DESIGNING ON THE EDGE

A DESIGN STUDY OF THE EDGE SEAL COMPONENT TO EXTEND THE SERVICE LIFE AND IMPROVE CIRCULARITY OF INSULATING GLASS UNITS

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A4

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MSc Building Technology

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TU Delft

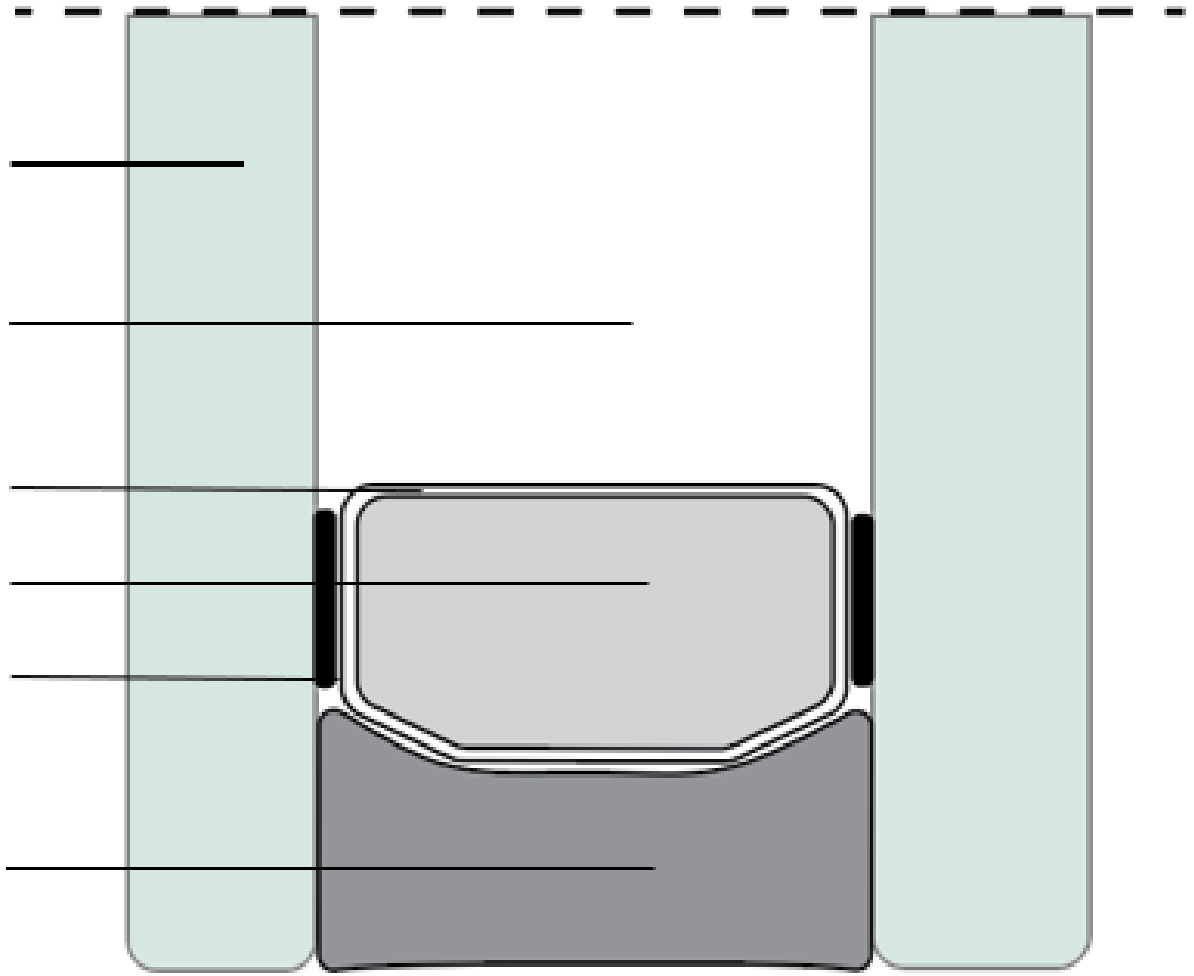
INSULATING GLASS

INSULATION GLASS UNIT (IGU)

https://www.guardianglass.com/eu/en/our-glass/glass-types/vacuum-insulated-glass

Insulation glass unit (IGU)

- Float glass
- Cavity
- Spacer
- Desiccant
- Primary sealant
- Secondary Sealant



DESIGN PROBLEM

GLASS = DURABLE & CIRCULAR
PREMATURE END-OF-LIFE
SERVICE LIFE 20-30 YEARS

Faidra Oikonomopoulou

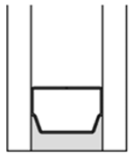
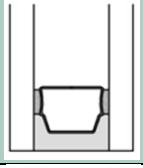
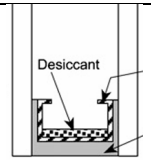
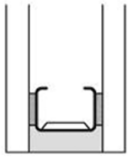
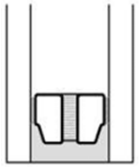
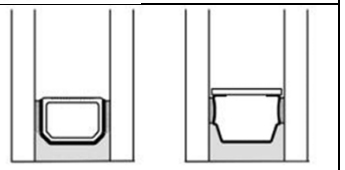
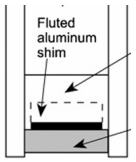
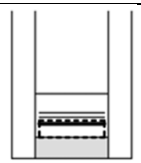
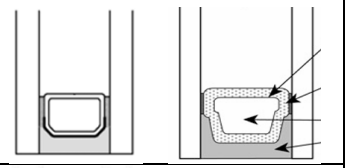
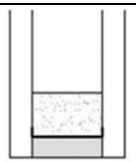
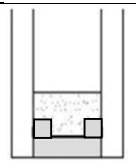
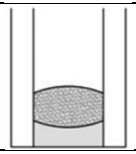
DESIGN PROBLEM

ADHESIVES
DIFFICULT DISASSEMBLY
CONTAMINATION

EXISTING ALTERNATIVES

Improved

Thermal performance

Standard	Single sealed 	Dual sealed 
Improved	Single sealed 	Dual sealed 
		Dual sealed 
		Dual sealed 
Composites	Single sealed 	Dual sealed 
		Dual sealed 
Foam	Normal shaped 	T-shaped 
Thermoplastic		Dual sealed 

RESEARCH GAP

REDESIGN IGU
IMPROVE DURABLE & ENABLE CIRCULAR

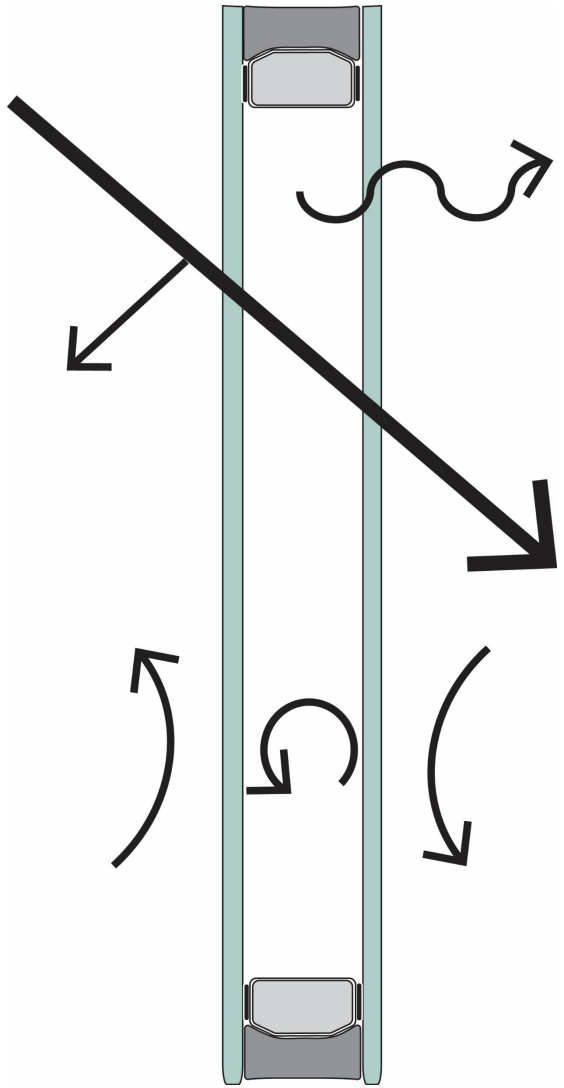
https://www.recovery-worldwide.com/en/artikel/glass-recycling-current-market-trends-3248774.html

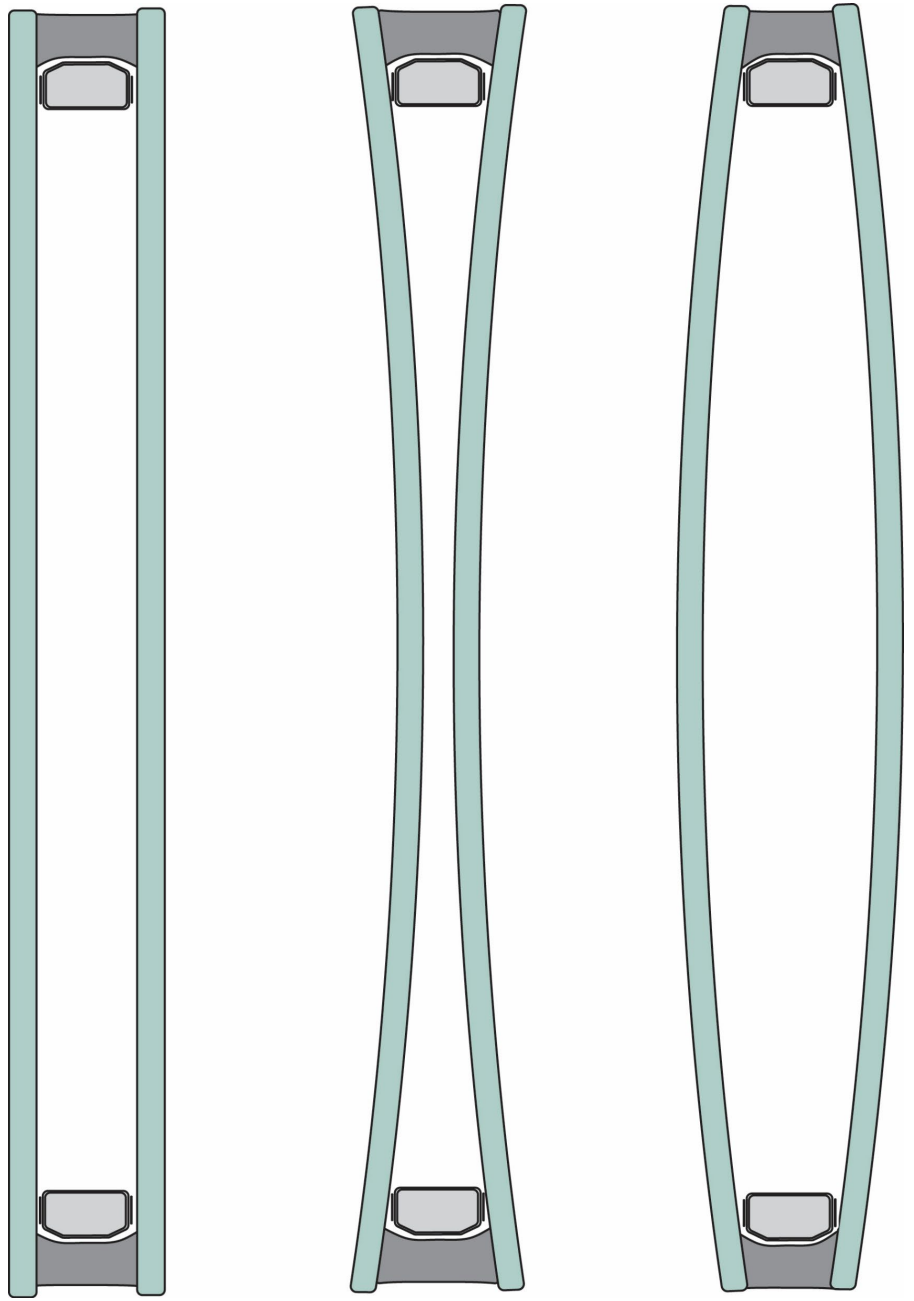
RESEARCH QUESTION

*How can **insulated glass units (IGUs)** be redesigned through material innovation and research-informed design to **enhance durability** and **enable circularity**, while maintaining the required performance of IGUs and ensuring compatibility with standard façade systems?*


HYBRID CONNECTION
THERMALLY DEBONDABLE ADHESIVE
FUSED GLASS

REQUIREMENTS





DESIGN CRITERIA

Material

Low thermal conductivity

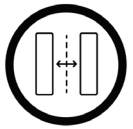
High tensile strength

Low water vapour permeability

Low gas permeability

Component

High thermal insulation



No thermal bridges

Mechanical stability

Allow movement

High environmental resistance

Water and air tight

Circular

No contamination

Demountable

Durable

Small scale

DESIGN CRITERIA

Thermal

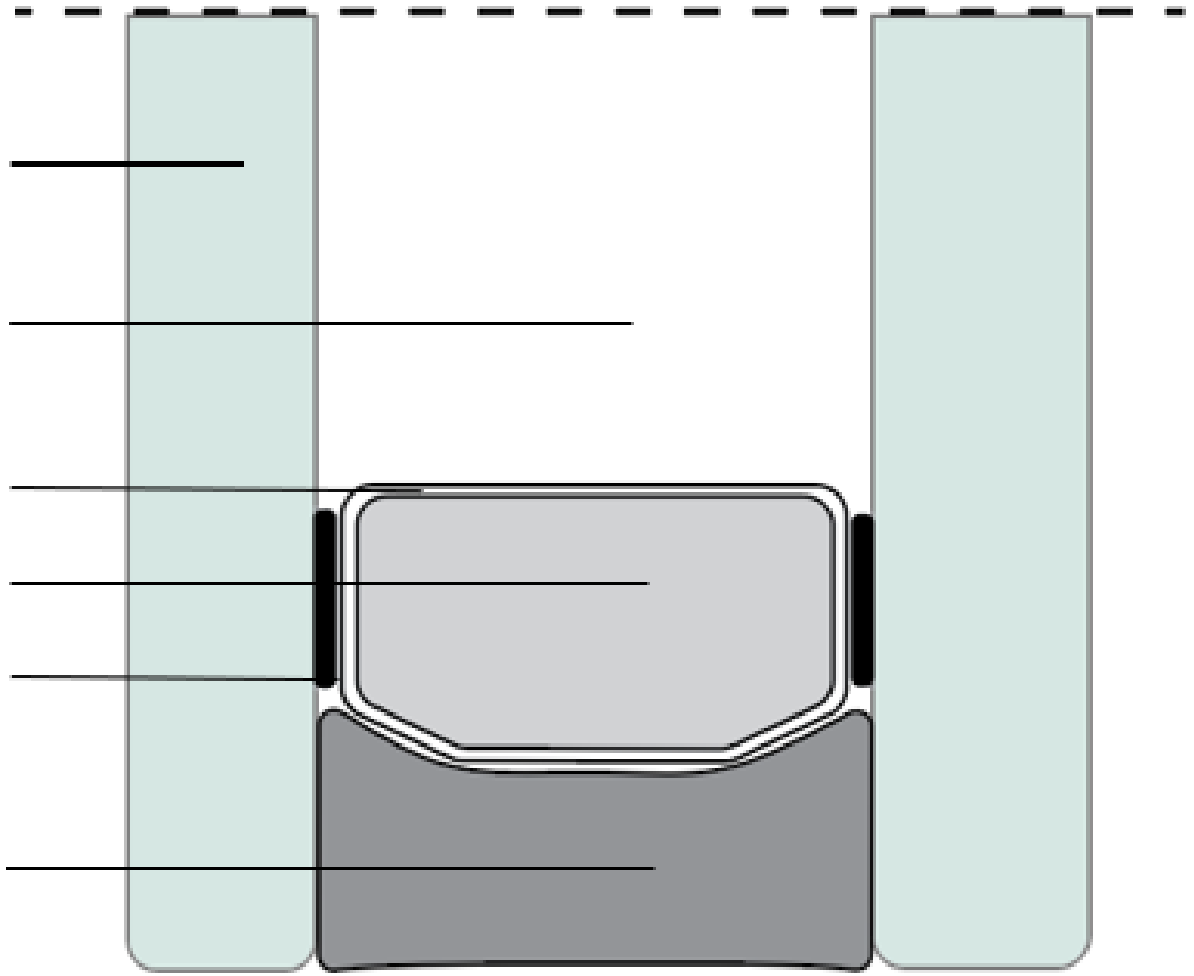
Mechanical

Durability

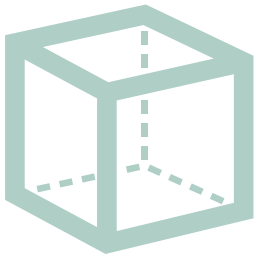
Circularity

Insulation glass unit (IGU)

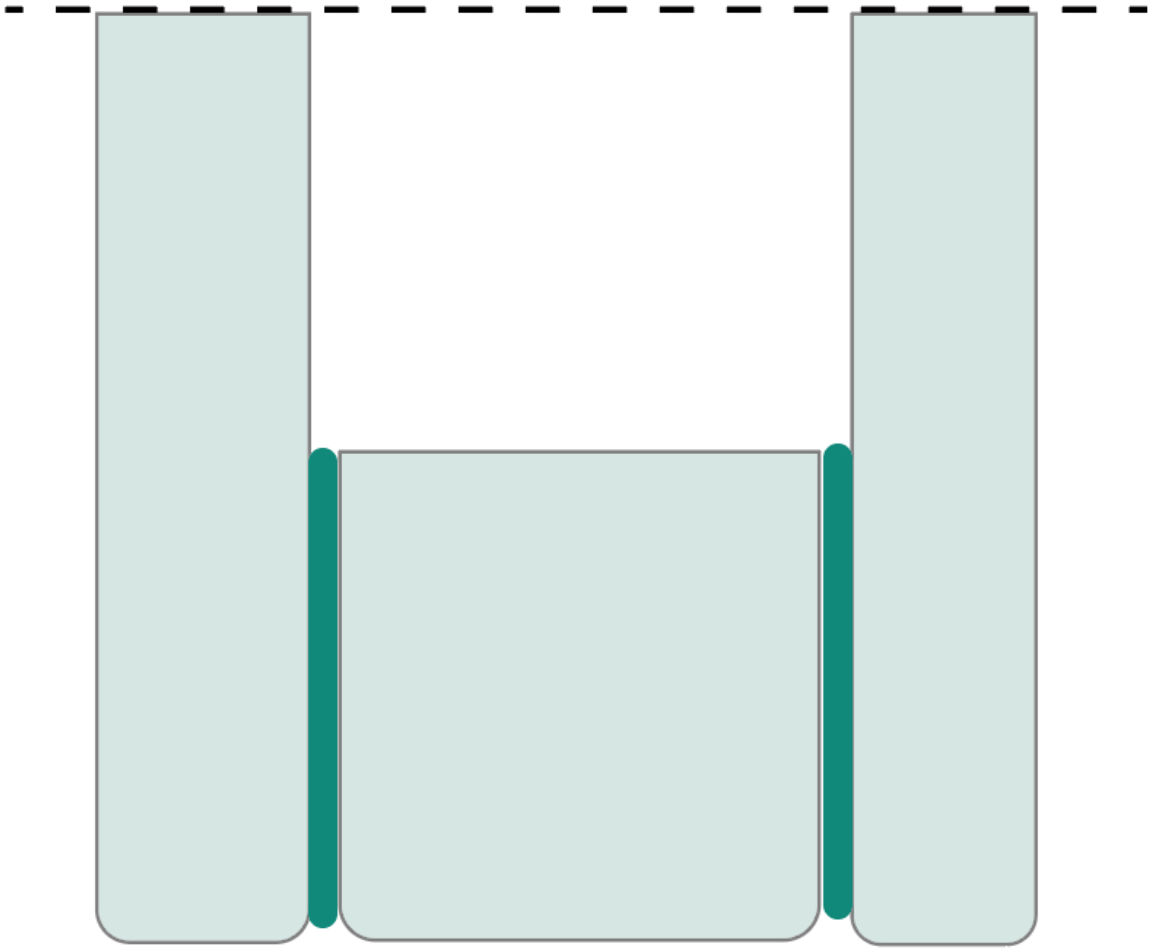
- Float glass
- Cavity
- Spacer
- Desiccant
- Primary sealant
- Secondary Sealant

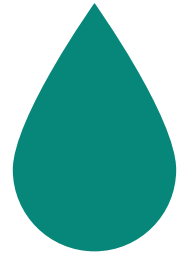


Insulation glass unit (IGU)



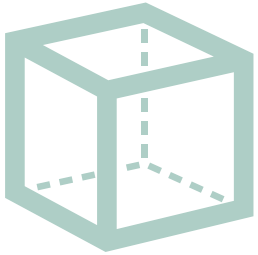
Spacer





Sealant

Insulation glass unit (IGU)



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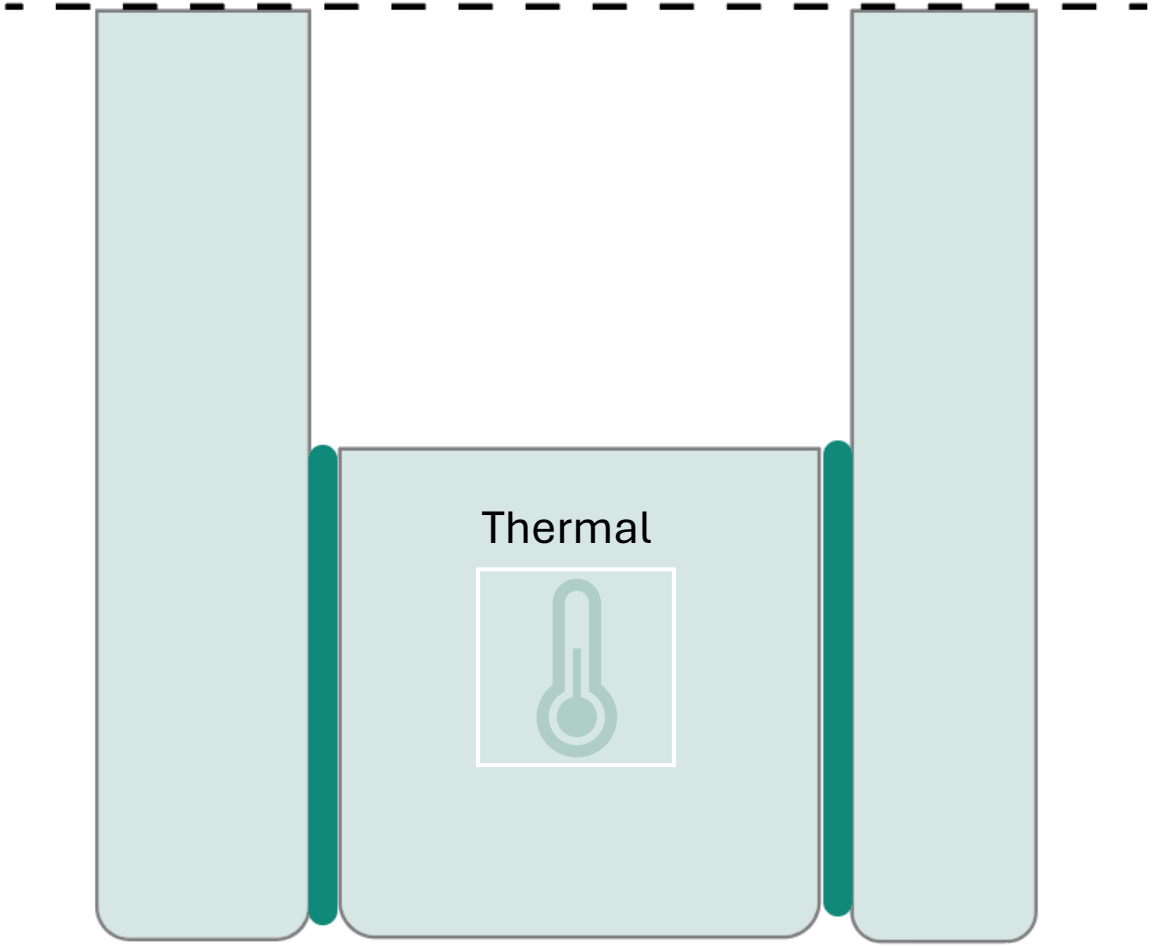
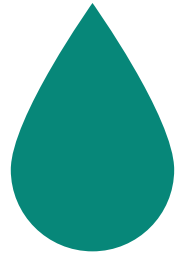
Low thermal conductivity

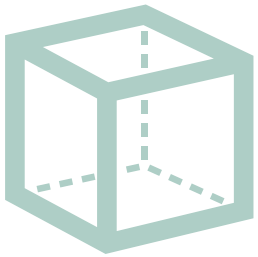




Sealant

Low thermal conductivity

Insulation glass unit (IGU)

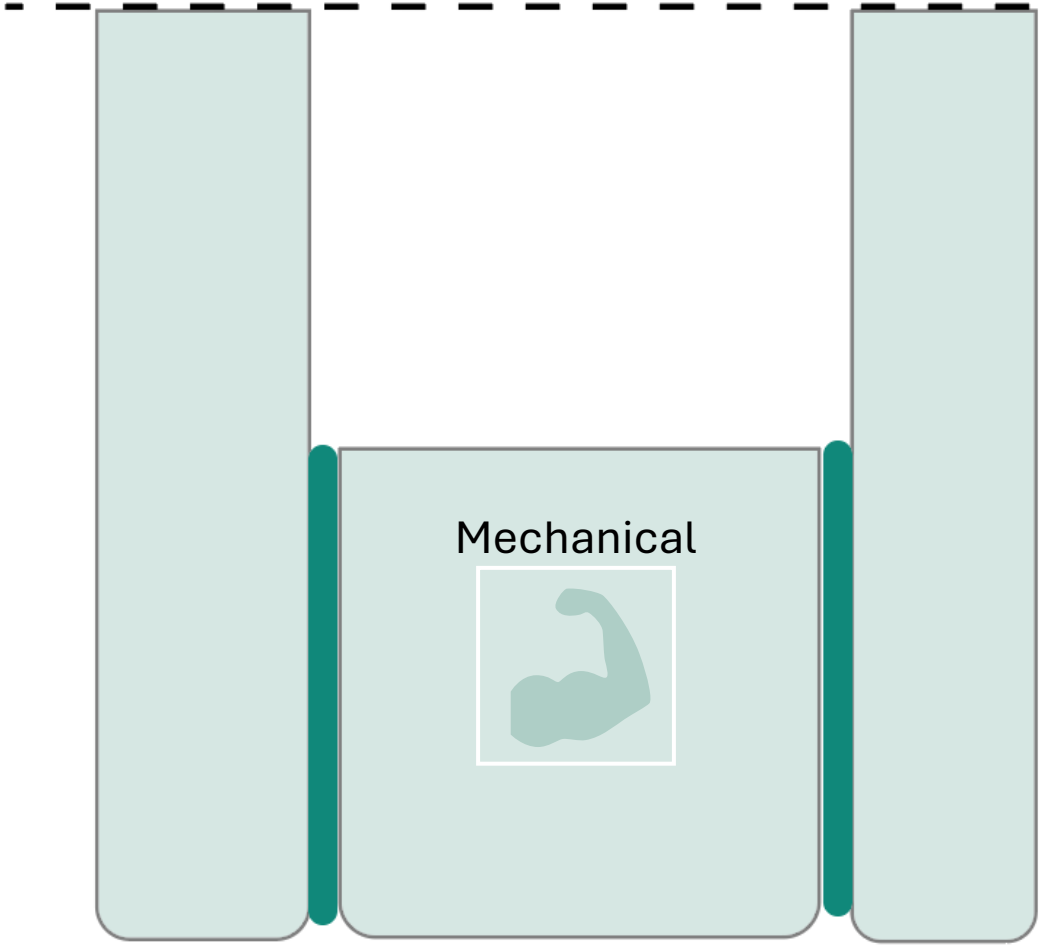


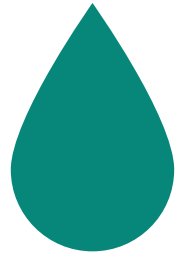
Spacer

Low thermal conductivity

Rigid

High compressive strength





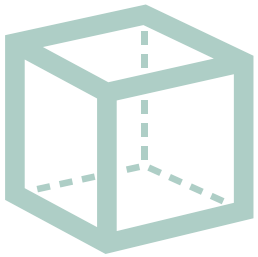
Sealant

Low thermal conductivity

Flexible

High tensile strength

Insulation glass unit (IGU)



Spacer

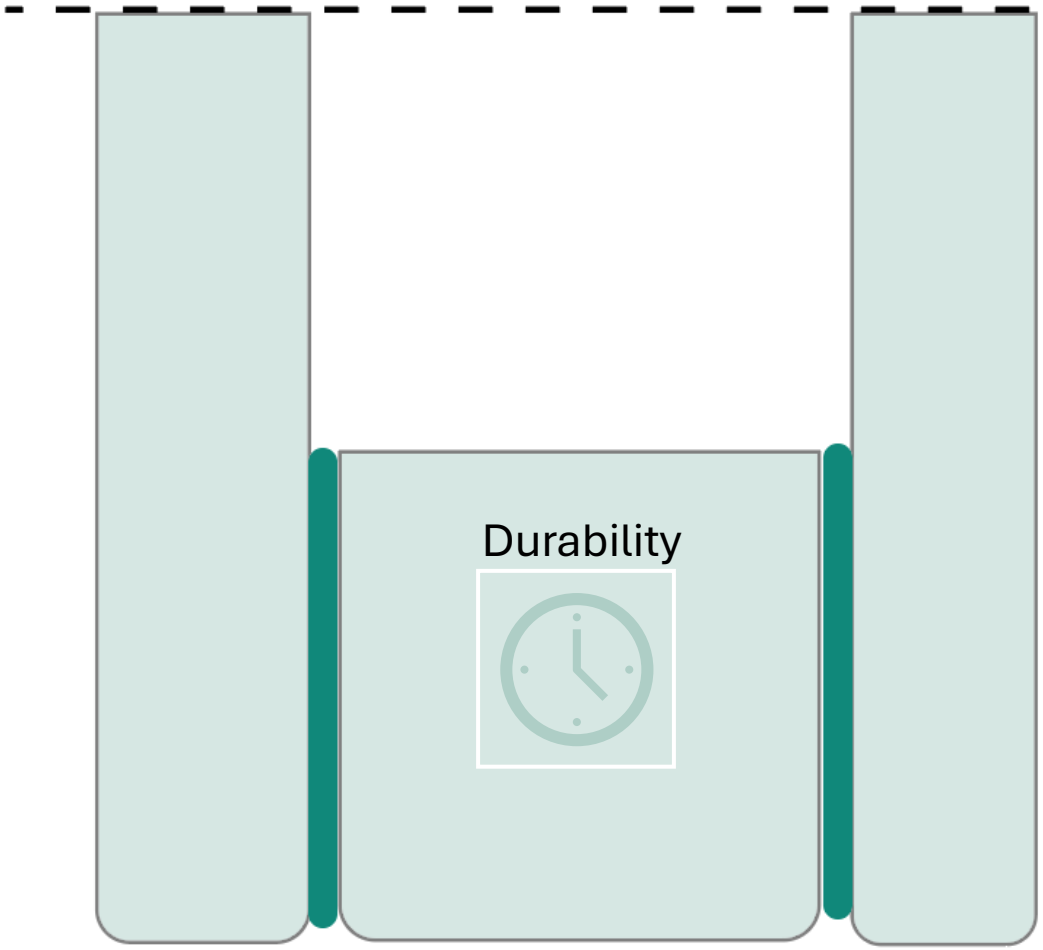
Low thermal conductivity

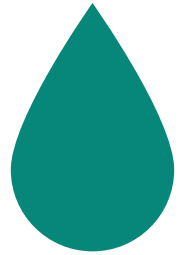
Rigid

High compressive strength

UV-resistant

Water and airtight





Sealant

Low thermal conductivity

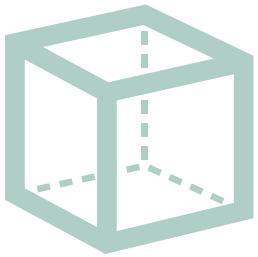
Flexible

High tensile strength

UV-resistant

Water and airtight

Insulation glass unit (IGU)



Spacer

Low thermal conductivity

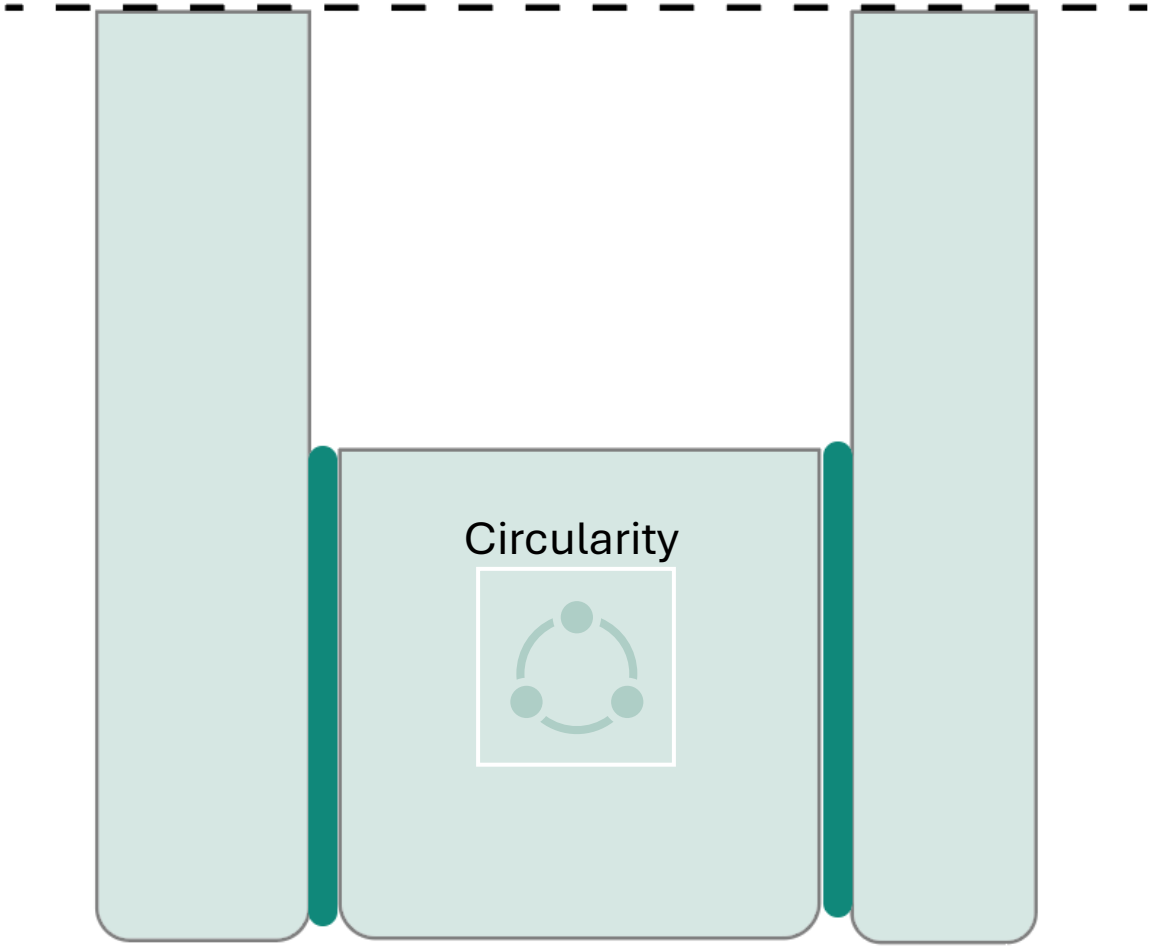
Rigid

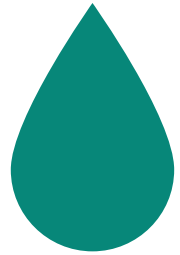
High compressive strength

UV-resistant

Water and airtight

Easily recyclable





Sealant

Low thermal conductivity

Flexible

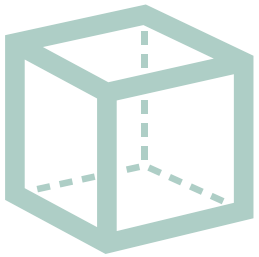
High tensile strength

UV-resistant

Water and airtight

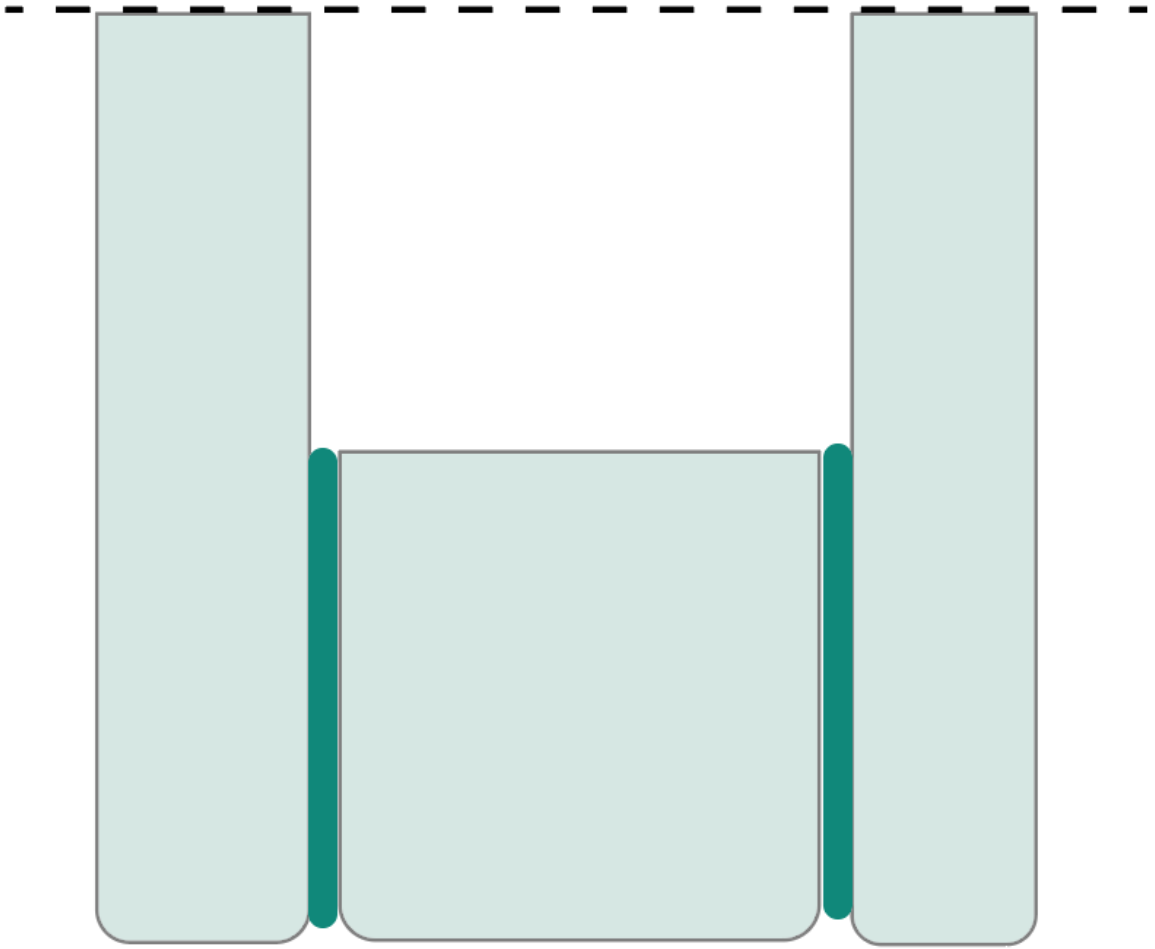
Demountable

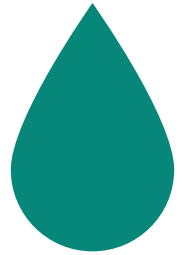
Insulation glass unit (IGU)



Spacer

Glass





Sealant

Plexiglas

PETG

PEEK

Silicone

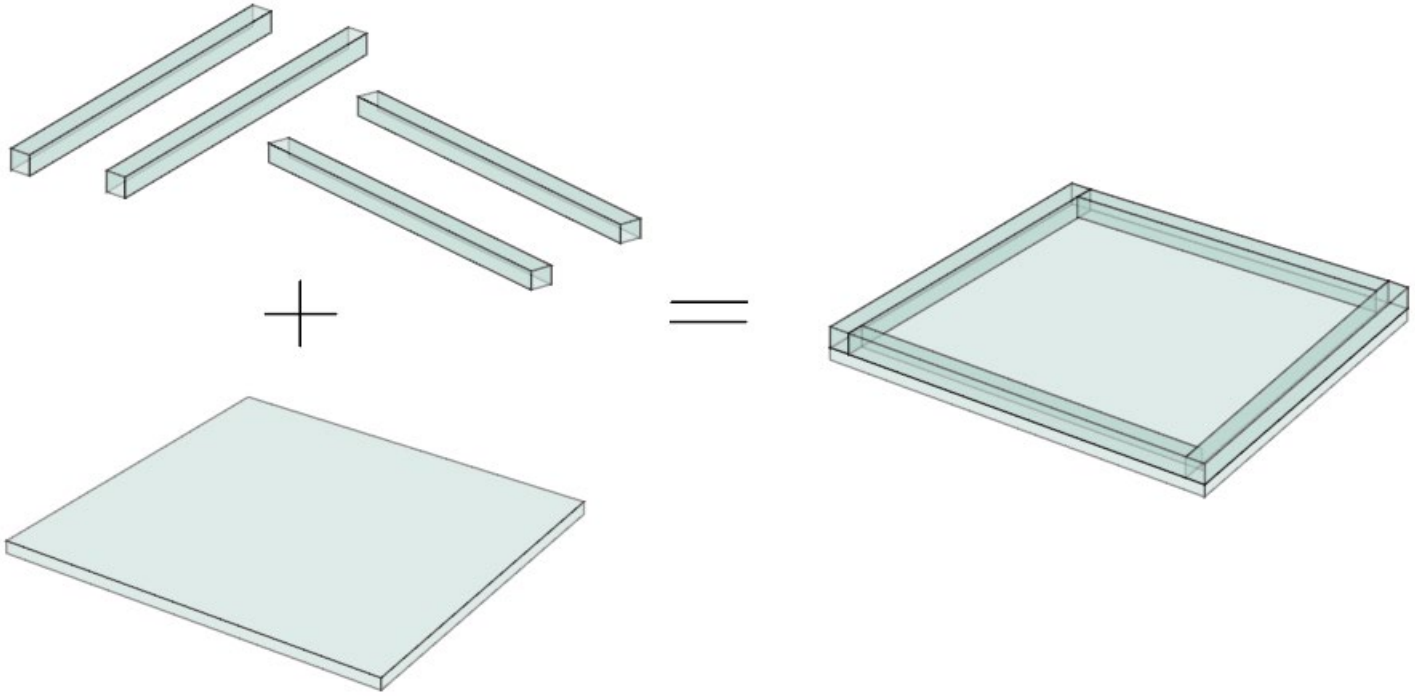

HYBRID CONNECTION
THERMALLY DEBONDABLE ADHESIVE
FUSED GLASS

HYBRID CONNECTION

FUSED GLASS

GLASS FUSION

- ✓ No adhesives
- ✓ Mono-material
- ✓ Durable
- ✓ UV-resistant
- ✓ Easier recycling



GLASS FUSION

Goal

Tack fuse

Firing schedule

Fusing temperature

Ramp

Hold

Compatibility

Chemical formula

Thermal expansion

Thickness

Defects

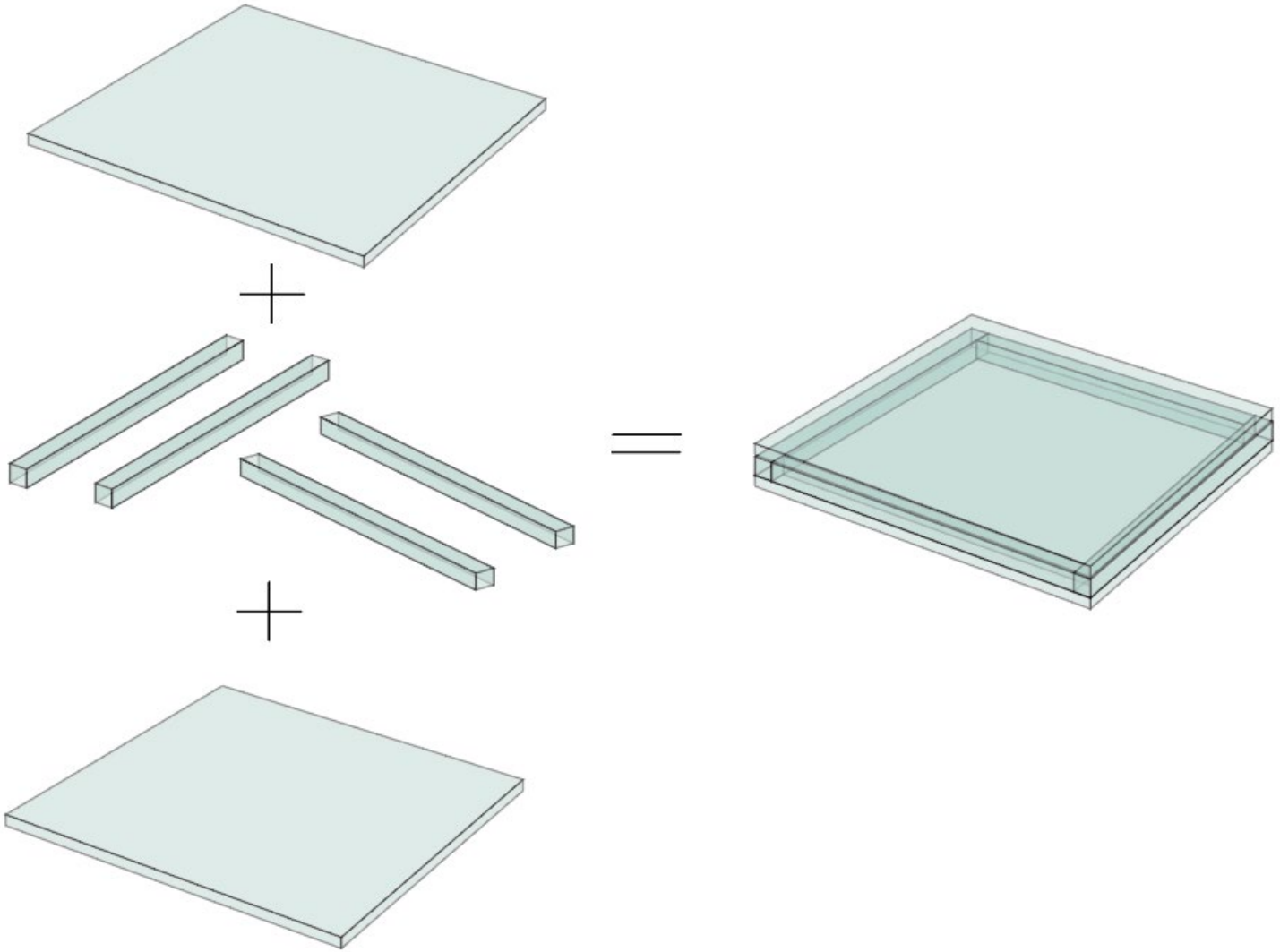
Devitrification

Slumping

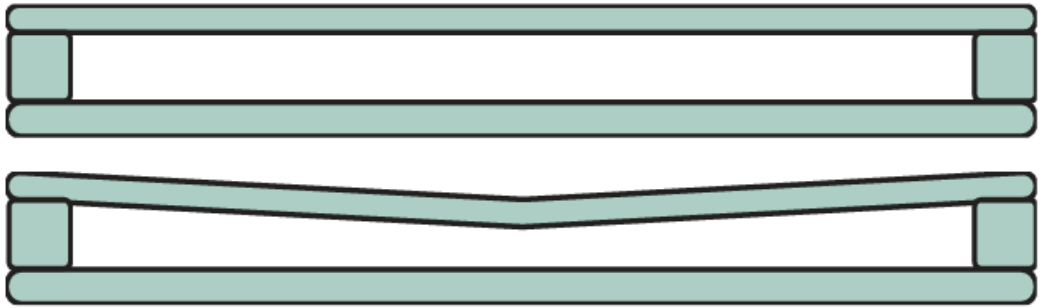
Thermal shock

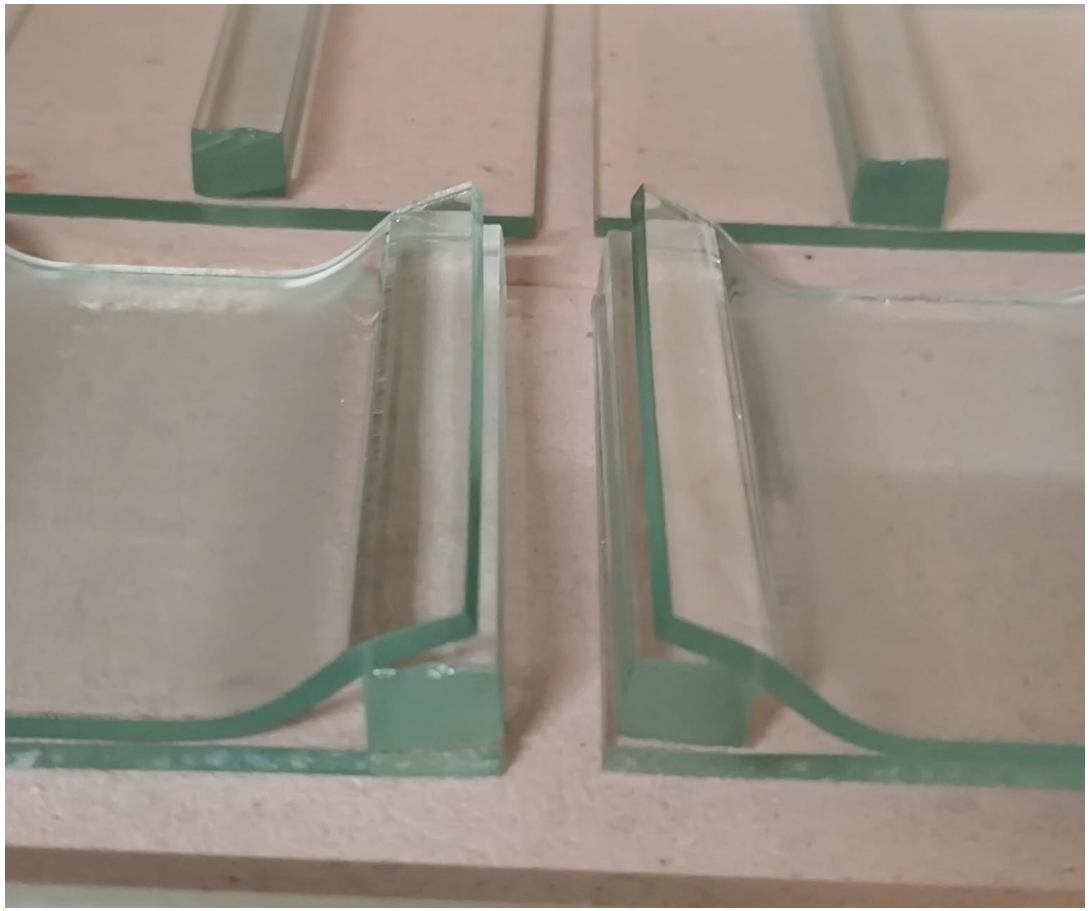
GLASS FUSION

- ✓ No adhesives
- ✓ Durable
- ✓ UV-resistant
- ✓ Mono-material
- ✓ Easier recycling



SLUMPING



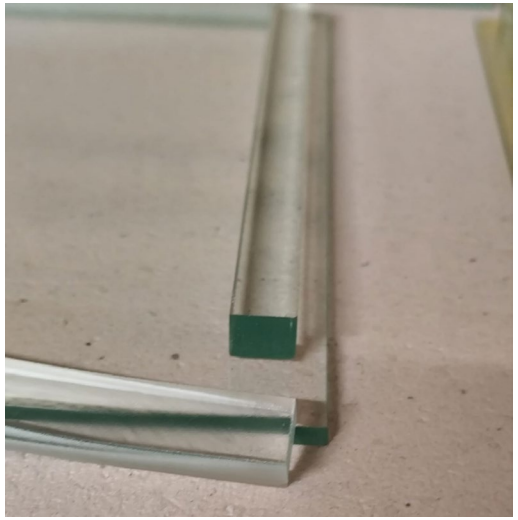


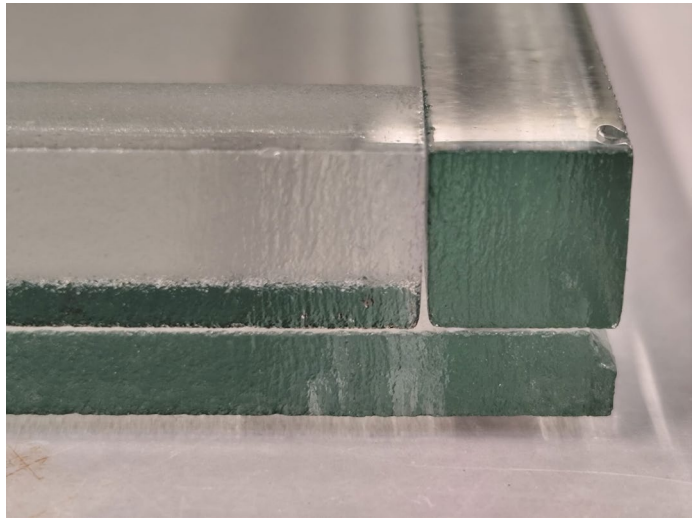
FUSED GLASS SPACER

Deformation

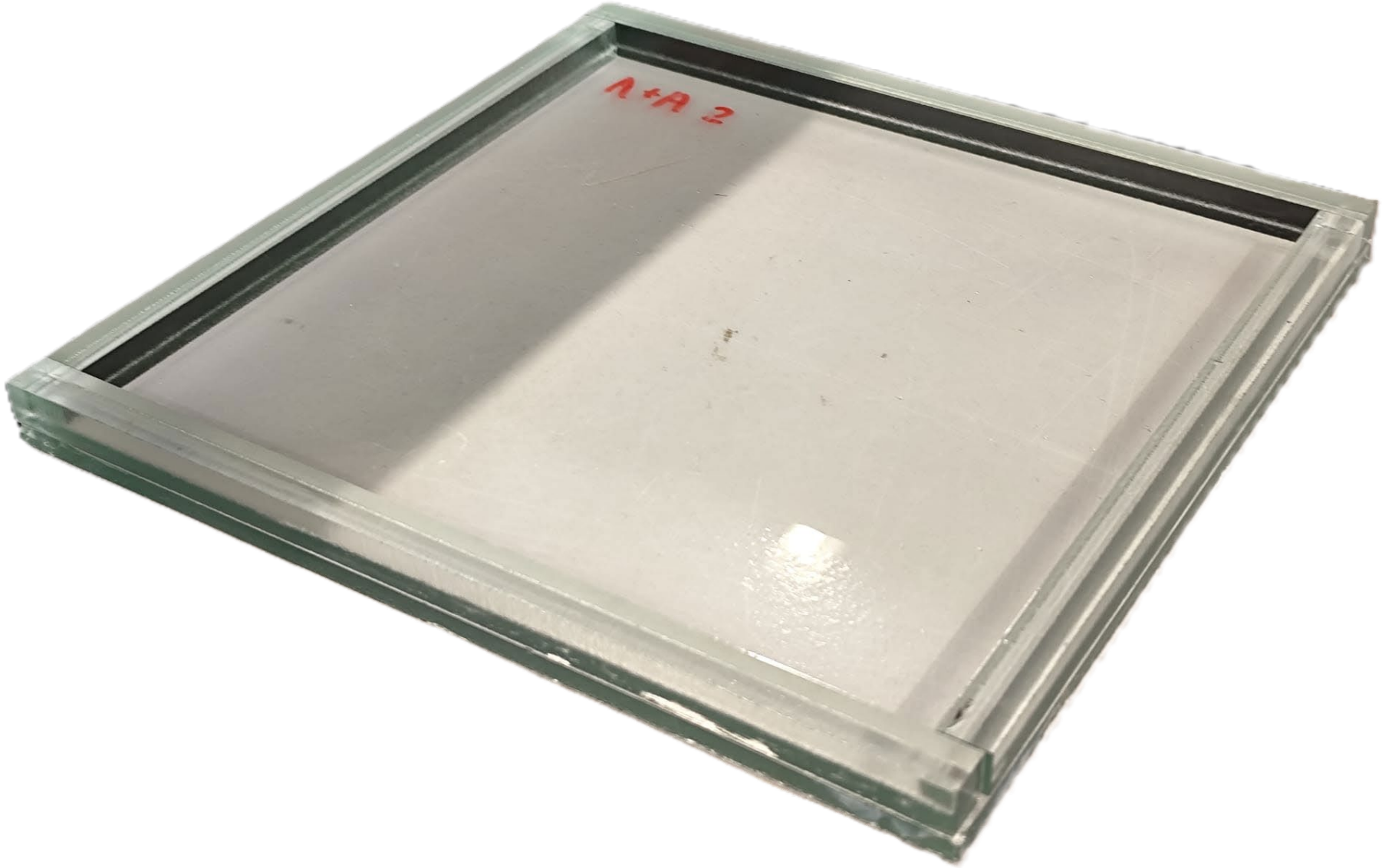
Fuse quality

Surface quality





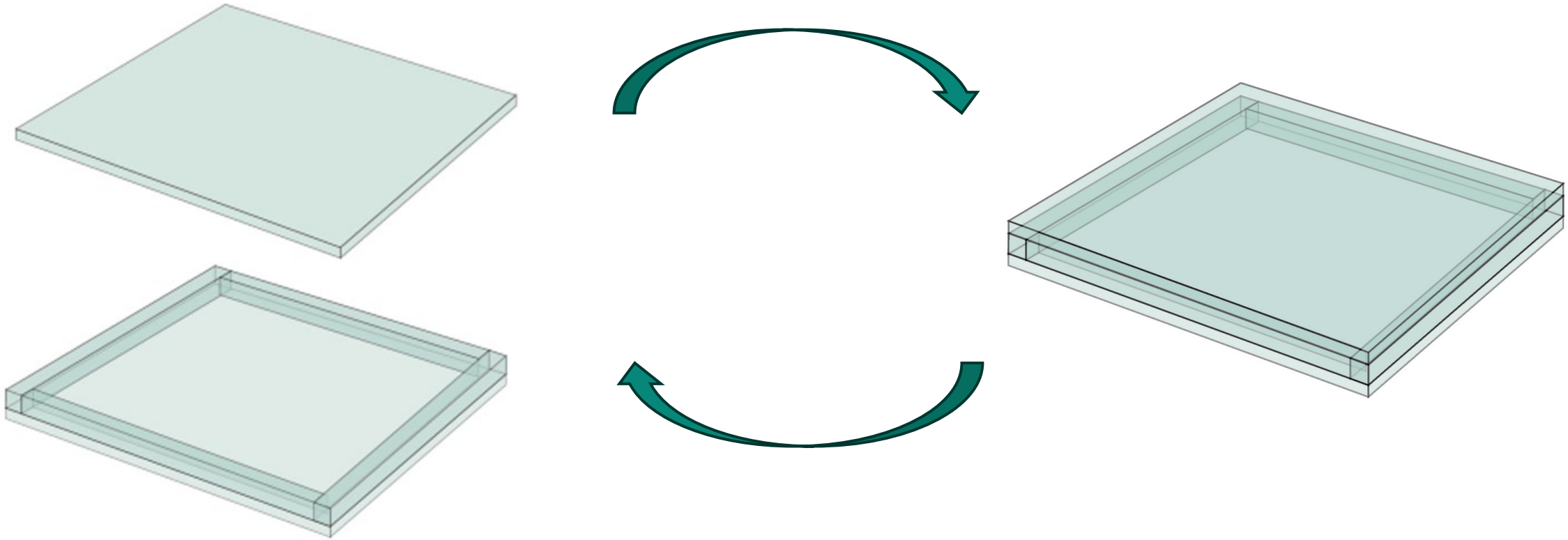
FUSED GLASS SPACER



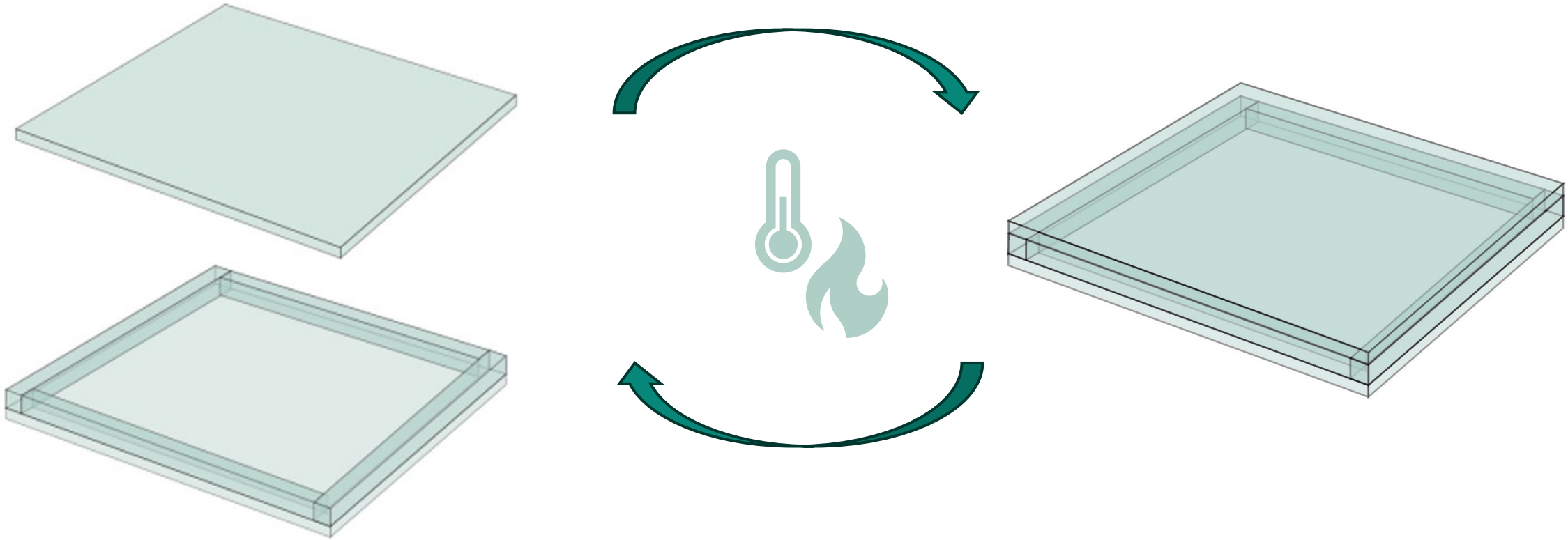
HYBRID CONNECTION

THERMALLY DEBONDABLE ADHESIVE

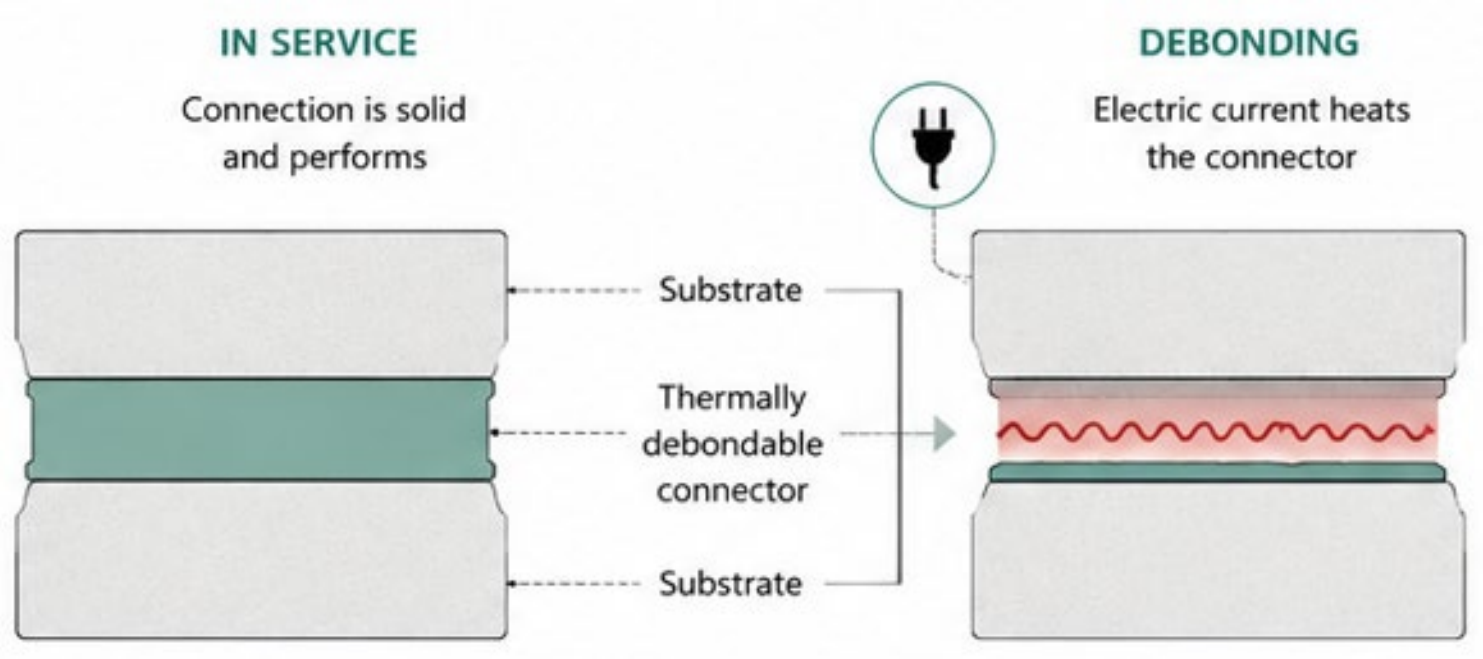
BONDING AND DEBONDING



THERMAL TRIGGER



EMBEDDED HEATING ELEMENT



THERMALLY DEBONDING

Heating element

Controlled heating

Embedded

Adhesive

Compatible

Adhesive strength

Thermally deformable

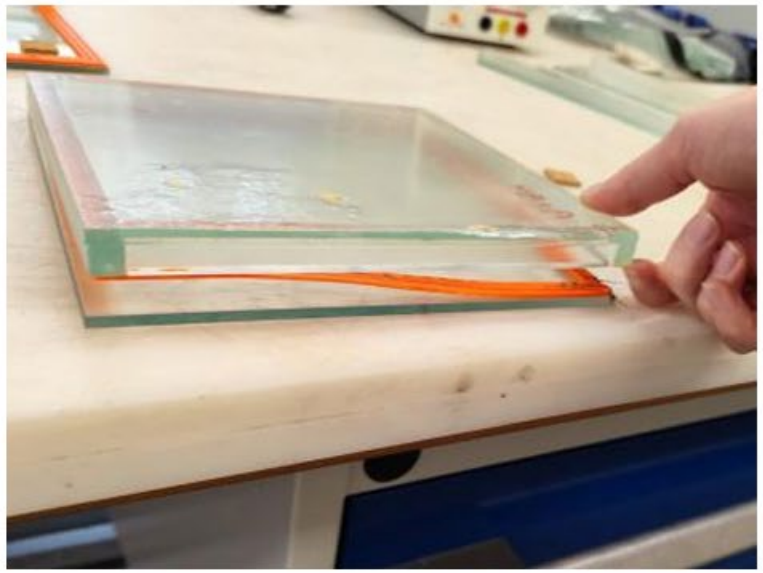
THERMALLY DEBONDING

Controlled heating

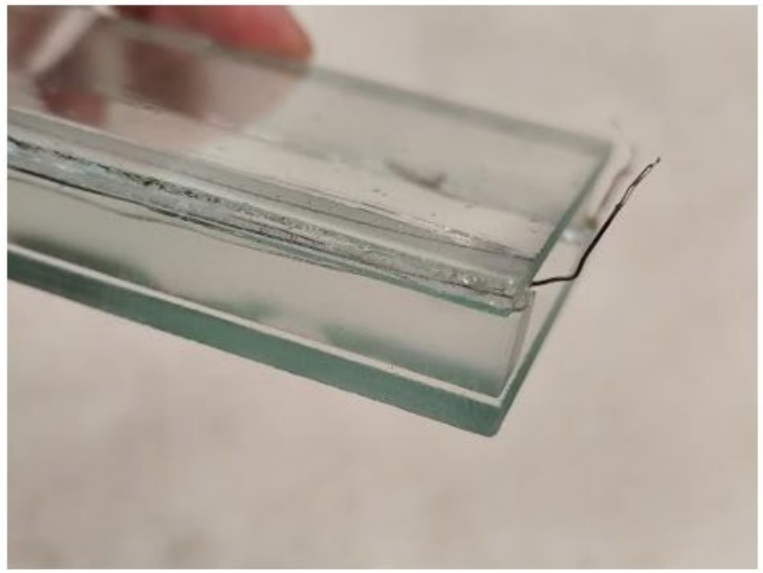
Integrated in facade

MATERIAL SELECTION

PMMA



3D printed PETG



PETG

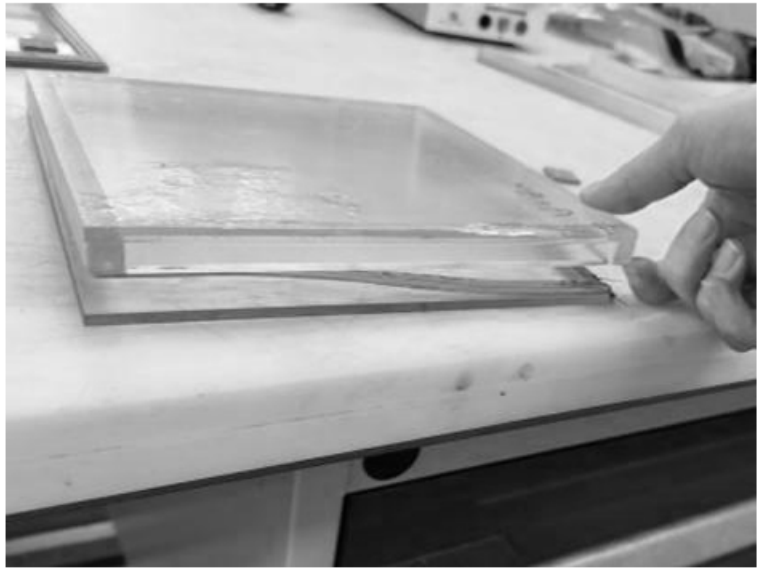
Thermally deformable

Compatible

Adhesive

MATERIAL SELECTION

PMMA



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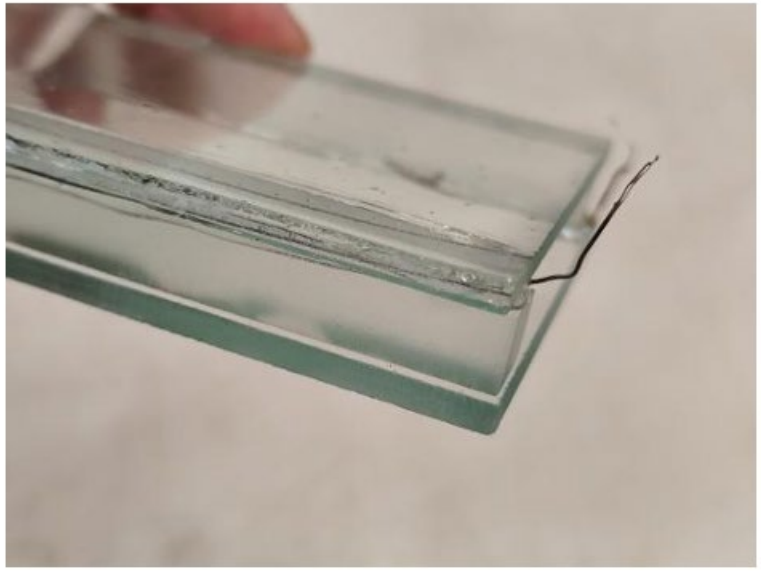


PETG

Thermally deformable

Compatible

Adhesive

LIMITATIONS

Thermal shock

- Hot edges
- Cold middle
- Crack formation

LIMITATIONS

Thermal shock

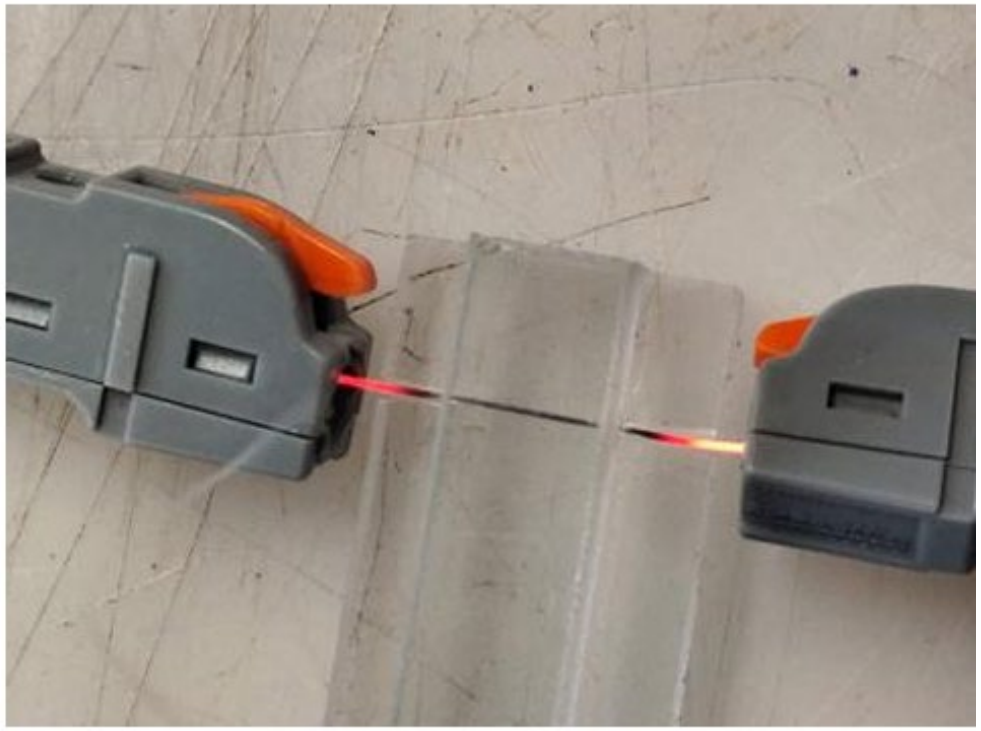
Deformation

- Oven samples
- Moderated heating and cooling
- Melting

LIMITATIONS

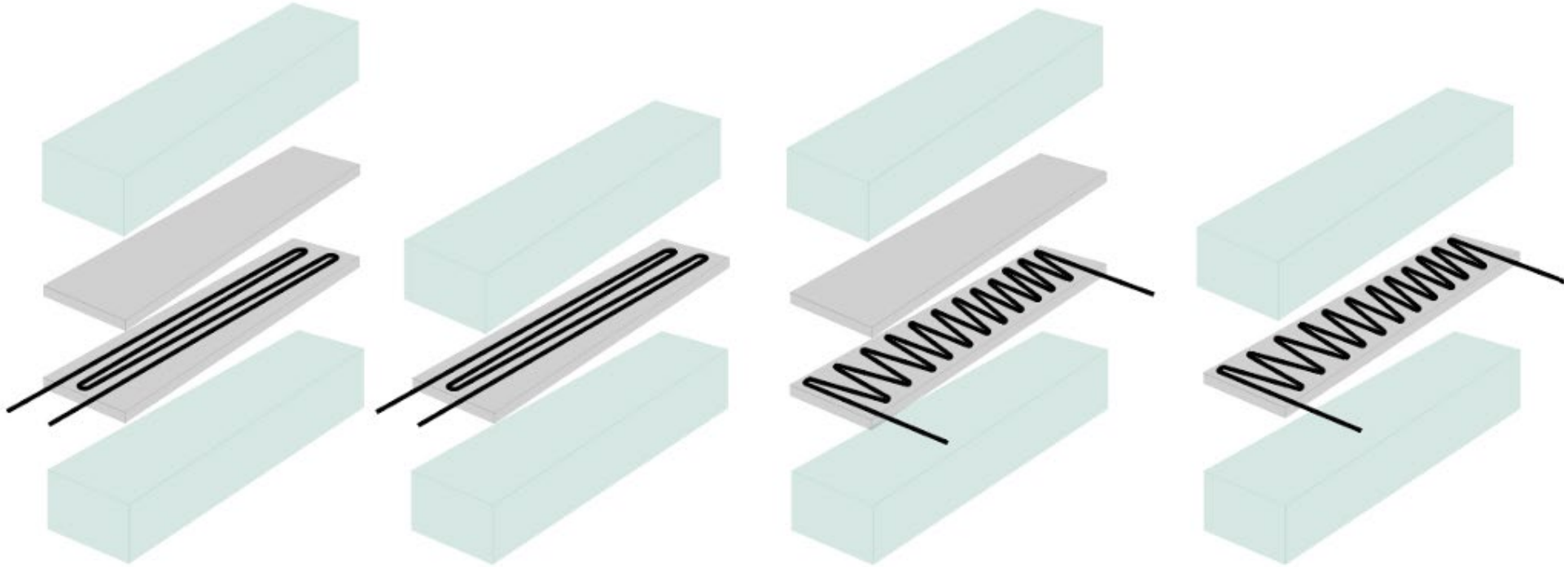
Thermal shock

Deformation

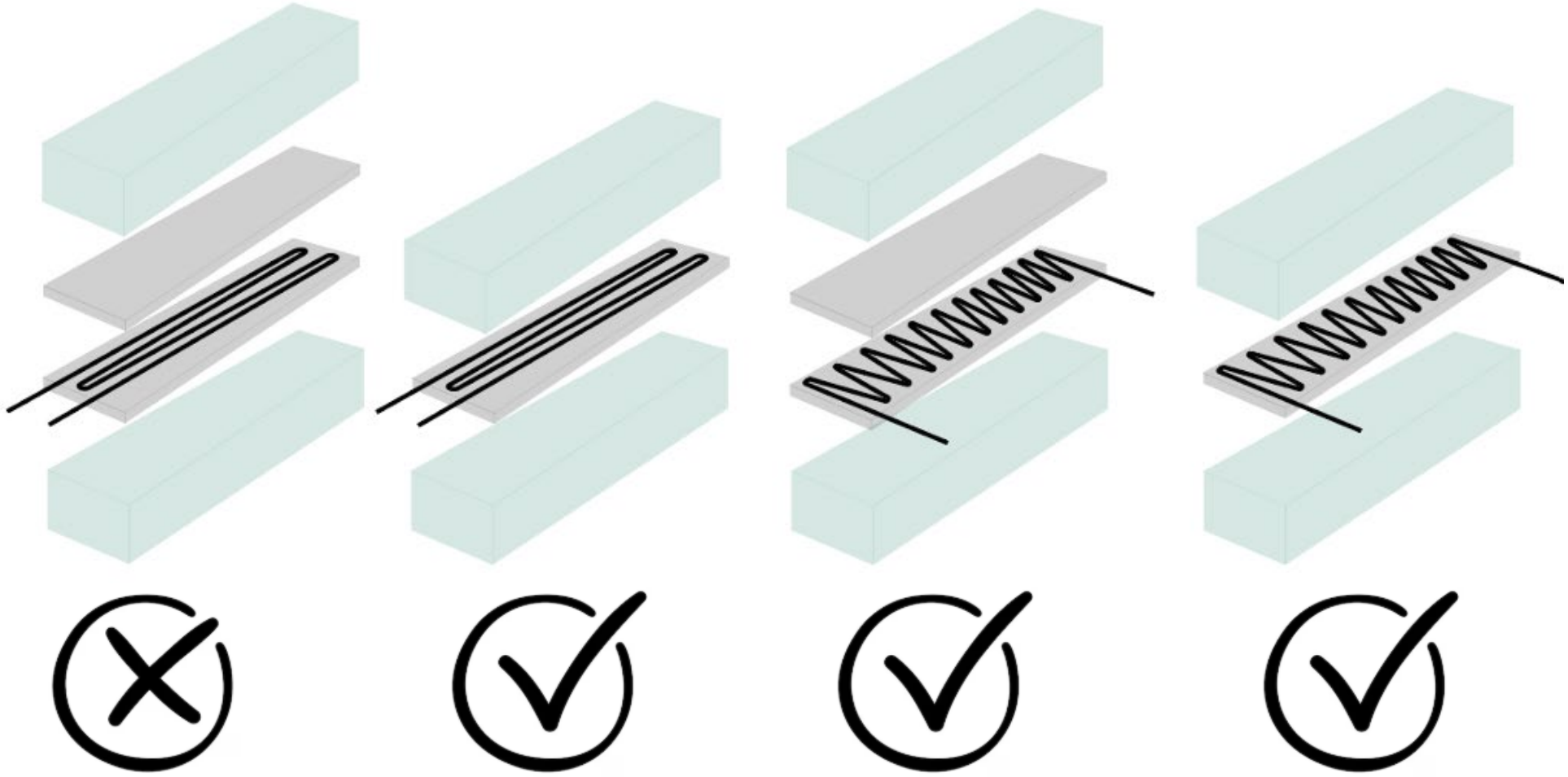


Melting of electrical connector

FINAL ITERATIONS



FINAL ITERATIONS




HYBRID CONNECTION
THERMALLY DEBONDABLE ADHESIVE
FUSED GLASS

DESIGN CRITERIA

Thermal

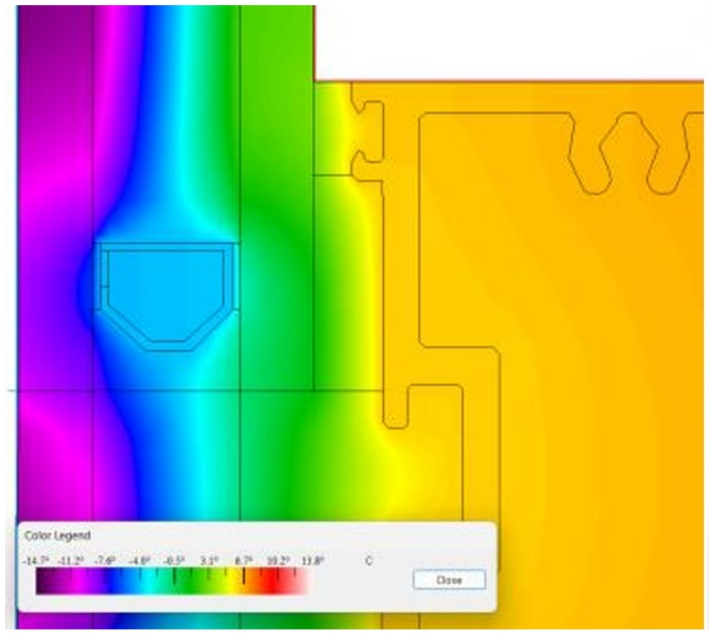
Mechanical

Durable

Circular

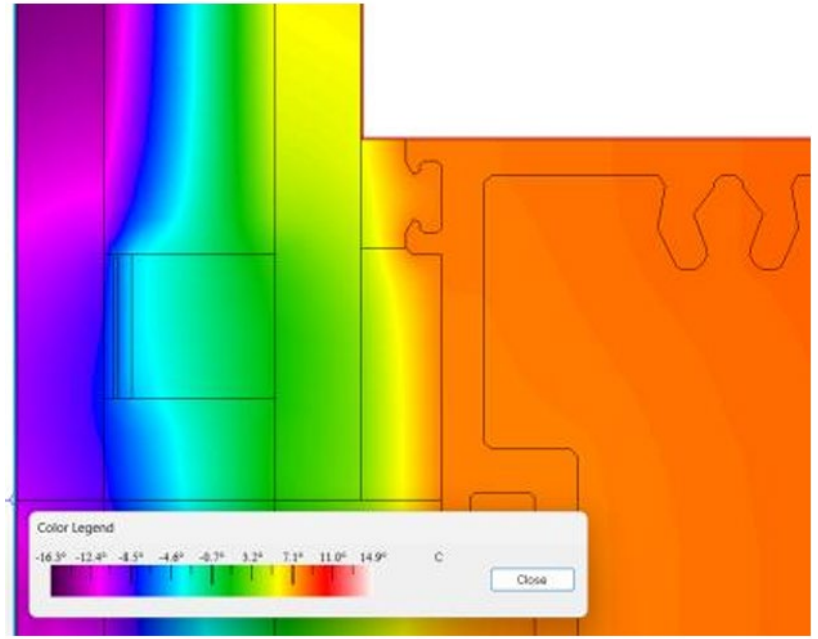
THERMAL PERFORMANCE

U-value glass = 2.55 W/m2K



U-value system = 4.44 W/m2K

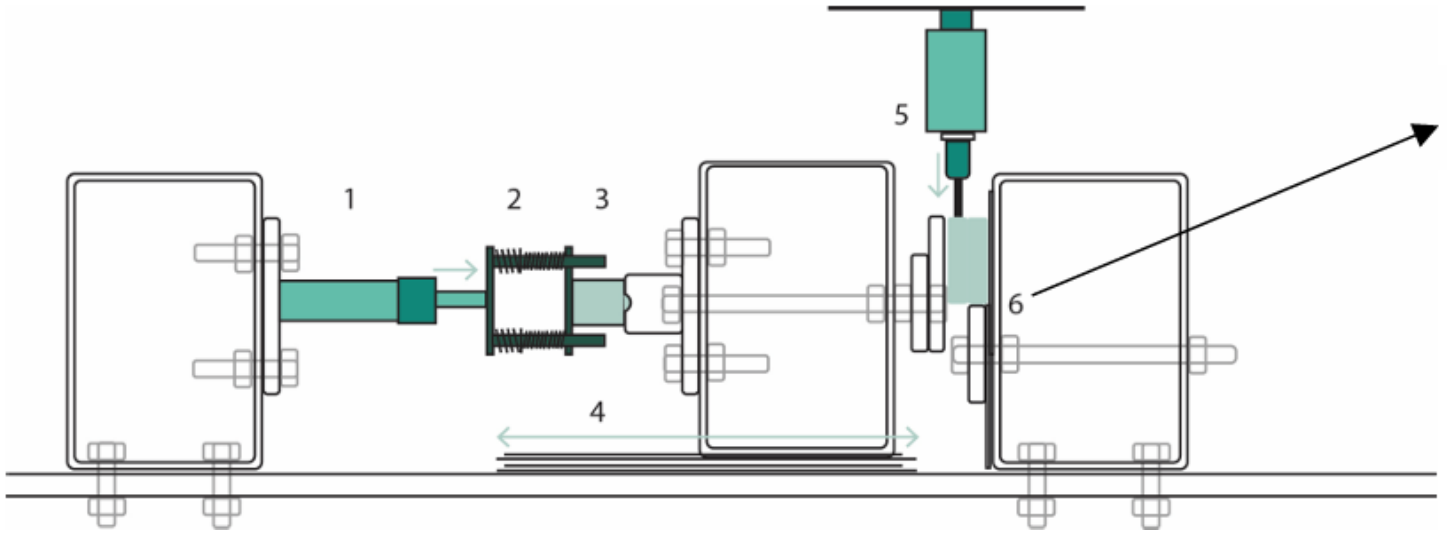
Standard metal spacer

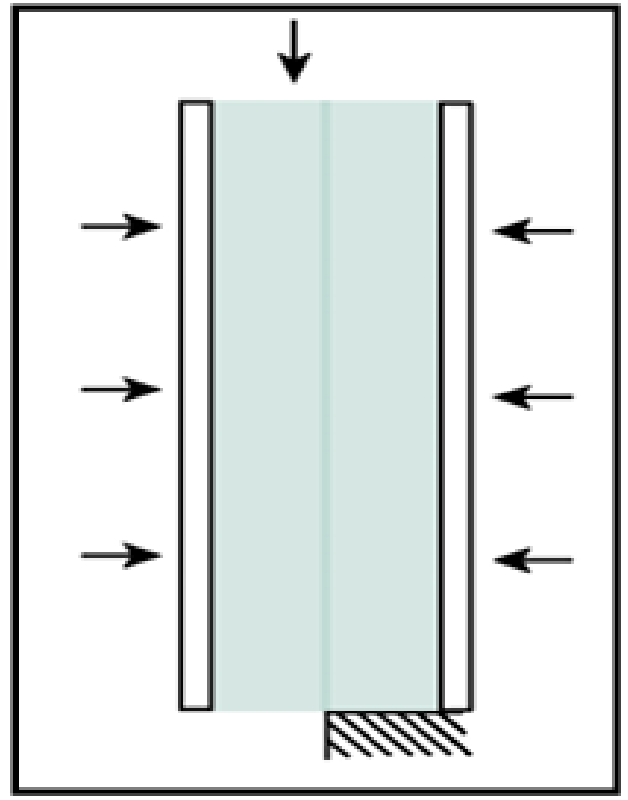


U-value system = 3.95 W/m2K

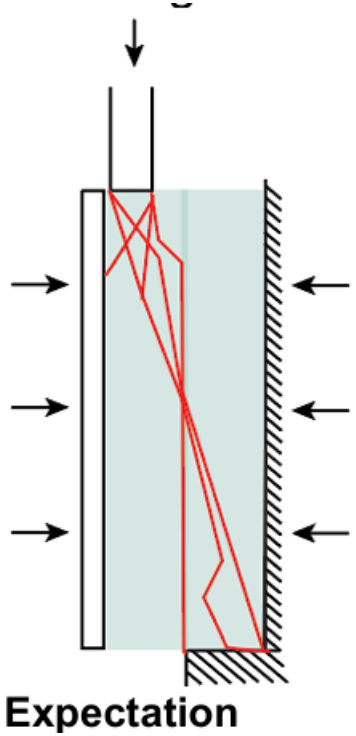
Redesign spacer

MECHANICAL PERFORMANCE

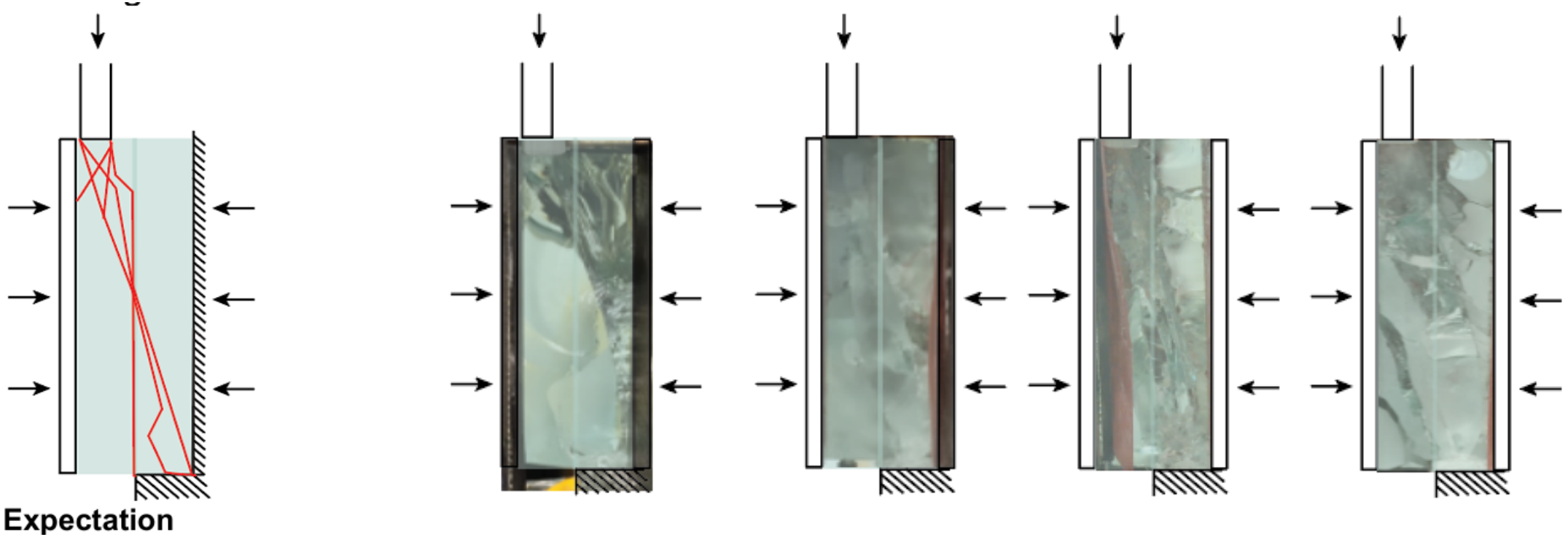




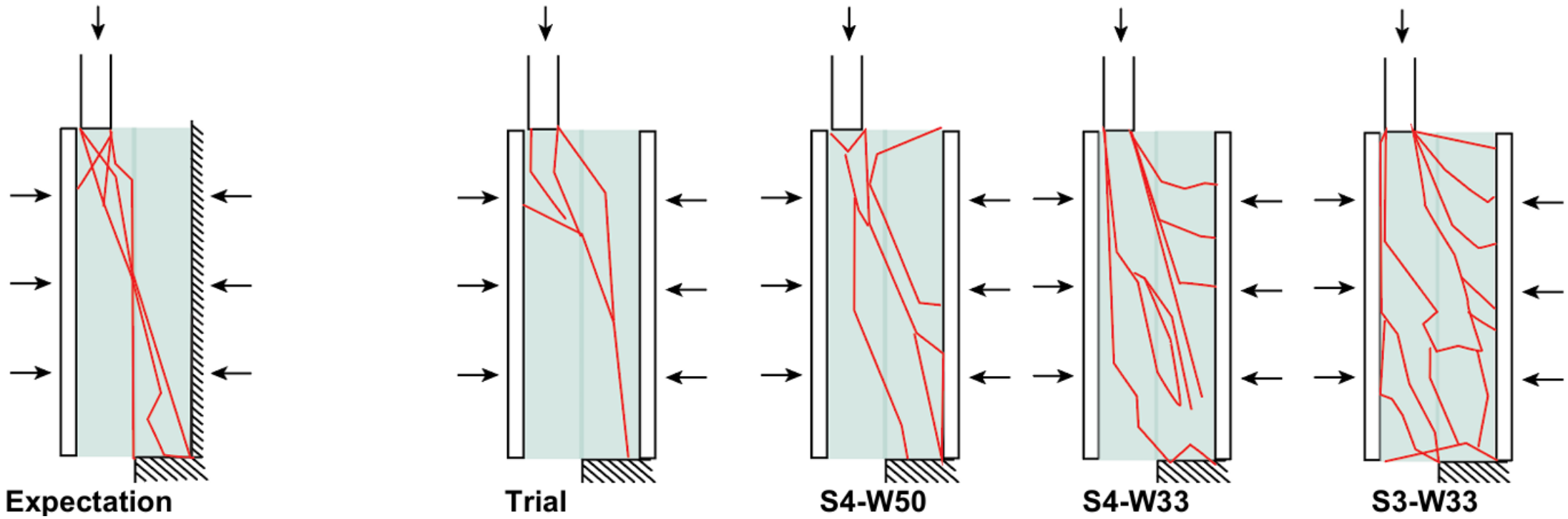
MECHANICAL PERFORMANCE



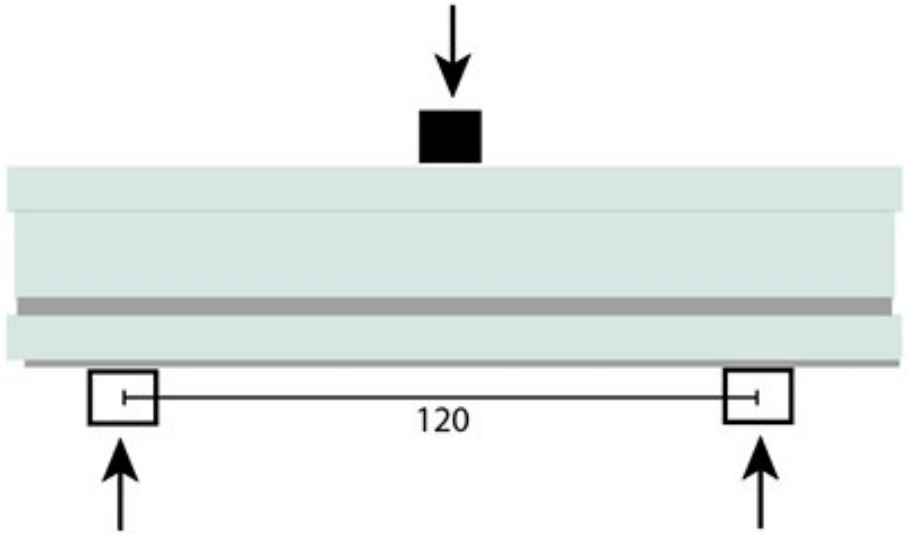
MECHANICAL PERFORMANCE



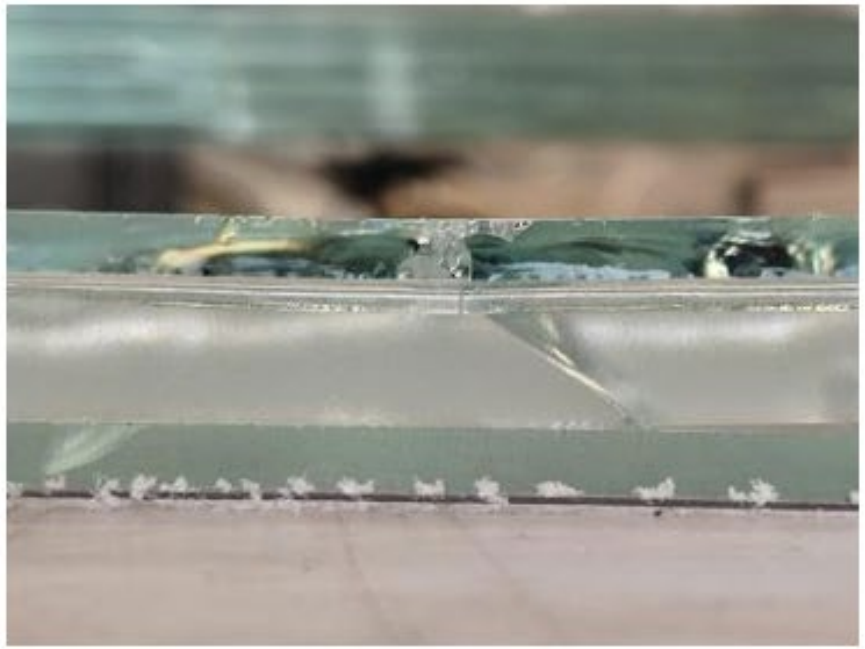
MECHANICAL PERFORMANCE



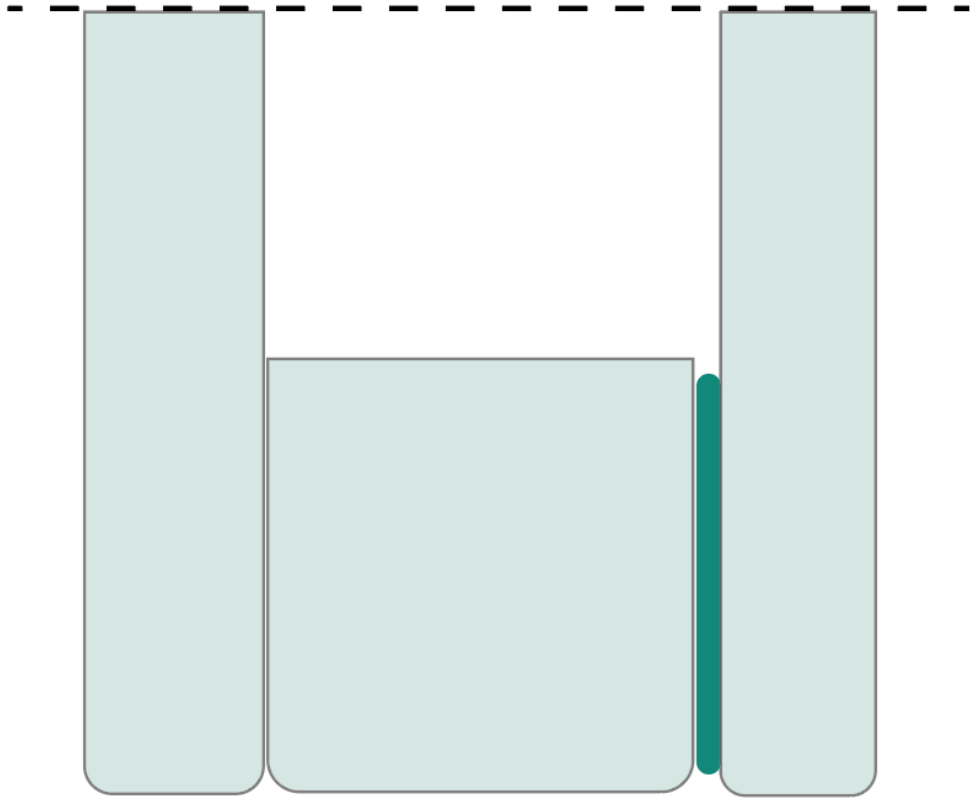
MECHANICAL PERFORMANCE



MECHANICAL PERFORMANCE

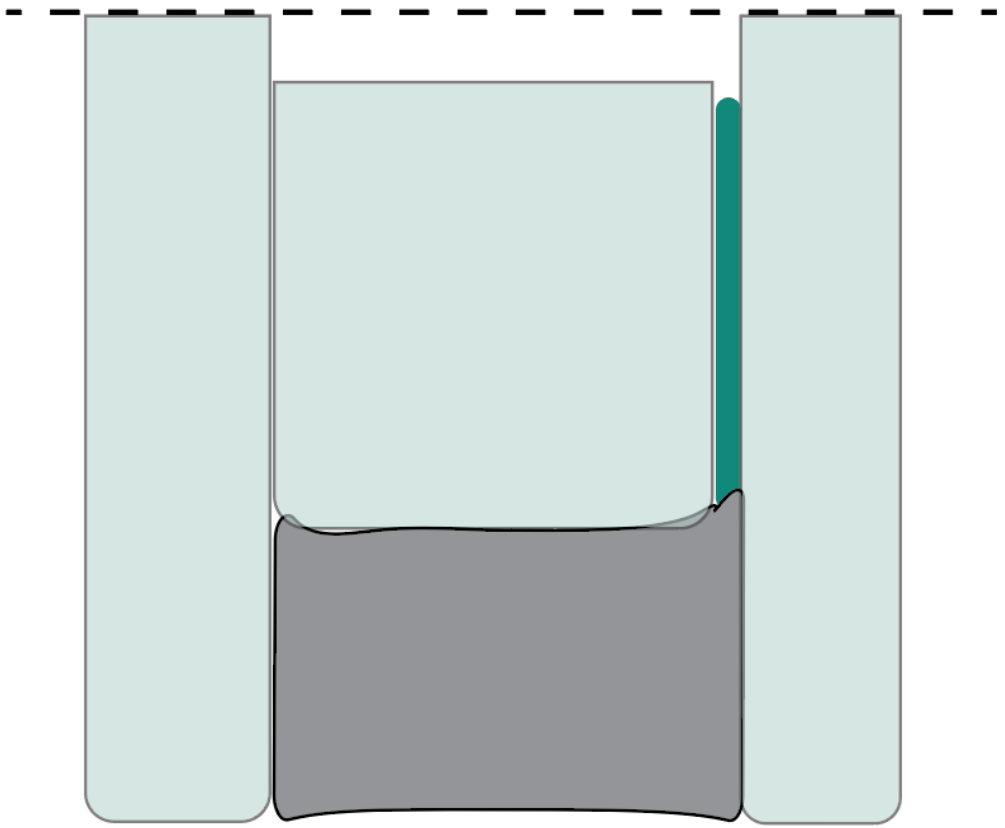


MECHANICAL PERFORMANCE



TOO STRONG

MECHANICAL PERFORMANCE

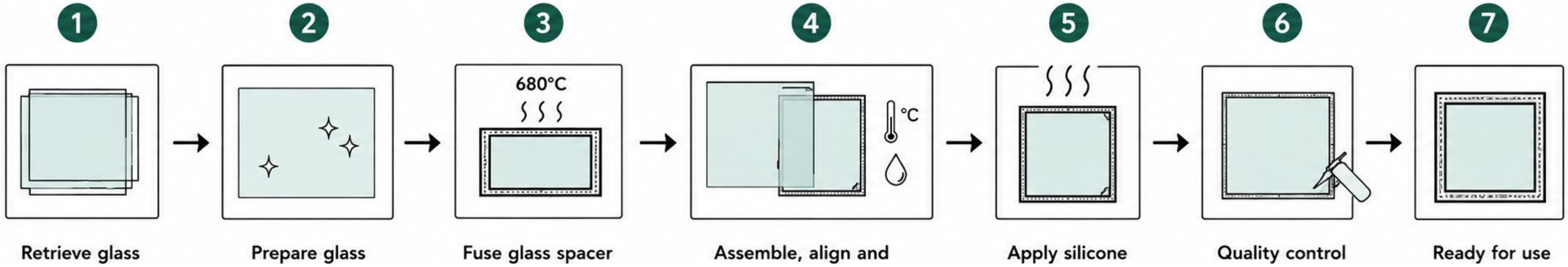


ADD SILICONE

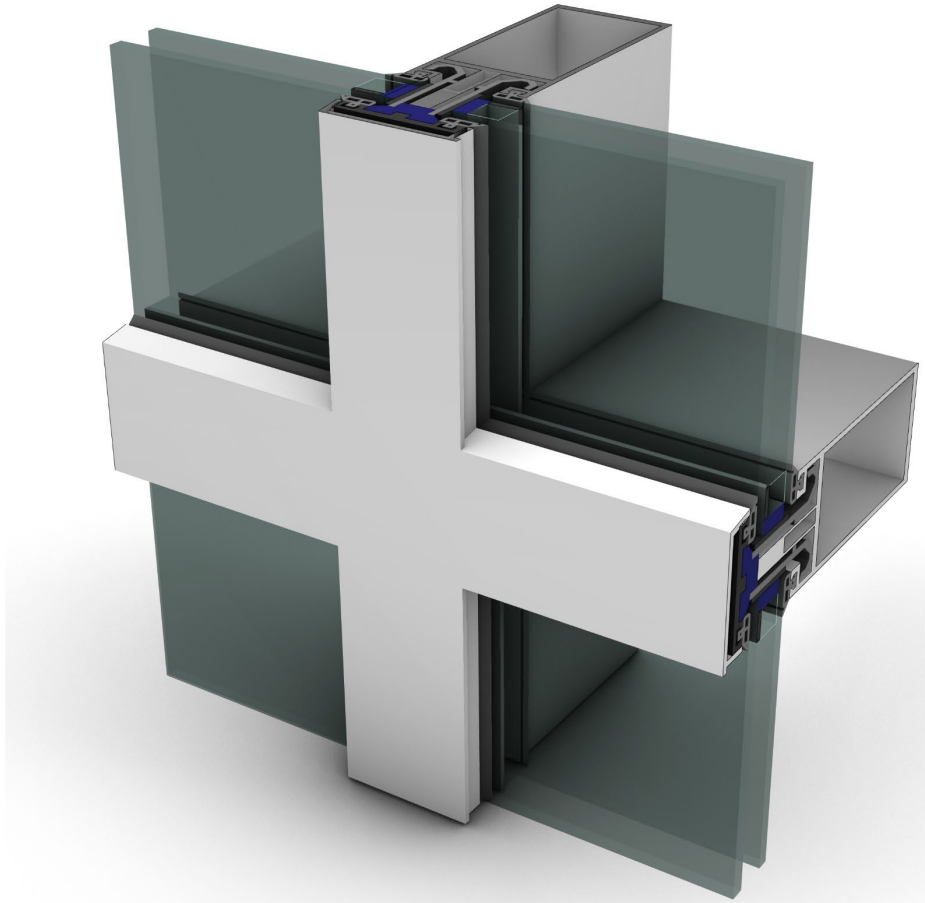
MECHANICAL PERFORMANCE

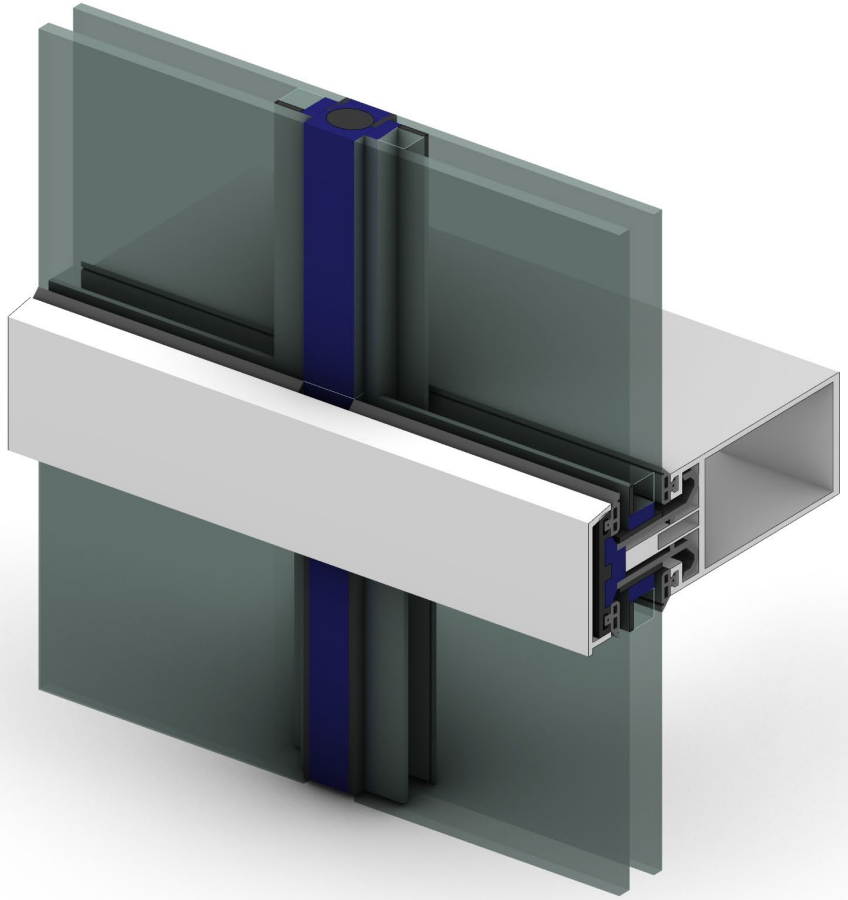
Silicone

IGU FABRICATION

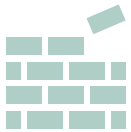


STANDARD FAÇADE SYSTEM





CIRCULAR ECONOMY



DESIGN FOR DISASSEMBLY

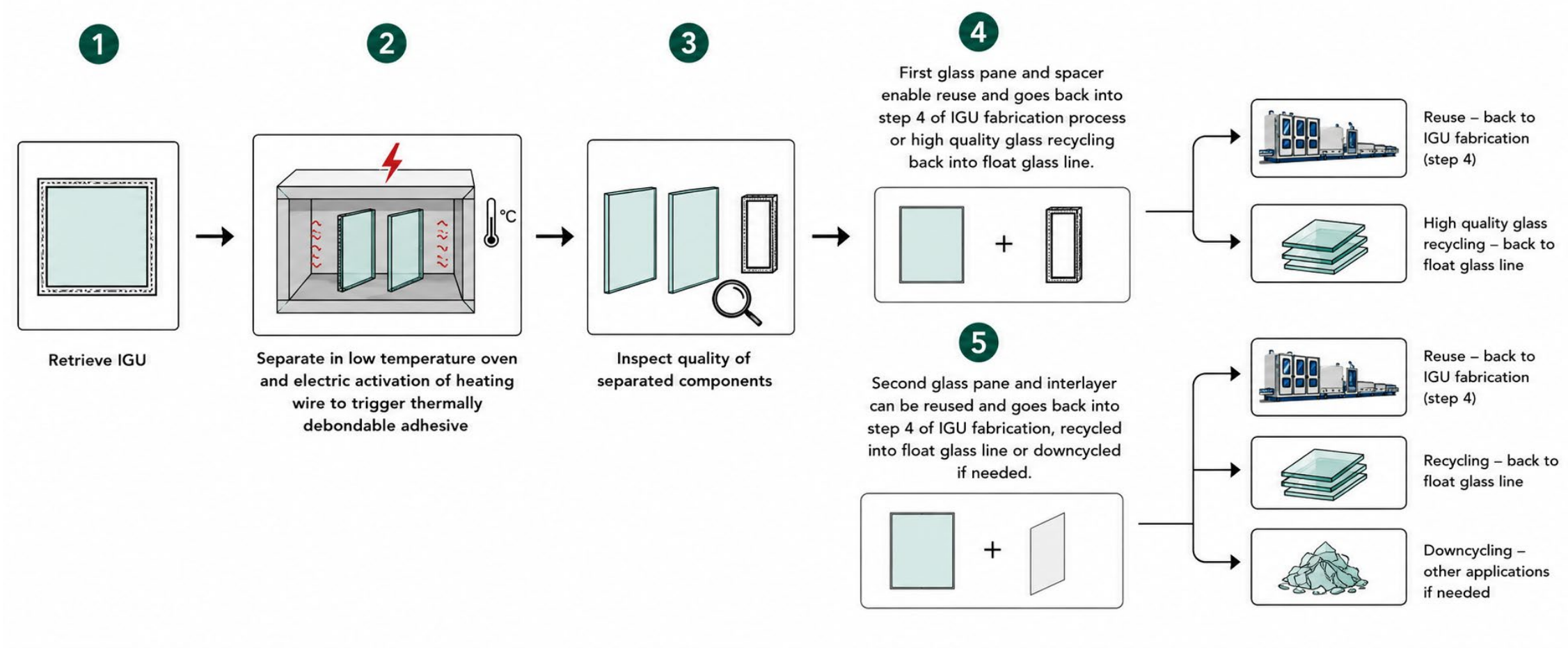
SELECTIVE DEBONDING

REUSE OF COMPONENTS

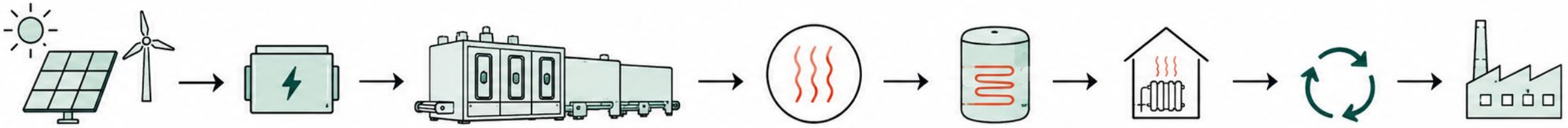
HIGH-VALUE MATERIAL RECOVERY

REINTRODUCTION INTO PRODUCTION

DEBONDING


1
2
3
4
5
Retrieve IGU
Separate in low temperature oven and electric activation of heating wire to trigger thermally debondable adhesive
°C
Inspect quality of separated components
First glass pane and spacer enable reuse and goes back into step 4 of IGU fabrication process or high quality glass recycling back into float glass line.
Second glass pane and interlayer can be reused and goes back into step 4 of IGU fabrication, recycled into float glass line or downcycled if needed.
Reuse – back to IGU fabrication (step 4)
High quality glass recycling – back to float glass line
Reuse – back to IGU fabrication (step 4)
Recycling – back to float glass line
Downcycling – other applications if needed

RENEWABLE ENERGY



On-site renewable energy generation
Solar PV / Wind

Energy storage
Balance & reliability

Energy for manufacturing processes
Ovens, robotics, systems

Heat recovery from ovens
Capture & recover waste heat

Heat storage
Buffer for reuse or distribution

Heat reuse or distribution
For facility needs or local networks

Debonding & recycling

New IGU production

ENERGY & SUSTAINABILITY BENEFITS

- Reduces dependence on fossil fuels
- Lowers CO_2 emissions
- Improves overall energy efficiency
- Supports circular economy through resource recovery

KEY QUESTION

Can the energy-intensive processes be offset by the value and impact of end-of-life recovery of high-quality materials?

DESIGN CRITERIA

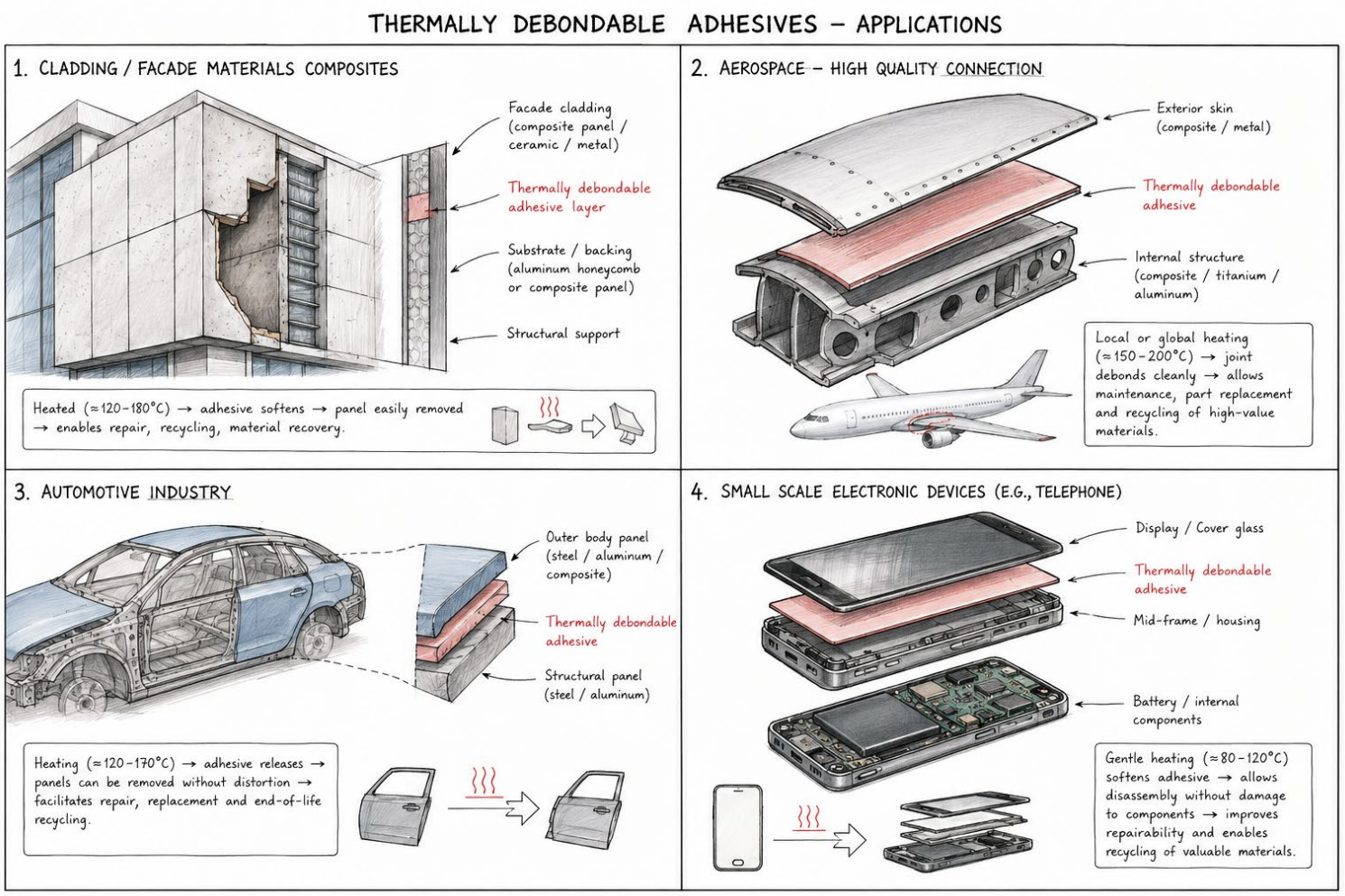
Thermal

Mechanical

Durable

Circular

FUTURE OPPORTUNITY



CONCLUSION

*How can **insulated glass units (IGUs)** be redesigned through material innovation and research-informed design to **enhance durability** and **enable circularity**, while maintaining the required performance of IGUs and ensuring compatibility with standard façade systems?*

THANK YOU

DESIGNING ON THE EDGE