AluFlux

Reuse of unrecycled metal waste

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Project duration: November, 2024 – June, 2025

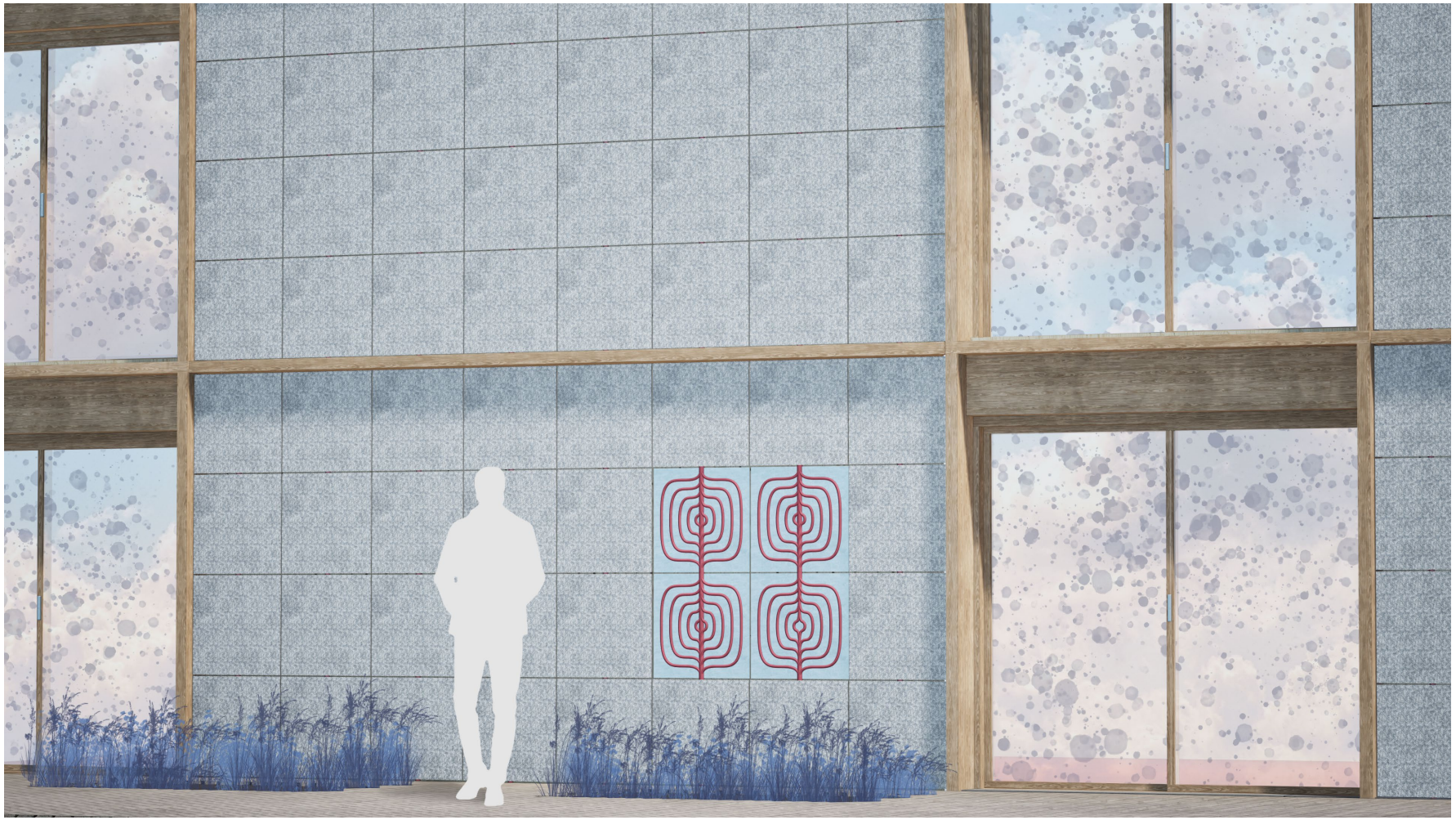
Thesis committee: Dr. ir. T. Bristogianni, TU Delft, supervisor
Dr. ing. M. Bilow, TU Delft

”Line of dump trucks being loaded with bauxite ore in an open pit in Saline County” (Alancaster, 2024)

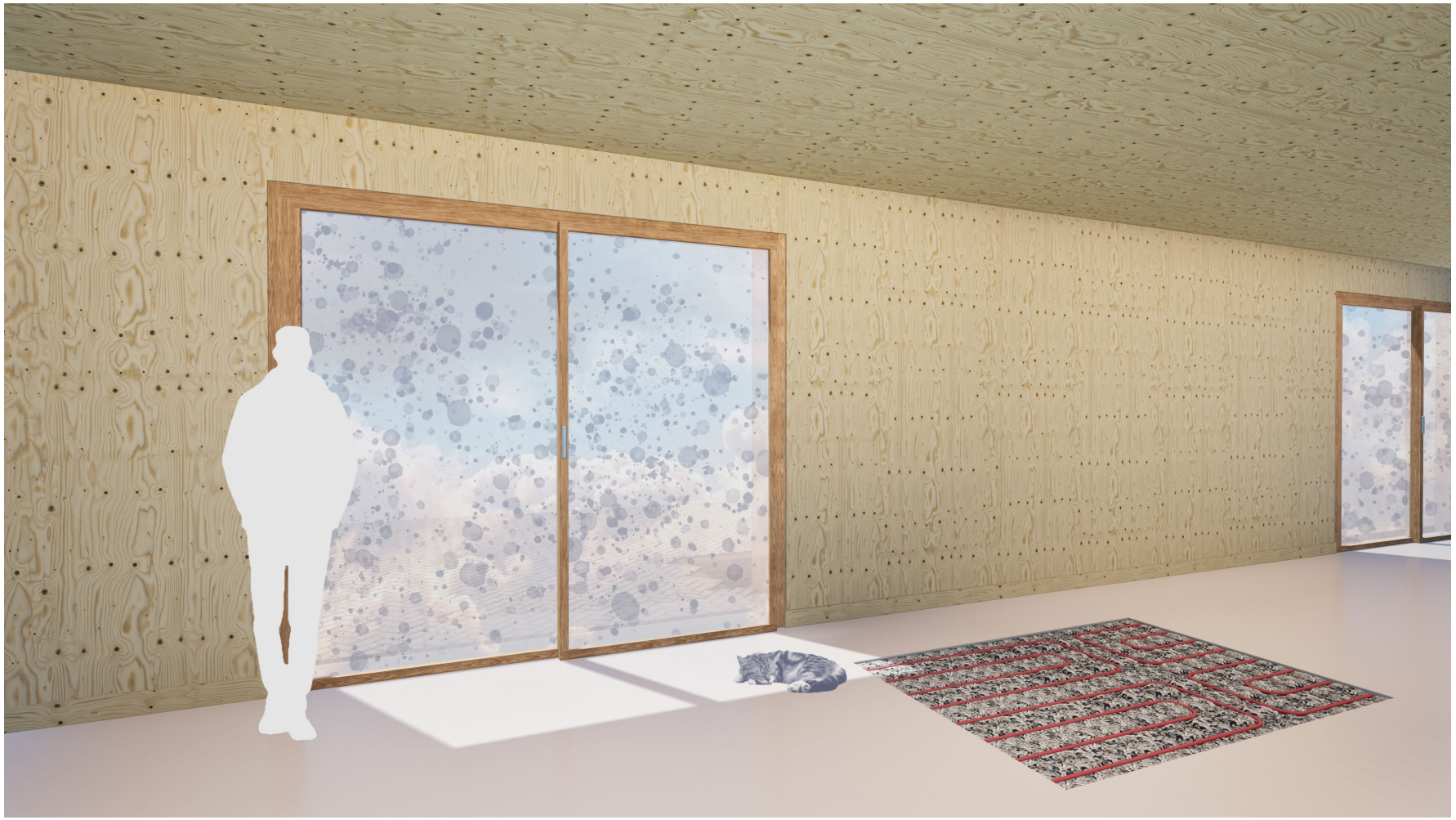
Introduction |

Aluminium scrap recycling. Photograph by unknown author (Aluminium, 2022)

AluFlux panel



AluFlux panel



Introduction | Context

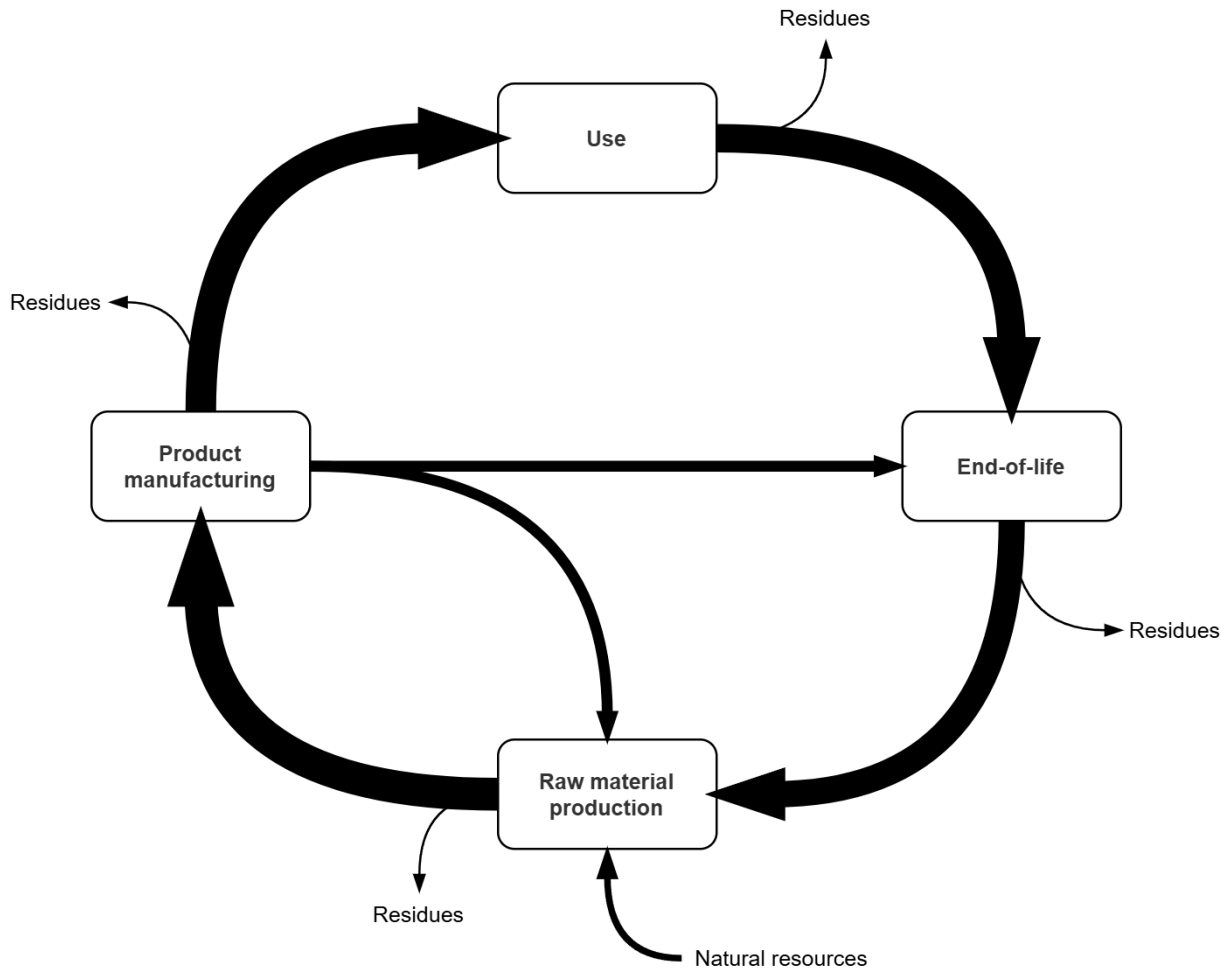
What is waste?

‘Unwanted or undesired materials’

Waste reduction

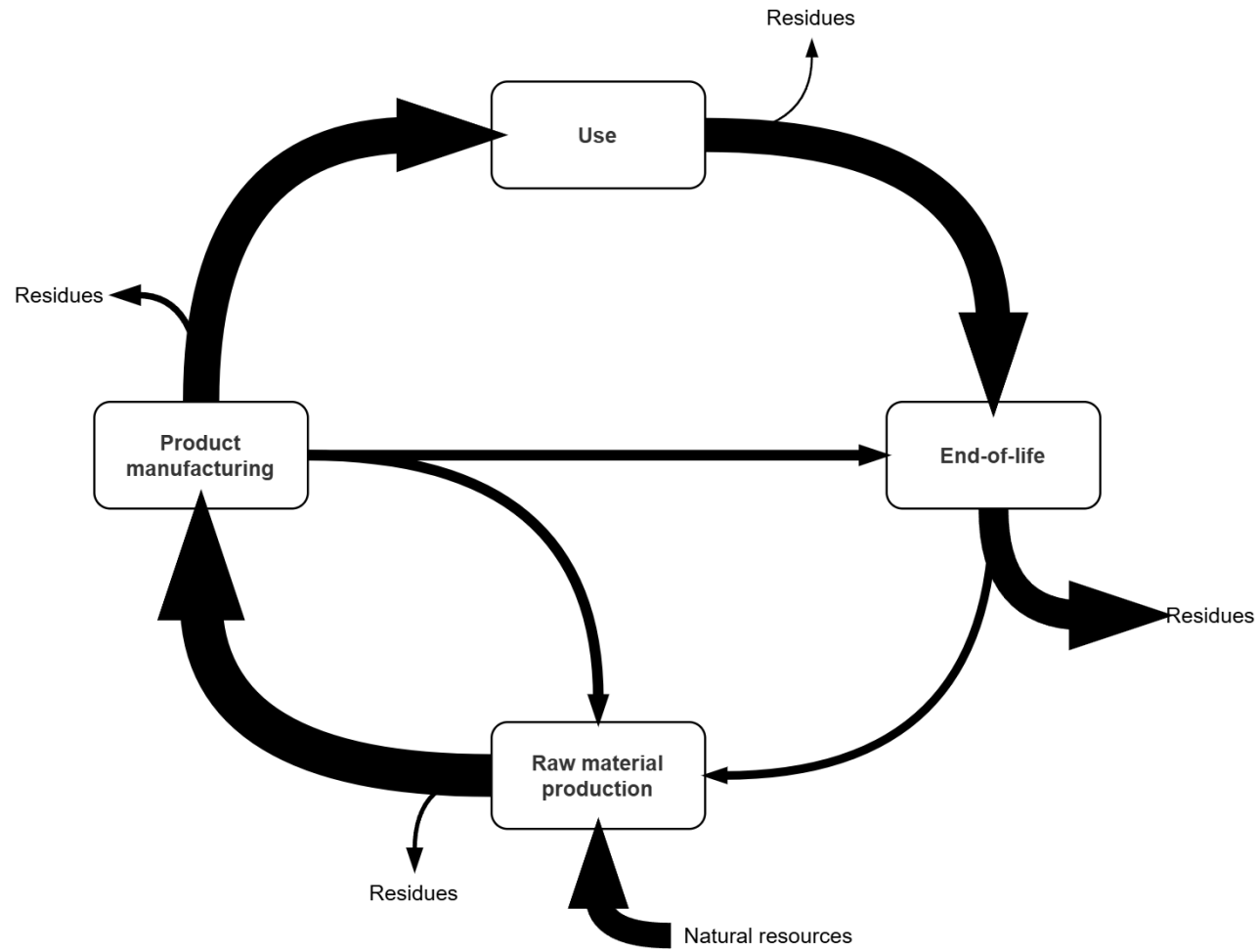
Circular economy

Literature research | Material flow

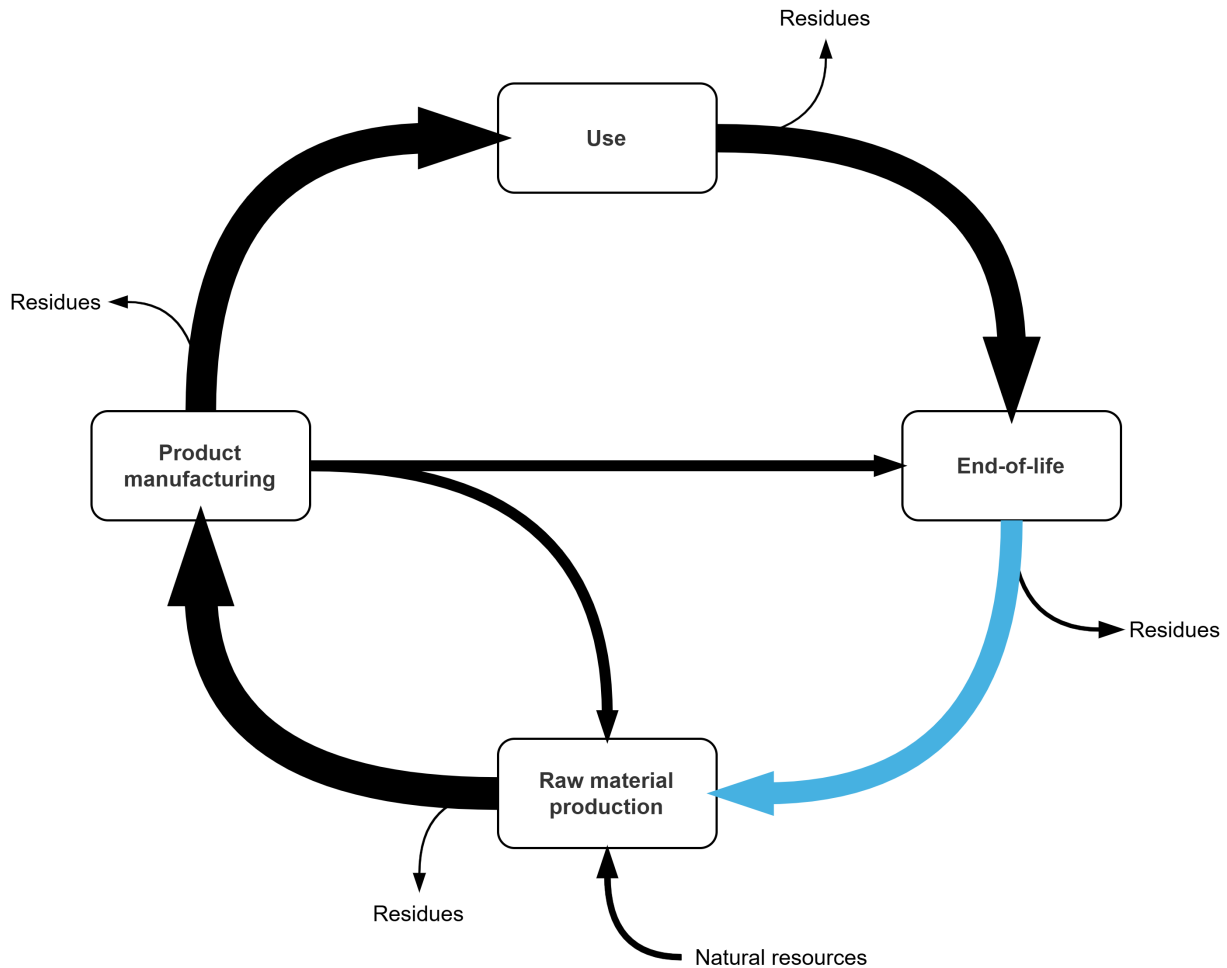


(Björkmanand Samuelsson, 2014)

Literature research | Material flow



Literature research | Material flow



Introduction | Context

Metal

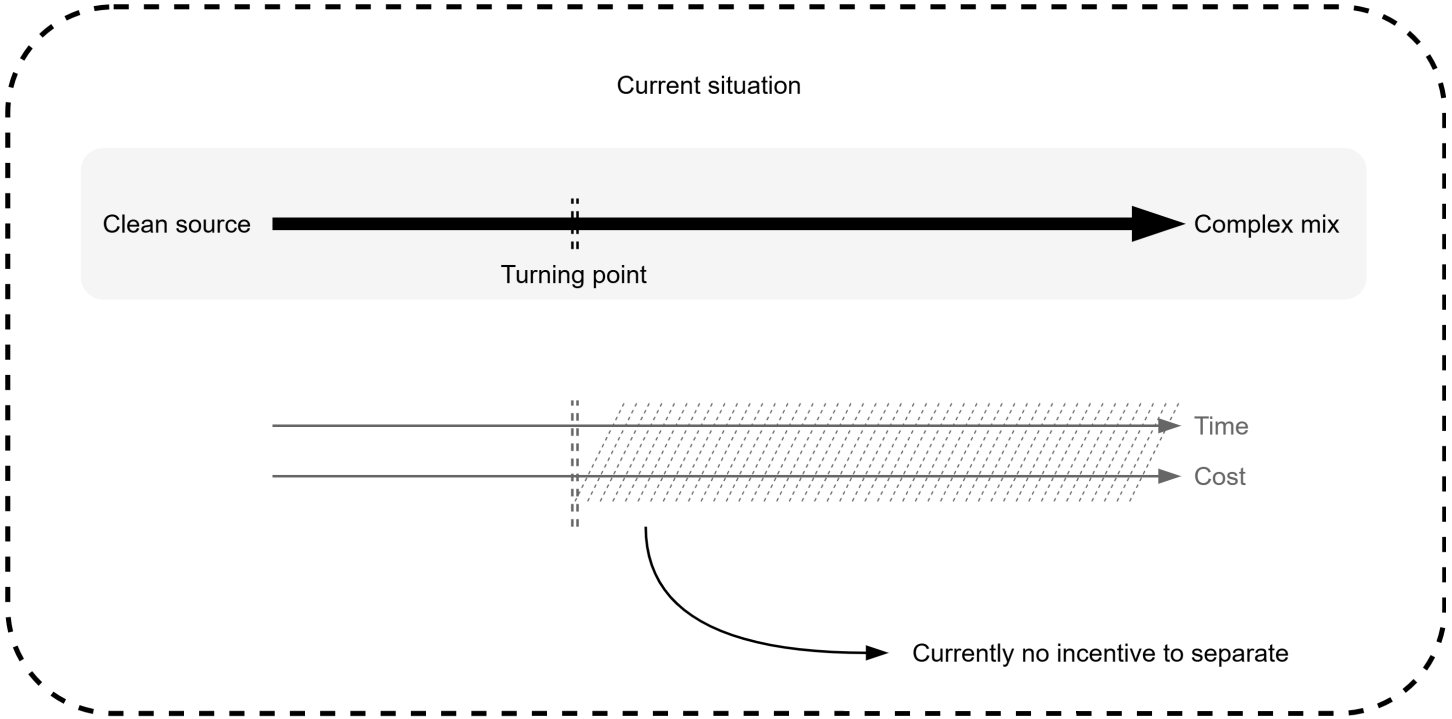
Exhaustible resource

High dependency on non-EU mining

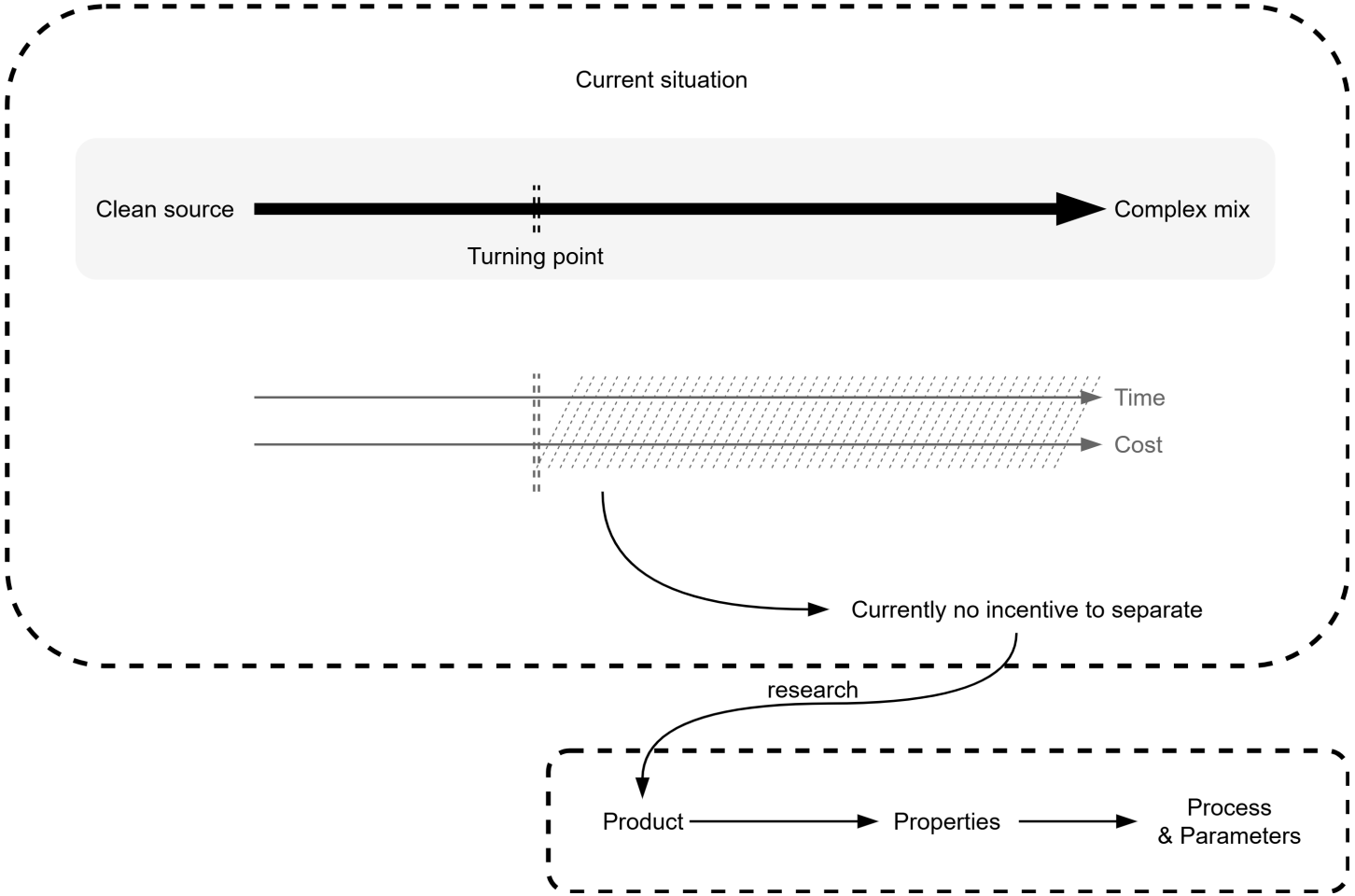
Endlessly recyclable

Introduction | Problem statement

Introduction | Problem statement



Introduction | Scientific research gap

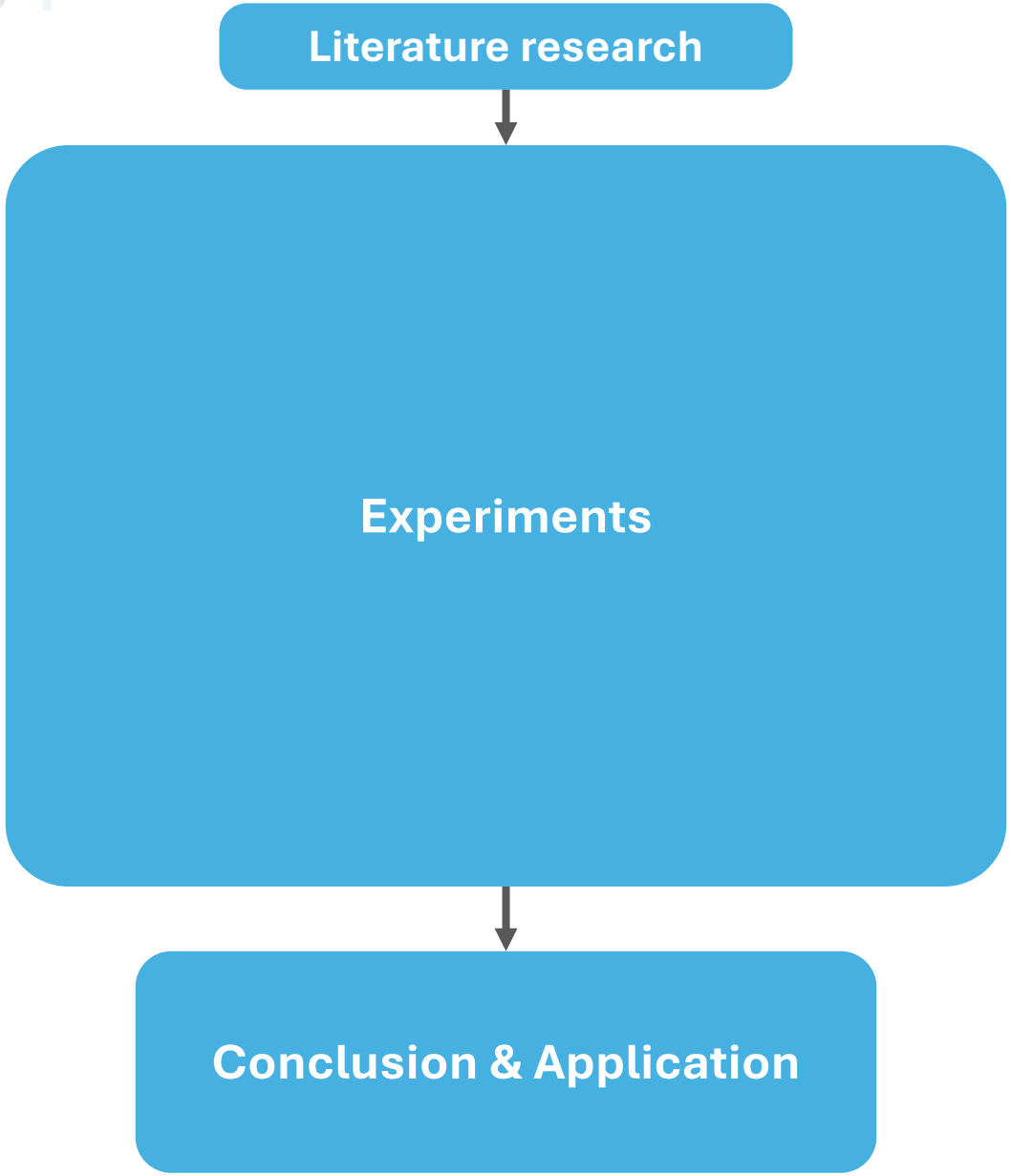


Introduction | Research question

Main question | “How can **unrecycled**, **mixed metal waste** be **reprocessed** into **new materials** for **architectural applications**?”

Methodology

Methodology



Material selection

Material selection | Criteria

Waste material

Locally available

Not shipped out of Europe

Landfilled or incinerated

Process-ability

Aluminium composite foils |

Aluminum composite foils

Composite

Aluminium

Polymer

Application

Barrier

Aluminum composite foils | Conclusion

Complex materials

Material composition

Material shape

Difficult to recycle

Relatively low aluminum

Conventional recycling methods

Experimentation

Experimentation | approach & framework

Focus

Aluminium

Polymer as byproduct

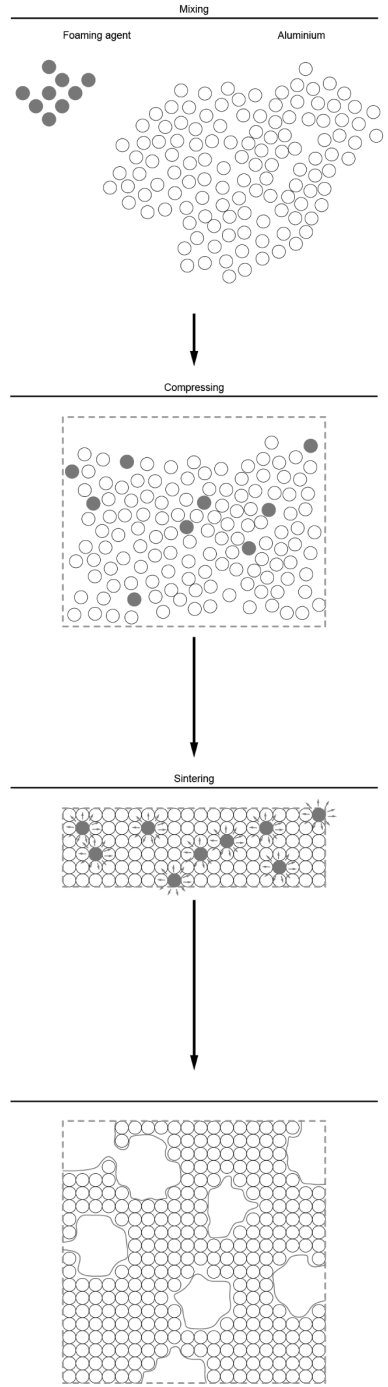
Polyethylene (PE)

Architectural purpose

Powder metallurgical approach

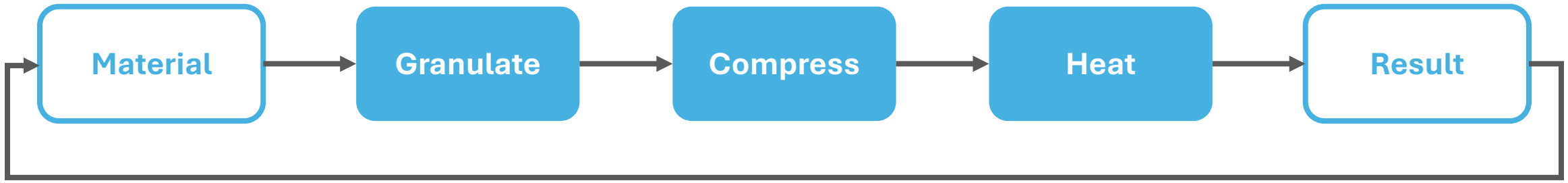
Foaming

Experimentation | appr ework

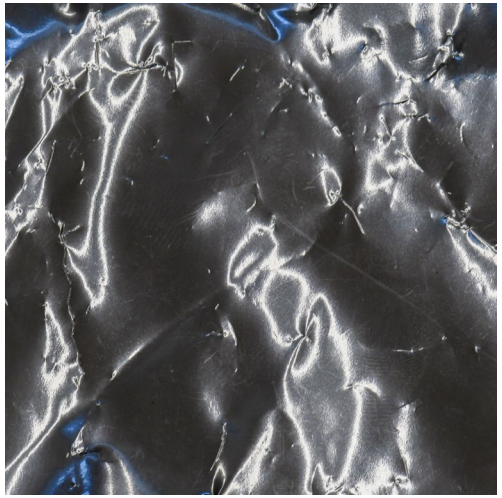


Experimentation | approach & framework

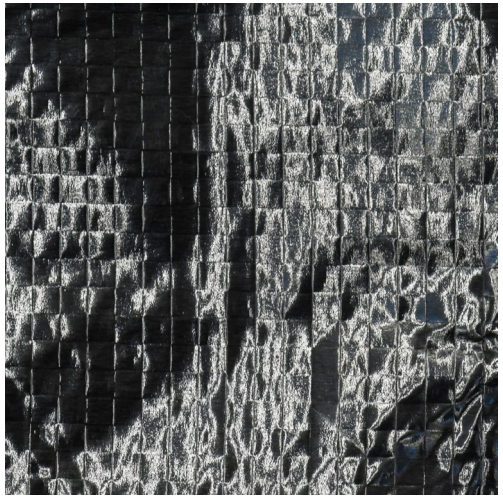
Experimentation | approach & framework



Sample material | materials

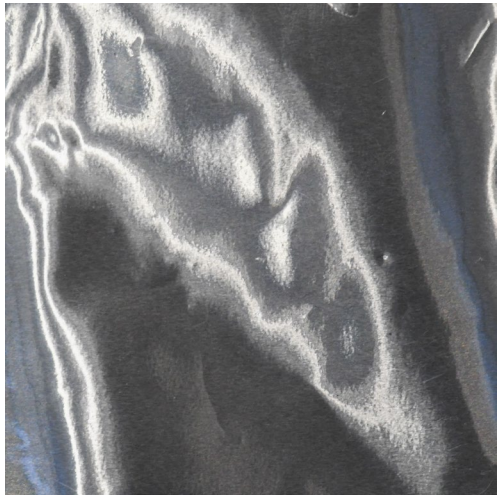


(S1) Crisp bags

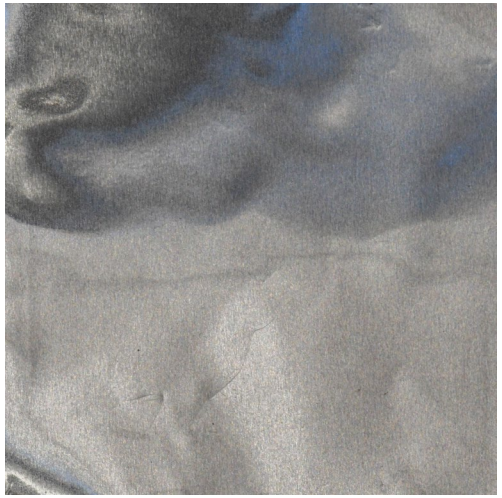


(S2) Flooring underlayer

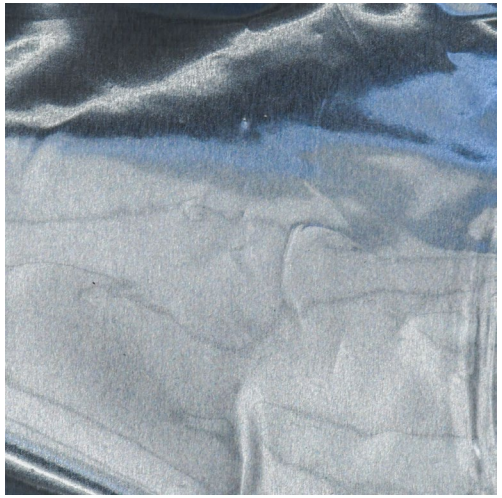
(S3) Coffee capsules



(S5) Medical packaging

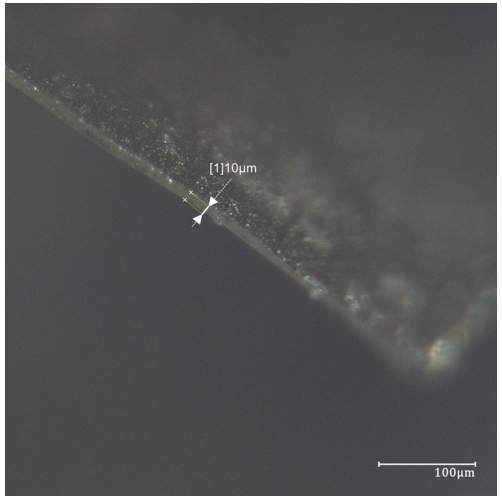


(S6) Food packaging

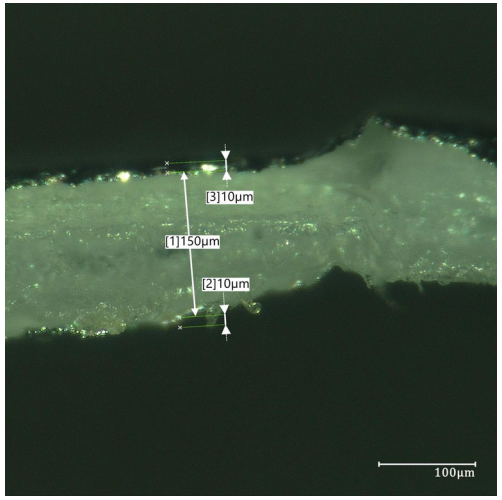


(S7) Food packaging

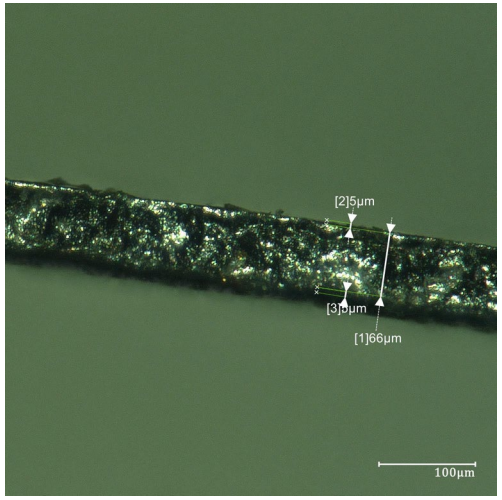
Sample material | materials



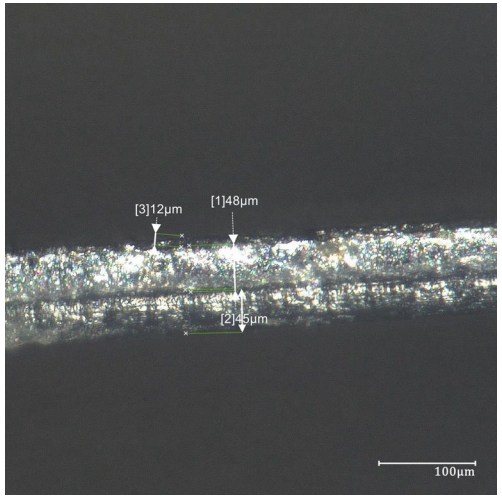
(S1) Crisp bags



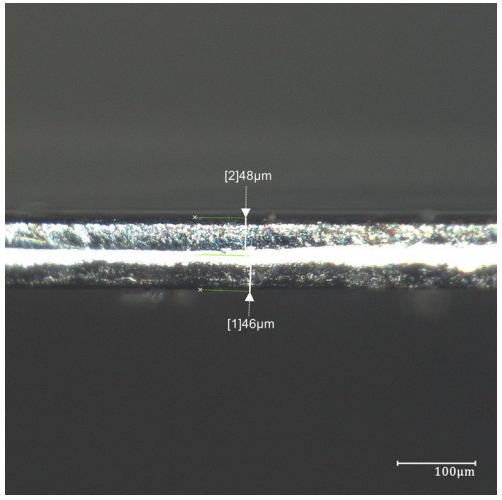
(S2) Flooring underlayer



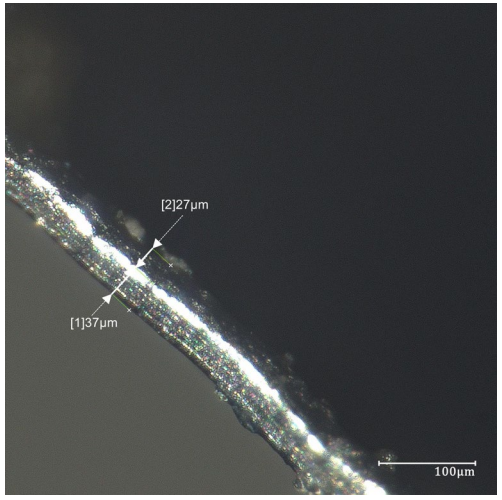
(S3) Coffee capsules



(S5) Medical packaging

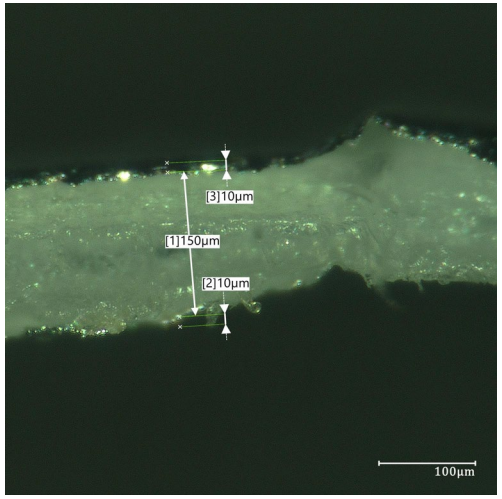


(S6) Food packaging



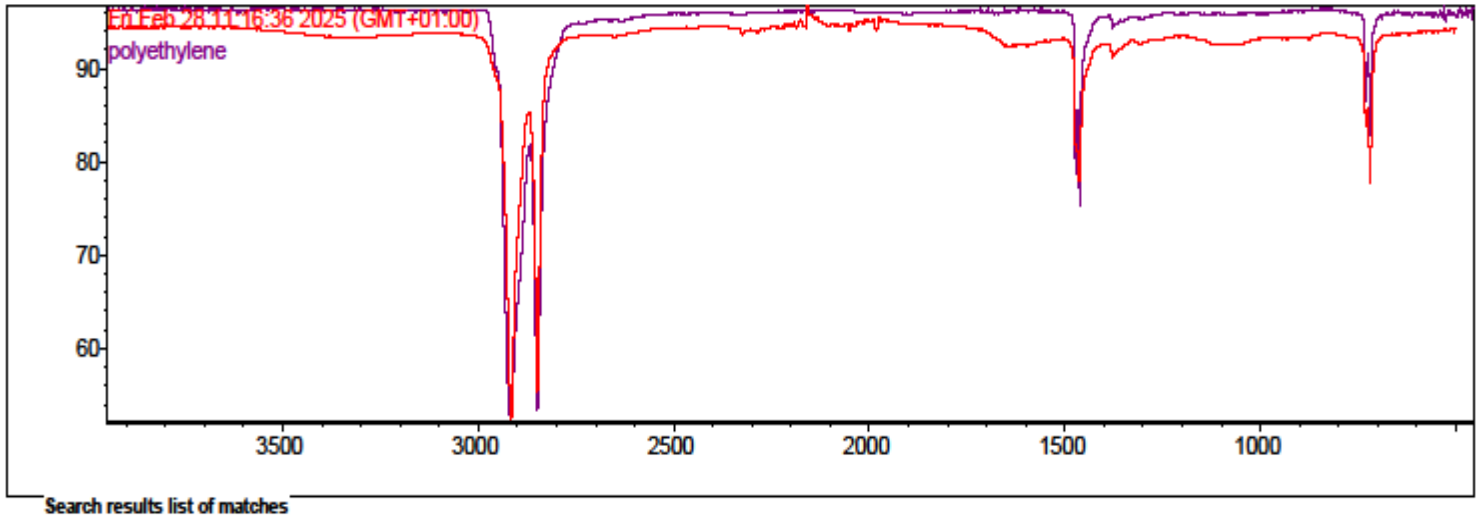
(S7) Food packaging

Sample material | materials | fourier



S2

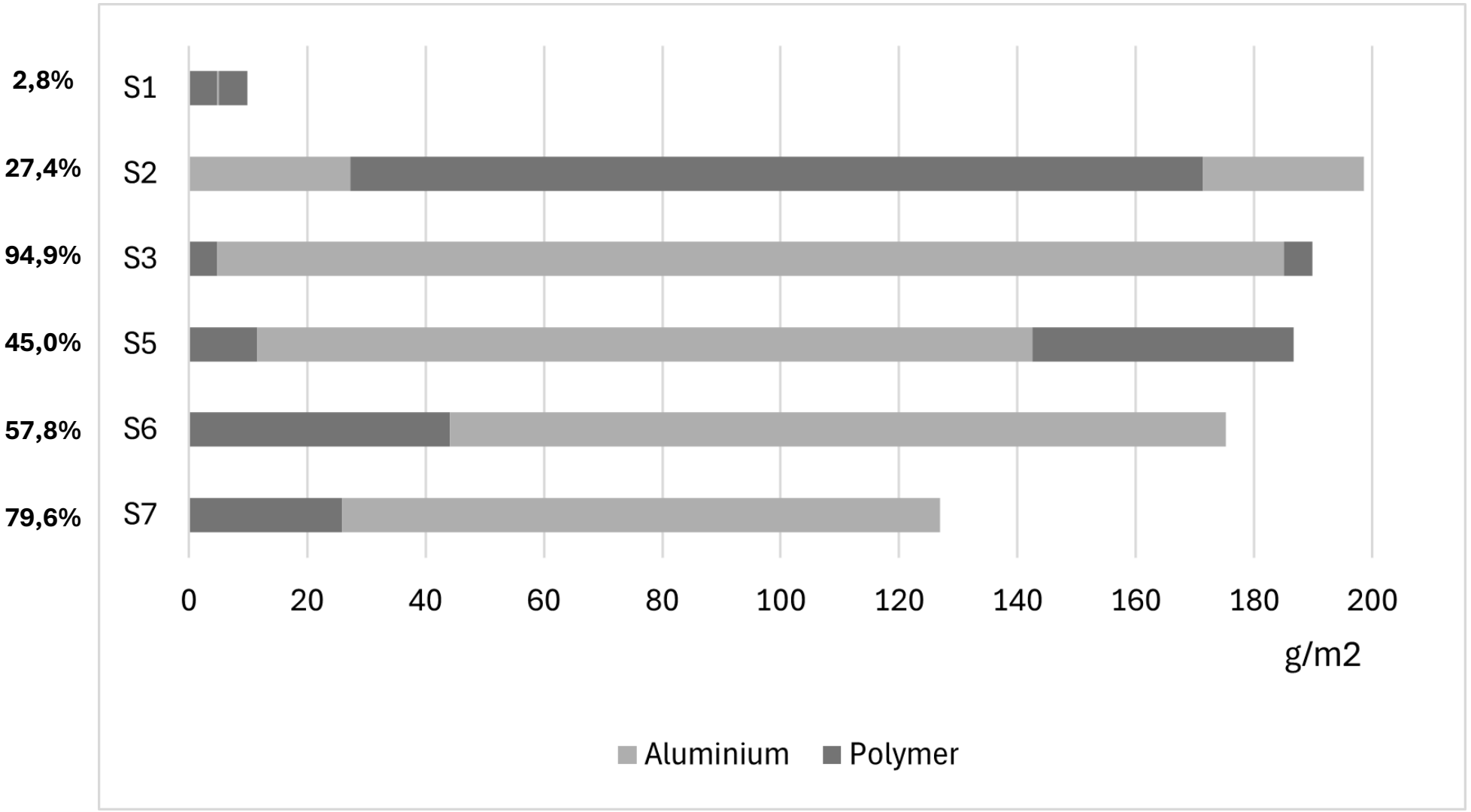
Search results for: Fri Feb 28 11:16:36 2025 (GMT+01:00)
Date: Fri Feb 28 11:18:06 2025 (GMT+01:00)
Search algorithm: Correlation
Regions searched: 3949.50-499.96



Search results list of matches

	Index	Match	Compound Name	Library Name
1	625	94.59	polyethylene	HR Nicolet Sampler Library

Sample material | materials



Experimentation | granulate

Paper shredder

Blender

Coffee grinder

Experimentation | granulate

Strings (5mm x 50mm)

Flakes (2-20mm)

Powder (<2 mm)

Experimentation | compress

Experimentation | heat

Results | powder

S1.P.CR

S2.P.CR

S3.P.CR

S4.P.CR

S5.P.CR

S6.P.CR

S7.P.CR

Material → Granulate → Compress → Heat → Result

Results | flakes

20 °C

S1.F.CR

S2.F.CR

S3.F.CR

S5.F.CR

S6.F.CR

S7.F.CR

110 °C

S1.F.CH

S2.F.CH

S3.F.CH

150 °C

S1.F.CH

Material → Granulate → Compress → Heat → Result

Results | strings

20 °C

S1.S.CR

S2.S.CR

S5.S.CR

S6.S.CR

S7.S.CR

110 °C

S1.S.CR

S2.S.CR

Material → Granulate → Compress → Heat → Result

Results | powder

S1.P.CR S2.P.CR S3.P.CR S4.P.CR S5.P.CR S6.P.CR S7.P.CR

Results | flakes

Experimentation

Why is the aluminium not connecting?

Oxidation (hypothesis)

Carbonation (hypothesis)

Solution

Quicker heating

Shorter heating

Experimentation | quick heating

S2

White powder?

Experimentation

Conclusion

The aluminium melts but doesn’t bind

The higher the PE, the more ‘trouble’

The PE makes ‘bubbles’

Questions

What is the ‘white powder’?

Experimentation | XRD analysis

Sample	Compound	
S2 650-700-750	Aluminium	Al
	Lime	CaO
	Calcite	$CaCO_3$
S2.F.CR 750	Aluminium	Al
	Lime	CaO
	Calcite	$CaCO_3$

Experimentation

Removing white powder

Sieve

Experimentation | sieving

Experimentation | results

S2.P.CR sieved

S5.P.CR sieved

S6.P.CR sieved

S7.P.CR sieved

Experimentation | results

S2.P.CR sieved

S5.P.CR sieved

S6.P.CR sieved

S7.P.CR sieved

Experimentation | thermal disengagement

Samples

Firm

‘Aluminium like’

Thermal disengagement

Oxygen environment

Pyrolysis

Experimentation

‘Cleaned aluminium’

Pressure

Heat

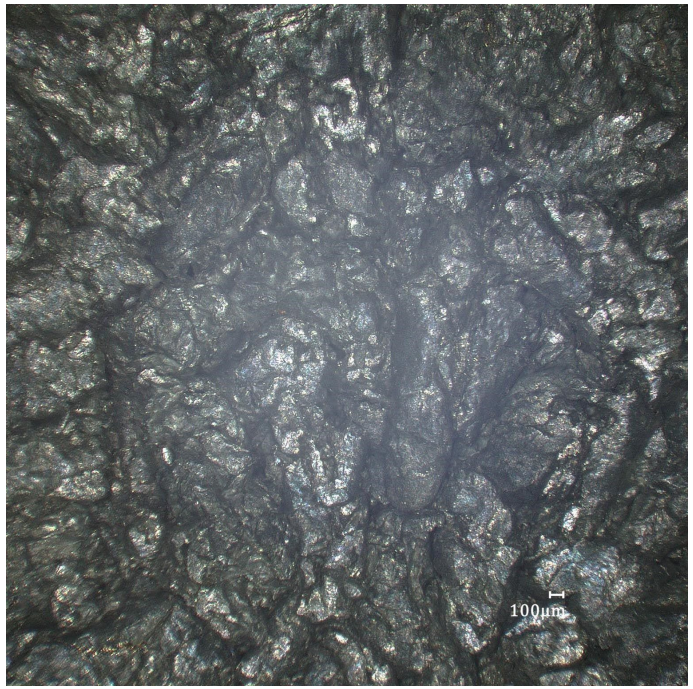
Experimentation | results

	50 MPa	100 MPa	200 MPa
S5			
S6			
S7			

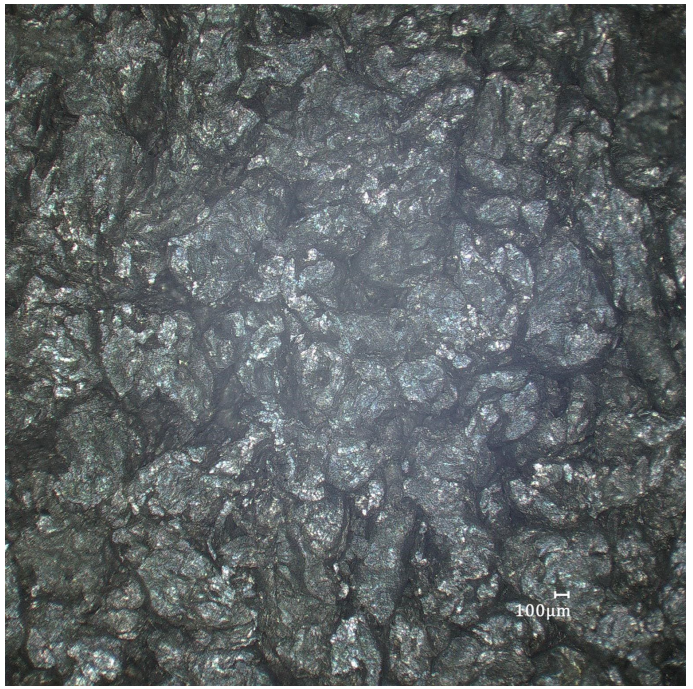
Material → Granulate → Compress → Heat → Result

Experimentation | results

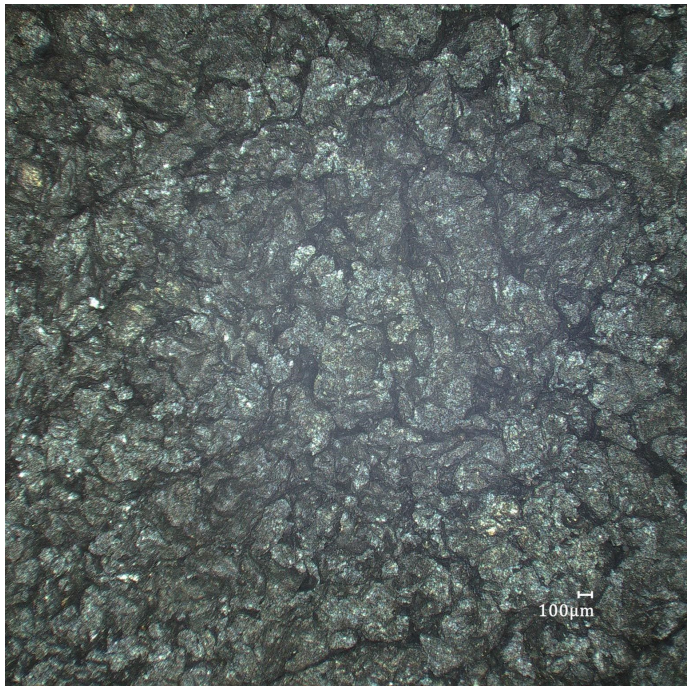
50 MPa



100 MPa



200 MPa



Experimentation | results

	50 MPa	100 MPa	200 MPa
S5			
S6			
S7			

Material → Granulate → Compress → Heat → Result

Validation |

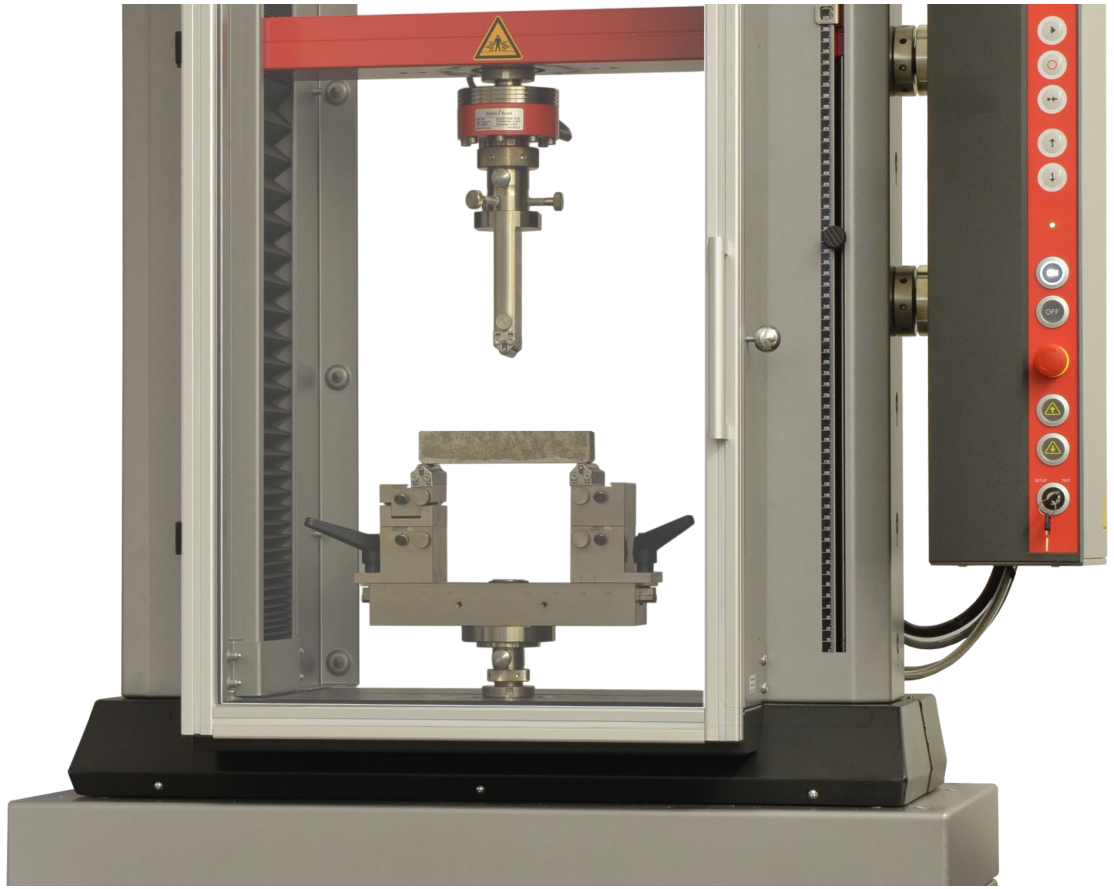
Validation

Bending test

3 point bending test

Flexural strength (σ)

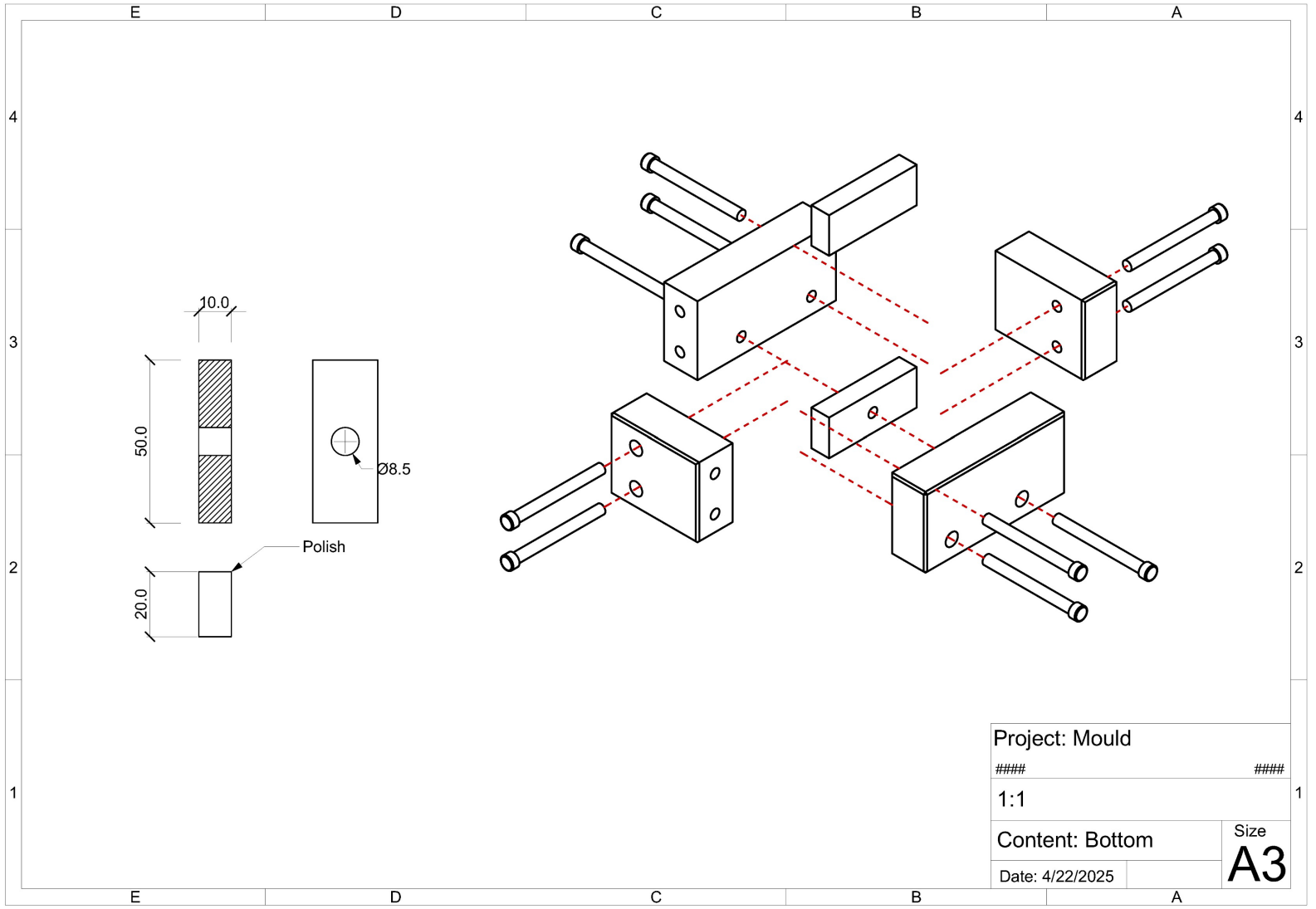
Flexural modulus (E_{flex})



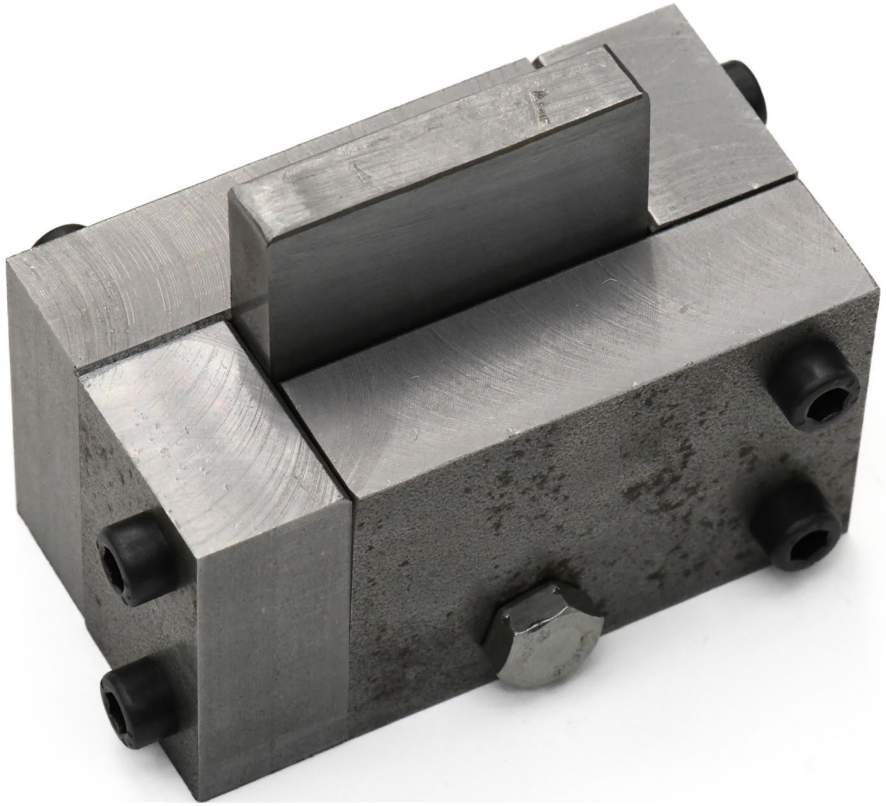
(Zwickroell, 2025)

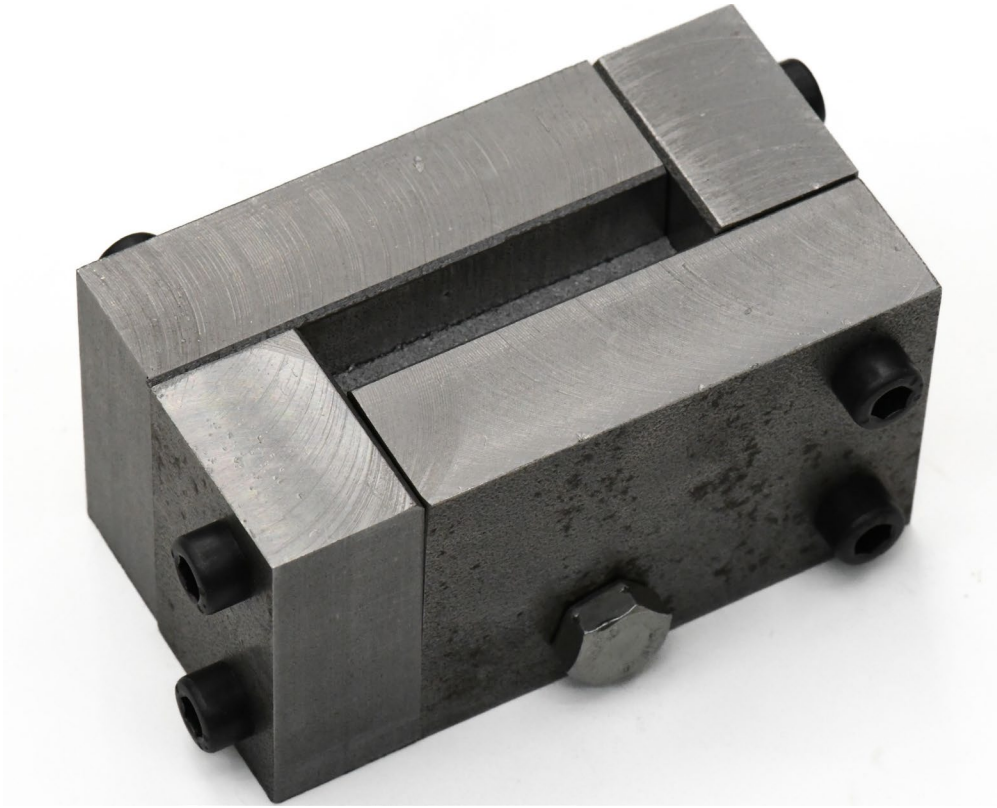
Validation

Beam shaped mould



Validation





Validation | samples

Sample	Pressure (MPa)	Temperature (°C)
B.150.700	150	700
B.200.700	200	700
B.250.700	250	700
B.150.750	150	750
B.200.750	200	750
B.250.750	250	750

Validation | samples

150 MPa

200 MPa

250 MPa

Validation | samples | fired

	150 MPa	200 MPa	250 MPa
700 °C			
750 °C			

Material → Granulate → Compress → Heat → Result

Validation | results

B.150.700

B.150.750

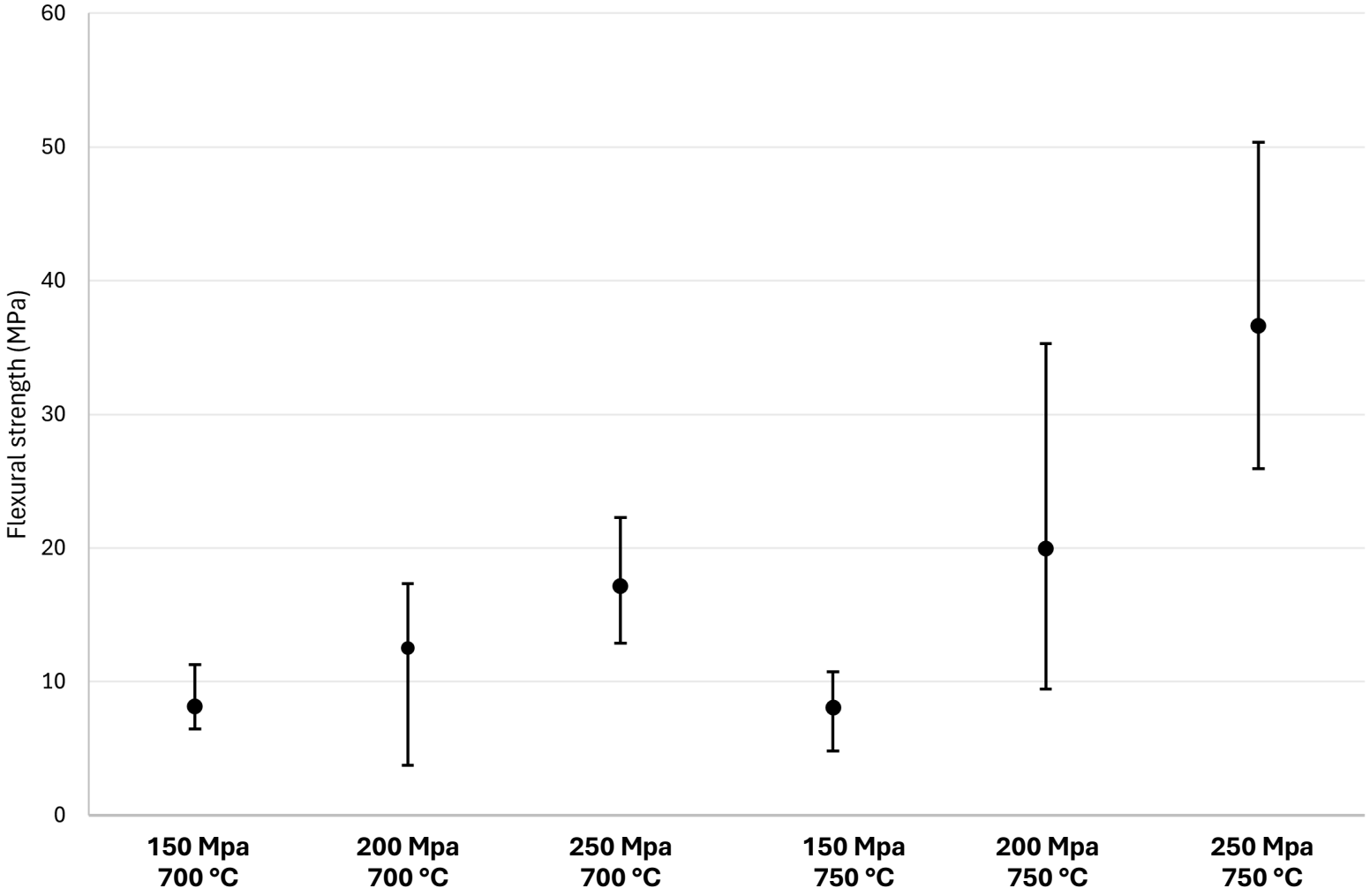
B.200.700

B.200.750

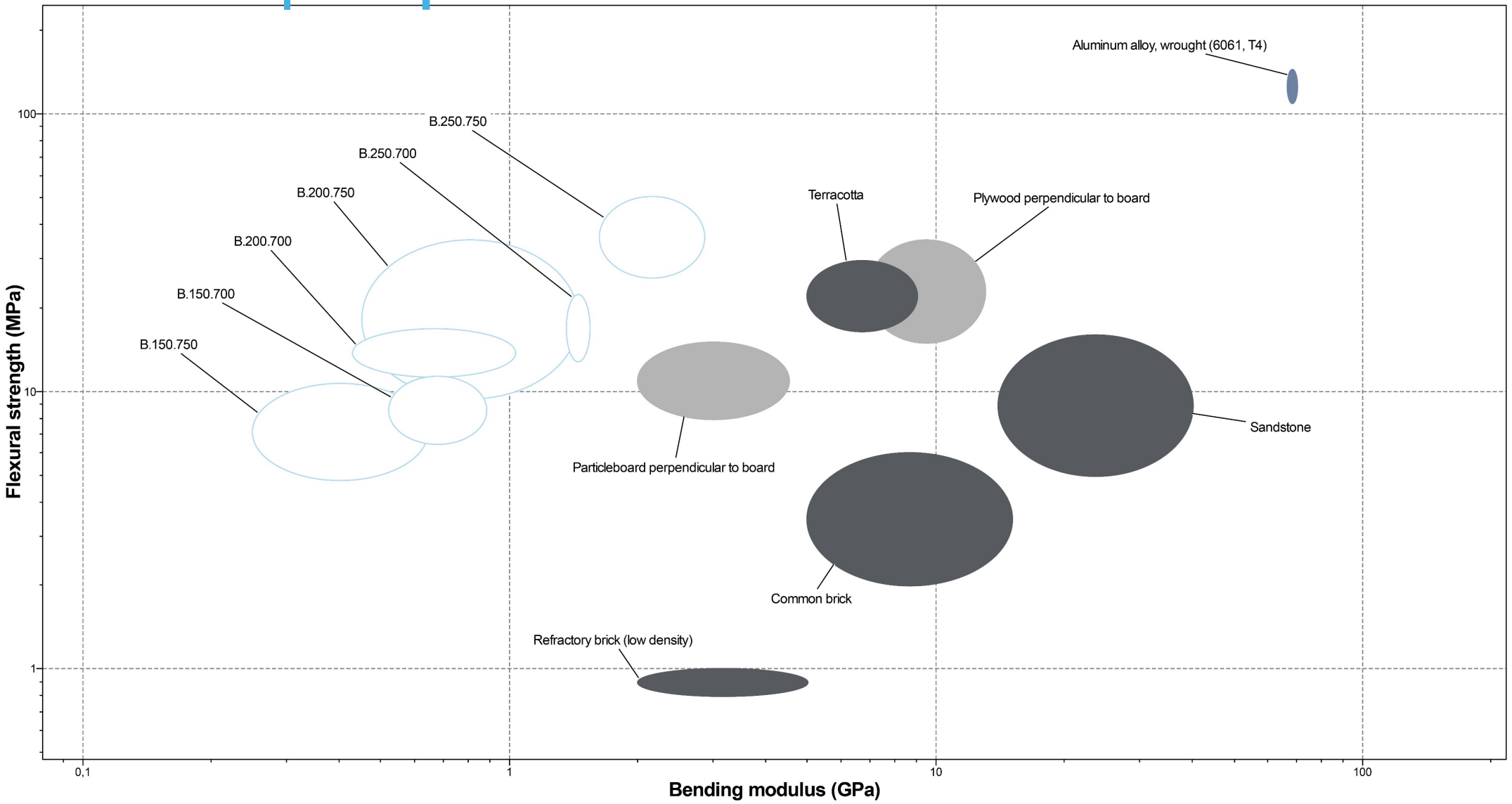
B.250.750

B.250.750

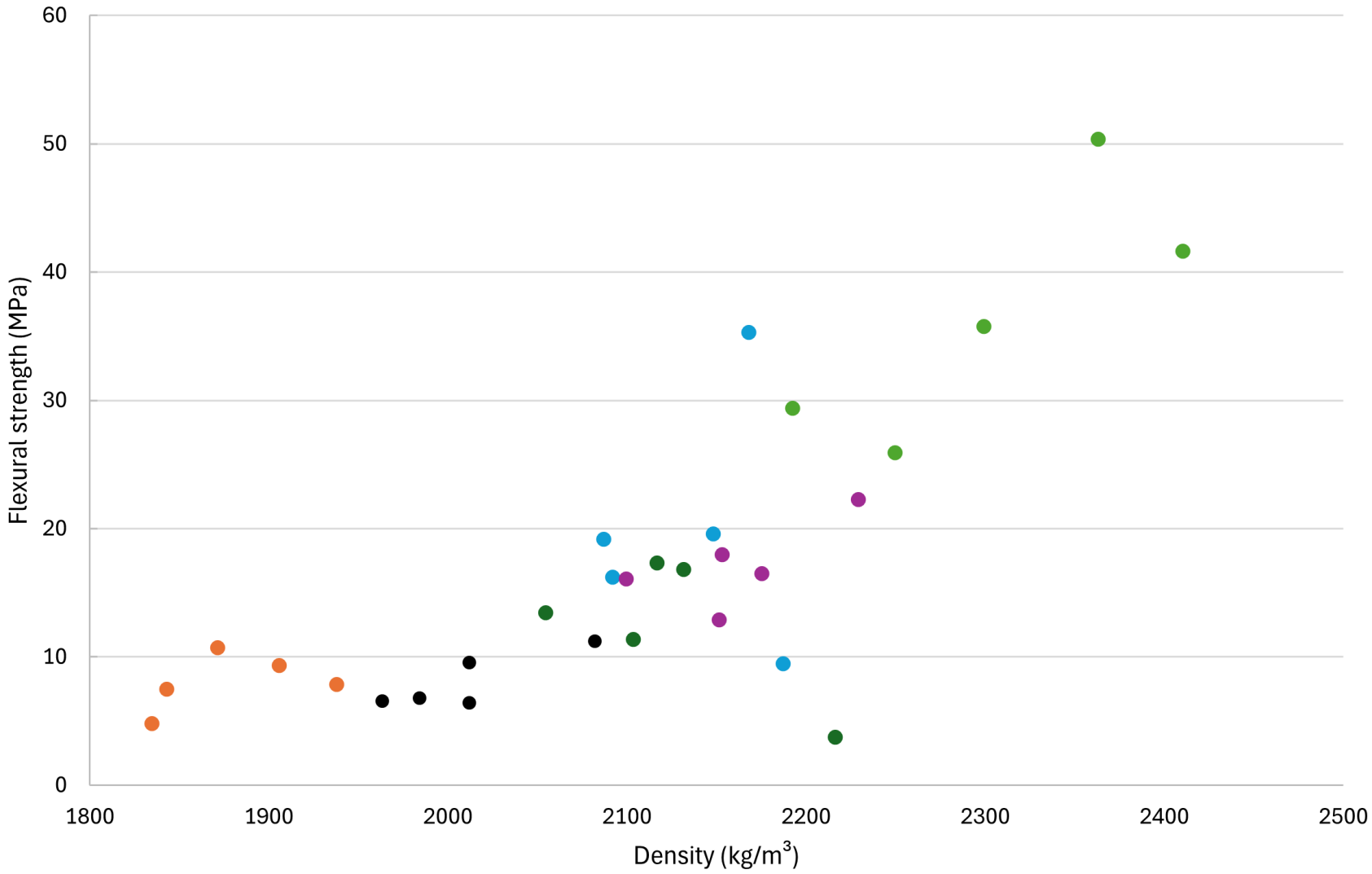
Validation | results



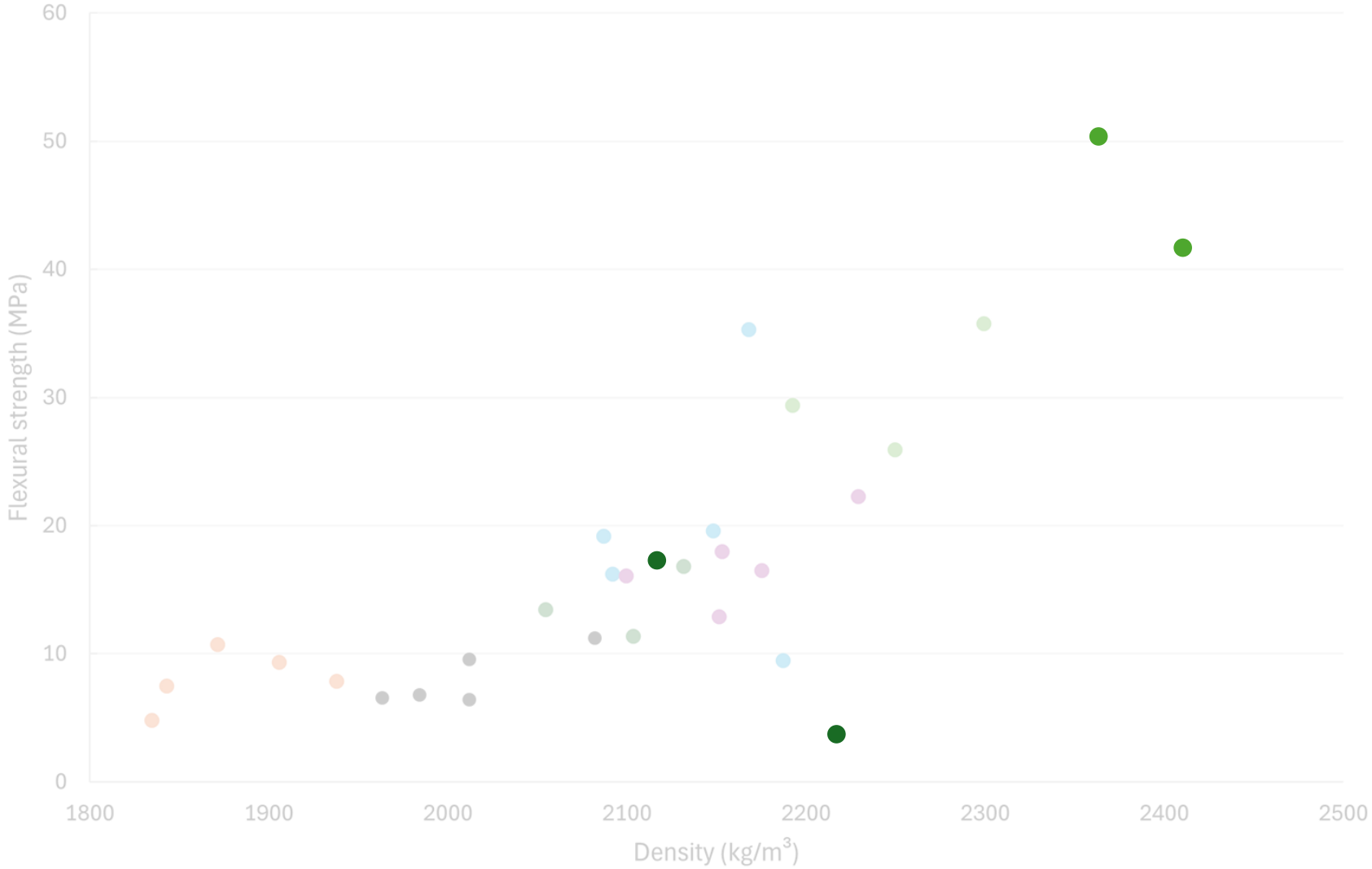
Validation | comparison



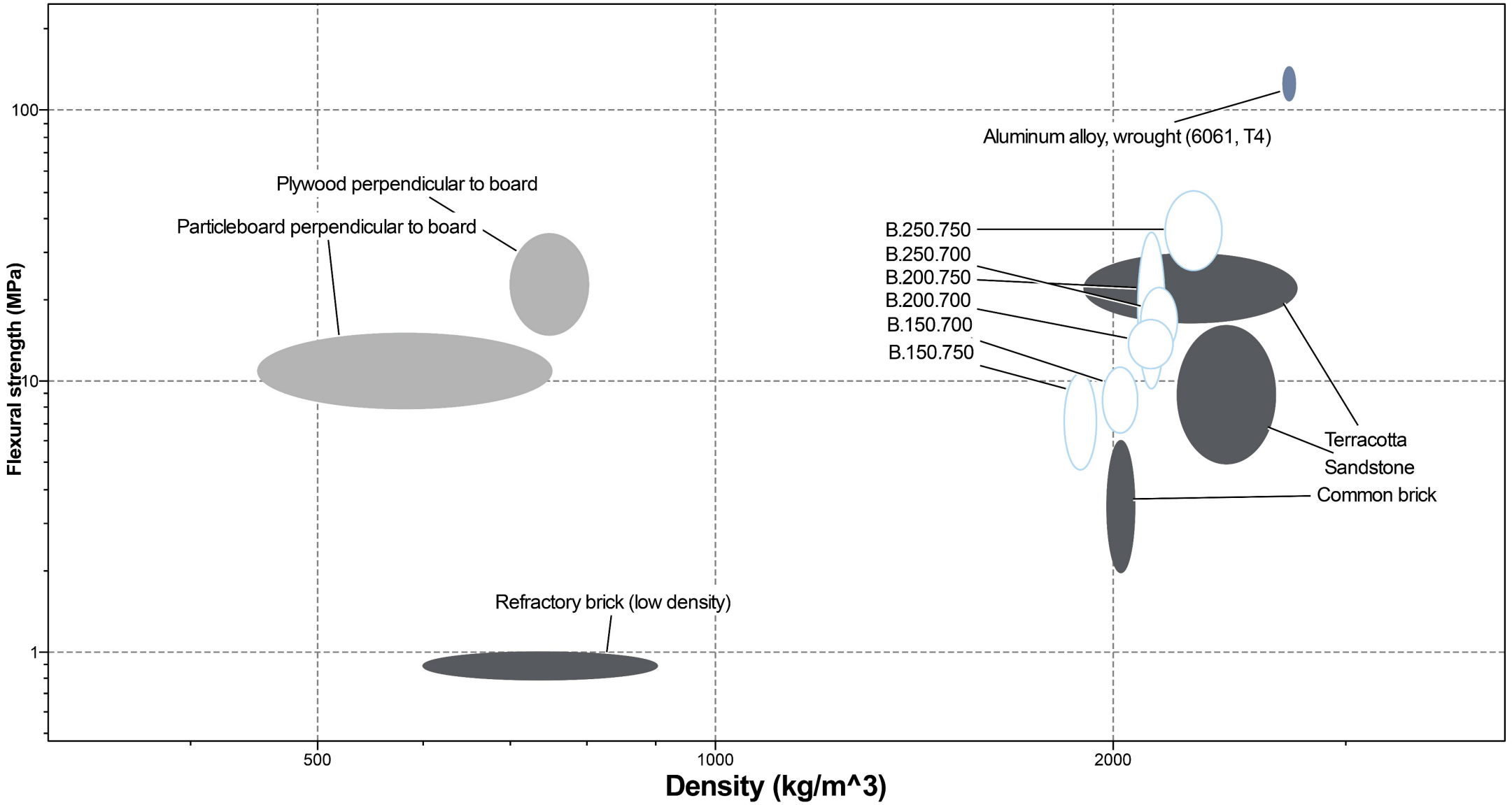
Validation | results



Validation | results



Validation | comparison



Validation | conclusion

Beam shape

Compaction gradient for lower pressures

Corners stay crumbly

Inhomogeneous compaction

Bending test

Identical samples give different results

Increasing temperature and pressure results in higher bending strength

Application

Application | aesthetic properties

Application | surface finish

Smooth untreated

Textured untreated

Polished

Semi polished

Application | composites

S1

S5

S3

S1 (sandwich)

Application | properties

Mechanical properties

50% bending strength of ‘general’ aluminium

Aesthetic properties

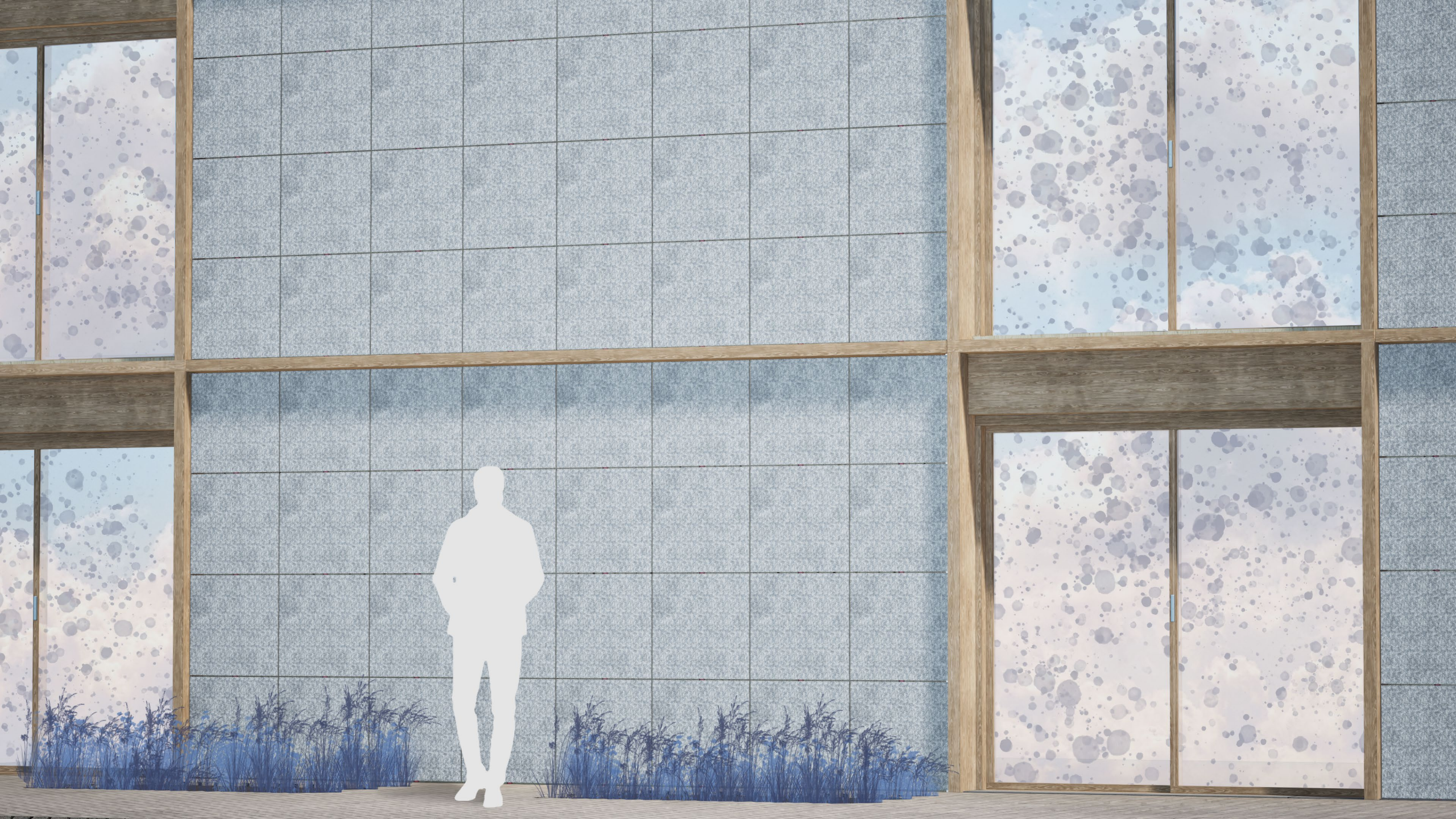
Non heated | reflective and visually very interesting

Heated | reflective after surface treatment, less interesting in general

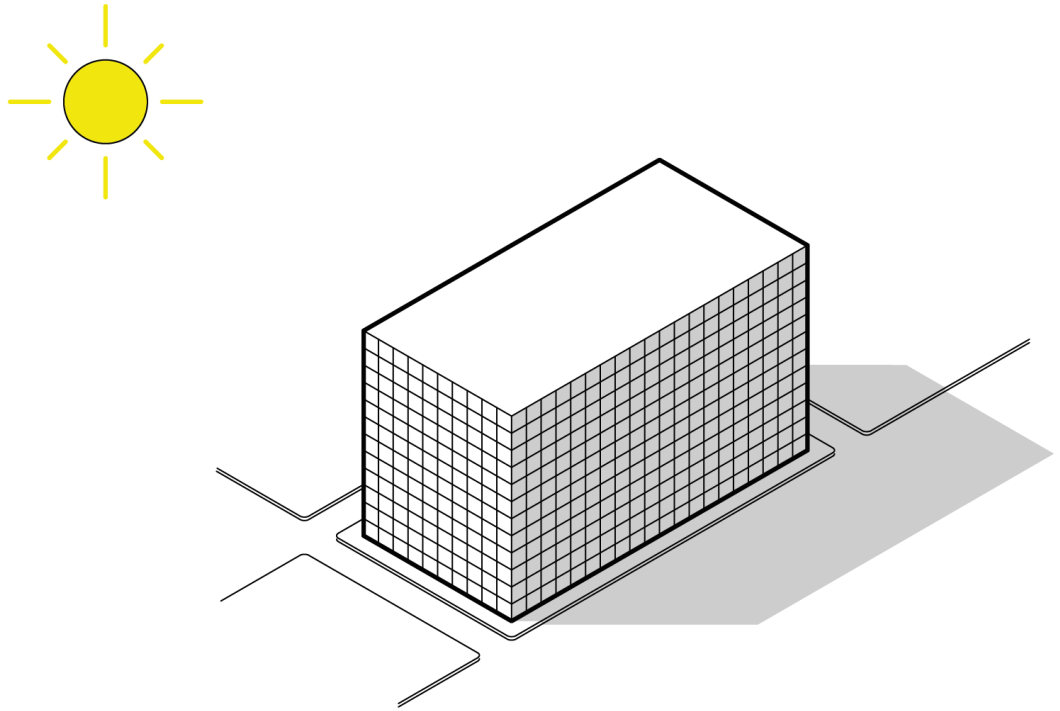
Thermal properties

Assumed to be comparable to normal aluminium

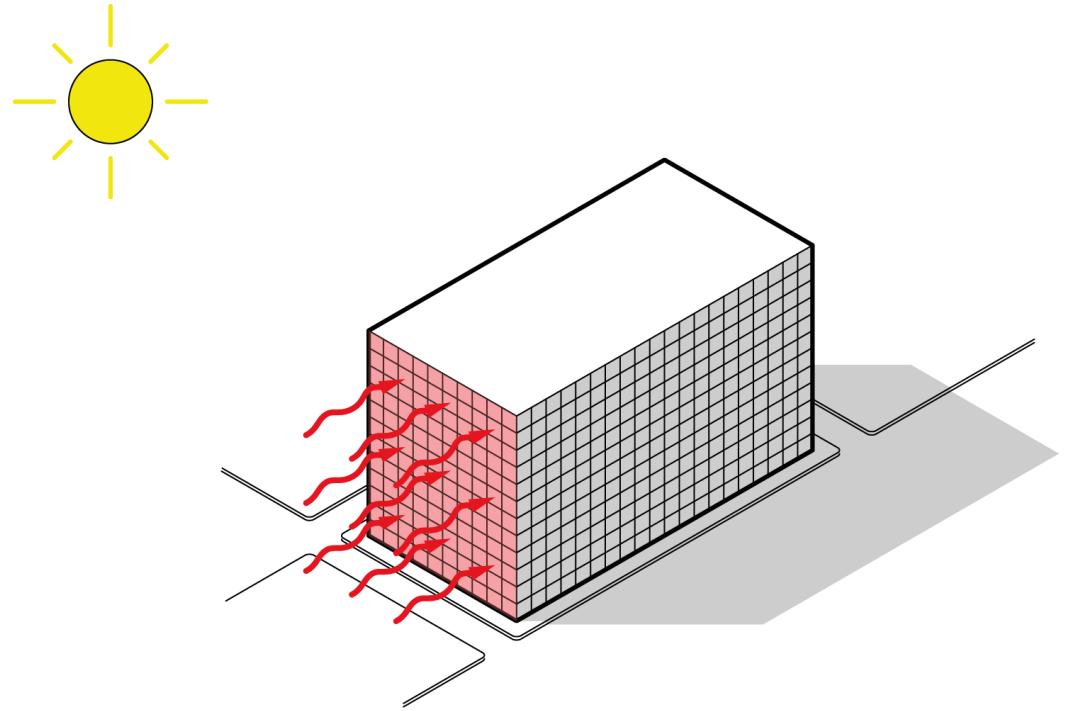
Application | AluFlux



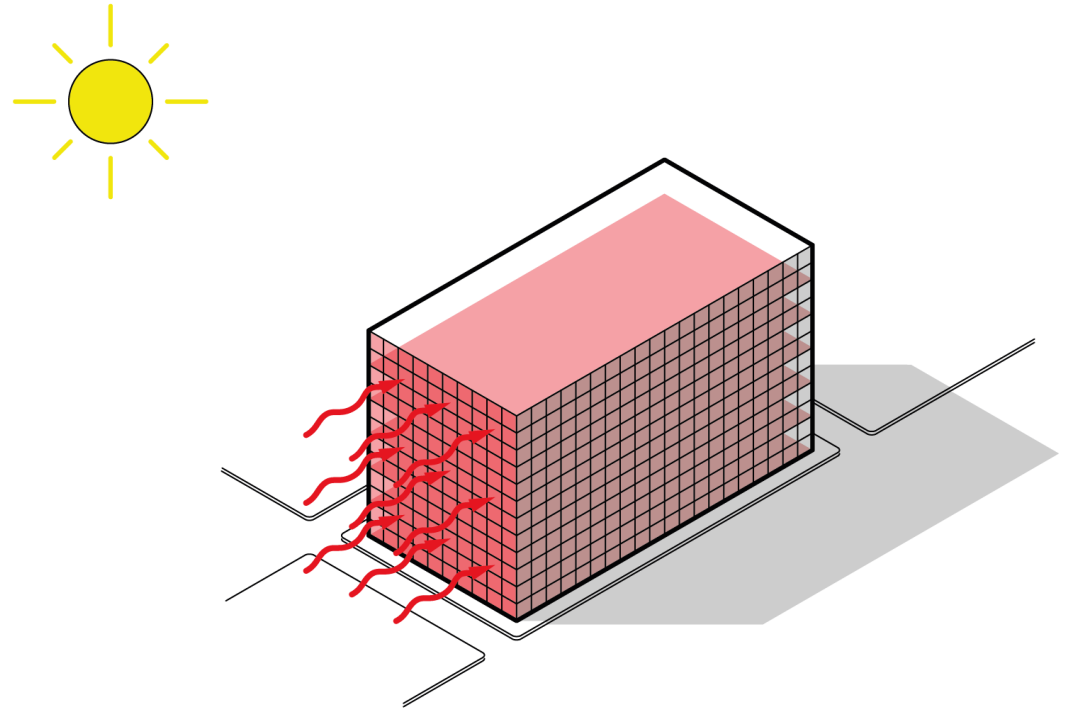
Facades as thermal heat exchanger



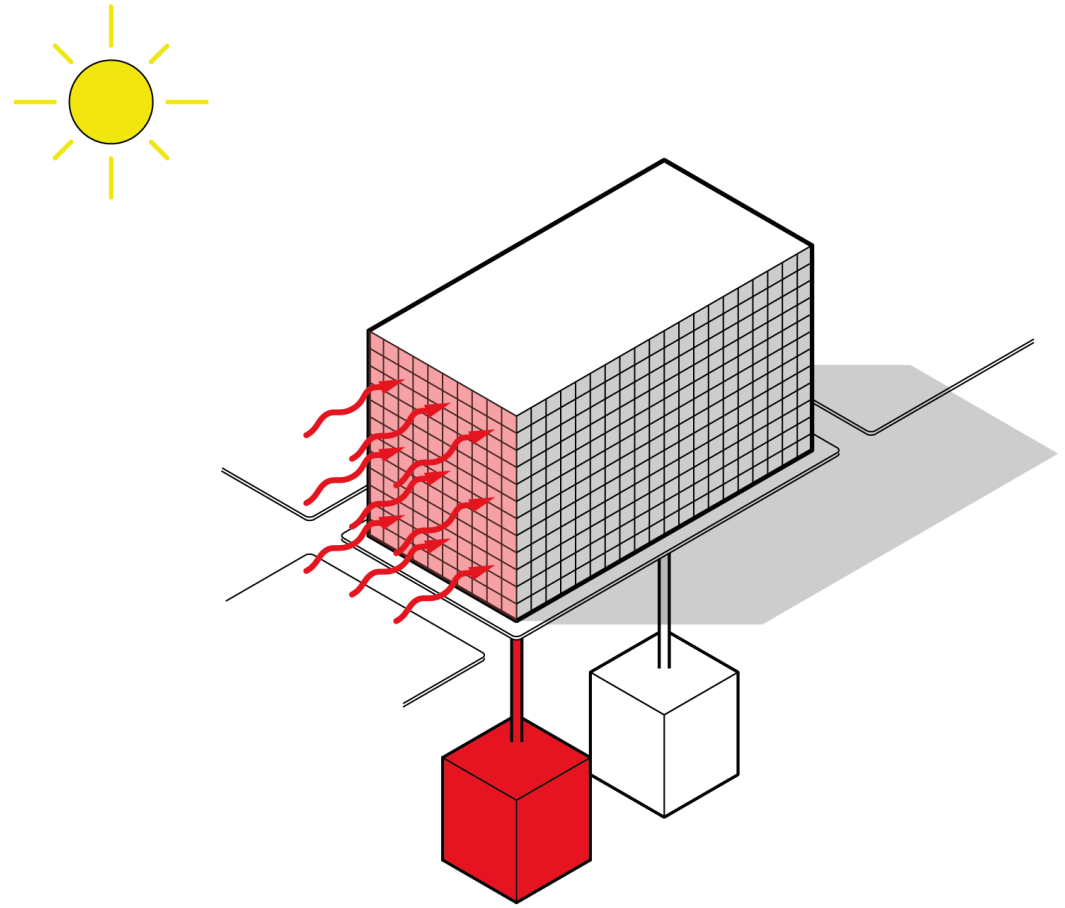
Facades as thermal heat exchanger | harvesting heat



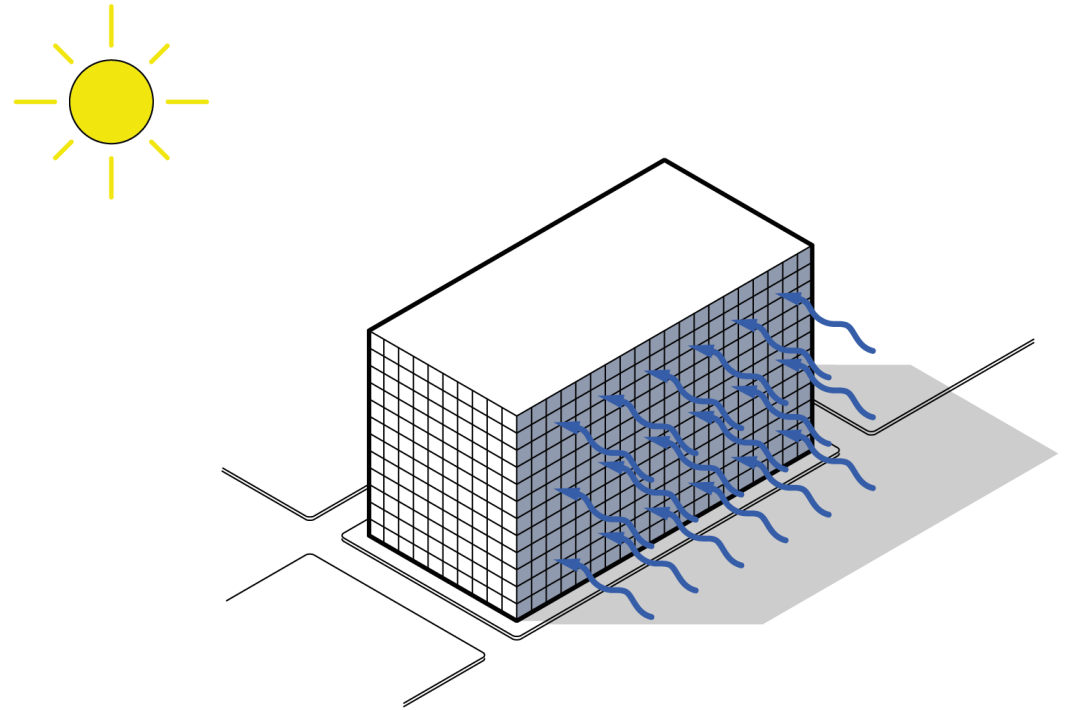
Facades as thermal heat exchanger | harvesting heat



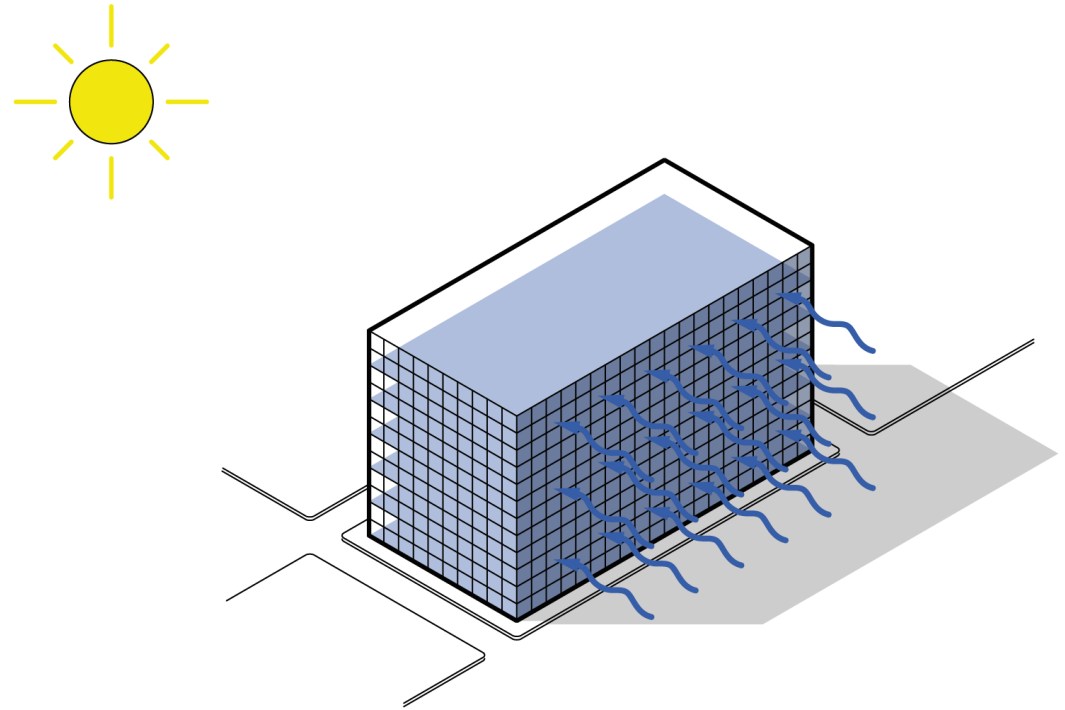
Facades as thermal heat exchanger | harvesting heat



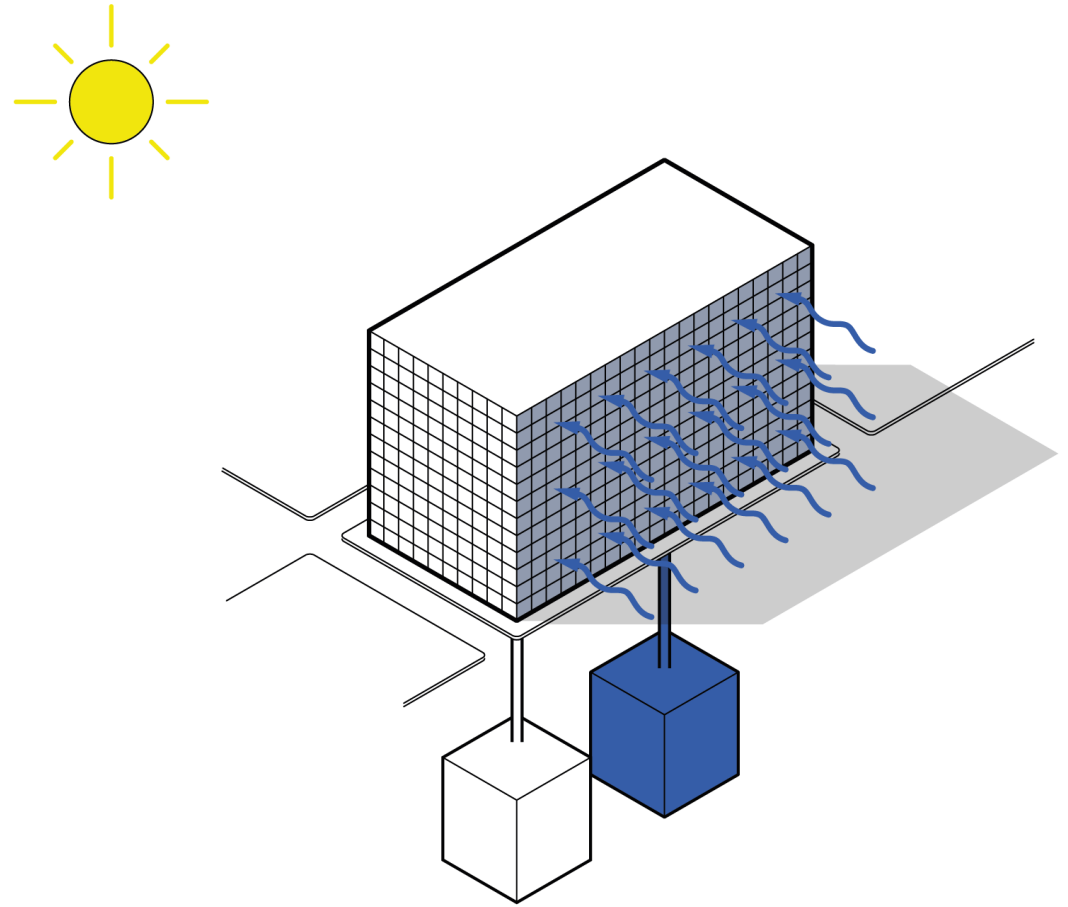
Facades as thermal heat exchanger | harvesting cold



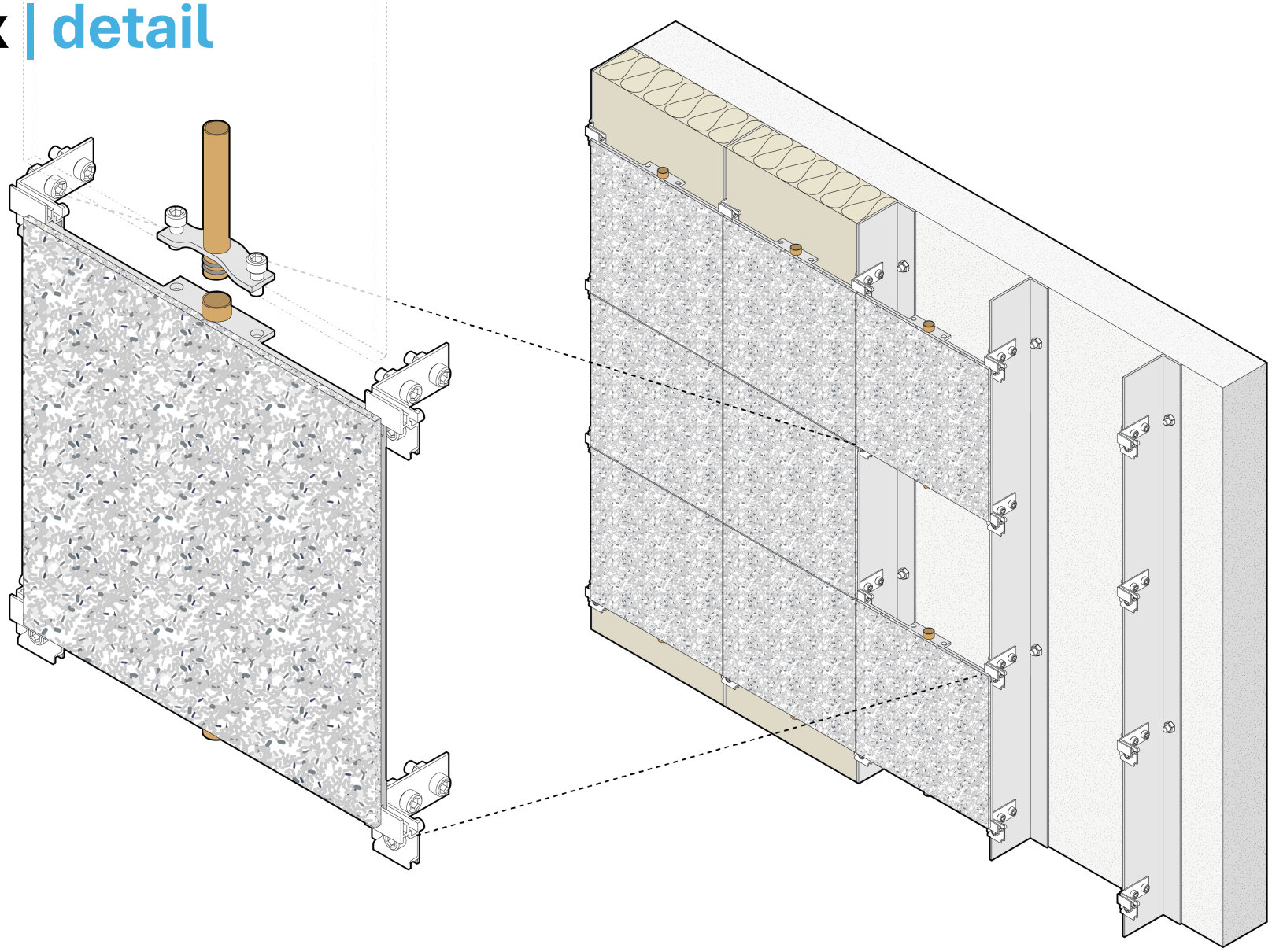
Facades as thermal heat exchanger | harvesting cold

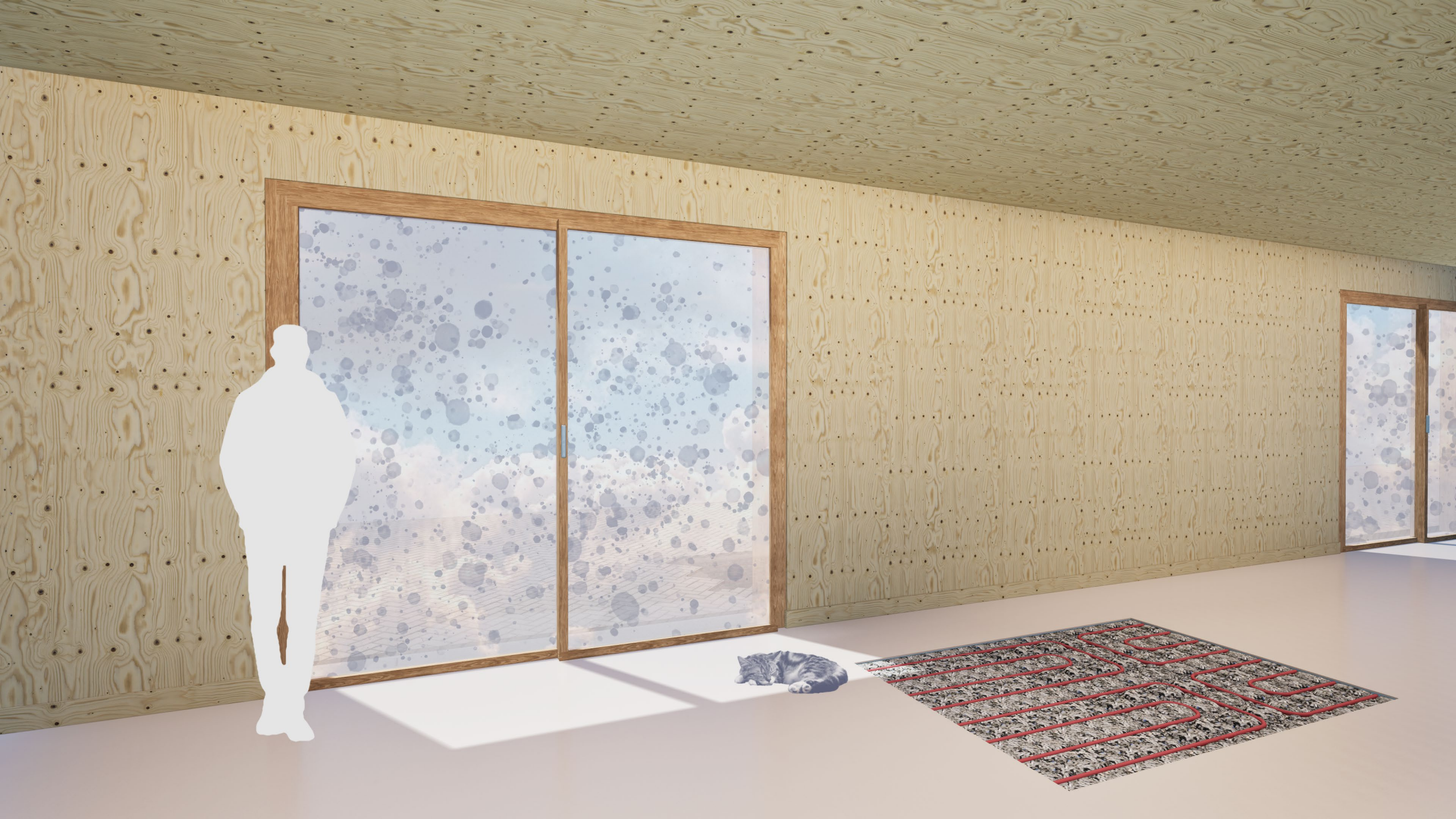


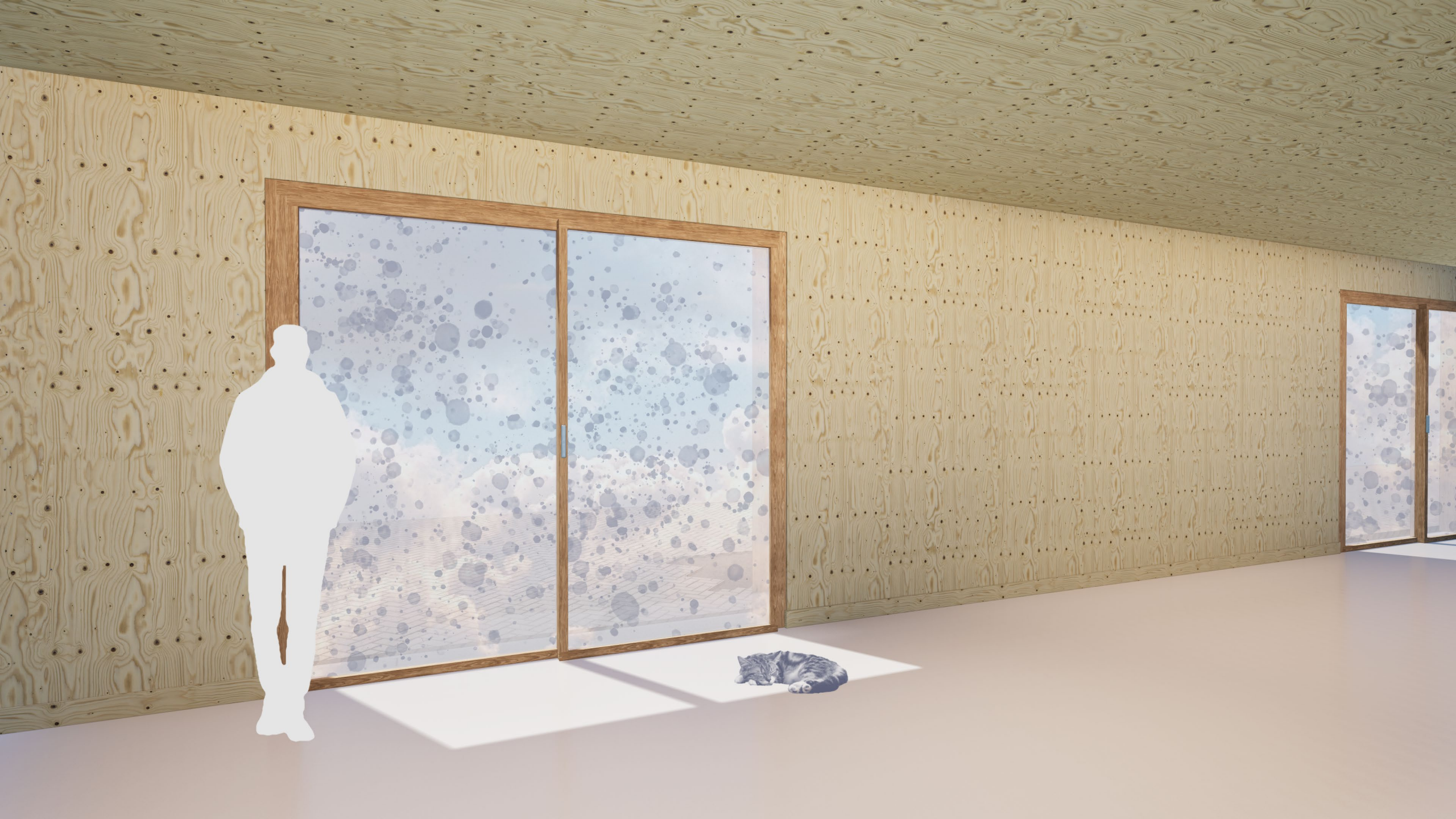
Facades as thermal heat exchanger | harvesting cold

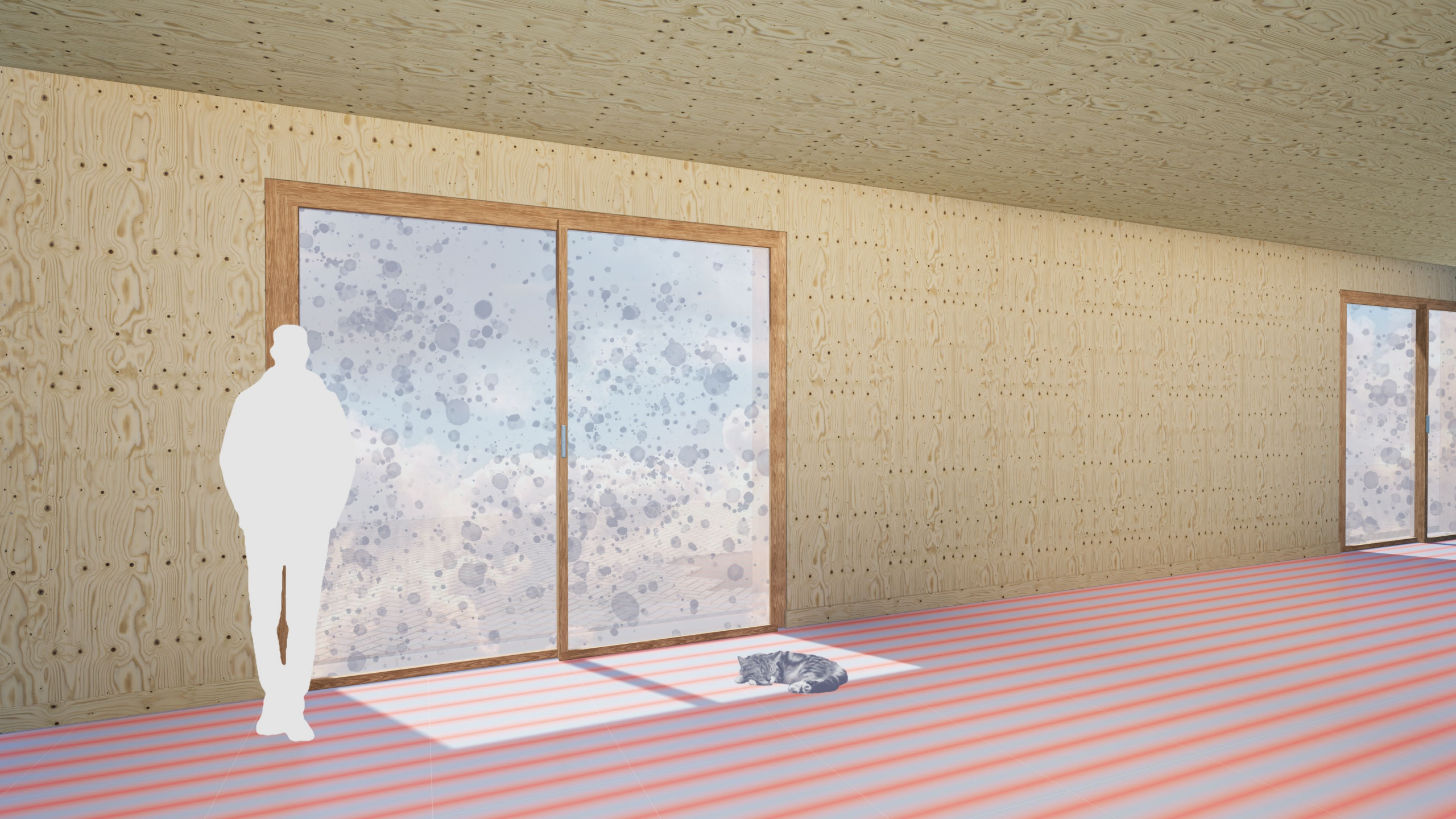


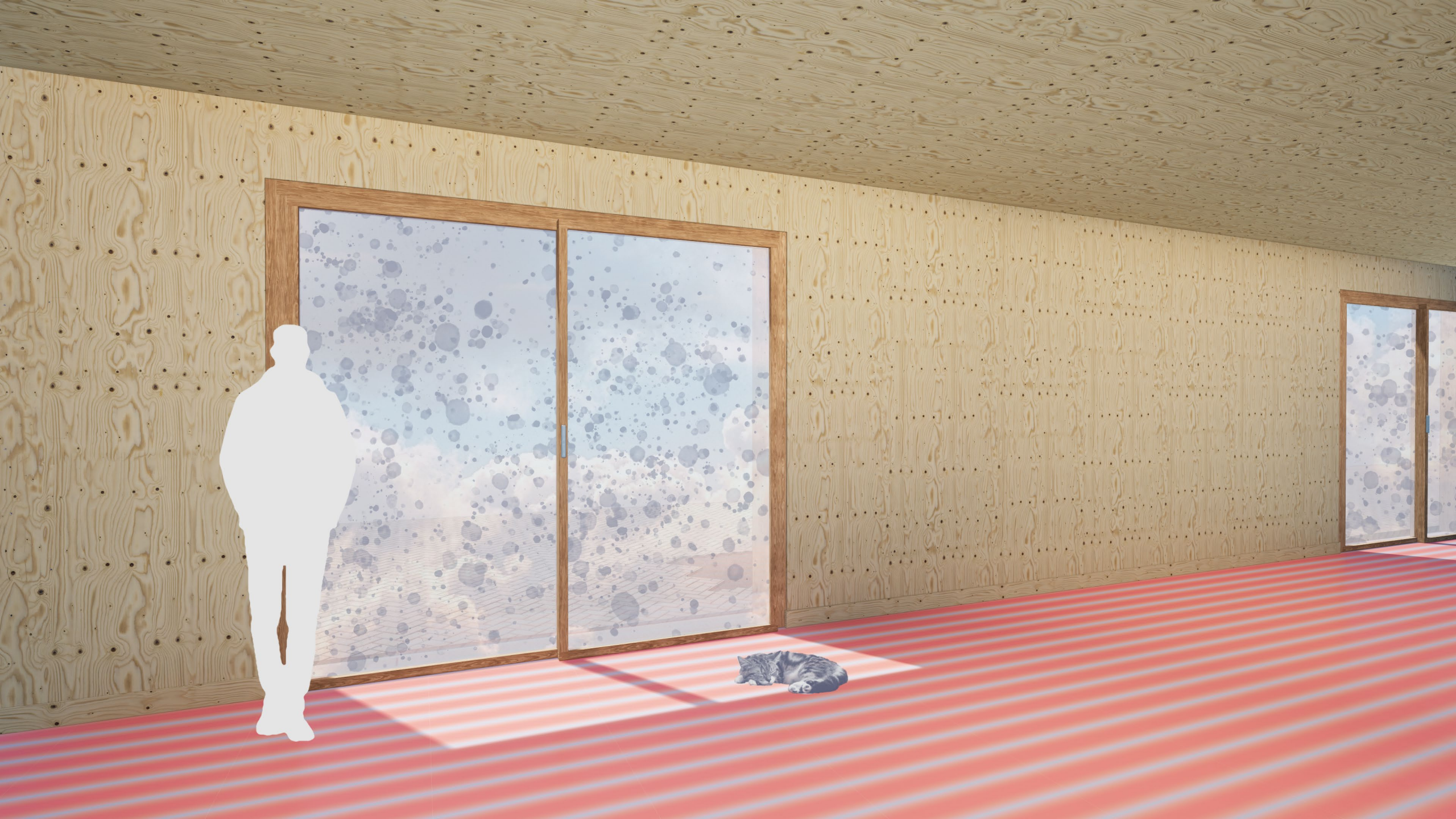
AluFlux | detail



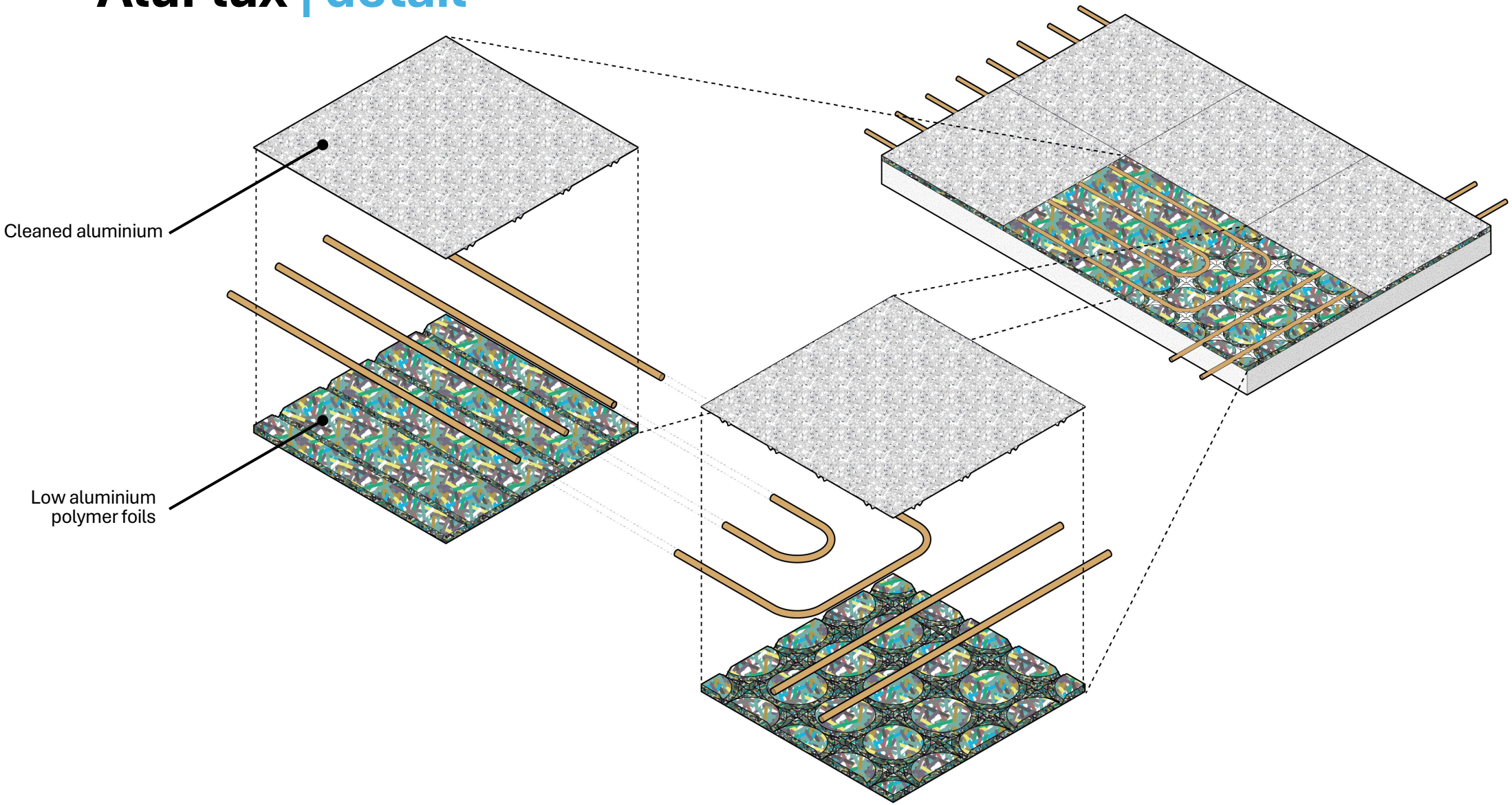




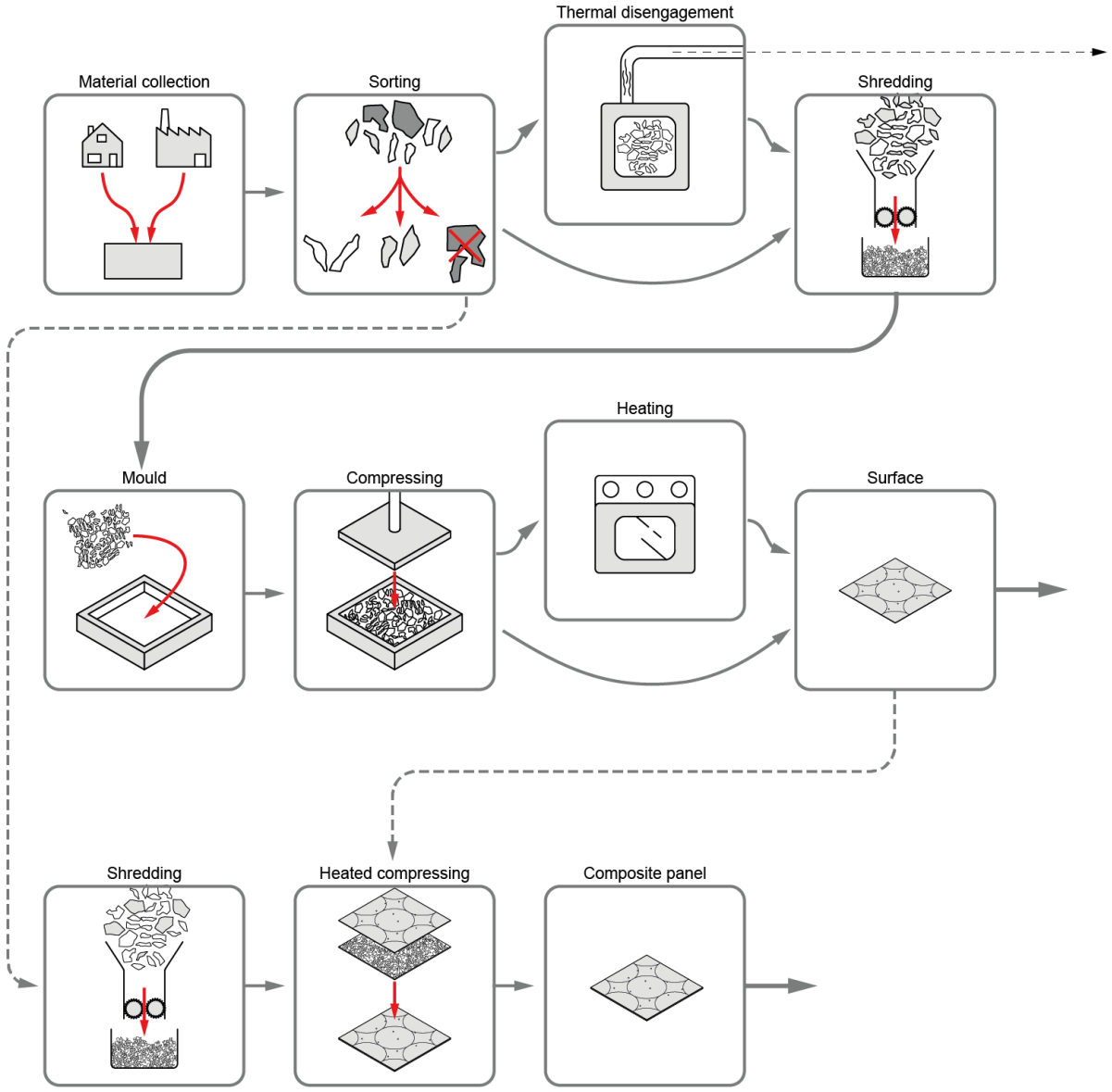




AluFlux | detail



AluFlux | production & assembly



Conclusion

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“How can **unrecycled**, **mixed metal waste** be **reprocessed** into **new materials** for **architectural applications**?”

Metal waste streams

Unrecycled due to complexity

Aluminium composite foils

Reprocessing

Labor intensive

Viable results

Application

AluFlux

Never the ‘perfect’ material – good enough

Limitations

Granulation size

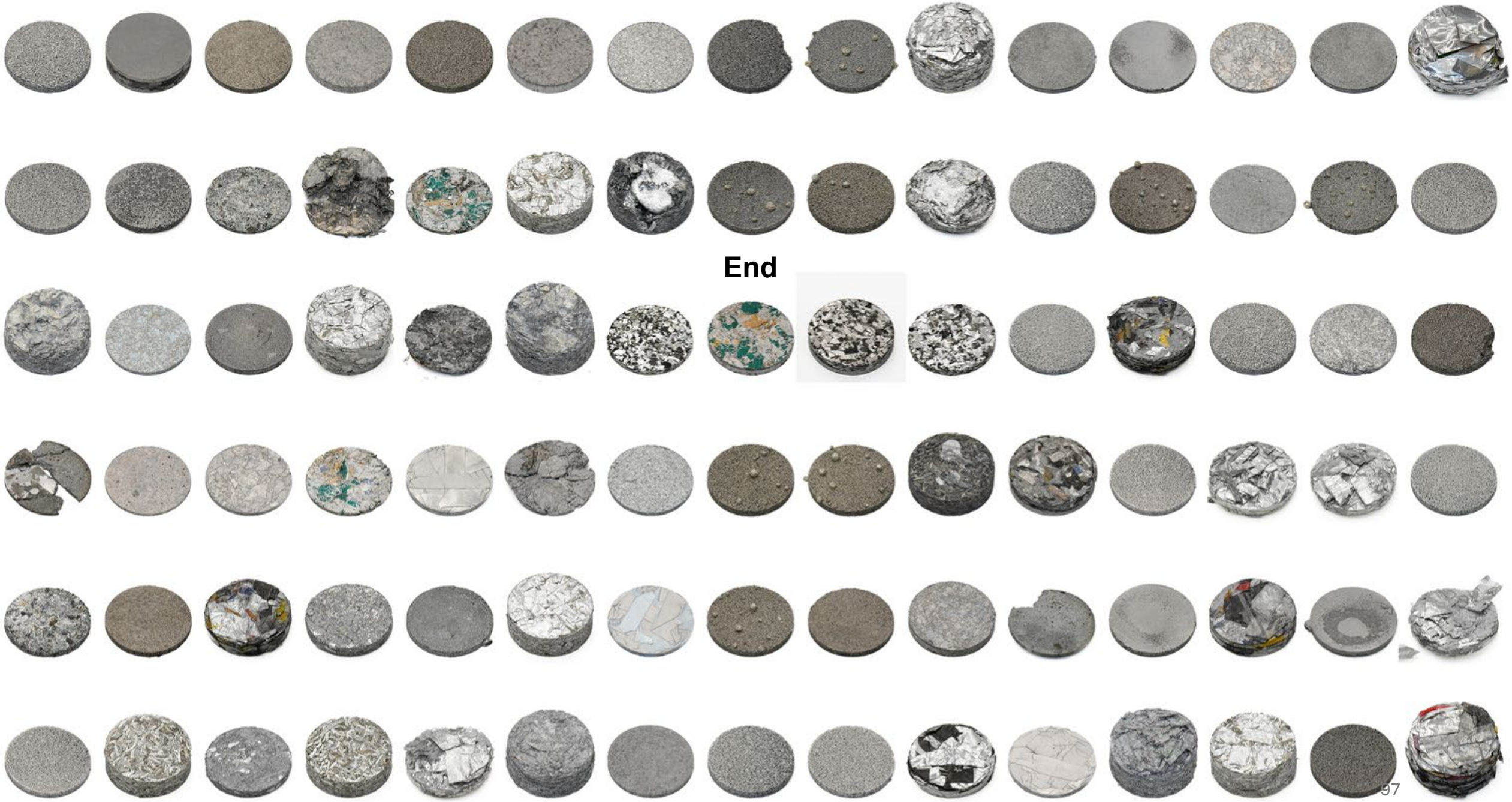
Smaller → better binding

Bigger → less surface for oxidation

Oxygen limited environment

Thermal disengagement

Heating → no oxidation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