THE RE∞ SEAL WINDOW

A Redesign of the edge seal of Insulated glass units
to facilitate easy and fast re-manucturing.

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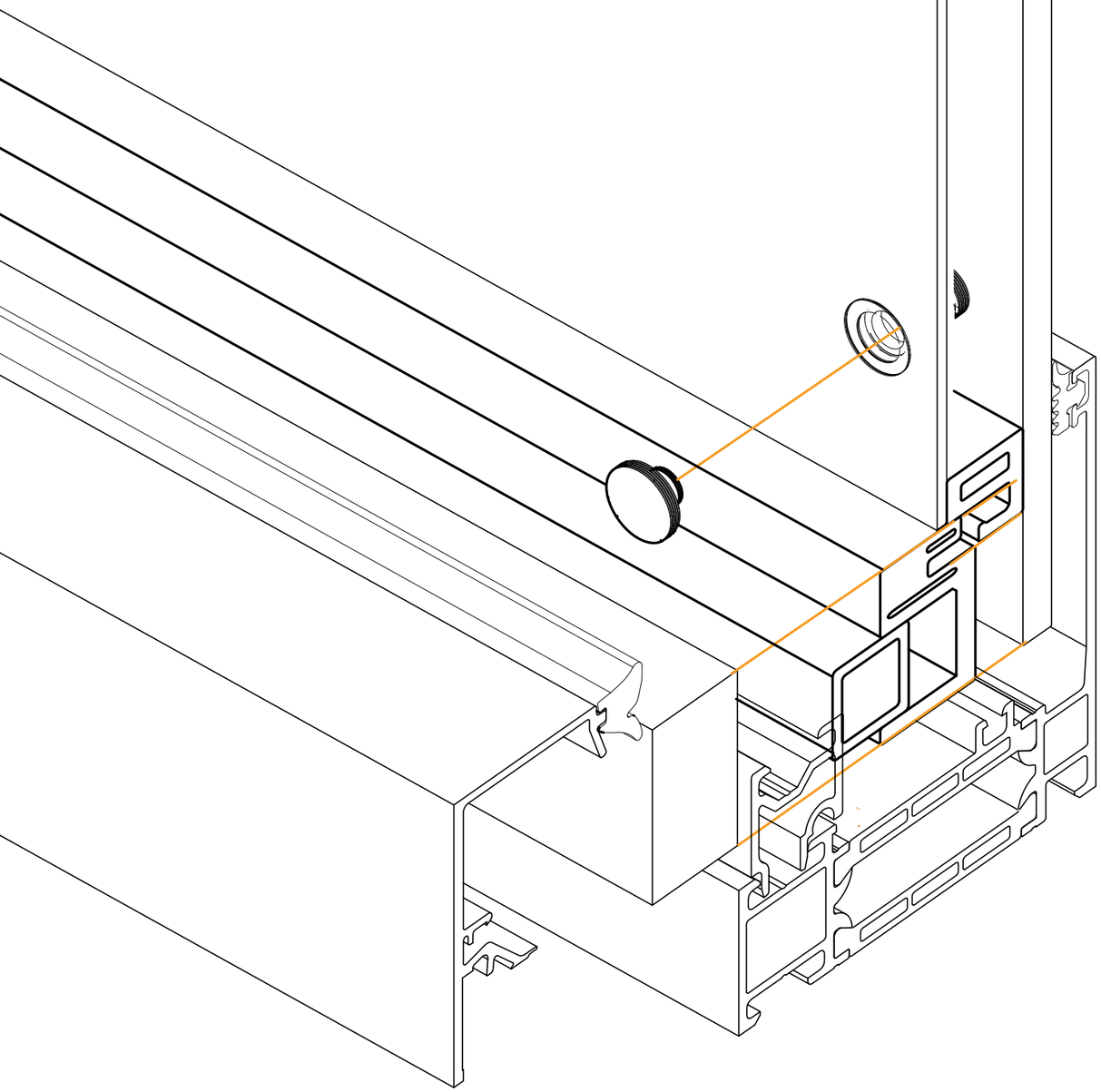
Mentors: Dr.Ir.F.A.Veer
Dr.ing.M. Bilow



20-20-20 EU Goals for 2020

-20%

20-20-20 EU Goals for 2020

-20%

0%

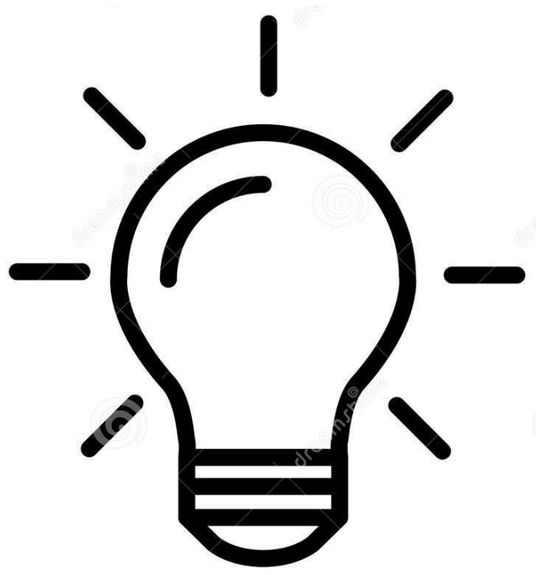
EU Goals for 2050

-90%

The Building sector

40 % materials

Biggest
Energy consumer



(Asif, Muneer, & Kubie, 2005)

The Building sector

replacement

Life cycle extension

Konstantinou (2014).

The building sector- life cycle extension

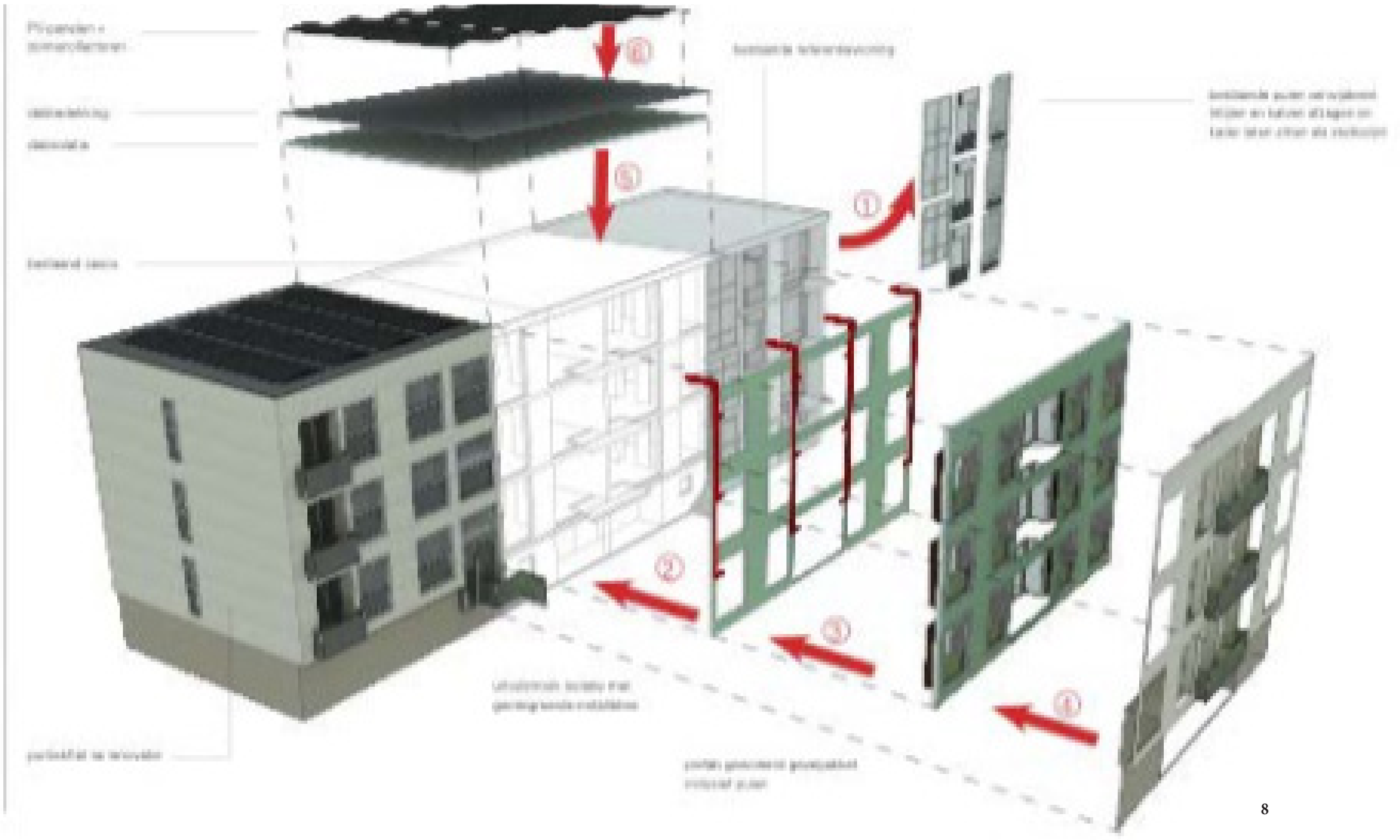
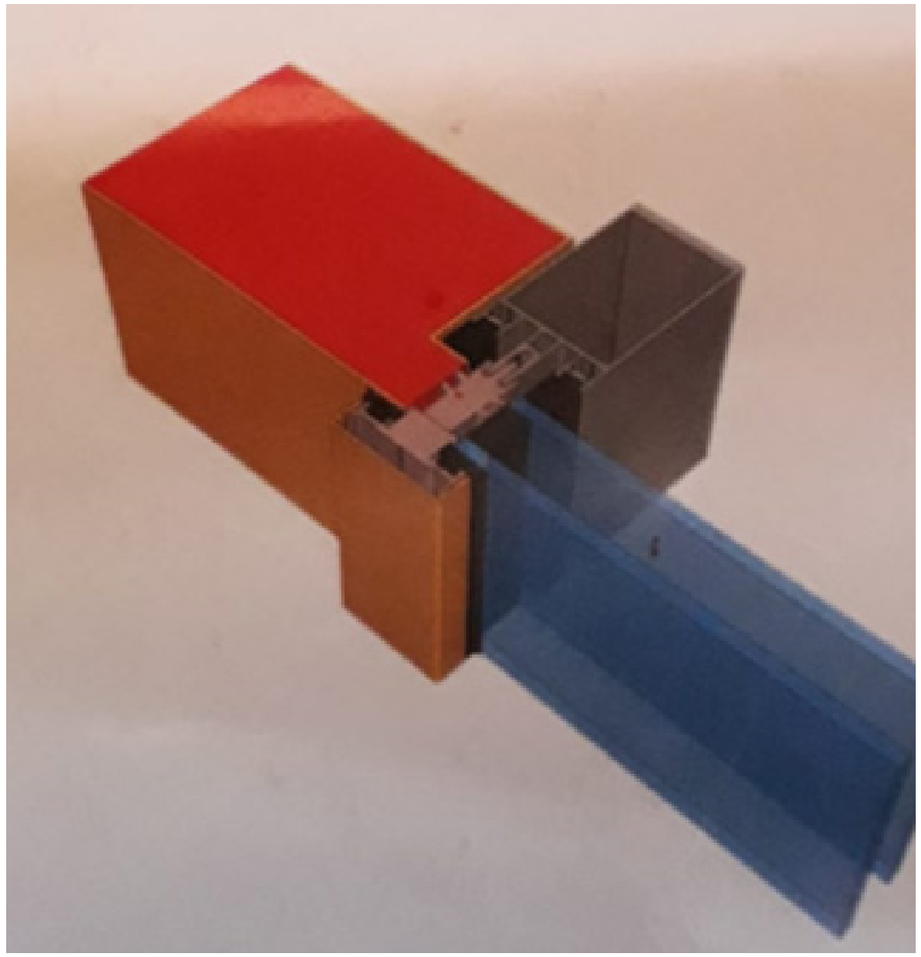


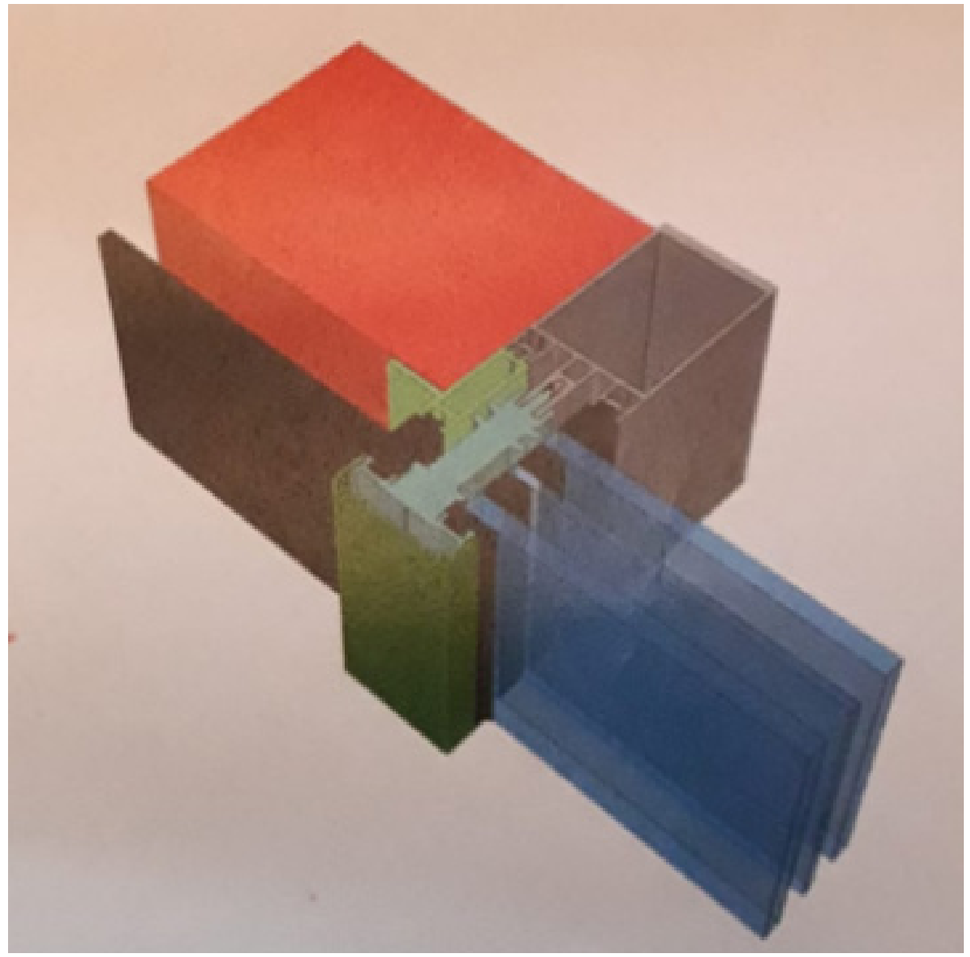
Figure 1. The 2ndSkin solution

Konstantinou (2014).

The building sector- life cycle extension

adjustable elements



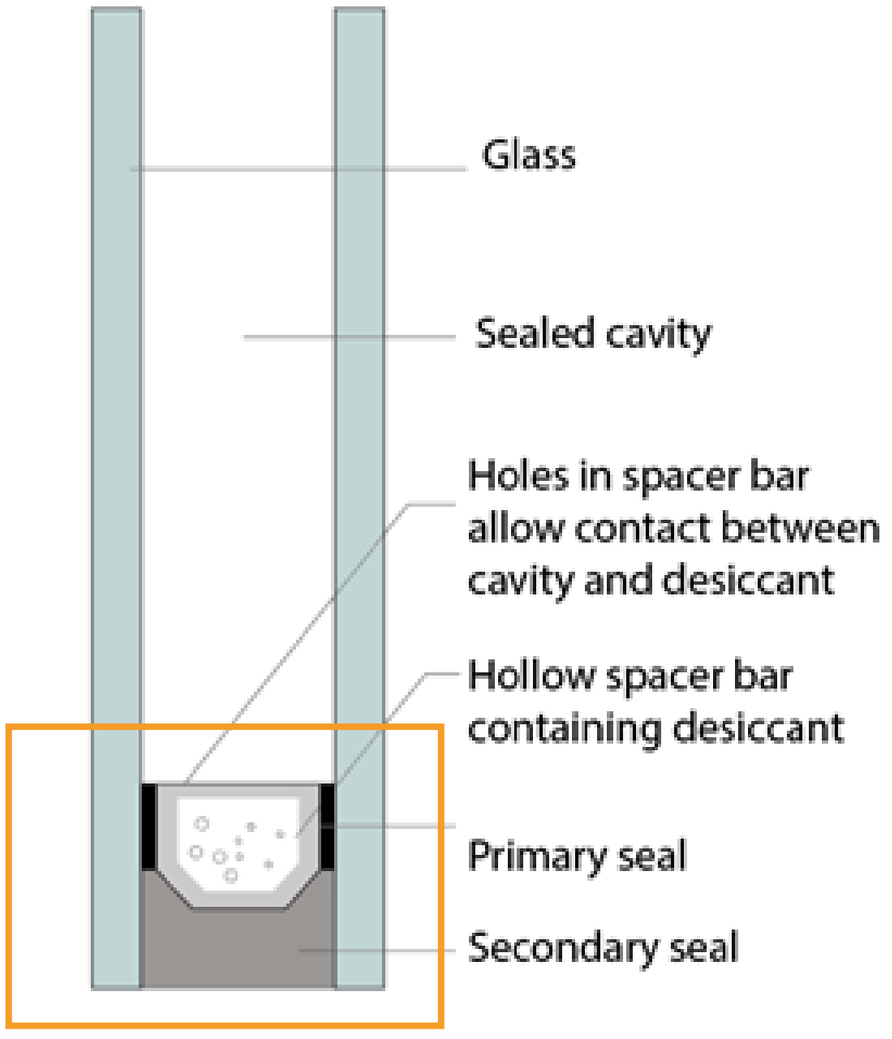


150000 tonnes of post-consumer glass -> aggregate

Critical material

-Coatings
-Foils
-Sealant

Components IGU:



components	Weight in percentage
Glass	97 %
Coating (Metal oxides which bring all the thermal properties to the glazing)	<0.01 %
Butyl sealant	0.1%
Sealant (polyurethane, polysulfide or silicone)	1%
Spacer bar (aluminium or warm edge (plastic composites(	1%
Desiccant (CAS number 1318-02-1 zeonites)	1%
Gas(Dehydratedair,argon,kryptonor xenon)	0.1 %
PVB interlayer if one (0.38)	0.2%

Mass percentages according to Saint Gobain. Window of 1*1 m

Problem statement:

Currently
No refurbishment possible in IGU

15-25 Years

1%

98%

-water vapour builds
- fogging
-corrosion on the glass
-Thermal performance is lost

Research question

"In what way can the edge seal of the Insulated Glass Unit (IGU) be redesigned for easy and fast remanufacturing after every ten years in order to achieve a life span >100 years "?

Literature review

Subquestion 1

What requirements should the new IGU meet to last more than 100 years taking into account every ten years of remanufacturing?

Subquestion 2

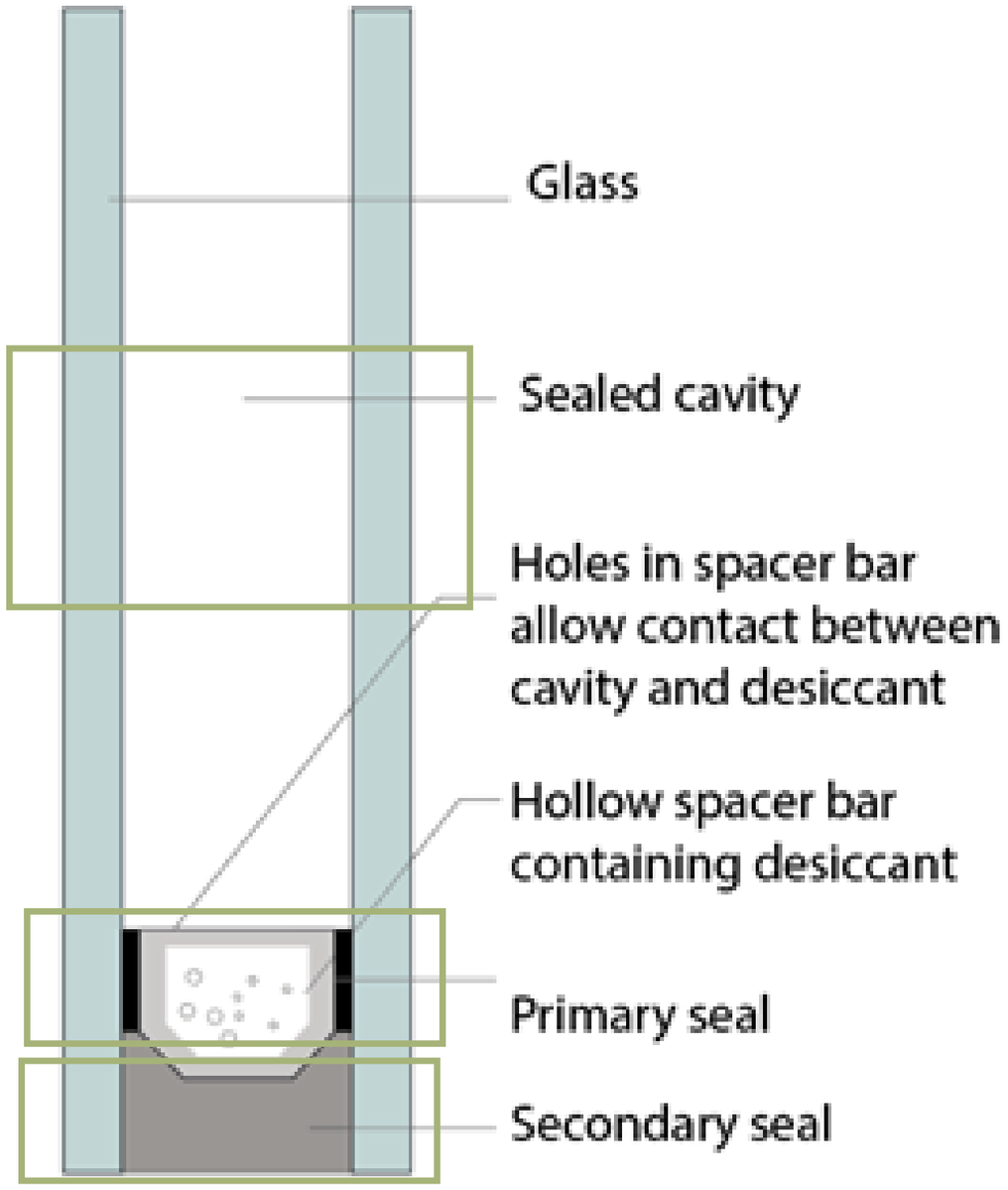
What are the design tools to create an IGU suitable for remanufacturing ?

subquestion 3

What window system is most suitable to start the new design of the IGU and allows easy and fast re-manufacturing?

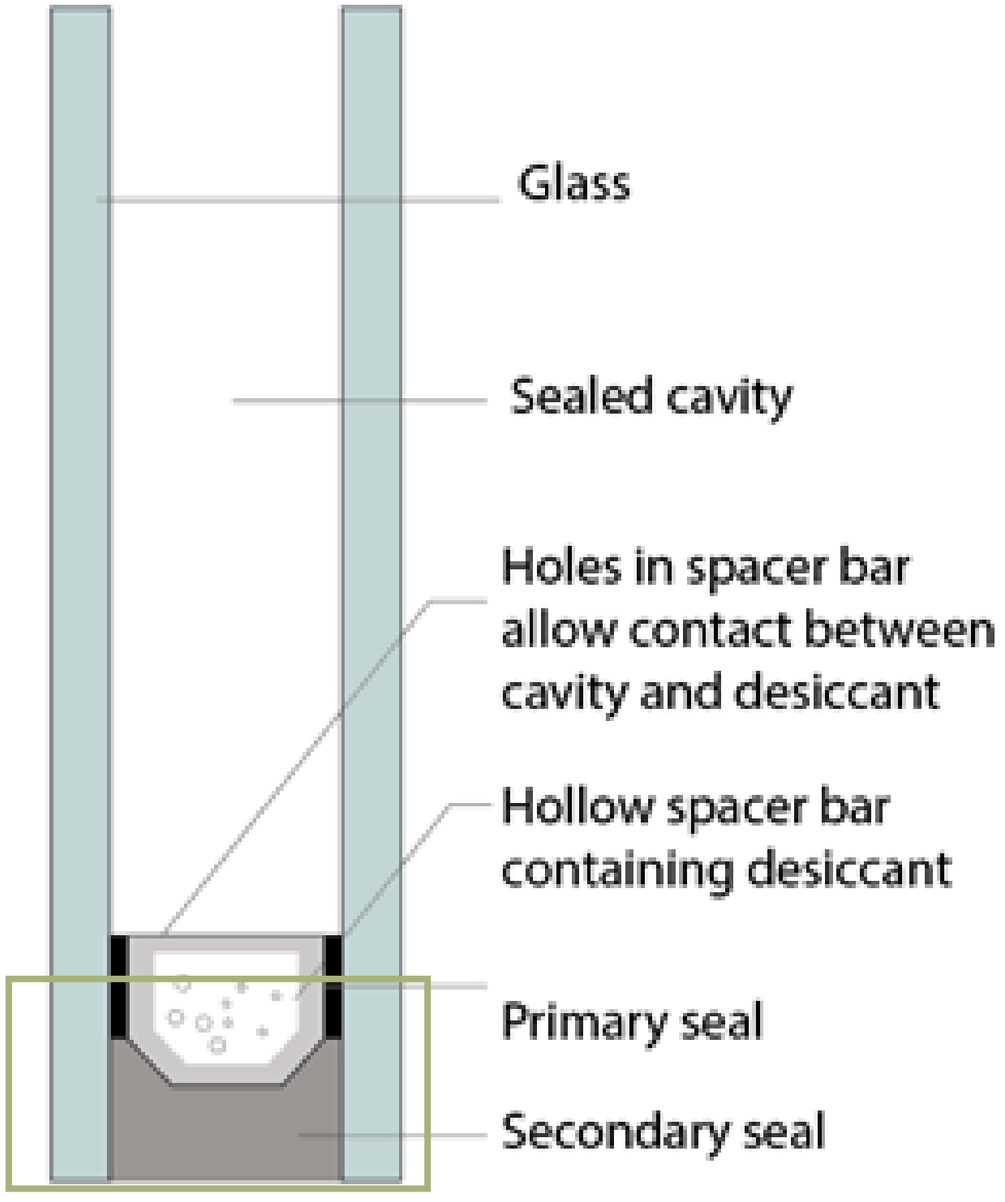
Subquestion 1

What requirements should the new IGU meet to last more than 100 years taking into account every ten years of remanufacturing?



Subquestion 1

What requirements should the new IGU meet to last more than 100 years taking into account every ten years of remanufacturing?

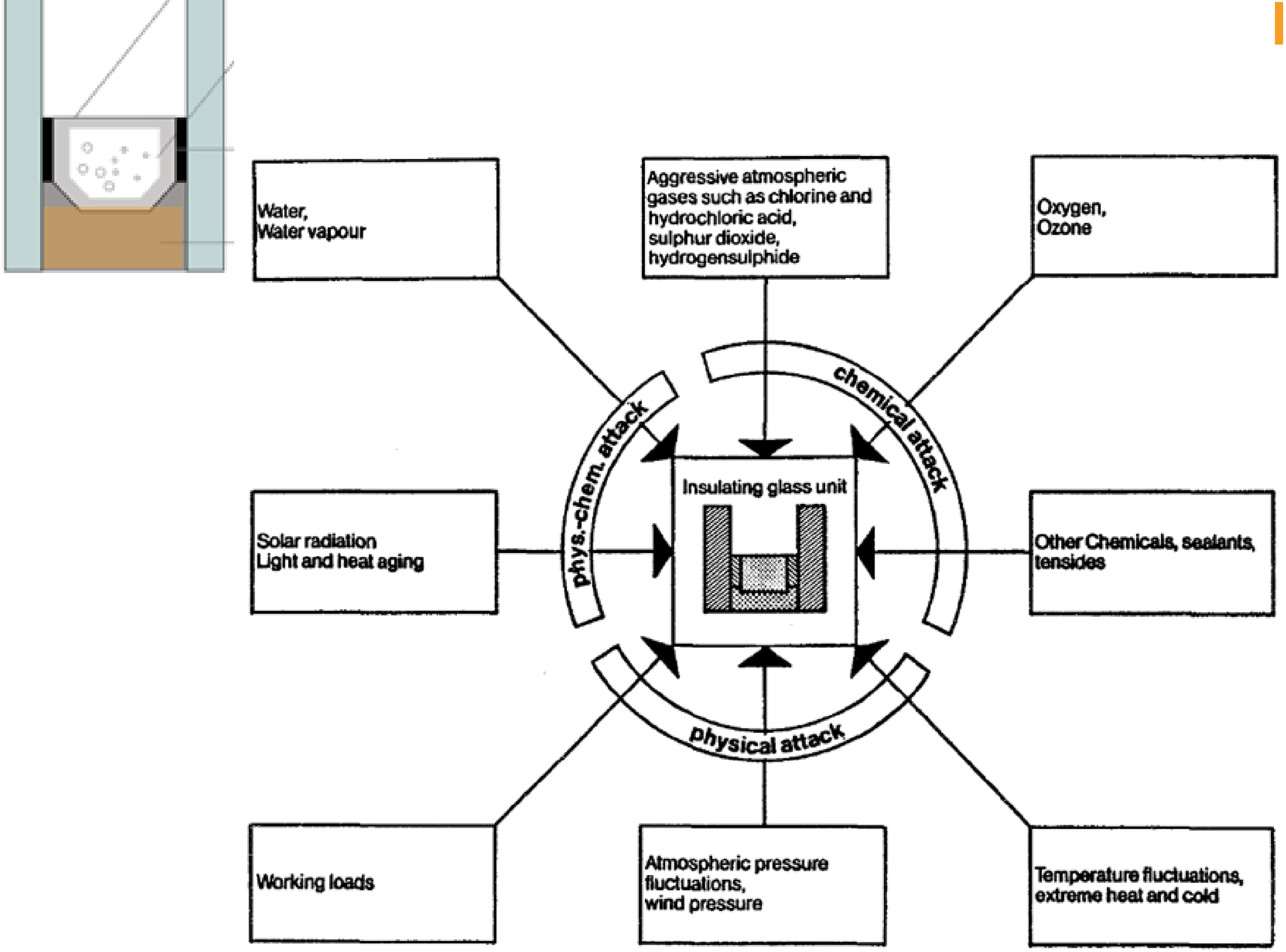


Primary seal prevents outgassing

Butyl (PIB)

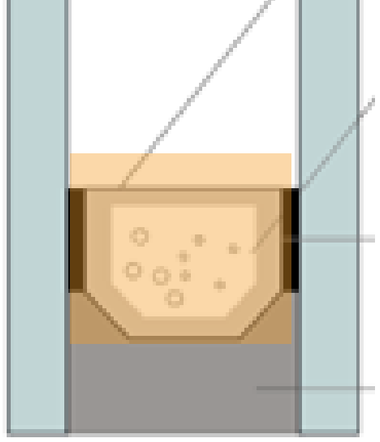
Secondary seal Protects primary seal

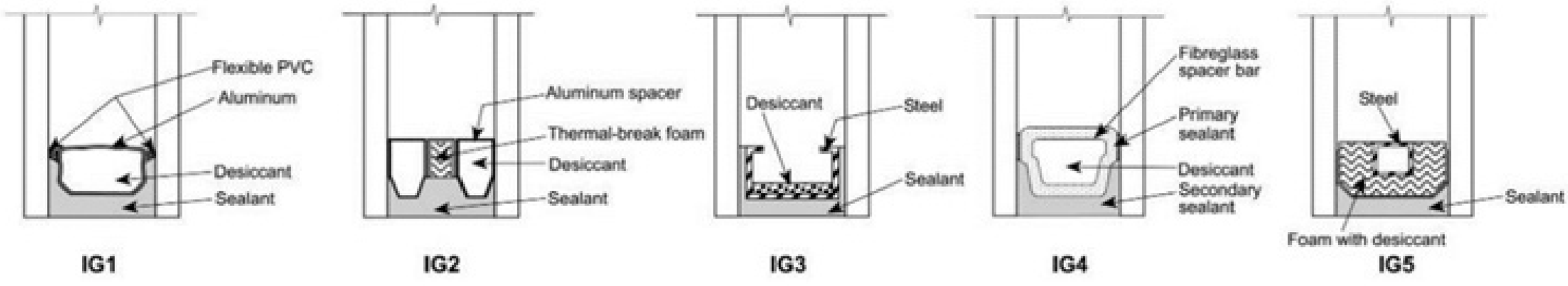
Polyurethane (PU), silicone (Si),
Polysulphide (PS) ,
Hot-melt butyl or
Epoxy-based sealants

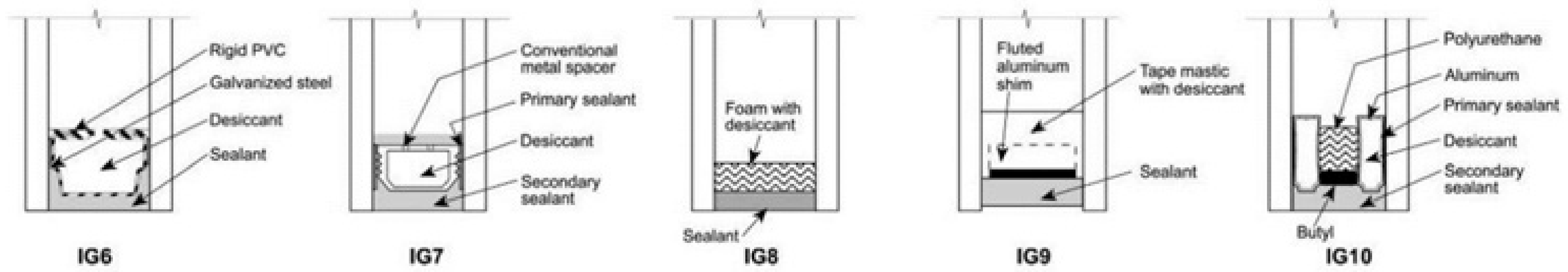

Water,
Water vapour
Aggressive atmospheric gases such as chlorine and hydrochloric acid, sulphur dioxide, hydrogensulphide
Oxygen,
Ozone
phys.-chem. attack
chemical attack
Insulating glass unit
Solar radiation
Light and heat aging
Other Chemicals, sealants, tensides
physical attack
Working loads
Atmospheric pressure fluctuations, wind pressure
Temperature fluctuations, extreme heat and cold

Wolf n.d.

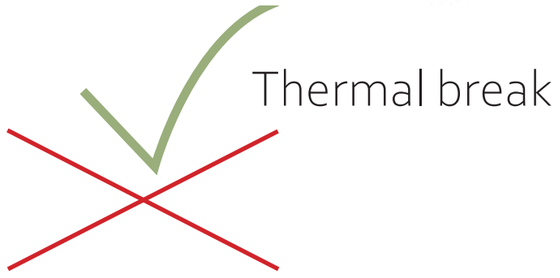
WarmEdgeTechnology Spacer bars





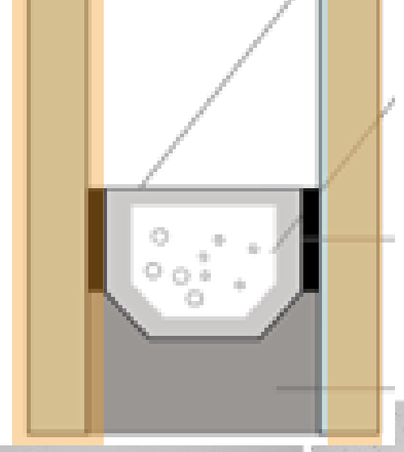


Non-metal combining materials

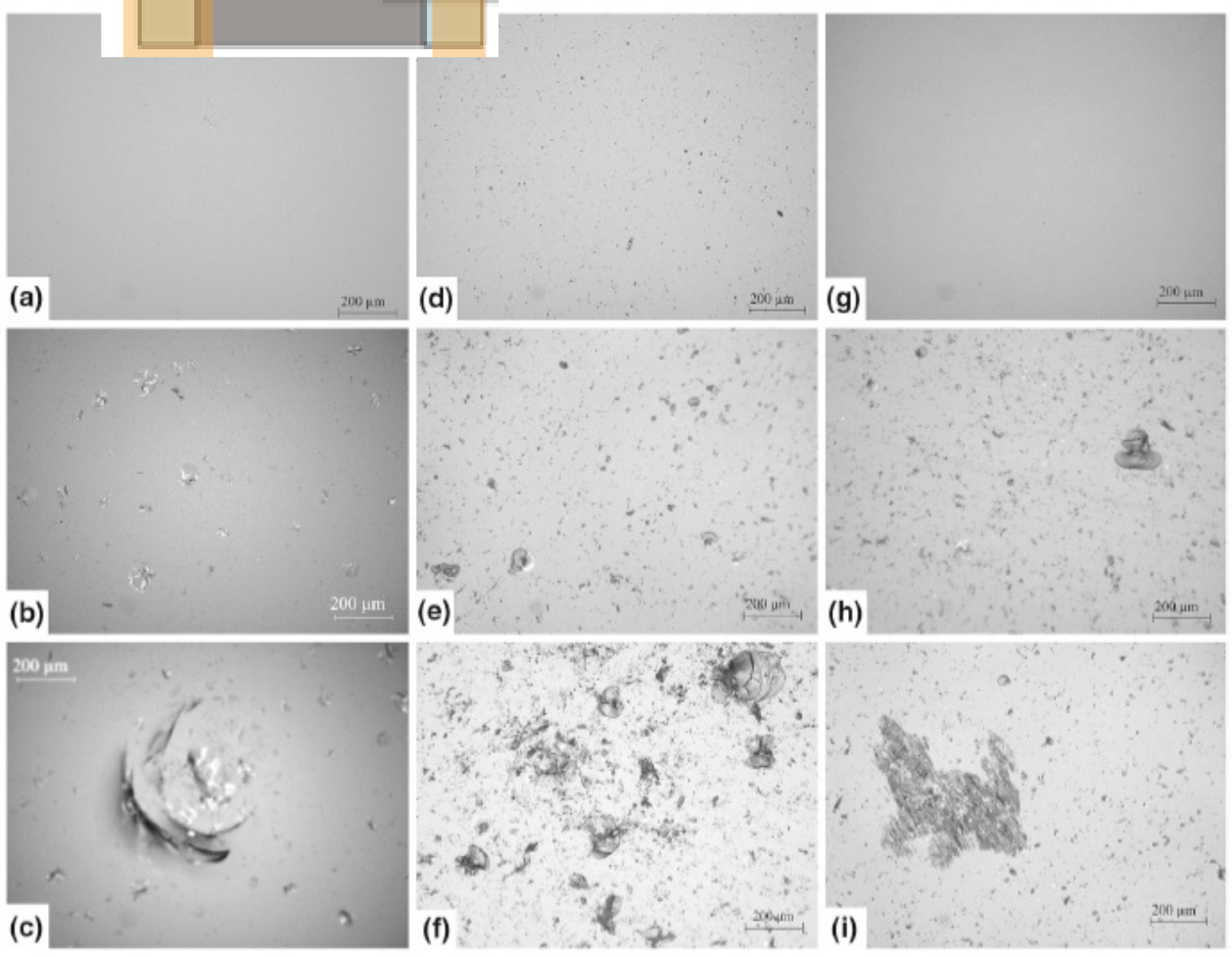


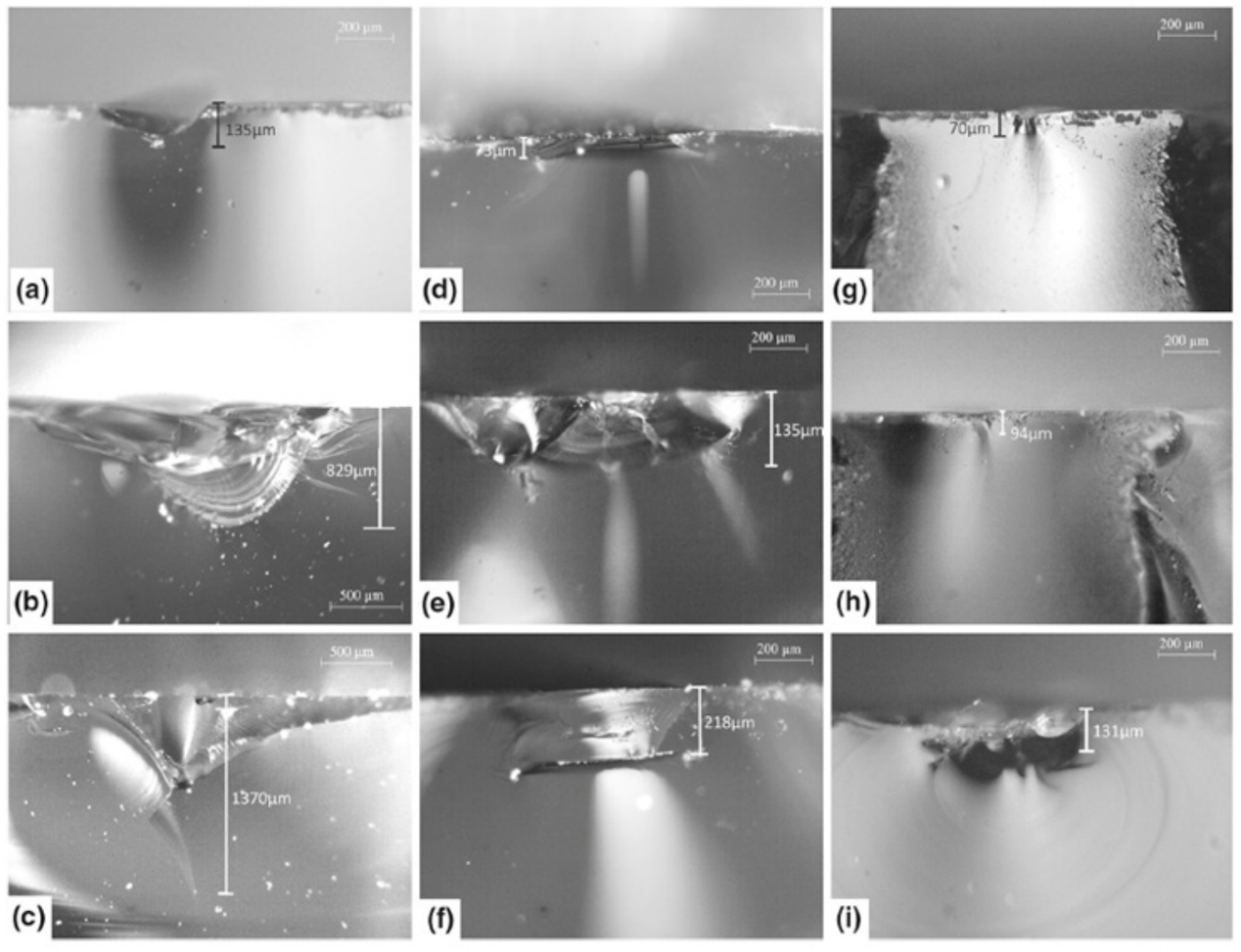
Thermal break

(Elmahdy, 2006)



Impact resistance

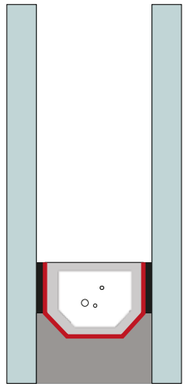




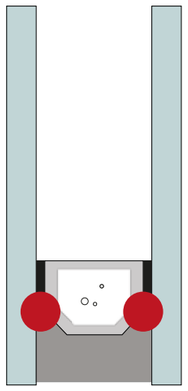
Float glass 1 mm magnitude

(Datsiou & Overend, 2017)

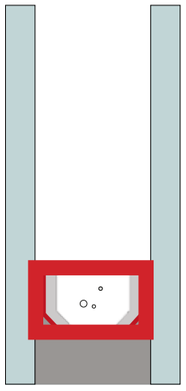
Subquestion 1: Answer



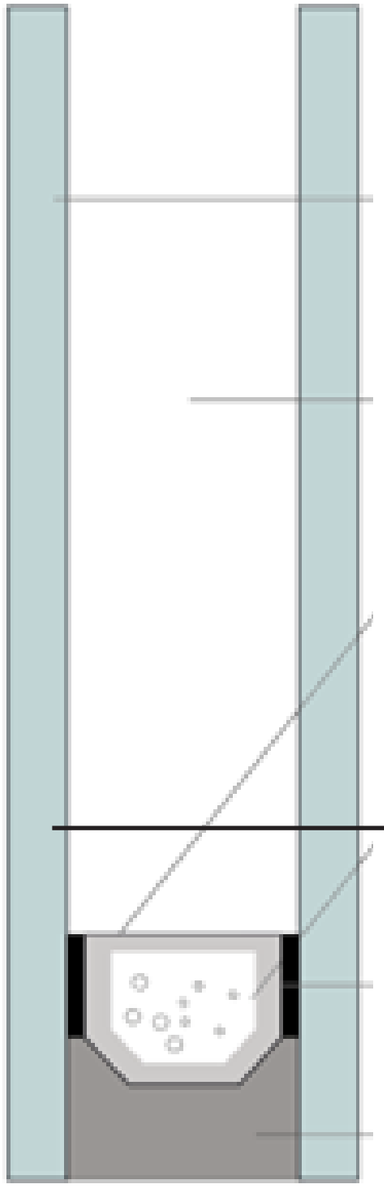
water /gas barrier

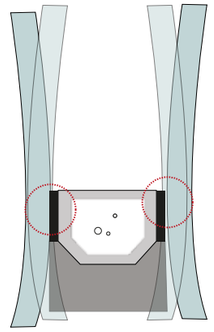


Gas barrier

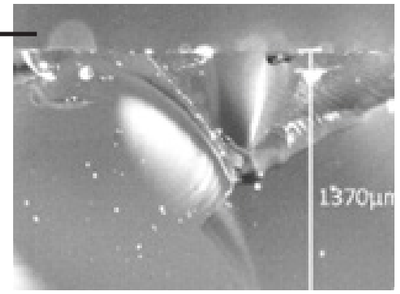


Rigid spacer bar





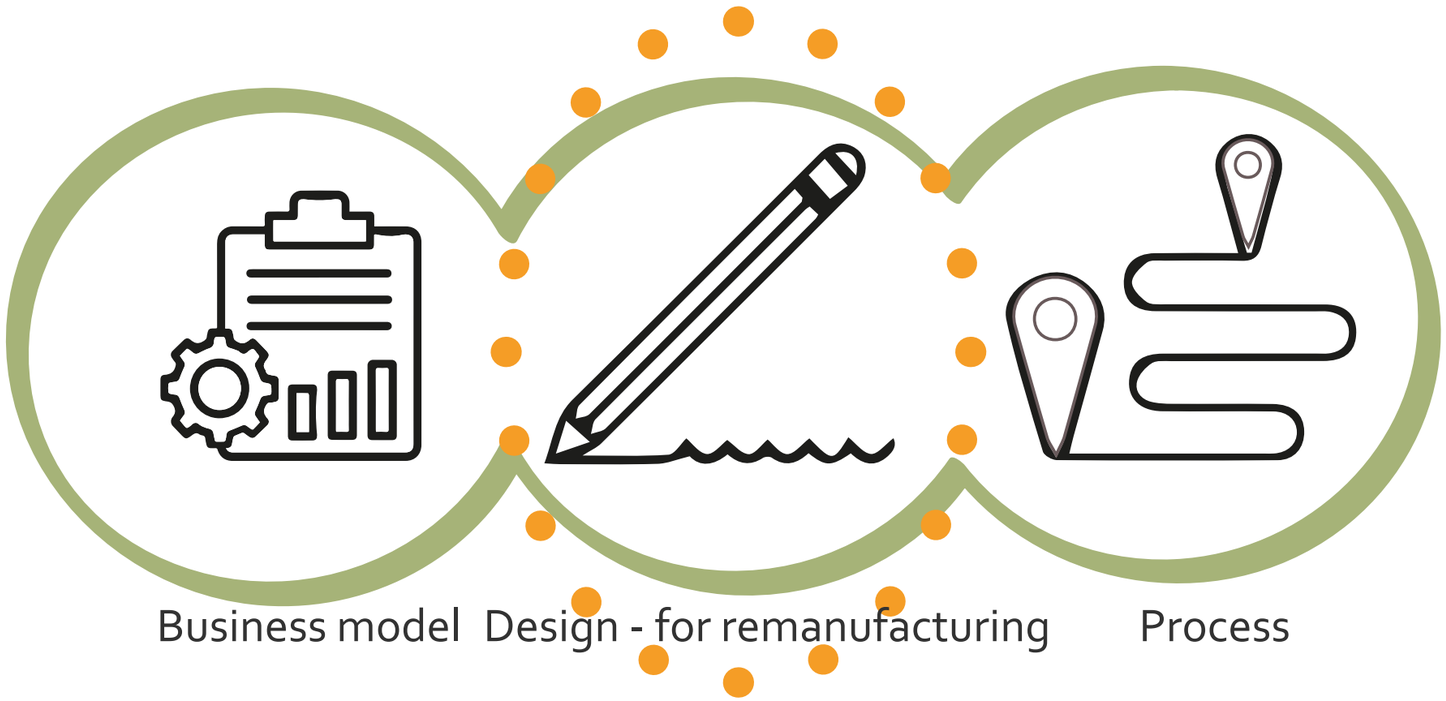
Atmospheric pressure difference



1 mm extra thickness

Subquestion 2:

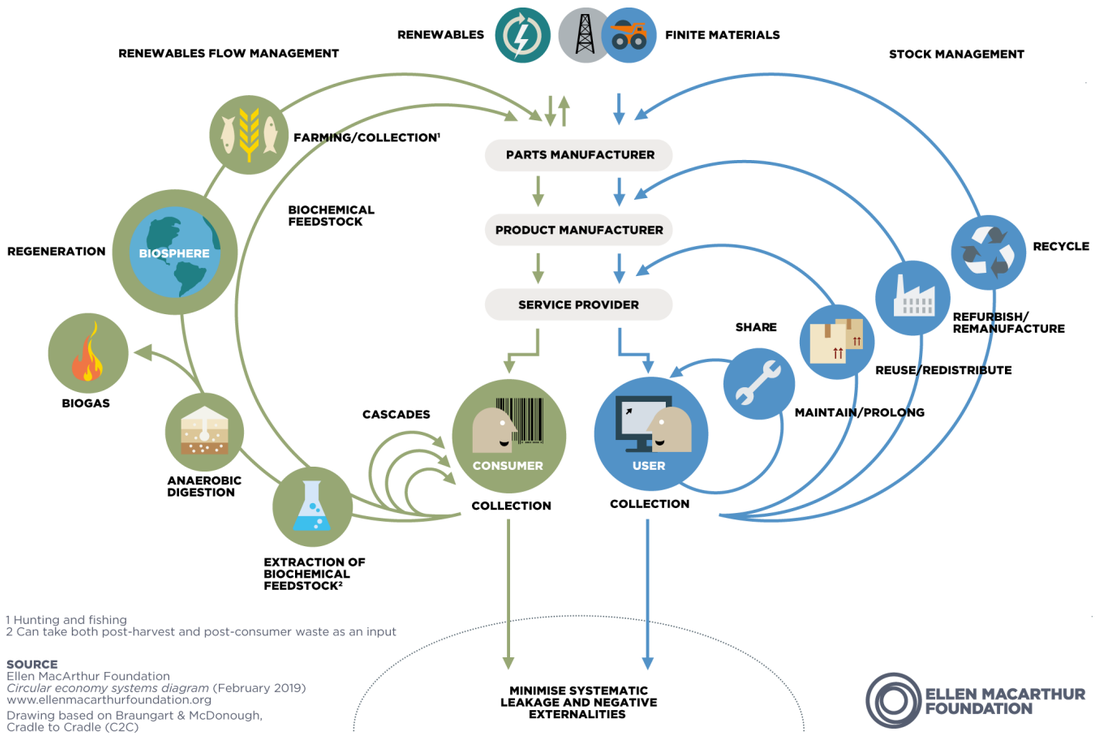
What are the design tools to create an IGU suitable for remanufacturing ?



(Vargas, 2019)

Circulair economy principles

Butterfly diagram

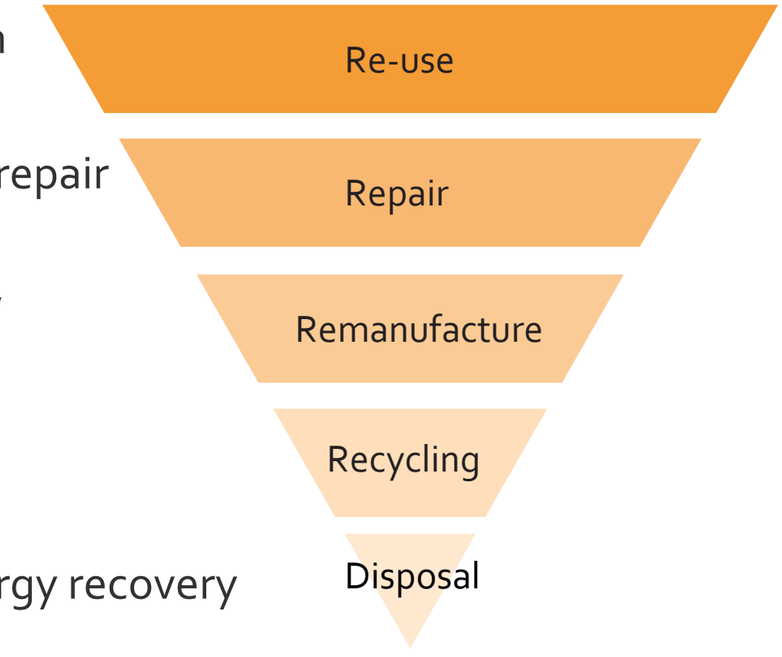


Prevent./ keep item

Checking, cleaning, repair

Checking, cleaning, change spare parts

Landfill without energy recovery



Design tools for a circular design

Documentation

Identification of materials &condition.

Materials

Durable materials-> multiple life time
Minimise amount of materials

Extra dimensions for susceptible surfaces

Design tools for a circular design

Standardizing

Make use of standardized elements, after years it can still be available for spare parts

Specialist technologies should be avoided

Easy by least amount of tools needed and minimum connection types

Disassembly

Divide product into parts or modules.put elements with the same remanufacturing period together. (avoid cross depending between modules)

Assembly method and sequence should be standard.

Choose materials that minimize pollution during extraction, processing usage and recycling.

Avoid finishes/ adhesives and coatings.

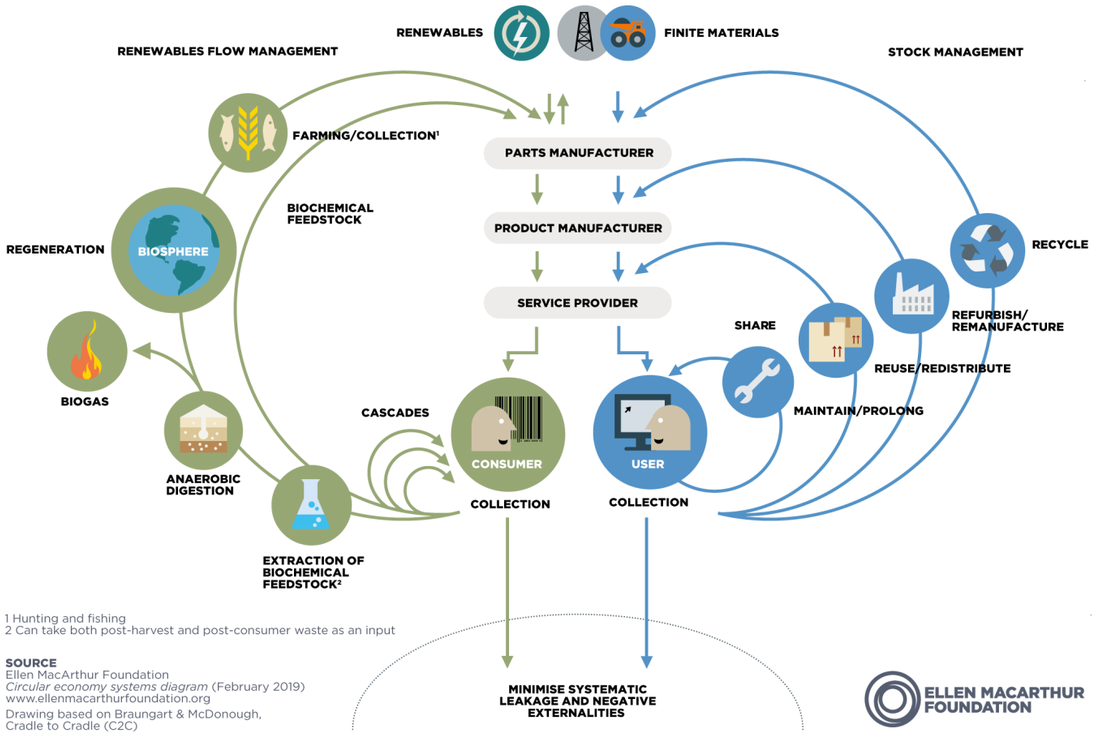
Design tools -> input for the concept

Standardizing

Documentation

Disassembly

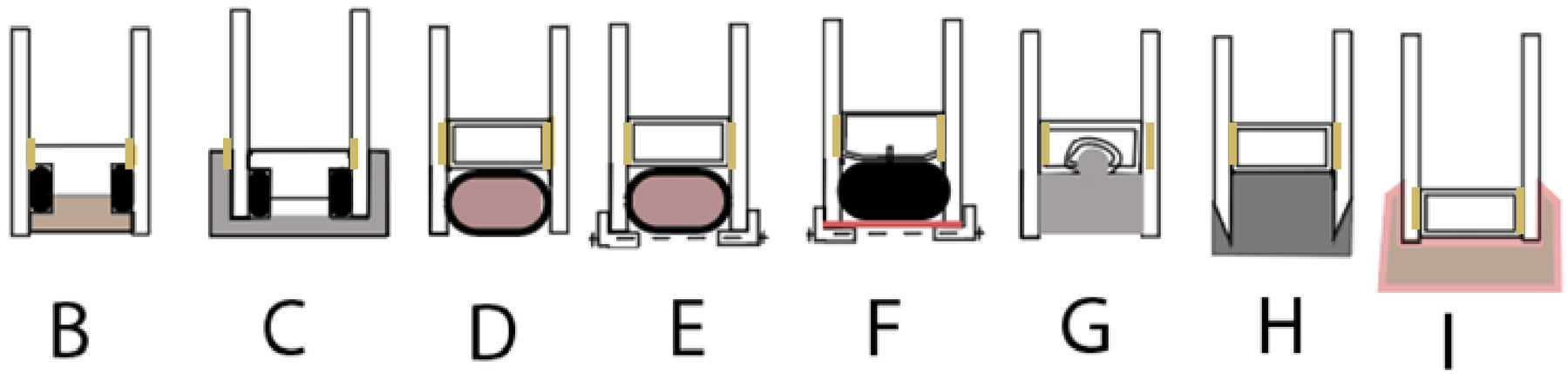
Materials

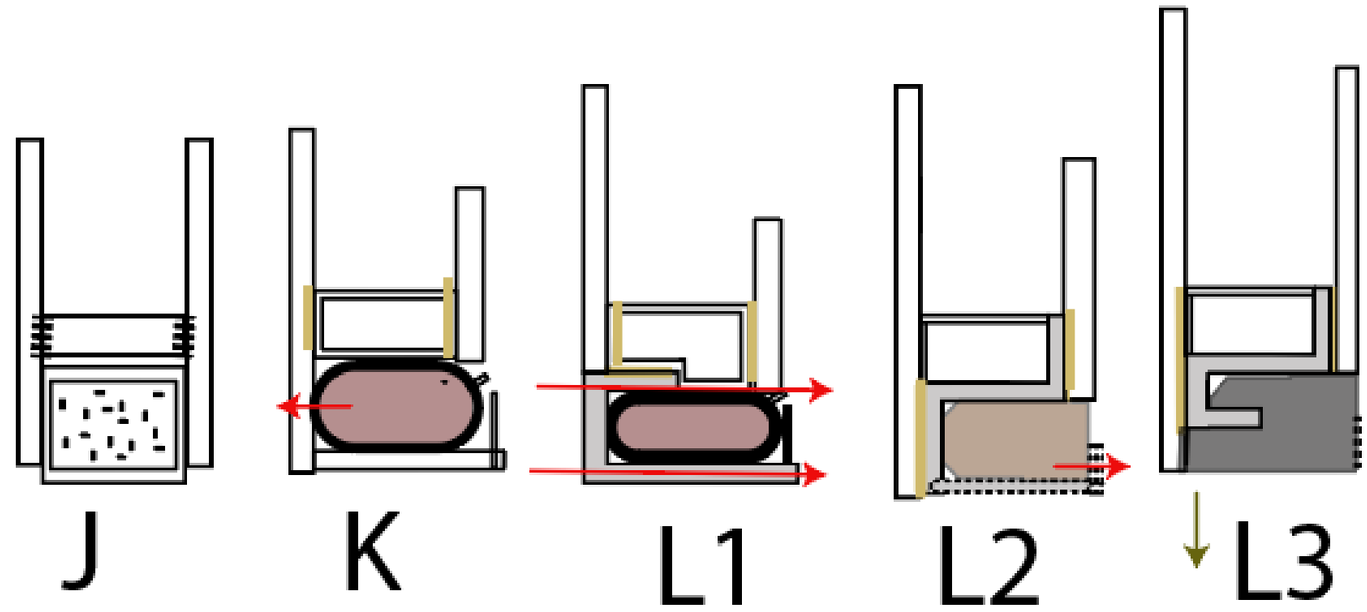


Concept design

	Ease of replacement
	Tension on the permanent bonding
	transfer of the loads
	Seam tightness
	Fabrication
	Heat flow

Different concepts

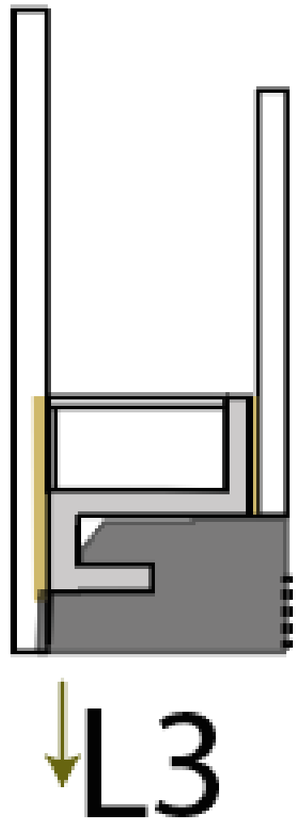




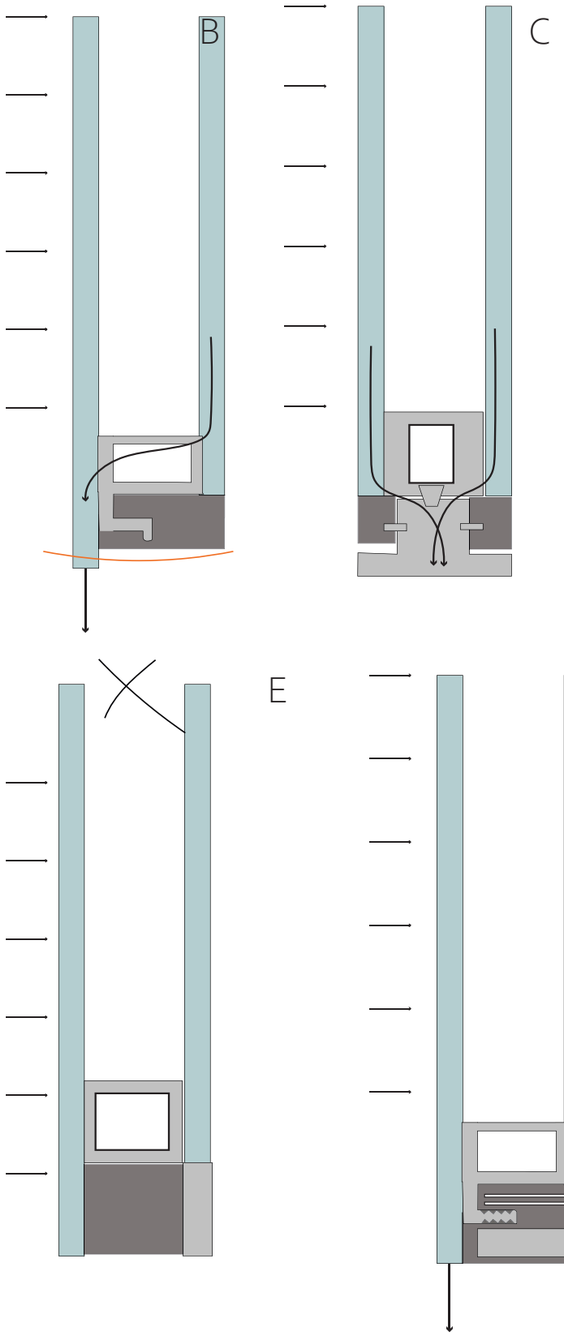
Glue
Stopper
Stiff material
Braces/bolt
Water barrier (tight enough)
o-ring
Tyre

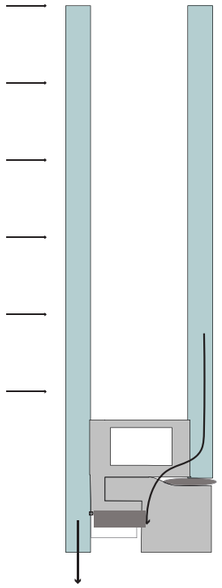
Different concepts

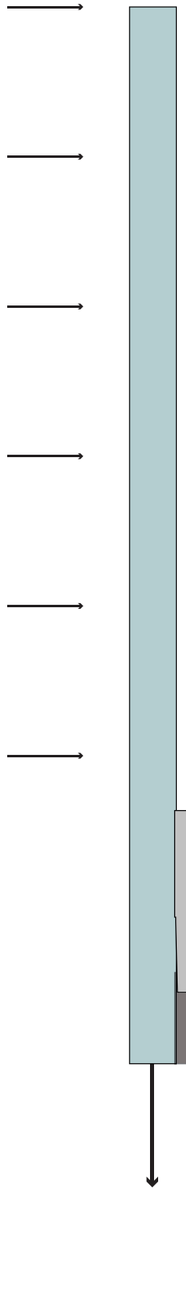
Aspect	Ease of replacement	Tension on the perma-nent bonding	Transfer of the loads	Seam tightness	Fabrication process	Heat flow
Original design	-	-	+	+	+	
B	+	-	+		+	+
C	+	+	+		+	-
D	+	-	+		+	+
E		+		+	+	
F	-	-	+	+	+	
G	+	-	+		+	+
H	+	+	-			+
I		+			+	+
J	+	+	+		-	+
K	+	-	-		-	+
L1	+	+	-	-	+	-
L2	+	+	+	-	+	
L3	+	+		+	+	+

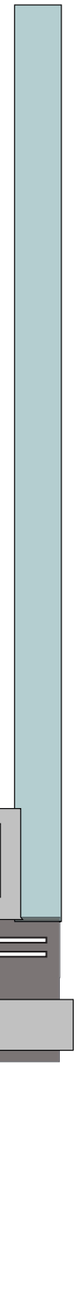


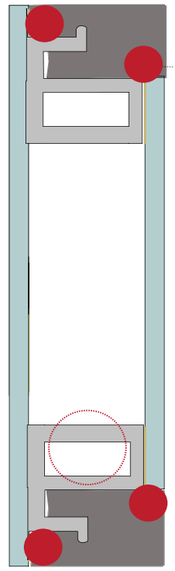
Concepts on load transmission



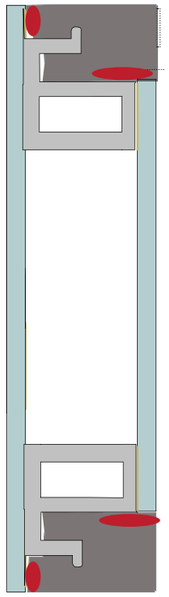




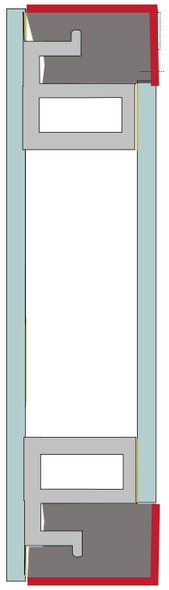




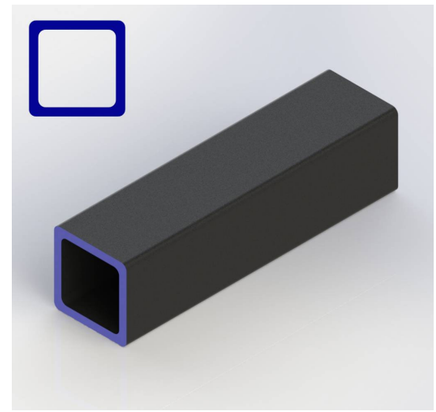
gas stopper



moisture stopping



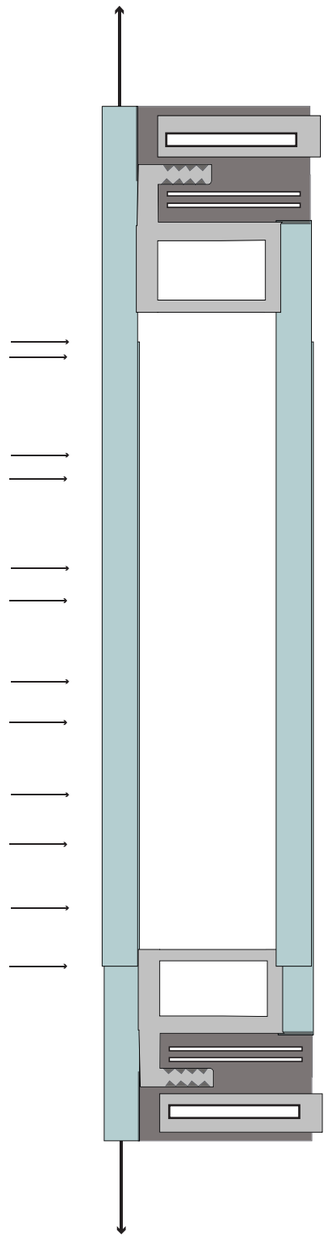
moisture stopping



Concept

Exterior

Interior



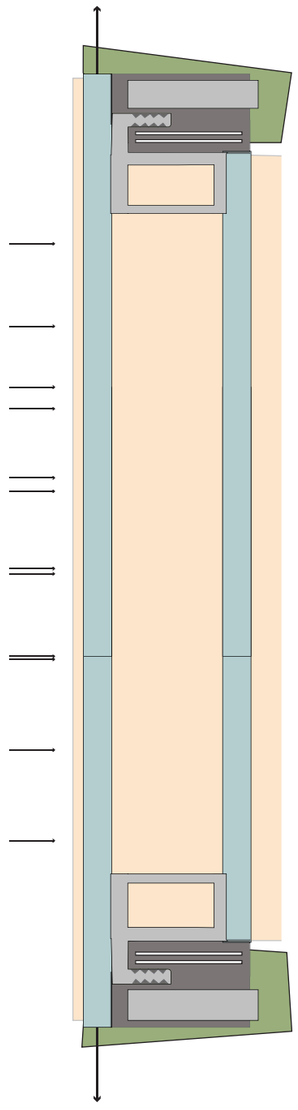
Bigger outer pane

Spacer bar glued to panes
Delo AD491 (Uv light)

Hollow section

Concept

Exterior



Interior

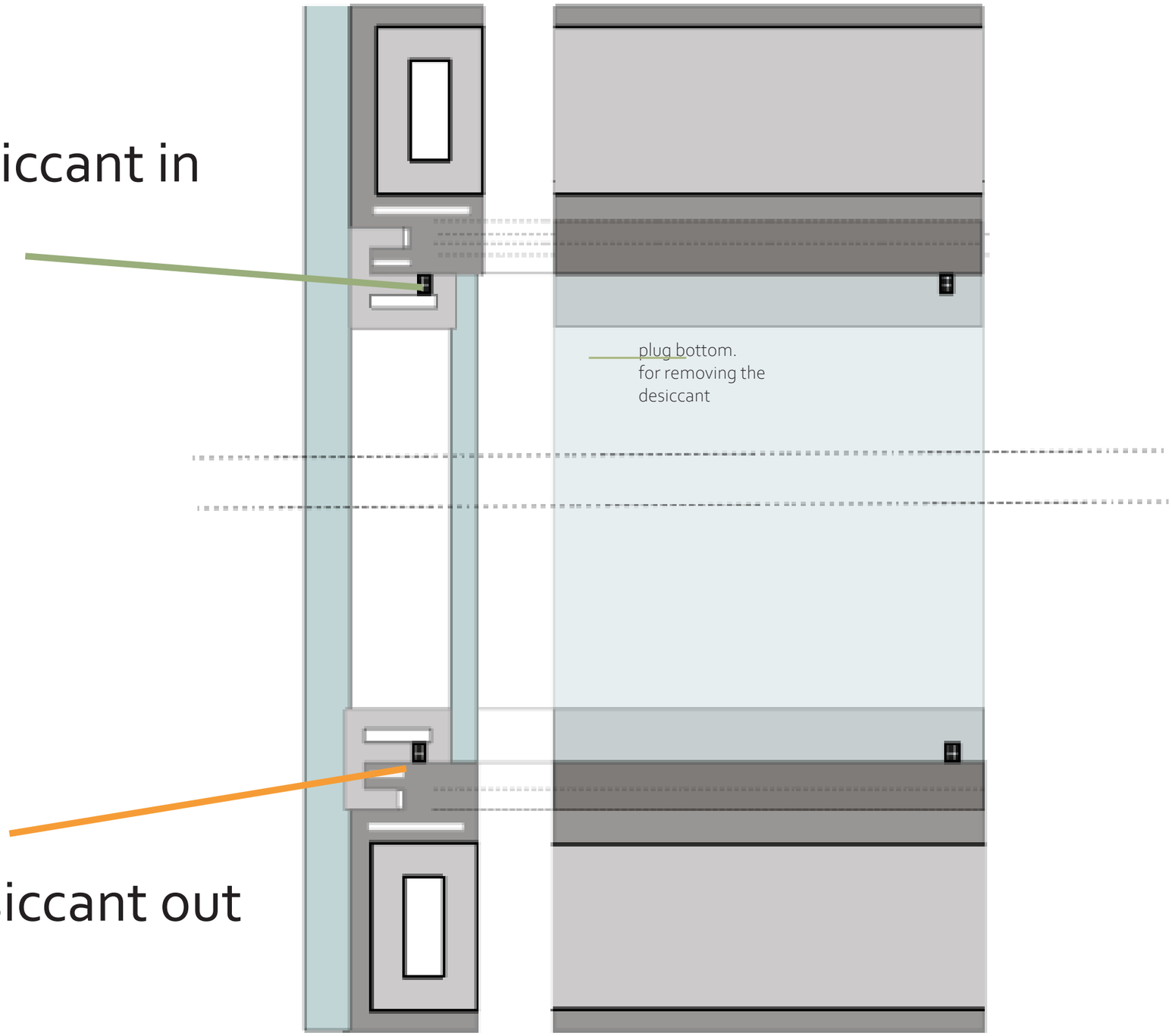
Spacer bar glued to panes
Delo AD491 (Uv light)

Permanent

replaceable

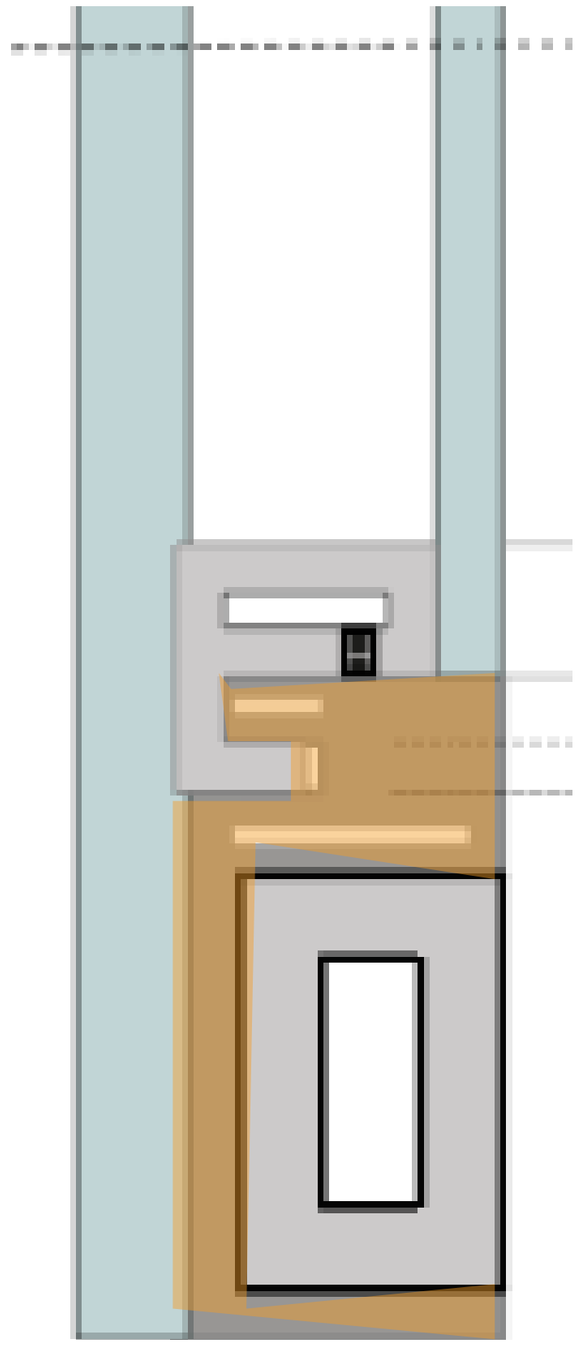
Place of the desiccant filling

Desiccant in



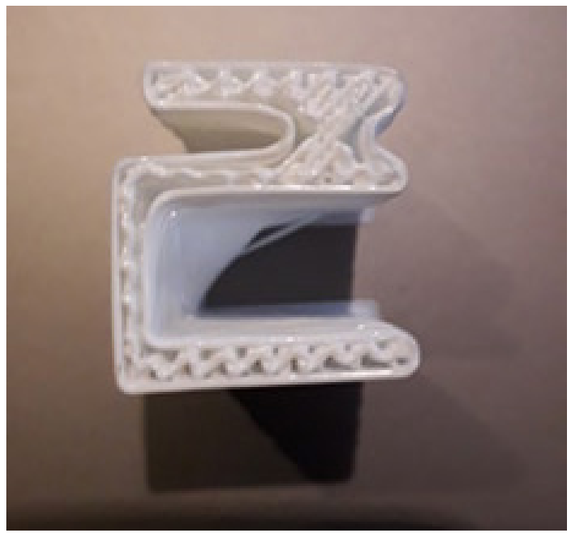
Desiccant out

Butyl profile form



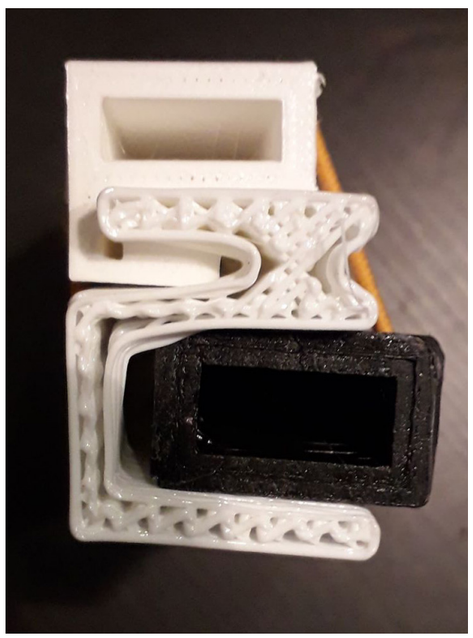
Rubber printing -> LAMA LAB

Fillament
nozzle size
feed rate
Infill pattern

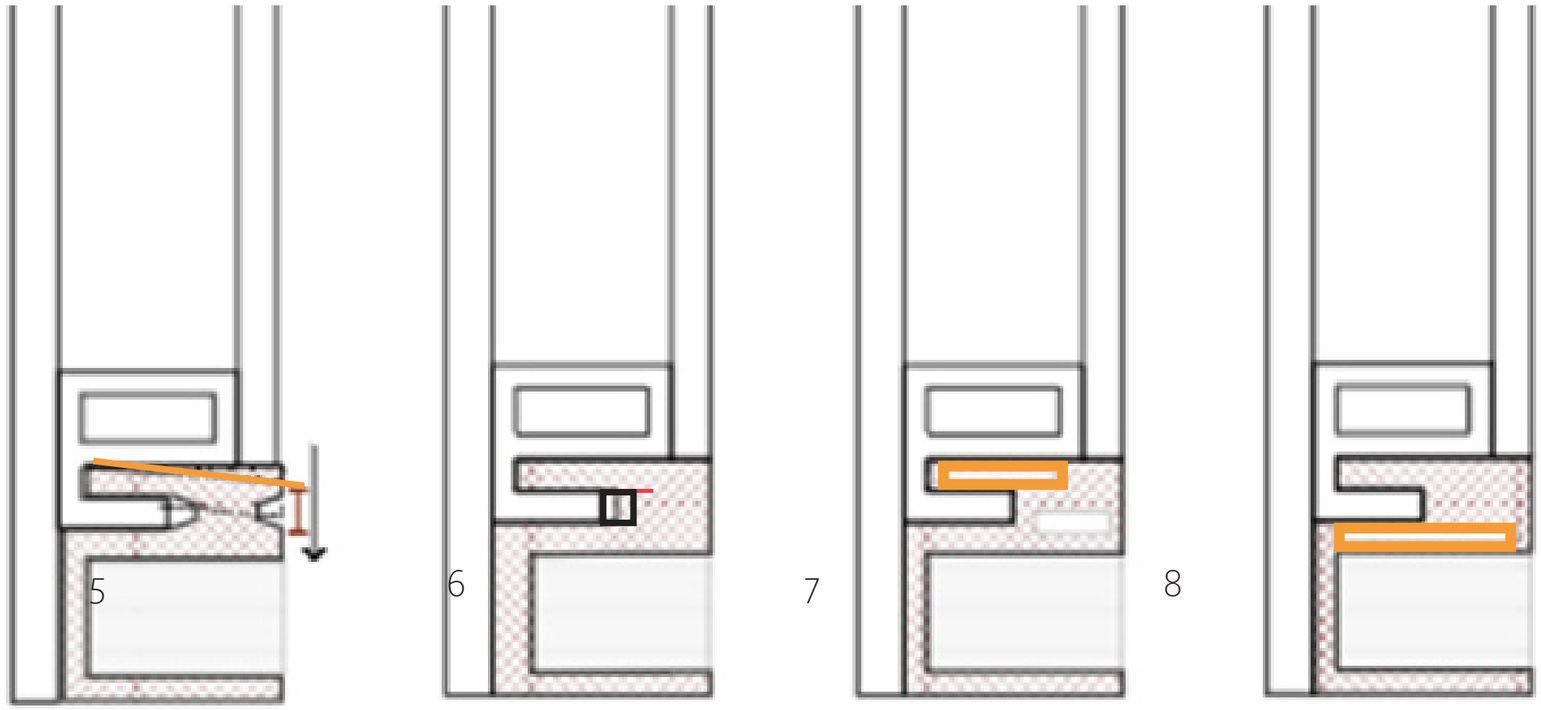




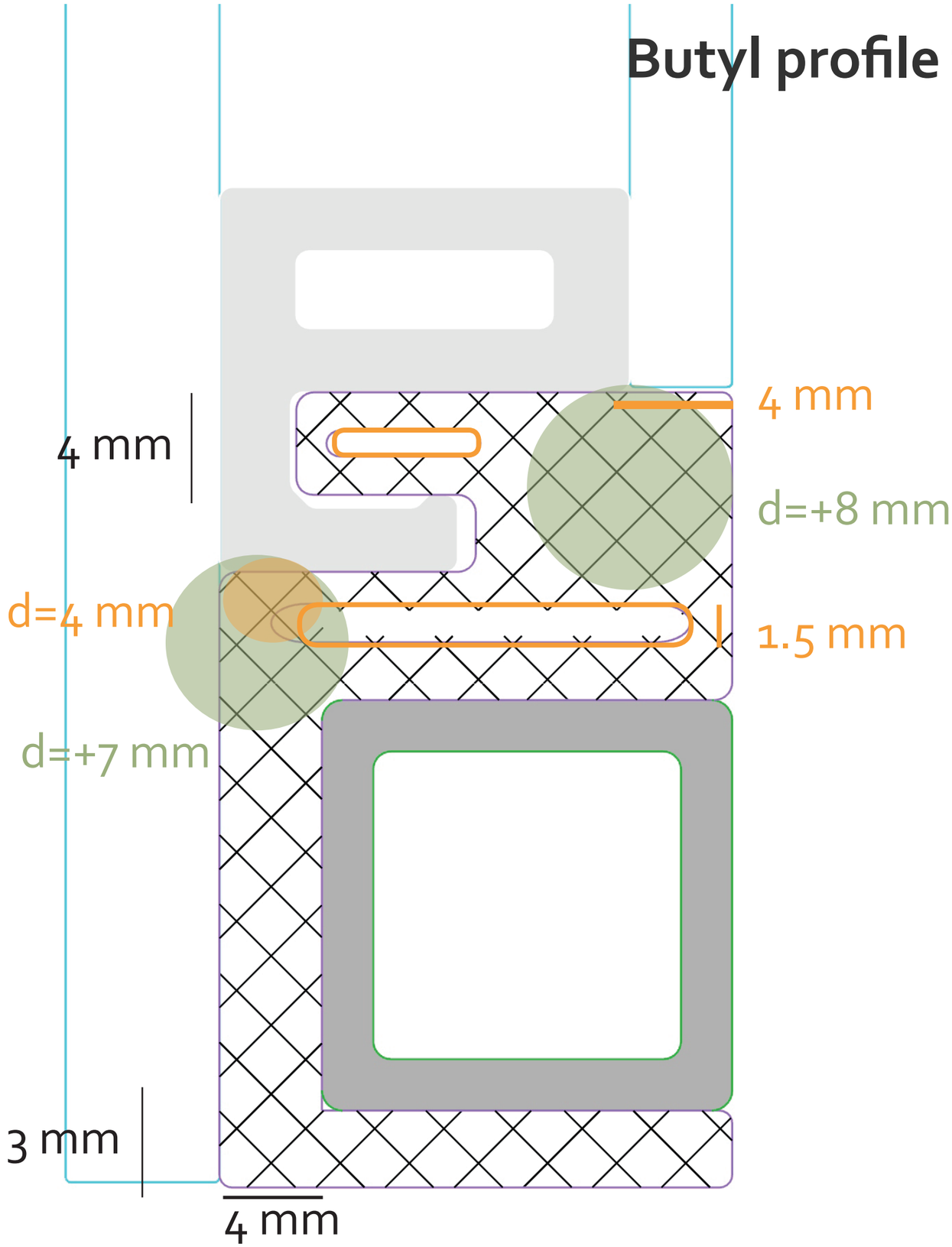


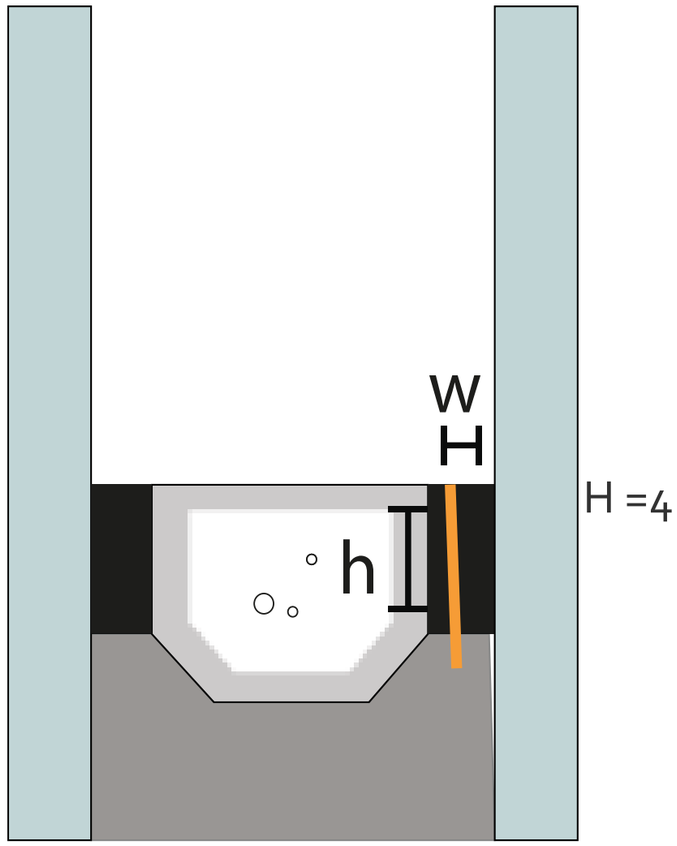



Interlocking experiments at LAMA LAB

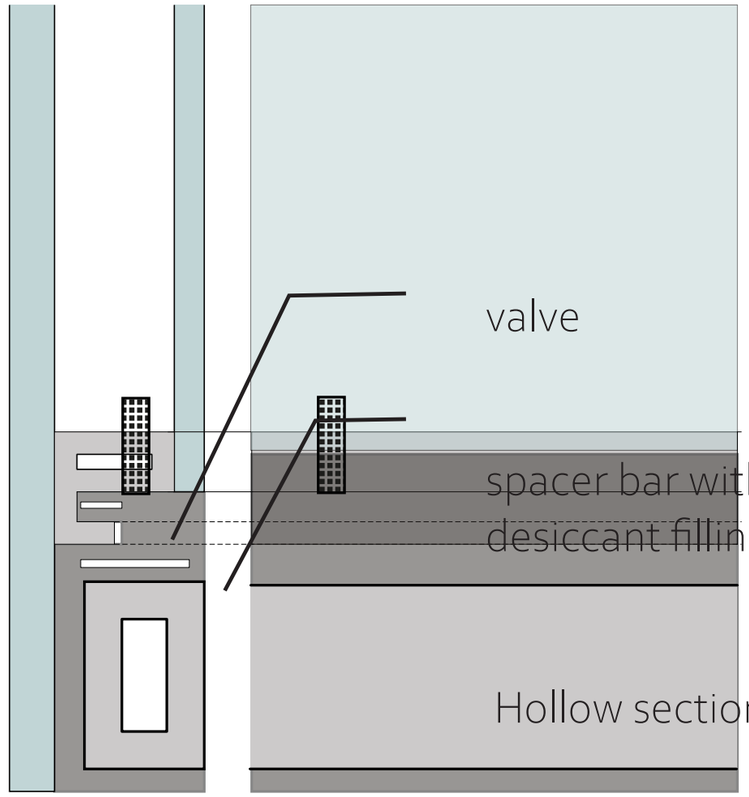


Butyl profile form

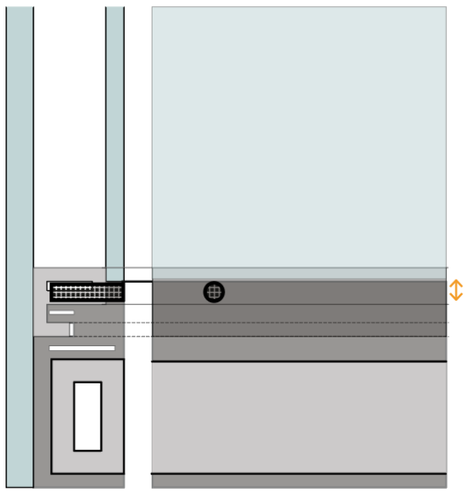


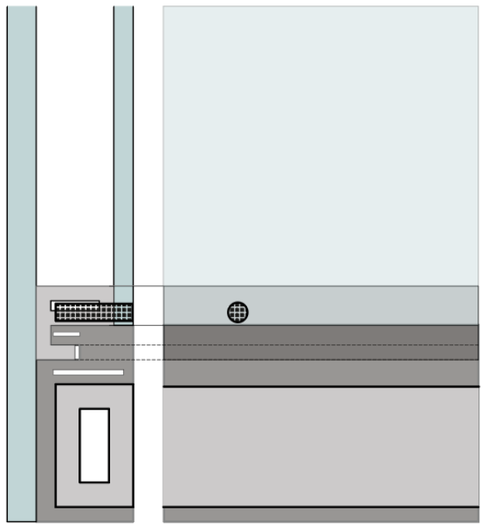


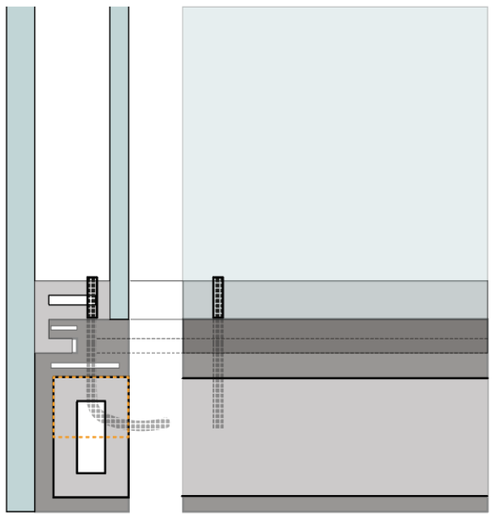
Place of the valve

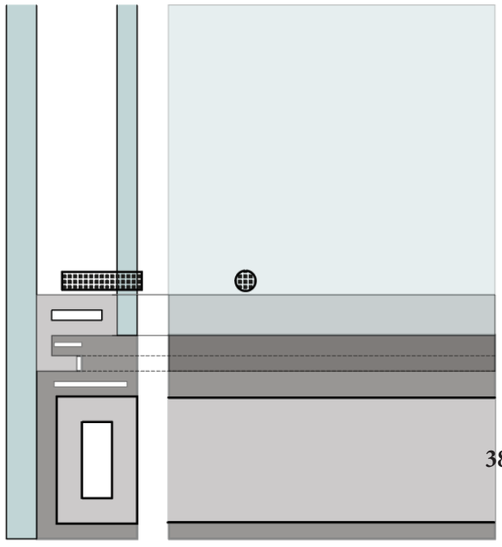


Preferred place for the valve



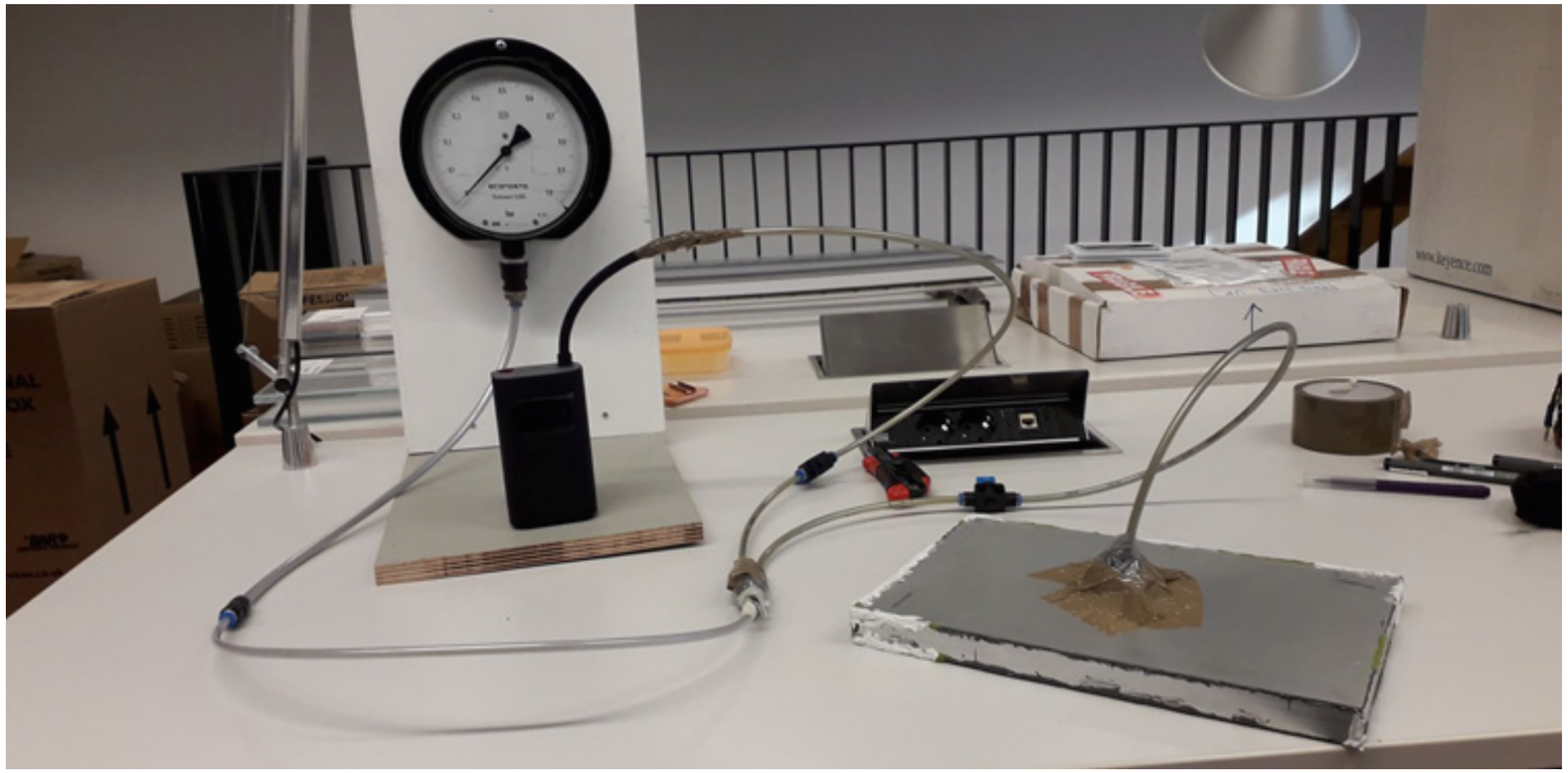






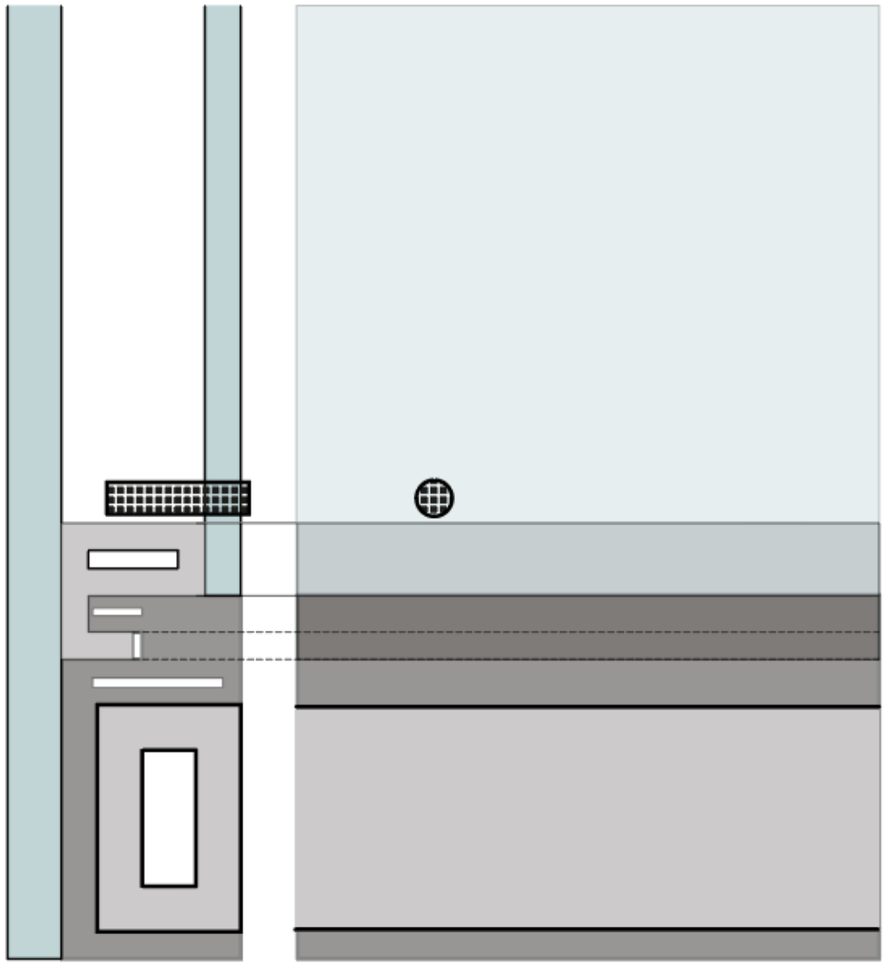
Test: Can glue be gas tight for a short moment (15 min)?

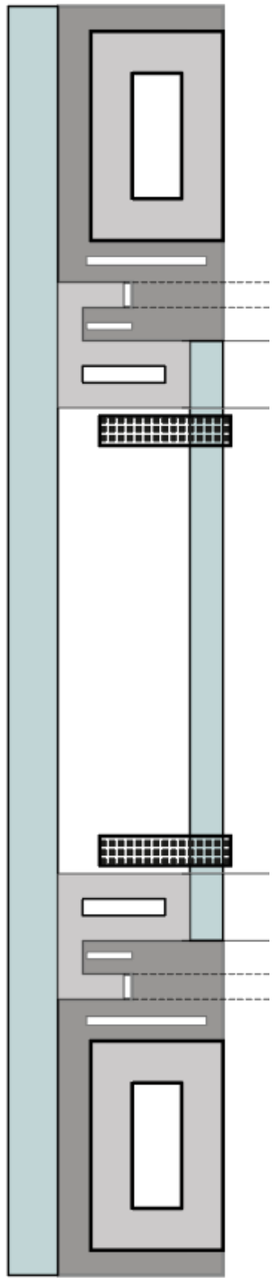
Over pressure 0.15 bar



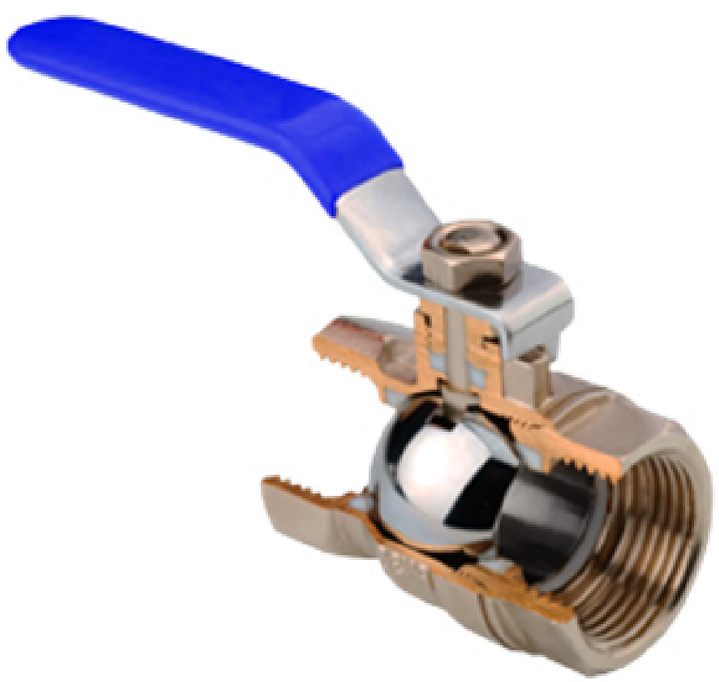
Aluminium panels

Place of the valve





Choosing the valve



Choosing the valve : requirements

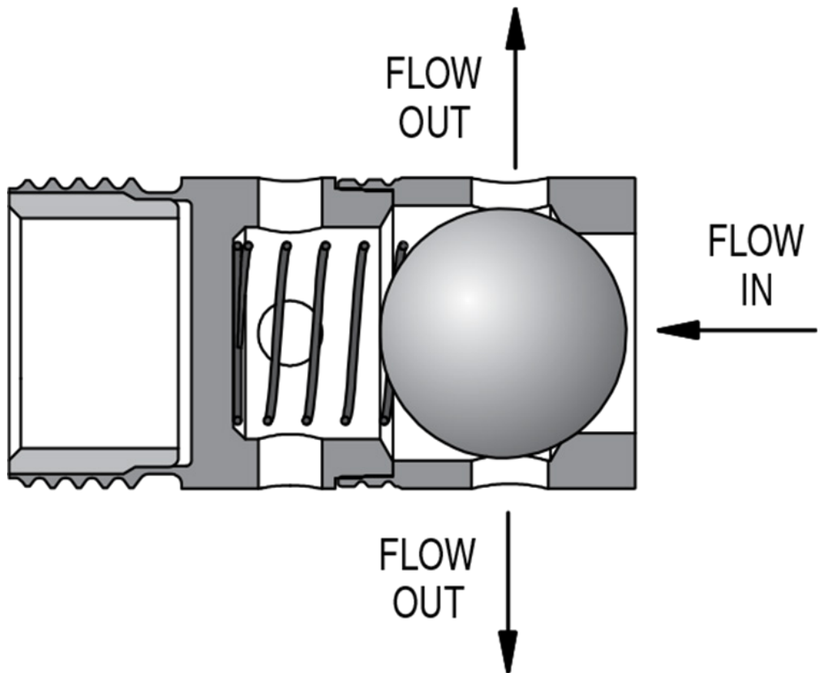
Diameter </ 8 mm
Durable materials
Horizontal/ vertical position
Easy field replaceable
Demountable
Cracking range (0.1 bar)
Suitable for gas

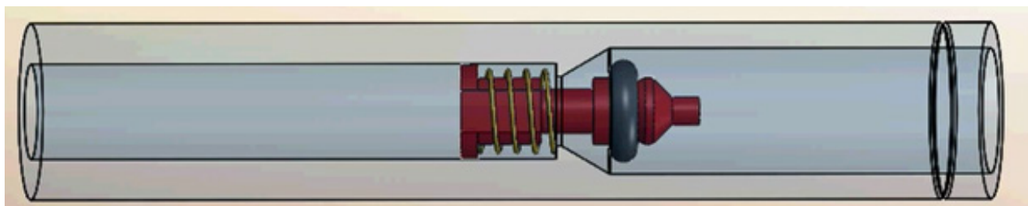
Choosing the valve : Evaluation

Aspect	Diameter <8 mm	Durable materials/ parts	Horizontal/ Vertical posi-tion	Easy field replacable	Demount-able	Cracking range
Ball valve	-	+	+	-	+	+
Gate valve	-	+	+	-	+	+
Globe valve	-		+	-	-	+
Butterfly valve	-	+	-	-	+	+
Swing check valve	-	+		-	+	+
Plug type check valve	-	+	+	-	+	+
Ball type check valve	-	+		+	+	+
Dual plate check valve	-			+	+	+
Dunlop	+	-	+	-		+
Blitz/mini-valve	+	-	+	+	-	+
Duckbill valve	+	-	+	+	+	-
Inline valve	+	+	+	+	+	+

Choosing the valve : Elaboration

Suitable valves





The valve

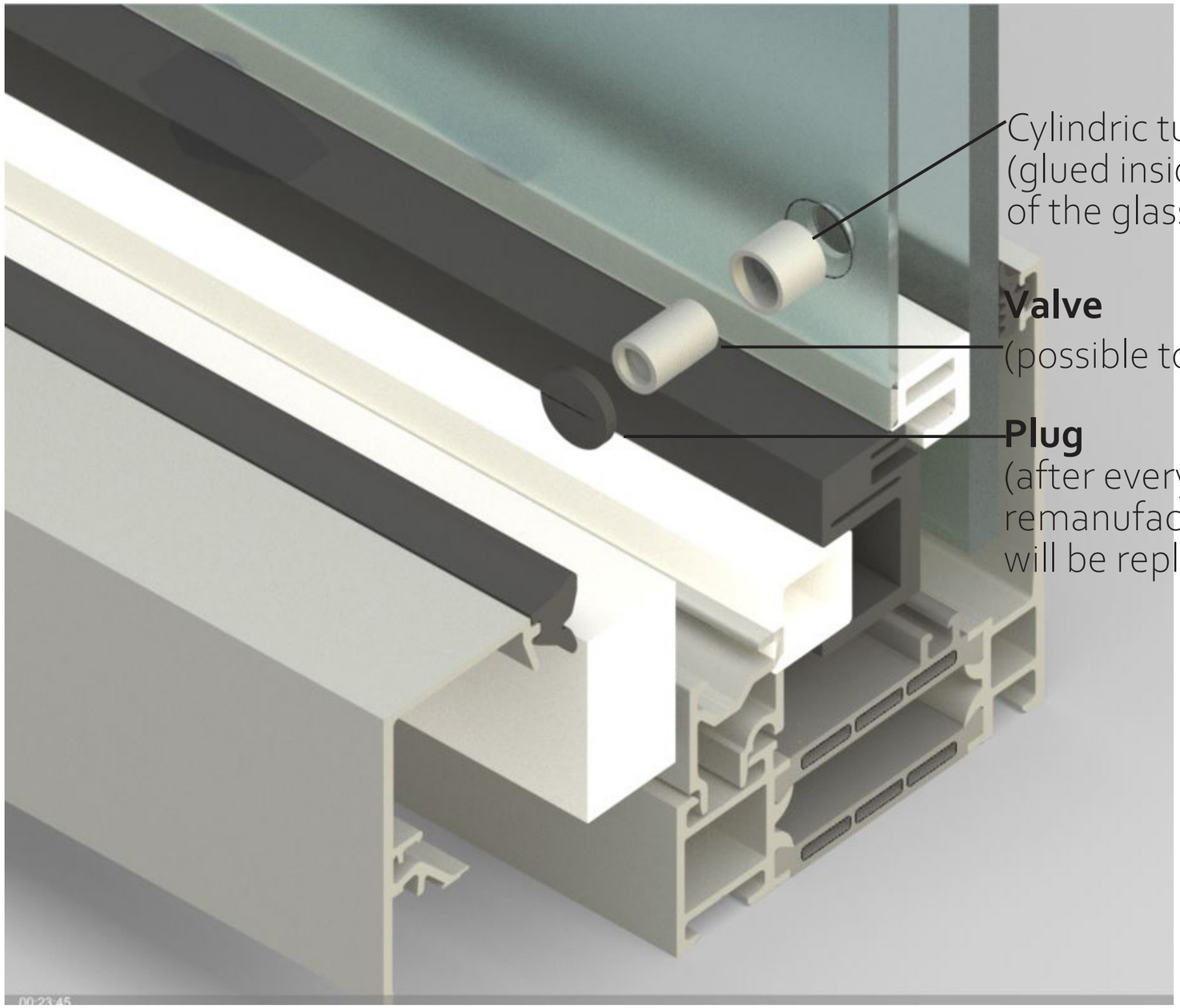


Figure 5.10.3.10: The chosen valve inside the glazing panel

Subquestion2

What are the design tools to create an IGU suitable for remanufacturing ?

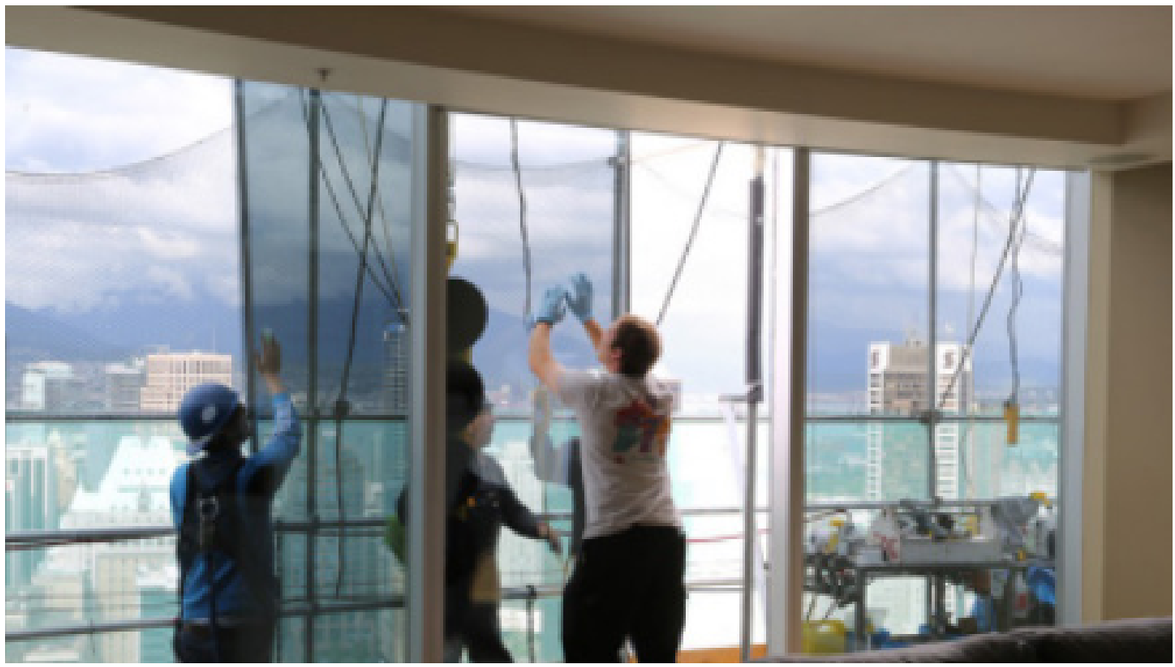
Evaluating subquestion 1:

Documentation	**Identification of materials &condition.** Remanufacturing : Contracted Remanufacturer -> col-laboration
Materials	**Durable materials-> multiple life times** (Glass, spacer bar, valve (bundled). hollow section. butyl , Plug for valves and desiccant just 1 cycle **Minimise amount of materials**
	Extra dimensions for susceptible surfaces Extra 1 mm for the outer glass pane
Standardizing	**Make use of standardized elements, after ages it can still be available for spare parts** X all components (except hollow section) has a special form. However, it is suitable for extrusion **Specialist technologies should be avoided** Fiberglass spacer bars are not widely available yet

Subquestion 3:

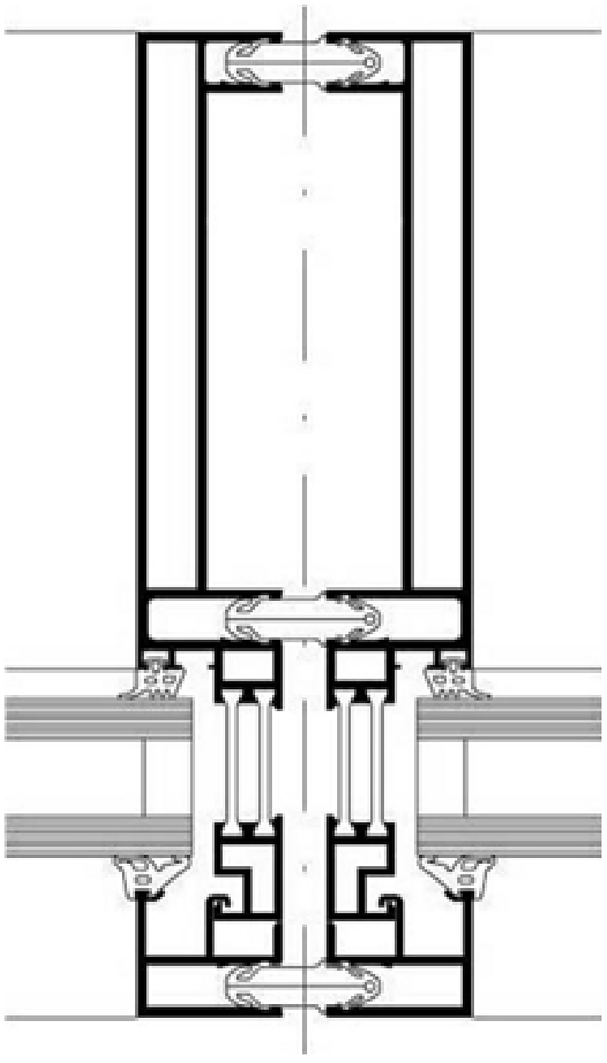
What window system is most suitable to start the new design of the IGU and allows easy and fast re-manufacturing?

What types of facades?

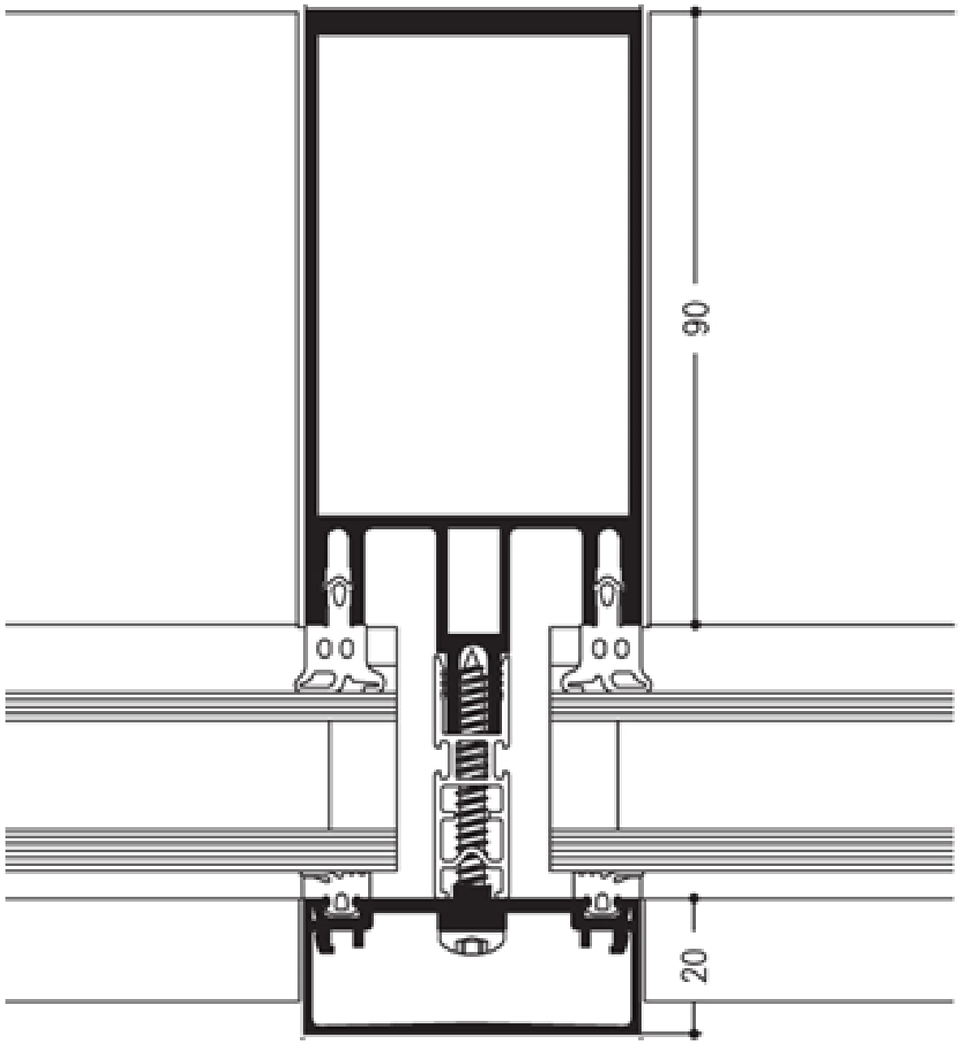


Re-Glazing of All Glass Curtain Wall Buildings
James Higgins1
, Brian Hubbs, P.Eng 2
, and Graham Finch, MASc, P. Eng 3

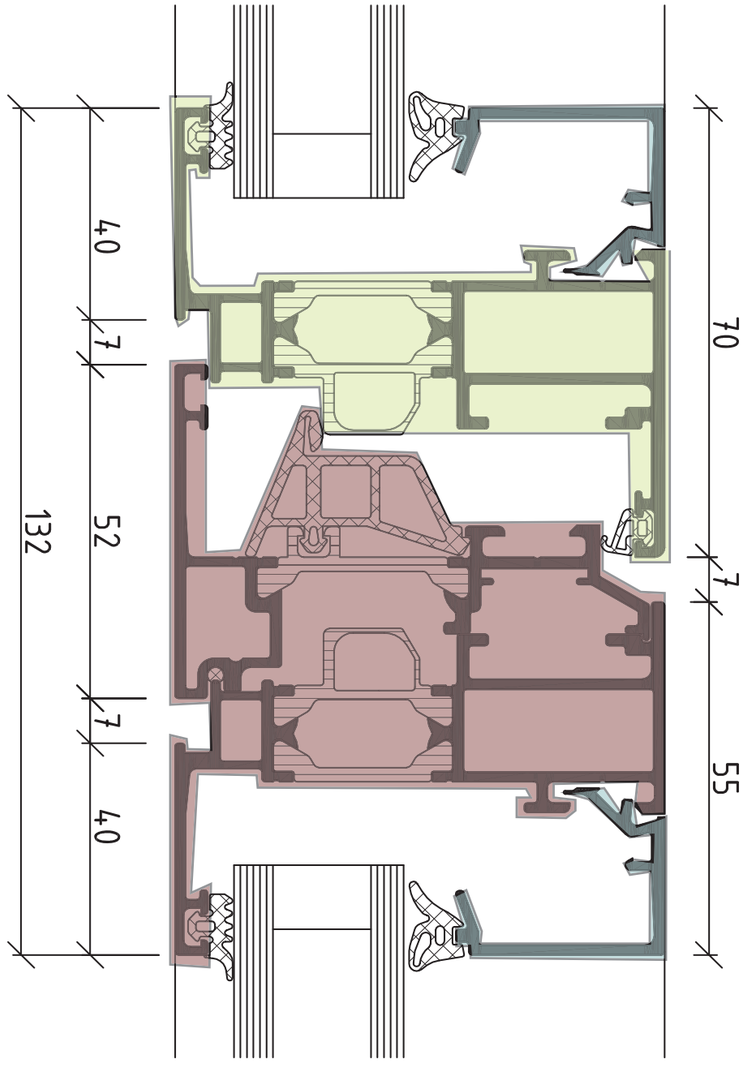
Unitised system



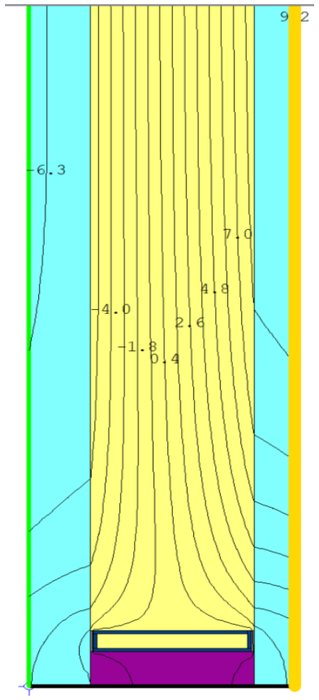
Stick system

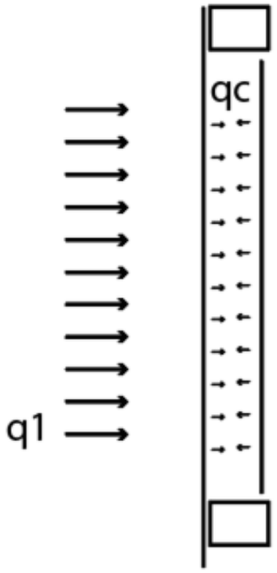


Window frame



Building physics/structural materialisation-dimensions





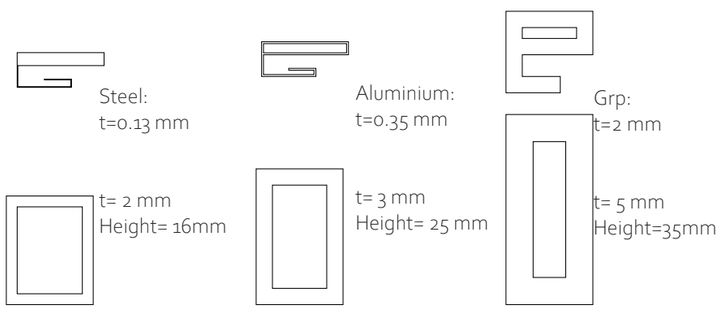
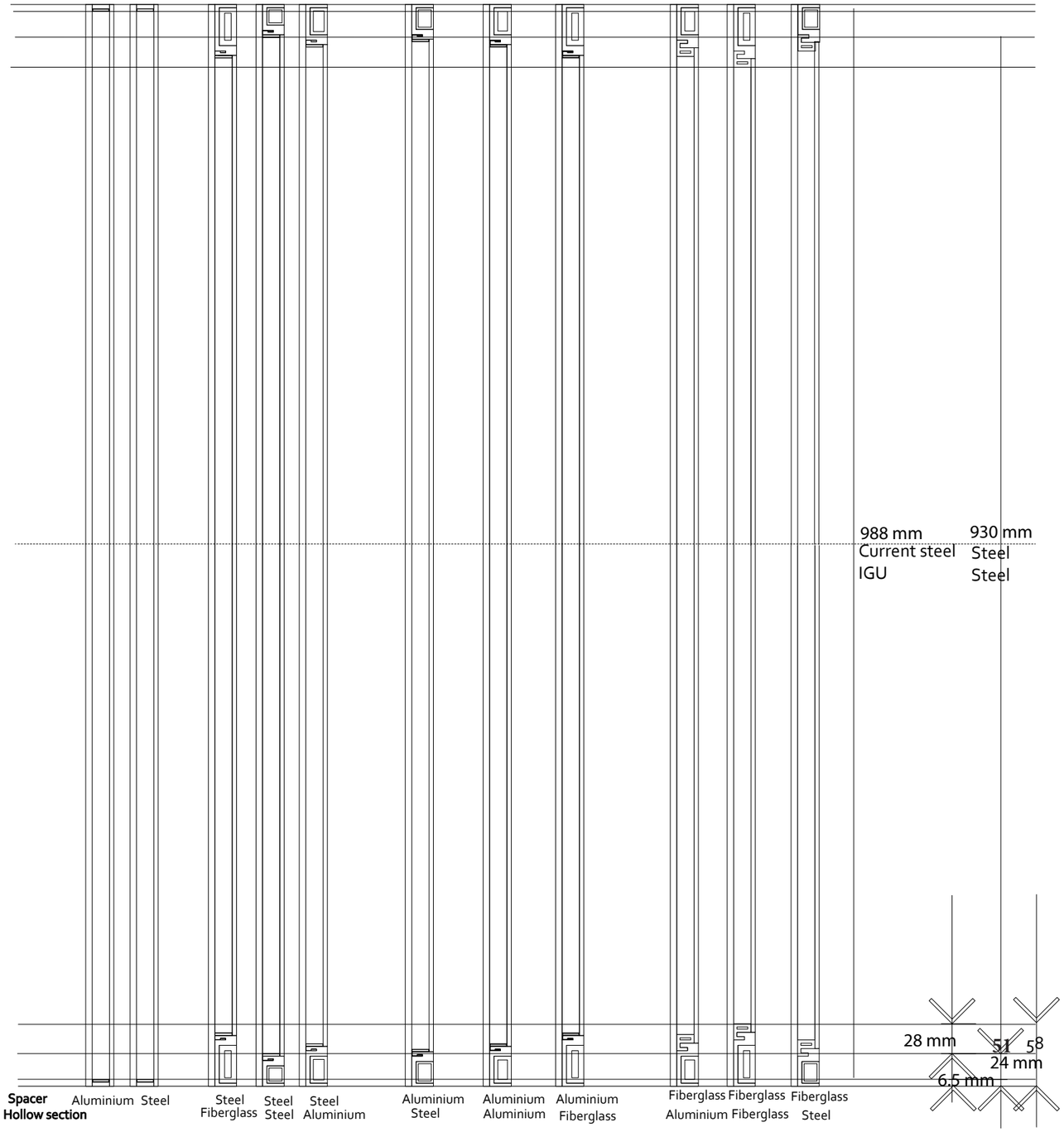
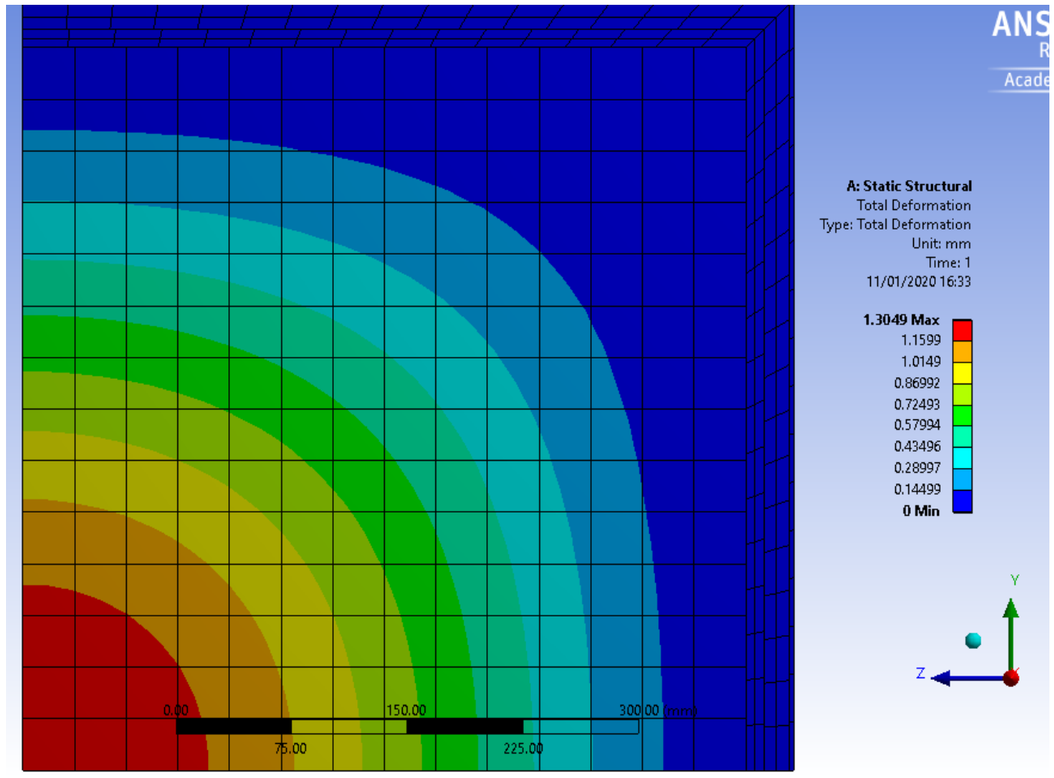
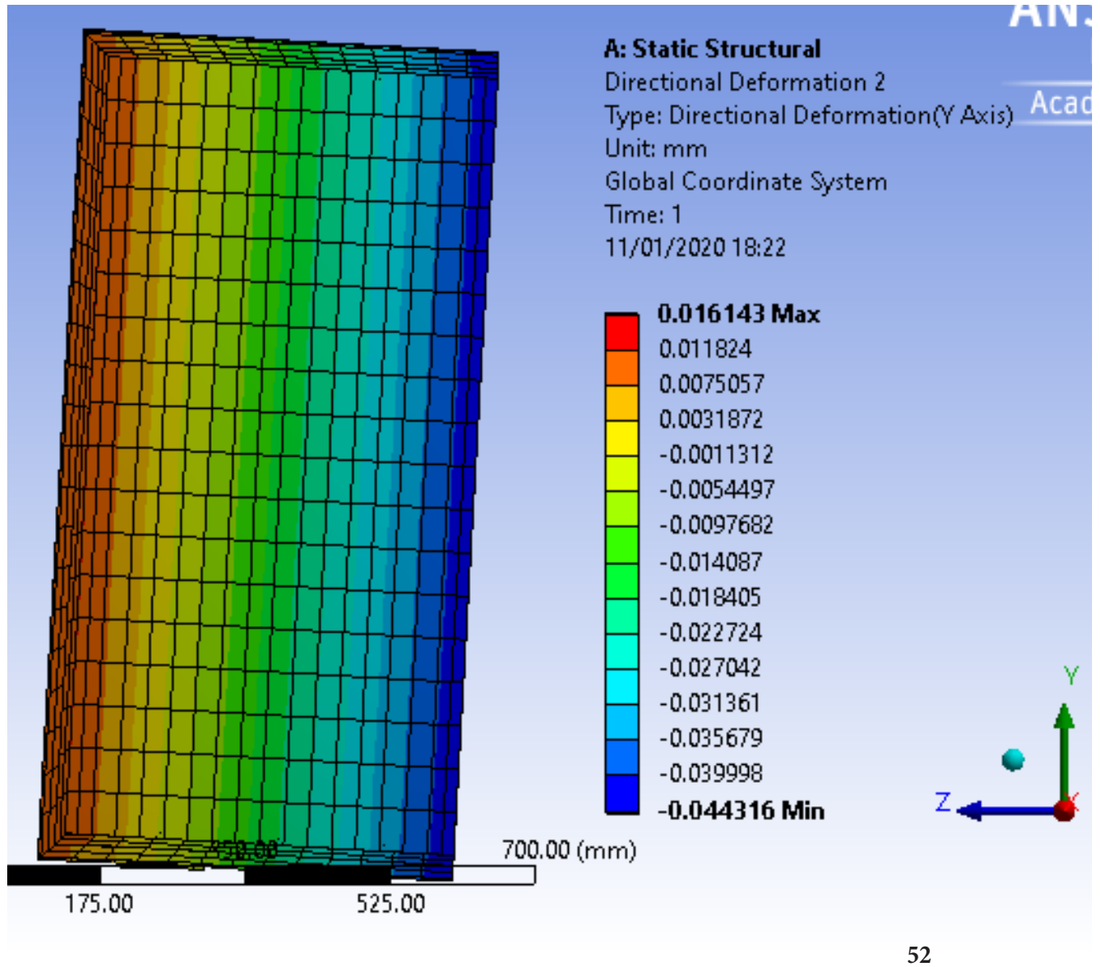


Figure 6.1.2.3: Respectively steel, aluminium and GRP profiles, dimensions of hollow sections by hand calculation and thickness of the spacer bar from literature studies. (Authors image)

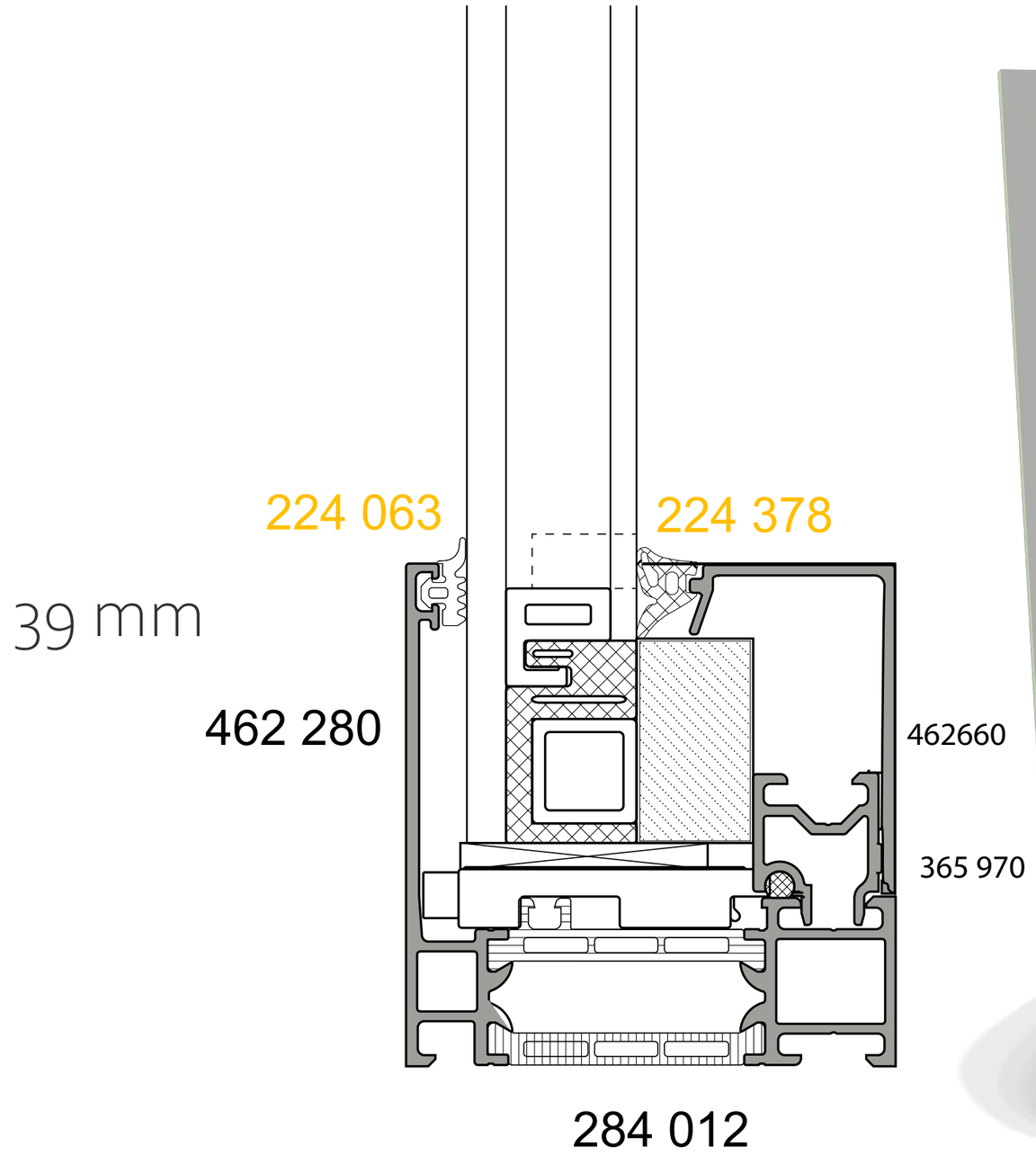


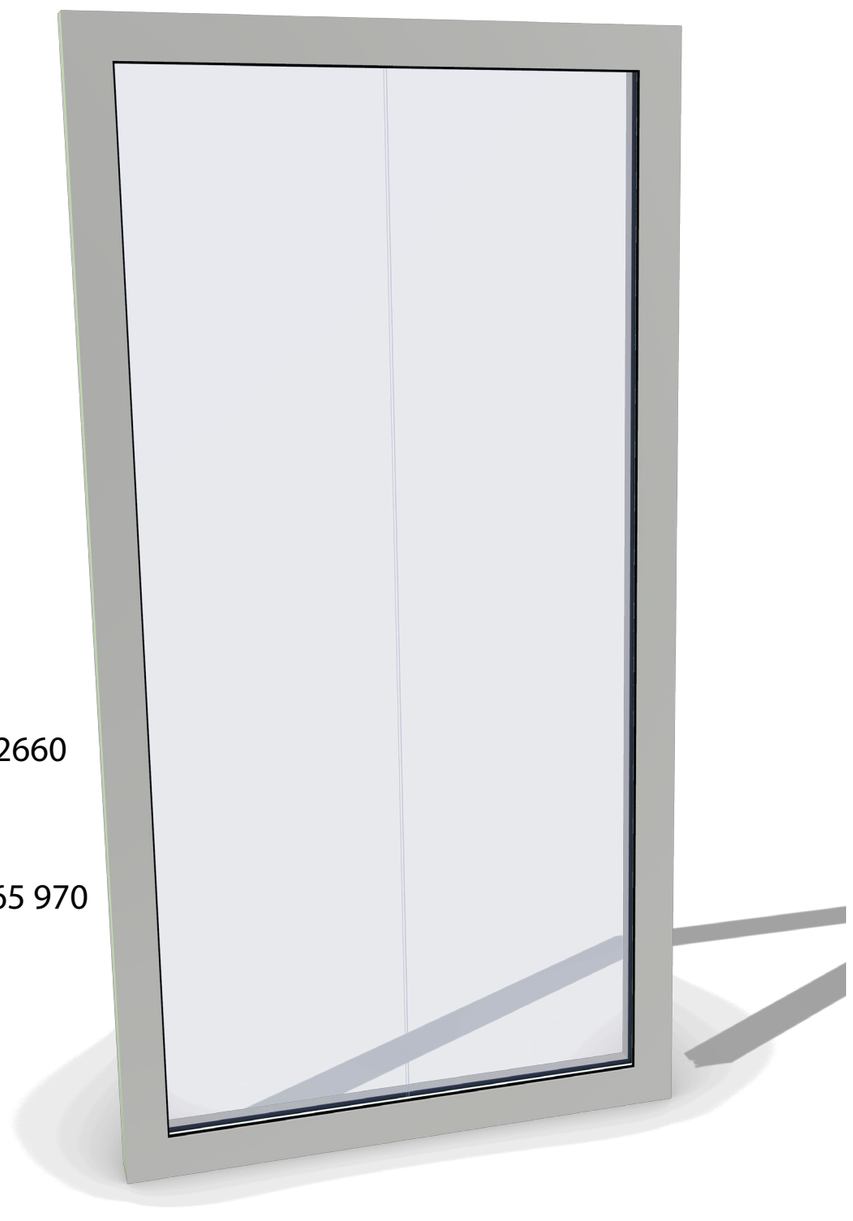
Building physics/structural materialisation-dimensions

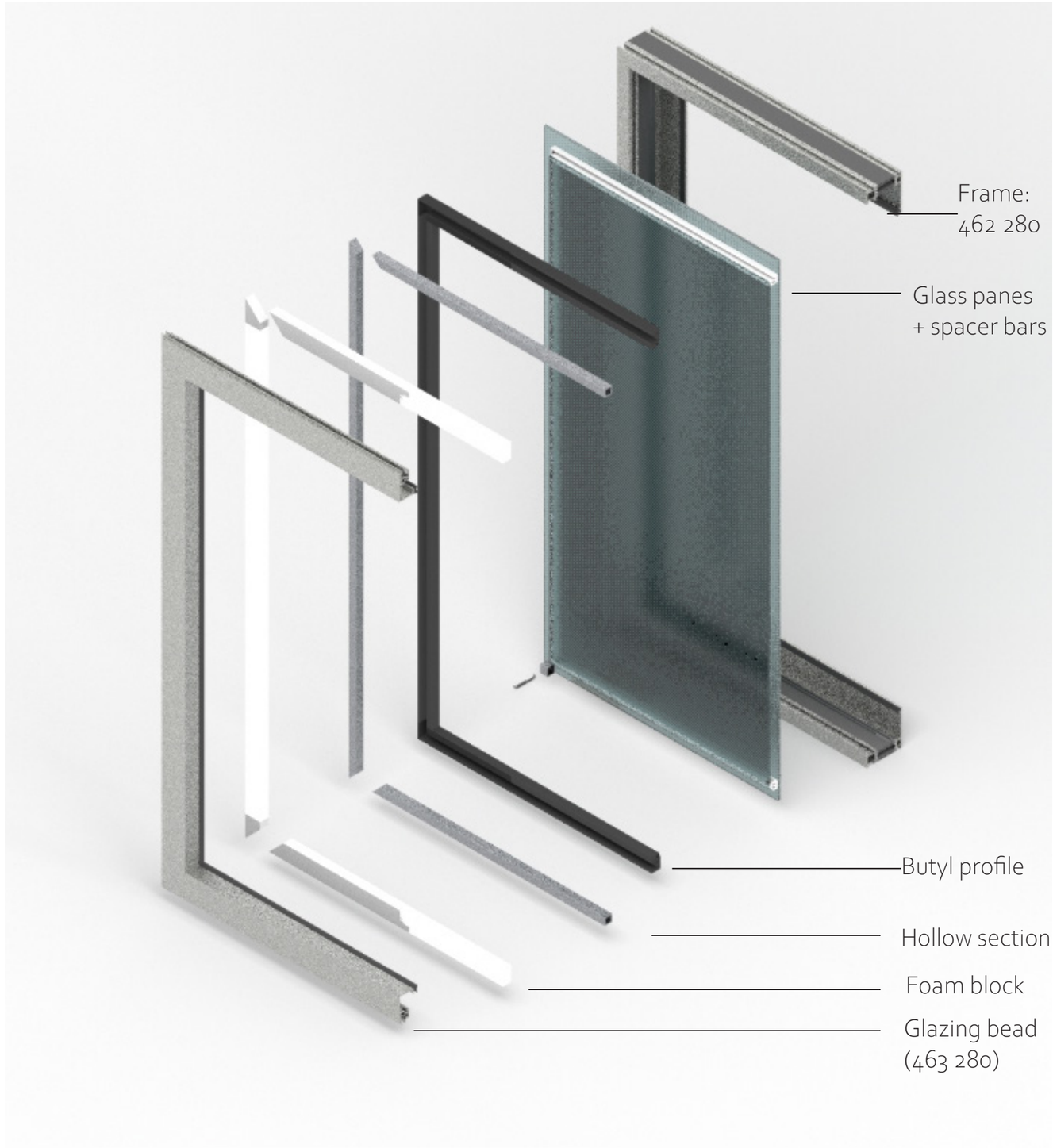




Final detail



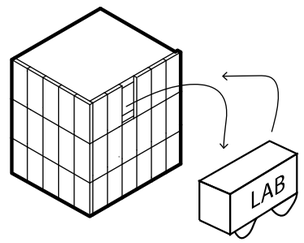



Frame:
462 280
Glass panes
+ spacer bars
Butyl profile
Hollow section
Foam block
Glazing bead
(463 280)

Concept placement

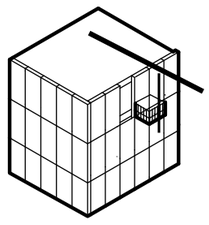
From the outside

In the LAB



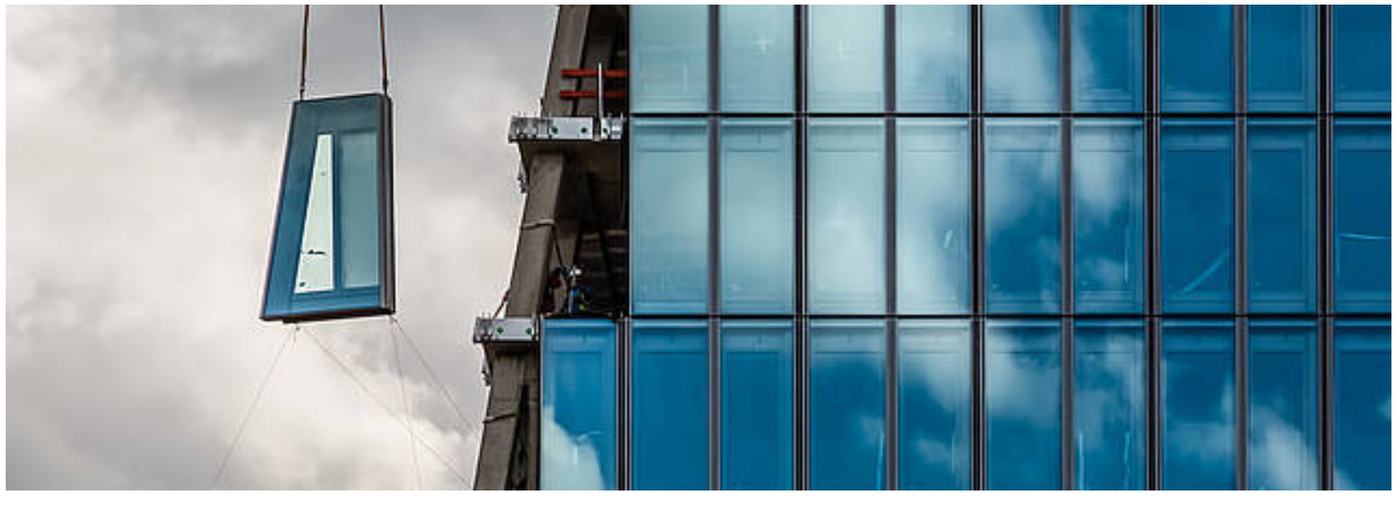
- Weather conditions
- Large enough gondel/ scaffold
- Requires enough space for the Lab to park
- Logistic planning- occupancy
- Sensitive to disruption- hindrance
- Safely lifting the IGU can be difficult
- Safety panel must be installed in the meantime
- + Good quality seal inside the LAB

In place



- Restricted by weather conditions
- Large enough gondel/ scaffold
- Less comfortable/ precise work
- Restricts the size of panel
- Restricted view in case of scaffold
- Requires time for a scaffold to build up
- LAB equipment must be carried and fit
- +Less chance of breaking the panel

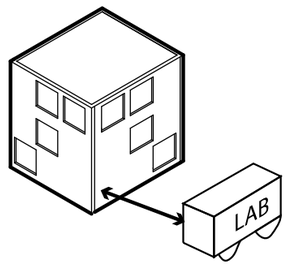
Unitised system



Concept placement

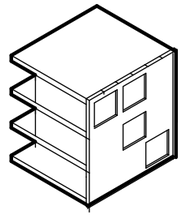
From the inside

In the LAB



Restrictions of glass sizing - available hall, elevator, staircase
Occupancy and planning. Busy during the day
Sensitive to disruption- hindrance
Safety panel must be installed in the meantime
Prone to breakage
Restricted to window-door systems
+ Good quality seal inside the LAB
+Less hindrance and disruption in view

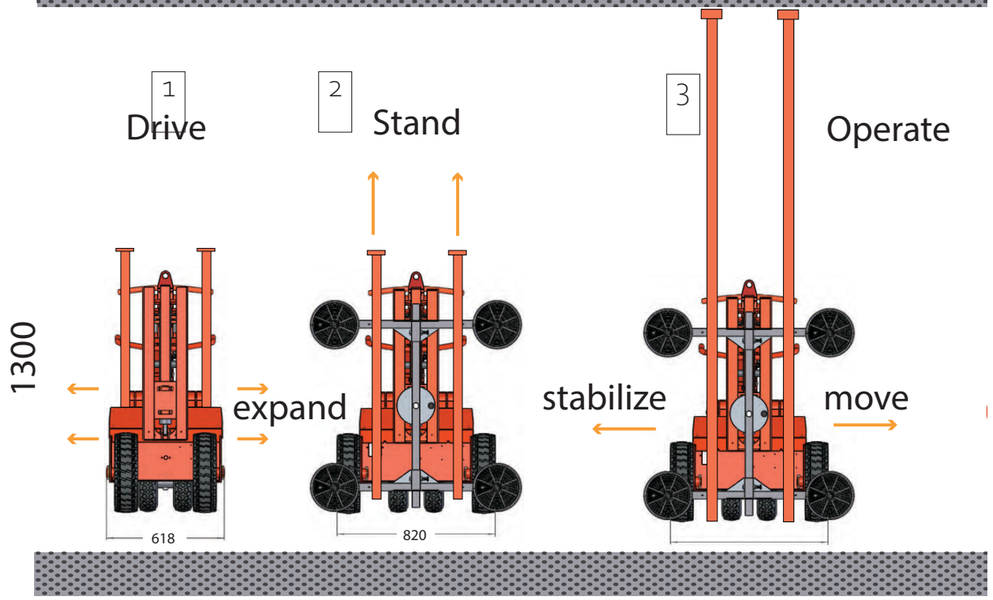
In place

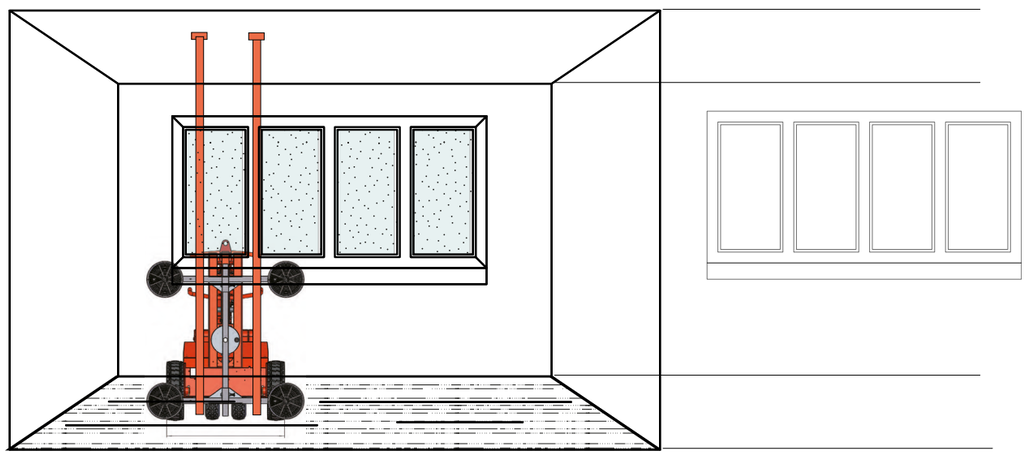


Restricted to window-door systems
LAB equipment must be carried and fit
+ Less chance of breaking the panel
+Less hindrance and disruption in view
+Protective environment

Buildability:Remanufacturing steps

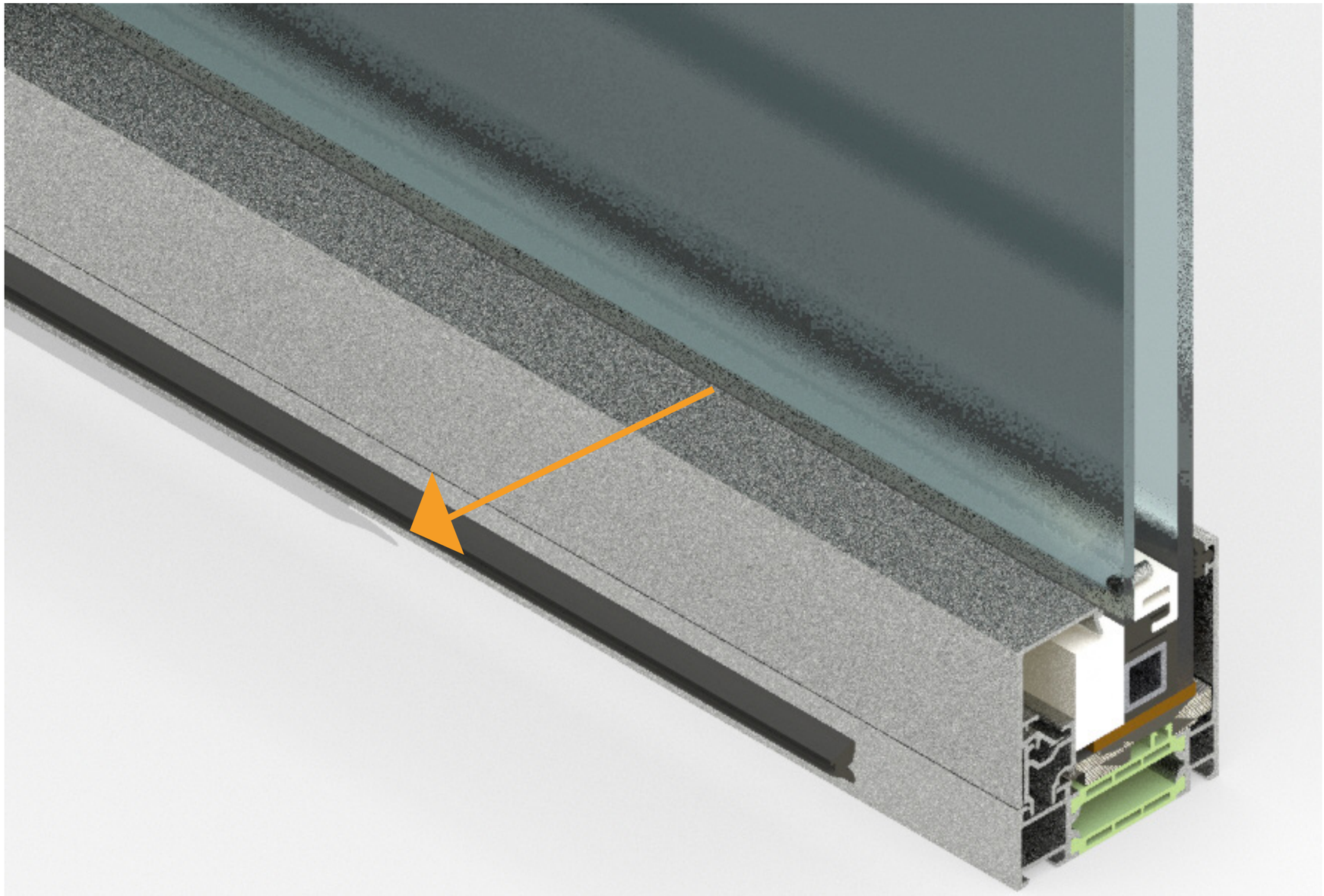
Step 1: First, install the glasslift and let it carry the glazing panel





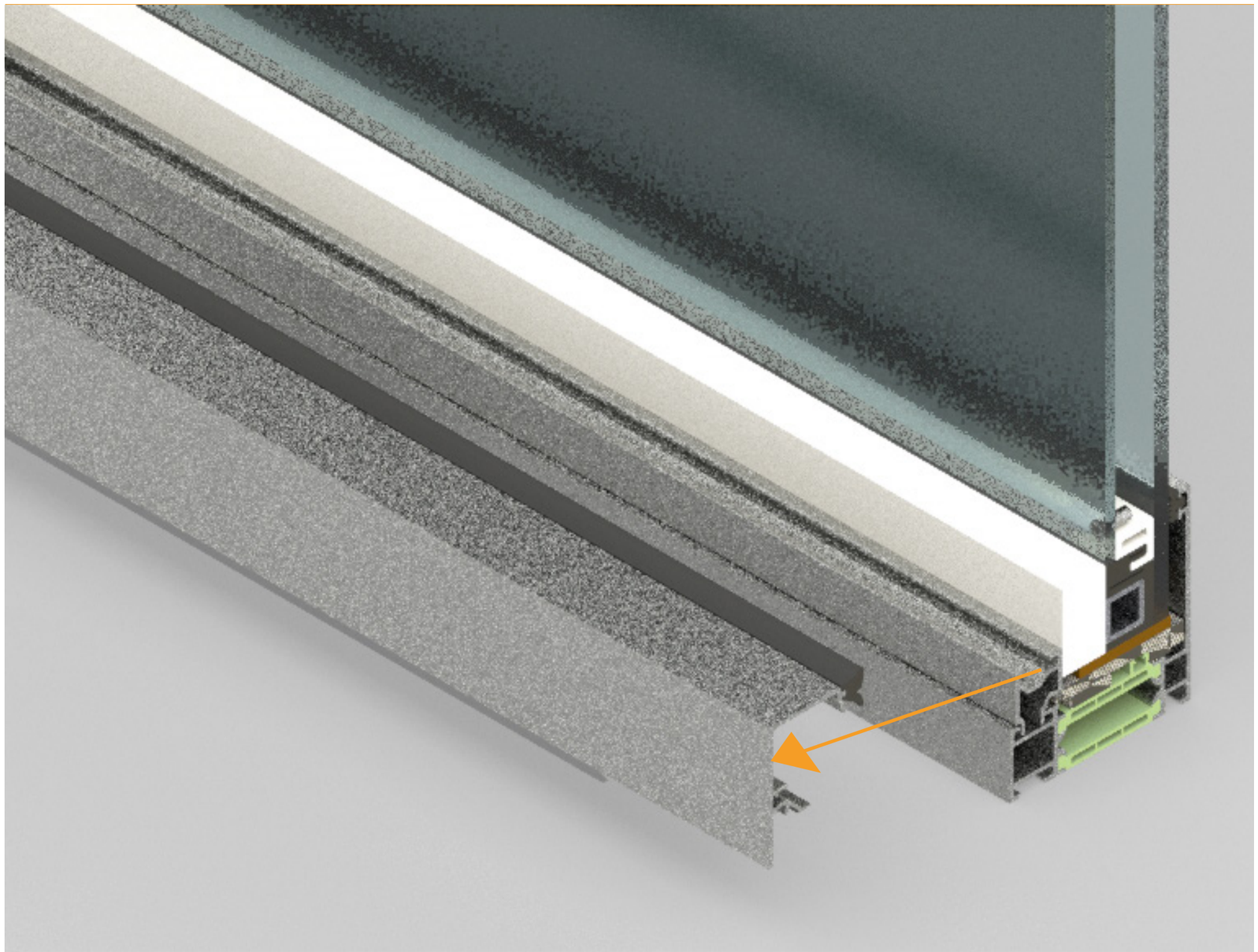
Buildability: Remanufacturing steps

Step 2: Then take away the EPDM gasket



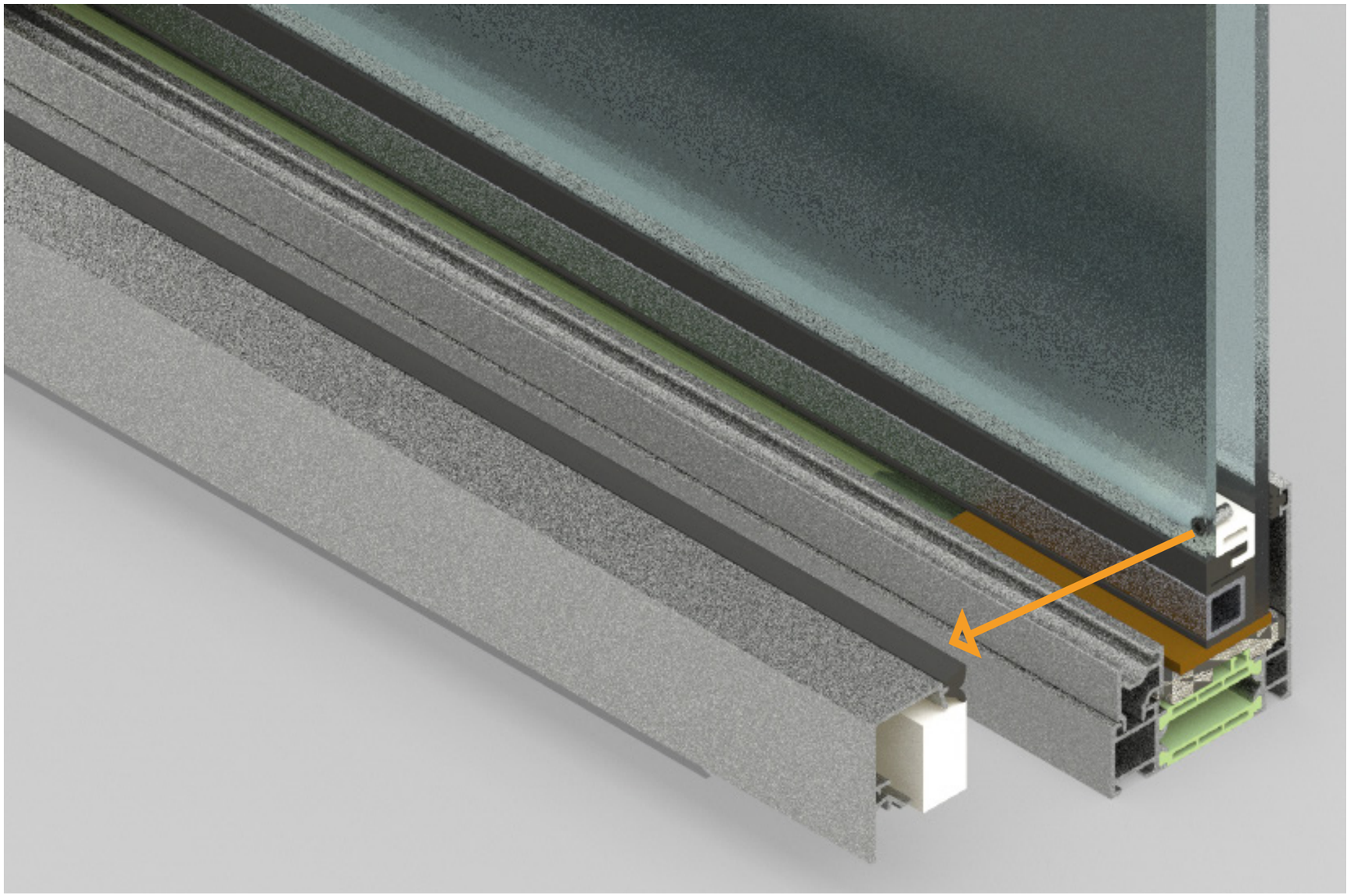
Buildability: Remanufacturing steps

Step 3: Take away the glazing bead



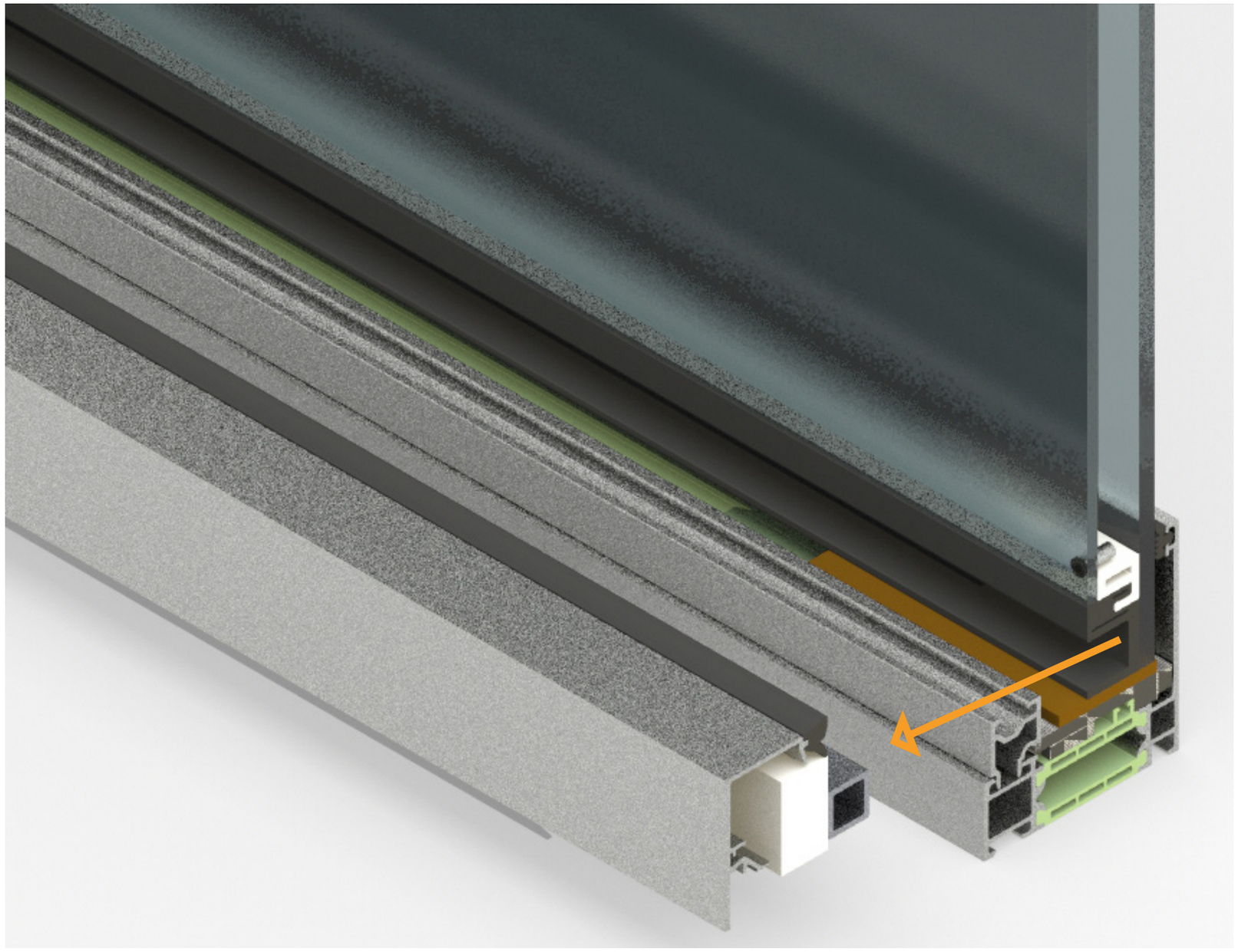
Buildability: Remanufacturing steps

Step 4:Take away the foam block



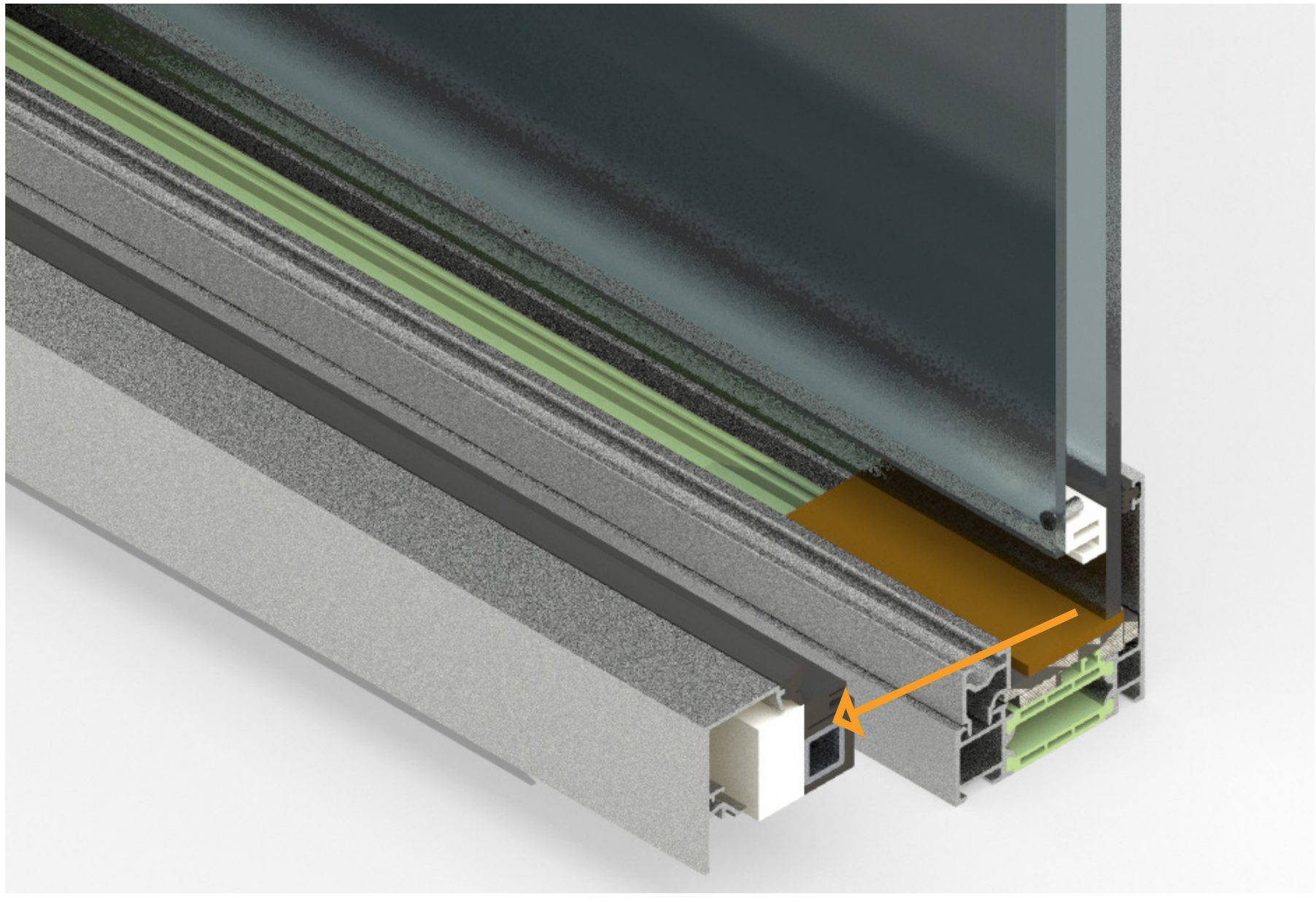
Buildability: Remanufacturing steps

Step 5: Take away the hollow section



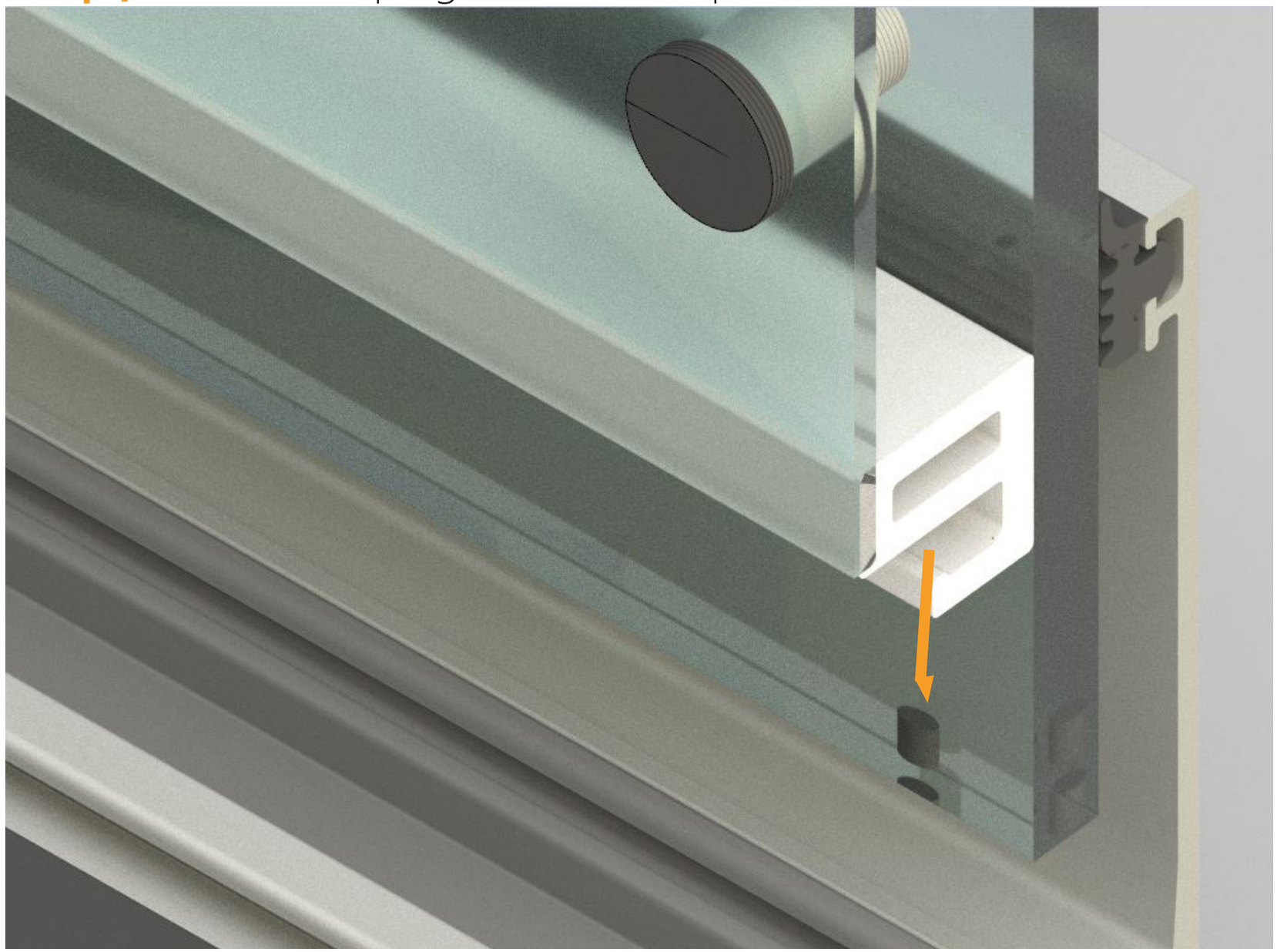
Buildability: Remanufacturing steps

Step 6: Now remove the butyl profile



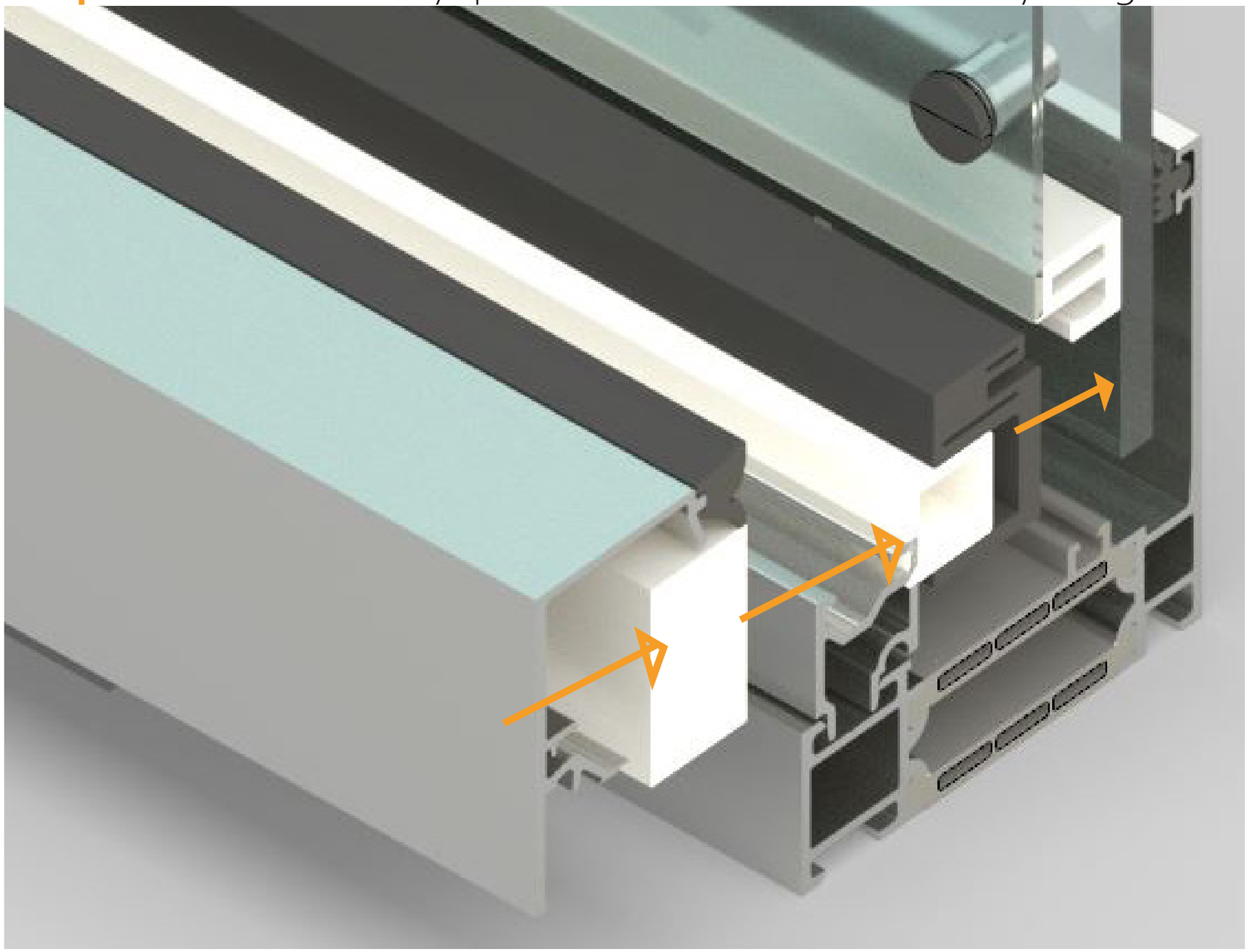
Buildability: Remanufacturing steps

Step 7: Take both plugs out of the spacer bar and fill with desiccant



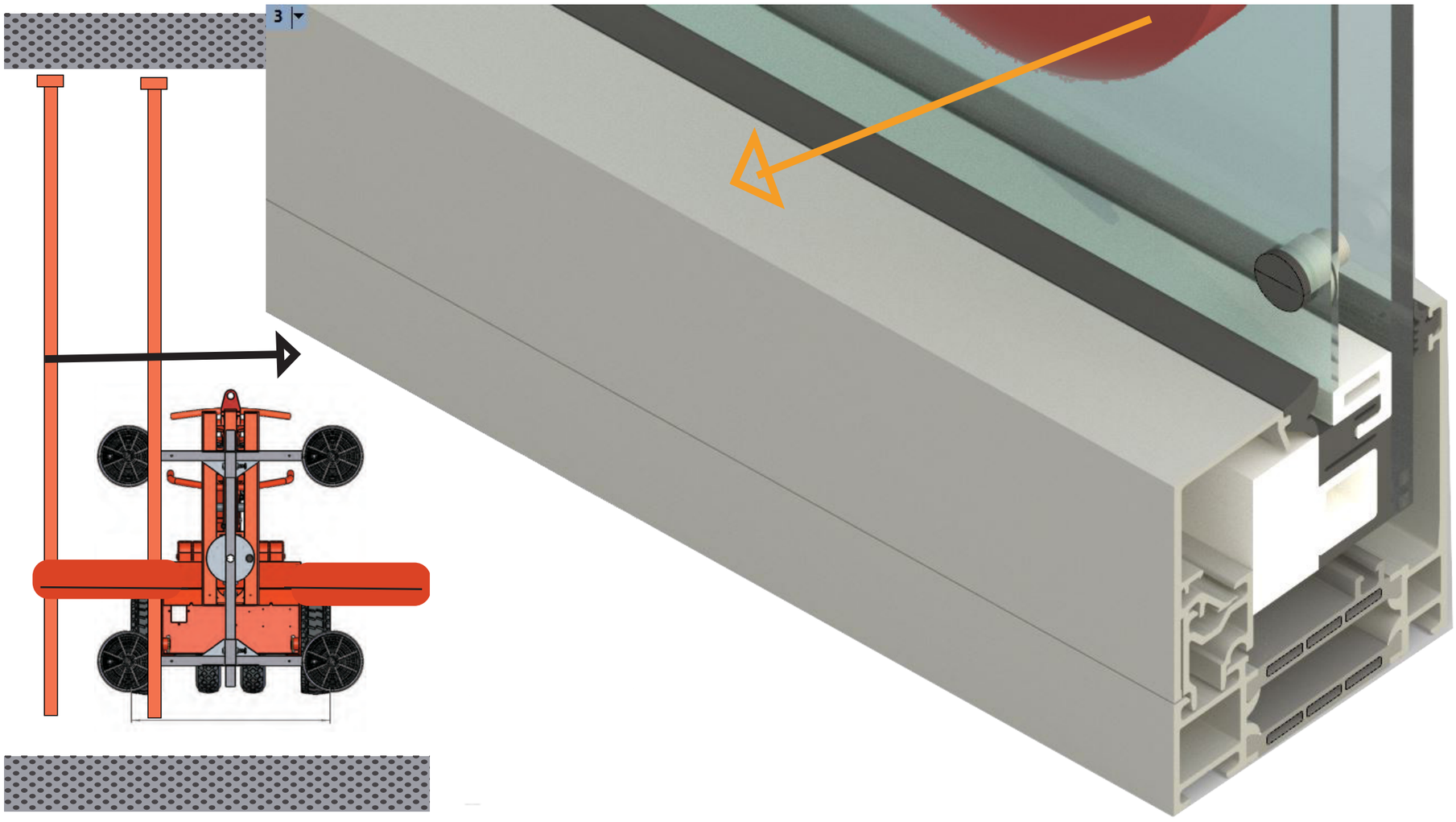
Buildability: Remanufacturing steps

Step 8: Place new butyl profile and re-assemble everything



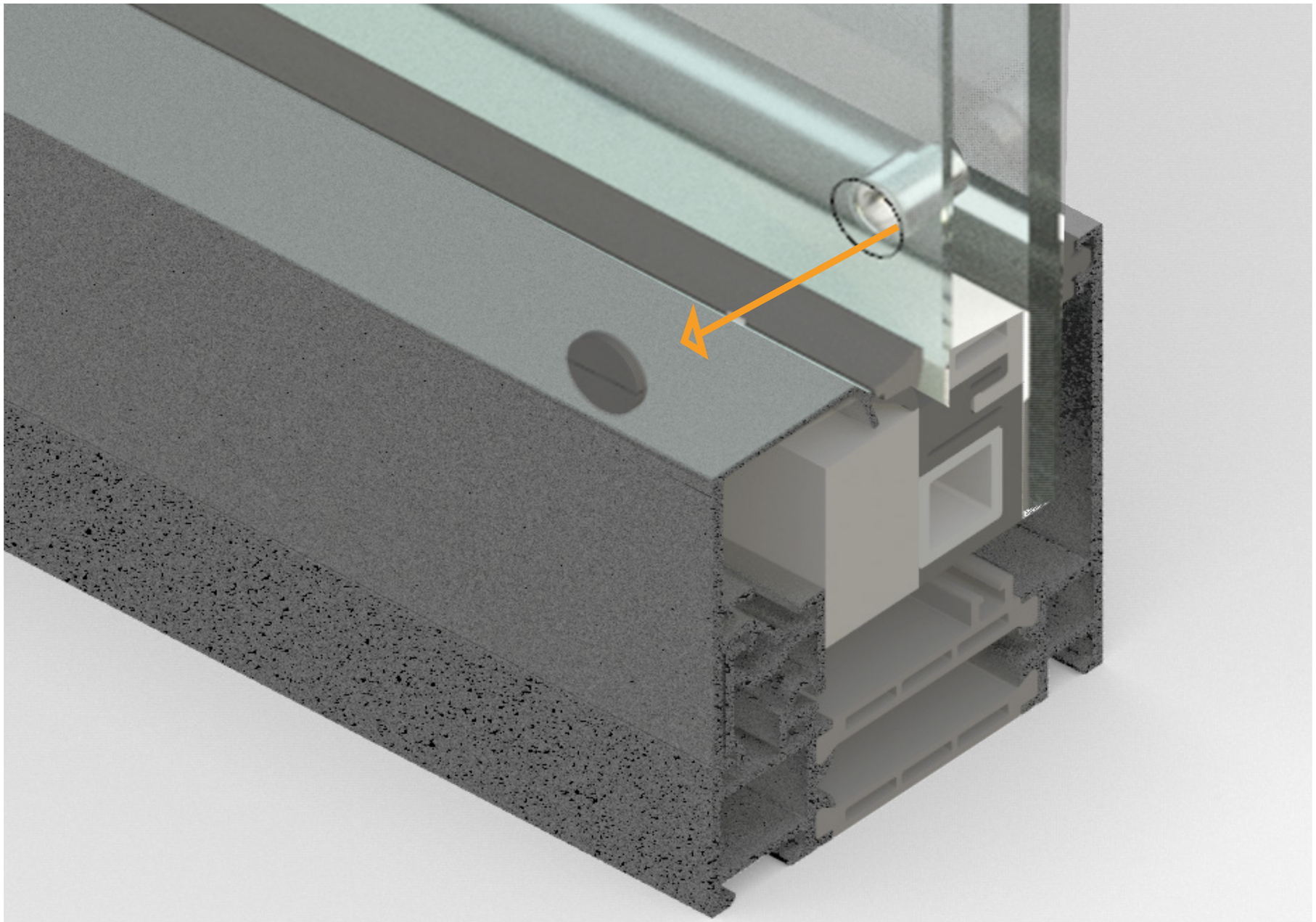
Buildability: Remanufacturing steps

Step 9: Remove the glass lifter (and attach to the next IGU)



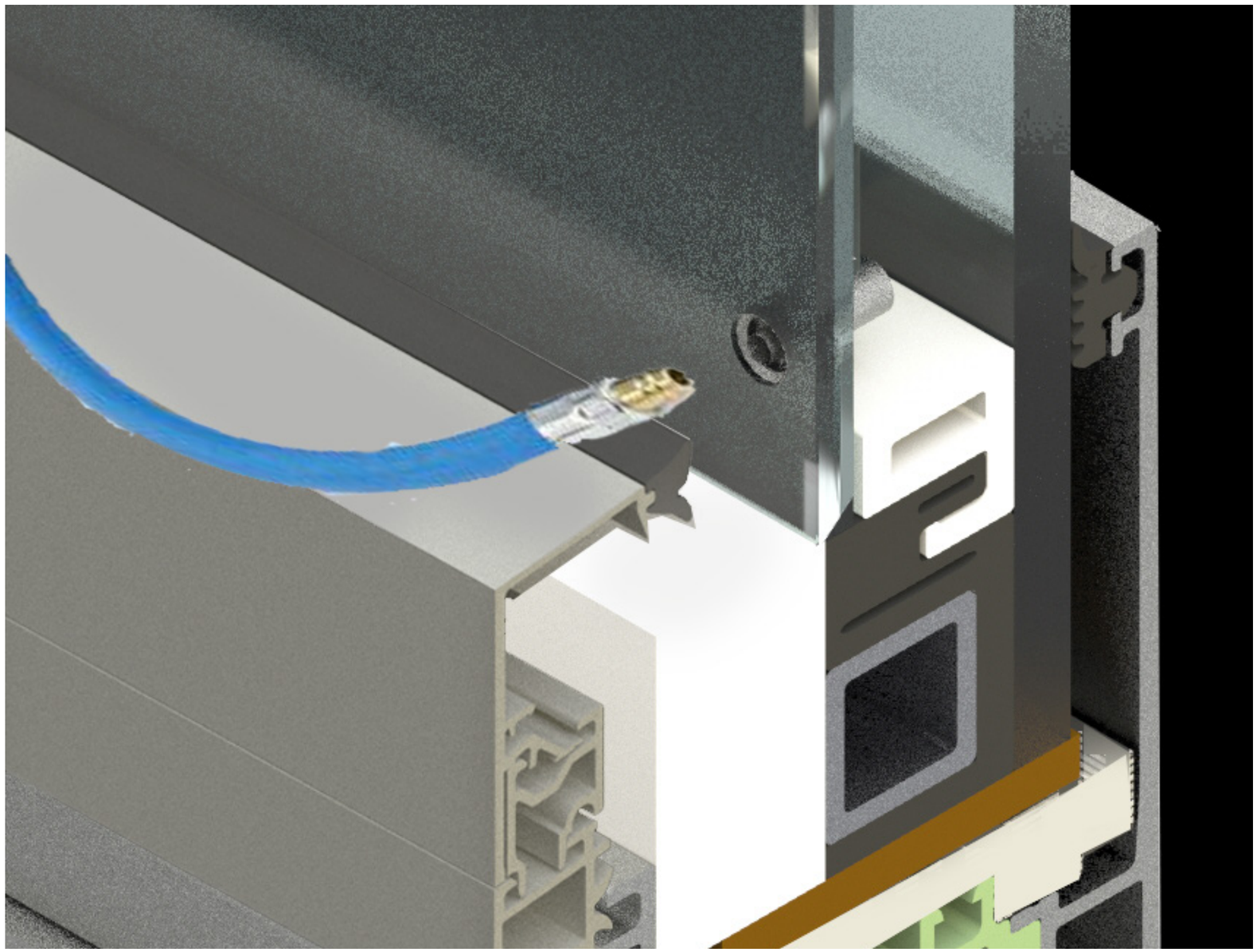
Buildability: Remanufacturing steps

Step 10: Open the valve by removing the plug



Buildability: Remanufacturing steps

Step 11: Fill up with Argon. (+at the top pump out the air).

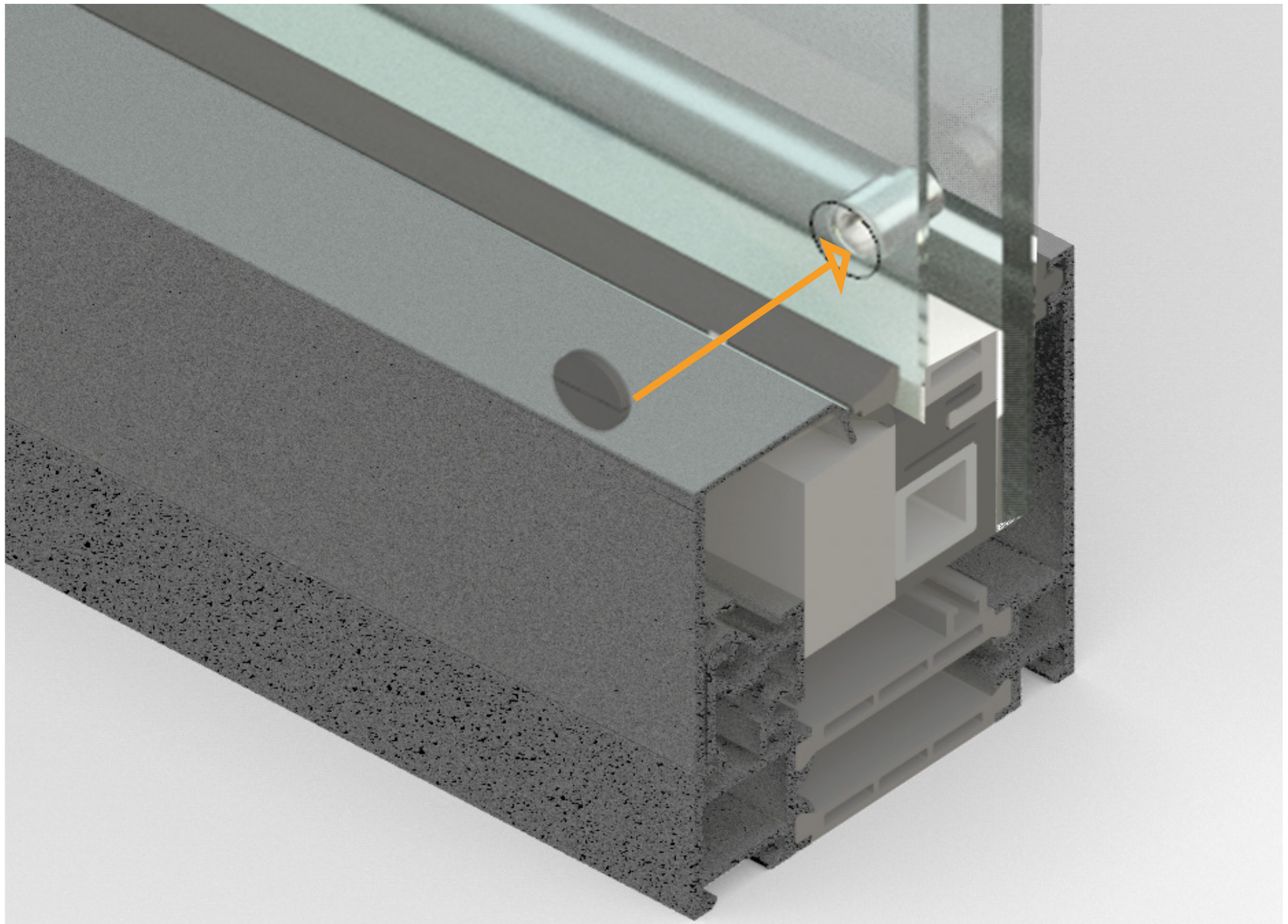


Buildability: Remanufacturing steps

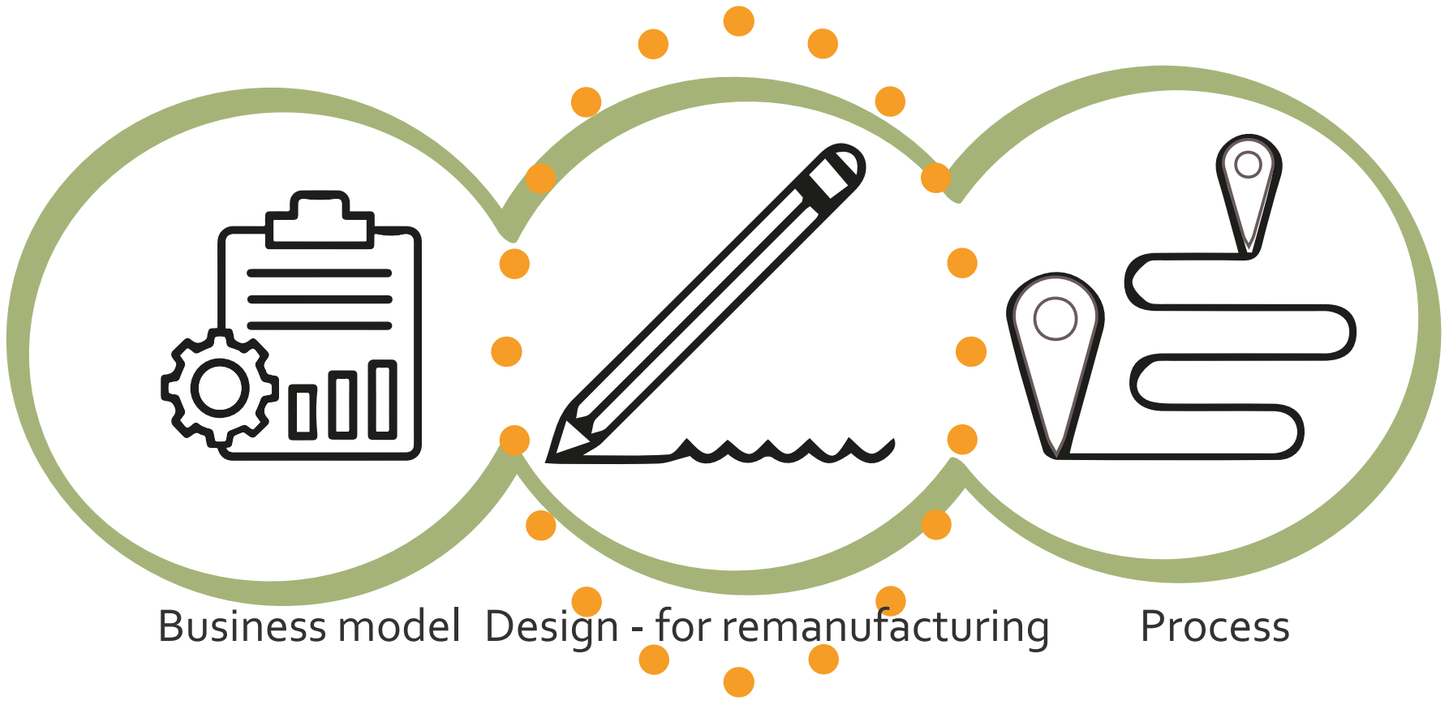
Step 12: Measure the Argon percentage at the top side.

Buildability: Remanufacturing steps

Step 13: Place a new plug to protect the valve



Evaluation & Conclusion



BUT STILL...

What is next for the design part?

Test **the real working with butyl**.. ?

Sag of the butyl profile is not considered yet in the construction part

A way to make Fiberglass also gas tight…coating?

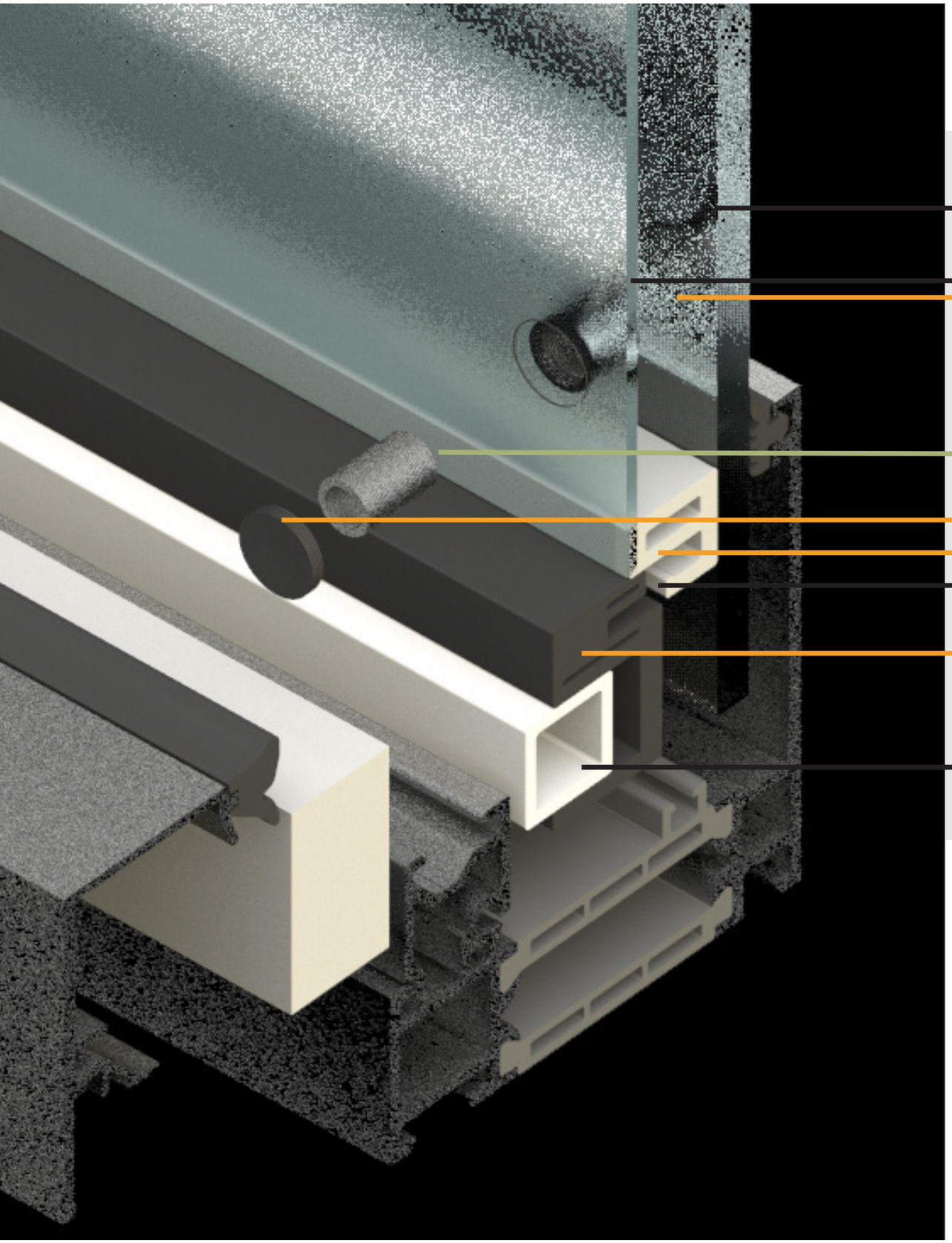
Spacer bar design that takes into account the atmospheric pressure difference

LCA research on the materials - regarding circular

Acoustics/ fire safety testings

Not for **structural glazing** yet (but this is not usual in the Netherlands tough)

IV



∞ cycles

∞ unless change needed

1 cycle

Glass

Cylindric metal tube

Argon

Valve

Plug for valve

Desiccant

Spacer bar

Butyl

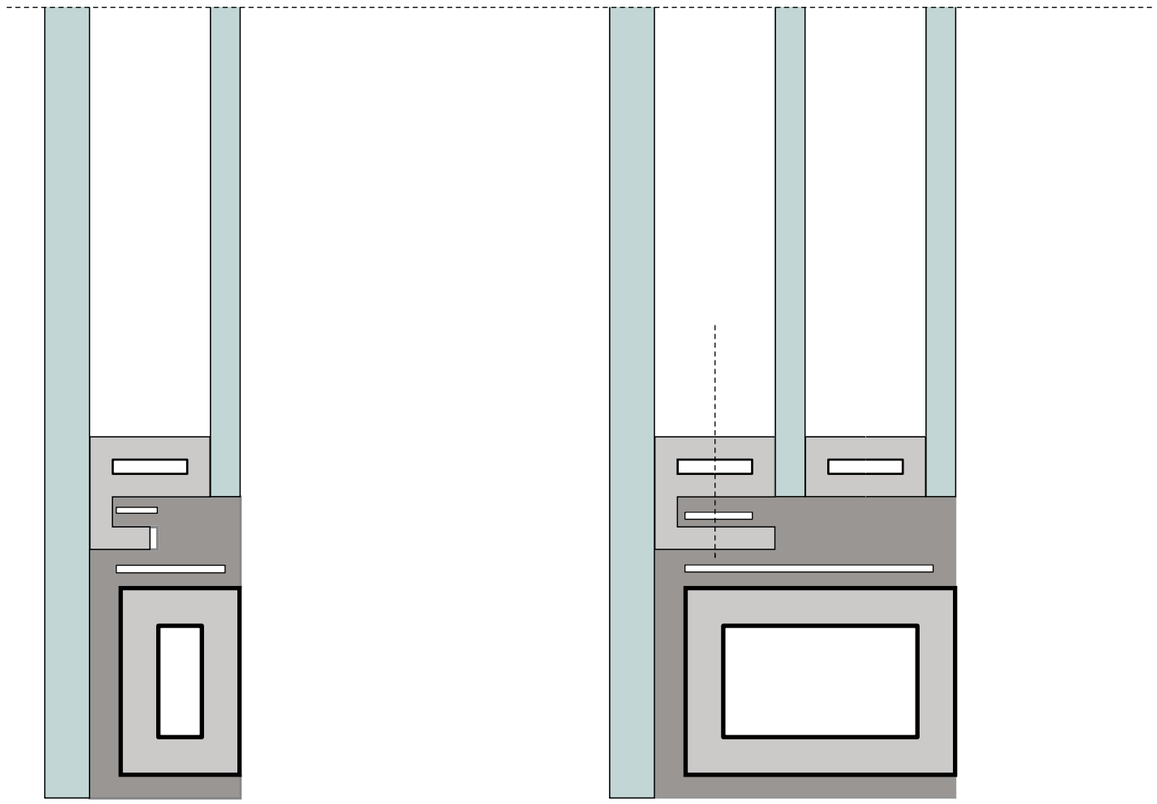
Hollow section

THE RE∞ SEAL WINDOW

A Redesign of the edge seal of Insulated glass units
to facilitate easy and fast re-manucturing.

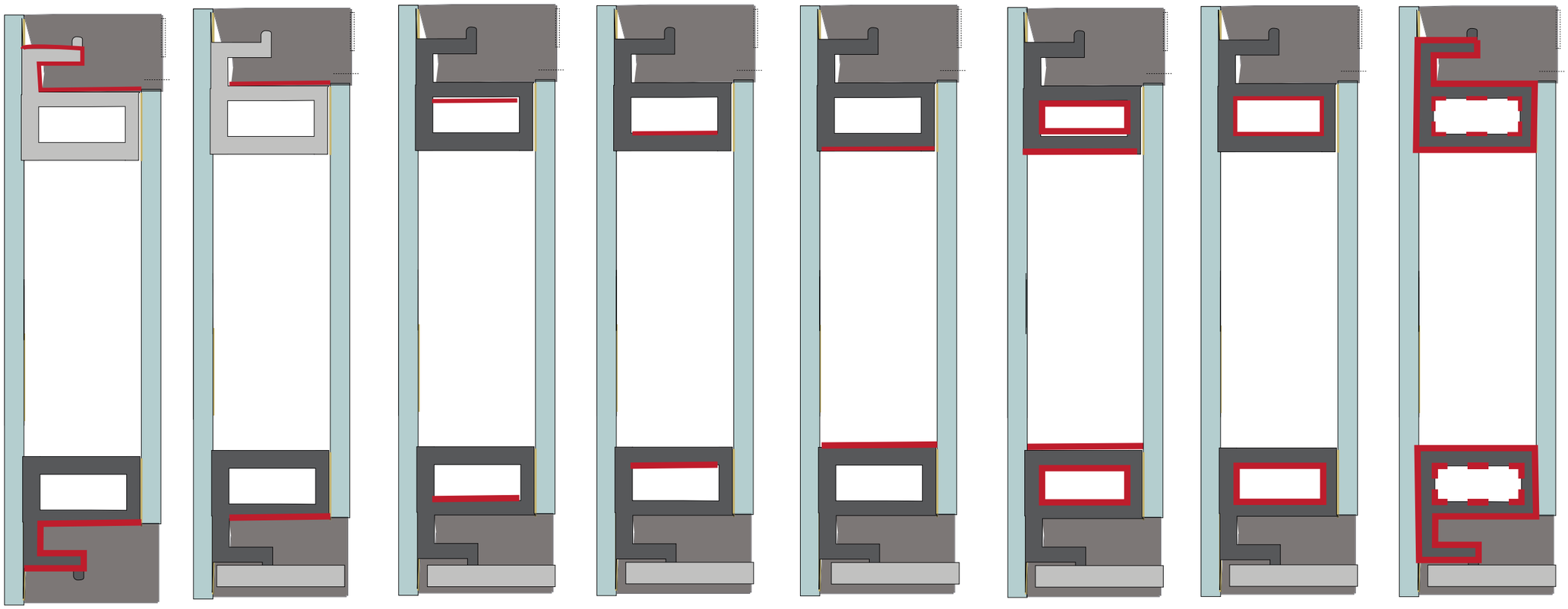
Thank You

Upgradability



A

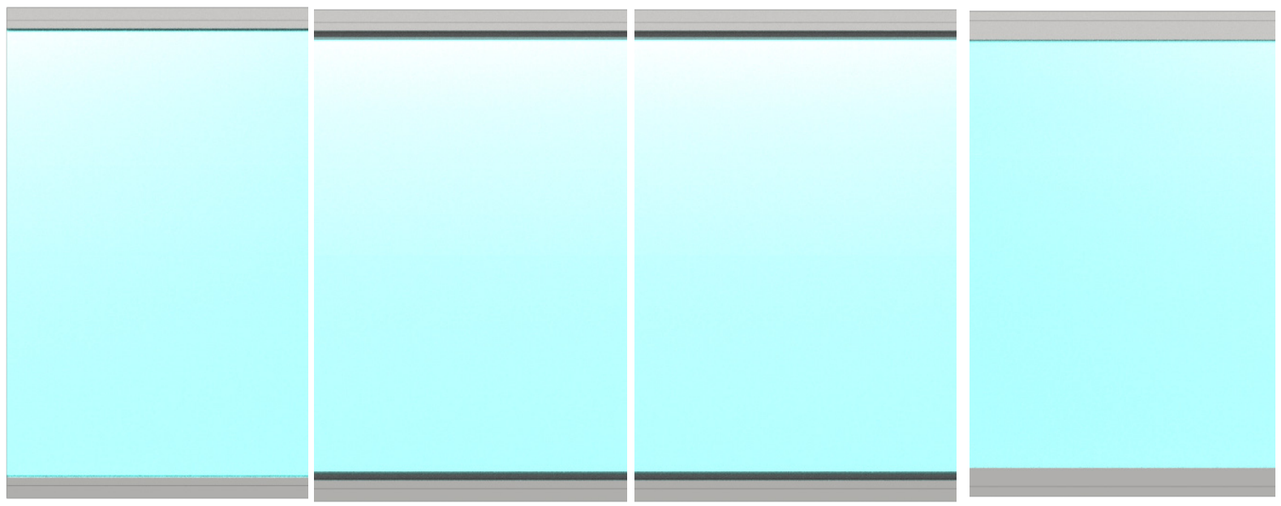
Fiberglass coatings

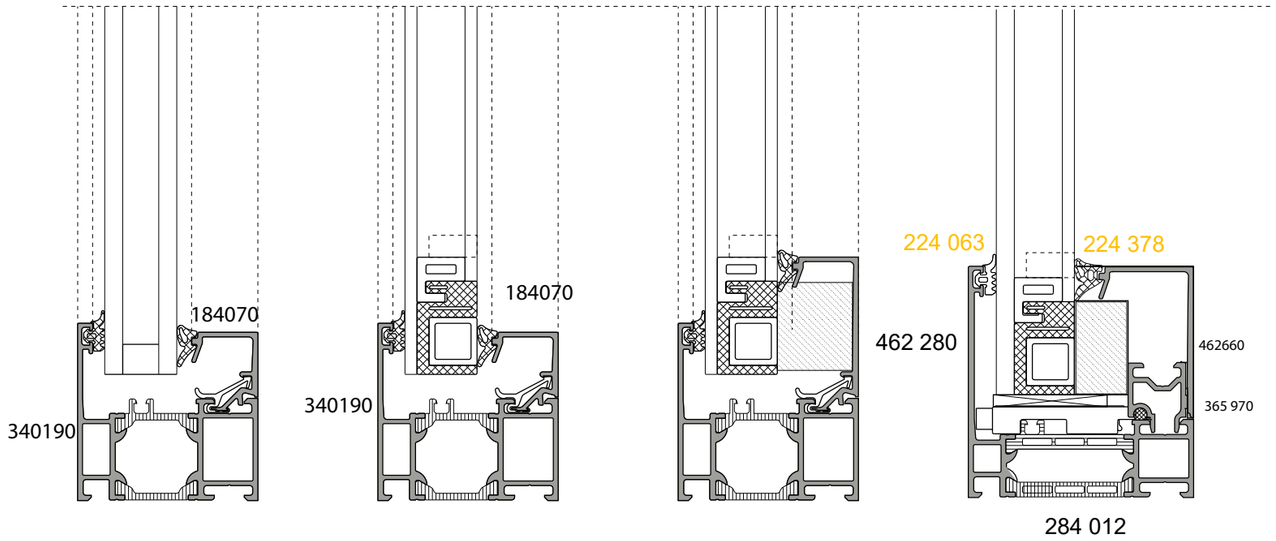


		Allows vapour at left side	Allows vapour on sides	Contact holes dessicant-cavity in the way	Contact holes dessicant-cavity in the way		Allows vapour on sides	
Coating	v	-	-	-	-	v	-	v
Foils	Fragile for rubber	-	-	-	-	Sight distraction	-	Sight distraction
Al profile	Transferring cold	-	-	-	-	Transferring cold	-	Transferring cold

A

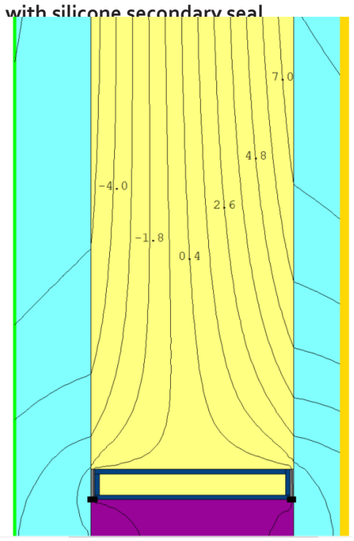
Proposal in facade



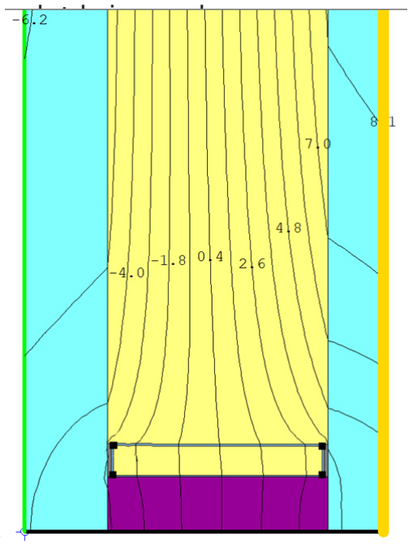


Building physics

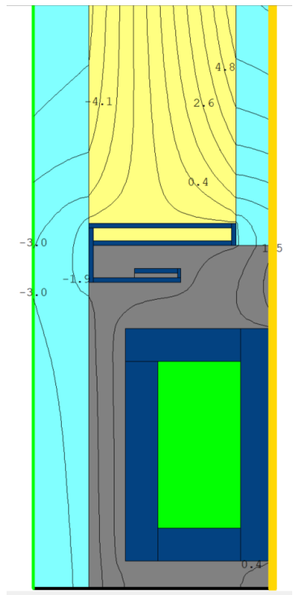
Conventional Aluminium spacer bar with butyl primary seal and with silicone secondary seal



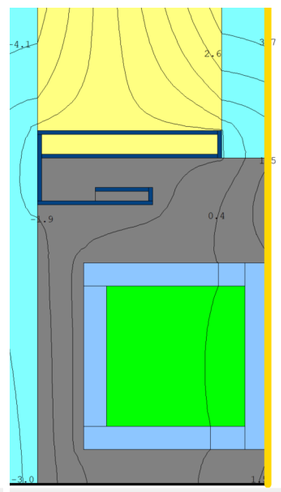
Conventional Steel spacer bar With silicone secondary seal and



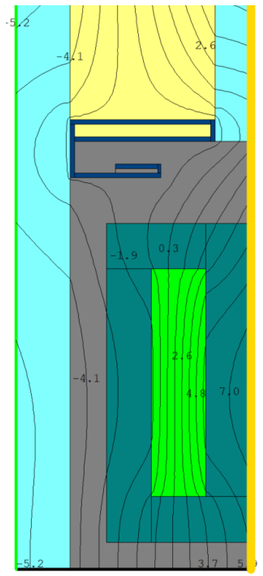
Aluminium spacer bar Aluminium hollow section



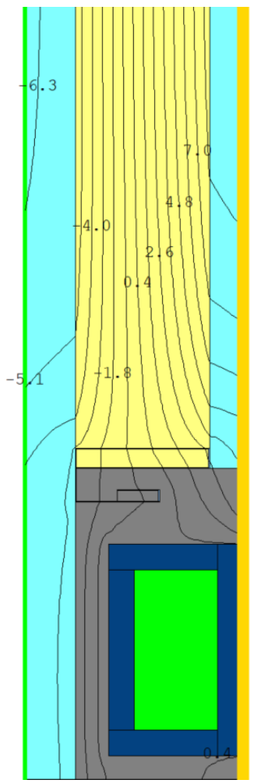
Aluminium spacer bar Steel hollow section



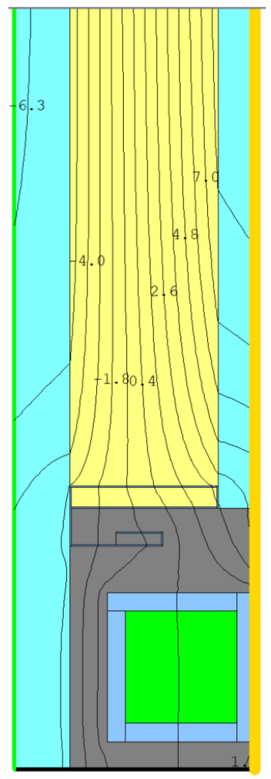
Aluminium spacer bar Fiberglass hollow section



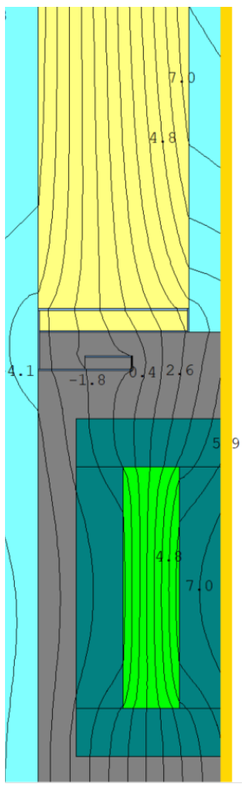
Steel spacer bar Aluminium hollow section

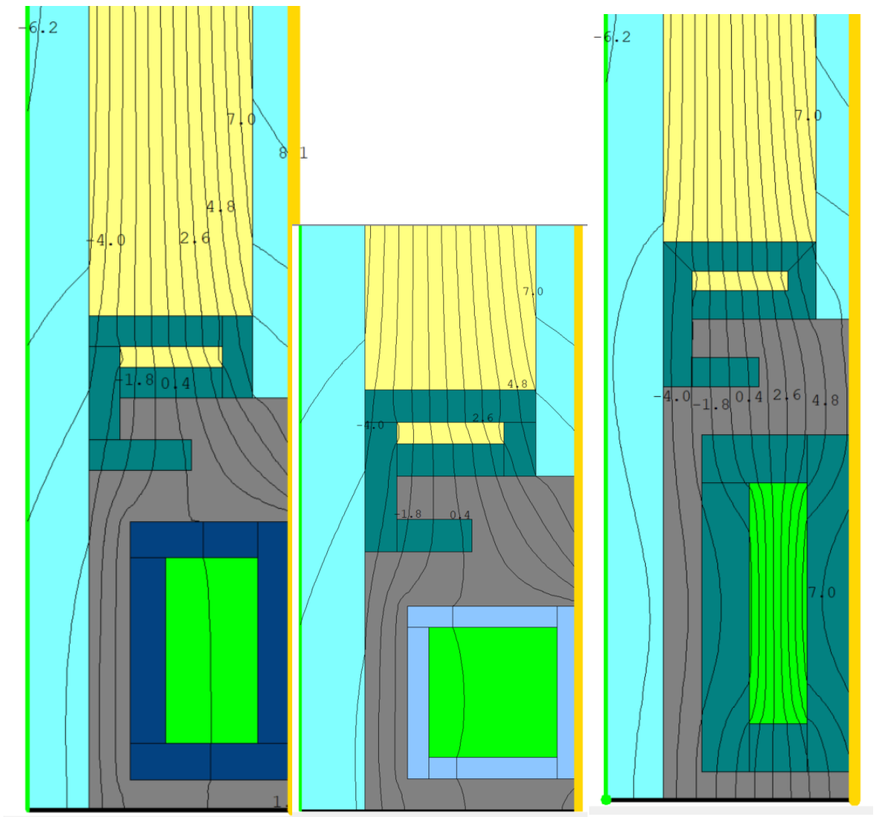


Steel spacer bar Steel hollow



Steel spacer bar Grp hollow section





Building physics

U value		spacer	Hollow section	U value	error
Base	theoretical			3	
	modeled	Aluminium		2.9952	
	modeled	Steel		2.9656	
New design		GRP	GRP	3.0037	1.33%
		Steel	GRP	3.0258	2.19%
		GRP	Steel	3.0538	1.84%
		Steel	Steel	3.0688	2.50%
		Aluminium	GRP	3.0757	3.17%
		GRP	Aluminium	3.1006	1.83%
		Aluminium	Steel	3.108	3.11%
		Steel	Aluminium	3.115	3.07%
		Aluminium	Aluminium	3.1531	2.96%
Final design		GRP	GRP	2.9801	1.13%

Valve options

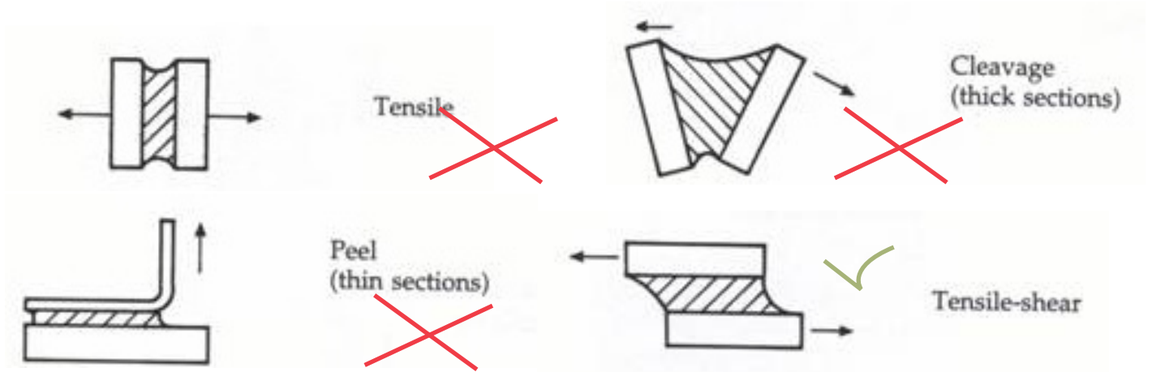
	Valve only	Valve for multiple windows	Valve with plug
Cost			
Reliability			
Dust free			
Ease of installation			
Amount of tools needed	Nothing	Hex key	Hex key
Glued connection			
Parts	Valve O-ring	Valve Plug Cylindric metal tube Plug Betaplug	Valve Plug Cylindric metal tube
Throw away	O-ring	Betaplug	Plug

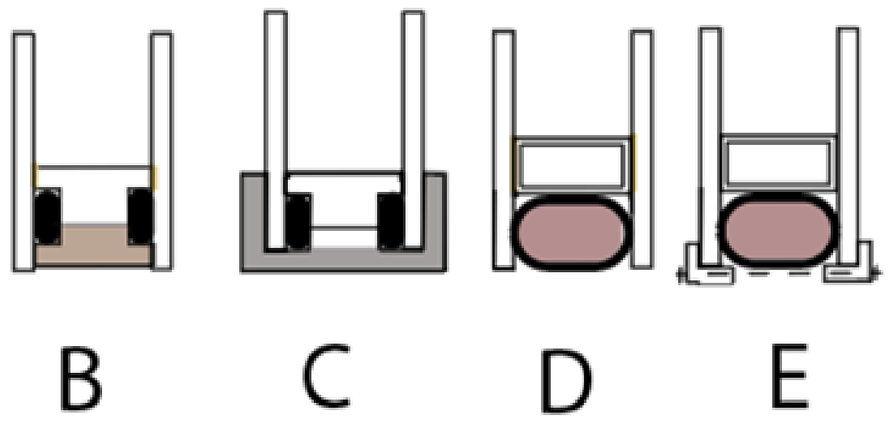
Table 5.10.3.1: Comparison between variants of installing the valves.

A

Concept variants

Tension on the permanent bonding

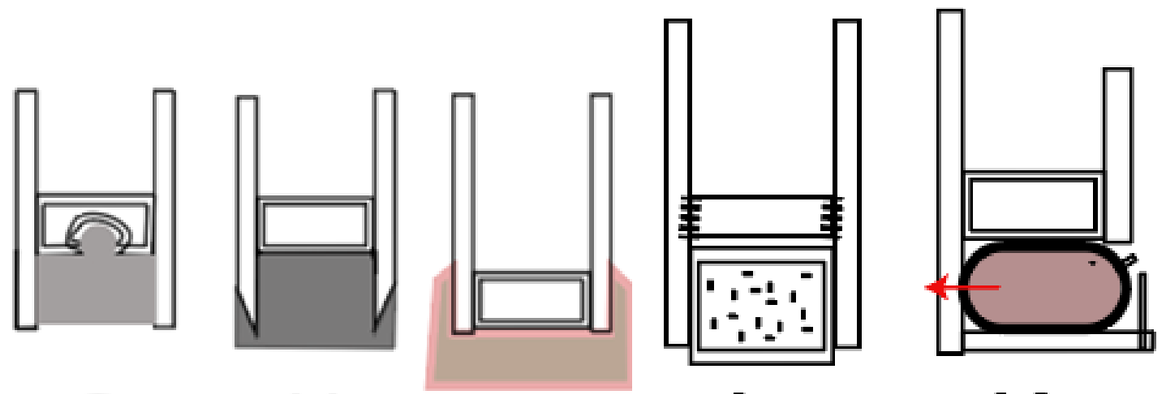




	Original	B	C	D	E
Ease of replacement	-1	1	1	1	0
Tension on the permanent bonding	-1	-1	1	-1	1
transfer of the loads	1	1	1	1	0
Seam tightness	1	0	0	0	1
Fabrication	1	1	1	1	1
Heat flow	1	1	-1	1	0

/www.adhesivestoolkit.com/

Concept variants

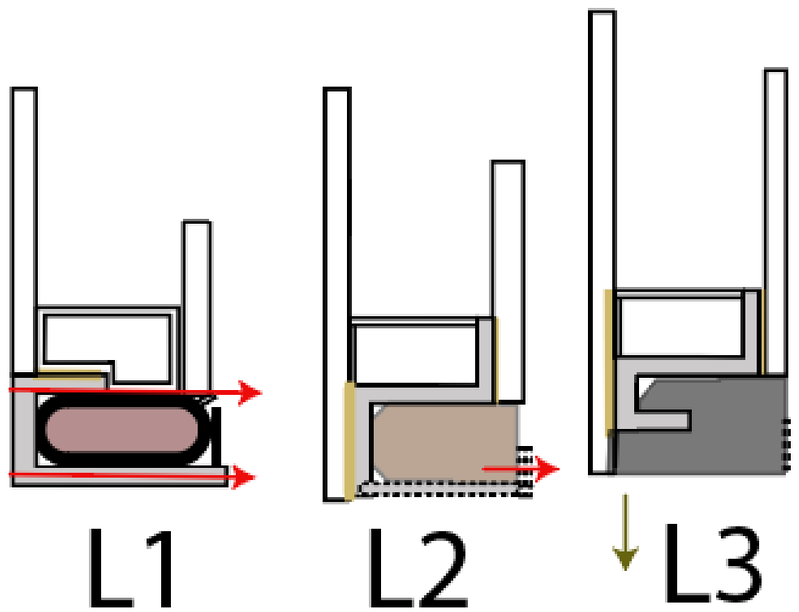


G H I J K

	G	H	I	J	k
Ease of replacement	1	1	0	1	1
Tension on the permanent bonding	-1	1	1	1	-1
transfer of the loads	1	-1	0	1	-1
Seam tightness	0	0	0	0	1
Fabrication	1	0	1	-1	-1
Heat flow	1	1	1	1	1

A

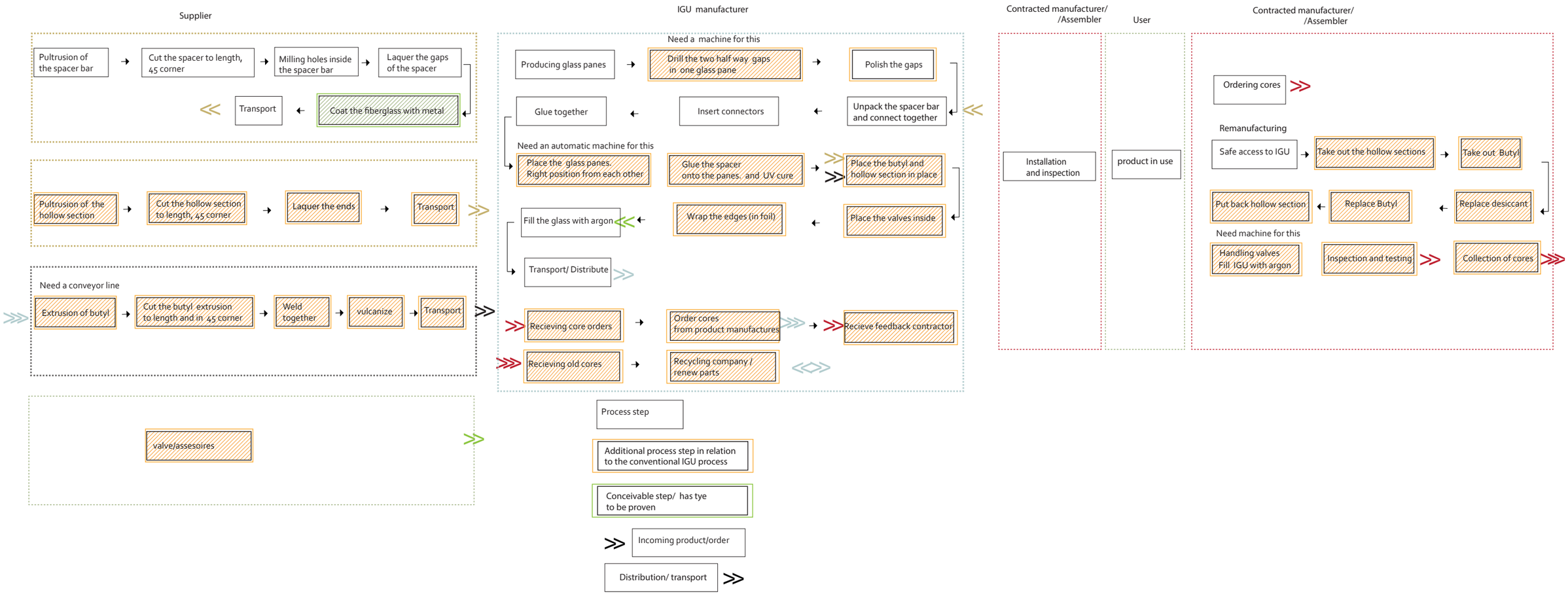
Concept variants



	I1	I2	I3
Ease of replacement	1	1	1
Tension on the permanent bonding	1	1	1
transfer of the loads	-1	1	0
Seam tightness	-1	-1	1
Fabrication	1	1	1
Heat flow	-1	0	1

OEM -	Remanufacturer from its own product. It retrieves ts own products arriving from service centres,trade-ins from retailers or end-of-lease contracts.	The company has and gain all the needed information concerning product design, availability of spare parts and service knowledge. The remanufacturing process could be integrated with the ordinary manufacturing process as the parts from te remanufactured products could be used in manufacturing.
CR-	Remanufacturing Companies that are contracted to remanufacture products on behalf of other companies. This usually means that the OEM owns the products but does not need to perform the actual remanufacturing of them.	Because the OEM still owns their products but have them remanufactured they can offer it to their customer for a lower price. For the remanufacturer the pluspoint is the consistent stream of business with fewer working capital requirements and risks also the company can ask for assistance from the OEM in terms of replacement, parts, design, testing specifications and tooling
IR-	Manufacturing companies with little or no contact with the OEM. Sometimes these companies are payed by the last owner or distributor to pick up discarded products. The typical IR is a private corporation with closely held ownership.	IR need to buy or collect cores for their process and spare parts for their products that are to be remanufactured. Generally, exchange of experience between IR and OEM concerning reprocessing to the proeduct is minimal

A


Supplier
Pultrusion of the spacer bar
Cut the spacer to length, 45 corner
Milling holes inside the spacer bar
Laquer the gaps of the spacer
Transport
Coat the fiberglass with metal
Pultrusion of the hollow section
Cut the hollow section to length, 45 corner
Laquer the ends
Transport
Need a conveyor line
Extrusion of butyl
Cut the butyl extrusion to length and in 45 corner
Weld together
vulcanize
Transport
valve/assesoires
IGU manufacturer
Need a machine for this
Producing glass panes
Drill the two half way gaps in one glass pane
Polish the gaps
Glue together
Insert connectors
Unpack the spacer bar and connect together
Need an automatic machine for this
Place the glass panes. Right position from each other
Glue the spacer onto the panes. and UV cure
Place the butyl and hollow section in place
Fill the glass with argon
Wrap the edges (in foil)
Place the valves inside
Transport/ Distribute
Recieving core orders
Order cores from product manufactures
Recieve feedback contractor
Recieving old cores
Recycling company / renew parts
Contracted manufacturer/ /Assembler
Installation and inspection
User
product in use
Contracted manufacturer/ /Assembler
Ordering cores
Remanufacturing
Safe access to IGU
Take out the hollow sections
Take out Butyl
Put back hollow section
Replace Butyl
Replace desiccant
Need machine for this
Handling valves Fill IGU with argon
Inspection and testing
Collection of cores
Process step
Additional process step in relation to the conventional IGU process
Conceivable step/ has tye to be proven
Incoming product/order
Distribution/ transport

A

Supplier

Pultrusion of the spacer bar → Cut the spacer to length, 45 corner → Milling holes inside the spacer bar → Laquer the gaps of the spacer → Coat the fiberglass with metal → Transport

Pultrusion of the hollow section → Cut the hollow section to length, 45 corner → Laquer the ends → Transport

Need a conveyor line

Extrusion of butyl → Cut the butyl extrusion to length and in 45 corner → Weld together → vulcanize → Transport

valve/assesoires

IGU manufacturer

Need a machine for this

Producing glass panes → Drill the two half way gaps in one glass pane → Polish the gaps → Unpack the spacer bar and connect together → Insert connectors → Glue together

Need an automatic machine for this

Place the glass panes. Right position from each other → Glue the spacer onto the panes. and UV cure → Place the butyl and hollow section in place → Place the valves inside → Wrap the edges (in foil) → Fill the glass with argon → Transport/ Distribute

Recieving core orders → Order cores from product manufactures → Recieve feedback contractor

Recieving old cores → Recycling company / renew parts

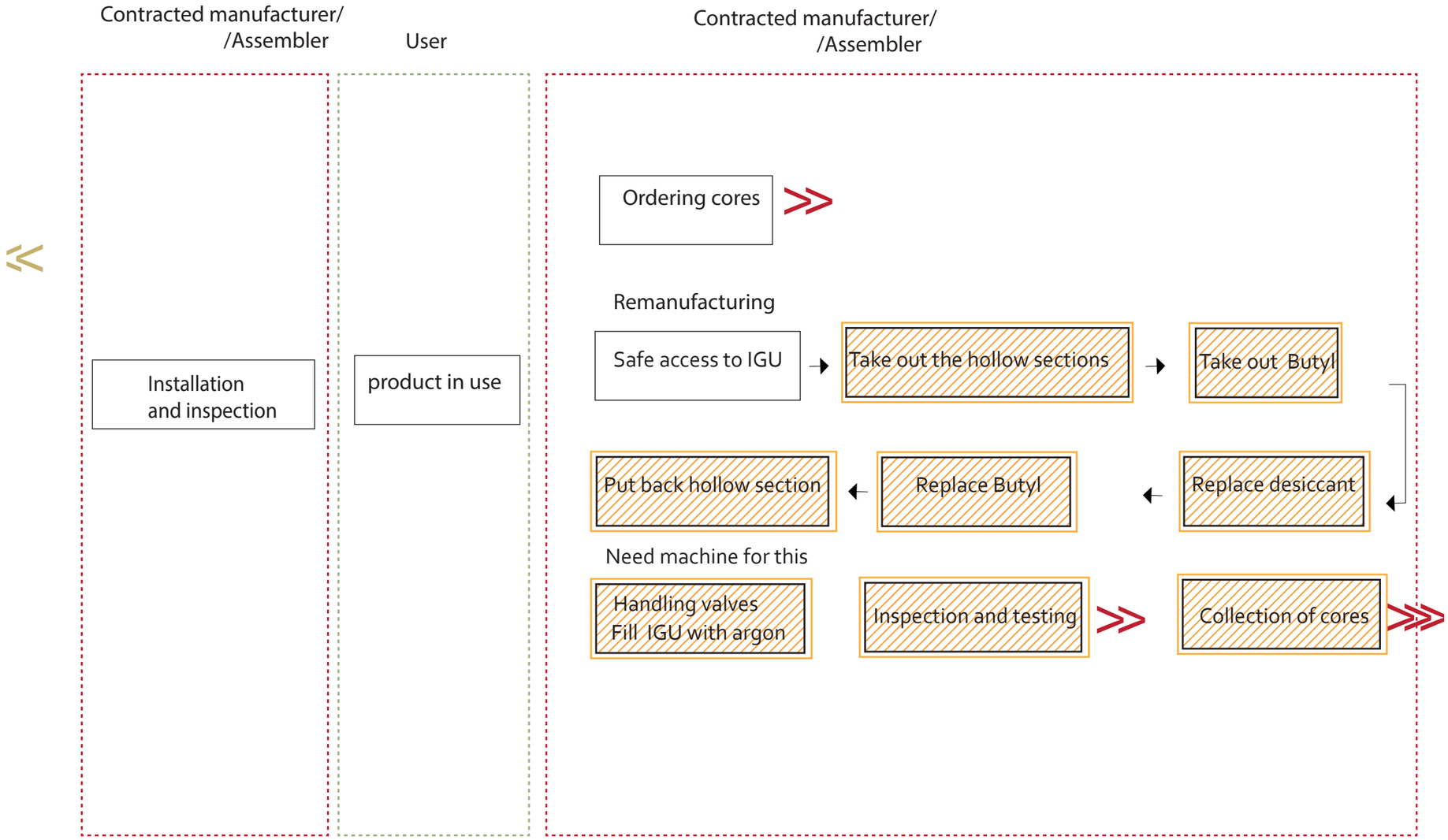
Process step

Additional process step in relation to the conventional IGU process

Conceivable step/ has tye to be proven

Incoming product/order

Distribution/ transport


Contracted manufacturer/
/Assembler
User
Contracted manufacturer/
/Assembler
Installation
and inspection
product in use
Ordering cores
Remanufacturing
Safe access to IGU
Take out the hollow sections
Take out Butyl
Replace desiccant
Replace Butyl
Put back hollow section
Need machine for this
Handling valves
Fill IGU with argon
Inspection and testing
Collection of cores