



From biomass to biochemicals and biomaterials - technological pathways and applications

Sabina Berne

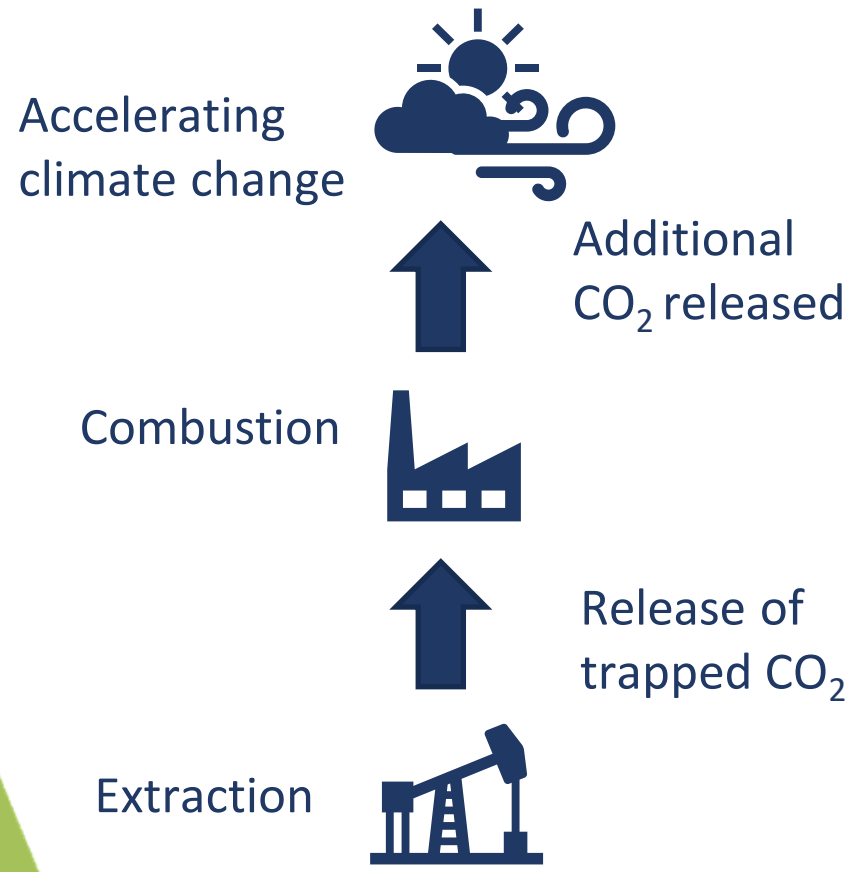
Univerza v Ljubljani



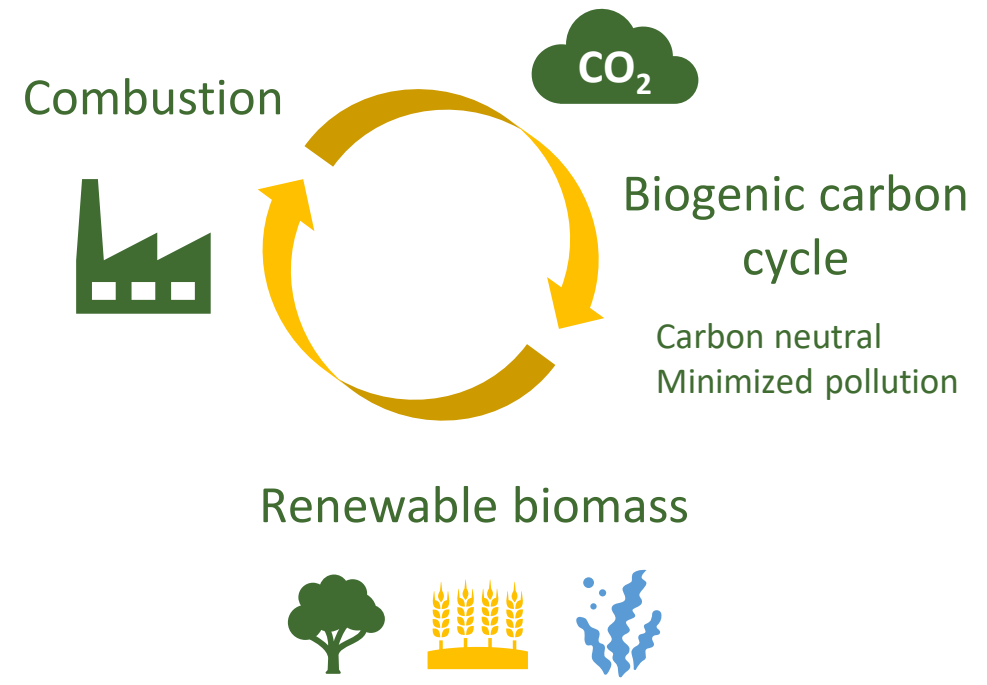


Why transition to the Bioeconomy?

Non-renewable fossil-based economy



Sustainable, circular bio-based economy





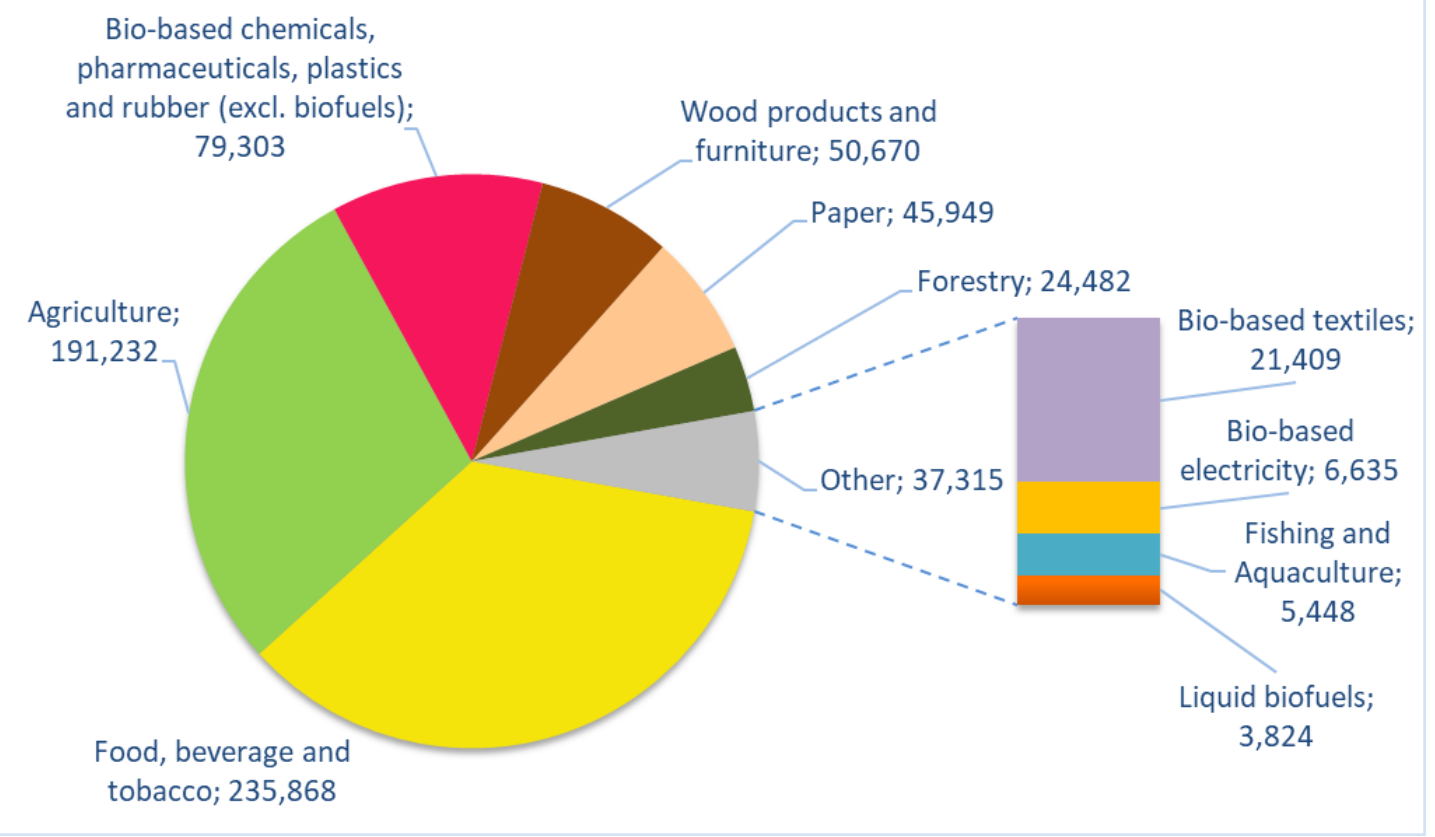
Bioeconomy in EU27

Turnover of selected sectors
€2.5 trillion

Employment in selected sectors
18 million

BIC_2023_Trend_Report

Value added by bioeconomy sector in 2020 (M €)



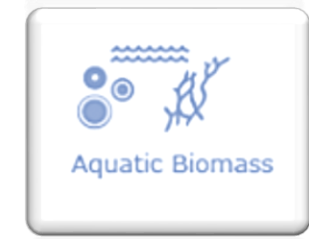
Ronzon et al. 2022; (DOI: 10.2760/761583)



What are bio-based products?

BIO-BASED PRODUCTS

Products that are **partly or wholly** derived from **biomass**.
Intermediates (fibers, composites, polymers, chemicals,...)
Semi-finished and final products



Food and feed



Materials



Chemicals



Energy and fuel



EN 16575:2014, European Committee for Standardisation, Technical Committee 411 (CEN TC/411) , Bio-based products – Vocabulary , Mandate M/492, August 2014.



Standardization of bio-based products

CEN/TC 411 'Bio-based Products' STANDARDS (EN 16575:2014)



Determination of bio-based content



Sustainability criteria



Terminology and communication

More on October 27, 2023, by Harmen Willemse (NEN):

“Bio-based content certification: Better Biomass Certificate”

https://www.nen.nl/media/PDF/IG_Biobased_product.pdf

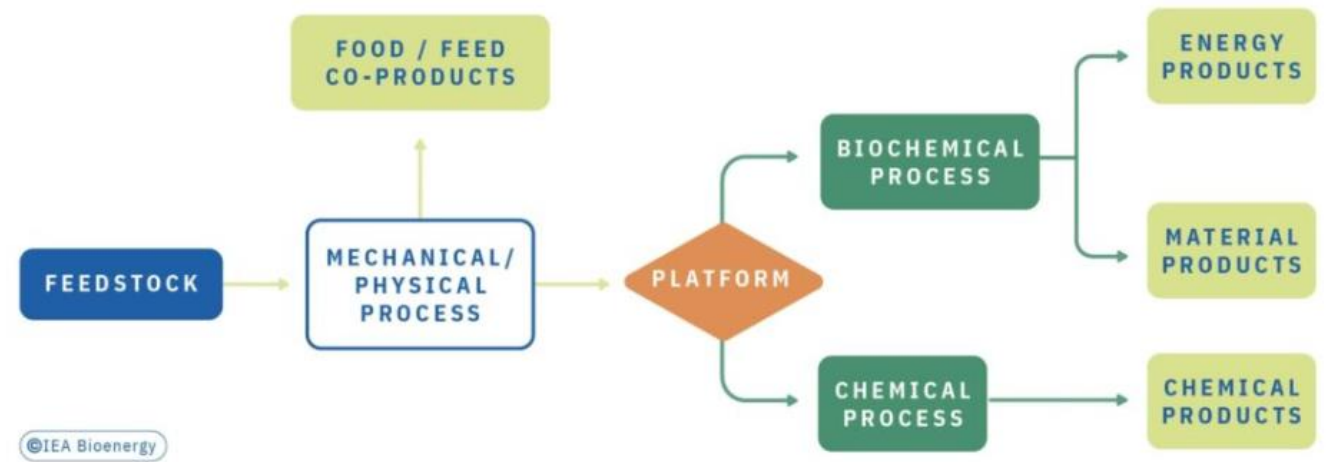


Key enabling strategy of bioeconomy

BIOREFINING

Sustainably process biomass into a spectrum of marketable bio-based products, such as food/feed ingredients, chemicals, materials, and bioenergy (power, heat, fuels)

- the IEA Bioenergy Task 42 Definition



©IEA Bioenergy

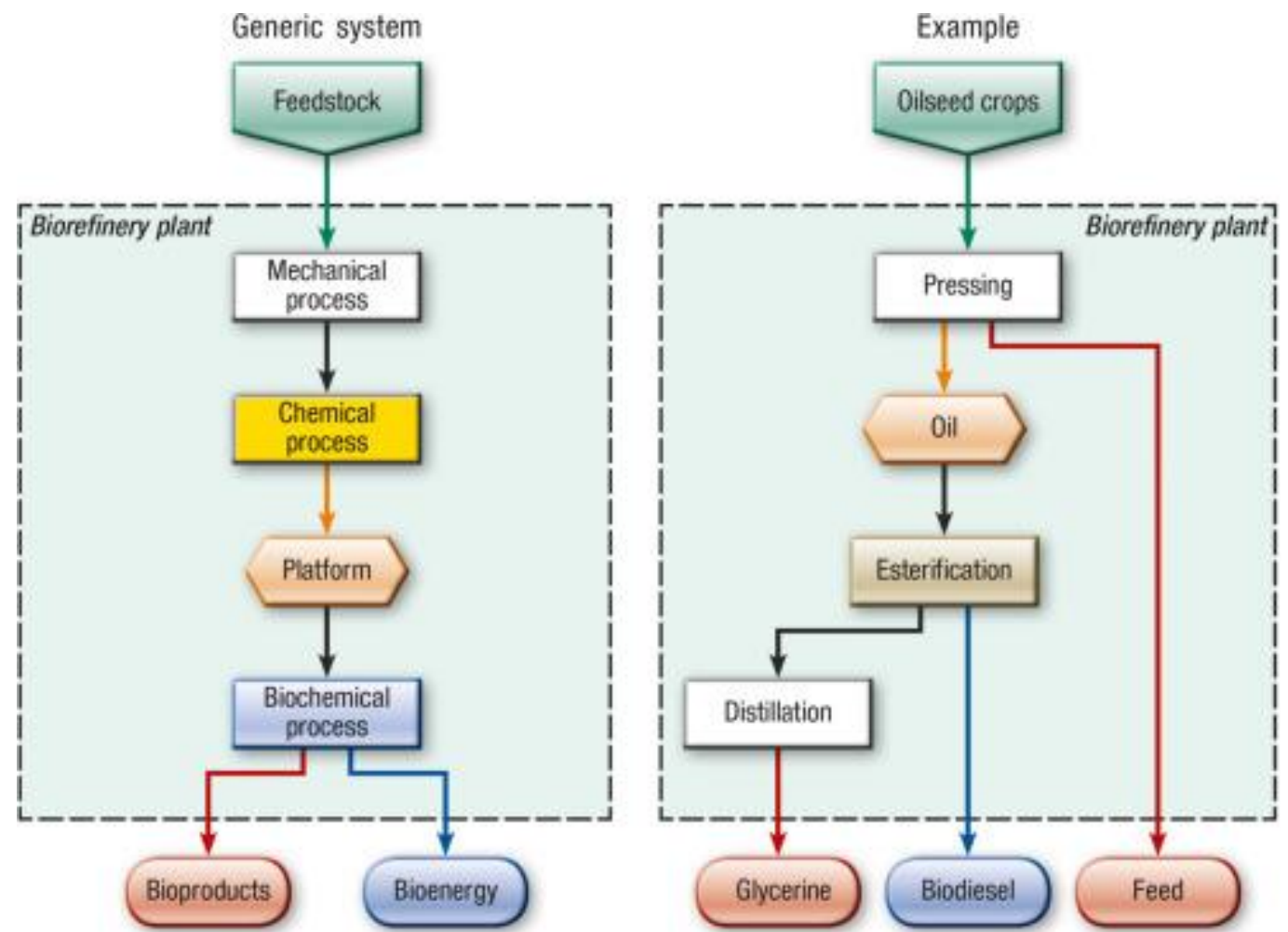


<https://www.ieabioenergyreview.org/biorefining/>



Biorefinery classification system

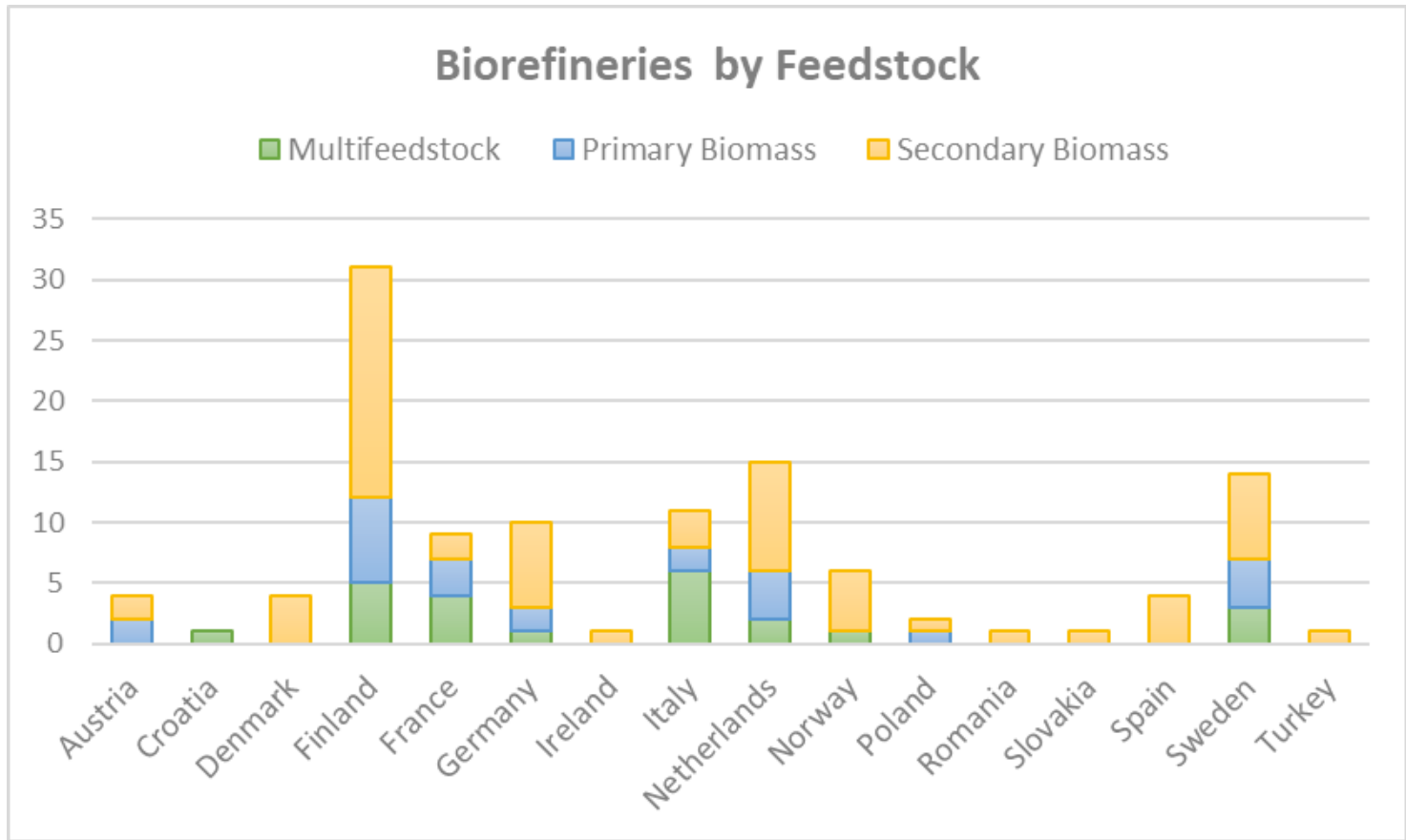
**IAE Bioenergy Task 42
and EU Biorefinery
Outlook to 2030**



https://www.ieabioenergy.com/wp-content/uploads/2014/09/IEA-Bioenergy-Task42-Biorefining-Brochure-SEP2014_LR.pdf



EU Biorefineries by country






Source
IEA Task 42 Country report
IAE Bioenergy 2020
Cepi Study 2021
BioRefineries Blog
Joint bioeconomy survey 2019

Global Biorefineries Atlas Portal: <https://task42.ieabioenergy.com/databases/>



Types of feedstocks

PRIMARY BIOMASS:

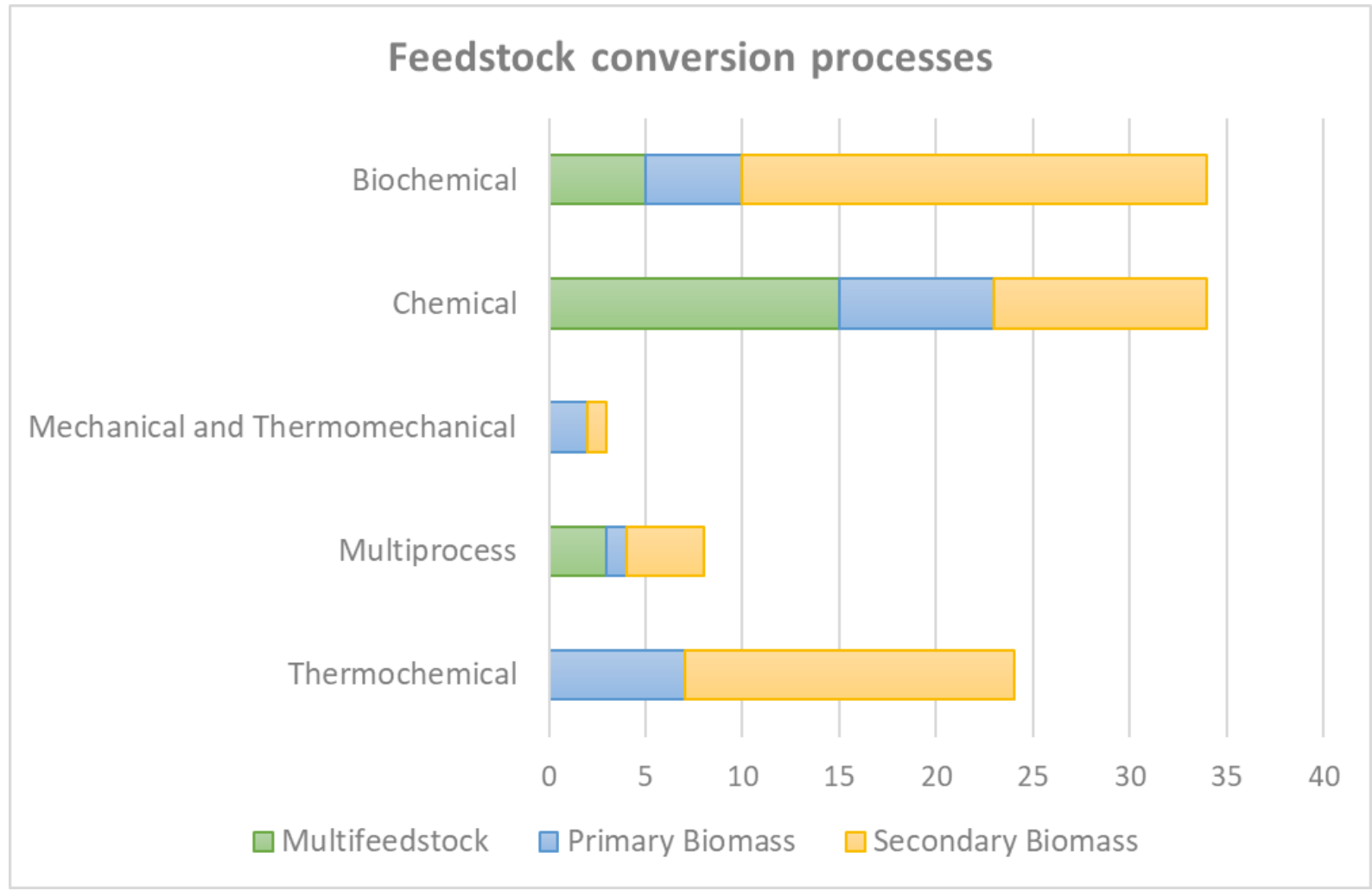
-  aquatic biomass
-  lignocellulosic biomass
-  dedicated crops

SECONDARY BIOMASS:

-  microbial biomass
-  aquatic biomass
-  residues from agriculture
-  forest-based industry
-  nature, landscape management
-  recycled bio-based products

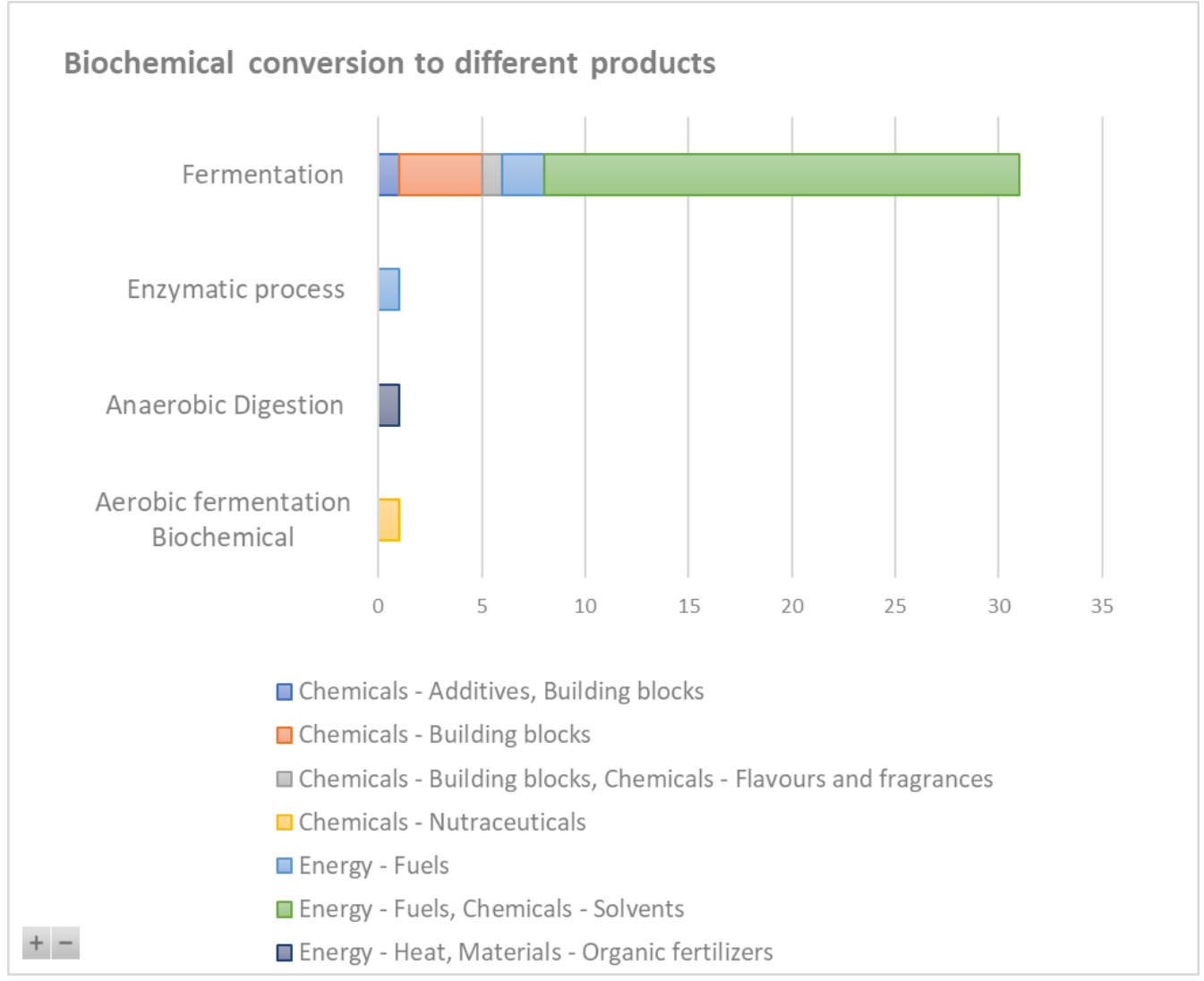


Conversion processes





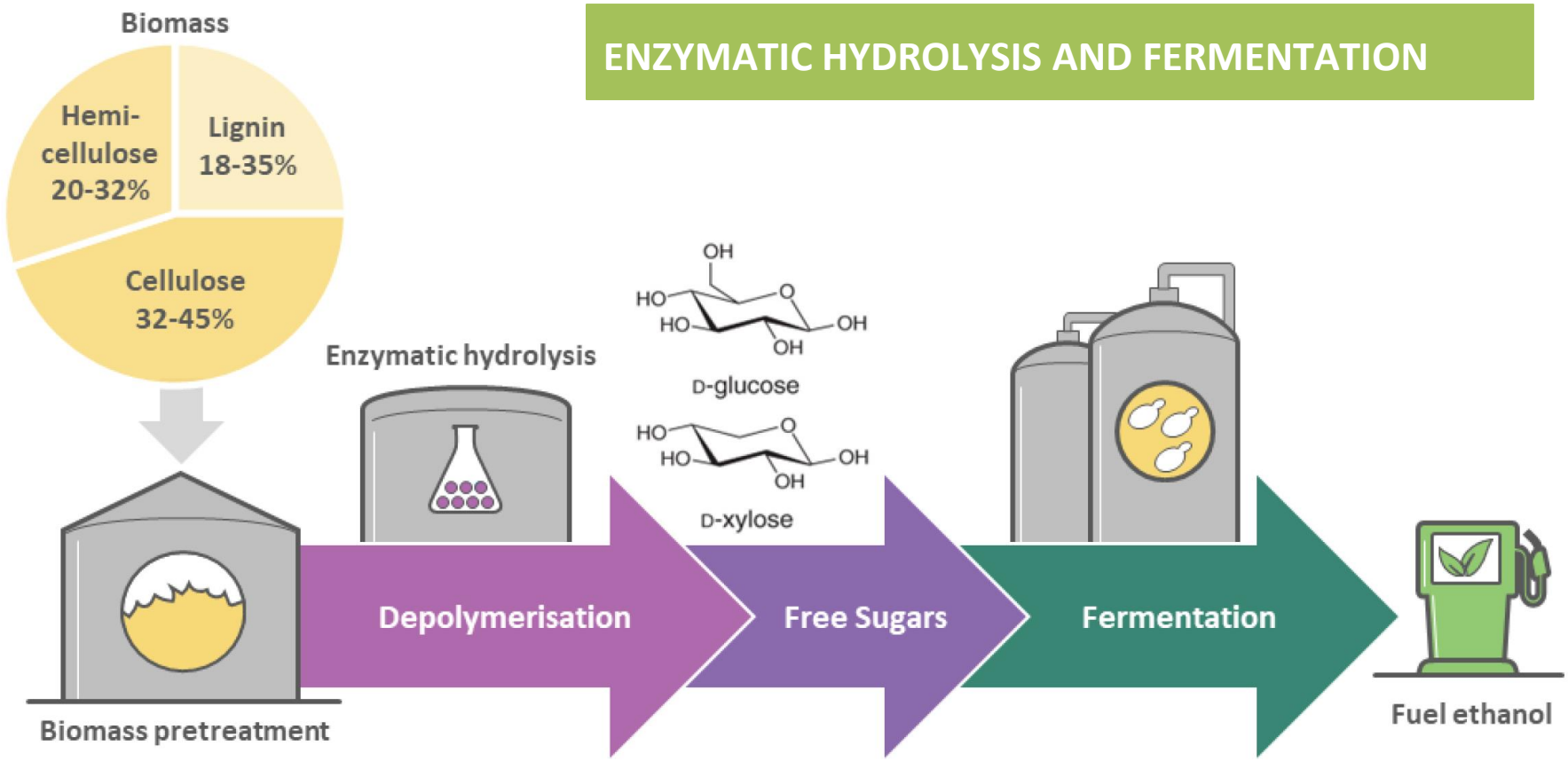
Biochemical conversion processes





Biochemical conversion processes

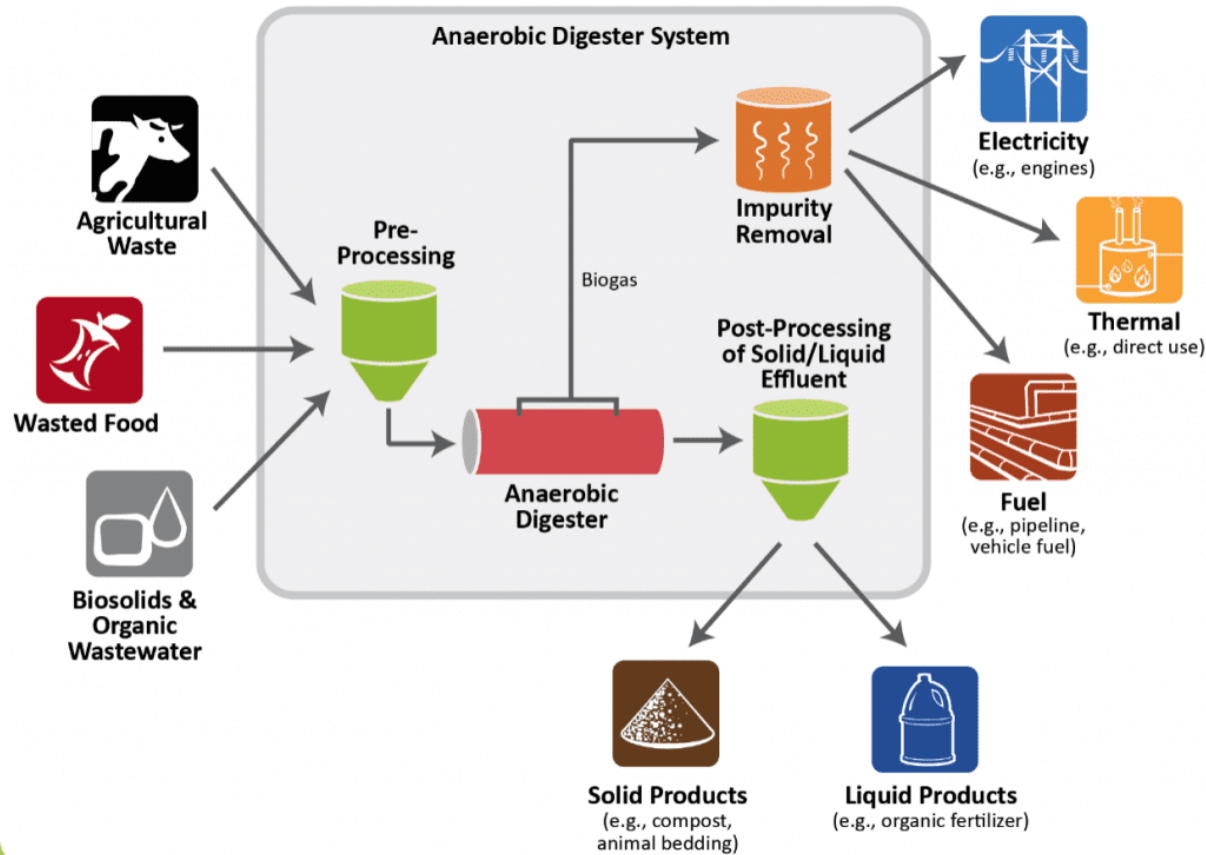
ENZYMATIC HYDROLYSIS AND FERMENTATION



Attfield et al., 2023 (<https://doi.org/10.3390/fermentation9070633>)



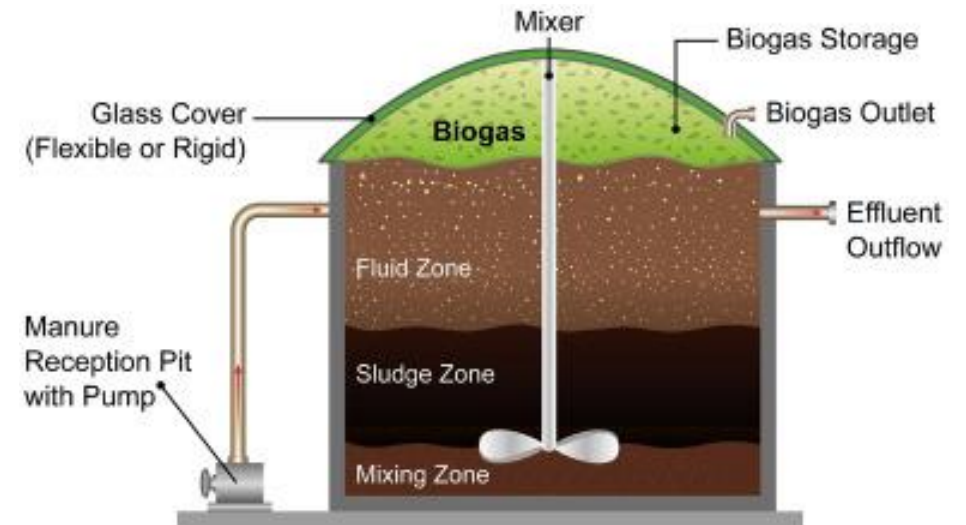
Biochemical conversion processes



Anaerobic Digester System © Copyright Tennessee Department of Environment & Conservation

ANAEROBIC DIGESTION

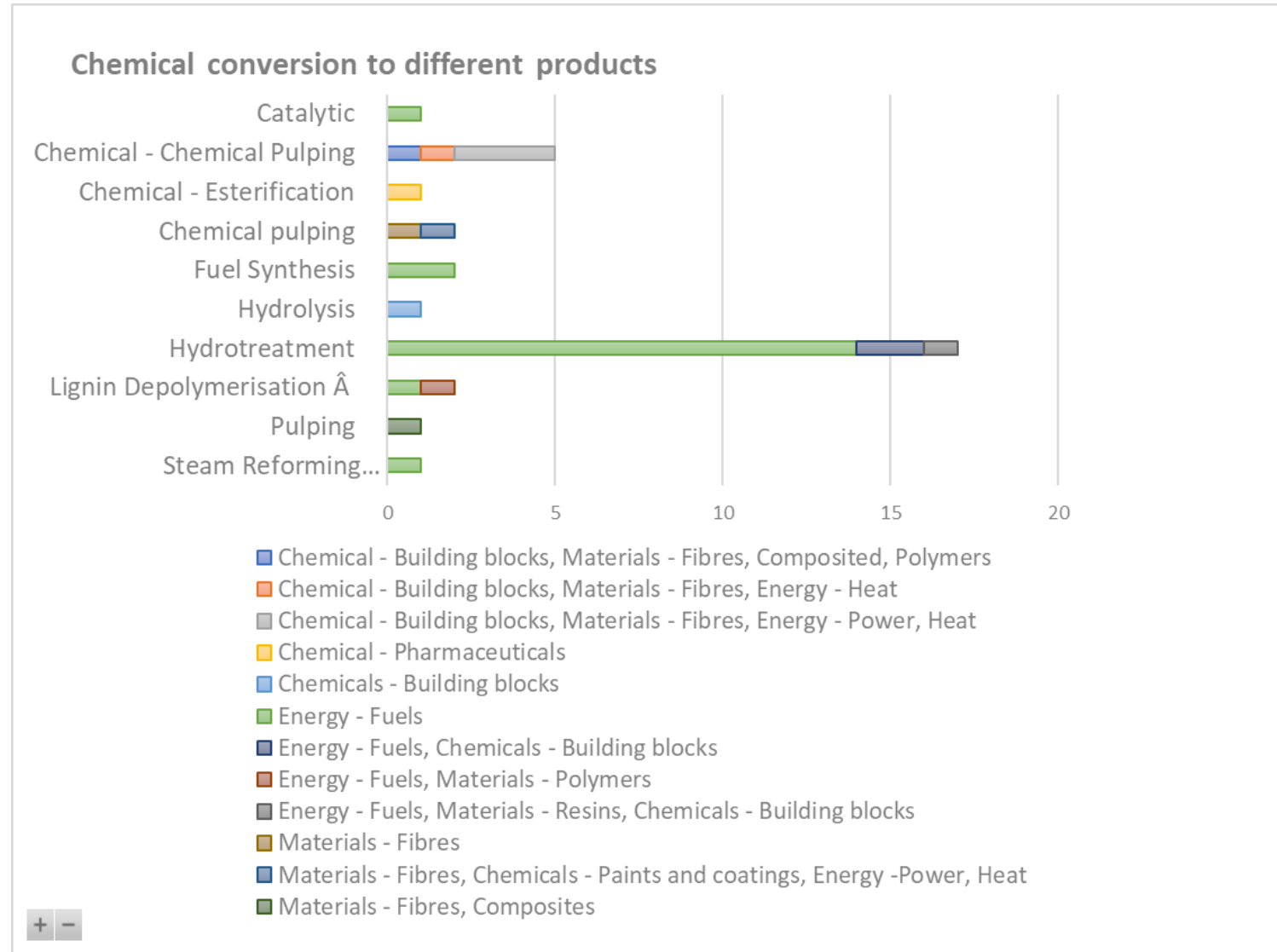
1. **Hydrolysis** (organic polymers to simple sugars)
2. **Acidogenesis** (sugars and amino acids into CO_2 , H_2 , NH_3 , and organic acids)
3. **Acetogenesis** (organic acids into acetic acid, CO_2 , H_2)
4. **Methanogenesis** (to methane and CO_2)



<https://doi.org/10.1016/j.rser.2020.110580>

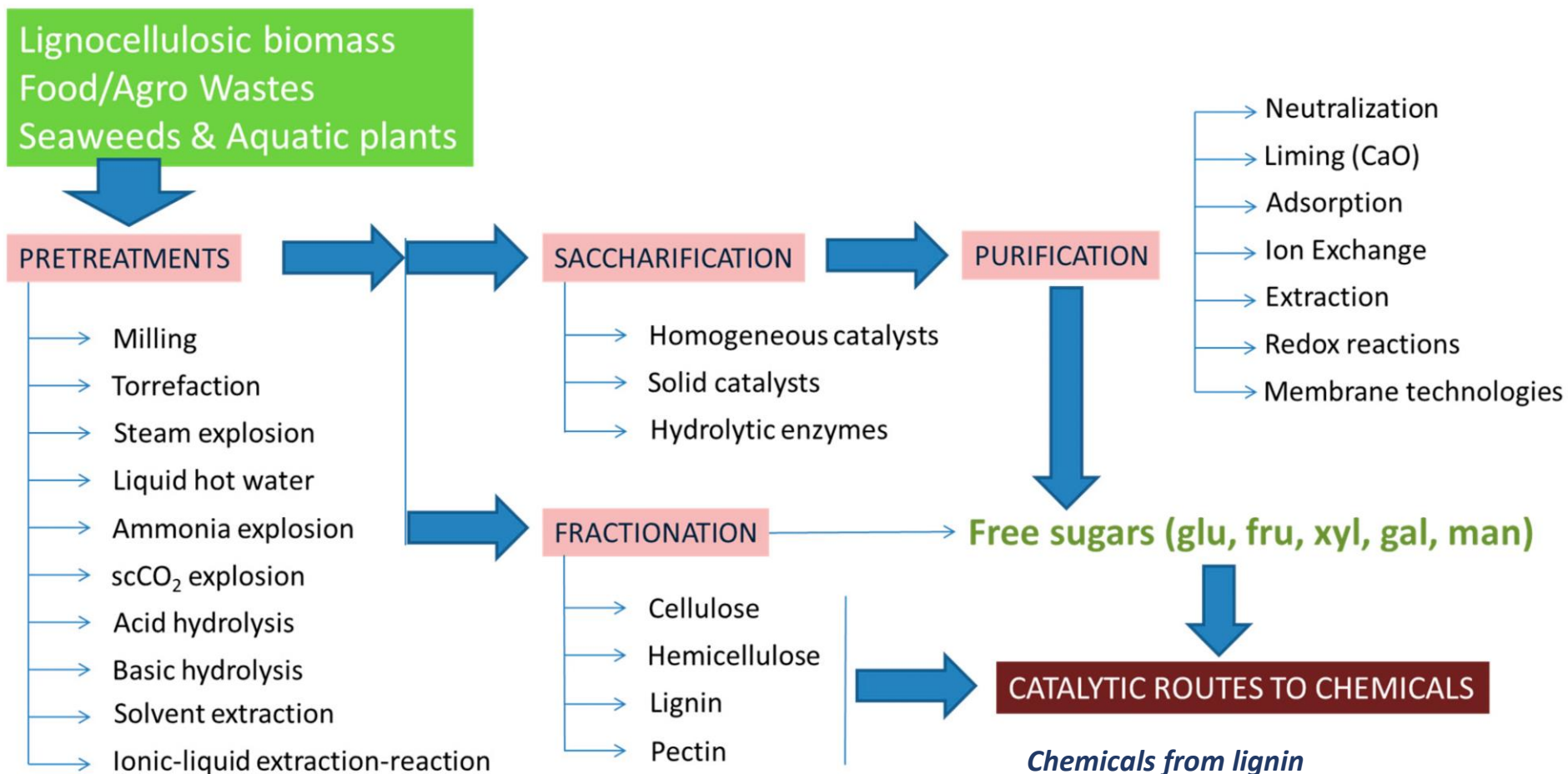


Chemical conversion processes





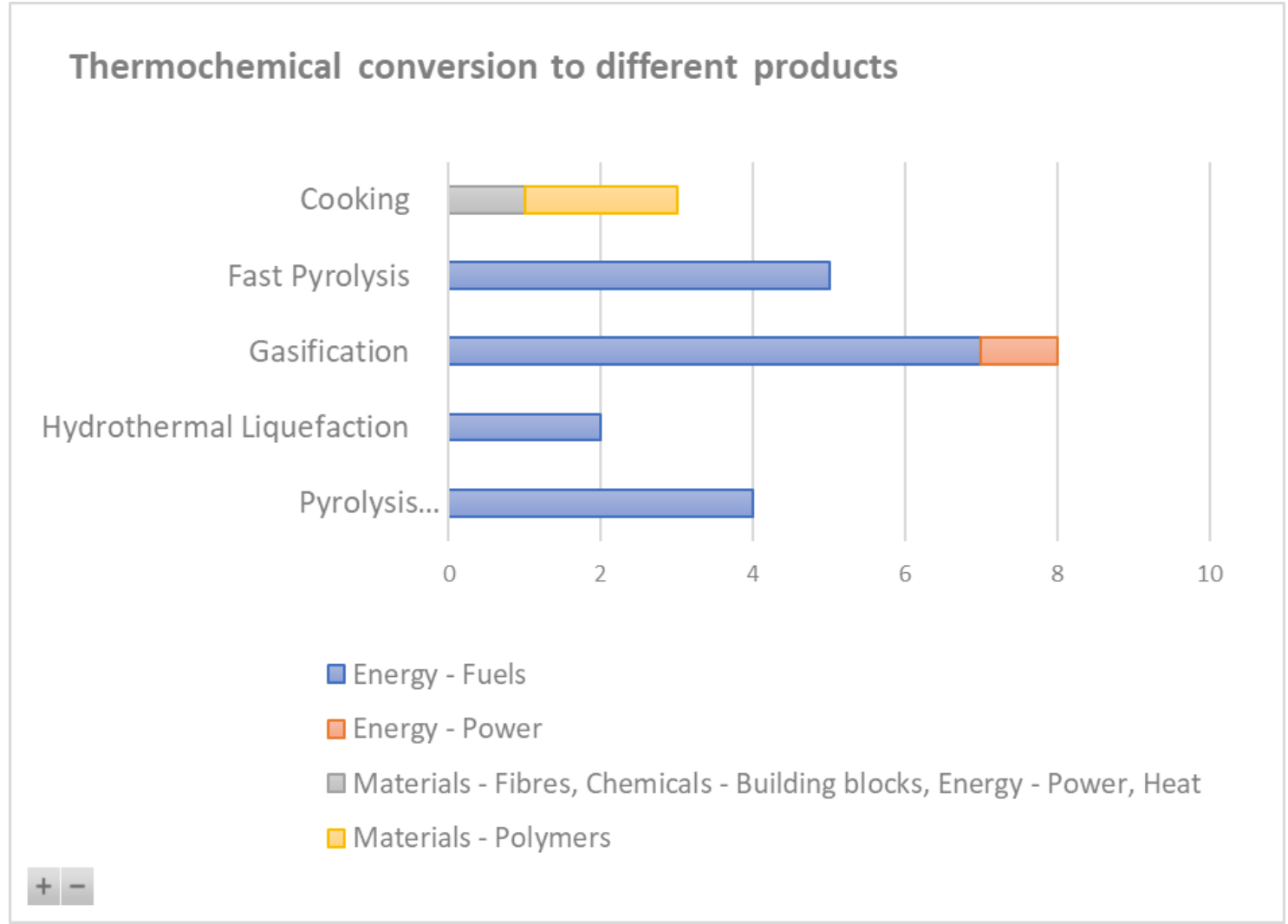
Chemical conversion processes



Esteban et al., 2018
(<https://doi.org/10.3390/catal8120637>)

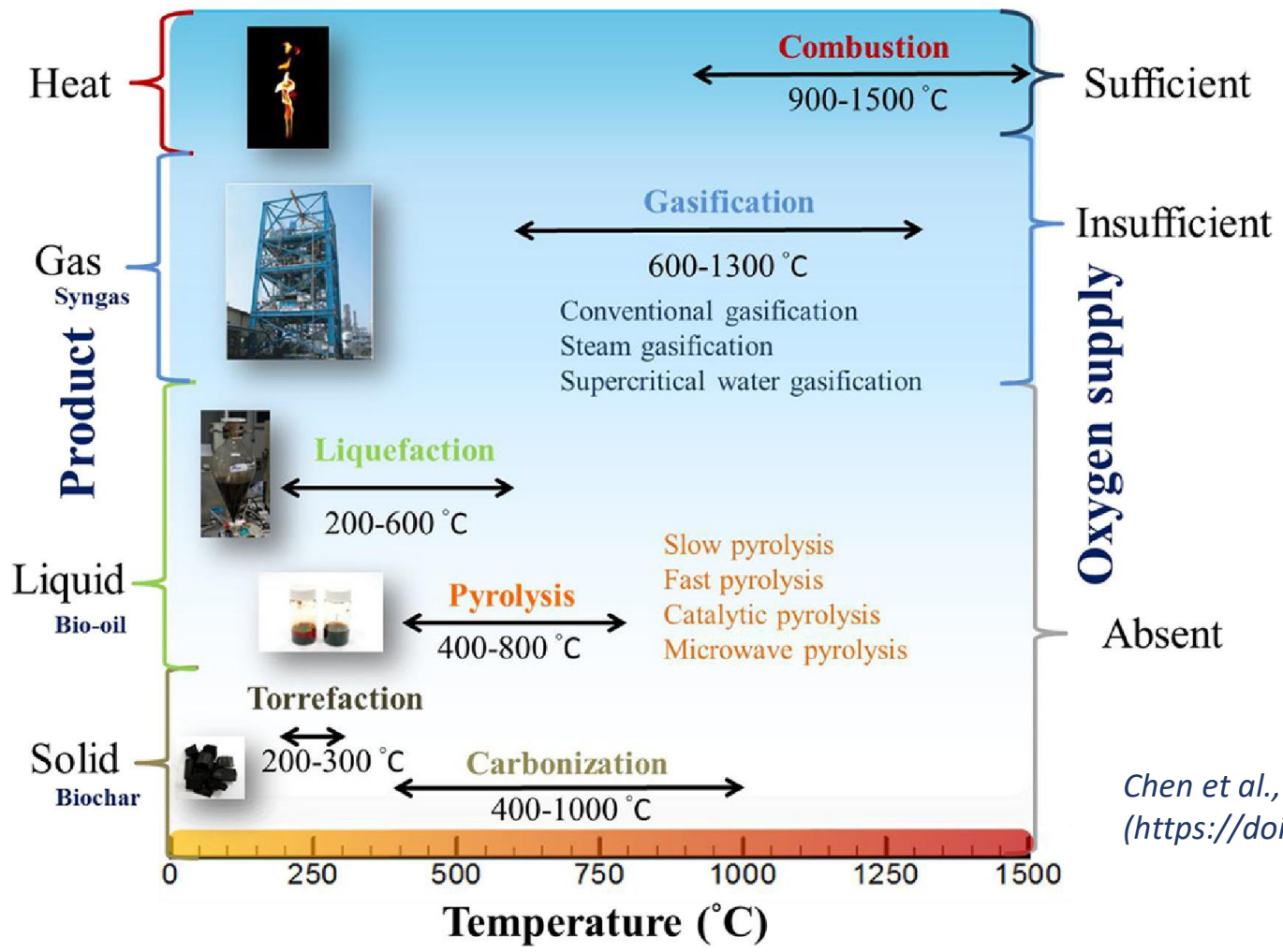


Thermochemical conversion processes





Thermochemical conversion processes



Chen et al., 2021
(<https://doi.org/10.1016/j.pecs.2020.100887>)



Biorefinery platforms

Intermediates linking feedstocks and marketable products

biochar



bio-naphta



lignin



biogas



organic juice / protein



bio-coal



bio-oils / oils



C5/C6 sugars



bio-hydrogen



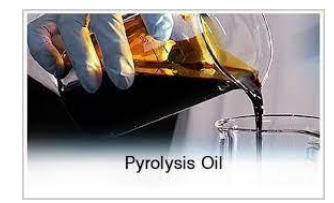
organic fibres



bio-crude



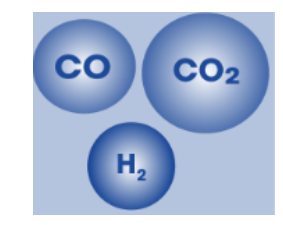
pyrolytic liquid



starch

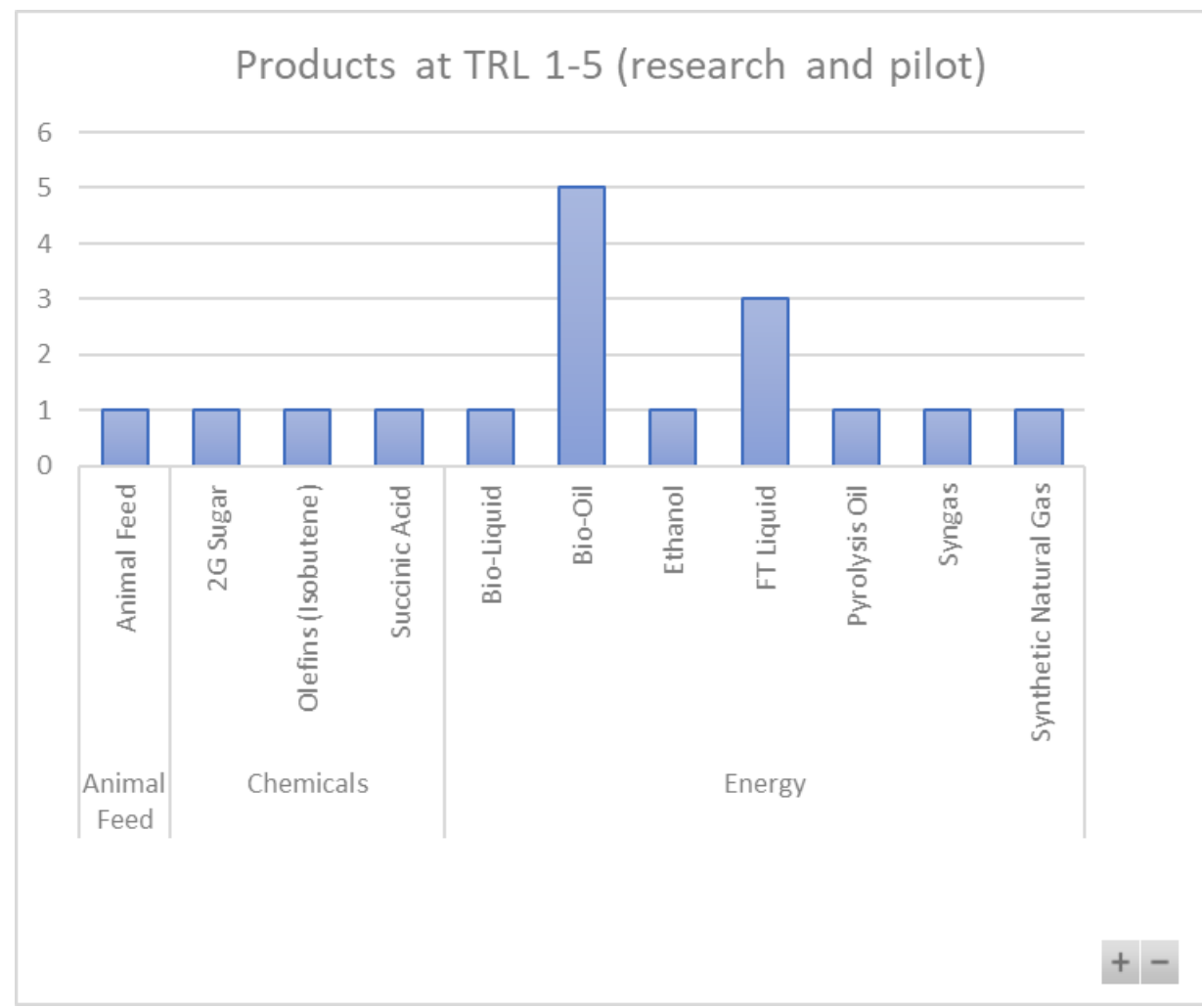


syngas / CO₂





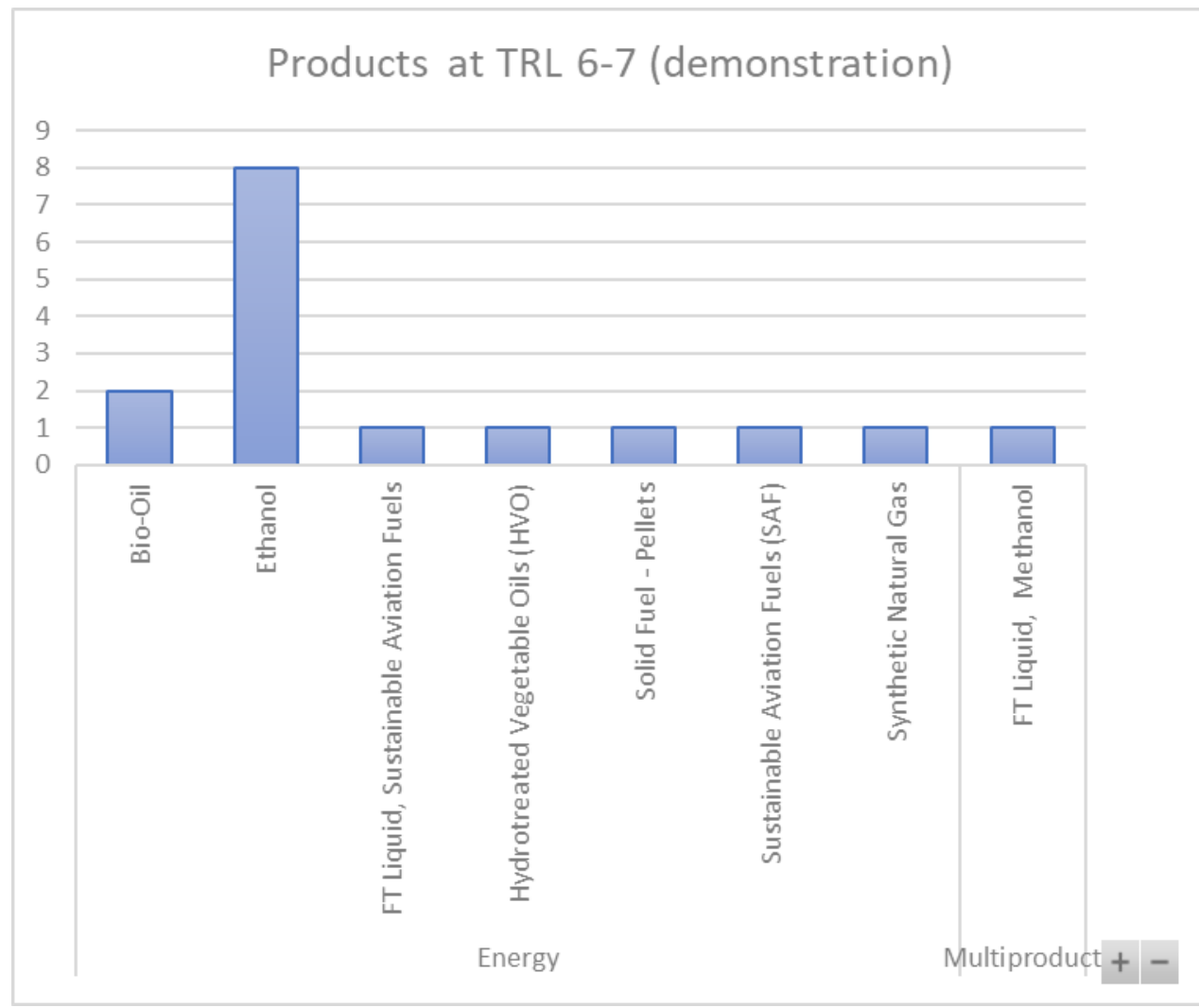
Biorefinery products



Production:
0.0001 ktons/year
up to 10 - 29 ktons/year



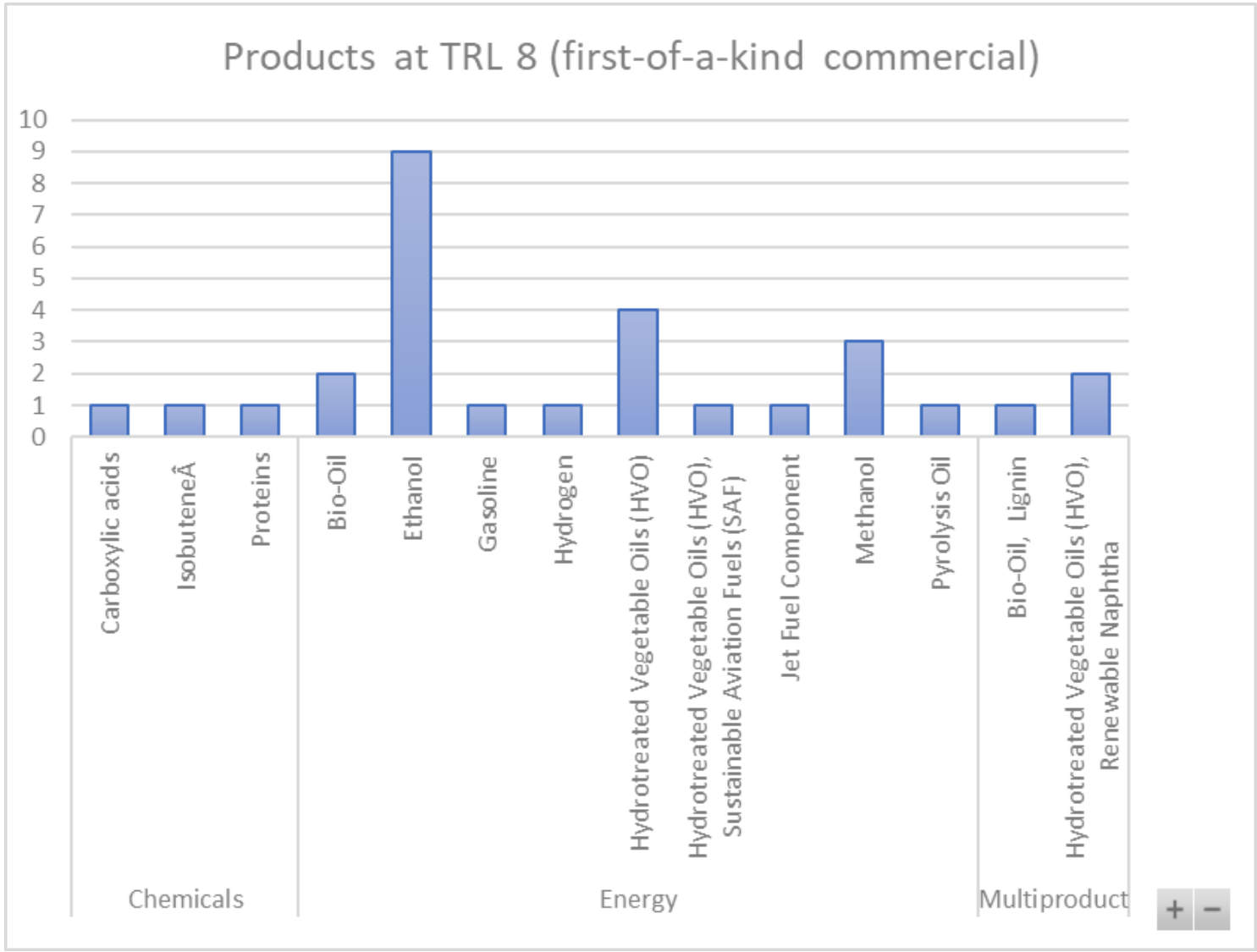
Biorefinery products



Production:
0.0001 ktons/year
up to 167 ktons/year



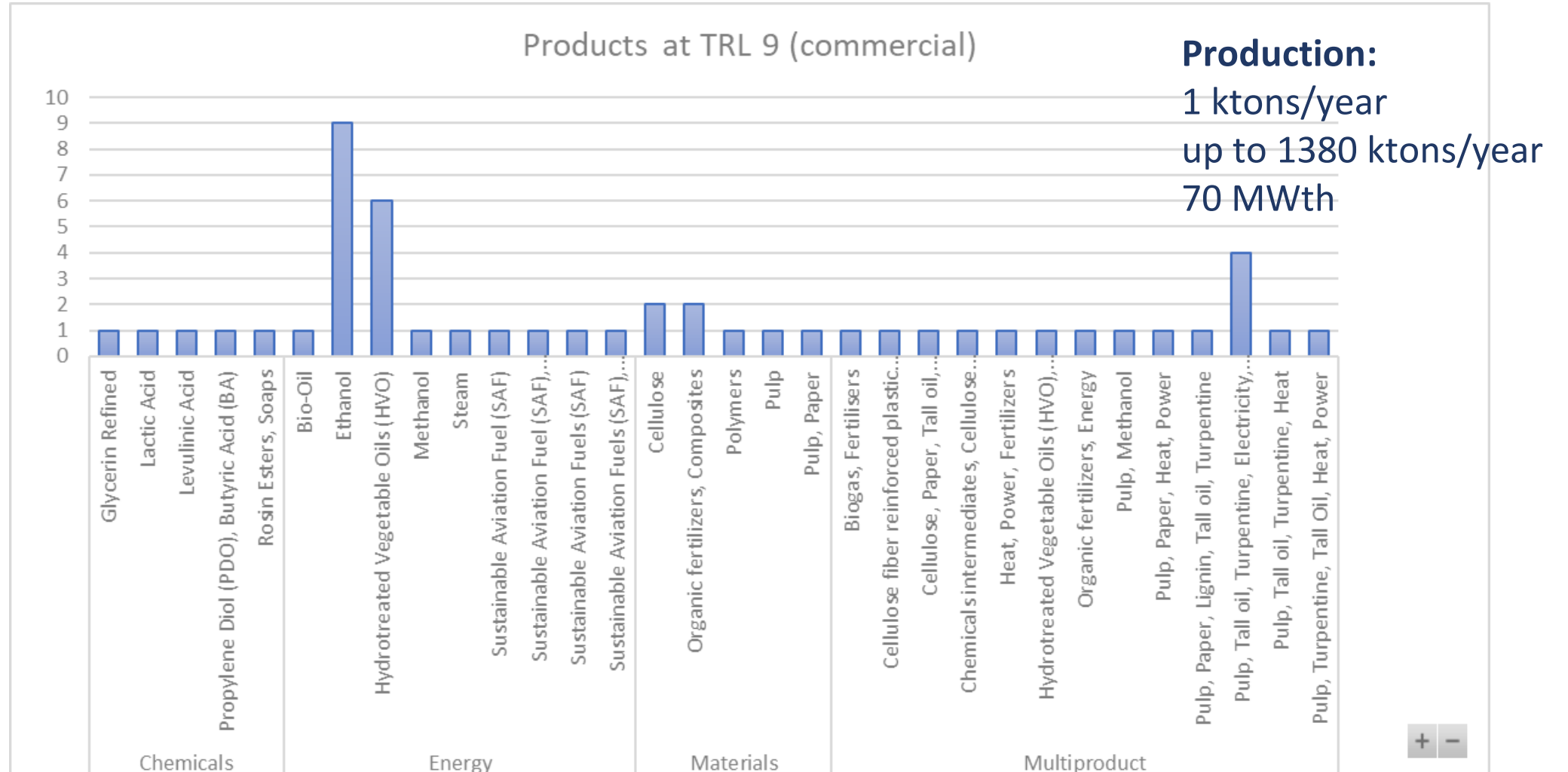
Biorefinery products



Production:
0.0001 ktons/year
up to 800 ktons/year



Biorefinery products

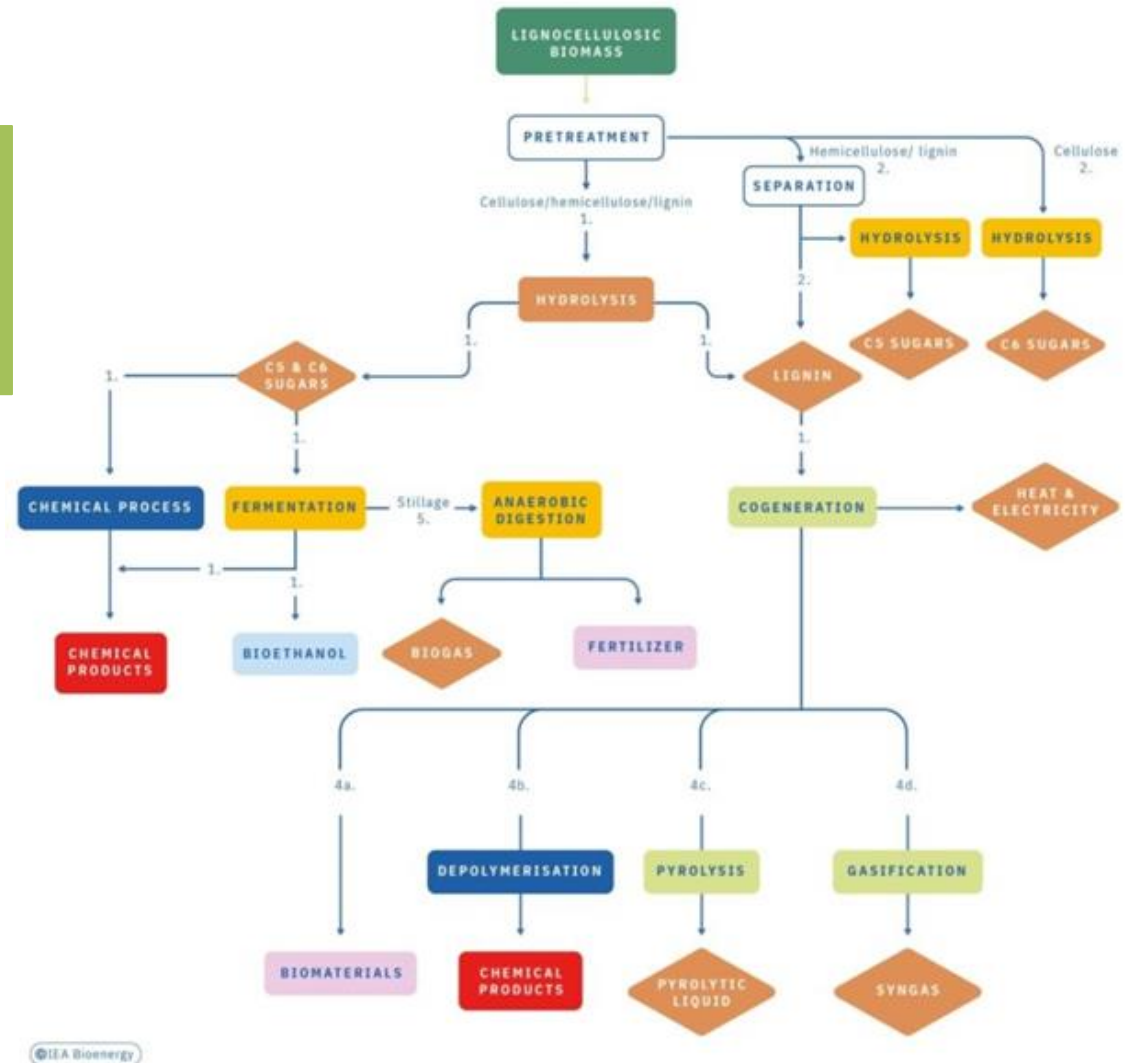




Biorefinery conversion pathways

How the feedstocks are converted into products via platforms and conversion processes

EU Biorefinery Outlook to 2030
(<https://data.europa.eu/doi/10.2777/103465>)



IEA Bioenergy



Biorefinery conversion pathways

BOTTOM-UP APPROACH

Extension/ upgrade of existing biomass processing facility

- | | |
|---|--------------|
| A. One platform (C6 sugars) biorefinery using sugar crops | TRL 9 |
| B. One platform (starch) biorefinery using starch crops | TRL 9 |
| C. One platform (oil) biorefinery using oil crops, wastes and residues | TRL 9 |
| D. Two-platform (pulp and spent liquor) biorefinery using wood | TRL 9 |

EU Biorefinery Outlook to 2030



Biorefinery conversion pathways

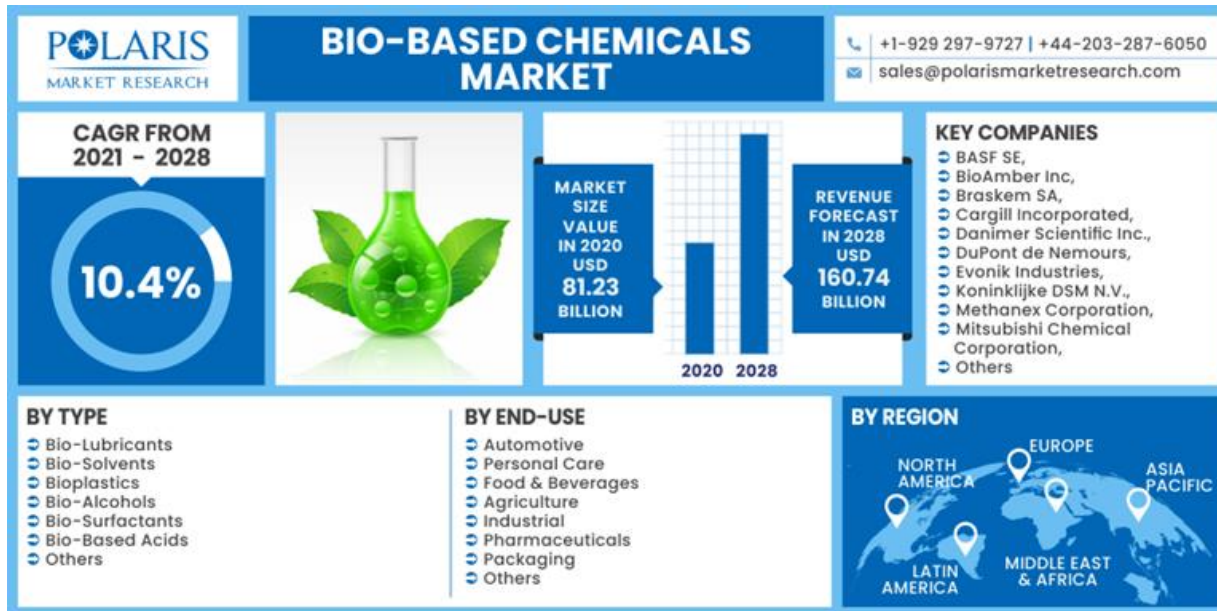
TOP-DOWN APPROACH

New industrial value chains, integrated systems

- E. Three-platform (**C5 sugars, C6 sugars and lignin**) biorefinery using lignocellulosic biomass **TRL 7-8**
- F. Two-platform (**organic fibers and organic juice**) biorefinery using green biomass **TRL 5-7**
- G. Two-platform (**oil and biogas**) biorefinery using aquatic biomass **TRL 5-6**
- H. Two-platform (**organic fibers and oil**) biorefinery using natural fibers **TRL 4**
- I. One platform (**syngas**) biorefinery using lignocellulosic biomass and municipal solid waste **TRL 7-8**
- J. Two platform (**pyrolytic liquid and biochar**) biorefinery using lignocellulosic biomass **TRL 4-5**
- K. One platform (**bio-crude**) biorefinery using lignocellulosic biomass, aquatic biomass and organic residues **TRL 5**



Bio-based chemicals and biopolymers market is growing



GLOBAL BIOPOLYMERS MARKET 2021-2025



17000+ Reports covering niche topics. Read them at [technavio](#)





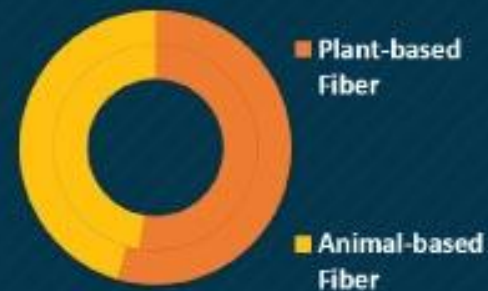
Increased demand for natural fibers

Global Natural Fiber Market

Market Drivers

- Growth in demand for organic and eco-friendly products
- Rise in demand for lightweight materials in automotive sector

By Type



US\$ 4.8 Bn



In 2022 (A)

Market Revenue

CAGR (2023–2031)

7.5%

By End-use



Key Players

- Barnhardt Natural Fibers
- Asha Cotton Industries
- The Flax Company SARL
- Dividan
- Castellins NV
- Jaydeep Cotton Fibers Pvt. Ltd

By Region

- Asia Pacific
 - Largest market share in 2022

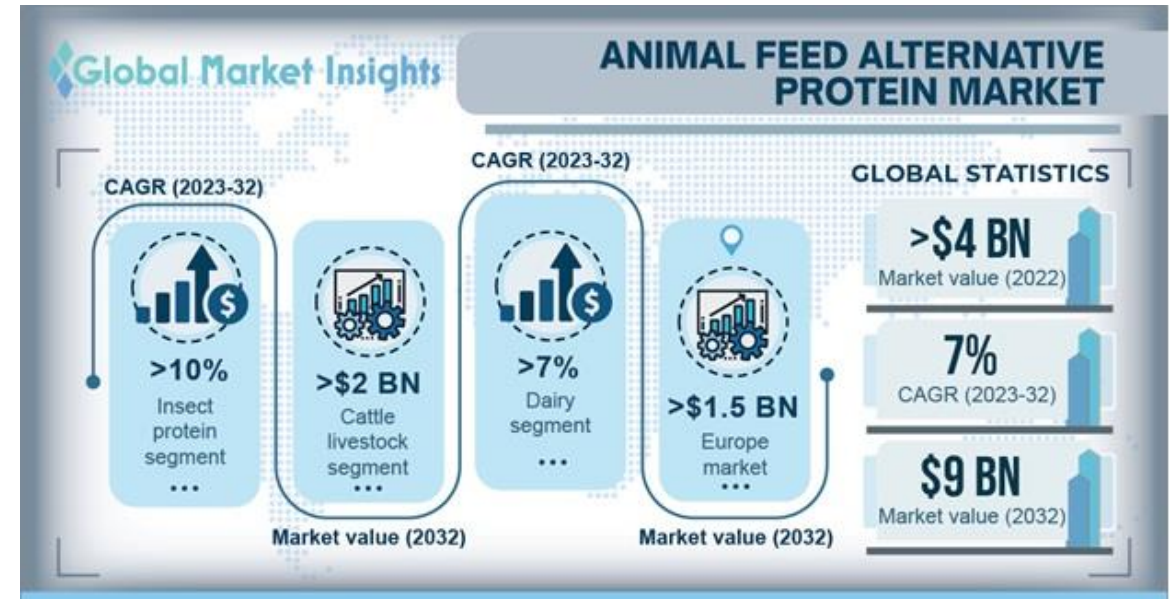
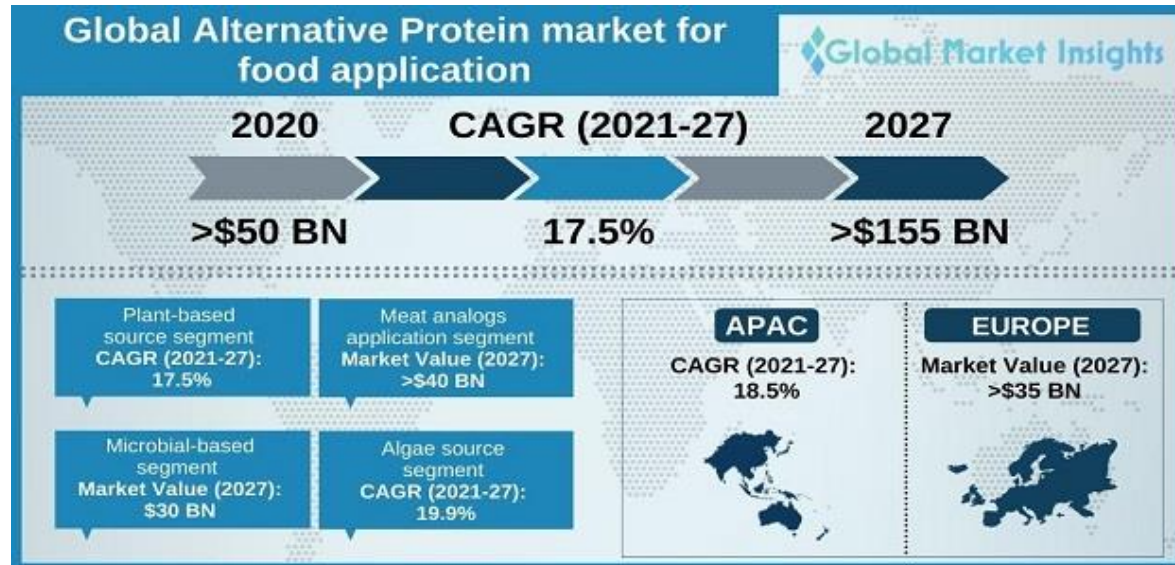


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Alternative protein market





Thank you!



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