EU Biorefinery Outlook to 2030

Studies to support R&I policy in the area of bio-based products and services

FINAL PRESENTATION AND MEETING
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EU Biorefinery Outlook to 2030
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Introduction
Structure and objectives of the study
This project is part of three studies for The Directorate-General for Research and Innovation (DG RTD)

The overall objective is to provide a range of new information and analysis that will help identify future policy directions, emerging technologies, societal demands, challenges and opportunities in the fields of the Bioeconomy related to bio-based products and the bio-based innovation.

Hence, DG RTD has commissioned three studies on support to R&I policy in the area of bio-based products and services:

**LOT 1** – Carbon economy

**LOT 2** – Life and biological sciences and technologies as engines for bio-based innovation

**LOT 3** – Biorefinery pathways and outlook for deployment (lot 3) “EU Biorefinery Outlook to 2030”
The study can be used to help make decisions & take actions to accelerate biorefinery deployment to 2030

AIM: To provide an **outlook for chemical and material driven biorefineries** enabling **stakeholders** such as the scientific community, industry (primary producers and manufacturers), investors, policymakers, and NGOs to take the present-day **decisions** necessary to **shape the future** sustainable bioeconomy
The study’s seven WPs meet the objectives of the EU Biorefinery Outlook to 2030 study...

- **Describe, categorise** and **develop** a robust **classification system** for different types of biorefineries and the products they could produce considering the needs of a range of stakeholders, including policy and decision makers in the EU and regional level

- **Report** on the **status of biorefinery development** and the **markets** for related bio-based chemicals and materials

- **Determine** the **attractiveness of different bio-based products** and their **market potential** (demand) based on **drivers** and benefits of **chemical and material driven biorefineries**, bio-based products and the applications and markets they could access

- **Identify** the technical and market **barriers** that need to be overcome to commercialise biorefineries

- **Identify** the **R&D&I needs** of biorefinery pathways and future **policy actions** that could incentivise their uptake
Develop scenarios for the potential ramp up of biorefinery deployment in Europe to 2030 taking into consideration technology, market and resource considerations as well as considering the policy lines of the European Green Deal.

Develop a roadmap for biorefinery deployment in the EU to 2030 segmented by biorefinery pathways, including the number of biorefineries, installed capacity by volume and capital investment in new biorefinery construction, type of actions required by different actors, and impact in terms of sustainability (GHG savings potential) and societal benefit (local jobs).

Engage relevant stakeholders in activities aimed at meeting above objective and develop communication materials to effectively communicate the outputs of the study.

WP5
WP6 with inputs from WP 1-5
Stakeholder Engagement & WP7
The study will be disseminated through partners websites, stakeholders, social media, and conferences

- The “EU Biorefinery Outlook to 2030” report will be made available for download from the dedicated webpage https://www.e4tech.com/biorefinery-outlook.php together with a link to the project video
- The study results will be disseminated by consortium partners through the partners organizations’ social media and websites. Sister projects will be approached by ICONS
- The database will be published by the JRC and BTG via a dashboard and short technical report
- All the participants in the workshops and SAG meetings will be informed
- As of February 2021, participation to the following events is planned:
  - Moving Towards a Competitive European Bioeconomy: Emerging Biorefinery Technologies & Pathways to Deployment (virtual conference) – 17/02/2021;
  - EUBCE 2021 (WP4 database presentation led by JRC and BTG - virtual conference) – 26-29/04/2021
  - Renewable Materials Conference 2021 (TBC - abstract submitted) – 18-20/05/2021.
- Shared to online external news multipliers with distribution agreement with ICONS.
EU Biorefinery Outlook to 2030 video
A consortium of 5 partners has developed the study over 14 months with 8 stakeholder events...

WP1: Biorefinery classification
Classification system for chemical and material driven biorefineries

WP2: Drivers and barriers for biorefineries
General and specific drivers and barriers for chemical and material focused biorefineries

WP3: Available and emerging biorefinery technologies and R&I needs
Analysis of different biorefinery pathways and R&D&I needs to overcome the barriers

WP4: EU and global biorefinery deployment
Database of key companies and their associated plants, existing and planned

WP5: Market prospects for biorefineries and scenarios to 2030
Demand outlook for biochemicals and biomaterials and supply ramp up for biorefineries

WP6: EU biorefinery outlook and roadmap for deployment
A roadmap with the actions needed to achieve the biorefinery outlook for deployment

WP7: Information and communication strategy
Communication of the project's results and key actions for stakeholders to drive the deployment of biorefineries
incorporating input from over 100 stakeholders through meetings, workshops and interviews

**Format of contribution:**
- Recommendation and reference to important reports, pilot plants, frameworks and laws
- Introduction of expert contacts
- Validation of the project findings (i.e. classification, pathways, barriers & drivers, roadmap)

→ Ensure that final roadmap is taken up, disseminated and implemented

The main comments and support were given by the SAG members whereby some comments aligned with those made by the EC.
EU policy context

Policy frameworks and strategies impacting the tender study
A circular biobased economy is important to help build a sustainable future and meet the EU Green Deal's targets.

- The study supports the action to facilitate the development and deployment of new sustainable biorefineries.

- Biorefineries have the potential to play an important role for the development of a carbon-neutral economy.

- Biorefineries can increase EU security of raw materials and improve business opportunities by creating local jobs.

- This study can help inform policy and biorefinery deployment can help achieve objectives at EU level.

EU Bioeconomy Strategy 2018

Biodiversity Strategy

Farm-to-Fork Strategy

EU GHG reduction by min. 55% by 2030 compared to 1990 levels

Circular Economy Action Plan

EU GHG reduction by min. 55% by 2030 compared to 1990 levels
This study focuses on biorefineries producing high value biobased chemicals and materials

Biorefineries producing non-traditional bio-based chemicals and materials complement existing alternatives to support the development of a climate neutral economy.

- **Fuels and energy focused biorefineries**
- **Bio-based chemicals and materials driven biorefineries**
- **Traditional biomass processing facilities (e.g. pulp & paper)**
- **Recycled carbon and CO₂-based chemicals and materials**
- **Co-processing of chemicals and materials in existing facilities**

| Out of scope | In scope | Covered at high level |
The BIO-TIC roadmap published in 2015 projects the development of 300 new biorefineries by 2030

- The European Commission’s Bioeconomy Strategy supports the deployment of biorefineries in the EU
- The definition of biobased chemicals and materials driven biorefineries is important when comparing different studies

<table>
<thead>
<tr>
<th>Biorefinery Outlook</th>
<th>BIO-TIC Roadmap</th>
</tr>
</thead>
<tbody>
<tr>
<td>overall new 42 biorefineries 2020-2030</td>
<td>overall new 300 biorefineries 2008-2030</td>
</tr>
<tr>
<td>• Focus on biorefineries producing <strong>bio-based chemicals and materials</strong></td>
<td>• <strong>Wider scope</strong> of types of biorefineries considered</td>
</tr>
<tr>
<td>• Analysis of period from 2020 -2030</td>
<td>• Analysis of period from 2008 -2030</td>
</tr>
<tr>
<td>• Estimate of new biorefineries which can <strong>realistically be deployed</strong> by 2030</td>
<td>• Estimate of <strong>new biorefineries needed</strong> to meet the estimated demand</td>
</tr>
</tbody>
</table>
Biorefinery classification and definition of pathways
For this study, the IEA's classification system was modified and extended to a classification system applicable for chemical and material driven biorefineries.

### FEEDSTOCK
- **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

### CONVERSION PROCESS
- **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

### PLATFORM
- Biochar
- Bio-coal
- Bio-crude
- Biogas
- Bio-oils
- Bio-hydrogen
- Bio-naphtha
- C5/C6 sugars
- Carbon dioxide
- Lignin
- Oils
- Organic fibers
- Organic juice
- Protein
- Pyrolytic liquid
- Starch
- Syngas
- *Other

### PRODUCT
- **Chemicals**
  - Additives
  - Agrochemicals
  - Building blocks
  - Catalysts & Enzymes
  - Colorants
  - Cosmeceuticals
  - Flavours & Fragrances
  - Lubricants
  - Nutraceuticals
  - Paints & Coatings
  - Pharmaceuticals
  - Solvents
  - Surfactants
  - *Other

- **Materials**
  - Composites
  - **Fibres**
    - Organic Fertilizers
    - Polymers
    - Resins
    - *Other

- **Food**
  - Animal Feed

- **Energy**
  - Cooling agents
  - Fuels
  - Heat
  - Power
  - *Other

*‘Other’ is included to enable new concepts, technologies or product categories to be included.

**‘Fibres’ group can be extended to subgroups e.g. textile fibres, paper and board fibres, carbon/specialty fibres and other fibres.**
11 Biorefinery Pathways have been distinguished based on different platforms used; 4 mature (A-D) and 7 still under development (E-K).

<table>
<thead>
<tr>
<th>Name</th>
<th>Feedstocks</th>
<th>Conversion Processes</th>
<th>Platforms</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>One platform (C6 sugars) biorefinery using sugar crops</td>
<td>Sugar crops</td>
<td>Extraction, fermentation, (chemical conversions)</td>
<td>C6 sugars</td>
</tr>
<tr>
<td>B</td>
<td>One platform (starch) biorefinery using starch crops</td>
<td>Starch crops</td>
<td>Extraction, fermentation, (hydrolysis, chemical conversions)</td>
<td>Starch</td>
</tr>
<tr>
<td>C</td>
<td>One platform (oil) biorefinery using oil crops, wastes and residues</td>
<td>Oil crops, waste/residue fats, oil and greases&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Pressing, transesterification, (hydrolysis, chemical conversions)</td>
<td>Oil</td>
</tr>
<tr>
<td>D</td>
<td>Two-platform (pulp and spent liquor) biorefinery using wood</td>
<td>Lignocellulosic wood/forestry</td>
<td>Mechanical processing, pulping, combustion, (separation, extraction, gasification)</td>
<td>Pulp, spent liquor</td>
</tr>
<tr>
<td>E</td>
<td>Three platform (C5 sugars, C6 sugars and lignin) biorefinery using lignocellulosic biomass</td>
<td>Lignocellulosic crop, wood/forestry, residues from agriculture and forestry</td>
<td>Pre-treatment, hydrolysis, fermentation, combustion, (thermo-/chemical conversions)</td>
<td>C5 sugars, C6 sugars, lignin</td>
</tr>
<tr>
<td>F</td>
<td>Two-platform (organic fibres and organic juice) biorefinery using green biomass</td>
<td>Green biomass&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Pressing, fiber separation, anaerobic digestion, combustion, (upgrading, separation)</td>
<td>Organic fibres, organic juice</td>
</tr>
<tr>
<td>G</td>
<td>Two-platform (oil and biogas) biorefinery using aquatic biomass</td>
<td>Aquatic biomass</td>
<td>Extraction, anaerobic digestion, combustion, (hydrolysis, chemical conversions)</td>
<td>Oil, biogas</td>
</tr>
<tr>
<td>H</td>
<td>Two-platform (organic fibres and oil) biorefinery using natural fibres</td>
<td>Natural fibres (e.g. hemp, flax)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Fiber separation, extraction, (chemical conversions)</td>
<td>Organic fibres, oil</td>
</tr>
<tr>
<td>I</td>
<td>One platform (syngas) biorefinery using lignocellulosic biomass and municipal solid waste</td>
<td>Lignocellulosic biomass&lt;sup&gt;c&lt;/sup&gt;, MSW</td>
<td>Pretreatment, gasification, gas conditioning, chemical conversions</td>
<td>Syngas</td>
</tr>
<tr>
<td>J</td>
<td>Two platform (pyrolytic liquid and biochar) biorefinery using lignocellulosic biomass</td>
<td>Lignocellulosic biomass&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Pyrolysis, separation, combustion, (gasification, cracking, extraction)</td>
<td>Pyrolytic liquid, biochar</td>
</tr>
<tr>
<td>K</td>
<td>One platform (bio-crude) biorefinery using lignocellulosic, aquatic biomass, organic residues</td>
<td>Lignocellulosic biomass&lt;sup&gt;c&lt;/sup&gt;, organic residues, aquatic biomass</td>
<td>Hydrothermal liquefaction, upgrading</td>
<td>Bio-crude</td>
</tr>
</tbody>
</table>

<sup>a</sup> Waste/residue fats, oils and greases belong to category "Other organic residues"
<sup>b</sup> Green biomass and Natural fibres belong to category "Lignocellulosic from croplands and grasslands"
<sup>c</sup> Lignocellulosic biomass includes Lignocellulosic from croplands, wood/forestry and residues from agriculture and forestry
Biorefinery pathways encompass the different process variants.

The process variants show development of the pathways towards generation of multiple valuable products for multiple markets.
# A high-level comparison assessment of the production of 8 case study bio-based products with their fossil alternatives shows both advantages and disadvantages ...

<table>
<thead>
<tr>
<th>Biobased chemical/material</th>
<th>Drop-in or Dedicated</th>
<th>Biorefinery pathways</th>
<th>Alternative (fossil or CO₂-based) pathways</th>
<th>Advantages/disadvantages to fossil alternatives</th>
<th>Other considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biobased chemicals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additive Propylene glycol (PG)</td>
<td>Drop-in A/B/E</td>
<td>C</td>
<td>glycerol</td>
<td>Fossil</td>
<td>hydration of propylene oxide</td>
</tr>
<tr>
<td>Building block 1,4 Butanediol (1,4 BDO)</td>
<td>Drop-in A/B/E</td>
<td>D</td>
<td>fermentation of sugars</td>
<td>Fossil</td>
<td>via acetylene, butadiene, maleic anhydride and propylene</td>
</tr>
<tr>
<td>Building block Methanol</td>
<td>Drop-in I</td>
<td>D</td>
<td>purification of side-stream gasification, chemical conv.</td>
<td>CO₂</td>
<td>natural gas + steam reforming reaction with hydrogen from electrolysis</td>
</tr>
<tr>
<td>Building block Lactic acid (LA) + PLA</td>
<td>Dedicated A/B/E</td>
<td>I</td>
<td>fermentation of sugars</td>
<td>Fossil</td>
<td>PP/PS/PE, derived from steam cracking of naphtha</td>
</tr>
<tr>
<td>Solvent Acetic acid</td>
<td>Drop-in D</td>
<td>I</td>
<td>fermentation of sugars Extract from spent liquor</td>
<td>CO₂</td>
<td>via methanol, acetaldehyde and alkane</td>
</tr>
<tr>
<td>Surfactant Fatty alcohol ethoxylate</td>
<td>Drop-in C + A/B/E</td>
<td>I</td>
<td>reaction of fatty alcohol from oils + ethylene oxide from sugars</td>
<td>Fossil</td>
<td>fatty alcohol by Oxo or Ziegler process + ethylene oxide derived from steam cracking of naphtha</td>
</tr>
<tr>
<td>Biobased materials</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fibre Microfibrillated cellulose (MFC)</td>
<td>Dedicated D</td>
<td>D</td>
<td>fission of cellulose</td>
<td>Fossil</td>
<td>plastic films and aluminium foil</td>
</tr>
<tr>
<td>Resin Lignin based phenolic resins</td>
<td>Dedicated E</td>
<td>J</td>
<td>recovery from black liquor pyrolysis lignocellulosic pyrolysis oil lignin fraction</td>
<td>Fossil</td>
<td>Phenol-based</td>
</tr>
</tbody>
</table>

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**EU Biorefinery Outlook to 2030**
Current deployment of biorefineries
EU and global biorefinery deployment has been identified and analysed

**Objective:** To provide an analysis of European (and global) biorefinery construction and planned development based on the biorefinery classification (WP 1), and construct a database in line with the classifications system.

**Key result:** A database was developed containing over 400 chemical and material driven biorefineries at commercial or demonstration scale in the EU and 10 non-EU countries\(^1\). Approximately 300 of these are in the EU.

Chemical and material driven biorefineries are **widely distributed** across the EU, particularly Western and Central Europe.

\(^1\)Norway, Switzerland, United Kingdom, USA, Canada, Australia, New Zealand, Japan, Brazil, China, India and Thailand
Pathways using food/feed crops and lignocellulosic wood/forestry dominate; more so in non-EU biorefineries

Pathways most prominent in the EU are the C6 sugar and starch platform (A and B) and the oil platform (C). These pathways – utilizing food and feed crops - together account for 56% of all biorefineries in the EU. The pulp and spent liquor pathway (D) makes up nearly 20% of biorefineries in the EU. Most biorefineries in this pathway use secondary feedstocks A-D make up over 80% of non-EU biorefineries identified in the database; more so than for the EU biorefineries.

Distribution of pathways by region (%), EU vs. Non-EU
Existing biorefineries produce drop-ins, smart drop-ins and dedicated products

From the biorefineries that produce chemical products, most produce dedicated bio-based chemicals. However, there are also a lot of biorefineries that produce drop-in, smart drop-in or a combination.

All the three bio-based product options (drop-in, smart drop-in and dedicated) appear to be able to compete in their market segments

The database was developed based on the JRC platform. Together with the JRC, it will be made widely available. Information on non-EU biorefineries could be made available through IEA Task 42
Barriers to deployment
Key drivers and barriers for biorefinery deployment were identified and analysed

**Objective:** to provide a comprehensive and structured analysis of the barriers & drivers that pertain to biorefineries as classified in WP 1.

**Key results:** A comprehensive and structured overview and analysis of key drivers and barriers was developed, structured around seven relevant categories. General drivers and barriers were elaborated, as well as specific drivers and barriers – focused on 10 product groups. All results were verified in stakeholder meetings and interviews.

**Relevant categories**

1. Business (perspective, models, etc.)
2. Innovation (advancing technology)
3. Economic (growth, jobs, etc.)
4. Access to feedstock (availability, flexibility, etc.)
5. Environmental (CO$_2$ mitigation, ...)
6. Societal (personal health, ..)
7. Policy and regulation

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<thead>
<tr>
<th>Product group</th>
<th>Chemical/Material</th>
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<tr>
<td>Additives</td>
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<tr>
<td>Solvents</td>
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</tr>
<tr>
<td>Surfactants</td>
<td>Microfibrillated cellulose</td>
</tr>
<tr>
<td>Fibres</td>
<td></td>
</tr>
<tr>
<td>Polymers &amp; Plastics</td>
<td>Thermoplastic starch &amp; Lactic Acid</td>
</tr>
<tr>
<td>Building blocks</td>
<td>1,4-butanediol</td>
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<td>Building blocks</td>
<td>Lactic acid</td>
</tr>
<tr>
<td>Building blocks</td>
<td>Methanol</td>
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<td>Resins</td>
<td>Lignin based phenolic resins</td>
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</table>
Stakeholders identified the main drivers as EU legislation and government support...

General drivers:

- The **need to reduce dependency on fossil materials and products and GHG emissions** Biobased products can have **functional benefits**, and/or environmental benefits, like replacing fossil materials, and lower toxicity and/or biodegradability.

- Governmental support such as **EU Green Deal** and support for **RD&D and scale-up**

- There is **growing awareness of the impacts**, e.g. on **jobs and economic growth**, thus giving rise to **rising demand**

- **Feedstock flexibility** and a **growing availability of source-separated waste**

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**Most important drivers**

- Forthcoming EU legislation (e.g. Green...)
- Government support for RD&D, scale-up
- Need to reduce fossil dependence
- Functional benefits
- Growing awareness of impacts
- Job growth, economic development in rural...
- Growing availability of source-separated...
- Flexibility in the supply chain
- Rising demand/market and promotional...
Non-technical barriers:

• The lack of economic viability, due to the gap between the market’s willingness to pay little or more for bio-based products and their high production costs. Also, there is lack of financial support for biobased products, and the lower competitiveness of EU biorefineries on the world market.

• Achieving plant scale up is challenging, because of the level of investment required, coupled with technology, market risk, and fossil competition is hindering financing.

• There is in many cases a lack of evidence on the full life-cycle sustainability.

• Concerns regarding certified sustainable feedstock supply and...
Technical barriers were identified: complex feedstock nature, novel conversion processes, improve infrastructure towards product price competitiveness

General technical barriers grouped into:

- **Feedstock related:**
  - Feedstocks are complex mixture of organic compounds (inorganics and vast amount of water require the use of different pre-treatment/valorisation processes).
  - Infrastructural barriers associated with the development of the European agricultural infrastructure (harvesting, collection and storage of the biomass and for residues/wastes management).

- **Conversion process related:**
  - Conversion processes must overcome significant costs and productivity barriers. Develop of a new set and combinations of conversion pathways, processes, and design of novel catalytic processes.

- **Platform and product related**
  - Technical developments to improve and improve product technical performance, price and assurance of real environmental benefits. Price competitiveness is also expected to improve via economies of scale, when the products are produced at large scale.
RD&I needs identified: more efficient and flexible process in the value chain & enhancement of bio-based products benefits

RD&I needs to overcome technical and non-technical barriers for 10 products.

- Financial support necessary over the full RD&I-trajectory because of the relatively low TRL (fundamental research, applied research and piloting, demonstration and market support).

- Develop robust, feedstock flexible, biorefining technologies and logistical systems (transport, storage) to process the full European available biomass potential, to meet a varying feedstock market demand (volumes over time and place, right quality).

- Develop primary technologies to convert low-quality biomass feedstocks in higher quality intermediates that meet the processing requirements of biorefining technologies.

- Develop more energy efficient and product selective secondary biorefinery processes (fermentation, gasification, incl. DSP) to increase market competitiveness.

- Development of a clear and understandable assessment approach, efficient communication strategy to enhance market acceptance and consumer awareness.
Market prospects for biorefineries - demand
We have defined two scenarios to help understand what is possible by 2030

Two scenarios are:

- the **high** case represents higher support and deployment for biorefineries and increased market share as a result of stronger drivers (i.e. significant growth of biochemical and biomaterial demand)

- the **low** scenario represents low increases in demand for bio-based chemicals and materials in the EU and mixed success in future deployment of biorefineries (baseline case - limited additional actions taken by stakeholders)
Demand for bio-based products 2019, and 2030 low- and high scenario: demand could triple by 2030

**High growth scenario**
- Potential demand can grow at 9.9% in average per year to over **16 Mtpa**
- Positive macroeconomics drive positive developments for all products
- **Policy incentives** will place drop-in and dedicated solutions with identical properties of traditional fossil-based products in a competitive position

**Low growth scenario**
- Low growth scenario could **reach 7.8 Mtpa only**
- **Slow economic growth** and **missing policy incentives** lead to business as usual
- Highest growth expected for **biopolymers** due to **brand driven developments and consumer awareness**

- Product groups definitions correspond to the JRC study. Not the complete bio-based market is covered.
- Production of paper and board is not included into the product groups.
- Fibres are limited to man-made fibres.
Results from different WPs on the 10 case study products are presented in Case Study formats.

The 10 case study products are:
1. 1,4 butanediol
2. Acetic acid
3. Biomethanol
4. Fatty acid PEG esters
5. Fatty alcohol ethoxylate
6. Lactic acid
7. Lignin based phenolic resins
8. Microfibrillated cellulose
9. Thermoplastic starch
10. Propylene glycol
Deployment of EU biorefineries to 2030

Supply ramp up growth scenarios
The ramp up supply model only considers the potential growth rate of biorefineries by 2030

- High growth scenario predicts 44 additional biorefineries by 2030
- Low growth scenario predicts 27 new biorefineries by 2030
- Pathways D and E contribute most new biorefineries in both scenarios
- The ramp up potential of specific pathways depends on ongoing activities and market trends.
Advanced biofuels could be sold into the chemicals and materials sectors supporting biorefinery deployment

• Some biorefinery pathways share their products with advanced biofuels. Under the high scenario assumptions, these are assumed to be built and supply a proportion to the chemicals sector as well as the fuels sector.
  • Pathways A, B and E all can produce ethanol
  • Pathway D and I produce biomethanol
  • Pathway J produces pyrolysis oil

• This option is considered in the model since these plants presents several opportunities for increased ramp up of biobased chemicals and materials supply in the EU
  • Potential large supply of biochemicals, but currently the willingness to pay does not exist
  • Electrification of road transport suggests a risk of decreasing market for liquid biofuels, therefore the potential to partially focus on chemicals and downstream materials.
    • It will also be important to consider in developments to the Renewable Energy Directive (RED II) and the demand for Sustainable Aviation Fuels
  • Reduced investment risk since these biorefineries could have two major target markets
In the high scenario, new or expanded biorefineries could add 3.1 million tonnes, and 1.1 million tonnes in the low scenario by 2030.

- The output presents the production capacity by year to demonstrate the progressive ramp-up EU biorefineries between 2020 and 2030.
- The current supply of from EU chemicals and materials based biorefineries is estimated at 4.6 million tonnes.

*Only demonstration scale and larger biorefineries (i.e. TRL 8-9) are expected to have an impact on the biorefinery deployment levels by 2030.*
For both scenarios, the EU demand could be higher than the projected supply in 2030

The shortfall in supply could be met through imports from non-EU countries and/or supply from alternative (alt) ramp-up routes

- **Crop based fuel driven biorefineries** switching focus to the chemicals market
- **Co-processing** in petroleum refineries to produce chemicals (e.g. olefins) or chemical feedstocks (naphtha, BTX, LPG)
- **Co-processing** in steam crackers to produce chemicals (e.g. olefins)
- **Co-processing** in methanol biorefineries
Fuel driven biorefineries and co-processing could be key supply sources of chemical and materials.

Current co-processing of bio-based feedstocks in steam crackers is unknown and not all co-processing in methanol plants has been captured in the 2020 estimate.

Alternative ramp up potential today vs. 2030

- Crop based fuel-focused biorefineries switching focus to the chemicals market
- Co-processing in petroleum refineries to produce chemicals (e.g. olefins) or chemical feedstocks (naphtha, BTX, LPG)
- Co-processing in steam crackers to produce chemicals (e.g. olefins)
- Co-processing in methanol plants
- TOTAL

EU Biorefinery Outlook to 2030

*Current co-processing of bio-based feedstocks in steam crackers is unknown and not all co-processing in methanol plants has been captured in the 2020 estimate.*
Roadmaps
Stakeholders and policy makers need to take action to accelerate towards the high deployment scenario

- The roadmap **actions** aim to **overcome barriers** to increase the likelihood of **reaching** the **outlook for deployment**

**Stakeholder type**
- Policy makers
- Bio industry & associations
- Chemical/material industry & Industry associations
- Academia & Research institutions
- NGOs & Civil societies
- Investment community

**Action type**
- Policy & regulation
- Support for RD&D and scale up
- Information and coordination

Actions are segmented by barrier groups and are listed in order of importance as indicated by stakeholders in WPs 2 and 3.
Policy & regulation is essential to close the large gap between the market’s willingness to pay and costs

Policy & regulation is required to achieve this through:

- **Policy** that supports chemicals and materials that provide environmental benefits (focused on GHG savings): bio-based, recycled, CO₂
  - GHG reduction targets, mandates (e.g. on products sold, in public procurement etc...), bans/reducing targets on use of fossil and non-recycled products, taxes on some fossil products and carbon

- Ensuring that where production costs are higher as a result of the above actions, EU competitiveness is supported (e.g. through the Carbon Border Adjustment Mechanism)
  - The requirement for this depends on which actions are taken
Policy & regulations need to be developed and implemented in 5 years to have an impact on 2030 deployment

One of these actions is required at least – a GHG reduction mandate is recommended

If mandates on sales are **not** developed, these actions could help support biorefineries and EU competitiveness
To achieve lower environmental impacts, the strategic direction should be focused on selected pathways:

Policy & regulation strategic direction is required to:

- Develop chemical and materials policies alongside other biomass and land uses policy such as the Common Agricultural Policy (CAP), on biofuels, on the bioeconomy, the circular economy and Farm to Fork strategy, renewable energy, can overlap and conflict.

- Scale up pathways with lower environmental impacts that are currently more expensive and at an earlier stage of commercialisation.
Supporting Research, Development & Demonstration and feedstock sourcing can help accelerate cost reduction.

**ECONOMIC DIRECTION**

- Support investigation of optimal use of EU biomass feedstock
- Conduct R&D focusing on cost reduction across all biorefinery pathways through continuing activities such as Horizon Europe, Circular Bio-based Europe and MS support
- Improve process economics by identifying connections between different pathways and other industries
- Establish partnerships to develop biorefineries on existing industrial sites to reduce costs
- Expand biomass/waste feedstock databases to identify low cost resources
- Harmonise bioproducts’ sustainability requirements with existing schemes

**Support for RD&D and scale up:**

- **RD&D** on all pathways to bring cost savings (Horizon Europe, Circular Bio-based Europe, MS level support)

**Information and coordination:**

- **Lower costs** by developing on existing industrial sites
- **Connections** between different pathways
- Identification of **low-cost feedstock**
Public finance for RD&D and scale up is crucial to commercialise lower TRL pathways by 2030

Support for RD&D and scale up actions focus on ensuring the level of investment required is provided, by co-financing with public funds via equity in companies and financing projects, as well as reducing costs through supporting shared facilities.

- **Sustainable Finance Taxonomy** Draft Act excludes the use of food and feed crops for bio-based chemicals and plastics.
- **Requirements** for financing need to be carefully considered to ensure sustainability without unnecessarily restricting biorefinery development.

EU Biorefinery Outlook to 2030
Environmental benefits need to be measured and broadly understood by all stakeholders.
Outlook for deployment
Aligned with the roadmaps and the supply scenarios we developed an outlook for the deployment by 2030

- **Assumptions** aligned with the roadmap actions being completed.

- **Policy** developments will help determine the overall and relative ramp-up of these pathways.

- Whilst the roadmaps suggest areas of policy that should be considered, they do not specify fixed policy actions including targets.

- Favourable policy developments for secondary feedstocks (non-crop) to produce chemicals and materials in the EU are assumed.
Pathways E, D, I all share products they produce with advanced biofuels and show the strongest supply ramp up potential

- Over 40 new biorefineries could be operational by 2030
- Additional 3.1 million tonnes capacity could be achieved in 2030 with significant volumes from:
  - Debottlenecking/expansion of existing biorefineries (primarily pathways A-E) ~0.5 million
  - New biorefineries ~2.6 million
- The scale of the biorefineries depends on the pathway, feedstock and market activity.

Chemical and materials driven biorefinery outlook for deployment – additional biorefineries by 2030

*Pathways B, G and K have been left out as they do not contribute to the overall supply ramp up.
Biorefinery deployment could result in overall GHG savings and increased raw material security for the EU

- Saving of 3.5 million tonnes of GHG emissions
- Substitution of 5.6 million tonnes of naphtha (fraction of crude oil)

Capital investment of 81 to 325 million EUR required to build the new demonstration biorefineries and ~3,300 to >13,335 million EUR to finance the new commercial biorefineries

- Development of biorefineries at existing brownfield site can result in lower the CapEx and OpEx
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:

- **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)

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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)


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.
Despite low historical investment, BIOEAST countries show significant availability of forest and agricultural residues.

Figure 2. Map of forest residue potential in BIOEAST initiative countries (kta dry matter)

Figure 3. Map of agricultural residue potential in BIOEAST initiative countries (kta dry matter)
The study can be used to help make decisions & take actions to accelerate biorefinery deployment to 2030

The study provides:

- Robust **biorefinery classification** system allows standardised categorisation
- Identification of **key drivers and barriers** highlights main areas of progress needed
- Development of **chemical and materials driven biorefinery database**
- Estimation of **demand** and potential **new biorefineries in the EU by 2030** based on ongoing activities
- A **roadmap** with a **set of actions** needed to be taken to accelerate the deployment of biorefineries by 2030
With the right conditions, EU demand / supply of bio-based chemicals and materials could grow significantly by 2030

- **Demand** for bio-based chemicals and materials could **triple by 2030** in in the high growth scenario

- In the **high growth deployment scenario**, new or expanded biorefineries could add **3.1 million tonnes**, and **1.1 million tonnes** in the low growth scenario **by 2030**

- For both scenarios, the **EU demand** could be **higher** than the projected **supply** in 2030
  - Existing **fuel driven biorefineries** and **co-processing** could be key **supply sources** of chemical and materials to fill the shortfall, as well as **imports** from non-EU countries

- Stakeholders and policy makers need to take **action** to reach **accelerate towards** the **high growth scenario**
The priority is to put in place policy and regulation that overcomes the economic viability barriers

- Putting **policy and regulation** in place in the **next 5 years** is **essential** to close the large gap between the **market’s willingness to pay** and **bio-based chemicals and materials production costs**
  - An EU mandate for GHG reduction in chemicals and materials sold (analogous to RED II) could have the largest impact (bio-based, recycled and CO$_2$-based)

- To achieve **lower environmental impacts** the strategic **policy & RD&D** direction should be focused on **selected pathways**

- Supporting **RD&D** and **feedstock sourcing** can help accelerate **cost reduction**

- **Public finance** for RD&D and scale up is crucial to **commercialise lower TRL pathways** by 2030

- **Environmental benefits** need to be **measured** and broadly understood by all stakeholders
With action taken and favourable economic conditions the deployment outlook could reach the high scenario

- **Additional 3.1 million tonnes capacity could be achieved in 2030** with significant volumes from:
  - debottlenecking/expansion of existing biorefineries (primarily pathways A-E) ~0.5 million
  - New biorefineries ~2.6 million - over 40 biorefineries could be built

- **Saving of 3.5 million tonnes of GHG emissions**
- **Substitution of 5.6 million tonnes of naphtha** (fraction of crude oil)

Capital investment of **81 to 325 million EUR** required to build the new **demonstration** biorefineries and ~**3,300 to >13,335 million EUR** to finance the new **commercial** biorefineries
Thanks

More information: www.e4tech.com/biorefinery-outlook.php

The information and views set out in this Studies on support to R&I policy in the area of bio-based products and services, Lot 3 Biorefinery pathways and outlook for deployment Service Contract EC DG-RTD no. 2018/RTD/F2/OP/PP-07281/2018/LC-01369322 are those of the author(s) and do not necessarily reflect the official opinion of the Commission. The Commission does not guarantee the accuracy of the data included in this study. Neither the Commission nor any person acting on the Commission’s behalf may be held responsible for the use which may be made of the information contained therein.