

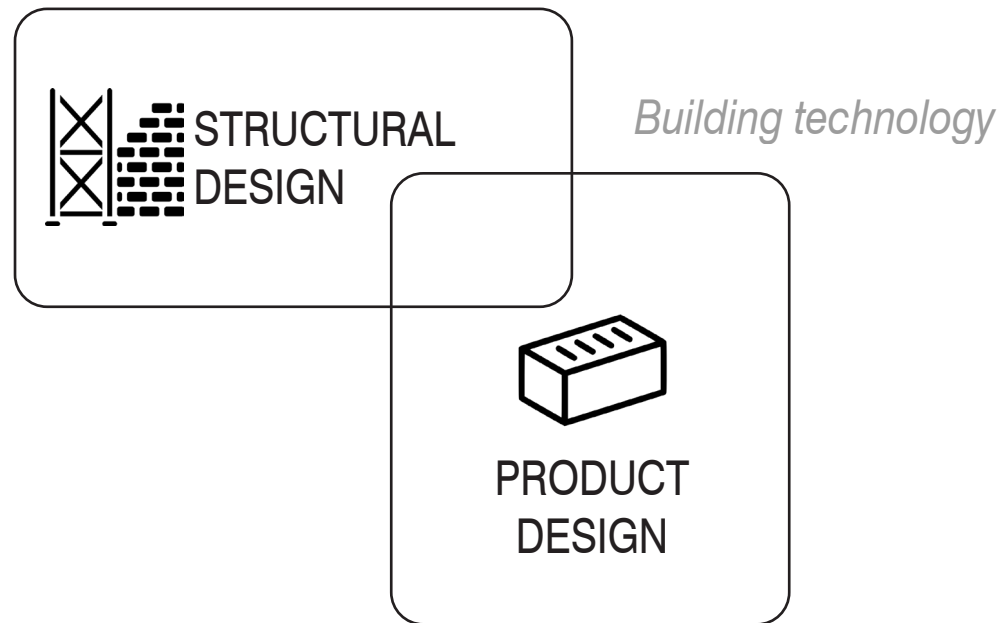
PLAX

Flax Fibre Reinforced Composites with Foamed PLA Core
for Fully Bio-based Sandwich Floor System

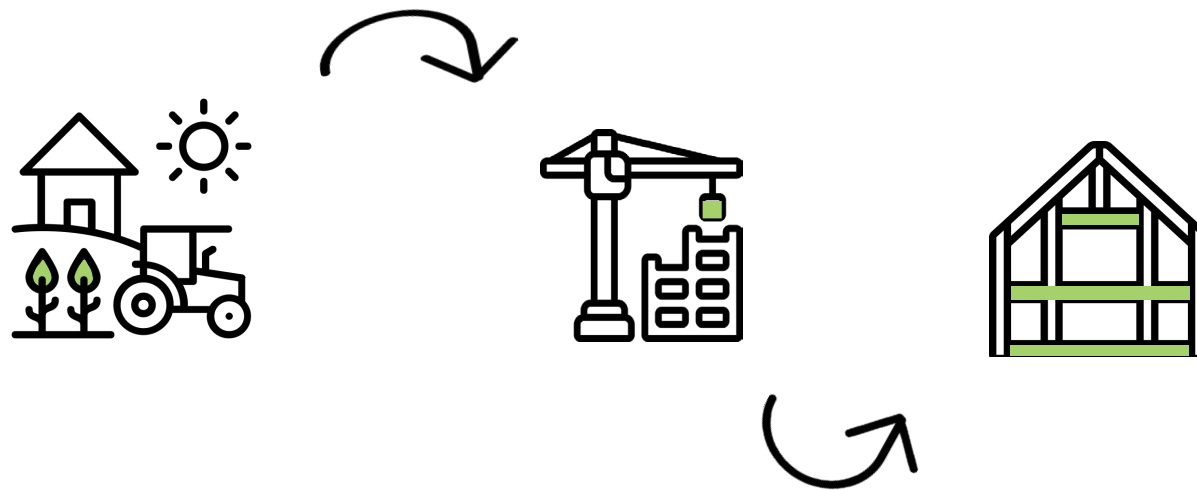


Ece Sel
TU Delft | Building Technology 2024
Mentors: Prof. Dr. Mauro Overend
Dr. Ing. Marcel Bilow
Faculty of Architecture and Built Environment

*Flax Fibre Reinforced Composites with Foamed PLA Core
for Fully Bio-based Sandwich Floor System*



from garden to the our buildings as floors



but why there is a need for that?



Global warming

but why there is a need for that?

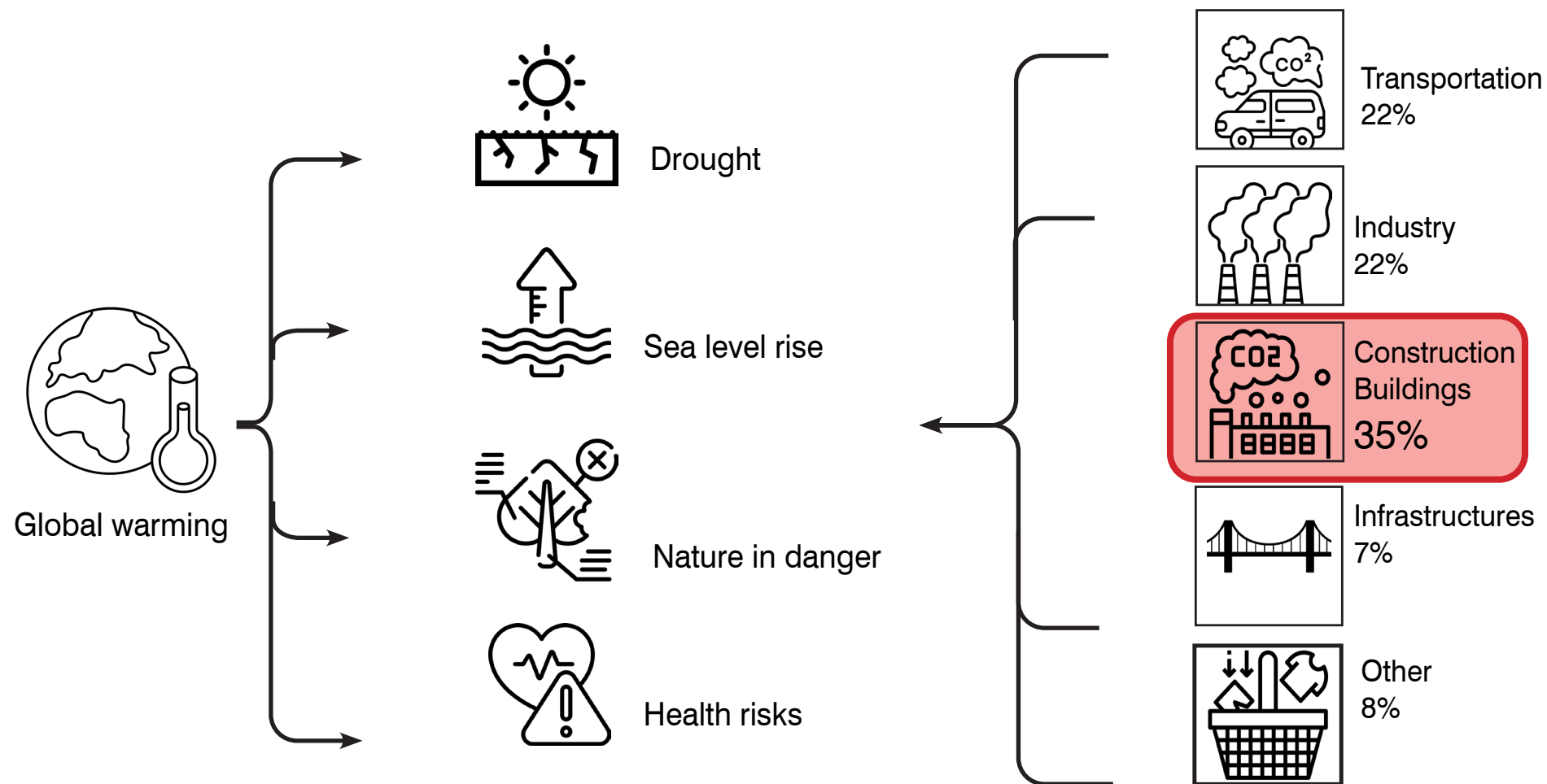
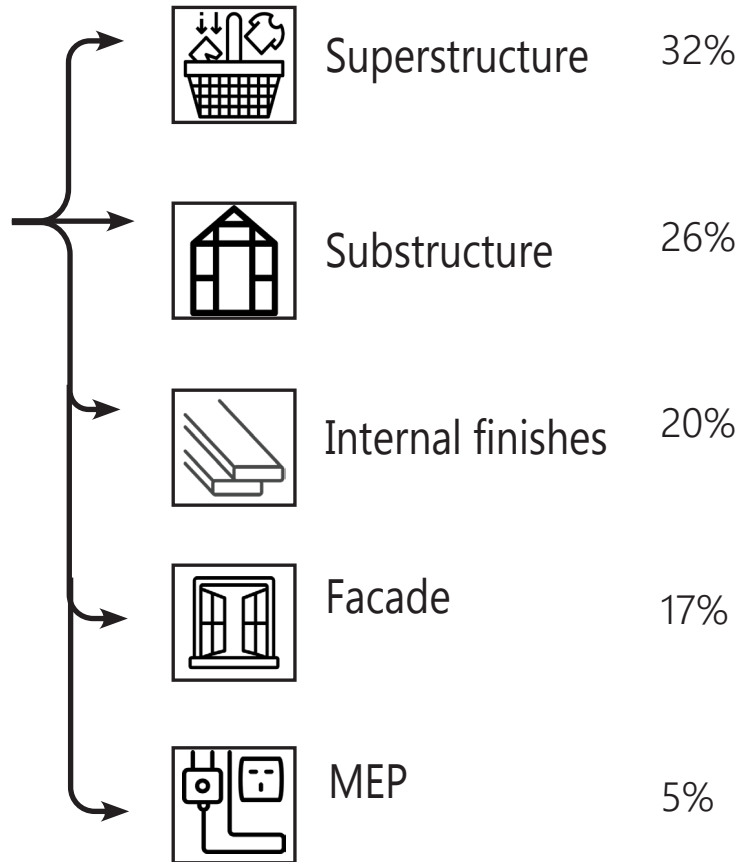


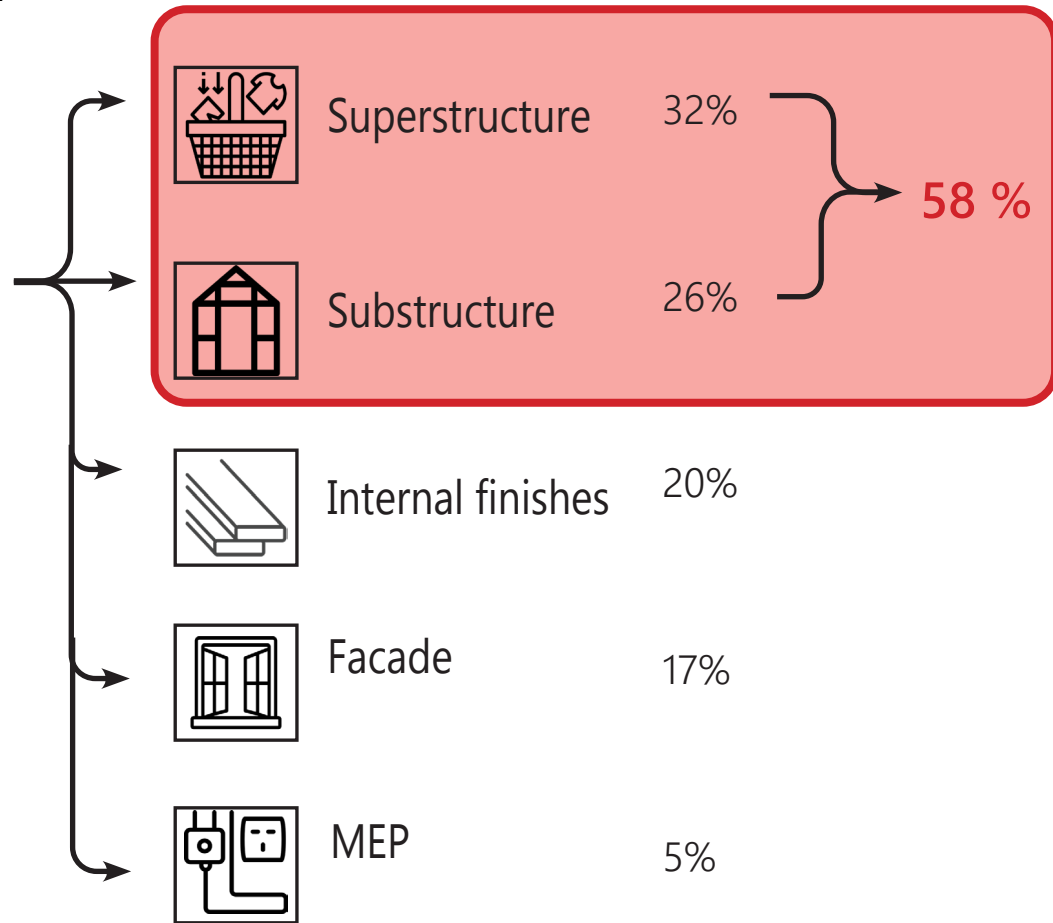
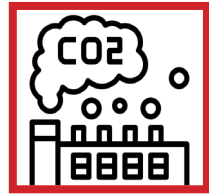
Figure 1: Carbon emission by sectors. (Why Buildings – Architecture 2030; ISA; Statista)

Construction
Buildings
35%

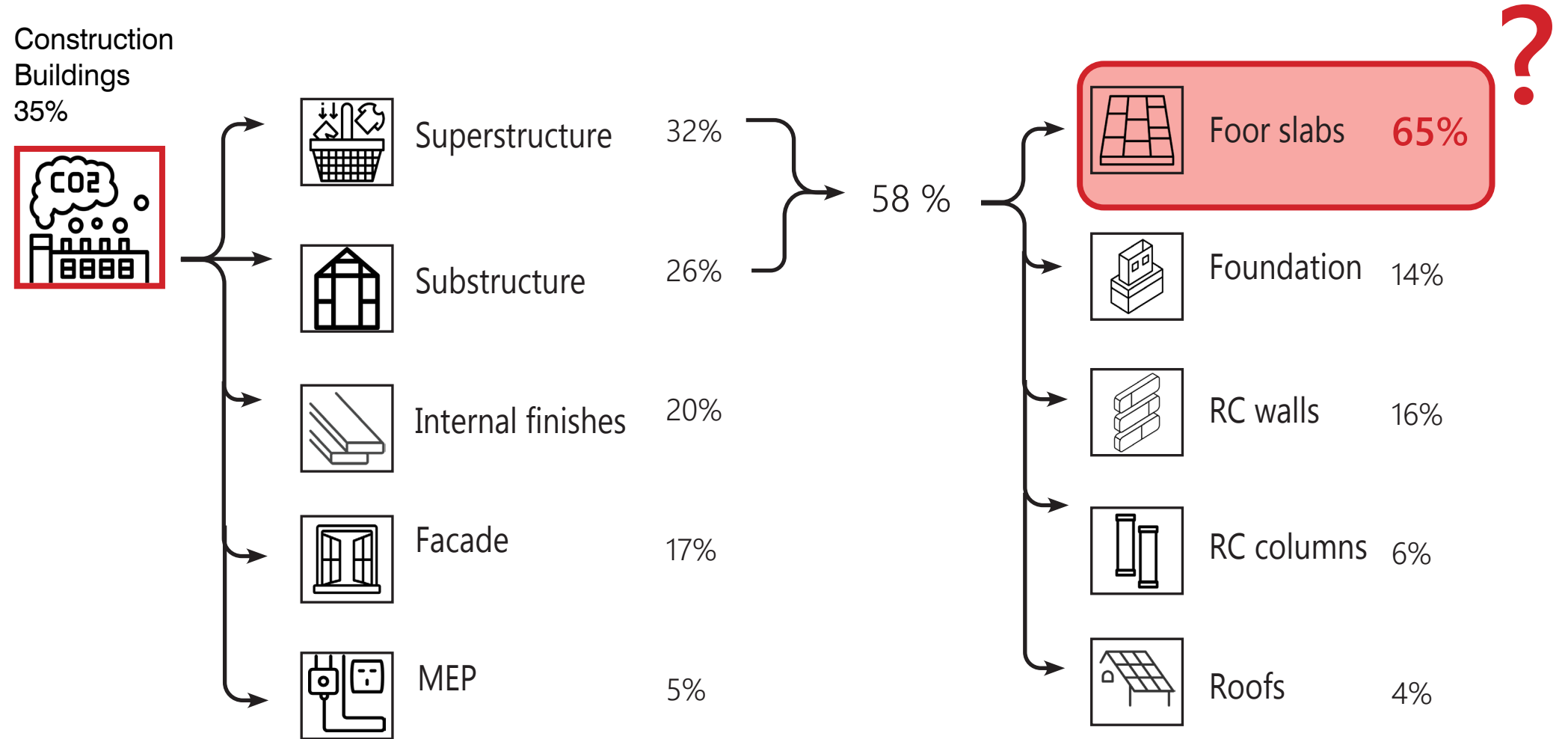


Source: Embodied carbon percentages of each building structures for a small scale building. Diagram is reproduced. (LETI,2023)

Construction
Buildings
35%

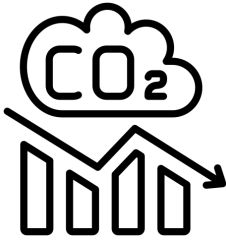


Source: Embodied carbon percentages of each building structures for a small scale building. Diagram is reproduced. (LETI,2023)

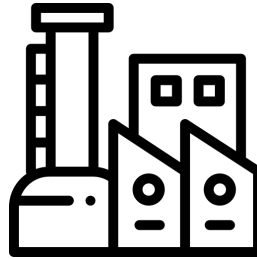


Source: Embodied carbon percentages of each building structures for a small scale building. Diagram is reproduced. (LETI,2023)

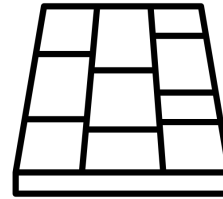
firstly setting the GOALs



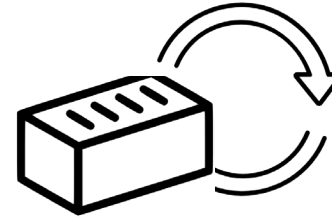
AIM
Reduction in
carbon footprint



TARGET
Construction industry
and materials



APPLICATION
FLOORS panels
(as the main approach)

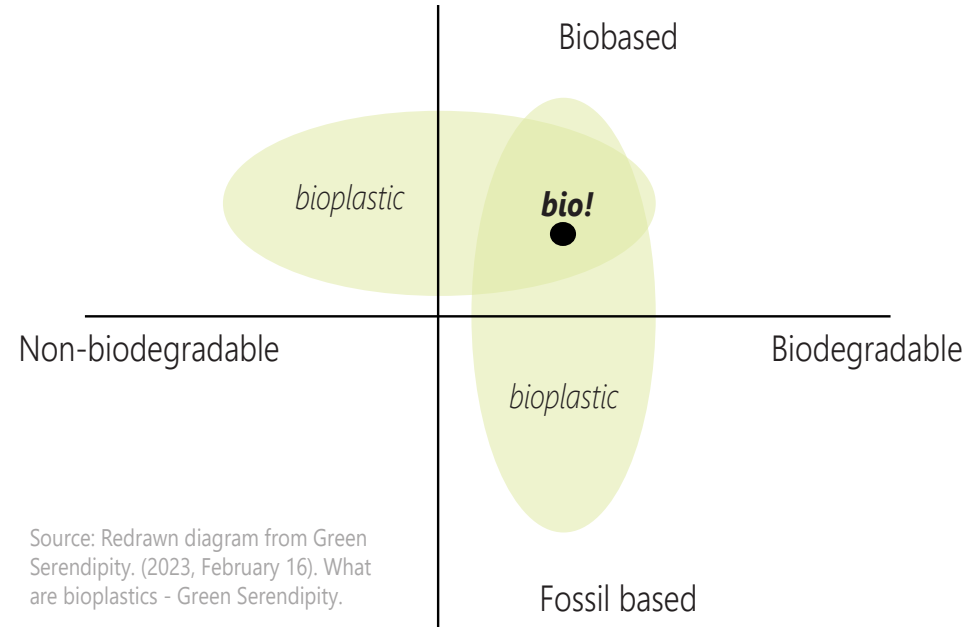


HOW
By going fully-biobased and
circular for components.

by going *GREEN* and *CIRCULAR*



Avoid fossil based

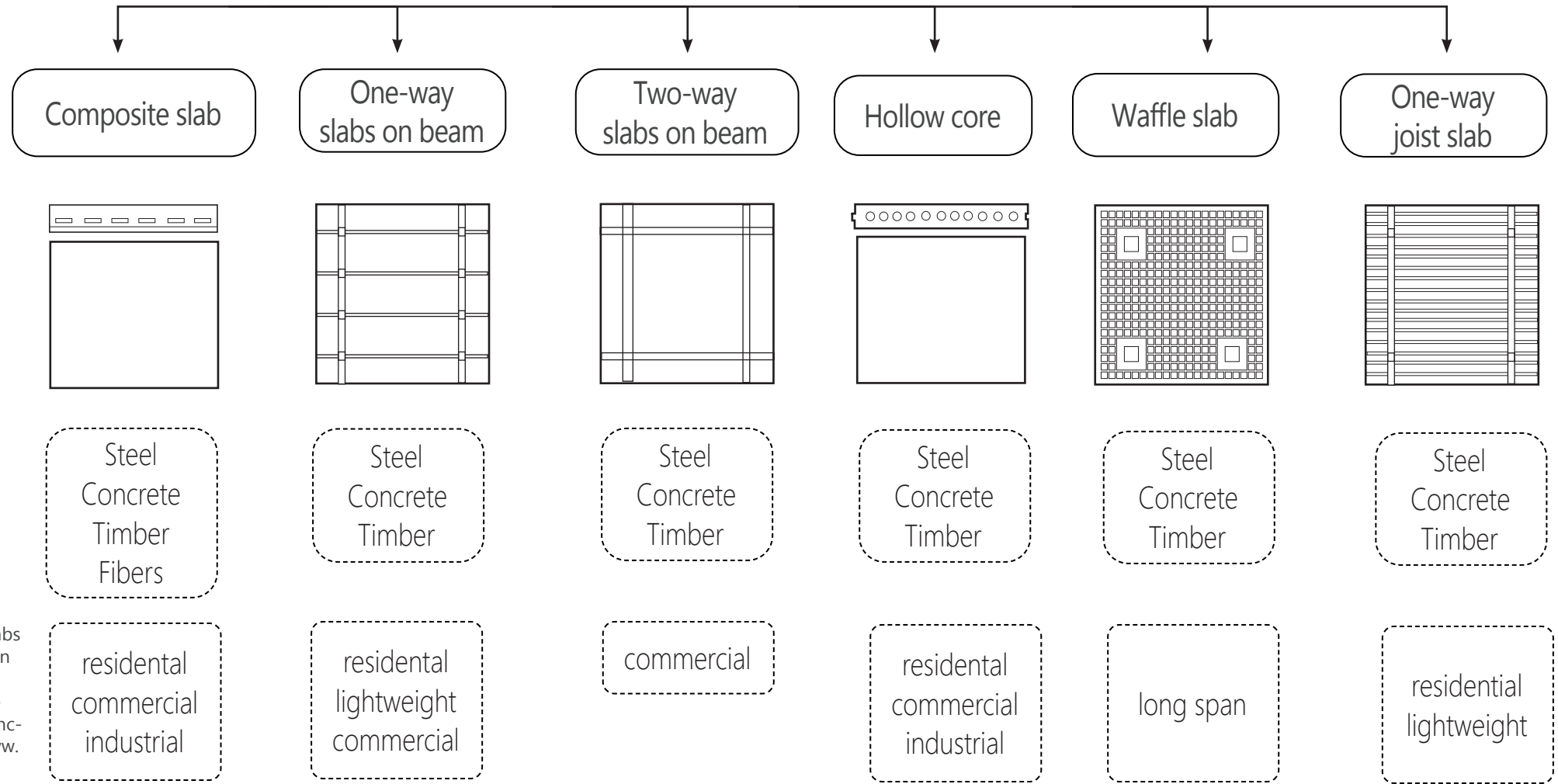


Source: Redrawn diagram from Green Serendipity. (2023, February 16). What are bioplastics - Green Serendipity.

chapter 1

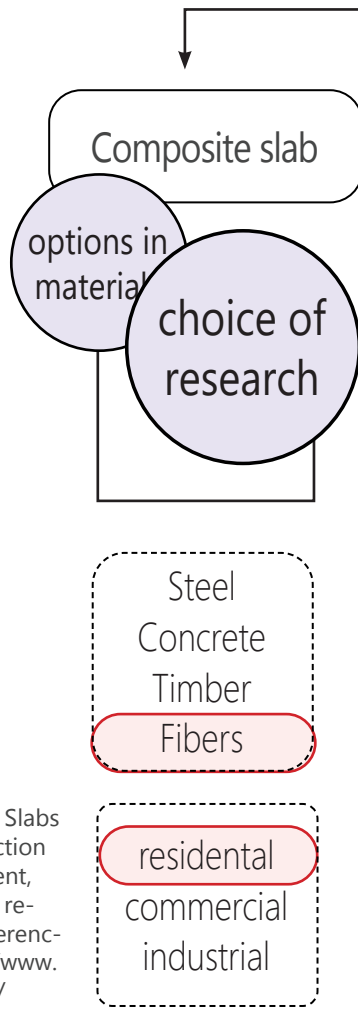
LITERATURE REVIEW

Floor Slabs



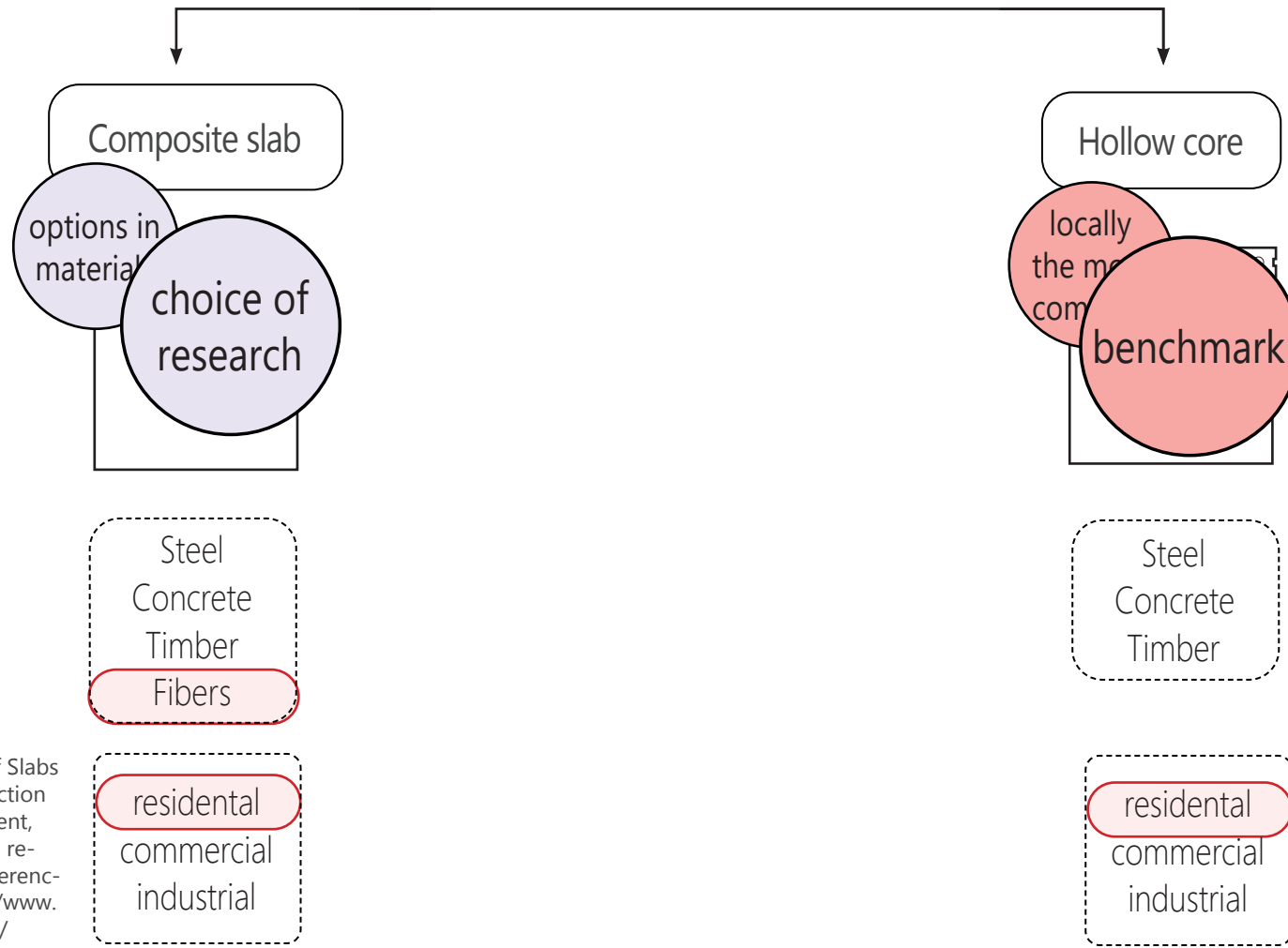
Source: Types of Slabs Used in Construction | UltraTech Cement, n.d.); Images are reproduced by referencing from <https://www.dimensions.com/>

Floor Slabs



Source: Types of Slabs Used in Construction | UltraTech Cement, n.d.); Images are reproduced by referencing from <https://www.dimensions.com/>

Floor Slabs

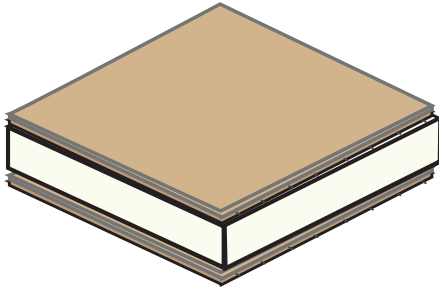


Source: Types of Slabs
Used in Construction
| UltraTech Cement,
n.d.); Images are re-
produced by referenc-
ing from [https://www.
dimensions.com/](https://www.dimensions.com/)

Floor Slabs



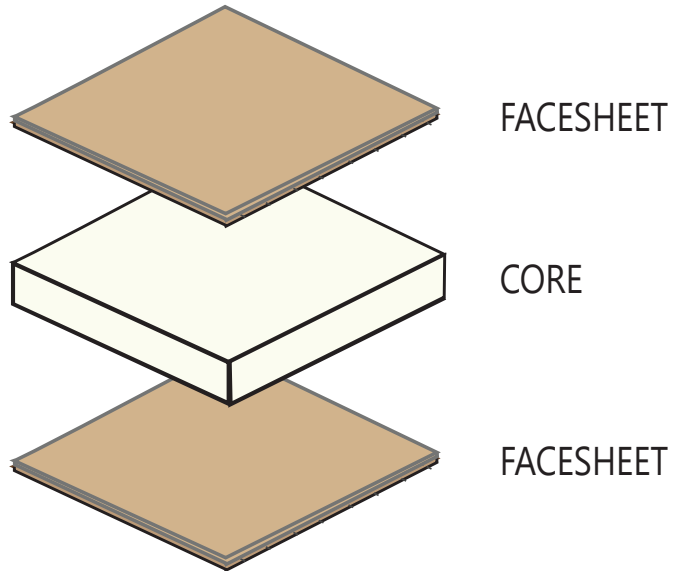
Composite Sandwich Slab



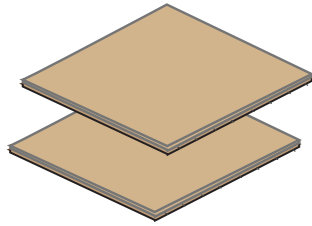
Floor Slabs



Composite Sandwich Slab

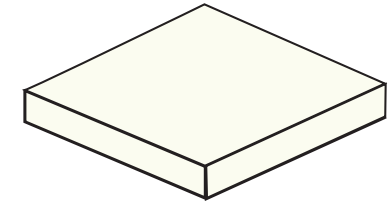


Sandwich panels



FACESHEET

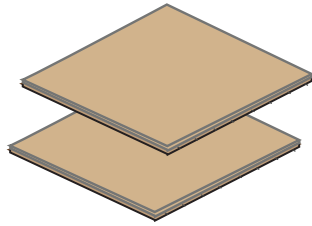
- Strength:
Tensile & Compressive
- Stiffness
- Durability
- Resistance



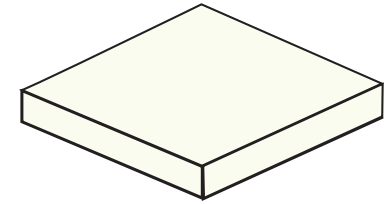
CORE

- Shear Strength
- Lightweight
- Resistance
- Acoustical & Thermal
properties
- Cost-effective

Sandwich panels



FACESHEET



CORE

- Strength:
Tensile & Compressive

- Stiffness

- Durability

- Resistance

within
research
framework

- Shear Strength:

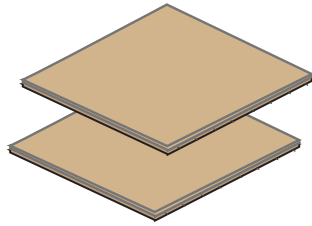
- Lightweight

- Resistance

- Acoustical & Thermal
properties

- Cost-effective

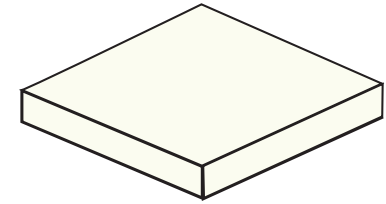
Sandwich panels



FACESHEET

- Strength:
Tensile & Compressive
- Stiffness
- Durability
- Resistance

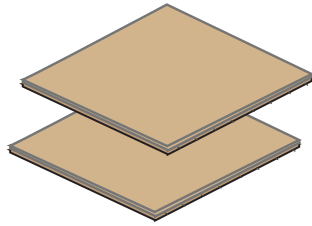
not
within the
framework



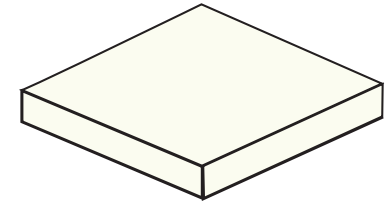
CORE

- Shear Strength:
- Lightweight
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- Cost-effective

Sandwich panels



FACESHEET

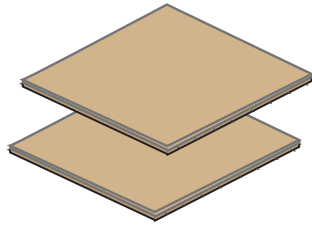


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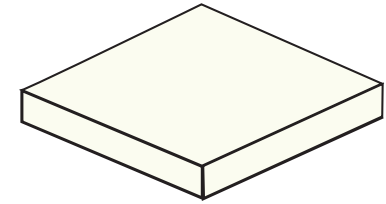
Material		Biodegr.	Renew.	Lightw.	Recycl.	Strength
Aluminium	X	X	X	✓	✓	✓
Steel	X	X	X	X	✓	✓
Glass fiber	X	X	X	✓	X	✓
Carbon fiber	X	X	X	✓	✓	✓
Plywood*	✓	✓	✓*	X	✓	✓

Material		Biodegr.	Renew.	Lightw.	Recyc.	Strength
Aluminum	X	X	X	X	X	✓
Polyurethane	X	X	X	X	-	✓
Styrofoam	X	X	X	X	-	✓
Rockwool	X	X	X	X	X	✓
Cardboard	✓	✓	✓	✓	✓	-

Sandwich panels



FACESHEET



CORE

Material		Biodegr.	Renew.	Lightw.	Recycl.	Strength
Aluminium	X	X	X	✓	✓	✓
Steel	X	X	X	X	✓	✓
Glass fiber	X	X	X	✓	X	✓
Carbon fiber	X	X	X	✓	✓	✓
Plywood*	✓	✓	✓*	X	✓	✓

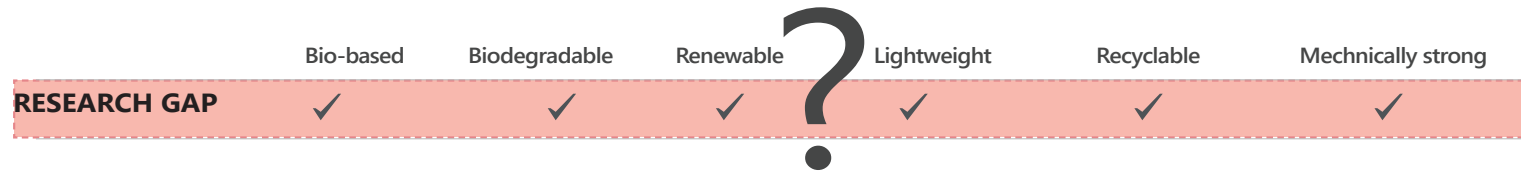
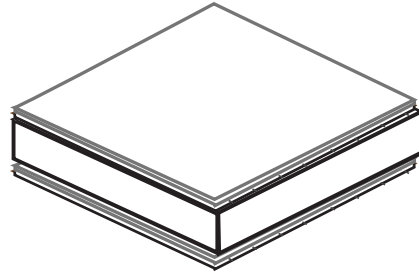
**RESEARCH
GAP**

✓ ✓ ✓ ✓ ✓ ✓

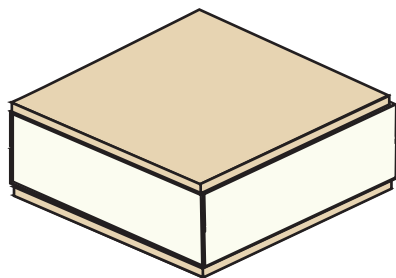
Material		Biodegr.	Renew.	Lightw.	Recyc.	Strength
Aluminum	X	X	X	X	X	✓
Polyurethane	X	X	X	X	-	✓
Styrofoam	X	X	X	X	-	✓
Rockwool	X	X	X	X	X	✓
Cardboard	✓	✓	✓	✓	✓	-

**RESEARCH
GAP**

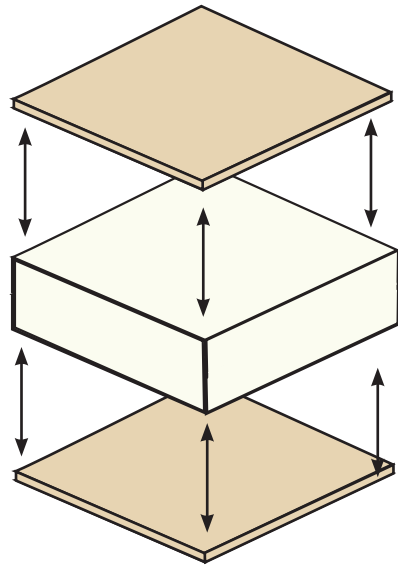
✓ ✓ ✓ ✓ ✓ ✓



“Could a novel fully-biobased sandwich flooring systems outperform conventional flooring systems”

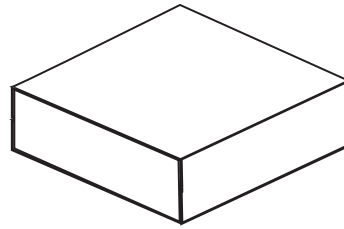


sandwich panel

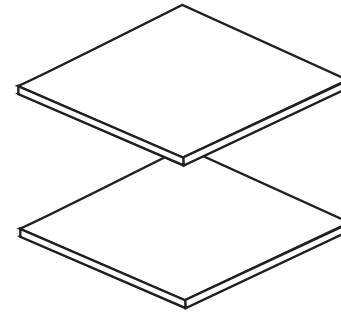


sandwich panel

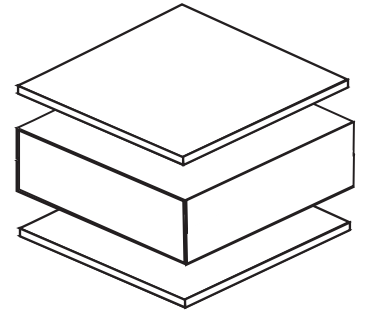
PHASE I: CORE



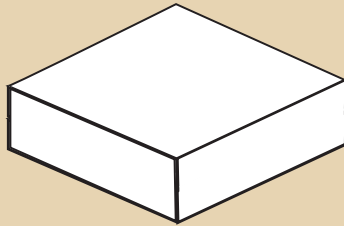
PHASE II: FACESHEET



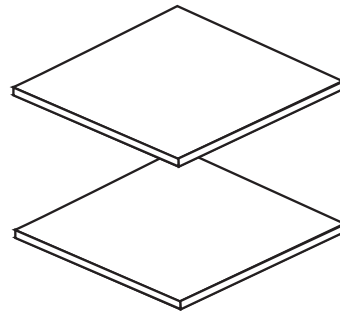
PHASE III: COMPOSITE



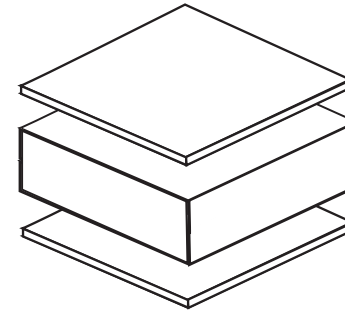
PHASE I: CORE



PHASE II: FACESHEET

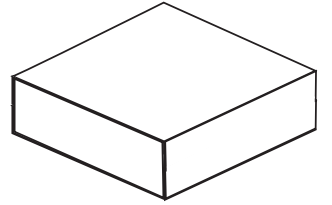


PHASE III: COMPOSITE



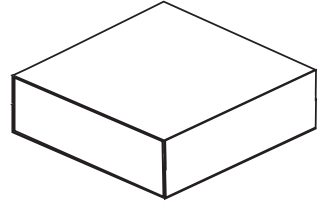
CORE

a building material that can be done easily?



CORE

a building material that can be done easily?

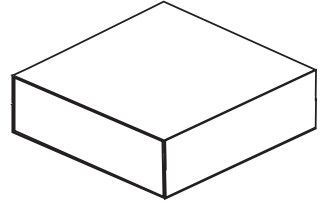


but, like how . . .

like, baking a cake at HOME?

CORE

a building material that can be done easily?

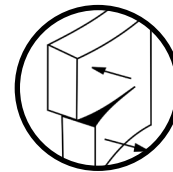


but, like how . . .

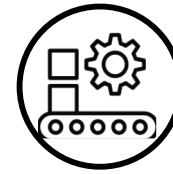
like, baking a cake at HOME?



lightweight



resist shear

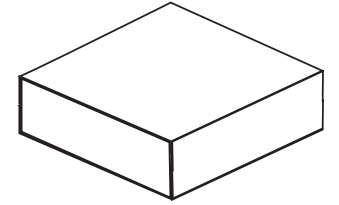
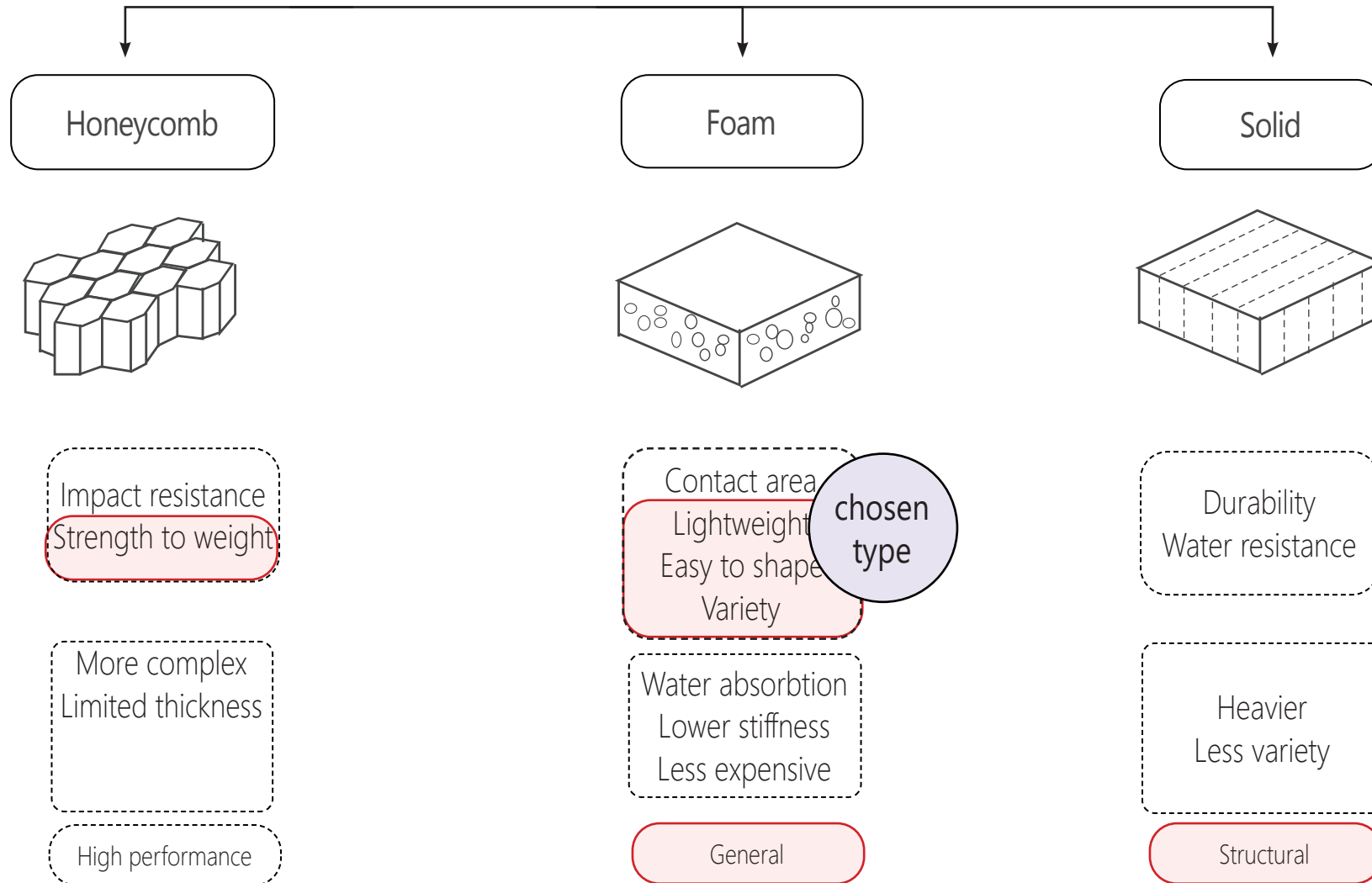


easy to make



green!

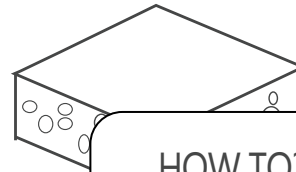
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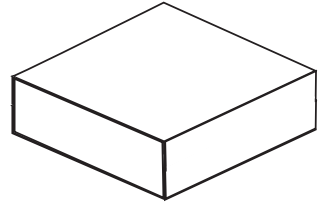
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Foam



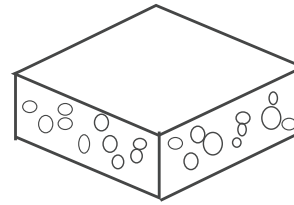
HOW TO?



CORE



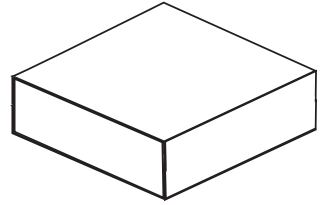
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Foaming

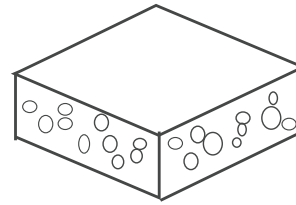


Air bubbles

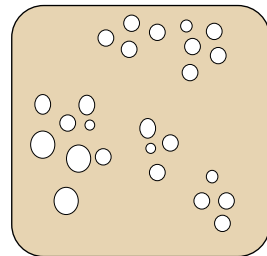


CORE

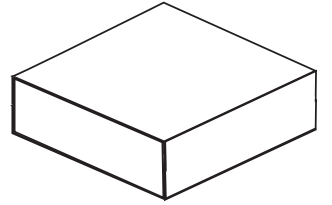
Foam



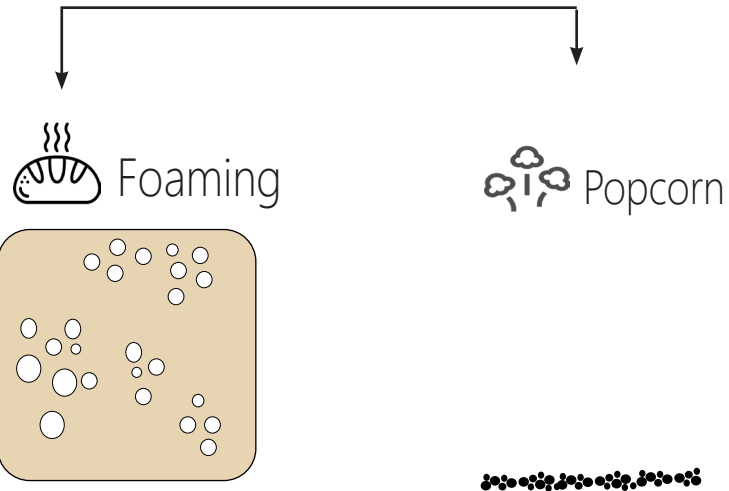
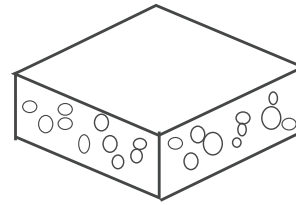
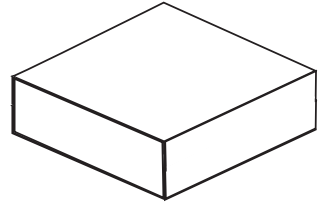
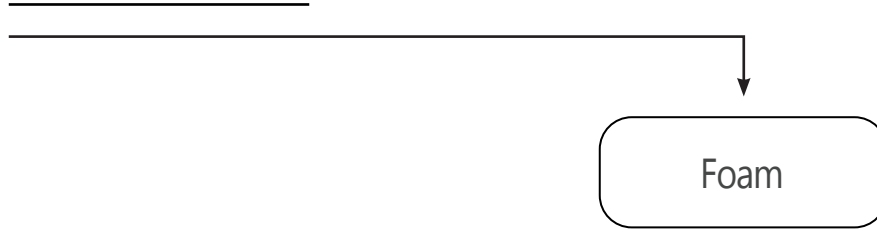
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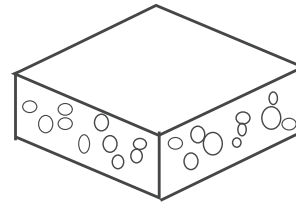
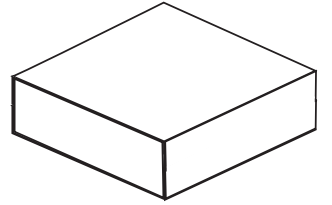
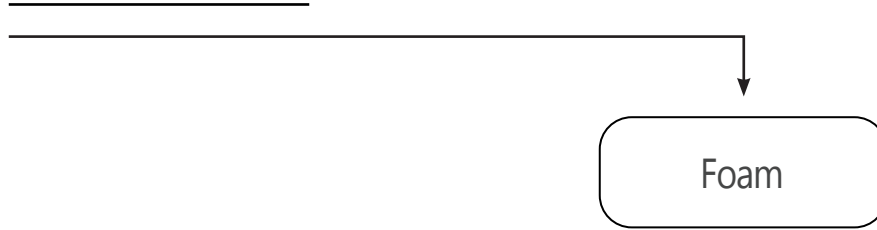
Air bubbles



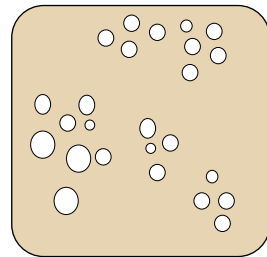
CORE



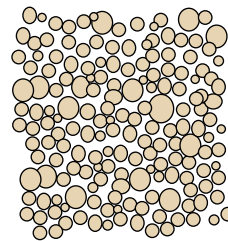
CORE



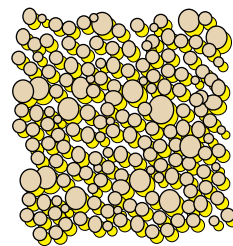
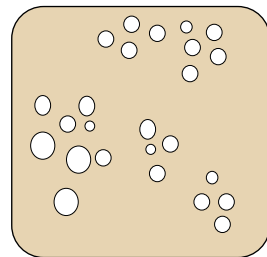
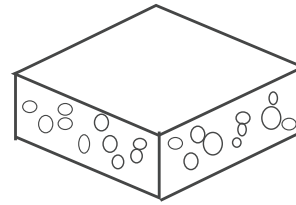
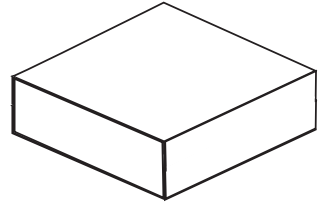
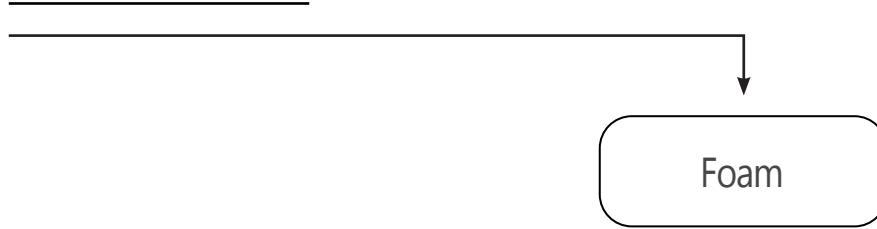
Foaming



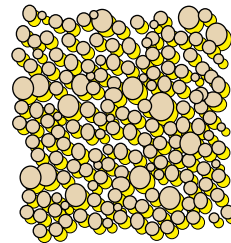
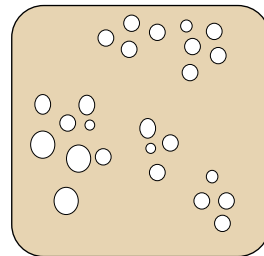
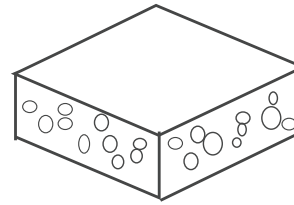
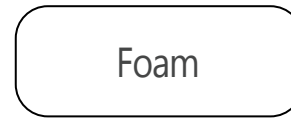
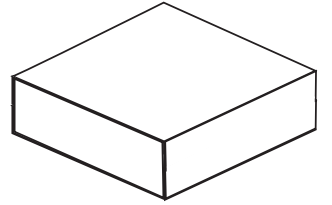
Popcorn



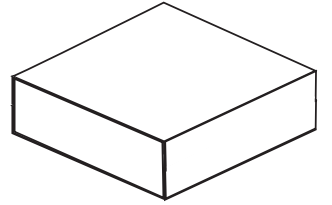
CORE



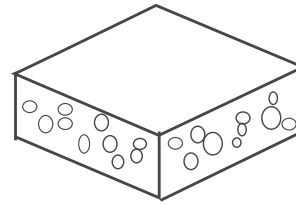
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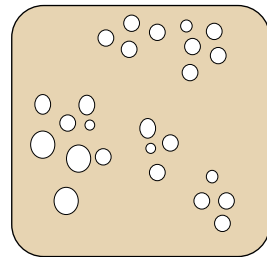
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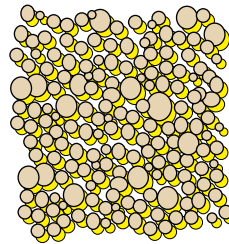
Foam



Foaming



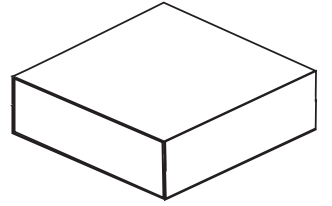
Popcorn



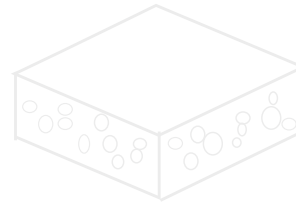
Dry



CORE



Foam



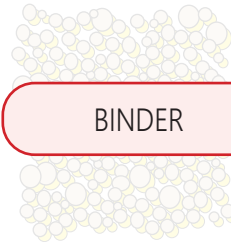
Foaming



FOAMING AGENT



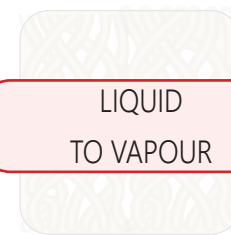
Pop-ing



BINDER

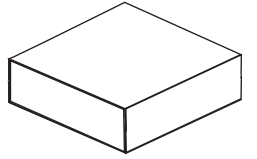


Dry

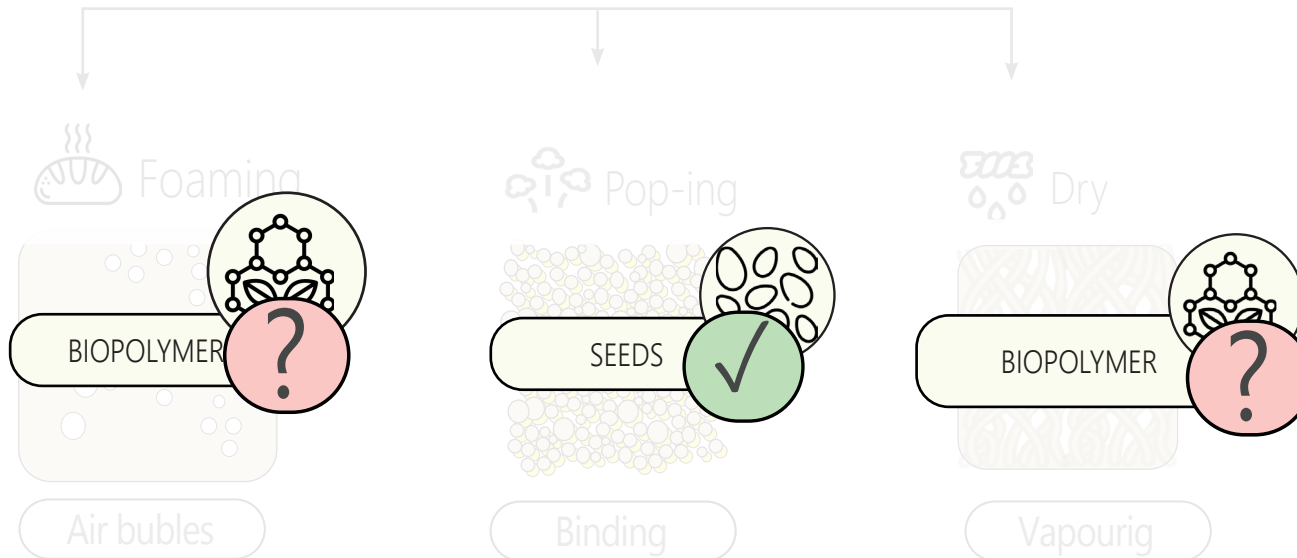
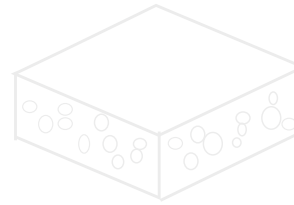


LIQUID
TO VAPOUR

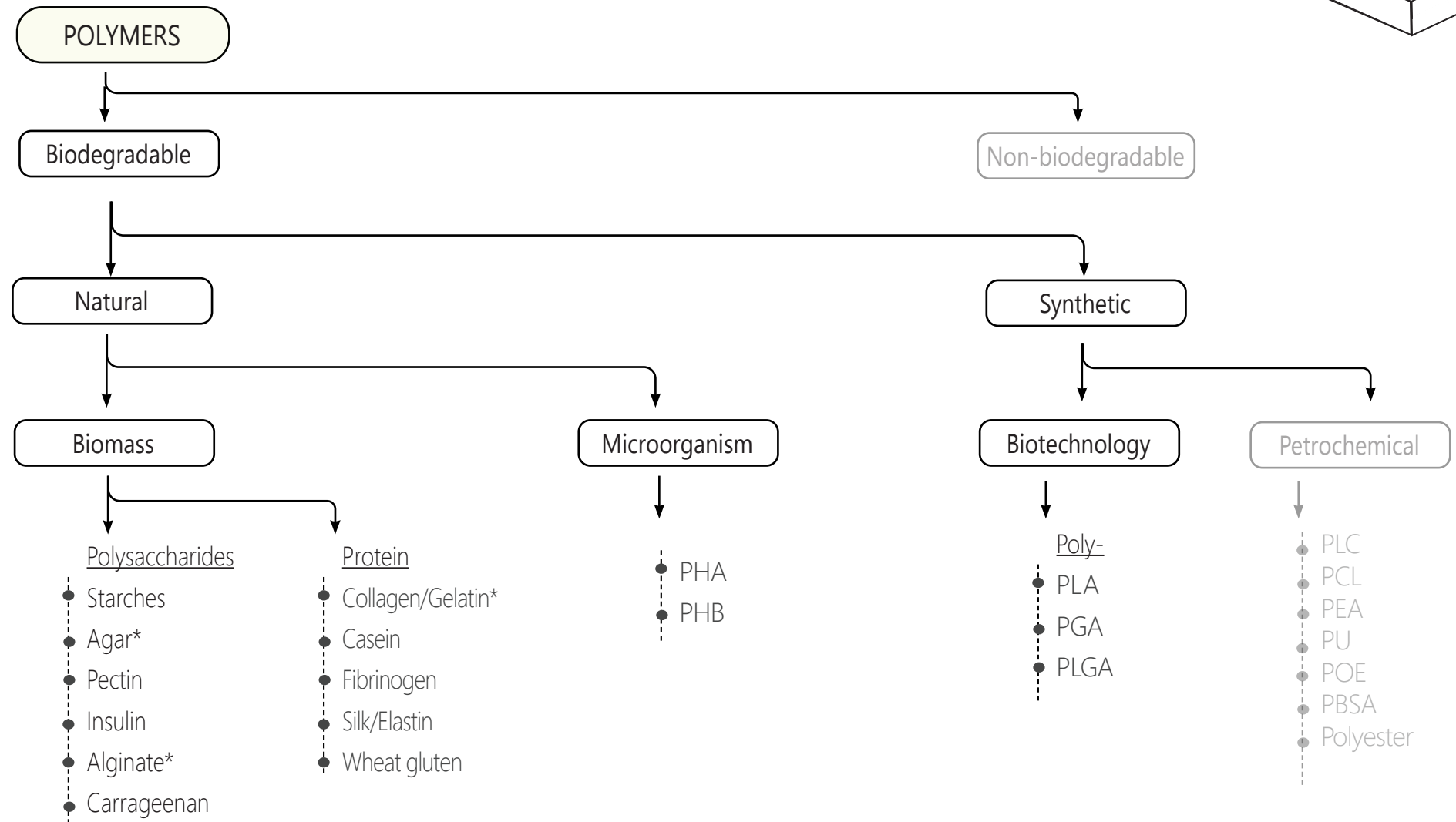
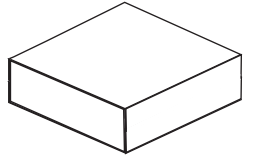
CORE



Foam

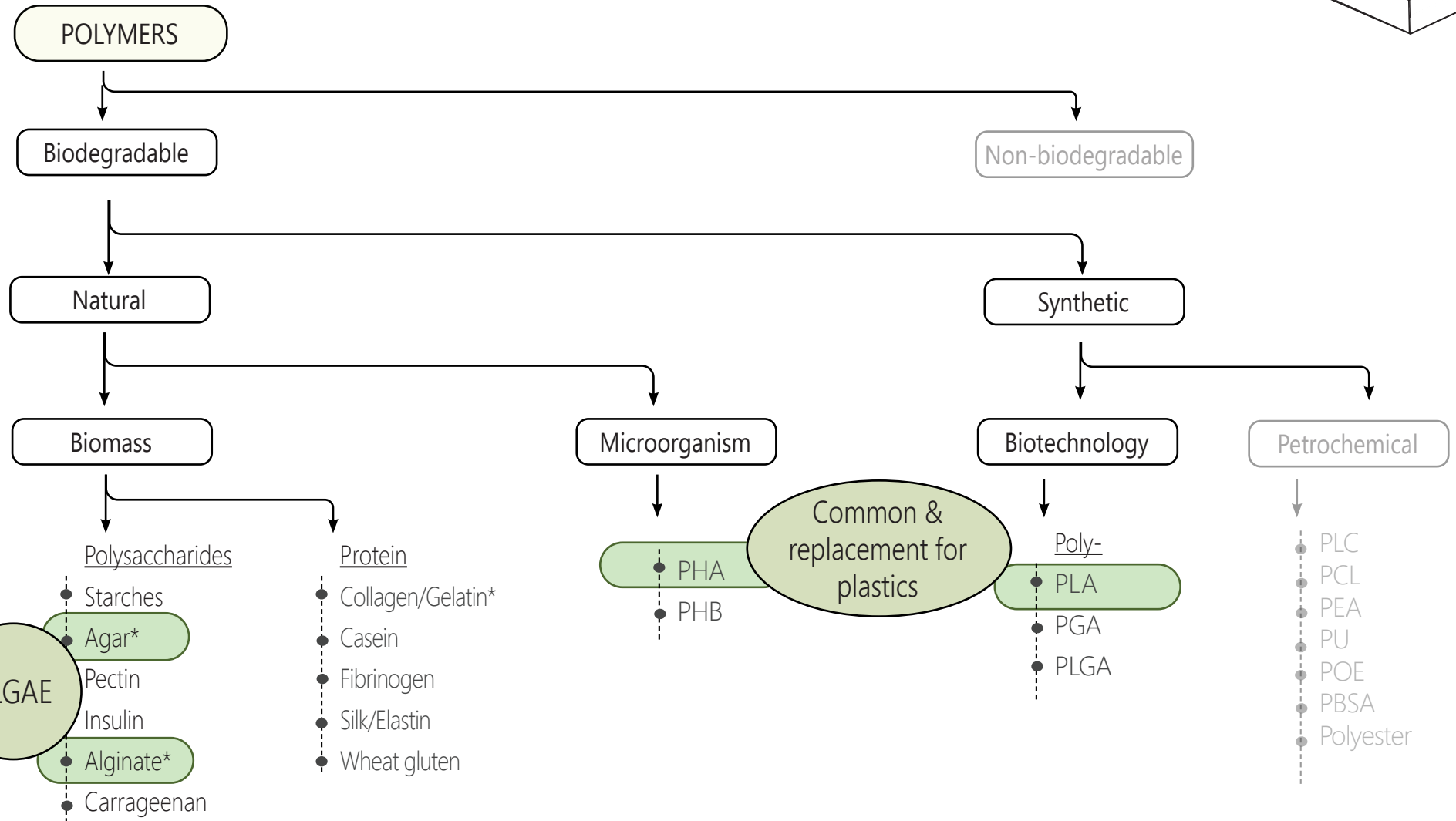
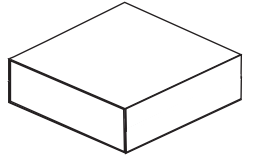


CORE



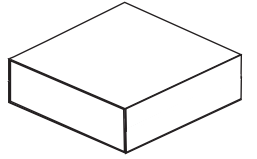
Source:
Showing the polymer categori-
sations based on their biode-
gradability. Chart is reproduced
and referenced from; Andrew
& Dhakal, 2022; Gurunathan et
al. 2015.

CORE



Source:
Showing the polymer cate
sations based on their bio
gradability. Chart is reprodu
and referenced from; Andrew
& Dhakal, 2022; Gurunathan et
al. 2015.

CORE



Alginate

- Natural
- Red-seaweed
- Stabilizing agent
- Biodegradable

Figure 3: Image of brown algae. (Adams, 2024)



Agar-agar

- Natural
- Brown-seaweed
- Stabilizing thickening agent
- Biodegradable

Figure 2: Image of brown algae. (Adams, 2024)

CORE

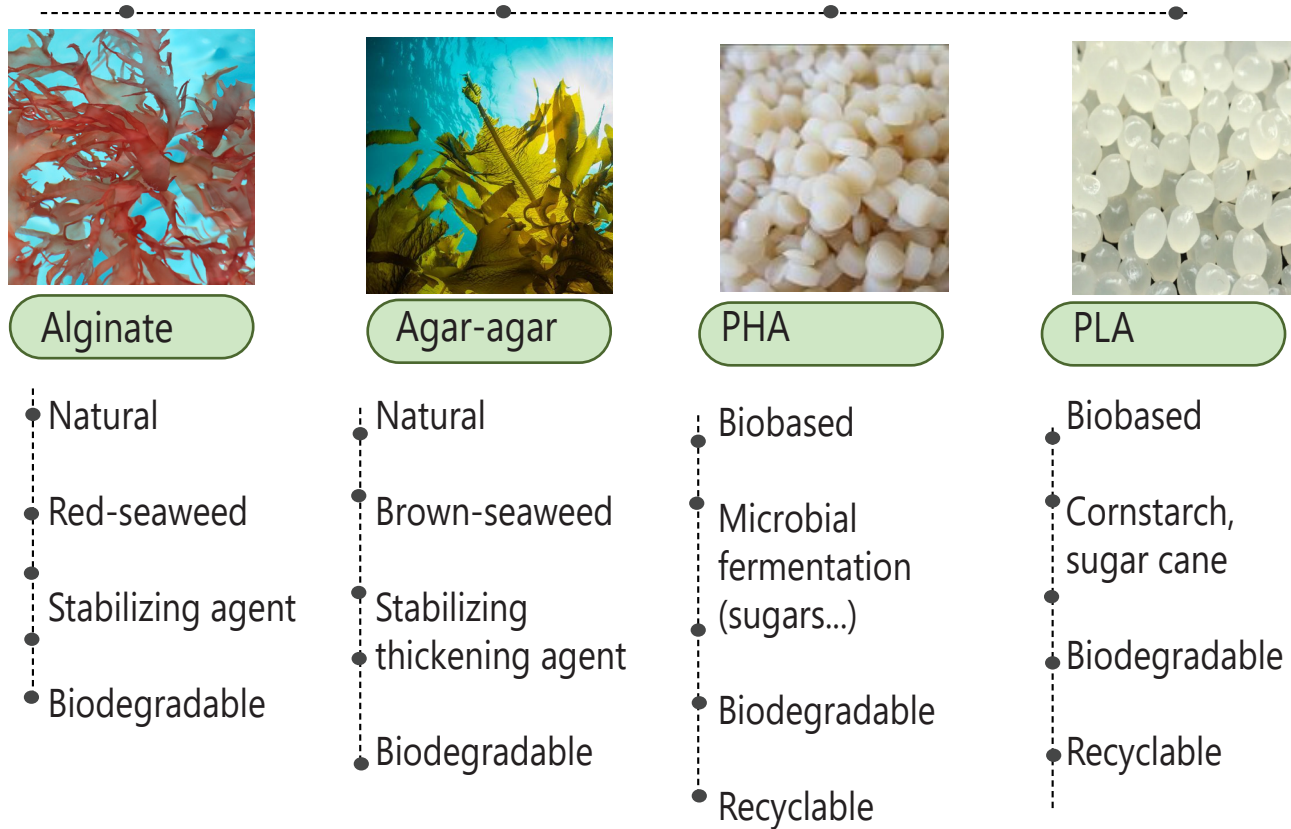
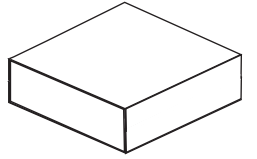


Figure 5: Image of brown algae. (Adams, 2024)

Figure 4: Image of brown algae. (Adams, 2024)

Figure 6: PHA Pellets. (Van Der Hoeven, 2020)

Figure 7: PLA pellets. (Bioplastics News, 2019)

CORE

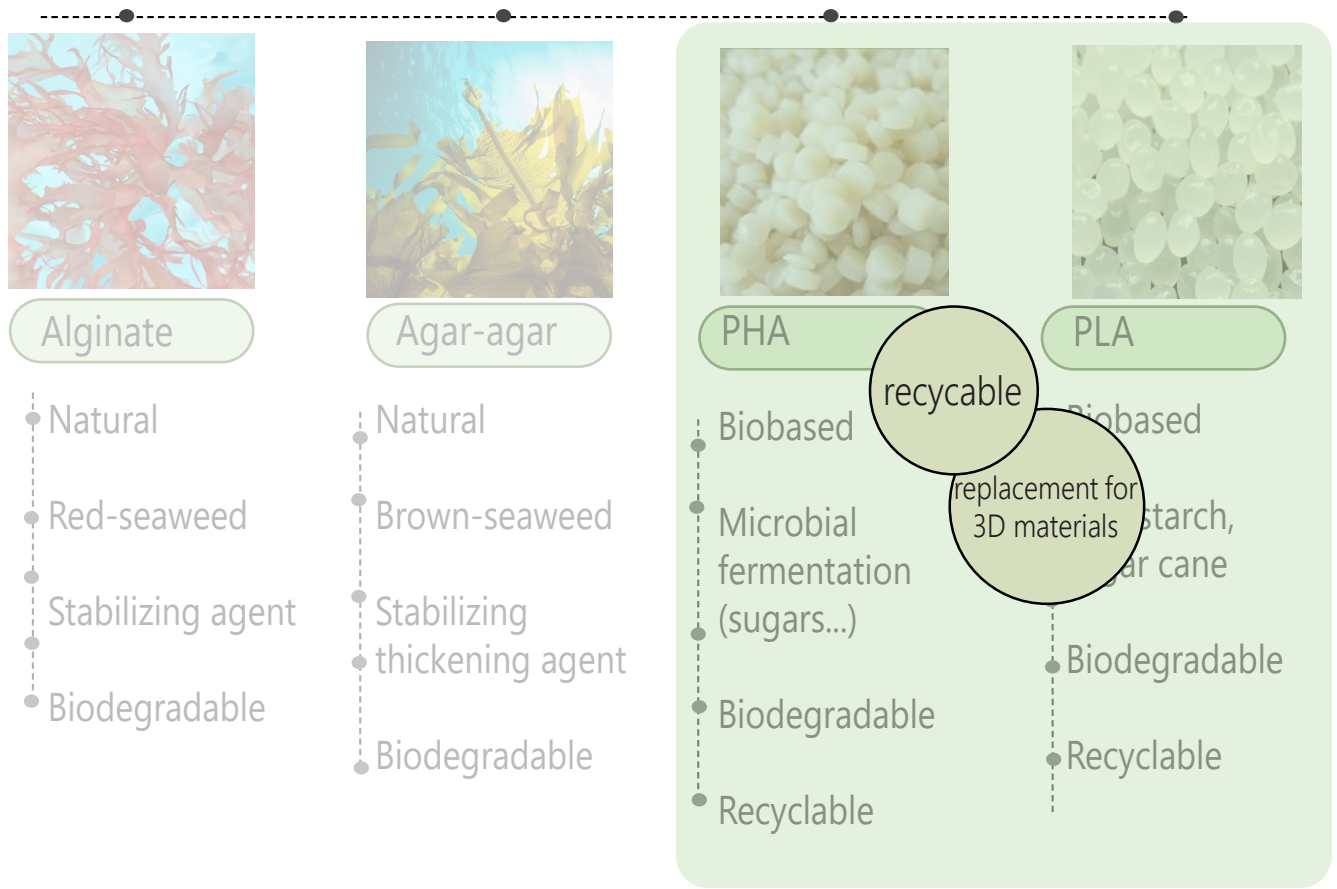
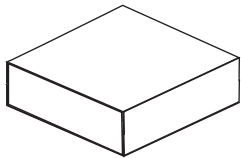


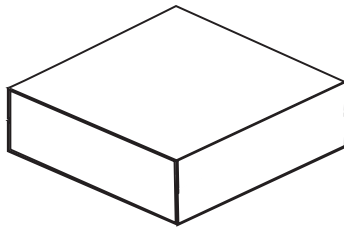
Figure 9: Image of brown algae. (Adams, 2024)

Figure 8: Image of brown algae. (Adams, 2024)

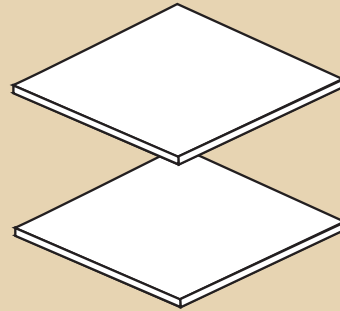
Figure 10: PHA Pellets. (Van Der Hoeven, 2020)

Figure 11: PLA pellets. (Bioplastics News, 2019)

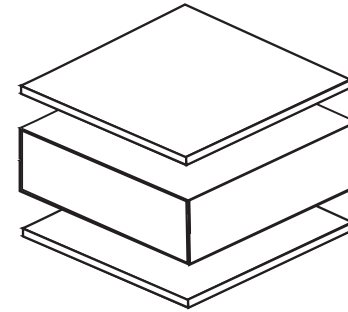
PHASE I: CORE



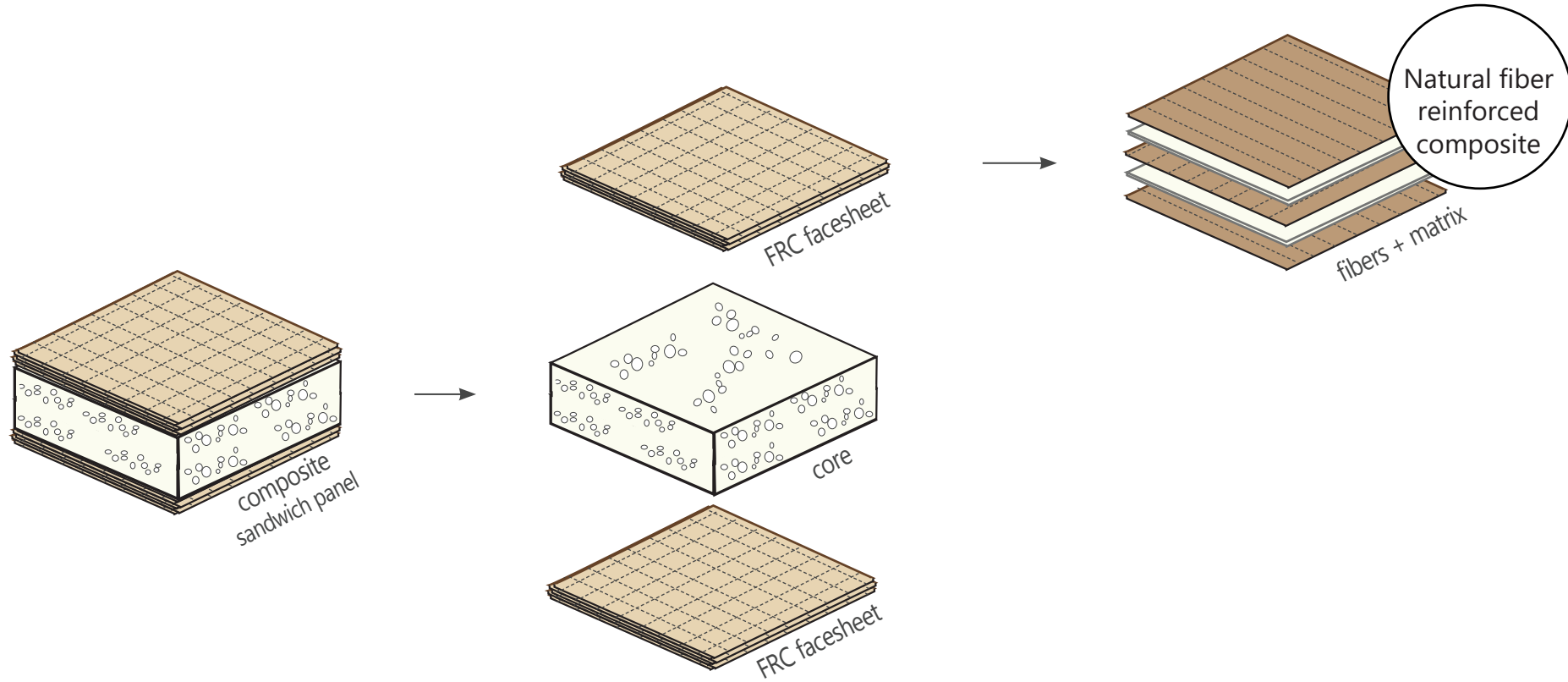
PHASE II: FACESHEET



PHASE III: COMPOSITE

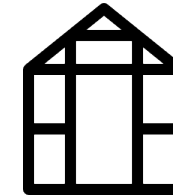
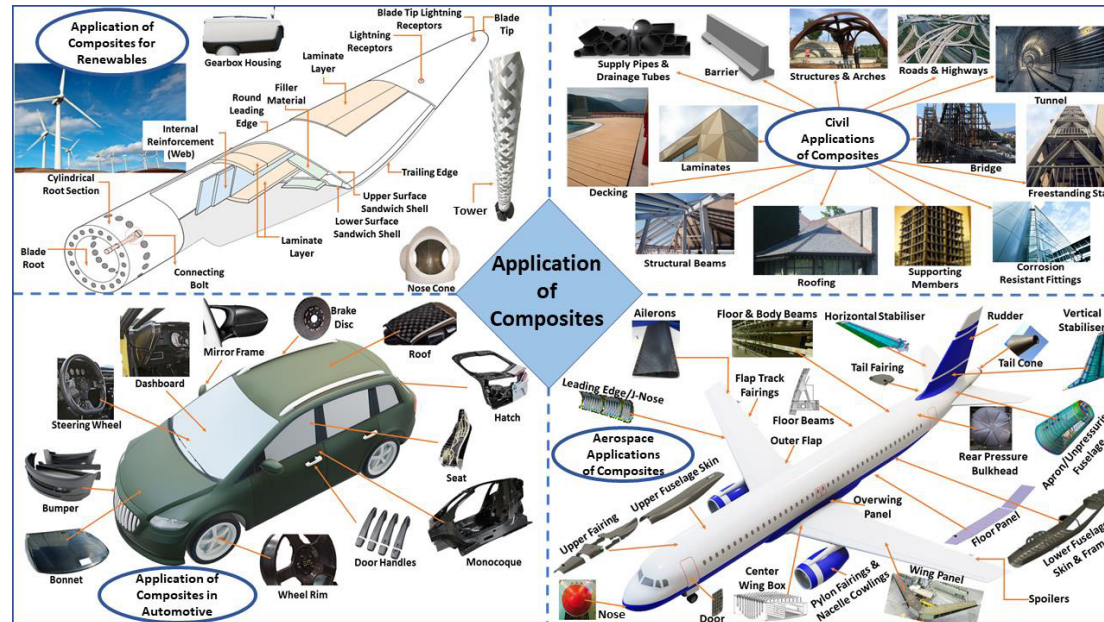


FACESHEET



FACESHEET

Fiber Reinforced Composites

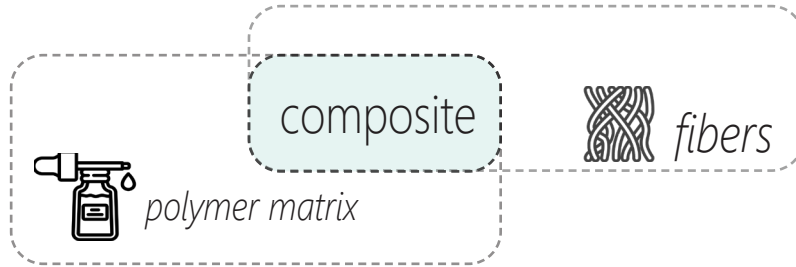


why not as building materials?

Figure 12: (A Review of Sensing Technologies for Non-Destructive Evaluation of Structural Composite Materials, n.d.)

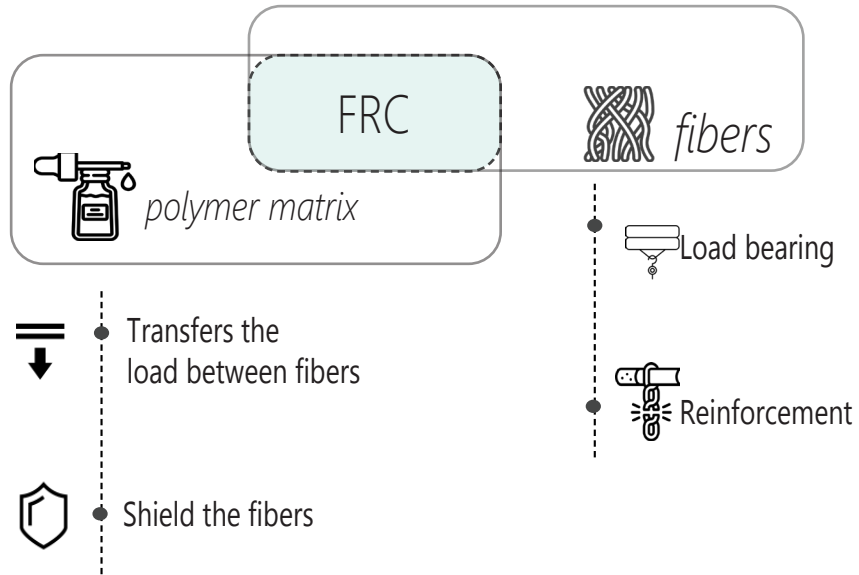
FACESHEET

Fiber Reinforced Composites

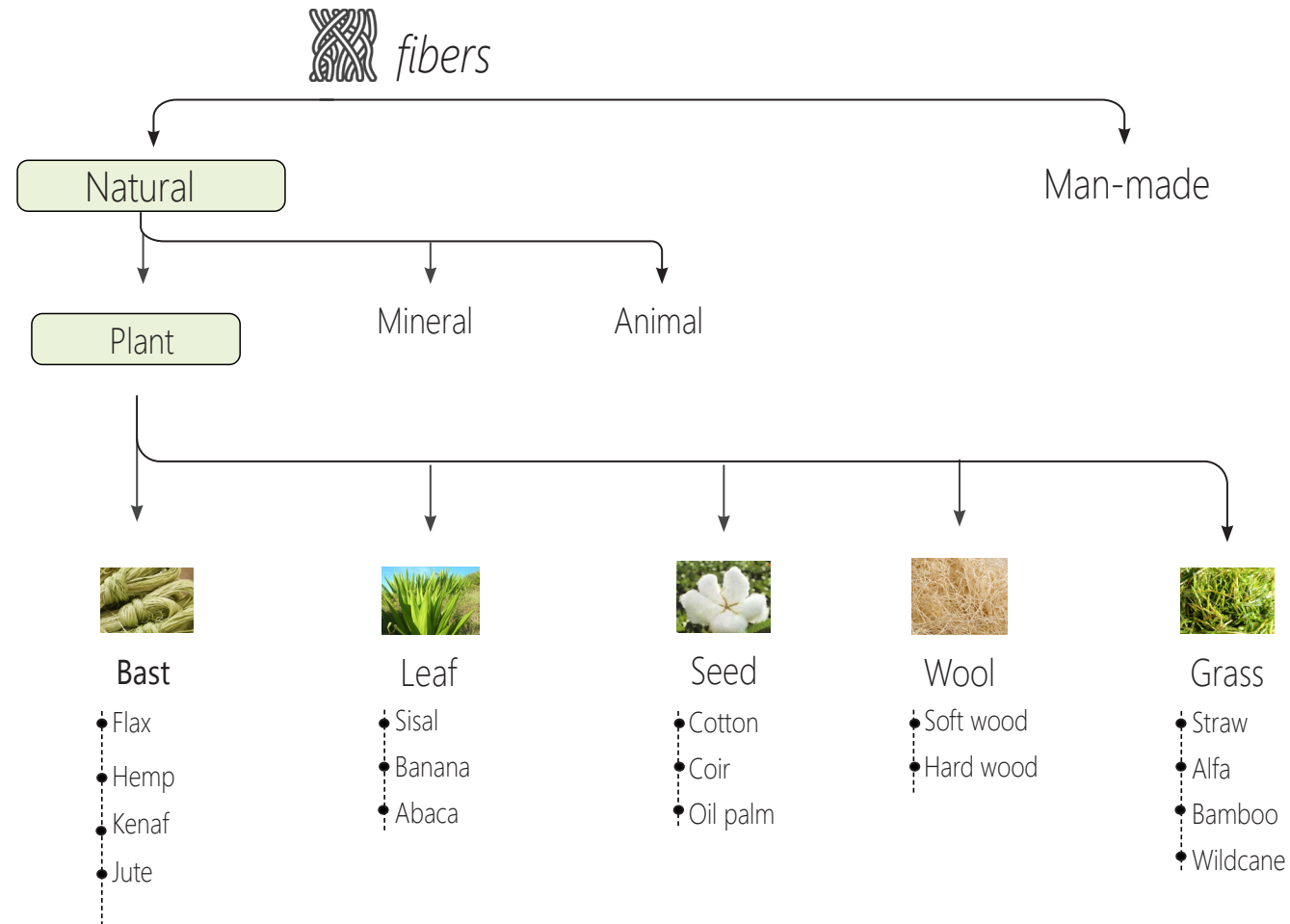


FACESHEET

Fiber Reinforced Composites



Natural fiber reinforced composite



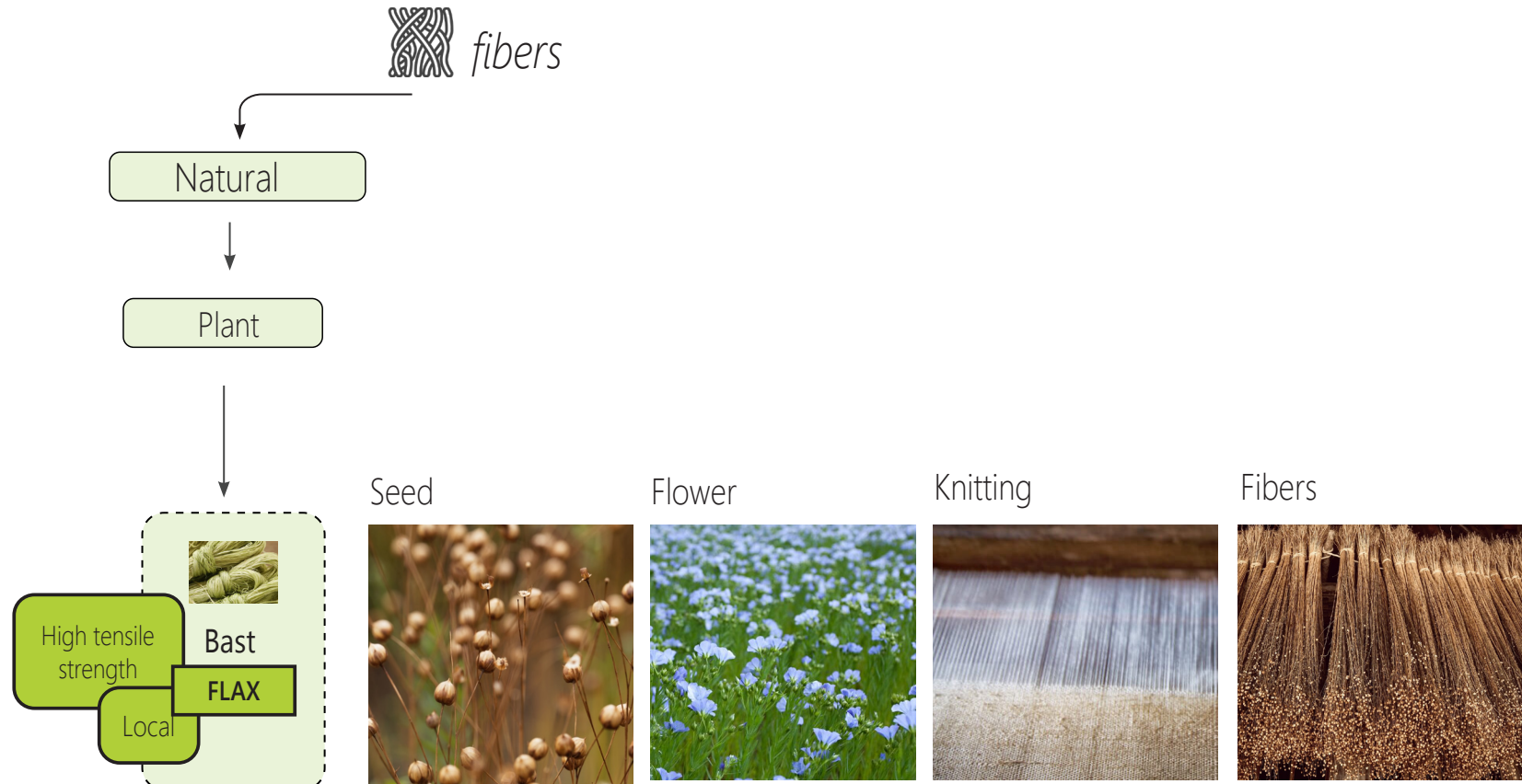
Source: Natural fibers classifications. Table reproduced referencing Houck 2015. Images, respectively; Allende 2021; School & School, 2018; Encyclopaedia Britannica, 1998; Mills 2023; Grass Fiber-based Paper for Sustainable Packaging Products, 2024.

Natural fiber reinforced composite



Source: Natural fibers classifications. Table reproduced referencing Houck 2015. Images, respectively; Allende 2021; School & School, 2018; Encyclopaedia Britannica, 1998; Mills 2023; Grass Fiber-based Paper for Sustainable Packaging Products, 2024.

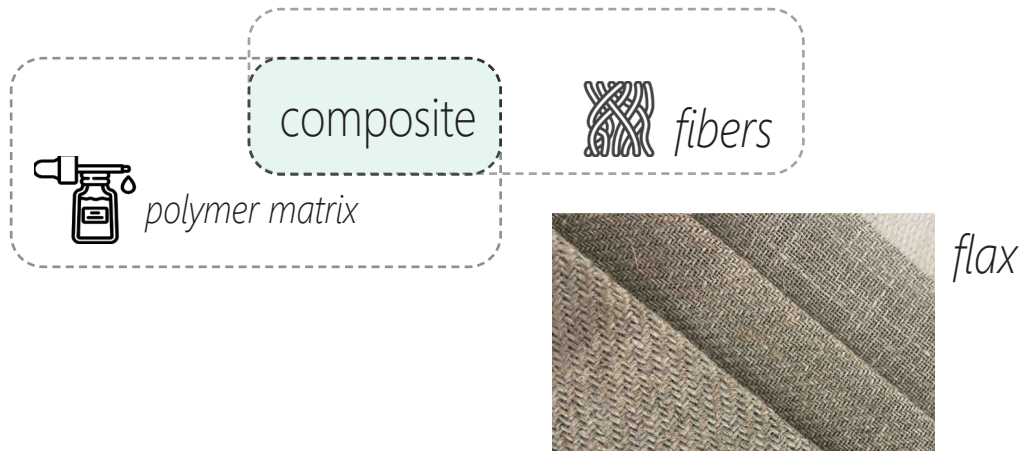
Natural fiber reinforced composite



Source: Natural fibers classifications. Table reproduced referencing Houck 2015. Images, respectively; Allende 2021; School & School, 2018; Encyclopaedia Britannica, 1998; Mills 2023; Grass Fiber-based Paper for Sustainable Packaging Products, 2024.

Figure 13: Top left, Flax seeds; Top right: Flax flower plant. (NouveauRaw, Amie-Sue., 2021); Bottom left: Woven flax fibers, (Textile Sphere 2019); Bottom right: Flax fibers (Trivedi, 2019).

Natural fiber reinforced composite

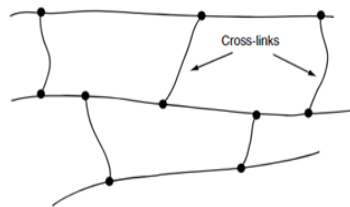


Natural fiber reinforced composite



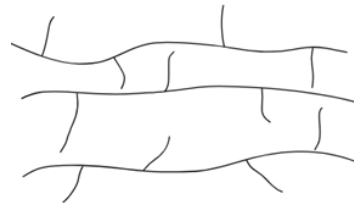
Thermosetting

crosslinked, no reshape

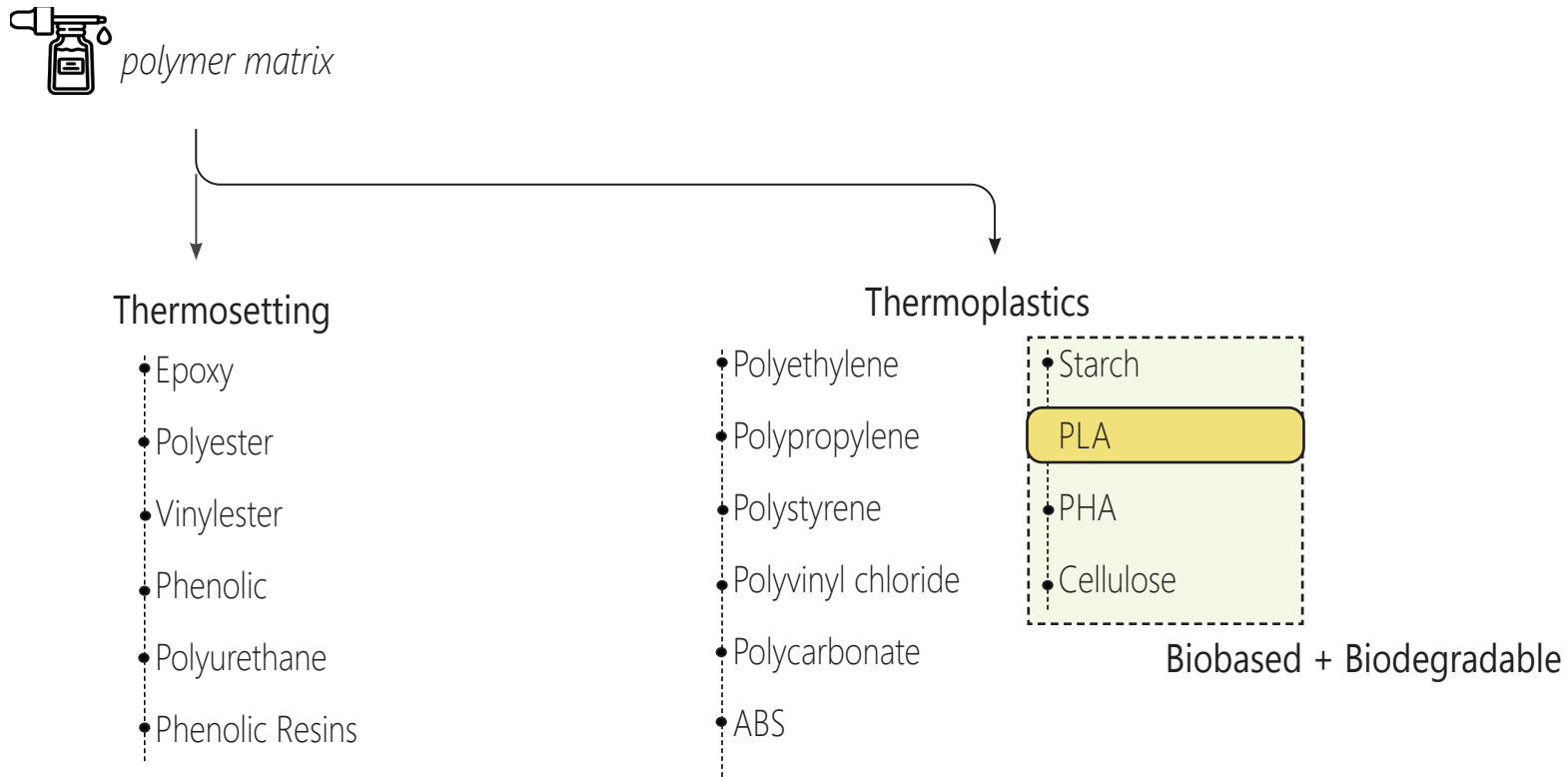


Thermoplastics

free-linked, reshapeable



Natural fiber reinforced composite



Source: Gholampour, 2019; Bastioli, 2001; Edgar et al., 2001; Volova, 2004; Sharma & Mudhoo, 2011, Clarinval (Smith) 2005; Ashby, 2012.



PLA

- Biobased
- Cornstarch, sugar cane
- Biodegradable
- Recyclable

Figure 15: PLA pellets.
(Bioplastics News, 2019)

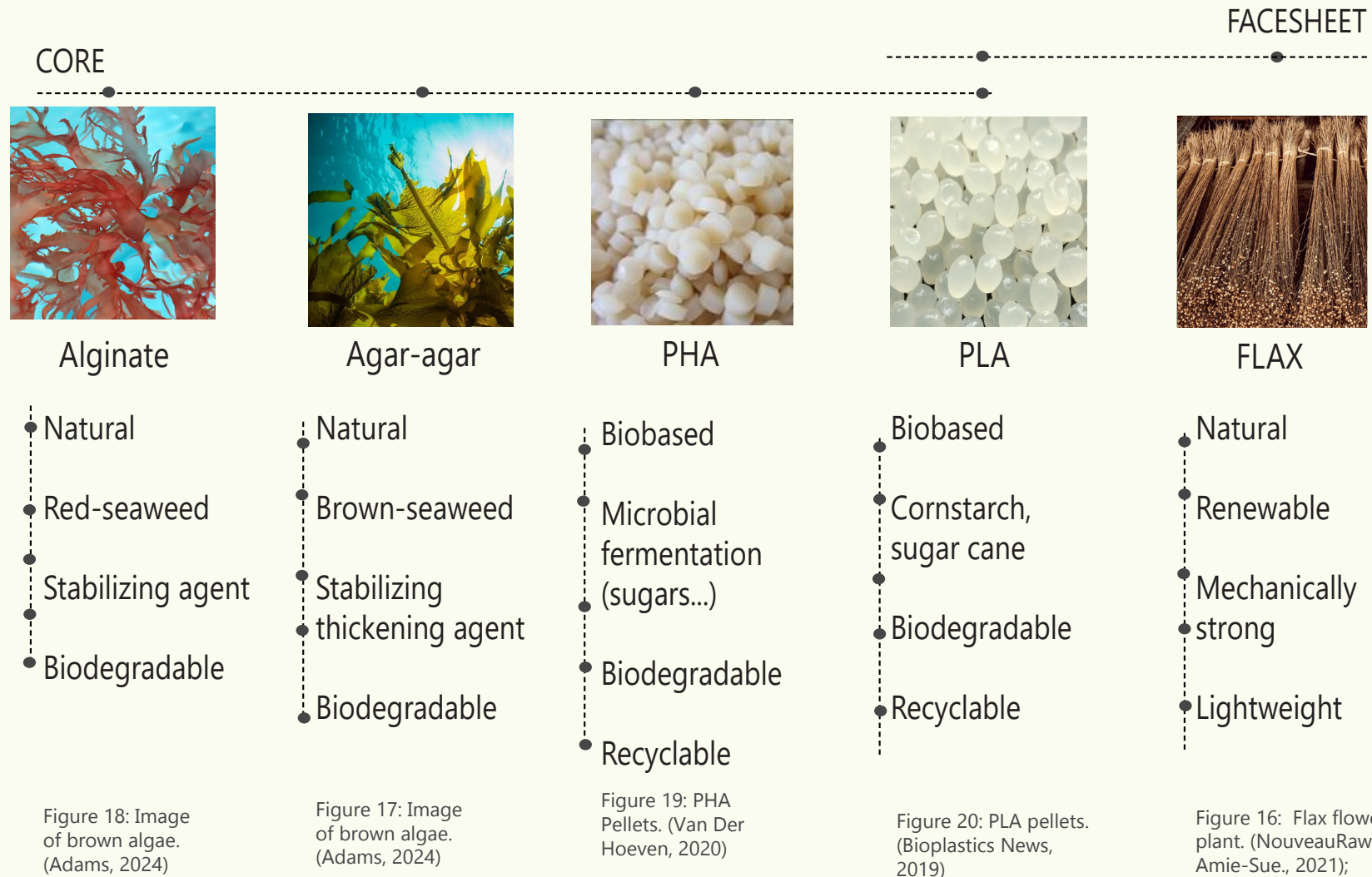


FLAX

- Natural
- Renewable
- Mechanically strong
- Lightweight

Figure 14: Flax flower plant. (NouveauRaw, Amie-Sue., 2021);

ALL MATERIAL SELECTION

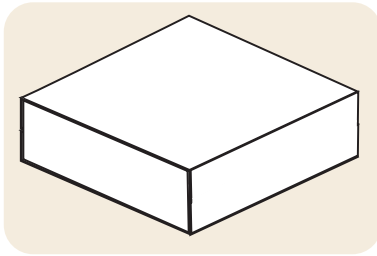


chapter II

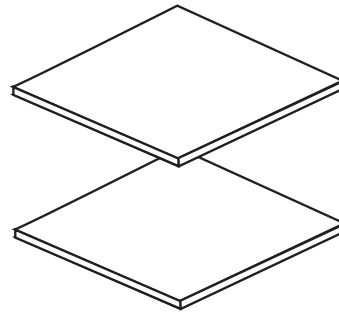
PRODUCTION & RESULTS

PRODUCTION & RESULTS

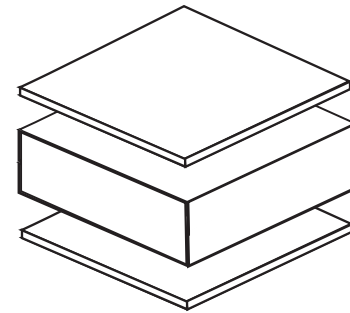
PHASE I: CORE



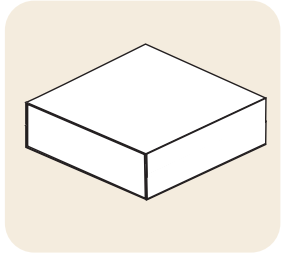
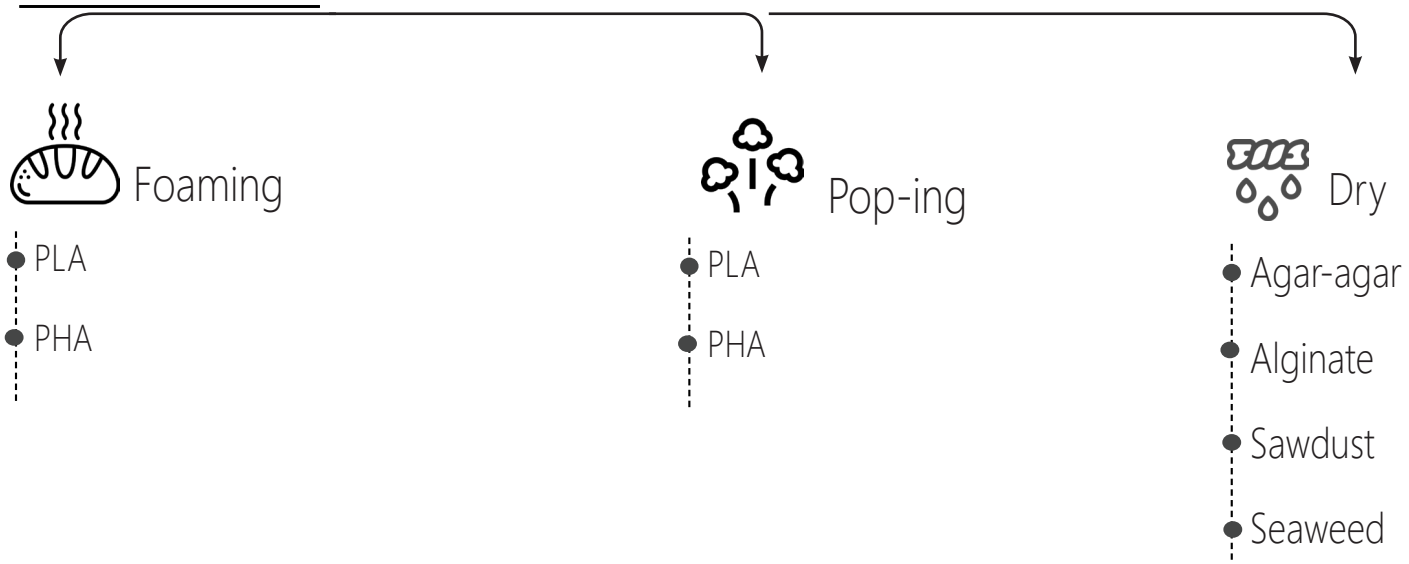
PHASE II: FACESHEET



PHASE III: COMPOSITE



CORE



CORE

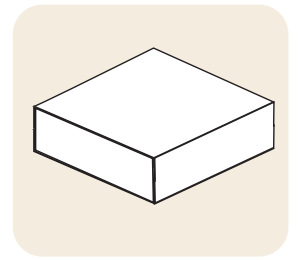


- PLA
- PHA

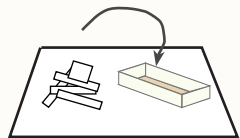


PLA & PHA

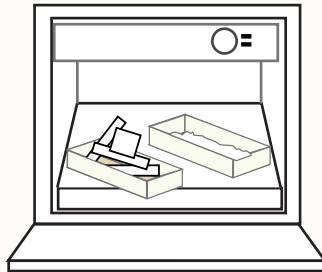
BAKING POWDER



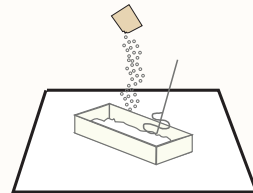
RECIPE 1: FOAMING



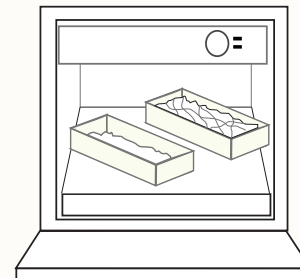
POLYMER



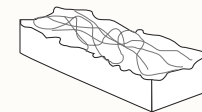
HEAT IT TO MELT



ADD BAKING POWDER

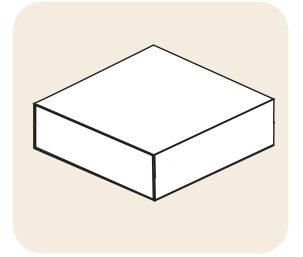
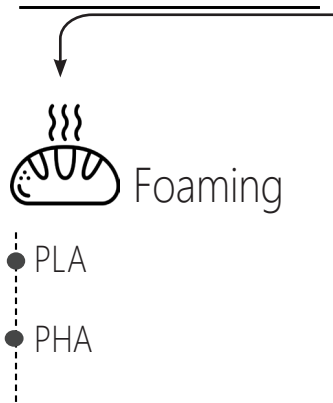


FOAM IT



READY!

CORE



RECIPE 1: FOAMING



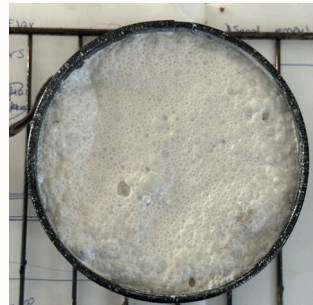
POLYMER



HEAT IT TO MELT



ADD BAKING POWDER

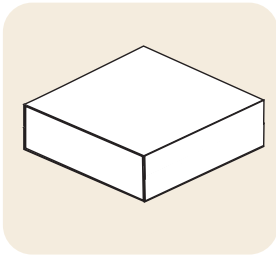
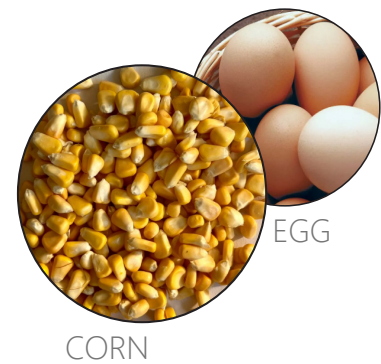


FOAM IT

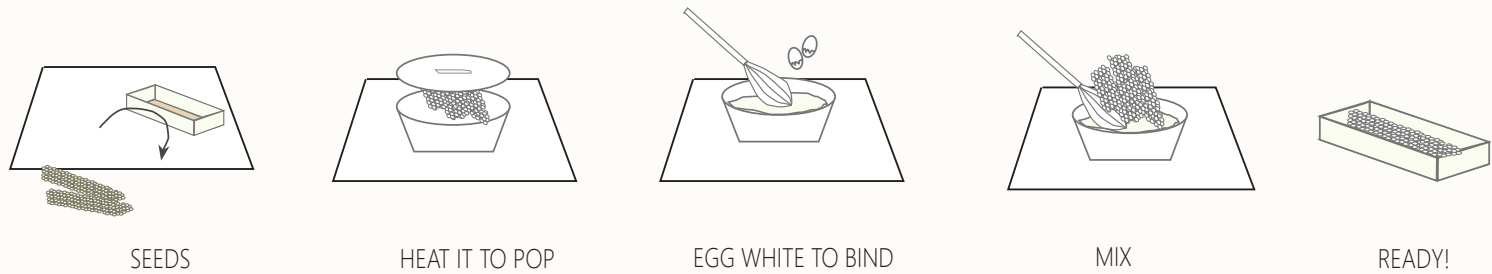


READY!

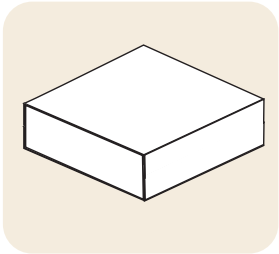
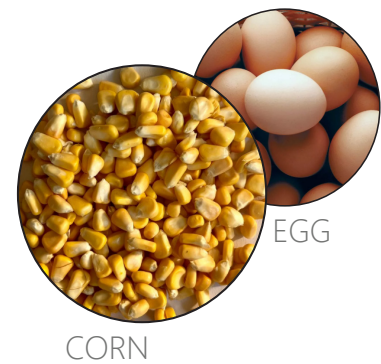
CORE



RECIPE II: POP-ING



CORE



SEEDS



HEAT IT TO POP



EGG WHITE TO BIND



MIX



READY!

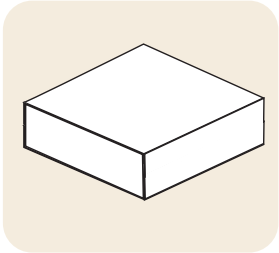
CORE



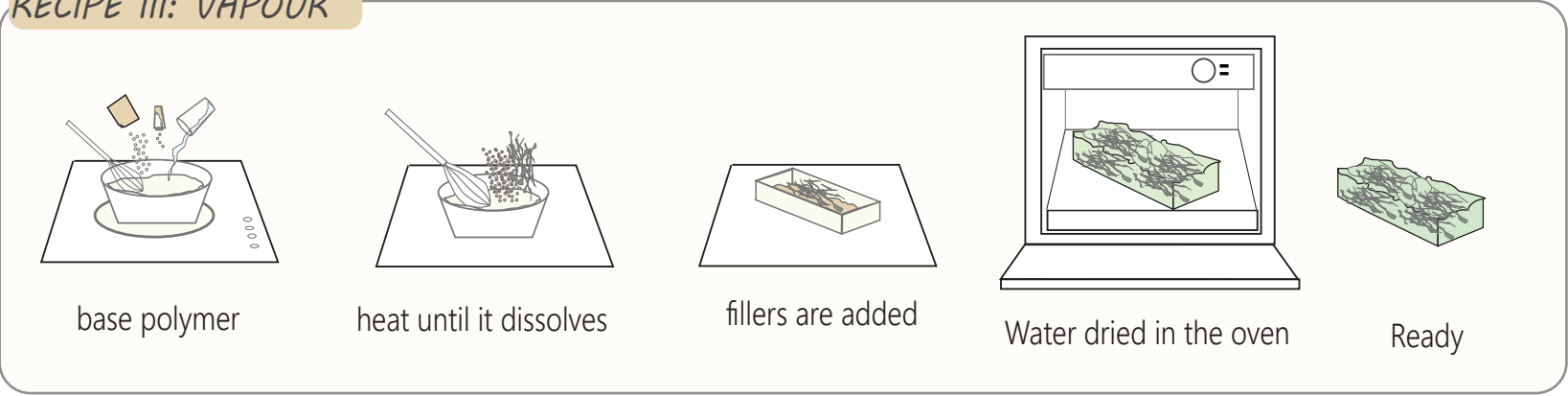
Figure 22: Image of brown algae. (Adams, 2024)

Figure 21: Image of brown algae. (Adams, 2024)

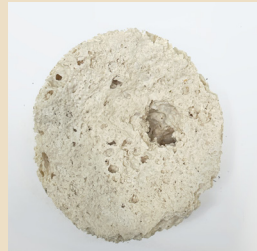
- Dry
- Agar-agar
 - Alginate
 - Sawdust
 - Seaweed



RECIPE III: VAPOUR



FOAM



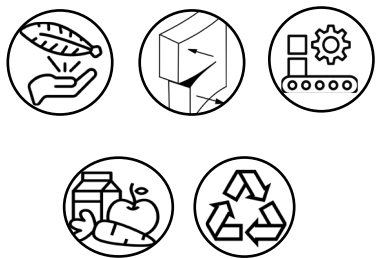
POPCORN



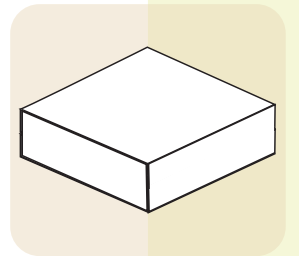
DRY



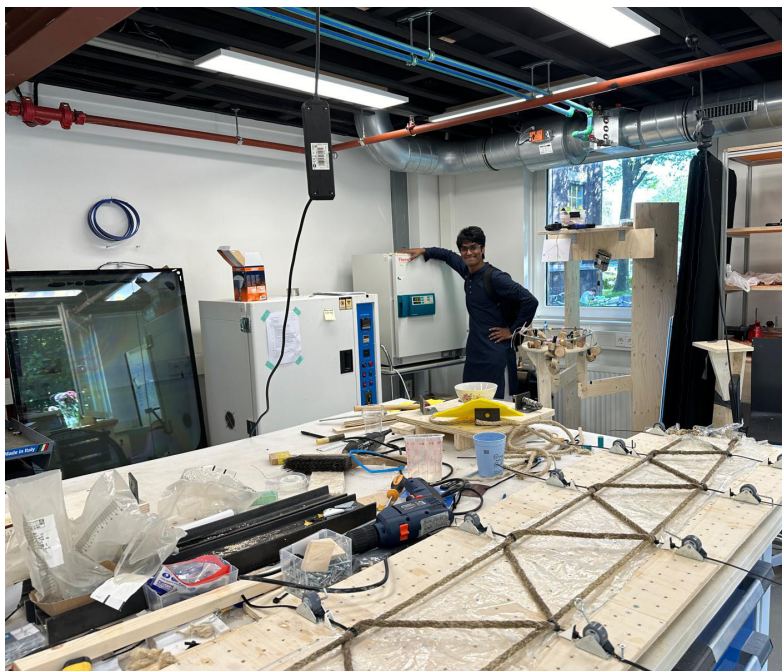
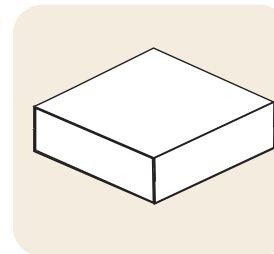




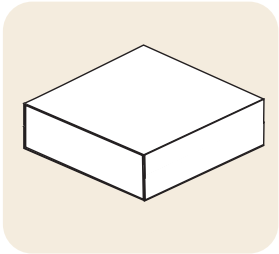
producing the foamed core



Foamed PLA

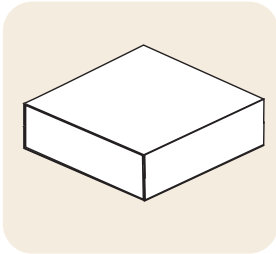


Foamed PLA



ID	Mass (gr)	Bak. powder ratio (%)	Melt. tempt (°C)	Heating time (hr)	Foam. tempt (°C)	Time (ht)
PL10A	100	10	180	1	180	1
PL10B	100	10	220	2	220	1
PL05A	50	10	190-200	1	190-200	30mins
PL10C	100	15	190-200	1	190-200	45mins
PL15A	150	10	190-200	1	190-200	45mins
PL20A	200	15	190-200	1.30	190-200	45mins
PL20B	200	20	190-200	2	190-200	1

Foamed PLA



ID	Mass (gr)	Bak. powder ratio (%)	Melt. tempt (°C)	Heating time (hr)	Foam. tempt (°C)	Time (ht)
PL10A	100	10	180	1	180	1
PL10B	100	10	chosen ratio PLA 85% B.powder 15%	2	220	1
PL05A	50	10		1	190-200	30mins
PL10C	100	15		1	190-200	45mins
PL15A	150	10		1	190-200	45mins
PL20A	200	15		1.30	190-200	45mins
PL20B	200	20	190-200	2	190-200	1

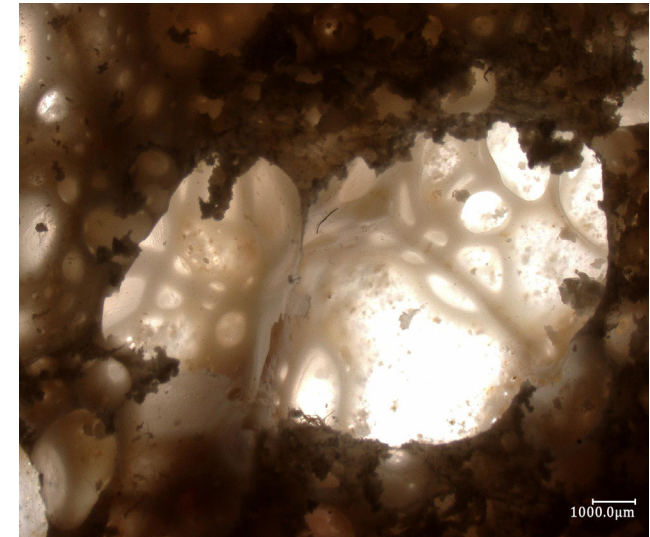
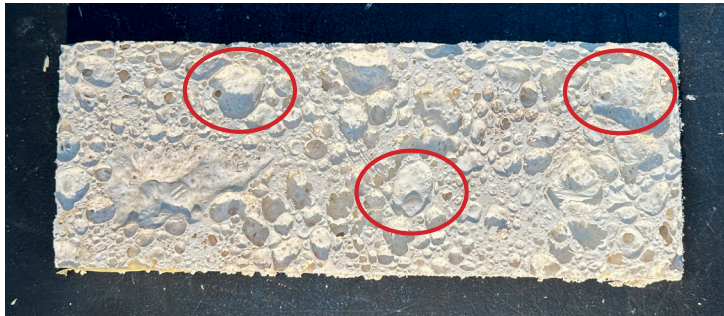
sample

10 sample

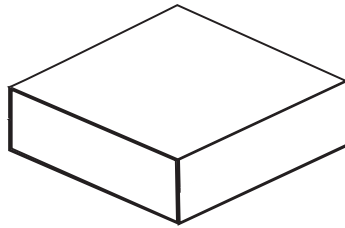
dimension

200 x 75 x 15-20mm

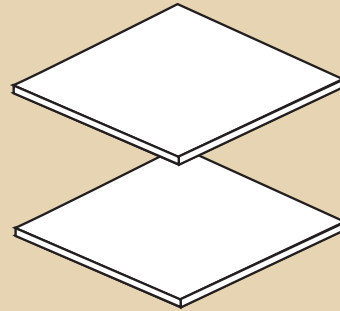
Foamed PLA



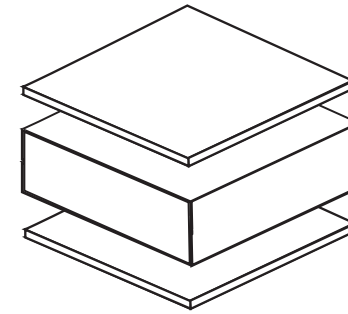
PHASE I: CORE



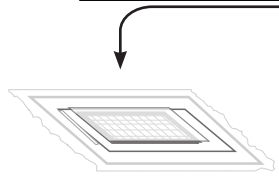
PHASE II: FACESHEET



PHASE III: COMPOSITE

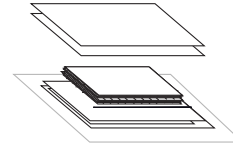


FACESHEET



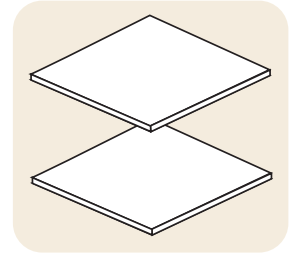
Resin Film Infusion

- FLAX / Biobased Epoxy
- Thermosetting resin
- Labour Intensive

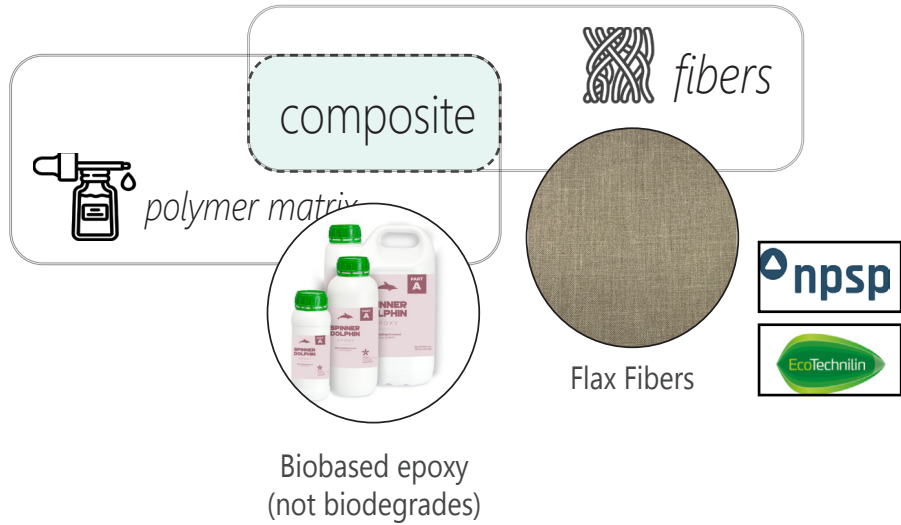
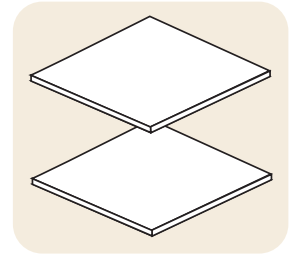


Film stacking method

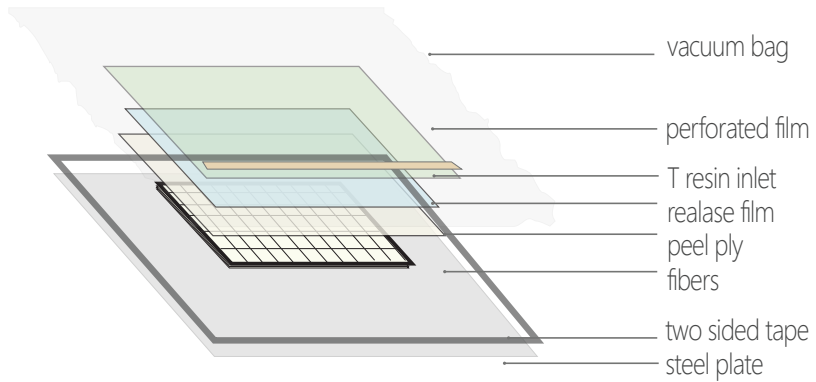
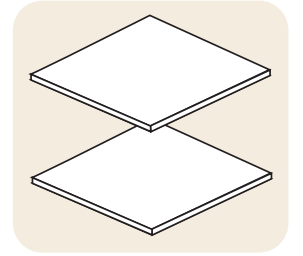
- FLAX / PLA
- Fully-biobased
- Easier to produce



FACESHEET



FACESHEET



TECHNIQUE : Thermoset Resin Infusion

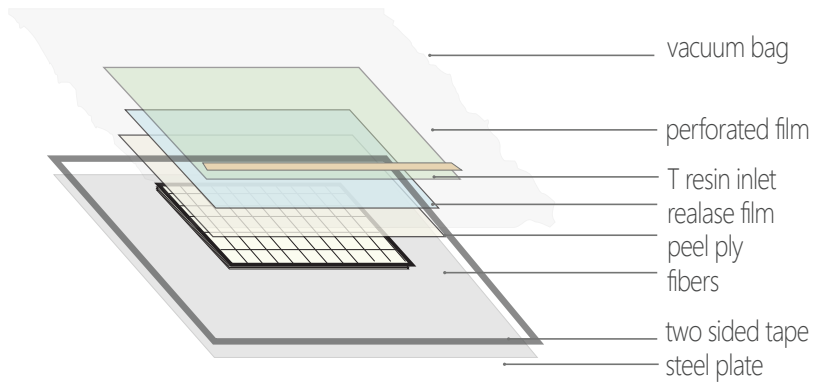
MATRIX : Bio-based Epoxy

FIBER : Woven Flax Fibers

RATIO : 30% Fiber Mass Fraction

WHERE: : Aircraft Hall & Aerospace TU Delft

FACESHEET



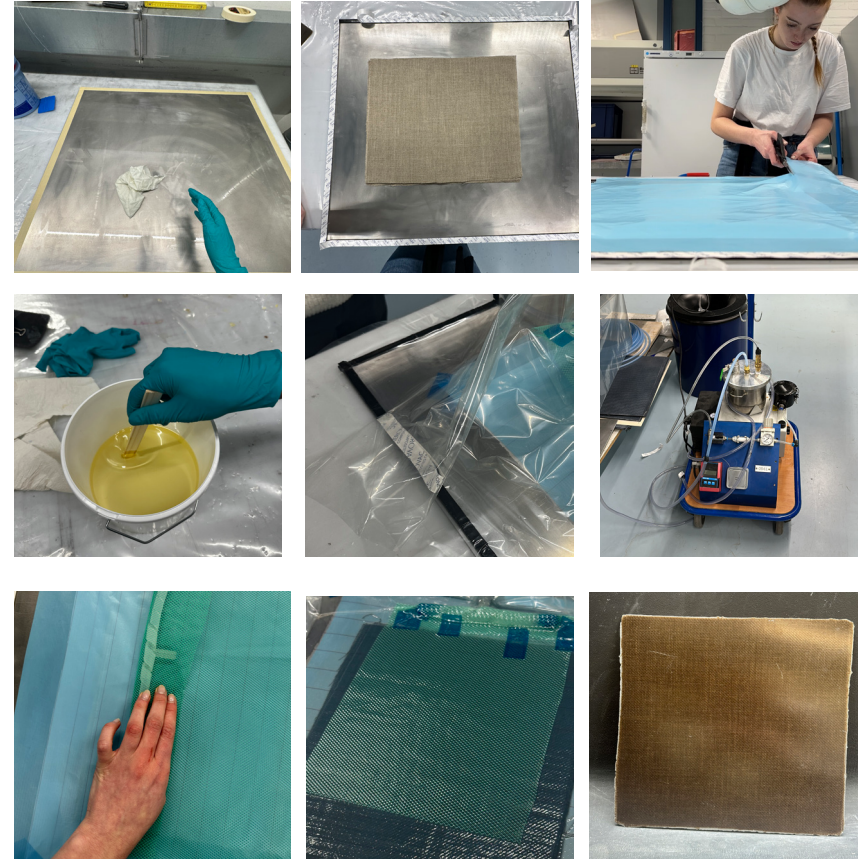
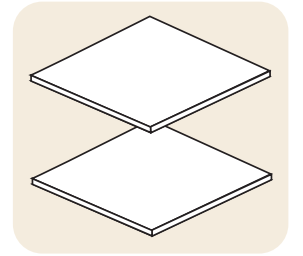
TECNIQUE : Thermoset Resin Infusion

MATRIX : Bio-based Epoxy

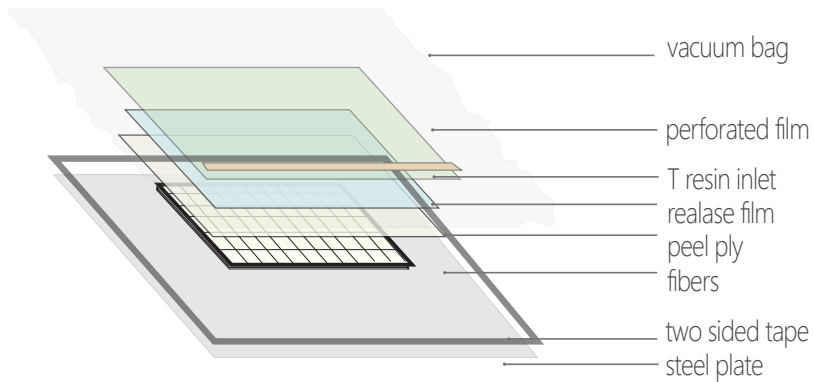
FIBER : Woven Flax Fibers

RATIO : 30% Fiber Mass Fraction

WHERE: : Aircraft Hall & Aerospace TU Delft



FACESHEET



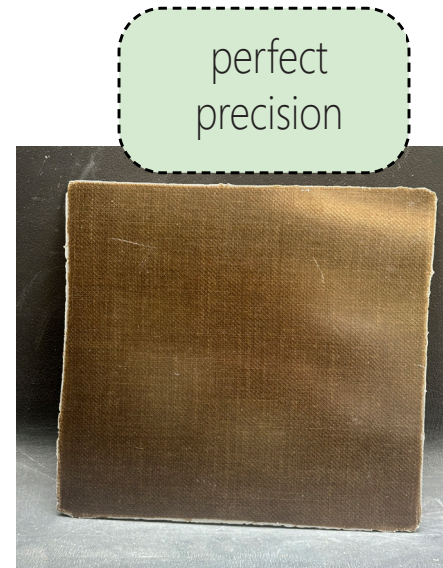
TECHNIQUE : Thermoset Resin Infusion

MATRIX : Bio-based Epoxy

FIBER : Woven Flax Fibers

RATIO : 30% Fiber Mass Fraction

WHERE: : Aircraft Hall & Aerospace TU Delft

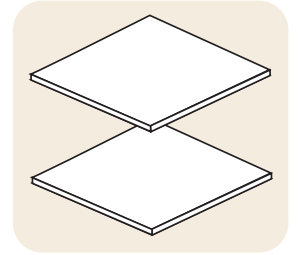


labour intensive

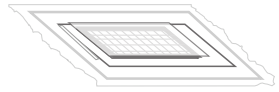
long procedure

resin waste

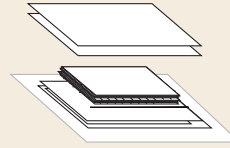
Not fully
biobased



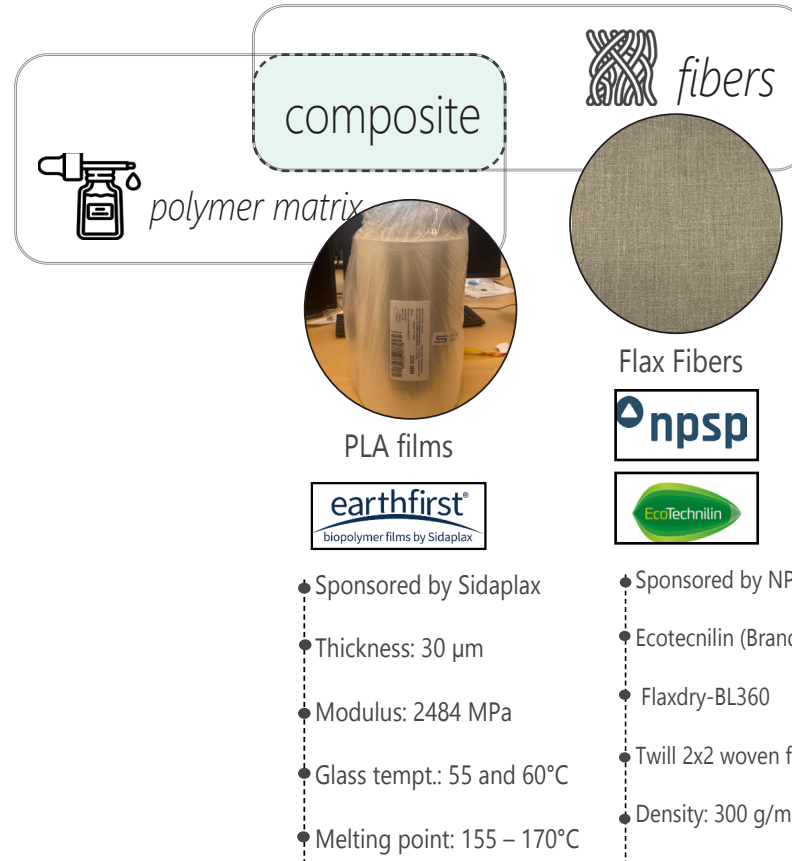
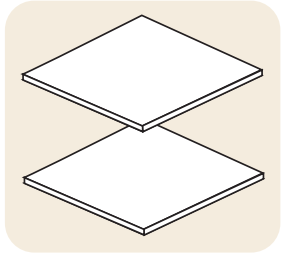
FACESHEET



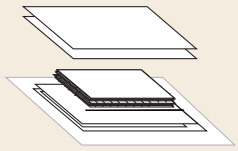
Resin Film Infusion



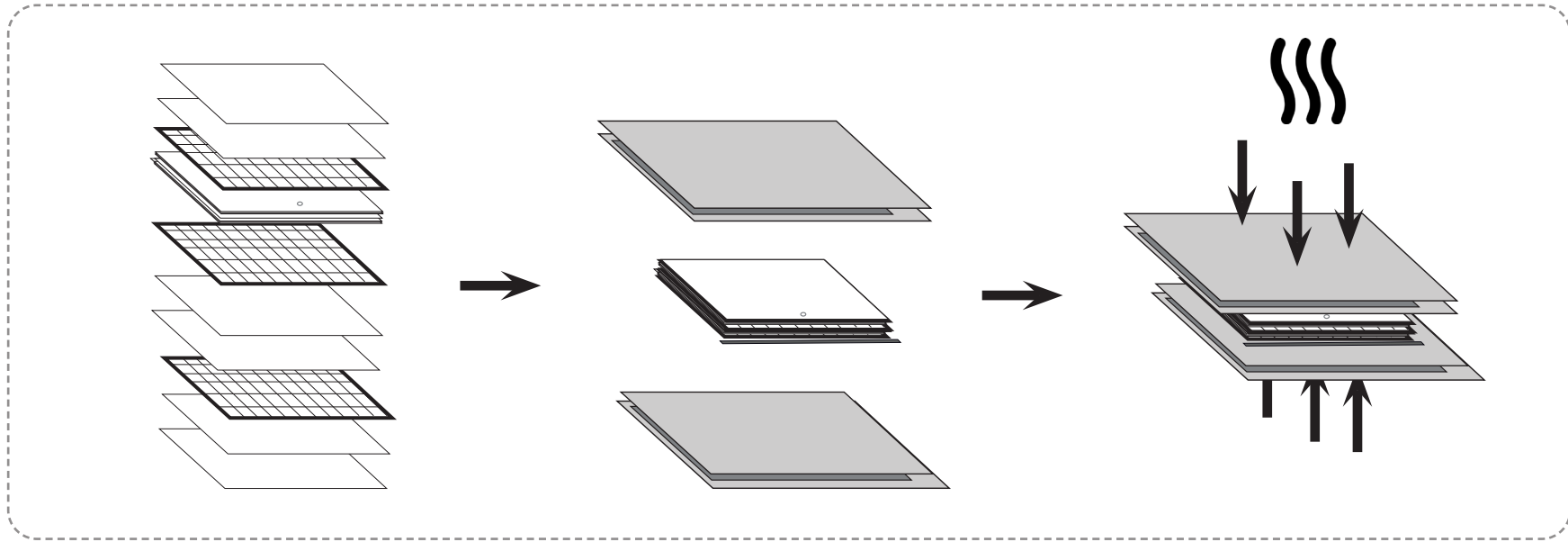
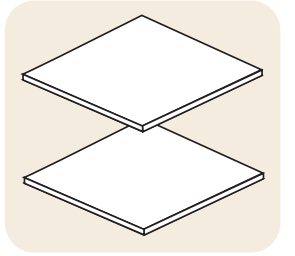
Film stacking method



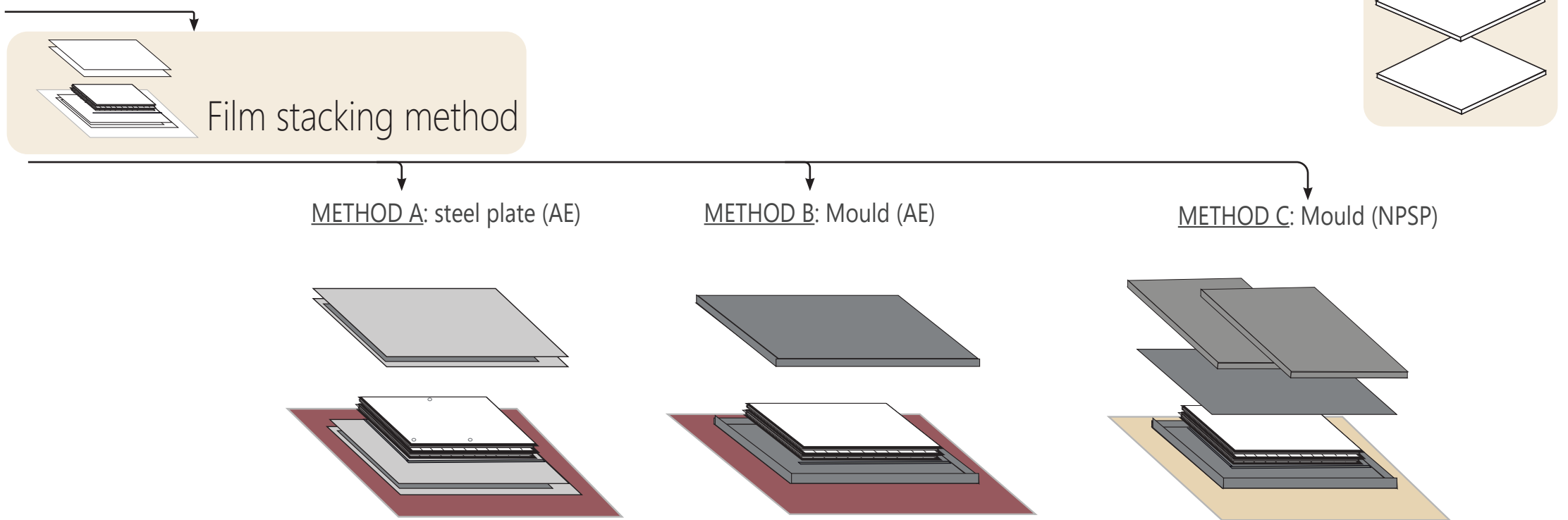
FACESHEET



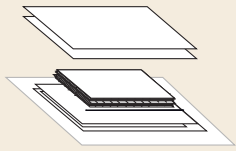
Film stacking method



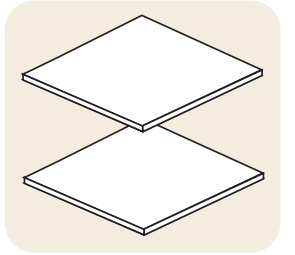
FACESHEET



FACESHEET



Film stacking method

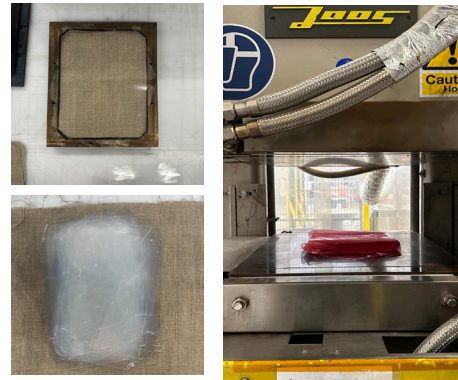


METHOD A: steel plate (AE)



Mach: : Advanced
Fiber/Mass : 50%
Pressure : 10Bar for 10mins
Heat : 180°C
Preheated : Yes

METHOD B: Mould (AE)



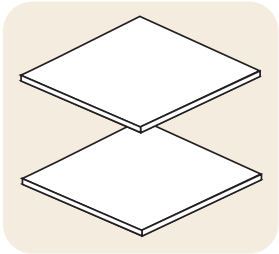
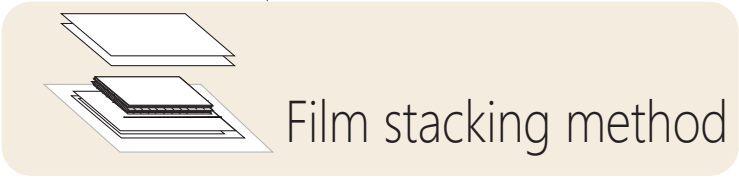
Mach: : Advanced
Fiber/Mass : 70%
Pressure : 6Bar for 8mins
Heat : 165°C
Preheated : No

METHOD C: Mould (NPSP)

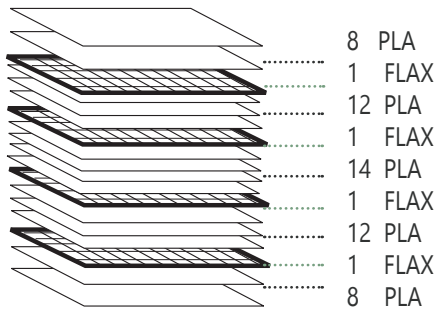


Mach: : Manual
Fiber/Mass : 50%
Pressure : 10Bar for 15mins
Heat : 180°C
Preheated : Yes

FACESHEET

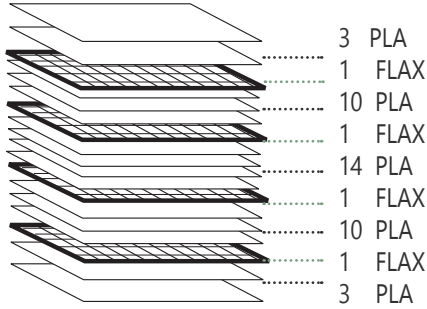


METHOD A: steel plate (AE)



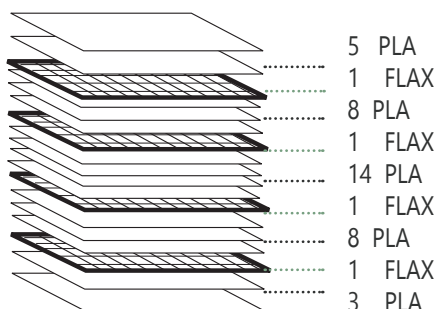
Mach: : Advanced
Fiber/Mass : 50%
Pressure : 10Bar for 10mins
Heat : 180°C
Preheated : Yes

METHOD B: Mould (AE)



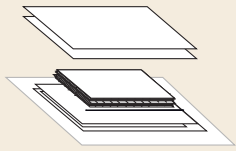
Mach: : Advanced
Fiber/Mass : 70%
Pressure : 6Bar for 8mins
Heat : 165°C
Preheated : No

METHOD C: Mould (NPSP)

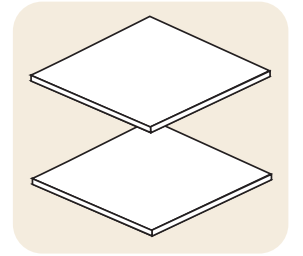


Mach: : Manual
Fiber/Mass : 50%
Pressure : 10Bar for 15mins
Heat : 180°C
Preheated : Yes

FACESHEET



Film stacking method

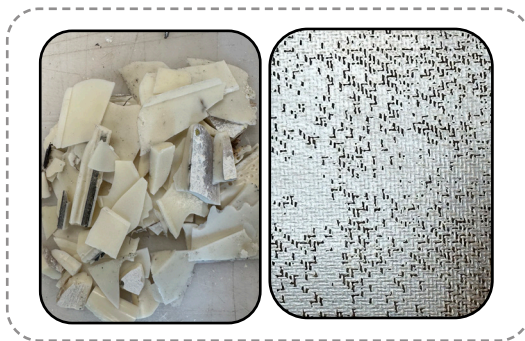


METHOD A: steel plate (AE)

Half Fail in PLA flow

Smooth surface

Not stiff

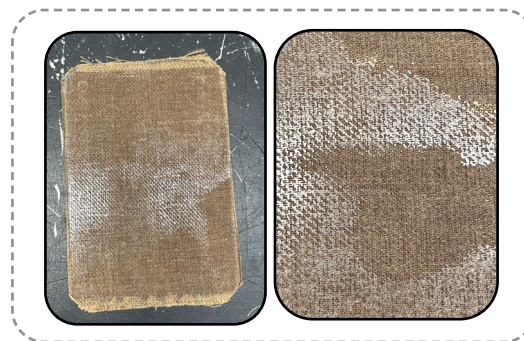


METHOD B: Mould (AE)

Fail in PLA flow

Rough surface

Stiff



METHOD C: Mould (NPSP)

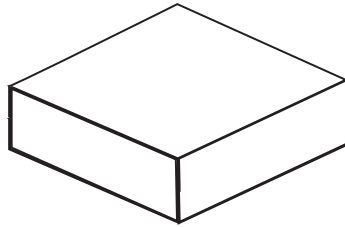
Well PLA flow

Smooth

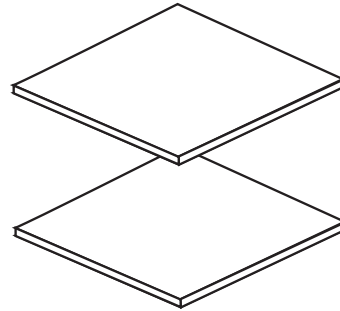
Stiff enough



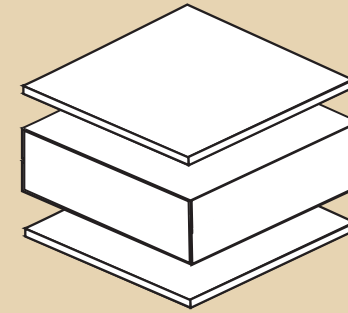
PHASE I: CORE



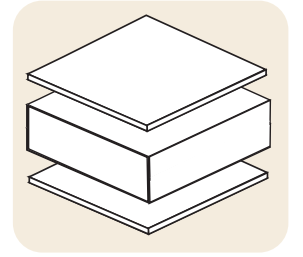
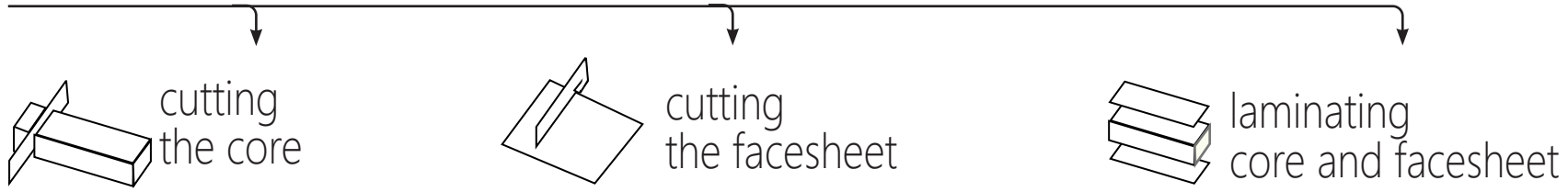
PHASE II: FACESHEET



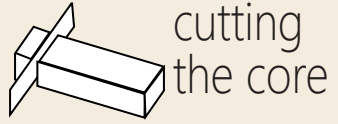
PHASE III: COMPOSITE



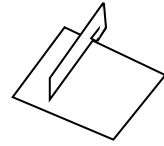
COMPOSITE



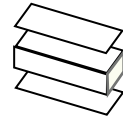
COMPOSITE



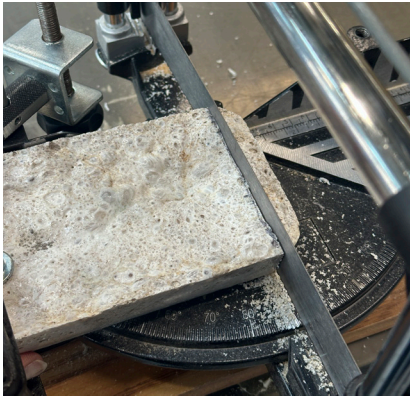
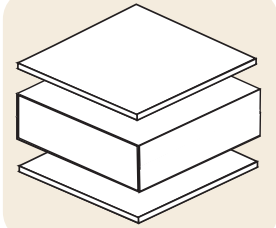
cutting
the core



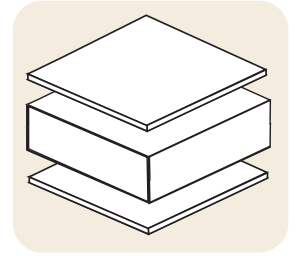
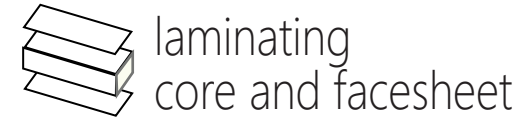
cutting
the facesheet



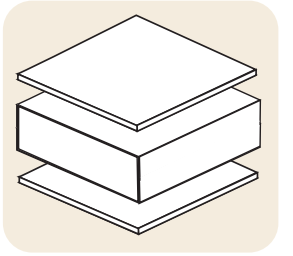
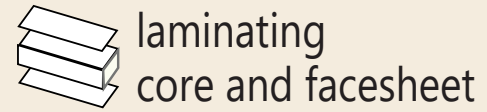
laminating
core and facesheet



COMPOSITE



COMPOSITE



Heat gun



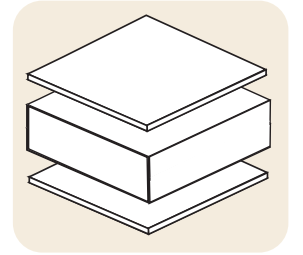
Light press

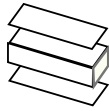


Glue-ing



COMPOSITE



 laminating
core and facesheet

Heat gun

No additional
material is used

Damage in fibers

Lose strength

Shrinkage 17%
thickness



Light press

No additional
material is used

Did not work

Shrinkage 50%
thickness



Glue-ing

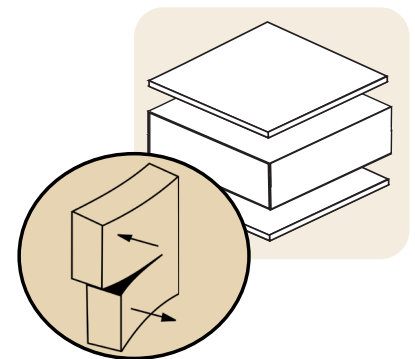
Easy to
handle

Non-biobased

Not well
suited for PLA

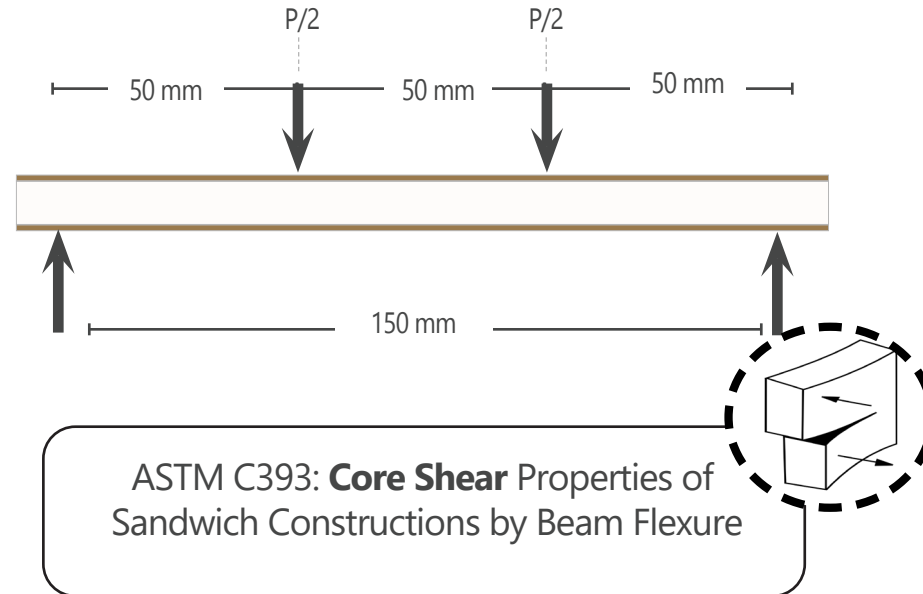


Testing the sandwich

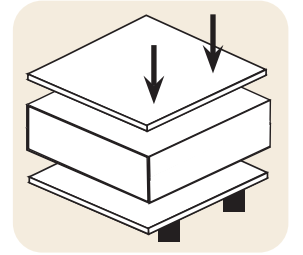


Shear Strength

TESTING



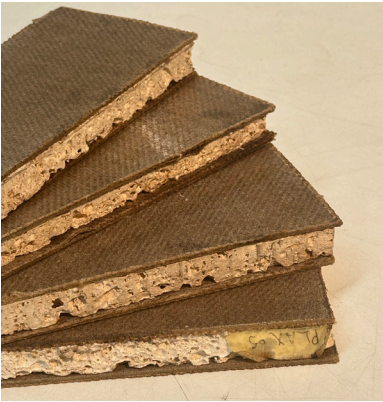
Location: ME TU Delft
Supervised by Fred Veer



TESTING

Specimens

PLAX A



Dimensions : 200mm x 75mm

Sample amount : 4 samples

Facesheet prod. : Film stacking

Lamination : Heating gun

Test : 4-point bending

PLAX B



Dimensions : 190mm x 75mm

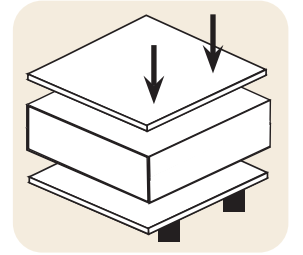
Sample amount : 5 samples

Facesheet prod. : Film stacking

Lamination : Epoxy

Test : 4-point bending

for
testing!!



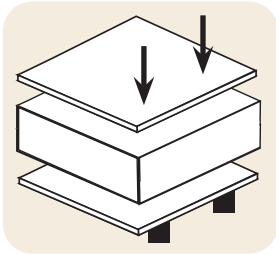
TESTING

Specimens

PLAX A



PLAX B



Material	facesheet thickness	core thickness	core weight	overall dimensions	overall thickness	overall weight
	mm	mm	gr	mm x mm	mm	gr
PLAX A1	1.95	-+ 11.0	107	200 mm x 75 mm	15	145
PLAX A2	1.2	-+ 13.5	141	200 mm x 75 mm	15.9	178
PLAX A3	1.3	-+ 15.0	140	200 mm x 75 mm	17.6	177
PLAX A4	1.35	-+ 13.0	90	200 mm x 75 mm	15.7	137

Material	facesheet thickness	core thickness	core weight	overall dimensions	overall thickness	overall weight
	mm	mm	gr	mm x mm	mm	gr
PLAX B1	2.4	21.8	108	190 x 75	26.6	178
PLAX B2	2.4	19.2	155	190 x 75	24	225
PLAX B3	2.4	17.65	184	190 x 75	22.45	254
PLAX B4	2.4	17.73	132	190 x 75	22.53	202
PLAX B5	2.4	15.94	133	190 x 75	20.74	203

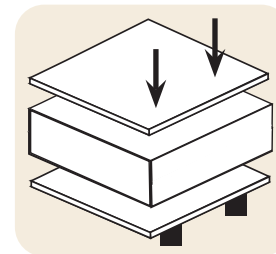
TESTING

Specimens

PLAX A



Material	facesheet thickness <i>mm</i>	core thickness <i>mm</i>	core weight <i>gr</i>	overall dimensions <i>mm x mm</i>	overall thickness <i>mm</i>	overall weight <i>gr</i>
PLAX A1	1.95	-+ 11.0	107	200 mm x 75 mm	15	145
PLAX A2	1.2	-+ 13.5	141	200 mm x 75 mm	15.9	178
PLAX A3	1.3	-+ 15.0	140	200 mm x 75 mm	17.6	177
PLAX A4	1.35	-+ 13.0	90	200 mm x 75 mm	16 mm 15.7	159 gr

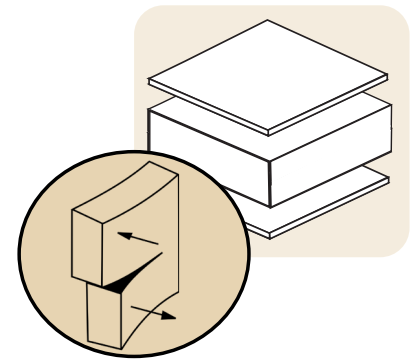


PLAX B



Material	facesheet thickness <i>mm</i>	core thickness <i>mm</i>	core weight <i>gr</i>	overall dimensions <i>mm x mm</i>	overall thickness <i>mm</i>	overall weight <i>gr</i>
PLAX B1	2.4	21.8	108	190 x 75	26.6	178
PLAX B2	2.4	19.2	155	190 x 75	24	225
PLAX B3	2.4	17.65	184	190 x 75	23.5 mm 22.45	254
PLAX B4	2.4	17.73	132	190 x 75	22.53	202
PLAX B5	2.4	15.94	133	190 x 75	20.74	203

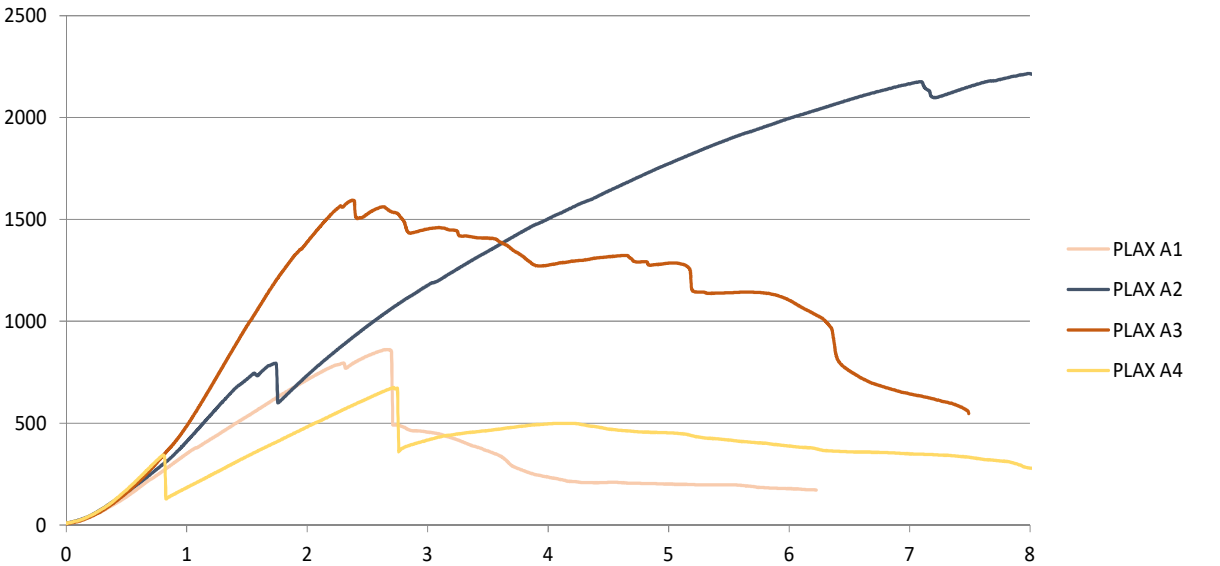
Results of the testing



Shear Strength

TEST

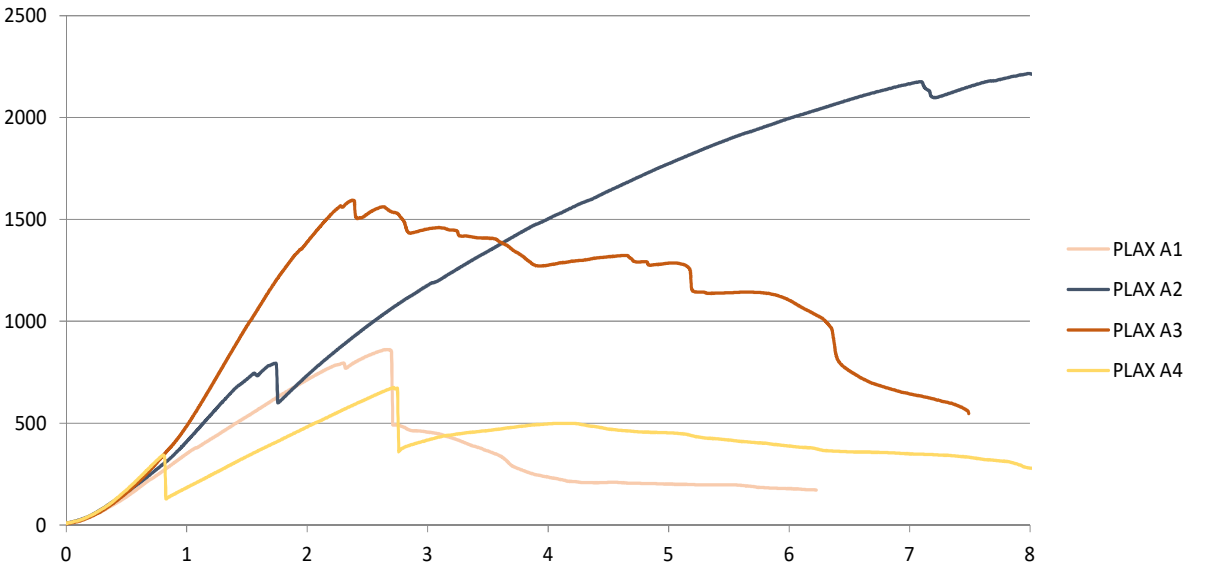
Results of PLAX A



ID	h_{core} mm	h_{all} mm	Mass core gr	Mass overall gr	F_{max} (N)	F_{yield} (N)	dL_{Fmax} (mm)	dL_{Fyield} (mm)	F_{shear_Ultim} (MPa)	$E_{Youngs\ modulus}$ (GPa)
PLAX A1	11.1	15	107	145	861.5	738.0	2.7	2.31	0.44	2.57
PLAX A2	13.5	15.9	141	178	2215.6	702.0	8.0	1.5	1.00	4.27
PLAX A3	15	17.6	140	177	1594.4	1376.0	2.4	2.0	0.65	4.36
PLAX A4	13	15.7	90	137	674.9	321.0	2.7	0.8	0.31	3.44

TEST

Results of PLAX A



ID	h_{core} mm	h_{all} mm	Mass core gr	Mass overall gr	F_{max} (N)	F_{yield} (N)	dL_{Fmax} (mm)	dL_{Fyield} (mm)	F_{shear_Ultim} (MPa)	$E_{Youngs\ modulus}$ (GPa)
PLAX A1	11.1	15	107	145	861.5	738.0	2.7	2.31	0.44	2.57
PLAX A2	13.5	15.9	141	178	2215.6	702.0	8.0	1.5	1.00	4.27
PLAX A3	15	17.6	140	177	1594.4	1376.0	2.4	2.0	0.65	4.36
PLAX A4	13	15.7	90	137	674.9	321.0	2.7	0.8	0.31	0.60 MPa

TEST

Results of PLAX A



ID	h_{core} mm	h_{all} mm	Mass core gr	Mass overall gr	F_{max} (N)	F_{yield} (N)	dL_{Fmax} (mm)	dL_{Fyield} (mm)	F_{shear_Ultim} (MPa)	$E_{Youngs\ modulus}$ (GPa)
PLAX A1	11.1	15	107	145	861.5	738.0	2.7	2.31	0.44	2.57
PLAX A2	13.5	15.9	141	178	2215.6	702.0	8.0	1.5	1.00	4.27
PLAX A3	15	17.6	140	177	1594.4	1376.0	2.4	2.0	0.65	4.36
PLAX A4	13	15.7	90	137	674.9	321.0	2.7	0.8	0.31	0.60 MPa

TEST

Results of PLAX A

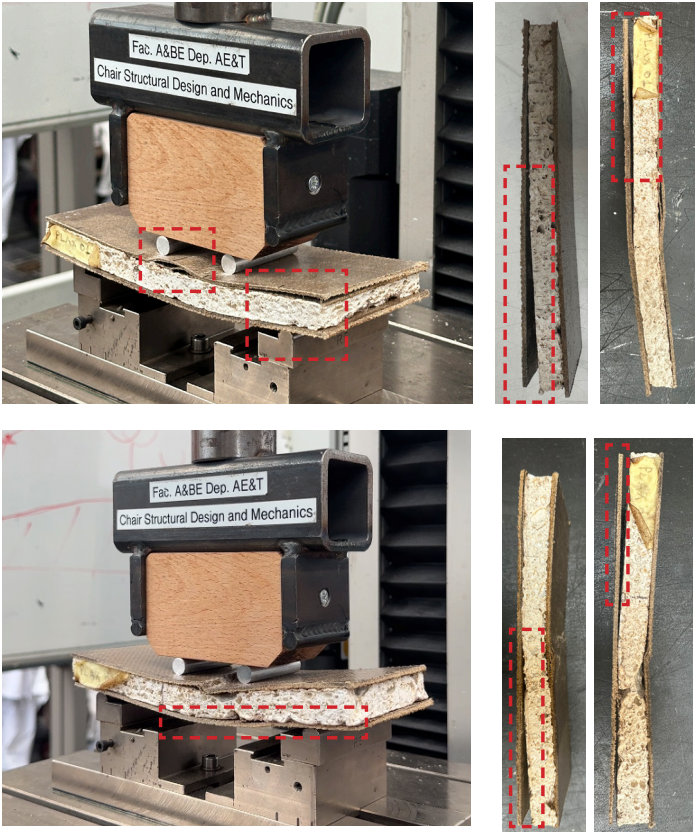


ID	h_{core} mm	h_{all} mm	Mass core gr	Mass overall gr	F_{max} (N)	F_{yield} (N)	dL_{Fmax} (mm)	dL_{Fyield} (mm)	F_{shear_Ultim} (MPa)	$E_{Youngs\ modulus}$ (GPa)
PLAX A1	11.1	15	107	145	861.5	738.0	2.7	2.31	0.44	2.57
PLAX A2	13.5	15.9	141	178	2215.6	702.0	8.0	1.5	1.00	4.27
PLAX A3	15	17.6	140	177	1594.4	1376.0	2.4	2.0	0.65	4.36
PLAX A4	13	15.7	90	137	674.9	321.0	2.7	0.8	0.31	0.60 MPa

Failure types

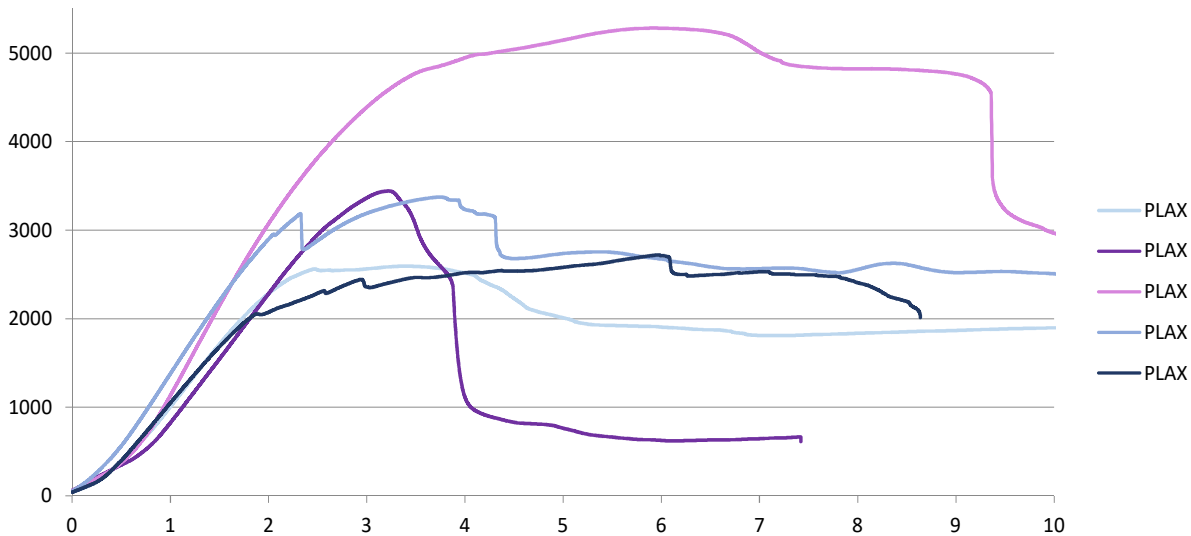


Delamination



TEST

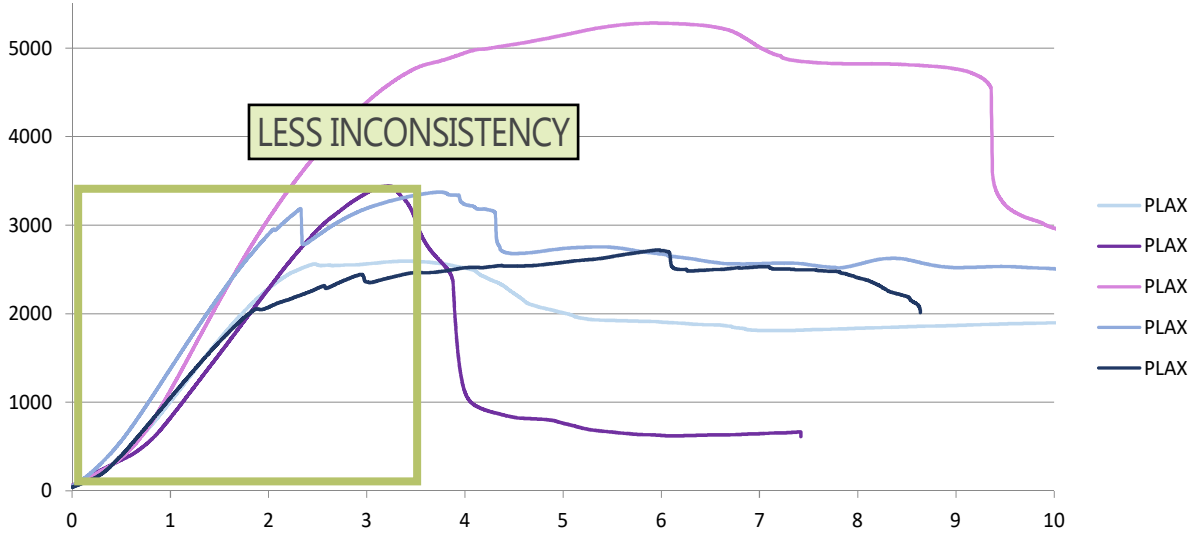
Results of PLAX B



ID	h_{core} mm	h_{all} mm	Mass core gr	Mass overall gr	F_{max} (N)	F_{yield} (N)	dL_{Fmax} (mm)	dL_{Fyield} (mm)	F_{shear_Ultim} (MPa)	$E_{Youngs\ modulus}$ (GPa)
PLAX A1	21.8	26.6	108	178	2593.4	2348.0	3.3	2.0	0.71	0.79
PLAX A2	19.2	24	155	225	3441.9	2715.0	3.2	2.3	1.06	1.11
PLAX A3	17.65	22.45	184	254	5284.0	4775.0	6.0	3.5	1.76	1.59
PLAX A4	17.73	22.53	132	202	3372.0	2942.0	3.8	2.1	1.12	1.65
PLAX A5	15.94	20.74	133	203	2720.9	2047.0	6.0	1.3	0.99	2.36

TEST

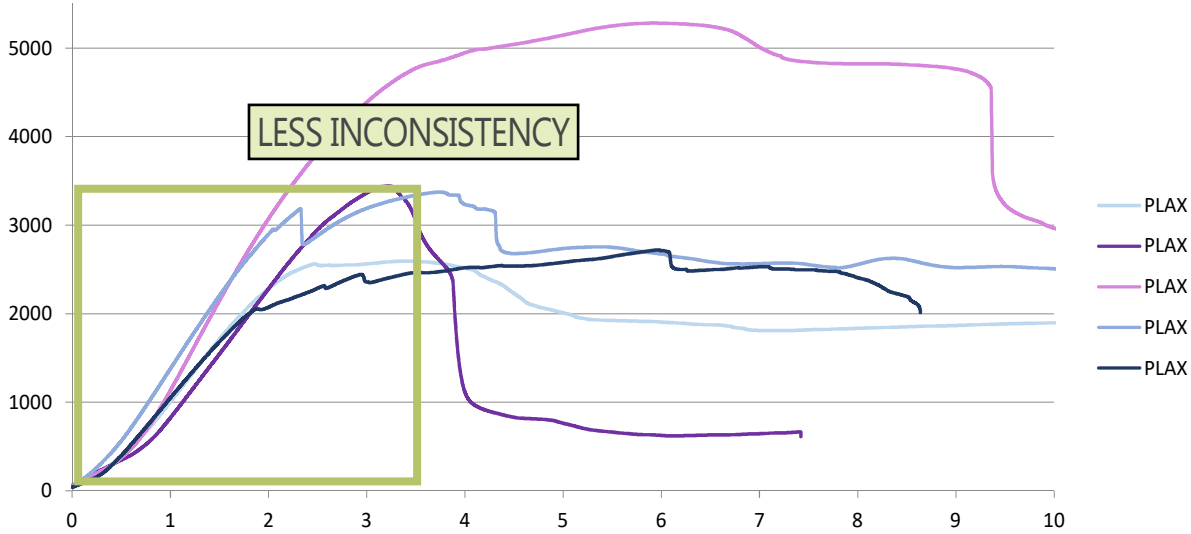
Results of PLAX B



ID	h_{core} mm	h_{all} mm	Mass core gr	Mass overall gr	F_{max} (N)	F_{yield} (N)	dL_{Fmax} (mm)	dL_{Fyield} (mm)	F_{shear_Ultim} (MPa)	$E_{Youngs\ modulus}$ (GPa)
PLAX A1	21.8	26.6	108	178	2593.4	2348.0	3.3	2.0	0.71	0.79
PLAX A2	19.2	24	155	225	3441.9	2715.0	3.2	2.3	1.06	1.11
PLAX A3	17.65	22.45	184	254	5284.0	4775.0	6.0	3.5	1.76	1.59
PLAX A4	17.73	22.53	132	202	3372.0	2942.0	3.8	2.1	1.12	1.65
PLAX A5	15.94	20.74	133	203	2720.9	2047.0	6.0	1.3	0.99	2.36

TEST

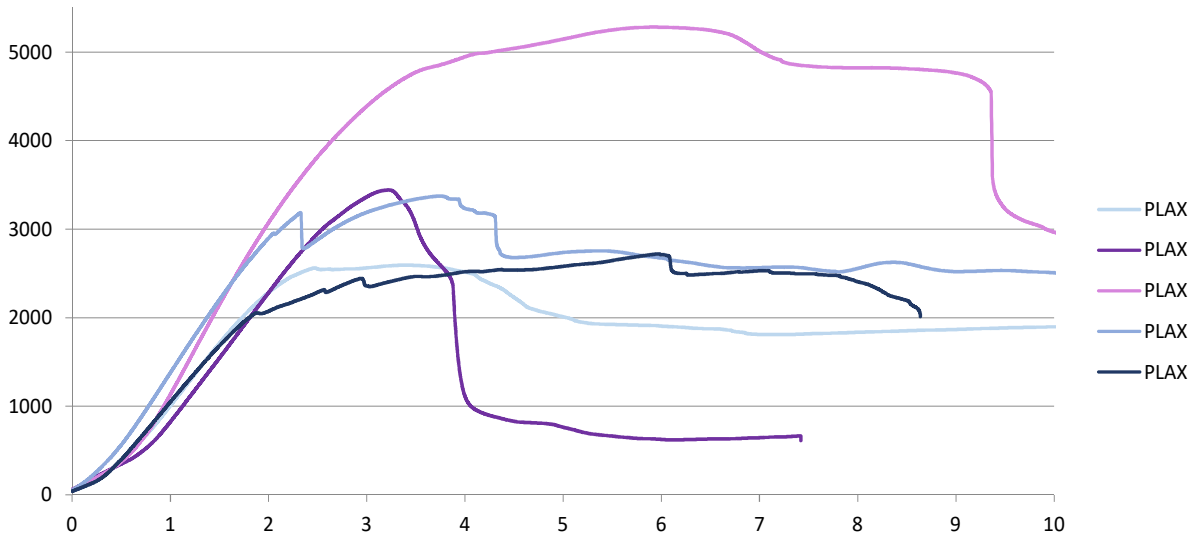
Results of PLAX B



ID	h_{core} mm	h_{all} mm	Mass core gr	Mass overall gr	F_{max} (N)	F_{yield} (N)	dL_{Fmax} (mm)	dL_{Fyield} (mm)	F_{shear_Ultim} (MPa)	$E_{Youngs\ modulus}$ (GPa)
PLAX A1	21.8	26.6	108	178	2593.4	2348.0	3.3	2.0	0.71	0.79
PLAX A2	19.2	24	155	225	3441.9	2715.0	3.2	2.3	1.06	1.11
PLAX A3	17.65	22.45	184	254	5284.0	4775.0	6.0	3.5	1.76	1.59
PLAX A4	17.73	22.53	132	202	3372.0	2942.0	3.8	2.1	1.12	1.65
PLAX A5	15.94	20.74	133	203	2720.9	2047.0	6.0	1.3	0.99	1.10 MPa

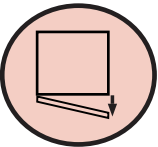
TEST

Results of PLAX B

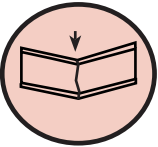


ID	h _{core} mm	h _{all} mm	Mass core gr	Mass overall gr	F _{max} (N)	F _{yield} (N)	dL _{Fmax} (mm)	dL _{Fyield} (mm)	F _{shear_Ultim} (MPa)	E _{Youngs modulus} (GPa)
PLAX A1	21.8	26.6	108	178	2593.4	2348.0	3.3	2.0	0.71	0.79
PLAX A2	19.2	24	155	225	3441.9	2715.0	3.2	2.3	1.06	1.11
PLAX A3	17.65	22.45	184	254	5284.0	4775.0	6.0	3.5	1.76	1.59
PLAX A4	17.73	22.53	132	202	3372.0	2942.0	3.8	2.1	1.12	1.65
PLAX A5	15.94	20.74	133	203	2720.9	2047.0	6.0	1.3	0.99	1.10 MPa

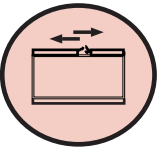
Failure types



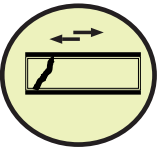
DELAMINATION (2)



BENDING FAILURE (1)



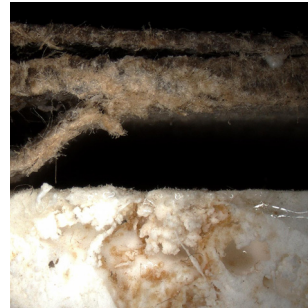
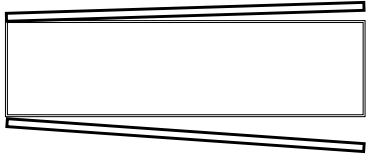
FACESHEET SHEAR FAILURE (1)



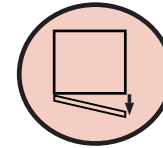
CORE SHEAR FAILURE (2)

TEST

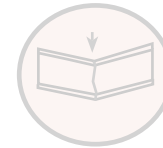
Results of PLAX B



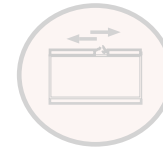
Failure types



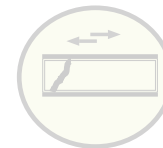
DELAMINATION (2)



BENDING FAILURE (1)



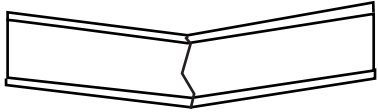
FACESHEET SHEAR FAILURE (1)



CORE SHEAR FAILURE (2)

TEST

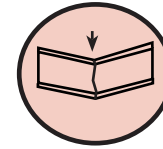
Results of PLAX B



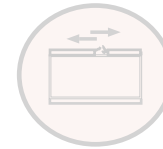
Failure types



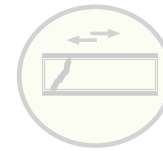
DELAMINATION (2)



BENDING FAILURE (1)



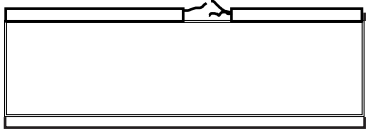
FACESHEET SHEAR FAILURE (1)



CORE SHEAR FAILURE (2)

TEST

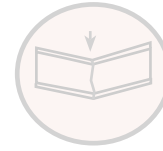
Results of PLAX B



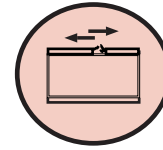
Failure types



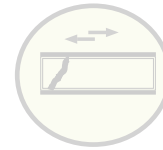
DELAMINATION (2)



BENDING FAILURE (1)



FACESHEET SHEAR FAILURE (1)



CORE SHEAR FAILURE (2)

TEST

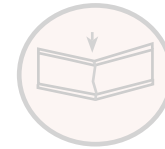
Results of PLAX B



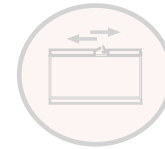
Failure types



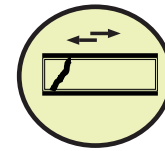
DELAMINATION (2)



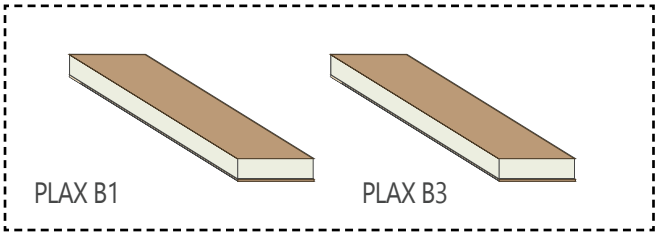
BENDING FAILURE (1)



FACESHEET SHEAR FAILURE (1)



CORE SHEAR FAILURE (2)



ID	h_{core} mm	h_{all} mm	Mass core gr	Mass overall gr	F_{max} (N)	F_{yield} (N)	$dL_{F_{\text{max}}}$ (mm)	$dL_{F_{\text{yield}}}$ (mm)	$F_{\text{shear_Ultim}}$ (MPa)	$E_{\text{Youngs modulus}}$ (GPa)
PLAX A1	21.8	26.6	108	178	2593.4	2348.0	3.3	2.0	0.71	1.24 MPa
PLAX A2	19.2	24	155	225	3441.9	2715.0	3.2	2.3	1.06	
PLAX A3	17.65	22.45	184	254	5284.0	4775.0	6.0	3.5	1.76	
PLAX A4	17.73	22.53	132	202	3372.0	2942.0	3.8	2.1	1.12	1.65
PLAX A5	15.94	20.74	133	203	2720.9	2047.0	6.0	1.3	0.99	2.36

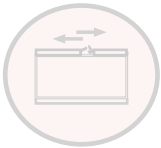
Failure types



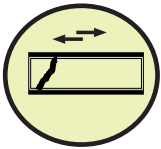
DELAMINATION (2)



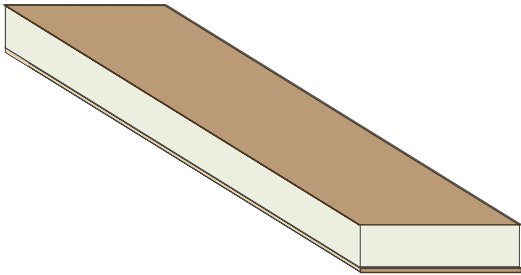
BENDING FAILURE (1)



FACESHEET SHEAR FAILURE (1)



CORE SHEAR FAILURE (2)



PLAX

$F_{\text{shear_core}}$: 1.24 MPa

$E_{\text{composite}}$: 1.50 GPa

W_{core} : 0.10 kN/m²

$W_{\text{facesheet}}$: 0.024 kN/m²

$\sigma_{\text{tensile.facesheet}}$: 125 MPa

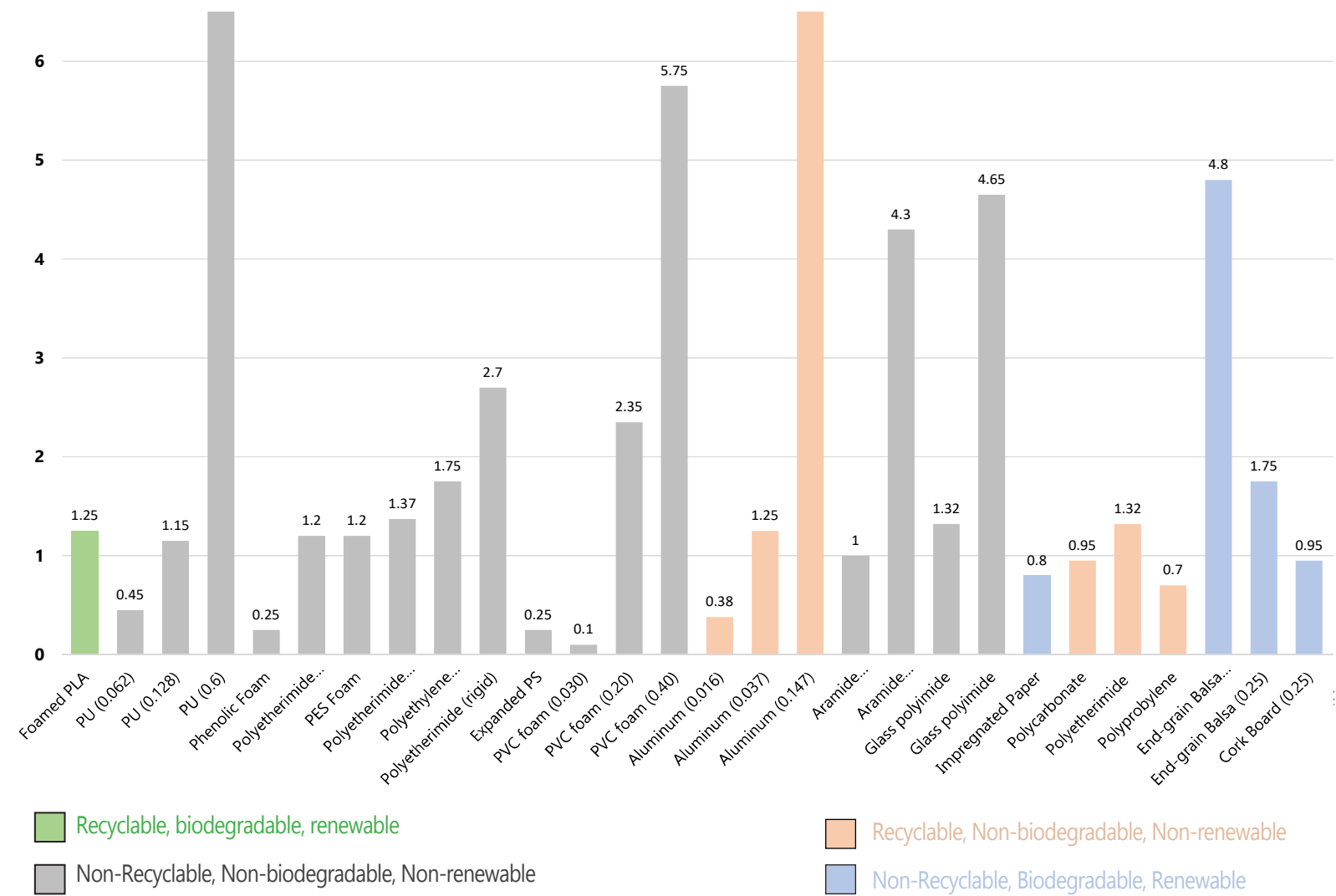
$E_{\text{facesheet}}$: 1.25 GPa

AVERAGE

Ref: Gosh, 2023

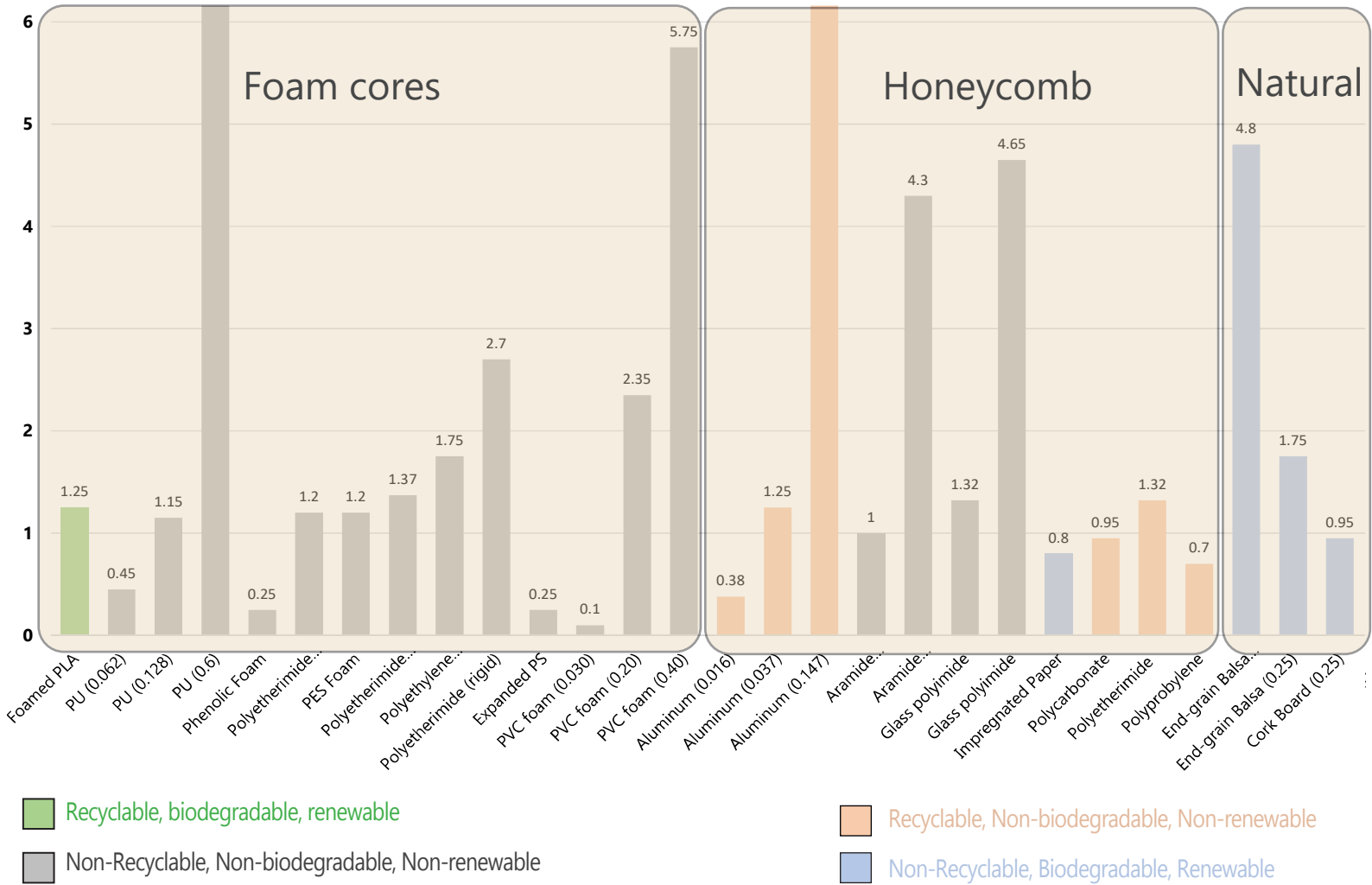
	ID	h_{core}	h_{all}	Mass	Mass	F_{max}	F_{yield}	$dL_{F_{\text{max}}}$	$dL_{F_{\text{yield}}}$	$F_{\text{shear_Ultim}}$	$E_{\text{Youngs modulus}}$	$I_{\text{estimated}}^*$
		mm	mm	core gr	overall gr	(N)	(N)	(mm)	(mm)	(MPa)	(GPa)	(mm ⁴)
AVERAGE	PLAX A	13.2	16.1	119.5	159.3	1336.6	784.3	3.9	1.6	0.6	-	11799.0
	PLAX B	18.5	23.3	142.4	212.4	3482.4	2965.4	4.5	2.2	1.1	1356.7	111520.4
DECISION	PLAX B1	21.8	26.6	108	178	2593.4	2348.0	3.3	2.0	0.71	0.79	150007.6
	PLAX B3	17.65	22.45	184	254	5284.0	4775.0	6.0	3.5	1.76	1.59	87900.3
	PLAX B*	19.73	24.53	146	216	3938.68	3561.5	4.67	2.77	1.24	1497.15*	53822.4

Result Comparison



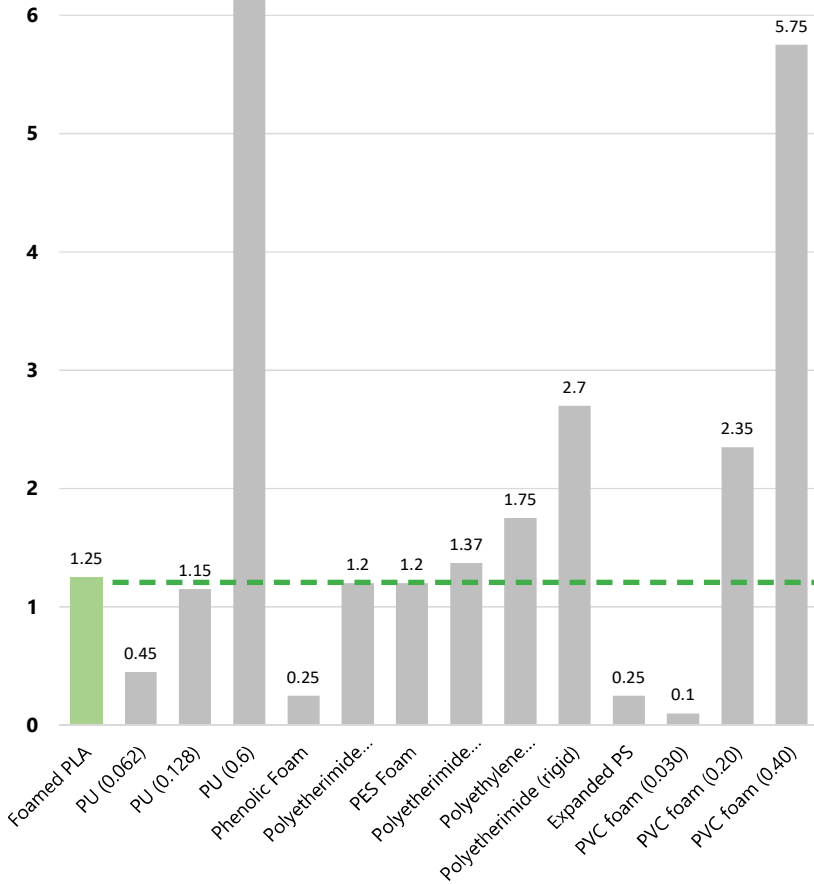
Result Comparison

Shear strength

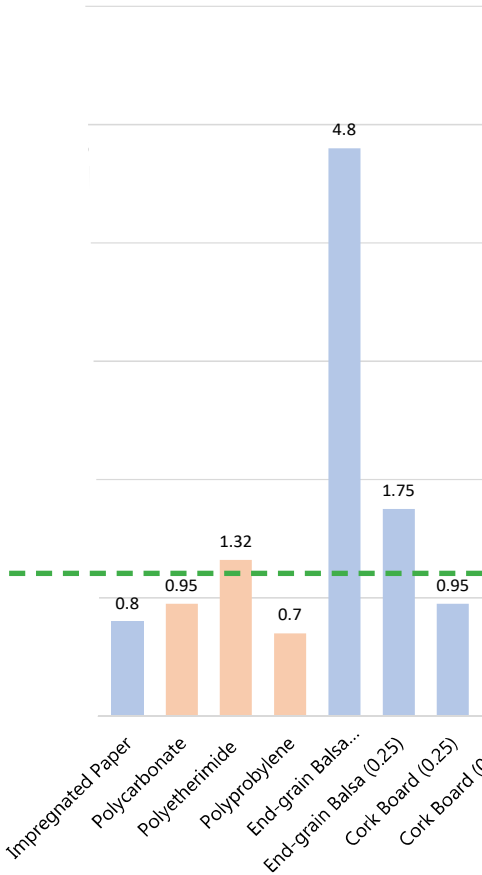


Result Comparison

Shear strength



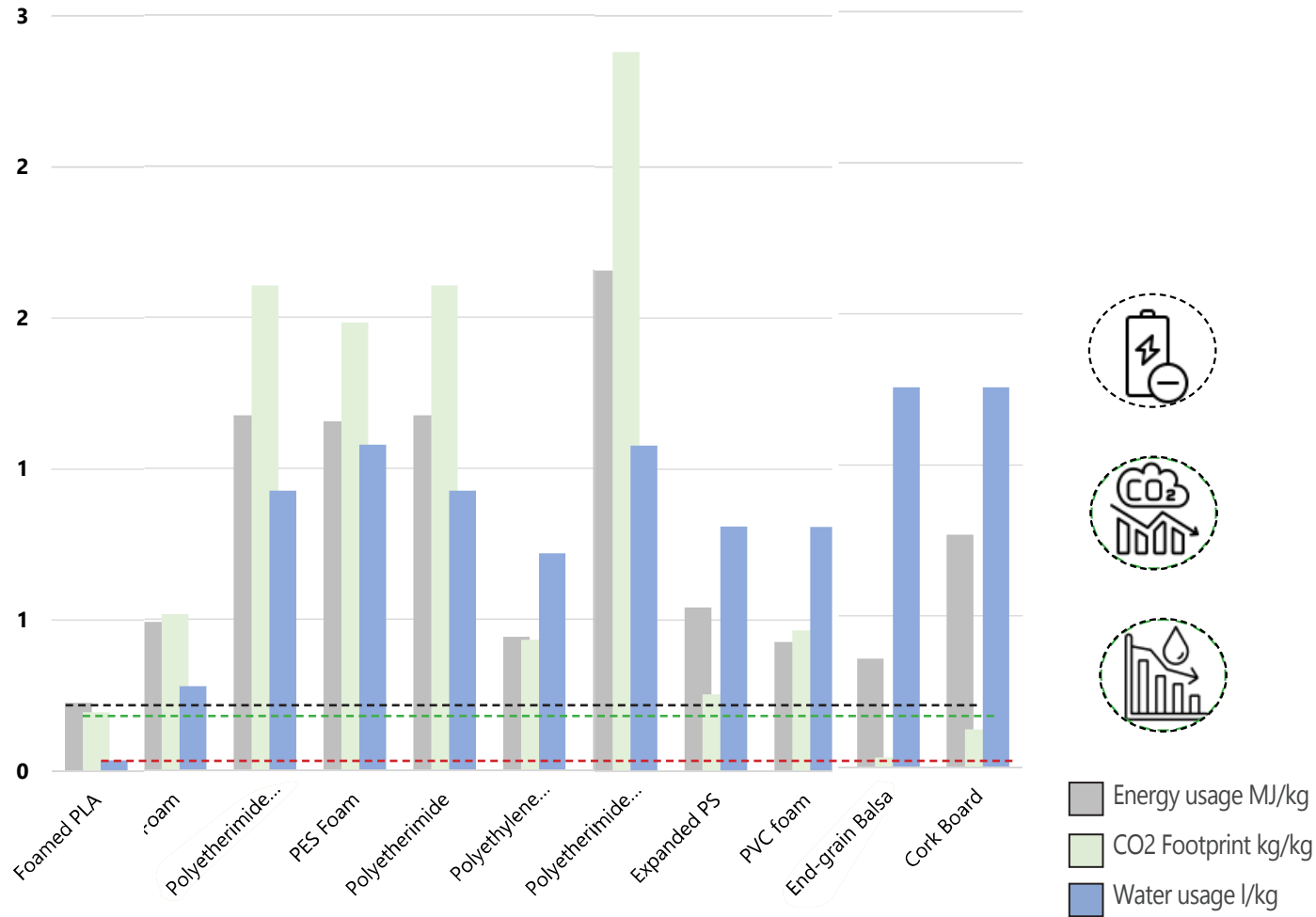
- Recyclable, biodegradable, renewable
- Non-Recyclable, Non-biodegradable, Non-renewable



- Recyclable, Non-biodegradable, Non-renewable
- Non-Recyclable, Biodegradable, Renewable

Result Comparison

Energy consumption, CO₂, water usage



chapter III

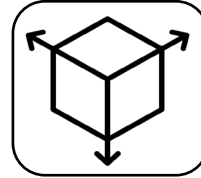
DESIGN & PRODUCTION LINE

DESIGN

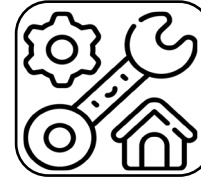
GOALS



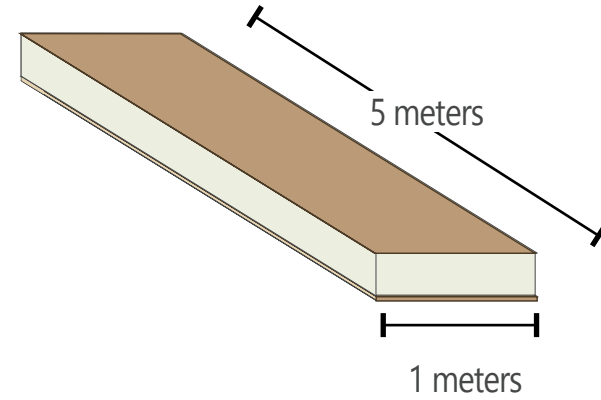
RESIDENTIAL

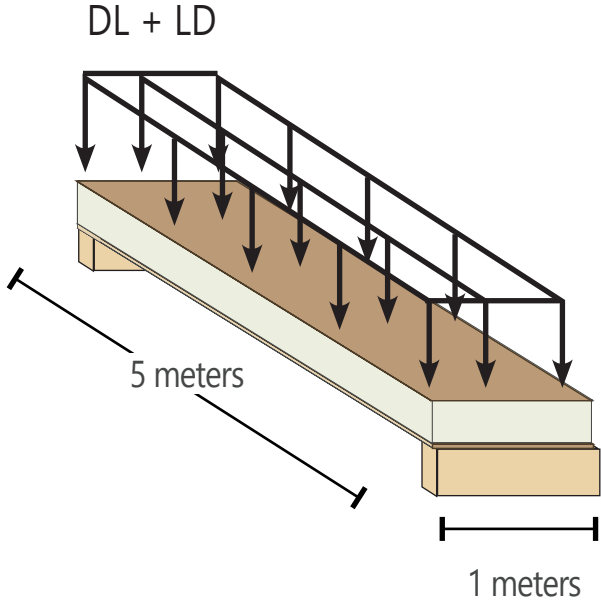


PREMANUFACTURED



EASY TO CONSTRUCT





PLAX

$F_{\text{shear_core}}$: 1.24 MPa

$E_{\text{composite}}$: 1.50 GPa

W_{core} : 0.10 kN/m²

$W_{\text{facesheet}}$: 0.024 kN/m²

$\sigma_{\text{tensile.facesheet}}$: 125 MPa

$E_{\text{facesheet}}$: 1.25 GPa

use	length	h overall	h facesheet	h core	width	A surface	Mass core	Mass facesheet	Mass overall	S support distance	a local distance	F core shear ultimate	F yield	σ max	σ facing bonding	E core Modulus P-Δ (GPa)	Is optimized			
	mm	mm	mm	mm	mm	mm ²	kg	kg	kg		mm	Mpa	Mpa		N/mm ²	Mpa	mm ⁴	mm ⁴	mm ⁴	
2.31	200	16	135	111	75	16000	107	19	145	150	50	0.44	1.00	12.66	11.28	2888.95	213.89	6273.03	12785	
200	16.9	1.2	13.5	75	75	16000	141	18.5	178	150	50	1.00	1.00	12.67	11.28	5401.67	384.43	4472.83	16050	
200	17.6	1.3	15	75	75	16000	143	19.5	177	150	50	0.65	1.00	12.67	11.28	5695.35	527.34	6489.93	15077	
200	15.7	1.35	13	75	75	16000	90	23.5	137	150	50	0.31	1.00	12.27	11.61	4204.58	343.28	5227.78	10781	
180	26.8	2.4	21.8	75	75	14250	188	35	238	150	50	0.92	1.00	15.48	12.68	705.0	19426.76	26440.20	167487	
180	24	2.4	19.2	75	75	14250	155	35	225	150	50	1.06	1.00	15.48	12.67	1001.00	78064.94	23081.69	150228	
180	22.45	2.4	17.45	75	75	14250	144	35	214	150	50	1.78	1.00	15.23	12.66	1440.22	60643.81	18178.51	16696	
180	22.53	2.4	17.73	75	75	14250	132	35	202	150	50	1.12	1.00	9.88	23.27	1430.47	6472.17	13211.16	1814	
180	20.74	2.4	15.94	75	75	14250	123	35	203	150	50	0.99	1.00	9.39	20.61	2446.50	44670.14	15222.40	7514	
1.6	200.0	16.1	1.5	13.2	75.0	16000.0	119.5	19.9	159.3	150.0	50.0	0.6	1.00	12.66	11.28	4592.7	367.2	5785.9	117391	
2.2	190.0	22.3	2.4	18.5	75.0	14250.0	142.4	35.0	212.4	150.0	50.0	1.1	0.0	9.6	23.5	1356.7	71823.7	18940.4	111520	
180	24.33	2.40	19.73	71.00	13215	144.00	35.00	214.00	150	50	1.24	0.00	10.22	24.72	1356.68	8583.15	22104.60	57322		
																	0.00	0.00	0	

M weight	f	b width	h overall	g	Ix	Iy	E face	E core	l core	l facesheet	Is optimized		is regular	E optimized
AN/m ²	m	m	m	m	m ⁴	m ⁴	AN/m ²	AN/m ²	m	m	AN/m ²	AN/m ²	AN/m ²	AN/m ²
0.567	5	1	0.1872	0.0936	0.000918	0	1700000	3000000	0.0009		3.888E-09	3.0338E-05	0.00091821	2794916.285
													0.000546884	
														2794916.285
														0

5 kN/m

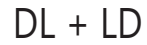
5 m

Load	Load Combination	Line Load	Shear	Bending Moment	Deflection
d inst.	1.35 x DL + 1.5 LL	V = v.L	F core shear ultimate	F tensile face ultimate	M max = v(l ²)/8
		AN/m	AN/m ²	AN/m ²	AN/m ²
0		5.45295	5.453	1235.68	13.632
				75.73542	15000
					17.04046875
					1736.833
					0.0200
					0.017235633

<

DESIGN

CALCULATIONS



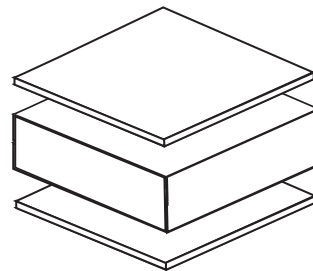
5 meters

1 meters

PLAX

 $F_{\text{shear_core}} : 1.24 \text{ MPa}$ $E_{\text{composite}} : 1.50 \text{ GPa}$
$$W_{\text{core}} : 0.10 \text{ kN/m}^2$$
$$W_{\text{facesheet}} : 0.024 \text{ kN/m}^2$$
 $\sigma_{\text{tensile.facesheet}}^*$: 125 MPa

*E_{facesheet} : 1.25 GPa



$h=0.0036\text{m}$, $W: 7.2 \text{ kg/m}^2$

$h=0.15\text{m}$, $W: 49.5 \text{ kg/m}^2$

Size	length	h oval	h flattened	h round	width	A mm ²	Mass kg/m	Mass flattened	Mass round	S support mm/m	a load mm	h from floor mm	h yield	h empty	a from bending	Energy Modulus (E=10 ¹¹ N/m ²) GPa-10	kg/mm ²	
	mm	mm	mm	mm	mm	mm ²	gr	gr	gr		mm	mm	mm	mm	mm		mm ²	
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	12765
2.31	200	16	1.95	11.1	75	95000	167	19	145	950	50	0.44	12.85	11.17	2883.95	211.63	6273.03	1276

Is optimized										Is regular		E-optimized		
Weight	f	b width	overall	g	lx	ly	Elach	Ecore	loore	lface sheet	A42 face sh. total	ESEAR	EBEND	
0.957	0	0	0.972	0.0926	0.000318	0	17.0000	1.0000	0.0000	0.0000	3.888E-03	3.02E-05	0.000993231	27.84E-05

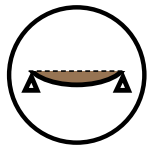
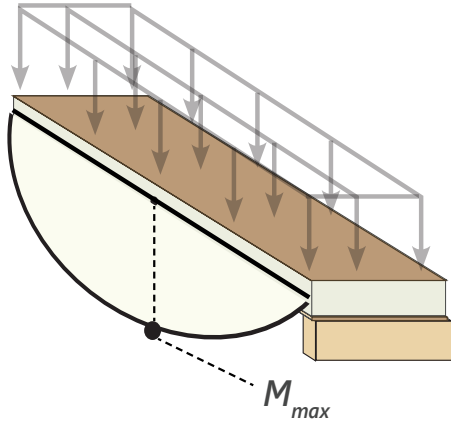
5 kN/m

5 m

		SAFE				SAFE				SAFE	
		Shear				Bending Moment				Deflection	
eLoad	Load Combination Line Load	Foore ultimate	Vmax = vlf/212	s = s max/1A	Ftensile/act esh	Mmax = mlf/218	o = Myll	s limit(Eurocode) L/250	s max (Sw. l'4)/384(E.I)		
d Inst.	135 ± DL + 15 LL V=V/L										
		kN/m²	kN/m	kN/m²	kN/m	kNm	kNm	m	m		
0	5.45295	5.453	1235.68	13.632	75.73542	15000	17.84046875	1736.833	0.0200	0.017235633	

DESIGN

CALCULATIONS



BENDING MOMENT

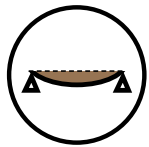
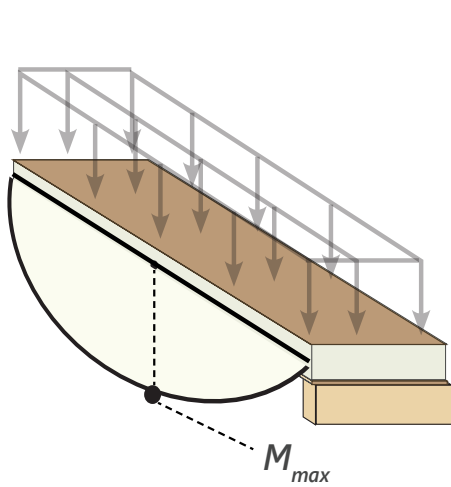
Stress Capacity

$$1736 \text{ kN/m}^2 \leq 12500 \text{ kN/m}^2$$

SATISFIES

DESIGN

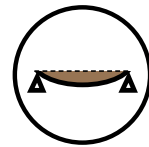
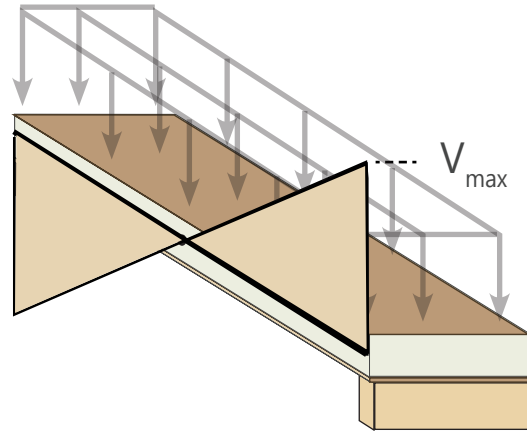
CALCULATIONS



BENDING MOMENT

$$1736 \text{ kN/m}^2 \leq 12500 \text{ kN/m}^2$$

SATISFIES



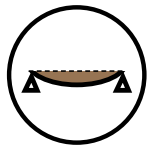
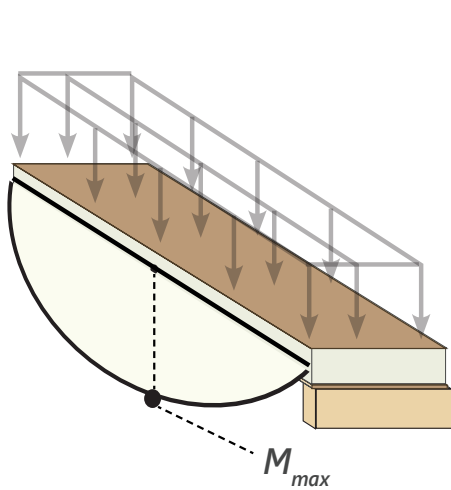
SHEAR FORCE

$$75.3 \text{ kN/m}^2 \leq 1240 \text{ kN/m}^2$$

SATISFIES

DESIGN

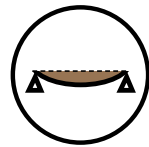
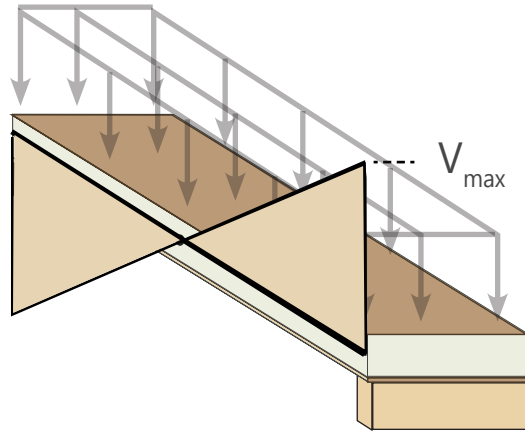
CALCULATIONS



BENDING MOMENT

$$1736 \text{ kN/m}^2 \leq 12500 \text{ kN/m}^2$$

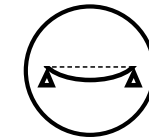
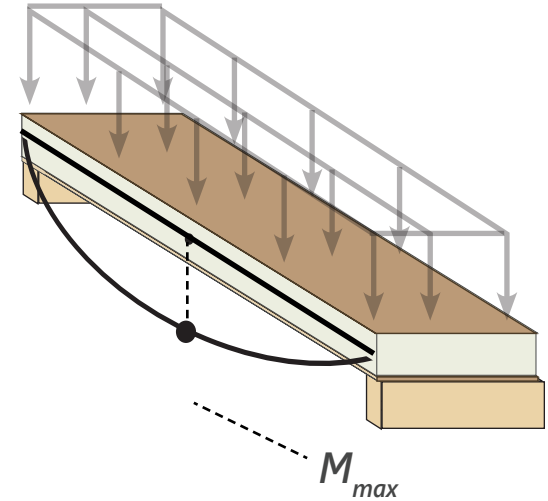
SATISFIES



SHEAR FORCE

$$75.3 \text{ kN/m}^2 \leq 1240 \text{ kN/m}^2$$

SATISFIES



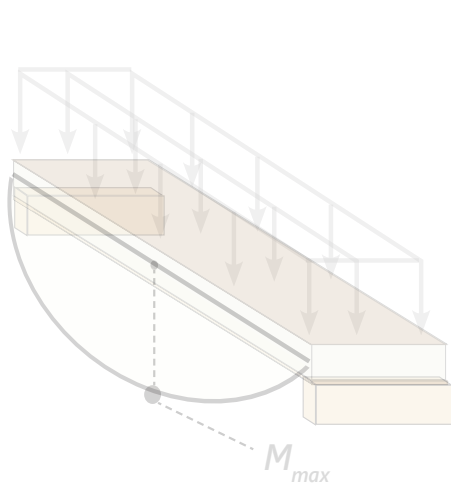
DEFLECTION

$$0.0199\text{m} \leq L/250 = 0.20 \text{ m}$$

BARELY SATISFIES

DESIGN

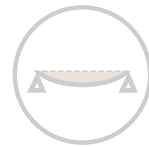
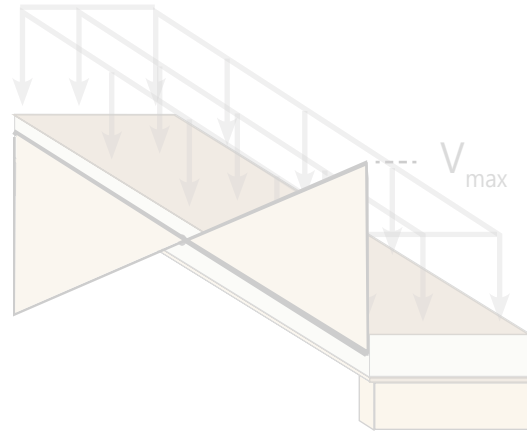
CALCULATIONS



BENDING MOMENT

$$1736 \text{ kN/m}^2 \leq 12500 \text{ kN/m}^2$$

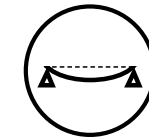
SATISFIES



SHEAR FORCE

$$75.3 \text{ kN/m}^2 \leq 1240 \text{ kN/m}^2$$

SATISFIES



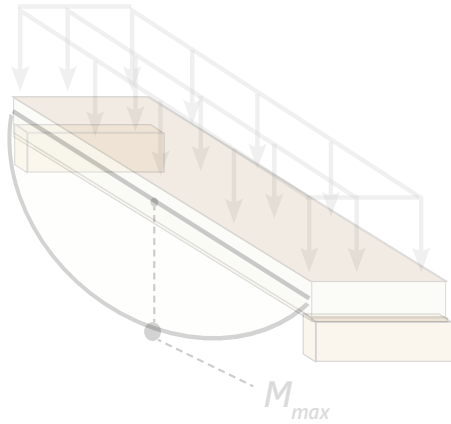
DEFLECTION

$$0.0199\text{m} \leq L/250 = 0.20 \text{ m}$$

BARELY SATISFIES

DESIGN

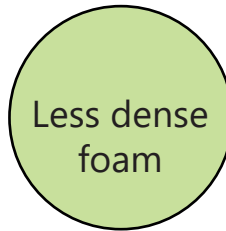
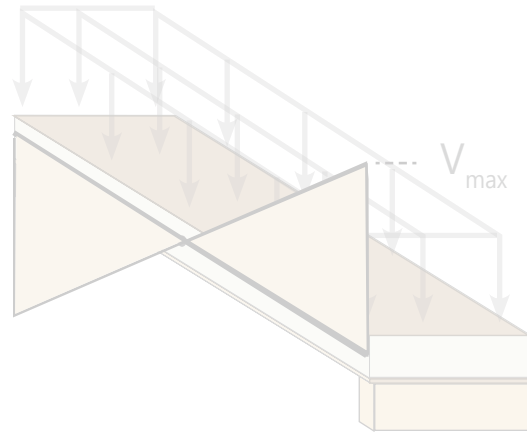
CALCULATIONS



BENDING MOMENT

$$1736 \text{ kN/m}^2 \leq 12500 \text{ kN/m}^2$$

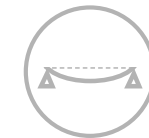
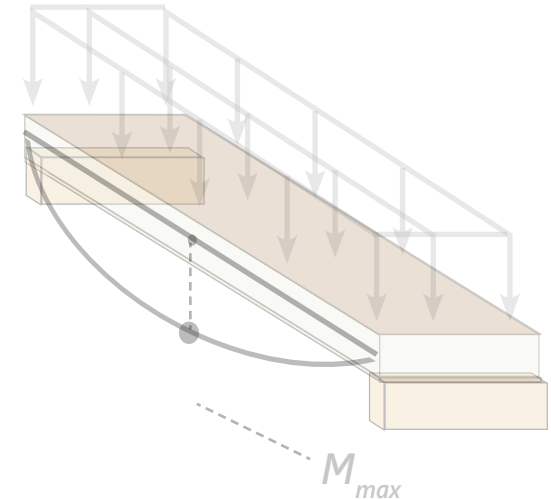
SATISFIES



Less dense foam

$$75.3 \text{ kN/m}^2 \leq 1240 \text{ kN/m}^2$$

SATISFIES



DEFLECTION

$$0.0199\text{m} \leq L/250 = 0.20 \text{ m}$$

BARELY SATISFIES

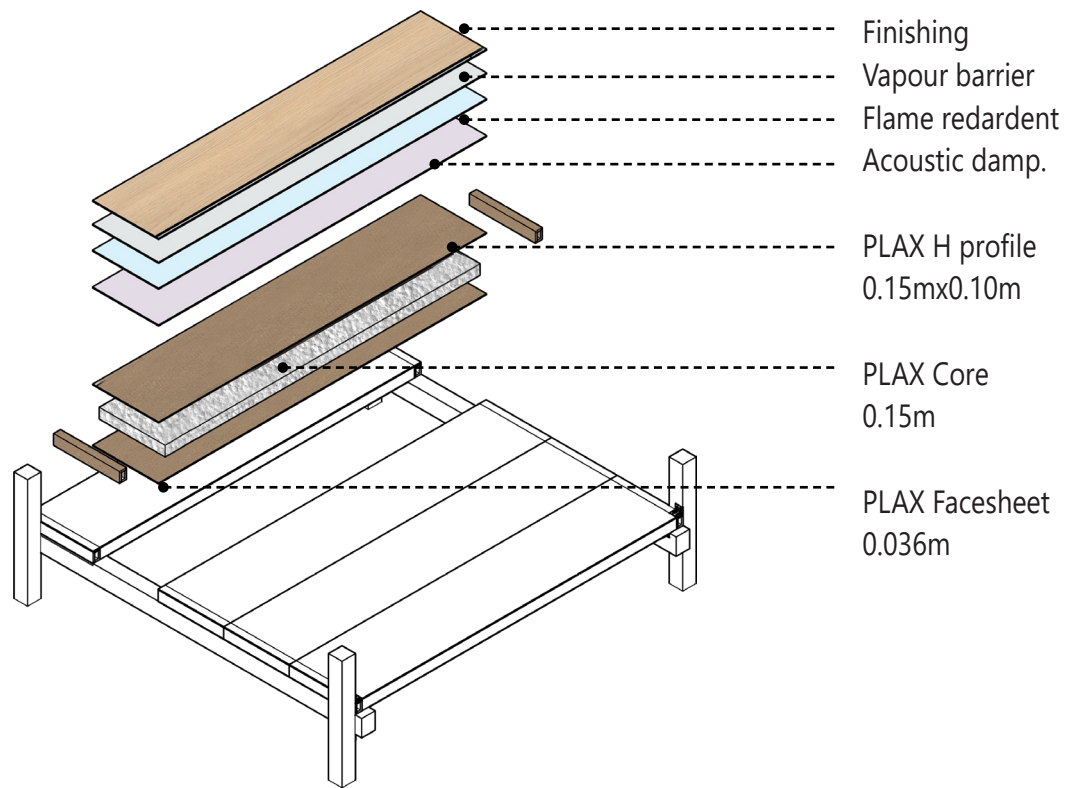


Figure 23: Exploded diagram of the proposed system with layers.

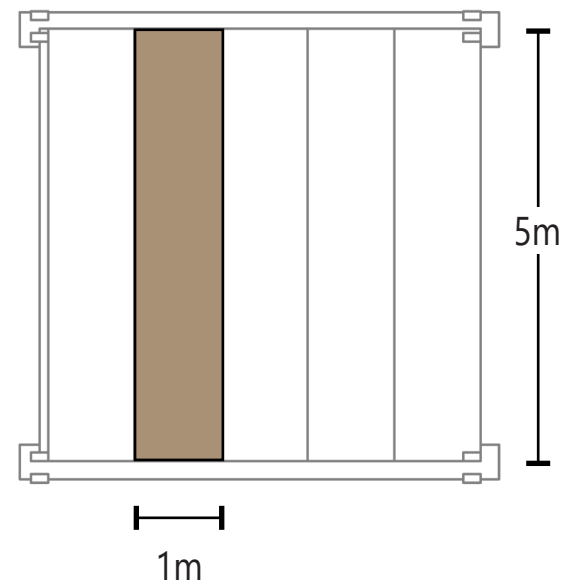
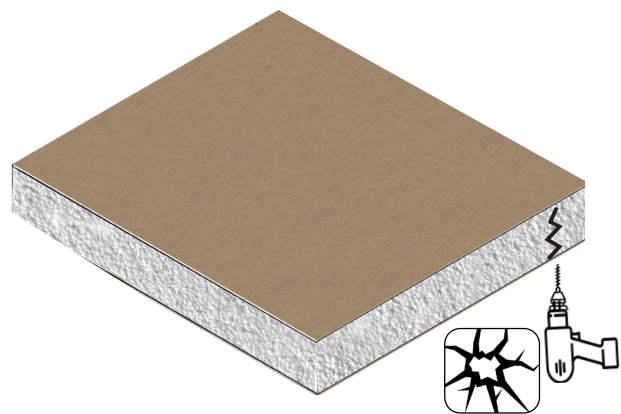
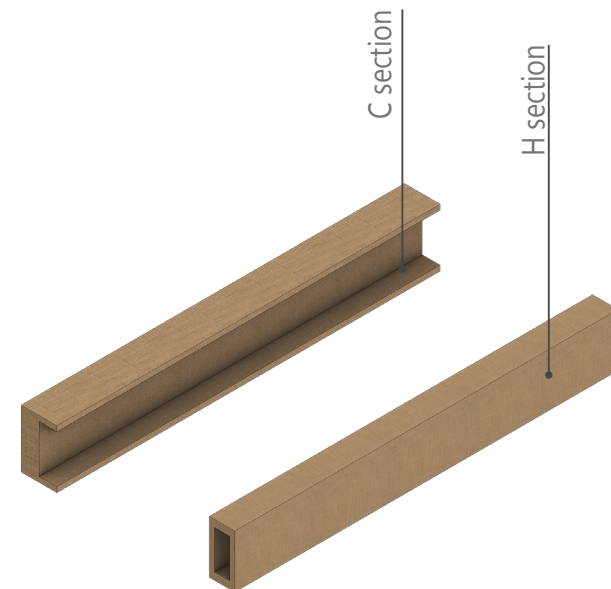
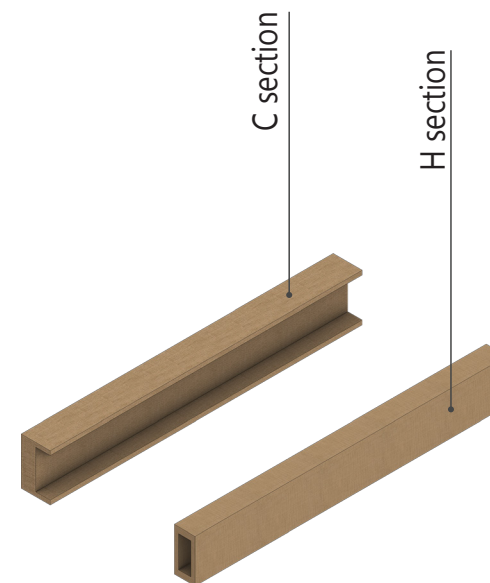
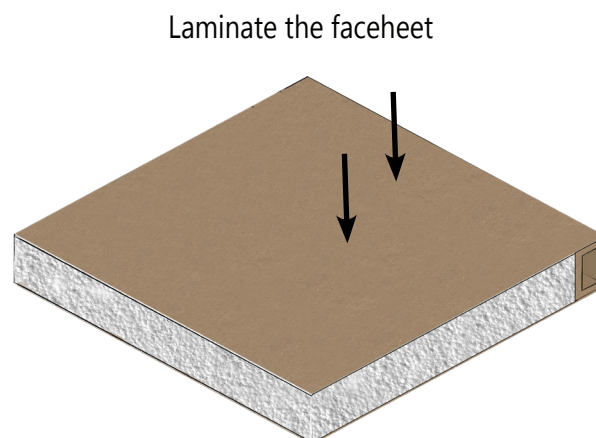
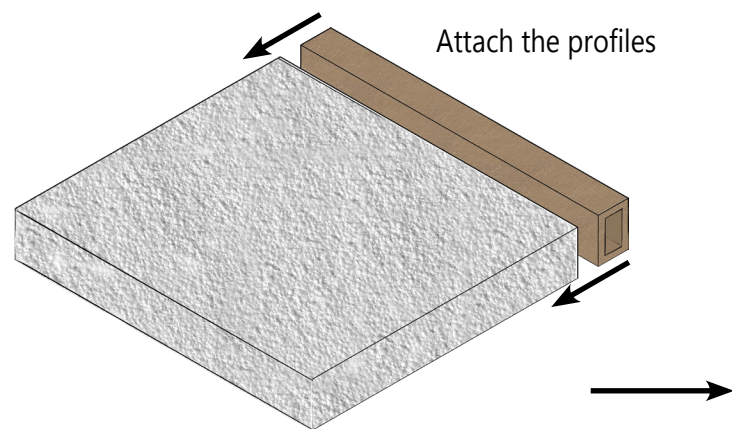


Figure 24: Exploded diagram of the proposed system with layers.



Flax / PLA Profiles, Hannurkar 2023, TU Eindhoven





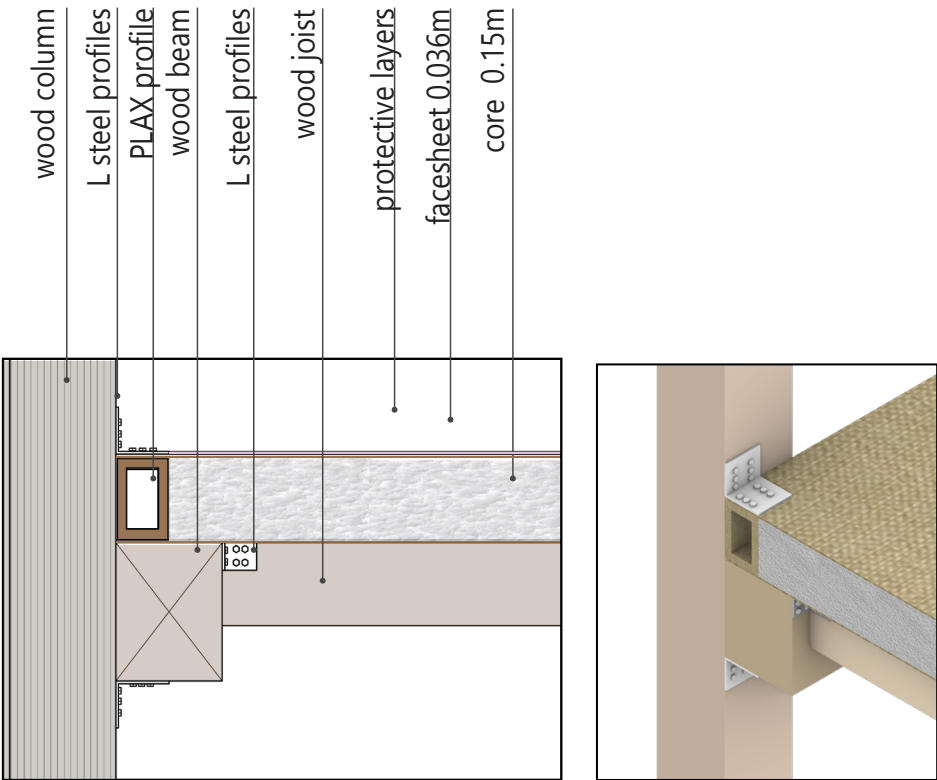


Figure 25: Column to floor detail

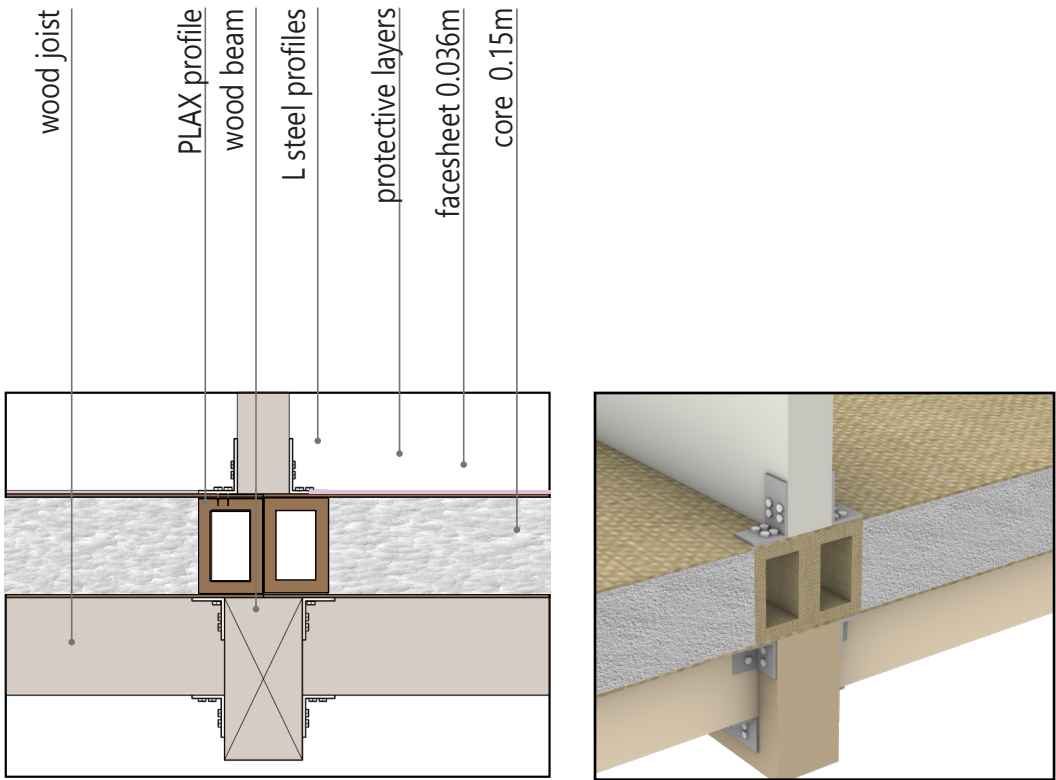
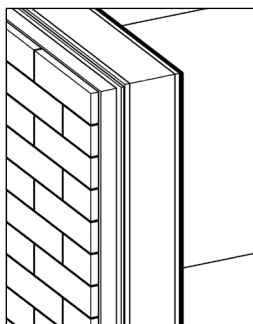


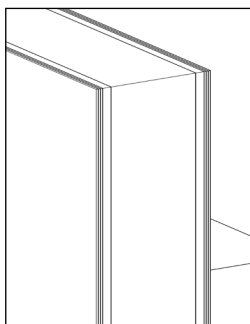
Figure 26: Beam to floor detail

DESIGN

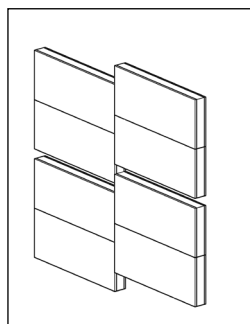
FURTHER POSSIBILITIES



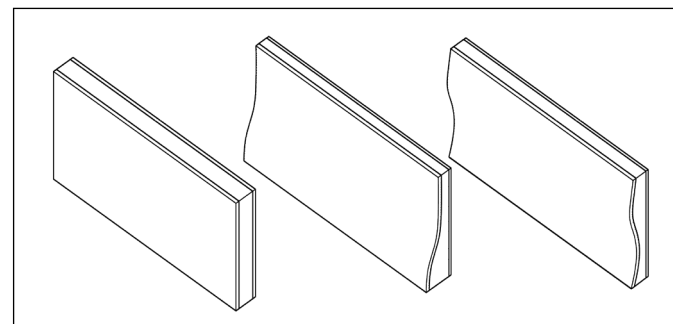
external walls



interior partitions

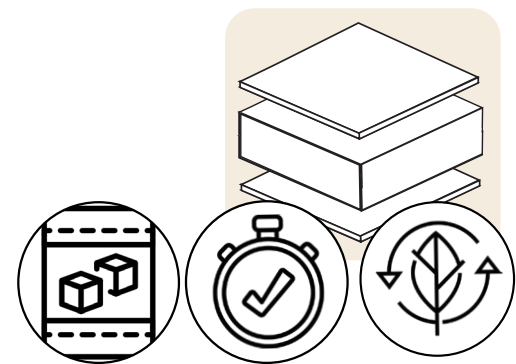


insulation &
acoustic panels



re/shapable design

Production line

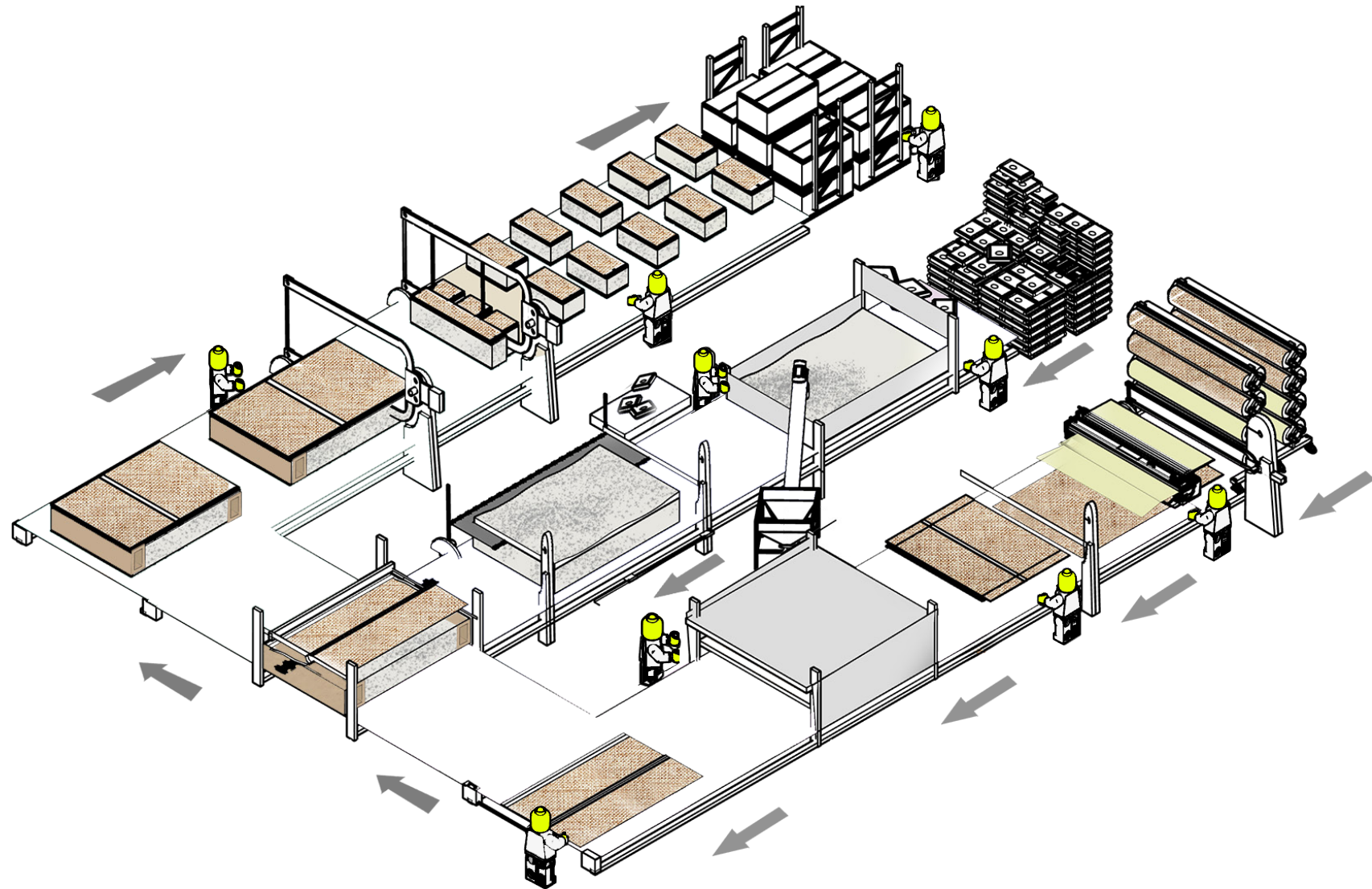


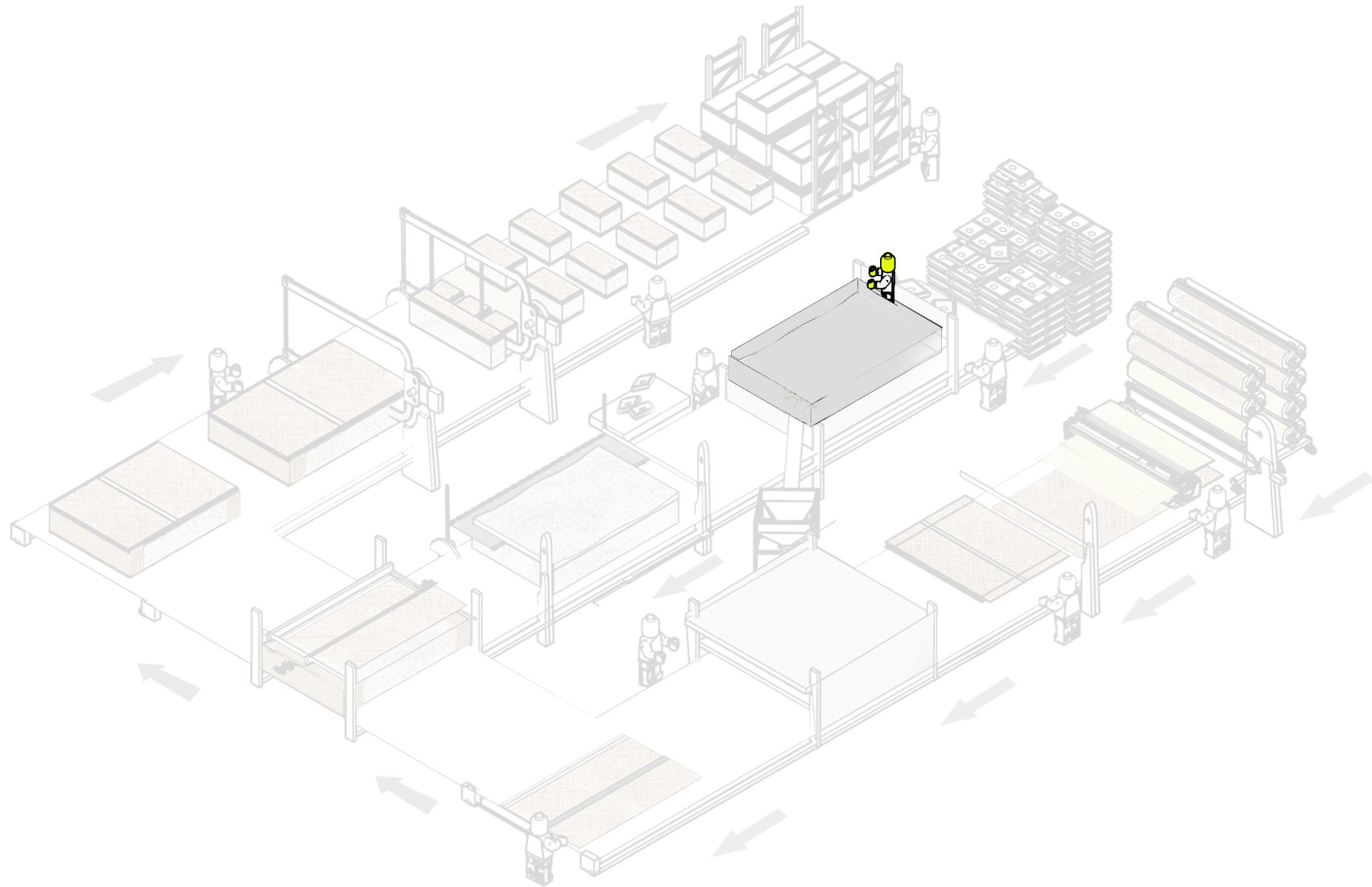
Easy

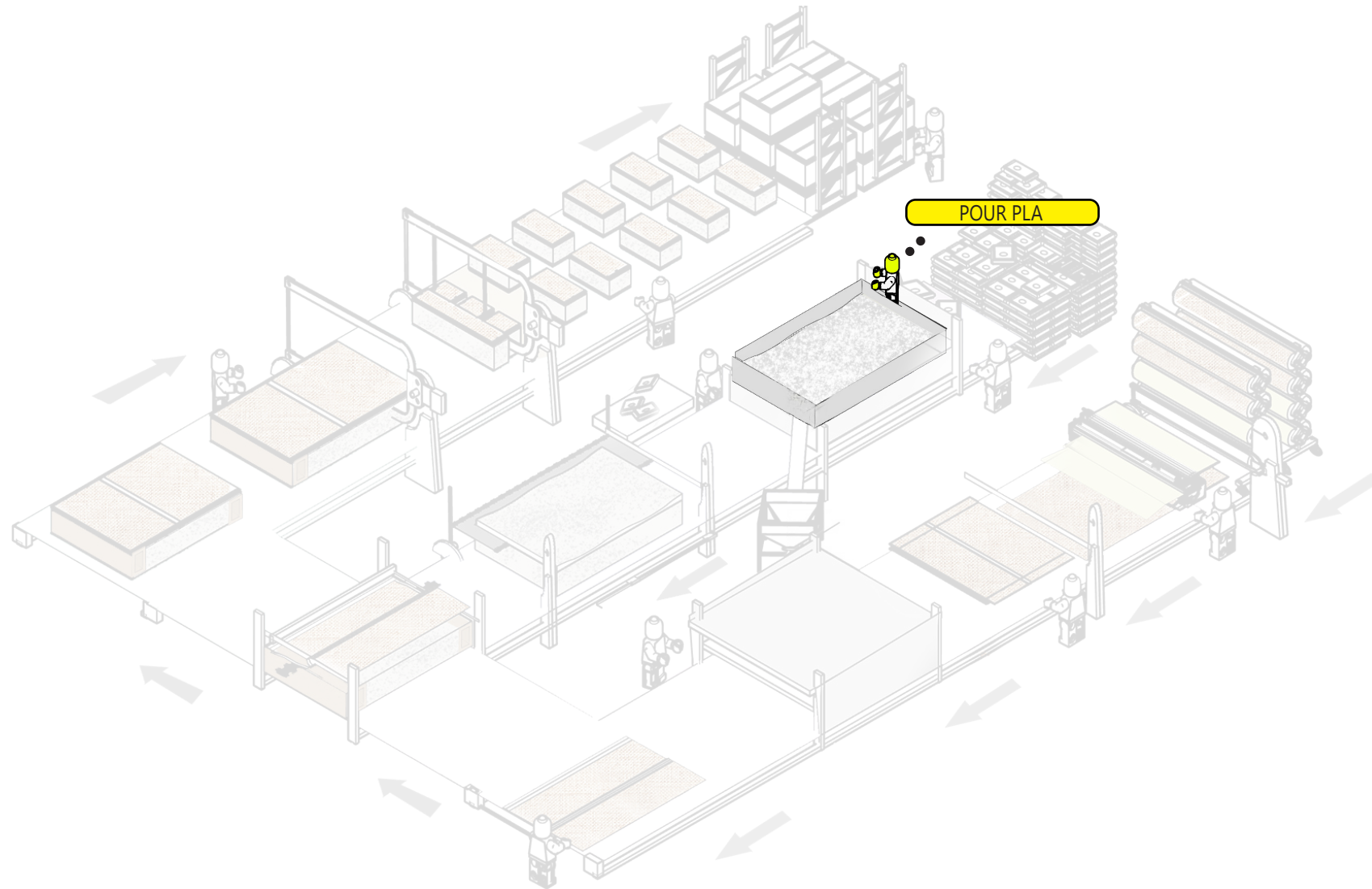
Rapid

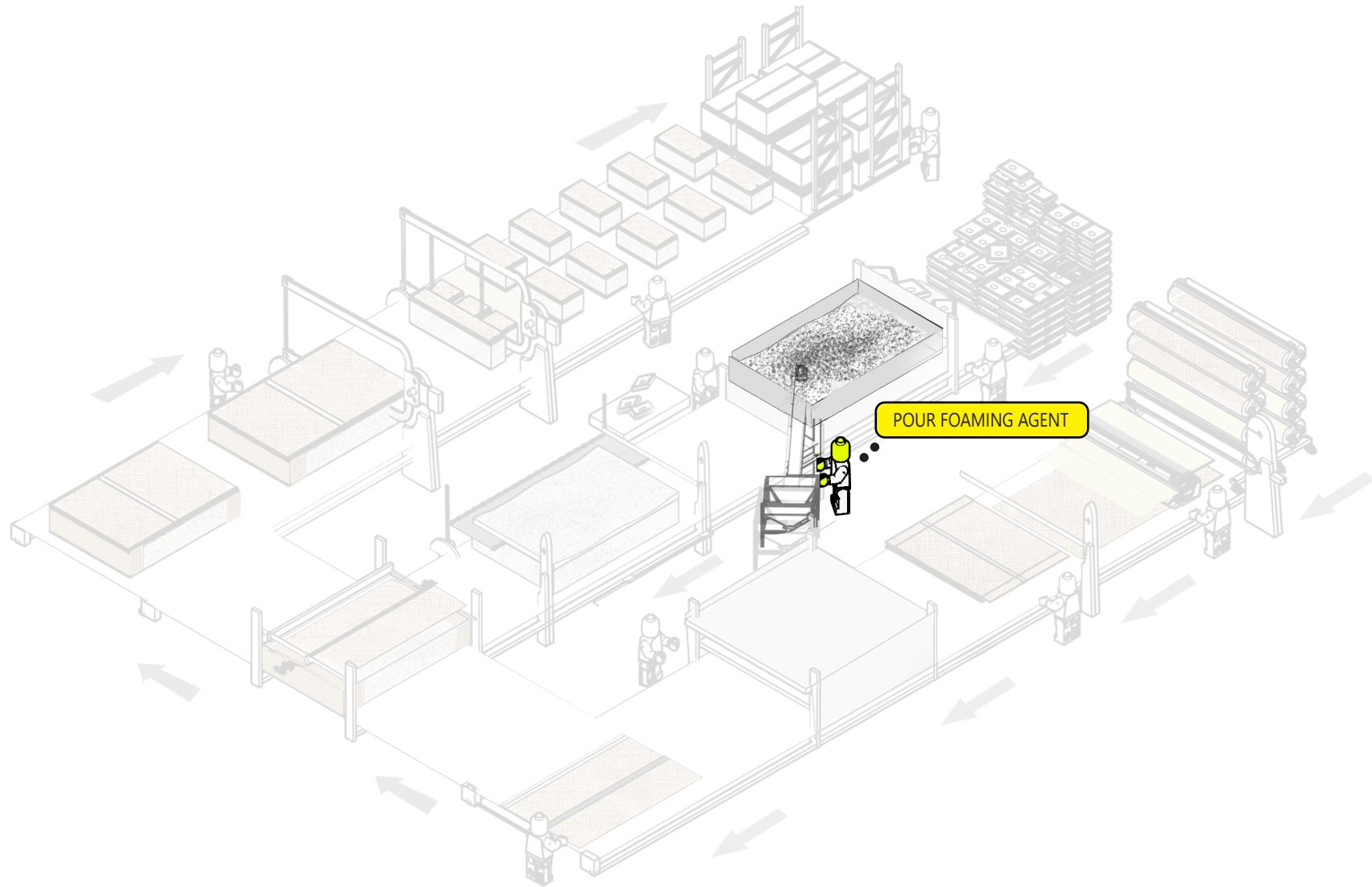
Green

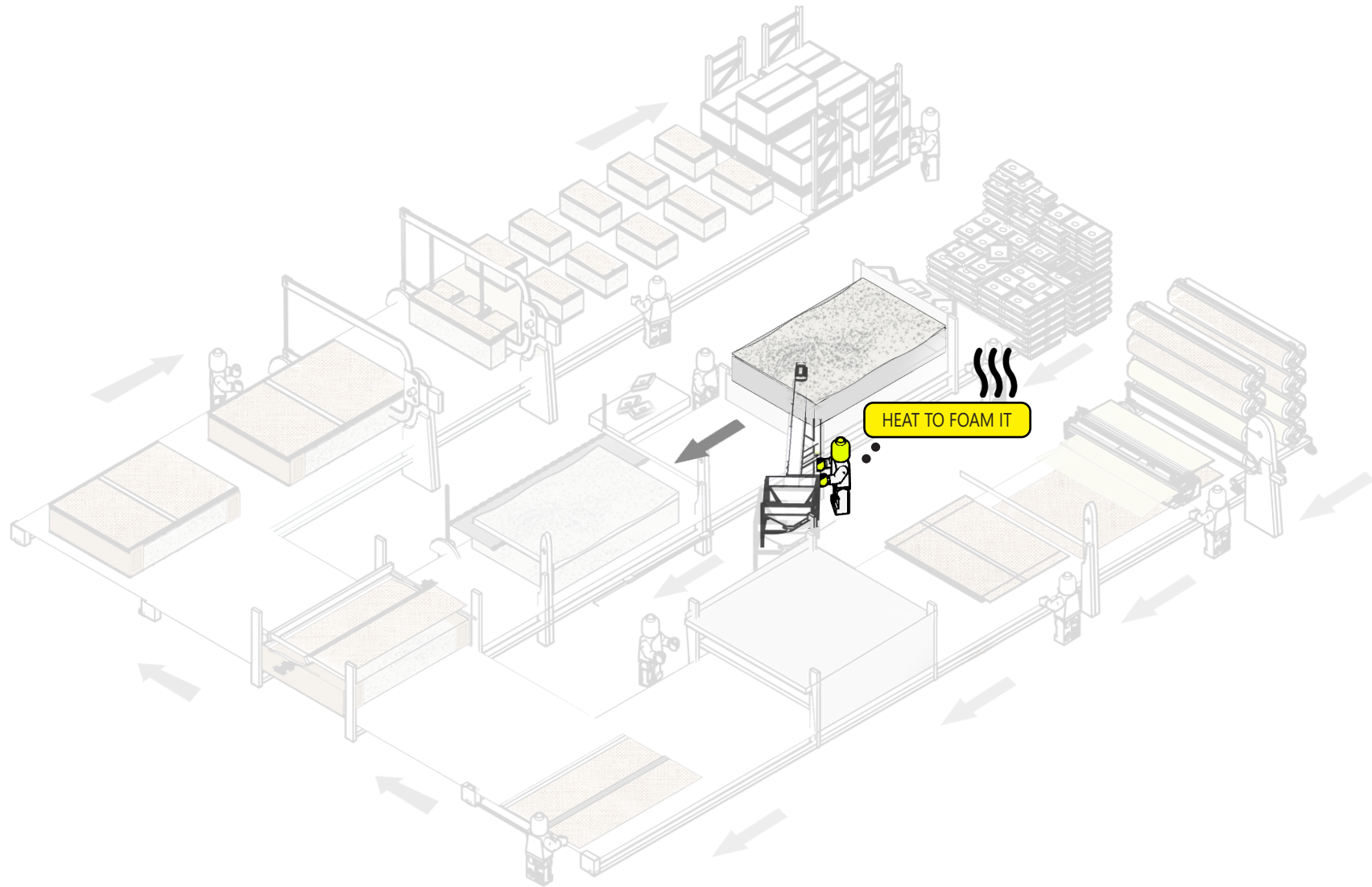
Production line

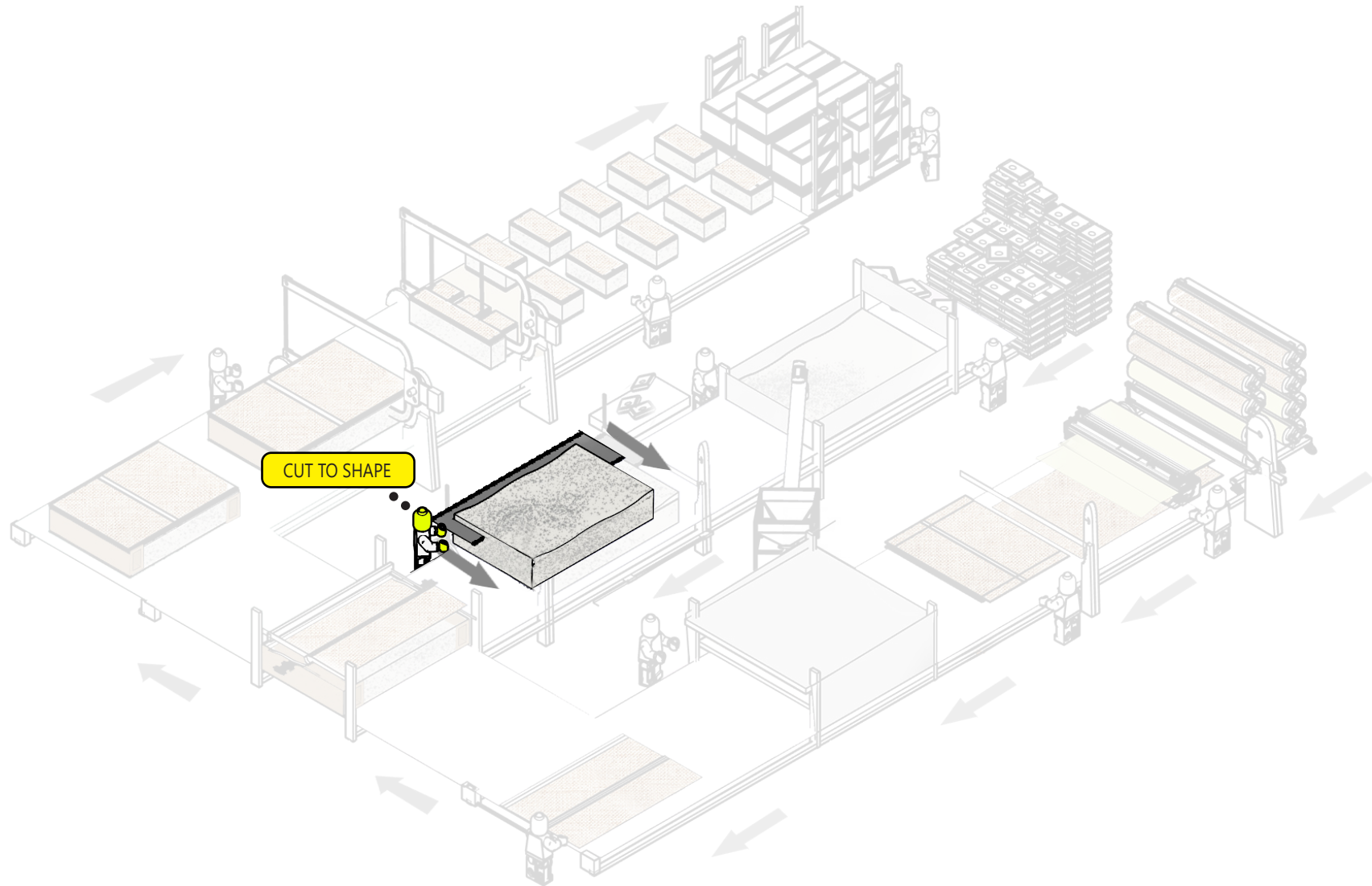


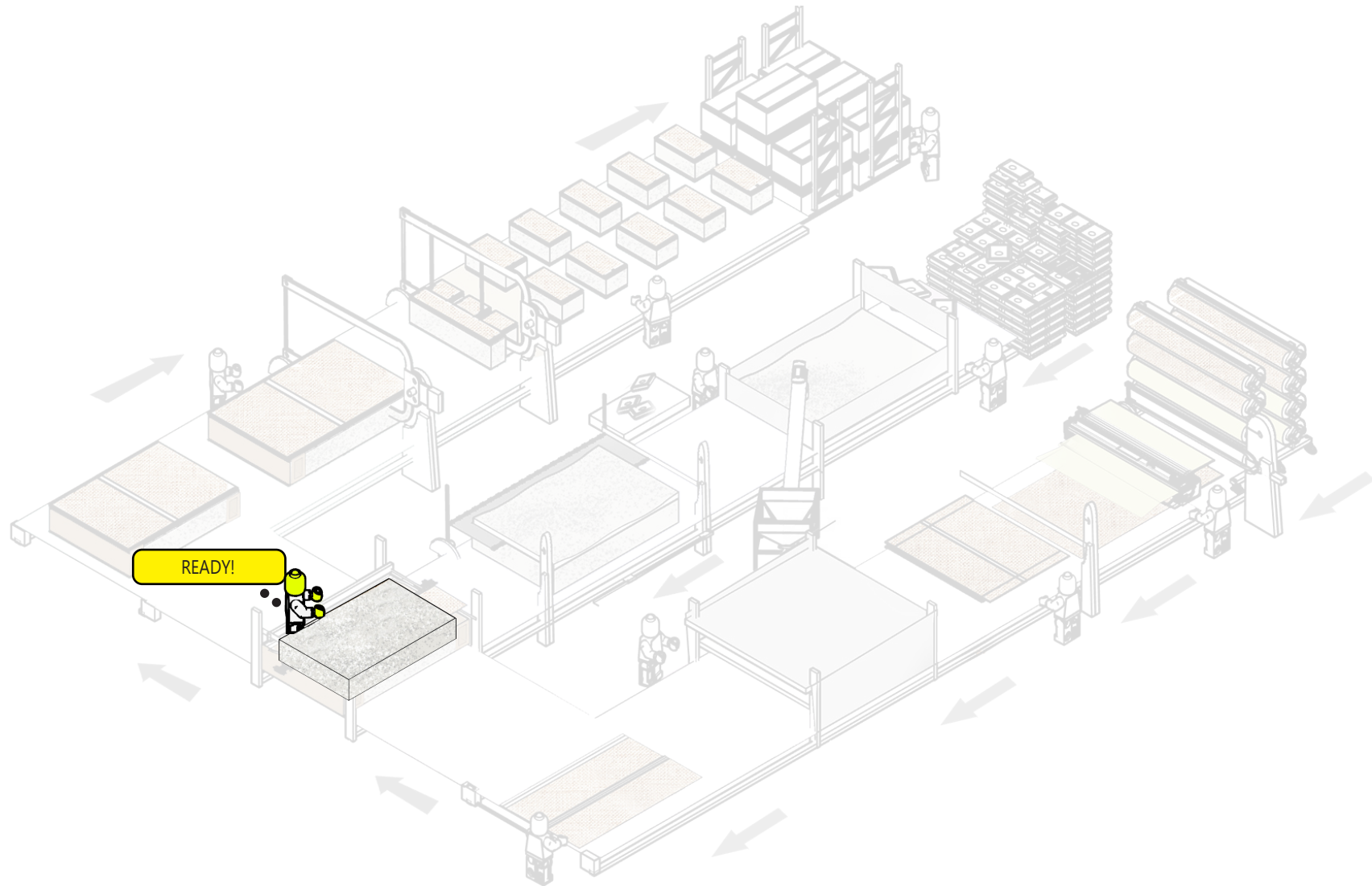


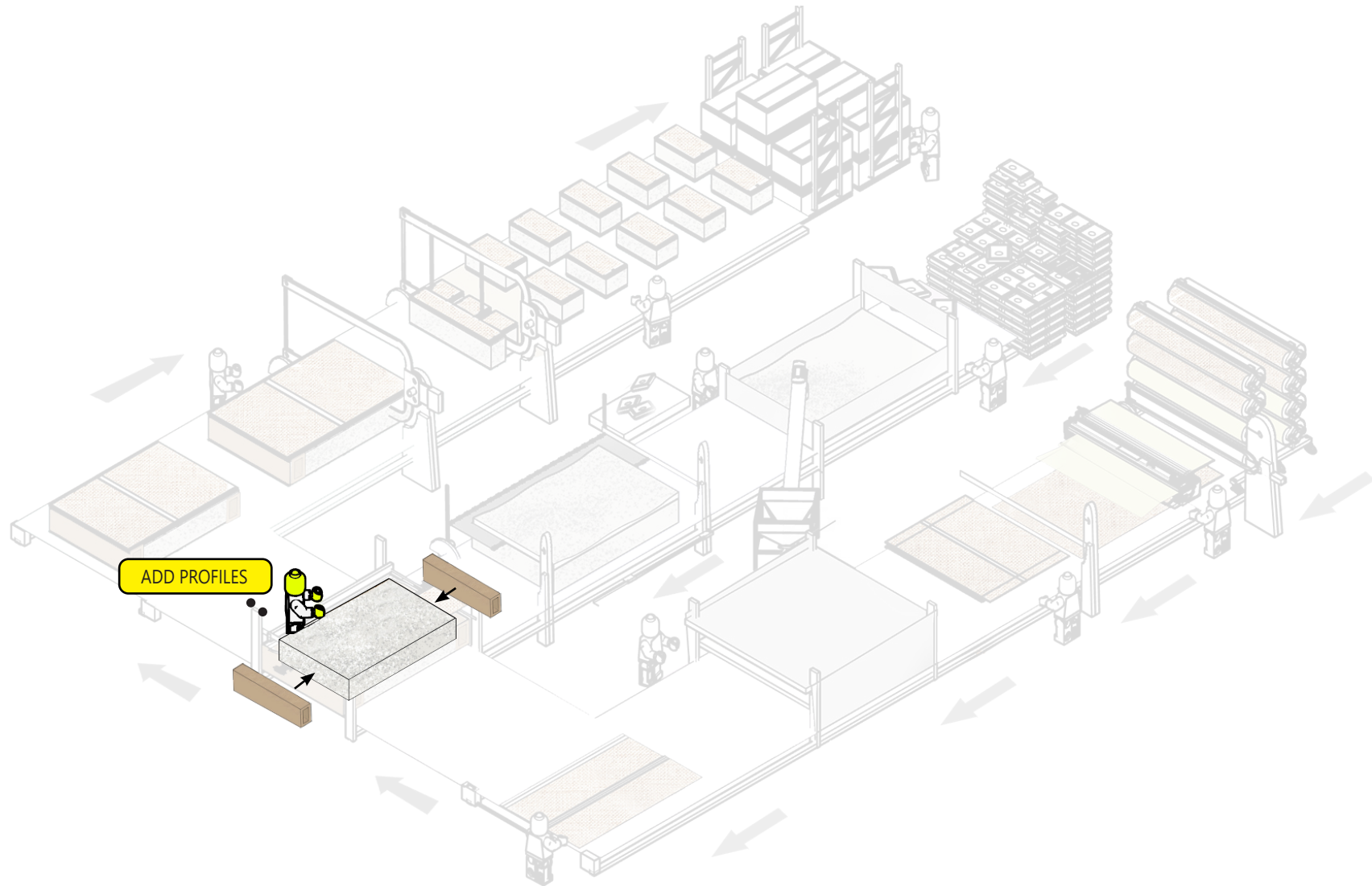


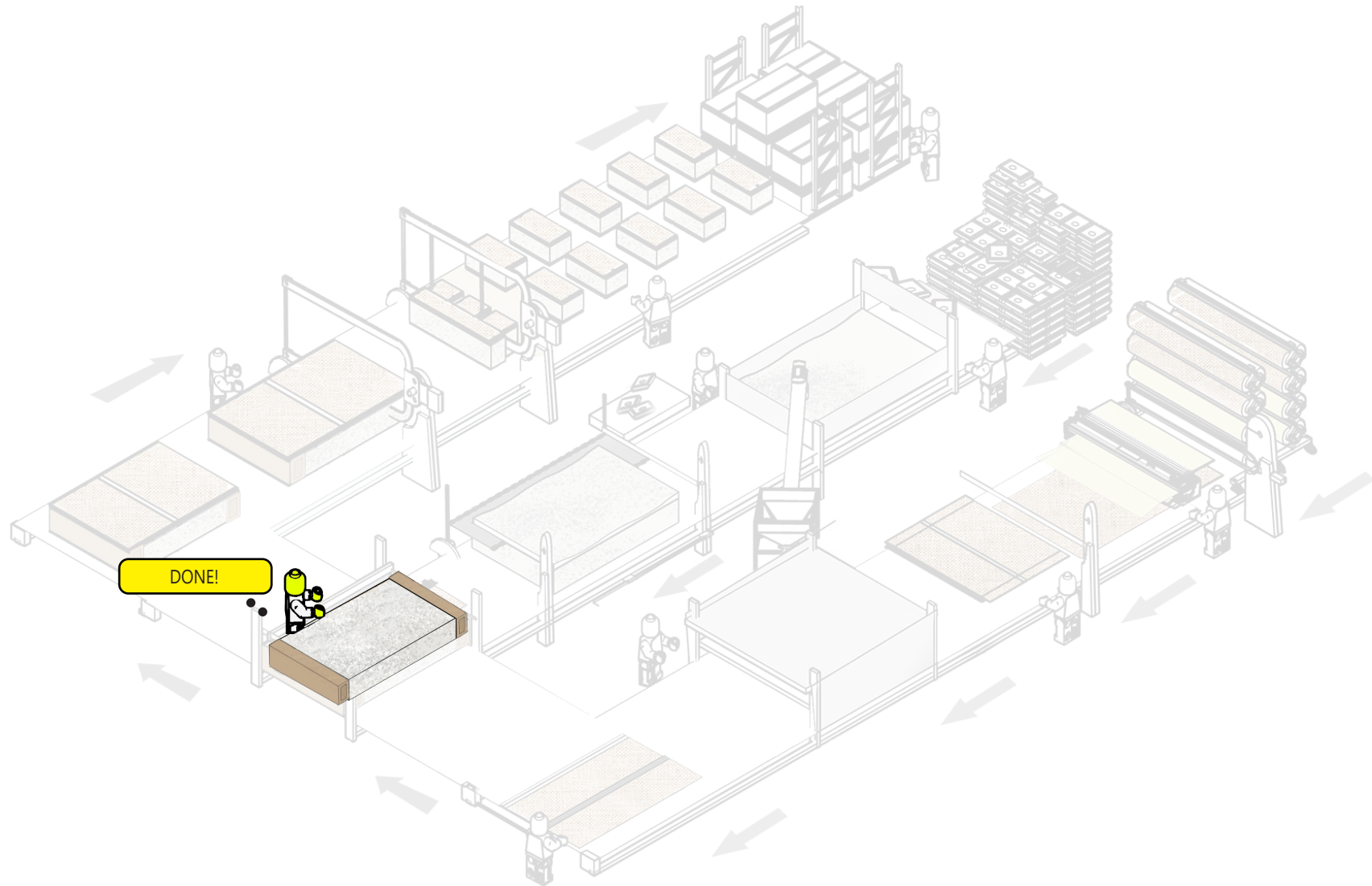


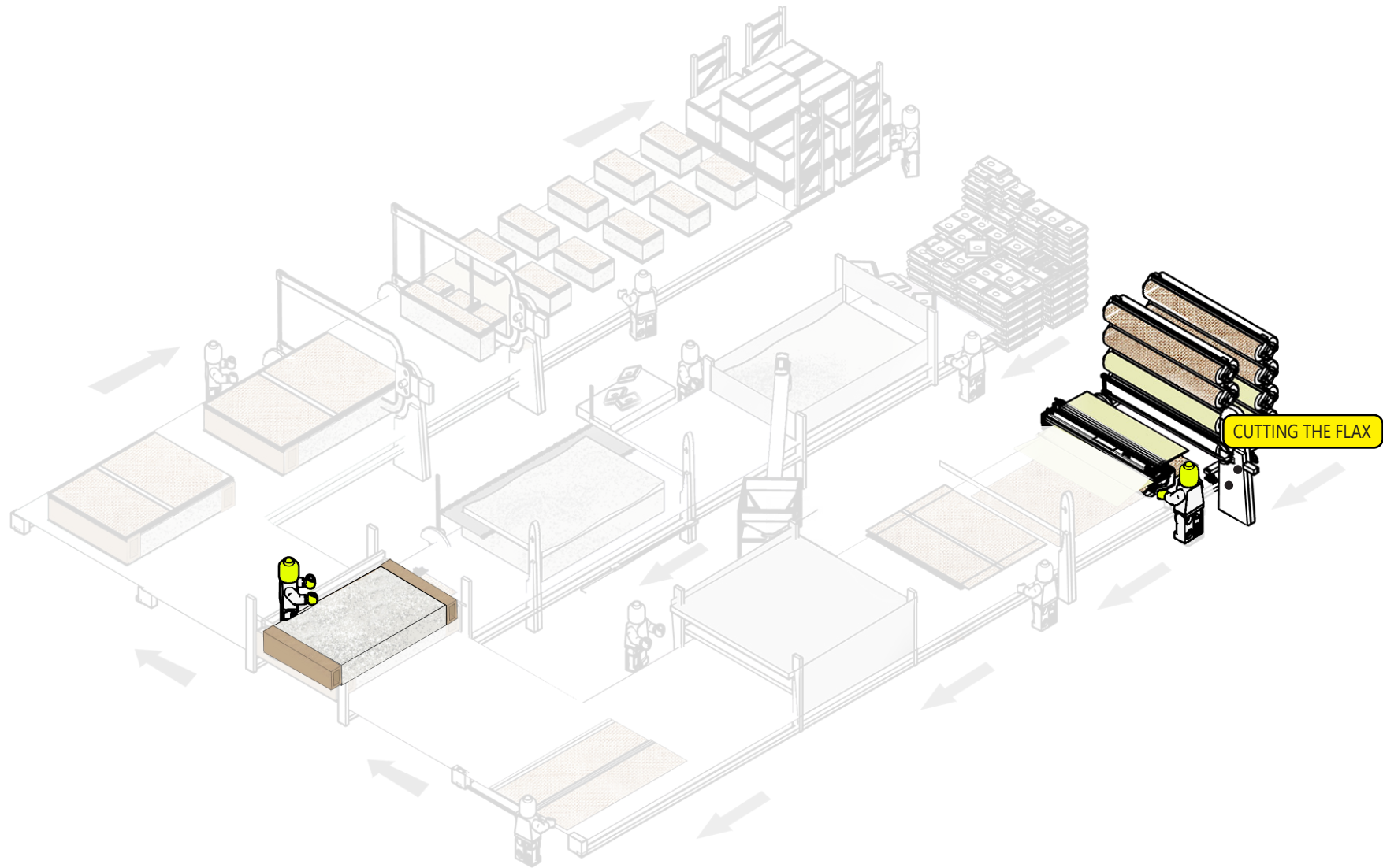


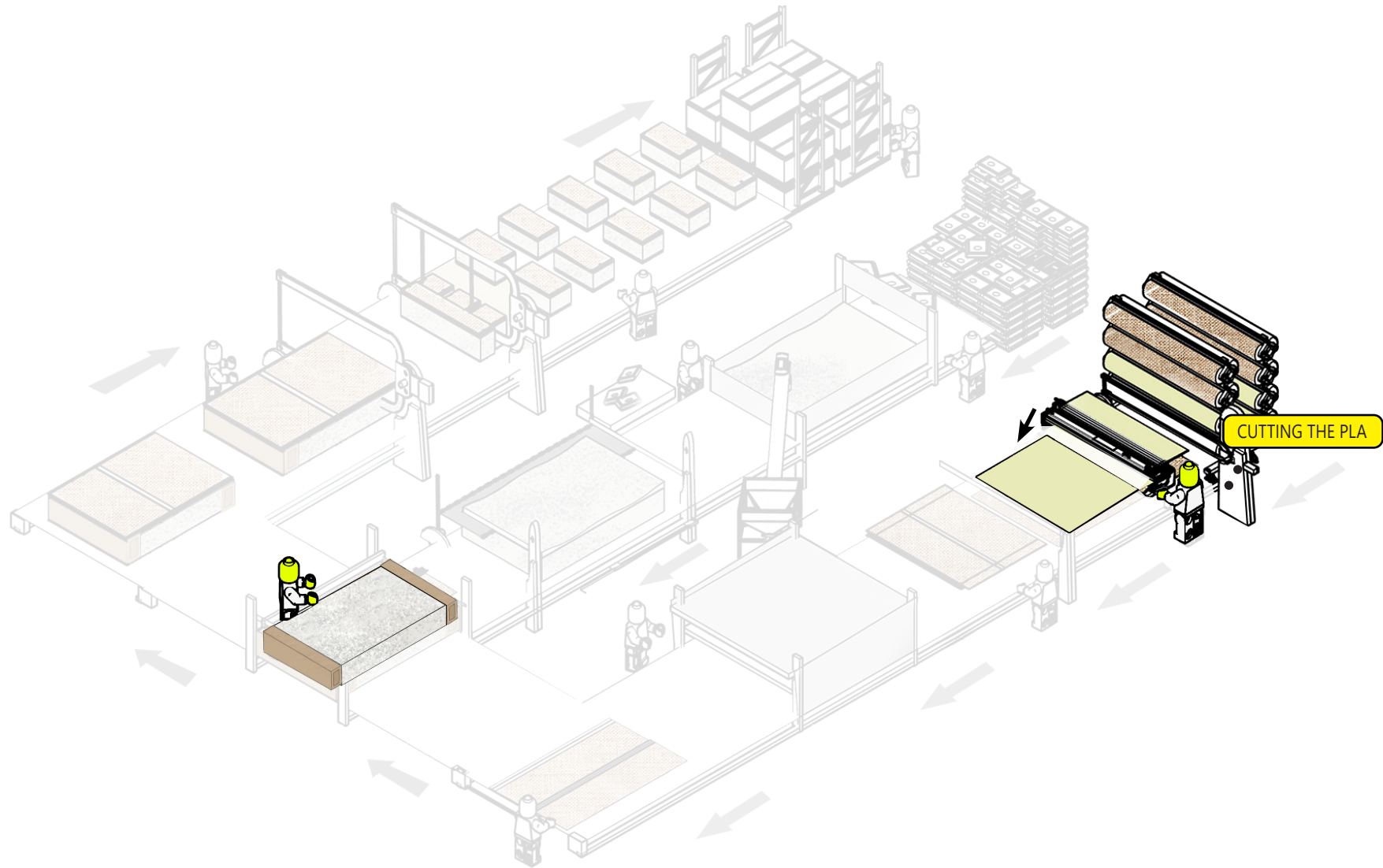


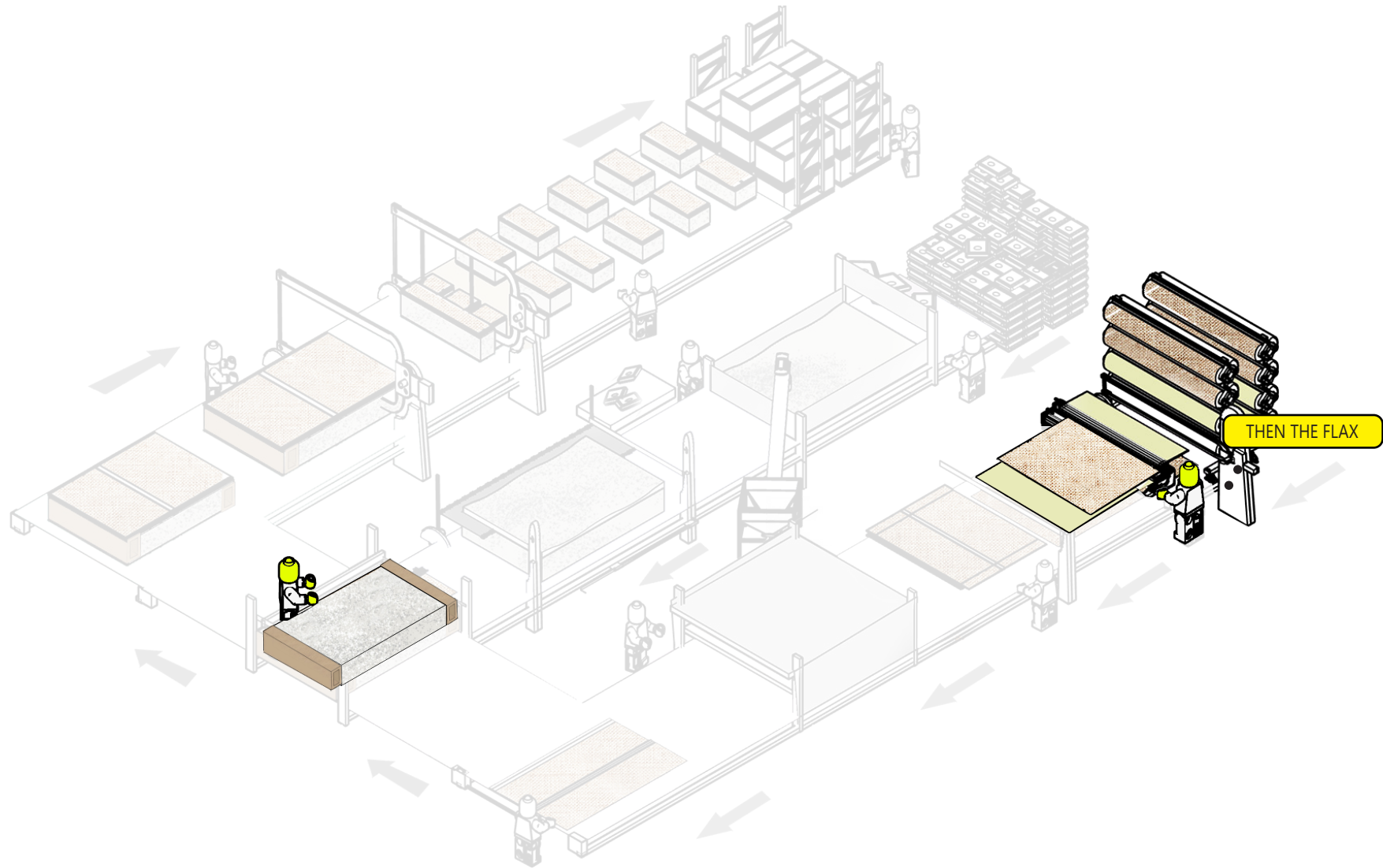


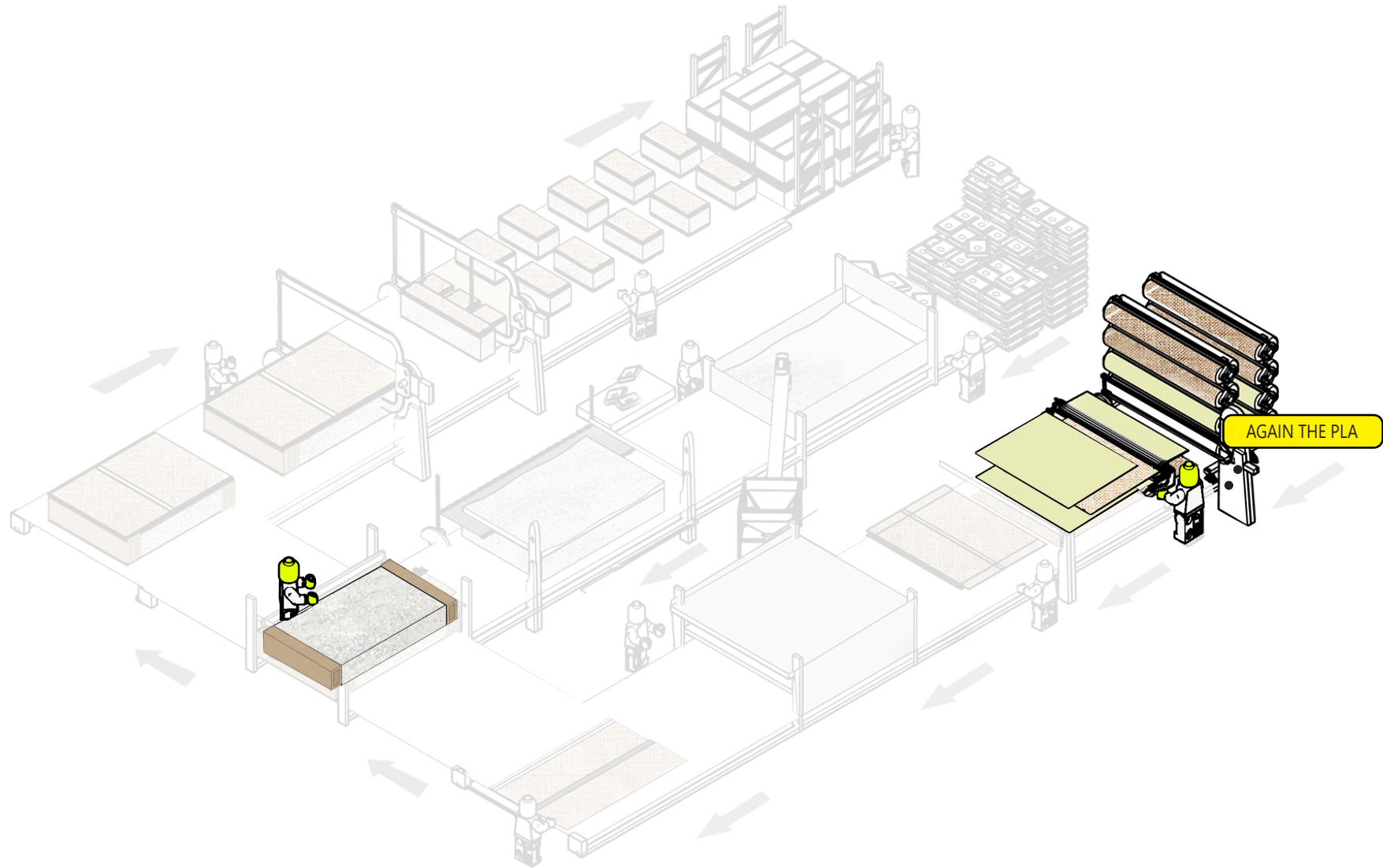


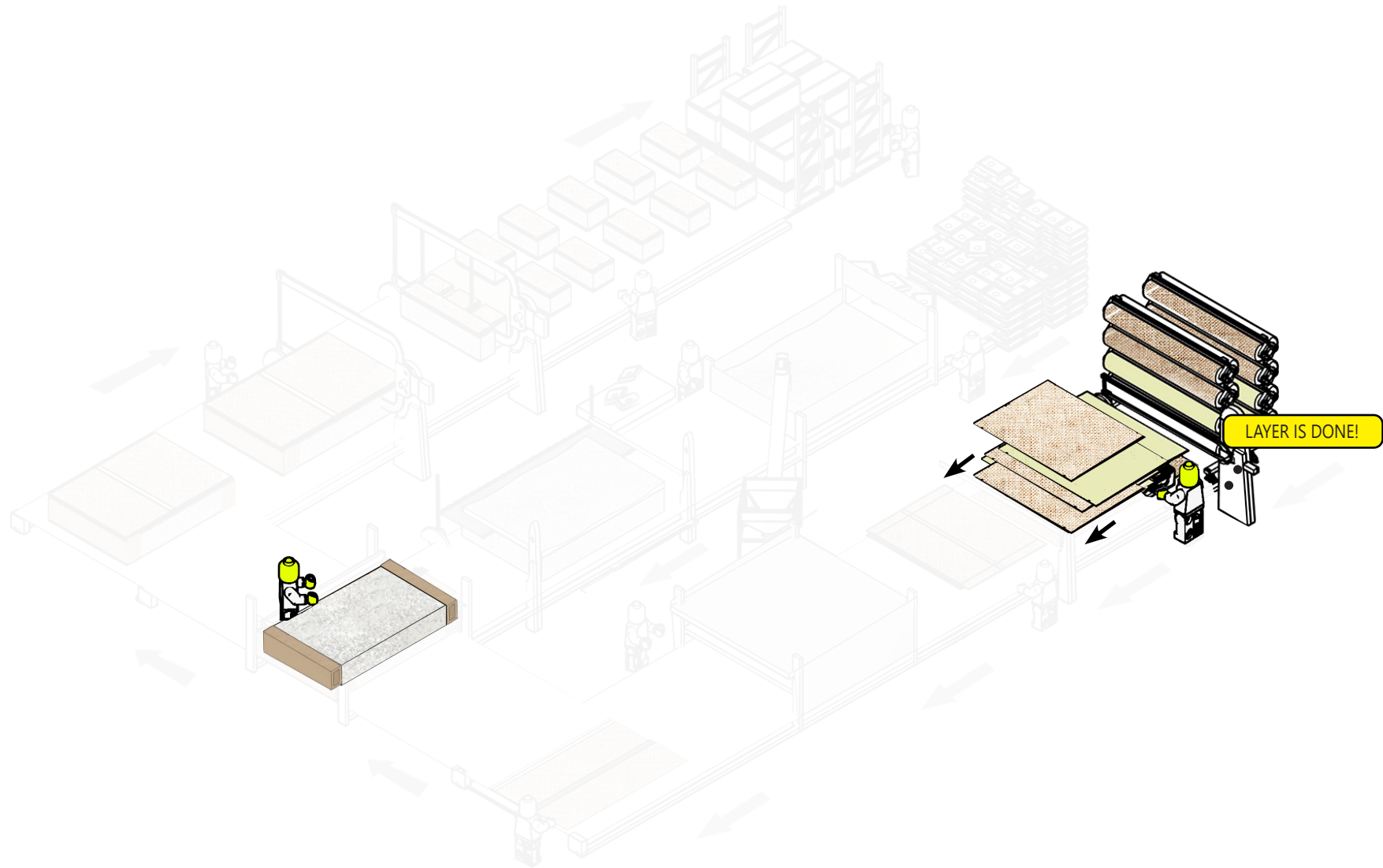


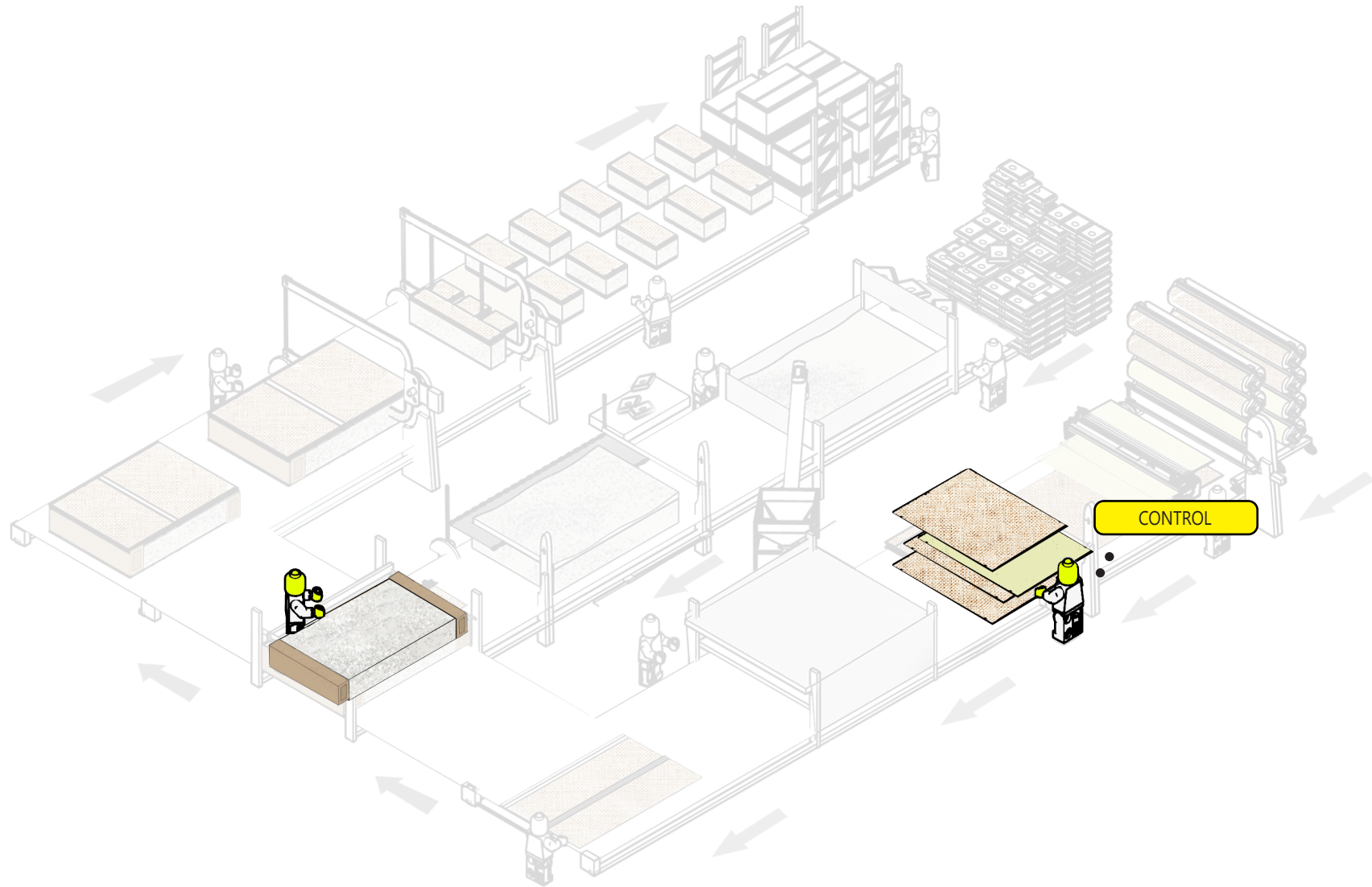


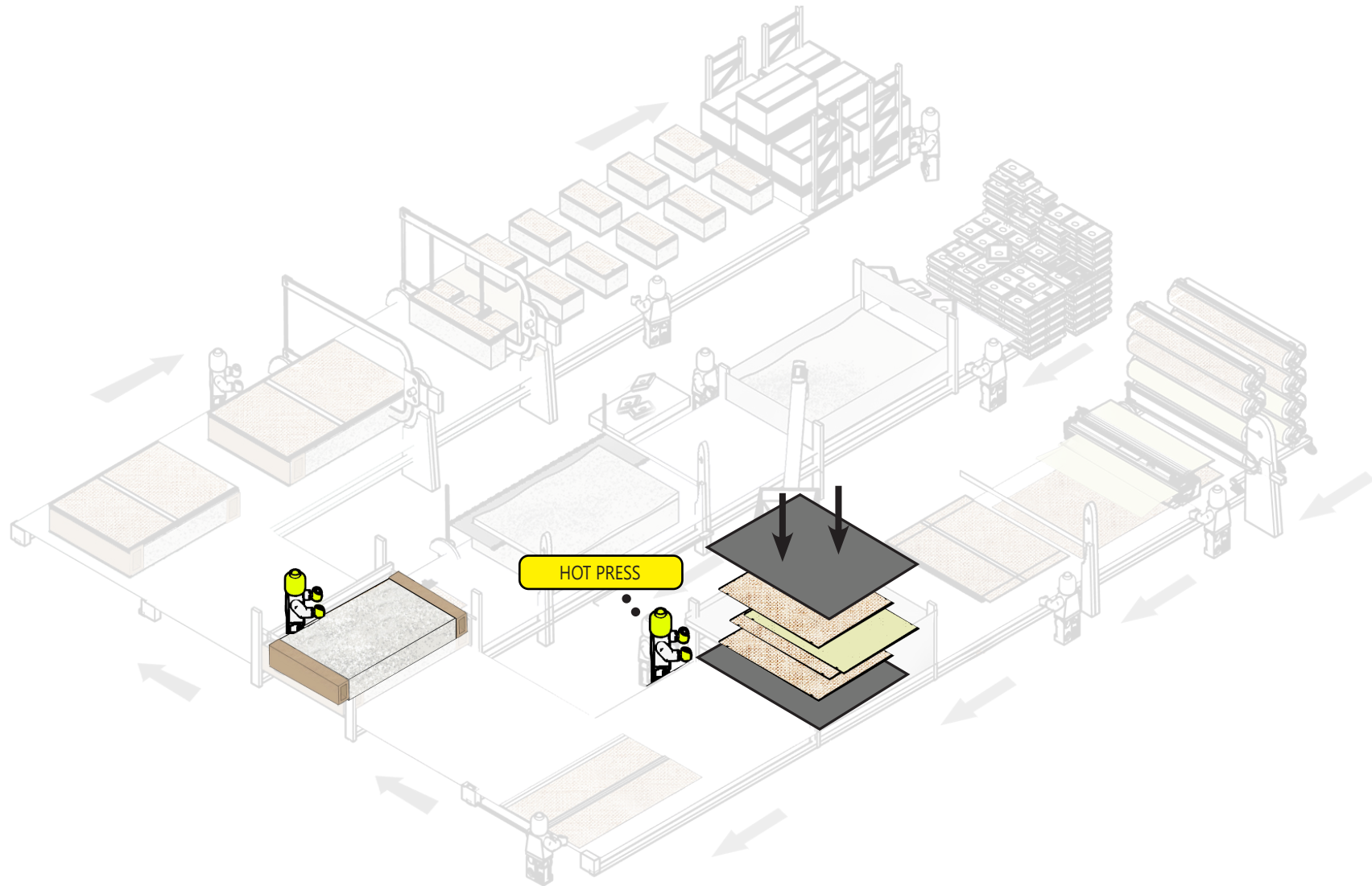


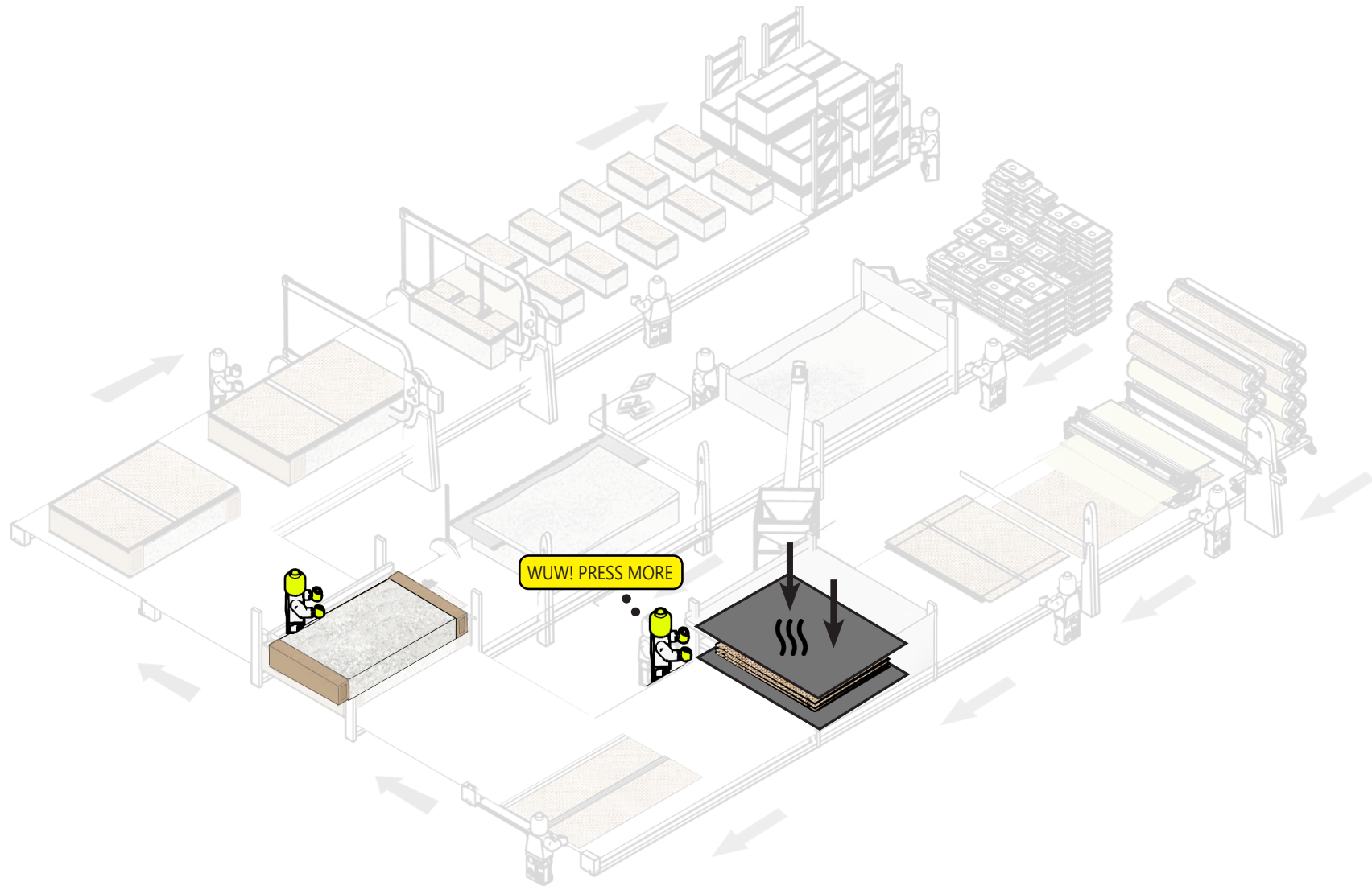


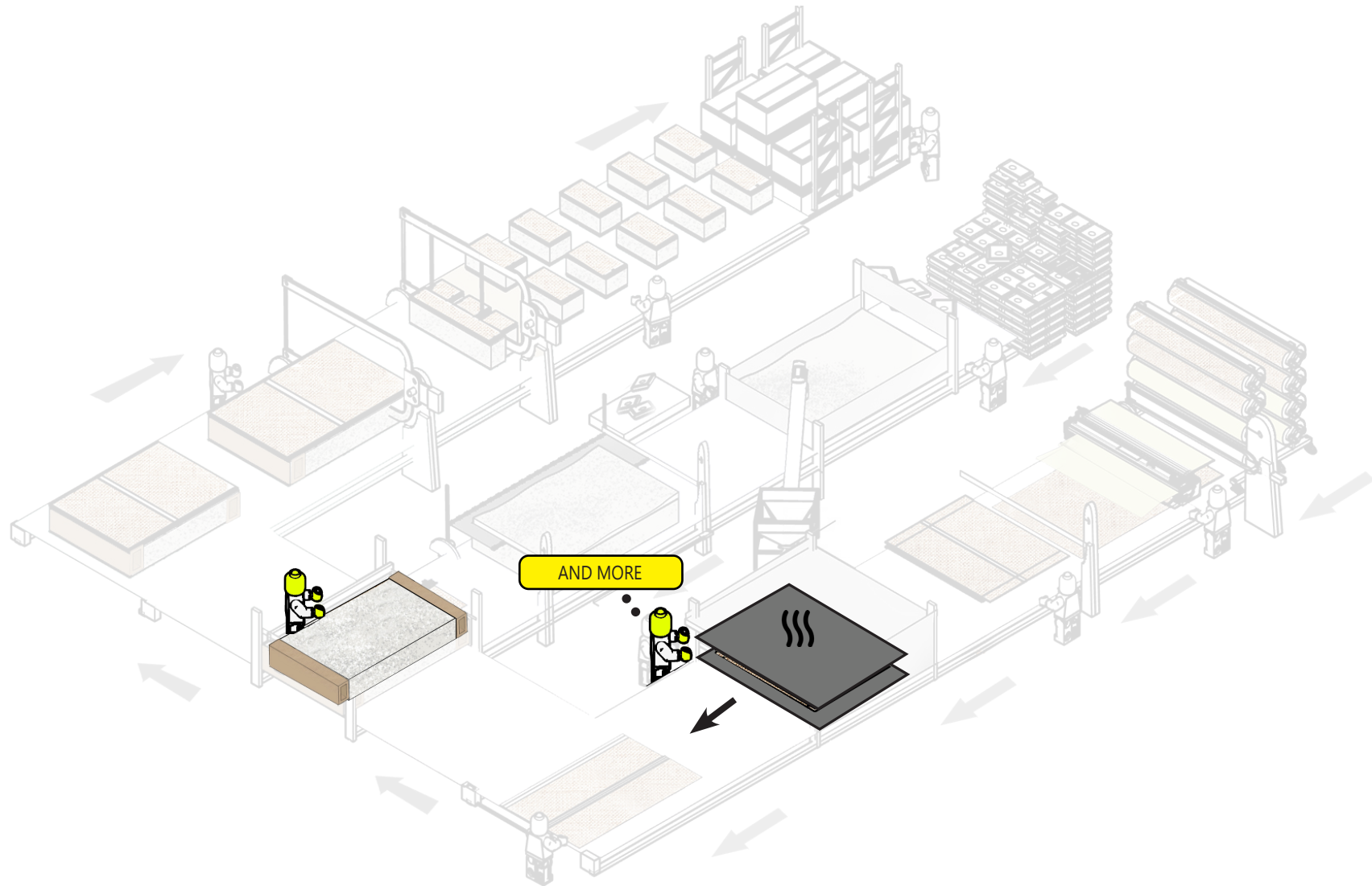


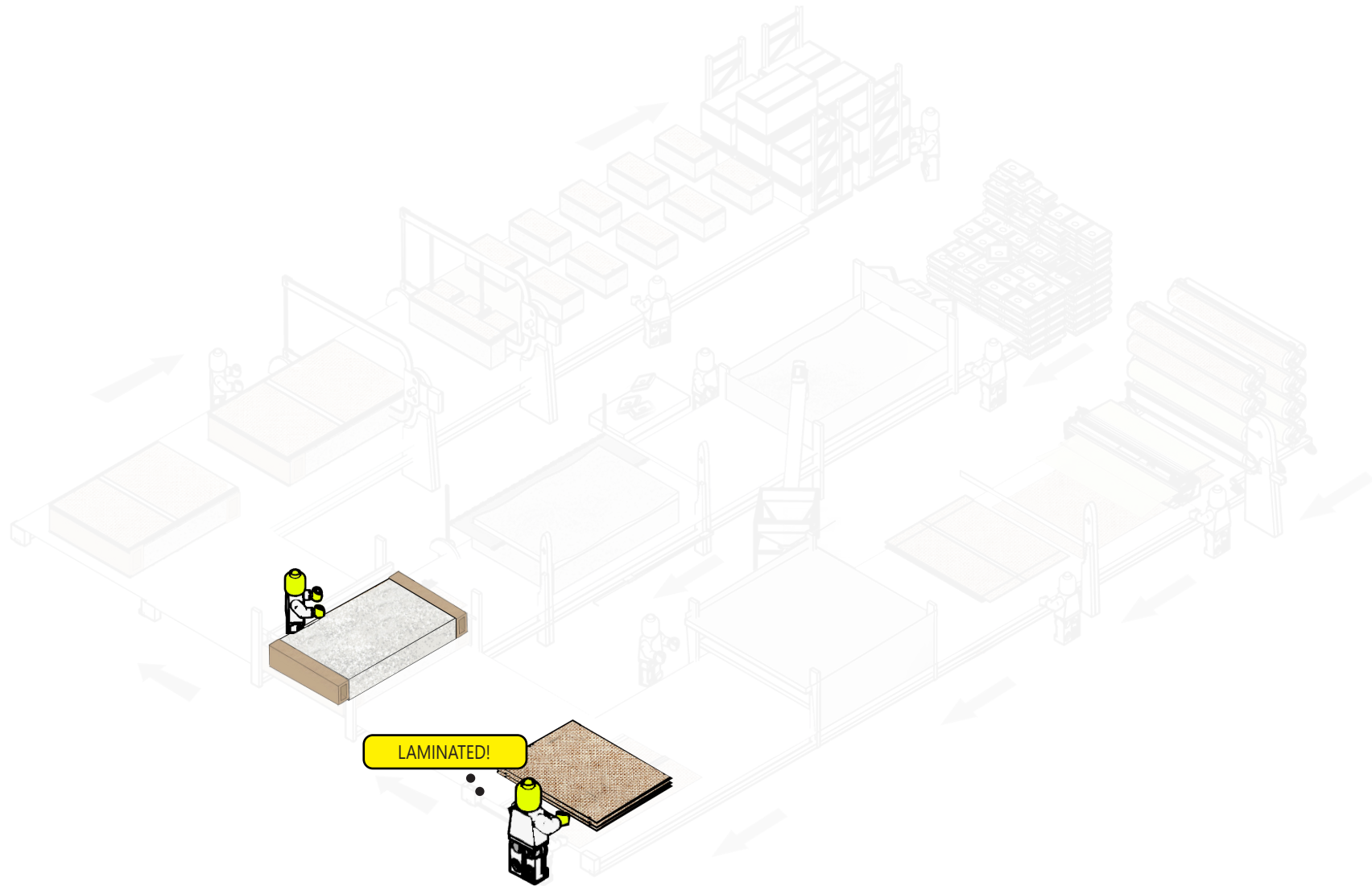


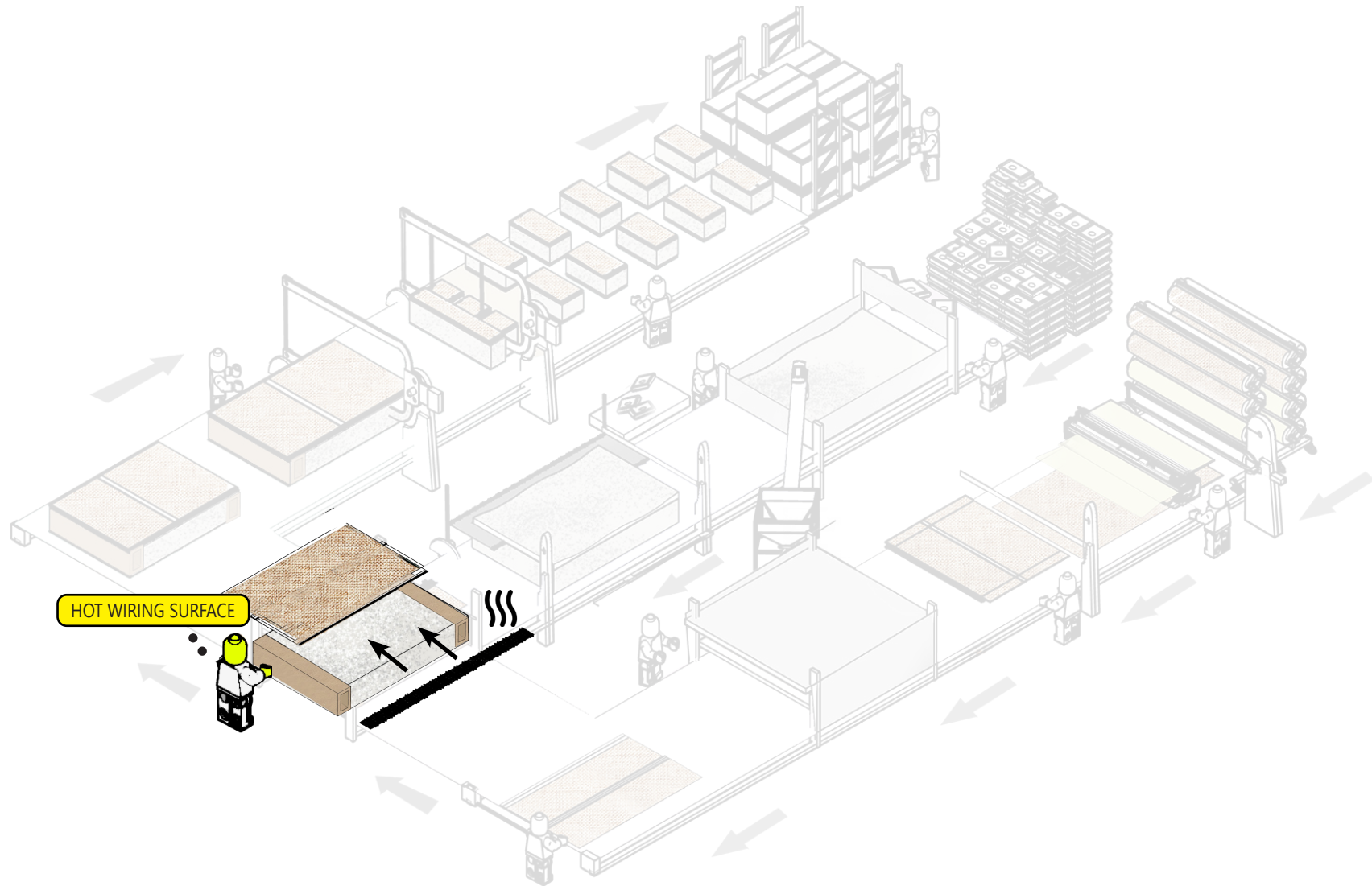


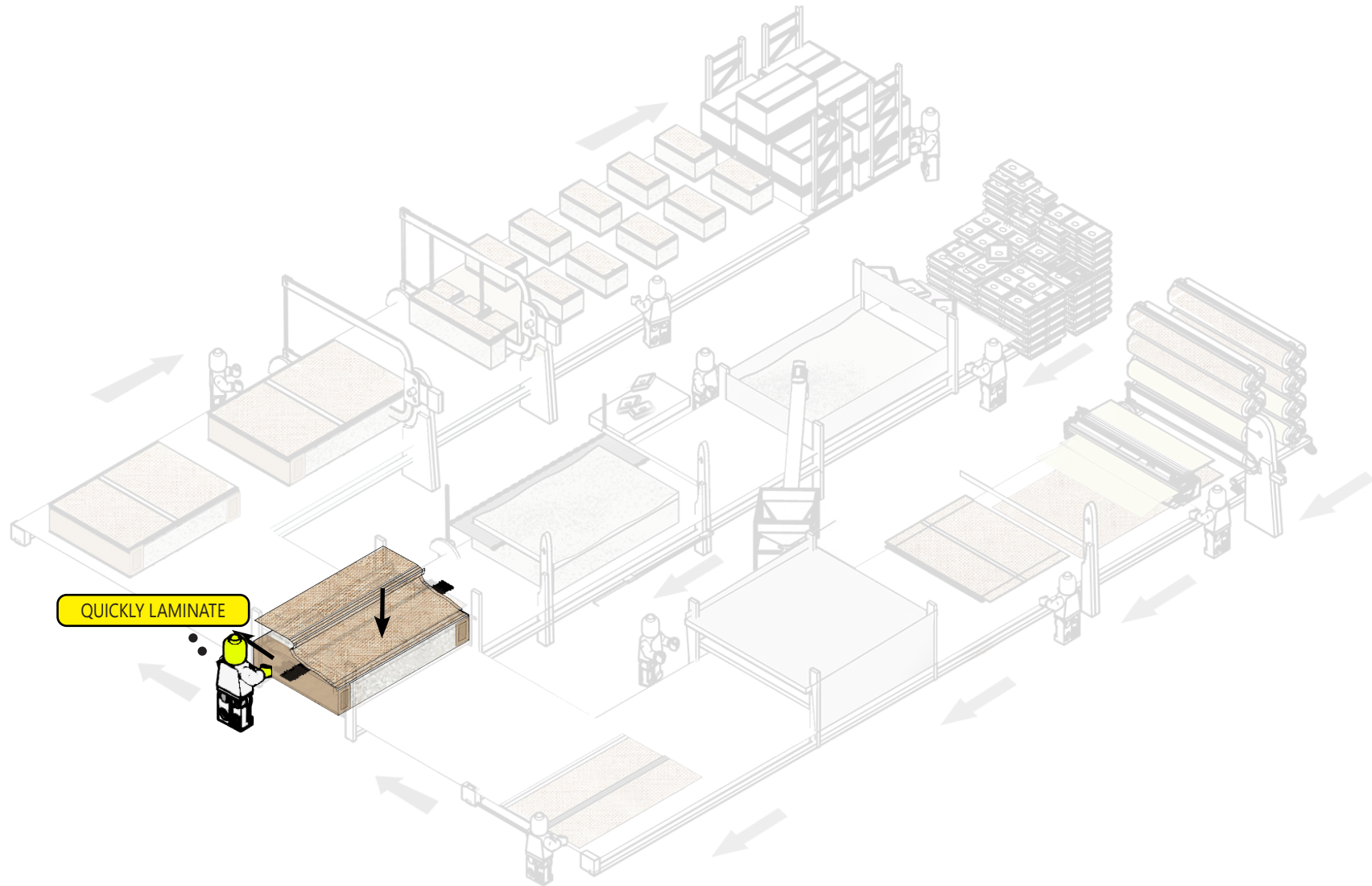


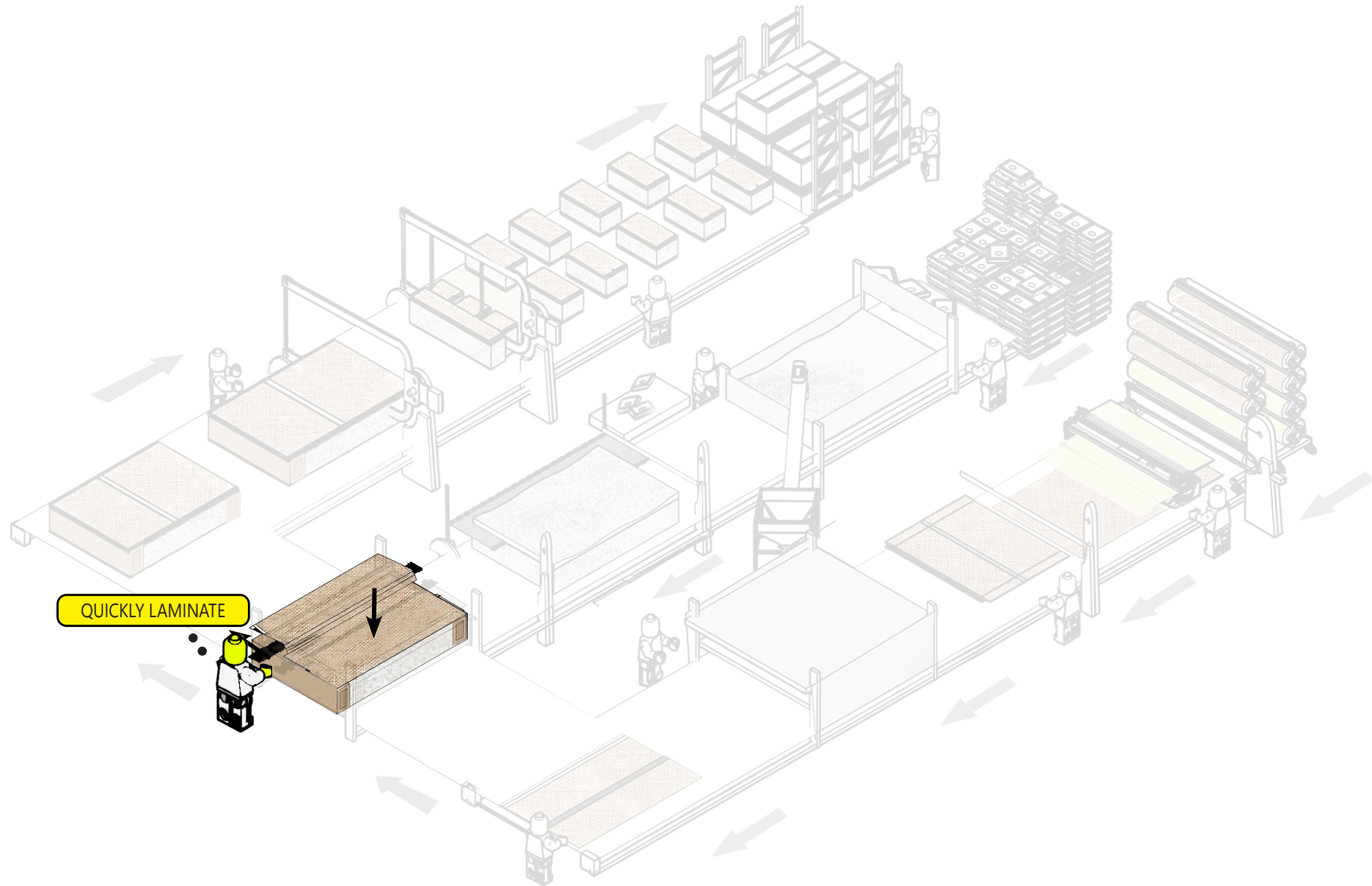


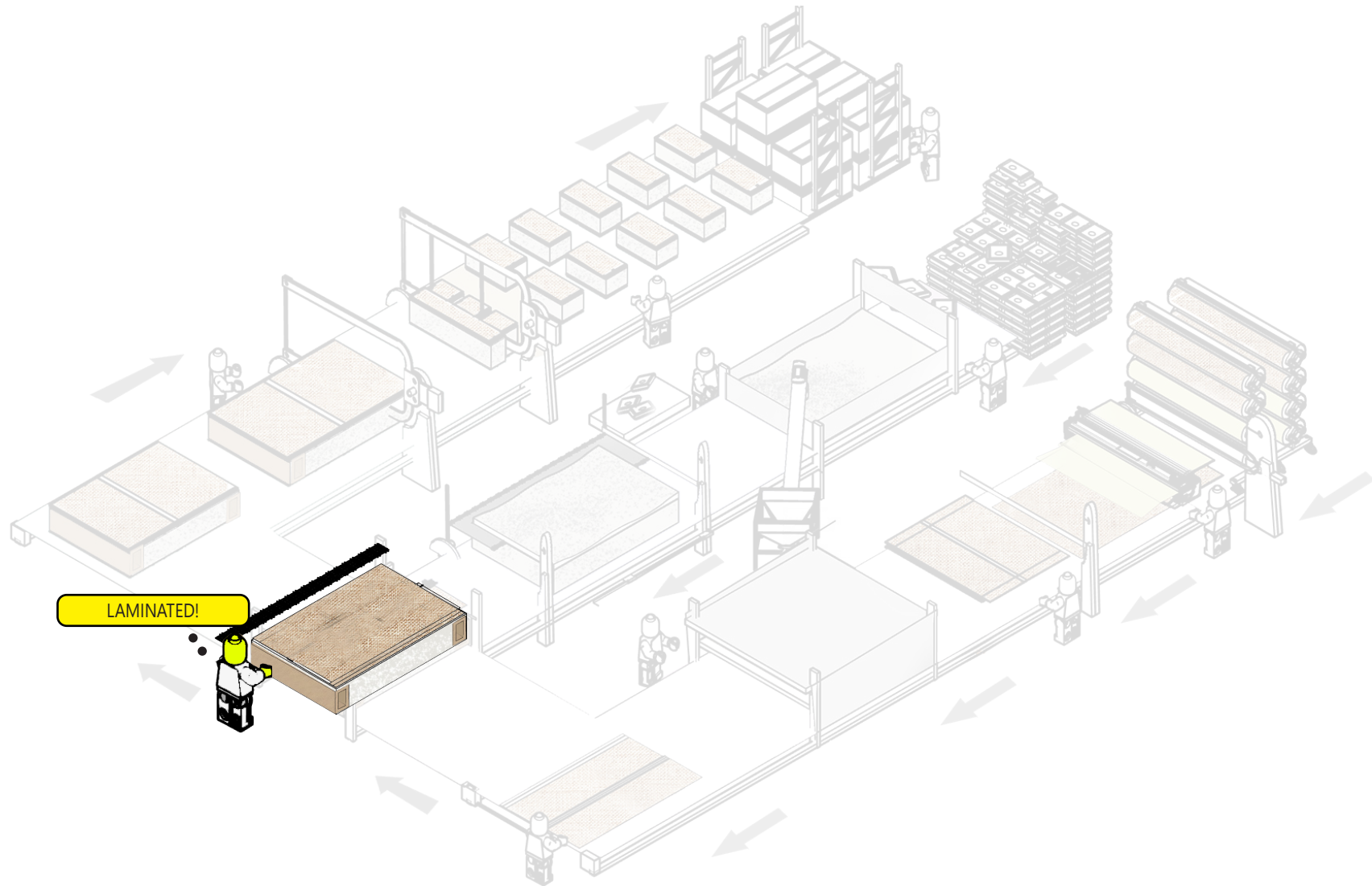


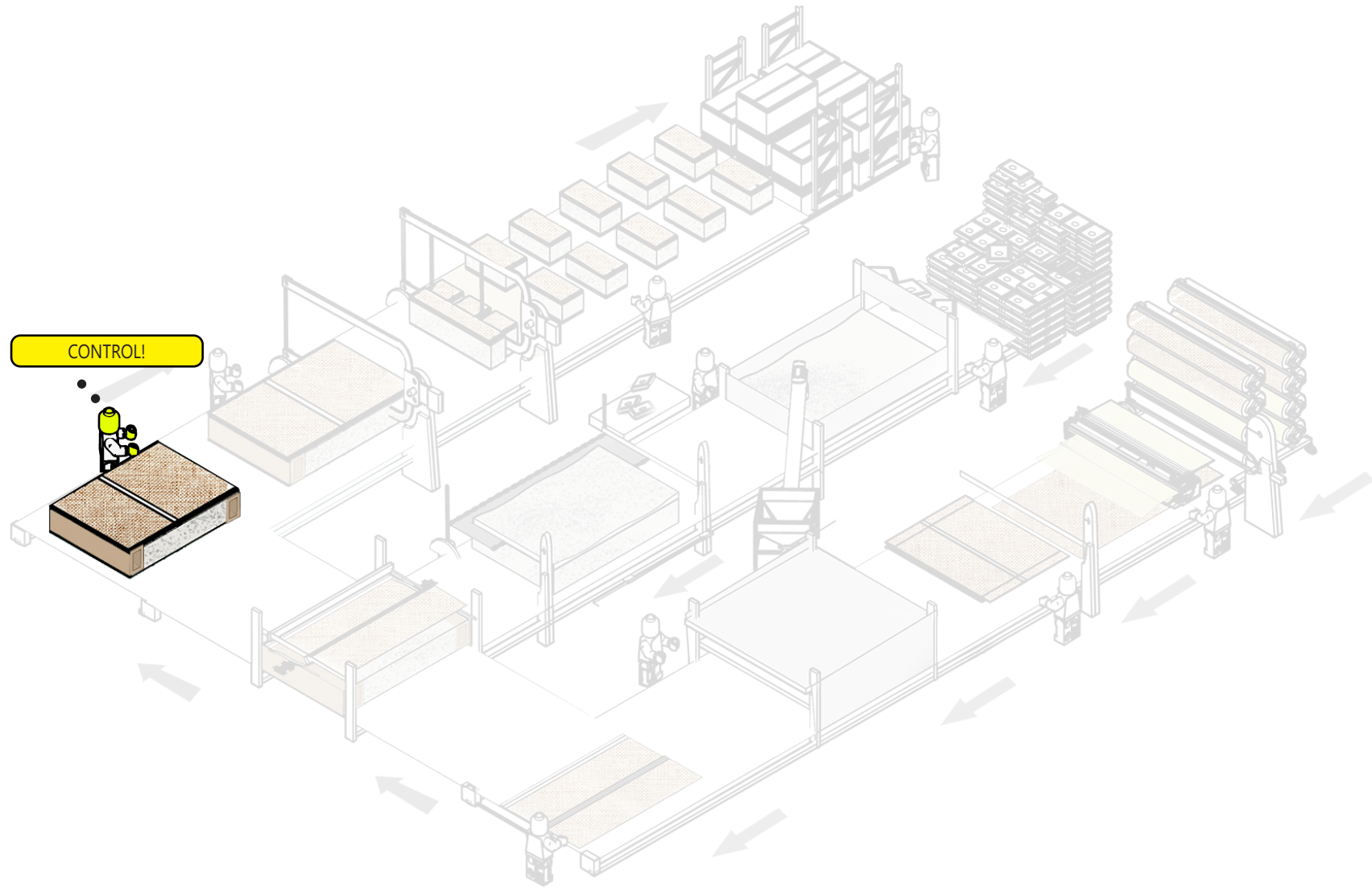


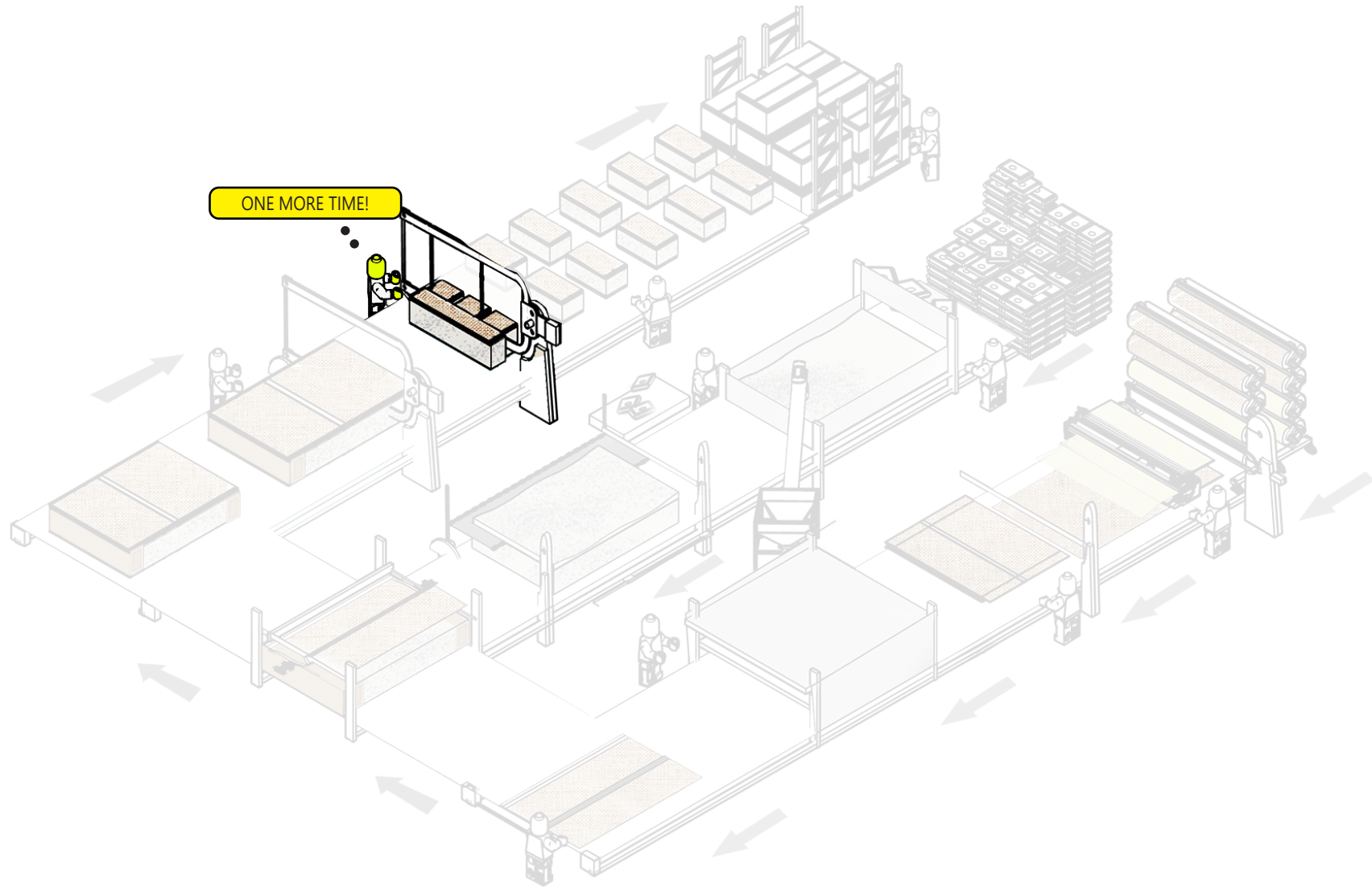


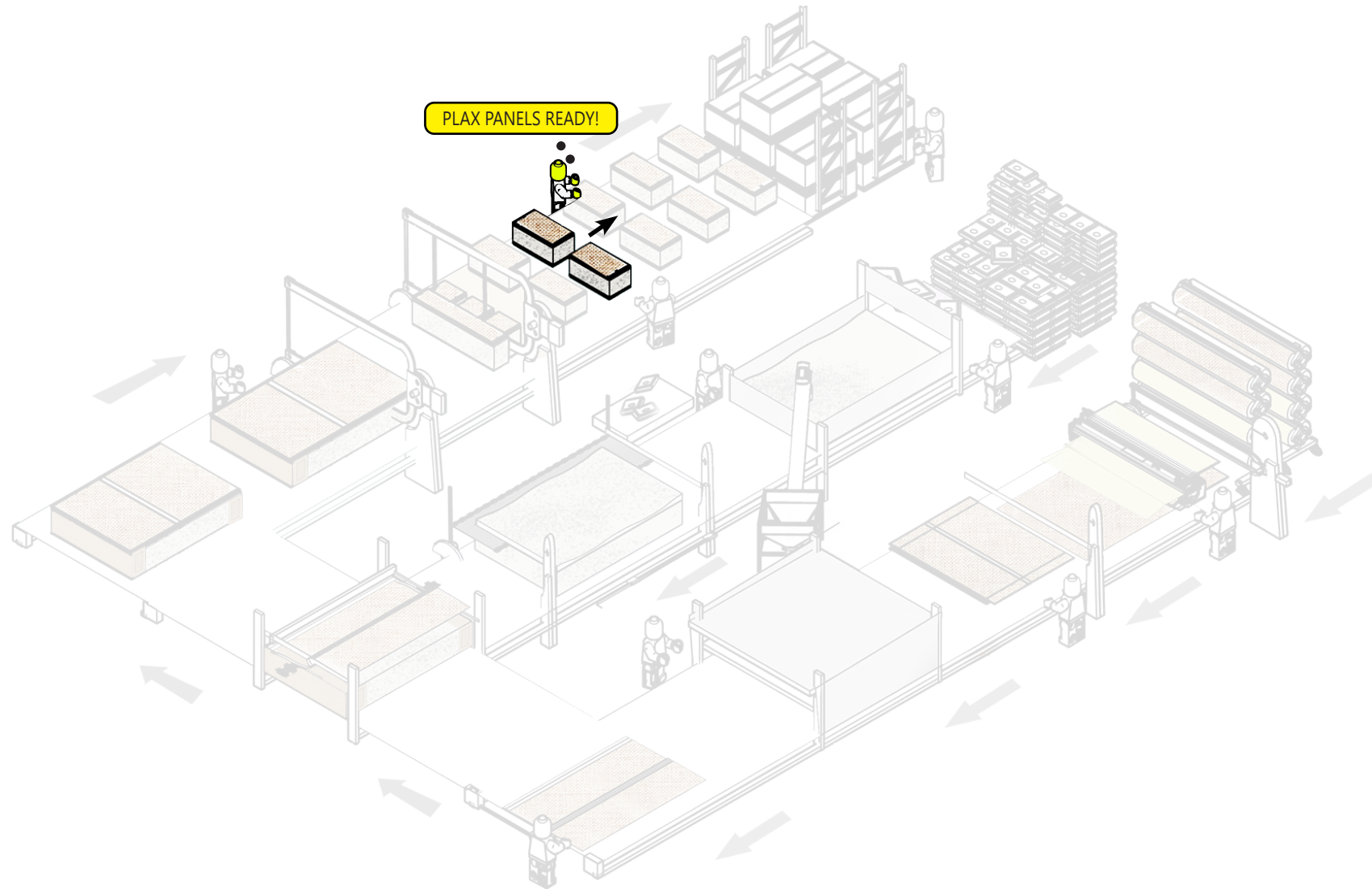


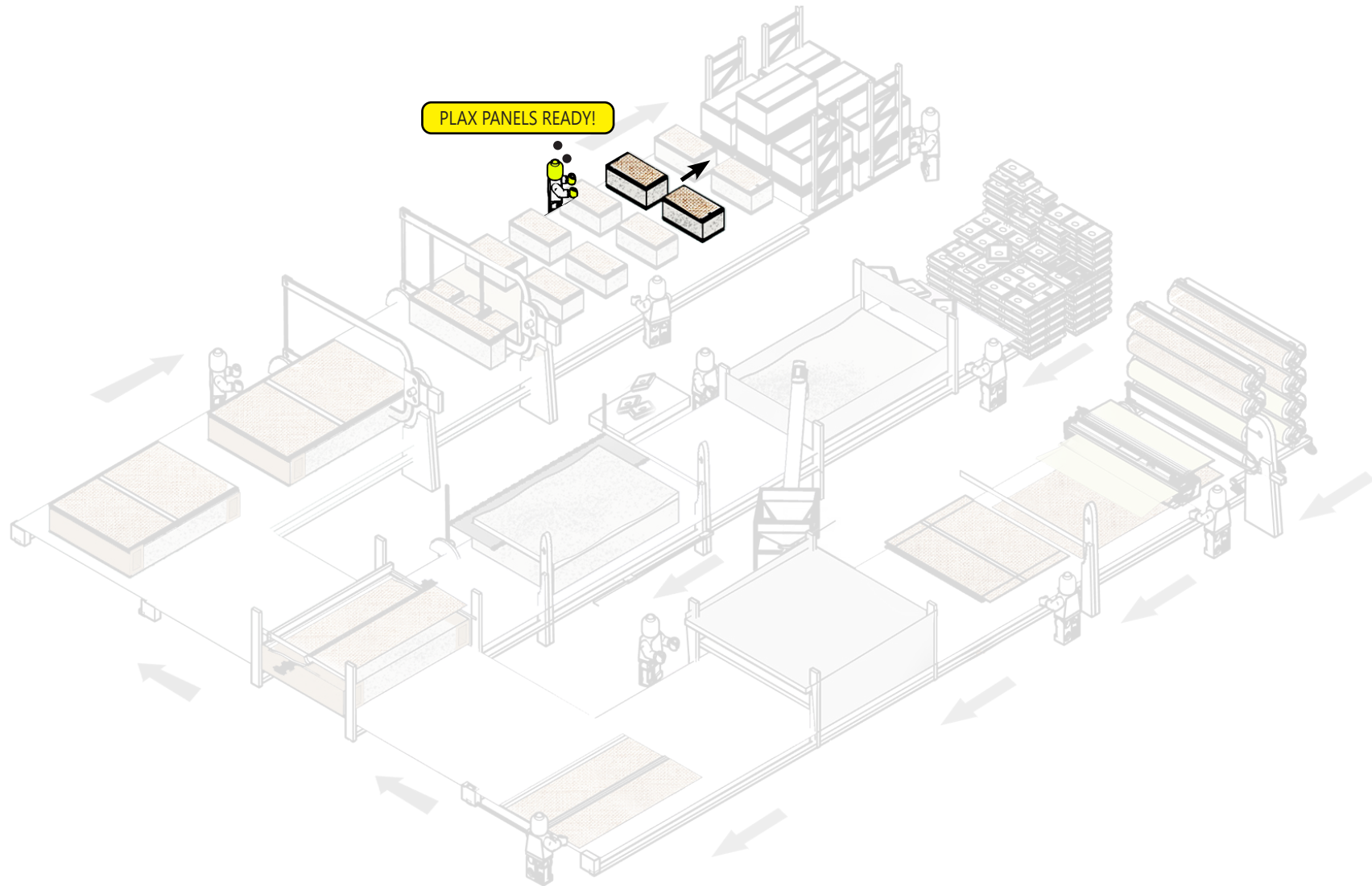


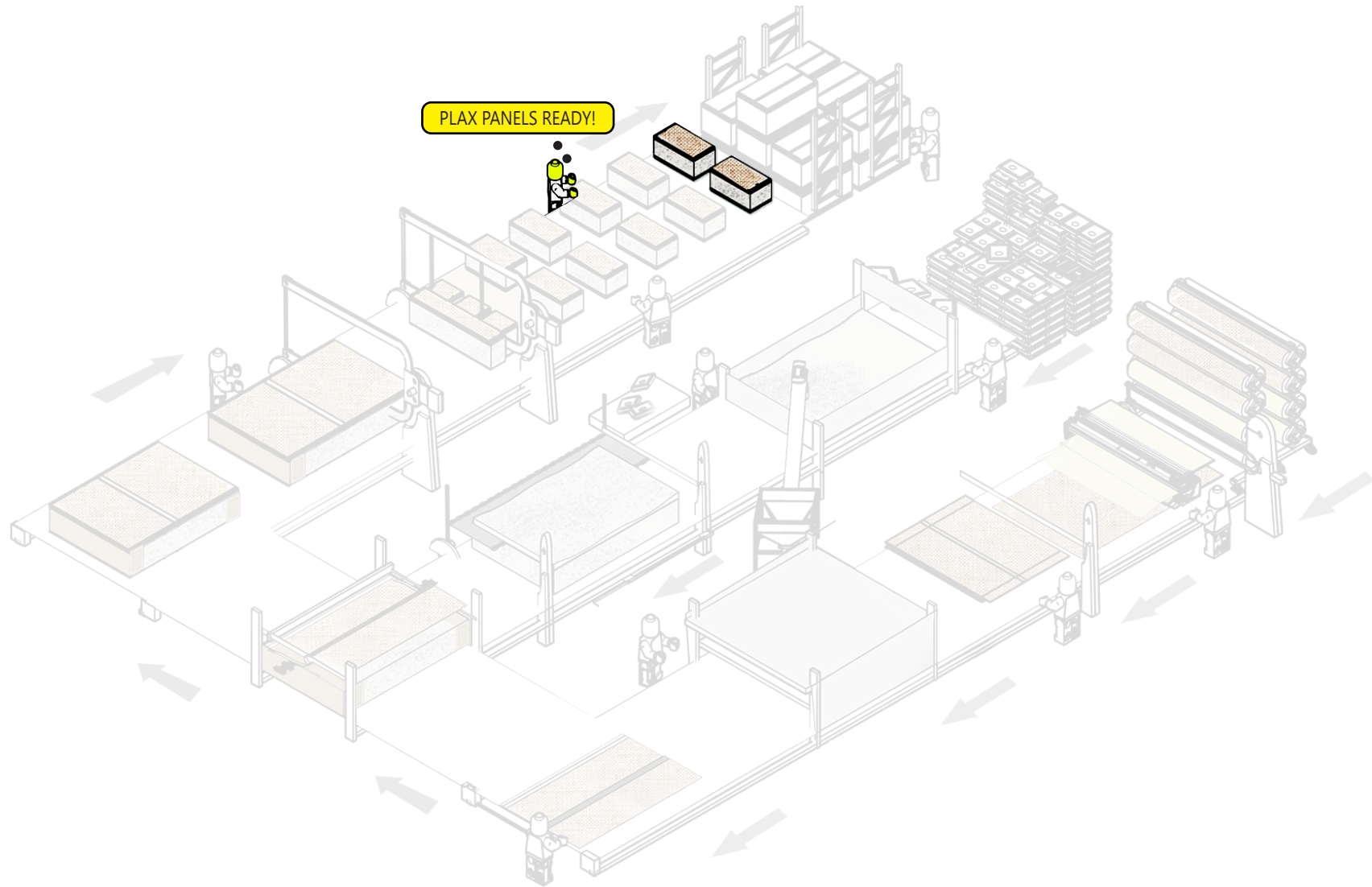


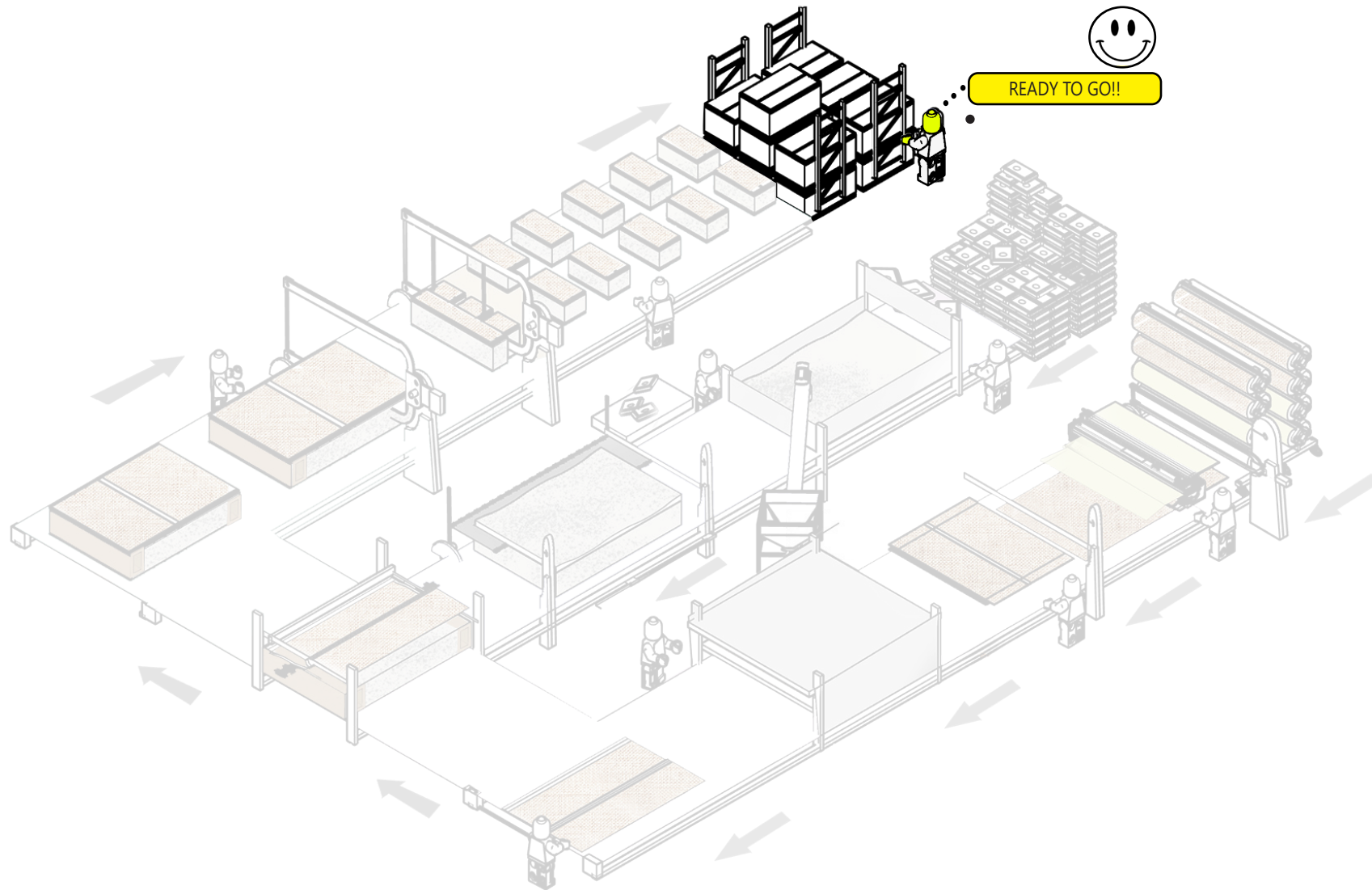


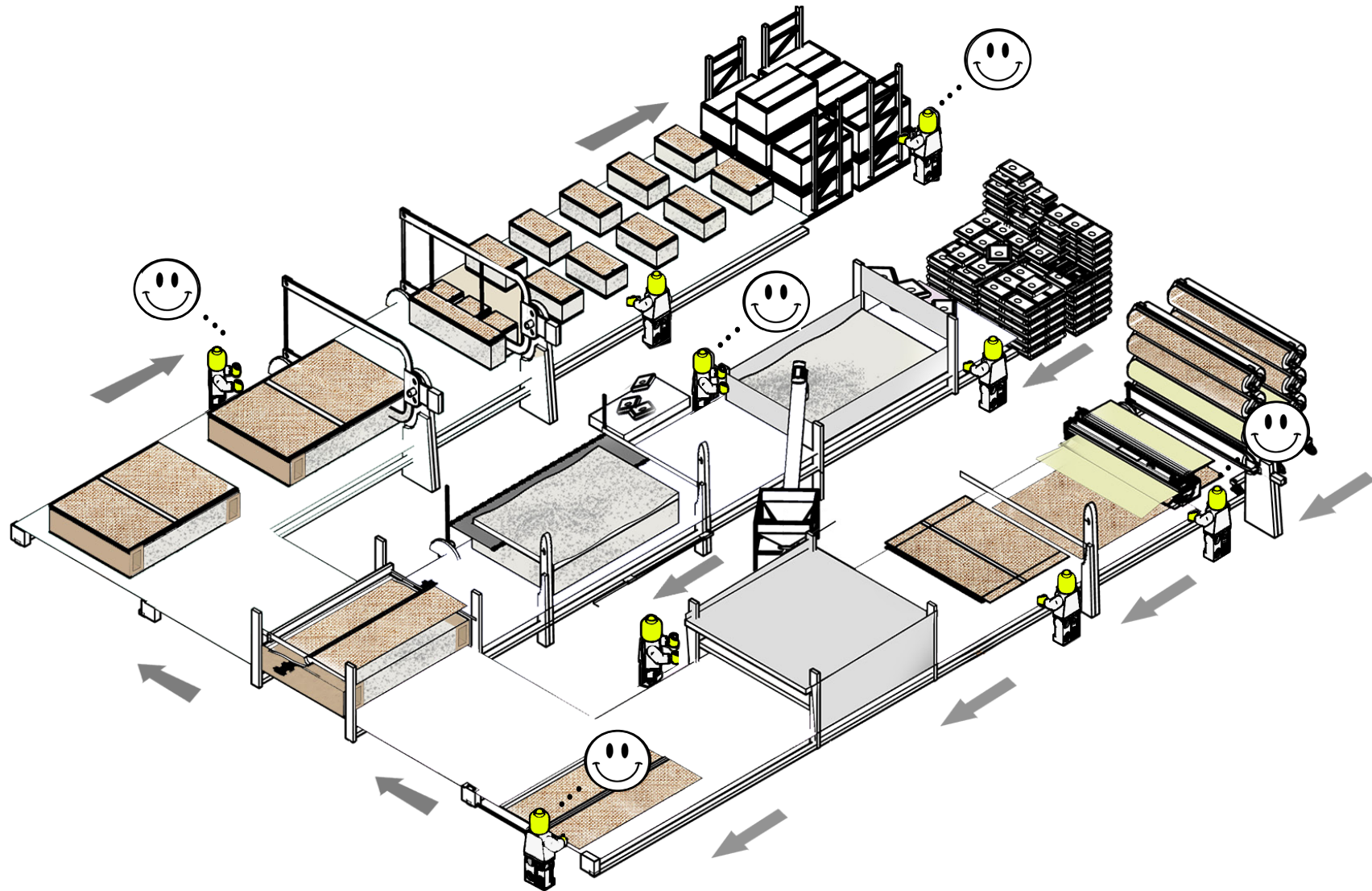
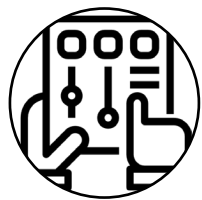












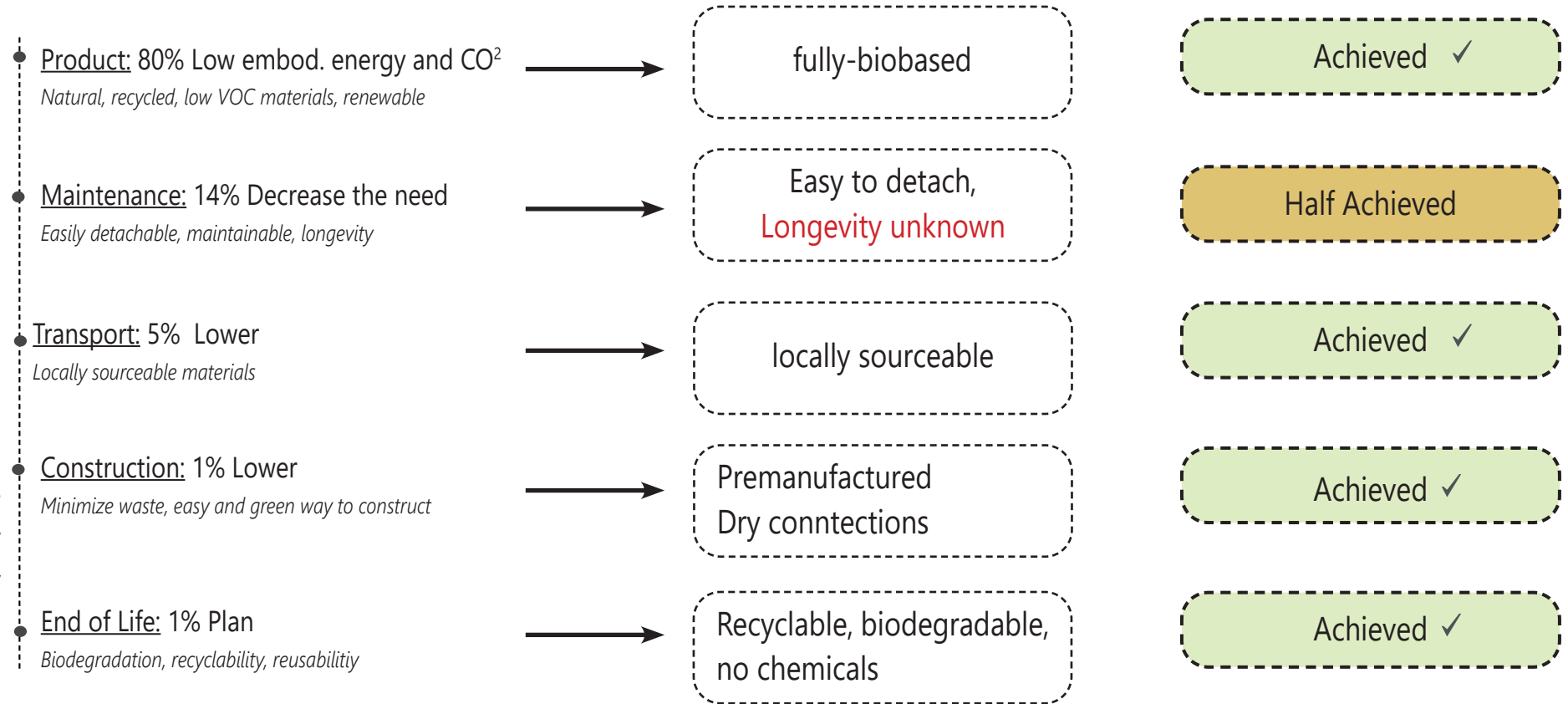
chapter 6

EVALUATION

BENCHMARKS

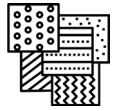


Building Industry

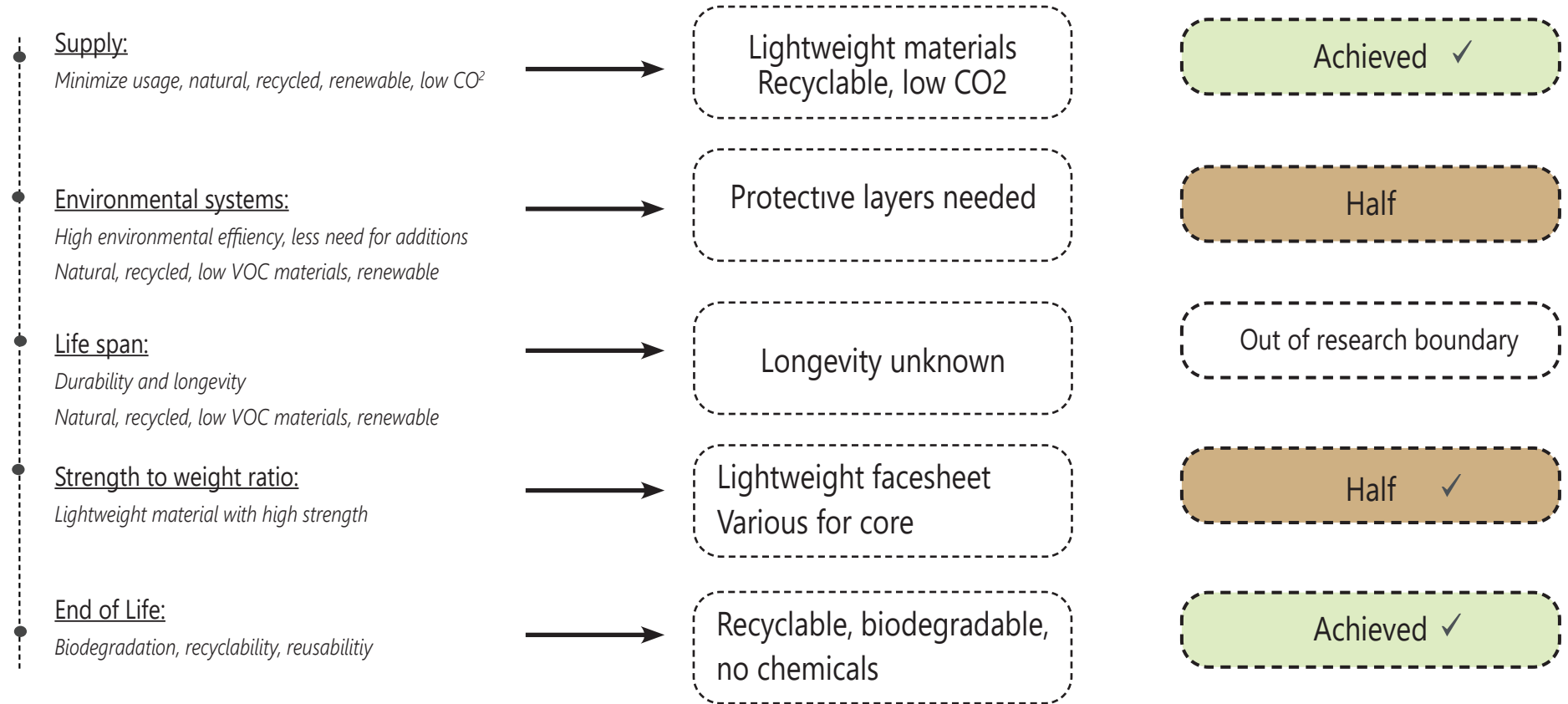


Source: LETI Climate
Emergency Design
Guide, 2023, [https://
www.levittbernstein.
co.uk/site/assets/
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BENCHMARKS



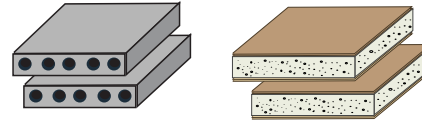
Materials



BENCHMARKS



Local Construction
Hollow core concrete slab



• <u>Mass</u>	→	PLAX 64 kg/sqm CHS 250 kg/sqm	Better ✓
• <u>Price</u>	→	PLAX 180€/sqm CHS 35€/sqm	Expensive
• <u>CO²</u>	→	PLAX 32.2 kg/kg/sqm* CHS 103.5 kg/kg/sqm	Better
• <u>Renewable, biobased</u>	→	PLAX is natural and biodegradable, renewable	Better ✓
• <u>Climate perspective</u>	→	PLAX needs protective layers (fire, moisture, heat..)	Not well

BENCHMARKS

Building Industry

- Product: 80% Low embodied energy and CO²
Natural, recycled, low VOC materials, renewable
- Maintenance: 14% Decrease the need
Easily detachable, maintainable, longevity
- Transport: 5% Lower
Locally sourceable materials
- Construction: 1% Lower
Minimize waste, easy and green way to construct
- End of Life: 1% Plan
Biodegradation, recyclability, reusability

Materials

- Supply:
Minimize usage, natural, recycled, renewable, low CO²
- Environmental systems:
High environmental efficiency, less need for additions
- Life span:
Durability and longevity
- Strength to weight ratio:
Lightweight material with high strength
- End of Life:
Biodegradation, recyclability, reusability

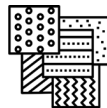
Local Construction

- Mass
- Price
- CO²
- Renewable, biobased
- Climate perspective

BENCHMAKS



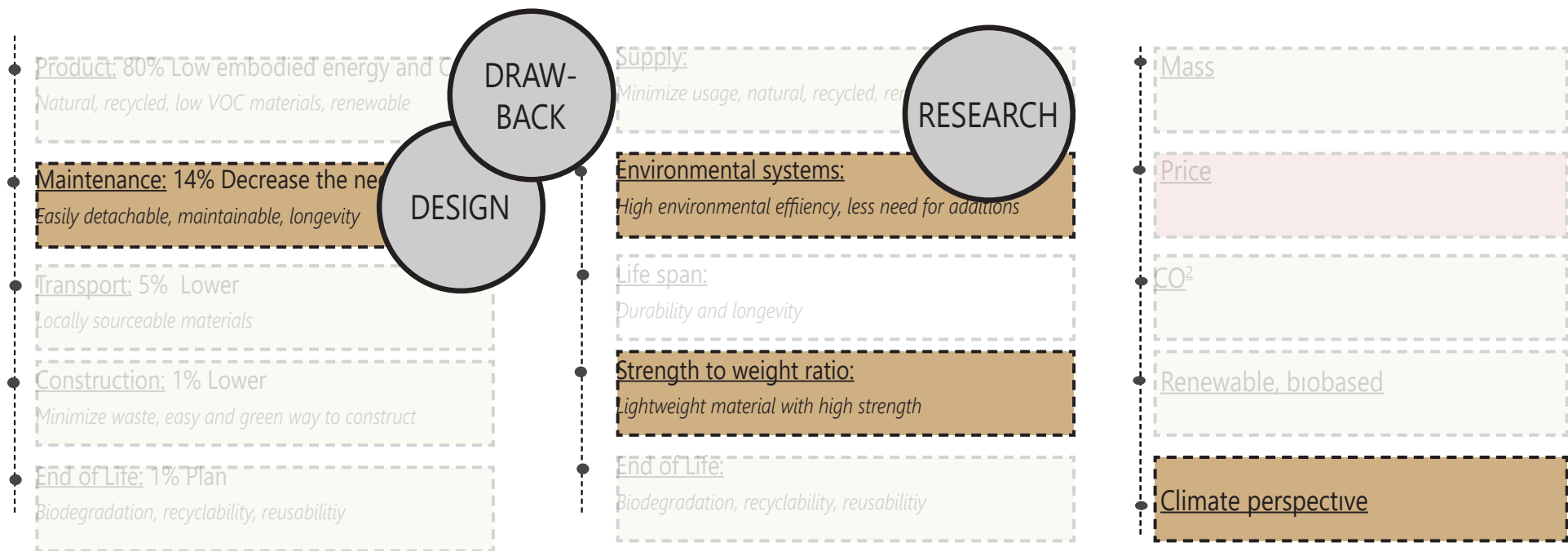
Building Industry



Materials



Local Construction



BENCHMAKS

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Local Construction

- Mass
- Price
- CO²
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- Climate perspective

ADAPTING

Could a novel biobased sandwich flooring outperform conventional flooring systems?



Bio-based



Biodegradable



Low Env.Impact



Lightweight



Recyclable



Mechanically strong



Could a novel biobased sandwich flooring outperform conventional flooring systems?



Bio-based



Biodegradable



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Smart Design



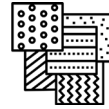
Price

Future recommendations



Structural

- Further verifying tests.
- Advancing the biobased profile idea.
- Possible usage as other building components.



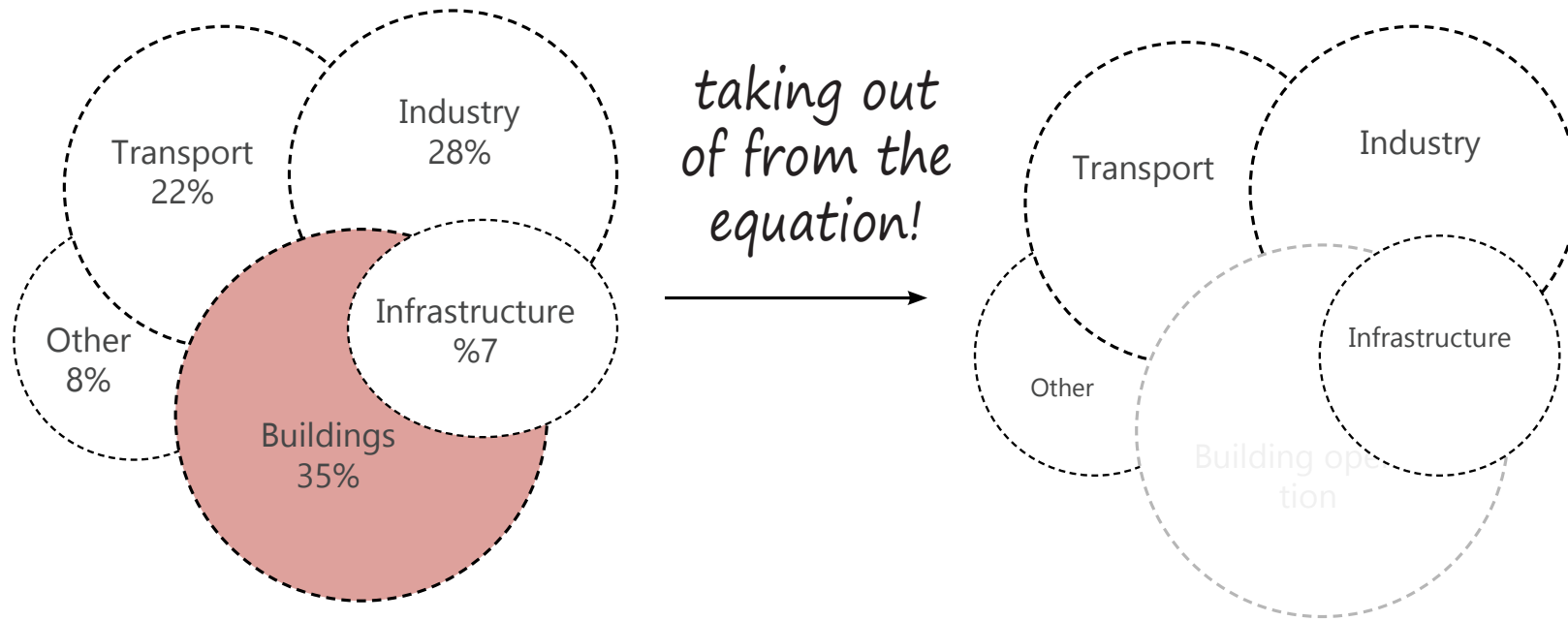
Climate Design

- Acoustical testing.
- Thermal testing.
- Possible material science based solutions.



Product

- Detailed Life cycle analysis.
- End of life scenarios.
- Realization of manufacturing.

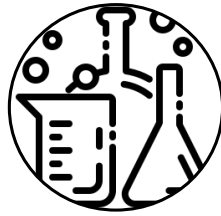


"A new way for architecture":

Only biobased materials: IS IT A POSSIBILITY?



Refuse



Improve



Adapt



*Make it
affordable*



QUESTIONS?

THANK YOU

 **TU Delft**
BK Bouwkunde

 **TU Delft** Aerospace Engineering

 **npsp**

earthfirst[®]
biopolymer films by Sidaplast
PLAX