Natural Fibres and the Environment –

environmental benefits of
natural fibre production and use

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Bio-based economy

....the solution for sustainable developments

...?...
Natural fibres

...the solution for environmental improvement ...?
Natural fibres

• Vegetable fibres (cellulose)
  – Seed hairs: Cotton, Kapok
  – Bast fibres: Jute, Kenaf, Flax, Hemp, Ramie
  – Leaf fibres: Sisal, Henequen
  – Leaf sheath: Abaca, banana
  – Fruit fibres: Coir

• Animal fibres (protein)
  – Wool: Sheep, Camel, Goat, Llama
  – Silk: Silkworm
Various Crops and Regions

- Cotton
- Flax
- Sisal
- Coconut
- Hemp
- Ramie
- Jute
- Silk
- Wool
- Kenaf
- Abaca
- Henequen
Natural fibres?

- **Mineral fibres**
  - Asbestos
  - Stone wool
  - Glass fibre

- **Man made fibres**
  - Viscose / rayon or regenerated cellulose
  - Regenerated protein fibre (soybean, casein)
  - Polymer fibre (polyester)
  - Chitosan (from chitin)
Natural fibres ...?

- Dietary fibres
- Food supplements (prebiotics) and health products
Natural fibres end use

- Textiles, yarns and woven fabrics
- Ropes, twines, cordage, nets
- Non-woven fabrics, tissues
- Composites
- Paper and board
- Fibre boards and insulation
- Bio-ethanol
- Mulch and compost
Value addition in fibre conversion

Production costs

3000 € / Mg

Agricultural production

Fibre production

Market

Textile fibre

Conversion steps

Production costs

2000

1000

Fibre crops

Cellulose

Non-woven

Pulp

Conversion steps

Energy crops

Geotextiles

Fourage

Animal Bedding

Energy

Conversion steps

Agro residues

Compost

Conversion steps

Waste biomass

Conversion steps

Added value

Valuennadditionninnfibrenconversion
Hemp / flax fibre quality chain

consumer

marketing & design

weaving

spinning

primary processing

agricultural production
Natural fibres production chain

Agricultural production

Fibre Extraction Process

Textile fibre processing

Textile manufacturing

Non-textile fibre processing

Paper / composites / nonwoven manufacturing

Consumer use

Disposal
Natural fibres production steps A

A - Agricultural Production
- sowing
- weeding, thinning
- harvesting
- drying / defoliation

B
- seeds
- leaves
- dust

CO₂

seeds
water/irrigation
fertiliser
pesticides
energy
Mechanized harvesting of hemp
Natural fibres production steps

B - Fibre extraction process
- retting / degumming
- fibre extraction / decortication / scutching
- fibre cleaning / washing
- drying

C1
- shives
- short fibre tow
- waste water

C2

A

energy
water

transport
storage
Dew retting of flax
Retting of coir
Natural fibres production steps C1

C1 - Fibre processing
- softening / lubricating
- hackling / carding / drawing
- spinning
- weaving
- finishing / dyeing / bleaching

C2
- shives
- short fibre tow
- waste water

D1
- transport
- storage

lubricants
energy
water
bleaching
chemicals
dyes
Processing of Coir

- Hand spinning of coir yarn
Wet processing of Coir

- Cold peroxide bleaching of coir
Wet processing of Coir

- Traditional coir dyeing in wood heated tubs.
Eco-friendly bleaching and dyeing of coir
Natural fibres production steps C2

- Shives
- Short fibre tow
- Waste water

C2 - Fibre processing
- Pulping/
- Compounding /
- Web formation/
- Blending

D2
- Black liquor
- Chemicals
- Waste water

C1
- Transport
- Storage
## Non-wood pulping

<table>
<thead>
<tr>
<th>Country</th>
<th>Capacity (Million tons)</th>
<th>% of total</th>
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<tbody>
<tr>
<td>China</td>
<td>15.2</td>
<td>71%</td>
</tr>
<tr>
<td>India</td>
<td>2.0</td>
<td>9%</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.3</td>
<td>1%</td>
</tr>
<tr>
<td>Peru</td>
<td>0.3</td>
<td>1%</td>
</tr>
<tr>
<td>Philippines</td>
<td>0.3</td>
<td>1%</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0.3</td>
<td>1%</td>
</tr>
<tr>
<td>USA</td>
<td>0.2</td>
<td>1%</td>
</tr>
<tr>
<td>Thailand</td>
<td>0.2</td>
<td>1%</td>
</tr>
<tr>
<td>Colombia</td>
<td>0.2</td>
<td>1%</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.2</td>
<td>1%</td>
</tr>
<tr>
<td><strong>10- Country Total</strong></td>
<td><strong>19.2</strong></td>
<td><strong>90%</strong></td>
</tr>
<tr>
<td><strong>Total World</strong></td>
<td><strong>21.3</strong></td>
<td><strong>100% (&lt; 7% total pulp)</strong></td>
</tr>
</tbody>
</table>
Non-wood pulp fibres

- Cotton linter
- Abaca
- Flax
- Hemp
- Kenaf
- Straw
- Sugar cane bagasse
- Bamboo

Banknote and security paper
Tea bags, filters
Sausage casing
Cigarette paper
Electrolyte condensor paper
Paper board / wrapping paper
Natural fibres production steps D-F

**D1 - End-product manufacturing**
- yarns
- apparel fabrics
- household textiles
- furnishings and wall covering
- upholstery
- sacking

**D2 - End-product manufacturing**
- paper & board
- non-woven packaging
- fibre boards and panels
- insulation
- horticultural products
- geotextiles
- composites

**E - Consumer use**

**F - Disposal**

Energy
Recycling raw materials
Transport
Storage
Life cycle assessment framework

Goal and scope definition
Inventory analysis
Impact assessment

Interpretation

Product Development and improvement
Strategic Planning
Public Policy making
Marketing
Other
Quantitative environmental impact LCA

- Criteria .. Standards ISO-14040-43
  - Whole life cycle of a product including its by-products
  - Raw material acquisition to product disposal
- Comparison between diverse environmental impact factors
  - Emissions and consumption of resources
- Eco-indicators – weighing / classification factors
- Interpretation
Weighing factors (Eco-indicator)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Cause</th>
<th>Value</th>
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<tbody>
<tr>
<td>Green house effect</td>
<td>CO$_2$</td>
<td>2.5</td>
</tr>
<tr>
<td>Ozone layer depletion</td>
<td>CFK</td>
<td>100</td>
</tr>
<tr>
<td>Acidification</td>
<td>(Sulfur)</td>
<td>10</td>
</tr>
<tr>
<td>Eutrophication</td>
<td>(Phosphate)</td>
<td>5</td>
</tr>
<tr>
<td>Smog</td>
<td>(Methane)</td>
<td>2.5-5</td>
</tr>
<tr>
<td>Pesticides</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>Heavy metals</td>
<td>(Lead)</td>
<td>5</td>
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</tbody>
</table>
World fibre production 1920-2006 (kton)

- Cotton
- Synthetic (petro-based)
- Man-made cellulose fibres *

Year:
- 1915
- 1925
- 1935
- 1945
- 1955
- 1965
- 1975
- 1985
- 1995
- 2005

Production:
- 0
- 5,000
- 10,000
- 15,000
- 20,000
- 25,000
- 30,000
- 35,000
- 40,000
Cotton vs polyester LCA

• Cotton requires less fossil resources (energy, fertilizer), but higher demand for water
  – Organic cotton (agrochemicals) vs GMO

No dramatic differences in
• Textile processing (dyeing and bleaching)
• Longer functional lifetime for blended fabrics
• Lower energy requirement in laundering for synthetic textiles
Agrofibre reinforced composites

- Agrofibre compounds for injection moulding implementation at commercial scale
- Strength of the elementary fibre is important not that of the fibre bundle

Injection moulded products from natural- fibre/plastic granules
Technology for natural fibre reinforced plastics

Raw materials → agrofibre PP → Extrusion → Granules → Injection moulding

PP
Fibre composites in automotive

- Applied as nonwoven mats combined with plastic sheets
- LCA advantage in weight reduction
Use of natural fibres in automotives

Use of Natural Fibres for Automotive Composites in Germany & Austria 1996-2002*  
Naturfasereinsatzes für Verbundwerkstoffe im Automobil in D & A 1996-2002* 

<table>
<thead>
<tr>
<th>Year</th>
<th>Flax/Flachs</th>
<th>Exotic (Jute etc.)</th>
<th>Hemp/Hanf</th>
<th>Total/Gesamt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>2,000</td>
<td>2,000</td>
<td>0</td>
<td>4,000</td>
</tr>
<tr>
<td>1999</td>
<td>7,000</td>
<td>2,300</td>
<td>300</td>
<td>9,600</td>
</tr>
<tr>
<td>2000</td>
<td>9,000</td>
<td>2,000</td>
<td>1,200</td>
<td>12,200</td>
</tr>
<tr>
<td>2001</td>
<td>8,500</td>
<td>5,000</td>
<td>1,600</td>
<td>15,100</td>
</tr>
<tr>
<td>2002*</td>
<td>9,000</td>
<td>6,000</td>
<td>2,200</td>
<td>17,200</td>
</tr>
</tbody>
</table>

*Forecast/Prognose

 nova-Institut 2002
Natural fibres vs synthetic / glass fibre

- In the production phase the score of fibre crops on CO$_2$ and greenhouse gas emission levels, fossil energy consumption and resources is much better.

- In composites, blended textiles or non-wovens the impact of synthetic resins on the LCA is large.
Natural fibres vs synthetic / glass fibre

• The utilisation phase contributes most to the impact

• Weight reduction in composites in automotive applications contributes to fuel savings

• For the same mechanical performance heavier constructive elements with natural fibre is required
Cradle to Cradle (C2C)

- W. McDonough M. Braungart
  - Remaking the way we make things
- Eco-efficient / effective design of products
- Reuse of waste to make new products
  - Waste becomes food.. Ever lasting cycles
- Ford / NIKE / …many companies follow
Bio-based economy and $C2C$

- Green Architecture and building
- Automotive industries … sustainable commerce
- Nutrient Upcyling, Triple-Top-Line, Eco-effectiveness, Industrial design,
- Technical and biological nutrients for everlasting consumption. (?)
Ecological footprint

Land area required per person to maintain his lifestyle (incl. food, energy, water, housing, clothing, travel, etc.)
Bio-based economy and Sustainable developments

• **KYOTO** and CO$_2$ neutral production

• Transition process

• Renewable resources for **energy** and **products**

• Exploitation of biomass from agro-industrial residues

• Value addition in materials, and ‘green’ chemicals
Competing claims for biomass resources

Sustainable production
  food supply security
  land use
  deforestation
  rural development

Rapid expansion of demand for energy purposes

DEVELOPMENT OF BIOREFINERY
R&D activities & sustainable development

- renewable energy from biomass residues
- building materials, recycling
- ‘green’ chemicals & polymeric products
- alternative technologies and sources for cellulose textile production (bamboo)
- horticultural substrates & biodegradable erosion control materials

and many other
Renewable raw materials

- Agroresidues of food and non-food crops
  - cotton stalks
  - rice straw / hull
  - sugar cane bagasse
  - corn cobs
  - coconut husk
  - jute sticks
  - palm oil residues
  - eucalypt bark
  - verge grasses, etc
Obvious surplus EFB
Options for sustainable residue utilisation

Bio-diesel (residual oil / pressing cakes)
Bio-gas, H₂ / ABE and ethanol fermentation
Bio-polymers (PLA, PHA)
Bio-oil pyrolysis / Charcoal
Fibres for paper, building boards and composites
Dissolving cellulose
“green” chemicals (lignin and furfural adhesives)
Biorefinery (cascading) of biomass

Biomass
- Extraction
  - Extraction
  - Residue
    - Drying
    - Chopping
    - Pelletising
  - Refining
  - Fuel
    - Gassify
    - Combustion
  - Disposal
    - Composting
    - Waste Compost

Extract
- Precipitation
  - Sugars
    - Protein, Lipids
      - Modification
        - Coatings
        - Biopolymers

Alcohol / H₂
- Paper / Board Adhesives
- Feed
- Energy
Coconut biorefinery C2C example
Biomass from agro-industrial residues

World production capacity coconut husk
15-20 million tons / year
Husk preparation (CFC/FAO project)

Coconut → Opening → Coconut husk → Milling
Building and construction materials

Binderless boards

husk
skin
shell
copra
First production line
Batangas Phillipines

- Multi daylight press
  15 tons/d capacity

Market: Japan
Heavy duty packaging
(pallets wood substitute)
Economical evaluation

- **Production:**
  - 10,000 tonnes board/year
  - 400,000 boards 4 ft*8 ft* 0.25 inch
    * 1,333 boards/day

- **Raw material**
  - 77,650,000 husks/year
    * 260,000 husks/day

- **Investment estimate**
  - 650,000 US$
• **Capital investment plan**
  – Production scale 10,000 tonnes board/year
  – Location / site

• **Marketing plans**
  – Eco-labeling (FSC) / Fair trade / quality certification
  – CDM / carbon credits

• **Social development plans**
  – Education plan
  – NGO involvement

• **Product development plan**
Business roll out plan

- **Demonstration industrial production**
  - Production units 10,000 tonnes board/year
  - Integrated whole nut utilisation (oil, press cake, shell, husk)
  - N. Sulawesi, Indonesia / Mindanao, Philippines
  - Franchising (?)

- **Common marketing strategy**
  - Trade mark / brand retail
  - Niche products (packaging / furniture) value addition

- **Social development strategy**
  - Village level involvement (housing / labour / schooling..)
Non-technical aspects of implementation plans

Financing structures and commercial developments

Clean development mechanism (CDM) and carbon trading

Common sales, common market, fair trade / ecolabeling

Socio-economic aspects – food vs fuel (biodiesel)

Political implications
Sustainability criteria

- Ecological: Wood substitute products to prevent deforestation
- Carbon credits / CDM
- Socio-economic – labour, income and housing
- Addressing poverty by supporting the incomes and livelihoods of commodity producers
- Fair trade and quality certification
• The Project seems more than feasible

• Prospects to apply for external funding are very good

• This kind of project is exactly what is needed as a pilot/example for other regions and countries
Conclusions fibres and the environment

Ecological impact assessments are complex and use incomparable weighing factors.

The impact of primary agricultural production of fibre crops on the LCA is marginal.

Restricted information available from industrial fibre production chains.
Conclusions fibres and the environment

The environment has become a major driver for industries and governments.

Natural fibres are a major renewable (CO$_2$ neutral) resource for bio-based economical developments.

Overall ecological performance of a crop improves when residues and by-products are better used.
Conclusions fibres and the environment

**Certification** of the sustainability of the fibre production chains for biomass energy and products is needed

Multi-stakeholder involvement needed:

Include outsider (food vs non-food) industries involved in energy and fibre products

*Now is the moment for active participation!*
There is no *waste*
when it’s bio-based