Asphalt Innovation Symposium 2024

December 12

Antwerp

University of Antwerp

University of Antwerp | SuPAR | Sustainable Pavements and Asphalt Research

Sessie 2B – Alternative Materials

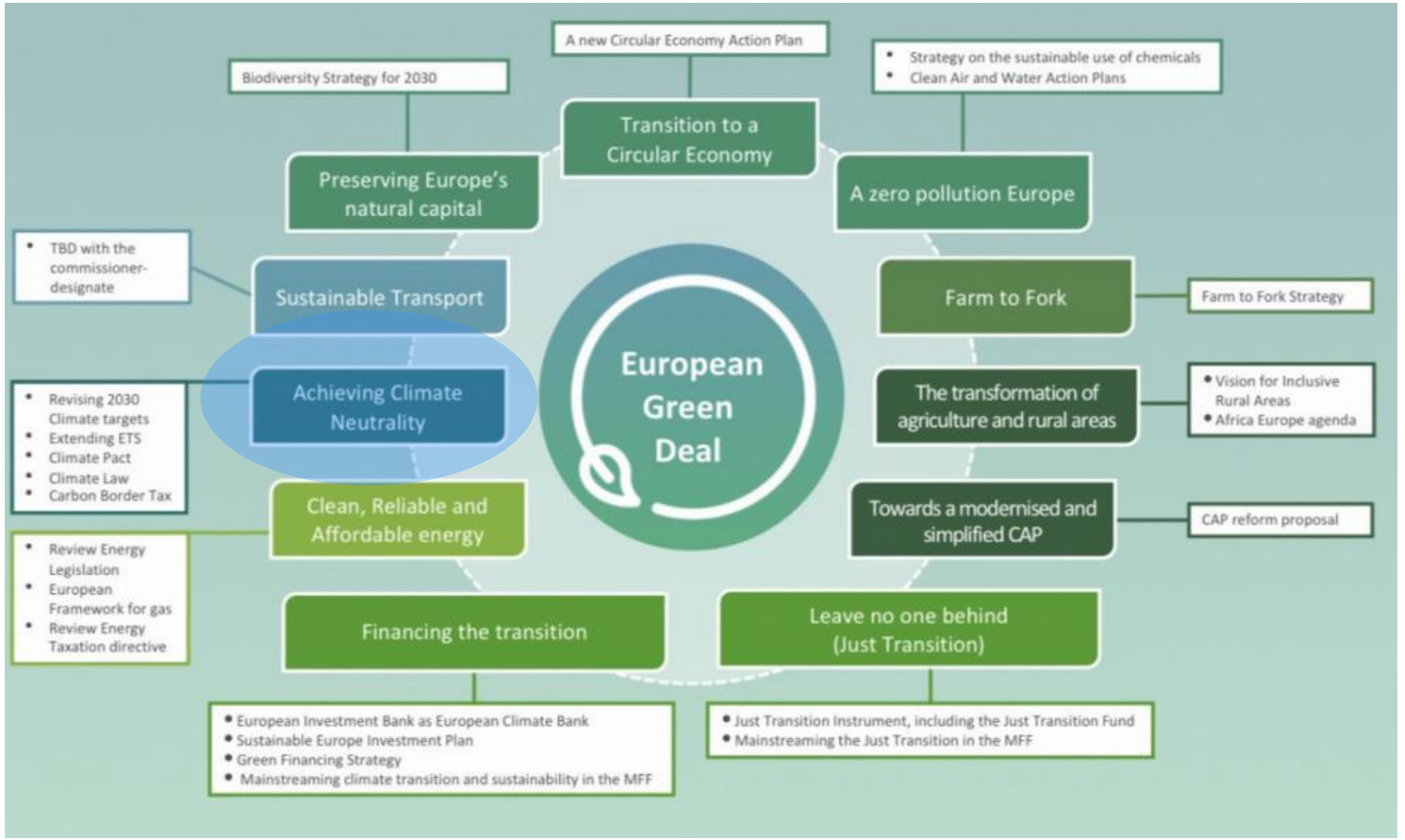
Bio-based binders: towards the decarbonisation of the asphalt pavement sector in Flanders?

S.Vansteenkiste, A.Destrée, A.Margaritis & A.Vanelstraete

Belgian Road Research Centre (BRRC)

Context

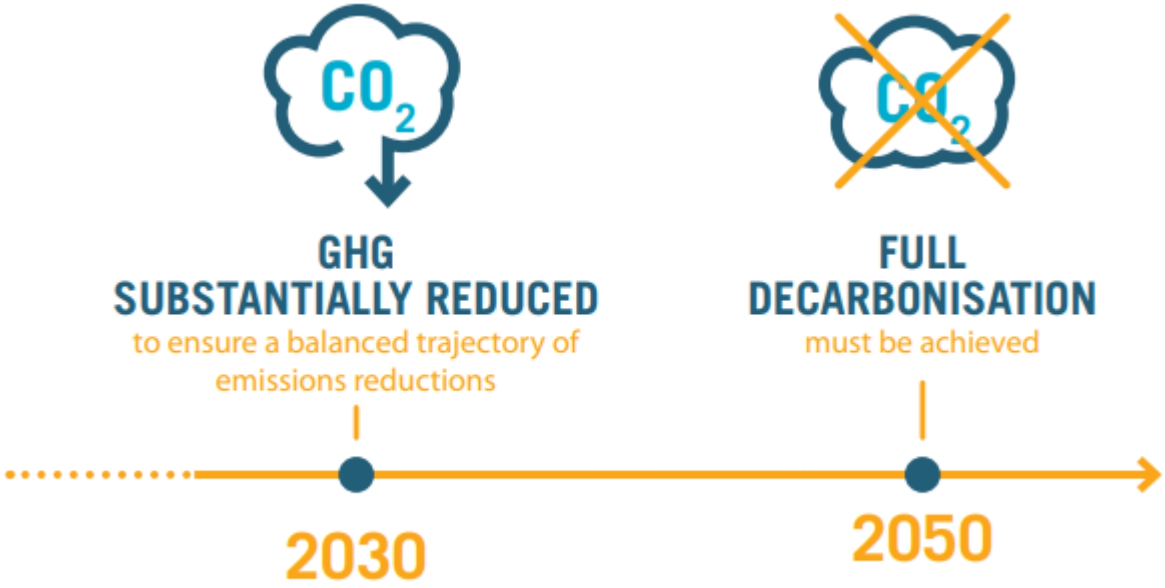
- **European Green deal launched in 2019 by European commission**



Source : https://www.mvovlaanderen.be/nl/agenda/wat-betekent-de-%E2%80%98european-green-deal%E2%80%99-voor-europa-en-vlaanderen

Context

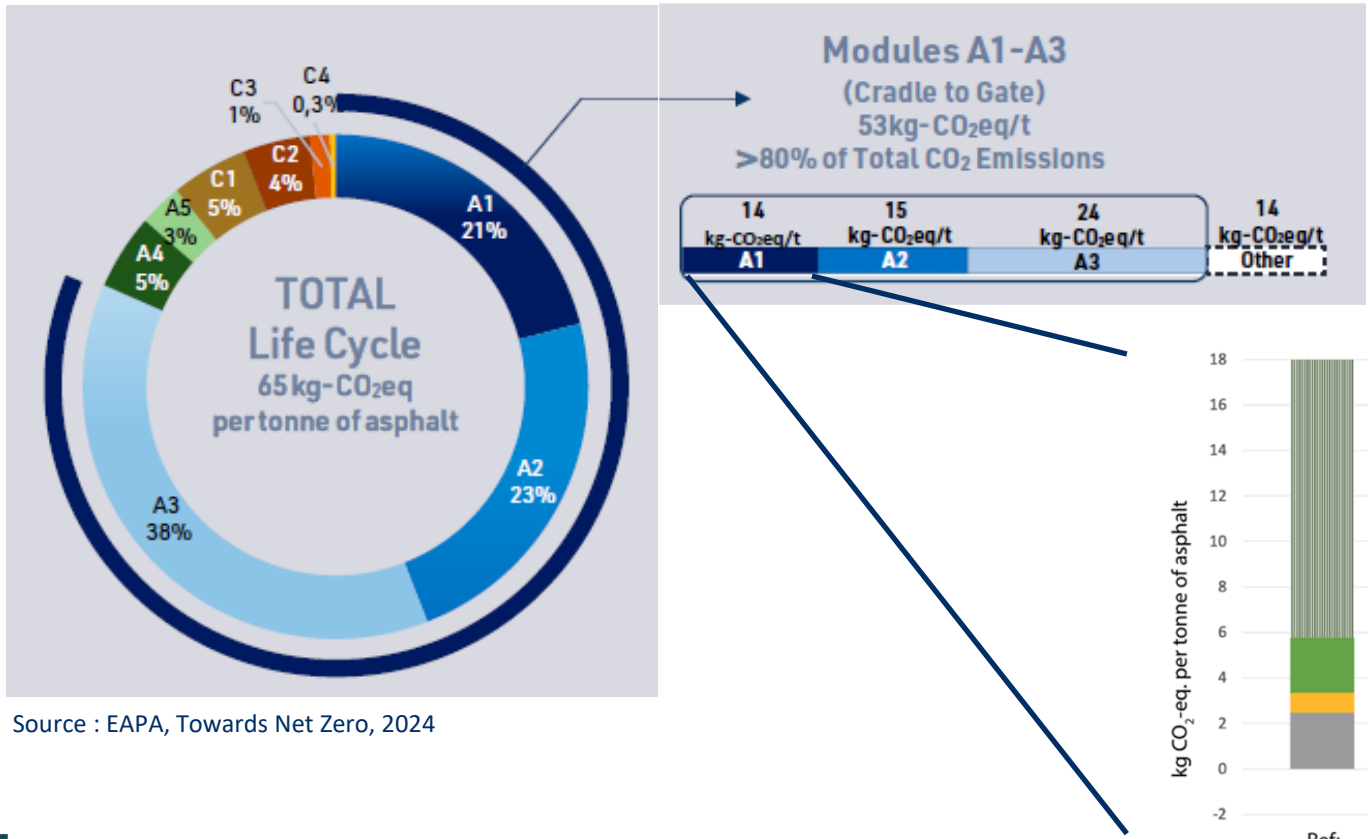
- **High ambitions to mitigate climate changes**



Source : https://www.bpie.eu/wp-content/uploads/2020/12/On-the-way-to-a-climate-neutral-Europe-_Final.pdf

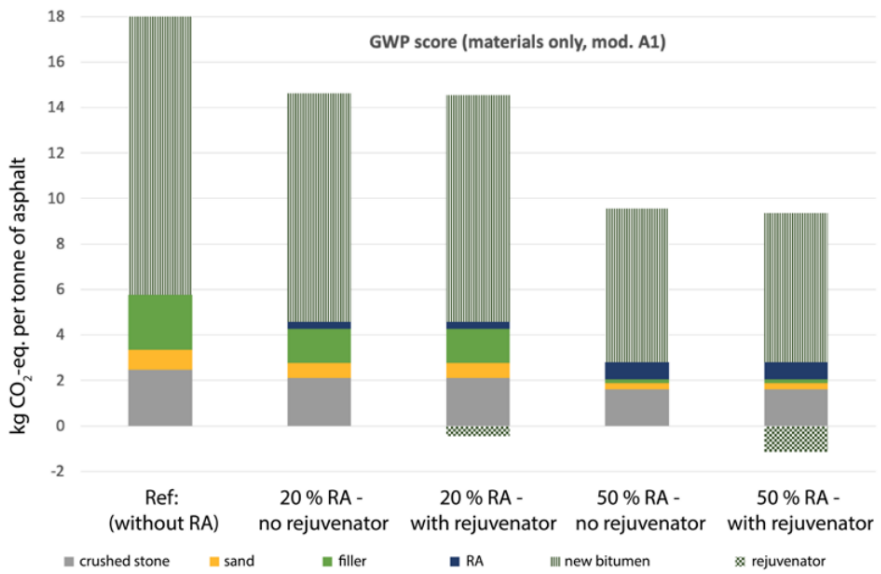
Context

- **Carbon footprint asphalt mixture**



Source : EAPA, Towards Net Zero, 2024

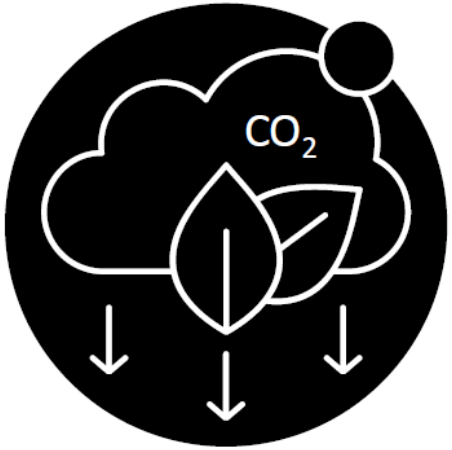
Large impact of bituminous binder



Source : Dossier 22, BRRC 2024

Why bio-based binders?

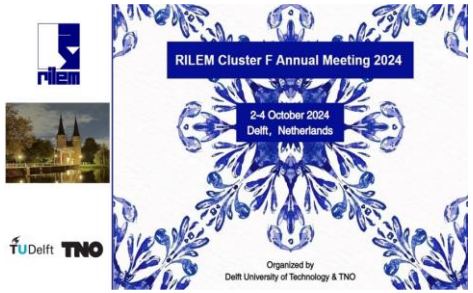
- To move away from fossil-based economy
- To make use of renewable – sustainable resources
- Bio-based binders contain biogenic carbon and may offer ‘carbon – credit’ (negative CO_2-footprint)
- Bio-based binders ↔ circular binders (may contain fossil components (e.g. plastics, rubber,…)



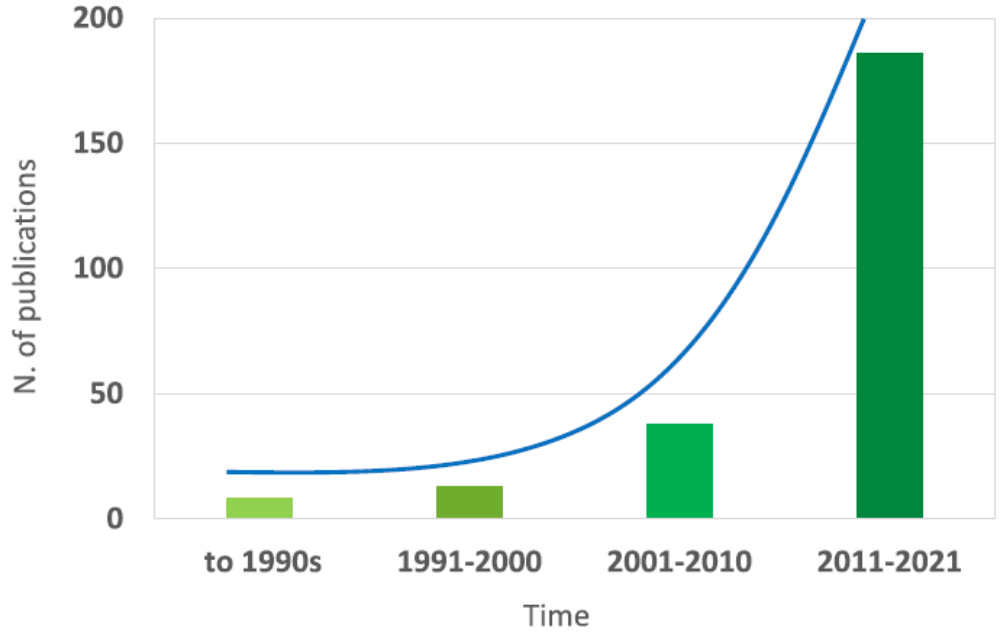
Source : https://bouwcirculair.nl/wp-content/uploads/2024/10/CIRCUROAD-UU-INNOV58-25-Sept-2024v1.pdf

Bio-based binders: growing interest wordwide

Workshop Biomaterials in Pavements 2024, Brazil



SESSION 7
Toward carbon-neutral pavements
Verena Rosauer



Papers related to use of lignin in asphalt

Source : Gaudenzi et al, Con.&Build.Mat., 2023

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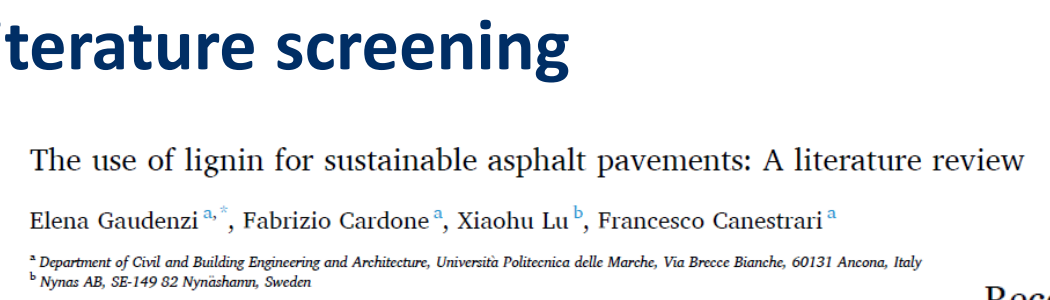
Bio-based binders: what is out there?

- **Literature screening**



The use of lignin for sustainable asphalt pavements: A literature review

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[b] Nynas AB, SE-149 82 Nynäshamn, Sweden

State-of-the-Art Review on the Behavior of Bio-Asphalt Binders and Mixtures

Ghazi G. Al-Khateeb [1,2,*], Sara A. Alattieh [1], Waleed Zeiada [1,3] amd Cassie Castorena [4]

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[2] Jordan University of Science and Technology, Irbid, Jordan
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[4] North Carolina State University, Raleigh, NC, United States of America
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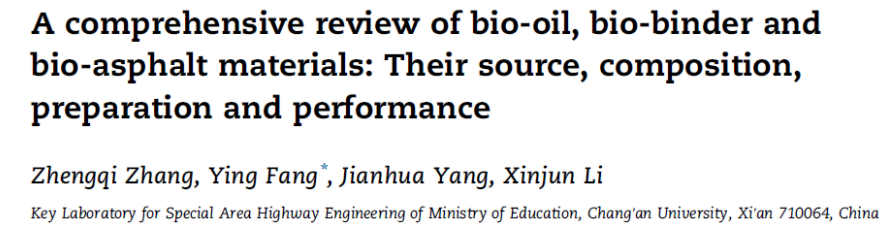

A comprehensive review of bio-oil, bio-binder and bio-asphalt materials: Their source, composition, preparation and performance

Zhengqi Zhang, Ying Fang*, Jianhua Yang, Xinjun Li

Key Laboratory for Special Area Highway Engineering of Ministry of Education, Chang'an University, Xi'an 710064, China

Recent advances and perspectives in circular bio-binder extender to substitute part of the fossil based binder in asphalt mixture

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- **Remarkable high variety of materials out there**
- **No (clear) terminology or standardization available**
  - Partial – full bitumen replacement – in combination with recycling RA
  - Additive (<20%) – bitumen extender (20-75%) – alternative bio-binder (> 75%)

Classification of bio-based binders

- **Biomass originates from plants, animals, micro-organisms**
- **3 categories of biomass:**
  - Wood & plant (vegetable materials)
    - Primary sources: derived from food, agriculture crops and forestry
    - Secondary sources: industrial residues (agriculture/forestry industry)
  - Waste oils
    - Arising from vegetable oil refining (bio-refinery) or waste cooking oils
  - Animal based: e.g. swine manure
- **Materials arising from processing:**
  - Extraction, (bio)refining, thermo-mechanical process (e.g. pyrolysis, liquefaction)

Classification of bio-based binders

- **Families based on origin/nature**
  - Vegetable oils and derivatives
  - Tall oil pitch/Pine tree rosin
  - Biochar
  - Food waste oils
  - By-products from paper industry
  - …

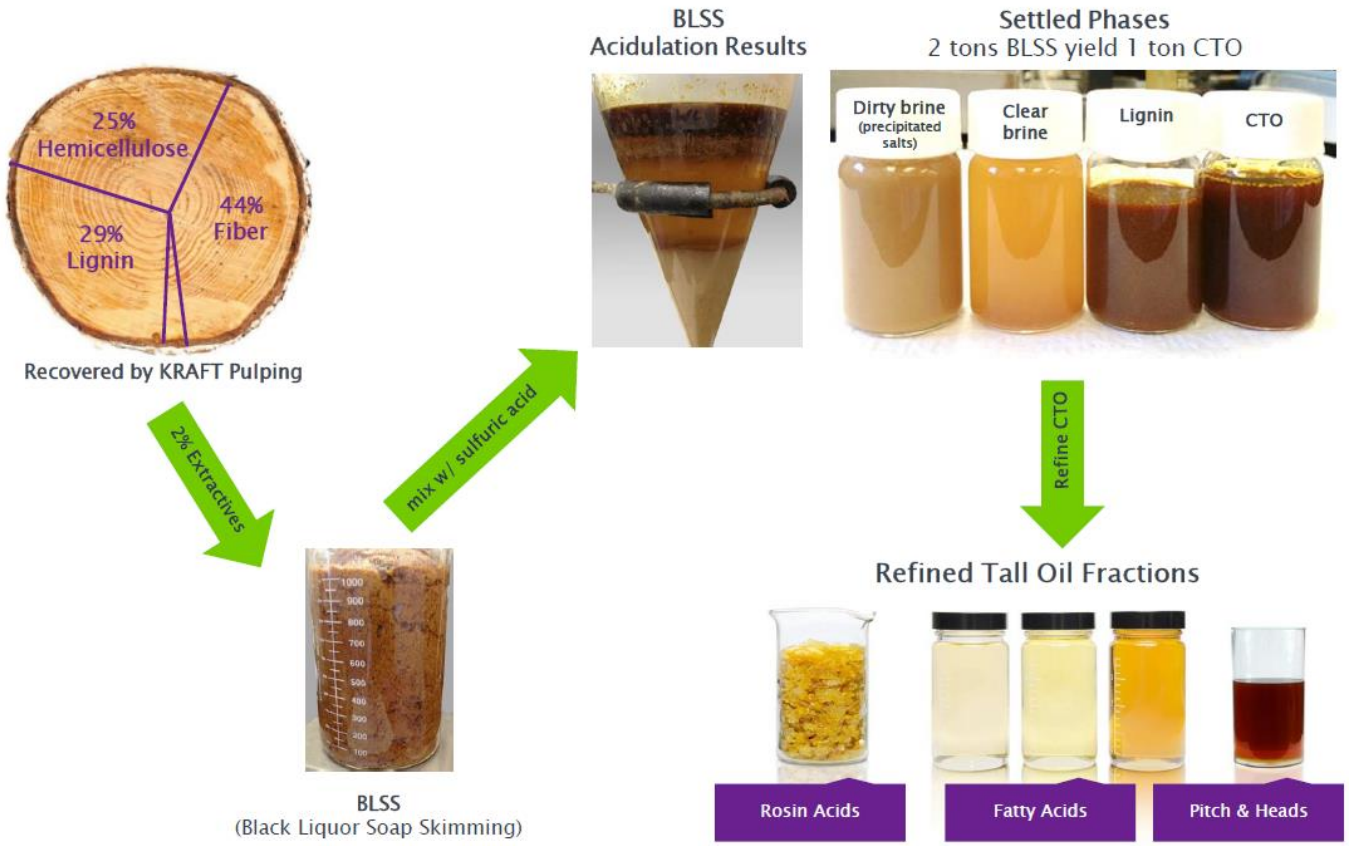
Vegetable oils and derivatives

- **Agriculture based oils:**
  - Extensive range available: linseed, soybean, rapeseed, cotton seed, palm, cashew nutshell liquid, …
  - Well known properties and widely used in other sectors (e.g. paint industry)
- **Opportunities:**
  - Acts as softener ⇒ rejuvenator
  - Following blending with other additives (e.g. lignin, polymers,…) or after polymerization (resin) to perform as binder
- **Challenges:**
  - Excessive land use (limited availability)
  - Competition with food products

Source: https://perfectimage.com/blogs/ingredient/soybean-oil

Source: https://www.oleon.com/news/rapeseed-oil-the-perfect-all-rounder-for-your-plant-based-food-processing-requirements

Pine-tree rosin – Tall oil pitch



Source: S.Jordahl, Ingevity 2017

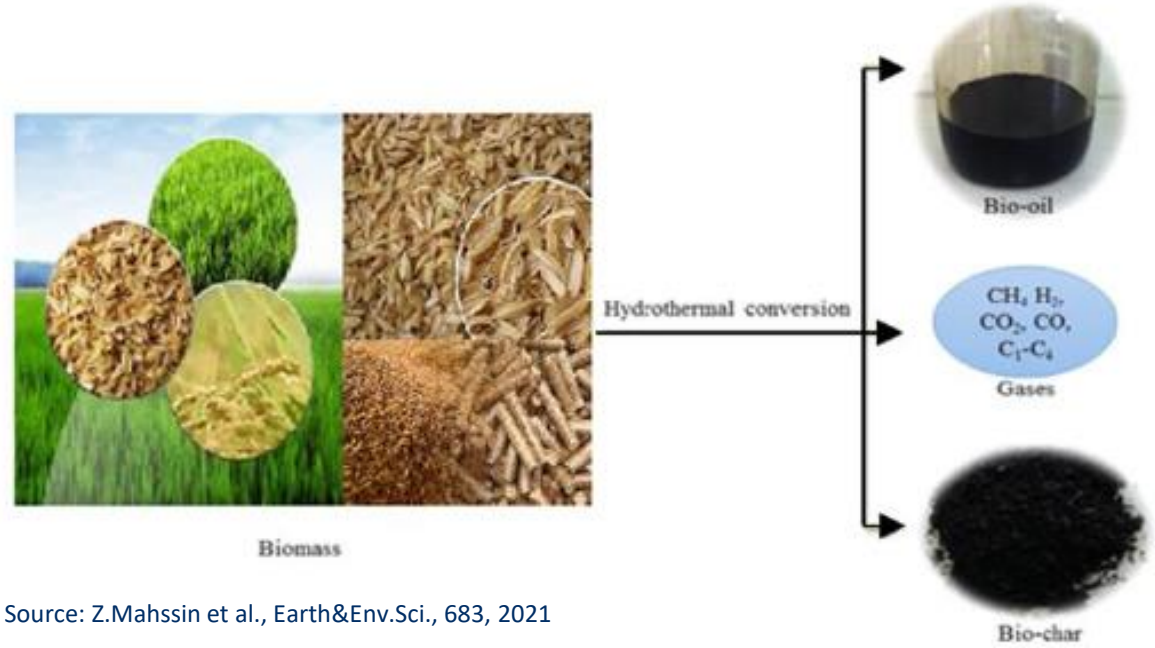
Opportunities:

- Availability (wordwide): MT scale
- Relatively high Technology Readiness Level (TRL) – extensive experience (lab/field)

Challenges:

- Regional supply dependence
- Use outside road applications

Bio-char products



Source: Z.Mahssin et al., Earth&Env.Sci., 683, 2021

- **Residue from pyrolysis or liquefaction conversion processes of biomass**
- **Opportunities:**
  - Sustainable re-use of biomass with added value
- **Challenges:**
  - Requires high temperatures, pressures and catalysts and process control
  - Large investments needed
  - Health&Safety concerns always present and to assess in depth

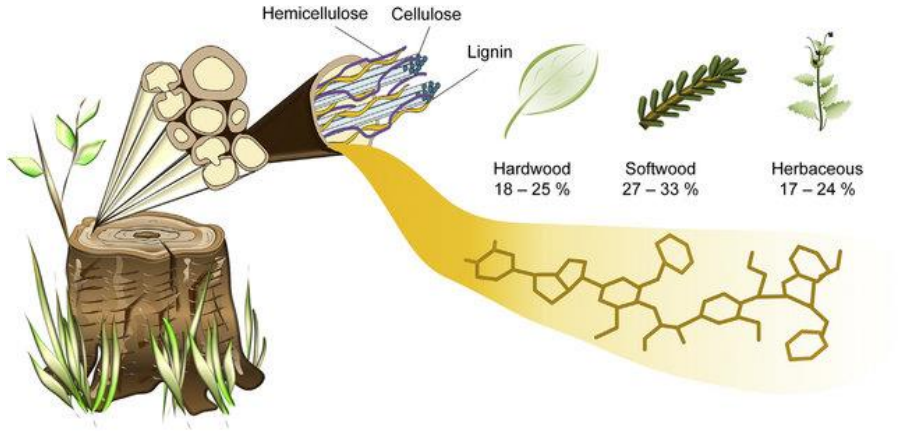
Food waste oils

- **Waste derived oils from food industry**
  - Also known as WCO (Waste cooking oil) or WEVO (Waste edible vegetal oil) or yellow grease
  - Consists of large variety of fatty acid/esters form vegetal origin
- **Opportunities:**
  - Increased circularity by recycling of waste oils
  - High availability, specially in Asia (up to 10 MT/year)
- **Challenges:**
  - Health&Safety concerns: impurities, H_2O content, thermostability, emissions and odour nuisance,…
  - Competition with production of bio-fuels

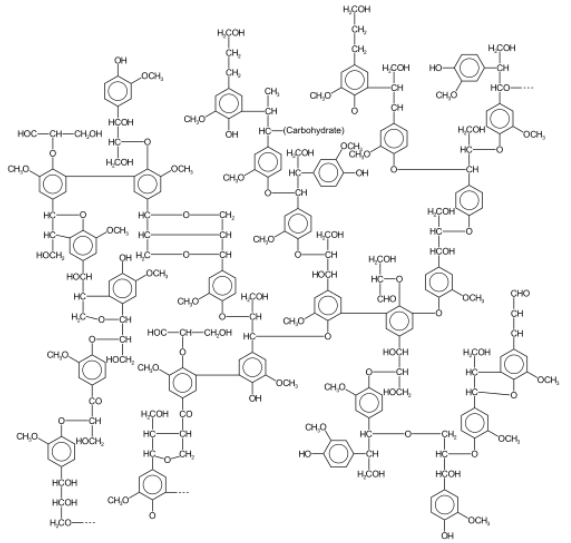
Source: https://gfcommodities.com/blog/the-yellow-grease-is-greener-the-hidden-treasure-behind-grease-collection/

By product paper industry - lignin

- **Structural polymer in many plant species: wood bark, hemp, jute, cotton, flax, straw,…**
- **15 - 30% of woody bio-mass**
- **Complex chemical nature depending on vegetal source**
- **Opportunities:**
  - High availability as by-product of paper industry worldwide estimated at 50 MT/year (second most abounded bio-product)
  - To create added value as currently lignin is mainly valorized as energy source (considered as waste)



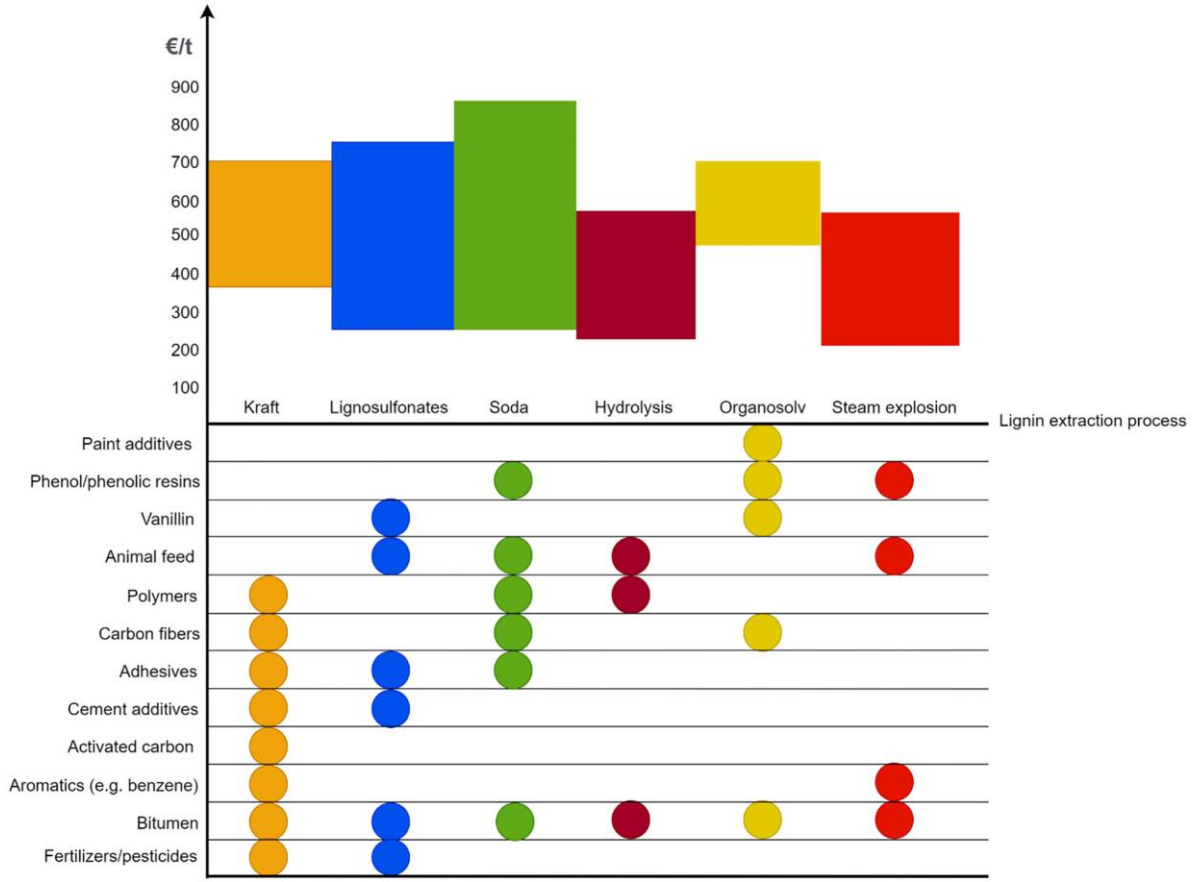
Source: J.Becker et al., Biotechnology Advances, 2019



Source: Idealized structure of lignin, Wikipedia, 2024

By product paper industry - lignin

- **Opportunities:**
  - Already some experience of its use for different types in multiple sectors
  - Availability of LCA-data confirming its positive contribution to sustainability, although harmonization needed for comparative assessment



Source: C.Moretti et al., Science of the Total Environment, 2021

By product paper industry - lignin

- **Challenges:**
  - High variability as function of vegetal source (plant and season) and subsequent processing

LIGNOSULFONATE		KRAFT LIGNIN		ENZIMATIC/ACID HYDROLYZED		ORGANOSOLV		SODA LIGNIN	
Sulfur (%)	3.5-8	Sulfur (%)	1-3	Sulfur (%)	0-1	Sulfur (%)	0	Sulfur (%)	0
Ash (%)	4-8	Ash (%)	2-6	Ash (%)	1-3	Ash (%)	0-0.5	Ash (%)	0-0.5
PH	2-12	PH	13	PH	-	PH	-	PH	11-13
OH phenolic (%)	2-2.5	OH phenolic (%)	2.6-4.5	OH phenolic (%)	3-9	OH phenolic (%)	3.4-3.7	OH phenolic (%)	2-5
Acids (%):	4-6	Acids (%):	4.1-6	Acids (%):	6-10	Acids (%):	7-8	Acids (%):	-
Purity	Moderate/Low	Purity	High	Purity	Moderate/Low	Purity	High	Purity	Moderate
Mw ($gmol^{-1}$)	1000-5000	Mw ($gmol^{-1}$)	1000-5000	Mw ($gmol^{-1}$)	2000-4500	Mw ($gmol^{-1}$)	1000-6000	Mw ($gmol^{-1}$)	1000-6000
D	2.5-7	D	2-8	D	1.5-3.2	D	1.5-4.4	D	-
Volume (Mt)	1	Volume (Mt)	55	Volume (Mt)	-	Volume (Mt)	-	Volume (Mt)	0.6
Moisture content (%)	5.8	Moisture content (%)	3-6	Moisture content (%)	4-9	Moisture content (%)	7.5	Moisture content (%)	2.5-5

Fig. 4. Different sources of lignin and their characteristic.

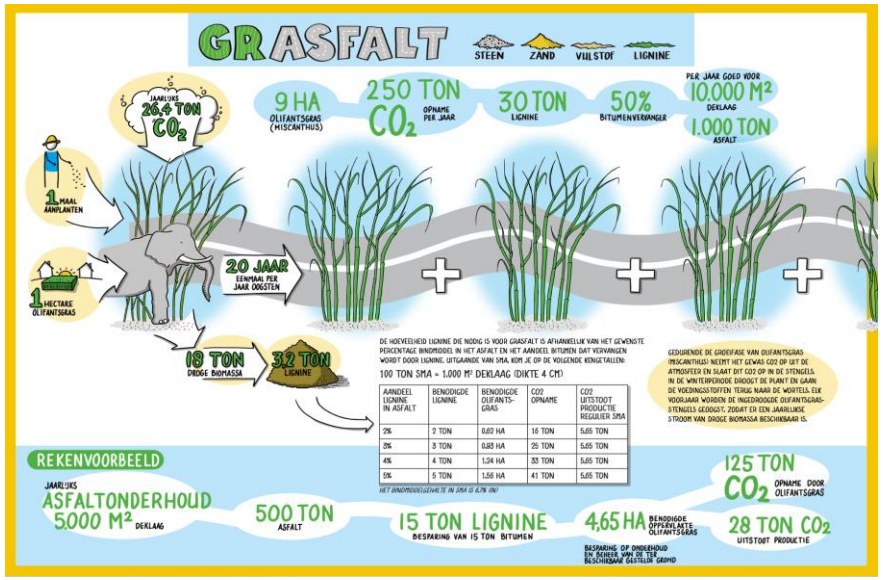
Source: E.Gaudenzi et al., Constr.Build.Mat., 362, 2023

Recent field experience in Flanders

- **First Flemish application with “bio-asphalt”**
  - Pilot-project initiated by POM Limburg and carried out on 25th June 2024
  - Business park – 's Gravenvoeren – Weersterweg
  - “Bio-asphalt” is an innovative asphalt mixture in which part of the binder was replaced with a “bio-based binder” lignin derived from elephant grasses

Source : https://pomlimburg.be/ruimte/bedrijventerreinen/voeren/

Source : https://greenelephant.be/



Source : https://www.grasfalt.nl/

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Recent on-site experience in Flanders

- **SMA-C wearing course**
  - Warm Mix Asphalt (~ 130 °C)
  - Addition of lignin instead of replacement?
- **Execution on site**
  - Little or no smoke during application
  - According to the workers, workability was comparable to that of traditional mixes
- **Mid and long-term durability**
  - Visual inspection (BRRC)

Conclusion

- A wide variety of bio-sourced materials out there
- Opportunities identified for their potential use as bio-binder
- Limited field experience in Flanders
- Lignin offers prospects for (partial) replacement of bitumen but challenges do remain

Outlook

- **BEAM project ‘Bio-binders for Eco-friendly Asphalt Materials’**
  - New consortium established involving BRRC (coordinator), SUPAR (UA) and VITO to conduct research on lignin as bio-binder
  - Pre-application proposal for SBO project within Materinex call is currently pending
  - Main challenges tackled:
    - Availability and selection of materials for partial or full replacement of fossil binders
    - Dealing with variability in properties in function of optimal targeted end-use
    - Further processing of products and impact on performance (binder and mix level)
    - LCA and LCCA analysis
    - Increased demonstration of feasibility in the field

Thank you for your attention

Questions?