CIRCULAR FACADE REFURBISHMENT

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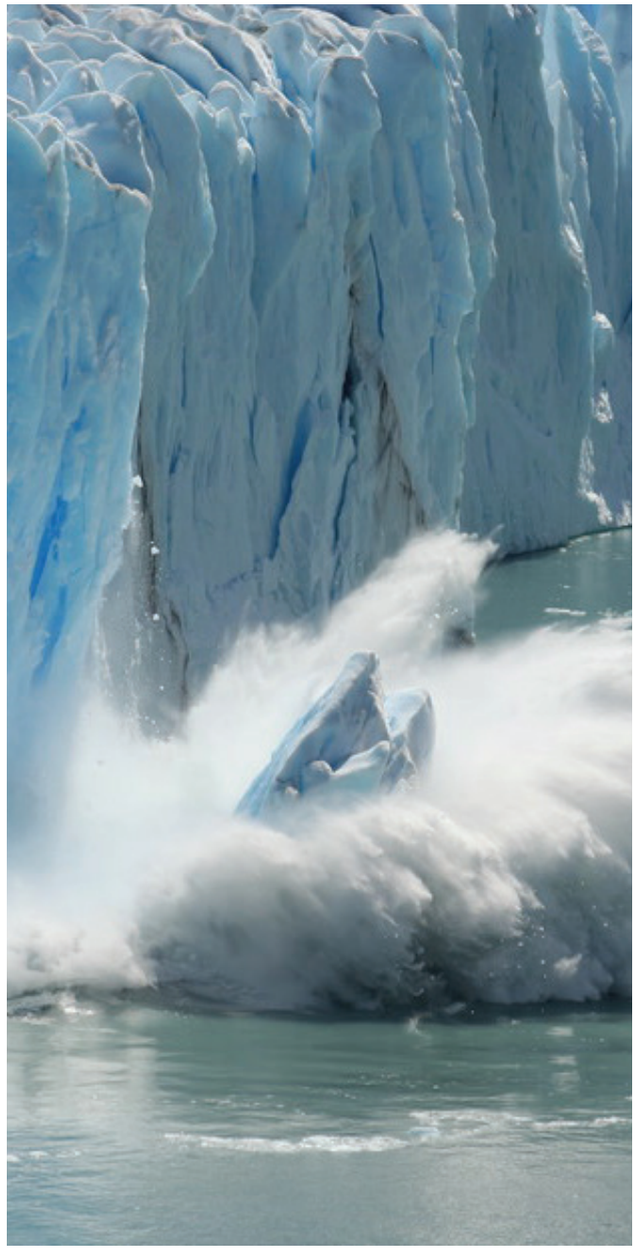
Graduation presentation
1 February 2018
MSc Building Technology

Our existance on earth is temporary...

The consequences of our actions
on earth are permanent...



Luckily we have come
to realise that we have to do something...

Paris Climate Agreement,
signed by 195 countries
on the 12th December 2015

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- Research question
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- *'How to design a circular facade?'*

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Demolition (1940-1945)

Rebuilding (1950-1975)

33% of the total housing stock in the Netherlands

(in numbers: 2.548.036 out of 7.721.321 dwellings).

(CBS, 2015)

PV panels on roof

Building services

Additional Insulation

Legislations

In 2030:
(Energieakkoord)

300.000 buildings have to be refurbished annually to be able to reach an energy neutral built environment in 2050

(SER, 2013)

Refurbishment (currently)

Demolition (1940-1945)

Rebuilding (1950-1975)

Refurbishment (currently)

Current refurbishment/ replacement rate:

ca. 3.000
residential buildings per year
with this rate it will take

250 years
to reach the goals of the Paris Agreement

(Mulder et al., 2015)

Demolition
(1940-1945)

Rebuilding
(1950-1975)

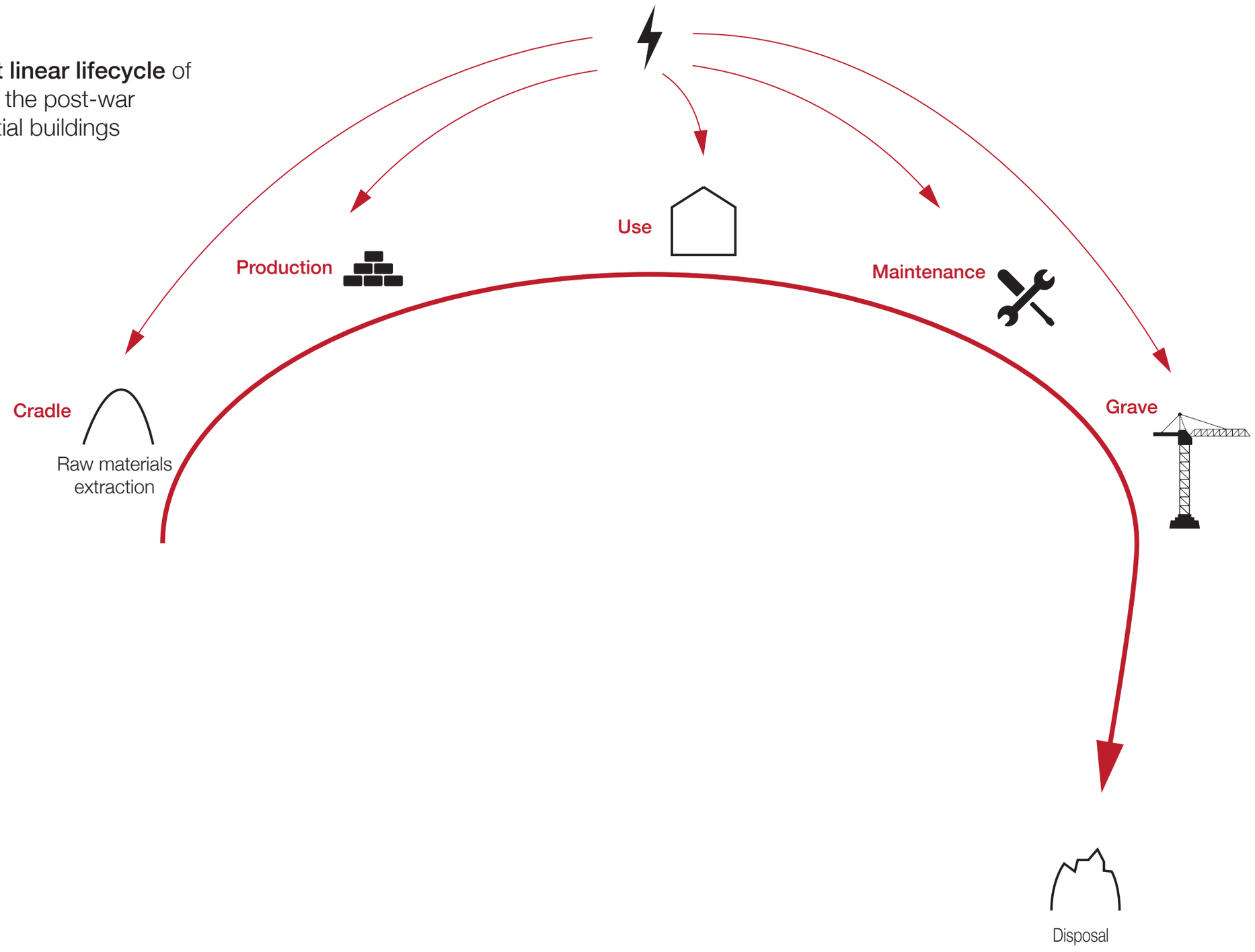
Refurbishment
(currently)

ca. 10.000 residential buildings were deconstructed the past year in the Netherlands.

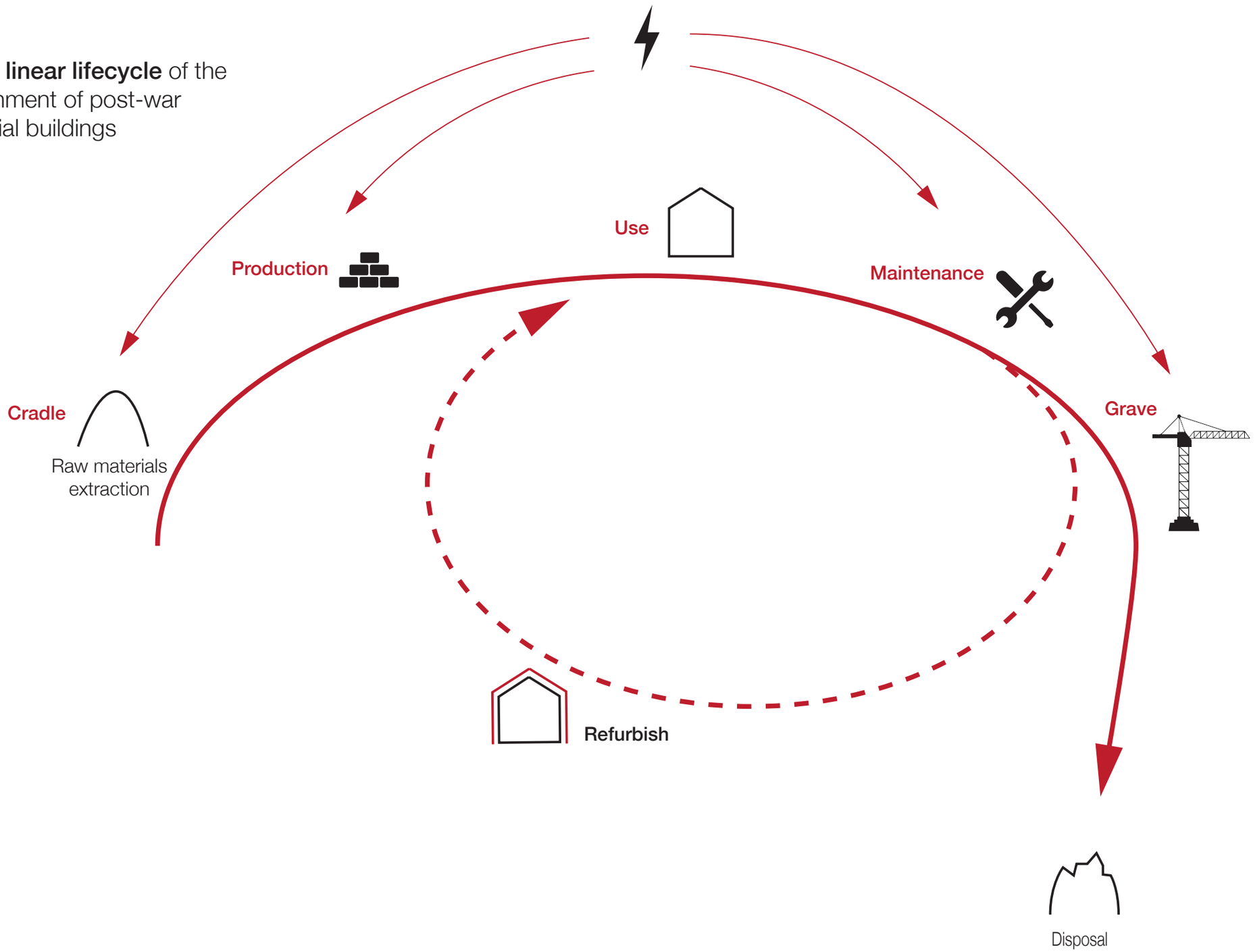
(CBS, 2017)

Deconstruction
(currently)

Current linear lifecycle of most of the post-war residential buildings



Current linear lifecycle of the refurbishment of post-war residential buildings



7% Landfill

5% Incineration

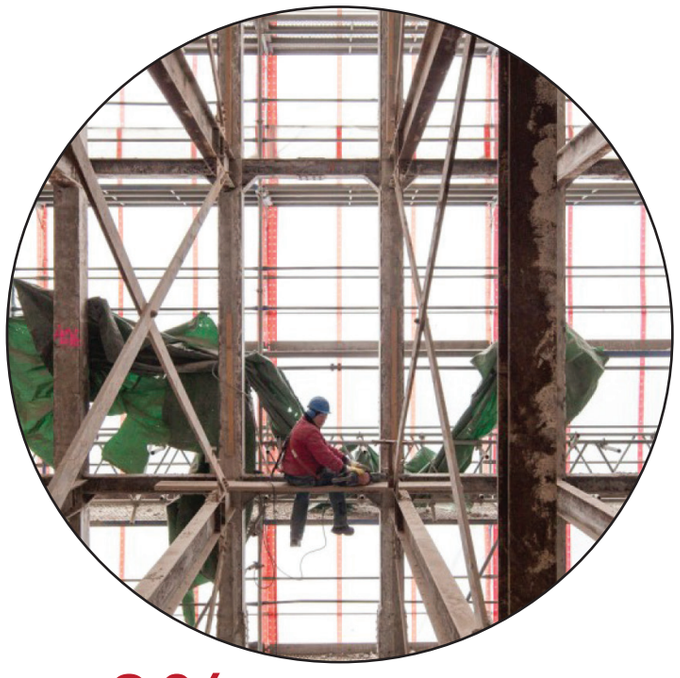
88% ~~Recycling~~

Downcycling (low-quality)

41.6% of total waste production in the Netherlands =

Construction Demolition Waste

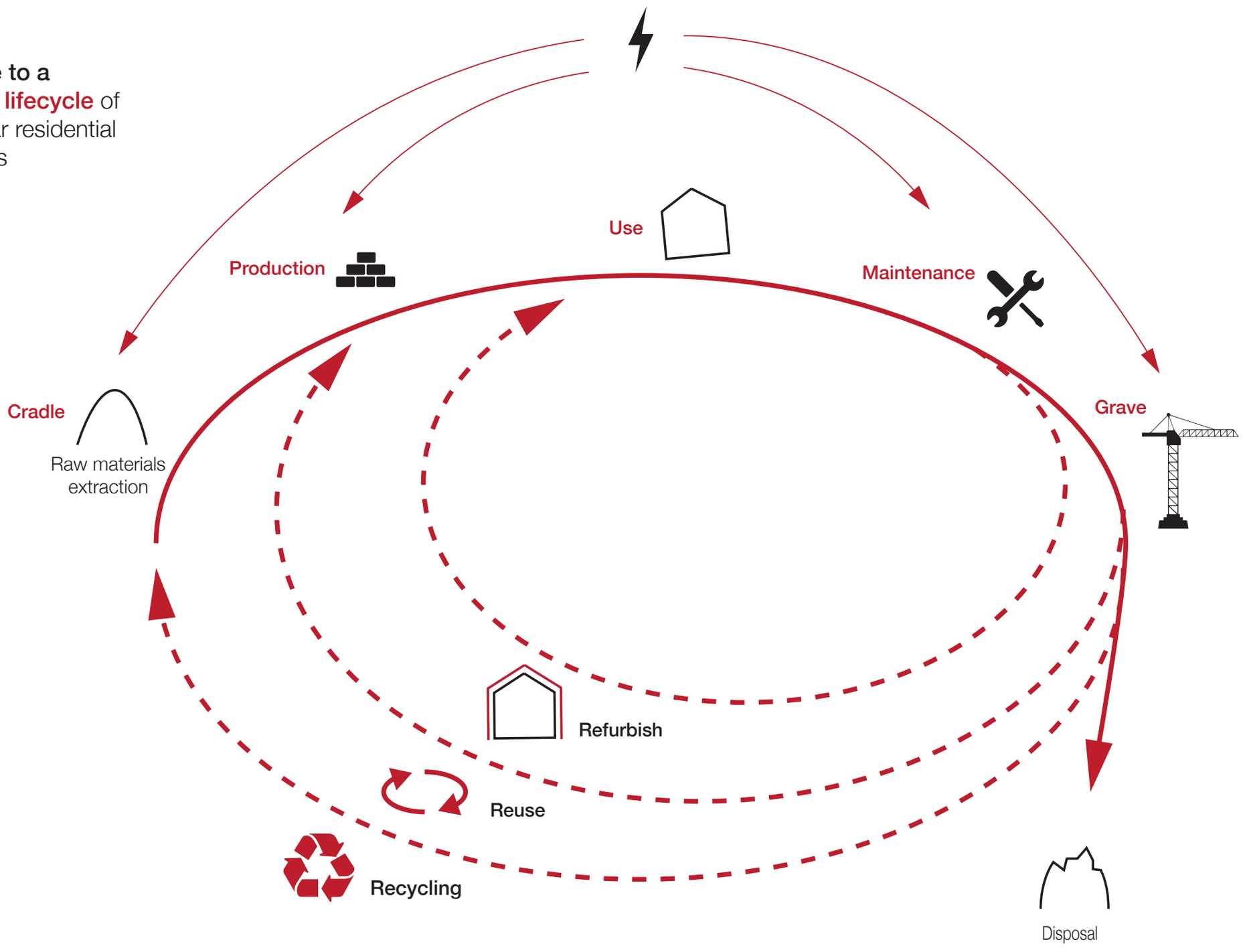
(CBS, 2015)



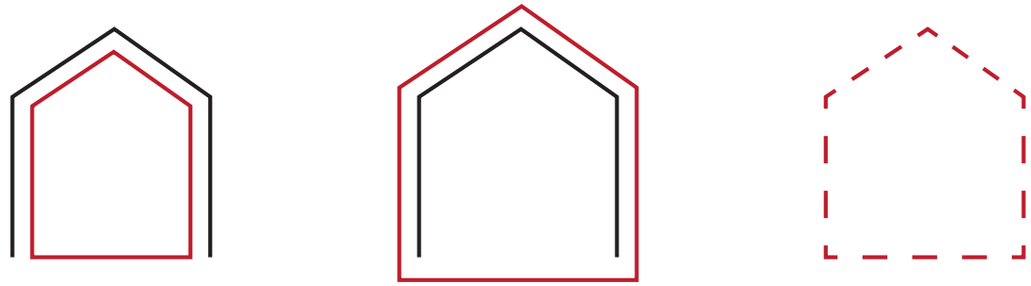
0% Reuse

(Deloitte, 2015)

Change to a circular lifecycle of post-war residential buildings



Refurbishment strategies



Add-in

Wrap-it

Replace

(Konstantinou, 2014)

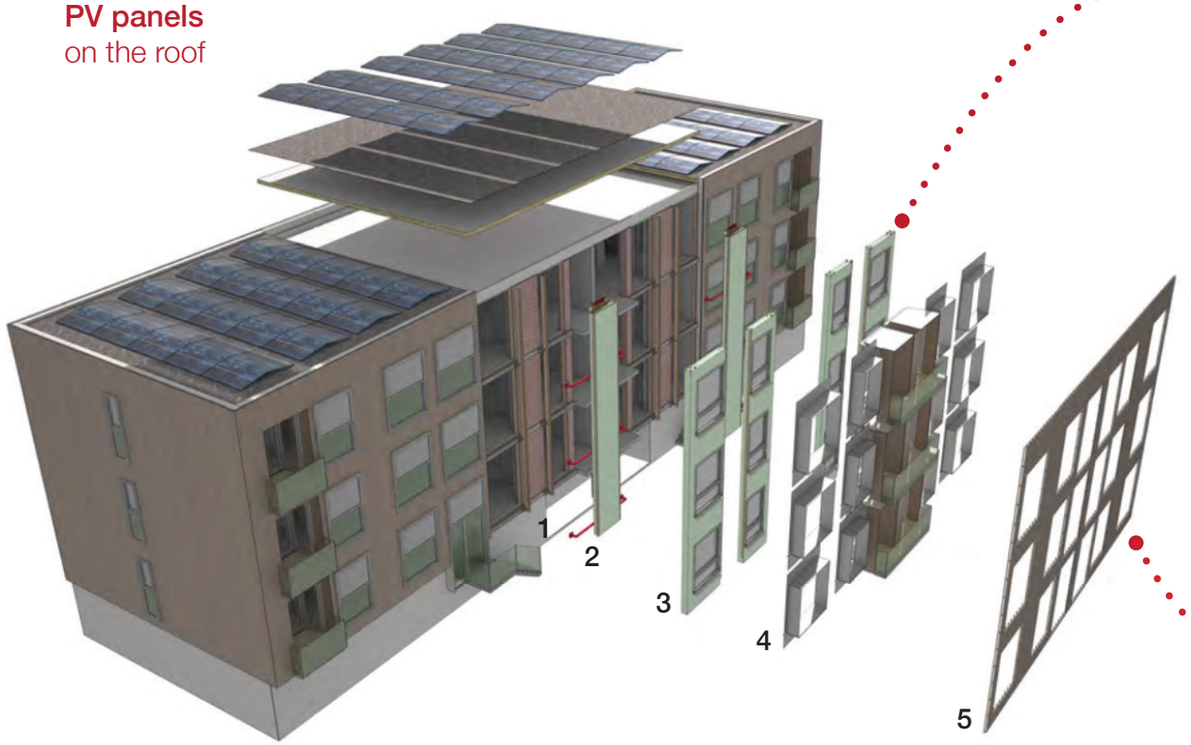
(Metisse, n.d.)

2nd Skin Facade Refurbishment system

(Klein & Konstantinou, 2017)

Prefabricated variant

PV panels
on the roof



Integrated building services
for heating, cooling and ventilation in 2nd Skin Facade

(Klein & Konstantinou, 2015)

Mock-Up: Prefabricated facade elements

Mock-Up: Bamboo cladding (left); brick cladding (right)

(Konstantinou, n.d.)

Case Study Building
Soendalaan, Vlaardingen

Exterior Insulation variant

How can the 2nd Skin Façade Refurbishment system be redesigned into a ***Circular 2nd Skin Façade Refurbishment system****, that optimises reuse and/or recycling of building materials and components?*

1.

Wat is the **Circular Economy**?

2.

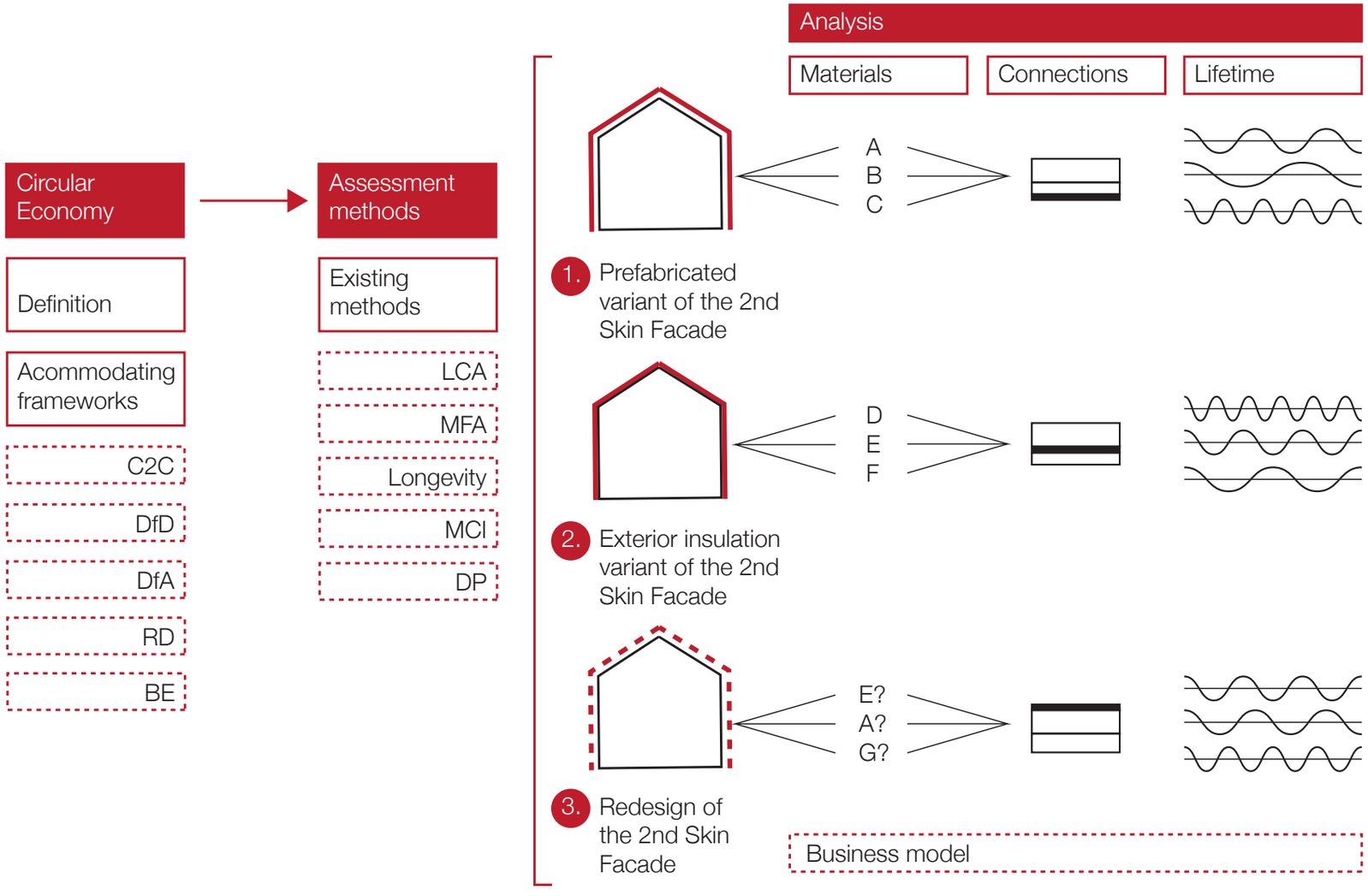
Wat assessment methods can be used to assess the **level of circularity** of the system?

3.

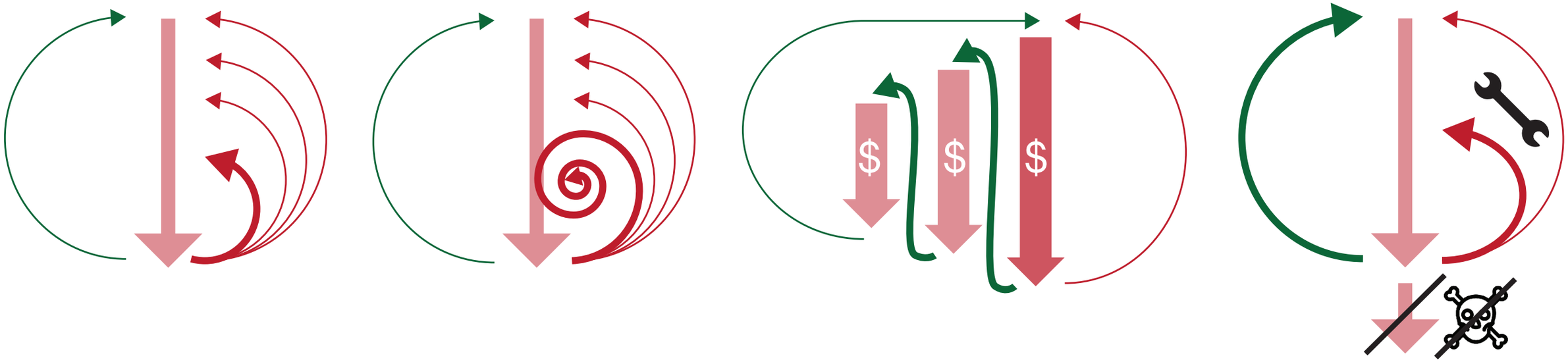
To what extent are the Prefabricated variant and the Exterior Insulation variant of the **2nd Skin Facade Refurbishment system circular**?

4.

How can the 2nd Skin Facade Refurbishment system be **improved in terms of circularity**?



Circular Economy aims to:
close and extend the loops of material cycles,
in order to **preserve value of materials**,
resulting in **decreased virgin material consumption and waste generation** in our current society.



The power of the inner circle

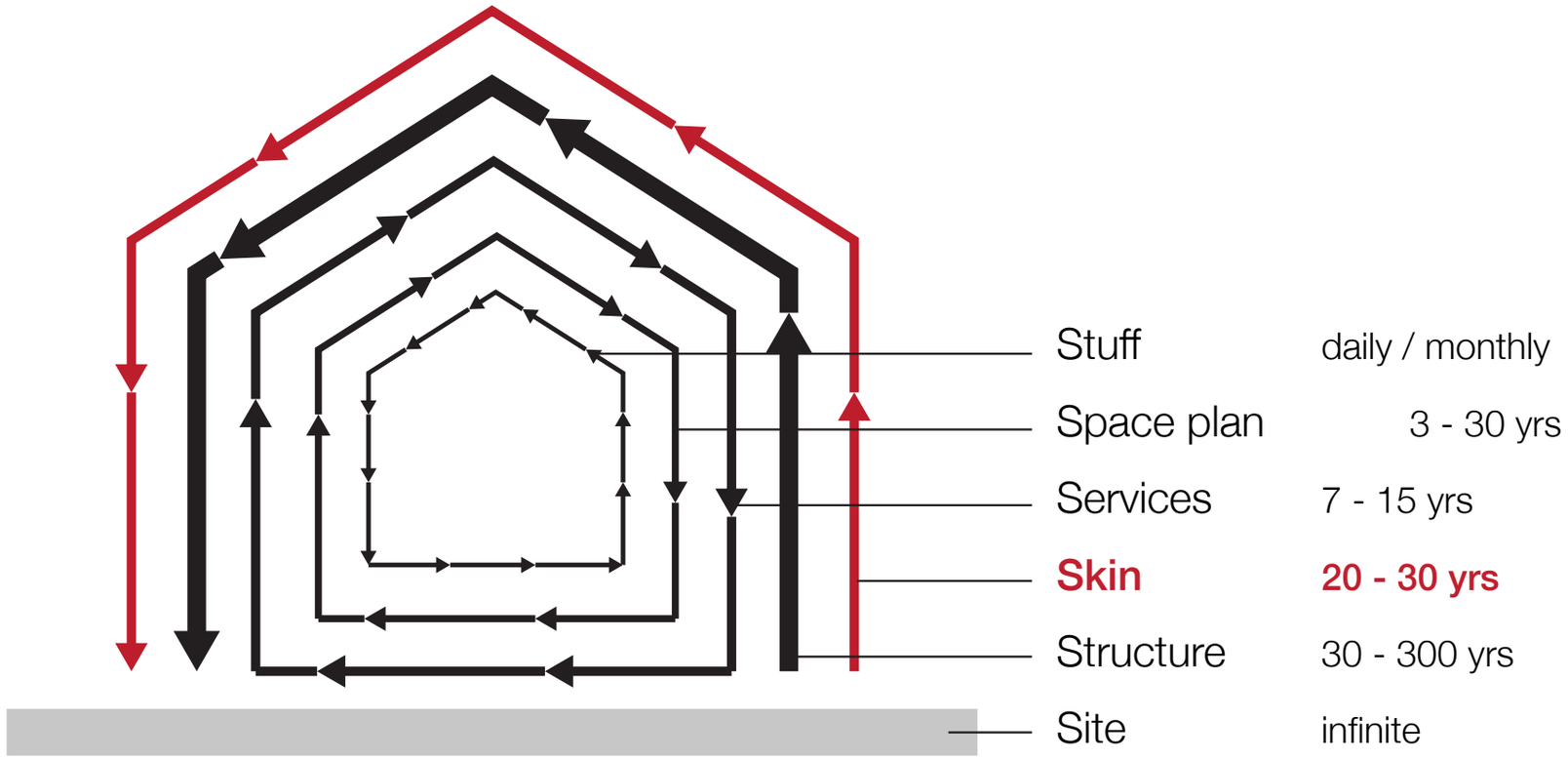
The power of circling longer

The power of cascaded use

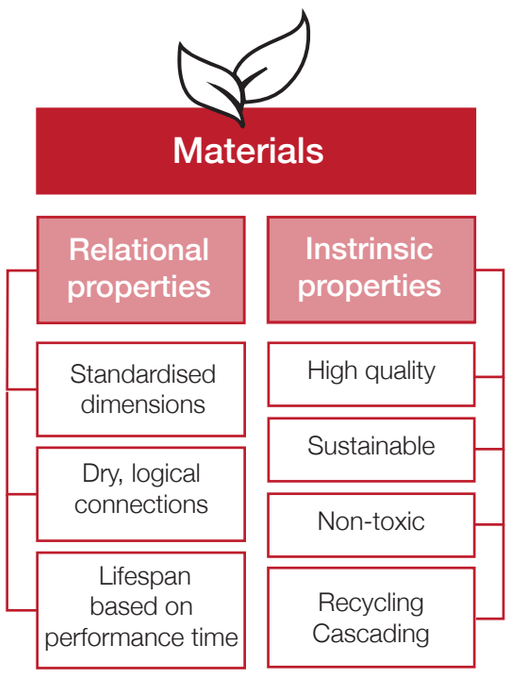
The power of pure inputs

(Ellen MacArthur Foundation, 2015)

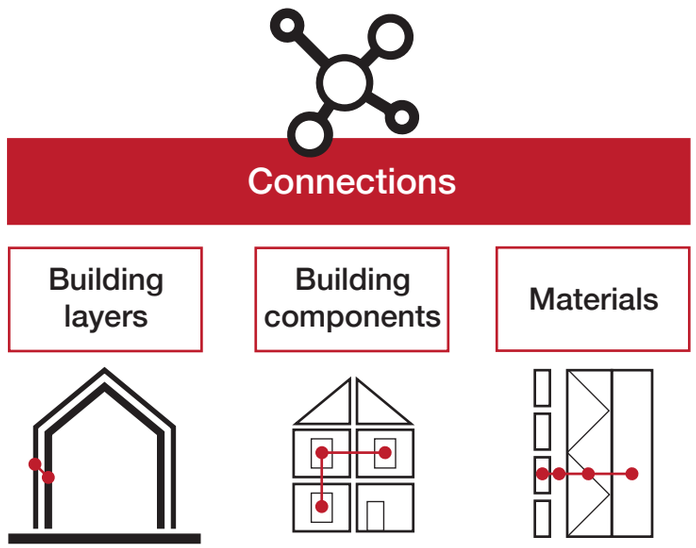
Shearing layers of change

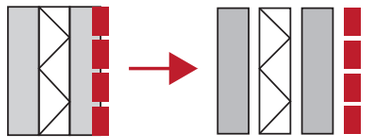


(Brand, 1994)



(Geldermans, 2016)





Permanent connections
between materials & components

Materials & components should be:
- technically separated
- independently accessible

to be able to be reused / recycled.

NRC news article
14th January 2018:

VIJF VOORSTELLEN VOOR EEN CIRCULAIRE ECONOMIE

Deze maandag verschijnen vijf transitieagenda's vol circulaire voorstellen. Eén maatregel uit elk rapport:

Kunststof Sigarettenpeuken bevatten veel slecht afbreekbaar plastic. Onderzoek of tabaksfabrieken medeverantwoordelijk kunnen worden voor het opruimen.

Voedsel en biomassa In 2050 eten we minder eiwit, en daarvan is 60 procent plantaardig (nu 40 procent).

Bouw Bedenk een meetsysteem voor gebouwen om te bepalen hoe circulair ze zijn.

Maakindustrie EU-regels belemmeren het vervoer van recyclebaar materiaal, zoals oude vliegtuigen. Breng zulke belemmeringen in kaart.

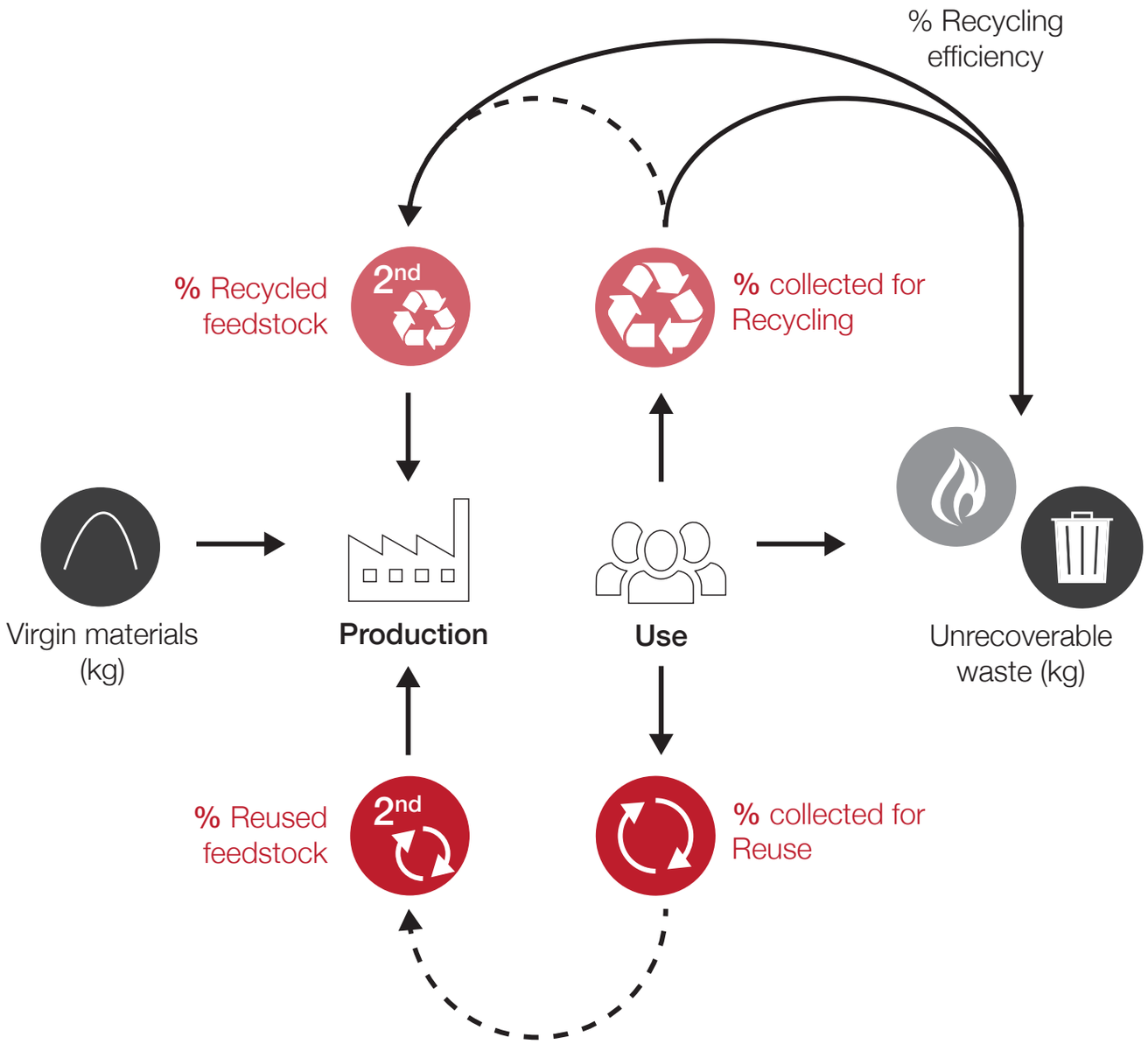
Consumptiegoederen Elk jaar danken we 1,2 miljoen matrassen af. Investeer in het ontwerpen van matrassen die te recyclen zijn.

(Van Santen & Pelgrim, 2018)

Circularity assessment method for buildings doesn't exist yet.

Material Circularity Indicator

(Ellen MacArthur Foundation & Granta Design, 2015)



Materials

Results of the calculation

LFI

Linear Flow Index
1 = Linear
0 = Circular

X

Utility
Lifetime of product / Lifetime of industry average product

MCI

Material Circularity Indicator
0 = Linear
1 = Circular

Disassembly Potential

(Durmisevic, 2010)

DF Functional Decomposition

SY Systematisation

RP Relational Patterns

BE Base Element specification

GE Geometry

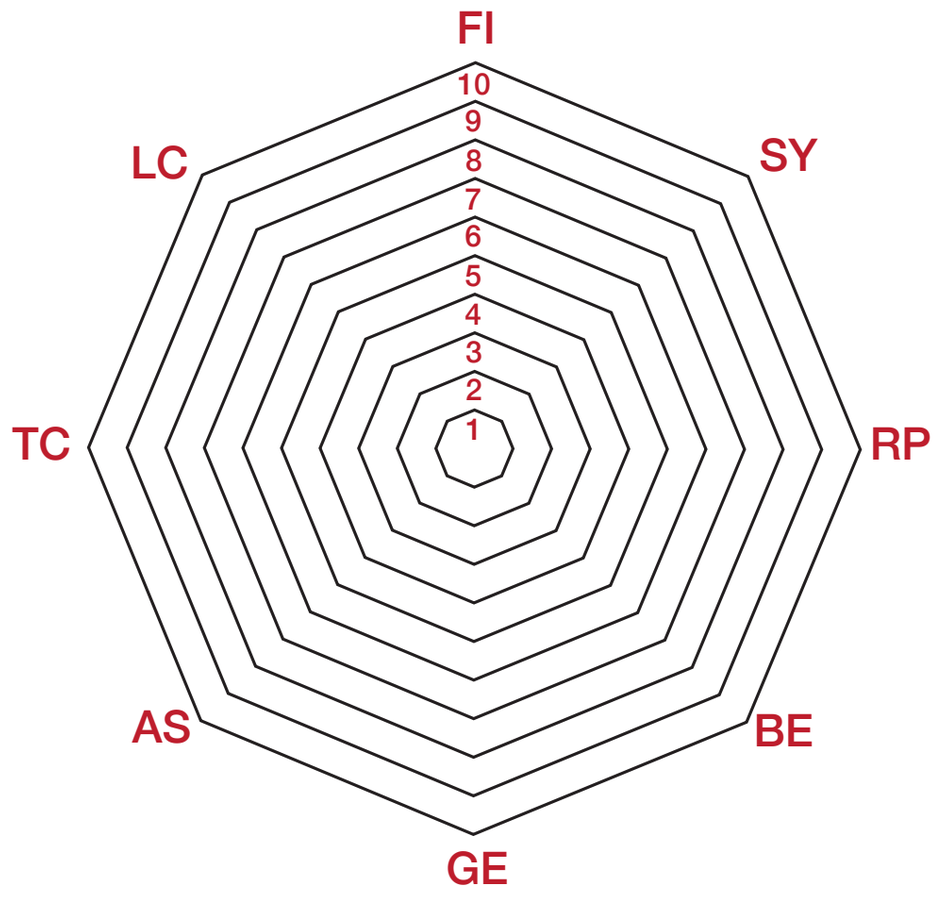
- Geometry of products edge
- Standardisation of products edge

AS Assembly Sequence

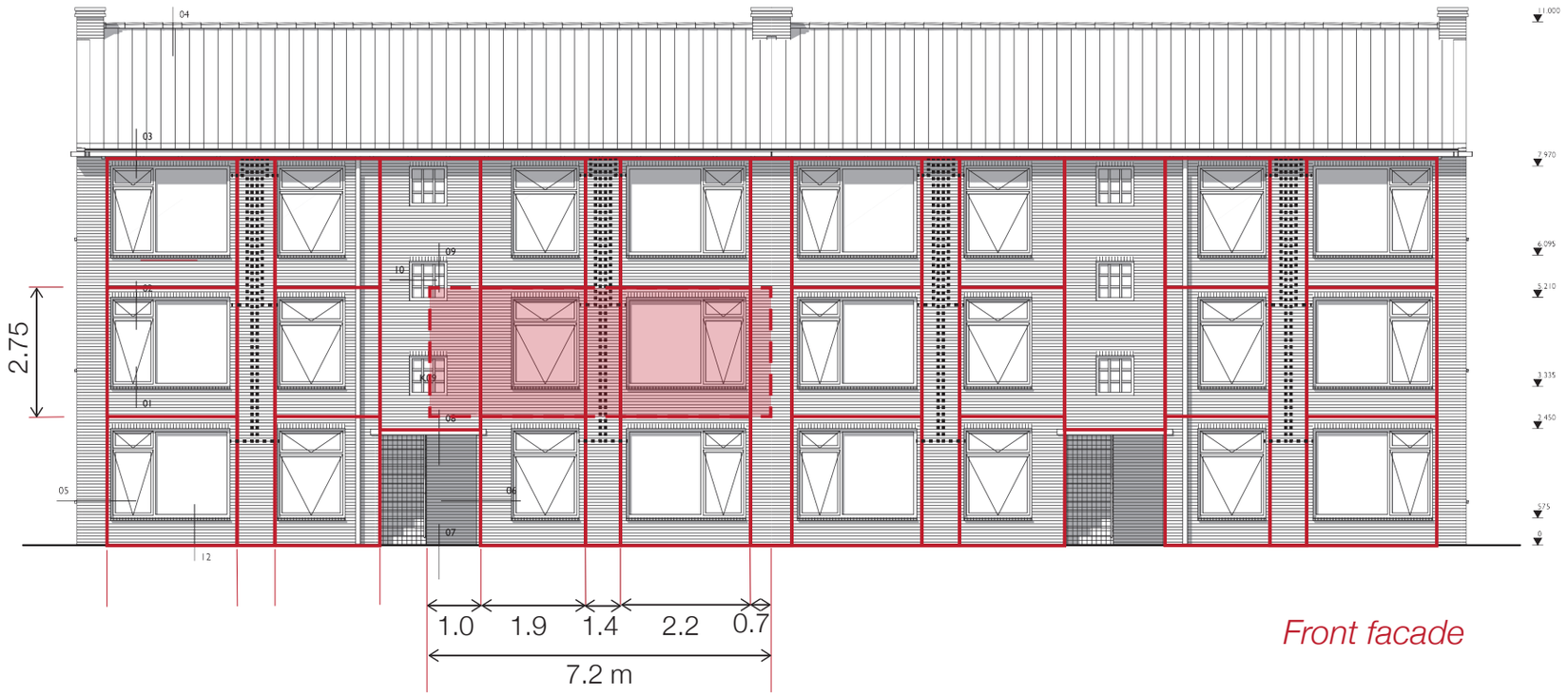
TC Type of Connection

LC Life Cycle Coordination

Connections



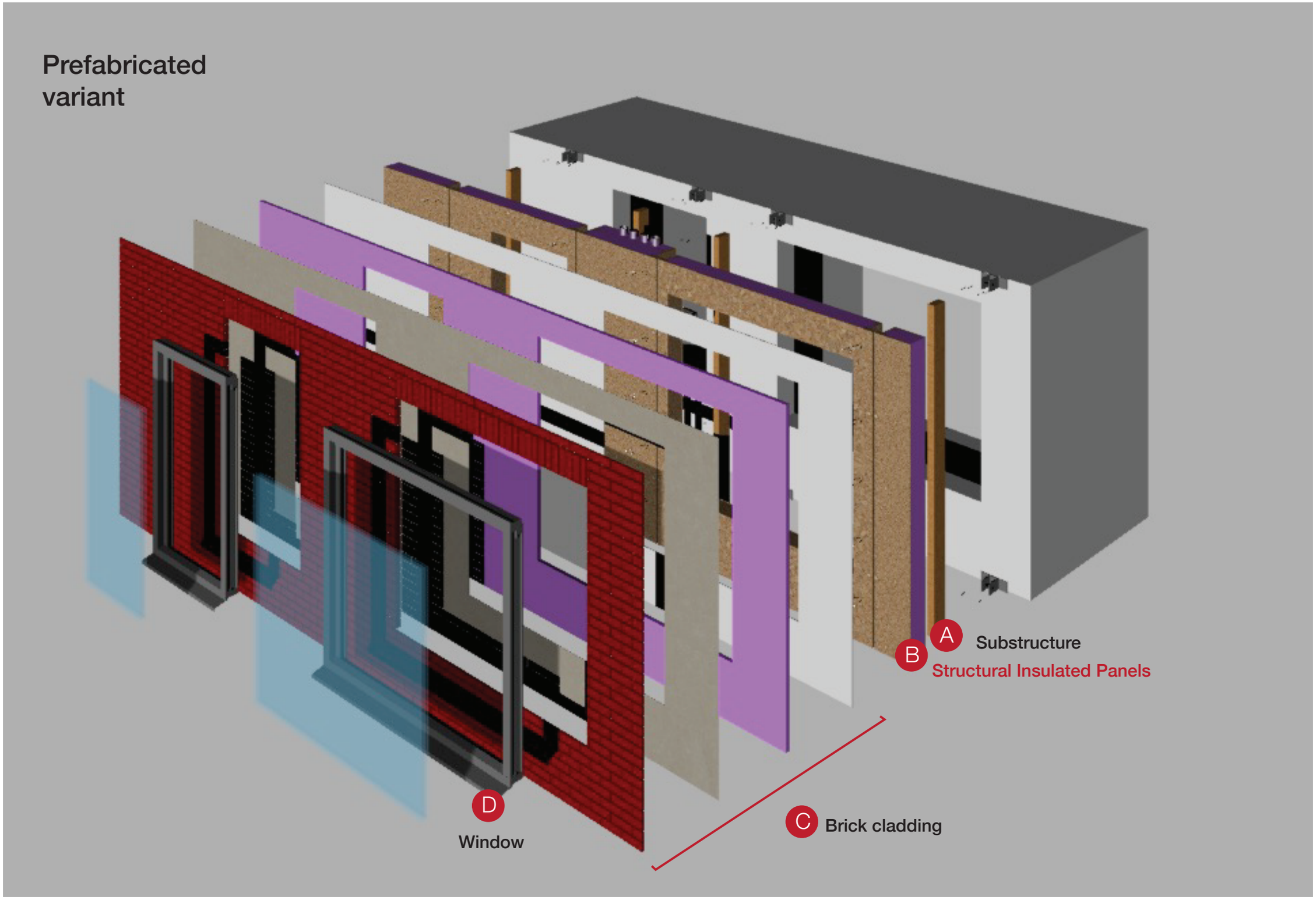
Functional unit



Front facade

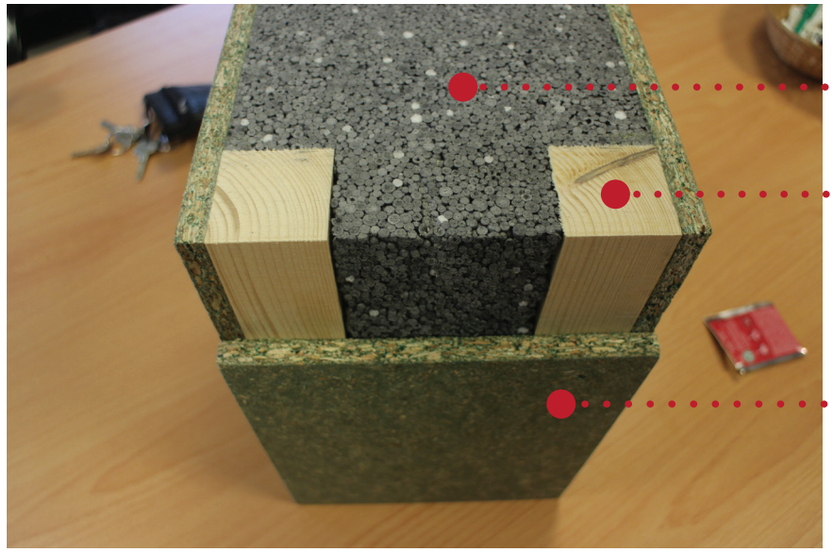
Case Study Building in Vlaardingen

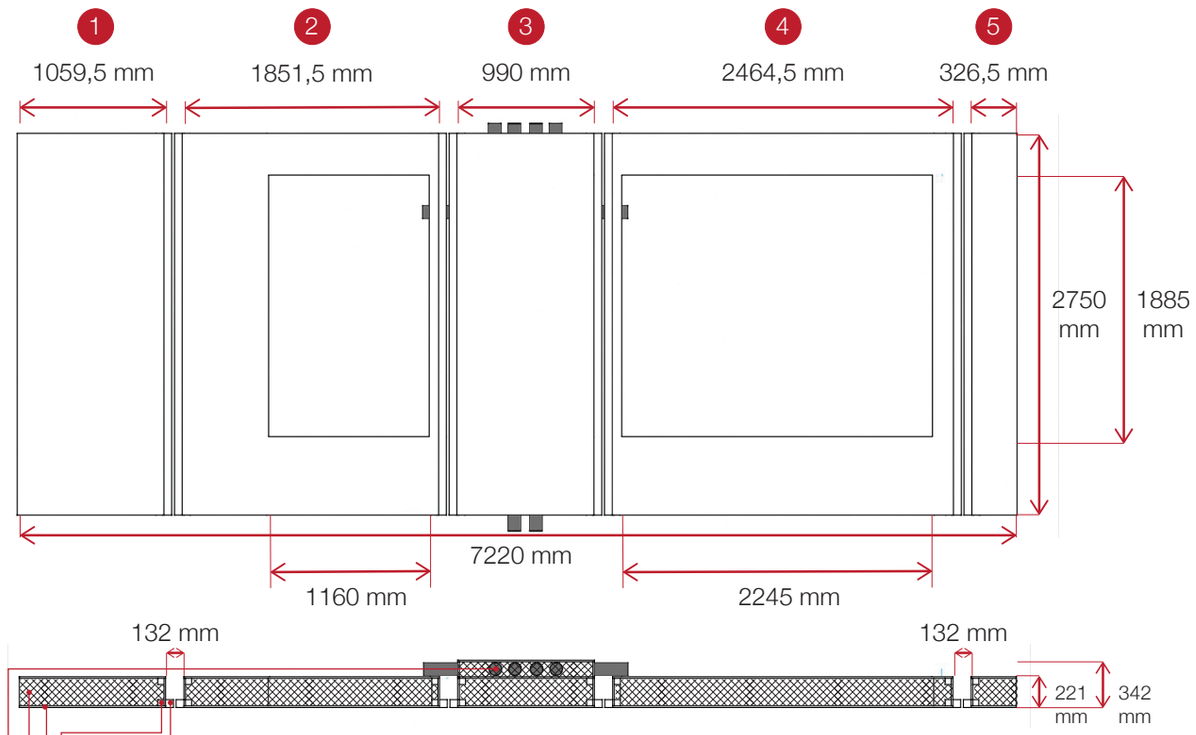
Prefabricated variant



B. Structural Insulated Panels

(Konstantinou, n.d.)





Materials

	Life cycle (yrs)	End of life scenarios			
		♻	♻	🗑	🔥
B4 Pinewood sticks 56 x 56 mm	0 25 50 75 100	0%	5%	10%	**85%**
B3 Pinewood stiffeners 44 x 44 mm	0 25 50 75 100	0%	5%	10%	**85%**
B2 Chipboard P5 12mm	0 25 50 75 100	0%	10%	5%	**85%**
B1 EPS insulation 197 mm	0 25 50 75 100	0%	5%	5%	**90%**
V1 PVC pipes Ø 90 mm	0 25 50 75 100	0%	**90%**	0%	10%

LFI = 0,73

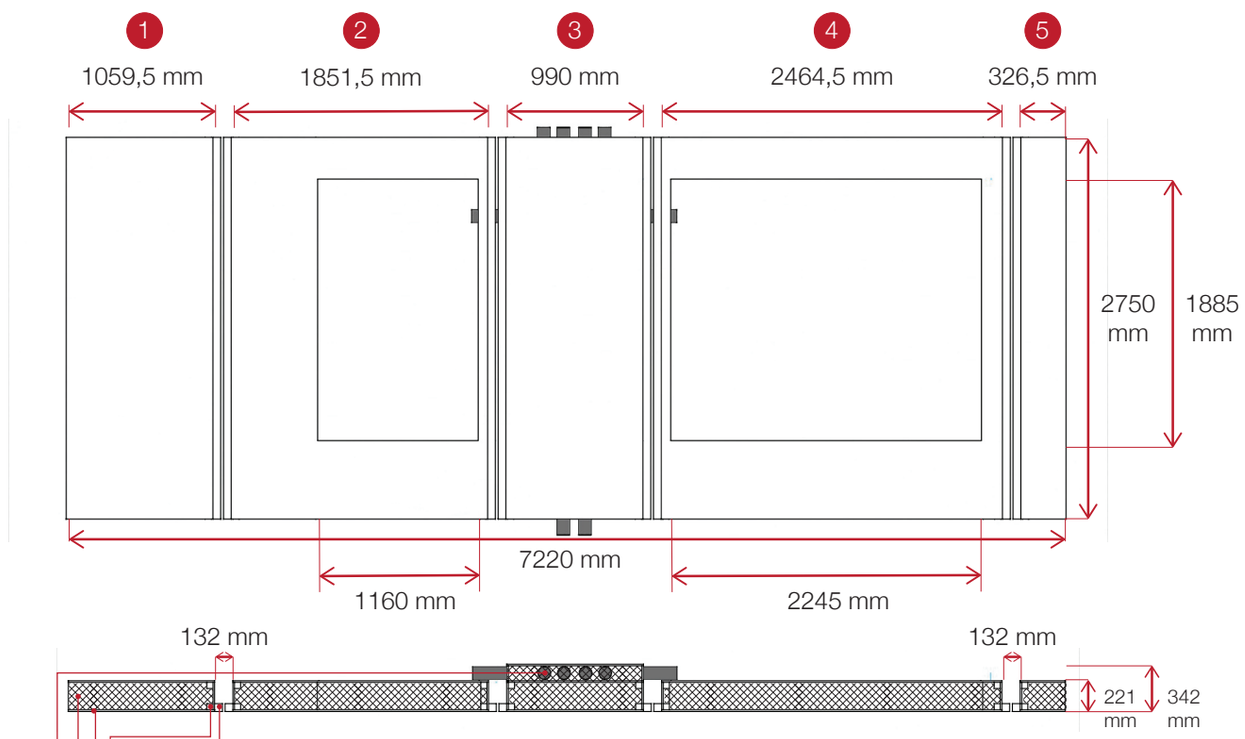
Linear Flow Index
1 = Linear
0 = Circular

X = 3,0

Utility
Lifetime of product / Lifetime of refurbishment (25 years)

MCI = 0,78

Material Circularity Indicator
0 = Linear
1 = Circular



B4
Pinewood sticks
56 x 56 mm

B3
Pinewood stiffene
44 x 44 mm

B2
Chipboard P5
12mm

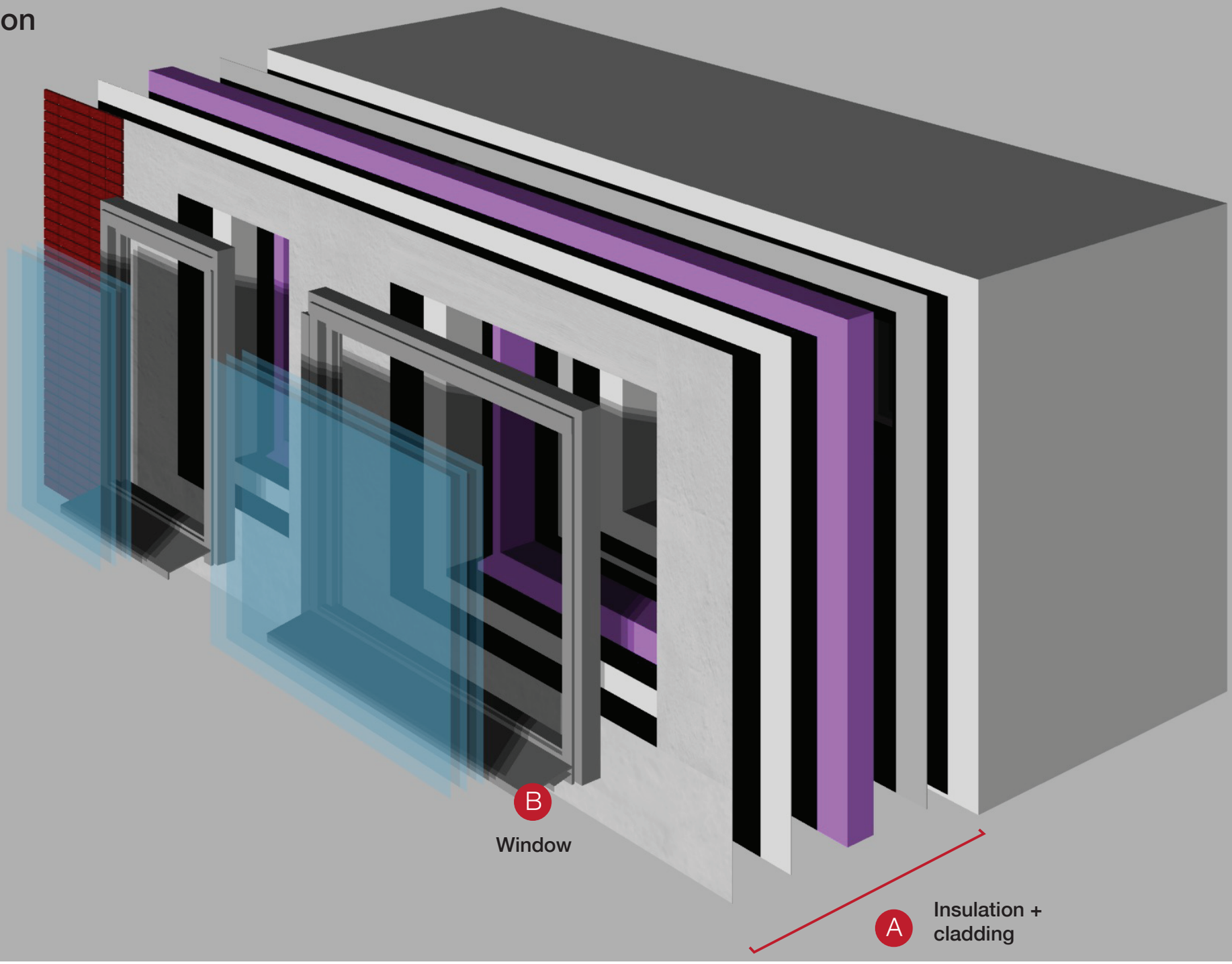
B1
EPS insulation
197 mm

V1
PVC pipes
Ø 90 mm

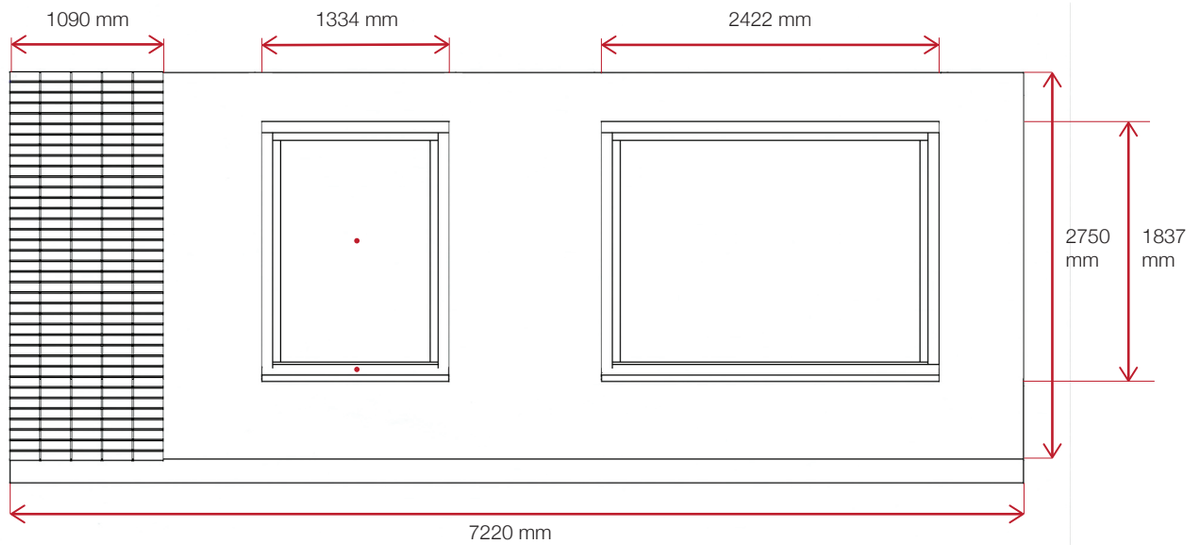
Connections

CONNECTION	CONNECTION DIAGRAM	INTERFACES	TYPE	ASSEMBLY	GRADING
B1 - B2 B1 - B3 B2 - B3			1. Indirect 2. Chemical	1. Surface contact	-
B4 - B2 B4 - B3			1. Indirect 2. Additional fixing device	1. Screwed	+++
V1 - B1 V1 - B2			1. Direct 2. Premade components	1. Surface contact	+/-

Exterior Insulation variant



Insulation + cladding



Life cycle (yrs)

O
Existing facade

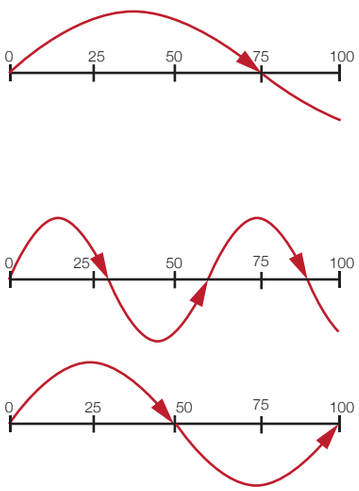
F1
PU-adhesive
3 mm

A1
EPS insulation
190 mm

F2
Mortar
3 mm

A2 (1)
Organic plaster
1,5 mm

A2 (2)
Brick strips
20 mm



End of life scenarios

	0%	5%	5%	**90%**
	0%	0%	10%	**90%**
	0%	0%	**91%**	9%

Materials

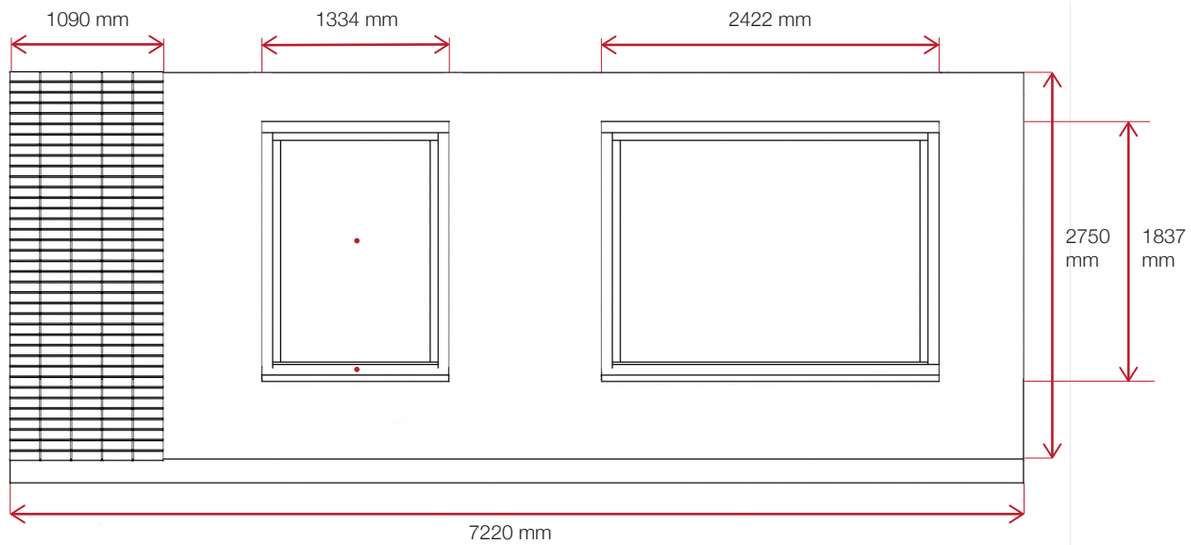
LFI = 1,00
Linear Flow Index
1 = Linear
0 = Circular

X = 1,2
Utility
Lifetime of product / Lifetime of refurbishment (25 years)

MCI = 0,25
Material Circularity Indicator
0 = Linear
1 = Circular

Example from practice:
Irreversible connection between existing facade and EPS insulation layer

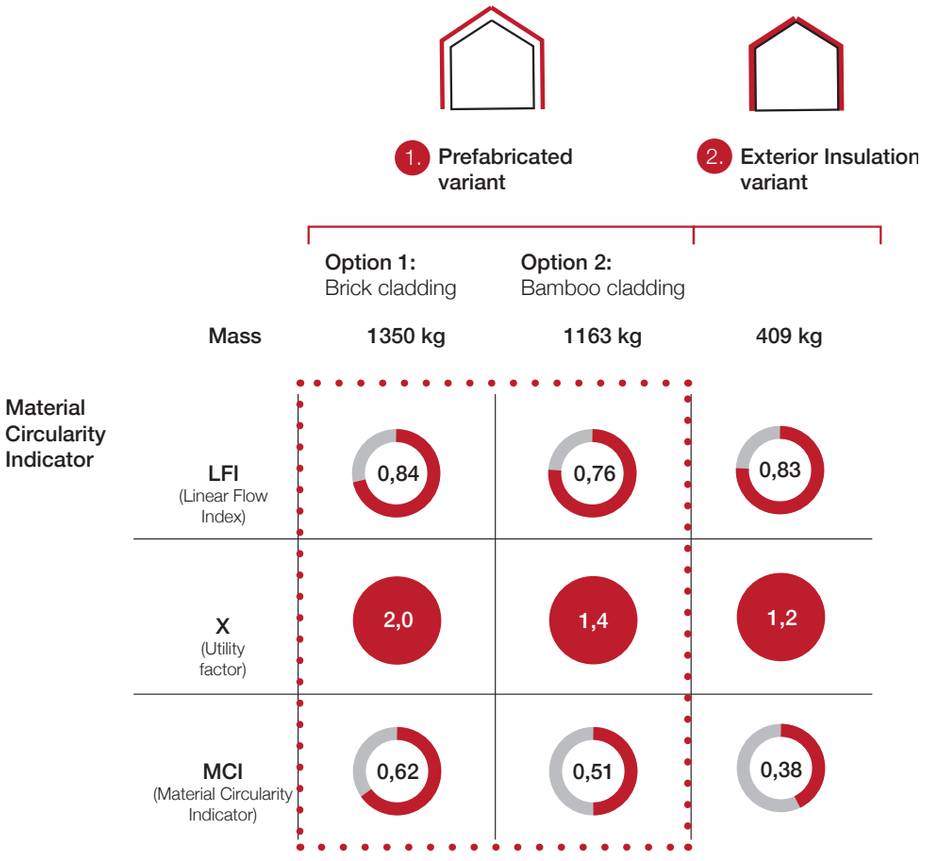
Insulation + cladding

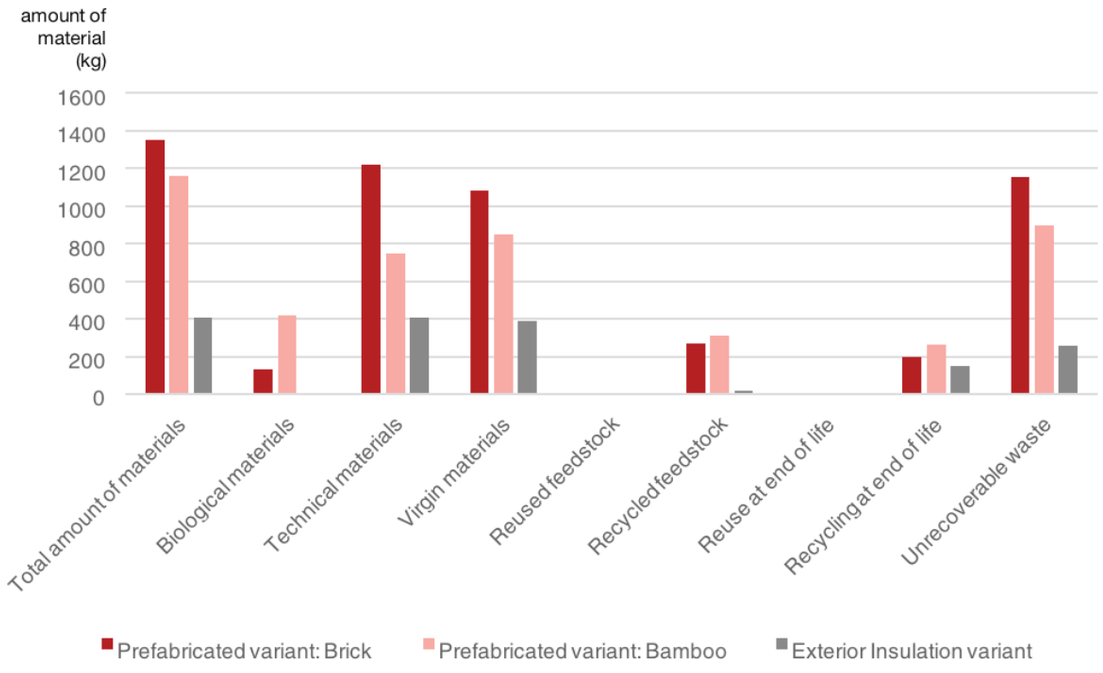


Connections

CONNECTION	CONNECTION DIAGRAM	INTERFACES	TYPE	ASSEMBLY	GRADING
A1 - O (F1 = connection material)			1. Indirect 2. Chemical material	1. Surface contact	-
A2(1) - A1 (F2 = connection material)			1. Indirect 2. Chemical material	1. Surface contact	-
A2(2) - A1 (F2 = connection material)			1. Indirect 2. Chemical material	1. Surface contact	-

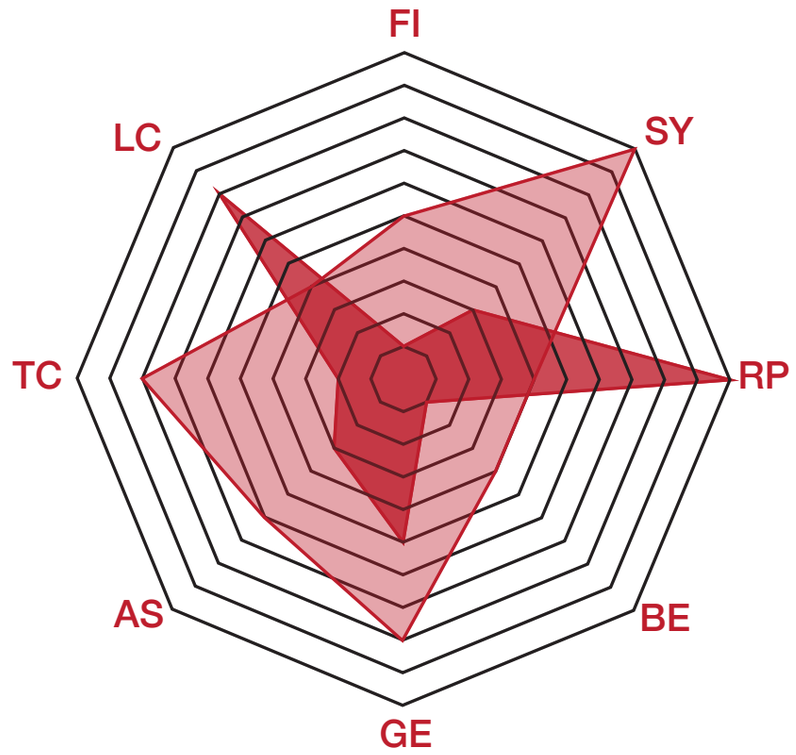
Comparison


1. Prefabricated variant
2. Exterior Insulation variant
Option 1: Brick cladding
Option 2: Bamboo cladding
Mass
1350 kg
1163 kg
409 kg
Material Circularity Indicator
LFI (Linear Flow Index)
0,84
0,76
0,83
X (Utility factor)
2,0
1,4
1,2
MCI (Material Circularity Indicator)
0,62
0,51
0,38


amount of material (kg)
1600
1400
1200
1000
800
600
400
200
0
Total amount of materials
Biological materials
Technical materials
Virgin materials
Reused feedstock
Recycled feedstock
Reuse at end of life
Recycling at end of life
Unrecoverable waste
Prefabricated variant: Brick
Prefabricated variant: Bamboo
Exterior Insulation variant

1. Prefabricated variant

2. Exterior Insulation variant



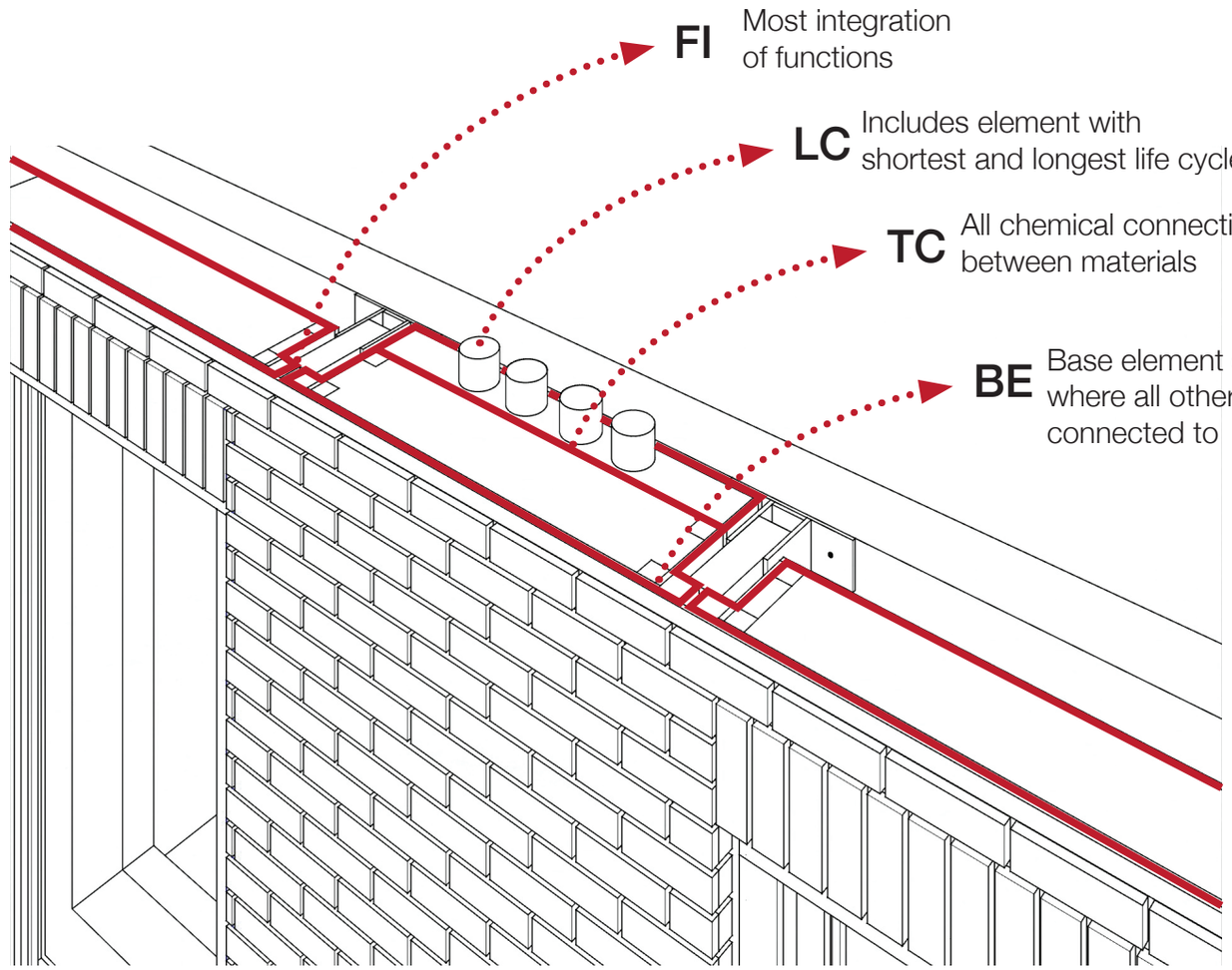
FI Functional Independence
SY Systematisation
RP Relational Patterns
BE Base Element Specification
GE Geometry of the Edge
AS Assembly Sequence
TC Type of Connection
LC Life Cycle coordination

Focus optimisation:
Structural Insulated Panels

LCI
= 0,73

X
= 3,0

MCI
= 0,78



Support tool during the design process

How to design a circular building product?
What options should be considered?

QUESTIONS	OPTIONS
What type of material is used for the component?	Biological material; Technical material
What type of feedstock does the material consist of?	2nd Reused feedstock; 2nd Recycled feedstock; All virigin materials
What is the end of life scenario of the component?	Reuse; Recycling; Incineration; Landfill
What is the life time of the component?	50-75 yrs; 25-50 yrs; 0-25 yrs

Materials

How is the component connected to its surrounding components?	Indirect + third component; Direct + additional fixings; Direct through premade geometry; Chemical connection
What does the geometry of the component's edge look like?	Open - Linear; Symmetric overlapping; Closed - Integral
Does the component represent only one function?	yes / no
Are multiple elements clustered into the (prefabricated) component?	yes / no
Can the component be removed from the facade without damaging other components?	yes / no
Is there a base element, to which all facade components are connected, present in the facade?	yes / no
Is the assembly sequence parallel, meaning multiple components can be placed at the same time?	yes / no
Is the component with the shortest lifetime situated closest to the outer surface and the component with the longest lifetime farthest?	yes / no

Connections

QUESTIONS

What type of material is used for the component?

What type of feedstock does the material consist of?

What is the end of life scenario of the component?

What is the life time of the component?

OPTIONS

Biological material

Technical material

Reused feedstock

Recycled feedstock

All virgin materials

Reuse

Recycling

Incineration

Landfill

50-75 yrs

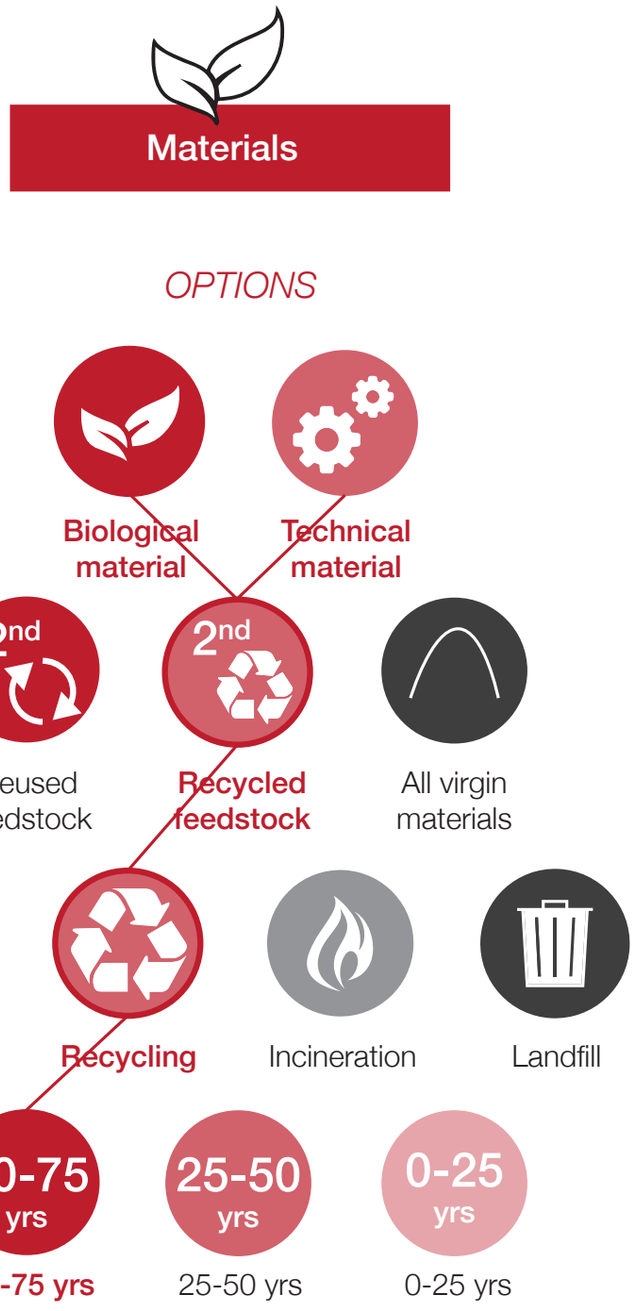
25-50 yrs

0-25 yrs

Structural Insulated Panels

EPS Insulation

Chipboard



Redesign

Recycled cotton insulation

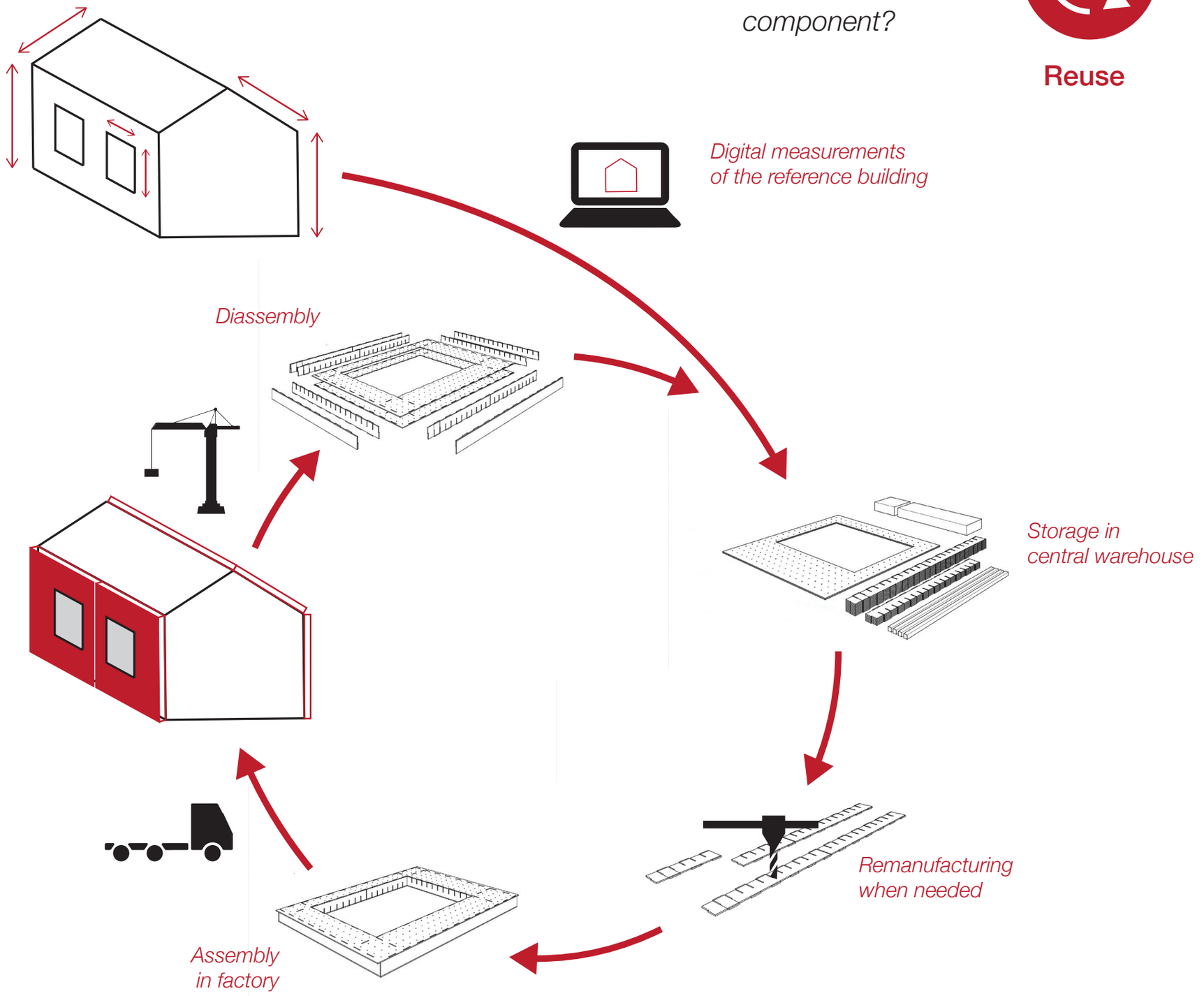
ECOBoard

Enable direct reuse
of the system for the refurbishment of multiple residential buildings

by increasing the level of standardisation of the components

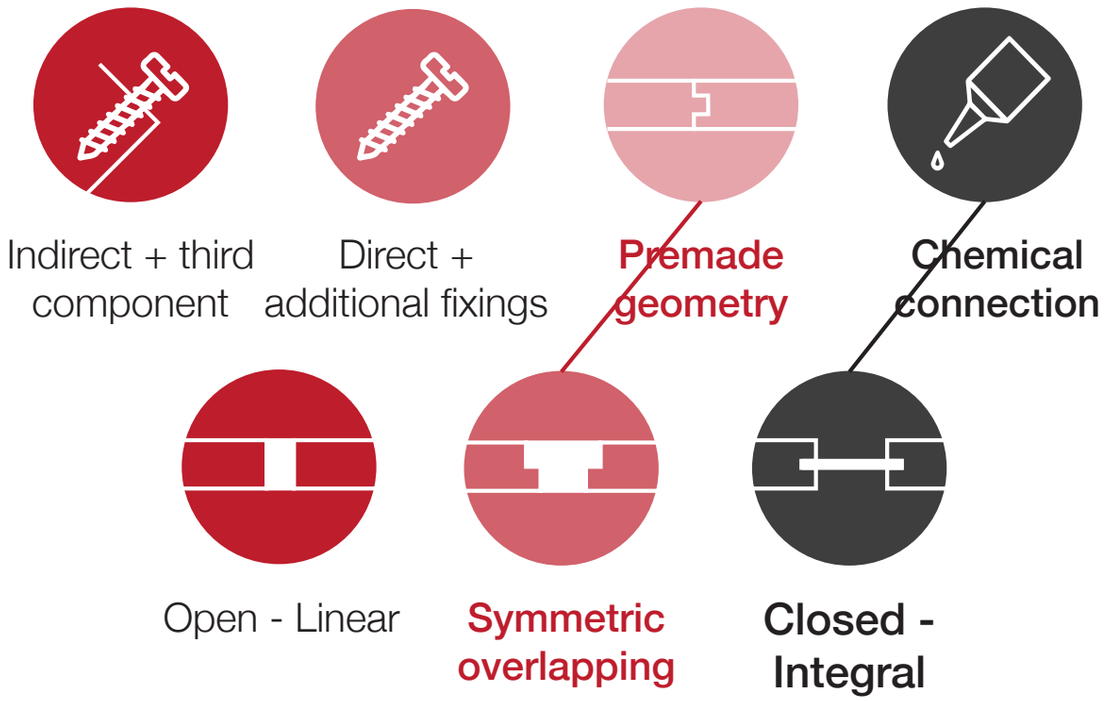
What is the end of life scenario of the component?

Reuse

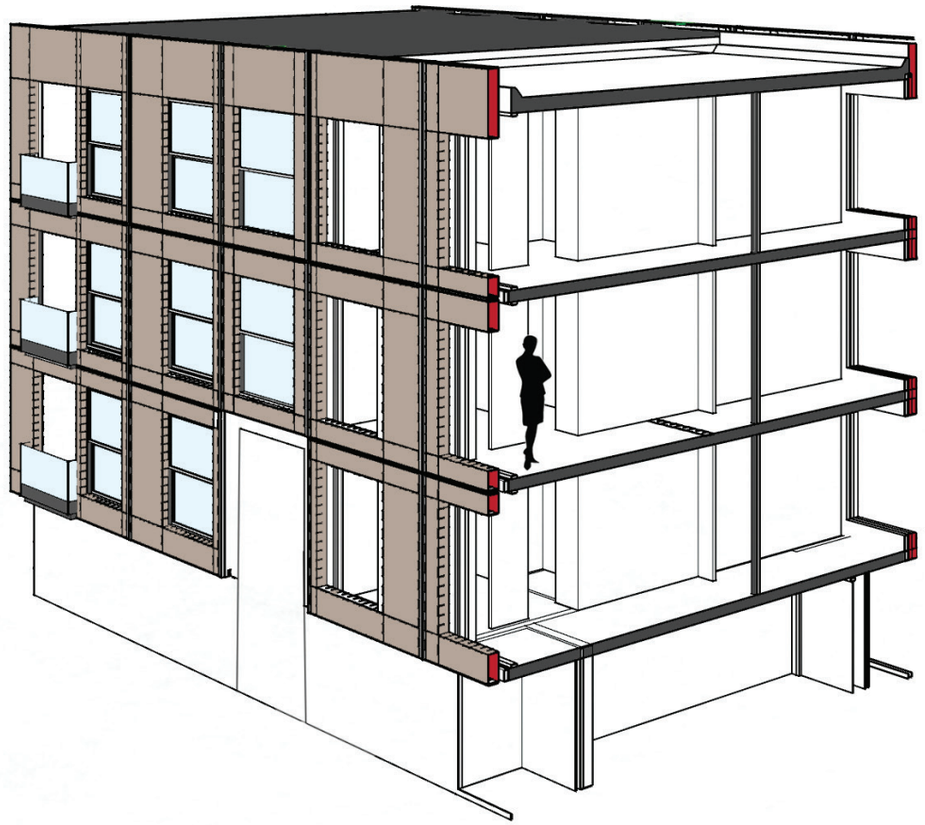


Connection redesign

How is the component connected to its surrounding components?



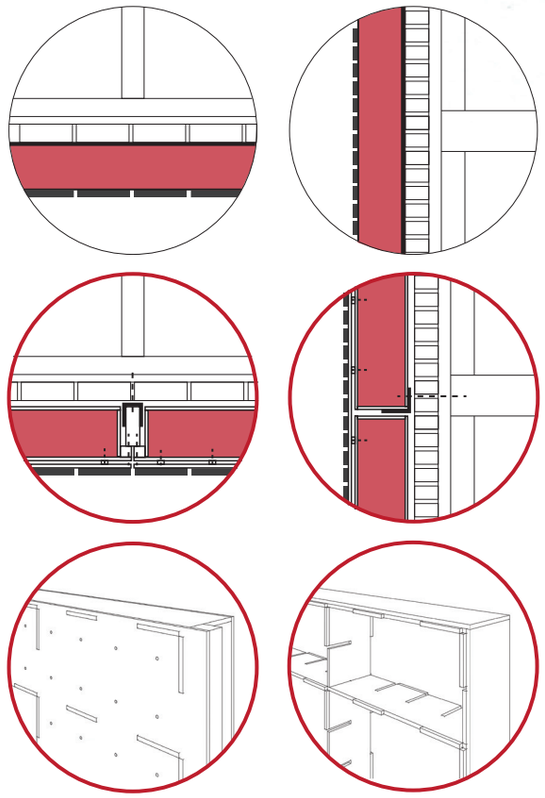
What does the geometry of the component's edge look like?



HOR. VERT.

Current joints:

Optimised joints:



Chemical connection

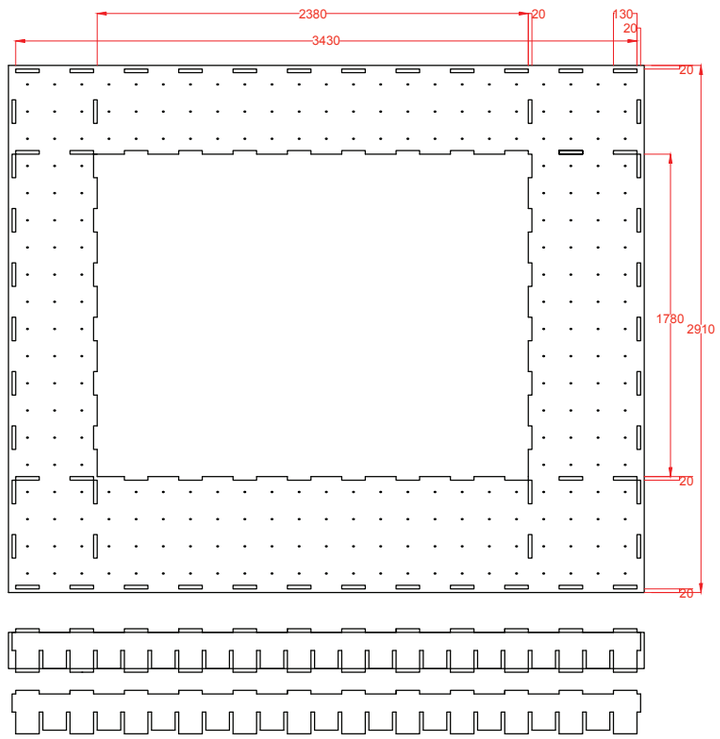
Indirect + third component

SIP-panel:
Direct through premade geometry

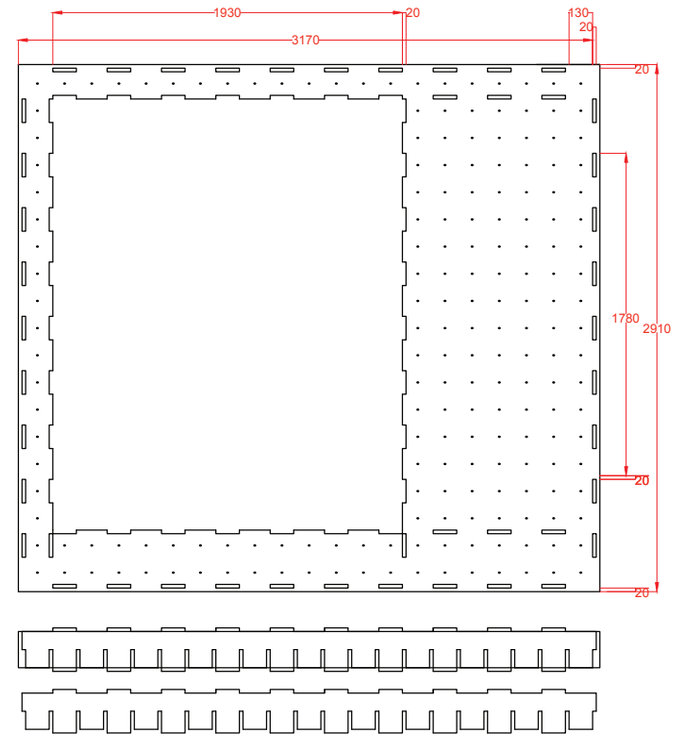
Symmetric overlapping

Case Study Building 1: Vlaardingen

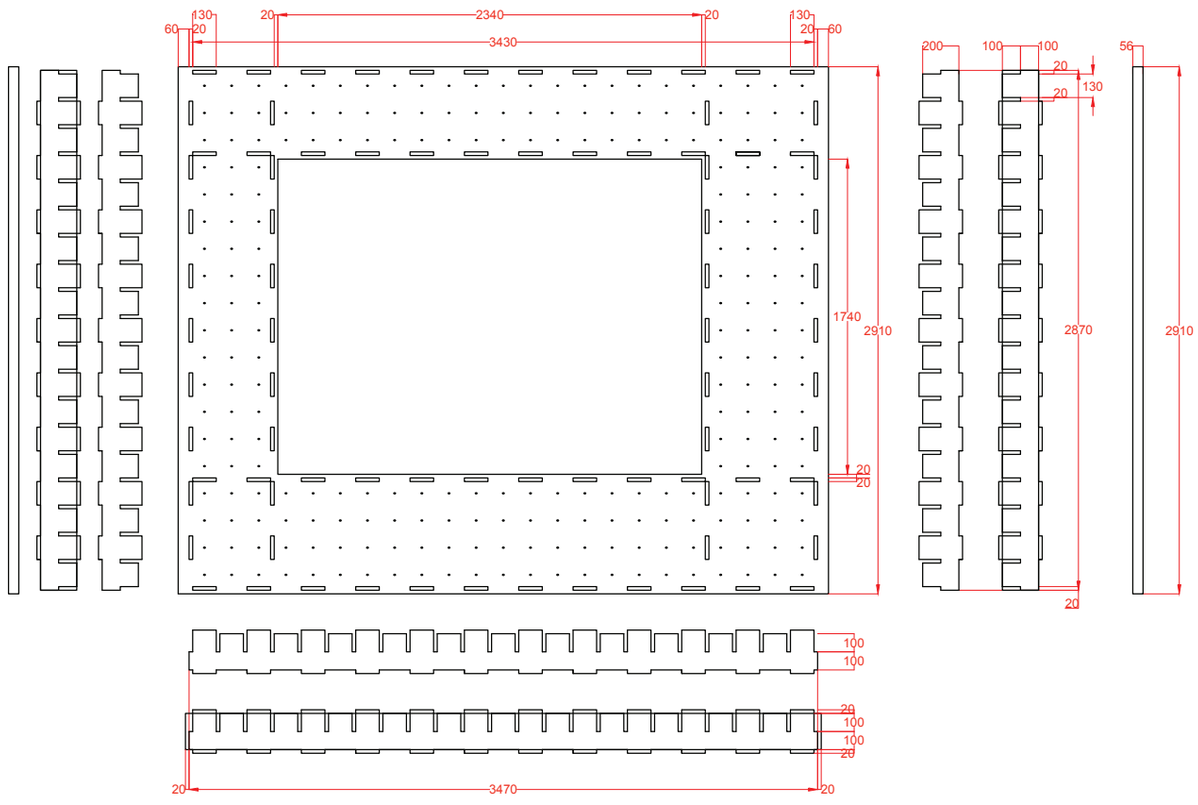
Case Study Building 2: Rotterdam

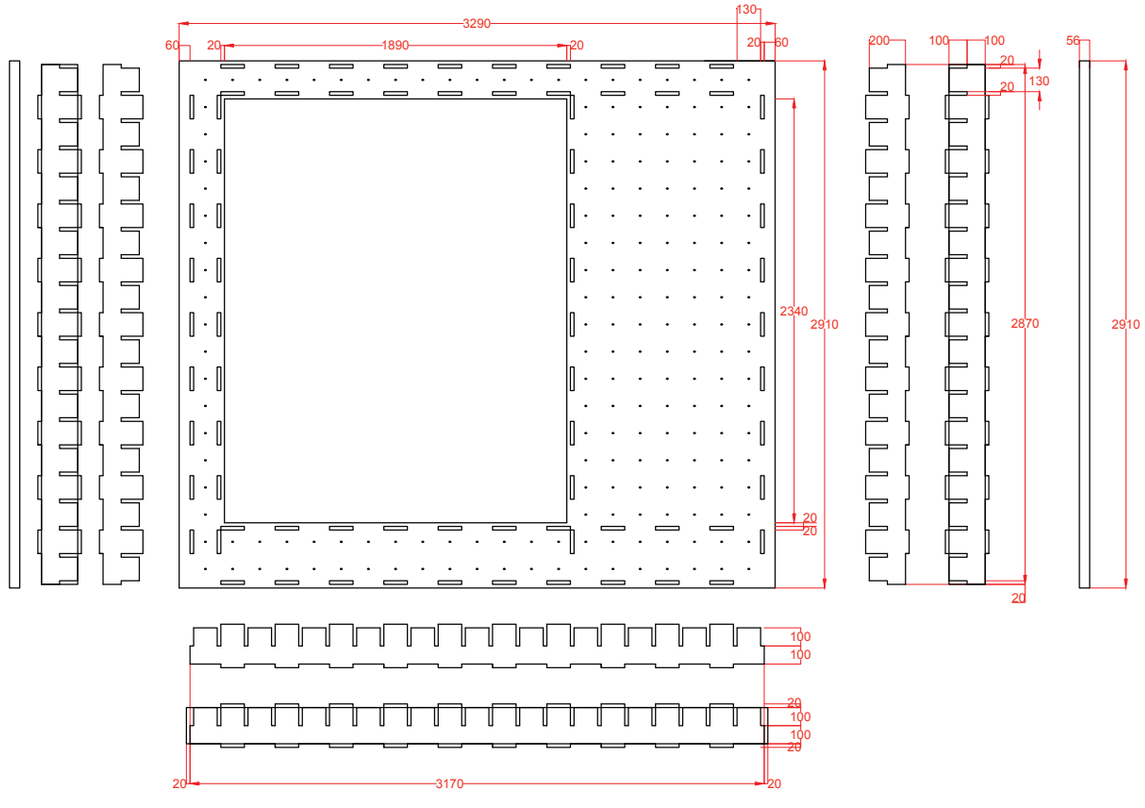


Case Study Building 1



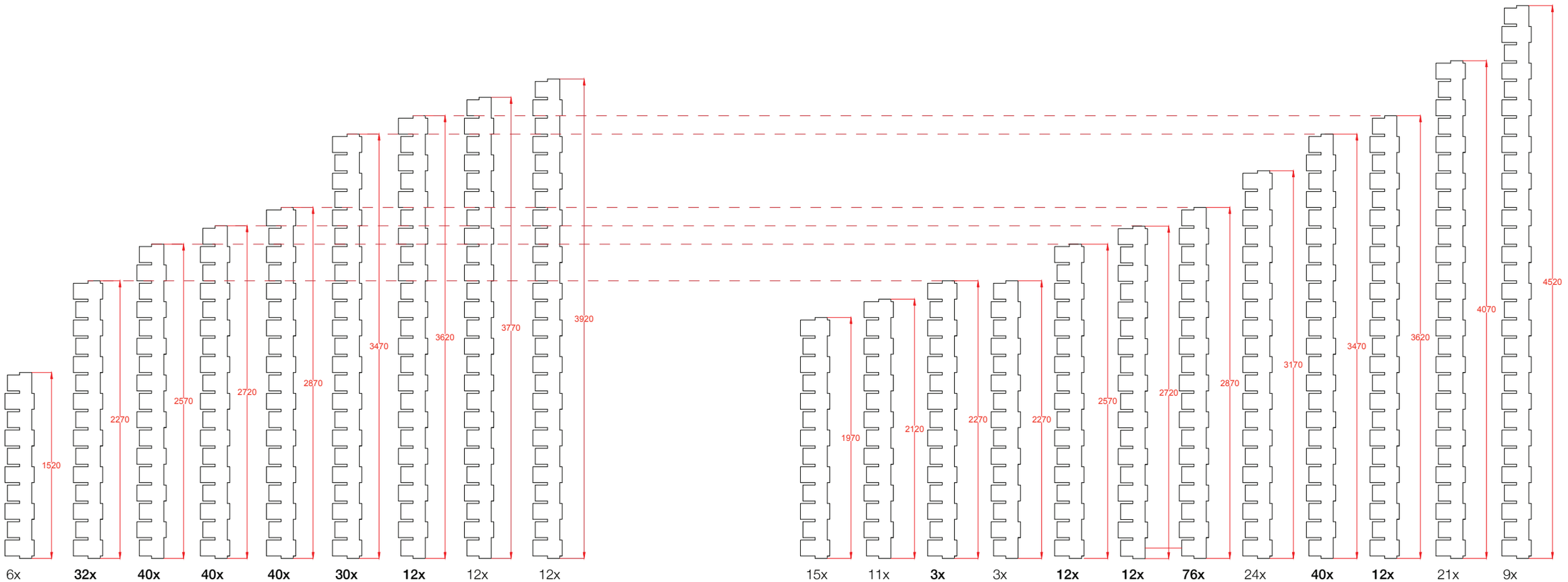
Case Study Building 2





What is the end of life scenario of the component?

Reuse

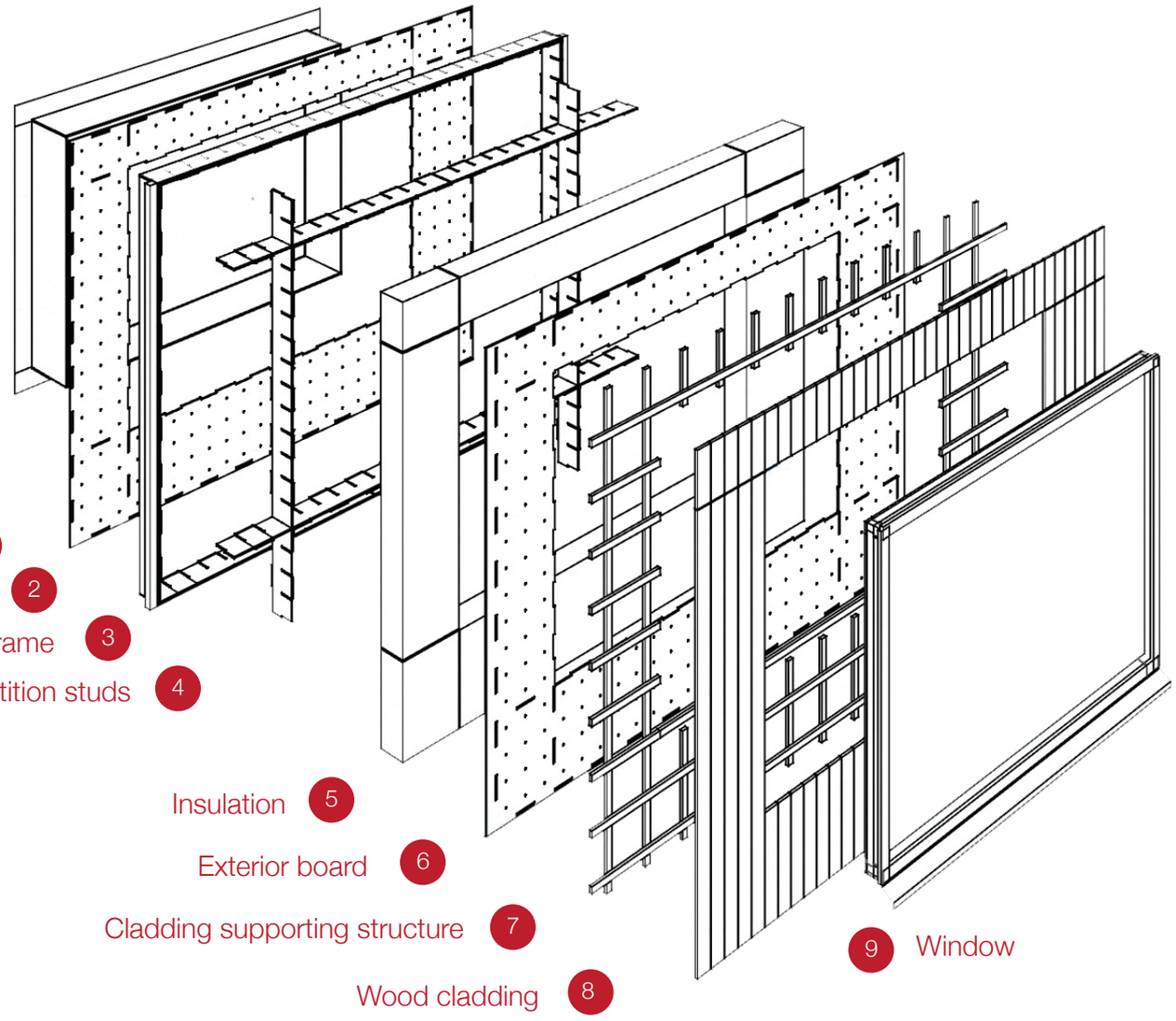


Case Study Building 1

49%
direct reuse

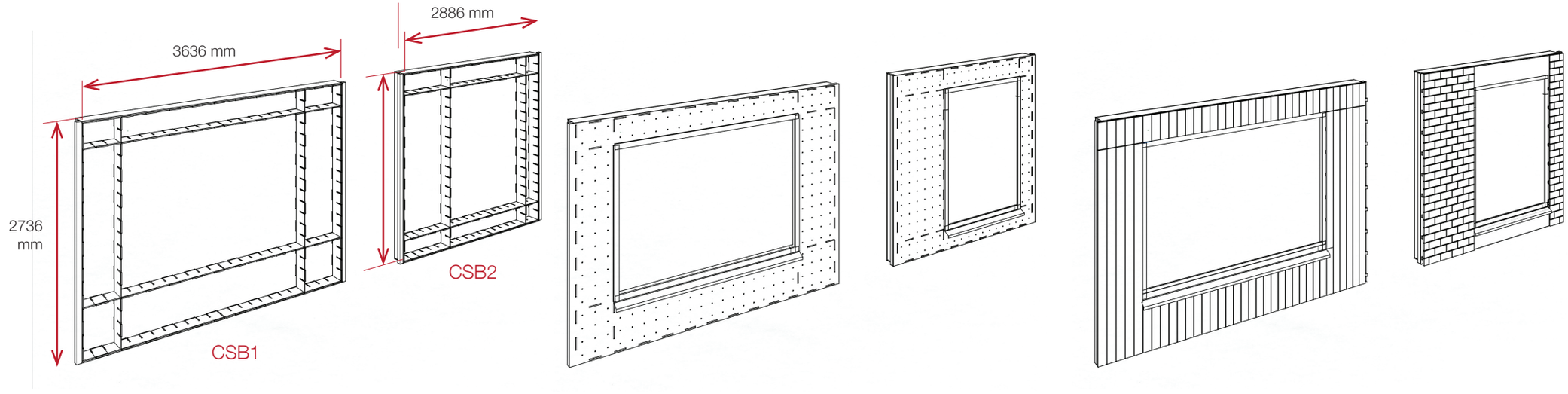
Case Study Building 2

46%
direct reuse



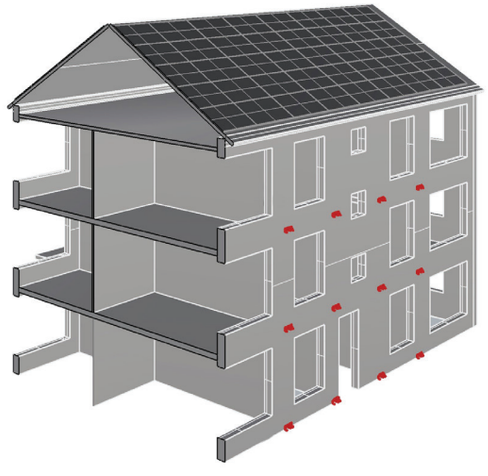
Are multiple elements clustered into the (prefabricated) component?

yes

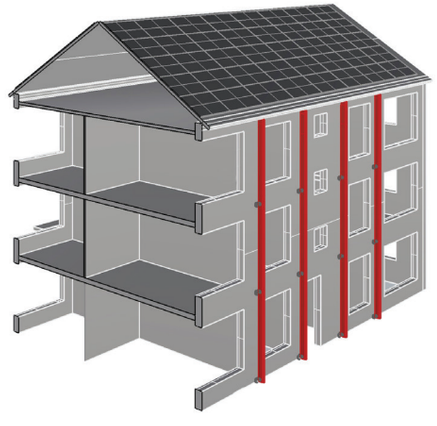


Is the assembly sequence parallel, meaning multiple components can be placed at the same time?

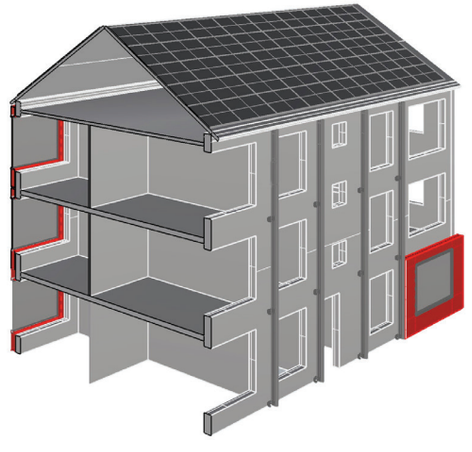
no



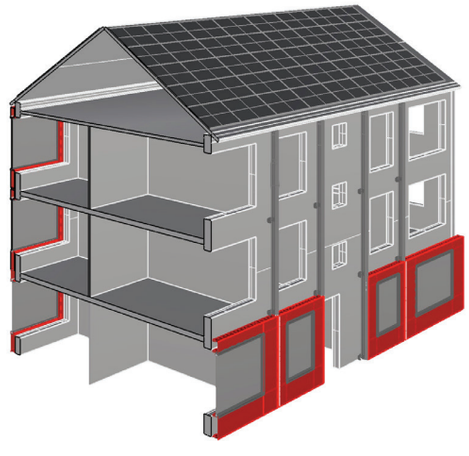
1.
Placement of the **stainless-steel anchors**



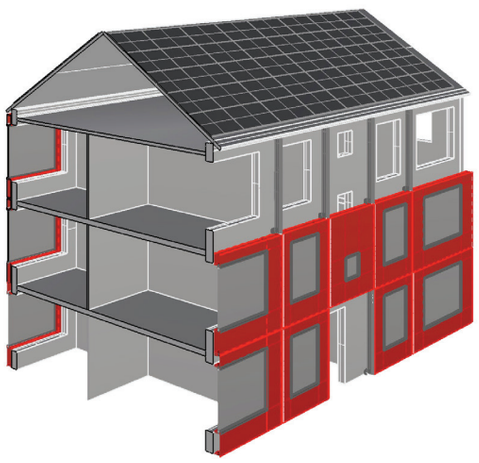
2.
Placement of the **substructure**



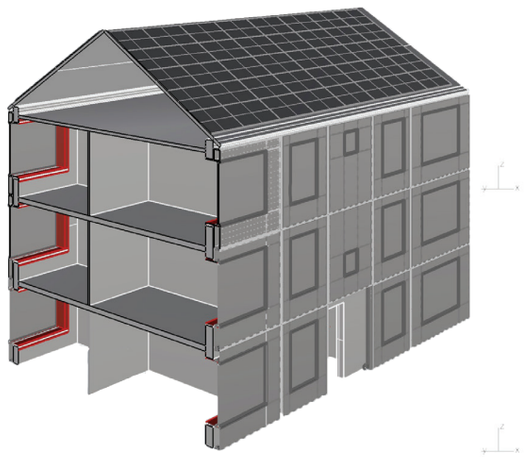
3.
Installation of the **first prefabricated module, screwed to substructure**



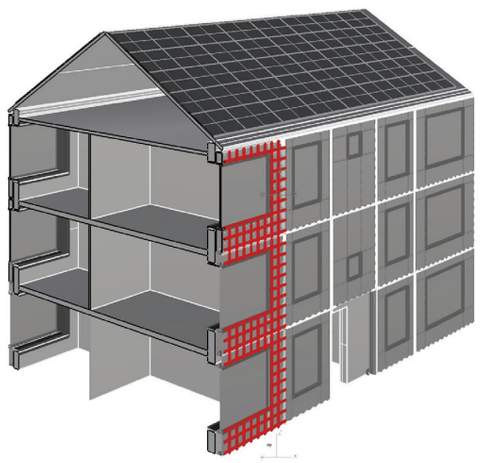
4.
Installation of the **first row of modules** at the ground floor level



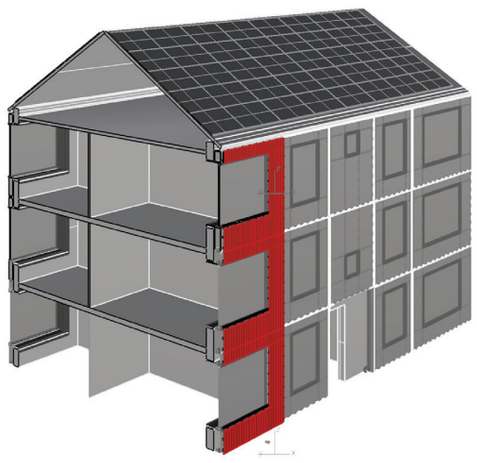
5.
Installation of the rest of the prefabricated modules, **row by row**



6.
When one module is placed, **the internal finishing in the room** can already start



7.
Placement of **the support structure of the cladding**



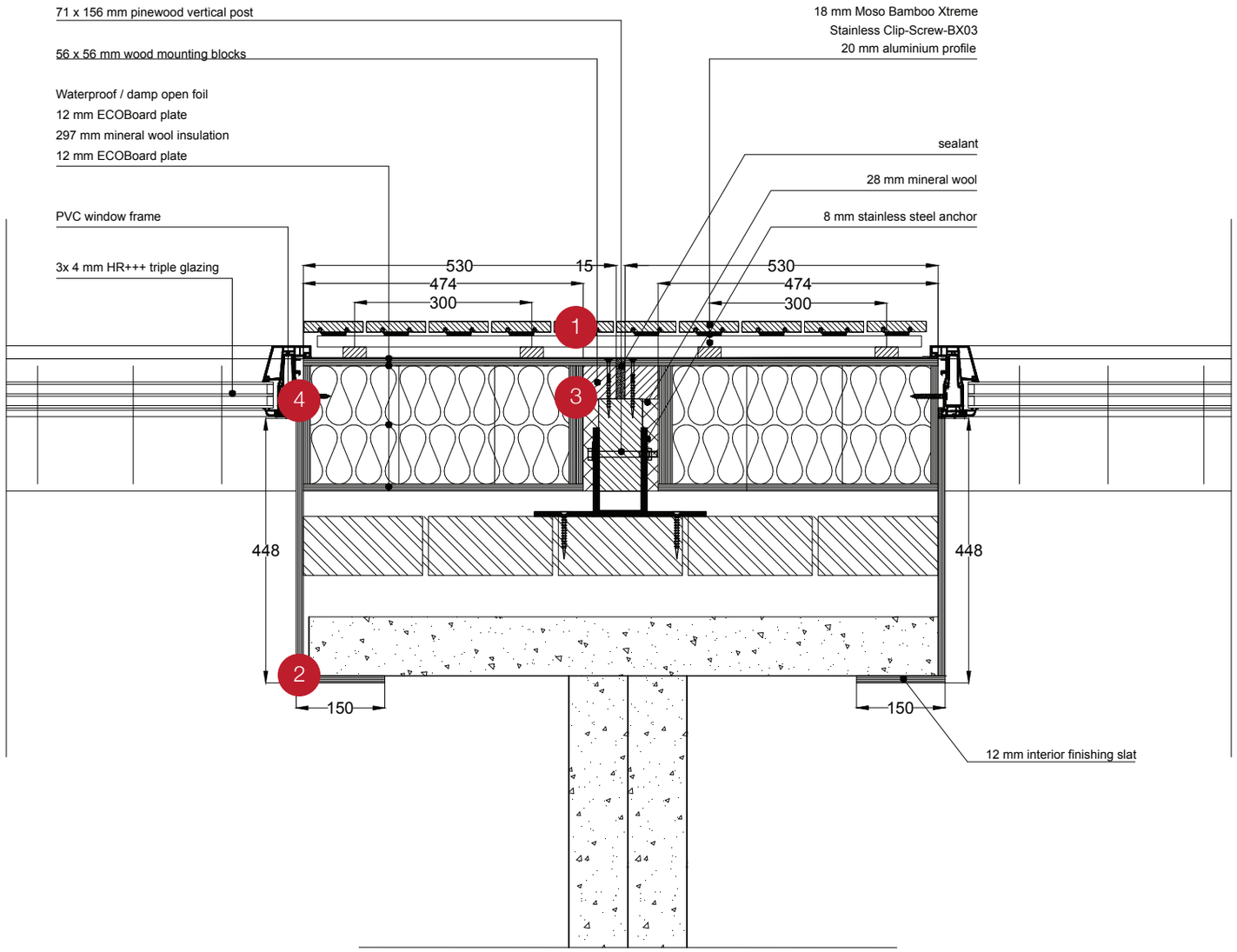
8.
Finishing with **facade cladding material**

Can the component be removed from the facade without damaging other components?

yes

Horizontal detail connection window

scale 1:20



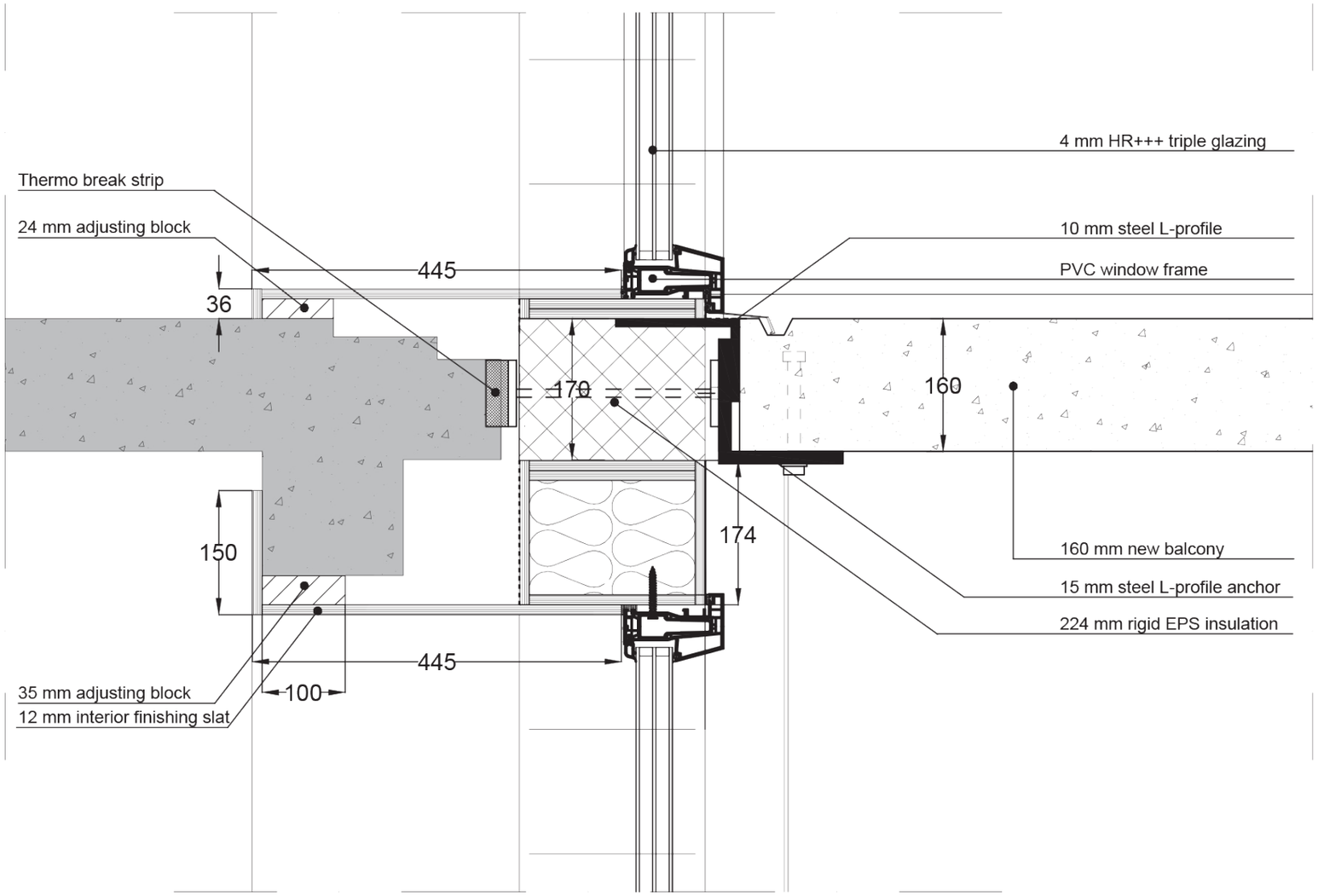
Reference timber prototype
(Petersen & Løvskogen, 2015)

Is there a base element, to which all facade components are connected, present in the facade?

yes

Vertical detail connection balcony

scale 1:10

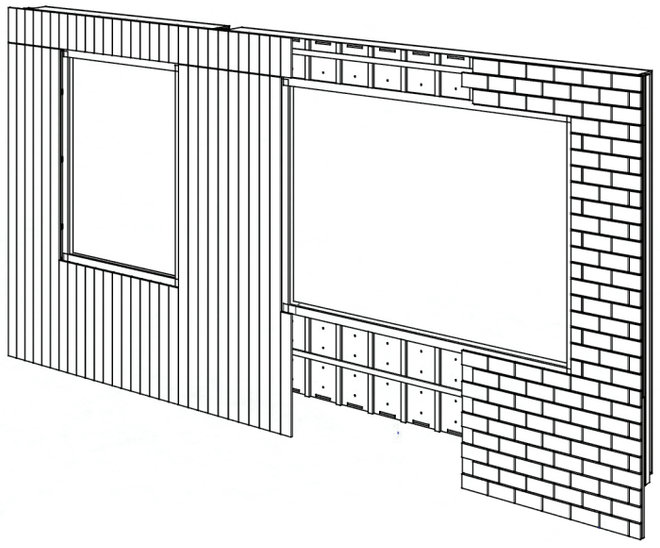


What could happen with the refurbishment system after a service life of 25 years?

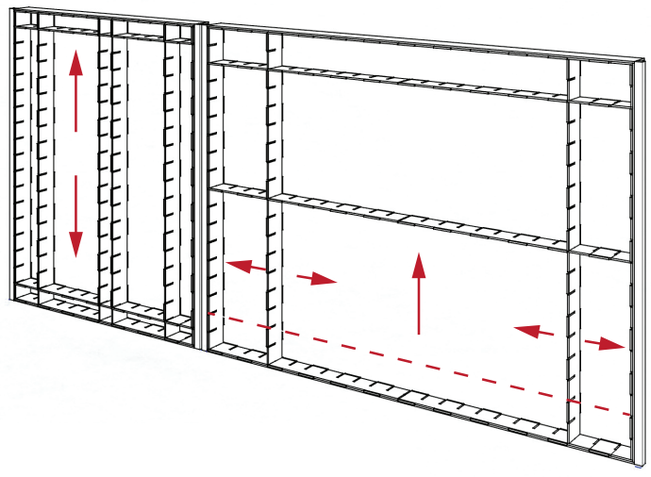
Does the component represent only one function?

no

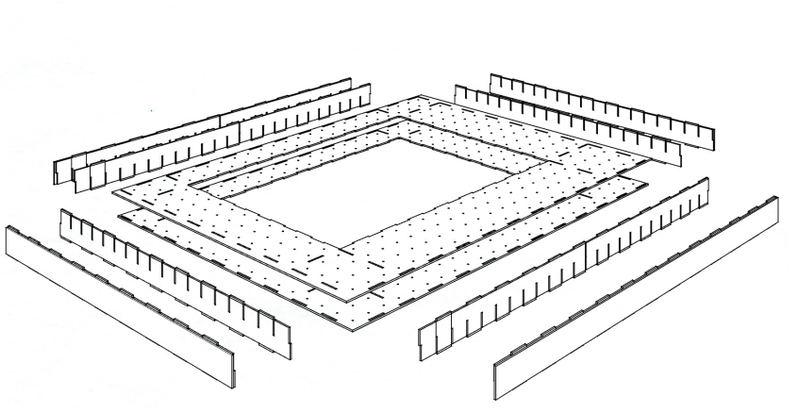
1 Scenario 1: **Maintenance**

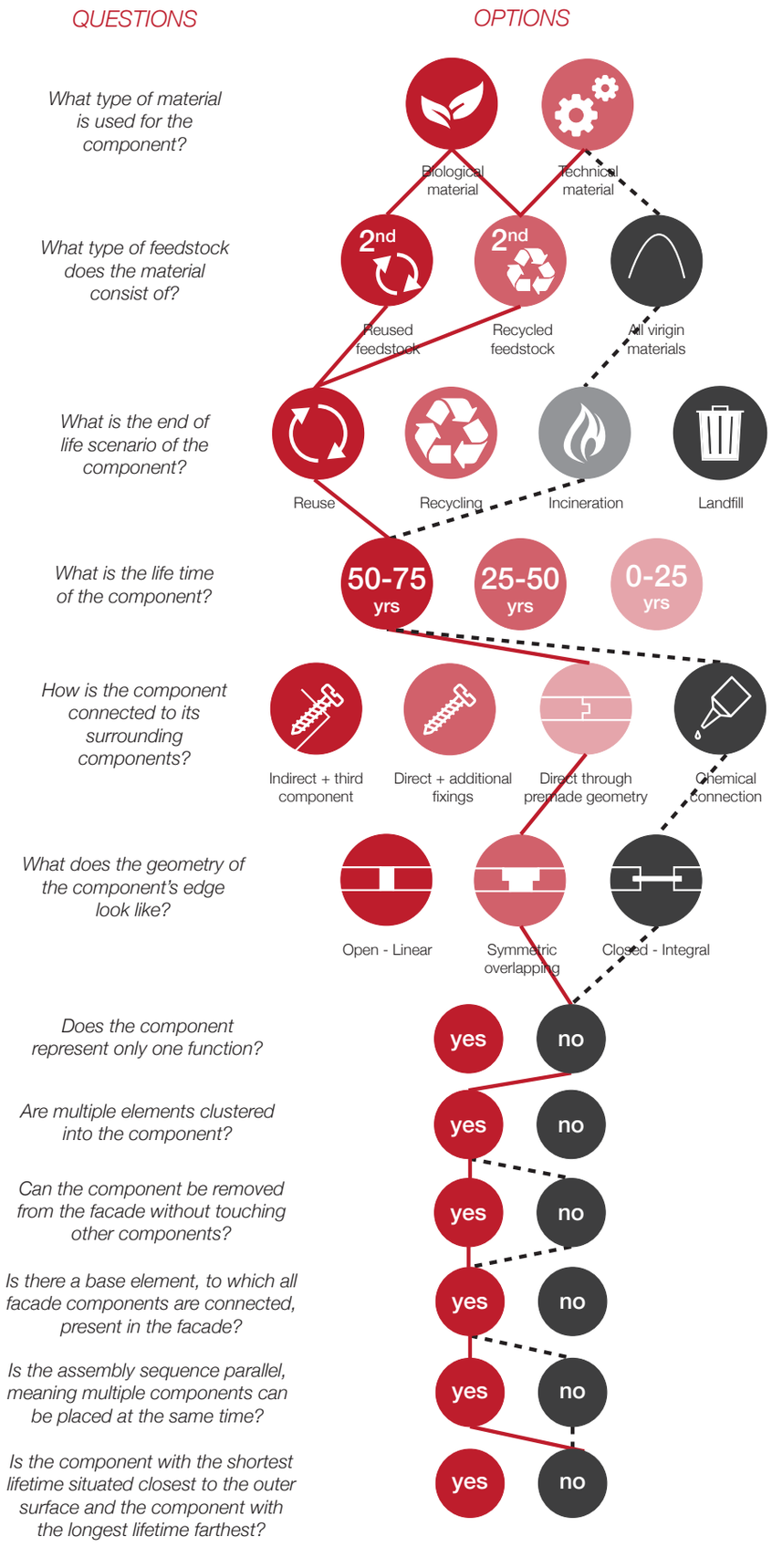


2 Scenario 2: **Function change**



3 Scenario 3: **Deconstruction**

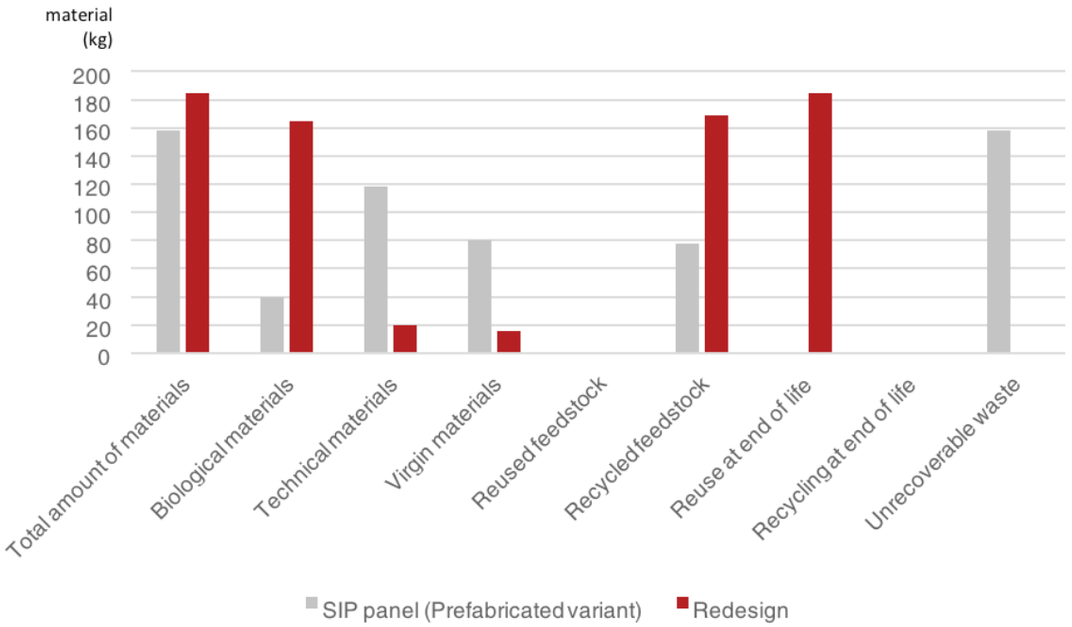



QUESTIONS
OPTIONS
What type of material is used for the component?
Biological material
Technical material
What type of feedstock does the material consist of?
2nd
2nd
Reused feedstock
Recycled feedstock
All virigin materials
What is the end of life scenario of the component?
Reuse
Recycling
Incineration
Landfill
What is the life time of the component?
50-75 yrs
25-50 yrs
0-25 yrs
How is the component connected to its surrounding components?
Indirect + third component
Direct + additional fixings
Direct through premade geometry
Chemical connection
What does the geometry of the component's edge look like?
Open - Linear
Symmetric overlapping
Closed - Integral
Does the component represent only one function?
Are multiple elements clustered into the component?
Can the component be removed from the facade without touching other components?
Is there a base element, to which all facade components are connected, present in the facade?
Is the assembly sequence parallel, meaning multiple components can be placed at the same time?
Is the component with the shortest lifetime situated closest to the outer surface and the component with the longest lifetime farthest?
yes
no

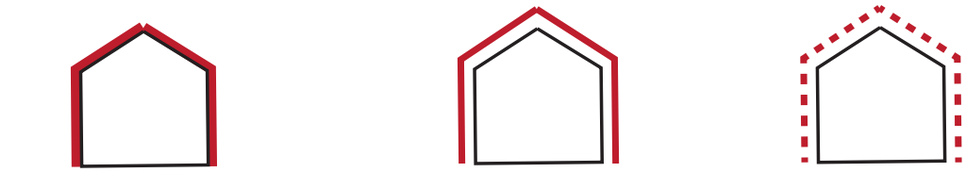
Material Circularity Indicator

		1. SIP panel (Prefabricated variant)	2. Redesign
	Mass	**158,3 kg**	**184,2 kg**
Feedstock	Biological	25%	89%
	Technical	75%	11%
	Reused feedstock	0%	0%
	Recycled feedstock	49%	92%
End of life scenarios	Reuse	0%	100%
	Recycling	0%	0%
	Landfill	0%	0%
	Incineration	100%	0%

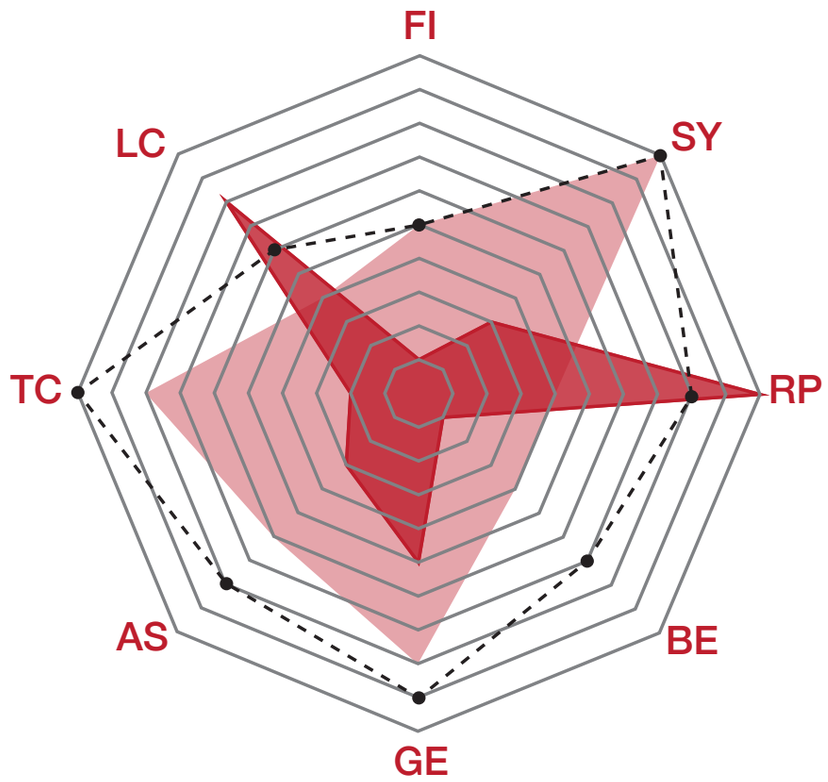
		1. SIP panel (Prefabricated variant)	2. Redesign
Material Circularity Indicator	**LFI** (Linear Flow Index)	0,75	0,04
	X (Utility factor)	1,0	3,0
	MCI (Material Circularity Indicator)	0,32	0,99



Disassembly Potential



1. Exterior Insulation variant
2. Prefabricated variant
3. Redesign



From our planet's point of view,
there's no throwing garbage out.
Because there is no "out".

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