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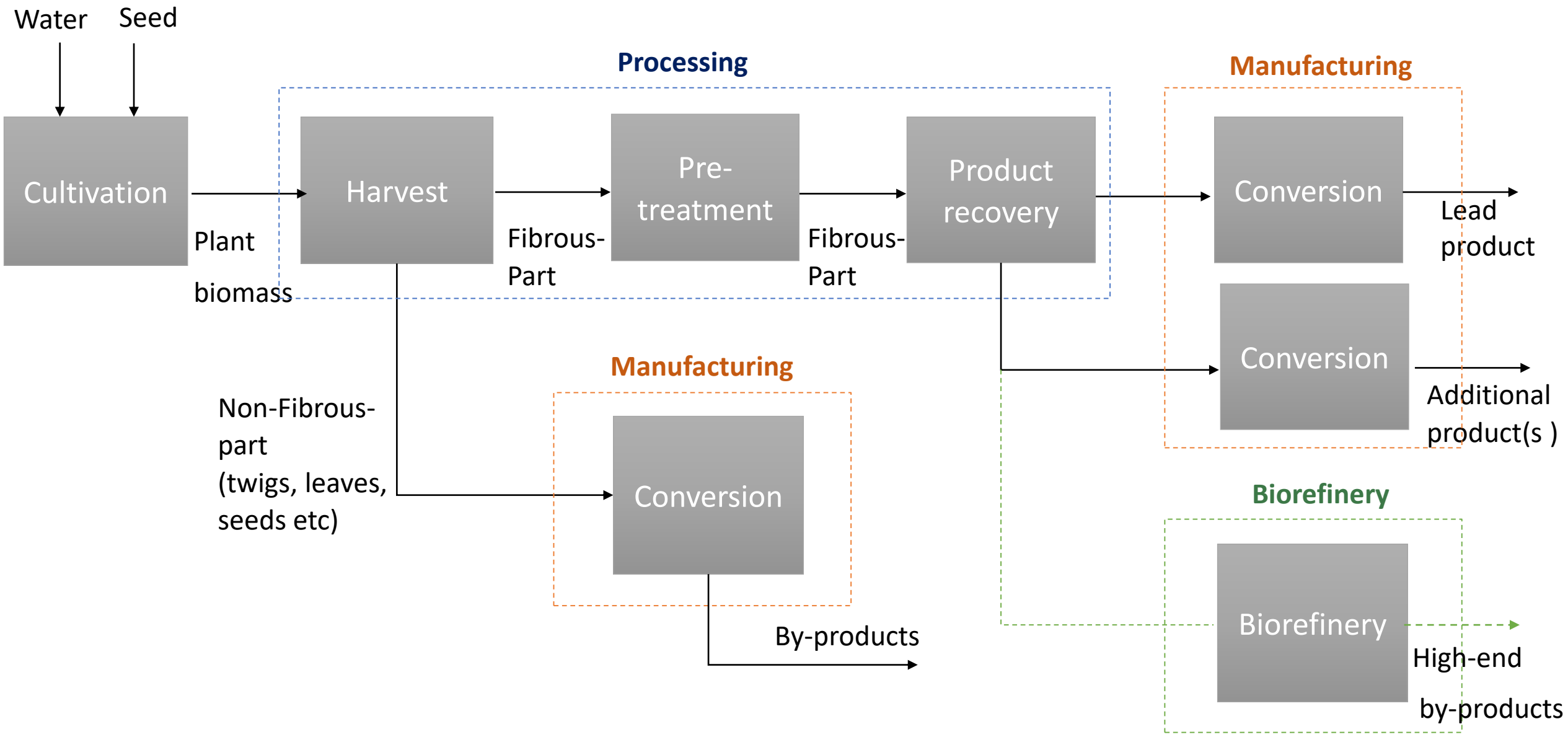
Identification and review of downstream options for the recovery of value from fibre-producing plants: Hemp, Kenaf, Bamboo




Production stages



Bast fibre plants

Hemp

Kenaf

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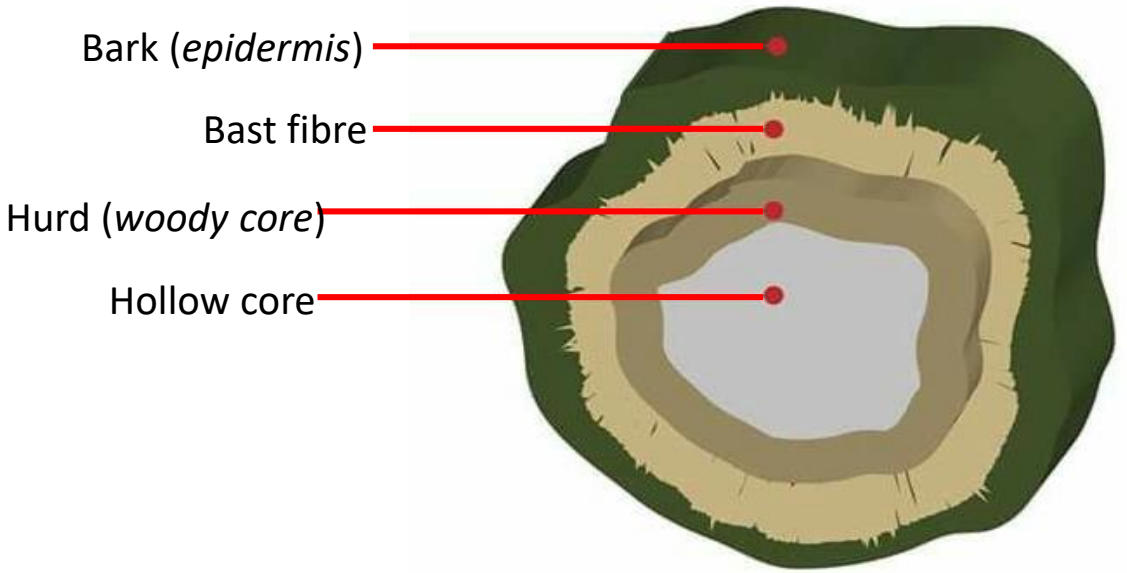
Bast fibre plants

- The “bast” produces long fibres (70-90% of the bast) and short fibres (10-30% of the bast).
- The hurd or woody core is the inner woody tissue which accounts for about 60-75% of the stem.
- Different bast plants have a different ratio of bast to woody core - Kenaf bast fibre is about 35% of the stem and hemp bast fibre is about 30%.



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Bast plant products

Bast fibre plant e.g. hemp

- Whole plant
  - Energy (e.g. bioethanol, biogas)
- or
- Stem
  - Bast Fibre
    - Long fibre
      - Conventional textiles
      - Bioplastics
      - Biocomposite textiles/ concrete
    - Short fibre
      - Cordage
      - Paper pulp
  - &
  - Woody tissue/core fibre
    - Construction composites
    - Insulation boards
    - Paper pulp
    - Bioethanol/biobutanol
    - Shives (animal bedding etc)
- &
- Seeds
  - Chemical extracts
    - Oil
      - Edible oil (e.g. hemp seed oil)
      - Personal products
      - Paint/varnish
    - &
    - Protein
      - Animal Fodder
  - or
  - Whole seed
    - Food
- &
- Leaves
  - Human food
  - Medicine

Part of plant | Intermediates | End-products

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Conventional textiles

- Hemp and kenaf fabrics are breathable, warm, moisture-wicking, antibacterial and biodegradable.
- Bast fibres can be easily blended with other fibres such as cotton to make lightweight softer fabrics.

Hemp fabric

Blended fabrics

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Plant fibre reinforced composites

- Fibre composites are made by embedding plant fibres in synthetic or biodegradable resins.
- PFRCs are being incorporated into thermoplastic matrix composites and are gaining traction in the automotive and aerospace industries.

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Construction materials

- Hemp and kenaf construction products range from insulating panels, non-woven felts for acoustic damping or levelling from woody tissue/hurds to fibre reinforced polymers for façade panels and concrete.
- The most commonly applied product in the building and construction sector is hempcrete.

Insulation matting

Fibre boards

Concrete (hempcrete)

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Paper products

- Paper pulp can be made either from short bast fibre or woody tissue.
- Paper made from kenaf bast fibre is reported to be comparable to paper from some softwoods and most hardwoods
- Paper from core fibre or woody tissue (hurd) is not as strong, but is easier to manufacture as well as softer, adsorbent and more suitable for hygienic products.

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Seed oils

- Hemp and kenaf seeds can either be used as a whole or crushed and pressed to produce oil and a residual seed cake.
- Hemp seeds contain 30% oil by weight, whereas kenaf seeds contain 20% oil.
- The residual seed cake has been proven to be a protein-rich feed for livestock.

Hemp seed oil

Kenaf seed oil

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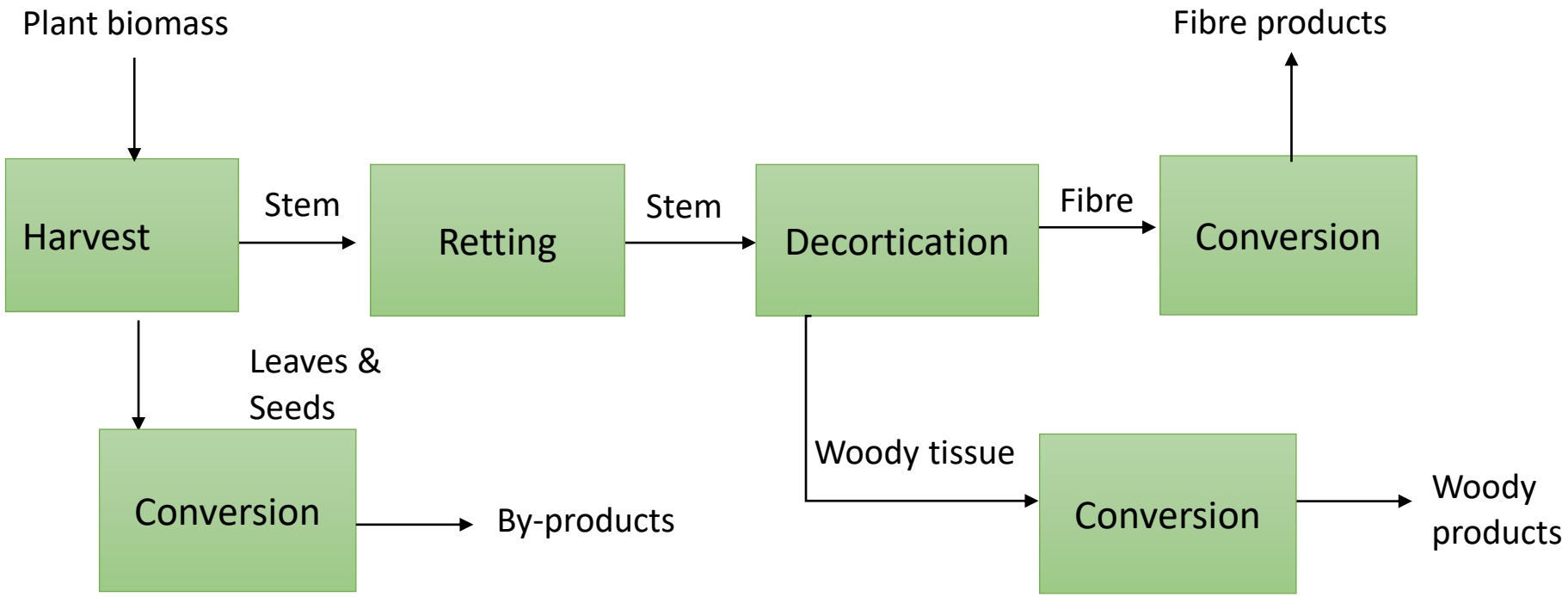
Bast fibre processing

- Stems are pre-treated to soften them through retting or degumming, which can be chemical, mechanical or high-pressure/temperature processes.
- Bast fibre is separated from woody tissue, into long & short fibre through a process known as decortication.



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Bast fibre processing

- Different retting pre-treatments result in different fibre length, colour, quality and strength. Water or dew retting are commonly used.

- Bast fibre processing is fairly standard via decortication – though there are slight variations depending on desired end-products (high-end vs low-end products).

- Various products can be produced at different stages of processing to potentially form a multi-product flow sheet.

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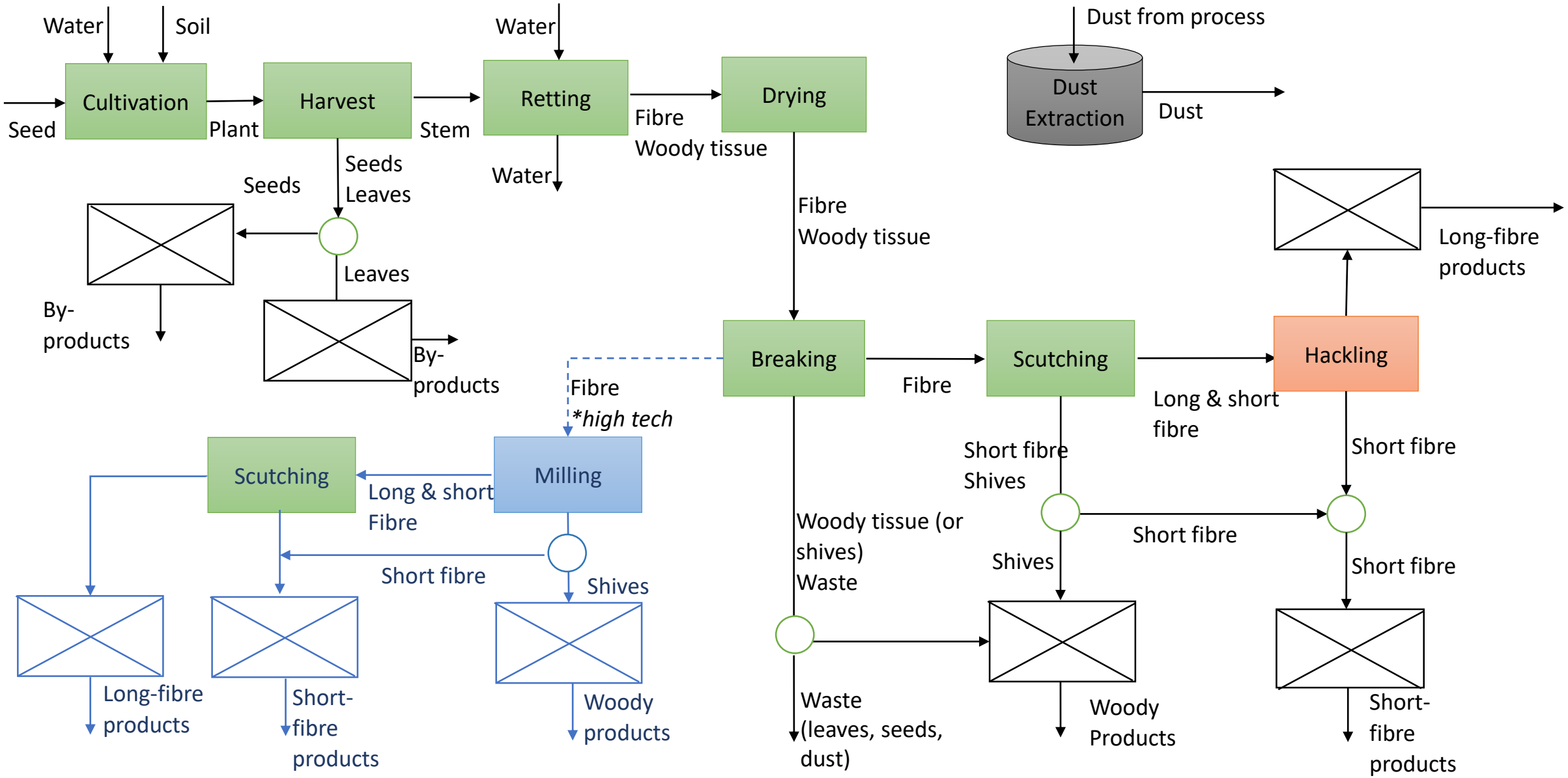
Bast fibre multi-product process flow sheet



Bamboo

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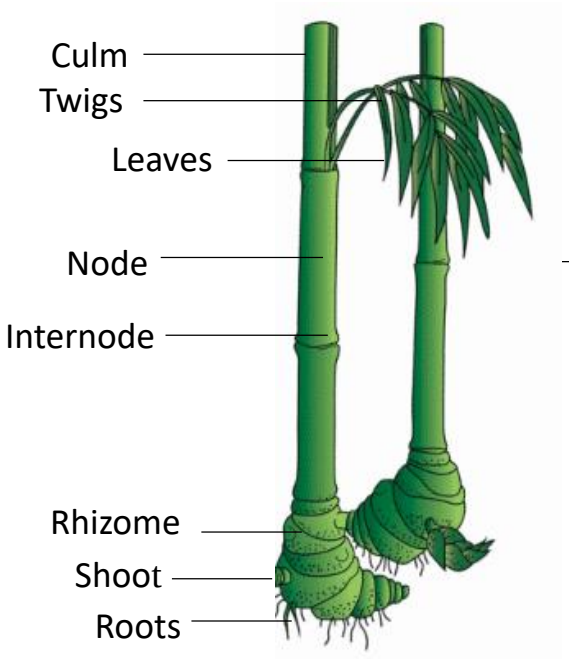
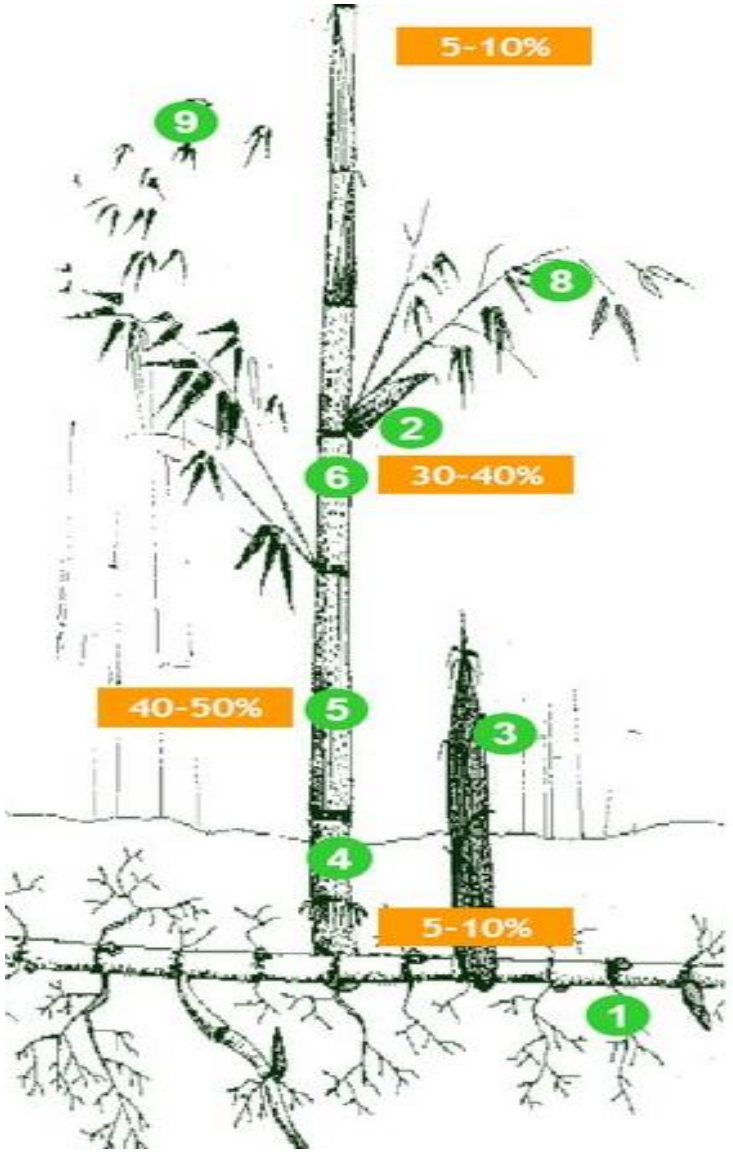
Bamboo products



- Whole plant → Energy; biofuels
- Whole plant → Paper & cardboard
- Culm (or / & / and/or) → Pulp → Rayon fibres → Textiles
- Culm → Natural fibres → Textiles
- Culm → Natural fibres → Polymer composites
- Culm → Strips → Woven products → Handicrafts
- Culm → Strips → Woven products → Furniture/decor
- Culm → Poles → Engineered "wood-based" composites → Flooring
- Culm → Poles → Engineered "wood-based" composites → Sporting equipment
- Culm → Poles → Engineered "wood-based" composites → Construction materials
- Branches & → Sticks → Mats, blinds, chopsticks
- Leaves & → Whole leaves or → Fodder (Manure)
- Leaves & → Chemical extracts → Medicine
- Shoots → Food

Part of plant | Raw products | Intermediate products | End-products

Uses of the parts of a bamboo plant



9	Leaves	Manure, Fodder
		Extracts, Medicine
8	Twigs	Brooms, Cloths
7	Top	Chopsticks, Toothpicks
		Bamboo poles
		Scaffoldings
6	Middle upper	Blinds, Mats, Carpet
		Chopsticks, Toothpicks
		Handicrafts
5	Middle lower	Flooring
		Laminated furniture
4	Base	Charcoal, Pulp
3	Shoots	Vegetable
2	Sheath & Rhizome	Handicrafts
1		
	Leftovers & processing waste	Fiber boards
		Charcoal
		Pulp
		Lumber
		Fuels

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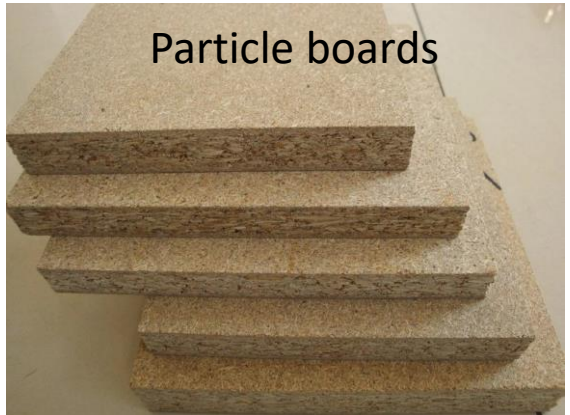
Wood-based products

- Bamboo has many applications in the construction and building industries due to its woody nature and similar properties to timber.
- The culm is either used whole as poles or split into strips to make woven products or engineered bamboo wood-composites.



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Fibre-based products - textiles

- There are two types of bamboo textiles – bamboo linen (also called “natural bamboo fibre”) extracted by mechanical or microbial processes.
- Bamboo rayon made through chemical treatments similar to the manufacturing of rayon viscose.

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Fibre reinforced composites

- Similar to bast fibre composites, bamboo fibres can be used to reinforce natural or synthetic polymer matrices.
- Bamboo-fibre reinforced plastic (BFRP) composites' tensile strength is comparative to mild steel and have a lower density, making them ideal for structural applications.

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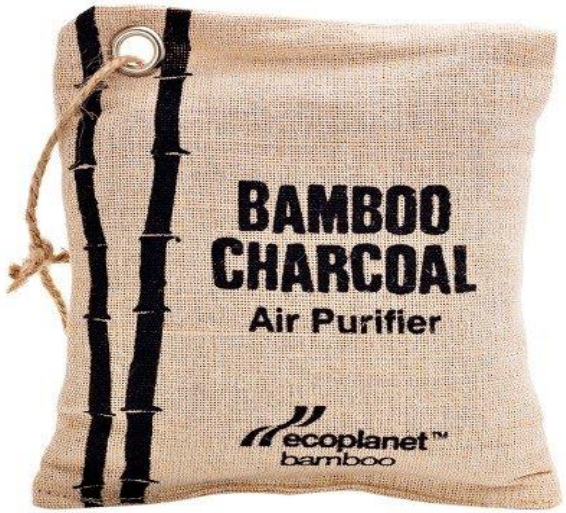
Energy based products

- Bamboo has a number of desirable characteristics as a fuel for combustion, such as a low ash content and alkali index compared to other bioenergy feedstocks.
- Bamboo culm can be processed into pellet form or other forms of fuels, such as biogas, bioethanol and charcoal.



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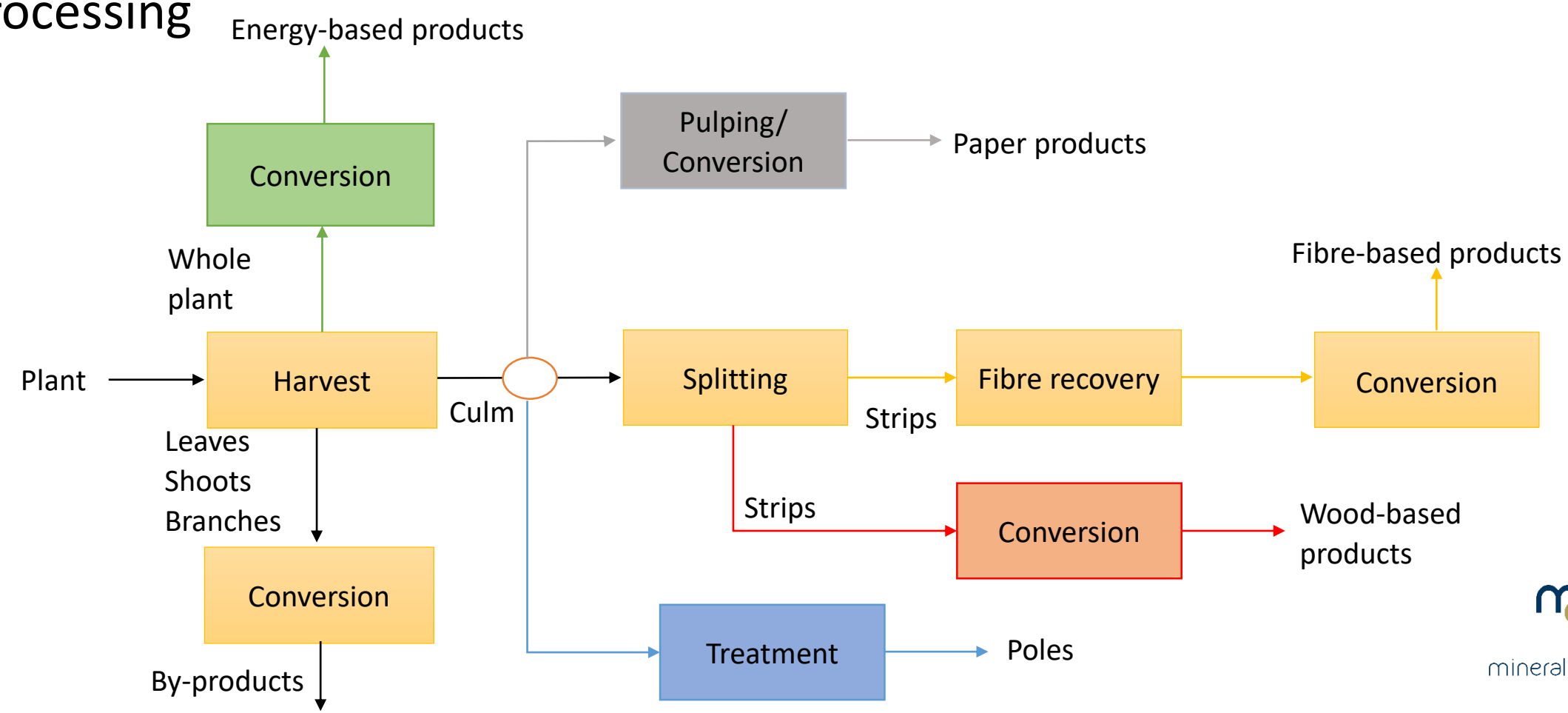
Bamboo processing

- Each product type requires a separate treatment or processes.
- Bamboo processing is more intensive and extensive than bast fibre processing



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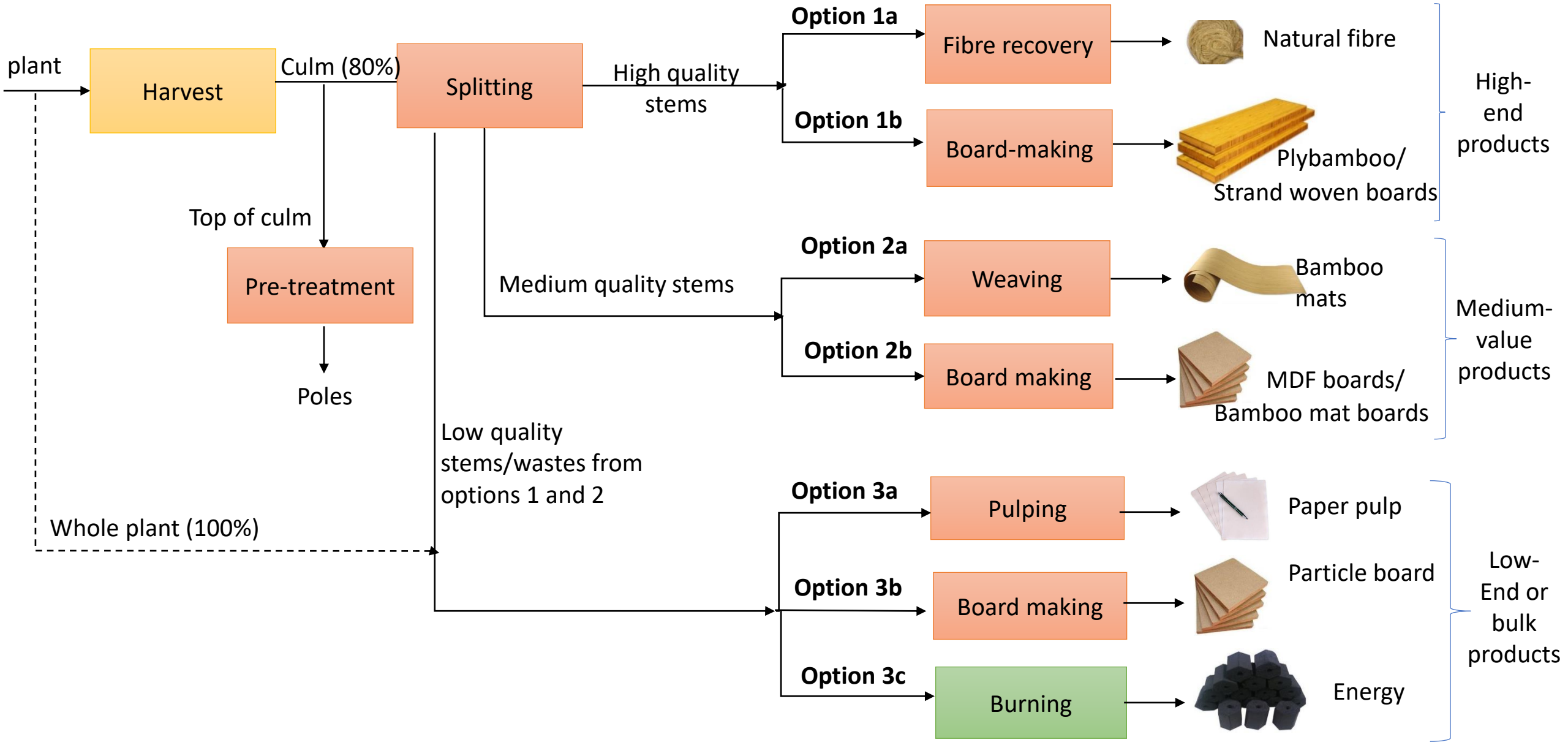
Bamboo multi-product flowsheet scenarios



Potential metal recovery

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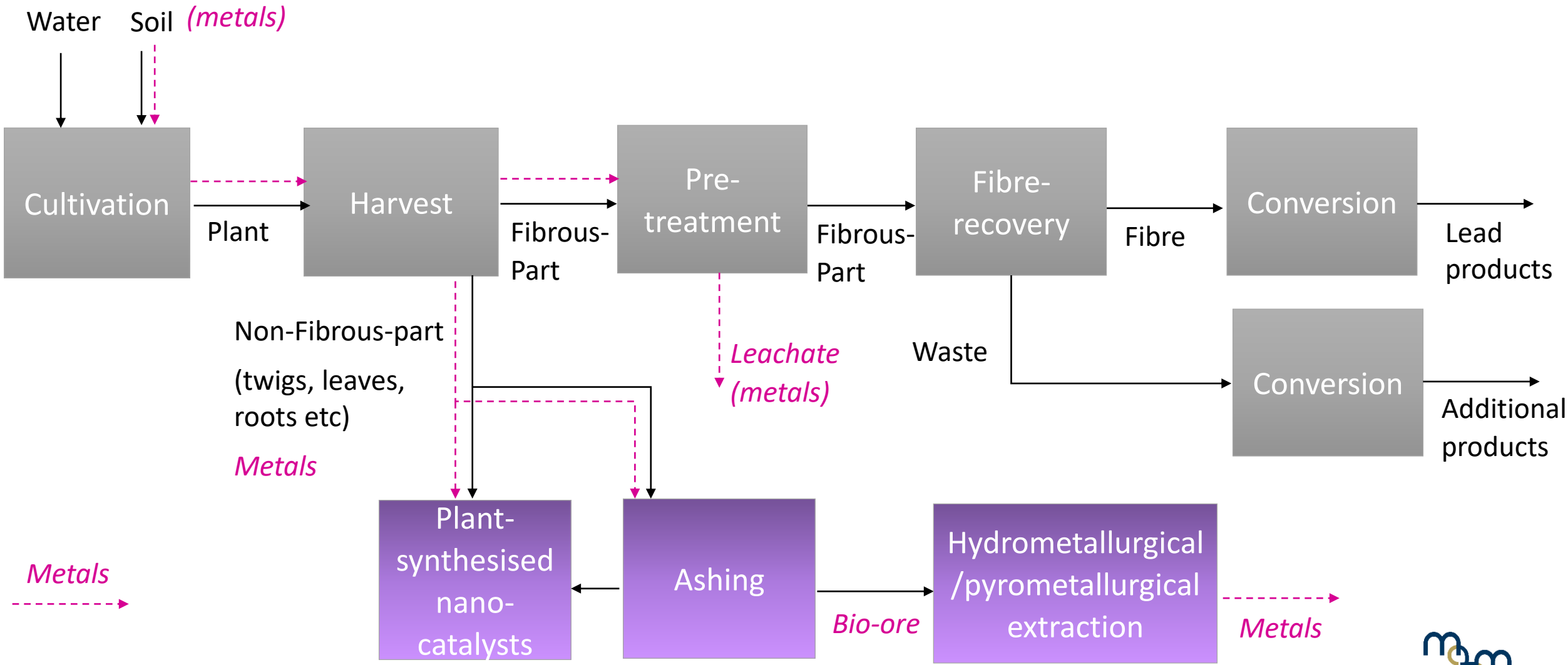
Potential integrated metal recovery process options



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**Alternatively use hyperaccumulators to recover metals/remove contaminants prior to growing fibres

Summary

- All the fibre-producing plants can generate multiple products however, the range of products and targeted markets differ for the different plant types .
- The selection of product recovery and treatment processes is highly dependent on desired product types and output of low-end vs high-end products.
- Therefore the exploitation of fibre-based plants will depend on the following;
  - ❖ The considered selection of lead and additional products and by-products
  - ❖ The relationship between the biomass properties, processing methods and desired quality of the intermediate and final products
  - ❖ Socio-economic drivers and environmental impacts
- Currently few holistic and systemic studies to inform decision-making on the selection of fibre-producing plants, products and processing methods

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Minerals to Metals project team