DESIGN FOR DISASSEMBLY
FOR FACADE COMPONENTS IN A CIRCULAR ECONOMY

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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
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\textsuperscript{EVO}
External sunshade unit
THEORETICAL BACKGROUND
PHYSICAL ANALYSIS | Literature findings

<table>
<thead>
<tr>
<th>Hierarchy level</th>
<th>Element</th>
<th>Sub-component</th>
<th>Component</th>
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</thead>
<tbody>
<tr>
<td>Material</td>
<td>$M_1$</td>
<td>$M_n$</td>
<td>Structural support frame</td>
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<td>$...$</td>
<td>$M_n$</td>
<td>Facade frame</td>
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<tr>
<td></td>
<td>$E_1$</td>
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<td>Infill components</td>
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<td>$...$</td>
<td>$E_n$</td>
<td>Sun shading system</td>
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<td>$E_1$</td>
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<td>Ventilation system</td>
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<td></td>
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<tr>
<td>Building</td>
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</table>
FUNCTIONAL ANALYSIS | Methodology

Functions definition (panel)

**Main function**
- Create a durable construction
- Provide a comfortable interior climate
- Support use of the building

**Primary function**
- Bear structural loads
- Keep materials and components in working condition
- Enable water and vapor management in construction
- Provide a comfortable temperature
- Create visual comfort
- Protect against fire
- Prevent falling out

**Secondary functions**
- Deviate wind loads
- Deviate impact loads
- Carry self weight
- Handle loads from structural and thermal expansion
- Secure an air and vapor tight construction
- Secure rain and water tightness
- Prevent energy losses
- Prevent surface temperature differences
- Control air exchange rate
- Control daylight radiation
- Provide light
- Prevent surface temperature differences
- Control air temperature
- Control air exchange rate
- Prevent energy losses
- Provide visual contact

**Supporting functions**
- Fix to primary structure of building
- Integrate joints to allow movement
- Allow damage free movement
- Allow vapor tight connection of parts
- Incorporate water sealing system
- Ventilate excessive heat
- Maintain air tightness
- Provide thermal insulation
- Supply sufficient fresh air
- Protect against fire
- Provide fire barriers
- Provide barriers at minimum height

**Detailed supporting functions**
- Deviate wind loads
- Deviate impact loads
- Carry self weight
- Handle loads from structural and thermal expansion

**Physical component**
- HEA 100
  - Existing
- Steel profile
  - Existing
- Aluminium frames
  - R7 72 by Alcoa
- Solar control glass
  - by Scheuten
- Top-Down Bottom-Up Automated interior blinds
  - with reflective coating
  - Topfix by Renson
- Centrally controlled motor
  - Sonesse® 50 R5485 by Somfy
- Metallized fabric screen
  - SilverScreen by Verosol
- IPE 80
  - Existing
- MEP installations
  - Existing facade

(Klein, 2013)
PRACTICAL DISASSEMBLY
PRACTICAL DISASSEMBLY | Alcoa RT 72 / RT 72 HI

- Polyamide strips are inserted in knurled aluminium profiles

Remove pins

Remove corner brackets

Remove insulation

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
- 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**
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

**Technical decomposition**
- Relational patterns
- Base element specification

**Physical decomposition**
- Geometry of product edges
- Assembly sequences
- Type of the connection
- Life cycle coordination

(Durmisevic, 2006)
DfD EVALUATION

ALCOA RT 72, RT 72 HI

TROX FSL-B-ZAB-SEK

RENSON FIXSCREEN 100EVO
DESIGN
Based on practical disassembly

Based on problem statement

From construction and other industries

Sketching

Based on existing design evaluation

PROBLEM STATEMENT

OBJECTIVES

REFERENCES

DESIGN PROPOSALS

EVALUATION
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**

**CHARACTERISTICS**
- uPVC core
- Snap-on aluminium cladding

**REFERENCES**
- EPDM gasket
- Aluminium glazing bead
- Aluminium profile
- uPVC thermal core
CHARACTERISTICS
PA66 thermal break
Snap-on aluminium profiles
ALCOA RT 72 | Design 3

CHARACTERISTICS
Closed profile thermal break
Mechanically fastened

REFERENCES
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
**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
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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)**

<table>
<thead>
<tr>
<th></th>
<th>Embodied energy (incl. primary production &amp; process)</th>
<th>Remanufacture energy (incl. recycling &amp; incineration)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emitted CO2 (kg/m)</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>PA 610 (GF 30-40%)</strong></td>
<td>23.91</td>
<td>6.64</td>
</tr>
<tr>
<td><strong>PA 66 (GF 30%)</strong></td>
<td>24.36</td>
<td>7.07</td>
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</table>

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<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Required energy (MJ/m)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PA 610 (GF 30-40%)</strong></td>
<td>377.79</td>
<td>103.27</td>
</tr>
<tr>
<td><strong>PA 66 (GF 30%)</strong></td>
<td>371.15</td>
<td>96.53</td>
</tr>
</tbody>
</table>

**Recycled polyamide**
- 89% less fossil fuel
- 32% less water
- 84% less CO$_2$

**PA 610**
Made out of castor oil seeds
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
REFERENCES

CHARACTERISTICS

Velcro strips glued on the perimeter of each insulation piece

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

CHARACTERISTICS
Point mechanical connections on perimeter of insulation pieces
- Penetration of casing
- Possible drawbacks in sound insulation
+ Easy reuse

Glass fibre sound insulation
Dot snap fasteners
Steel casing
50-60 insulation parts per unit (some of which small)

Any new design should not increase fire load

No perforation of casing (air tightness)
Magnetic connections are the most interesting to develop.
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

REFERENCES

Neogrene
25% less fossil fuel
25% less energy
CHARACTERISTICS
Homogeneous element
Semi-rigid PVC

+ Recyclable
+ Less elements

- Material rigidity
Neoprene buffer with protrusions
PVC zip guide with cut-outs

Aluminium side channel

CHARACTERISTICS
Interlocking elements

+ Easy disassembly
+ No adhesives

- Additional production processes
RENSON FIXSCREEN 100\textsuperscript{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
Bauxite mining in million tonnes (USGS data, 2006)
Alumina refining in million tonnes (USGS data, 2006)
Aluminium primary production in million tonnes (USGS data, 2006)
The Greater Picture | Aluminium

Aluminium secondary production in million tonnes (USGS data, 2006)
Aluminium use in construction: 35%

Destinations of EU aluminium scrap exports:
- 37% China
- 28% India

Construction waste collection rate: 95%

Recycling of finished products: 22%

Sources:
- (IAI 2013)
- (European aluminium statistics)
- (IAI 2015)
- (IAI 2013)
Plastics production in million tonnes (PlasticsEurope data, 2015)
**THE GREATER PICTURE | Plastics**

**Plastics use in construction**

- 20%

**Destinations of EU plastics scrap exports**

- 87% to China

**Construction waste recycling**

- 20%

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**Plastics used in construction**

- PE-LD, PE-HD, PP, PS, PS-E, PVC, ABS, ASA, SAN, PMMA, PA, PC, OTHER, PUR

- 40, 140, 70, 175, 610, 120

**Sources:**

- PlasticsEurope, 2012
- Velis, 2014
- PlasticsEurope, 2012
Iron ore mining in million tonnes (USGS data, 2016)
Steel production in million tonnes (USGS data, 2016)
THE GREATER PICTURE | Steel

Steel use in construction

33%

(Eurofer, 2016)

Destinations of EU steel scrap exports

58% Turkey

(BIR, 2015)

Construction waste recycling

92%

(Eurofer, 2012)

Recycled material in crude steel

EU: 54%

China: 11%

(BIR, 2015)
THE GREATER PICTURE | The meaning

NOT FULLY RECYCLED PRODUCTS
RESOURCES IN CONSTRUCTION
LONG DISTANCE TRANSPORTATION
ENERGY
POLLUTION
INFORMATIONAL VALUE

www.plan-c.eu
## CONCLUSIONS | A basis for a dialogue

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**NOT YET FULLY READY FOR THE CIRCULAR ECONOMY**

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### MENTALITY

**ALCOA**

“No, not at the moment”

**TROX**

“No, we only produce new products”

**RENSON**

“No, no demand from the market yet”

---

### Does your company currently have a reclaiming scheme?

**ALCOA**

“No, not at the moment”

**TROX**

“No, we only produce new products”

**RENSON**

“No, no demand from the market yet”

---

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

**ALCOA**

“Aluminium scrap exports to China”

**TROX**

“Logistics and guarantees”

**RENSON**

“Organization of the whole process”
## CONCLUSIONS | A basis for a dialogue

## EXPECTED LIFETIME OF FACADE COMPONENTS

1 - 75 YEARS

<table>
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<th>Material</th>
<th>Lifetime (years)</th>
<th>End-of-life (current)</th>
<th>Assembly</th>
<th>Reuse</th>
<th>Recycle</th>
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<tbody>
<tr>
<td>Profile</td>
<td>Powder RAL coated aluminium (6060)</td>
<td>75</td>
<td>Recycling</td>
<td>Pinned</td>
<td>○</td>
<td>●</td>
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<tr>
<td>Case</td>
<td>Coated steel</td>
<td>50</td>
<td>Recycling</td>
<td>Screwed</td>
<td>○</td>
<td>●</td>
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<tr>
<td>Fabric</td>
<td>Polyester - PVC</td>
<td>10</td>
<td>Recycling</td>
<td>Welded</td>
<td>○</td>
<td>●</td>
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<tr>
<td>Supply air filter F7</td>
<td>Glass fibre paper (pleated)</td>
<td>1</td>
<td>Incineration</td>
<td>Fitted</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Gaskets</td>
<td>EPDM</td>
<td>25-30</td>
<td>Incineration</td>
<td>Pushed</td>
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<tr>
<td>Thermal break strip</td>
<td>Polyamide (PA66 GF30%)</td>
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<td>Rolled</td>
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<tr>
<td>Heat recovery</td>
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<td>?</td>
<td>Fitted</td>
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## CONCLUSIONS | A basis for a dialogue

### END-OF-LIFE SCENARIOS  >  >  >  RECYCLING MOSTLY, NO REUSE

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**CONCLUSIONS** | A basis for a dialogue

**GREATEST SPOTTED PROBLEM  > > >**

**LACK OF INFORMATION**

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CONCLUSIONS | A basis for a dialogue

EXPECTED FUTURE DEVELOPMENTS  >  >  >

REGULATORY CHANGES

PRODUCT DEVELOPMENT
THANK YOU