Kinetic Thin Glass Façade

A study on the feasibility of a water- and airtight
kinetic façade with a bending-active thin glass element

Özhan Topçu | 4510674 | P5

Context

- Transparency in buildings is an increasing trend

Hiroshi Senju Museum, Karuizawa, Japan

Chanel Amsterdam, Amsterdam, Netherlands

Apple Fifth Avenue, New York City, USA

Context

- Transparency in buildings is an increasing trend
- Rapid development of research and production techniques

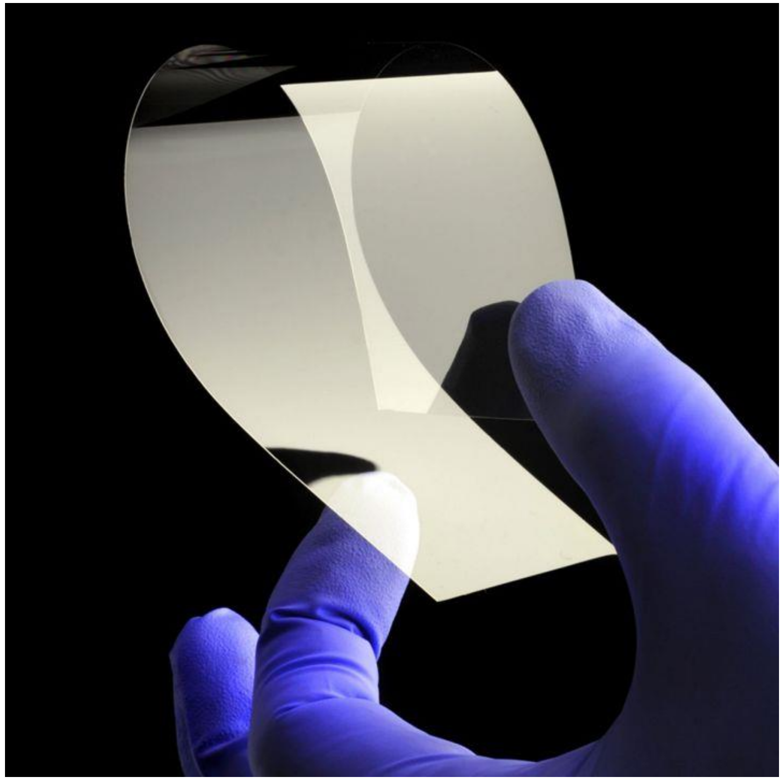
"Initially, it was not the architects who took architecture into the modern age, but rather engineers and planners from so called non-artistic disciplines"

Mirko Baum

Context

- Transparency in buildings is an increasing trend
- Rapid development of research and production techniques

→ alternative product: chemically strengthened (ultra) thin glass*



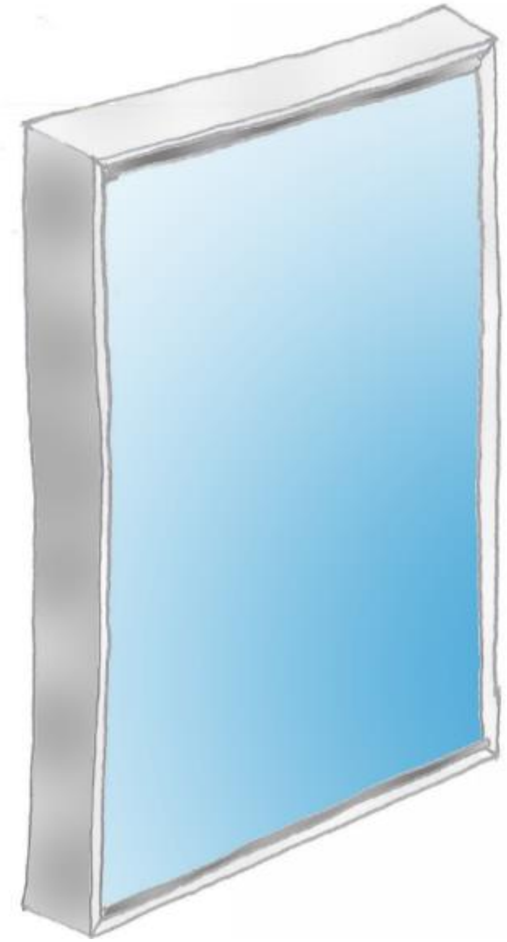
** Thin glass → $t < 2$ mm*

Ultra thin glass → $t < 0.1$ mm

Context

Possible design

bending-active, kinetic thin glass element



Context

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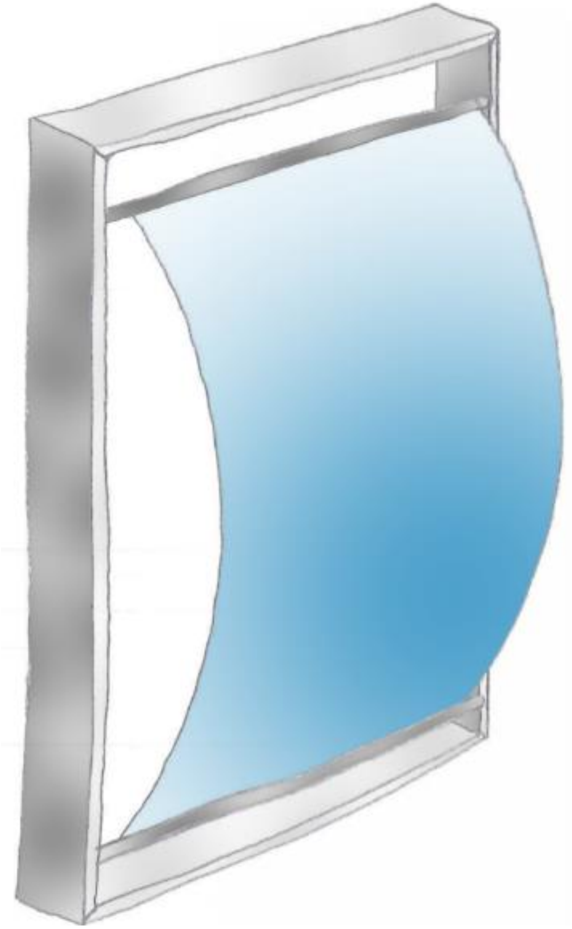
bending-active, kinetic thin glass element



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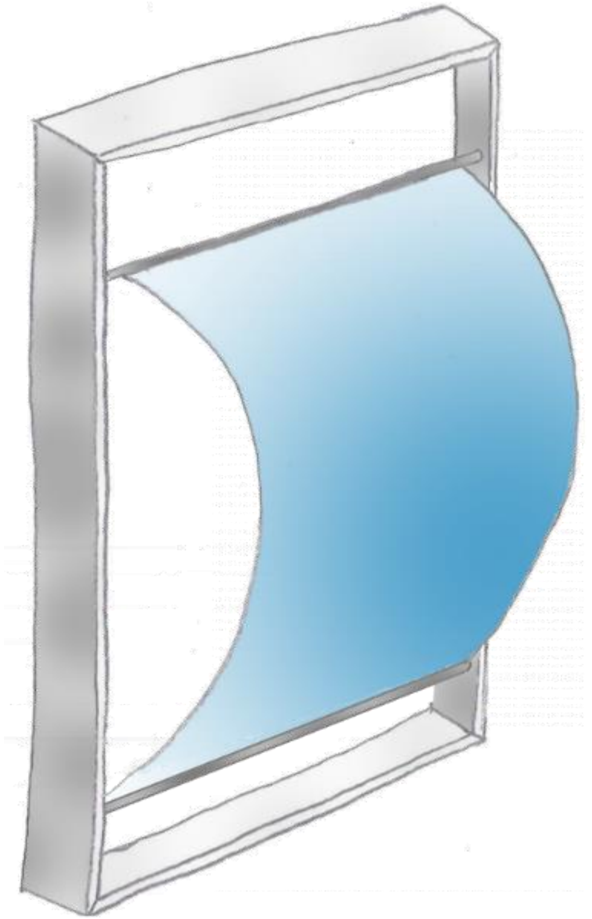

Context

Possible design

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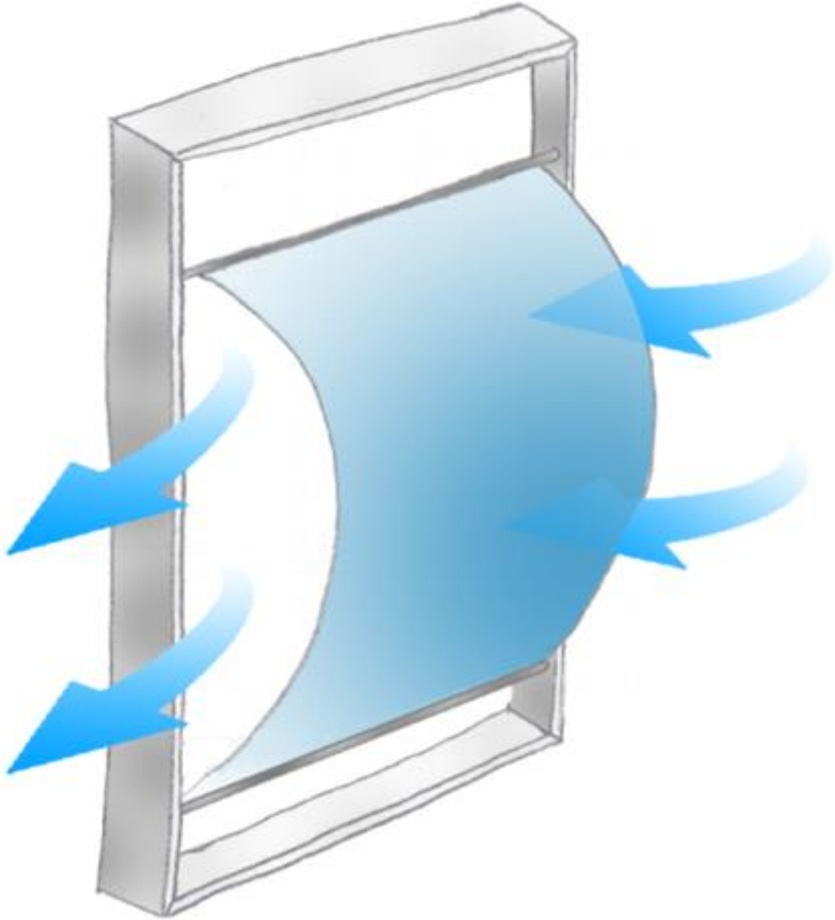
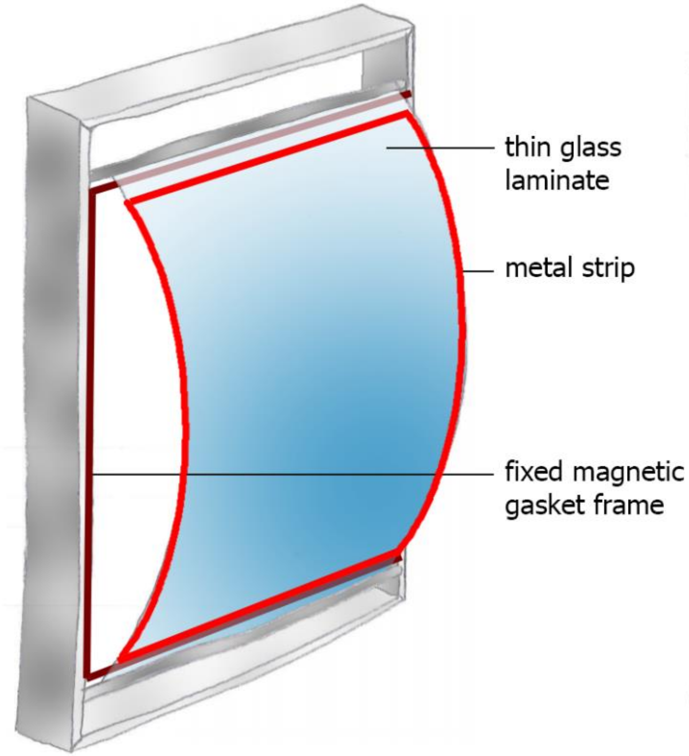


Research Question

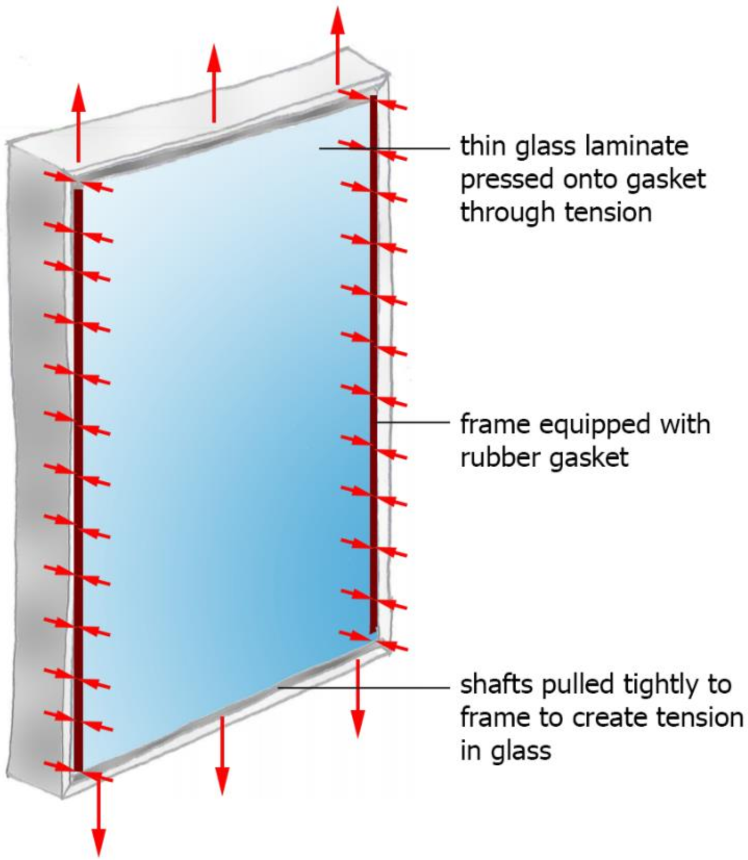
"How can a kinetic façade element featuring a bendable thin glass panel be designed to be water- and airtight in closed condition?"

Design Choice

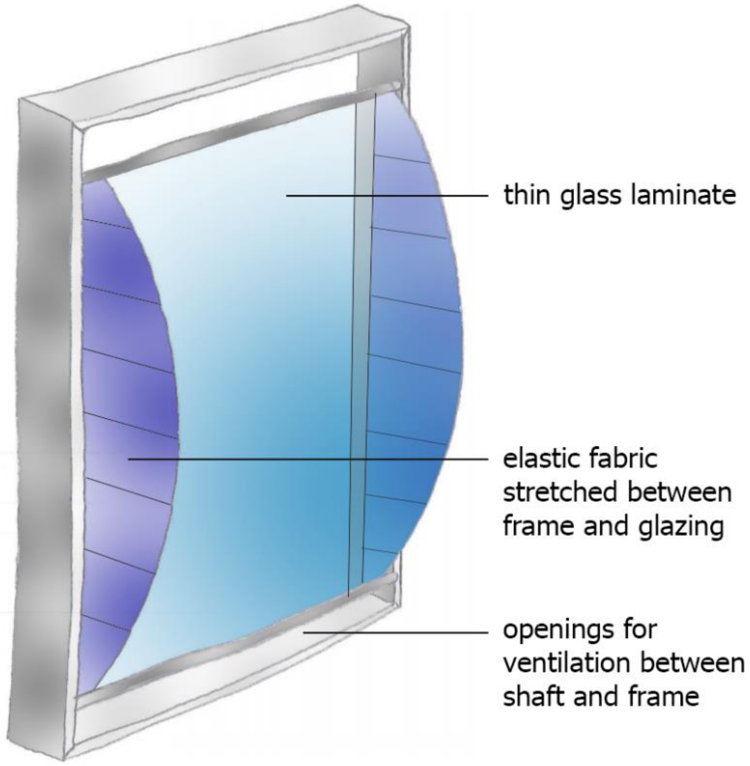
Option 1: Magnetic Force



Option 2: Tensile Force



Option 3: Elastic Fabric

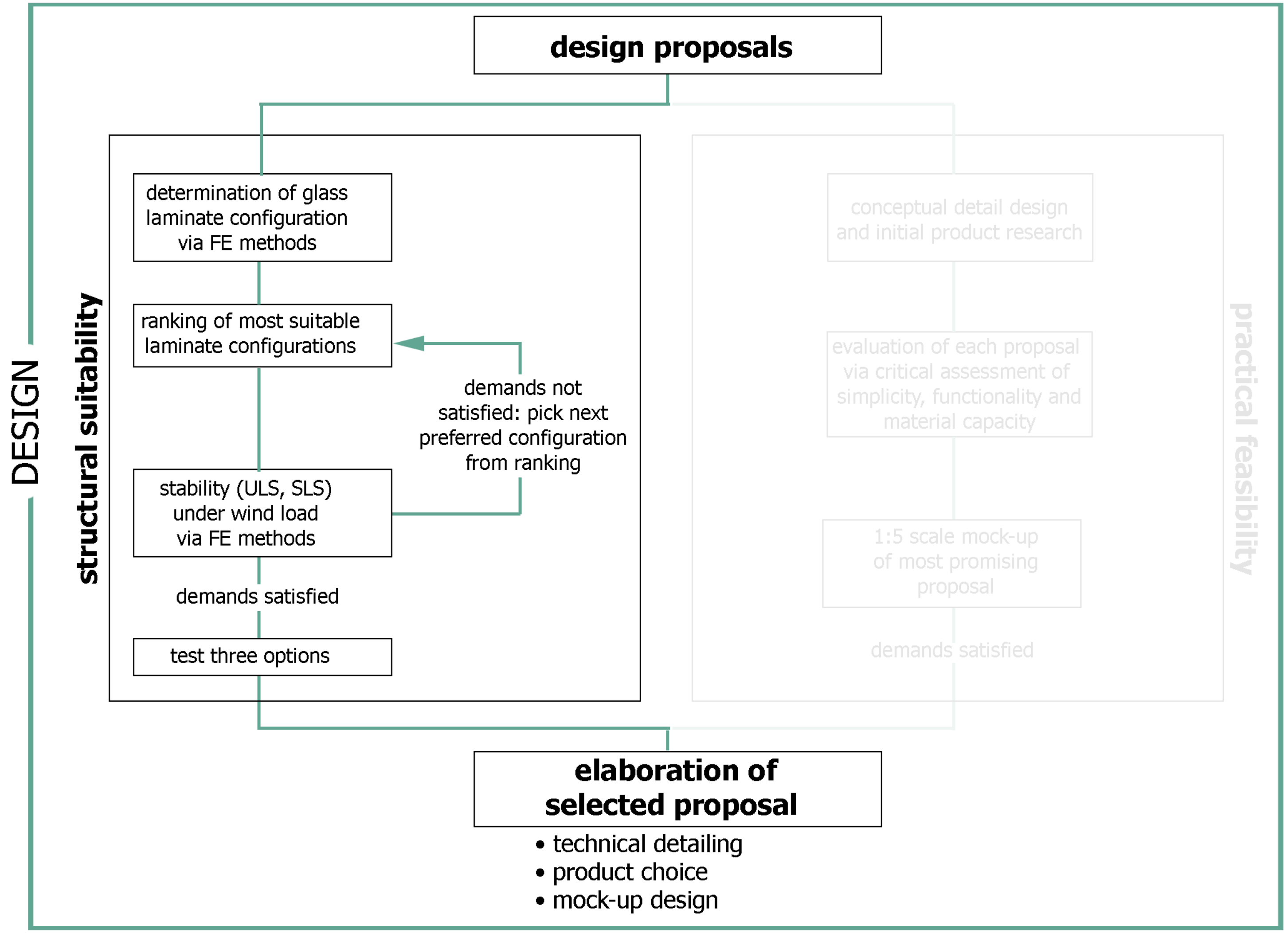


Approach and Methodology

design proposals

DESIGN

Approach and Methodology



Structural Suitability

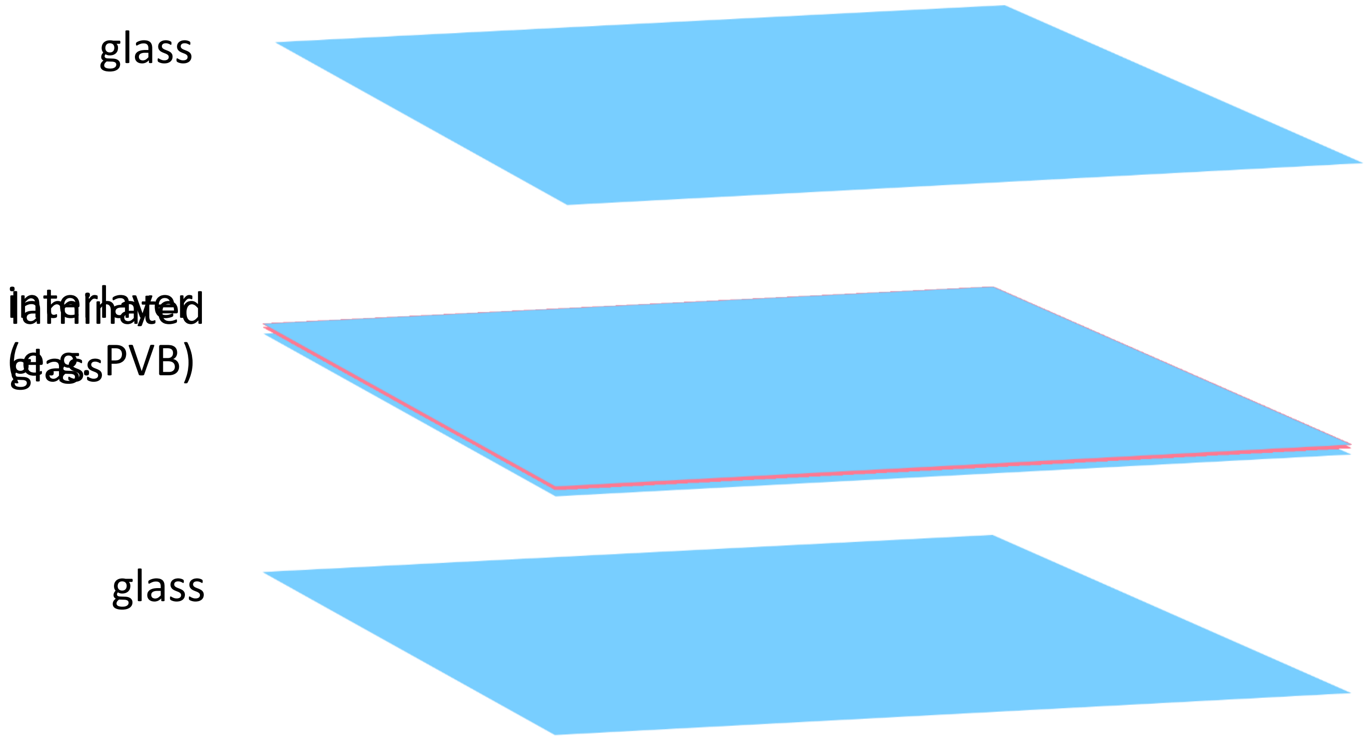
Glass Laminate Configuration

Structural Suitability

Glass Laminate Configuration

- Safety Regulations
- Adding stiffness

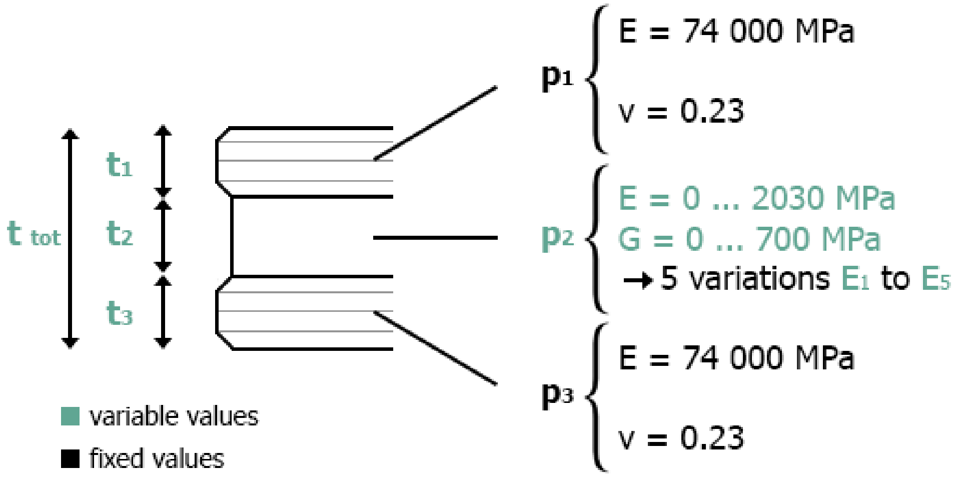
etc.



Structural Suitability

Glass Laminate Configuration

- **smallest radius** that can be achieved by controlled bending (**lowest stress**)
- highest **stability** of the glass laminate against external loads (e.g. wind)
- **minimum** required **force** to achieve the radius



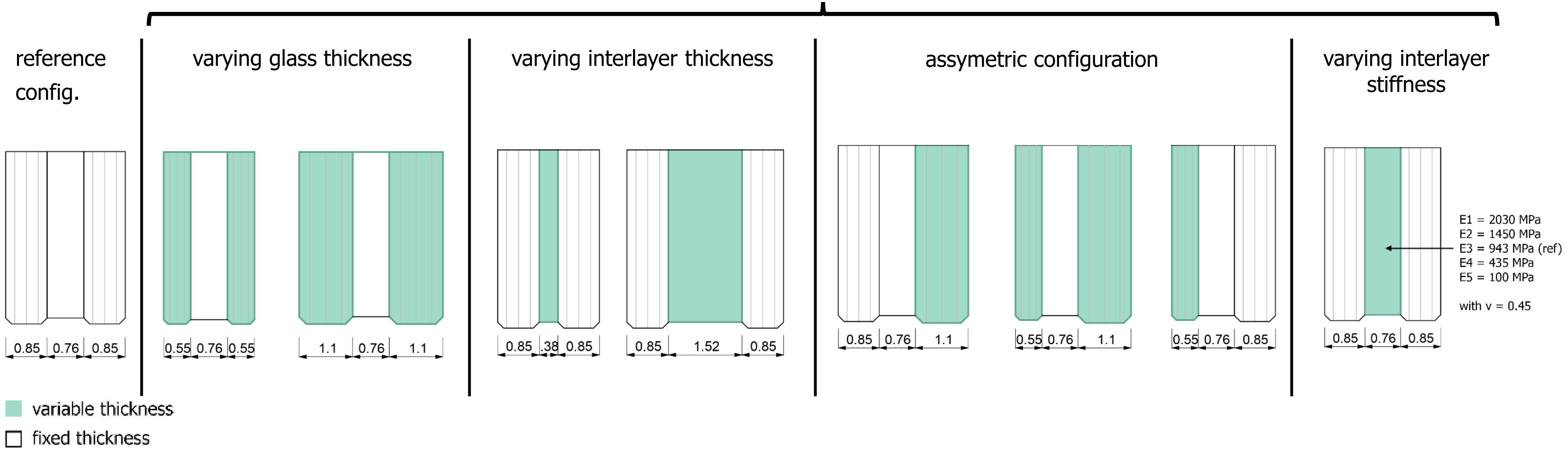
t_1 / t_3 =	0.55		0.85		1.1	[mm]
t_2 =	0.38		0.76		1.52	[mm]
P_2 =	E_1	E_2	E_3	E_4	E_5	
			ref			

Structural Suitability

Glass Laminate Configuration

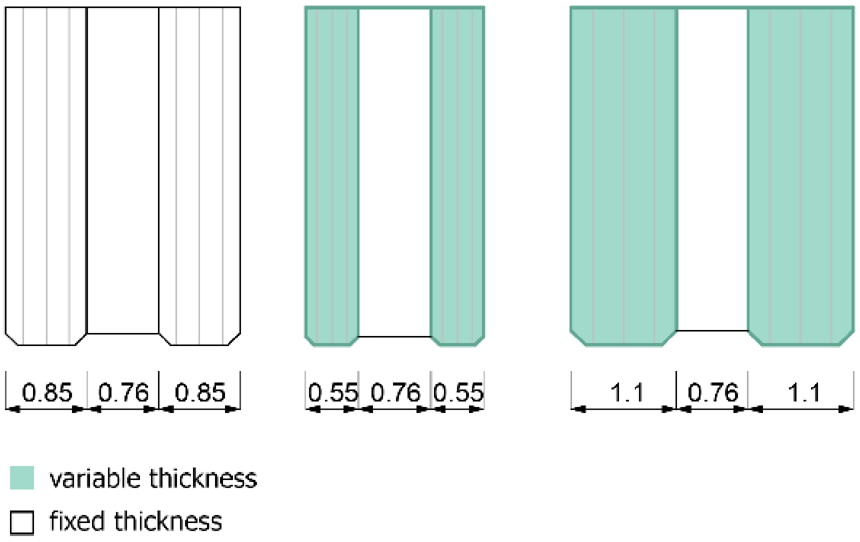
- **smallest radius** that can be achieved by controlled bending (**lowest stress**)
- highest **stability** of the glass laminate against external loads (e.g. wind)
- **minimum** required **force** to achieve the radius

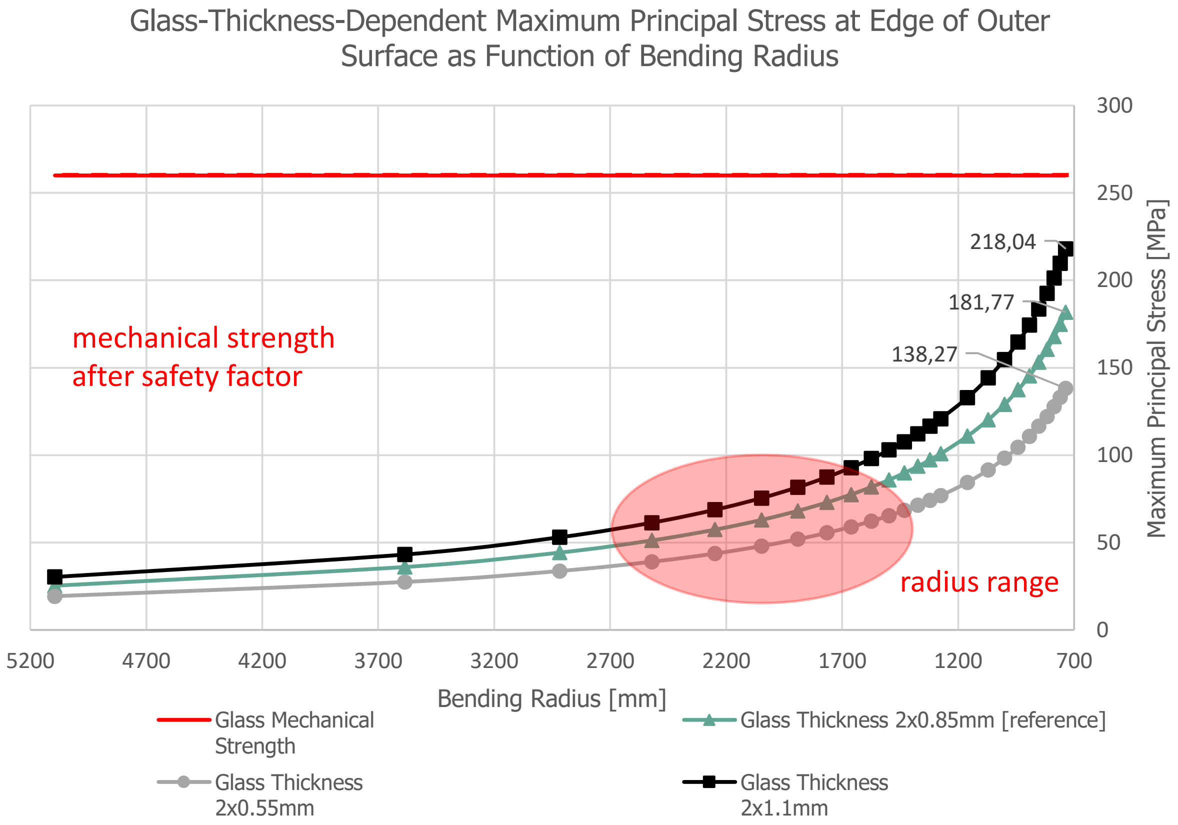
90 possible configurations!



Evaluation of Results: Glass Thickness Effect

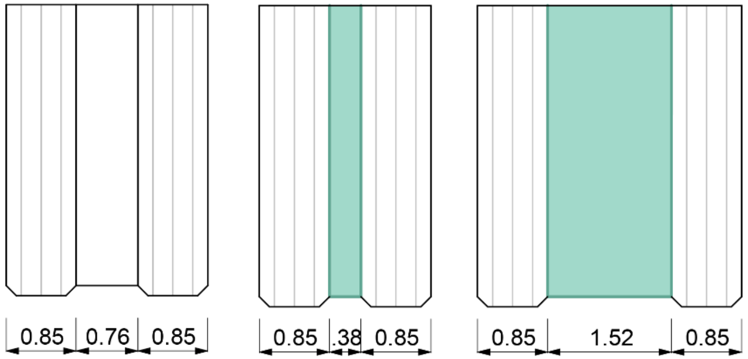
The thicker the glass,
the higher the max. principal stresses

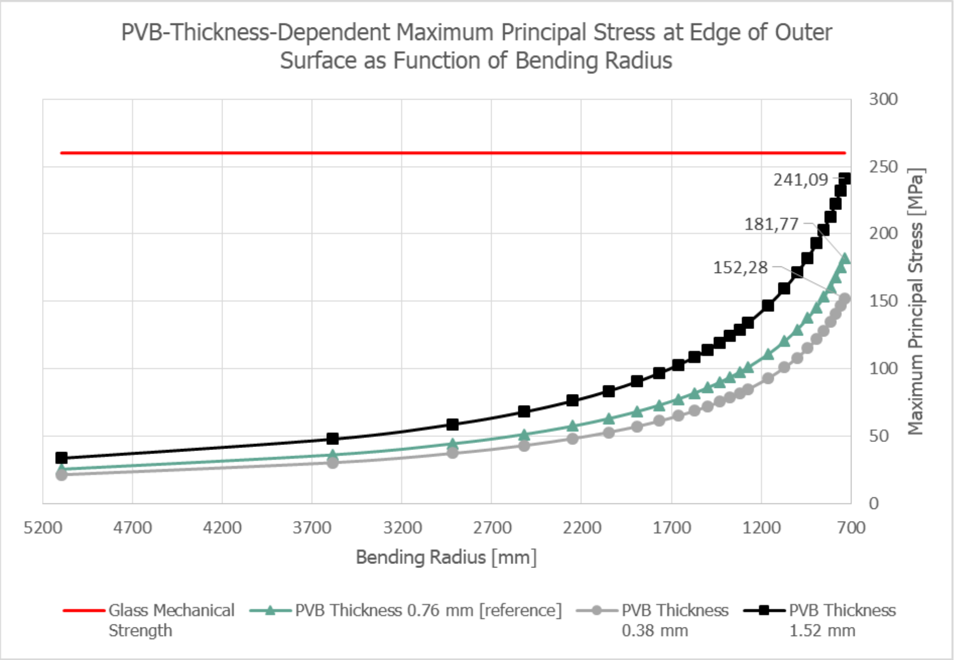




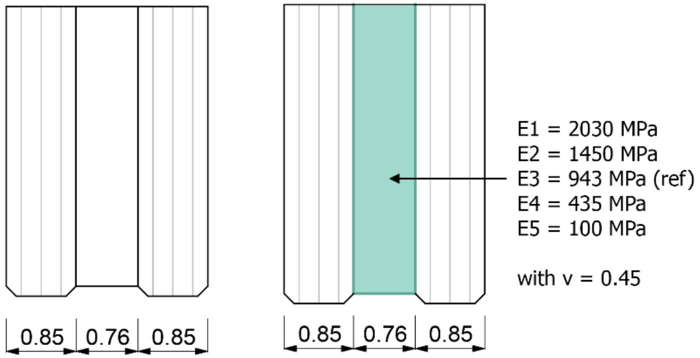
Structural Suitability

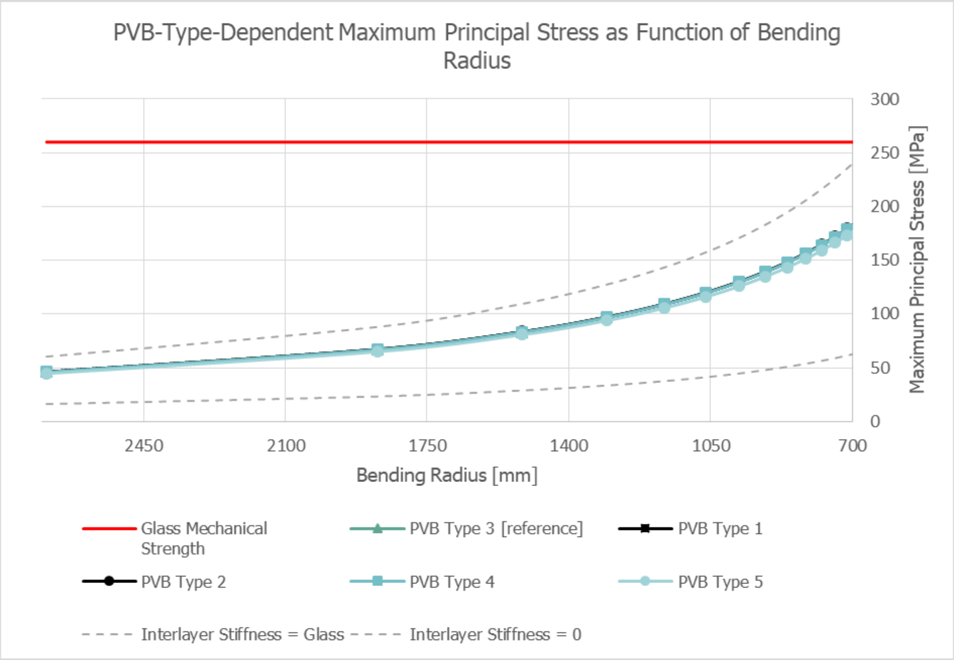
Interlayer Thickness





Interlayer Stiffness



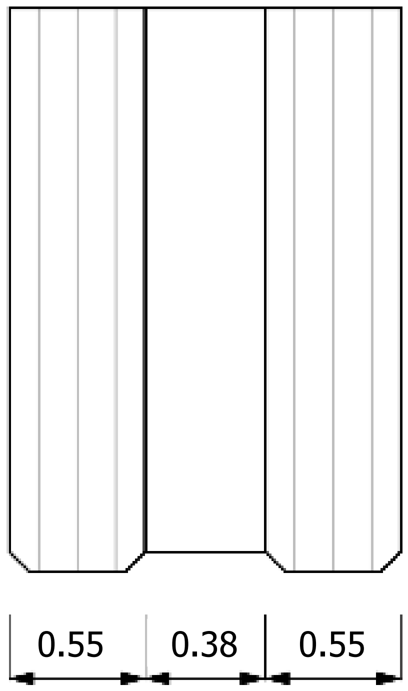


Structural Suitability

Evaluation of Results: Ranking

Choice No.	1st glass thickness t_1 [mm]	PVB thickness t_2 [mm]	2nd glass thickness t_3 [mm]	PVB Type p_2	final value [%]
1	0.55	0.38	0.55	E5	-43,8
2	0.55	0.38	0.55	E4	-40,6
3	0.55	0.38	0.55	E3	-40,4
4	0.55	0.38	0.55	E2	-40,35
5	0.55	0.38	0.55	E1	-40,33
6	0.85	0.38	0.55	E5	-37,4
7	0.85	0.38	0.55	E4	-34,2
8	0.85	0.38	0.55	E3	-34
9	0.85	0.38	0.55	E2	-33,95
10	0.85	0.38	0.55	E1	-33,93
11	1.1	0.38	0.55	E5	-30,9
12	1.1	0.38	0.55	E4	-27,7
13	0.55	0.76	0.55	E5	-27,6
14	1.1	0.38	0.55	E3	-27,5
15	1.1	0.38	0.55	E2	-27,45
16	1.1	0.38	0.55	E1	-27,43
17	0.55	0.76	0.55	E4	-24,4
18	0.55	0.76	0.55	E3	-24,2
19	0.55	0.76	0.55	E2	-24,15
20	0.55	0.76	0.55	E1	-24,13

preferred



softest interlayer

Structural Suitability

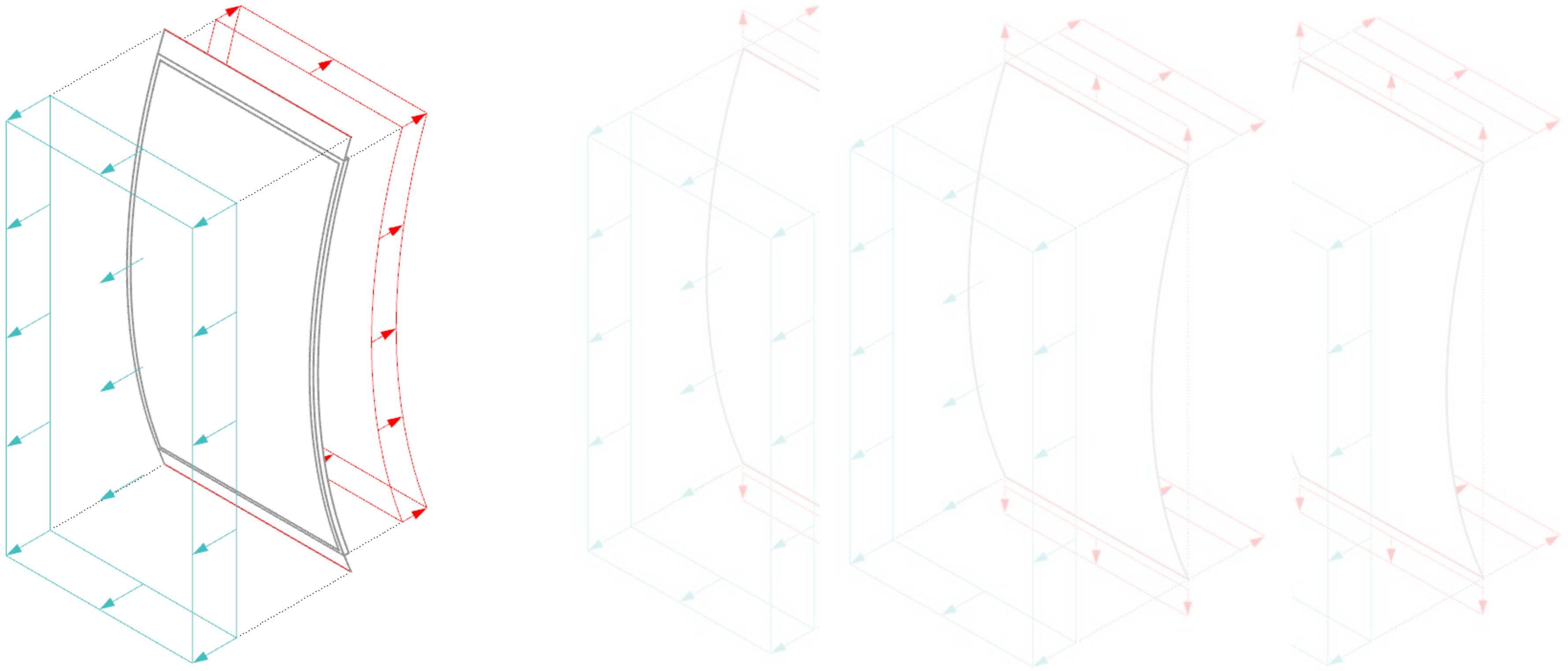
3 Options under Wind Load

Option 1: Magnetic Force

Option 2: Tensile Force

Option 2+3: Tensile Force / Elastic Fabric

Option 3: Elastic Fabric



wind load

support reactions

Structural Suitability

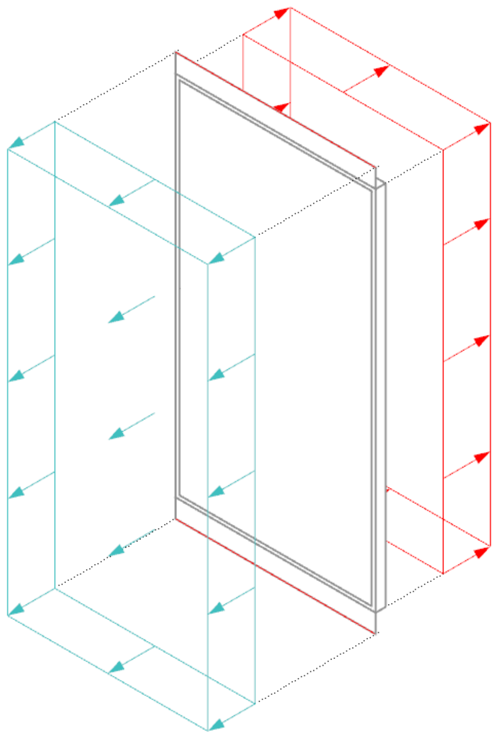
Option 1: Magnetic Force

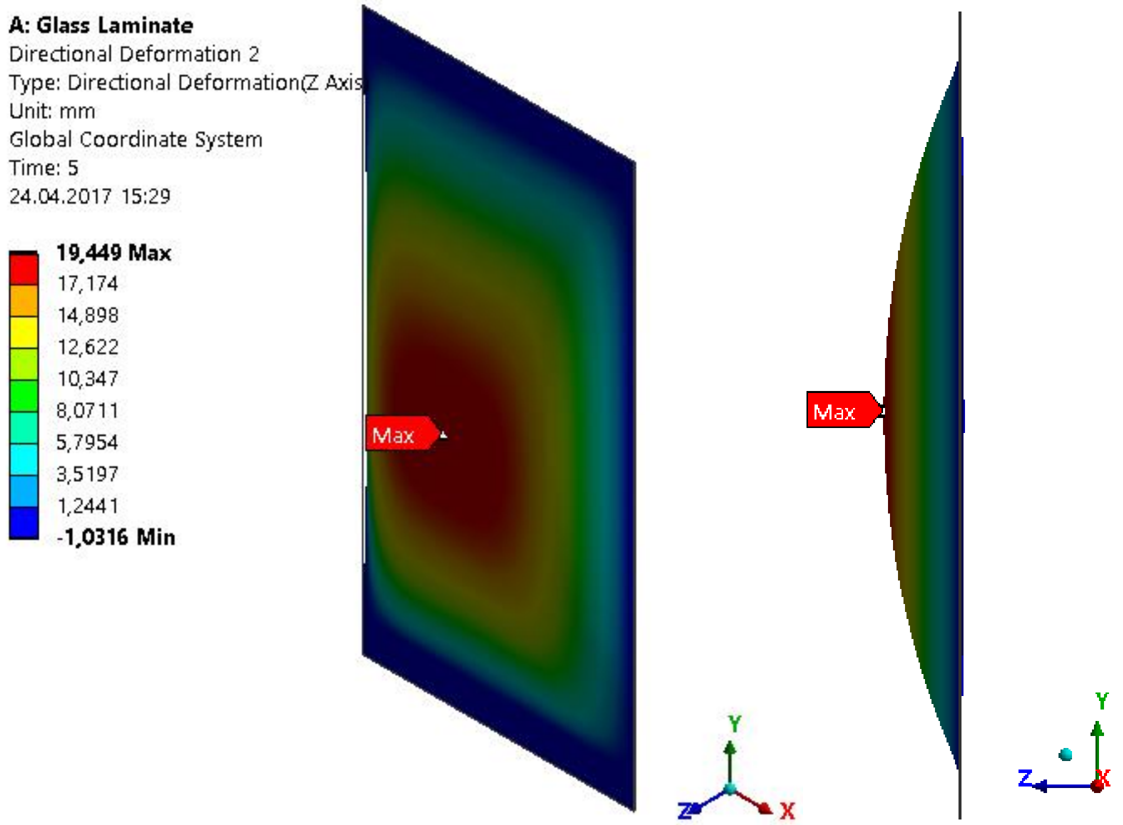
Method: Wind suction on glass surface supported by magnetic force

Decisive properties:

- Max. deformation under wind load

Flat glass





→ max. deformation = 19.5 mm

Structural Suitability

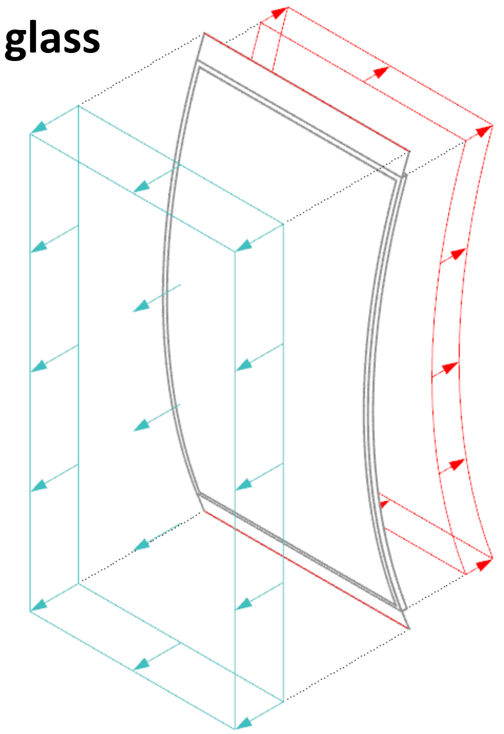
Option 1: Magnetic Force

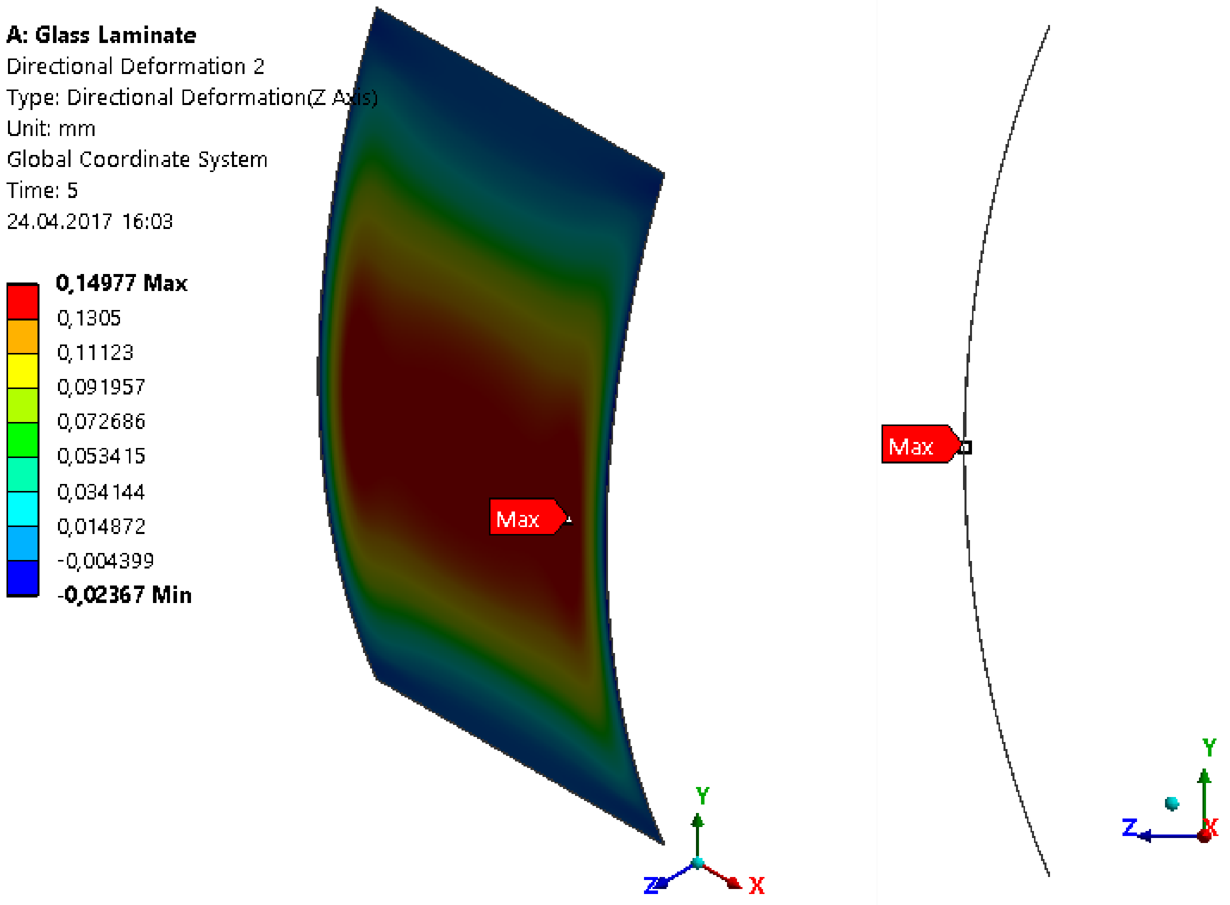
Method: Wind suction on glass surface supported by magnetic force

Decisive properties:

- Max. deformation under wind load

Curved glass





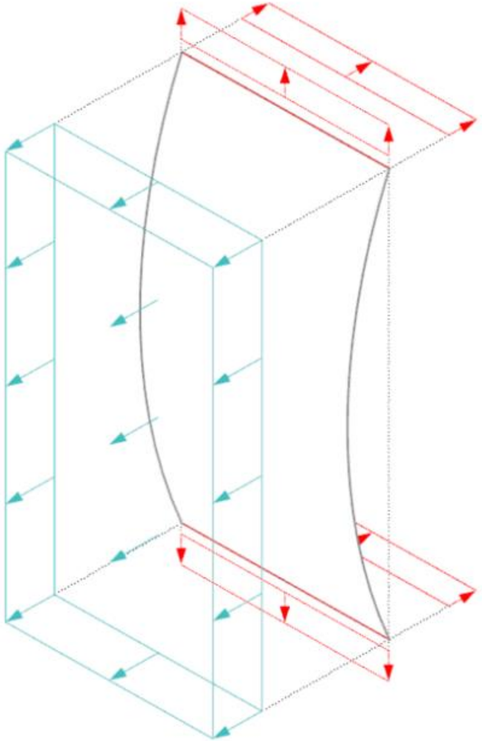
→ max. deformation < 1 mm (!)

Structural Suitability

3 Options under Wind Load

Option 1: Magnetic Force

Option 2 + 3: Tensile Force / Elastic Fabric



wind load

support reactions

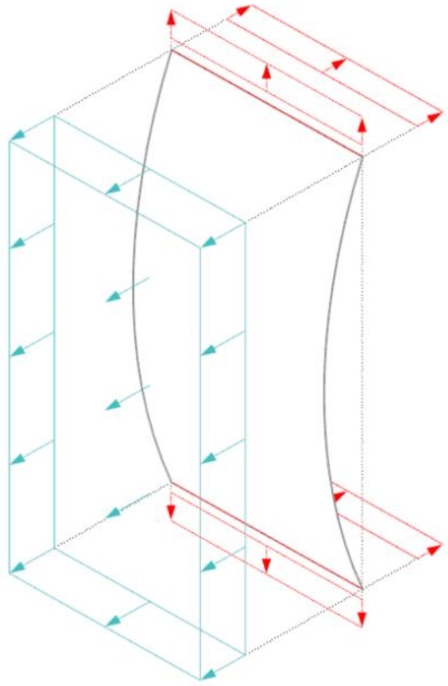
Structural Suitability

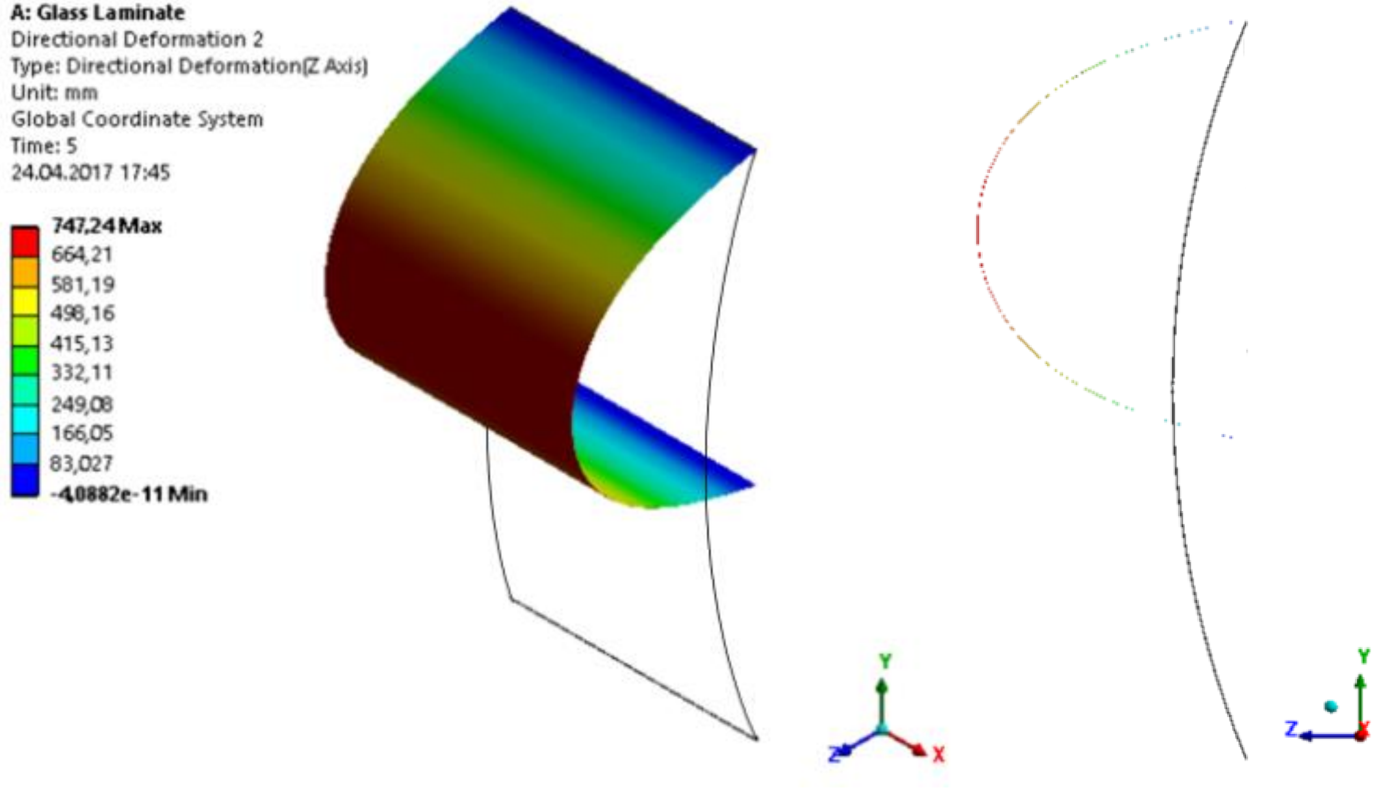
Option 2+3

Method: Wind suction on curved glass supported by two shafts

Decisive properties:

- Max. deformation under wind load



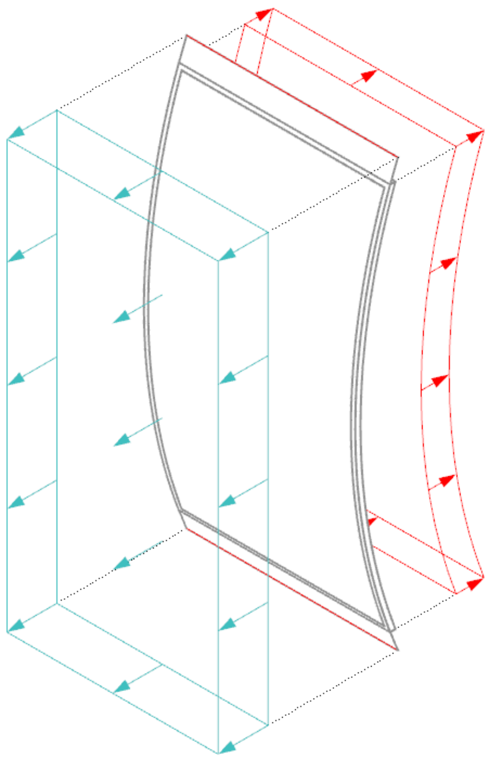


⟶ tensile force of **2550 N** required to keep stable!

Structural Suitability

3 Options under Wind Load

Option 1: Magnetic Force

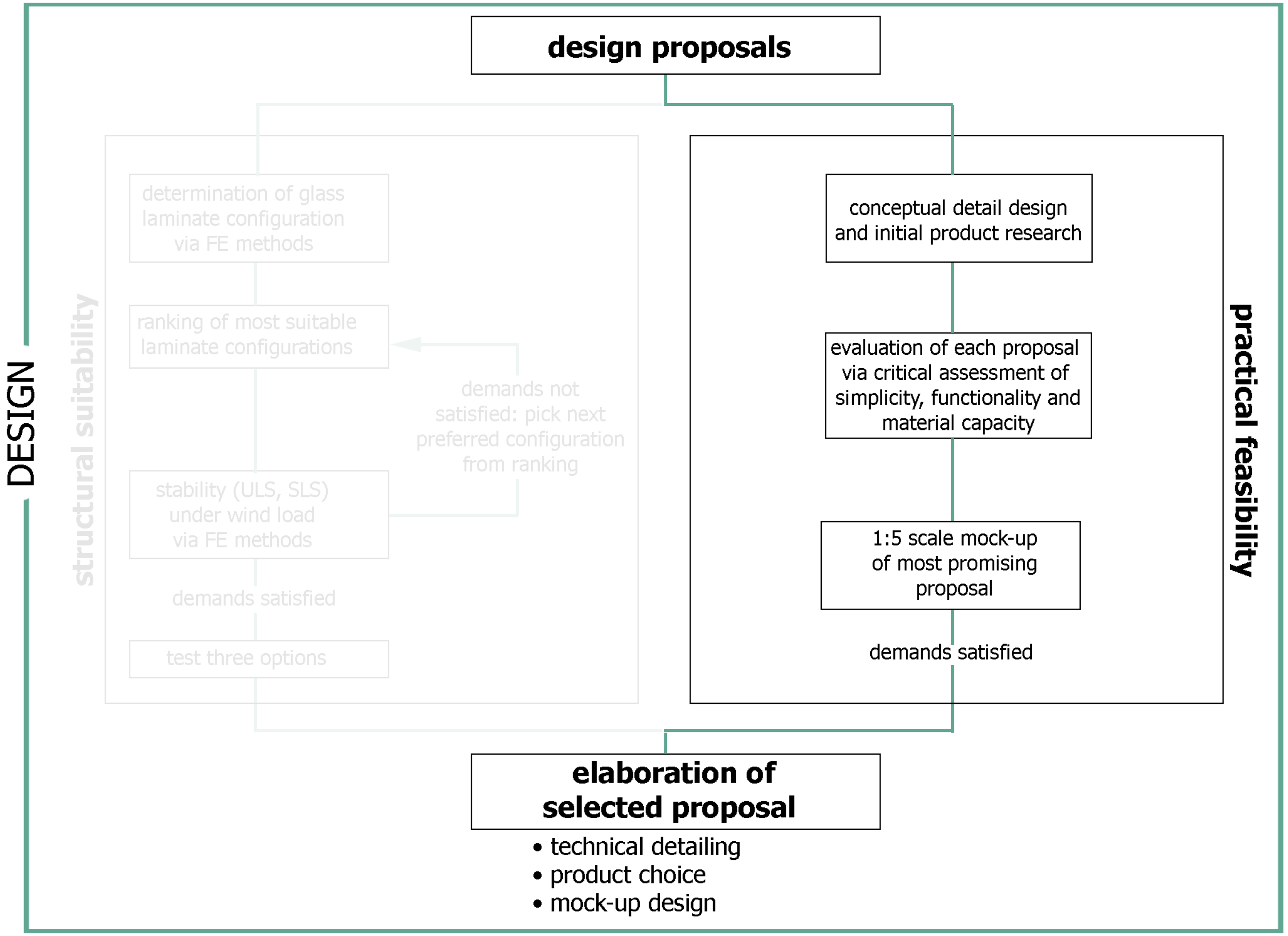


Option 2 + 3: Tensile Force / Elastic Fabric

wind load

support reactions

Approach and Methodology



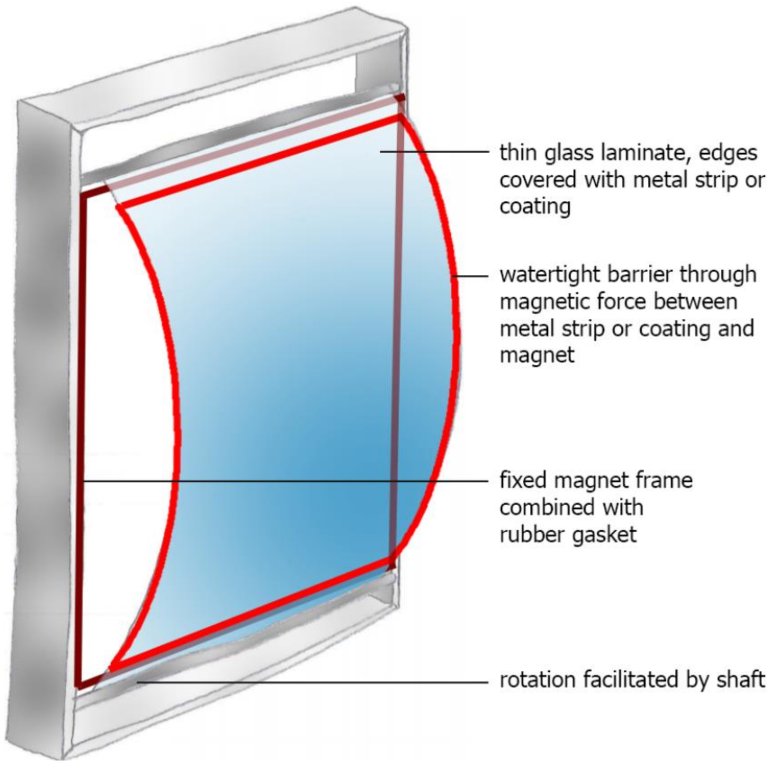
Practical Feasibility

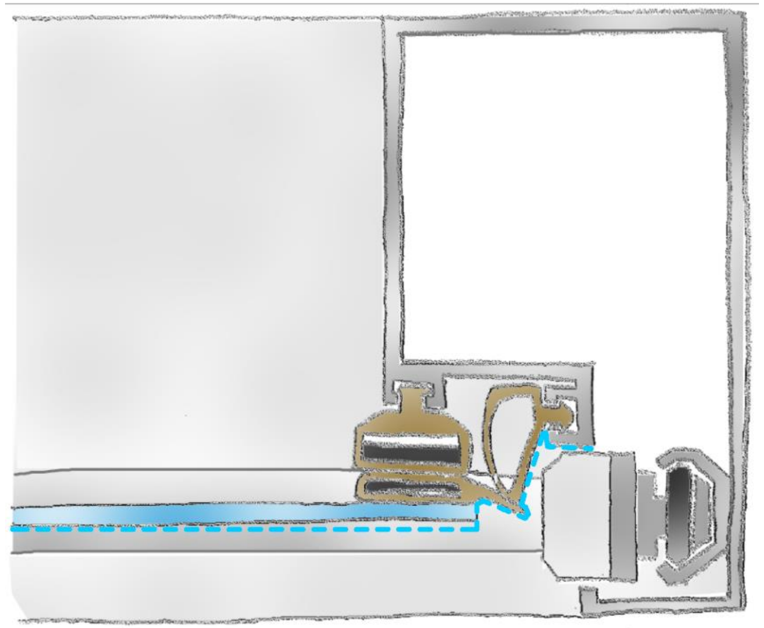
Option 1: Magnet

Practical Feasibility

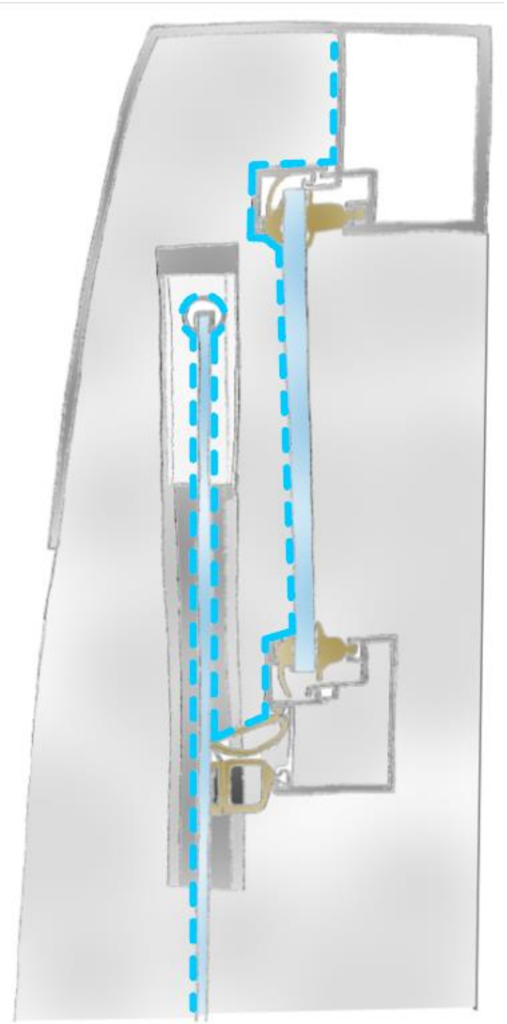
Option 1: Magnet

Water- airtightness possibly achievable with elaboration of conceptual details





lines of defence



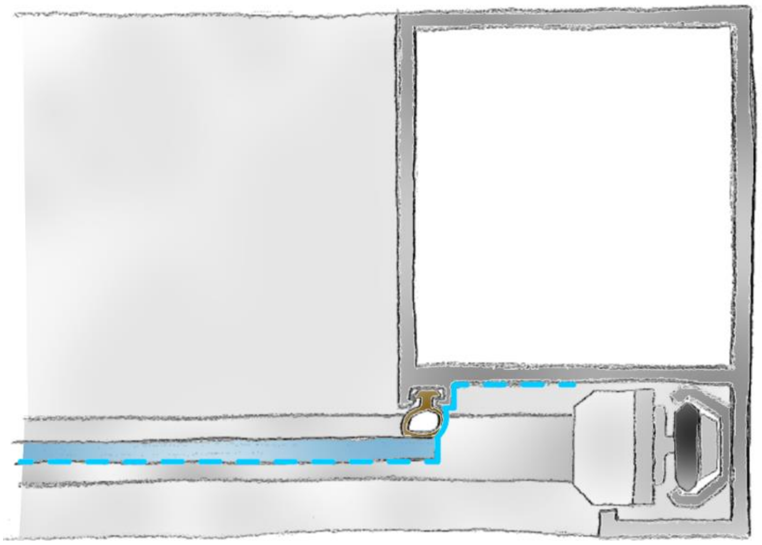
Practical Feasibility

Option 2: Tension

Practical Feasibility

Option 2: Tension

- gaps in corner joints
  → would require similar solution as magnet



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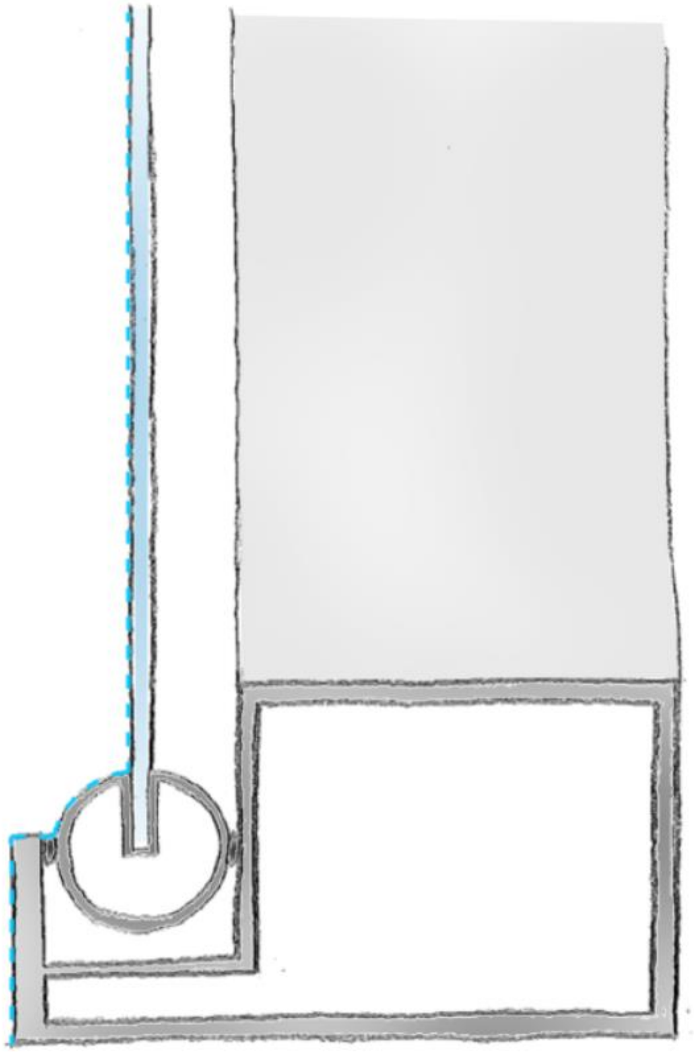

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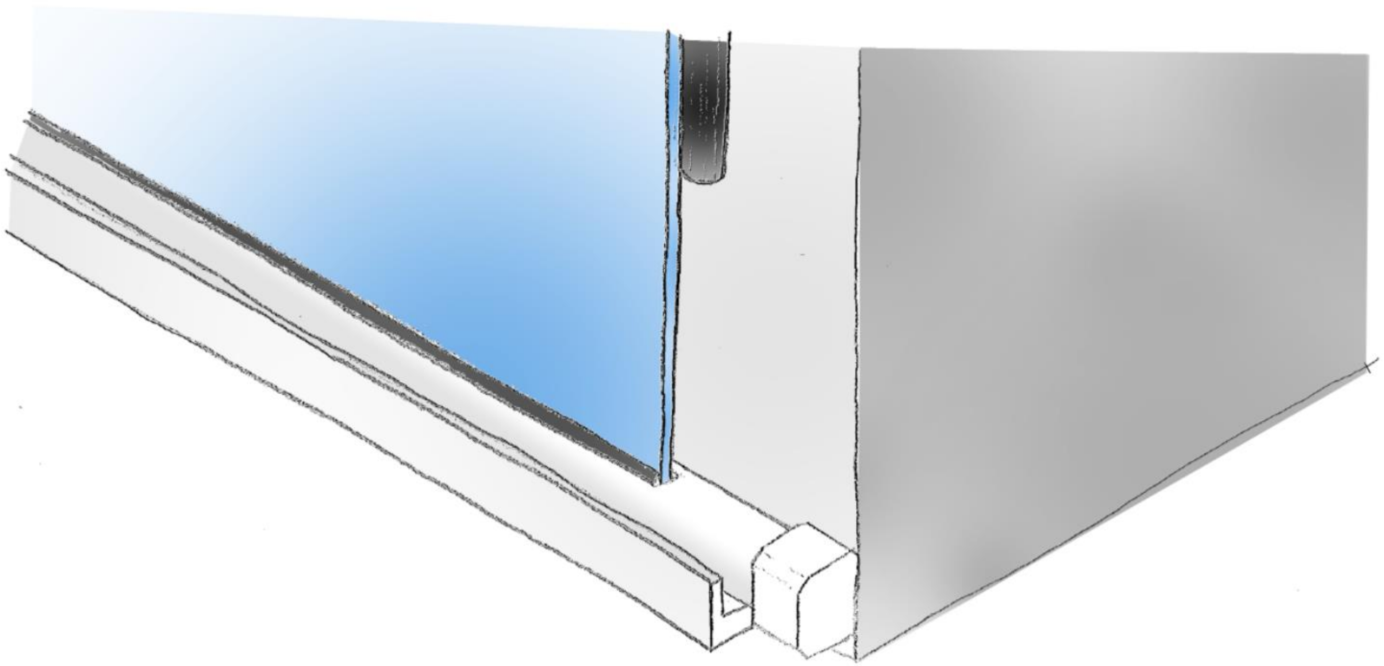

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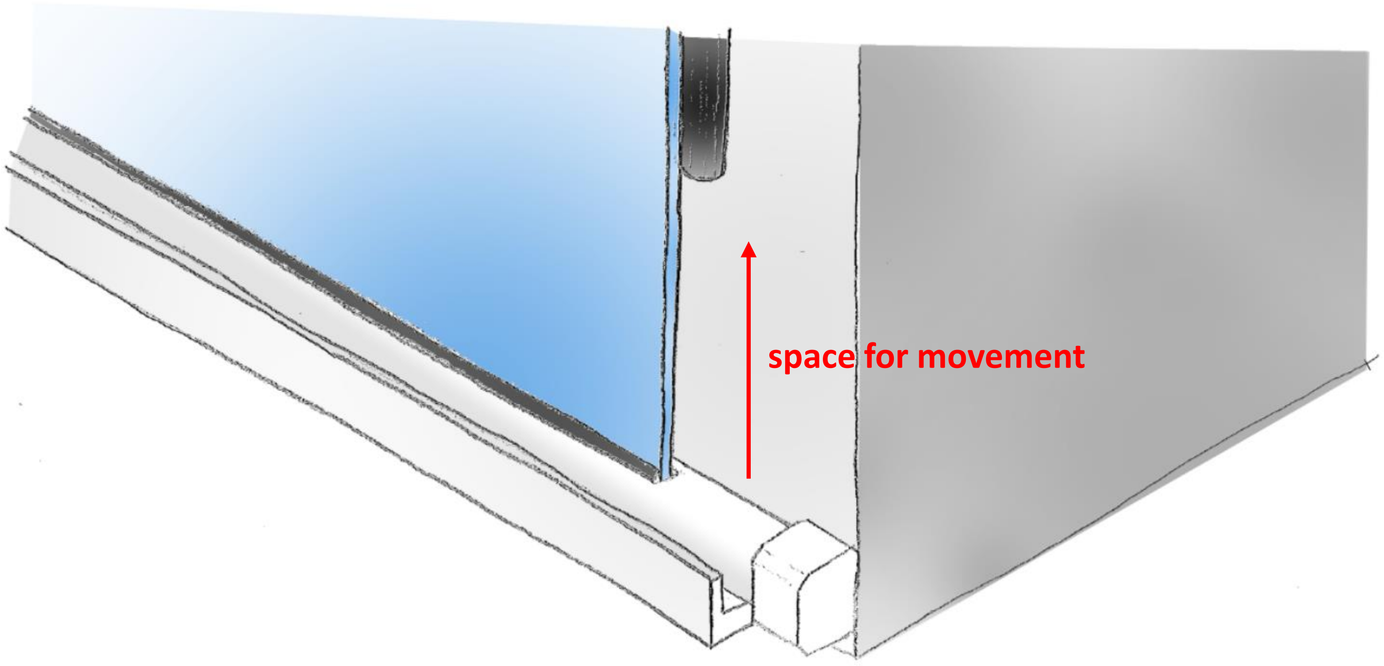

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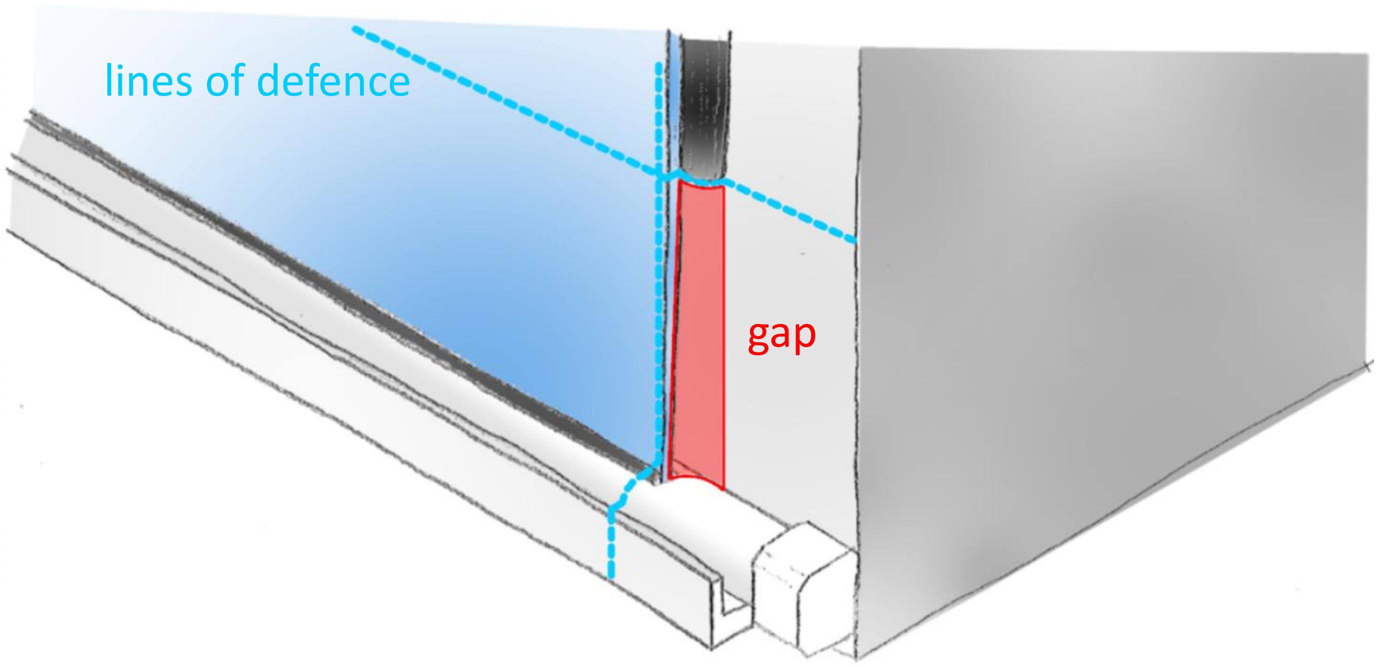


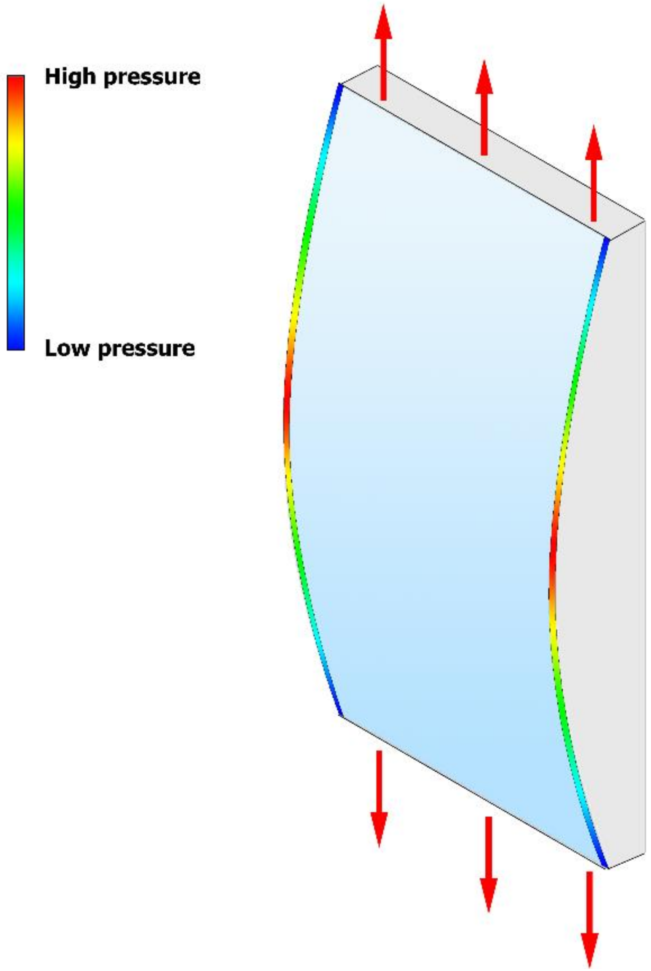
Practical Feasibility

Option 2: Tension

- gaps in corner joints
  → would require similar solution as magnet

Further concerns:

- Large force required against wind load
- Pressure not likely to be equally distributed



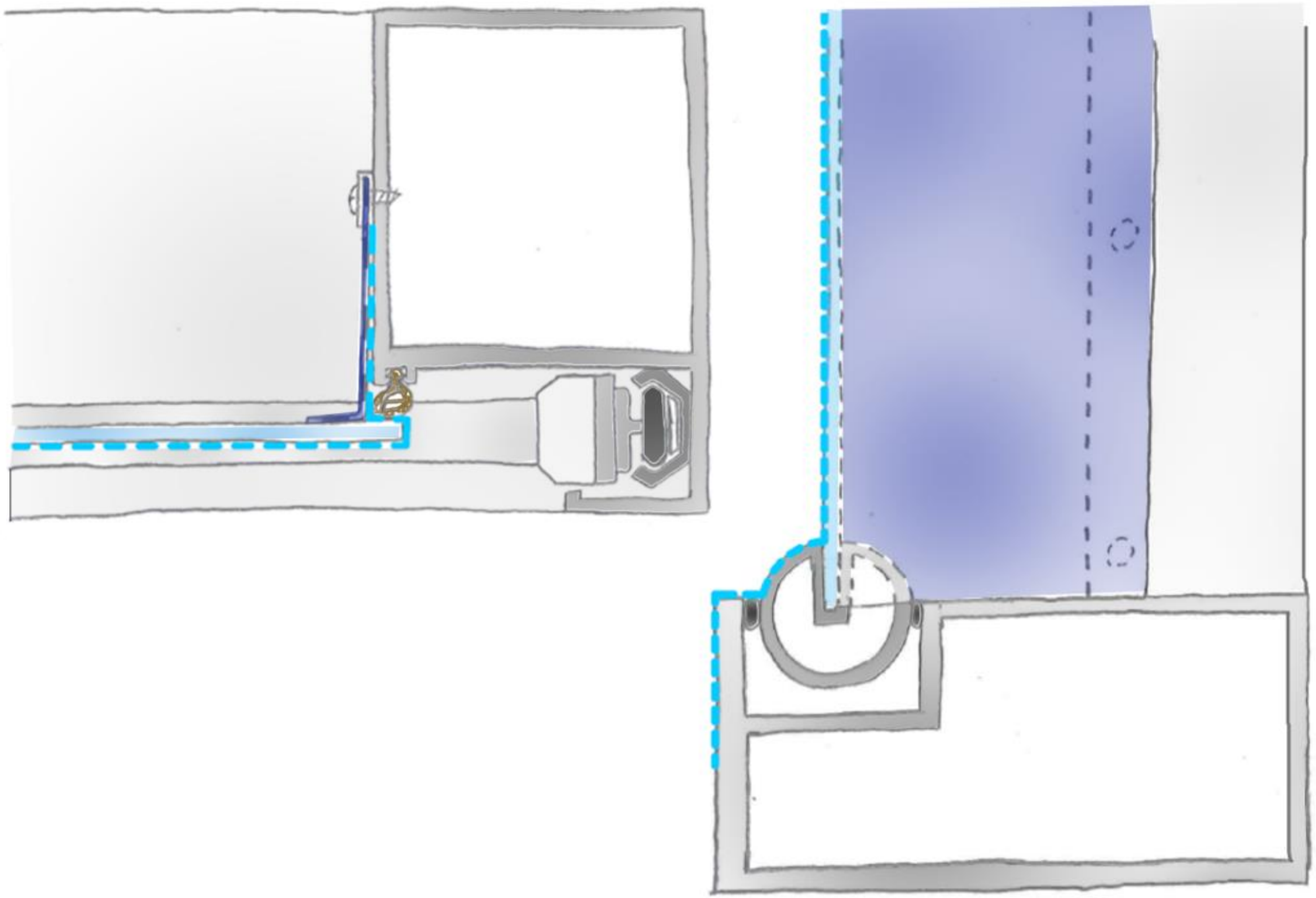
Practical Feasibility

Option 3: Elastic Fabric

Practical Feasibility

Option 3: Elastic Fabric

- Leakage at corner joint



Practical Feasibility

Option 3: Elastic Fabric

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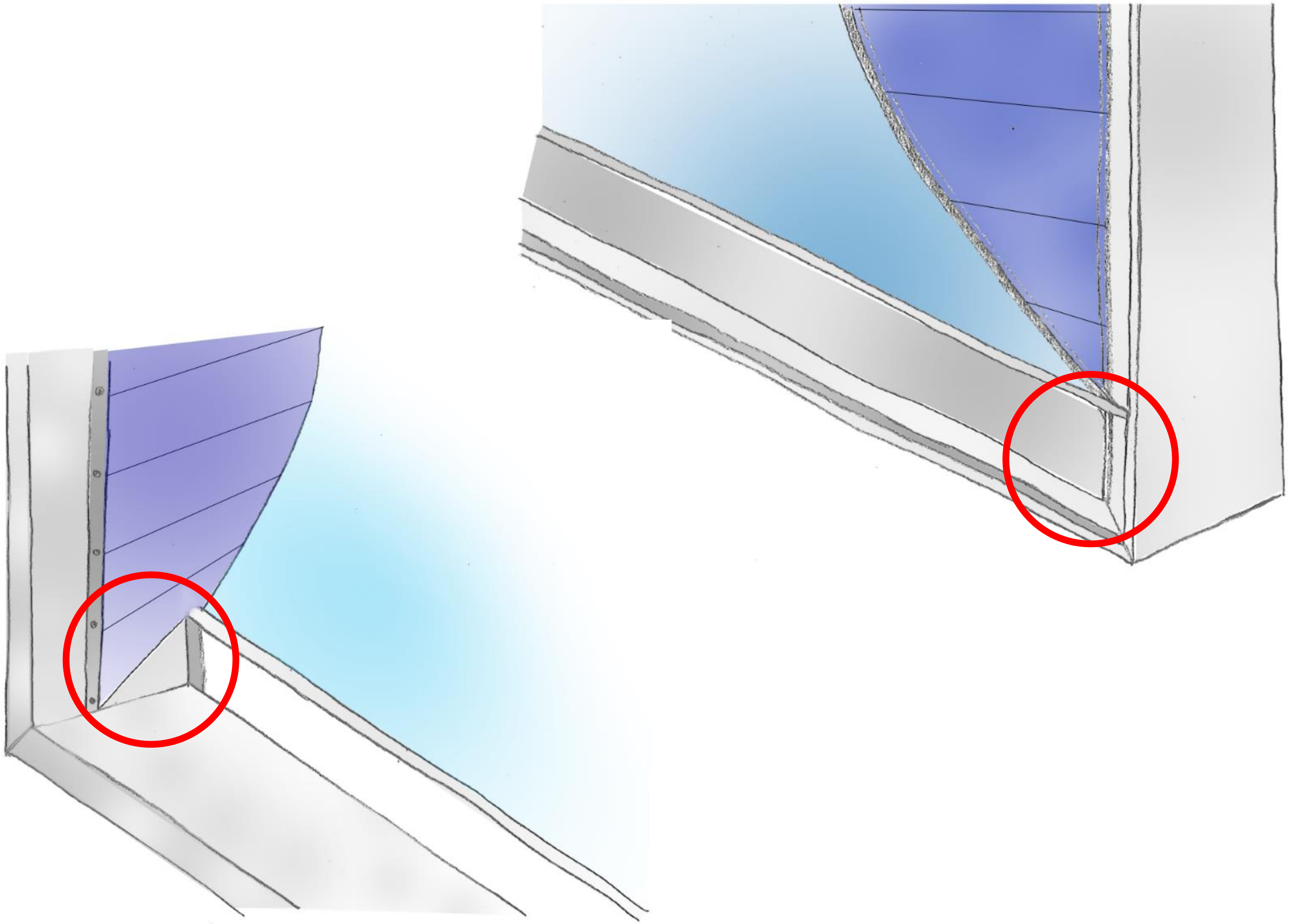
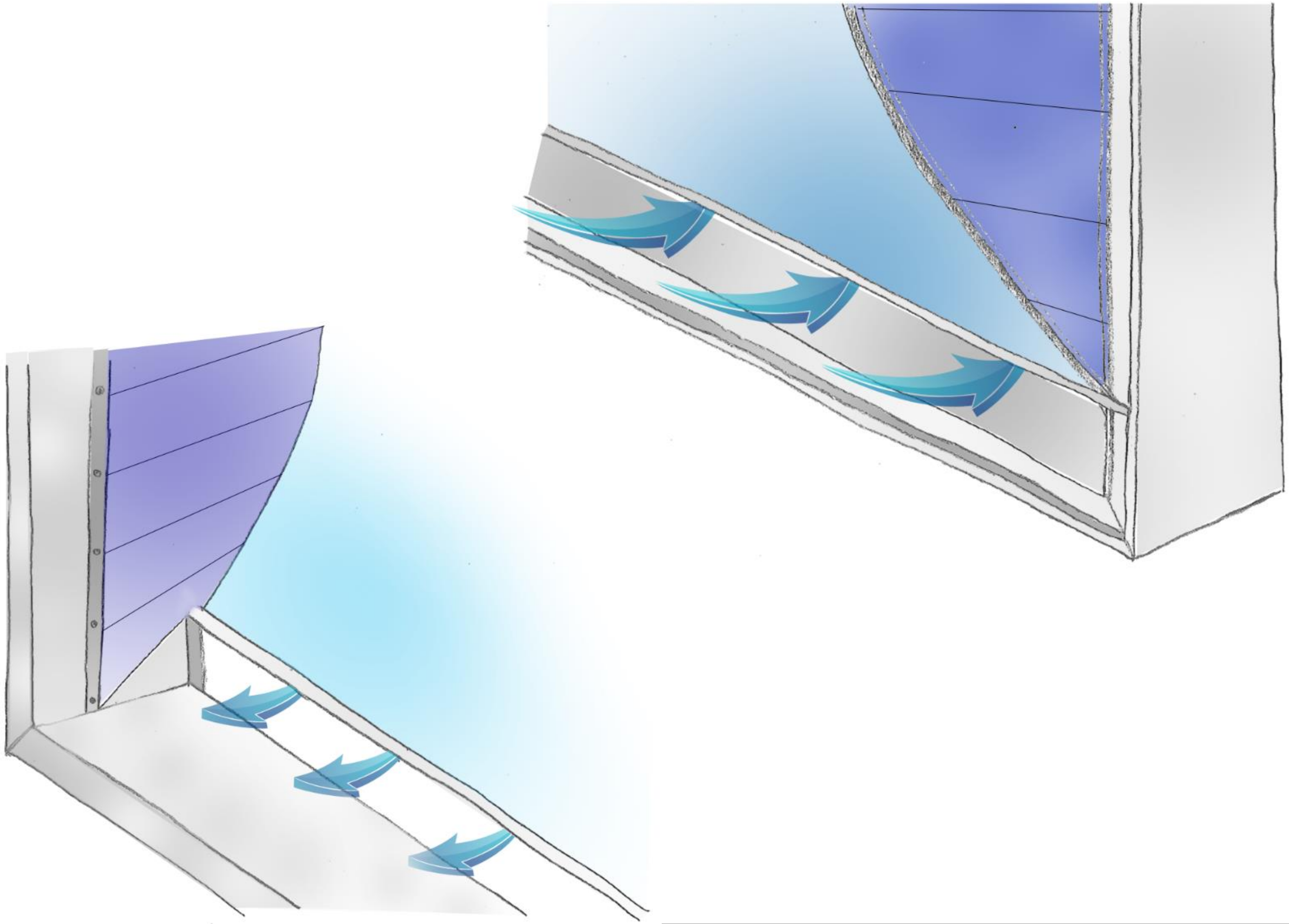


Practical Feasibility

Option 3: Elastic Fabric

- Leakage at corner joint
- Ventilation gap limited



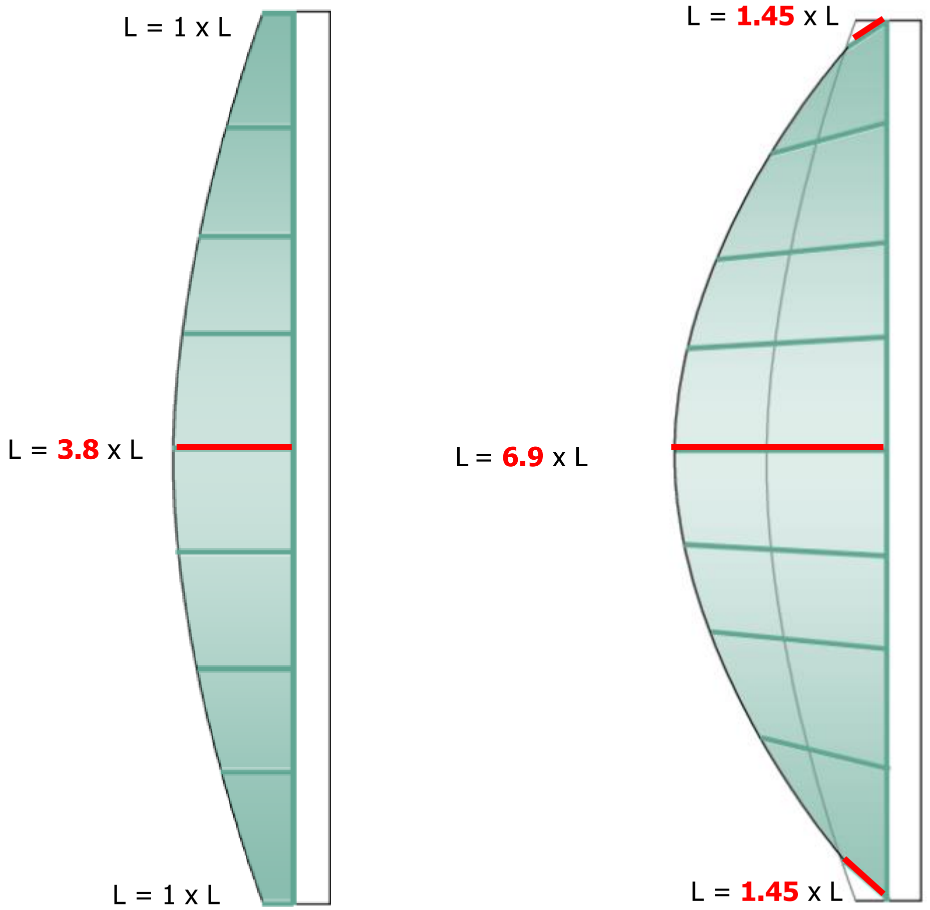
Practical Feasibility

Option 3: Elastic Fabric

- Leakage at corner joint
- Ventilation gap limited

Further concerns:

- High elasticity required + unequal stretching
- Obstruction of view

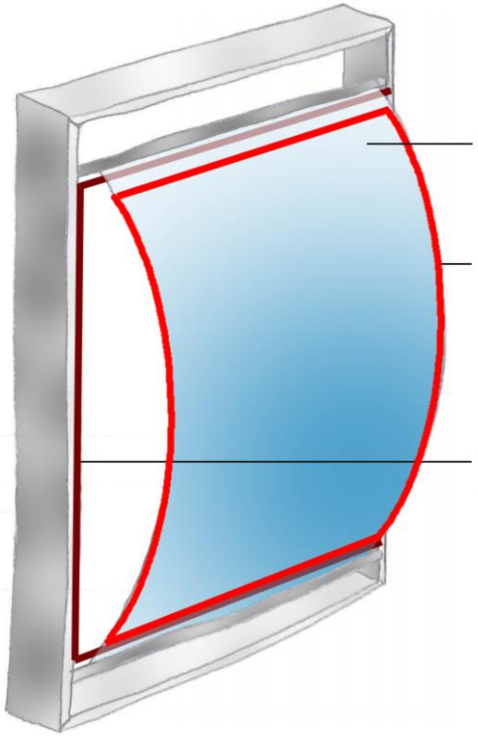


Selection of Design

	Option 1		Option 2		Option 3	
	+	-	+	-	+	-
practical feasibility	o magnet can provide enough pulling force for water- airtightness o magnet pulling force adjustable	o additional horizontal frames required o abrupt opening move-ment due to magnetic holding force (only if permanent magnet)	o simple gasket detail possible	o unequally distributed pressure o additional horizontal frames required o extra force required to keep water- and airtight	o bent edges permanently sealed	o limited ventilation gap o leakage at corners o possible abrasion of fabric due to over-stretching o obstruction of view
structural suitability	o magnetic pulling force can also be used against wind suction			o large force required to keep glazing shut o applied force may result in bending of shafts		o large force required to keep glazing shut o applied force may result in bending of shafts o fabric may pull back edges of glazing with tendency to return to original length

Design Choice

Option 1: Magnetic Force



Option 2: Tensile Force

Option 3: Elastic Fabric

Expected Performance of the Proposed Design

Requirements / Qualities	
watertightness	✓
airtightness	✓
thermal insulation	✗
acoustic insulation	✗
safety	✓
stiffness under high wind load	✗
natural ventilation	✓
transparency / optical quality	✓
cost-effectiveness	✗

Case Study

Possible Applications

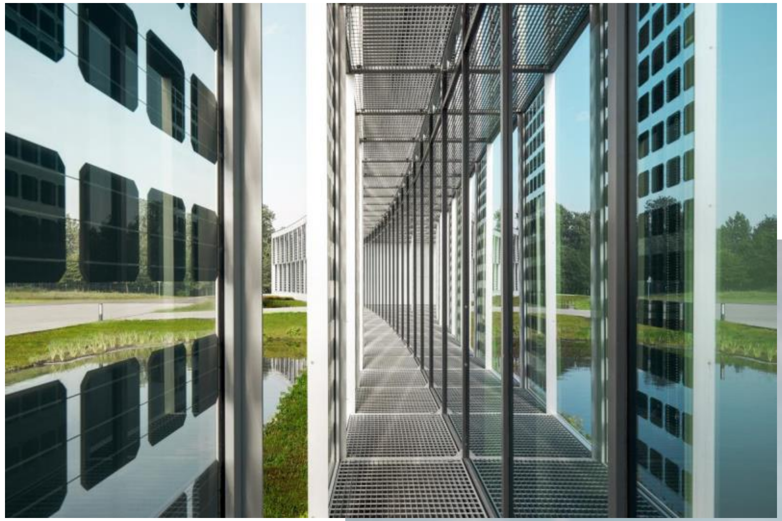
Greenhouse/
Botanical Garden

Interior Glazing
Double Skin Facade
Glass Roof/
Single Skin Facade
Application
Glass Dome

Requirements / Qualities	
thermal insulation (only if heated and unheated spaces are divided)	✗
acoustic insulation	✗
safety	✓
transparency / optical quality	✓
transparency / optical quality	✓
showcasing the innovation	✗

Case Study

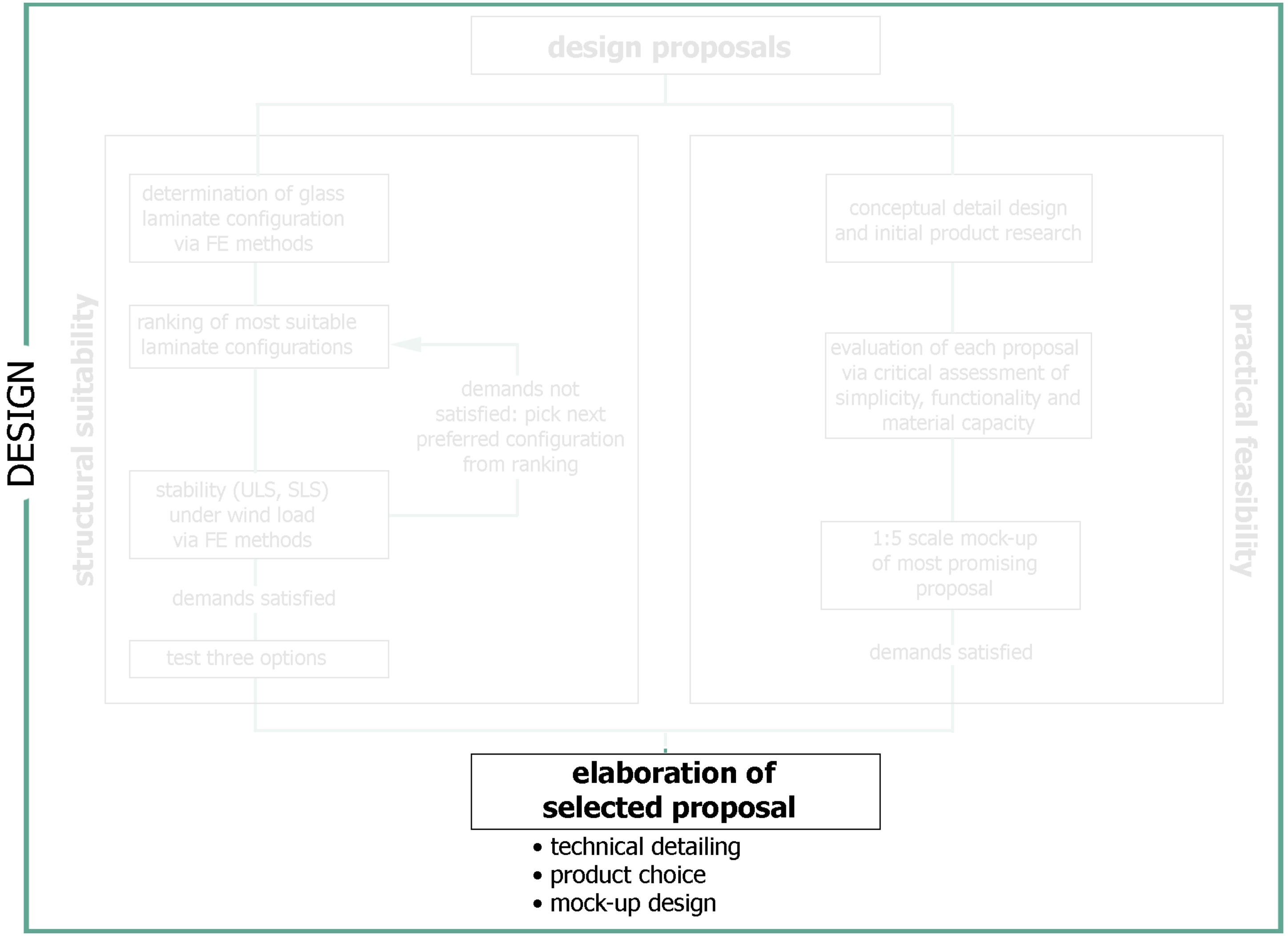
AGC Technovation Center, Gosselies, Belgium



- Outer skin of open double-skin façade
- No thermal and acoustic insulation
- Functions solely as sun-protective layer and for power generation
- "Show room" for company's innovative product range

→ Alternative design: closed cavity façade

Approach and Methodology



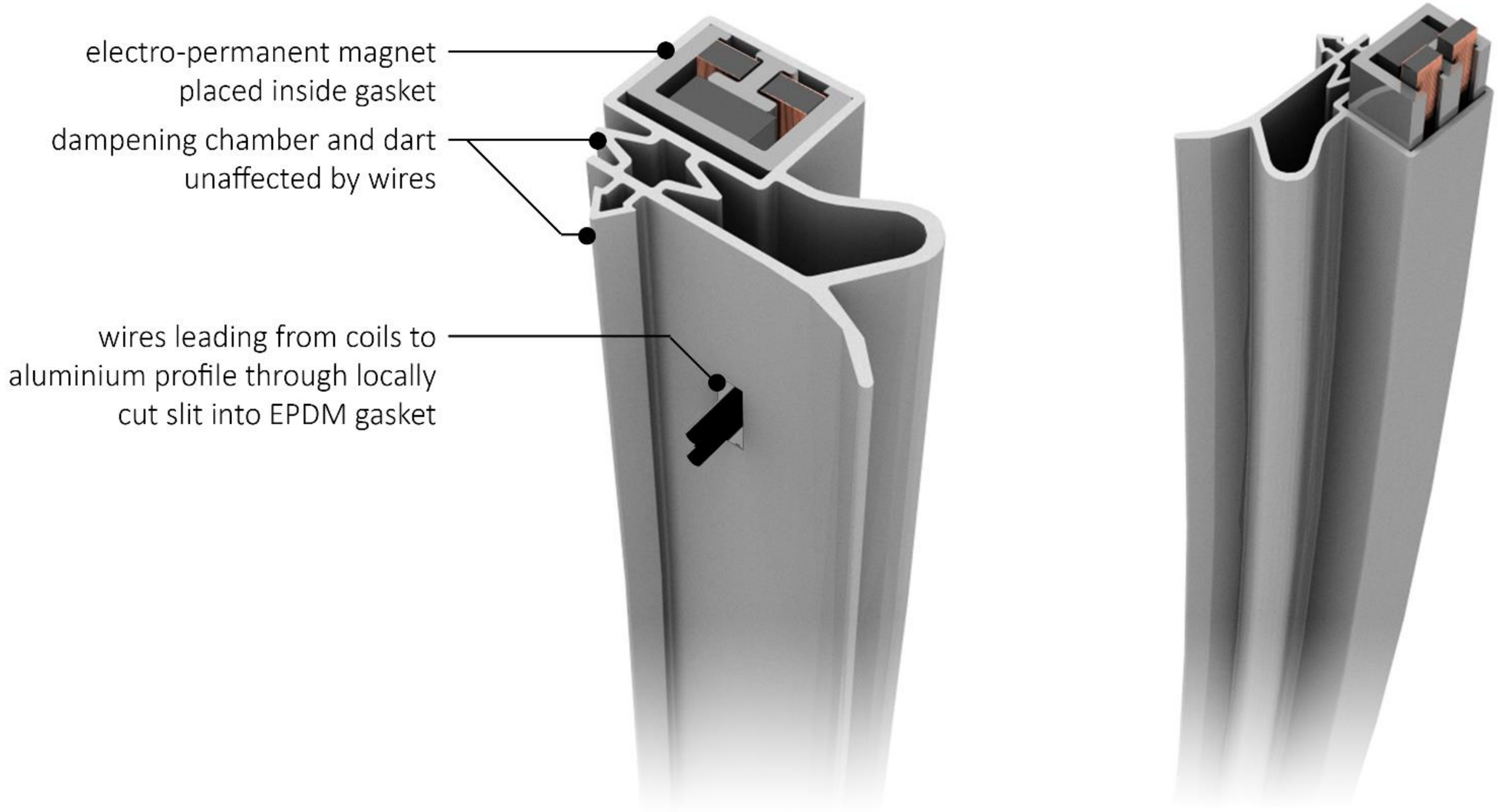
Elaboration of Selected Design

Focuses:

- Magnet-gasket design
- Mode of operation (kinetics)
- Facade profile design
- Manufacturing, assembly

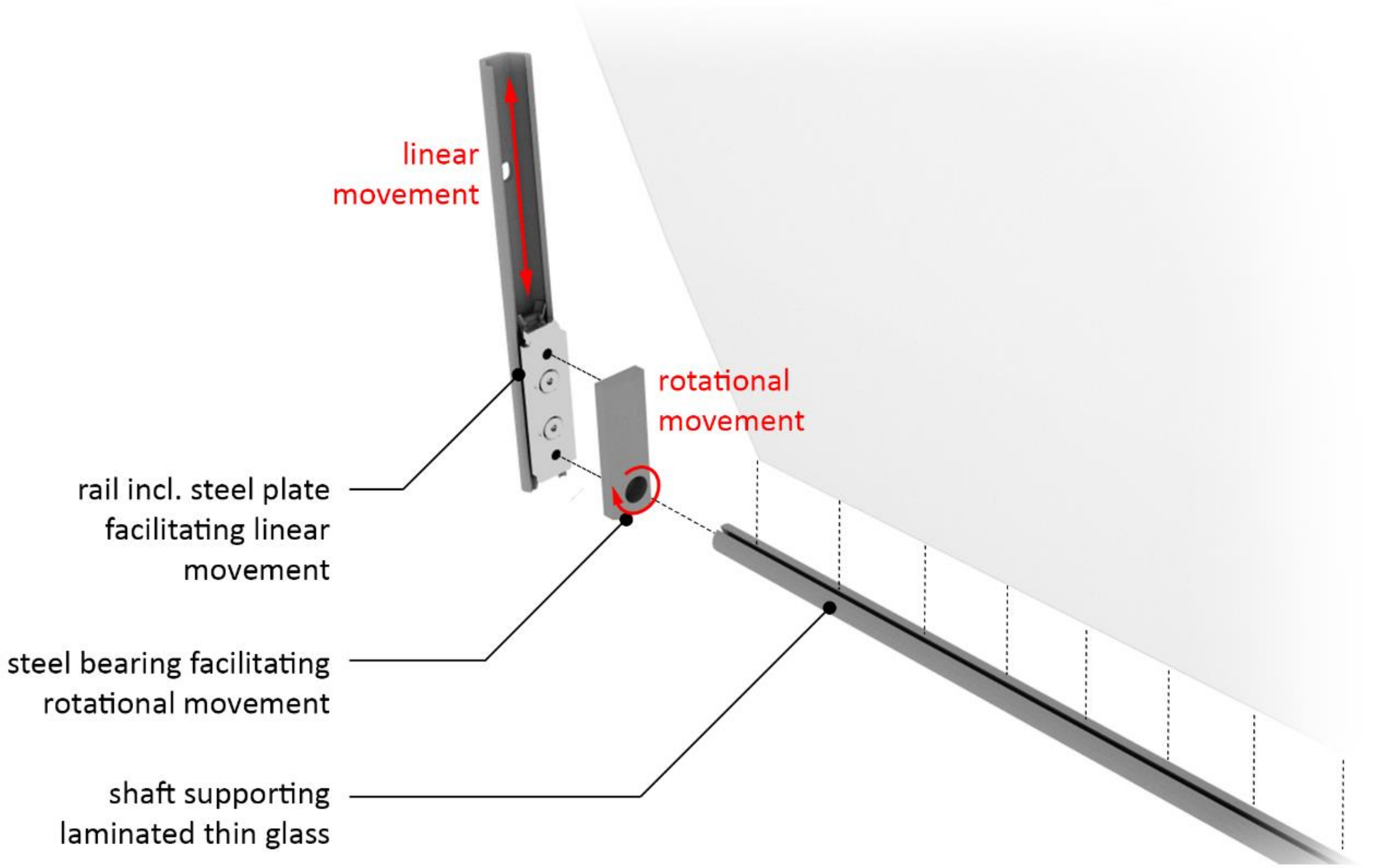
Elaboration of Selected Design

Gasket with Embedded Switchable Magnet



Elaboration of Selected Design

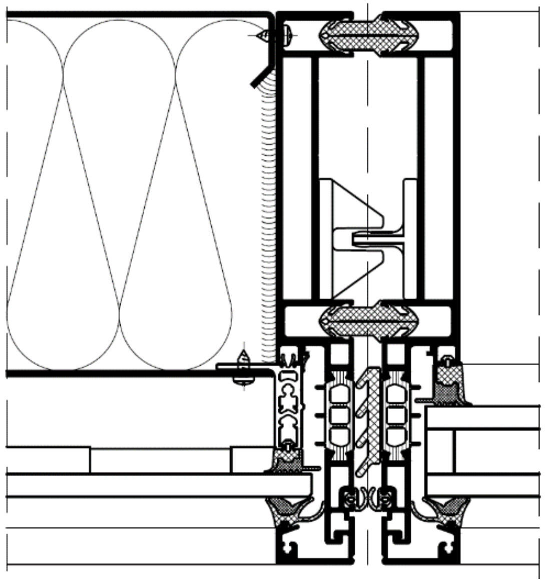
Mode of Operation



Elaboration of Selected Design

Façade Profile Design

- Unitised system

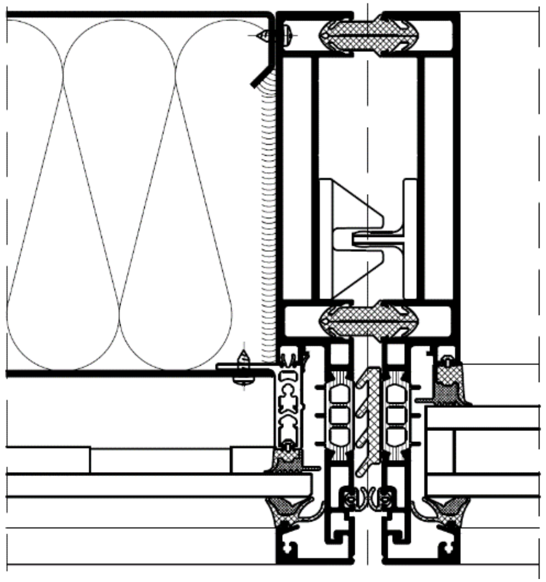


Schüco USC 65 unitised system

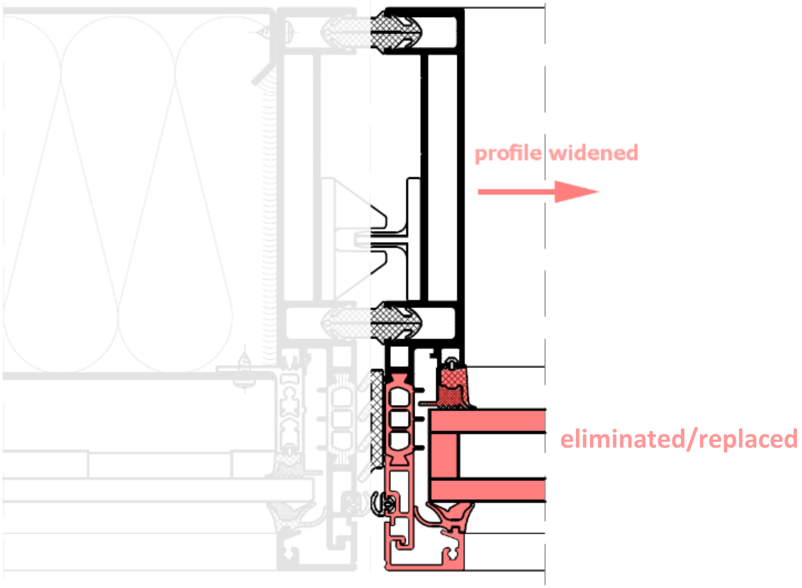
Elaboration of Selected Design

Façade Profile Design

- Unitised system
- Adjustments made to fit design



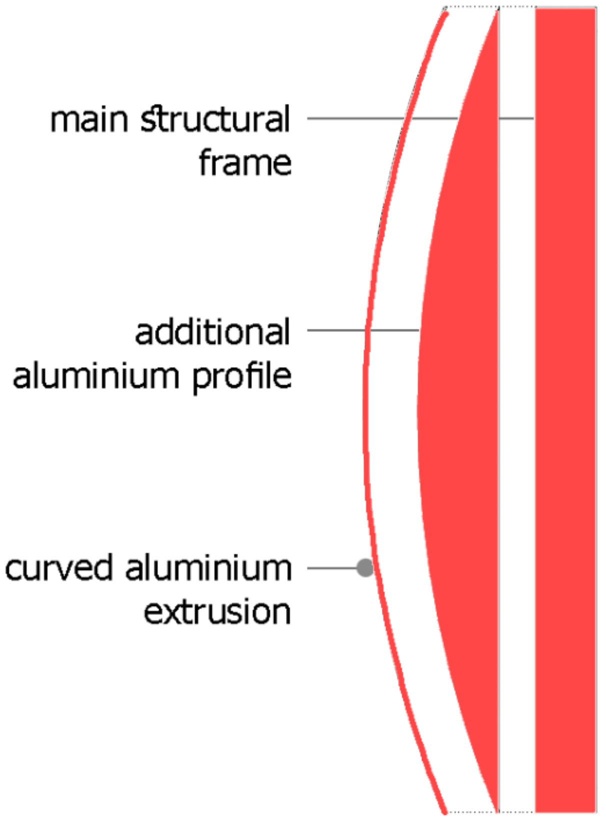
Schüco USC 65 unitised system

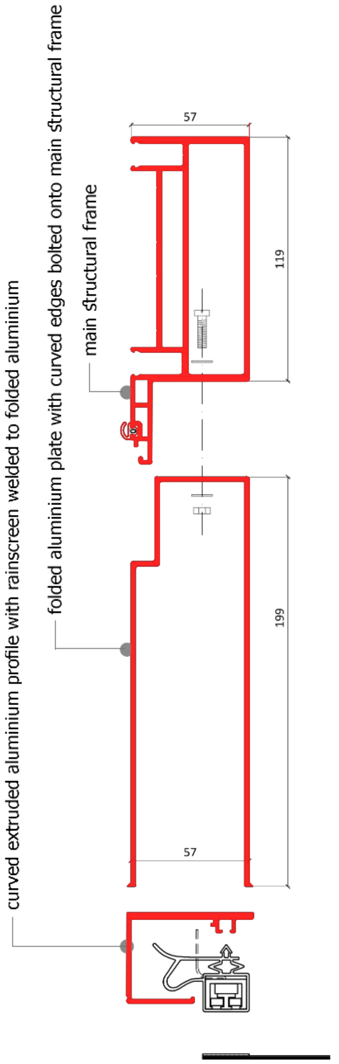


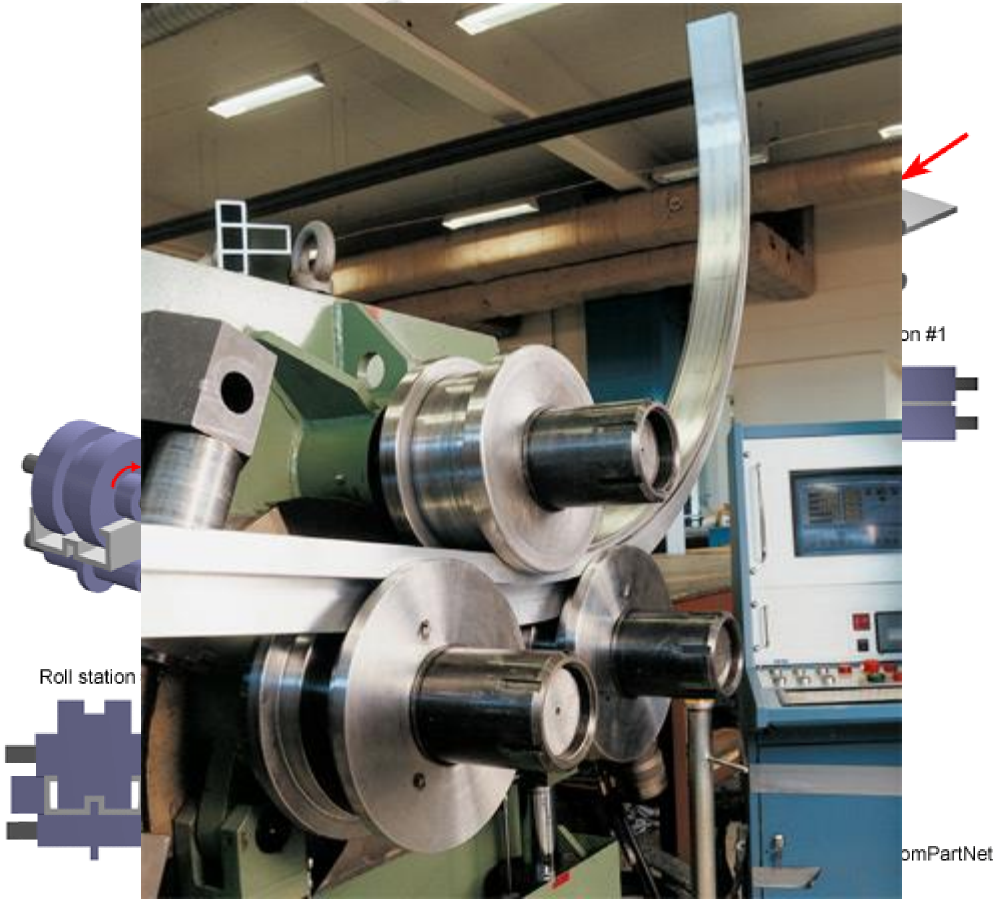
- Profile widened (to house rail, magnetic gasket etc.)
- Outer gasket eliminated (now single sided)
- Insulating layer eliminated (double-skin facade)

Elaboration of Selected Design

Façade Profile Design





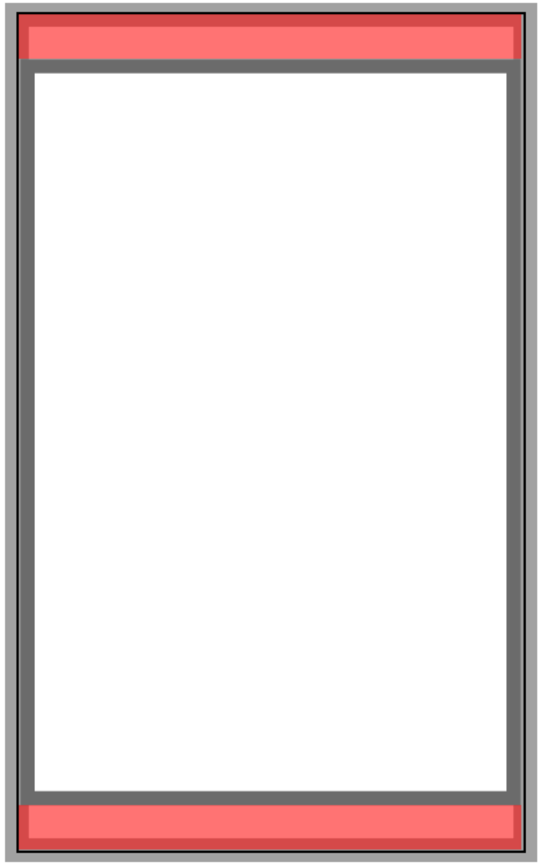


(source: aluminiumdesign.net)

Elaboration of Selected Design

Façade Profile Design

- Gap between main frame and additional transom

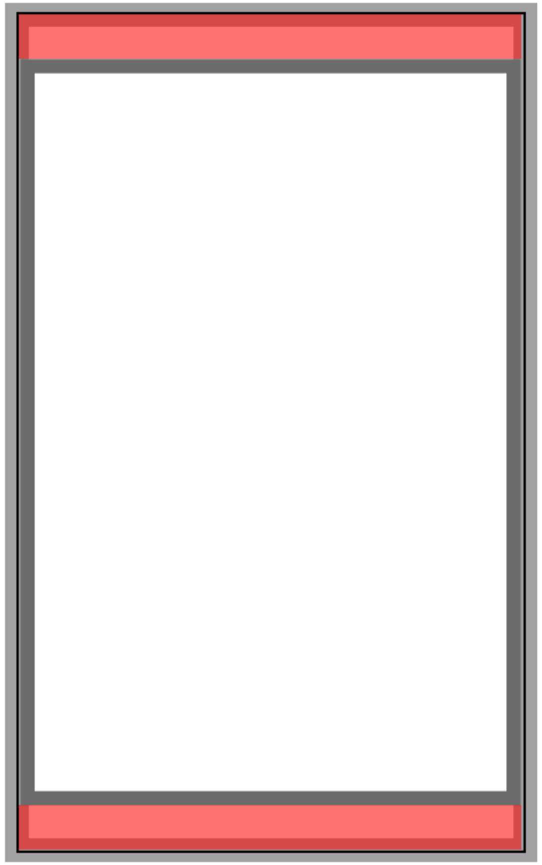


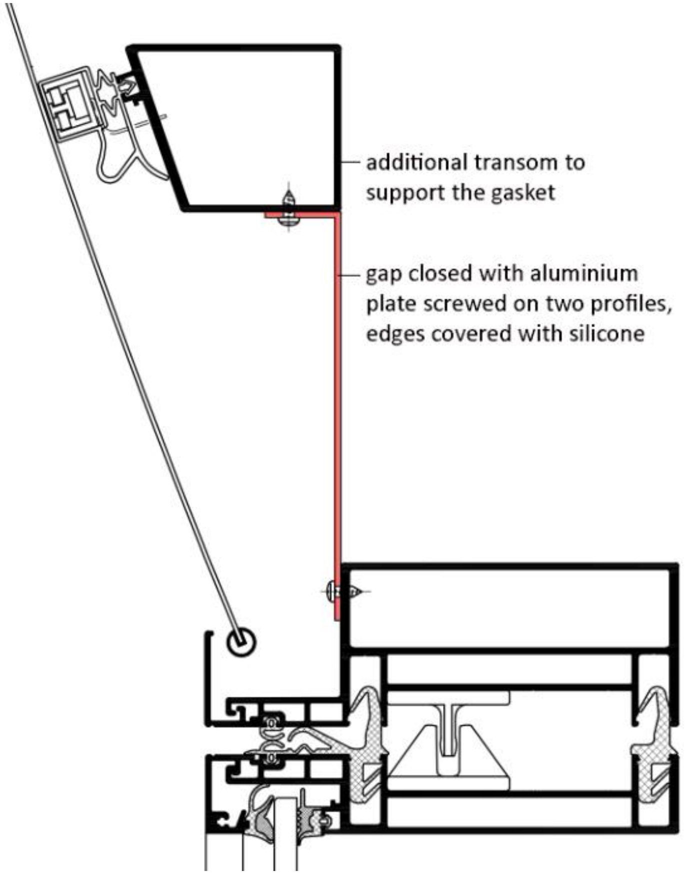
Elaboration of Selected Design

Façade Profile Design

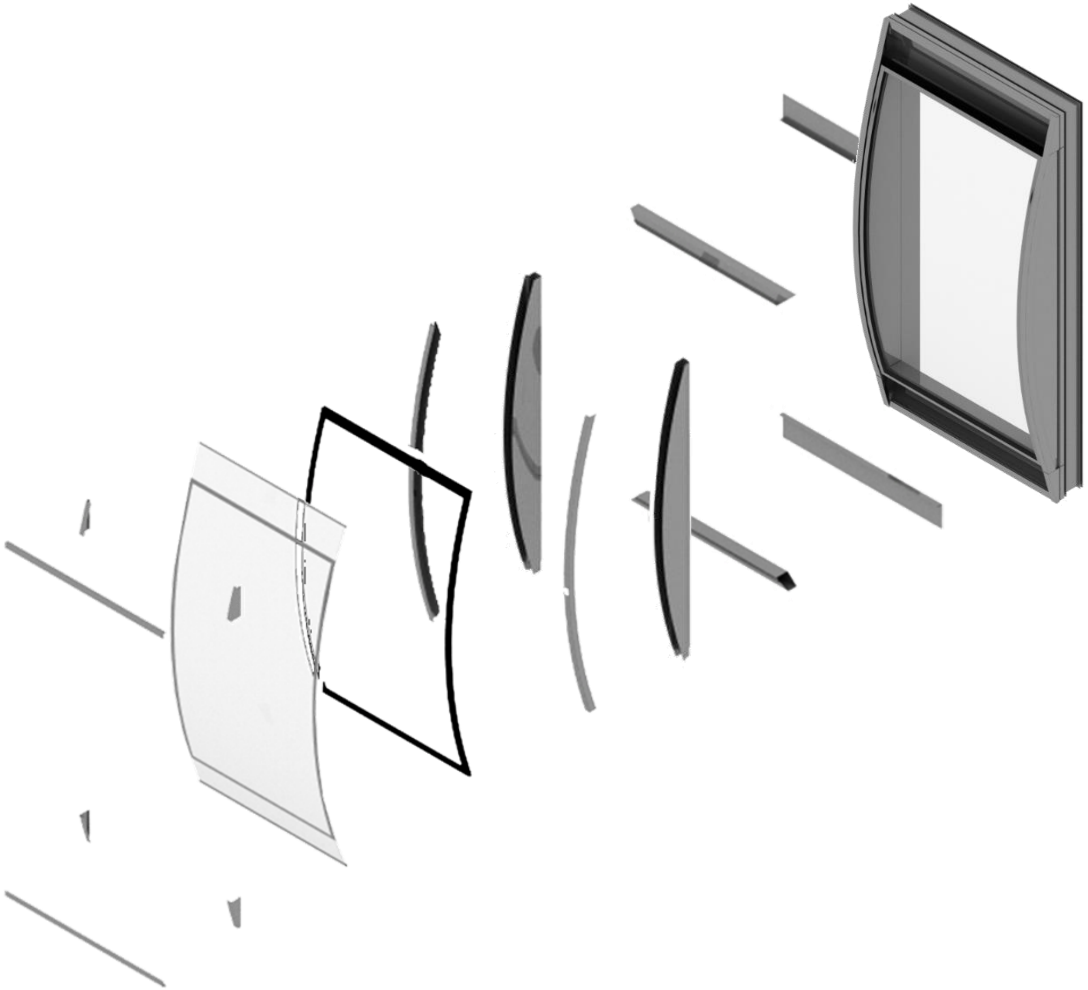
- Gap between main frame and additional transom

→ covered with aluminium plate, edges made airtight with silicone



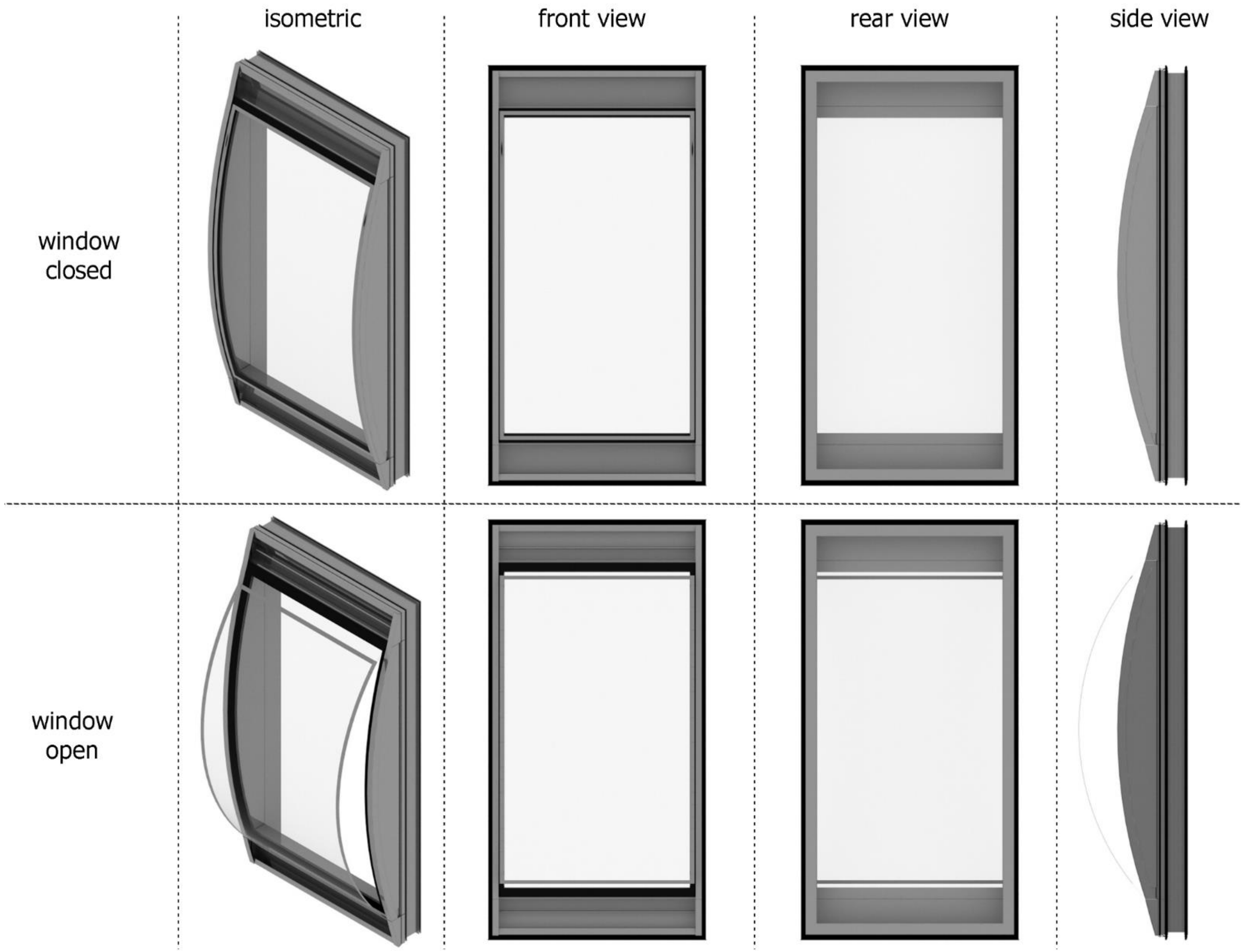


Final Design



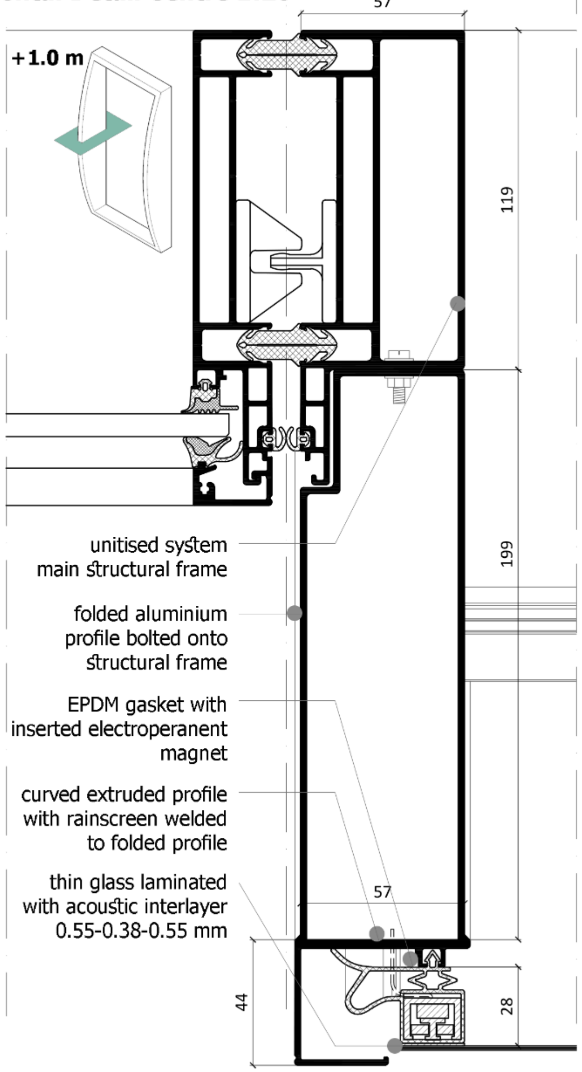
Final Design

Final Design

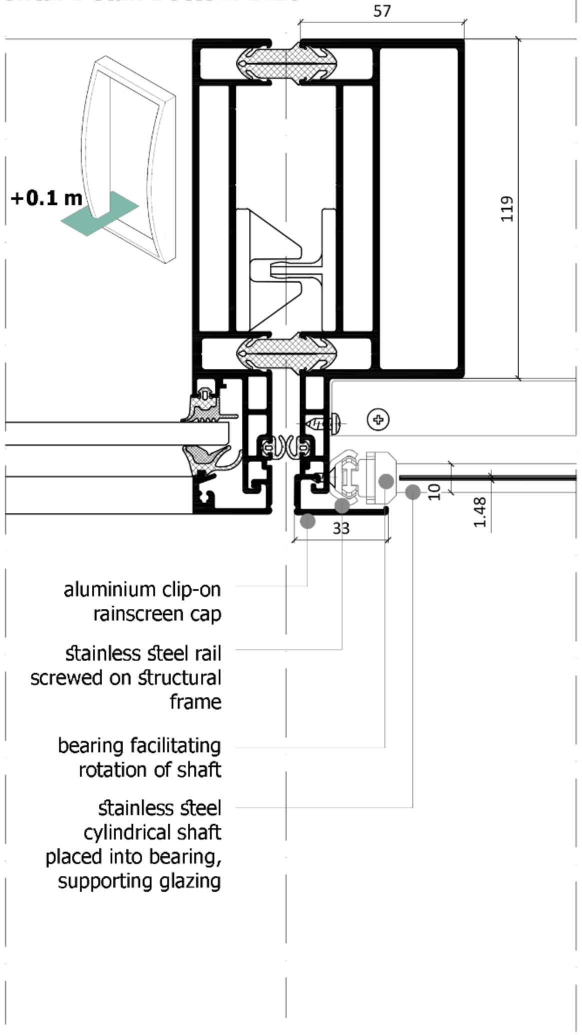


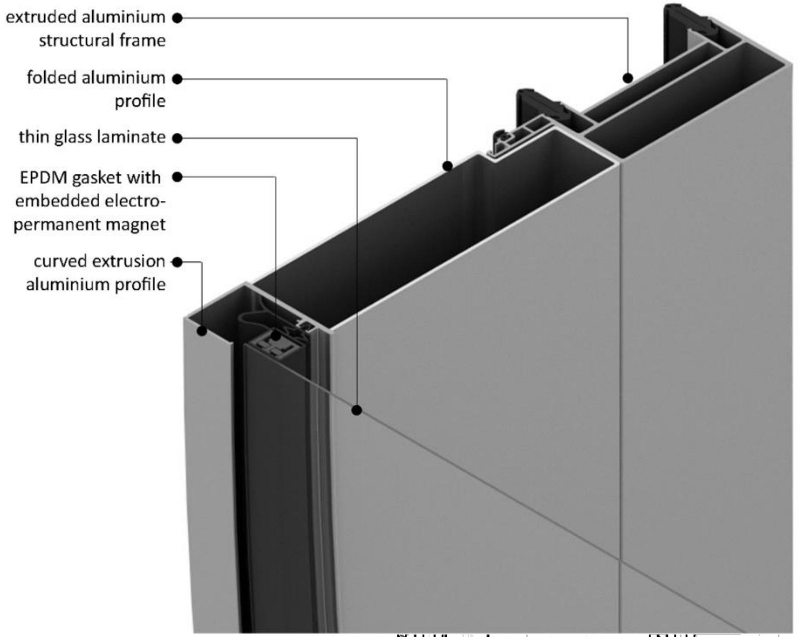
Final Design

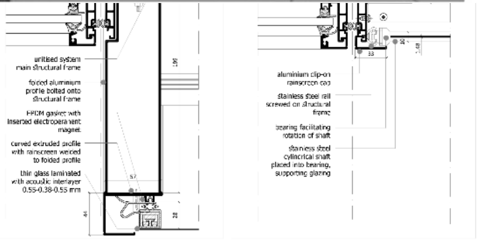
Horizontal Detail Centre 1:20



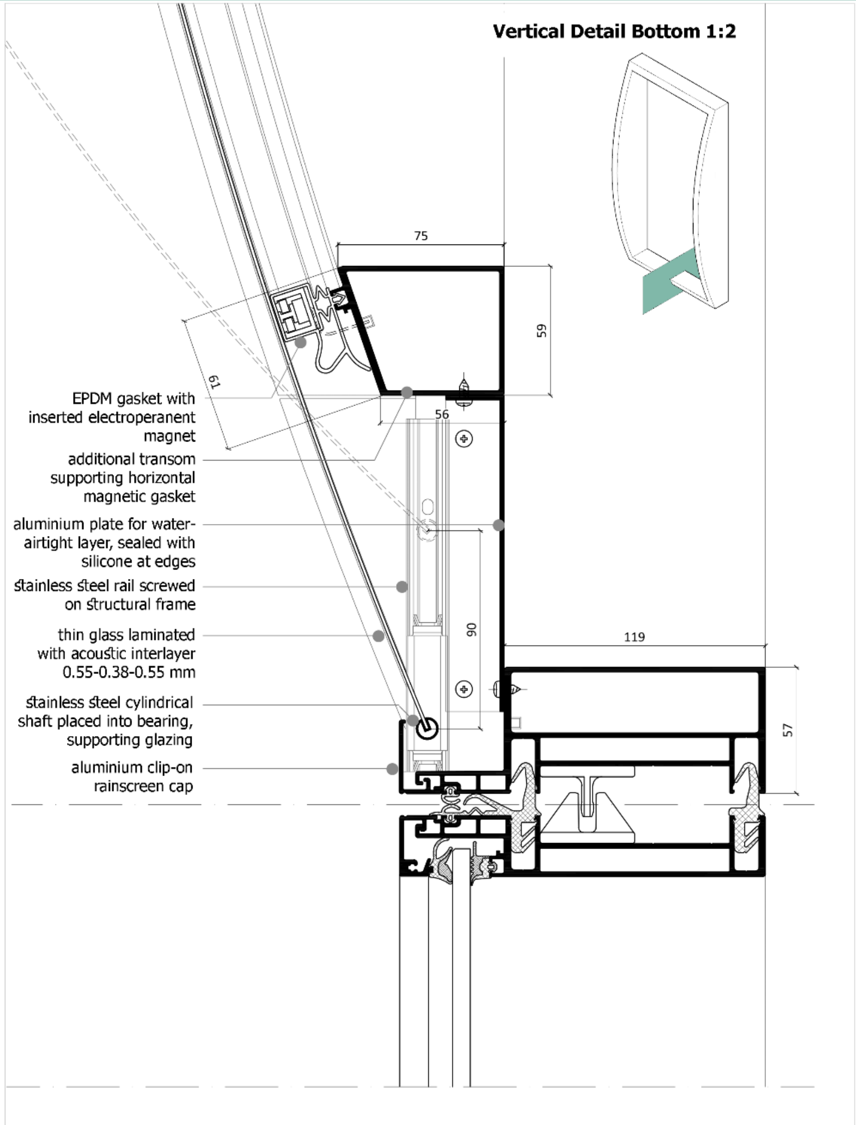
Horizontal Detail Bottom 1:20

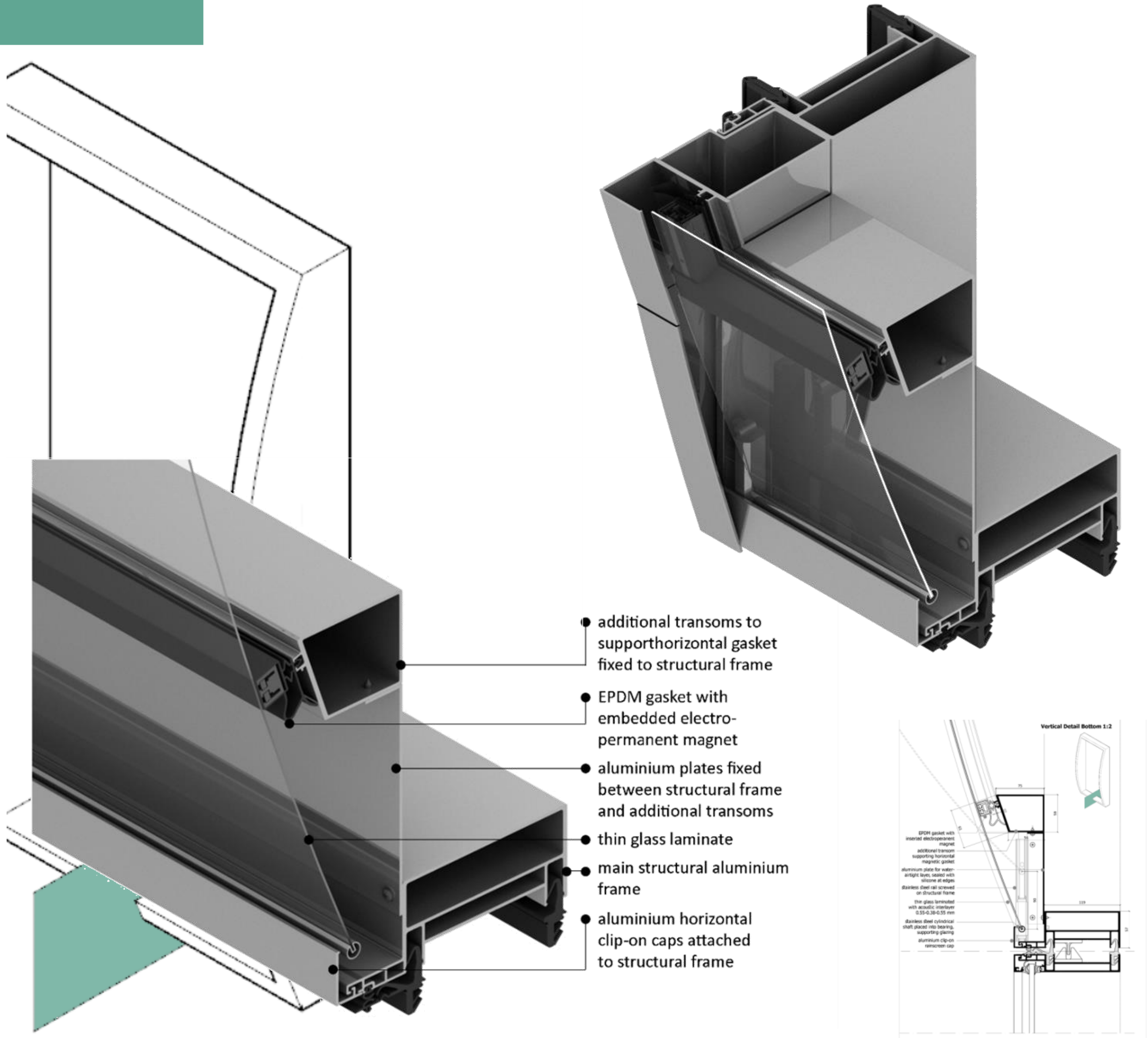


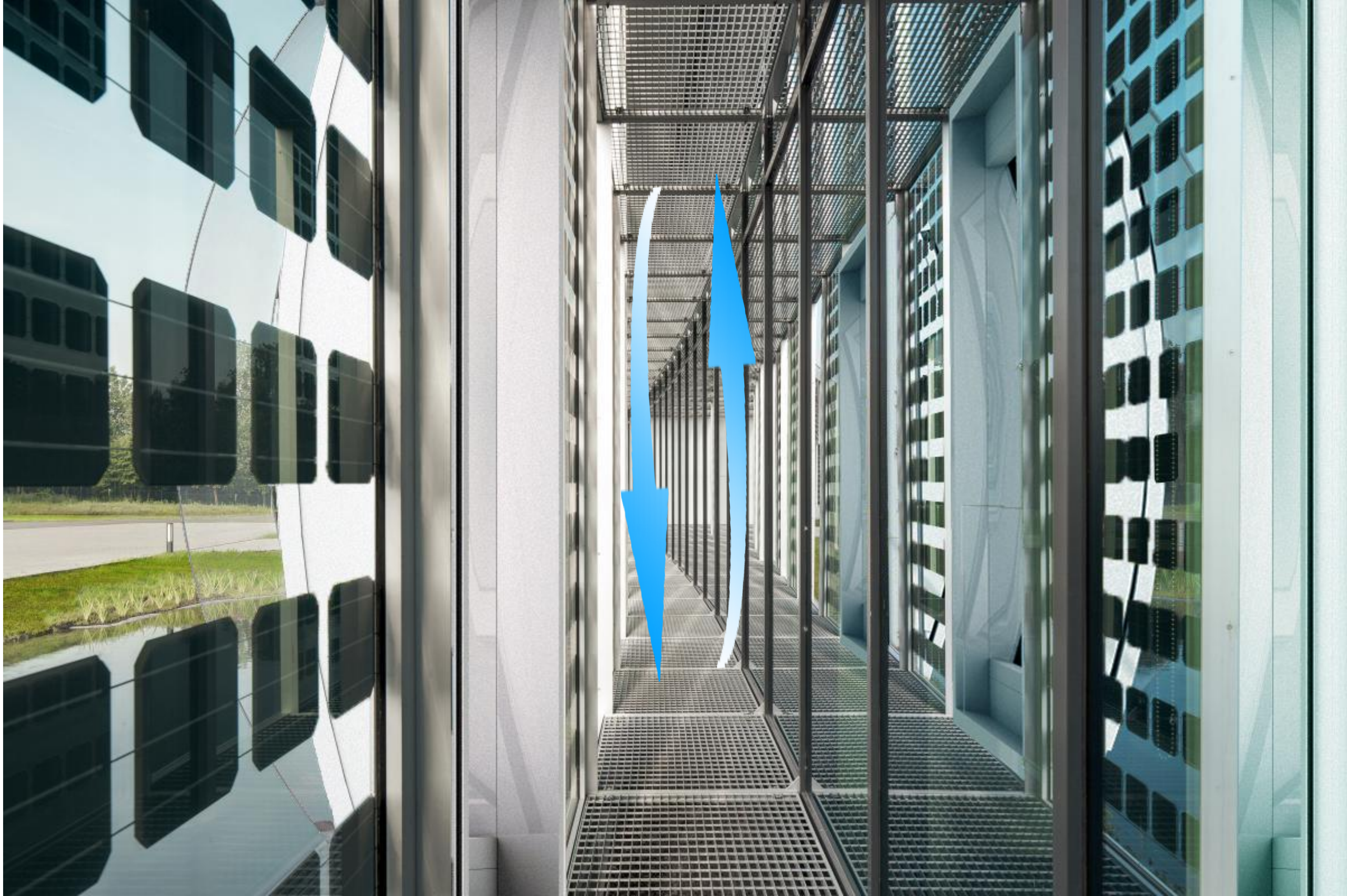




Final Design







Conclusion

Answer to Main Research Question:

"How can a kinetic façade element featuring a bendable thin glass panel be designed to be water- and airtight in closed condition? "

Design involves:

- Glazing consisting of two thin glass elements (0.55 mm) laminated with acoustic interlayer (0.38 mm) with metallic strip attached
- Switchable electro-permanent magnets placed inside the gasket
- Principle of active bending (1D-linear movement to 2D-deformation)
- Bespoke facade profiles designed to acommodate requirements

Discussion

- Research does <u>not</u> present optimal or only possibility to achieve the goal
- Meant to offer new **insights** into the field and form a **basis for further research**
- Many choices made during the process are **subjective**, although supported by numerical data and arguments from previous literature

→ main objectives fulfilled within theoretical framework:

1) Addition of a **second layer of glazing** to comply with safety regulations

2) Investigation of possibilities to combine the bending of thin glass with **water- and airtightness** properties

Reflection & Recommendations

Possibilities & Limitations

- **Sustainability** (reduced use of raw materials, lightweight loadbearing structures)
  ⟶ increased use of aluminium for stiffness
- **Cost reduction** (reduced use of raw materials, lightweight loadbearing structures)
  ⟶ chemical strengthening process, necessity of bespoke elements
- **New architectural impressions**
  ⟶ large variety of new possibilities, new architectural era?

Recommendations for further research

- Investigation of **other possible uses** for thin glass in architecture

  ⟶ for bending: sun shading, solar power generation, structural (load reduction)

  ⟶ building parts/types: glass roof, greenhouse, interior glazing, single skin
- Possibility to make **insulating glass unit** (double glazing)

Thank you for your attention!