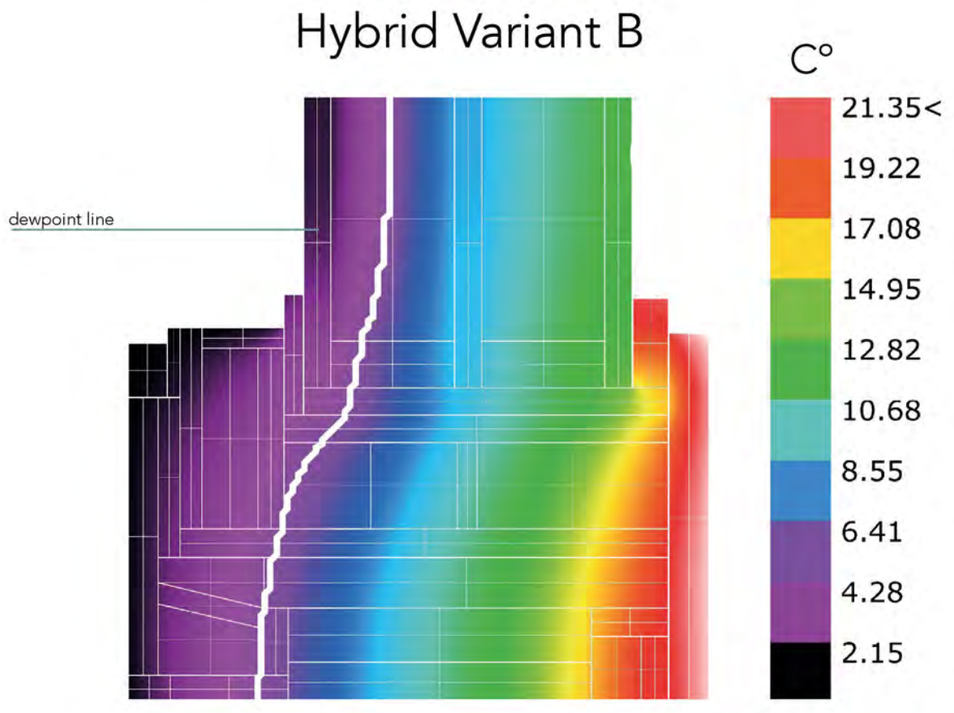
Material flows **briefly analysed**

Testing through **physical prototypes**

Limited research **warranties & serv.**

Analysis on **thermal transmittance**





Further Research



Further Research

Analysis on other **window components**

Focus on **other circularity scenarios**

Analysis at a larger scale **Circular BE**

Ellaborate **physical prototypes for testing**

Development of **Warranties & Serv.**

Improvement of **U-value (passive house)**

WHAT'S NEXT?

RemanWindows 2.0

Understand the **Potential for Rem. other BP**

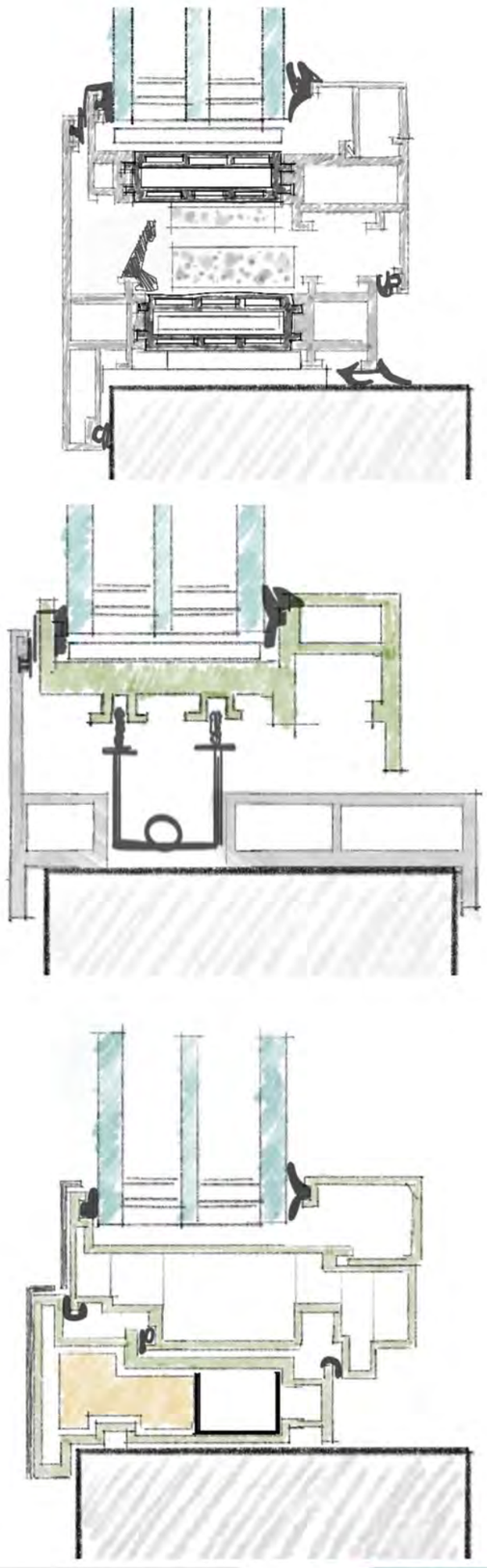
Development of **Circular Business Models**

Focus on **Warranty & Service**

Improvement on **Product Architecture**

Focus on **Tolerances & Movements**

Learn from **Other Industries...**



Thank you.

questions + feedback?