Kennisdag 'De bouwsector in transitie: digitale revolutie of terug naar de natuur?''

BIOBASED LUCHTKANALEN

DOOR SPREKER: KEVIN WINIARCZYK

BIM MODELLEUR – VALSTAR SIMONIS

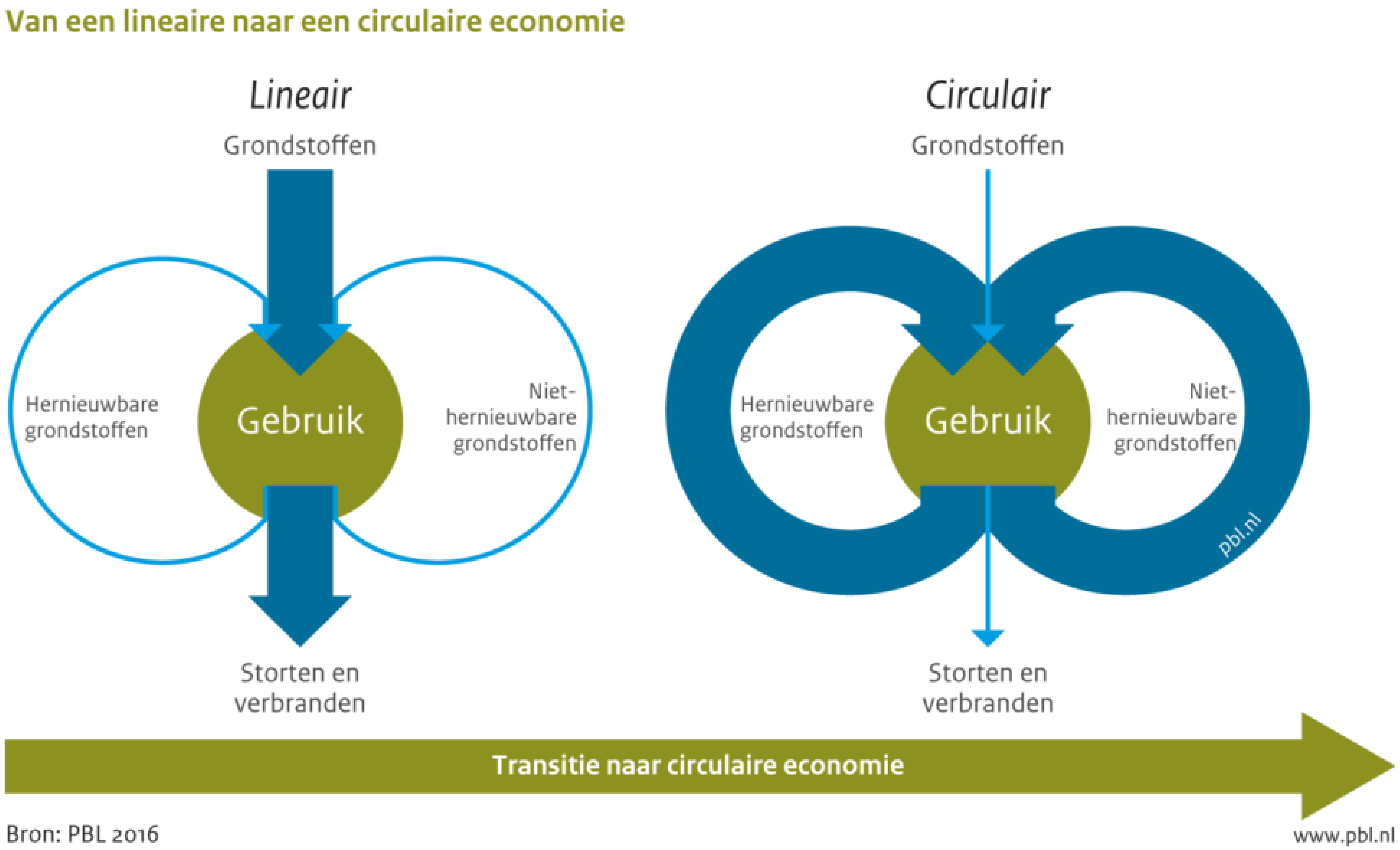
TU Delft

VALSTAR SIMONIS
ADVISEURS INSTALLATIETECHNIEK

Circularity ambitions

Netherlands by 2050

- 50% of raw material reduction 2030
- Efficient use of materials
- Use of renewable materials to prevent depletion of resources



Source:
PBL (2016)

Challenge

HVAC systems

- Sheet metal ducts
  - schools, offices and hospitals
- High-density metals
- Raw materials – depletion of resources

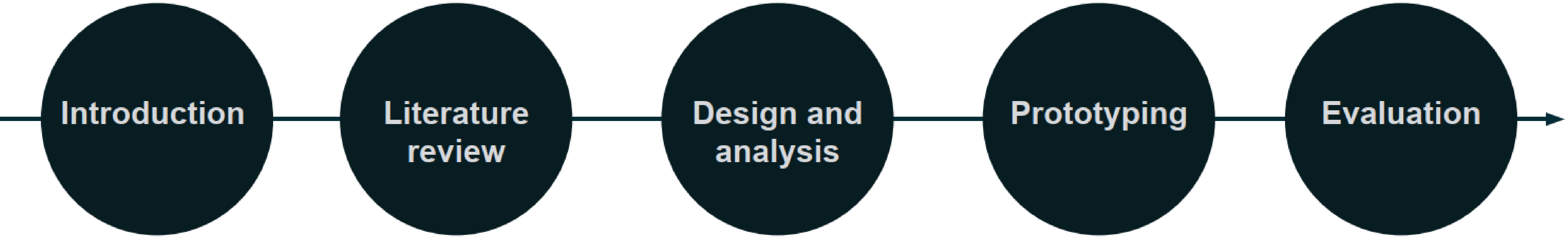
Objective

Non-renewable | Renewable

Research question

What are the potentials and limitations of **bio-based materials** to replace **sheet metal** for the construction of **air duct** components by maintaining the same **quality**?

Methodology



- Sheet metal ducts
- Circularity
- Bio-based materials & manufacturing methods

- Design goal
- Design requirements
- Material analysis / LCA
- Design variations
- Final design

- Geometry
- Connections

- Conclusion
- Recommendations

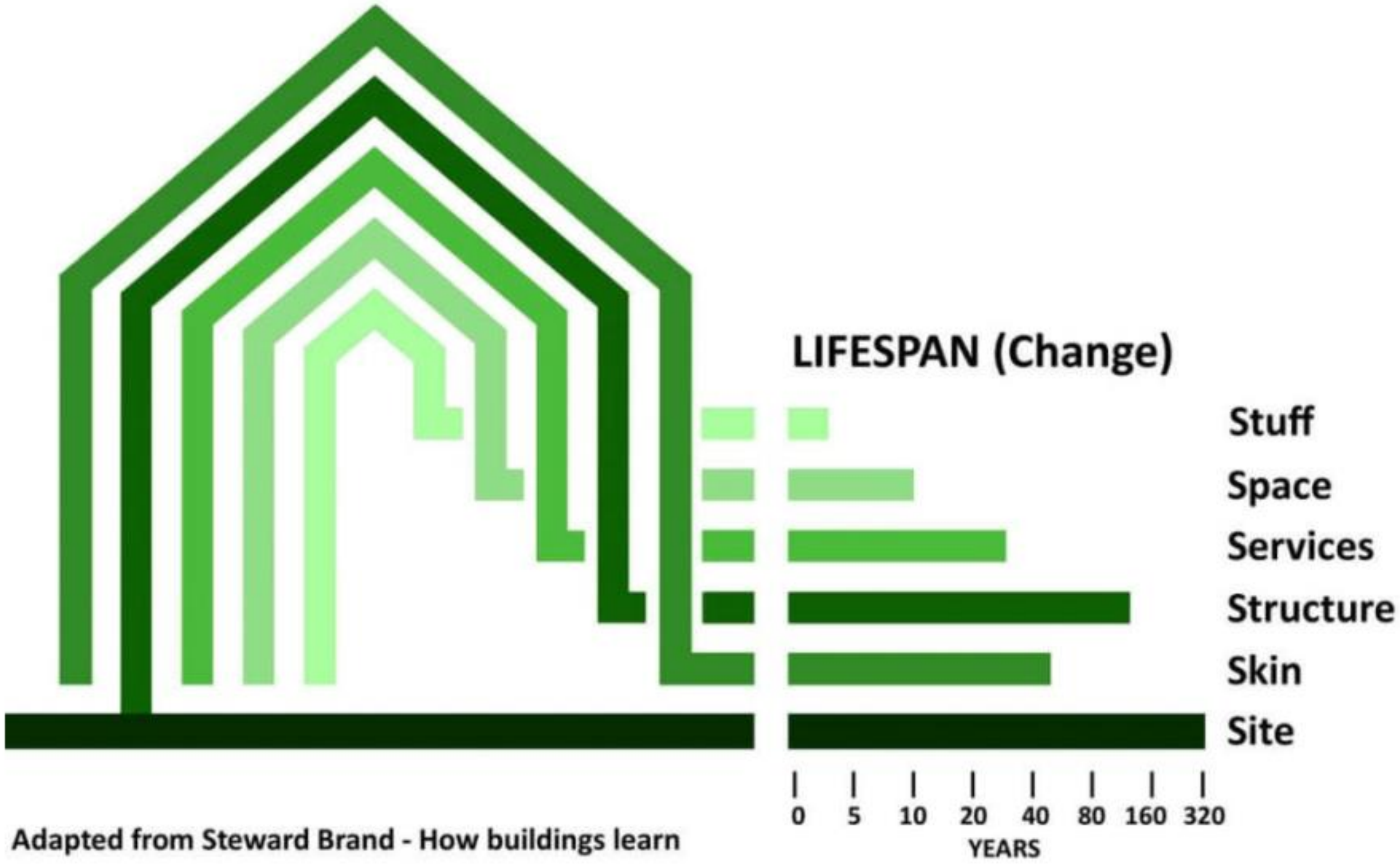
Sheet metal air ducts

spiral ducts

Source:
Langer (2022)
Accu duct (2006)

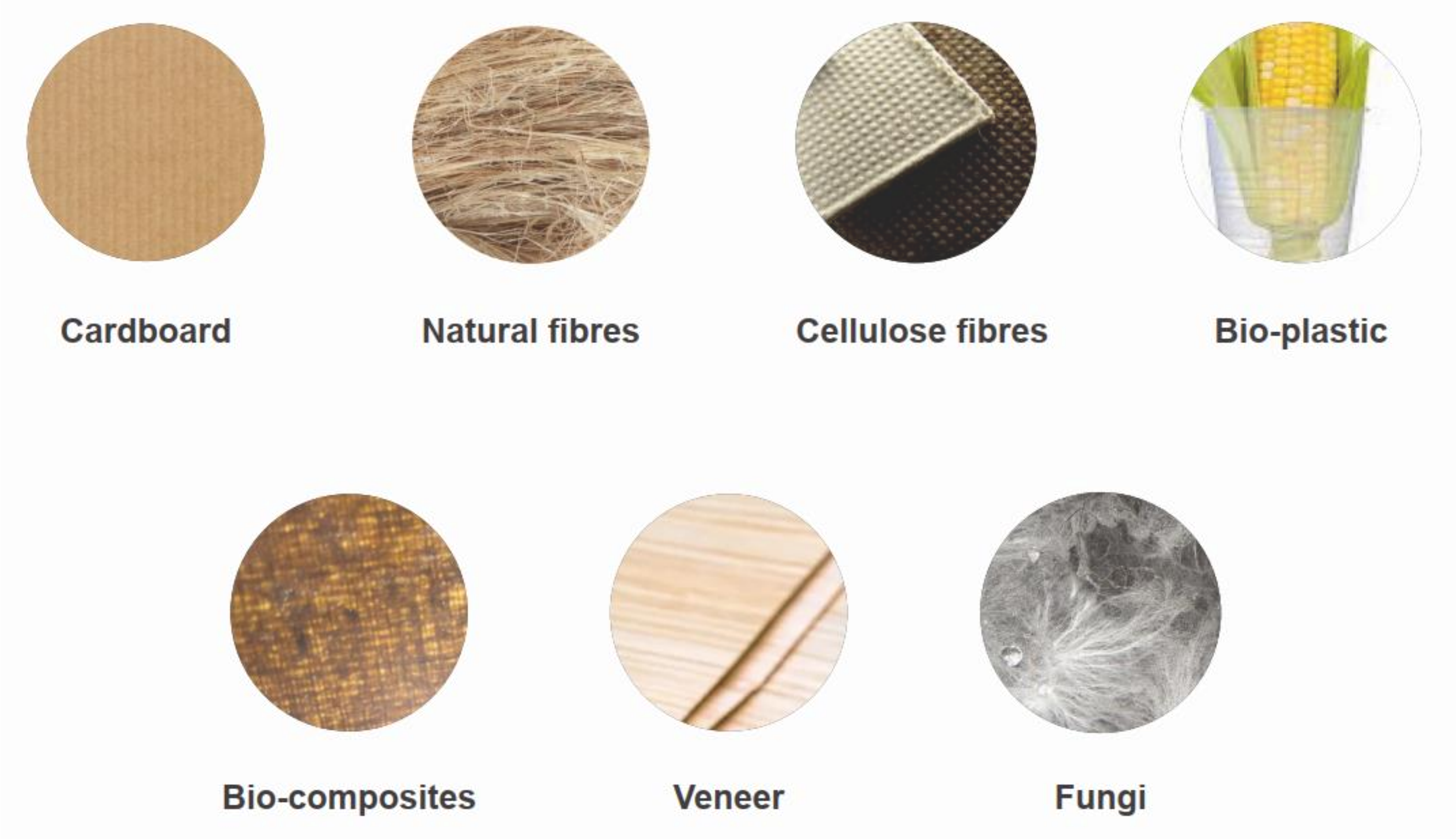
Circularity

shearing layers



Source:
Brand (1994)

Bio-based materials



Manufacturing methods

Cardboard

Spiral winding
Packaging manufacturing

Natural fibres

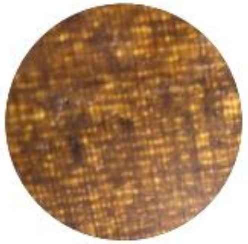
Weaving

Cellulose fibres

Compression moulding
(water, heat, pressure)

Bio-plastic

Extrusion
Foam moulding
Injection moulding
AM



Bio-composites

Pultrusion
Filament winding
Hand & spray lay-up
Vacuum bagging
Compression moulding

Veneer

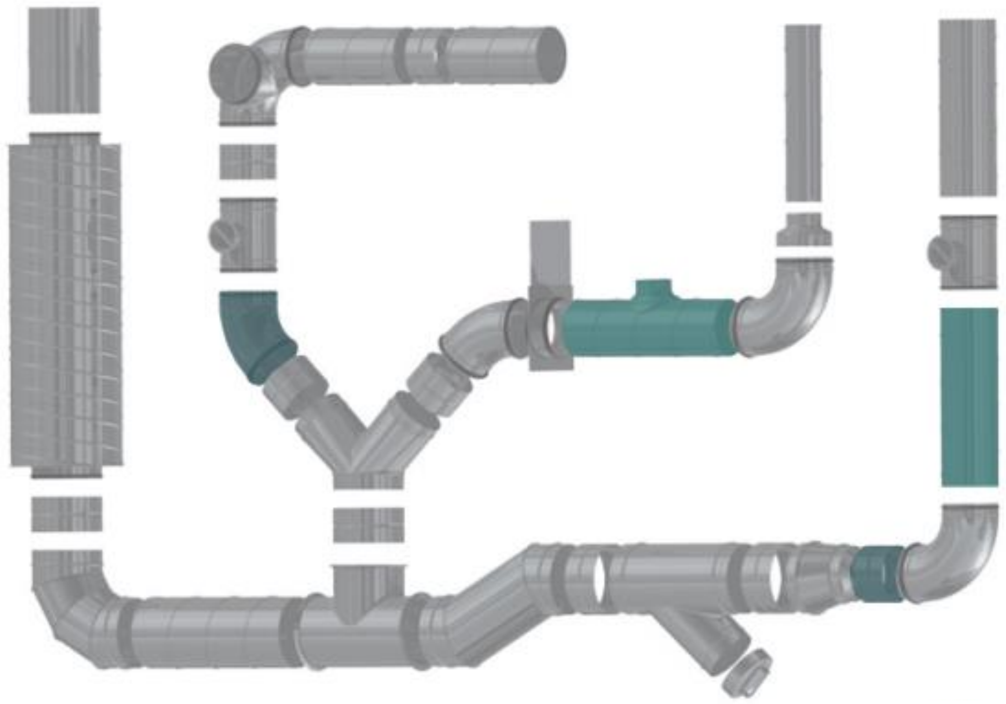
Rotary cutting

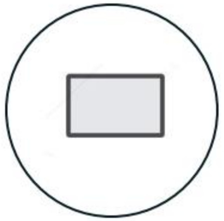
Fungi

Moulding

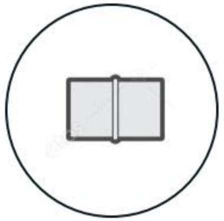
Design goal

round spiral duct





Linear duct



Joint

Bend

T-piece

Source:
Alnor (n.d.)

Design requirements

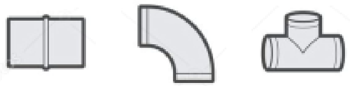
- **Boundary conditions** (for air duct component)
  - Geometry
  - Mass production
  - Renewability
- **1. Functional**
  - Weight
  - Airtightness
  - Installation noise
  - Moisture resistance
  - Chemical emission
  - Fire resistance
  - Aesthetics
- **2. Circularity**
  - Local production
  - Carbon footprint
  - Ease of (dis) assembly
- **3. Manufacturing**
  - Material costs
  - Manufacturing costs
  - Ease of production
- **4. Installation**
  - Material workability
- **5. Use**
  - Maintenance
  - Adaptability

Division (existing) manufacturing methods

Manufacturing method

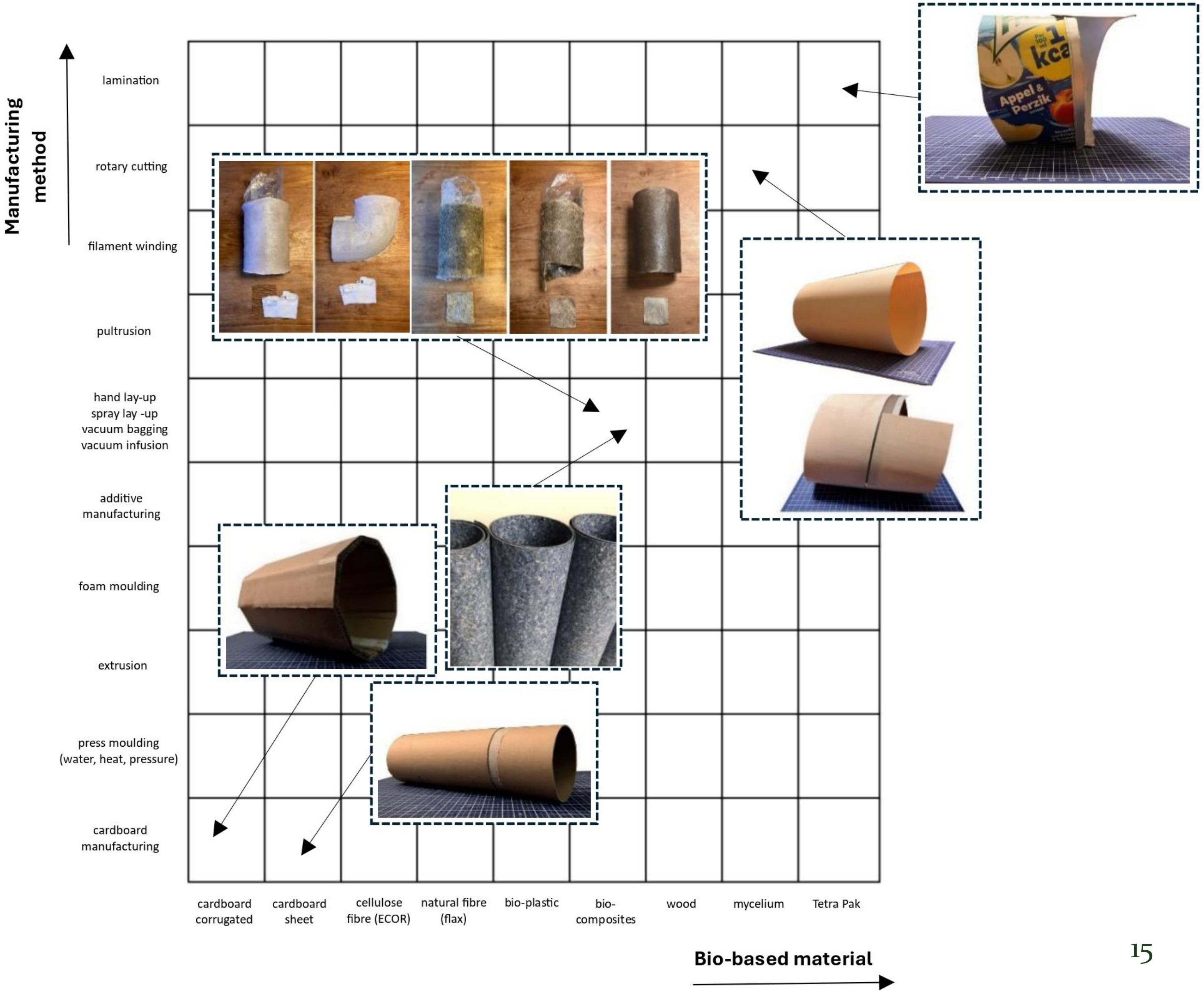
- 

  Linear components (linear duct)
  - Cardboard spiral winding — Cardboard
  - Cardboard corrugated — Cardboard
  - Rotary cutting — Wood veneer
  - Extrusion — Bio-plastics
  - Foam moulding — Bio-plastics
  - Pultrusion — Bio-composites fibres
  - Filament winding — Bio-composites fibres
  - Weaving - textiles — Natural fibres
  - Water, heat, pressure moulding — Celullose fibres
  - Compression moulding (sheets) — Bio-composite non-woven fabric
  - Packaging manufacturing — Tetra Pak
- Complex components (joint, bend, t-component)

  
  - Cardboard cutting — Cardboard
  - Hand lay-up — Bio-composites woven fabric
  - Spray lay-up — Bio-composites woven fabric
  - Vacuum bagging — Bio-composites woven fabric
  - Vacuum infusion — Bio-composites woven fabric
  - Compression moulding — Bio-composites non-woven fabric
  - Injection moulding — Bio-plastics
  - Moulding — Mycelium
  - AM — Bio-plastics
  - Packaging manufacturing — Tetra Pak

Design matrix

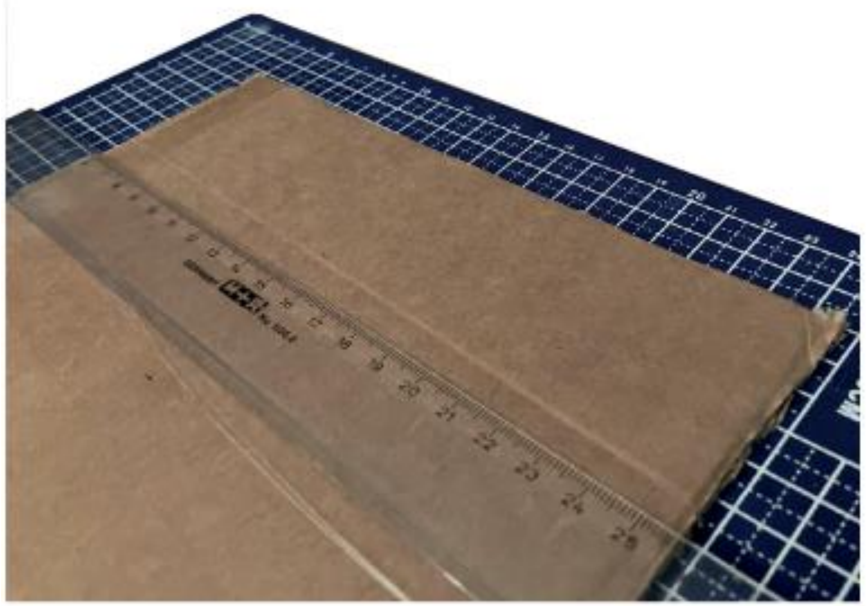
- Manufacturing methods
- Bio-based materials
- Experimental research by modelling

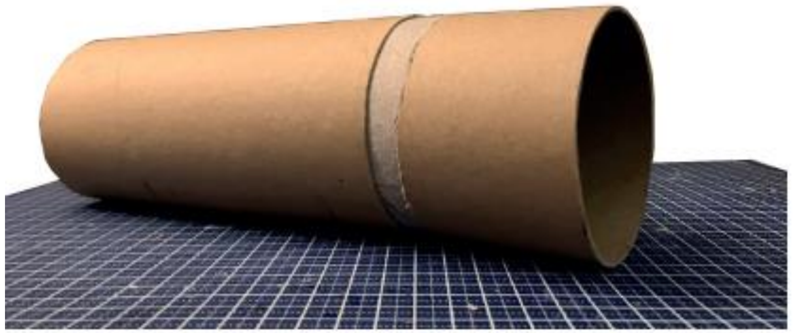


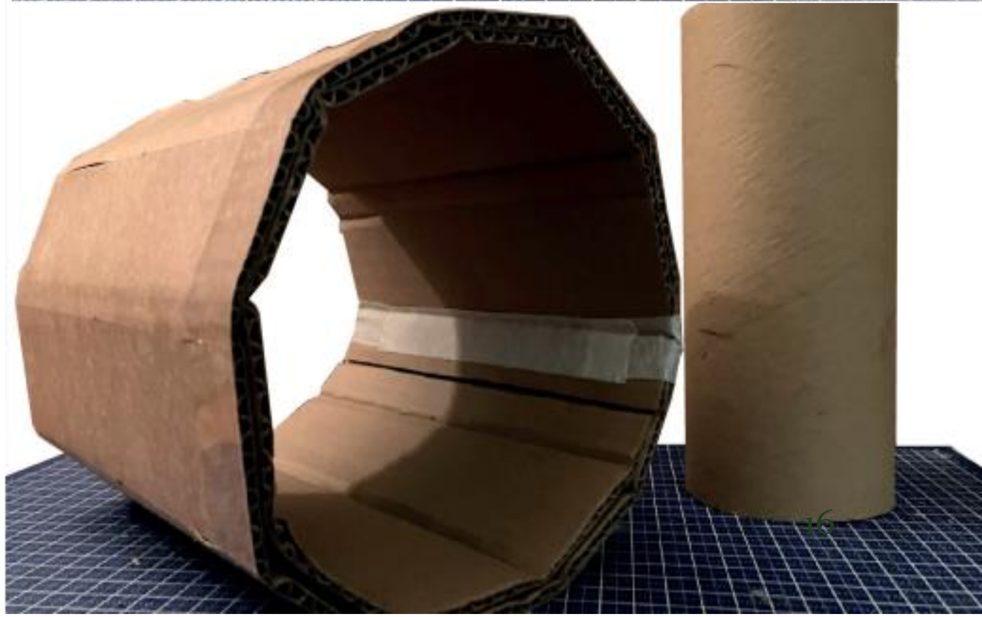
Cardboard

+ lightweight
+ assembly
+ easy transportation (corrugated cardboard)

- polygonal shape (corrugated cardboard)
- poor moisture resistance



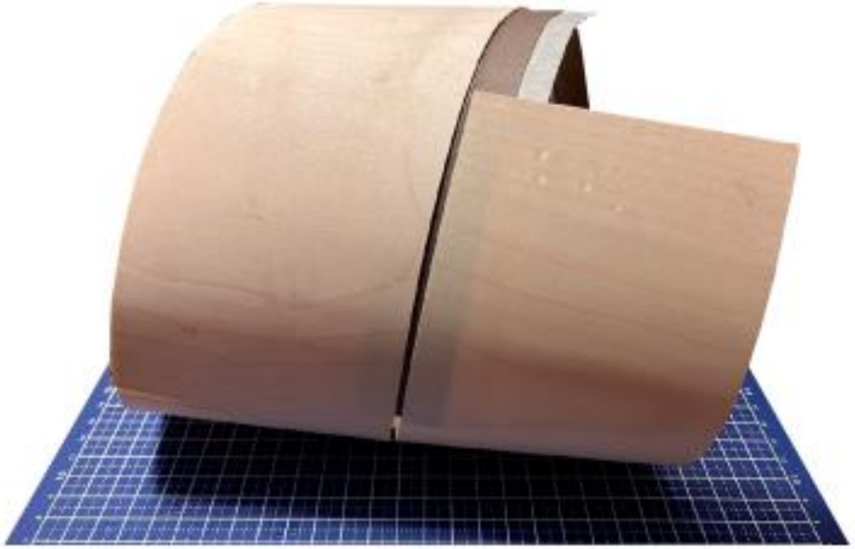




Veneer

+ lightweight
+ aesthetics

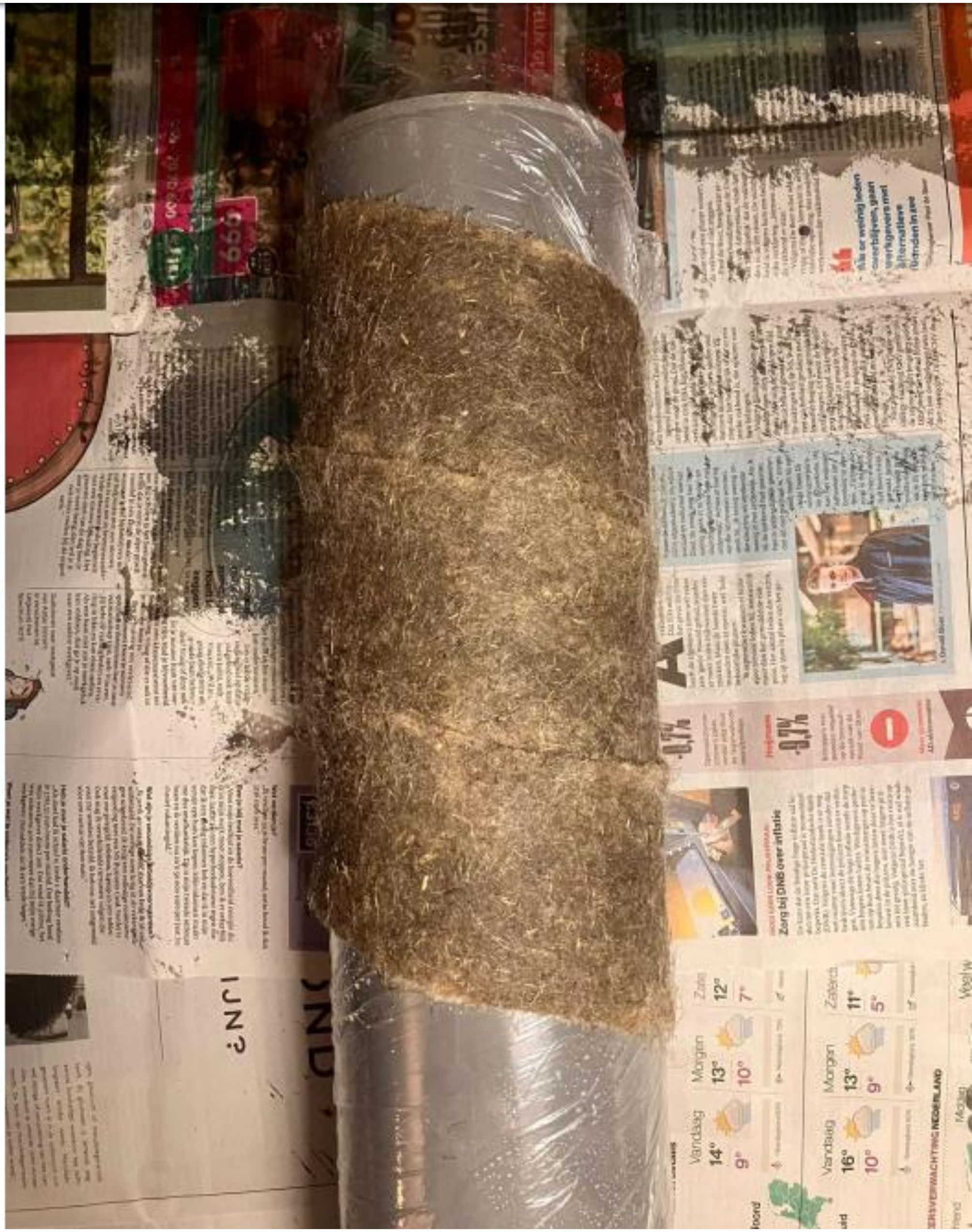
- sensitive for temperature changes
- fragile



Bio-composite

+ robust

- time consuming production process
- expensive



Non-woven flax fibres

Clothing waste

Woven flax fibres

BOUWFYSICA
NEDERLANDS VLAAMSE BOUWFYSICA VERENIGING

Bio-composite (old jeans)

Source:
PlanQ (2022)

Tetra Pak

+ for 95% bio-based
+ renewable
+ smooth surface
+ easy cleanable

Source:
Dubbelfris (n.d.)

Assessment

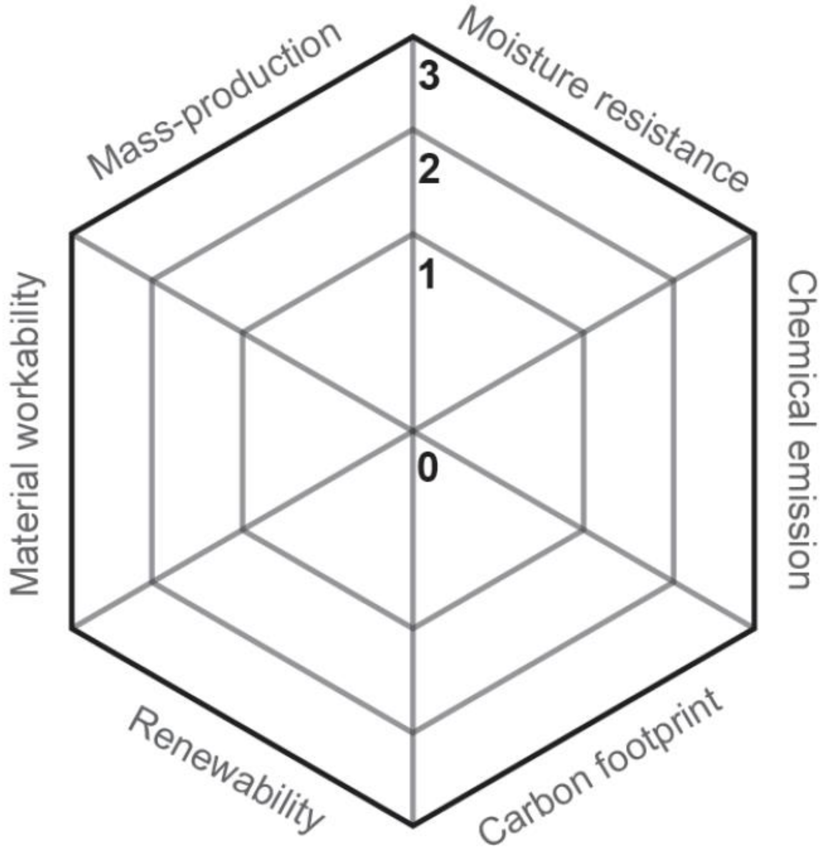
	Manufacturing method	Material	Geometry	Mass-production	Renewability
	Linear				
●	Spiral winding cardboard	Cardboard	●	●	●
	Corrugated cardboard production	Cardboard	O	●	●
●	Rotary cutting	Wood veneer	●	●	●
●	Extrusion	Bioplastic	●	●	●
	Foam moulding	Bioplastic	●	O	●
	Filament winding	Biocomposite fibres	●	●	O
	Pultrusion	Biocomposite fibres	●	●	O
●	Compression moulding: sheets	Biocomposite woven fabric*	●	●	●
	Weaving - textiles	Natural fibres: woven fabric	O	●	●
	Celullose fibres	Celullose fibres	●	O	●
●	Packaging manufacturing	Tetra Pak	●	●	●
	Complex				
●	Cardboard cutting	Cardboard	●	●	●
●	Injection moulding	Bioplastic	●	●	●
	Hand lay-up	Biocomposite woven fabric*	●	O	O
	Spray lay-up	Biocomposite woven fabric*	●	O	O
	Vacuum bag	Biocomposite woven fabric*	●	O	O
	Vacuum infusion	Biocomposite woven fabric*	●	O	O
●	Compression moulding	Biocomposite non-woven fabric*	●	●	●
	Moulding	Mycelium	O	O	O
	AM	Bioplastic	●	O	●
●	Packaging manufacturing	Tetra Pak	●	●	●

BOUWFYSICA
NEDERLANDS VLAAMSE BOUWFYSICA VERENIGING

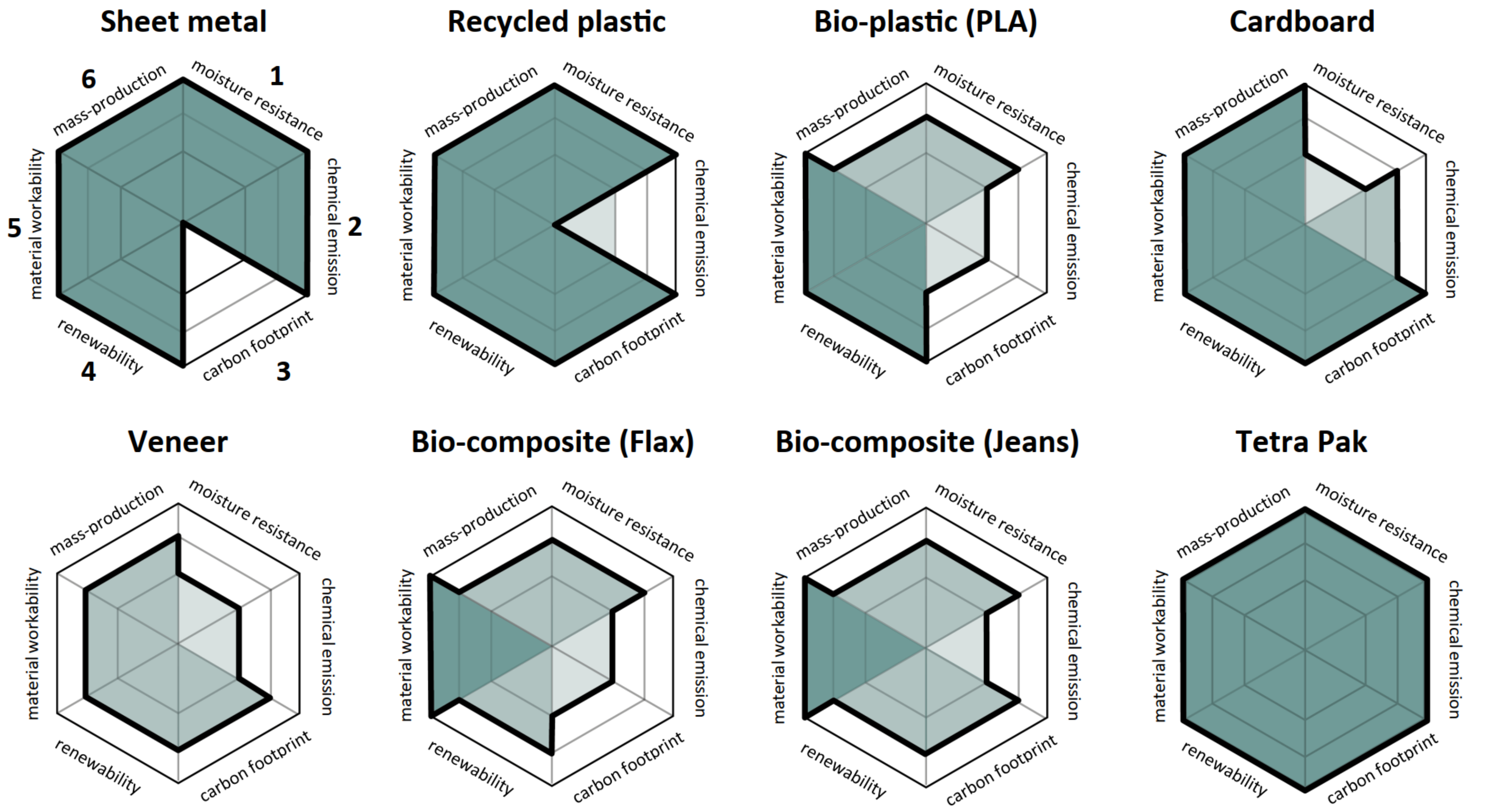
Overall assessment

linear duct

1. Moisture resistance – **Lifespan**
2. Chemical emission – **Health and comfort**
3. Carbon footprint – **Environmental impact**
4. Renewability – **End-of-life scenario**
5. Material workability – **Installation / weight**
6. Mass-production – **Scalability**

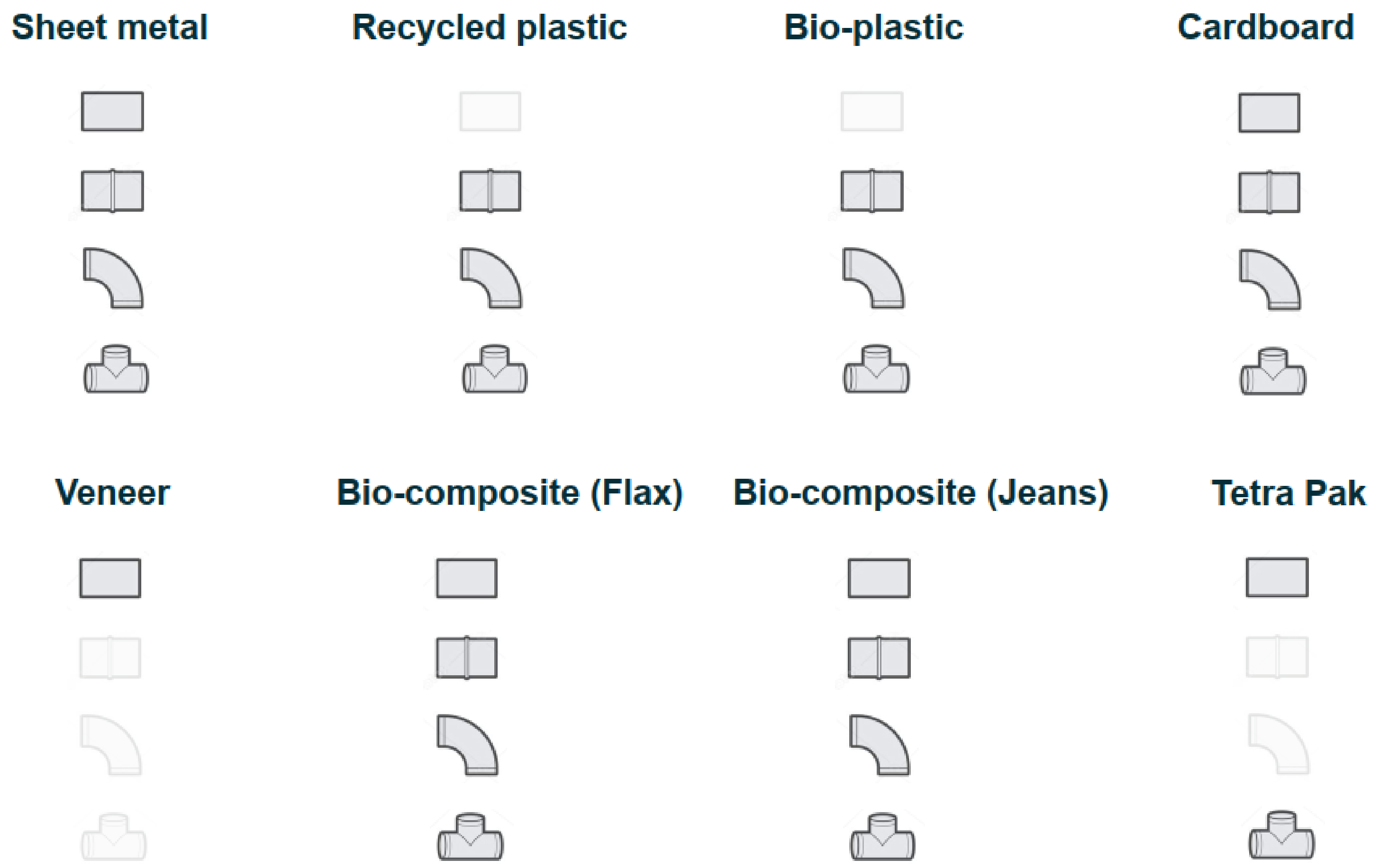


Assessment overview



1. Moisture resistance 2. Chemical emission 3. Carbon footprint 4. Renewability 5. Material workability 6. Mass-production

Suitable materials per component

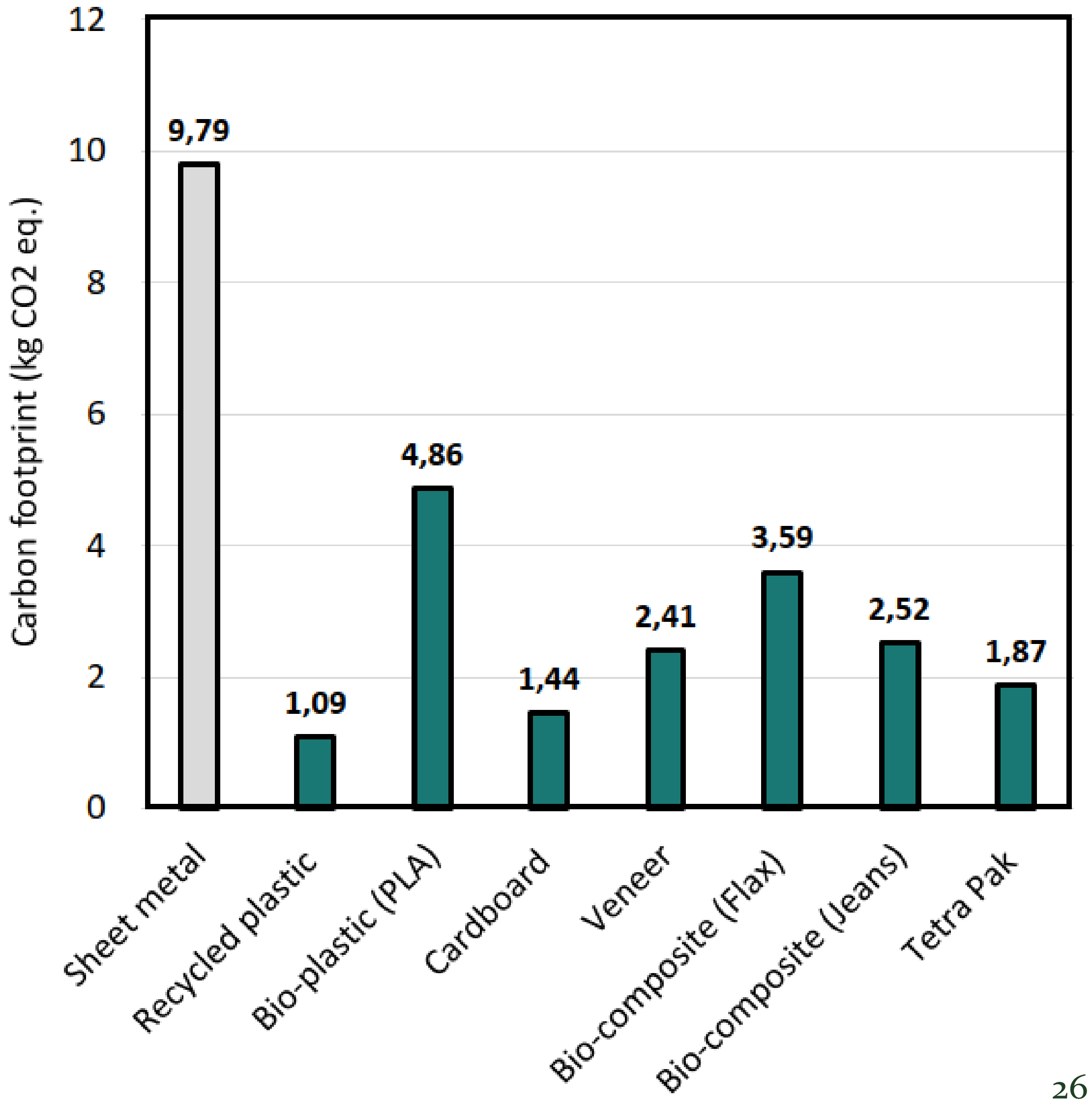


LCA comparison with sheet metal

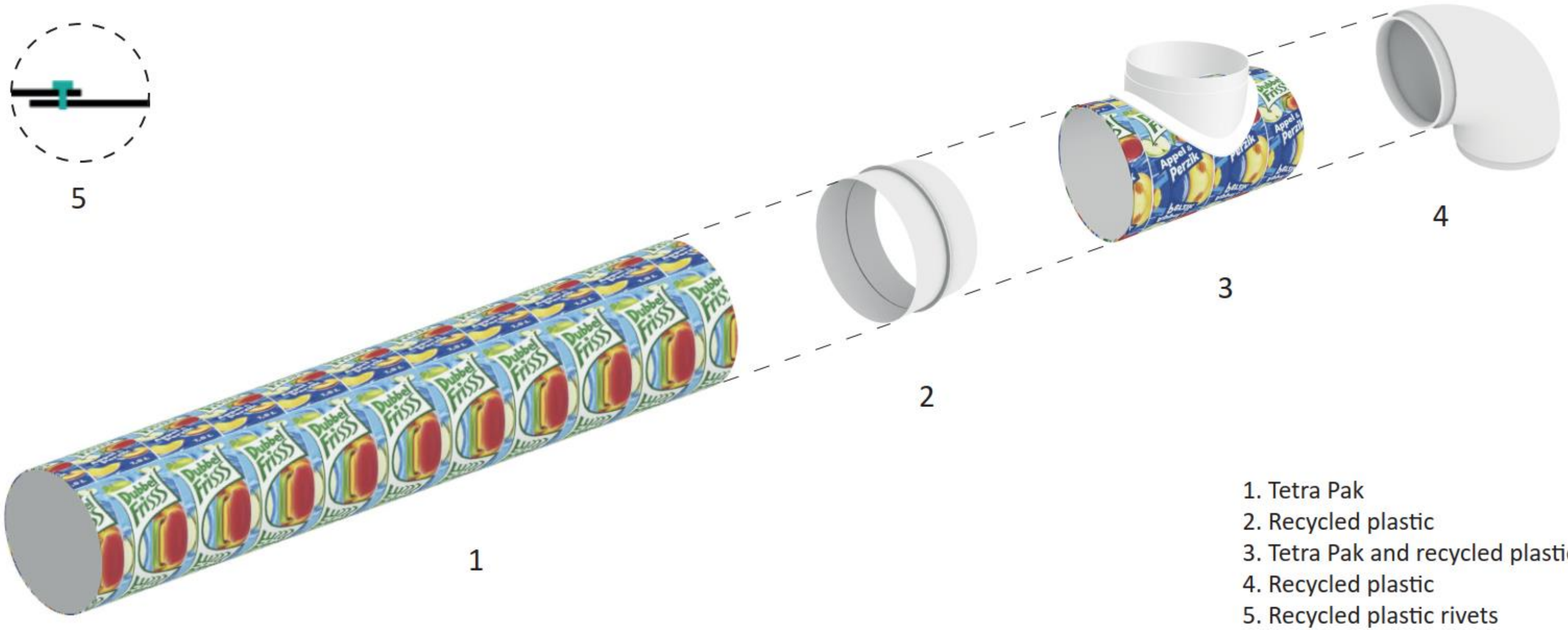
1 meter linear duct and 160 mm diameter

- Thickness sheet metal - 0,5 mm
- Thickness selected (bio-based) materials;
  - recycled plastic, bio-composites, bio-plastic, Tetra Pak - 2,0 mm
  - cardboard, veneer - 3,0 mm

- Assuming same lifespan as sheet metal, in practice most likely not the case.



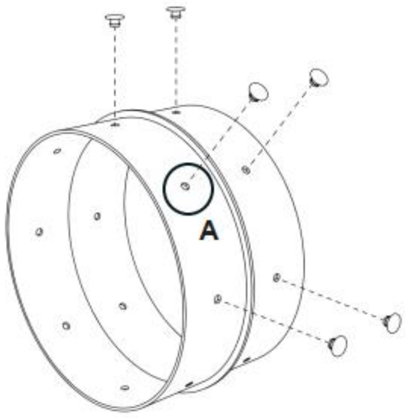
Final design



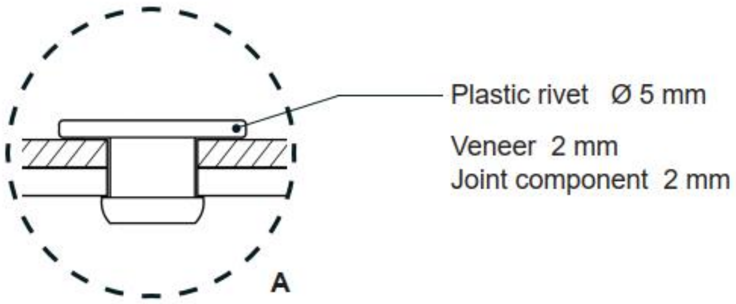
1. Tetra Pak
2. Recycled plastic
3. Tetra Pak and recycled plastic
4. Recycled plastic
5. Recycled plastic rivets

Connections

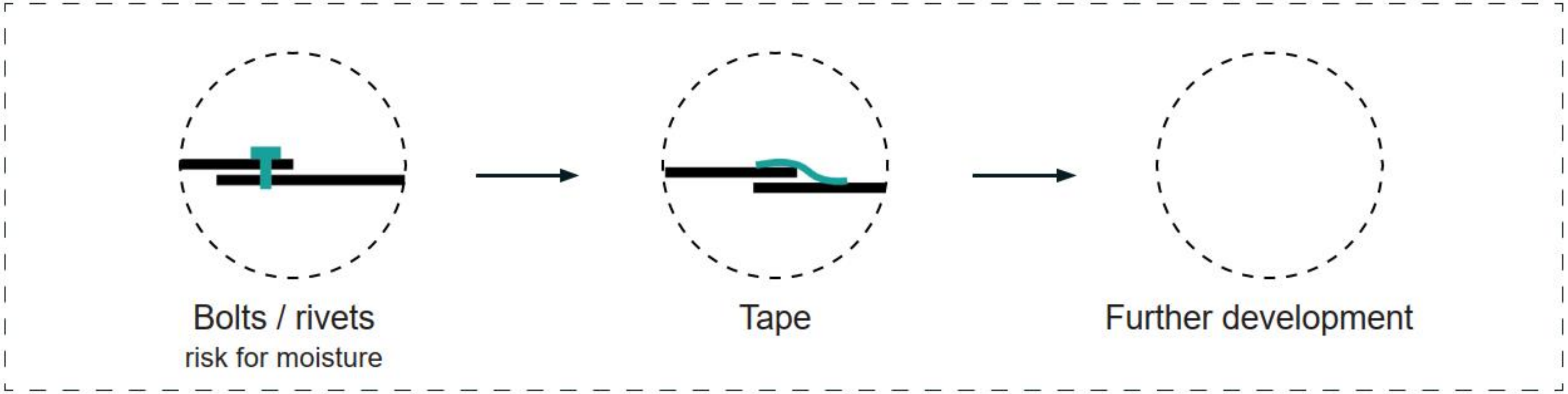
between components



Exploded view



Detail



Bolts / rivets
risk for moisture

Tape

Further development

Prototyping

Conclusion

Possibilities

+ Mass-production linear components: **Tetra Pak**
+ Low **carbon footprint**
+ **Circular** strategies: reuse and recycle

Limitations

- Mass-production of **complex components**
- Meeting **quality** of sheet metal ducts:
  - chemical emission (VOC’s)
  - moisture resistance
- Connections between components is challenging
- **Lifespan** unknown

Further research

- Determine lifespan under increased temperature and humidity rates (affecting carbon footprint)
- Experimental research of moisture resistance and chemical emission (VOC’s)
  - recycled plastics and bioplastics
- Explore other materials and connections: giant bamboo

Questions?