SIAPARTNERS

Biorefining: Opportunities for Europe by 2050

Focus on biofuels and bioplastics

Climate Analysis Center | CONSULTING FOR GOOD

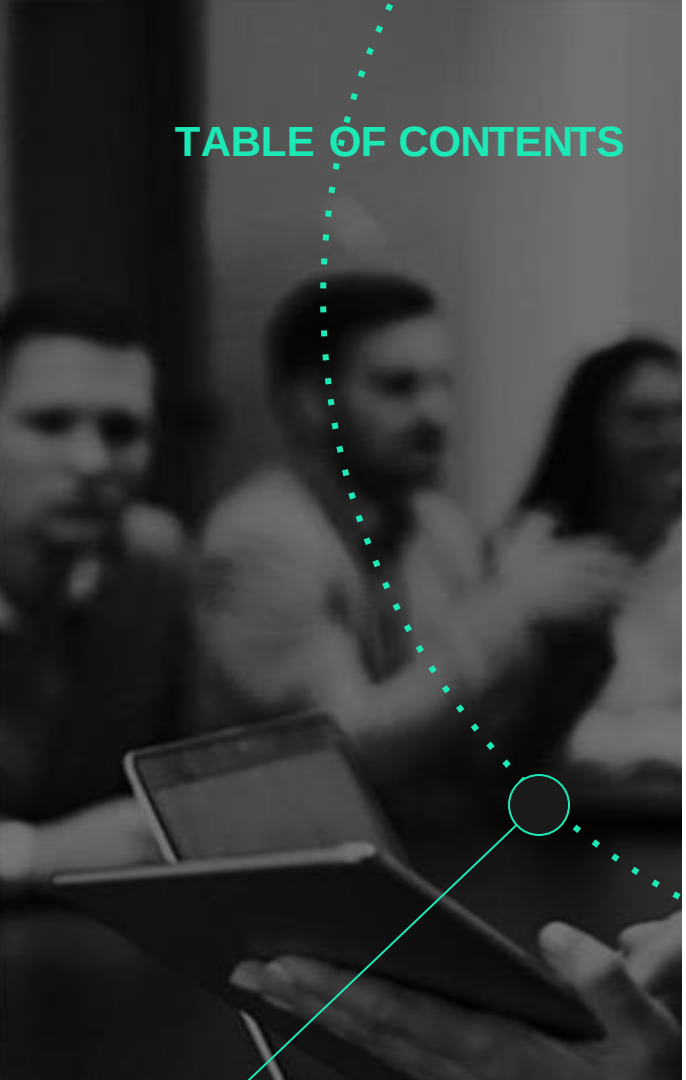
Executive Summary

The goal of achieving net zero emissions by 2050 requires significant efforts from countries, industries, and citizens to reduce, recycle, and replace the use of fossil based products in all sectors of the economy. Europe has been successful in increasing the turnover of the bio-based economy by more than 40% in less than a decade and thanks to dedicated national bioeconomy strategies, and agricultural resources, the European Union has a leading role in biorefining.

Although several market segments show dynamic evolution perspectives, our study is focused on two main markets: bioplastics and biofuels. These renewable resources are gaining popularity in the chemical, construction, transport, and packaging industries as they offer alternatives to products derived from petroleum and may help these markets reach carbon neutrality in the frame of the European Green Deal.

To predict how the production capacities of biofuels and bioplastics will evolve in the next 30 years, Sia Partner conducted a study and developed three scenarios based on regulatory, technological, and societal breakthroughs, as well as long-term trends. The scenarios range from conservative and supportive to advanced, depending on the deployment of advanced generation technologies (2G+) encouraged by government incentives. The study estimates that the additional European production capacity of biofuels and bioplastics by 2050 could be up to 2000 new biorefinery units, assuming absolute European sovereignty for bio feedstock resources and no importation of finished products. The study also analyzed four key parameters to qualify the benefits of biorefining in the fuels and plastics sectors: **environmental impact, energy sovereignty, agriculture stress, and resource impacts.**

To meet the increasing European demand for biofuels and bioplastics by 2050, the actors in the biorefining and oil industry must transform their business models. Sia Partners proposes three main levers to help overcome the challenges of the biorefining sector by 2050: supportive policies for the expansion of regional bioeconomy strategies and R&D, feedstock supply by setting up flexible logistic systems to exploit the full potential of available biomass in the EU, and a business model based on the bio-economy to develop new capacities and aim for high potential markets.



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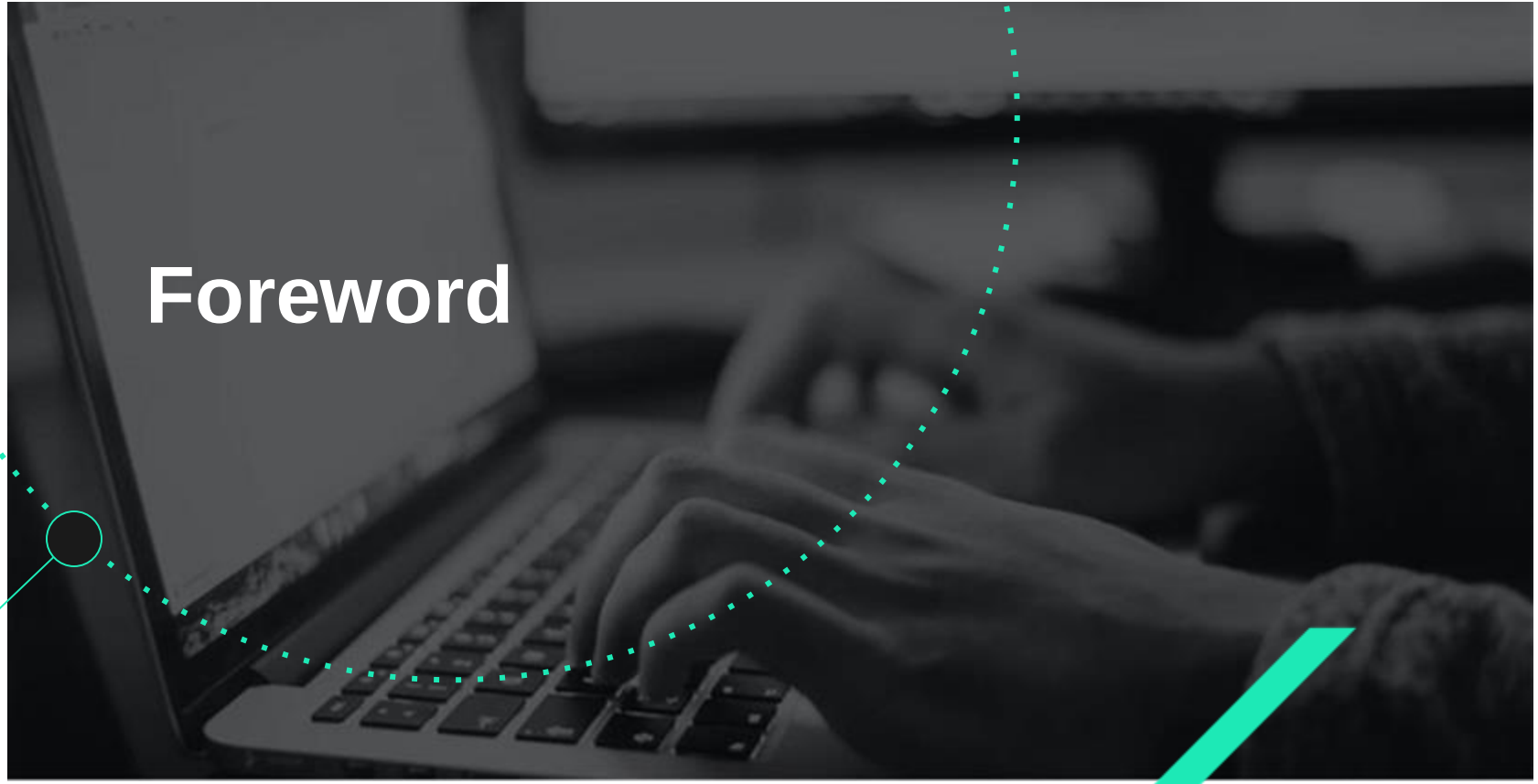


Foreword

Foreword

Scope and objectives of the study

The main objectives of this study are to assess the impact of the energy transition on the biorefining sector particularly the opportunities for the replacement of fossil-based products by biosource products for fuels and plastics in Europe by 2050. The study also aims to provide recommendations on how to prepare for this transformation.

In the context of the energy crisis, Sia Partners has conducted research using scenarios that assume Europe will have complete sovereignty over its energy supply by 2050.

Scope of the Study

Focus on biofuels and bioplastics

Thanks to the implementation of dedicated national bioeconomy strategies and the availability of agricultural resources, the European Union has established a leading position in the bioeconomy. **In 2018, 803 biorefineries were identified in Europe compared to 75 fossil refineries. The diverse locations of biomass resources and the wide variety of bioproducts available have enabled the biorefining sector to capture an increasing share of the fossil-based products market.**

Biorefineries essentially convert biomass feedstocks into the following main class of valuable products:

- **Bio-based chemicals:** including platform chemicals, solvents, polymers, paints, cosmetics, adhesives, lubricants, plasticizers
- **Liquid biofuels:** including bioethanol, biodiesel and bio-based jet fuel
- **Bio-based composites and fibers**: including wood-plastic composites, natural fibres composites

The range of products derived from biorefining has helped us identify specific market segments for detailed analysis. Although several market segments show dynamic evolution perspectives, our study is focused on **two main markets: bioplastics and biofuels.**

Biofuels

Biofuels are liquid or gas fuels produced from biomass. They are incorporated into fuels of fossil origin such as gasoline and diesel.

- **Ethanol**: it is a substitute for gasoline, it can be used pure or in a mixture with oil products
- **Biodiesel**: this category includes various substitutes for diesel, made from oils from oil plants, animal fats or waste oil

Scope of application

Aviation sector | **Maritime sector** | **Road transport**

Bioplastics

The term "bioplastic" refers to "biosourced" and/or biodegradable plastics:

- A **biosourced plastic** is made of polymers of renewable origin (resources of plant origin)
- **Biodegradable plastic** decomposes by the action of micro-organisms

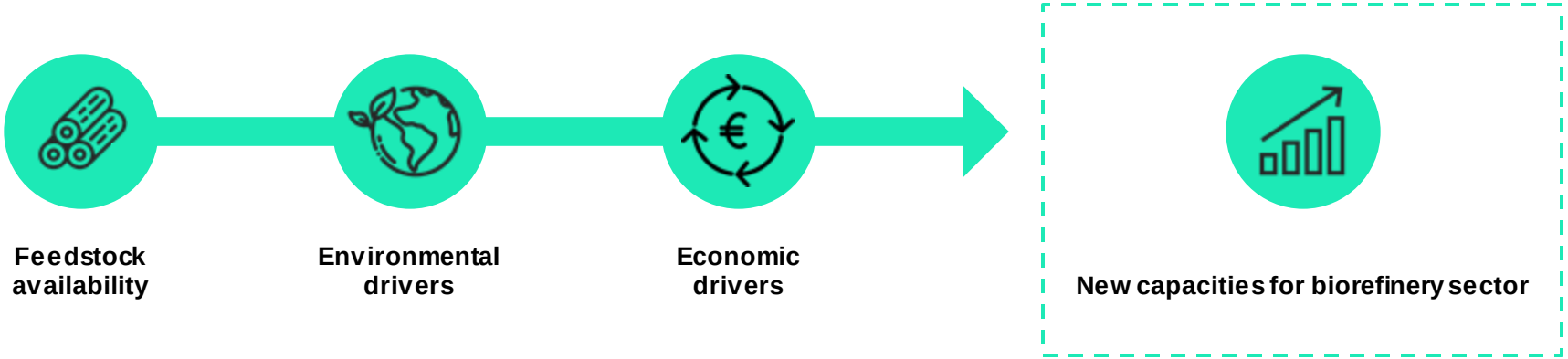
Scope of application

Packaging | **Consumer goods** | **Construction** | **Electronics**

Foreword

Scope and objectives of the study

Sia Partners has analyzed **3 main factors** to compute the biofuel and bioplastic demands in 2050 and thus, to estimate the evolution of biorefining in next decades in Europe.



Foreword

Scope and objectives of the study

To estimate the evolution of these 3 factors by 2050, Sia Partners has focused on **3 trends**.

Technological advances

- Use of new bioresources
- Improvement of production processes

Regulations

- Renewable energy directives
- Regulation for biofuels and bioplastics

Societal breakthroughs

- Increasing concern regarding energy sovereignty
- Global interest in the circular economy

Introduction

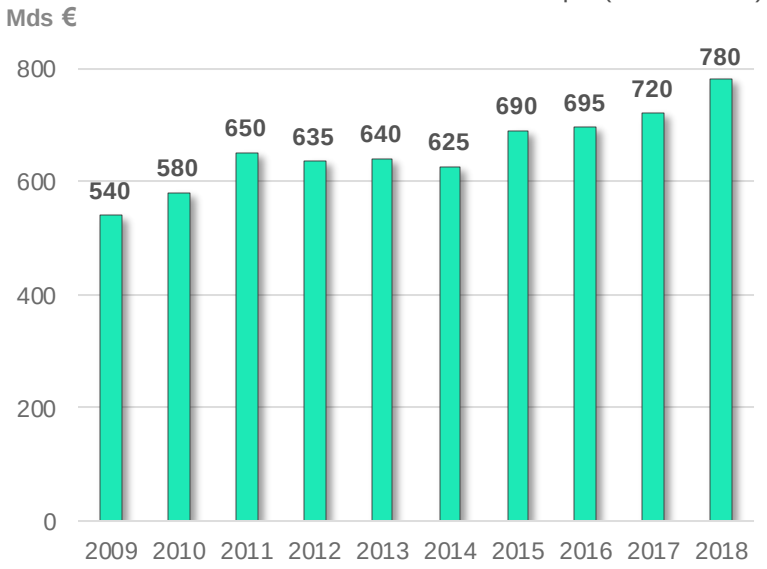
Introduction

In Europe, the turnover for the bio-based economy has increased by more than 40% in less than a decade.

Introduction

European bio-based economy trends: turnover & main drivers

Evolution of bio-based market value in Europe (2009 – 2018)



Source: Eurostat 2021

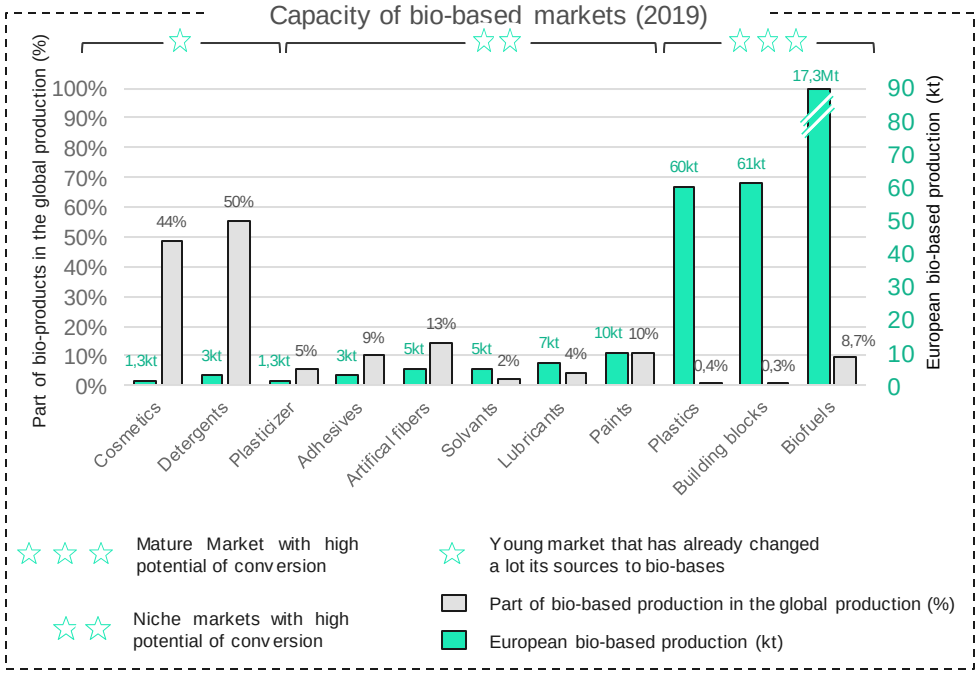
Over the past decade, the bio-economy in Europe has experienced significant growth and development, with the overall bio-based market expanding by more than 40% in less than 10 years. This progress can largely be attributed to 4 key drivers that have propelled the bio-economy forward.

- **Policy & Regulations.** Regulatory incentives have an impact on a wide range of biorefinery pathways. RED II, REACH, WFD, CEP, LULUF among others have promoted bio-based products.
- **Business & Economy.** Bio-products have multiple applications and advantages for marketing.
- **Feedstocks.** Most feedstocks are available from different sources and reduce supply risks (compared to fossil-based products).
- **Climate Change & Citizen.** Using biomass as a feedstock offers GHG savings and may generate biodegradability properties.

Driven by supportive regulations, technological and emerging requirements, the bioeconomy is addressing the major challenges of 21st century industry: producing goods more efficiently, at a lower cost while reducing its impact on the environment.

Introduction

Classification of bio-based markets



We have identified two types of markets:

Low potential markets (cosmetics, detergent). A large majority of fossil based products that could be substituted, are already replaced. There is a low potential of bio-based conversion in these markets.

Mature markets with high potential of conversion (biofuels, plastics). These markets have a low incorporation rate of bio-based production and a high level of production. Increasing the incorporation rate will depend on the capacity of substitution.

Focus on high potential markets

Biofuels. Almost 9% of the global production of fuels is bio-based. If we look at the annual production of this mature market, there is a real opportunity to improve this proportion and expand the biofuels market.

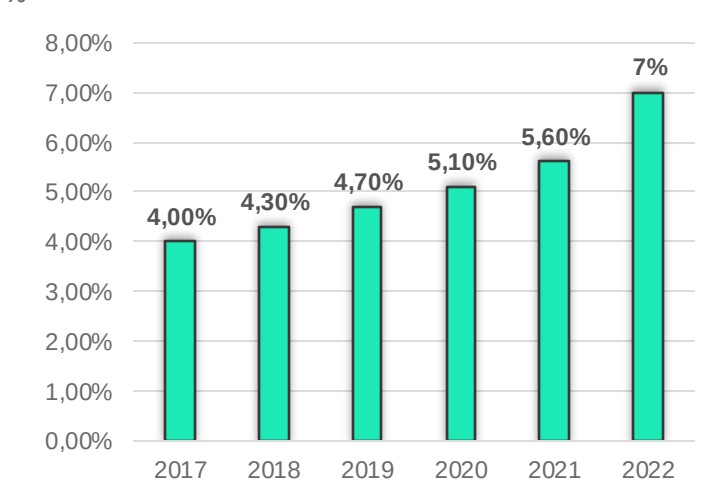
Plastics. 0.4% global production is bio-based.

There is a wide range of bio-based markets available. The biofuel and bioplastic markets are particularly interesting for companies as they offer a low incorporation rate that can be improved upon, as well as significant potential for growth in each respective market.

Introduction

Overview of the biofuels market

Growth of the share of biofuels supply in global fuel supply of fuel in European Union (transport sector)



Sources: Sia Partners analysis//

The portion of biofuel in the overall fuel supply has increased significantly, nearly doubling since 2017 and is now reaching 7% as of 2022.

The EU is among the five biggest biofuel suppliers and the first supplier of biodiesel accounting for **32.3% of the global supply.**

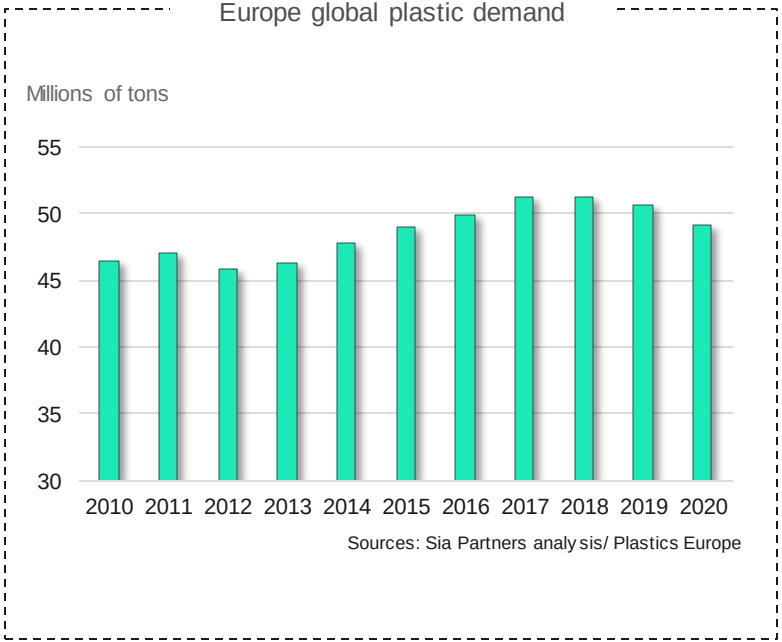
This growth can be explained by the promotion of biofuels in the European Union and regulation reinforcement in the last 20 years.

- **European Directive** (2003)**.** Regulatory directive to promote biofuels, with the goal of achieving **5.75% of biofuels in the share of renewable energy.**
- **Renewable Energy Directive « RED » (2009).** The purpose of this directive is to set **a target of 20% of renewable energy** in the share of renewables and a target of **10% of biofuels in the energy supply in the transport sector** for each country.

Biofuels are considered a relevant candidate for this study due to their potential for growth and the certainty of their market evolution.

Introduction

Overview of the bioplastics market



Overview of the world of plastic demand and its repercussions

Over the past decade, the demand for plastic has remained consistently high, with Europe experiencing a steady 5% growth in this sector. Furthermore, the global production of plastics has seen a substantial increase, rising from 279 million tons in 2011 to 359 million tons in 2018. EU production represents at least 15% of the world production *(source: Plastics Europe).*

The share of bio-based production represents only 1% (2.11 Millions of tons).

The amount of plastic waste entering the ocean every year is estimated to triple by 2040 and reach 29 millions of tons *(source: National Geographic).*

The European Union has implemented a regulatory framework for waste management, which acknowledges the importance of bioplastics and their significant contribution towards more efficient waste management. Through the promotion of bioplastics, the EU aims to minimize plastic pollution and its adverse effects on the environment.

The main environmental concerns of the European Union and major observers motivate companies to include the expansion of bio-based plastics in their growth strategy.

Driven by supportive regulations, technological and emerging requirements, the value of the bio-based market has increased by 40% over the last decade. The production of bio-based products in the EU has increased significantly over the last 20 years.

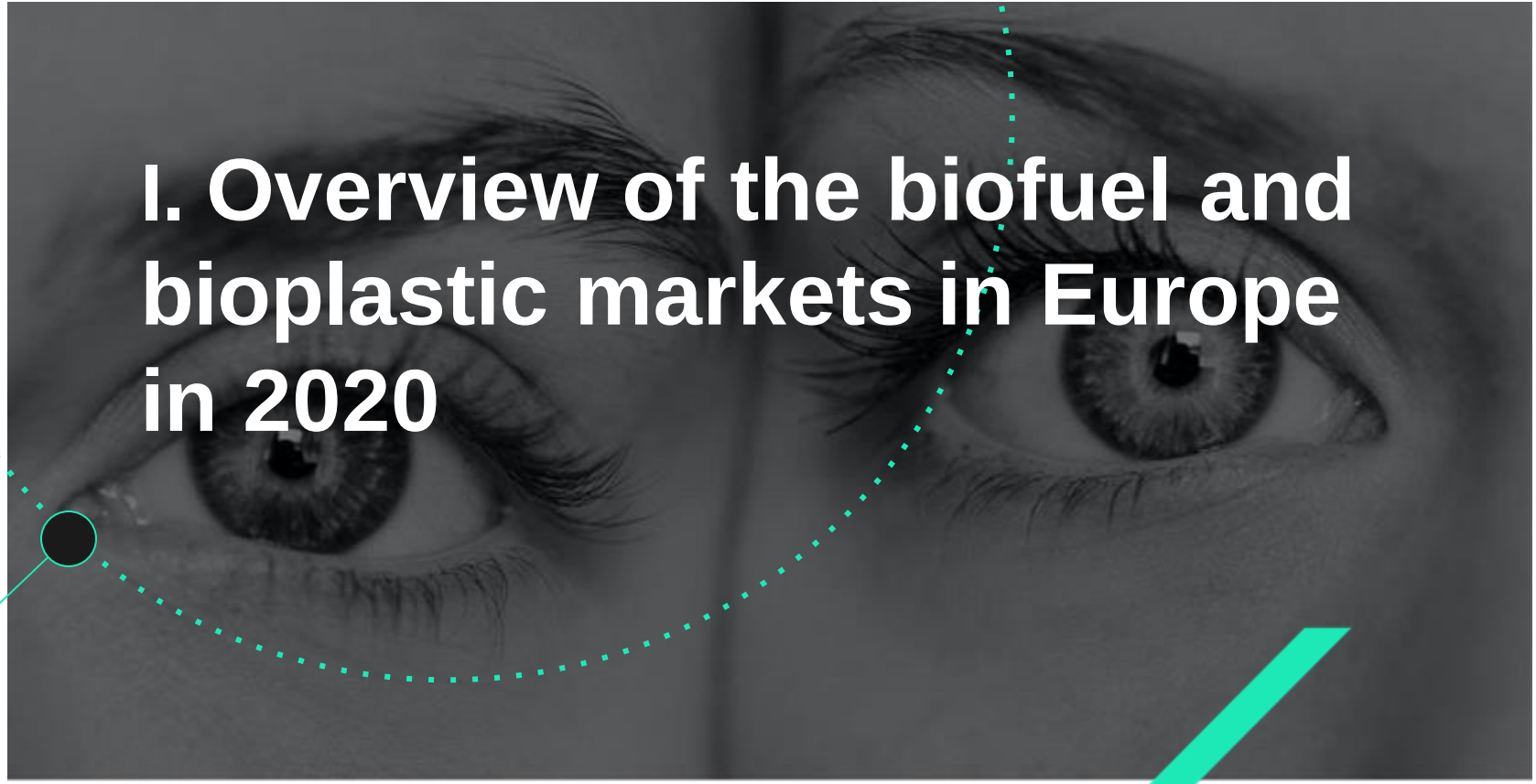
Biofuels and bioplastics, due to their high development potential, are markets with the best prospects for the coming decades.

x3

The production of biofuels **has tripled** over the last two decades. This evolution is explained by the legislative framework set up by the European Union with the Renewable Energy Directive.

15%

For the bioplastics sector, the expectation of a high demand for plastics in the coming decades is pushing Europe to devote particular attention to the development of bio-plastics, of which they are already a major supplier (15% of world supply).

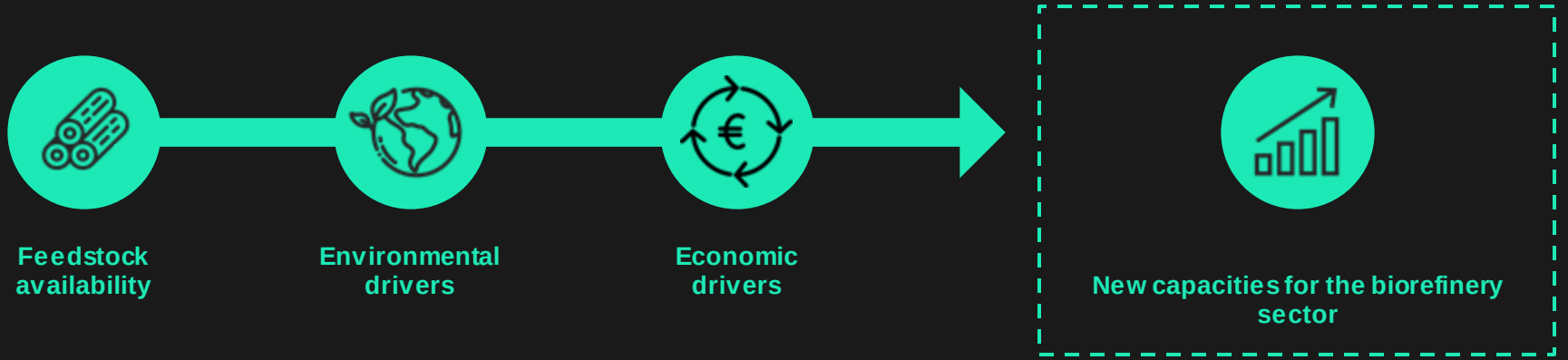


I. Overview of the biofuel and bioplastic markets in Europe in 2020

I. Overview of biorefining in Europe in 2020 - Focus Biofuels & Bioplastics

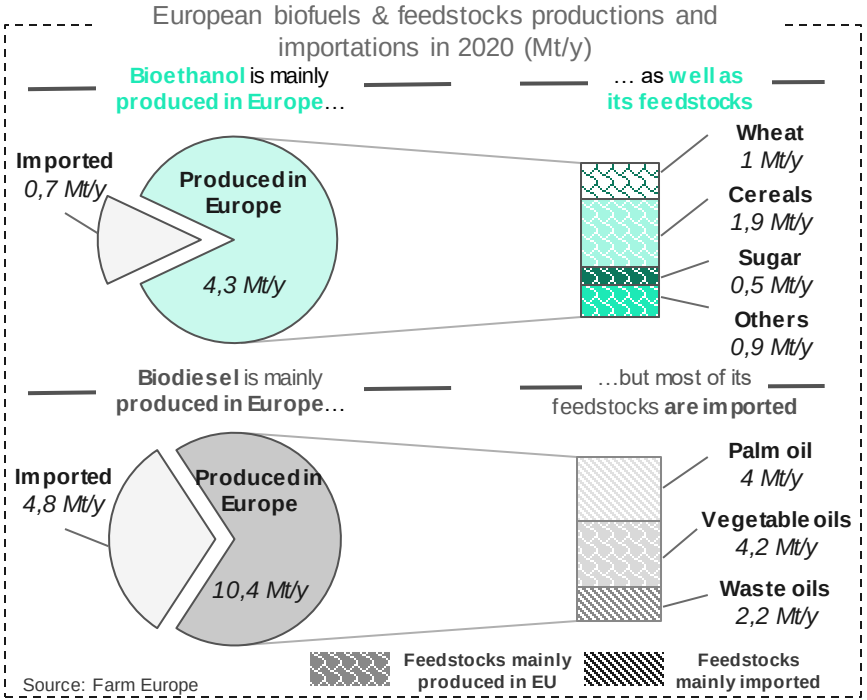
Introduction concerning the three main factors

Sia Partners has analyzed 3 main factors to compute the demand of biofuels and bioplastics by 2050 and thus, to estimate the evolution of biorefining in coming decades in Europe.



I. Overview of the biofuel and bioplastic markets in the EU in 2020

Used feedstocks and imported palm oil are mainly European agricultural resources



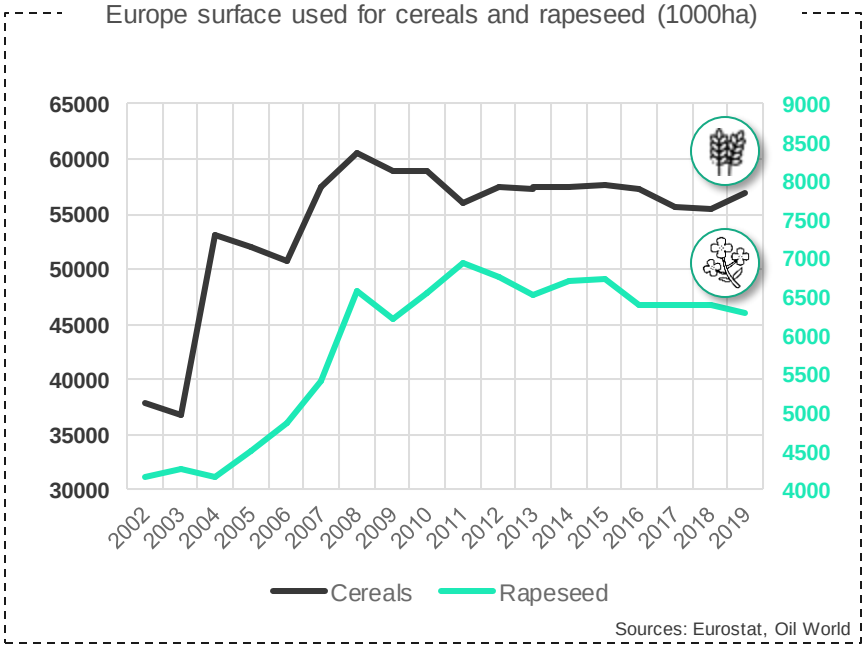
European diversity of agricultural resources is encouraged by the Common Agricultural Policy (CAP). It ensures stable and affordable supply of feedstocks, thanks to a set of policies that want to safeguard farmers' income and contribute to support rural development. The CAP accounts for one third of EU budget. **In addition to the CAP, one driver for using biomass is the diversity of feedstocks** that can be used.

In 2020, Europe produced 4.3 Mt of bioethanol (used both for biofuel and bioplastics), and **imported 0.7 Mt**. Europe has a **high level of self-sufficiency of feedstocks for domestic production of bioethanol** thanks to its supply of cereals and other agricultural resources. Bioethanol production consumes only 3% of Europe cereals output, as the harvesting of non-food crops is regulated. For **biodiesel, Europe produced 10.4 Mt and imported 4.8 Mt**. For this **domestic production, Europe heavily relies on palm oil importations**. However, the use of palm oil and soybean oil is controversial for its environmental impact, in particular for deforestation. **Hence the EU has banned the use of both palm oil and soybean oil from 2023**.

Cereals are the most representative feedstock for bioethanol, while vegetable oil and palm oil for biodiesel. Currently, Europe is more self-sufficient in bioethanol production compared to biodiesel. The basket of bio feedstocks do not include feedstocks of 2nd generation. It will be a challenge in the future to replace these resources by increasing the share of "waste".

I. Overview of the biofuel and bioplastic markets in the EU in 2020

The growing production of biomass in Europe is an asset for bioproducts development



The overall production of agricultural biomass in the EU has increased significantly in the last decades. This is the result of a progressive increase in the yields and improvements in agro-management.

In particular, the main feedstocks produced in Europe for biofuels and bioplastics are rapeseed oil and cereals. This graph shows a general expansion of the areas used for cultivation between 2002 and 2010, followed by a plateau, which can be explained by:

- A growing demand, after mandatory incorporation of first-generation biofuels under Europe's 2003 Directive on biofuels
- A slow down of support for first generation biofuels after 2012 with the mandatory reporting of indirect land use change (ILUC) factors
- The competition with other regions, with relatively high costs of feedstock produced in Europe because of necessary environmental sustainability standards and restricted use of genetically modified organisms

Europe has a significant opportunity for biomass production due to the availability of arable lands. The Common Agricultural Policy ensures a steady supply of feedstocks. However, the development of first-generation feedstocks for biofuels and bioplastics have slowed down due to regulations on land use competition.

I. Overview of the biofuel and bioplastic markets in the EU in 2020

Bio-based products need to be cost competitive to thrive

Feedstock price evolution
(Index base 100 = 2010)*

*Source: Macrotrends, Fred economic data

Price Volatility** (2010-2021)	Rapeseed oil	Wheat	Oil
	Low *0,185*	Low *0,197*	Medium *0,302*

** Average price standard deviation (2010 – 2021). Sia Partners analysis

Biorefineries seek to **convert bioresources into a large portfolio of marketable biobased products**. Biorefining products often substitute fossil based products in **well-established markets with already optimized value chain.**

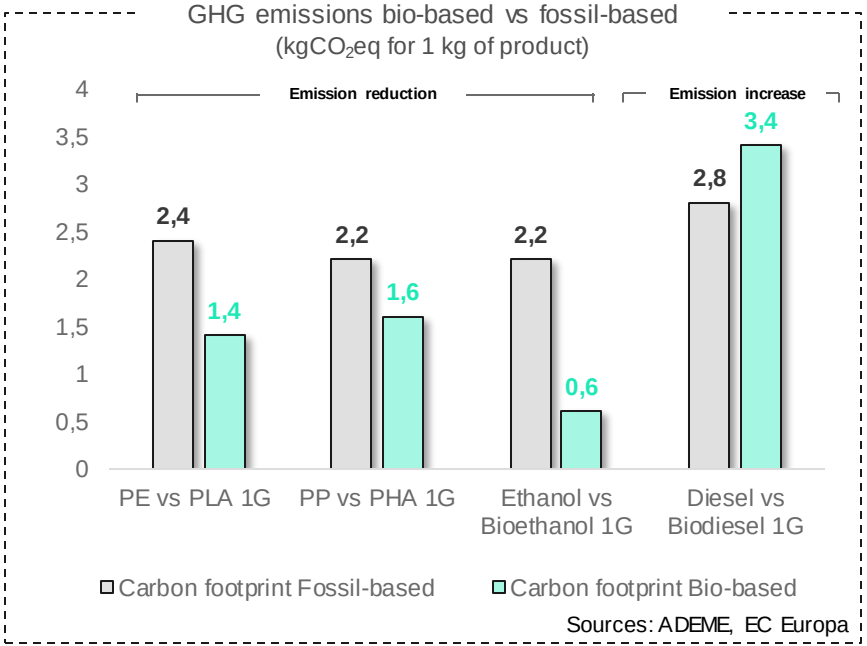
To successfully develop, they need to show economic advantages over traditional products. Bio-based feedstock provides stability for investors and are attractive thanks to the main assets below:

- **Stability.** Using European produced feedstock reduces the instability associated with oil price volatility and crisis in oil-supplier countries (see chart on the left)
- **Flexibility.** Biorefineries develop multiple products having applications on many markets. Thus, companies are reducing their reliance on one specific market.
- **Features.** Some bioproducts have greater properties than fossil-based products such as lower life cycle costs, biodegradability, resilience etc.
- **Job creation.** Biorefineries offer a significant opportunity to develop and protect jobs related to rural economies.

Some key economic benefits from the biobased economy include price stability of the biomass feedstock compared to oil, rural economic development, etc. These advantages are essential to compete with the already optimized fossil-based markets.

I. Overview of the biofuel and bioplastic markets in the EU in 2020

Having some significant environmental benefits, biobased products still need acknowledgment



As highlighted in the opposite chart, **most of the bio-based products have lower GHG emissions** as they capture CO_2 while the plant is growing. However, there are some significative exceptions such as diesel which is **less carbon intensive than its bio-based counterpart.**

This kind of exception can be explained by the following points:

- **Current land use.** Bioproducts need dedicated crops, replacing natural land that used to stored carbon.
- **Process maturity.** Transformation from biomass to final product are new processes and technologies which are very energy intensive as they are not optimized yet.
- **LCA standardization.** There are no specific instructions to develop LCA right now. Some studies are taking into account end of life while other don't.

While having some proven environmental benefits, biobased products can have significant GHG emissions. Processes still need to be optimized to reduce the biomass conversion carbon footprint.

Overview of the biofuel and bioplastic markets in the EU in 2020

Conclusion

Feedstock availability

Europe has a large diversity of agricultural resources that ensure self-sufficiency for the production of bioplastics and biofuels, which represent a minimal share in the use of agricultural resources (3%).

Economic drivers

Europe can depend on a consistent supply of feedstocks at a reliable price, which are notably less susceptible to market fluctuations compared to oil. This will help facilitate the growing demand for bio-based goods.

Environmental drivers

However, it is important to note that despite proven environmental benefits, greenhouse gas emissions can be further reduced by optimizing the processes and origins of bio-resources.

II. Trends impacting biofuel and bioplastic markets

II. Trends impacting biofuel and bioplastic markets

Introduction to the three main trends

To estimate the evolution of these 3 factors by 2050 Sia Partners has focused on 3 trends.

- **Technological advances**
  - Use of new bioresources
  - Improvement of production processes

- **Regulations**
  - Renewable energy directives
  - Regulation for biofuels and bioplastics

- **Societal breakthroughs**
  - Increasing concern regarding energy sovereignty
  - Global interest in the circular economy

II. Trends impacting biofuel and bioplastic markets

Focus on technology - advanced and conventional feedstocks

Generations	Description	Maturity	Benefits	Drawbacks	Project samples
1st Generation Feedstock	**Biomass for human or animal consumption** ▪ Vegetable oils: *soya, sunflower, rapeseed, etc.* ▪ Starch: *corn, wheat, potato, etc.* ▪ Glucose: *sugar cane, sugar beet, etc.*	●●●●	▪ Industrial scale reached ▪ Mature technologies	▪ Competition with agro-food industry ▪ Risk of deforestation	**Bioplastics**: First large scale European manufacturing plant in Grand Puits by 2024 **(100kt/y)** **Biofuels**: La Mede Biorefinery is already producing **500kt/y** biodiesel
2nd Generation Feedstock	**Non-food biomass.** ▪ Lignocellulosic biomass: wood, co-products or waste from agriculture or wood (sugar cane bagasse, straw, etc.) ▪ Non-food vegetable oils: castor and used oils	●●○○	▪ Large biomass availability ▪ Incentive regulatory framework ▪ Current industrialization phase	▪ Low competitiveness with conventional sector	**Bioplastics**: Manufacture of 2nd generation PLA from several biosourced materials: straw; corn cane and sugar cane bagasse **Biofuels**: Crescetino in Italy, Eni produces **40kt/y** of advanced bioethanol
3rd Generation feedstock	**Waste & Algae** ▪ Sugars or oils produced by micro-organisms: Micro algae, bacteria, fungi, yeasts, etc. ▪ Municipal waste: organic waste, wastewater, etc.	●○○○	▪ No competition with food ▪ Less land use constraints	▪ Uncertainties on the energy cost of the technology ▪ Technology in development (demonstration step)	**Bioplastics**: Extraction of organic matter contained in waste water from agri-food processes. Fermentation of this waste for the production of 3rd generation PHA. **Biofuels**: CEA is trying to develop 3rd generation biofuels – Basic and applied research level **(10 to 15 M€/y)**

While the majority of biofuels and bioplastics are produced from biomass derived from agricultural raw materials, benefits of advanced feedstocks lead players to invest in research projects to reach industrial scale processes.

II. Trends impacting biofuel and bioplastic markets

Technical challenges in the next decades

Feedstock technical barriers

Improving biomass harvesting methods
Some difficult terrains in central and southern Europe cannot be exploited with the current harvesting technologies.

Stabilizing biomass supply
Developing stable importations, storage and transportation systems are necessary to secure a continuous supply. Quality and costs of current technologies mitigate bioeconomy development.

Enhancing pre-treatment process.
Due to the complex and diverse nature of biomass, issues such as low product concentration, multiple side products or energy intensive processes need to be addressed.

Conversion process optimizations

Reducing energy intensity
Thermochemical advanced biomass (residues, algae) conversion to added value products is energy intensive, reducing environmental and economical advantages. Hence, the optimization of energy utilization and new conversion processes should be explored (biochemical, etc.)

Scaling-up new technologies
Validation of technologies at demonstration scale is expensive and research teams have limited engineering know-how for industrialization. Collaborations between researchers and industrial players need to be increased.

Product innovations

Increasing cost competitiveness
When providing the same properties, biobased products can compete with their fossil based counterparts. Scaling up technologies, optimizing processes and reducing biomass feedstock is necessary.

Increasing product quality
Some biobased products may have lower quality and performances compared to conventional alternatives. Modification of conversion processes where biomass is altered is needed to improve competitiveness.

In the coming years, the development of the bioeconomy will be determined by technological breakthroughs. These improvements cover the entire value chain of biorefineries, from biomass to processing and configuring the features of the products generated.

II. Trends impacting biofuel and bioplastic markets

Latest regulations on biofuels

2020 — Sustainable Finance Taxonomy

Establishment of an EU classification system for sustainable activities

- **Biofuels made from food-and-feed crops do not meet the EU's green taxonomy criteria**

2021 — ReFuelEU Aviation and FuelEU Maritime

Initiative requiring ships and planes to progressively switch to alternative fuels

- **Ships to reduce their energy GHG intensity by 2% by 2029, 6% by 2034 and 13% by 2039**
- **SAF blending volumes in aviation fuel, rising from 2% in 2025 to 5% in 2030, and 63% in 2050**

2018 — Revisions of the Renewable Energy Directive (RED)

RED II

Set of policy initiatives to make Europe climate neutral in 2050 which includes sustainability criteria for feedstocks and the following targets for 2030:

- **32% Renewable Energy Sources consumption** → **This target was increased to 45%**
- **14% of the energy consumed as renewable energy in road and rail transports** → **This target was increased to 32%**
- **3.5% advanced biofuels and biogas in final consumption of energy in the transport sector (0.2% in 2022)** → **2.2% of advanced biofuels and 2.6% of RFNBO**

Future RED III

Emanate from the provisions of the Fit-for-55 package and reinforced in May 2022 as part of the RePowerEU plan*.

In progress (2023)

Europe regulations aim to create a stable, long-term policy framework for biofuels, to increase investor confidence and allow the expansion of biofuel production. Even if the future RED III will encourage the development of biofuels, and their role in the transition to electricity mobility, the reinforcement of sustainability rules for feedstocks could be a brake for advanced generation technology development.

* RePowerEU: a plan to produce clean energy, promote energy savings and diversify energy supplies in response to energy market disruption in 2022

II. Trends impacting biofuel and bioplastic markets

Regulation for bioplastics

REACH

Identification of chemical substances to improve the protection of human health

Bioplastics can replace chemical substances, so bio-based products contribute to health and safety

2007

Single-use plastics Directive

EU-wide ban for 15 items (plates, straws…) made of expanded polystyrene by 2021

Uncertainty for bioplastics related to the ban of single-use plastic

2019

Sustainable Finance Taxonomy

The establishment of an EU classification system for sustainable activities

At least 20% of sustainable non-fossil sources used in chemical and plastic products by 2030

2020

New Circular Economy Action Plan

Targets for landfill, reuse and recycling to be met by 2030 and 2035

All plastic packaging recyclable by 2030

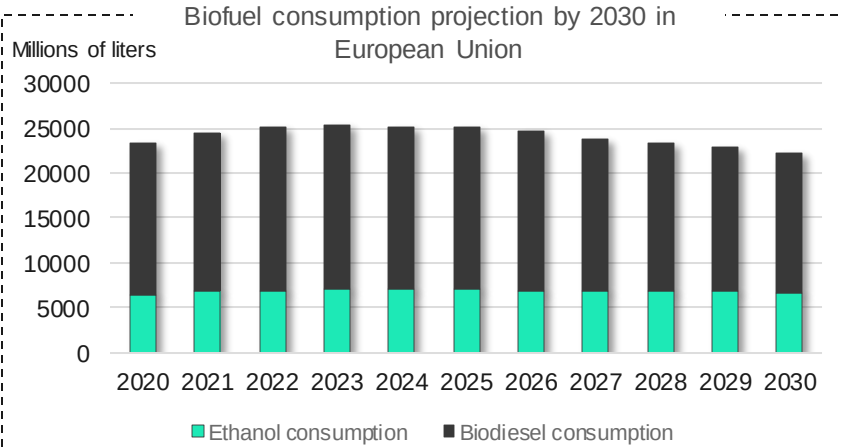
Producers should prioritise the use of organic waste and by-products as feedstock

2021

The European regulations have been put in place with the goal of promoting the growth of bioplastics production. This is primarily aimed at reducing Europe's reliance on traditional plastic production, as well as mitigating the environmental impact of plastic waste.

II. Trends impacting biofuel and bioplastic markets

Biofuels demand in the transport sector



% of decennial changes in volume	Ethanol	Biodiesel
2009 – 2019	20,1 %	91,1%
2020 – 2030 (estimated)	5,5 %	- 9,7%

Sources: Sia Partners analysis/OECD-FAO Agricultural Outlook 2021-2030

Slightly declining demand but stronger substitution from fossil fuels by 2030.

The growth rate of biofuels production and consumption in Europe is expected to slow down by 2030 compared to the past decade. Additionally, the OECD, predicts a decrease in the percentage of diesel and gasoline used in the transport industry's overall energy consumption over the next 10 years.

Total EU biofuels consumption is projected to decline by 0.7% per year by 2029, but the share of advanced biofuels is expected to rise to 24% from 17% currently.

Despite the increase in biofuels incorporation targets (7% from 1G biofuels, 3% from 2G biofuels), there are still many obstacles to the development of biofuel demand:

Decline of thermal vehicles (especially those with diesel engines):
The European Commission predicts the end of combustion engine car sales by **2035.**

Support and development of alternative mobility solutions:
Hydrogen and electric vehicles capturing new market shares.

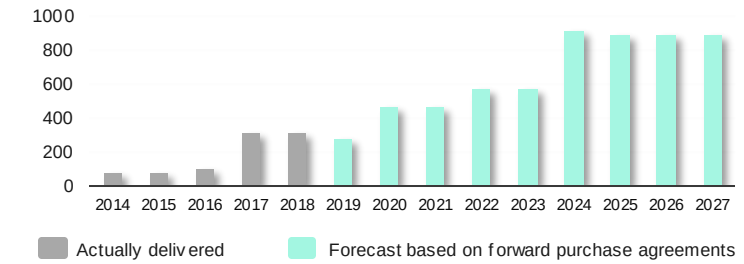
Despite a significant demand for bio-fuels in Europe, the fuel market is currently facing sustainability challenges due to the rise of alternative mobility and the ongoing crisis. However, the production capacities of biofuels in Europe present an opportunity to export to other regions where thermal engine production will still continue beyond 2035.

II. Trends impacting biofuel and bioplastic markets

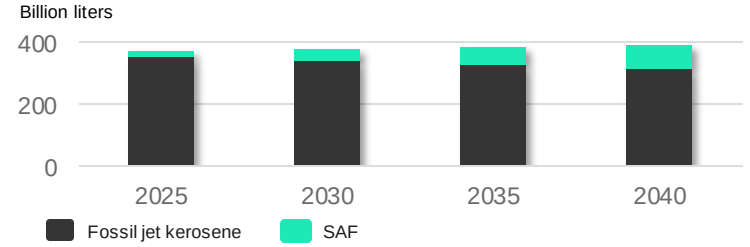
The growing market of sustainable fuels in the aviation and shipping sectors will impact refineries

Sustainable aviation fuel annual consumption

1. Annual volumes of aviation biofuel ordered by airlines via partnerships (M liters/year)



2. IEA Aviation fuel consumption in the Sustainable Development Scenario, 2025-2040



Sources: Sia Partners Analysis and IEA

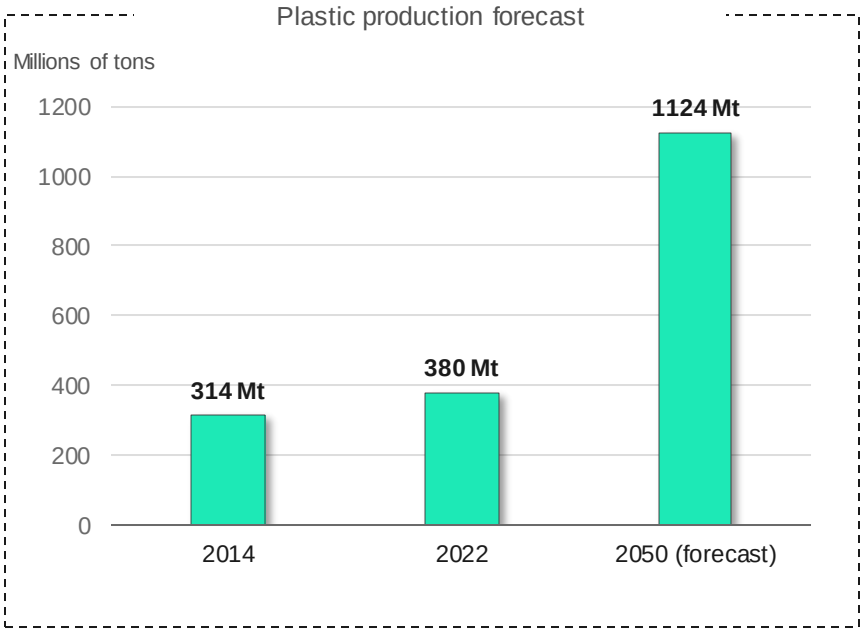
As air traffic grows, **the aviation sector faces a complex challenge to reduce its climate impact.** Under the Fit for 55 initiative, **the European Commission proposed a ReFuelEU Aviation regulation mandating minimum SAF blending volumes in aviation fuel, rising from 2% in 2025 to 5% in 2030 and 63% in 2050**.
For the production, since most commercially available Sustainable Aviation Fuels (SAFs) are produced with plant oils today, power-to-liquid and new feedstocks without land use impact are needed.

For the maritime transport sector, the EU has set annual average carbon intensity reduction obligations of 75% in 2050 compared to the 2020 average (with sub-targets such as 26% in 2040). **The International Maritime Organization (IMO) aims to reduce greenhouse gas emissions from ships by 50% by 2050 compared to 2008.** The adoption of LNG and alternative biofuels are encouraged to achieve these goals.

The consumption of biofuels for the aviation and shipping sectors is expected to scale up driven by blending objectives and by growing demand.

II. Trends impacting biofuel and bioplastic markets

Towards a plastic circular economy by 2050



Currently, the **annual production of plastic exceeds 380 million tons** and is growing at a **rate of over 4%**. This is mainly attributed to the vast range of uses and applications that it offers.

Consequently **6,300 million tons of plastic waste has been generated since 1950,** raising significant concerns about the negative impact it has on the environment.

According to the Center for International Environmental Law (CIEL), in 2019 the production and incineration of plastic emitted 850 million tons of greenhouse gases into the atmosphere. **To put this in perspective, this amount is equivalent to one and a half years' worth of emissions from France.** Without action, the EU will see a further 46% increase in plastic packaging waste by 2030.

The use of renewable raw materials would allow the plastic packaging sector to reduce its carbon emissions and minimize plastic waste.

The increasing generation of plastic waste and its high greenhouse gas emissions is driving the shift to a circular plastic economy. Introducing bioplastics can help achieve the ambitious goal of sourcing at least 20%* of the carbon used in plastic and chemical production from sustainable, non-fossil resources which could help reach climate neutrality.

*source: European Commission, EU policy framework on biobased, biodegradable and compostable plastics, 2022 Nov. 30th

II. Trends impacting biofuel and bioplastic markets

Conclusion

Trends affecting the competitiveness of biorefineries

Technological advances

- The industrial development of bioresources from first generation of biomass has reached its maximum level and is now locked at 7% by EU regulations
- It is necessary for actors of the biorefining sector to refocus on the exploitation of second generation of biomass in order to reach an industrial level of production over the next decades

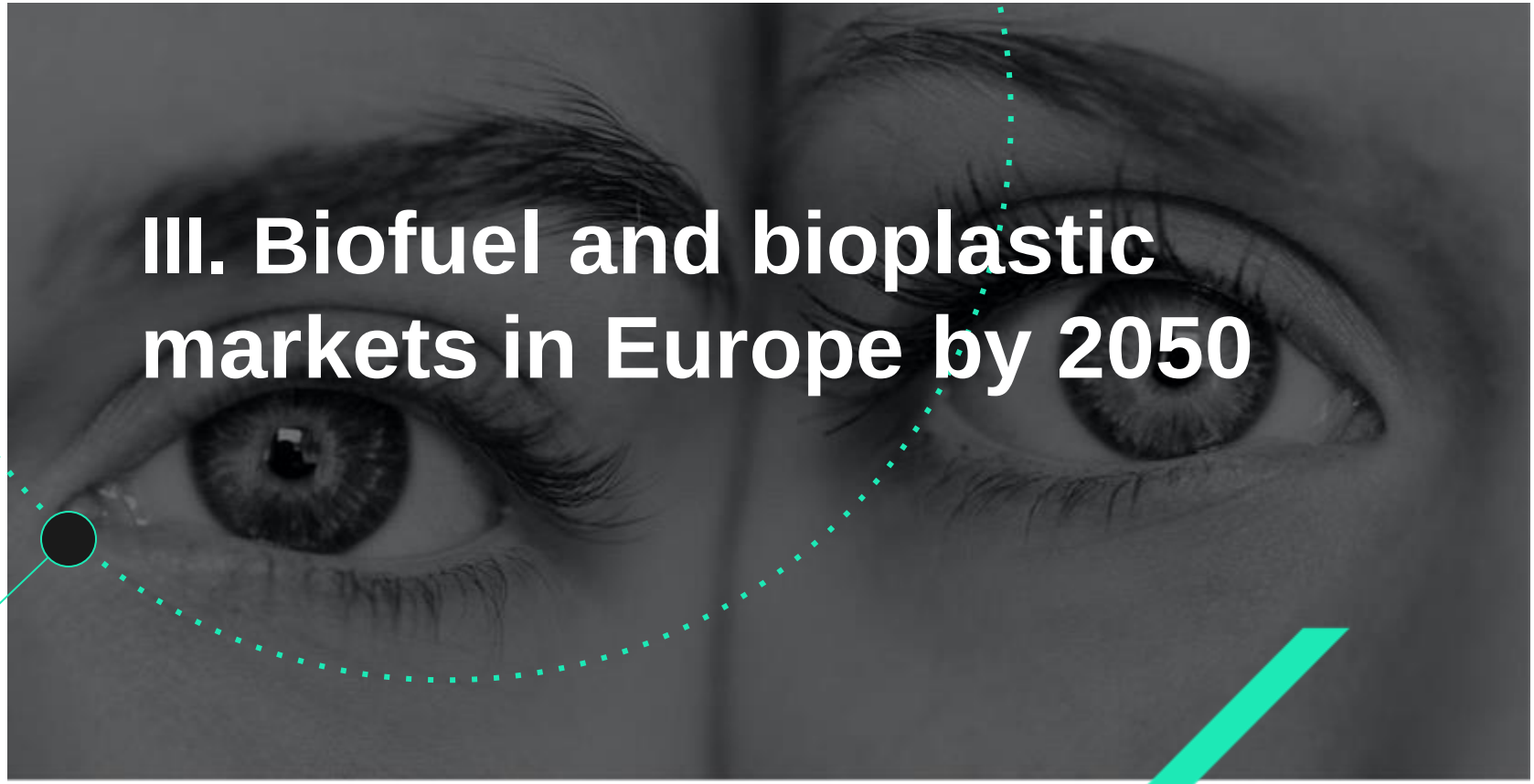
Regulations

The growth of the biorefining sector is supported by the introduction of environmental performance standards. By 2030 targets are:

- 32% minimum as renewable energy of consumed energy for road and rail transports
- 2.2 % advanced biofuels and biogas in final consumption of energy in the transport sector (0.2% in 2022)
- At least 20% of sustainable non-fossil sources used in chemical and plastic products

Societal breakthroughs

- Total EU biofuel consumption is projected to decline by 0.7% per year by 2029 due to the development of alternative mobility
- The increasing plastic production, 1124 Mt expected in 2050 and its high greenhouse gas emissions is driving the transition to a circular plastic economy which promotes the development of bioplastics



III. Biofuel and bioplastic markets in Europe by 2050

III. Biofuel and bioplastic markets in Europe by 2050

Introduction

Sia Partners has developed a top-down modelling tool to quantify the evolution of European biorefining by 2050 and investigate key parameters:

Environmental impact

How much GHG savings from this transition?

Energy sovereignty

How is it impacting European import dependence?

Agriculture stress

What feedstocks are needed? Are they cultivated in Europe?

Resources impacts

Is it possible to produce 100% of the bioproduct locally?

Refinery sector transformation

How will the refining industry need to adapt?

III. Biofuel and bioplastic markets in Europe by 2050

Modelling the bioeconomy overview in 2050

1. Projecting the 2050 demand for plastics and fuels In Europe

- **1.1. Detailed study of the different markets and their levers/barriers to growth**
  - **Three main trends** impacting future demand have been identified
    - Technological advances
    - Regulations
    - Societal breakthroughs
- **1.2. Modeling plastics and fuel potential by 2050**
  - **The overall fuel and plastic demand** (fossil + bio-based) has been forecasted to 2050

2. Analyzing the bio-based share in this upcoming demand

- **2.1. Detailed analysis of the bio-based markets and their levers/barriers to growth**
  - **Three main trends** impacting future demand have been identified
    - Technological advances
    - Regulations
    - Societal breakthroughs
- **2.2. Comprehensive study of the technological advances to come**
  - **Feedstock technical barriers, conversion process optimization and new production innovation** have been assessed
- **2.3. Definition of 3 possible scenarios for future European bioeconomy development**
  - Based on trends evolution, **3 possible futures on technological advances to come** have been investigated. Impact on **PLA, Bio-PE, PHA, Biodiesel & Bioethanol** has been investigated

3. Measuring the impacts of the bioeconomy scaling-up

- **3.1. Detailed bottom-up analysis to calculate future externalities**
  - Each market & technology has been associated with **a representative feedstock** *(Ex: PLA 1G has been considered as produced from wheat)* – **Then feedstock's yield, water footprint, GHG emissions** etc.. has been finely studied
- **3.2. Interpretation of the results through 5 key parameters**
  - The results have been analyzed under the **prism of 5 key dimensions**
    - Environmental impact
    - Energy sovereignty
    - Agriculture stress
    - Resources impacts
    - Refinery sector transformation

III. Biofuel and bioplastic markets in Europe by 2050

Description of three potential futures for the European bioeconomy

Based on trends analyzed in part II, Sia Partners has drawn 3 possible scenarios for future European biorefining development.

Technological advances	Depending on the amount of investment made and the speed at which demonstrators are scaled up to industrial scale, advanced generations could heavily thrive
Regulations	The political commitment to favor bio-products from feedstocks which do not compete with food will also be a decisive element to draw the European 2050 landscape
Societal breakthroughs	Ultimately, public opinion and the desire of consumers to use products with a lower environmental impact could also support the development of advanced generations

1. Conservative Scenario

No real incentive from governments to develop advanced technologies. *Most bio-products on the market are from 1st generation, few from the 2nd generation and none from 3rd generation.*

2. Supportive scenario

Strong support from European governments. *Advanced generation bioproducts represent most of the bio-based market with high deployment of 2nd generation technologies while the 1st generation decline.*

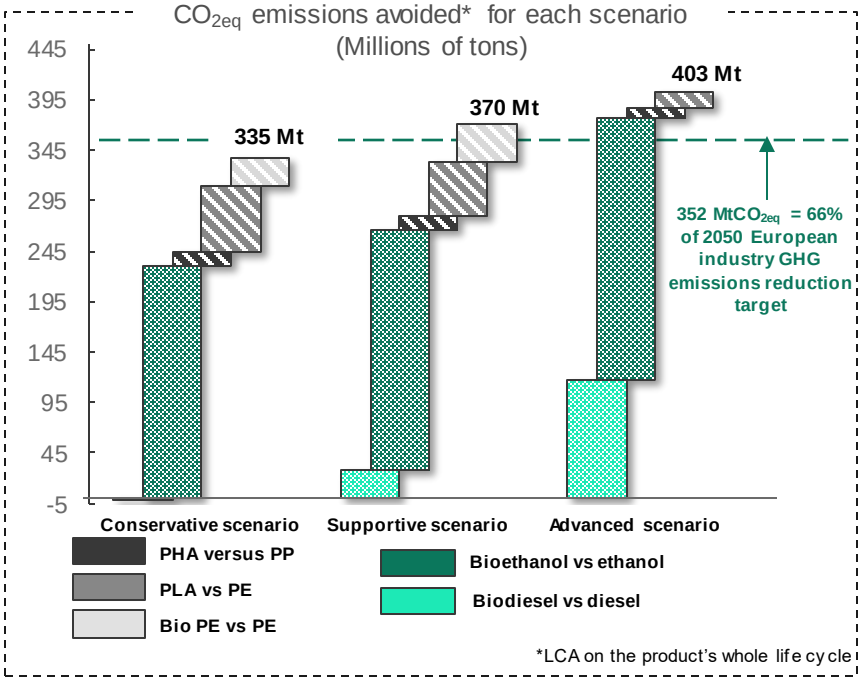
3. Advanced scenario

Many technological breakthroughs thanks to heavy support from institutions. *There is no more 1st generation product on the market. The 3rd generation counts for most of bio-based products.*

− **Increasing advanced generations (2G+) technologies deployment** **+**

III. Biofuel and bioplastic markets in Europe by 2050

Positive environmental impacts to meet European emission reduction targets



Graphic analysis

- The transition towards bioeconomy in the fuel & plastic markets would drastically contribute to the reduction of industry CO_2 emissions – Supportive and advanced scenarios allowing more than 2/3 of 528 $MtCO_{2eq}$ European emission reduction targets

Key noticeable points

- Some bio-products have negative environmental impacts vs their fossil counterparts (e.g., Biodiesel 1G)
- Bioplastics and first-generation technologies are way less advantageous from a GHG emissions perspective – to decarbonize the European economy emphasis should be placed on advanced biofuel generations

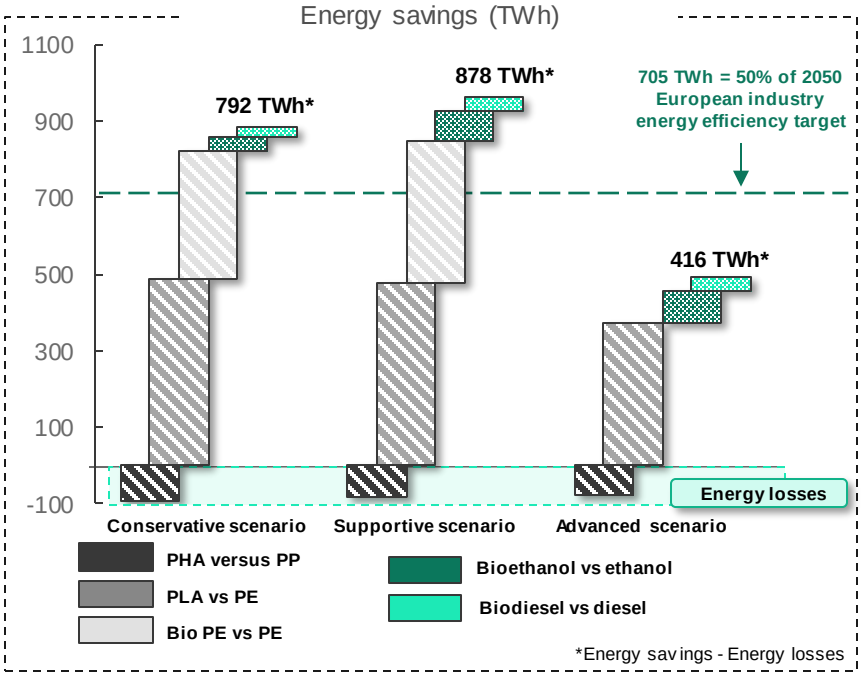
To be noted

- The environmental impact of bioproducts is currently under debate. There is uncertainty about the real impact of bioproducts due to a lack of regulations to frame LCAs. The results in literature have great variation depending on the scope and assumptions used

Despite difficulties in measuring the real impacts of bioproducts (on GHG) (no LCA standards, high CO_2 emissions range in literature), it seems that they would actively participate in the industry's reduction objectives.

III. Biofuel and bioplastic markets in Europe by 2050

The use of local agricultural energy resources reduces the demand for imported fossil fuels



Graphic analysis

- Conservative and supportive scenarios would allow to contribute by more than half of 1410 TWh European reduction target for industry sector. It comforts that a large scale deployment of biofuel and bioplastics could support energy efficiency policies.

Key noticeable points

- Based on low-maturity processes, advanced generations require more energy than already optimized processes used for 1st generation
- While having fewer environmental gains, bioplastics possess significant energy saving potential compared to biofuels.

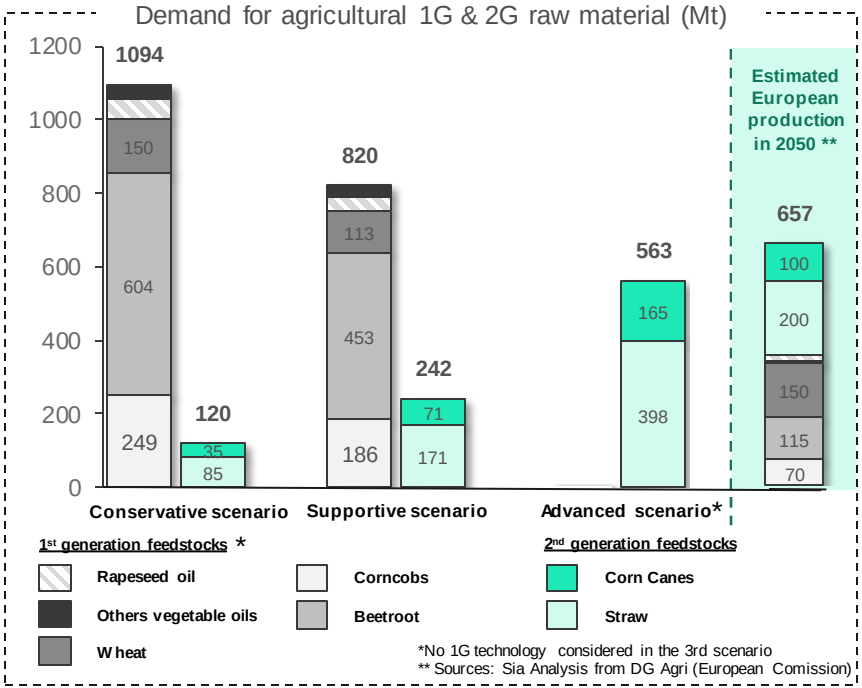
To be noted

- Apart from the scientific literature review, there is little public information on energy needs to transform feedstocks to marketable products – specifically for advanced generations. It is therefore complicated to predict energy gains from technological advances and industrial scaling-up.

In the case of 100% local production of all bioproducts in 2050, Europe would drastically improve its energy resilience by using local and less energy-intensive bioresources instead of importing fossil energy resources to produce the same amount of goods.

III. Biofuel and bioplastic markets in Europe by 2050

100% local production of bioproduct demand would burden the European farming sector



Graphic analysis

- In the conservative and supportive scenarios, Europe would not produce enough feedstocks to meet the demand.
- In 2050, Europe would produce roughly 300Mt of cereals and 115Mt of beetroot, while the conservative scenario requires 399Mt of cereals and 604Mt of beetroot.

Key noticeable points

- The 1st generation feedstocks needed for bioproducts threaten the availability of cereals, vegetable oil and sugar for human and animal feed consumption.
- With a potential 2nd generation feedstock production of around 300Mt, Europe would be self-sufficient in the 2 first scenarios in terms of crop residues.

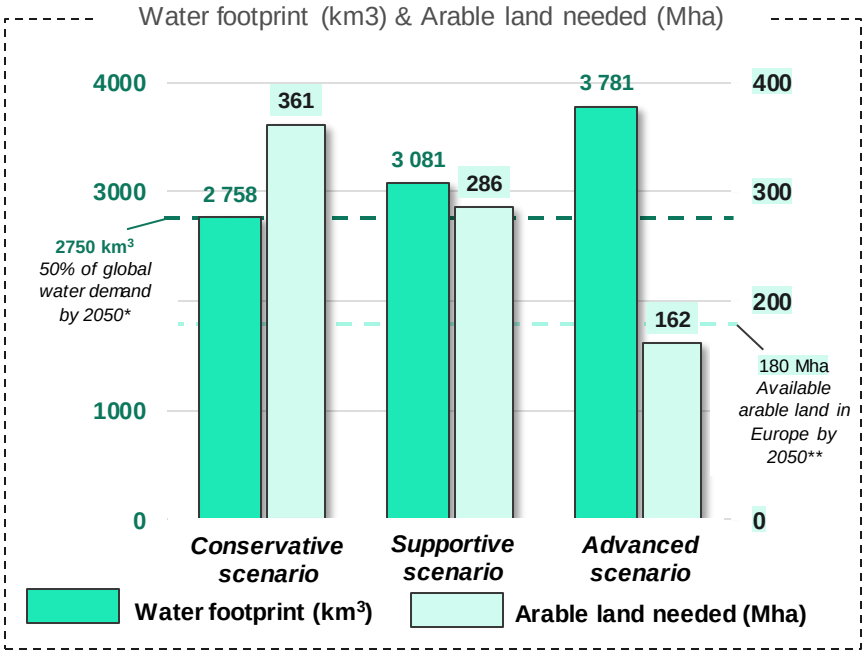
To be noted

- For domestic production, Europe already has a trade deficit of vegetable oil that can be tackled by the development of 2G and 3G. And in 2050, Europe has to both limit the loss of arable land and develop waste-based bioproducts and advanced technologies of production to limit the importations of final bioproducts.
- Advanced scenario leads to a complete self-sufficiency

The use of 2nd and 3rd generation feedstocks, which represent non-food biomass, is needed to reduce imports dependency and to ensure food security.

III. Biofuel and bioplastic markets in Europe by 2050

There are also physical limits on resources to supply 100% of demand with local production



Graphic analysis

- Many of the scenarios **exceed European limits** in terms of access to the resources necessary for their successful development.

Key noticeable points

- 2G & 3G minimize the risk on land use and have potential for improvement in terms of water demand efficiency since their process is not yet mature
- Next-generations bioproducts have a greater water footprint - using total biomass, including stems and leaves which is more efficient to reduce the water footprint and land-use.

To be noted

- The increase in arable land over the generations **is mainly due to the significant use of straw and wood** (lignocellulosic material) which need more space but do not compete with food. *Example: 0,18t of wood residues can be collected per ha while 3,5 t of corn are harvestable per ha.*

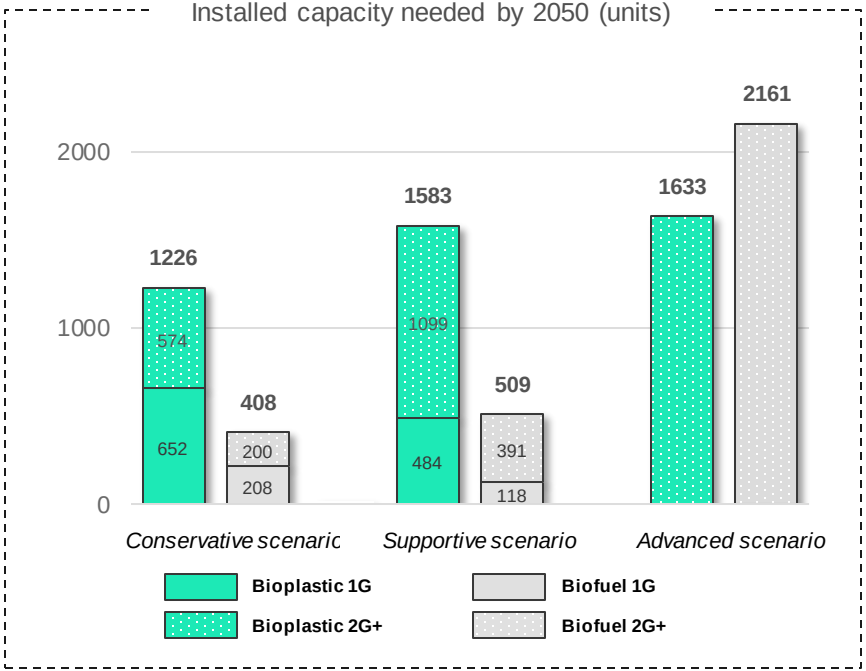
*Agricultural & rural development, EC Europa, 2021

**Environnemental Outlook to 2050, OECD, 2012

With limited arable land and water available for agriculture, Europe would have to deal with feedstocks scarcity and usage competition to potentially supply 100% of the demand locally. Nevertheless, arable land needed for the advanced scenario does not compete with the food industry as its main feedstock is based on biomass waste.

III. Biofuel and bioplastic markets in Europe by 2050

Provided Europe wants to be self-sufficient by 2050, a large number of new facilities will be needed



Graphic analysis

- In many of the scenarios, the current biorefinery units need to be tripled by 2050. Although this seems ambitious, these scenarios are based on a very strong assumption of complete European sovereignty without considering any importation.

Key noticeable points

- Many pathways for remodeling the refinery sector are contemplated. It may come from:
  1. Expanding existing biorefineries
  2. Developing new biorefineries
  3. Co-processing already existing fossil-based refineries
  4. Re-focusing fossil-based refineries.

It is likely to be a mixture of all these solutions.

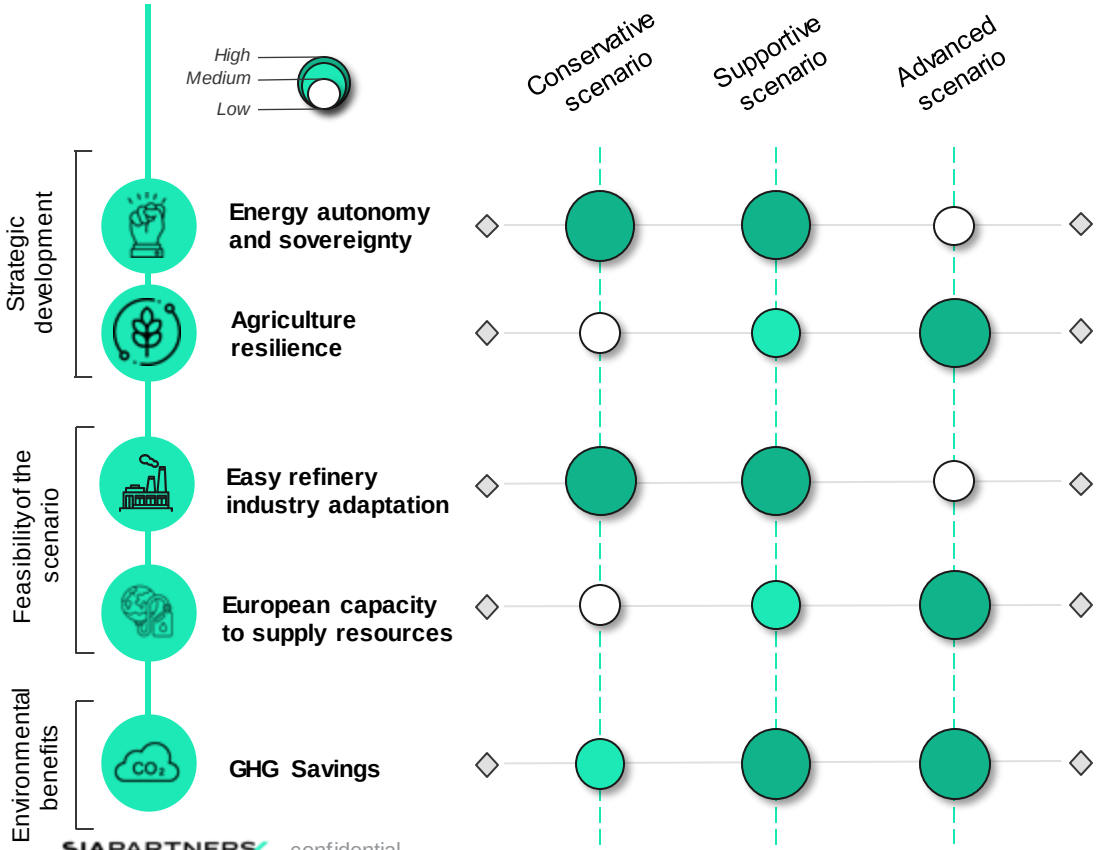
To be noted

- Following size have been considered for the above analysis
  - 1G bioplastic – 100kt/y
  - 2G bioplastic – 30 kt/y
  - 1G biofuel – 0,5 Mtep/y
  - 2G biofuel - 0,15 Mtep/y

The necessary conversion of the refining sector will require significant support mechanisms from governments for the scaling up of a large number of demonstrators to industrial plants. It is a very interesting opportunity for the actors in place or who would like to launch activities.

III. Biofuel and bioplastic markets in Europe by 20500

Comparison of the 3 possible scenario by 2050



The supportive scenario seems to be the most viable option for the future.

- **The supportive scenario possesses great balance** between feasibility and positive impacts
- While the advanced scenario **reduces stress on ressources and agriculture**, it needs **heavy energy optimization** to become fully conceivable
- **The conservative scenario may be the most achievable** but it would **stress European resources**

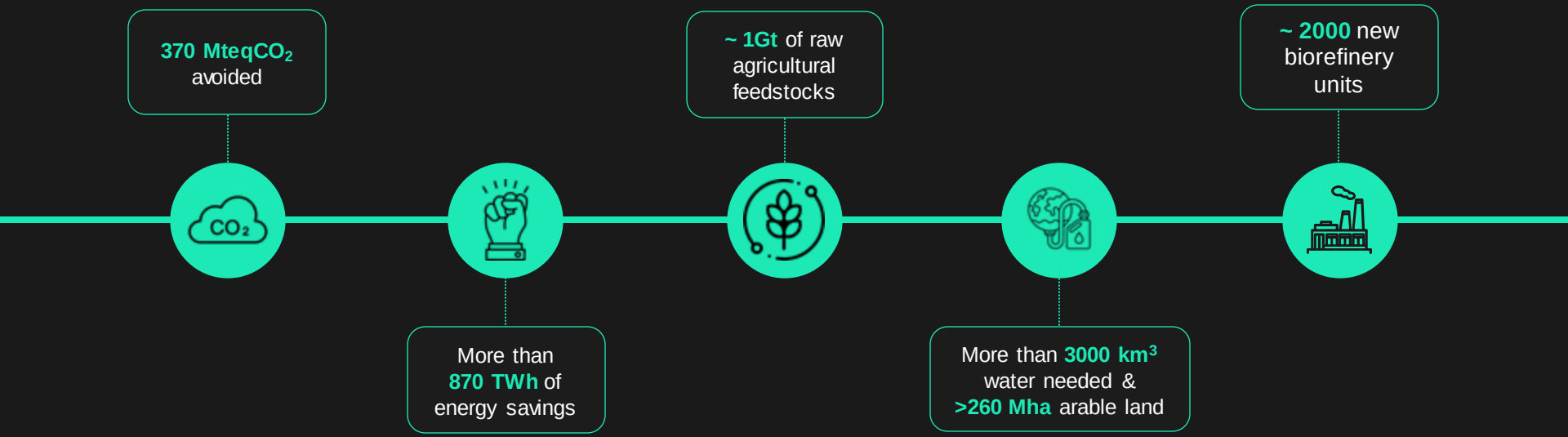
The results stress European agriculture capacity

- The results are based on prospective hypothesis by 2050 **which may evolve in the coming years**
- All scenarios need agricutural & industrial technology advancements to be achievable with the current European capacity

III. Biofuel and bioplastic markets in Europe by 2050

Conclusion

- Although based on assumptions of rapid development of bioplastics and biofuels, the **supportive scenario** seems to be a good compromise at European level between **positive externalities** and the **need for transformation.**
- It would enable **significant changes in the European economy** but would require **significant agricultural breakthroughs to reduce resource consumption** as illustrated below.
- It is also important to remember that these scenarios are based on assumptions of **absolute sovereignty** and are consequently **very ambitious by nature**



IV. Conclusion and global recommendations for transformations

IV. Conclusion and global recommendations for transformations

Introduction

To meet the growing need for biofuels and bioplastics in Europe by 2050, the different actors in the chain of biorefining must transform their business models to survive or expand their production. Sia Partners propose 3 main levers to overcome the challenges of the biorefining sector by 2050 and contribute to a green deal European objective in transport, industry, construction, chemical and other derived sectors of bioplastics:

Support Policies

Feedstock Supply

Business model based on the bio-economy

IV. Conclusion and global recommendations for transformations

Introduction

Sia Partners has identified two primary actors that play a crucial role in the transformation of the biorefining sectors.

Oil industry

Refiners
Chemicals companies
Petrochemicals companies

Bio-based industry

Biorefiners
Agricultural organisations
Agro-industry

IV. Conclusion and global recommendations for transformations

Stay competitive thanks to public support and cost reduction: Sia Partners convictions

A strict policy framework to achieve the EU's emission reduction targets

BIOFUELS

- EU Objectives: **90% cut in greenhouse gas emissions** from the transport sector is needed by 2050
- **End of thermal engines in 2030** and competition with electricity engines

BIOPLASTICS

- All plastic packaging **bio-based by 2030**
- **Demand for plastics** will increase significantly by 2050 in various sectors (packaging, construction, automobile industry…)

A mobilisation of public authorities is necessary to allow these sectors to be transition sectors towards a zero-carbon Europe

Regulation

- Establish a standard for sustainability of biobased products

Research & Innovation

- Aim for self-sufficiency at a European level for biomass production

Support & subsidies

- Subsidising the prices of output products to increase their competitiveness
- Increase the quota of land eligible for biomass production

Biofuels and bioplastics are highly viable solutions for achieving the European low-carbon strategy targets.

IV. Conclusion and global recommendations for transformations

Harnessing the full potential of sustainable raw materials for a competitive circular bioeconomy

Bio-based product chains are subject to short-term constraints related to the supply of feedstock

The potential of EU bio-feedstocks is high:

- Primary crops agricultural
- Forest
- Byproducts
- Post-consumer residues
- Construction waste

Therefore, there will be **demand for these feedstocks from various sectors in competition with the biorefinery sector**

The biorefinery sector will also have to deal with the ban on feedstock imports from outside of Europe

The supply of feedstock at mid and long-term is also not guaranteed

Overcome the challenges and reach the objectives in terms of feedstock production to accelerate the development of advanced technologies

Develop better mapping of regional and local bio-feedstock resource locations

Enhance the bioeconomy by supporting establishment of **biomass and waste supply companies**

Create agricultural policies to expand lands dedicated to energy markets

Improve research and development **on micro-algae crops**

To achieve the 2050 targets, robust and flexible logistical systems need to be implemented to process the diverse European biomass potential.

IV. Conclusion and global recommendations for transformations

Biorefining: an opportunity to maintain margin production and stay on the market despite the decline of fossil products

Issues for the oil industry

Reach the Decarbonization targets	Aim markets with high potential	Reach energy sovereignty
The upcoming end of the fossil-based market should be an opportunity for companies **to strengthen their reputation** by promoting bio products and taking a **leading role** to reduce their carbon footprint in the EU.	Aimed at **high potential markets** in which **activity will be maintained** maritime and aviation sectors, and bioplastics with a multitude of markets to be addressed (packaging, cars, etc.).	Invest in **new biorefining capacity** to **diversify its supply** of end products. The scaling up of production will require **the establishment of partnerships** with other players in the sector such as agro-industries.

Bioplastics and biofuels are a way for pure players in the fossil industry to maintain their levels of activity despite a difficult context for their sectors of origin in the coming decades.

IV. Conclusion and global recommendations for transformations

Biorefining: a promising sector for the bioeconomy

Biorefinery main barriers

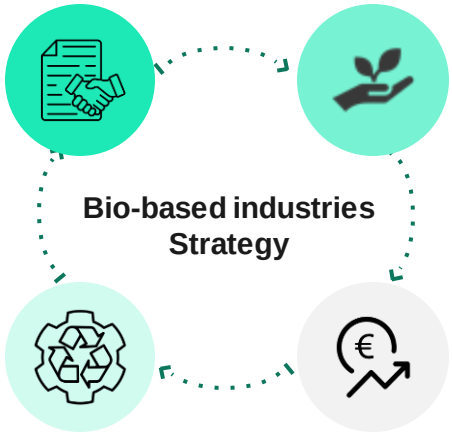
- **Highly fluctuating and rising biomass prices**
- **No support for biorefinery projects**
- **Difficulty to scale up production**

Use the policies support

Rely on various EU regulations such as the Circular Economy Package, the updated Waste Framework Directive, and the EU Green Deal

Value products from the agricultural sector

Biorefineries are a way to offer a new activity to the industry and to **strengthen the economic development** of rural areas



Addressing consumer concerns

A company that goes bio-based is seen **as willing and proactive** to find solutions to reduce its carbon footprint

Developing partnerships for a circular economy at regional level

Take advantage of the knowledge on biomass production to **create strategic partnerships** with downstream actors

The biorefinery sector can become a major sector of the biobased industry and one of the major sectors of the bioeconomy.

IV. Conclusion and global recommendations for transformations

Conclusion

In order to achieve the goals for the biorefinery sector:

- **New capacities for biorefinery sector**

Sia Partners has estimated the three main transformations that need to grow by 2050

Support Policies

- Support the expansion of regional bioeconomy strategies
- Support R&D to reduce costs in all biorefinery pathways

Optimize the use of European biomass

- Establish a complete diagnosis of the available and operable biomass in the identified areas
- Supporting the establishment of biomass supply companies in order to set up flexible logistic systems

Develop a new business model towards bioeconomy strategies

- Analyze the best local partnerships in France and Europe
- Improve the level of biofuel and bioplastic production by using a new type of biomass such as waste

Appendix
Glossary

Glossary

- ADEME Agence De l'Environnement et de la Maîtrise de l'Énergie
- CAP Common Agricultural Policy
- FAO Food and Agriculture Organization
- GHG Green House Gas
- IEA International Energy Agency
- LULUC Land Use and Land Use Change
- OECD Organisation for Economic Co-operation and Development
- PE Polyethylene
- PHA Polyhydroxyalkanoates
- PLA Polylactic acid
- REACH Registration, Evaluation, Authorisation and Restriction of Chemicals
- RED Renewable Energy Directive
- RFNBO Renewable Fuels of Non Biological Origin
- SAF Sustainable Aviation Fuel
- SDGs Sustainable Development Goals
- WFD Waste Framework Directive

Appendix
Acknowledgments and contacts

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