FIBRE & FUEL CROPS
for zero waste Biorefineries

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According to 4FCROPS (www.4fcrops.eu) energy crops categorized:

Oil crops (sunflower, rapeseed, Ethiopian mustard, etc.)

Fibre crops (kenaf, flax, hemp, cotton, etc.)

Lignocellulosic crops (giant reed, switchgrass, miscanthus, cardoon, reed canary grass, etc.)

Short rotation forestry (eucalyptus, poplar, willow, etc.)

Sugar crops (sweet sorghum, sugar beets, etc.)

Energy Crops and/or Fibre Crops should have:

- High yields (biomass yields, oil yields, sugar yields)
- Low production cost (low inputs for water and fertilizers, etc.)
- Environmental friendly way of cultivation
- The ability to be cultivated in low fertility agricultural areas and/or marginal land with satisfactory yields in order to avoid the competition with food

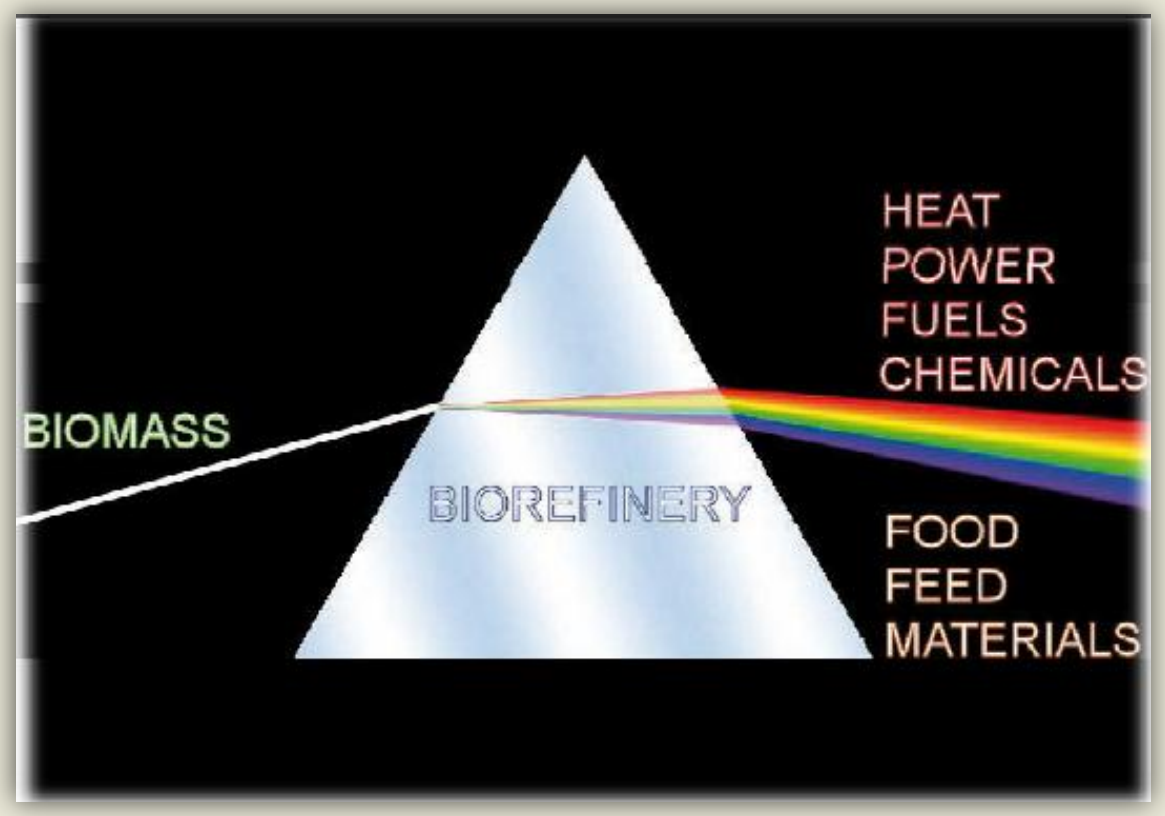
Which are the *main driving forces* for the cultivation of *energy crops*?

- The growing need for **starch** and **sugar** plant species as source for **bioethanol production**
- The growing need for **biodiesel**, **aviation biofuels** and **biochemicals** from **oil crops**
- The growing need for **solid biomass** to obtain **heat and electricity**, either directly through combustion or indirectly through conversion for use as fuels. **Lignocellulosic-rich raw materials** can used to produce fuel like **methanol**, **biodiesel**, **synthetic gas**, and **hydrogen** (using thermal and thermochemical processes by direct or indirect liquefaction or gasification) and **ethanol** (through hydrolysis and subsequent fermentation)
- To produce **biogas** from energy/biomass crops

Conversion path, main products and use per crop group

Crops	Conversional path	Main product	Use
Oil crops	Direct combustion	Heat, Power, Heat & Power	Bioenergy
	Transesterification	Biodiesel (FAME)	
	Hydrogenation	HVO	
	Refining	Lubricant	Biomaterials
	Transesterification & hydrogenation	Surfactant	
Fiber crops	Fleece production	Fiber composites, Insulation mats, etc.	Biomaterials
Lignocellulosic crops (perennial grasses & SRF)	Direct combustion	Heat, Power, Heat & Power	Bioenergy
	Gasification & synthesis (thermochemical route)	FT Diesel , Ethylene	Bioenergy Biomaterials
	Hydrolysis & fermentation (biochemical route)	Fuel ethanol, Chemical ethanol, 1,3-PDO, Ethylene	Bioenergy Biomaterials
Sugar Crops	Fermentation	1,3-PDO Fuel ethanol Chemical ethanol & ethylene	Biomaterials Bioenergy Biomaterials

The members of IEA Bioenergy Task 42 have agreed on the following definition for biorefinery: **"Biorefinery is the sustainable processing of biomass into a spectrum of marketable products (food, feed, materials, chemicals) and energy (fuels, power, heat)"**



Zero - waste biorefinery approach on fibre and fuel crops

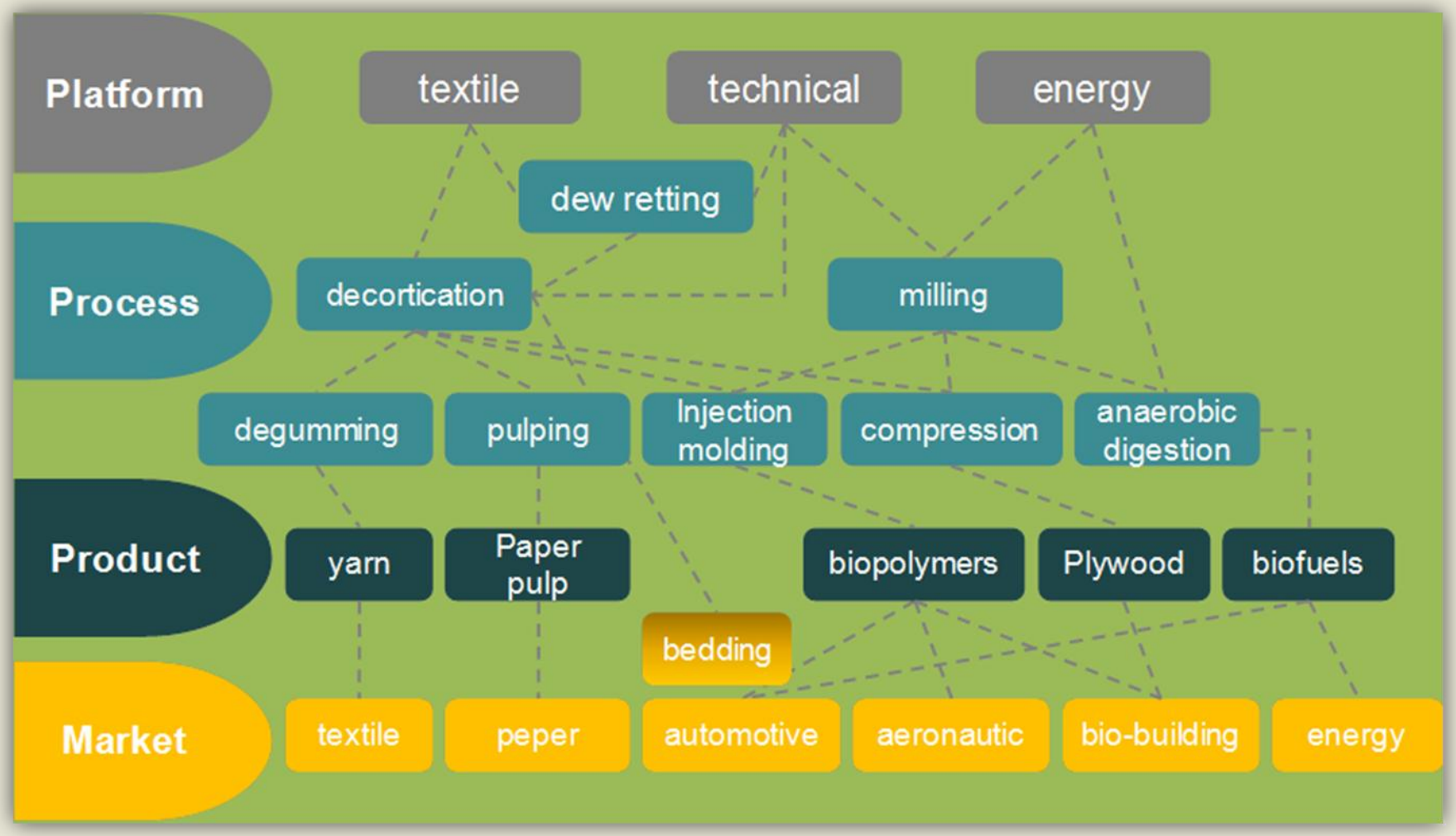
The development of **biorefinery processes** (the sustainable processing of biomass to a spectrum of marketable products and energy) is an **absolute necessity** and it is **the key to meet** this **vision towards bio-based economy** that includes the:

- the use the available biomass as efficiently as possible and with the lowest environmental impact,
- energy consumption,
- manufacturing costs and CO_2 footprint,
- the redefinition of the transformation routes,
- and the change in products specifications according to the new processes performances and limitations.

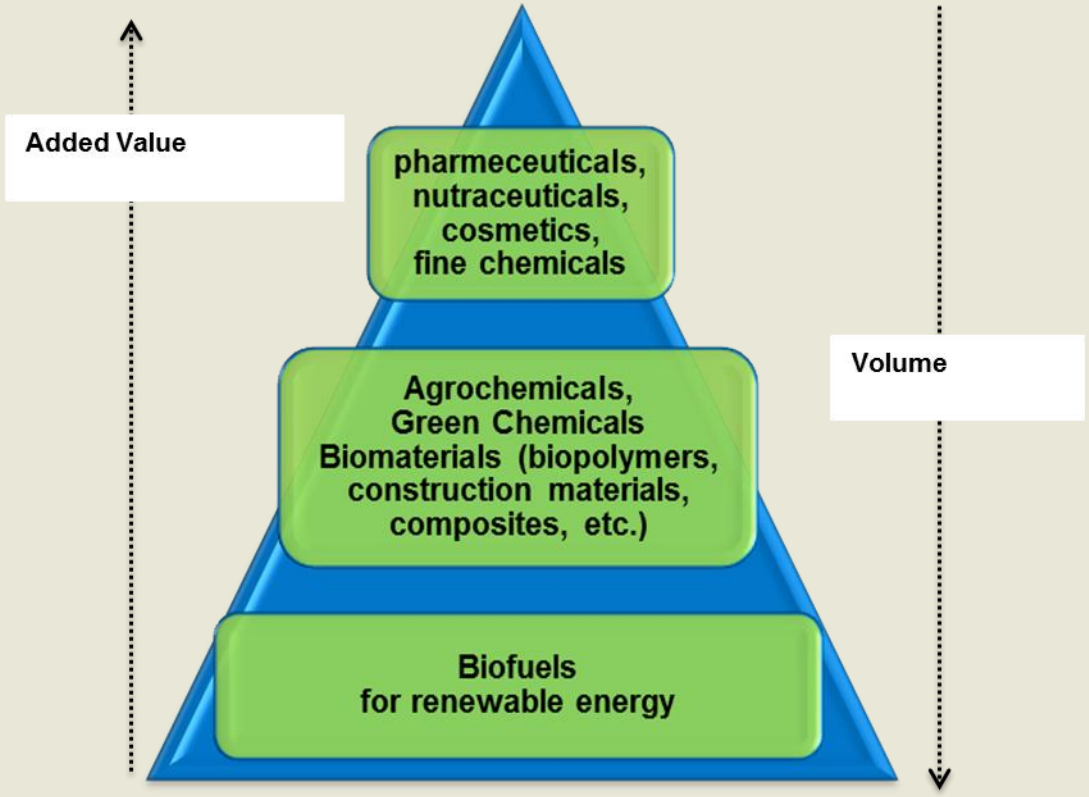
Biorefineries

- **Biorefineries** can use **various combinations of feedstock** and **conversion technologies** to produce **a variety of products**.
- **Most of the existing biorefinery concepts use limited feedstocks and technologies**, solely produce **ethanol** or **biodiesel** and further generally focus on producing **biofuels**, with the consequence of substantially **reducing the added value of the biomass chain**.
- A **relatively small fraction** is used for **chemistry** and **chemical products** that have a **higher added value**.
- **Economical** and **production advantages** increase with the overall **level of integration in the biorefinery**.
- The **benefits** of an **integrated biorefinery** are mostly based in the **diversification in feedstocks** and **marketable final products**.

The main platforms, process, products and markets in a biorefinery concept of fibre crops



Pyramid value of the added economic value of the biomass uses



The added value is the highest at the top of the pyramid and the lowest at the bottom. On the contrary, the volume of biomass needed for the applications is the lowest at the top of the pyramid and the highest at the bottom of the pyramid (www.bio-basedeconomy.nl).

Important FUEL and FIBRE crops in South Europe

Oil crops

Sunflower

Safflower

Cuphea

Castor

Fibre Crops

Kenaf

Flax

Hemp

Cotton

Nettle

Lignocellulosic crops

Giant reed

Cardoon

Elephant grass

Phalaris sp.

Sugar Crops

Sweet sorghum

Sugar beets

Oil crops for South Europe

Sunflower is a native of America but can be successfully cultivated in the Mediterranean region for oil production (food and biodiesel). Currently, it's cultivation area has been significantly increased due to high-yielding hybrids (more than 3000 kg/ha seed yields with 40% oil content) and seed yields and due to mechanization improvement.

Safflower is probably native to an area bounded by the eastern Mediterranean annual winter crop. Its seed yields can reach 1700 kg/ha with oil content varied 28 to 40%. It is salt and drought tolerant and can be cultivated in those areas where other oil plants fail.

Cuphea is native to Mexico, central and South America and can be cultivated in the Mediterranean region. It is a spring oil crop with yields of 400 kg/ha and oil content varied from 16 to 42%. It's a source of Lauric acid and can replace coconut oil.

Castor is native to Eastern Africa and can be successfully cultivated in the Mediterranean region. It is an annual spring crop and under favorable soil and climatic conditions yields around 5000 kg/ha with oil content of 50% can be achieved.

Fiber crops for South Europe

Flax is an annual winter or spring crop that its origin should be from Iran or Kurdistan that can be cultivated in some areas in the Mediterranean region. It is cultivated either for its fibrous stems or for its linseed or both. It is considered as multipurpose crop. The fibre flax is more resistant to drought and high temperatures compared to linseed.

Hemp is originated from central Asia and it can be cultivated in the Mediterranean region. Hemp belongs to the oldest group of plants used by humans. In Europe the area of its cultivation is 15,000 ha. Its seeds contain 35% oil and 46-70 % of the oil content is the linoleic acid. The whole plant give 8-16 t/ha dry matter yields (fibre yields 2-4 t/ha).

Kenaf is an annual spring crop endemic to Africa. It can be grown in the Mediterranean region and is very cold sensitive. The optimum temperature is 15 to 29^0C. Kenaf is one of the fibre allied to jute and shows similar characteristics. There are several uses for the core and the bark, while the whole crop has high protein. Its seed oil is edible and has high concentrations of omega antioxidants.

Lignocellulosic crops for South Europe

Giant reed grows wild in the Mediterranean region (south of Europe and north of Africa) and it is considered the champion of the biomass crops due to its high biomass yields (up to 40 t/ha dry matter yields) and the fact that can be cultivated with satisfactory yields in marginal lands with a life time 15 to 20 years.

Cardoon is originated from the Mediterranean region and it was known by the ancient Egyptians, Greeks and Romans. It is not irrigation since its vegetative phase take places from October to May and dry yields of 12 t/ha can be anticipated in medium fertility fields. In fields with high depth its lifetime could be 10 years.

Elephant grass can be cultivated in the Mediterranean region but does not tolerate much frost. It can tolerate precipitation from 200 to 4000 mm and annual temperatures of 13.6 to 27.3 ^{0}C. The reported yields varied a lot from 14t/ha to 84 t/ha.

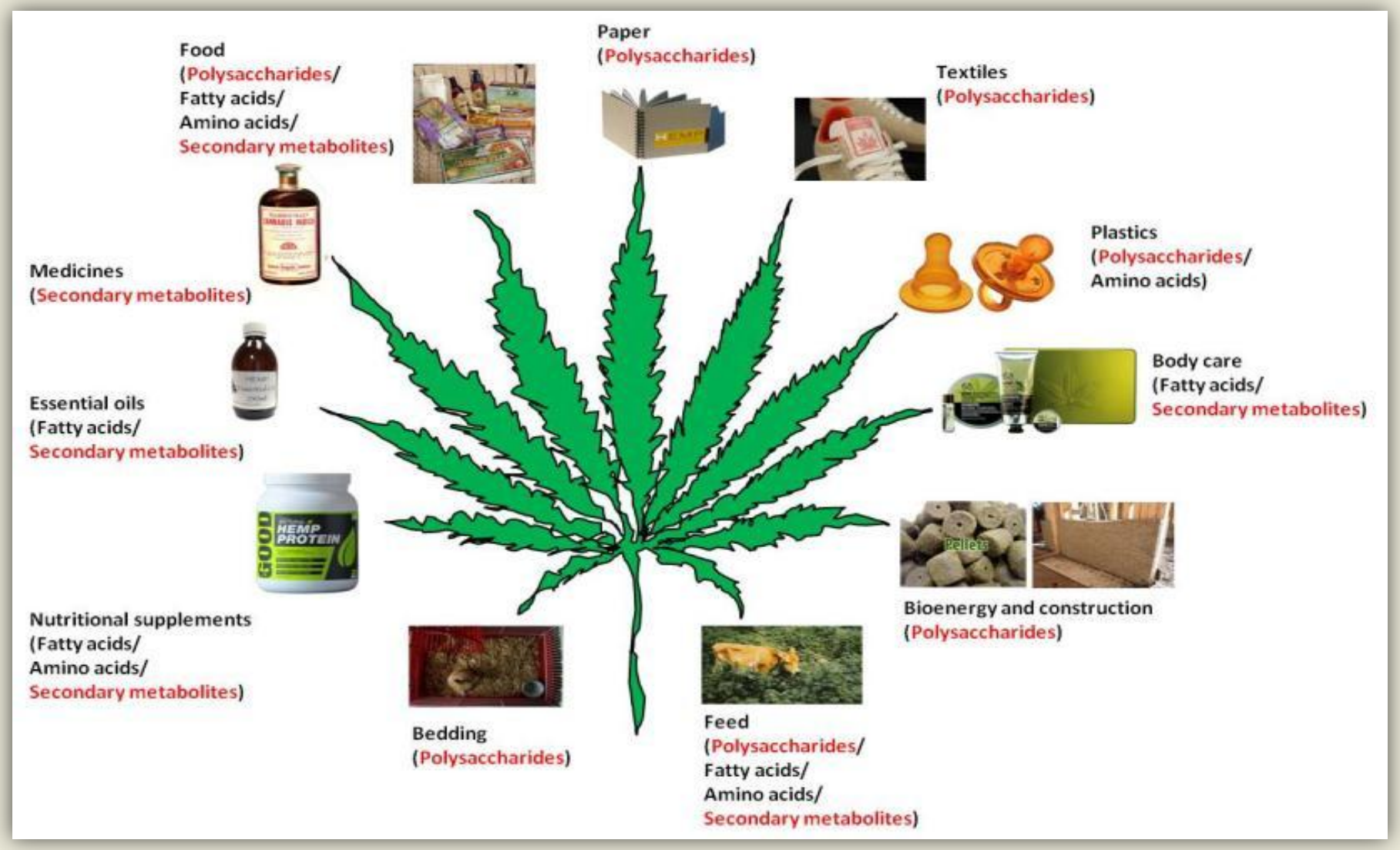
Phalaris aquatica is to the Mediterranean region, it has been dispersed throughout the world by agronomists and farmers for its value as forage in pastures. It is reported dry matter yields around 10 t/ha. One of its important characteristic its low lignin content.

Sugar crops for South Europe

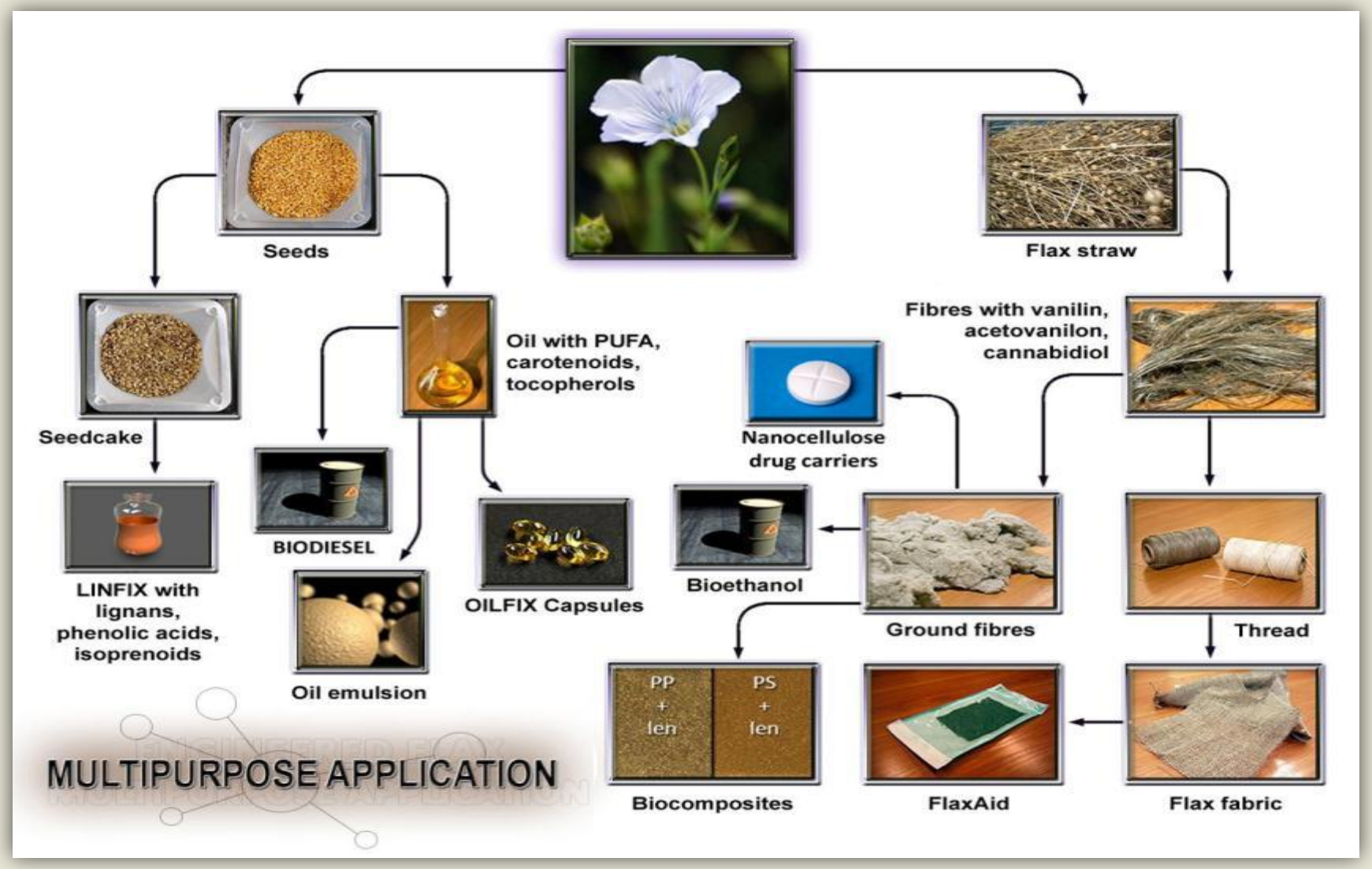
Sweet sorghum is originated from Africa and it is cultivated for its sweet stems which are used mainly for syrup production. It can be successfully cultivated in the Mediterranean region as a potential energy crop for bioethanol production. It is a cold sensitive annual spring crop. Its optimum temperatures for grow are 27 to 30^0C. It has the ability to absorb water more effectively than other crops and has a better ability to regulate water loss to the atmosphere.

Sugar beets is a biennial vegetable that can be grown commercially in a wide range of temperate climates. It is used to be cultivated for sugar production (either for sugar for food or for sugar for bioethanol). At the harvest the leaves have to be removed first and then the roots are being removed and cleaned. The roots should be collected when the sugar is at its highest content. The leaves can be used as animal feeding or natural fertilizer.

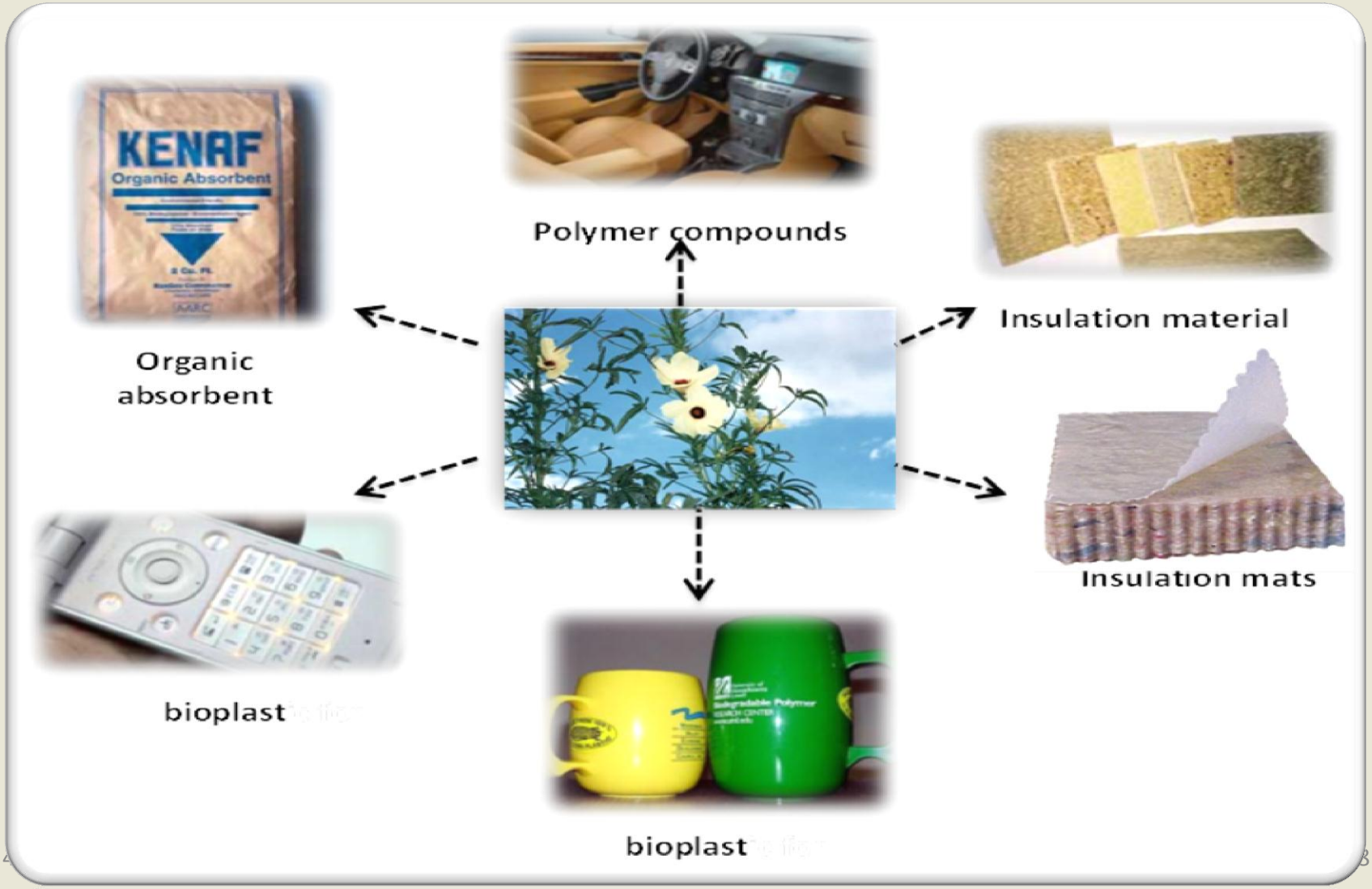
Hemp products (modified from Small and Marcus, 2002)



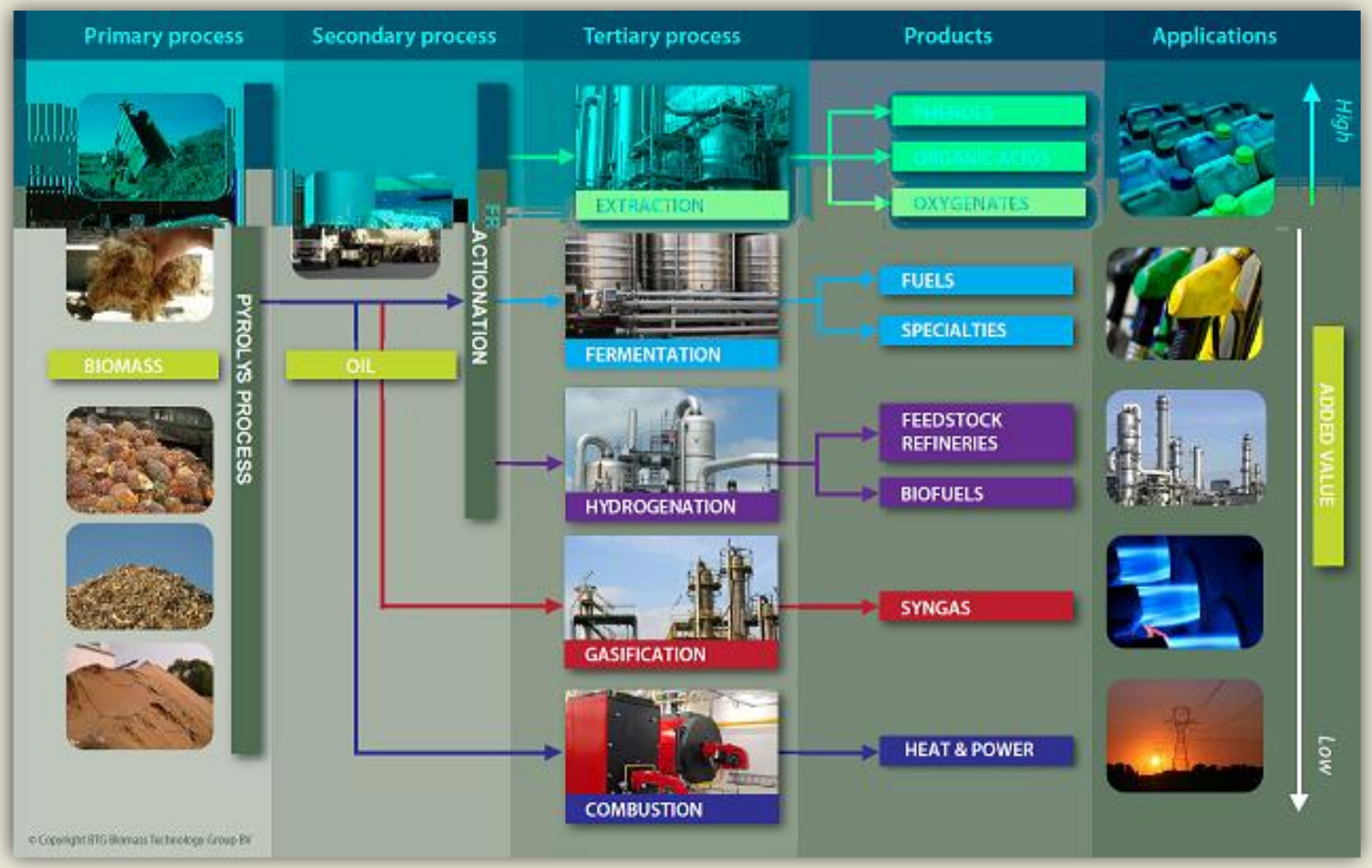
Flax products (source: Prof. Jan Szopa, University of Wroclaw)



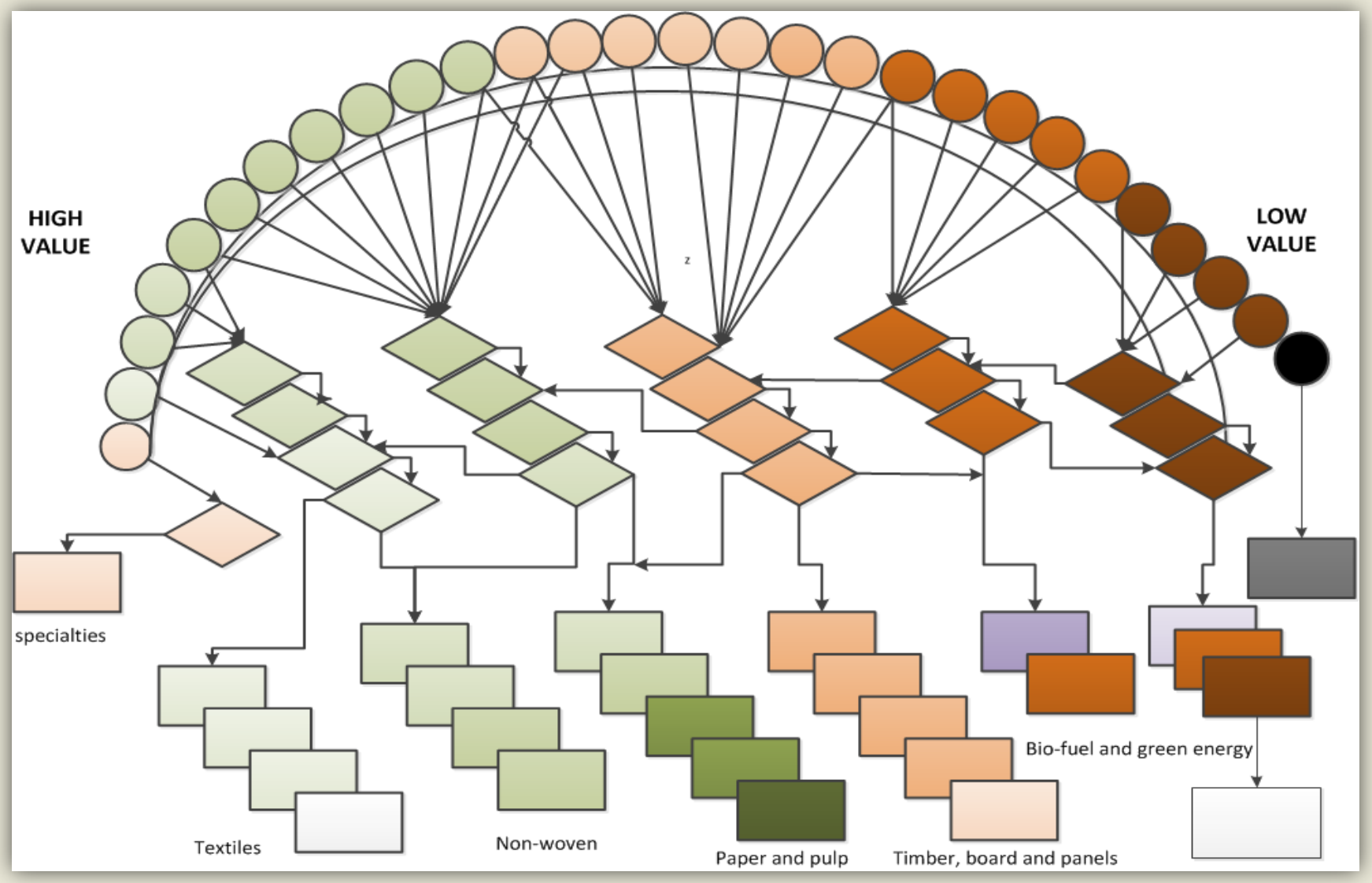
Kenaf products



Perennial grasses products and applications



Markets (Cellulose Matrix)



Thank you very much for your attention

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