BIODEGRADABLE MATERIALS

A research and design handbook; enhancing the use of biodegradable materials on building's envelopes in NL.

by Eleni Ganotopoulou /4256670

Mentors: 1st_Tillmann Klein , 2nd_Fred A. Veer
Research Definition:
Problem statement  
Research Question  
Methodology  

set of criteria / constraints  

Research:
Research A  
Research B1 + B2  
Research Comparisons  
Research Results  

a1 reason of disuse  
a2 general benefits  
a3 general flaws & defects  

b1 particular properties  
b2 production techniques  
typical sizes & types  

primary material’s selection  
secondary material’s selection  
comparisons evaluation phase  

details 1:20, 1:10, 1:5 calculations  

Design:
Case study  
Redesign Proposal A  
Redesign Proposal B  
Redesign Proposal C  

Conclusion
Problem definition

Current Materials
- shortage of water
- finite resources
- harmful gases
- embodied energy and processing
Problem definition

Building industry

3000 Mt/year of raw materials

40% solid waste accumulates in landfills

30% of CO2 emissions

28.1% EU industry
Problem definition

Health problems
- carcinogenic
- VOCs emissions
- bad indoor air quality
- Sick Building Syndrome
- Respiratory problems
  - asthma, allergies
- renewable resources
- low embodied energy
- low emissions
- reusable and recyclable

Biodegradable materials
Research Question

“Which products and systems will enhance the use of biodegradable materials on building envelopes in the Netherlands? How can we enhance their use as facade components?”

01 I which biodegradable materials & products are already available in the market?
02 I Which are the parameters that affect the performance of these materials?
03 I Which properties and characteristics do biodegradable materials present? how do they perform?
04 I which production processes & techniques are involved in the production of biodegradable products?
05 I How can manufacture availability influence the design of such products?
06 I Can be prefabricated? what kind of production technology, equipment and processes is needed to result in biodegradable building products of low embodied energy and cost?
### Biodegradable materials - categories:

#### Traditional
- Peat sod
- Wattle & daub
- Wood

#### Earthen
- Limestone
- Earthbags
- Mud coating
- Rammed-earth
- Cordwood
- Adobe bricks
- Compressed earth blocks (CEB)
- Clay dyes

#### Forestry
- Cork
- Papertubes
- Papercrete
- Paperstone

#### Farming
- Sheep wool

#### Agriculture
- Hemp
- Bamboo
- Straw bale

#### Matress indust.
- Coconut fiber
- Natural rubber
- Horse hair
- Seaweeds
- Cactus
- Cotton
- Linen
- Goose down

#### New technologies
- Ingo-corn fibers
- Canatex
- Pine sap
- Zelfo
- BatiPlum feathers
- Nettle Textile
- Muschroom (packaging material)
- Moniflex

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*Table based on table in “Possibilities of applying biodegradable materials in solid building envelopes in the Netherlands”, (Sgouropoulou, 2013, p.43-44)*
**Biodegradable materials - categories:**

### Traditional
- Peat sod
- Wattle & daub
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---

**Criteria:**

01. Local Availability
02. In Surplus (quantity)
03. Prefabrication potentials

---

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### Biodegradable materials - categories:

<table>
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<tr>
<th>Traditional</th>
<th>Earthen</th>
<th>Forestry</th>
<th>Matress indust.</th>
<th>New technologies</th>
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<td>- Cork</td>
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<td>- Wattle &amp; daub</td>
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<td>- Cotton</td>
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<td>- compressed earth blocks (CEB)</td>
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<td>- clay dyes</td>
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<th>Agriculture</th>
<th>12 selected materials</th>
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<td>- Sheep wool</td>
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<td>- Bamboo</td>
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<td>- Straw bale</td>
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<td></td>
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### Criteria:

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03. Prefabrication potentials

*Table based on table in "Possibilities of applying biodegradable materials in solid building envelopes in the Netherlands". (Sgouropoulou, 2013, p.43-44)
Selected Materials

01 I Unfired earth
02 I Rammed-earth
03 I Straw
04 I Sheep wool
05 I Wood-fibers
06 I Flax
07 I Hemp
08 I Hemp-lime
09 I cellulose
10 I Papercrete
11 I paperboards
12 I Cork products
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08 I Hemp-lime
09 I cellulose
10 I Papercrete
11 I paperboards
12 I Cork products
RESEARCH A
Reasons of Disuse
Main countries:
Netherlands
United Kingdom
Germany
Austria
France
Portugal (cork)
Materials documentation

- Products type/ size
- Products composition
- Properties
- Production processes
- Positive-negatives
- Applications
- Design advices
### Materials documentation

#### Product type

<table>
<thead>
<tr>
<th>Company</th>
<th>Materials content</th>
<th>Specific properties</th>
<th>Environmental durability</th>
<th>Processability</th>
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<tr>
<td>JOCAVI</td>
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<td>Environments</td>
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### Insulation ROLL

<table>
<thead>
<tr>
<th>Company</th>
<th>Materials content</th>
<th>Specific properties</th>
<th>Environmental durability</th>
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### Insulation TULLES

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<tr>
<td>Environments</td>
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### Products tables

<table>
<thead>
<tr>
<th>Source/Company</th>
<th>Rok Mountain¹</th>
<th>Doshay</th>
<th>Thermoloose</th>
<th>NaturePRO</th>
<th>Literature</th>
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<tbody>
<tr>
<td>country</td>
<td>UK</td>
<td>NL, BE</td>
<td>UK</td>
<td>UK</td>
<td>worldwide</td>
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<tr>
<td>products</td>
<td>Rolls &amp; Batts</td>
<td>Rolls</td>
<td>Rolls &amp; Batts</td>
<td>Rolls &amp; Batts</td>
<td>Insulation wool</td>
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<tr>
<td>Product Composition</td>
<td>wool 95% &gt;85% 60% 75% 82% 60% Keratin (protein)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>other substances</td>
<td>5% mold filters (polyester) 15% PET 30%/13%/15% recycled polyester 50% recycled plastic bottles -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additives/binder</td>
<td>borax Molybdenum 1% &gt;10% polyester 2% borax 10% Borax ite -</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>insect repellent&lt;sup&gt;2&lt;/sup&gt;</td>
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</table>

### General Properties

<table>
<thead>
<tr>
<th>Density (kg/m³)</th>
<th>19-20</th>
<th>22-25</th>
<th>25</th>
<th>19</th>
<th>10-30,20-60&lt;sup&gt;20&lt;/sup&gt;</th>
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<tbody>
<tr>
<td>Price</td>
<td>7,25-21,77 €/m²</td>
<td>7,12-20,76 €/m²</td>
<td>4,24-14,28€/m²</td>
<td>5,84-29,84€/m²</td>
<td>9,44 €</td>
</tr>
<tr>
<td>Price / lilo</td>
<td>7,63-9,17 €/kg</td>
<td>5,80-8,99€/kg</td>
<td>3,70-5,80€/kg</td>
<td>6,14-10,46€/kg</td>
<td>11,560 €&lt;sup&gt;38&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

### Mechanical Properties

| note: mechanical properties avo (<strong>found for sheep wool insulation products</strong> (in literature as can be found only for wool fiber) |
|----------------|-------|-------|----|
| Thermal & combustion | Properties | Thermal cond. (k) | 0.059 | 0.035 | 0.015-0.038 | 0,040 | 0,035-0.040<sup>20</sup> |
| (Cp) Specific heat | capacity (J/kgK) | 1700 | 1720 | 1700 | - | 960-1300<sup>22</sup> |
| Expansion coefficient | - | - | - | - | 15-30 ppm |
| Maximum service T | - | < 150 °C | - | - | 110-120 °C |
| Decomposition T | - | > 250 °C | - | - | - |
| Plane (ignition point) | - | 580-600 °C | 500 °C | > 560 °C | 560°<sup>21</sup> |
| Humidity<sup>24</sup> | - | - | - | - | R<sup>2</sup> |

### Hygro-thermal properties

| Water absorption | 35% | 30-35% | 25-34% | 40% | 30-40%<sup>24</sup> |
| Vapour Permeability | (Gg/m Pa) | - | - | - | - |
| Vapour diffusion (m/s) | 1.2<sup>27</sup> | 1.4 | 1.2<sup>27</sup> | 1.3 | 1.2<sup>27</sup> |
| Vapour resistivity | 10 MNs/m² | 5-20 MNs/m² | 9 MNs/m² | 5-15 MNs/m² | - |
| Air flow resistivity | - | - | - | - | - |

### Acoustic properties

| Sound absorption (As) | 0-500 Hz | - | 0,91 (100mm) | 1,00 (100mm) | - |
| Sound Reduction (Sw) | - | - | 40-54 dB | - | - |

### Primary material production: energy and Co2

| Embodied energy | - | - | 6.75 MJ/kg | 70 MJ/kg | 20.9 MJ/kg<sup>21</sup> |
| CO₂ footprint | Kg/ha | - | - | - | 12.36 MJ/kg<sup>21</sup> |
| Water Usage (l/ha) | - | - | - | - | 160,000 |
| REY content | - | - | 20.37% | - | 180,000 |

### Material recycling: energy, CO₂ and recycle fraction

| Embodied energy, recycled wool (cable to cable) | 20.9 MJ/kg | - | - | - |
| Heat of combustion | - | - | 20.3 KJ/g<sup>22</sup> | - | - |
| Combustion CO₂ | - | - | 1.39 | - | 1.84 kg CO₂<sup>23</sup> |
Products levels - prefabrication

- **Material**: raw material (clay, silt, sand)
- **Commercial Material**: clay powder, ProCrea unfired bricks, Claytec unfired bricks, Sumatec, Ecoterre™
- **Element**: conluto unfired bricks
- **Sub Component**: Claytec clay panels
- **Component**: insulation wall, Claytec clayboard + particleboard, drywall + clayboard, adobe/CEB + clayboard
- **Building Part**: rammed-earth prefabricated panels & claddings
- **Building**: CEB/adobe building, rammed-earth building, prefabricated rammed-earth building
Research comparisons

Graphs, tables and charts

- Price per kg / price per m²
- Thermal conductivity, $\lambda$ (W/mK)
- Specific heat capacity, $C_p$ (J/kg K)

- Embodied energy, MJ/kg
- Compressive strength Vs density
- Young's modulus Vs density
thermal conductivity

dry density

thermal conductivity

compressive strength

material's composition

specimen geometry

moisture content

product shape/content

rigidity & flexibility level

research results / remarks

binders/stabilizers

optimum level ratio (d/h) ~5

increase fire / pest resistance

durability in weathering

thickness

decreases thermal insulation

increases compress. strength

Research results / remarks
Catergories:

a. thermal-acoustic
Insulating materials

b. self-supportive
insulating materials

b. structural –thermal
mass materials

- high thermal insulation
  $\lambda$: 0.038 – 0.048 W/mK
  flexible / semi-flexible

- medium thermal insulation
  $\lambda$: 0.048–0.250 W/mK
  semi-flexible / rigid

- low thermal insulation
  $\lambda$: 0.065–1.50 W/mK
  rigid

Material:

- sheep-wool
- flax
- hemp
- cellulose flackes
- wood-fibers
- cork
- paperboards
- strawboards
- hemp-lime
- papercrete
- straw bales/panels
- adobes/CEB
- rammed-earth
Input ----------> Production Processes -----------------> Output

raw materials:

Bulk materials (water addition)

Fibrous materials

Granules/flakes:

primary process:

Manual shaping/forming
casting/moulding
via compression or extrusion

shaping-deformation
via scouring-carding, etc
via breaking, scrunching, heckling, etc

Shaping:
via wet or dry forming

Secondary process:

Machining: cut

Heat treatment:
steam, pressure
Machining: cut
Surface treatment:
plate, paint

product
FACADE
DESIGN
Bernadette Maria School  Primary school / Public Building / Delft
Case study

Dimensions:
~3.5 X 7.3 m.

1: 243 m²
2: 986 m²
3: 68 m²
Case study

Details 1:10
existing

- horizontal battens, 22X75 mm
- rockwool insulation, 75mm
- breathable membrane
- steel HEA 120
- timber stud, 50X150
- aluminium profile

- HPL facade panel, glued
glue battens, 22X75 mm
- vertical battens, 22X50 mm

- plasterboards, 2X12.5 mm
- vapour barrier
- rockwool insulation, 2X75 mm
- steel hollow column, 80X80X5 m
- Rc wall: 3.5 m2 K/W

008.

- timber (kozijn) 90X114 mm
- Insulated glazing

009.

- Rc floor: 3.5 m2 K/W
- plasterboards, 2X12.5 mm
- vapour barrier
- rockwool insulation, 2X75 mm
- steel hollow column, 80X80X5 m
- MDF 8X45 mm

002.

- pavement
- aluminium wetslag

+0+P

- sand-cement floor finish
- foundation 300X450 mm
- reinforced concrete in situ
- insulated lightweight plank

1. aluminium roof cap
2. plywood, 15 mm
3. two layers bitumen APP
4. self-supporting prefabricated
5. roof structure: plywood, 15 mm
6. rockwool insulation, 200 mm
7. vapour barrier
8. plywood, 15 mm
9. sound absorbent ceiling panel
10. (Ecoplan master B, 40mm)
11. steel IPE 270
3D-exploded current facade
South-East Facade (Bernadette Mariaschool, Delft)

1. facade openings
   timber windows frames
   painted in white colour
   surface treatment:
   enameled with aluminium

2. Facade cladding:
   HPL facade panels, various sizes, glued

3. facade sub-structure:
   timber battens 22X75
   horizontal and vertical

4. thermal - acoustic Insulation
   Rockwool insulation
   (max: 150mm /min: 70mm)

5. main structure
   steel hollow columns: 80X80X5 mm
   steel beams HEA 120
   timber beams-columns: 150X50 mm
   plywood panels 15mm

6. internal wall finish
   plasterboards 12.5 mm X2
Design Proposals

Proposal A

1) clay plaster
   skim finish (5mm)
2) sealing tape
3) clayboards (25 mm)
4) vapour barrier
5) sheep-wool insul.(150mm)
6) breathable membrane
7) rammed-earth
   prefab.panels (125mm)
8) larger roof overhang
9) concrete base

Proposal B

1) Kraft Paper - wallpaper
2) strawboards (18 mm)
3) vapour barrier
4) flax insulation (150mm)
5) breathable membrane
6) render - compatible
   wood-fiber exterior insulation

Proposal C

1) cork facade (60/80 mm)
2) facade sub-structure
3) breathable membrane
4) strawboards (25mm)
5) compressed earth bricks
   (113 X115 X240 mm),
   adhesive mortar (10mm)
6) timber headers and studs
   (50 X 150 mm)

Design scope:

A | design precautions
B | comparison
01 | cost
02 | assembling
03 | maintenance
04 | environment
05 | performance
Proposal A

Elevation // scale 1:50

- enamelled with aluminium
- window timber frame
- prefab. rammed-earth (3 different colours)
- concrete footing
- natural stone window’s sill

Dimensions:
- 3633
- 890
- 850
- 800
- 750
- 650
- 570
- 478
- 428
- 3610
- 887
- 1250
- 1696
- 1250
- 350
- 7243
- 3632.73

Scale: 1:50
vapour barrier
Clayboards
25 x 625 1500
clay plaster
sheep-wool insulation roll
Construction - Assembly

breathable waterproof membrane
rammed-earth prefabricated panels
max. 1500x800 x 125
strawboards
18 x 1200 x 2400
Construction - Assembly

Kraft paper wallpaper
**Construction - Assembly**

**Flax battens insulation**
150 x 600 x 1200
breathable waterproof membrane
Construction - Assembly

Wood-fibers insulation
80 x 790 x 1200
Construction - Assembly

plaster + paint
strawboards
18 x 1200 x 2400
breathable waterproof membrane

CEB
115 x 113 x 240
sub-structure (22 x 75)
Cork facade boards
external insulation
100 x 500 x 1000
Construction - Assembly

Proposal A

Proposal B

Proposal C
Maintenance work

Proposal A
- linseed oil / lime-wash coating
  ~ 6-12 months

Proposal B
- refreshment of plaster / paint
  ~ 5-10 years

Proposal C
- replacement of damaged panels
  ~ 10-15 years
Wall thickness - Rc value

A
- d: 229 mm
- Rc: 3.94 m²k/W

B
- d: 355 mm
- Rc: 4.56 m²k/W

C
- d: 260 mm
- Rc: 6.54 m²k/W

D
- d: 295 mm
- Rc: 3.93 m²k/W
**B detail**

- **timber window frame (90X114)**
  - with insulating glazing, enameled with aluminum coating and painted in white colour

- **timber beam, 50X150**
- **aluminum windows sill**
- **strawboards (18mm) Ecoboards, coated with Kraft paper vapour barrier**
- **flax insulation (150mm) breathable membrane**

- **render-compatible wood-fibers external insulation**
  - Pavatex Diffutherm, 90mm

- **self-supporting strawboards, Ecoboards (18mm)**
  - coated with thick Kraft paper vapour barrier
  - flax insulation, Isowool (150mm) breathable membrane

- **render-compatible wood-fibers external insulation**
  - Pavatex Diffutherm, 90mm

- **plastic fixing anchors**

**fixing used for wood-fibers to the timber frame**

**horizontal section-B2 detail**

- **timber window frame enameled with aluminium painted in white colour with insulating glazing**
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Calculations_ Input Data</th>
</tr>
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</table>

### General

<table>
<thead>
<tr>
<th>Density</th>
<th>Width</th>
<th>Length</th>
<th>Thickness</th>
<th>Items</th>
<th>Volume (m3)</th>
<th>Weight (kg)</th>
<th>Price F (€)</th>
<th>Price E/kg</th>
<th>Price F (€/m3)</th>
<th>TOTAL COST</th>
<th>X(€/m²)</th>
<th>Rc (m²)</th>
<th>Ms</th>
<th>M</th>
<th>TOTAL embed CO₂/kg CO₂/kg/m²</th>
<th>TOTAL CO₂</th>
</tr>
</thead>
</table>

### Specific Dimensions

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
</table>

### Primary cost

- **Steel structure A (BFM)**
  - 7800 kg
  - Price: 4.7500 €
  - Cost: 135.94 €
  - Total: 450.60 €

### Thermal properties

- **Thermal insulation**
  - **Steel structure A (BFM)**
  - 7800 kg
  - Price: 4.7500 €
  - Cost: 135.94 €
  - Total: 450.60 €

### Environmental parameters: embodied energy + CO₂ footprint

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
</table>
Proposals A, B, C: significant mass compared with current facade relatively similar cost (except proposal C)
Environmental figures

Embodied energy per each facade
Total (GJ) and per unit of mass (MJ/kg)

- Current: 111 GJ, 143.4 MJ/Kg
- Case A: 187 GJ, 42.36 MJ/Kg
- Case B: 71 GJ, 63.41 MJ/Kg
- Case C: 127 GJ, 43.27 MJ/Kg

CO2 emissions per each facade
Total and per unit of mass (1 kg Co2 per 1kg)

- Current: 973 kg, 7.77 kg/Kg
- Case A: 1025 kg, 5.18 kg/Kg
- Case B: 276 kg, 3.48 kg/Kg
- Case C: 662 kg, 3.21 kg/Kg

Proposal B: lower embodied energy (ca. half from others)
lower CO2 emissions (ca. 1/3 of Case study and case A, 1/2 of case B)
### Calculations & Conclusion

**Proposal B:**
- lower maintenance
- best Rc (smaller thickness)
- lower embodied energy (ca. half from others)
- lower CO2 emissions (ca. 1/3 of Case study and case A, 1/2 of case B)

<table>
<thead>
<tr>
<th></th>
<th>case A</th>
<th>case B</th>
<th>case C</th>
<th>CaseStudy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>€</strong></td>
<td>1.852,05</td>
<td><strong>1.935,53</strong></td>
<td>2.397,54</td>
<td><strong>1.624,62</strong></td>
</tr>
<tr>
<td>craftsmanship level:</td>
<td>++ medium</td>
<td><strong>+ standard</strong></td>
<td>+++ high</td>
<td>+ standard</td>
</tr>
<tr>
<td>maintenance frequency:</td>
<td>+++ 6-12 months</td>
<td>+/- <strong>5-10+ years</strong></td>
<td>- 10-15+ years</td>
<td>- 10-15 years</td>
</tr>
<tr>
<td>maintenance work:</td>
<td>limewash coating</td>
<td>refreshment plaster/paint</td>
<td>replacement damaged facade cladding</td>
<td>replacement damaged facade cladding</td>
</tr>
<tr>
<td>possible damaging:</td>
<td>erosion, mechanical damage</td>
<td>peeling off, mechanical damage</td>
<td>erosion, mech damage, colour fading (UVradiation)</td>
<td>mechanical damage, colour fading (UVradiation)</td>
</tr>
<tr>
<td>thermal resistance Rc:</td>
<td>4.56 m²K/W</td>
<td><strong>6.54 m²K/W</strong></td>
<td>3.93 m²K/W</td>
<td><strong>3.94 m²K/W</strong></td>
</tr>
<tr>
<td>sound reduction:</td>
<td><strong>xx no indication/ assumed similar</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fire resistance:</td>
<td><strong>xx no indication/ assumed similar</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>total mass:</td>
<td>4353 kg</td>
<td><strong>1126 kg</strong></td>
<td>2932 kg</td>
<td><strong>771 kg</strong></td>
</tr>
<tr>
<td>total embodied energy</td>
<td>187 GJ</td>
<td><strong>71 GJ</strong></td>
<td>127 GJ</td>
<td><strong>111 GJ</strong></td>
</tr>
<tr>
<td>total CO2 footprint</td>
<td>1025 kg</td>
<td><strong>276 kg</strong></td>
<td>662 kg</td>
<td>972,40 kg</td>
</tr>
</tbody>
</table>
SUGGESTIONS

CONCLUSION
01 I which biodegradable materials & products are already available in the market?
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02 Which are the parameters that affect the performance of these materials?
Various factors affect differently the materials. A parameter can affect negatively one property of the material while at the same time improve one other.

01 Which biodegradable materials & products are already available in the market?

02 Which are the parameters that affect the performance of these materials?
01 Which biodegradable materials & products are already available in the market?

02 Which are the parameters that affect the performance of these materials?

03 Which properties and characteristics do biodegradable materials present? how do they perform?
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02 I Which are the parameters that affect the performance of these materials?

03 I Which properties and characteristics do biodegradable materials present? how do they perform?

Properties tables present all those characteristics that can inform about the performance characteristics of those materials.
01 I which biodegradable materials & products are already available in the market?

02 I Which are the parameters that affect the performance of these materials?

03 I Which properties and characteristics do biodegradable materials present? how do they perform?

04 I which production processes & techniques are involved in the production of biodegradable products?
01 Which biodegradable materials & products are already available in the market?

02 Which are the parameters that affect the performance of these materials?

03 Which properties and characteristics do biodegradable materials present? how do they perform?

04 Which production processes & techniques are involved in the production of biodegradable products?

Most important ones:
01 shaping via casting and moulding
02 forming via fiber processing
03 wet or dry process. (heat and pressure treatment)
01 Which biodegradable materials & products are already available in the market?

02 Which are the parameters that affect the performance of these materials?

03 Which properties and characteristics do biodegradable materials present? How do they perform?

04 Which production processes & techniques are involved in the production of biodegradable products?

05 How can manufacture availability influence the design of such products?
The available production technology and processes influence significantly the products types resulted of the materials.

01 Which biodegradable materials & products are already available in the market?

02 Which are the parameters that affect the performance of these materials?

03 Which properties and characteristics do biodegradable materials present? how do they perform?

04 Which production processes & techniques are involved in the production of biodegradable products?

05 How can manufacture availability influence the design of such products?
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02 Which are the parameters that affect the performance of these materials?

03 Which properties and characteristics do biodegradable materials present? How do they perform?

04 Which production processes & techniques are involved in the production of biodegradable products?

05 How can manufacture availability influence the design of such products?

06 Can be prefabricated? What kind of production technology & processes are needed to result in biodegradable building products of low embodied energy and cost?
01 I Which biodegradable materials & products are already available in the market?

02 I Which are the parameters that affect the performance of these materials?

03 I Which properties and characteristics do biodegradable materials present? How do they perform?

04 I Which production processes & techniques are involved in the production of biodegradable products?

05 I How can manufacture availability influence the design of such products?

06 I Can be prefabricated? What kind of production technology & processes are needed to result in biodegradable building products of low embodied energy and cost?

Yes they can be, but this sub-question was not much examined. It needs further research.
Problems encountered during research:
- Numerical values of properties  
  \textit{(Varying in a great extent)}
- Accuracy of companies info  
  \textit{(e.g. materials content)}
- real cost estimation
- Embodied energy (definition-estimation)

Standard Design Precautions:
Protection from:
- splashing water/ rainwater /water
- any source of high moisture

Prevent / avoid:
- moisture build-up in the construction
- contact with ground

Let:
- materials to breathe
- to dry via air-cavities (when necessary)
Numerous possible combinations can be made between the different categories of biodegradable materials in order to construct an outer, intermediate and inner leaf on a building envelope that with a relatively small wall thickness can present good performance characteristics.

Possible Research topics:
01/ technology processes-products
02/ implementation on special cases
03/ similar methodology for other group of materials
04/ prefabrication on-site
thank you!