EU Biorefinery to 2030

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Sustainability is our business

Some things have changed since 2021

EU Biorefinery Outlook to 2030 was completed in 2021 – the biorefining landscape has changed

E4tech is now ERM (Environmental Resources Management)

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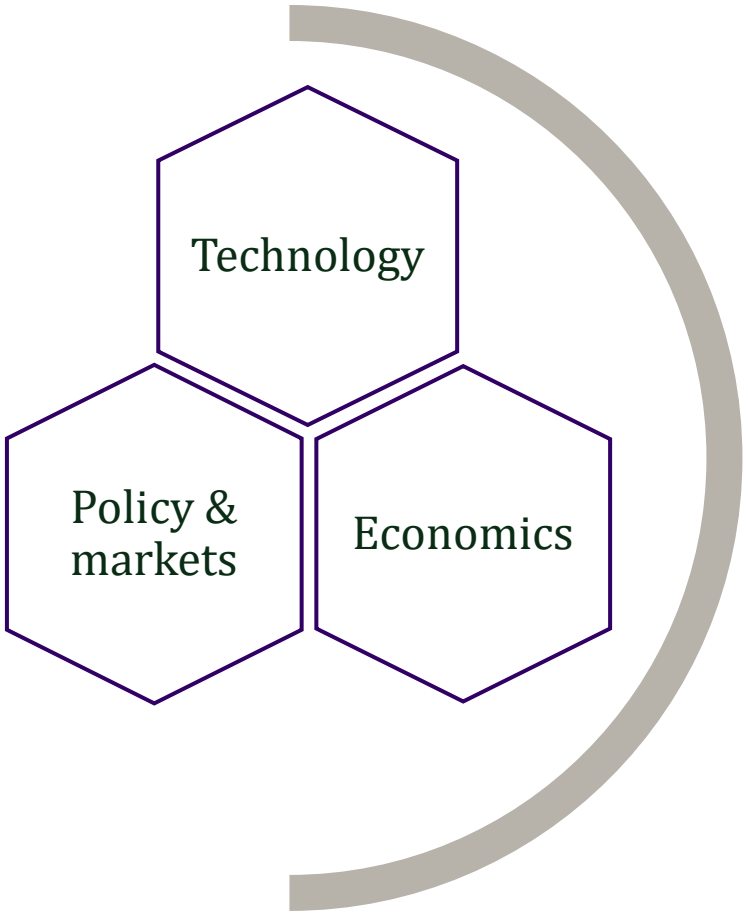
ERM's Sustainable Energy Solutions team has a 20+ year track record supporting clients on energy transition challenges and opportunities



Broad and deep expertise across the low carbon energy system

- Hydrogen
- Electrolysis
- E-fuels
- Biofuels
- Low carbon chemicals
- Chemical recycling
- Liquid organic H_2 carriers
- CO_2/H_2 Transport
- EV charging
- System flexibility
- Electricity, gas & heat networks
- Low carbon buildings
- Low carbon industry
- Low carbon transport
- Fuel cells
- Batteries
- Carbon capture, utilisation, storage
- Engineered CO_2 removals
- Nature-based solutions

Low Carbon Fuels & Sustainable Chemicals

Guiding fuel and chemical industry transitions to low carbon products. Supporting with policy, market and stakeholder demands, emerging technologies and value chains, diversification and growth, investment opportunities, decarbonisation and circularity.

Example Clients

- Airbus
- Avantium
- bp
- British Airways
- Ceres Power
- Dutch Government
- European Bank for Reconstruction & Development
- European Commission
- Goldman Sachs
- IFC
- INEOS
- Johnson Matthey
- LanzaTech
- Q8
- Repsol
- SHV Energy
- Sumitomo Corporation
- Swire
- Toyota
- UK Department for Business,
- UK Department for Transport
- World Economic Forum Low Carbon Emitting Technologies

- LOW CARBON PRODUCT STRATEGIES
- TECHNO-ECONOMIC MODELLING & ANALYSIS
- SUPPLY CHAIN & VALUE POOL ANALYSIS
- MARKET ANALYSIS
- PRE-FEASIBILITY STUDIES
- TECHNICAL & COMMERCIAL ASSESSMENTS

What are defossilised fuels, chemicals and materials?

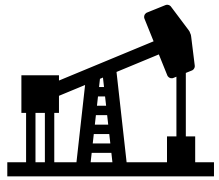
What makes up renewable and recycled (defossilised) products?

...and what are the pros and cons

Green/blue H_2 and atm/biogenic CO_2 could lead to carbon-neutral or negative embodied emissions.

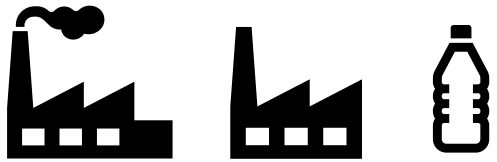
Access to green/blue H_2. Efficiency and cost of atm CO_2.

CO_2 H_2



Options to mitigating process emissions using CCUS, electrification and renewable electricity use, green/blue hydrogen or bioenergy. Also alternative processing technologies

Retrofitting and costs



Litter, landfill, incineration: undesirable for GHG and wider environmental reasons

Sustainable biomass feedstock could lead to carbon-neutral or negative embodied emissions.

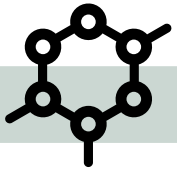
Competition for other uses and challenges securing supply.

Careful consideration of sustainability.

Mechanical recycling typically has low GHG emissions

Degradation and downgrading

Contamination and mixing



Often “Virgin-like” quality and can accept more materials

Typically higher GHG emissions than mechanical recycling

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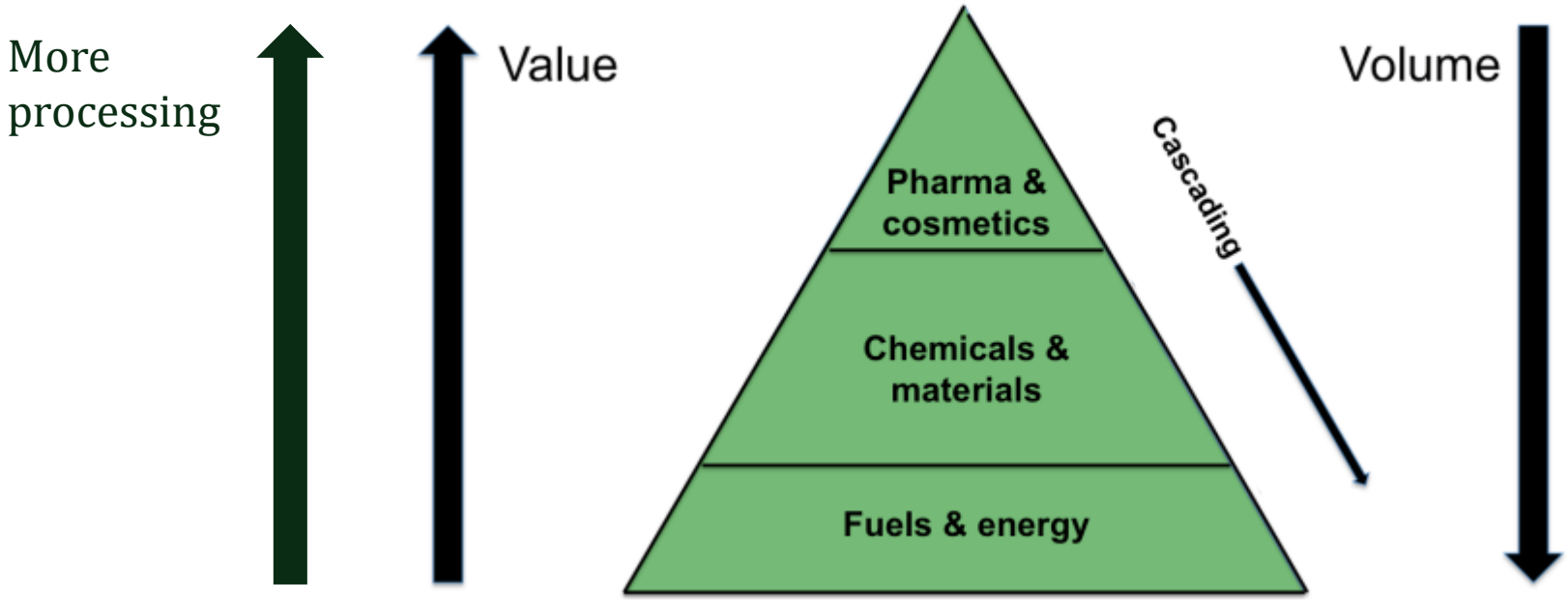
Biorefining to produce chemicals and materials

Cascading uses of biomass can lead to higher returns, lower resource use and reduced GHG emissions



The sustainability of the biomass remains crucial
Residues/wastes are preferred with no/low land use change

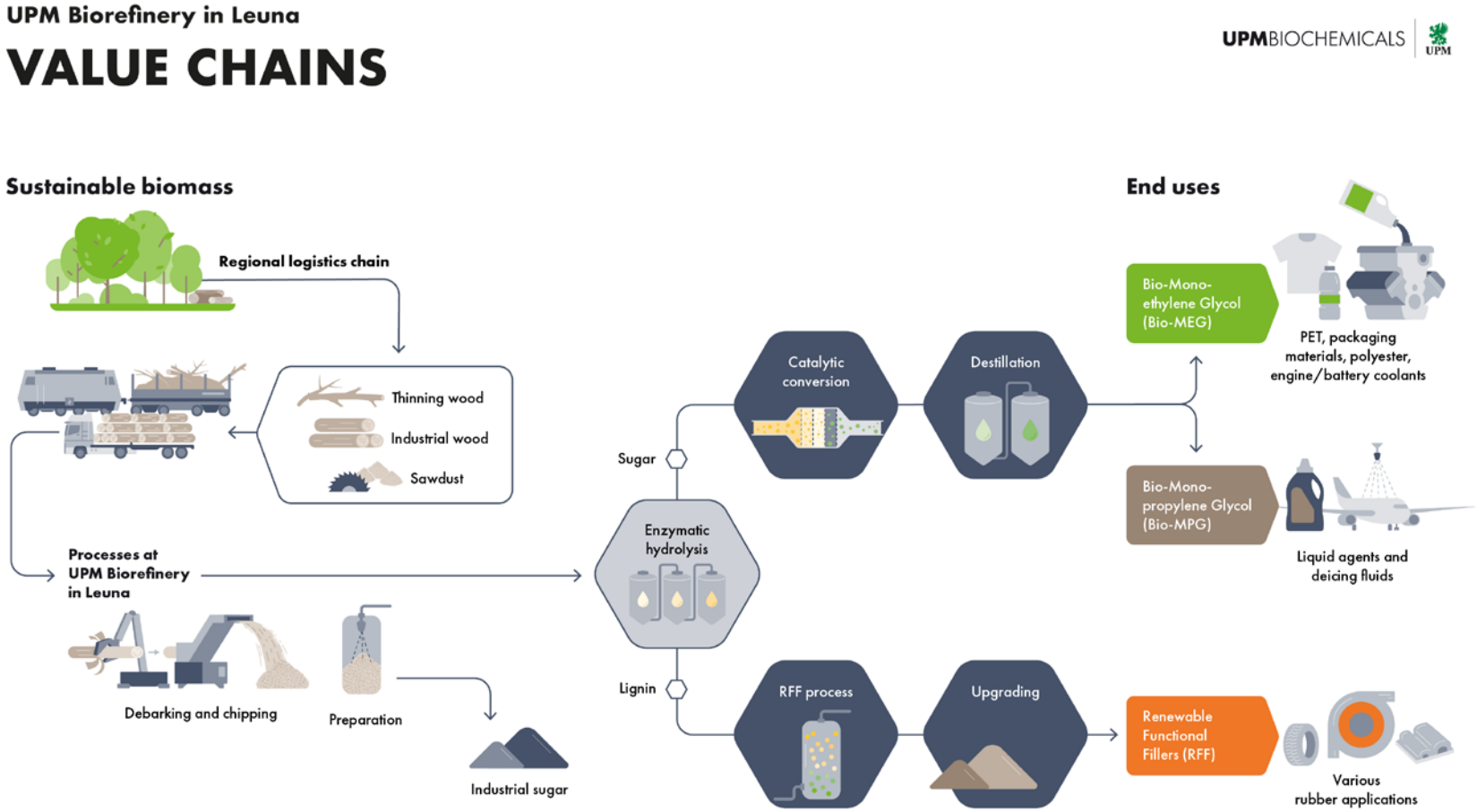
Source: adapted from Vis et al (2014)

Biomass conversion can produce multiple types of products via different technologies at varying levels of maturity from a range of biomass feedstocks

Many of the processes/technologies are also being applied to other biomass and plastic wastes

FEEDSTOCK	CONVERSION PROCESS	PRODUCT
Primary biomass • Aquatic biomass • Lignocellulosic from croplands and grasslands • Lignocellulosic wood/forestry • Oil crops • Starch crops • Sugar crops • *Other **Secondary biomass** • Microbial biomass • Residues from agriculture • Residues from aquatic biomass • Residues from forestry • Residues from nature and landscape management • Residues from recycled bio-based products • *Other	**Biochemical** • Aerobic conversion • Anaerobic digestion • Enzymatic process • Fermentation • Insect-based bioconversion • *Other **Chemical** • Catalytic • Esterification • Hydrogenation • Hydrolysis • Methanation • Chemical Pulping • Steam reforming • Water electrolysis • Water gas shift • *Other **Mechanical and thermomechanical** • Blending • Extraction • Mechanical & thermomechanical disruption & fractionation • Mechanical pulping • Separation processes • *Other **Thermochemical** • Combustion • Gasification • Hydrothermal liquefaction • Pyrolysis • Supercritical conversion • Torrefaction & Carbonization • *Other	**Chemicals** • Additives • Agrochemicals • Building blocks • Catalysts & Enzymes • Colorants • Cosmeceuticals • Flavours & Fragrances • Lubricants • Nutraceuticals • Paints & Coatings • Pharmaceuticals • Solvents • Surfactants • *Other **Materials** • Composites • **Fibers • Organic Fertilizers • Polymers • Resins • *Other **Food** **Animal Feed** **Energy** • Cooling agents • Fuels • Heat • Power • *Other

UPM is building a large biorefinery using beech wood in Germany



Source: UPM

Clariant's cellulosic ethanol plant in Romania is to close

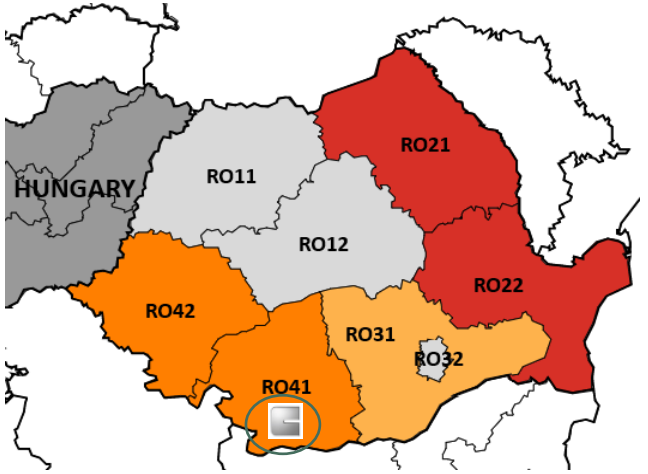
December 06, 2023

Clariant shuts its sunliquid® bioethanol plant in Romania

Ad hoc announcements pursuant to Art. 53 LR | Corporate | Global

AD HOC ANNOUNCEMENT PURSUANT TO ART. 53 LR

- **Strategic review concluded: Board of Directors has decided to close bioethanol plant in Podari, Romania, and to downsize related activities in Germany**
- **Asset impairments of approximately CHF 110 million and provisions relating to closure of approximately CHF 60 – 90 million in Q4 2023**
- **Anticipated cash impact of CHF 110 – 140 million in 2024**
- **Continued focus on execution of Clariant's purpose-led growth strategy**

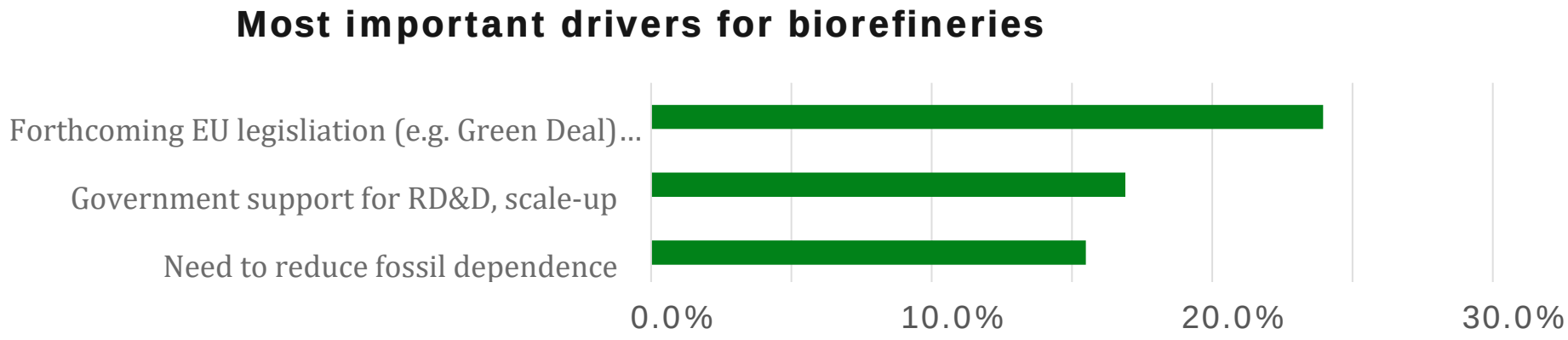


- Clariant's commercial scale cellulosic ethanol plant in Podari, Romania commenced operations in June 2022. Construction commenced in September 2018.
- It uses Clariant's Sunliquid technology and can process 250 ktpa of cereal straw to produce 50 ktpa of cellulosic ethanol.
- Long-term contracts with more than 300 farmers (usually within a radius of 80km)
- Harvesting operations including baling, transport and storage, are being coordinated, managed and monitored digitally
- Clariant's Podari site is ISCC EU and the requirements of the RED II.

Source: Clariant

What are the drivers and barriers/challenges for biorefining?

Stakeholders identified the main drivers as environmental policy, government support and reducing fossil feedstock use



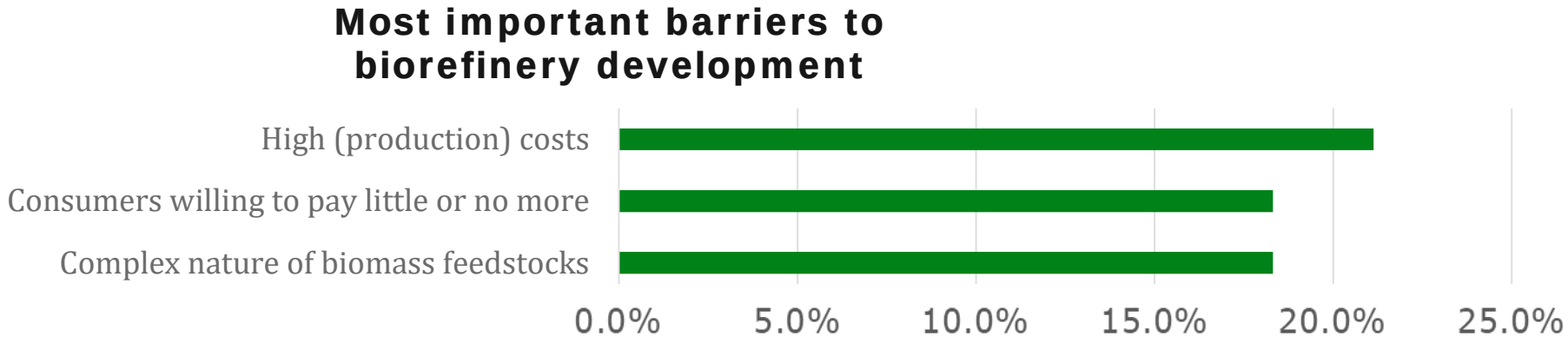
Source: stakeholder engagement as part of EU Biorefinery Outlook to 2030 project for the European Commission

Drivers for circularity and renewability are increasing…

…and some drivers are different since 2021

- Net zero ambitions – focus today is Scopes 1+2 today. More companies are working on Scope 3
- Ban and taxes on single use plastics
- Extended producer responsibility (EPR) – plastics focus
- Bio-based and recycled content targets
- Green procurement – mainly brand owners and some governments
- Emissions Trading Schemes and Carbon Boarder Adjustment Mechanism – increased carbon price in existing schemes and possibility of wider coverage. New ETS in planning in some countries/regions
- Sustained higher crude oil prices?

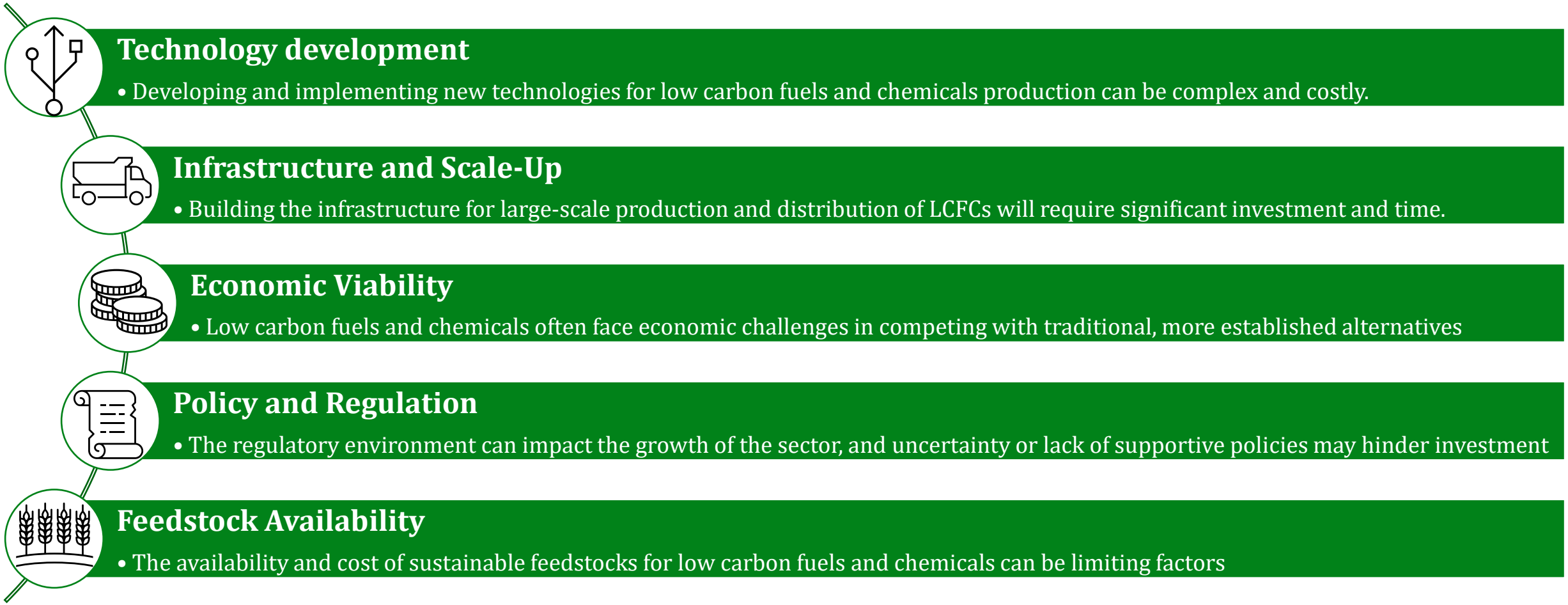
The main barriers and challenges are economic viability related



Source: stakeholder engagement as part of EU Biorefinery Outlook to 2030 project for the European Commission

Key challenges

...as well as uncertainty related to policy and technologies



Sustainable and low-cost feedstock at the right quality is key to success

- Biomass **feedstock** is often a limiting factor of **capacity** and a major factor in **economics**
- The **availability of biomass** can be influenced by many **factors** including the distance to feedstock source, mobilization of feedstocks/supply infrastructure, management practices, harvesting practices and machinery, as well as seasonal and annual variations in biomass yields.

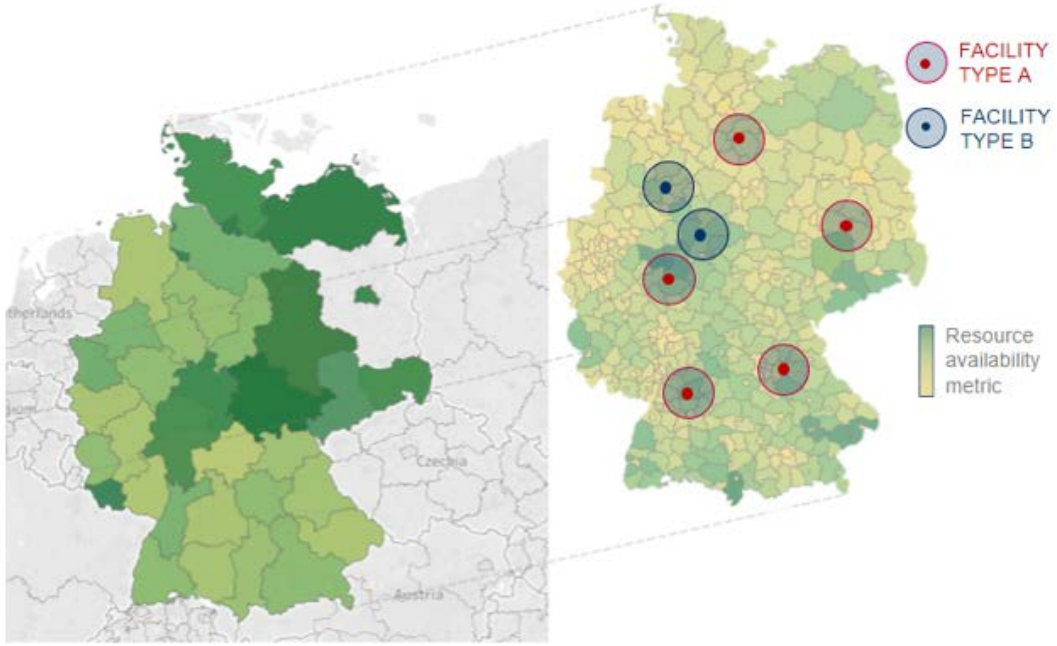


Illustration of resource mapping for biorefineries for a given economic collection radius

The type of investment needs to be considered to estimate the capital investment of a biorefinery

For the same process technology, the CapEx tend to follow this order:

Highest Capex

Greenfield biorefinery

New biorefinery on a **brownfield site** (lower capex from shared services such as steam, water, power, storage, logistics etc…) e.g. UPM Leuna, Germany

Re-purposing/conversion of a plant on existing **brownfield** site (highly project dependent as it only some equipment can be reused) – e.g. Green Biologics to converted a US ethanol plant to n-butanol and acetone facility in 2015 – now closed

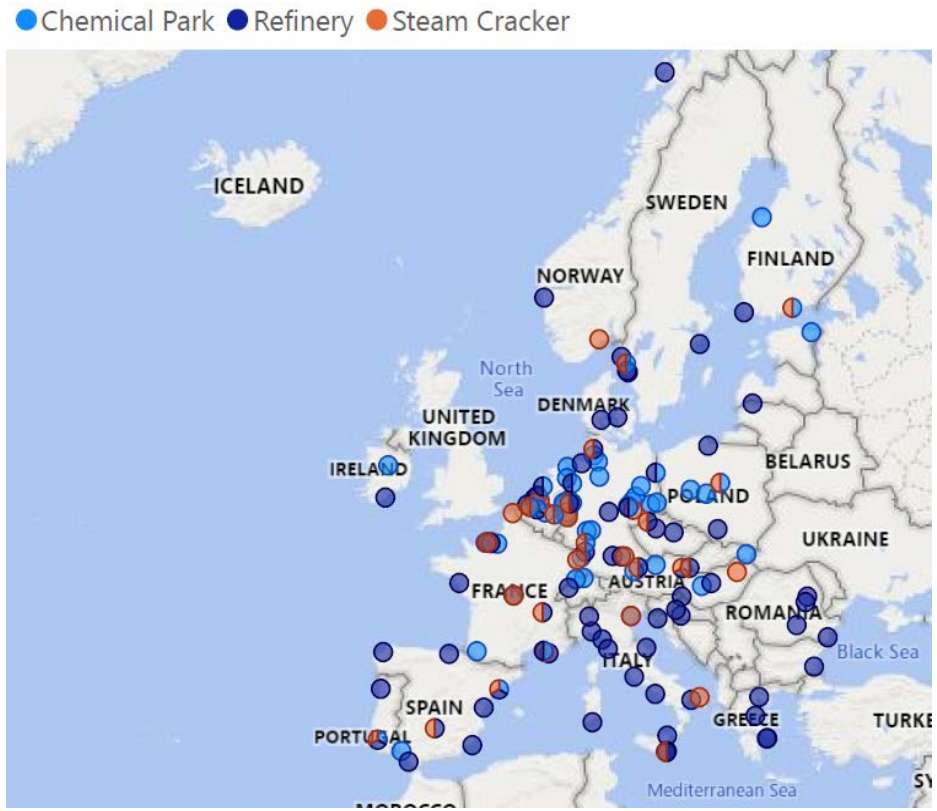
Expansion of a biorefinery on a **brownfield site** (e.g. valorizing a side stream) – capacity increase often limited

Debottlenecking (improving processes, revamping or new equipment) to increase the capacity of existing biorefineries - capacity increase is limited however

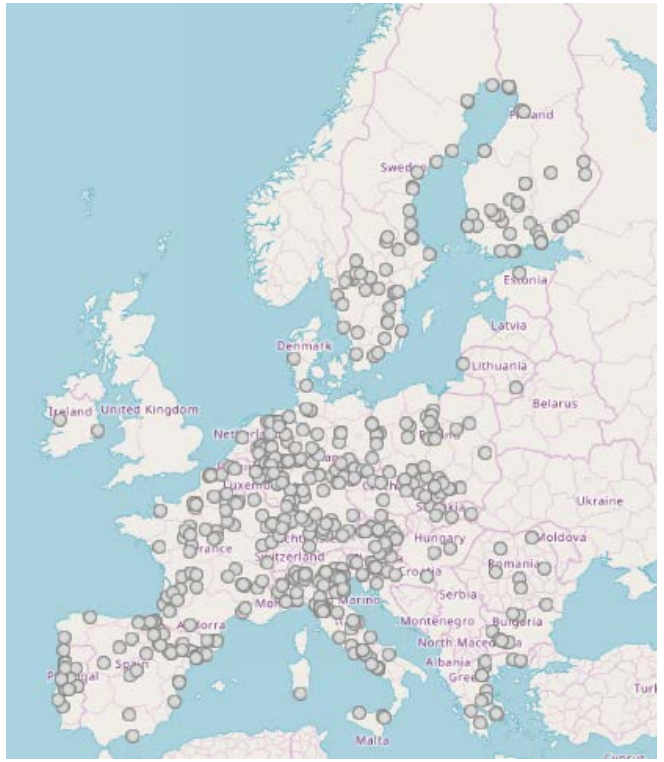
Co-processing / refocus of existing plants from fuels to chemicals (drop-in such as methanol)

Lowest capex

There are many existing brownfield sites in the EU that could be candidates for biorefinery development



Map of chemical parks, steam crackers and crude refineries in the European Union *(Source: Oil&Gas Journal Database, Enerdata Refinery Database, Petrochemicals Europe, European Chemical Site Promotion Platform)*



Pulp and Paper mills in the European Union *(Source: JRC Bio-based industry visualiser, 2020)*

Timber manufacturing in the European Union *(Source: JRC Bio-based industry visualiser, 2020)*

Note: Sugar and starch processing facilities in the European Union also included in the report but not shown here

What else needs to be achieved to accelerate deployment?

- **Policy** and **regulation** is **essential** to close the large gap between the **market's willingness to pay** and **bio-based chemicals** and **materials** production **costs**
- Supporting **RD&D** and **feedstock sourcing** can help accelerate **cost reduction**
- **Public finance** for RD&D and scale up is crucial to **commercialise less technically mature** pathways
- **Environmental** benefits need to be **measured** and broadly understood by all stakeholders

What does this mean for you?

- Biorefining project development:
  - Who could be your **partners**?
  - What levels of **biomass** could be required? Is the biomass **available**?
  - Identification of a **market need**
  - What would a viable **business model** look like?
  - Are there **existing industries** to work with?
- What **support** is available?
- Monitor **policy** developments

Thanks!

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