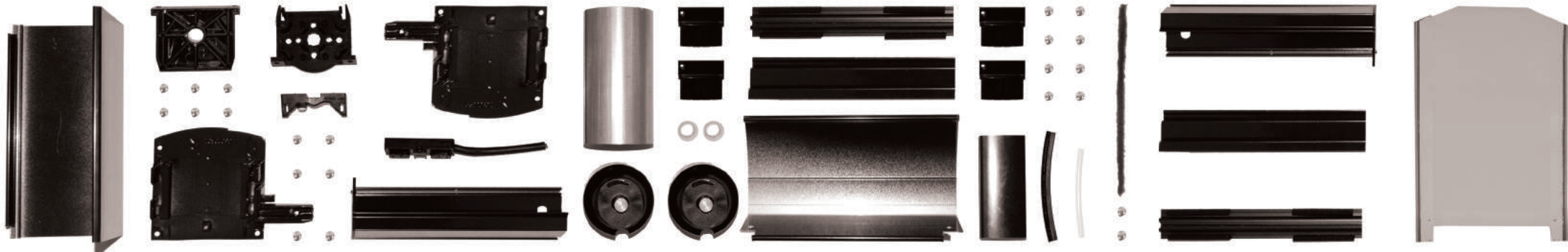


CHRISTINA MICHAEL / 4368665

DESIGN FOR DISASSEMBLY FOR FACADE COMPONENTS IN A CIRCULAR ECONOMY



1st mentor: Tillmann Klein
2nd mentor: Bob Geldermans

Daily supervisor: Juan Azcarate - Aguerre

INTRODUCTION



IFPSS PILOT PROJECT

EWI

NORTH FACADE

4 PANELS

Panel 1 - Low cost

Panel 2 - Supply services &
energy generation

Panel 3 - All-inclusive functional

Panel 4 - All-inclusive high end



Mock-up panels at EWI building

PROBLEM STATEMENT

CONSTRUCTION SECTOR (EU)



50%
EXTRACTED RESOURCES



42%
ENERGY



35%
WASTE

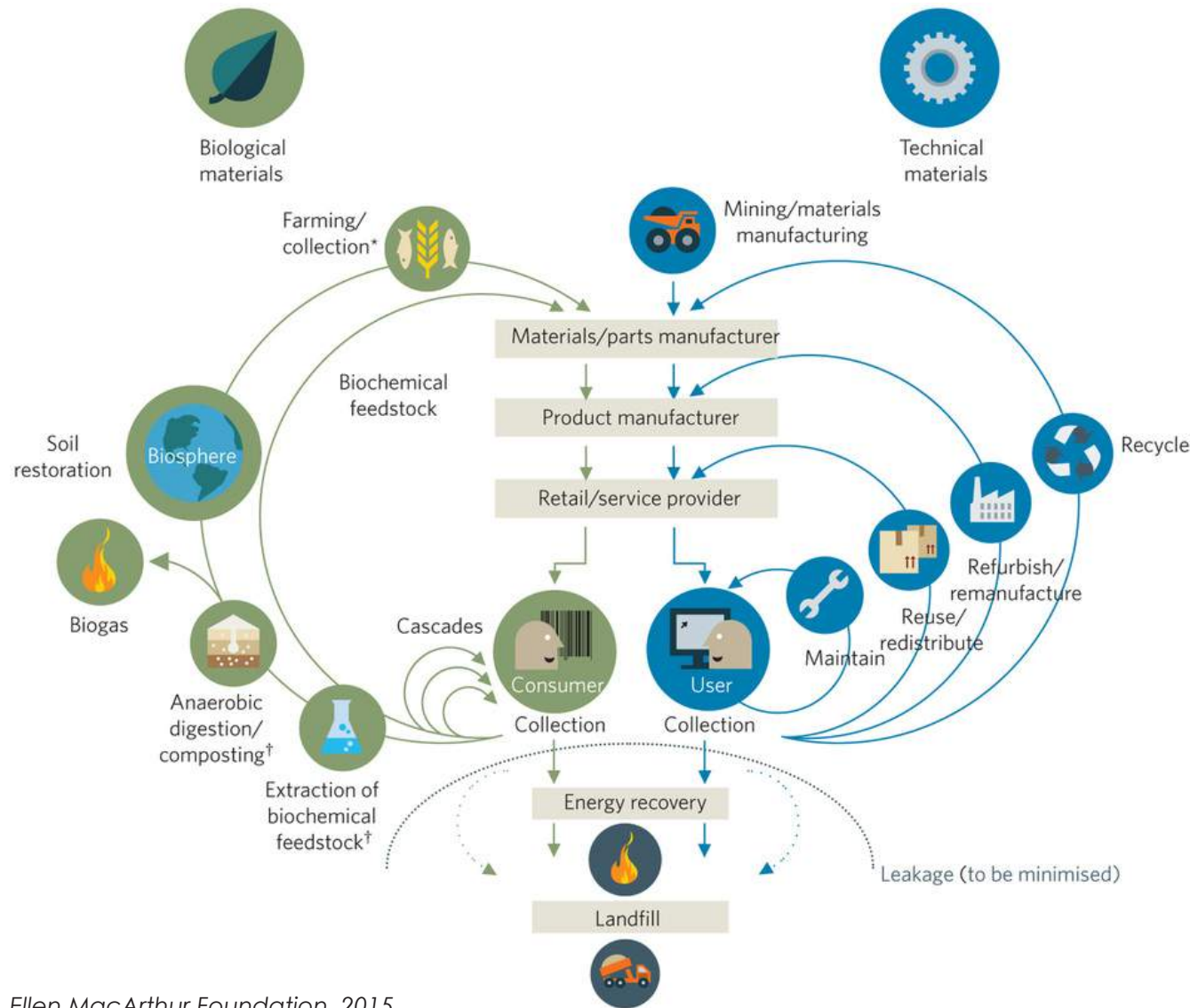


35%
GREENHOUSE EMISSIONS

European Commission. (2011).
Roadmap to a Resource Efficient Europe

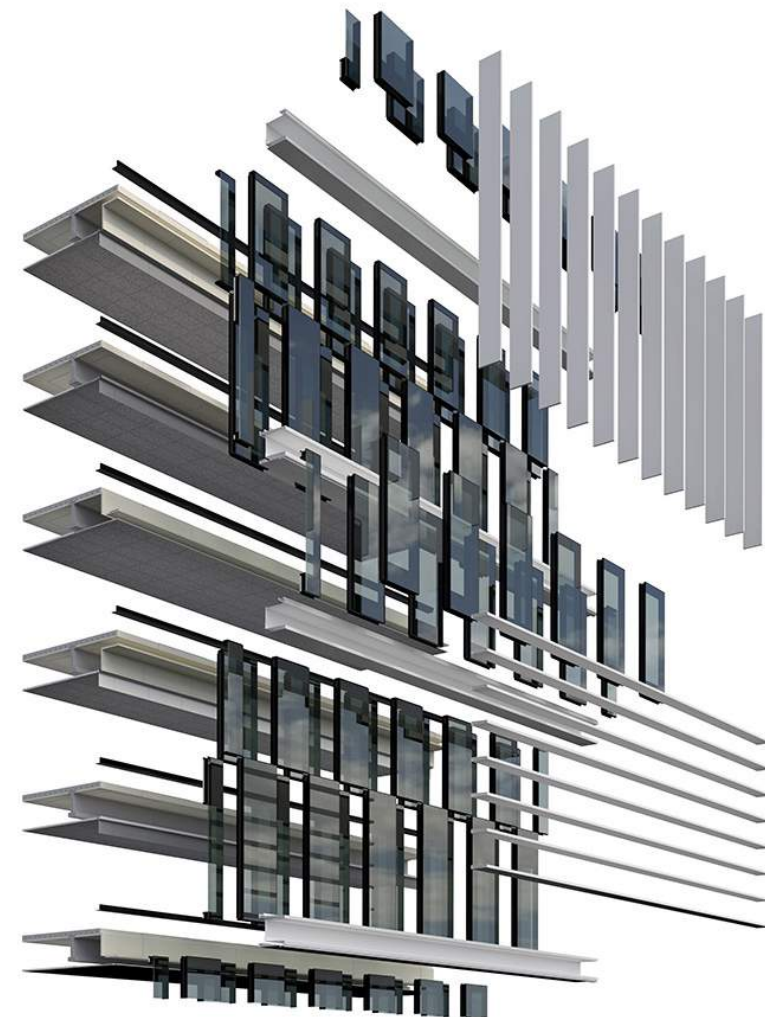


DFD IN CIRCULAR ECONOMY | Means & context



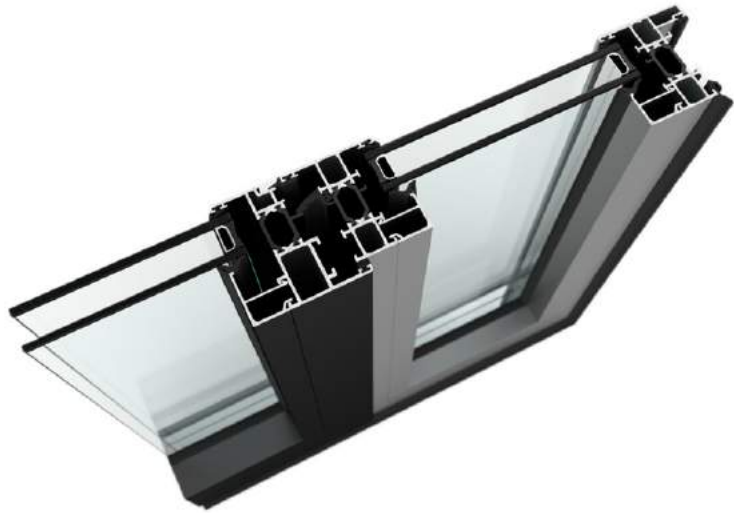
Ellen MacArthur Foundation, 2015

www.batessmart.com



Objective: Investigate the possibilities and impacts of Design for Disassembly strategies for facade components in the Circular Economy

LIMITATIONS | Three components



RT 72 / RT 72 HI
Aluminium window frames



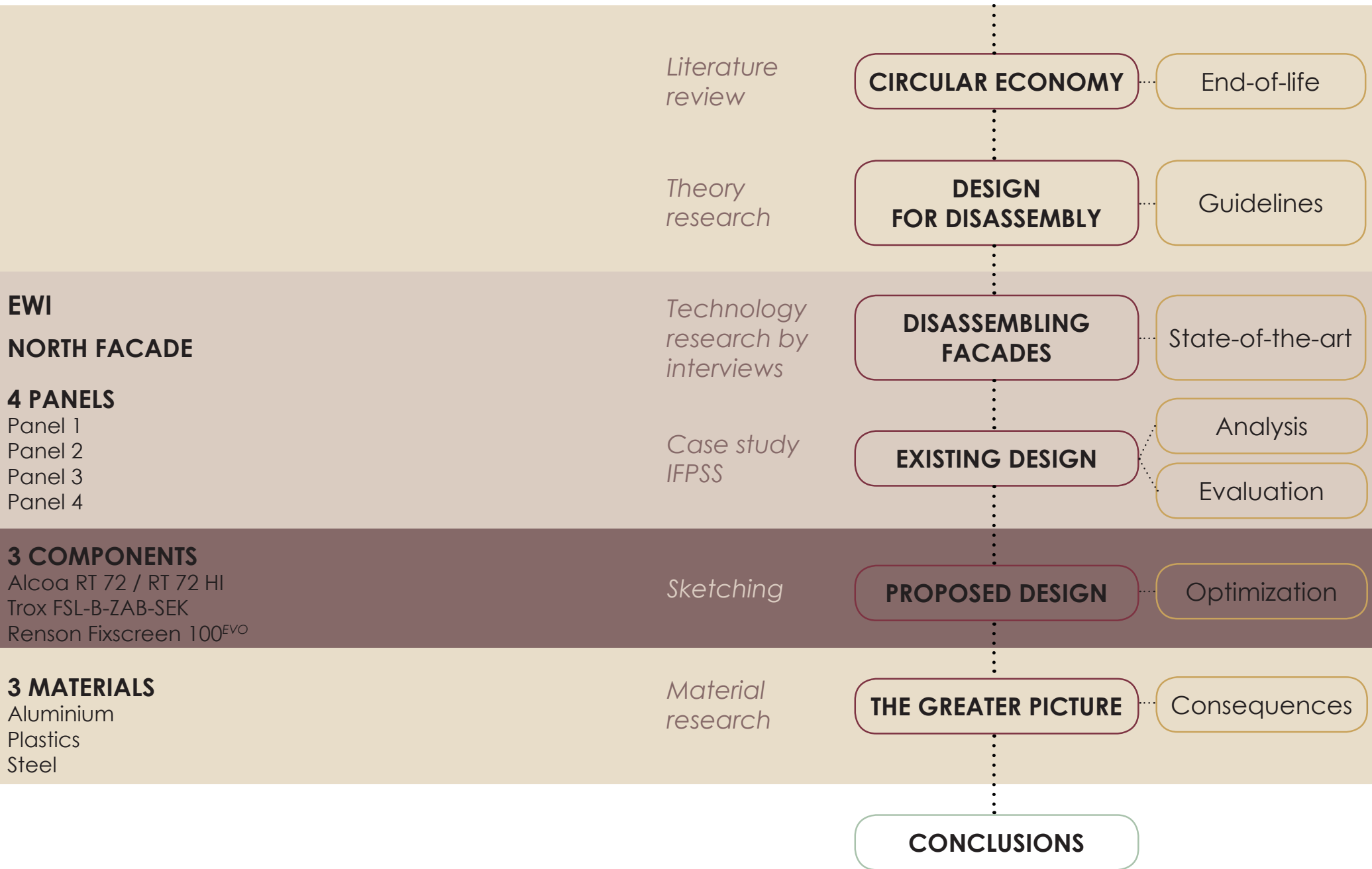
FSL-B-ZAB-SEK
Decentralized air handling unit



FIXSCREEN 100^{EVO}
External sunshade unit



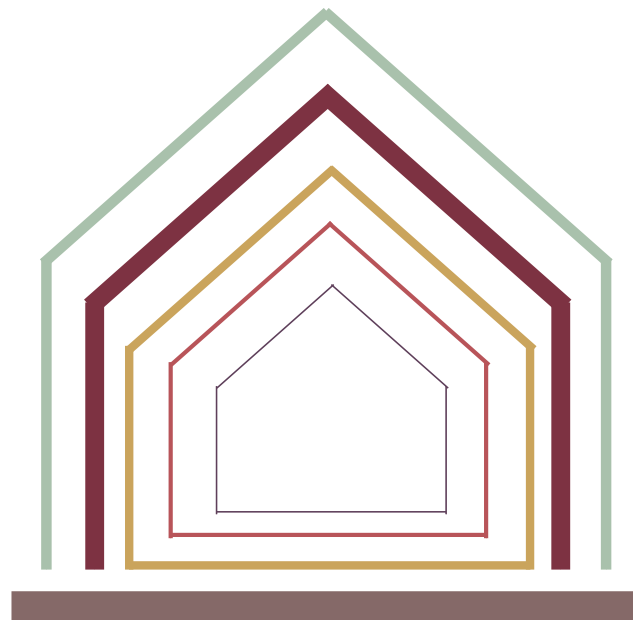
METHODOLOGY



THEORETICAL BACKGROUND

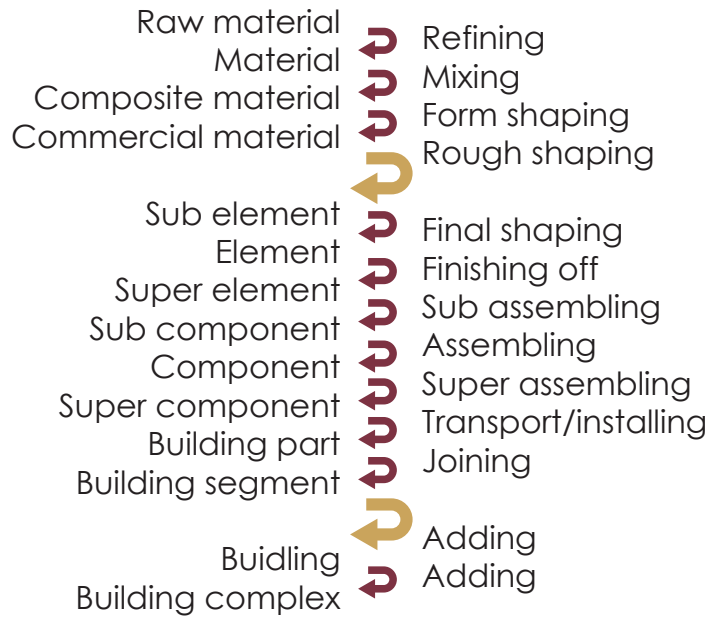


PHYSICAL ANALYSIS | Literature findings

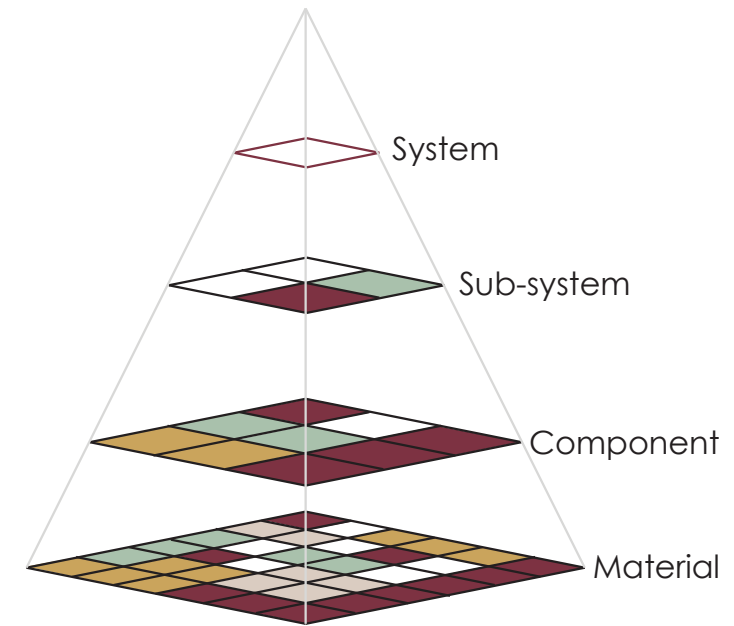


- Site (eternal)
- Services (7-15)
- Structure (30-300)
- Space (3-30)
- Skin (20)
- Stuff (Daily)

(BRAND, 1994)



(ECHKOUT, 2006)

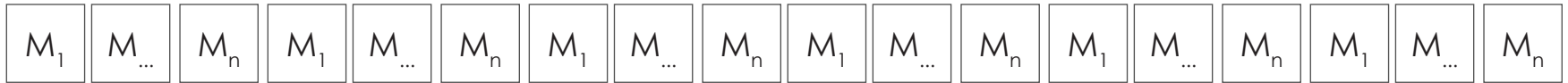


(DURMISEVIC, 2006)

PHYSICAL ANALYSIS | Selected model

Hierarchy level

Material



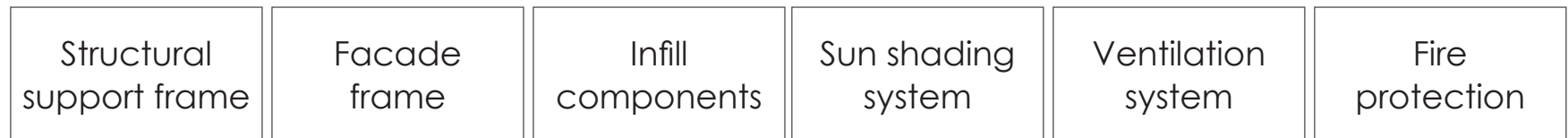
Element



Sub-component



Component



Sub-system



System

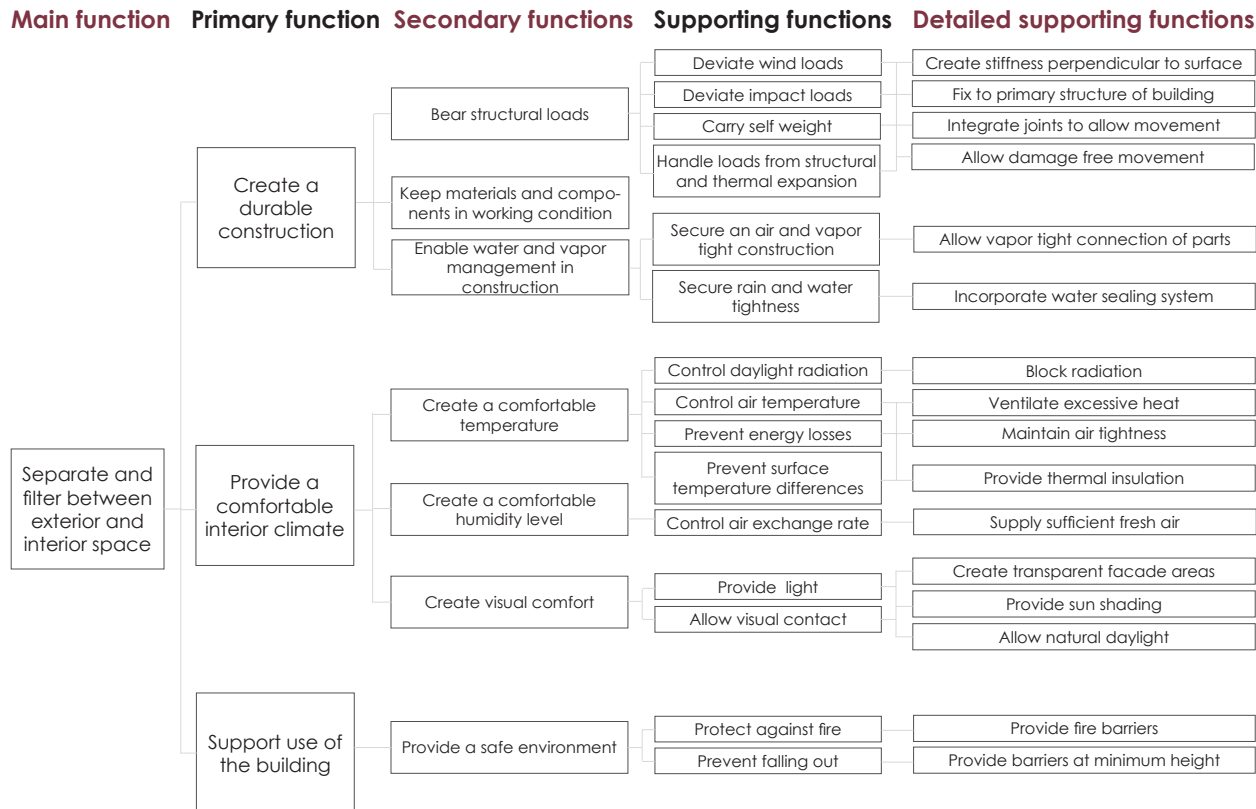


Building

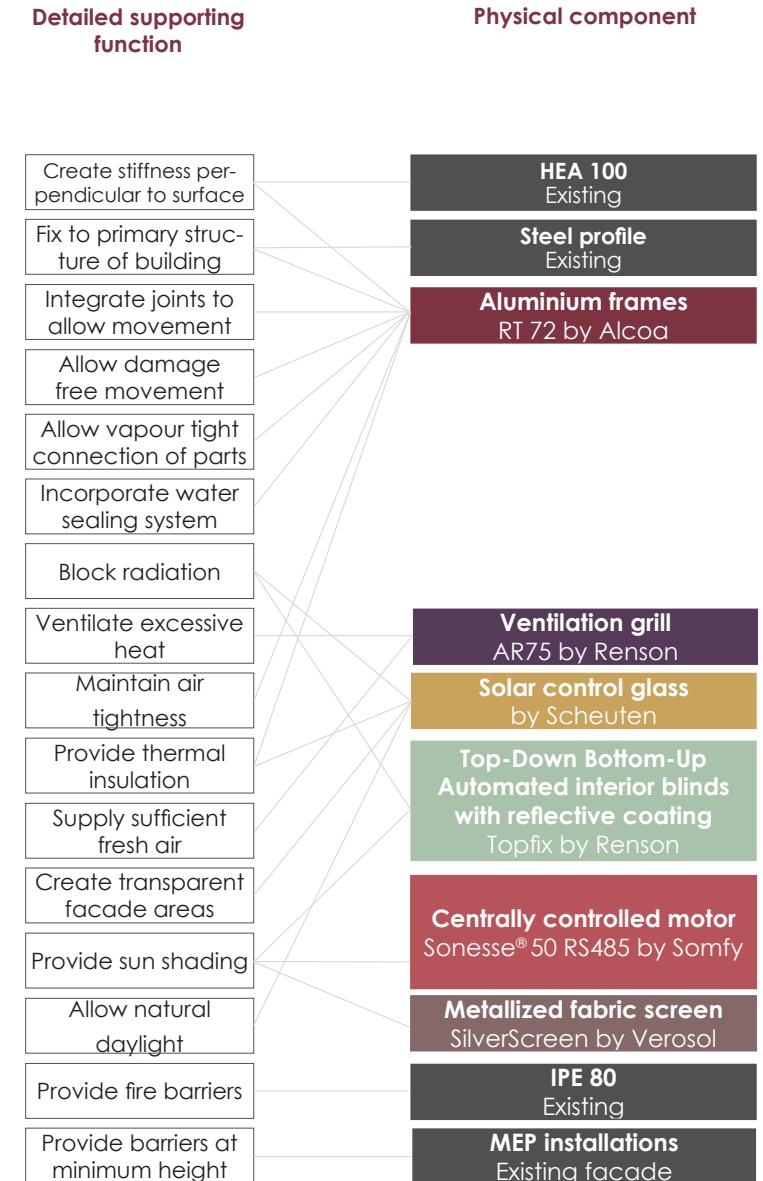


FUNCTIONAL ANALYSIS | Methodology

Functions definition (panel)

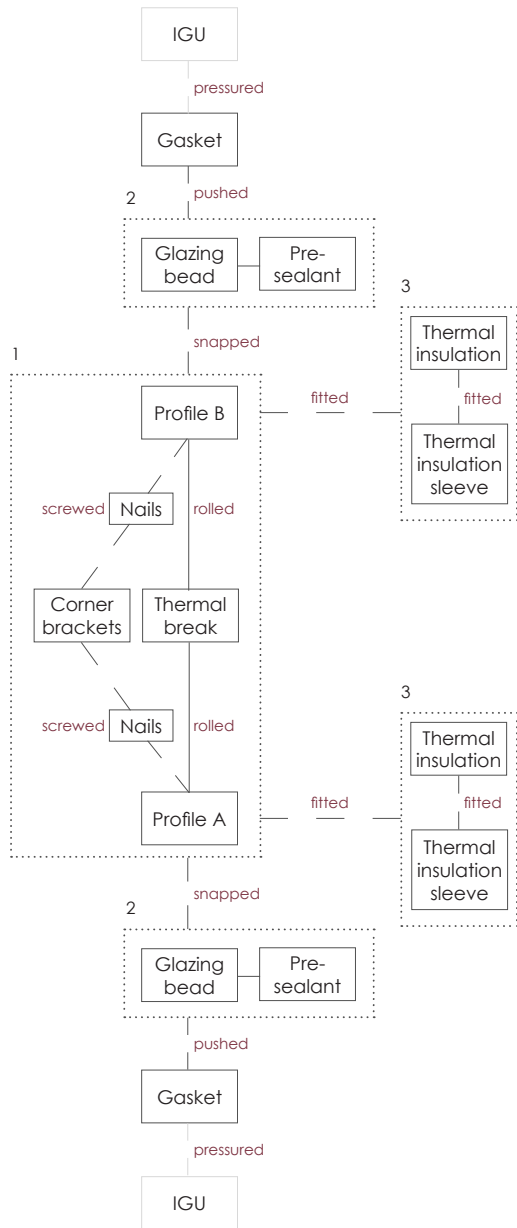


Functions structure (panel)

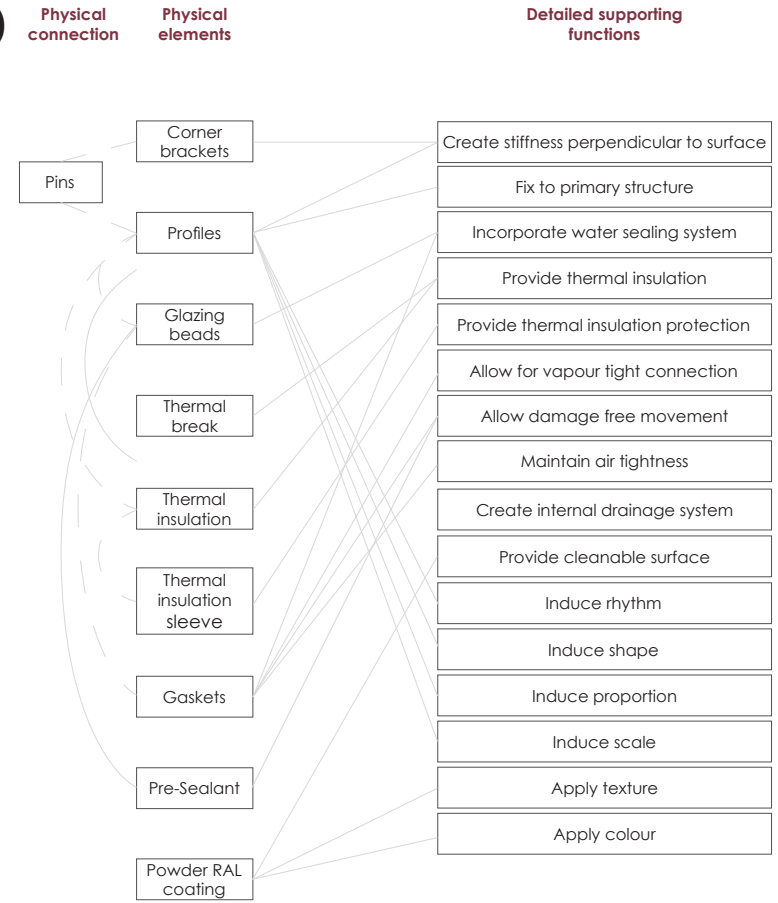


FUNCTIONAL ANALYSIS | Methodology

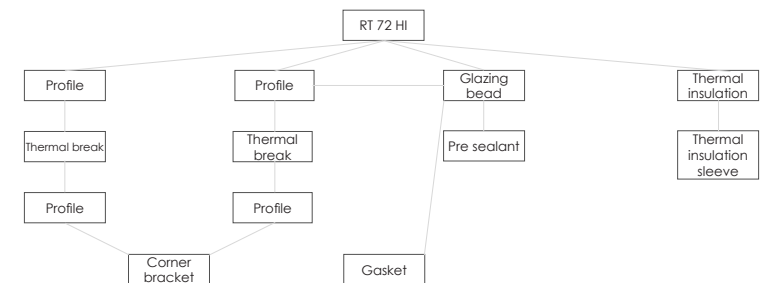
Configuration diagram (component)



Functions structure (component)



Relational patterns (component)



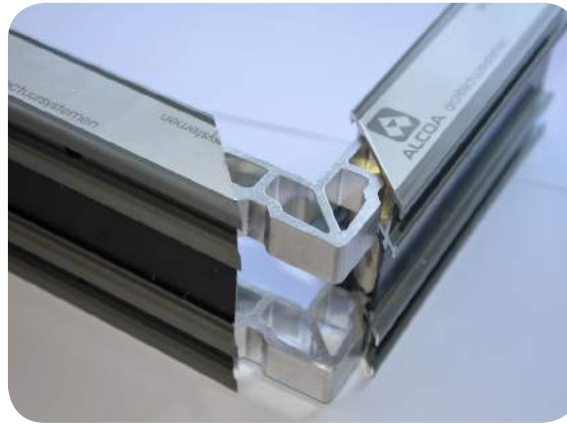
PRACTICAL DISASSEMBLY



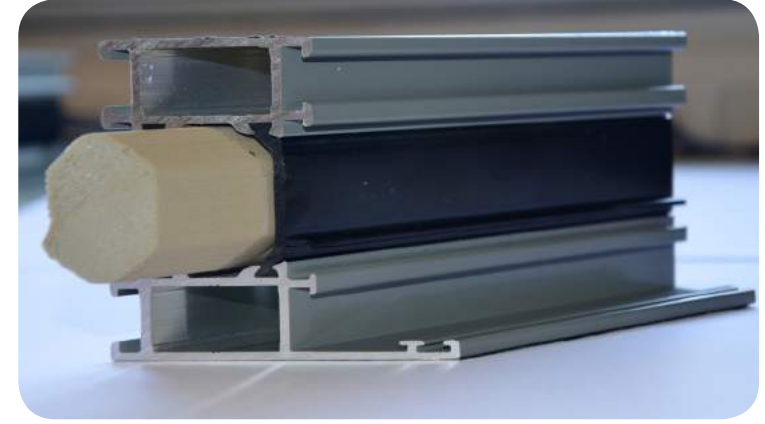
PRACTICAL DISASSEMBLY | Alcoa RT 72 / RT 72 HI



Remove pins



Remove corner brackets



Remove insulation



Polyamide strips are inserted in knurled aluminium profiles



Recyclable aluminium profiles & corner brackets

Possibility of reuse



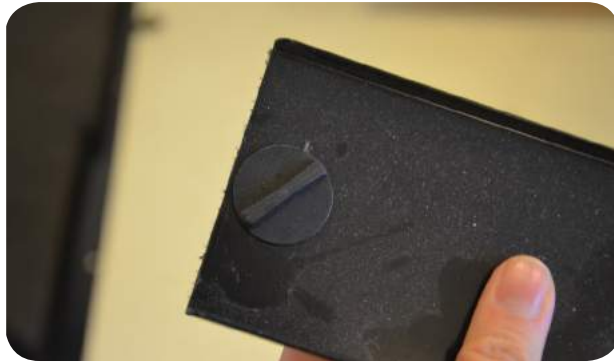
Inseparable aluminium profiles & polyamide thermal break

Non recyclable polyamide thermal break

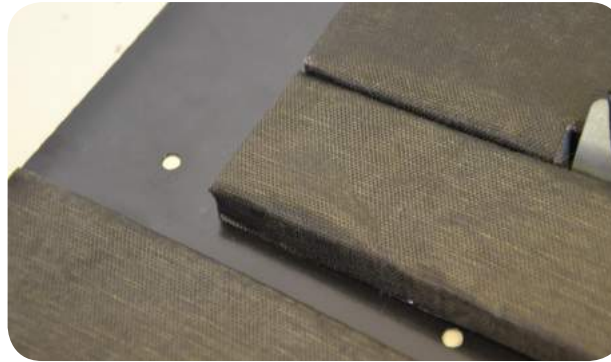
Non recyclable thermal insulation

Poor identification of materials

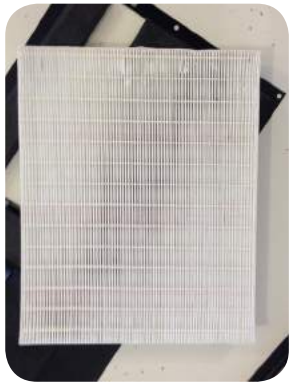
PRACTICAL DISASSEMBLY | Trox FSL-B-ZAB-SEK



Filter casing fastener - no tools needed



Sound insulation glued to casing



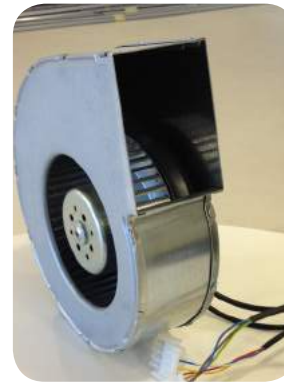
GF air filter



Mechanical valve



Heat recovery



Fan component



GF disposable air filter



Heat exchanger

Easy access to short lifetime elements



Easy disassembly for short lifetime elements

Parallel disassembly

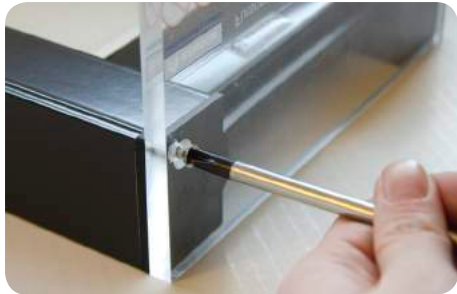
Inseparable sound insulation & steel casing

Inseparable aluminium fins and copper pipes

Disposable non-recyclable filters

Poor identification of materials

PRACTICAL DISASSEMBLY | Renson Fixscreen 100^{EVO}



Unscrew end caps of side channels



Unscrew side channels covers and profiles



Slide out zip guides



Unscrew box cover profile



Unscrew box covers



Unscrew cable unit



Snap out integrated switch



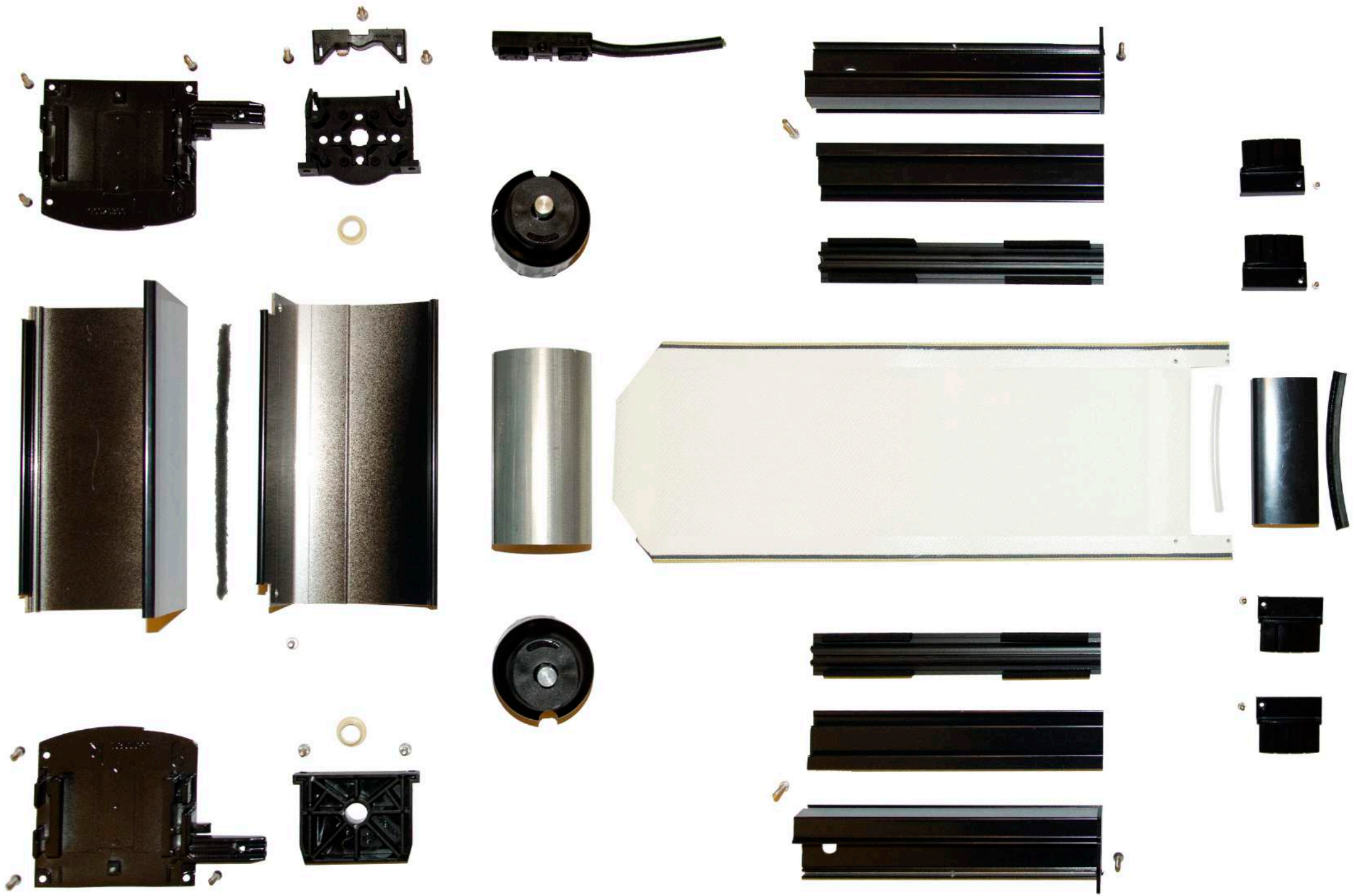
Push out motor support



Unscrew bottom bar end caps

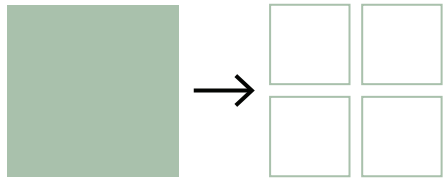
Almost everything can be taken apart
Most elements are recyclable
+ Connect & Go easy disassembly of textile tube
Texyloop recycling scheme

- Glued connection of zip guide & zip buffer
Poor identification of materials

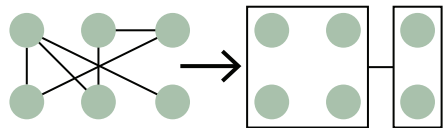


DfD EVALUATION | Criteria

Functional decomposition

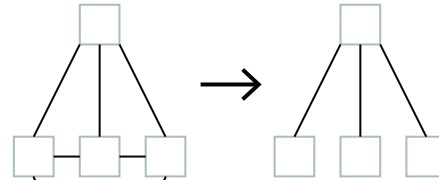


Functional independence

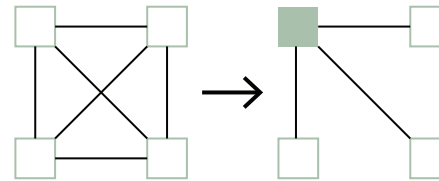


Systematization & Clustering

Technical decomposition

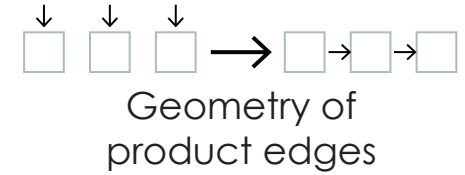


Relational patterns

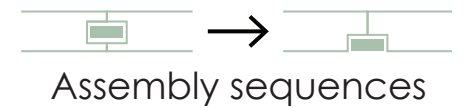


Base element specification

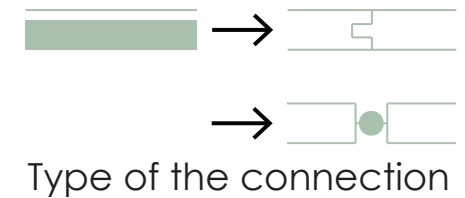
Physical decomposition



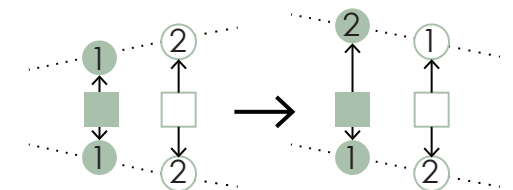
Geometry of product edges



Assembly sequences

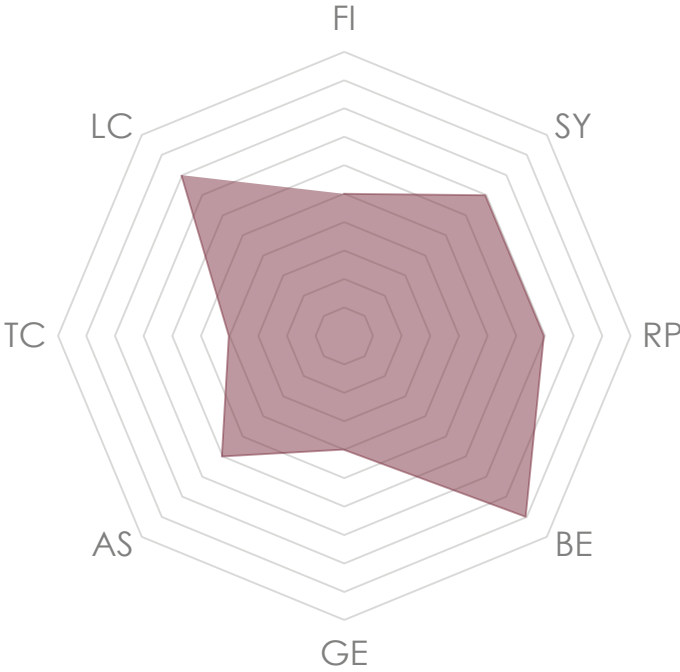


Type of the connection

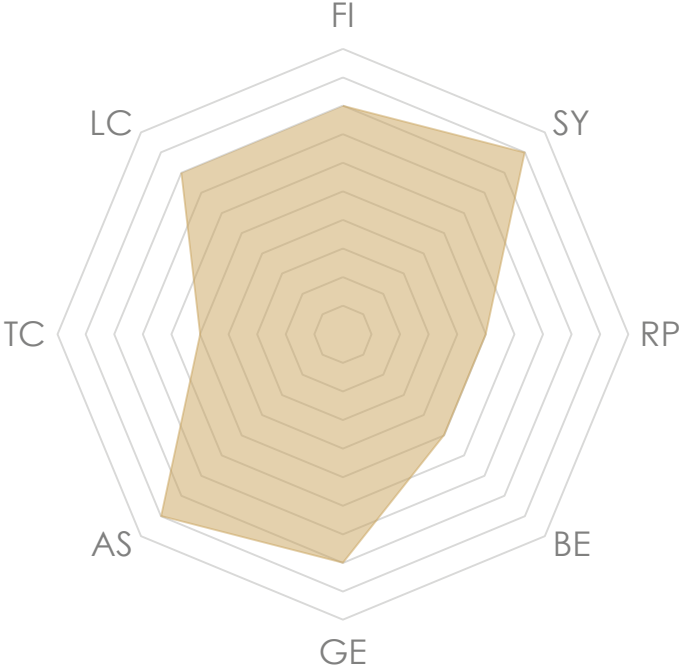


Life cycle coordination

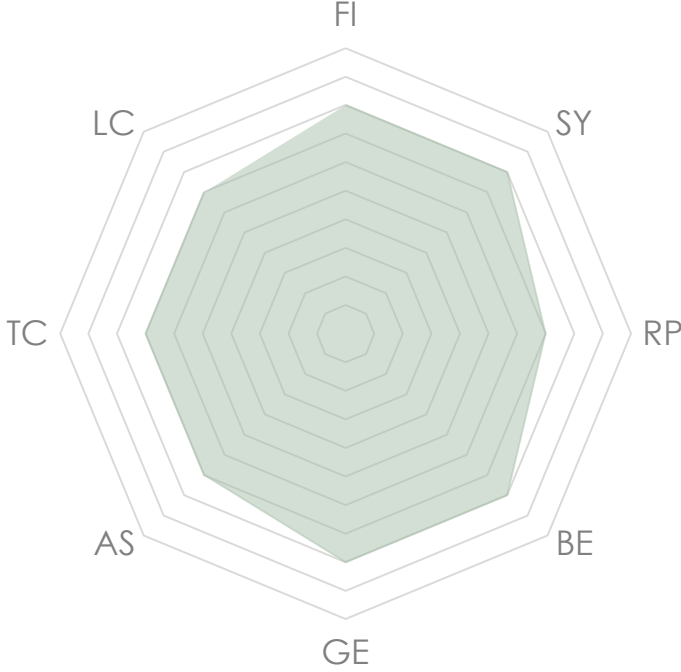
DfD EVALUATION



ALCOA RT 72, RT 72 HI

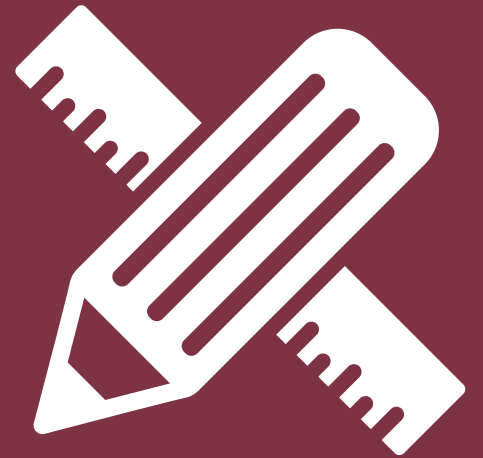


TROX FSL-B-ZAB-SEK



RENSON FIXSCREEN 100^{EVO}

DESIGN



DESIGN | Methodology

*Based on
practical disassembly*

PROBLEM STATEMENT

*Based on
problem statement*

OBJECTIVES

*From construction
and other industries*

REFERENCES

Sketching

DESIGN PROPOSALS

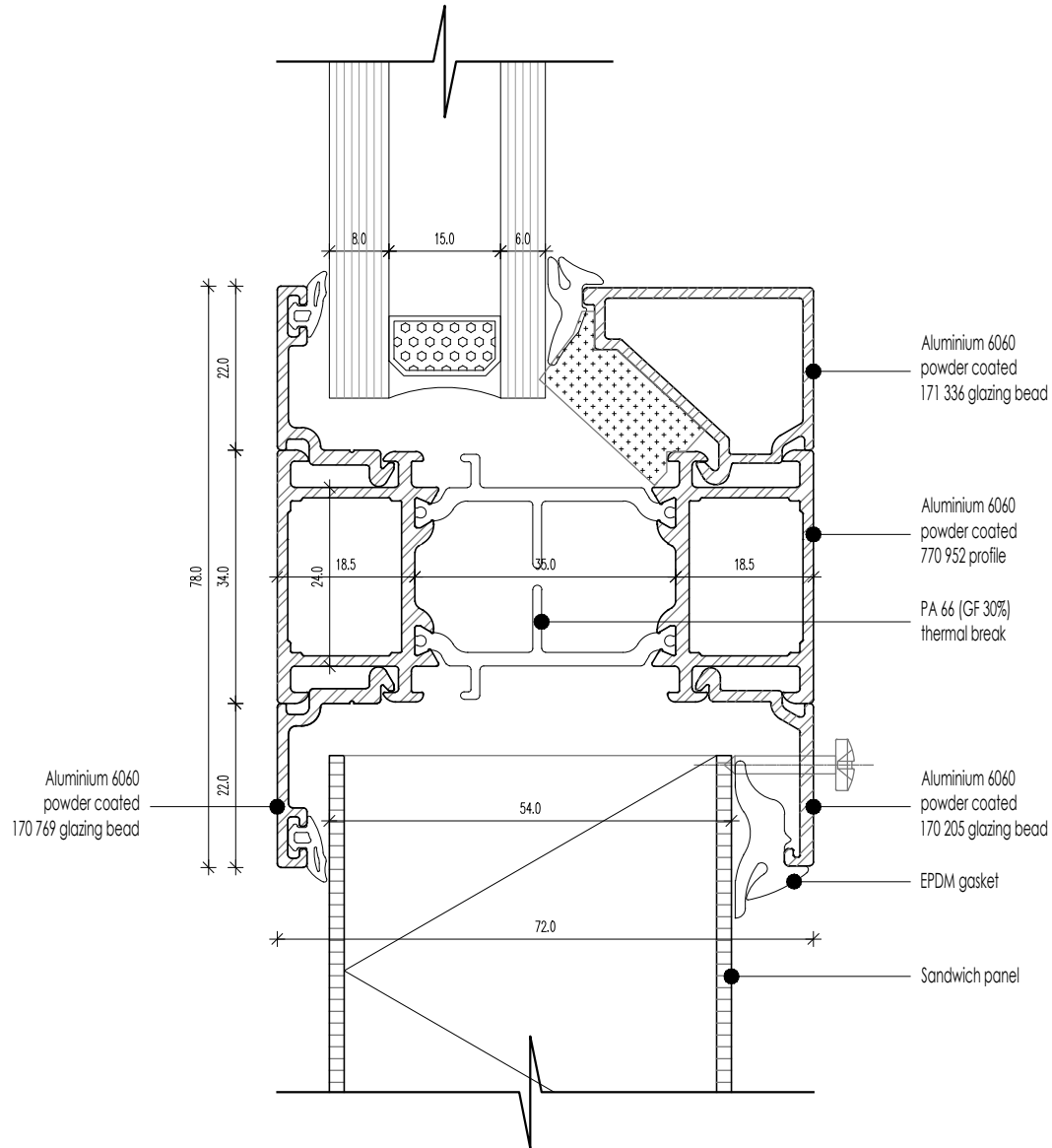
*Based on existing
design evaluation*

EVALUATION

RESEARCH

DESIGN

ALCOA RT 72 | Thermal break / aluminium profile connection



PROBLEM STATEMENT (1)

Inseparable aluminium profiles & polyamide thermal break

OBJECTIVES (1)

Separate elements
Make frame homogeneous

REFERENCES (1)



Timber frame
Aluminium cladding

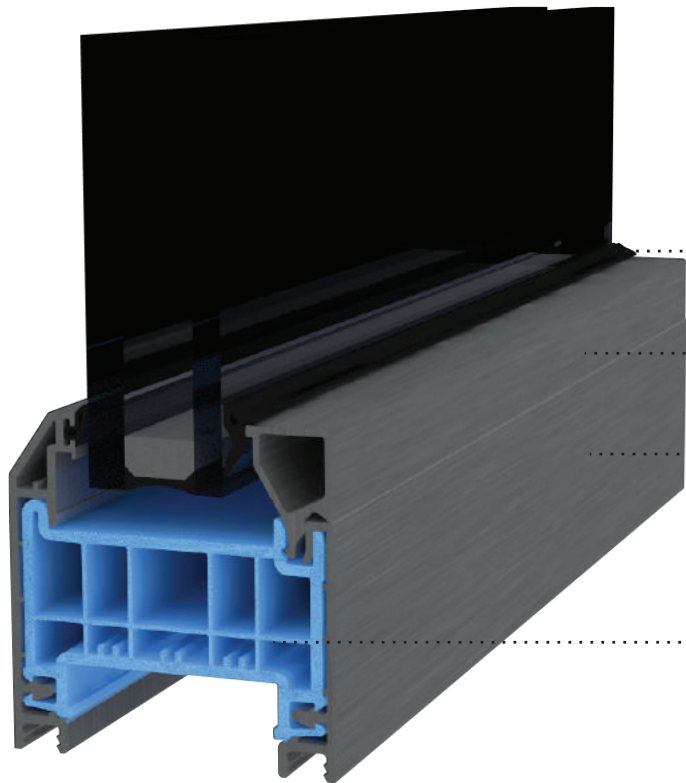


uPVC



GFRP
(Xframe by
PRO TEC)

ALCOA RT 72 | Design 1

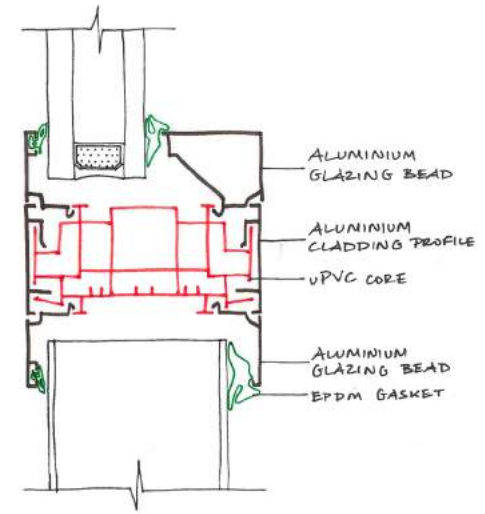


EPDM
gasket

Aluminium
glazing bead

Aluminium
profile

uPVC
thermal core



ALUMINIUM
GLAZING BEAD

ALUMINIUM
CLADDING PROFILE

uPVC CORE

ALUMINIUM
GLAZING BEAD

EPDM GASKET

REFERENCES

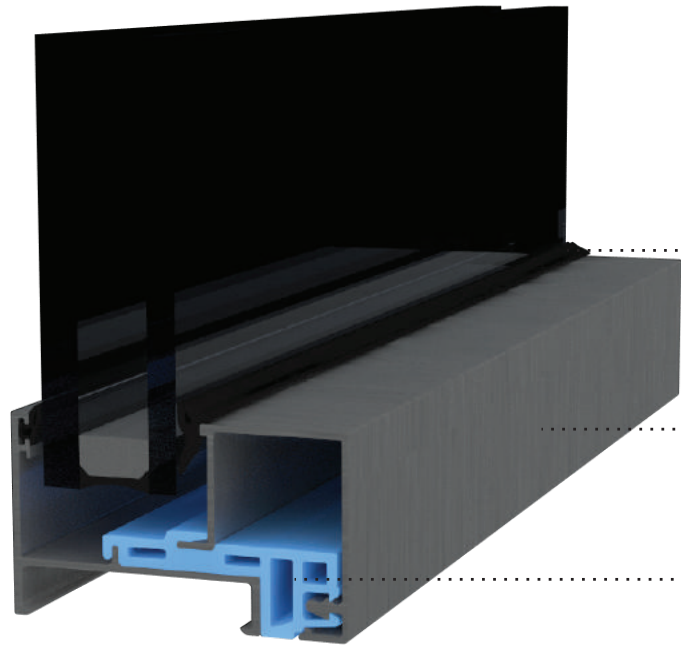


CHARACTERISTICS

uPVC core

Snap-on aluminium cladding

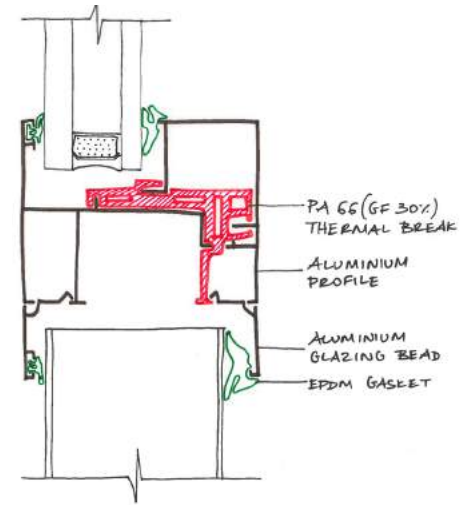
ALCOA RT 72 | Design 2



EPDM
gasket

Aluminium
profile

Polyamide
thermal break



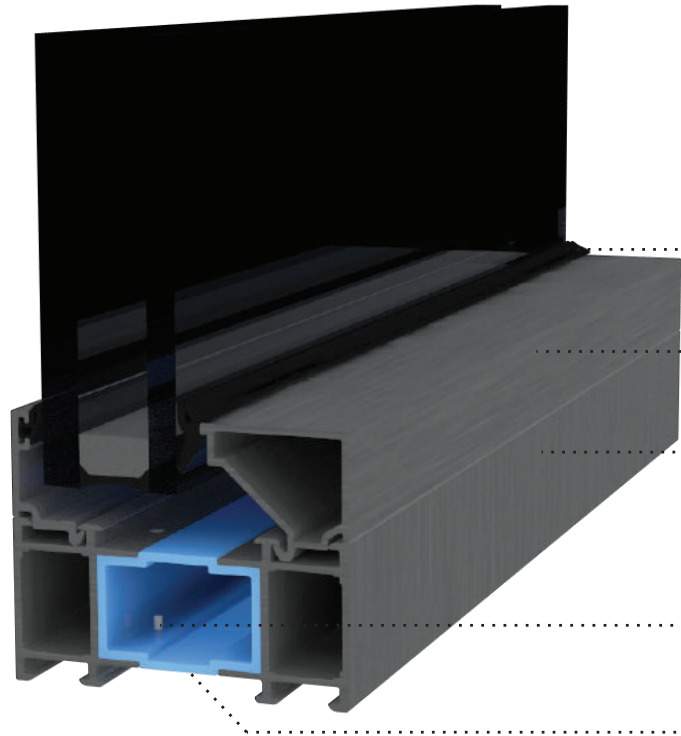
REFERENCES



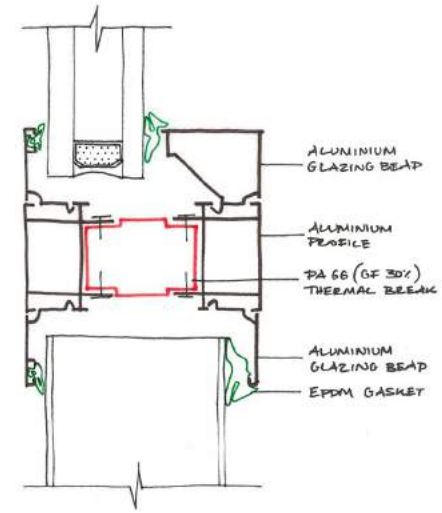
CHARACTERISTICS

PA66 thermal break
Snap-on aluminium profiles

ALCOA RT 72 | Design 3



- EPDM gasket
- Aluminium glazing bead
- Aluminium profile
- Stainless steel pin
- Polyamide thermal break



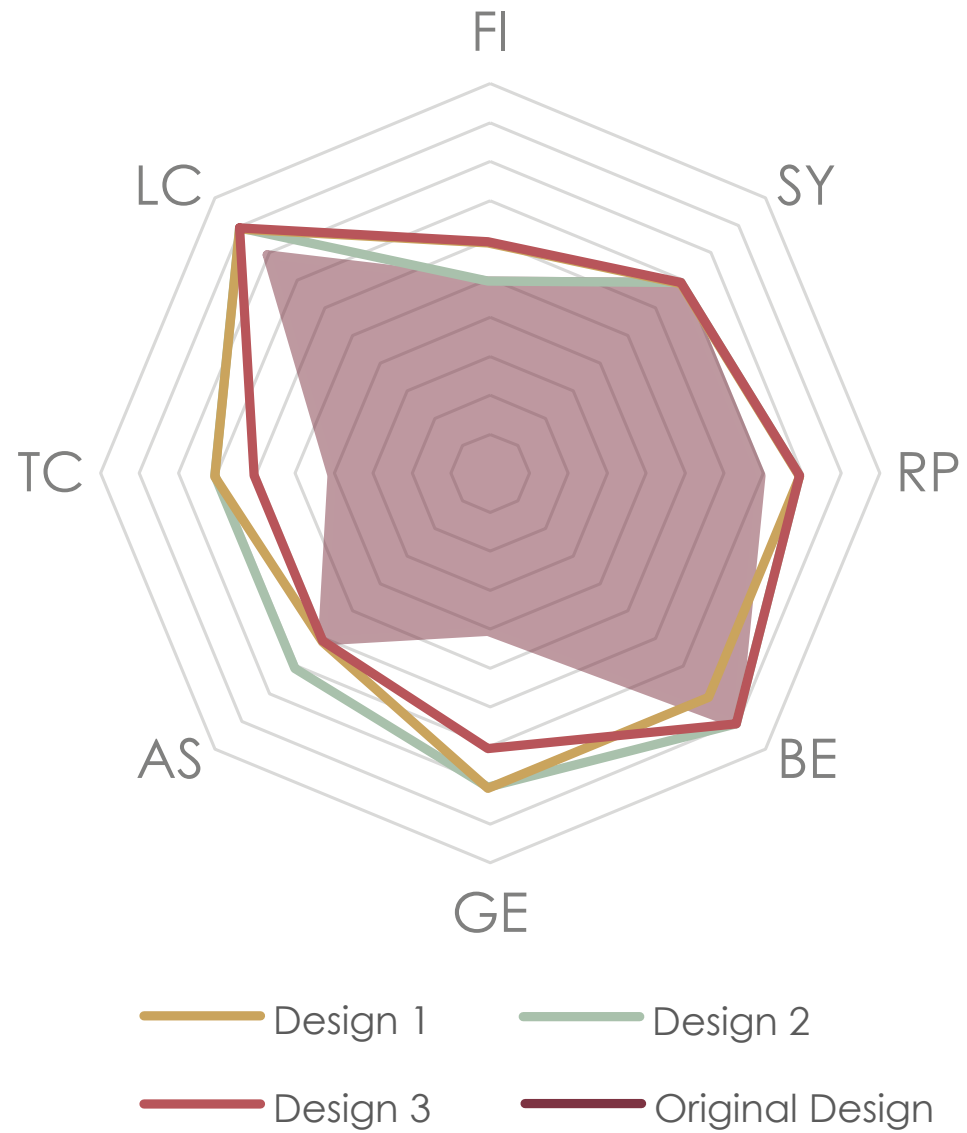
REFERENCES



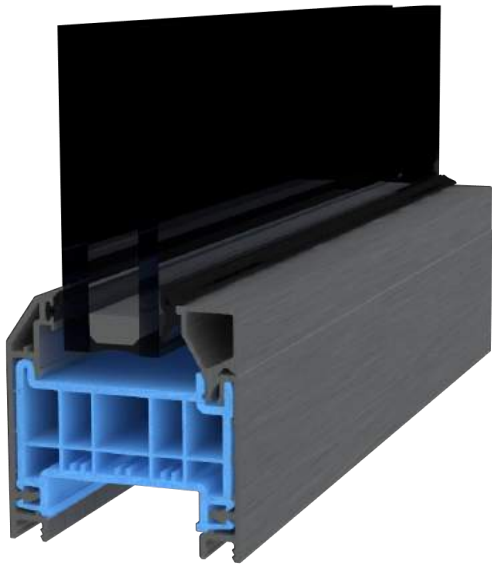
CHARACTERISTICS

- Closed profile thermal break
- Mechanically fastened

ALCOA RT 72 | Design Evaluation



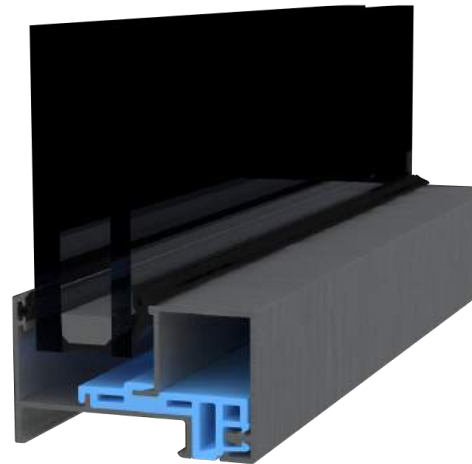
ALCOA RT 72 | Company input



DESIGN 1

Production difficulties in welding corners

PVC not ideal for recycling

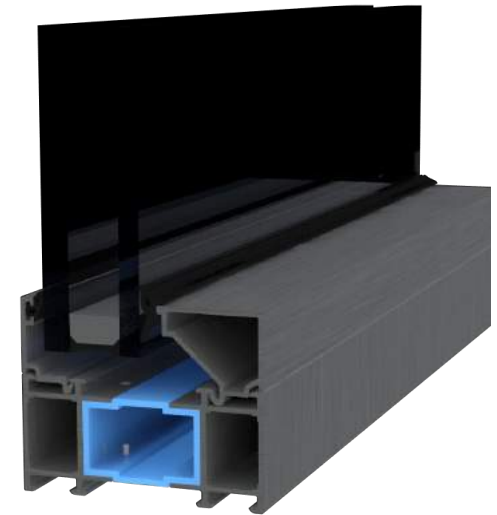


DESIGN 2

Larger distance between aluminium profiles

ABS instead of PA

Space for thermal insulation



DESIGN 3

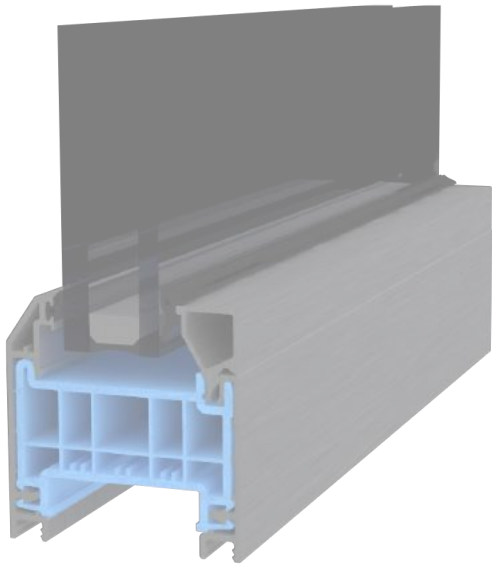
Long assembly & disassembly time

ABS instead of PA

Space for thermal insulation

Possible noise problem in factory

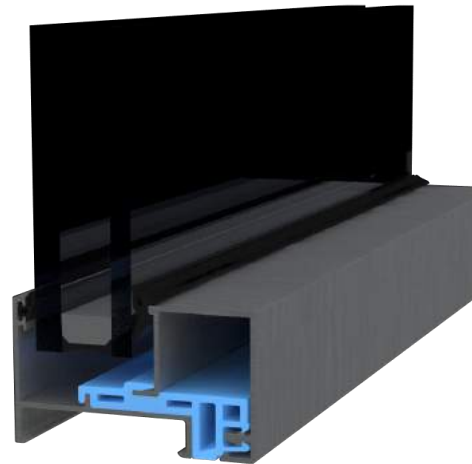
ALCOA RT 72 | Company input



DESIGN 1

Production difficulties in welding corners

PVC not ideal for recycling

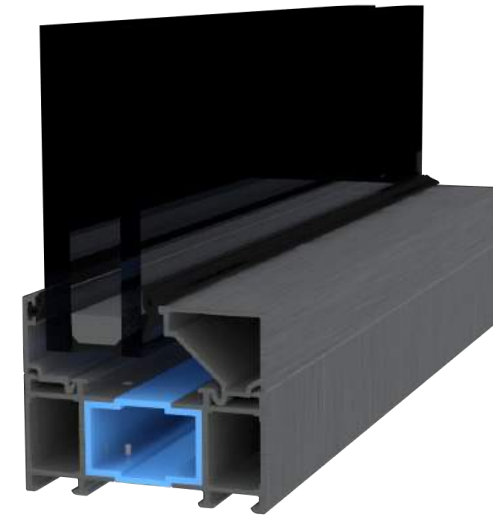


DESIGN 2

Larger distance between aluminium profiles

ABS instead of PA

Space for thermal insulation



DESIGN 3

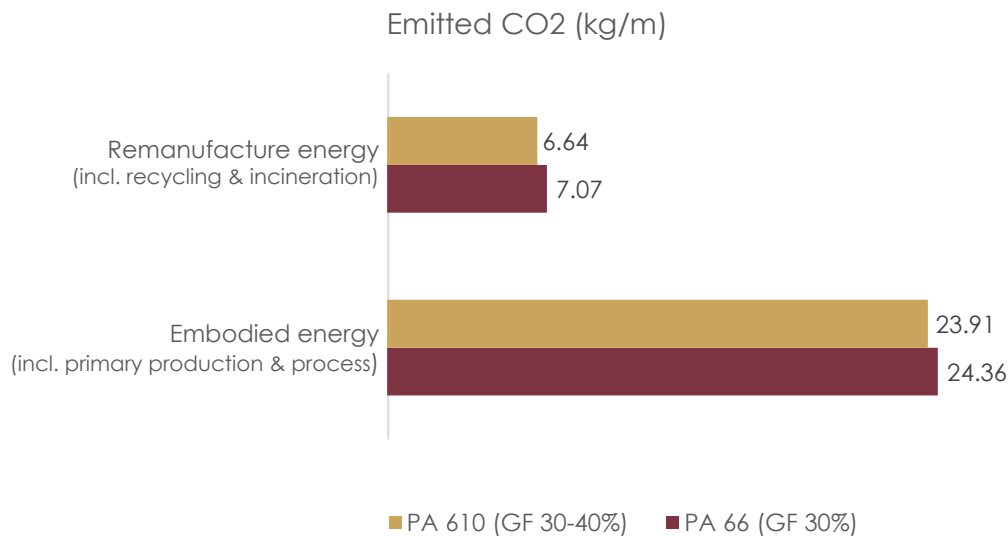
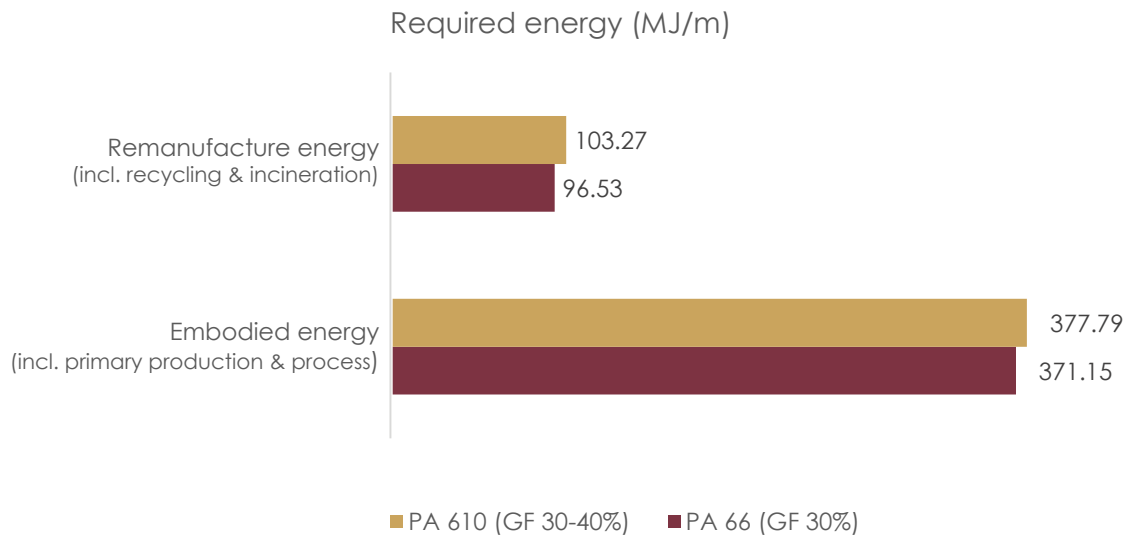
Long assembly & disassembly time

ABS instead of PA

Space for thermal insulation

Possible noise problem in factory

ALCOA RT 72 | Thermal break material



PROBLEM STATEMENT (2)

Polyamide thermal break (PA 66 GF 30%) is non recyclable

OBJECTIVES (2)

- Increase recycling fraction of polyamide
- Use more sustainable material for thermal break

REFERENCES (2)



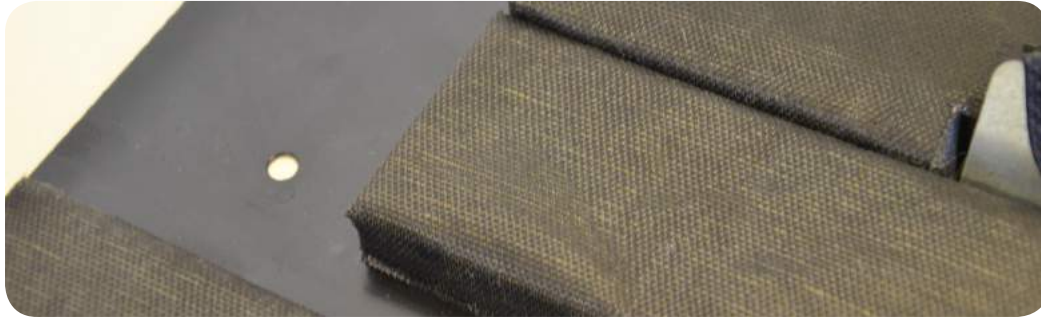
Recycled polyamide

- 89% less fossil fuel
- 32% less water
- 84% less CO₂

PA 610

Made out of castor oil seeds

TROX FSL-B-ZAB-SEK | Steel casing / sound insulation connection



PROBLEM STATEMENT

Glued sound insulation to steel casing makes recycling harder

OBJECTIVE

Separate elements to ease recycling and reuse

REFERENCES



Velcro



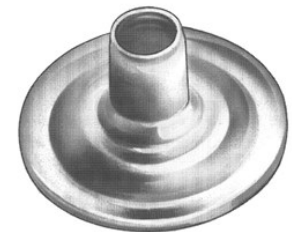
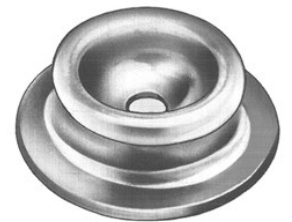
Fit in



Magnet

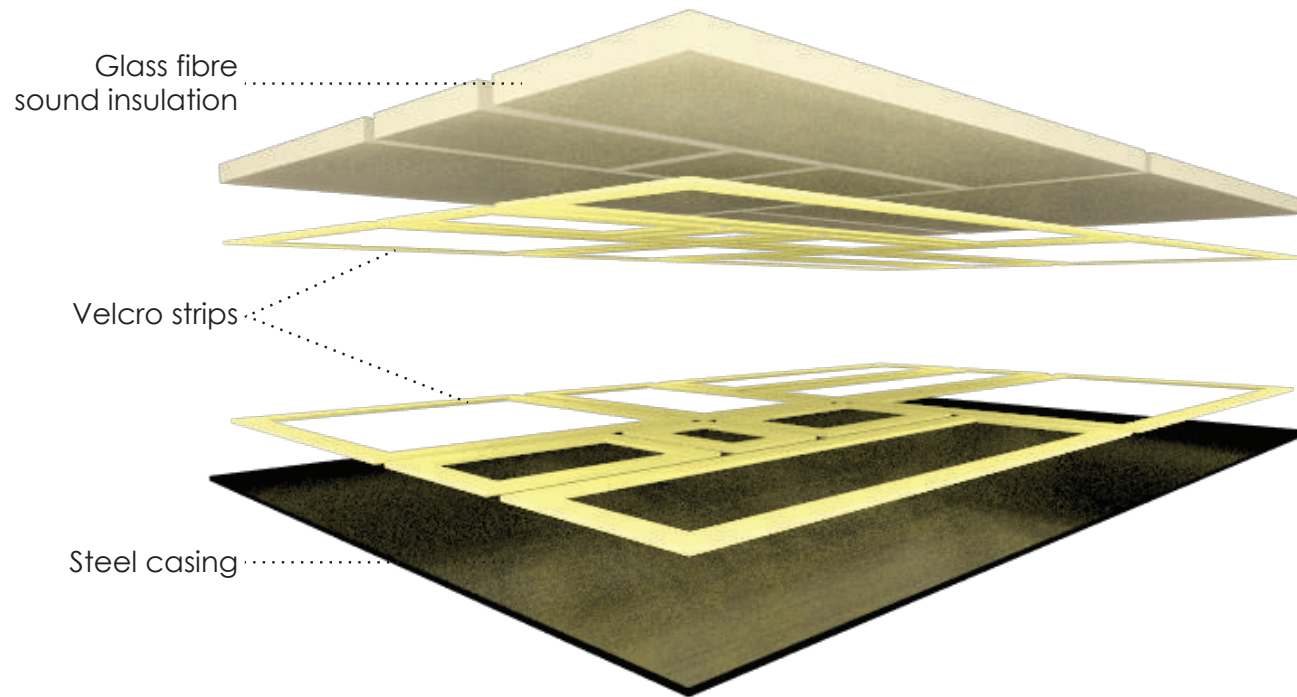


Elastic band



Dot snap

TROX FSL-B-ZAB-SEK | Design 1



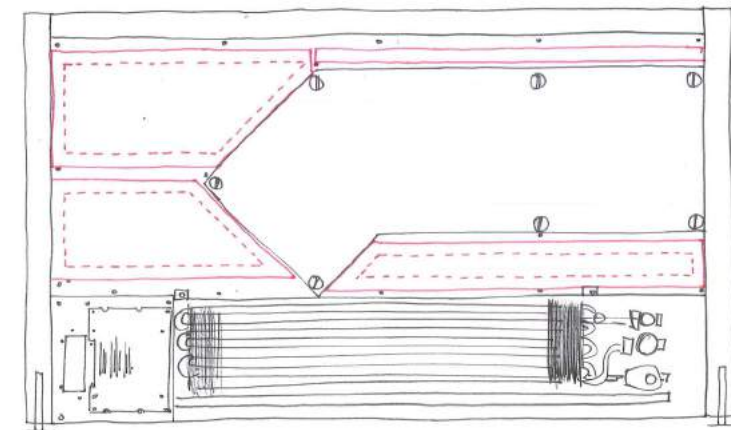
REFERENCES



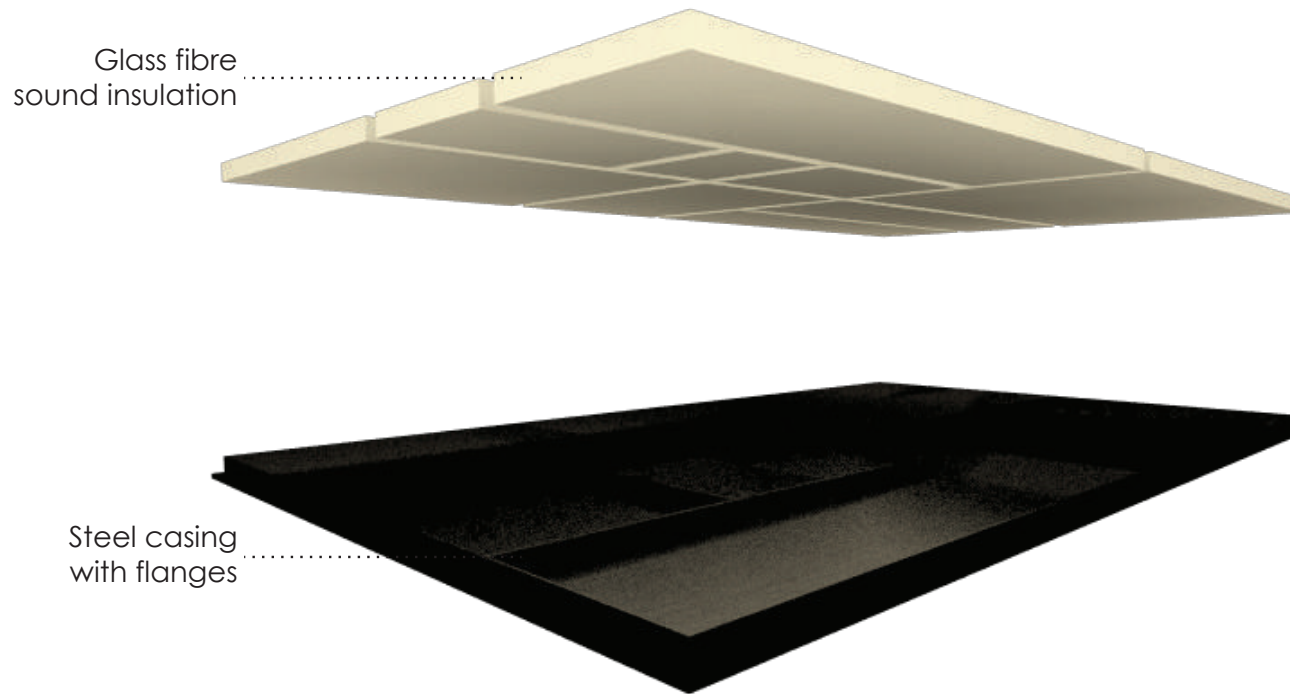
CHARACTERISTICS

Velcro strips glued on the perimeter of each insulation piece

- Need for adhesive
- + Less glued surface
- + Easy reuse



TROX FSL-B-ZAB-SEK | Design 2



REFERENCES

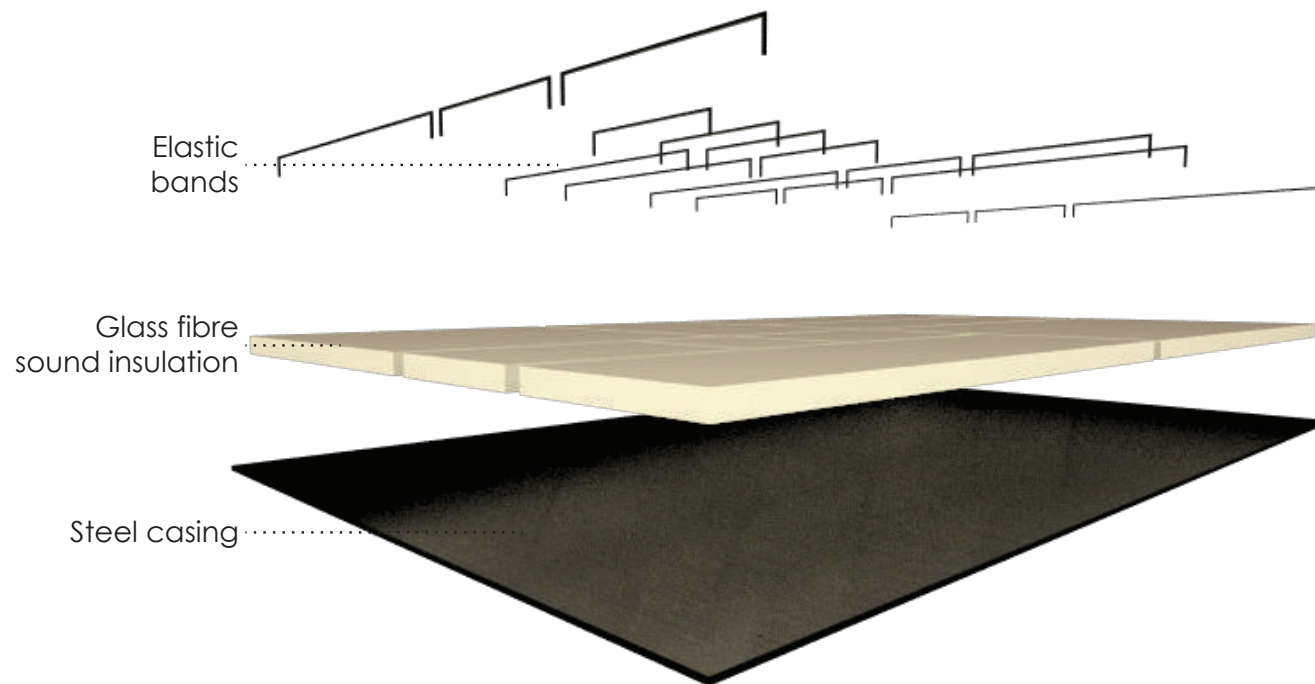


CHARACTERISTICS

Insulation is fitted in steel casing flanges

- More material
- More energy in producing
- + No contamination
- + Easy reuse

TROX FSL-B-ZAB-SEK | Design 3



REFERENCES

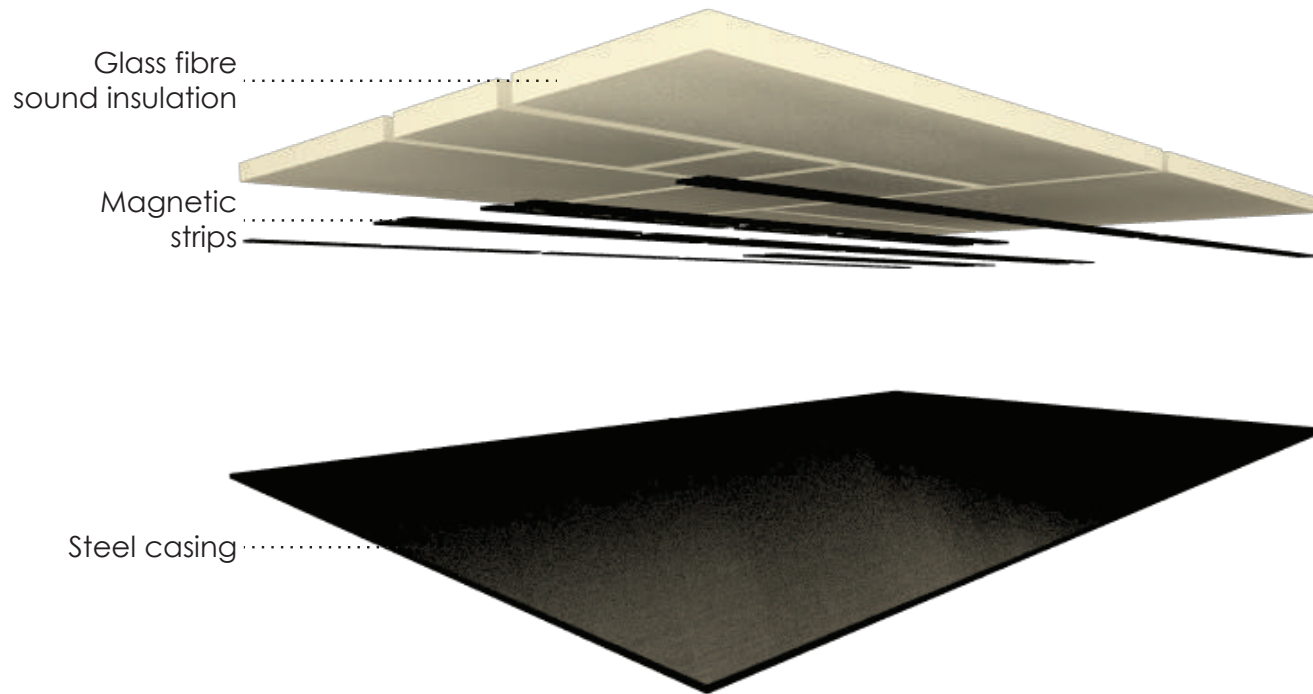


CHARACTERISTICS

Insulation kept in place by elastic bands

- Penetration of casing
- + No contamination
- + Easy reuse

TROX FSL-B-ZAB-SEK | Design 4



REFERENCES

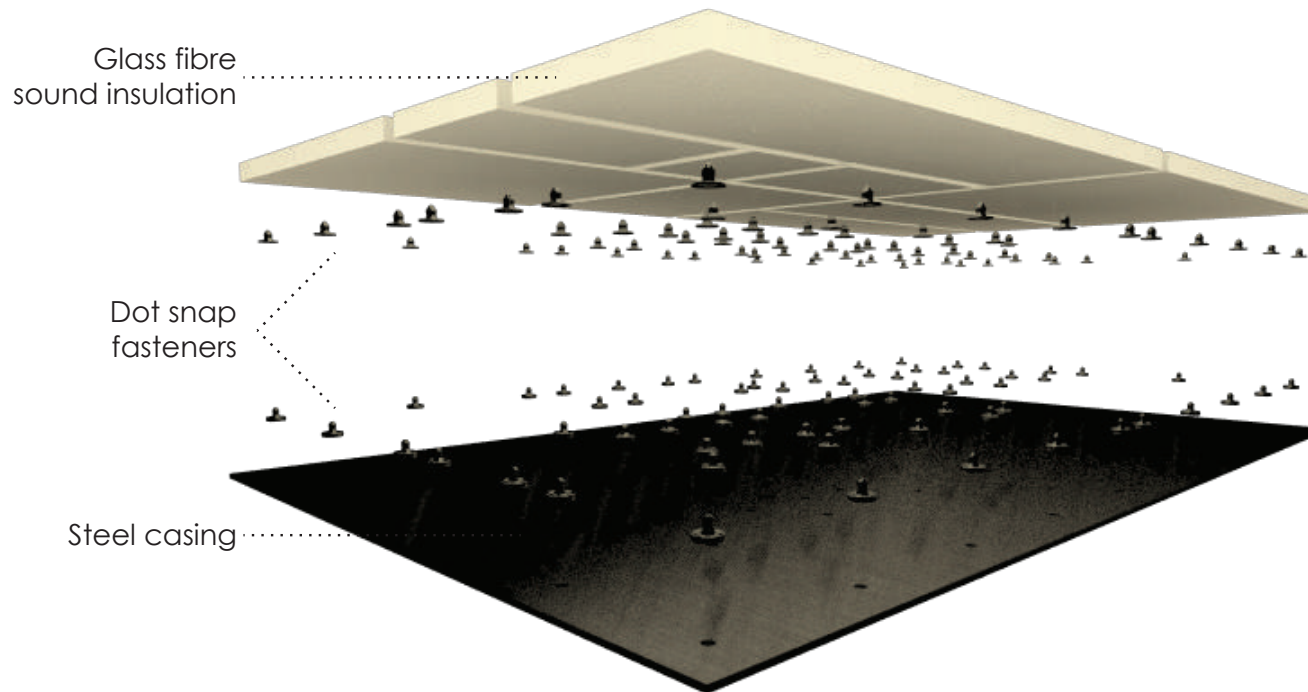


CHARACTERISTICS

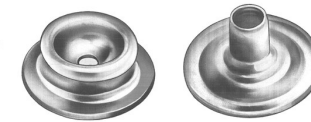
Magnetic surface glued on
perimeter of insulation pieces

- Need for adhesive
- Magnet resources
- + Less glued surface
- + Easy reuse

TROX FSL-B-ZAB-SEK | Design 5



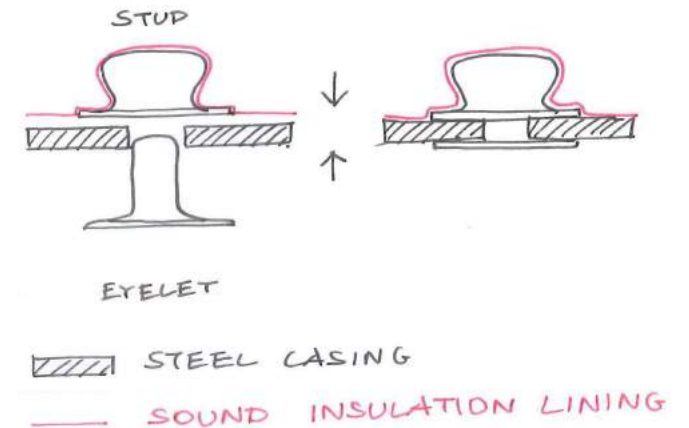
REFERENCES



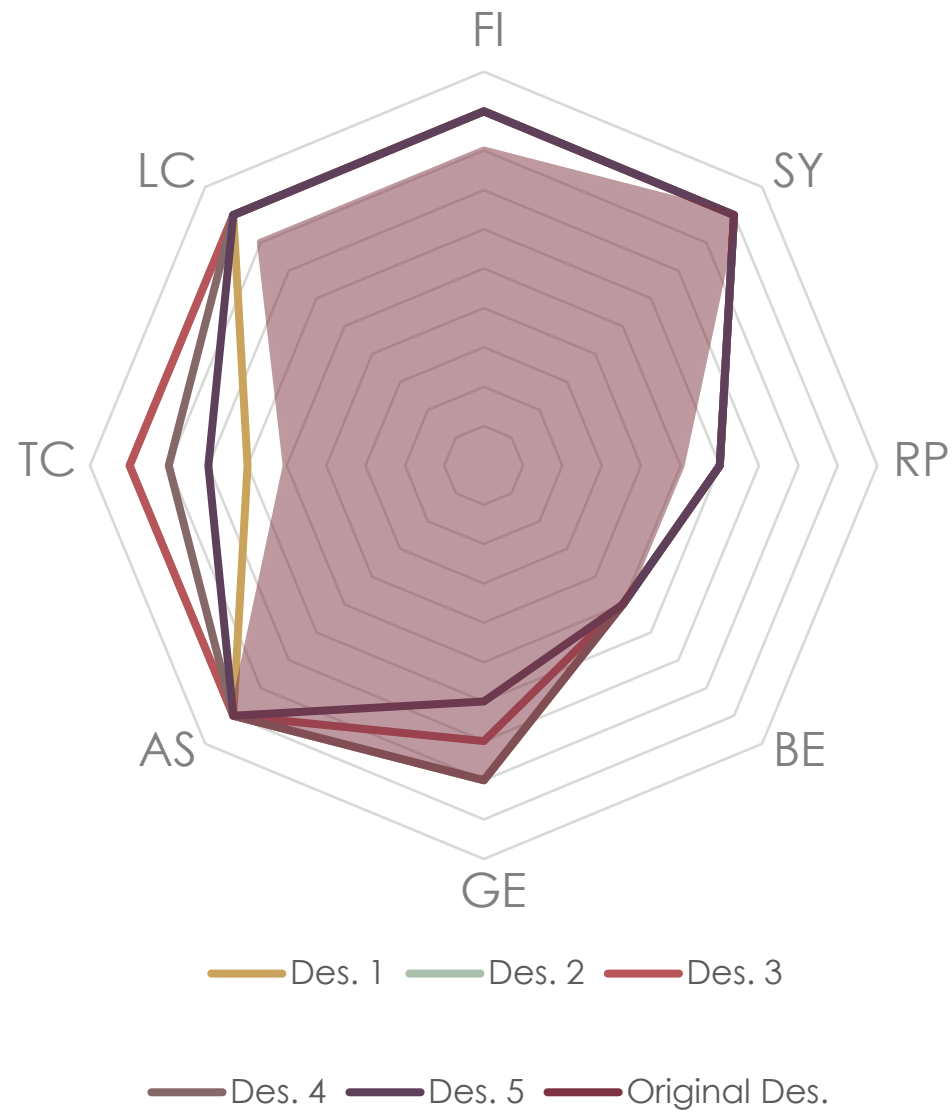
CHARACTERISTICS

Point mechanical connections on perimeter of insulation pieces

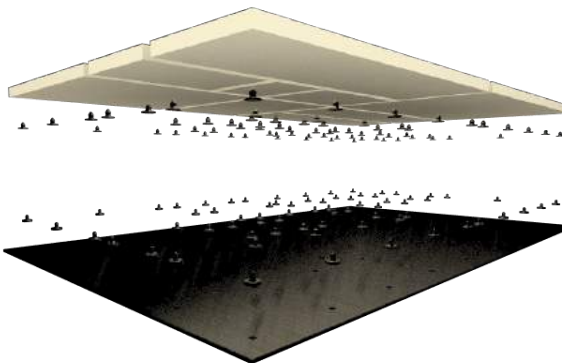
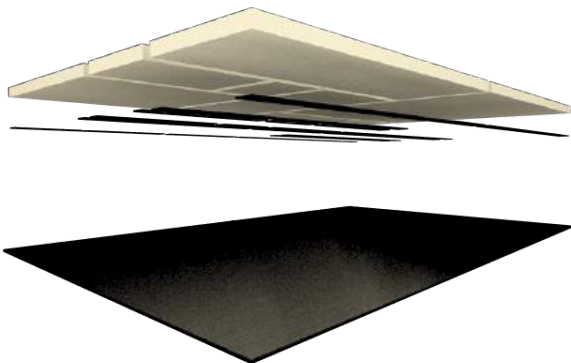
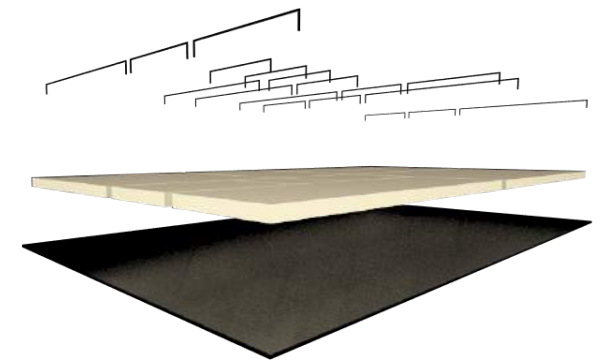
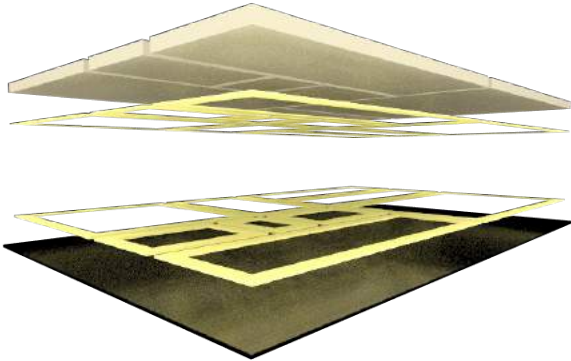
- Penetration of casing
- Possible drawbacks in sound insulation
- + Easy reuse



TROX FSL-B-ZAB-SEK | Design Evaluation



TROX FSL-B-ZAB-SEK | Company input

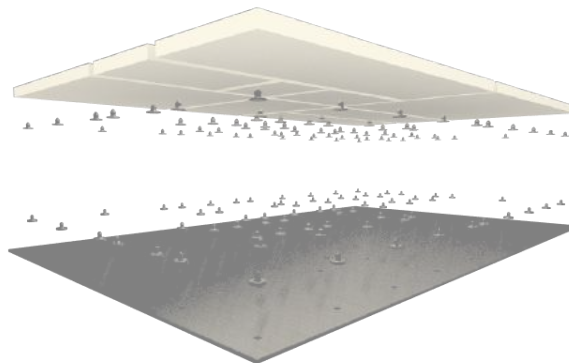
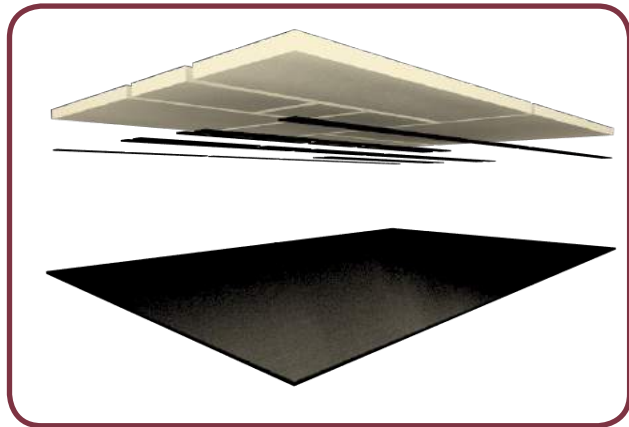
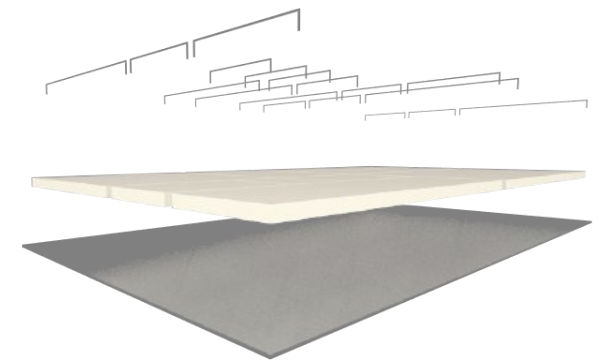
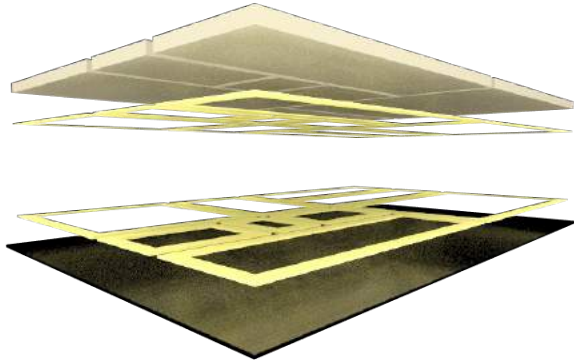


50-60 insulation parts per unit
(some of which small)

Any new design should not
increase fire load

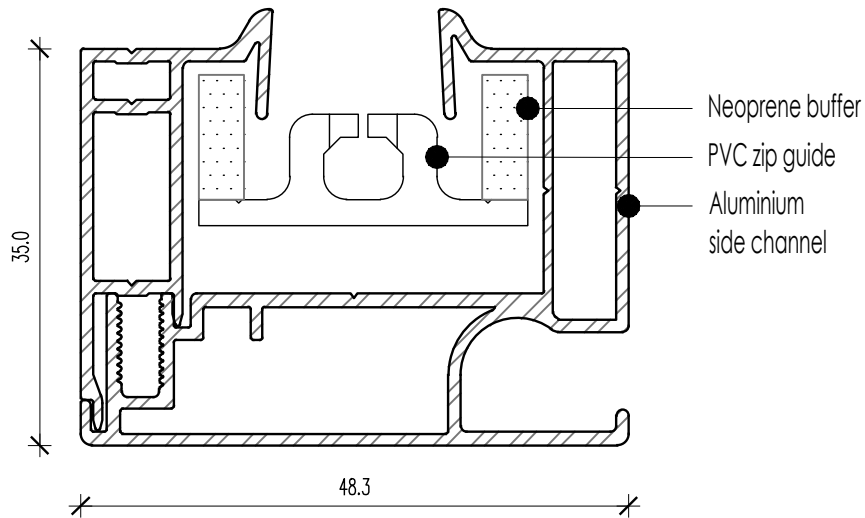
No perforation of casing
(air tightness)

TROX FSL-B-ZAB-SEK | Company input



Magnetic connections are the most interesting to develop

RENSON FIXSCREEN 100^{EVO} | Buffers to zip guide connection



PROBLEM STATEMENT (1)

Neoprene is non recyclable.

OBJECTIVE (1)

Replace neoprene with a more sustainable material

PROBLEM STATEMENT (2)

Neoprene buffers are glued to PVC zip guides

OBJECTIVE (2)

Separate elements

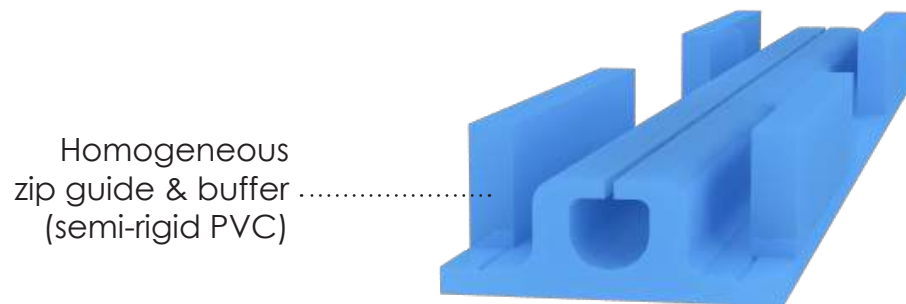
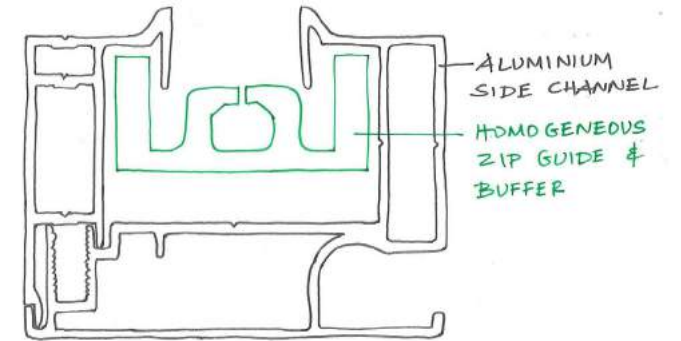
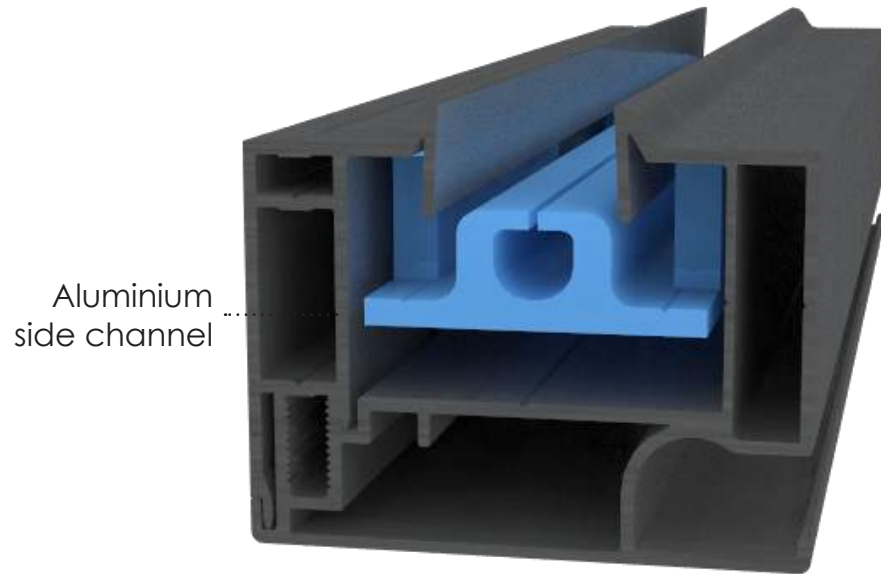
REFERENCE



Neogreene

25% less fossil fuel
25% less energy

RENSON FIXSCREEN 100^{EVO} | Design 1

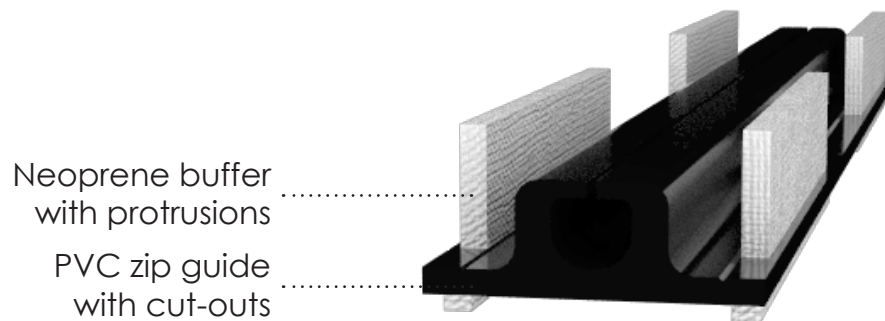
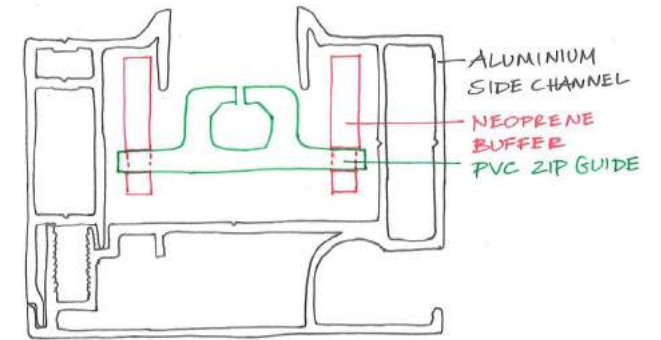
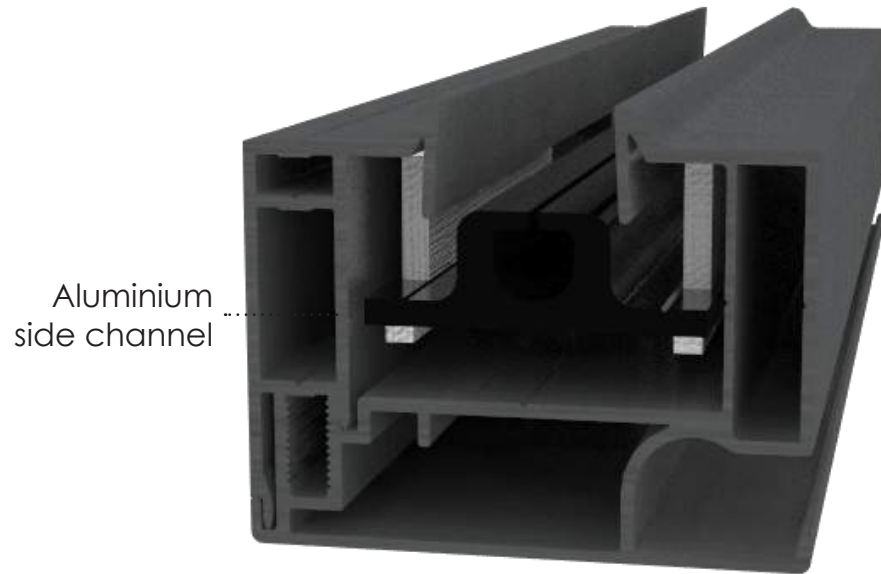


CHARACTERISTICS

Homogeneous element
Semi-rigid PVC

- + Recyclable
- + Less elements
- Material rigidity

RENSON FIXSCREEN 100^{EVO} | Design 2



CHARACTERISTICS

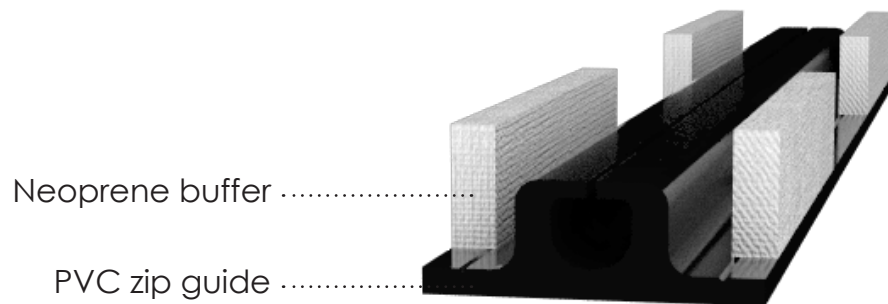
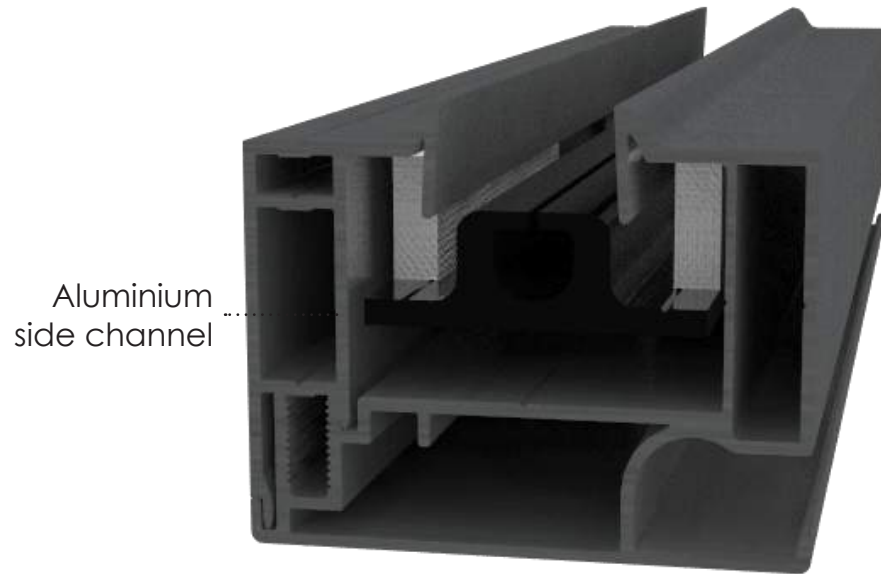
Interlocking elements

+ Easy disassembly

+ No adhesives

- Additional production processes

RENSON FIXSCREEN 100^{EVO} | Original design



CHARACTERISTICS

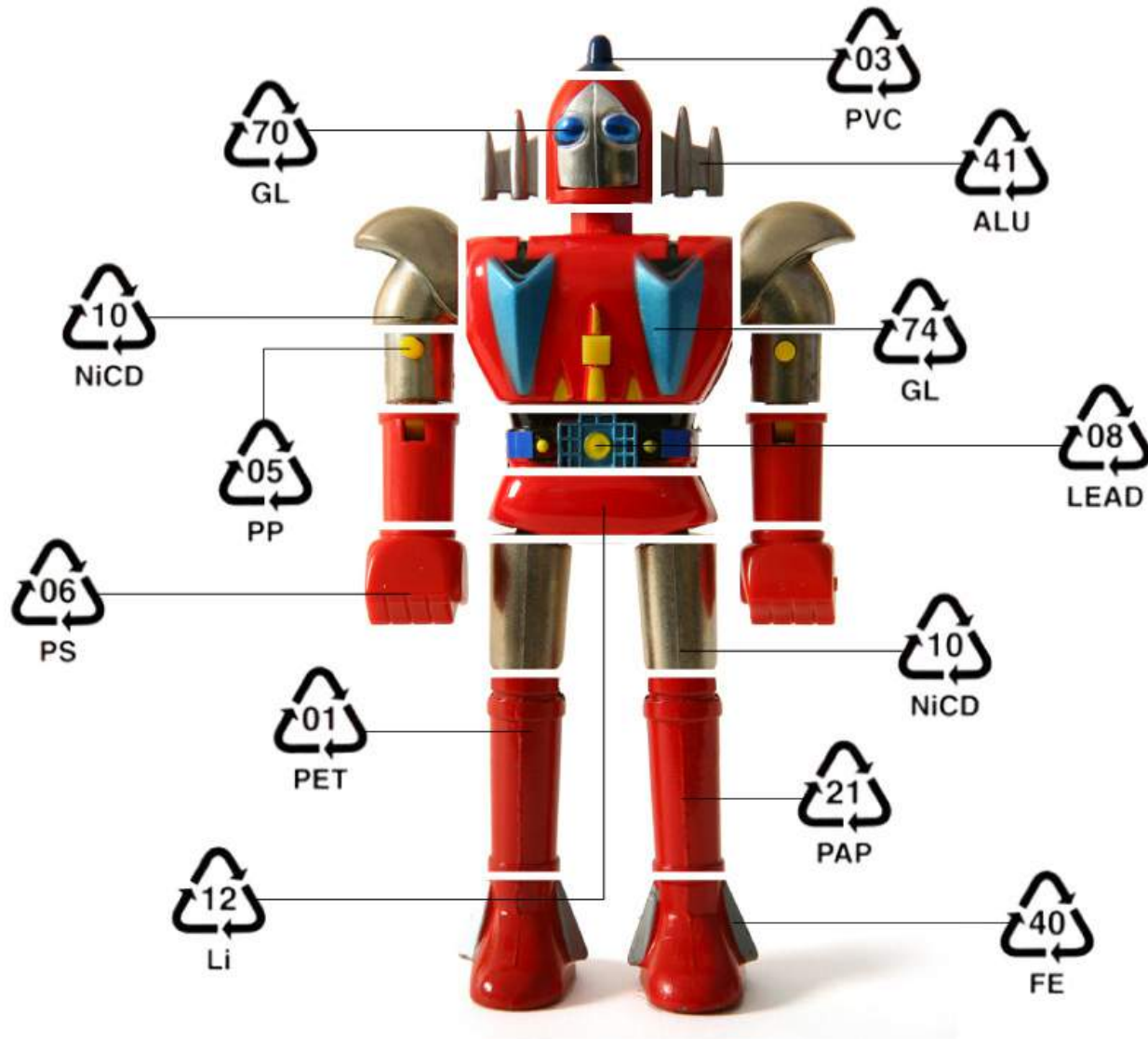
Glued buffers to zip guides

- + Easy to separate
- + Simple and fast production

- Use of adhesives

Is it worth it to change it?

GENERAL RECOMMENDATION | Identification



MATERIAL

COMPONENT FUNCTION

RECOMMENDED END-OF-LIFE

SUPPLIER

DISASSEMBLY INSTRUCTIONS



THE GREATER PICTURE



THE GREATER PICTURE | Aluminium



Bauxite mining in million tonnes (USGS data, 2006)

THE GREATER PICTURE | Aluminium



Alumina refining in million tonnes (USGS data, 2006)

THE GREATER PICTURE | Aluminium



Aluminium primary production in million tonnes (USGS data, 2006)

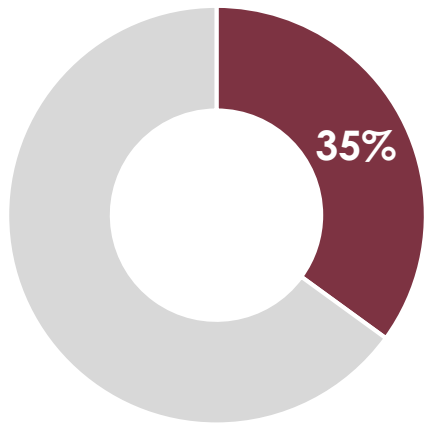
THE GREATER PICTURE | Aluminium



Aluminium secondary production in million tonnes (USGS data, 2006)

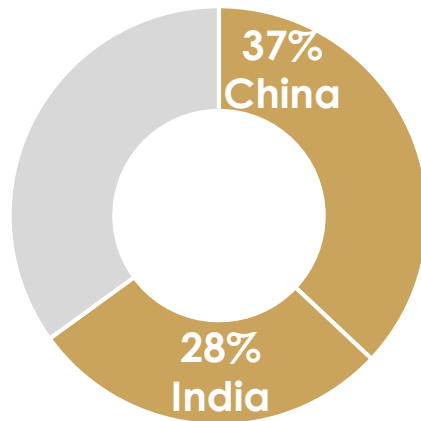
THE GREATER PICTURE | Aluminium

Aluminium use
in construction



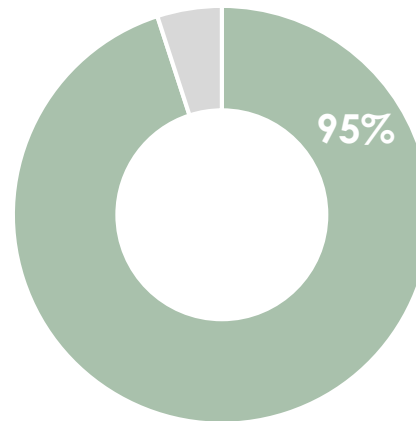
(IAI 2013)

Destinations of EU
aluminium scrap exports



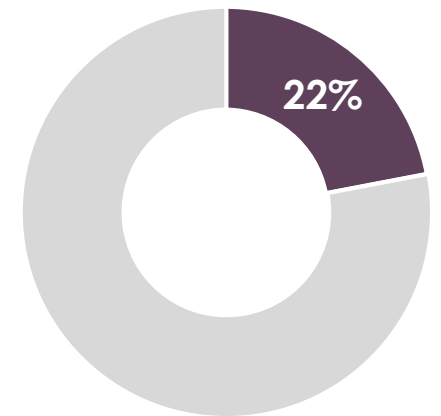
(European aluminium
statistics)

Construction waste
collection rate



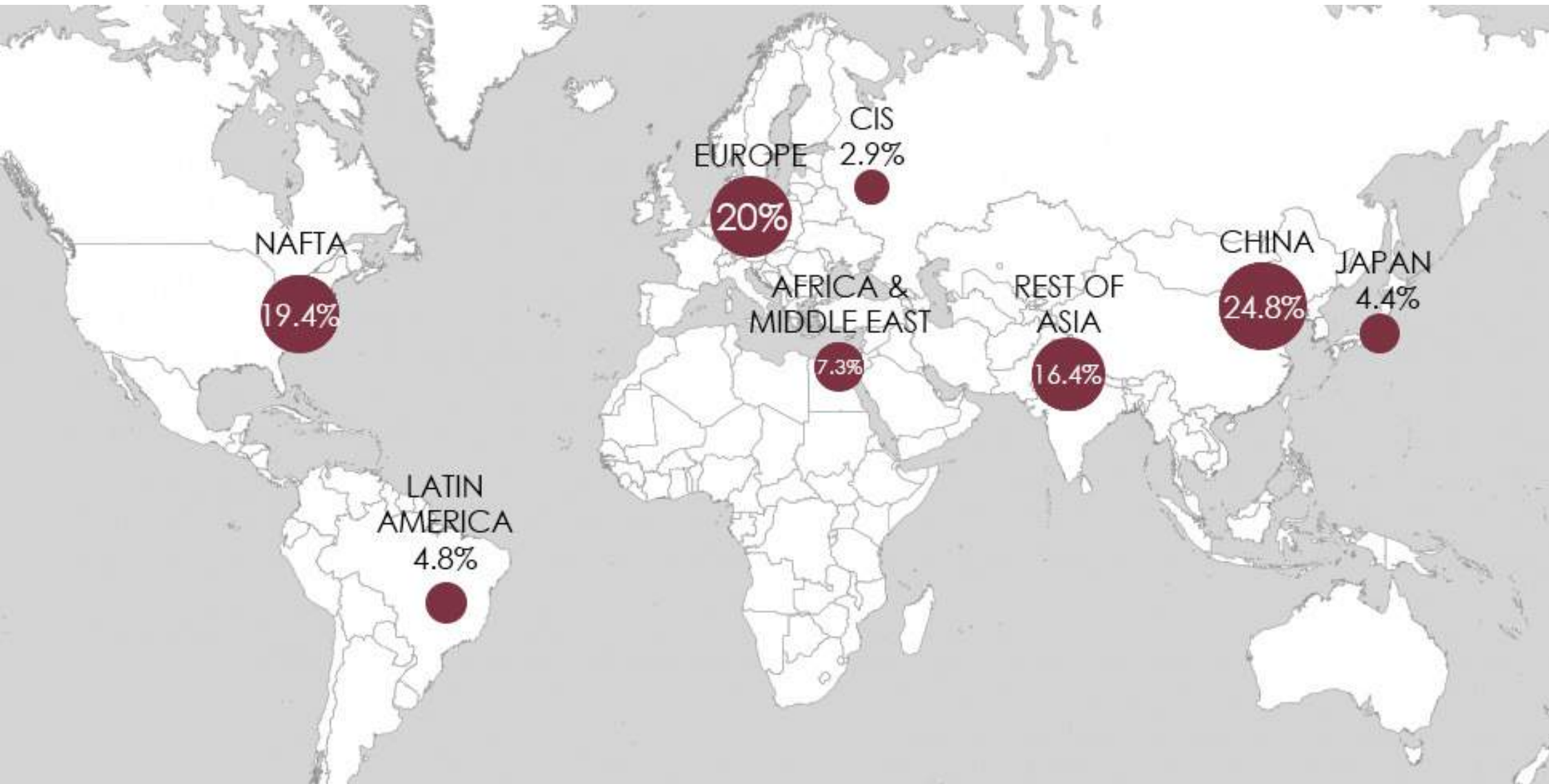
(IAI 2015)

Recycling of
finished products



(IAI 2013)

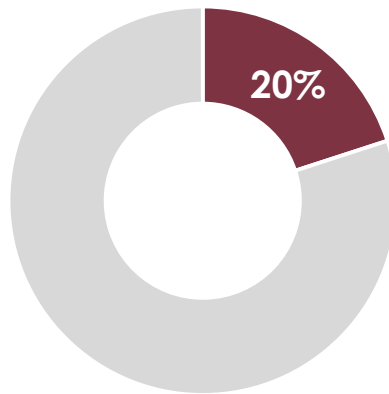
THE GREATER PICTURE | Plastics



Plastics production in million tonnes (PlasticsEurope data, 2015)

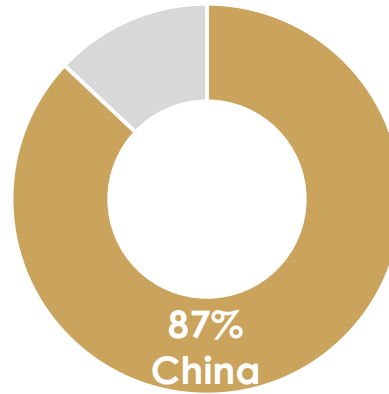
THE GREATER PICTURE | Plastics

Plastics use in construction



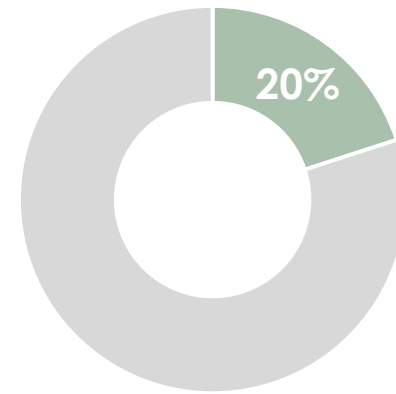
(PLASTICSEUROPE, 2012)

Destinations of EU plastics scrap exports



(VELIS, 2014)

Construction waste recycling



(PLASTICSEUROPE, 2012)

Plastics used in construction



(PLASTICSEUROPE, 2012)

THE GREATER PICTURE | Steel



Iron ore mining in million tonnes (USGS data, 2016)

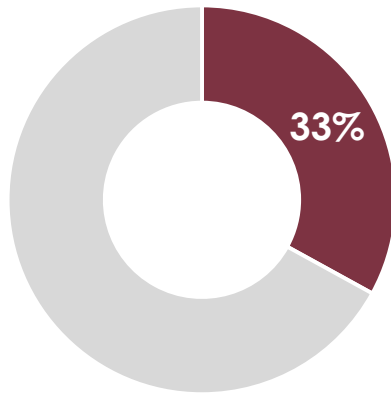
THE GREATER PICTURE | Steel



Steel production in million tonnes (USGS data, 2016)

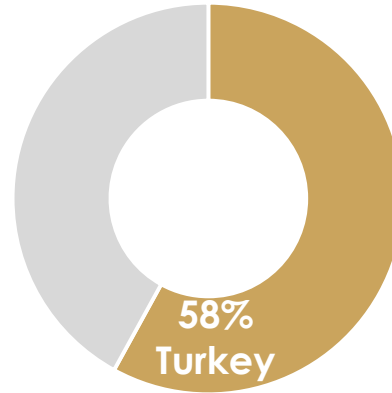
THE GREATER PICTURE | Steel

**Steel use
in construction**



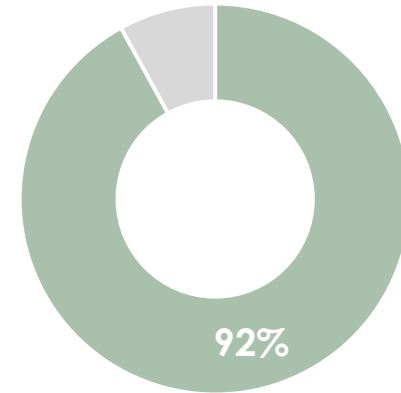
(EUROFER, 2016)

**Destinations of EU
steel scrap exports**



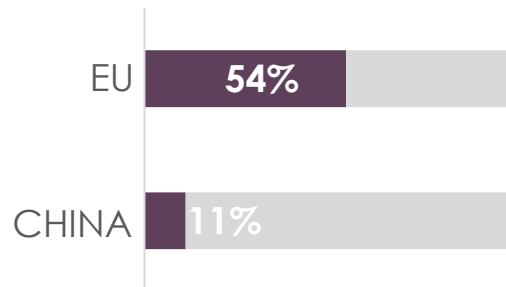
(BIR, 2015)

**Construction waste
recycling**



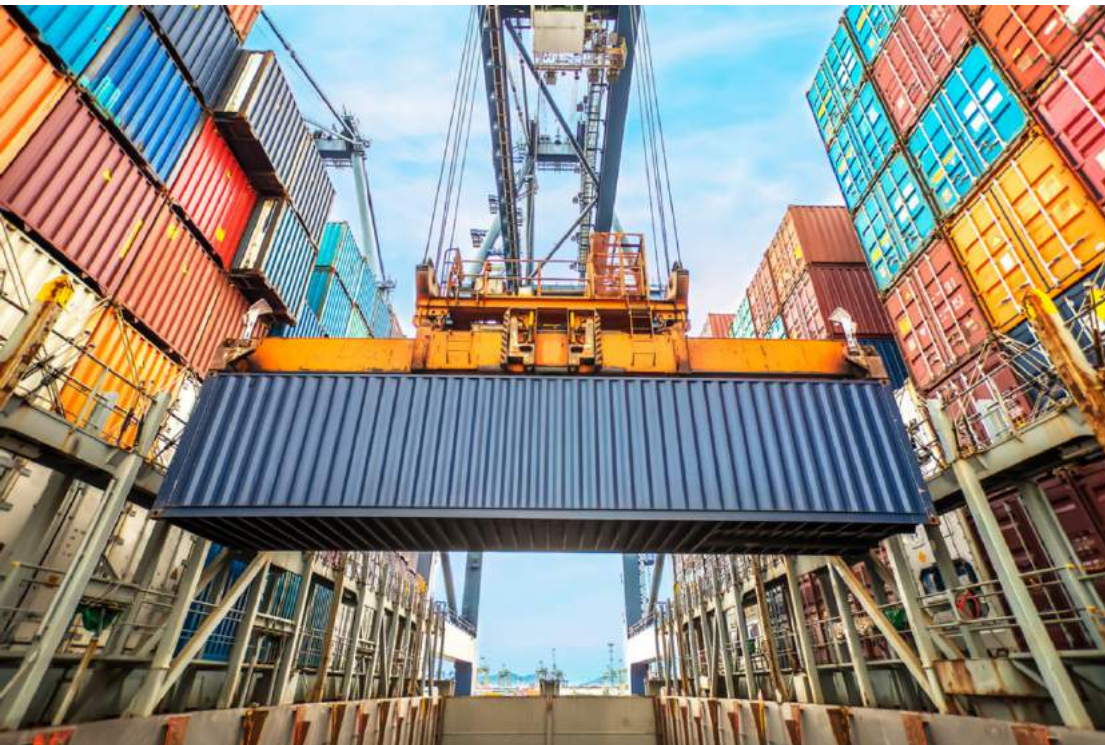
(EUROFER, 2012)

**Recycled material
in crude steel**



(BIR, 2015)

THE GREATER PICTURE | The meaning



NOT FULLY RECYCLED PRODUCTS

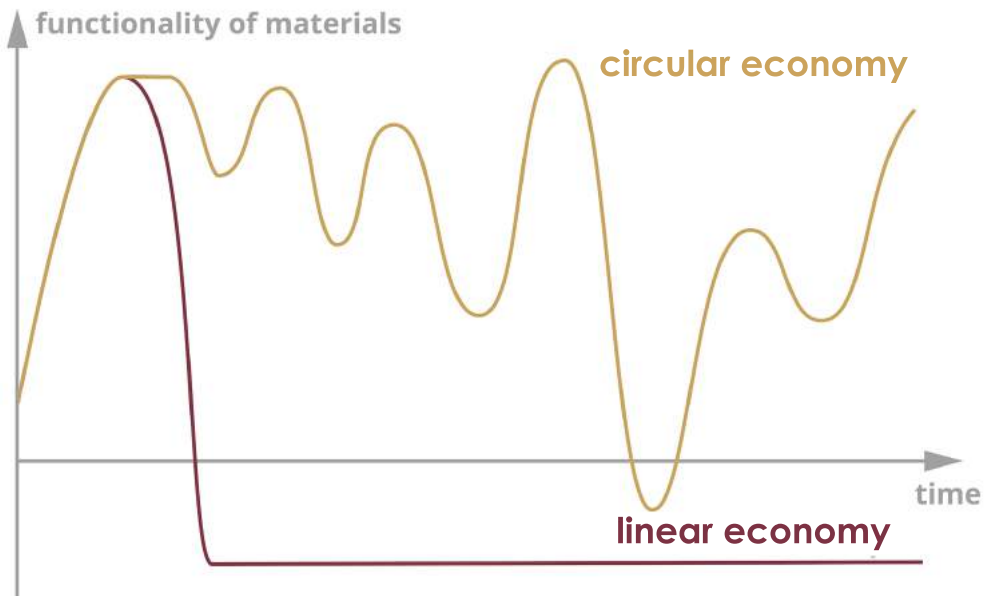
RESOURCES IN CONSTRUCTION

LONG DISTANCE TRANSPORTATION

ENERGY

POLLUTION

INFORMATIONAL VALUE



CONCLUSIONS



CONCLUSIONS | A basis for a dialogue

NOT YET FULLY READY FOR THE CIRCULAR ECONOMY >>>

MENTALITY

ALCOA

TROX

RENSON

Does your company currently have a reclaiming scheme?

“No, not at the moment”

“No, we only produce new products”

“No, no demand from the market yet”

What do you consider to be the greatest challenge in reclaiming products?

“Aluminium scrap exports to China”

“Logistics and guarantees”

“Organization of the whole process”

CONCLUSIONS | A basis for a dialogue

EXPECTED LIFETIME OF FACADE COMPONENTS >>>

1 - 75 YEARS

Element	Material	Lifetime (years)	End-of-life (current)	Assembly	Reuse	Recycle
Profile	Powder RAL coated aluminium (6060)	75	Recycling	Pinned	○	●
Case	Coated steel	50	Recycling	Screwed	○	●
Fabric	Polyester - PVC	10	Recycling	Welded	○	●
Supply air filter F7	Glass fibre paper (pleated)	1	Incineration	Fitted	-	-
Gaskets	EPDM	25-30	Incineration	Pushed	-	-
Thermal break strip	Polyamide (PA66 GF30%)	?	Incineration	Rolled	-	-
Heat recovery	Aluminium	?	?	Fitted	○	●
Fans	Galvanized steel	?	?	Screwed	○	●
Box profile	Powder RAL coated aluminium (6063)	75	Recycling	Screwed	○	●

CONCLUSIONS | A basis for a dialogue

END-OF-LIFE SCENARIOS >>>

RECYCLING MOSTLY, NO REUSE

Element	Material	Lifetime (years)	End-of-life (current)	Assembly	Reuse	Recycle
Profile	Powder RAL coated aluminium (6060)	75	Recycling	Pinned	○	●
Case	Coated steel	50	Recycling	Screwed	○	●
Fabric	Polyester - PVC	10	Recycling	Welded	○	●
Supply air filter F7	Glass fibre paper (pleated)	1	Incineration	Fitted	-	-
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Thermal break strip	Polyamide (PA66 GF30%)	?	Incineration	Rolled	-	-
Heat recovery	Aluminium	?	?	Fitted	○	●
Fans	Galvanized steel	?	?	Screwed	○	●
Box profile	Powder RAL coated aluminium (6063)	75	Recycling	Screwed	○	●

CONCLUSIONS | A basis for a dialogue

GREATEST SPOTTED PROBLEM >>>

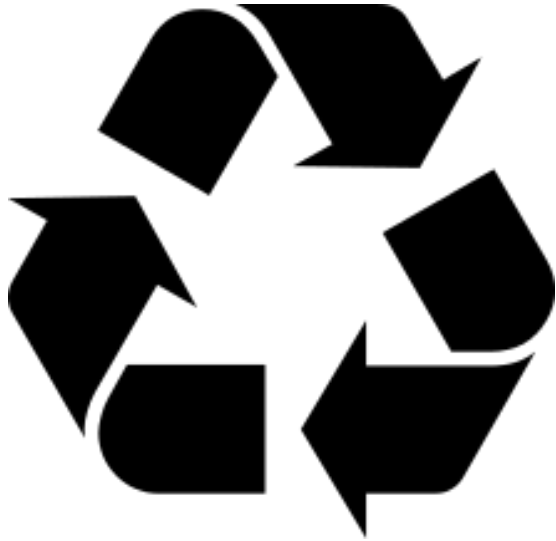
LACK OF INFORMATION

Element	Material	Lifetime (years)	End-of-life (current)	Assembly	Reuse	Recycle
End caps	?	?	?	Screwed	●	?
Buffers	Neoprene	?	?	Glued	-	-
Fabric	Polyester - PVC	10	Recycling	Welded	○	●
VFL leaf spring	Stainless steel	?	?	?	?	●
VFL casing	?	?	?	?	?	?
Thermal insulation	Phenolic foam	?	Incineration	Fitted	○	-

CONCLUSIONS | A basis for a dialogue

EXPECTED FUTURE DEVELOPMENTS >>>

REGULATORY CHANGES



PRODUCT DEVELOPMENT



THANK YOU

