European Commission

# Development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels

Executive Summary

Research and Innovation

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EUROPEAN COMMISSION

# Development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels

***Executive Summary***


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The project was executed by a Consortium comprising:


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# Executive Summary

## Introduction

This Executive Summary outlines the key findings of the project "*Development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels*", under Contract No: CINEA/2022/OP/0004/SI2.884011. The project was executed by a Consortium comprising EXERGIA (Leader), Politecnico di Torino (POLITO), BEST - Bioenergy and Sustainable Technologies, BTG Biomass Technology Group BV, Wageningen Institute for Environment and Climate Research (WENR) and E3-Modelling.

The objective of the project is to investigate and analyze the factors influencing **the industrial growth of advanced and sustainable biofuels production,** in the context of the relevant EU policy and regulatory framework. Firstly, this involves leveraging recent industrial capacity data and plans from key stakeholders in the sustainable transportation sector, such as fuel producers, technology developers, and other market actors. Secondly, it includes the examination and analysis of various aspects such as the potential demand for advanced drop-in biofuels, resource availability and supply prospects, technological maturity as well as social and environmental impacts. Finally, the project identifies vital investments and actions necessary to expedite the transformation of the industry's outlook. The comprehensive analysis of the study is outlined in the Final Report of the project.

## Project Tasks

The following Tasks were executed in line with the Terms of Reference of the Project.

Task 1 – Analysis of demand potential of alternative to fossil fuels for transport

Quantifying different transport demand scenarios for 2030 and 2050, along with the potential uptake of advanced biofuels in this sector is vital for understanding the industrial capacity required for production under different conditions. This task involved analysing existing EU and national policy measures to estimate their impact on deploying advanced biofuels up to 2030 and beyond. The PRIMES-TREMOVE and PRIMES Maritime models were then used to quantify plausible scenarios for the uptake of advanced biofuels in transport under various assumptions. The modelling used in this study takes the policy framework of the Fit for 55[1] package, the REPowerEU[2] plan and the EU Green Deal[3] targets, as a starting point and differentiates across scenarios based on modelling and policy assumptions, projecting the potential for advanced biofuels to meet the targets.

The policy portfolio incorporates key EU energy, climate and transport policies and EC legislative proposals within the Fit for 55 policy package or the REPowerEU plan that, among others, include the Renewable Energy Directive (RED II)[4], the EU Emissions Trading System

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[1] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the regions 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality
[2] Communication From the Commission to The European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the regions REPowerEU Plan
[3] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the regions the European Green Deal
[4] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast)

(ETS)[5], the new ETS covering also road transport[6], the Energy Taxation Directive (EU ETD)[7], the $CO_2$ emissions standards for cars, vans[8] and heavy-duty vehicles[9], FuelEU Maritime[10], ReFuelEU aviation[11], and the Alternative Fuel Infrastructure Regulation (AFIR)[12]. The project examined several scenarios, distinguished by initiatives from the Fit for 55 policy package or the REPowerEU plan as outlined in Figure 1.

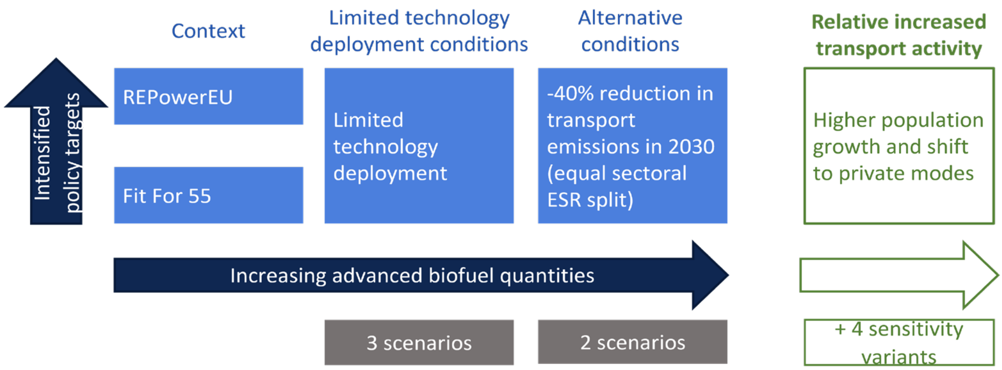


Figure 1 Scenario implementation framework

For each main policy framework, scenarios were further distinguished by considering two sets of basic drivers:

- "Limited Technology Deployment" (LTD): It was assumed that technologies such as electric vehicle batteries, alternative fuels infrastructure, electrolyzers and direct air capture would not deploy as fast as expected by 2030.

[5] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC
[6] Directive (EU) 2023/959 of the European Parliament and of the Council of 10 May 2023 amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union and Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading system
[7] Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity
[8] Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting CO2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011 (recast)
[9] Regulation (EU) 2019/1242 of the European Parliament and of the Council of 20 June 2019 setting CO2 emission performance standards for new heavy-duty vehicles and amending Regulations (EC) No 595/2009 and (EU) 2018/956 of the European Parliament and of the Council and Council Directive 96/53/EC
[10] Regulation of the European Parliament and of the Council on the use of renewable and low-carbon fuels in maritime transport, and amending Directive 2009/16/EC, July 2023
[11] Regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport (ReFuelEU Aviation), Sept. 2023
[12] Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU

- "Effort Sharing Regulation (ESR variants)"[13]: Conditions were modeled in which transport segments achieve 40% (GHG) emissions reduction by 2030 compared to 2005, aligning with the scope and overall target of the ESR.

Additional simulations were conducted to assess the impact of increased transport activity on the promotion of advanced biofuels under both main policy frameworks.

Finally, a scenario was developed to quantify the provisional agreement on RED III[14,15] aiming to meet the GHG intensity target[16] within the context of Fit for 55. The analysis also highlights certain conditions under which the potential for advanced biofuels may be higher, providing industry stakeholders with insights to navigate development conditions to meet demand.

The scenarios anticipate a significant rise in biofuels use by 2030, ranging from ca. 32 to ca. 40 Mtoe encompassing all types of biofuels. The overall increase is attributed to the uptake of advanced biofuels, specifically those related to Annex IX Part A and Part B fuels. The combined demand for renewable electricity and RFNBOs is expected to range from 9 to 17 Mtoe (Figure 2). In 2030, the demand for biofuels is mainly foreseen in road transport accounting for 85-88% of total consumption. While the Emissions Trading System (ETS) influences demand across sectors, the uptake in aviation and maritime transport is primarily driven by mandates for Sustainable Aviation Fuel (SAF) and the imperative to reduce GHG intensity in energy use, respectively. Current policies and scenarios suggest that by 2030, advanced biofuels (Annex IX Part A) might constitute about half of the total biofuel consumption in transport (47% to 51%, or 15 to 22 Mtoe), and biofuels from waste oil and fats (Annex IX Part B) about 9 to 10 Mtoe (or ca. 23% to 28%). Specifically, under the RED scenario, which quantifies the provisional agreement on RED III via the GHG intensity target, conventional biofuels are projected to contribute with 10.6 Mtoe/yr, Annex IX Part A fuels with 18.4 Mtoe/yr and Annex IX Part B with 9.0 Mtoe/yr.

By 2050, the scenarios predict a more extensive adoption of electrification in road transport, leading to a diminished reliance on internal combustion engines. Advanced biofuels are expected to be fully mature and widely deployed. The projections indicate a shift in biofuel utilization towards aviation and maritime sectors, propelled by increased SAF blending mandates or post-2030 GHG intensity reduction targets. Biofuel demand in the EU is anticipated to reach 45-47 Mtoe by 2050, with advanced biofuels comprising nearly 90% of this amount.

The sensitivity variants, which consider a higher-than-expected increase in road transport activity, suggest an even greater biofuel uptake, with an additional 2 to 3 Mtoe/yr being supplied by advanced biofuels. These variants also predict a rise in liquid fuel demand by 14 to 17 Mtoe in 2030, which could be met by advanced biofuels as an alternative to fossil fuels, indicating a possibility for further uptake. Modelling results indicate that biofuel uptake could grow more rapidly, particularly until 2030, in line with the SAF aviation targets set by the ReFuelEU Aviation Regulation.

Moreover, factors not fully covered by the current models could drive additional biofuel

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[13] Regulation (EU) 2018/842 of the European Parliament and of the Council of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013
[14] It is noted that the study analysis was performed before the final adoption of RED III.
[15]Directive (Eu) 2023/2413 of the European Parliament and of the Council
of 18 October 2023
[16] The compliance with the RED III provisional agreement via the RES-T target is met across all other scenarios.

demand. These factors include potential delays or barriers to emerging technologies, such as electric vehicles or batteries, the scaling of renewable energy and power grids required for widespread electrification, or the crediting of biofuels toward CO2 standards targets. Industry-led voluntary actions could also contribute to further biofuel adoption beyond the present projections.

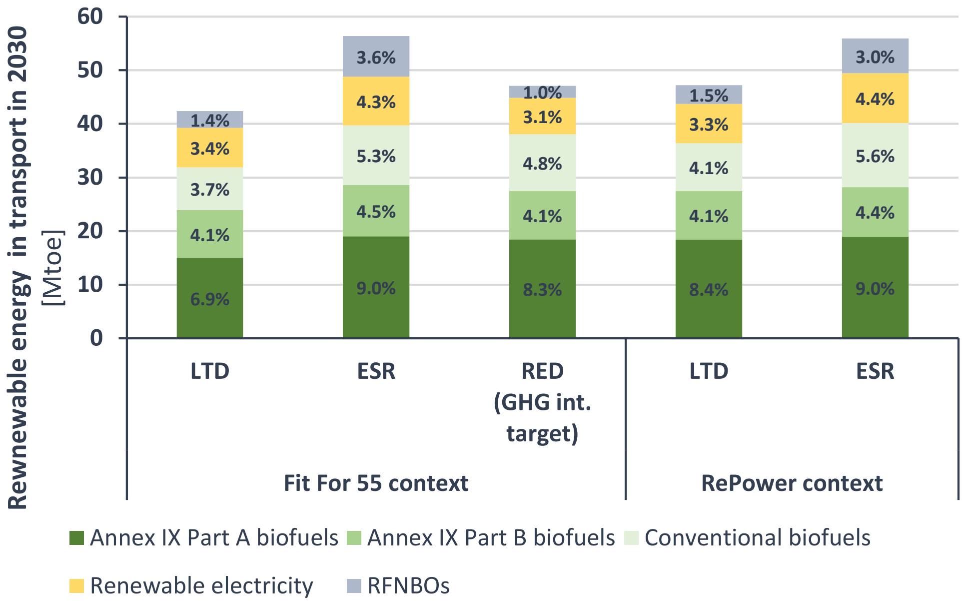


Figure 2 Renewable energy in transport (2030)

## Task 2 – Analysis of the resource potential for drop-in advanced biofuels

Cost-supply curves were developed at a regional level to assess biomass resources for generating drop-in advanced biofuels by 2030 and 2050 within the EU, UK, and the Associated Third Countries. This quantification aimed to determine which demand levels for advanced biofuels could be met by biomass from these regions and how it may underpin industrial capacity development for the production of drop-in fuels.

Overall, the work builds on existing biomass potential studies, enhanced with updated baseline data, methodologies, and scenario assumptions that were developed as follows:

- The latest CAPRI baseline run data for 2030 and 2050 published in the 2022 report were utilized providing new agricultural land use baseline scenarios.
- Waste assessments for 2030 and 2050 projections considered the most recent regional EUROSTAT waste statistics as a starting point.
- For forest biomass potential, both primary and secondary, the S2BIOM data and specific scenarios were employed to align with low, medium, and high mobilization scenarios for drop-in fuels.
- New quantification approaches were developed for the proposed new types of Annex IX Part A and B biomass, not previously assessed, involving extensive data collection.

- Data was processed at NUTS 2/3 regional level, necessitating several disaggregation and data processing steps.

- Cost levels from earlier studies were adjusted to 2020 figures accounting for inflation up to that year.

- Novel biomass resources such as algae, Direct Air Capture (DAC) were not considered in this study.

Out of 61 biomass types eligible under Annex IX Part A and B of RED, 13 were not assessed with respect to the biomass potential they could deliver because (a) they are residues or co-products from biomass conversion processes to conventional transport fuels, and therefore uncertainty exists in the analysis due to the wide palette of possible biomass to biofuel pathways (b) they overlap with other categories, and allocation is not straightforward, (c) for the specific case of algae categories, the estimation is challenging due to the lack of data. Consequently, 48 types of biomass remained for potential assessment.

Technical potential for each biomass type was established, further delineated into three deployment levels by 2030 and 2050, corresponding to Low, Medium, and High mobilization scenarios. This potential considers the maximum availability under current technology options (such as harvesting techniques, infrastructure, and accessibility) and minimal sustainability constraints per the RED framework, such as the exclusion of food crops (considering however their residues, which are included in the technical potential, as the use of the residues is allowed under the RED framework) and spatial confinements due to other land uses and ecological reserves. The High mobilization scenario assumes proactive measures for technological advancement in agricultural and forestry practices, as well as biofuel technology uptake, with a high demand and willingness to pay for biomass. This scenario facilitates the production and utilization of biomass for energy over other uses. The Medium scenario mirrors a continuation of current trends, while the Low scenario indicates a lower prioritization of biomass for energy, favouring other uses.

Figure 3 illustrates the technical potential for Annex IX/A and B biomass by 2030 and 2050 under different mobilization scenarios, detailing the distribution across biomass-supplying sectors. The most significant biomass types in terms of potential are primary residues from arable crops, manure and stemwood and primary forestry residues. By 2050 dedicated lignocellulosic crops gain importance. A comparison with Eurostat 2021 data suggests that the low technical potential of biomass for energy is approximately 50% higher than 2021 consumption. Furthermore, statistical data on current domestic solid biomass use from primary and secondary forestry and agricultural sector for energy, shows that the 2030 biomass potentials in the low mobilization scenario are still at least 20% to 40% higher than the current usage[17]. The analysis also suggests substantial room for the exploitation of agricultural solid biomass, even in the low mobilization scenario. For the medium and high mobilization scenarios, current consumption levels are still modest compared to the projected availability by 2030, especially for agricultural biomass.

It is noted that the unassessed biomass types, while eligible under RED criteria, are not expected to significantly alter the final potential estimates for 2030 in this study. Additionally, it is recognized that achieving higher yields[18] of crops through targeted research and

[17] Biomass groups considered: Primary biomass from forests, Secondary woody biomass (Chips, saw dust and other wood particles and wood pellets, Post consumer wood, Black liquor, Agricultural solid biomass, Renewable municipal waste.

[18] Higher than the underlying CAPRI assumptions on typical yield increases.

innovation (R&I) or advanced agricultural practices could further augment biomass availability.

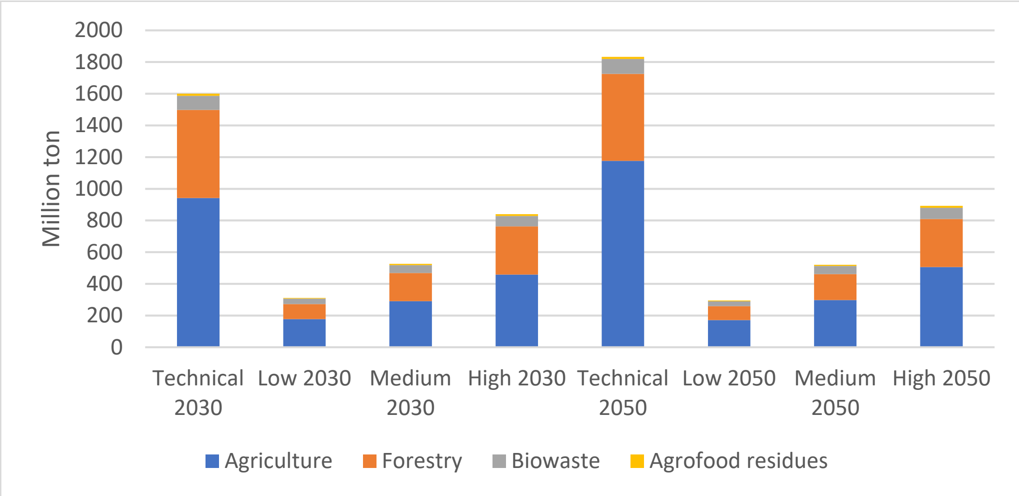


Figure 3 Annex IX/A, B biomass potential in technical, low, medium, and high potentials in 2030 and 2050 and distribution over sectors delivering biomass

## Task 3 – Analysis of potential for industrial capacity of drop-in advanced biofuels

Task 3 encompassed an analysis of the potential for industrial capacity of drop-in advanced biofuels production. This analysis took into account both (a) existing and planned infrastructures rooted in mature technical knowledge, and (b) the nascent industrial capacities emerging from new value chains. The objective was to gather and consolidate actual data from industries and industry associations engaged in technology development, biofuel production, and distribution.

An industry survey was carried out, entailing the identification of target groups and value chains, the creation of a stakeholder matrix, and the development, testing, and implementation of an industry survey. This survey targeted significant industry players within Europe, as well as key non-European players active in the European market (e.g., through the provision of relevant technologies), covering various technological routes. External experts, equipped with industrial and research experience, participated in the analysis, aiding in the scrutiny and validation of the information and data procured from the industry. They bolstered this with research on existing reports and datasets.

As of 2023, four technologies have reached market maturity and are widely deployed in Europe. With respect to the EU biofuel installed capacity, FAME is at the forefront with around 9.9 million t/yr, followed by HVO and ethanol with 5.1 million t/yr each, and biomethane from anaerobic digestion with around 3.8 billion m³/yr. Distinguishing the split between food/feedstock and Annex IX Part A and B feedstocks is challenging due to the combined reporting. Based on the EU Biofuels Barometer 2020 production values and converting these into Mtoe to reflect different heating values, the installed capacity for conventional biofuels is estimated at 13 Mtoe/yr (including 4.6 Mtoe/yr of FAME, 5.3 Mtoe/yr of HVO, 3.2 Mtoe/yr of ethanol); advanced biofuels and biogas at 4.6 Mtoe/yr (with 3.2 Mtoe/yr of biomethane, 1.1 Mtoe/yr of waste-based FAME, 0.3 Mtoe/yr of other liquid fuels); and 3.1 Mtoe/yr from biofuels based on Annex IX Part B feedstocks (FAME, HVO). The proportional shares are 63%

conventional biofuels, 7% advanced biofuels, 15% biogas, and 15% biofuels based on Annex IX Part B feedstocks.

Under the current market conditions, there is an obvious lack of investment in large-scale demonstration facilities to produce advanced biofuels; this constitutes an important barrier to further technology development and deployment. If legislation and targets remain unstable, the investments in advanced biofuels capacity will be very limited due to perceived risks from regulatory uncertainty.

Industry projections estimate that the capacity expansion for advanced biofuels and biomethane across all demand sectors could reach 23.6 Mtoe/yr by 2030[19], with specific details for the different value chains provided in Table 1. Transesterification and hydrotreatment of intermediate crops could be significant contributors, conditional upon their inclusion in the list of eligible feedstocks in future legislation and if their cultivation and supply are accordingly incentivized. From a technical standpoint, capacity expansion could accelerate rapidly as some technology providers are on the cusp of commercializing their technologies.

| Technology/Feedstock category | Production Capacity [Mtoe/y] | | |
|---|---|---|---|
| | 2023 | 2030 | 2050 |
| Biomethane from anaerobic digestion[20] | 3.20 | 15.0 | 45.1 |
| Transesterification of e.g., brown grease | 1.06 | 1.5 | 1.5 |
| Transesterification of intermediate crops | - | 2.8 | 2.8 |
| Hydrotreatment of tall oil | 0.14 | 0.2 | 0.4 |
| Hydrotreatment of intermediate crops | - | 2.4 | 5.4 |
| Lignin boost of fatty acids | - | 0.1 | 0.7 |
| Advanced ethanol | 0.13 | 0.3 | 1.9 |
| ATJ | - | 0.1 | 7.7 |
| Gasification + methanol | 0.00 | 0.2 | 5.7 |
| Gasification + SNG | 0.00 | 0.6 | 14.9 |
| Gasification + FT | - | 0.1 | 5.3 |
| Pyrolysis | 0.04 | 0.2 | 0.8 |
| HTL | 0.00 | 0.0 | 1.7 |
| **Total advanced biofuels/biomethane** | **4.57** | **23.6** | **94.0** |

Table 1 Estimated capacity expansion by industry for advanced biofuels/biomethane (all consumption sectors)

Looking toward 2050, feedstock availability particularly for scaling up SAF production (feedstock for oil-based biofuels), becomes a central issue. Nevertheless, based on associations data and discussion/analysis with industry experts, production from

[19] Expected contributions: Biomethane 15.0 Mtoe/yr: the whole biomethane production would not be allocated to the transport sector, since the fleet would not even be prepared for such high biomethane use; FAME and HVO based on current Annex IX Part A-listed feedstocks 1.7 Mtoe/yr; FAME and HVO based on cover crops (not yet part of Annex IX Part A) 5.2 Mtoe/yr; Technologies based on lignocellulosic materials 1.6 Mtoe/yr.
[20] It is assumed that under current market conditions, 10% of the reported quantities will be for use in transport (Part A /B feedstocks).

lignocellulosic materials could potentially reach 174.8 Mtoe/yr. This significant volume highlights the extensive potential feedstock base of lignocellulosic materials relative to oil crops, signifying that the commercialization of lignocellulosic-based technologies is crucial for achieving substantial biofuel production volumes beyond 2030.

The development of viable production technologies has historically taken years or even decades, as evidenced by the longevity of many actors in the biofuel sector. The lead time for project viability is also quite significant, with pre-feasibility and feasibility studies requiring up to two years for securing sufficient biomass feedstock access, and up to three years from the final investment decision to reaching full operational capacity at the facility[21]. This timeline underscores the urgency for establishing advanced biofuel production facilities that can contribute to meeting the 2030 targets. Therefore, finalizing relevant regulations and instituting strong incentives for deployment is crucial.

The diversity of biofuel technologies, the sourcing of feedstocks from different sectors (such as agriculture, forestry, pulp & paper, agro-processing, wood-processing, waste processing, industrial flue gases and potentially also aquatic biomass/algae) and the flexibility of most technologies concerning the end product are considerable assets. This flexibility allows for adaptation to evolving market needs. The multitude of technology providers strategically also enhances the likelihood of meeting advanced biofuels targets, despite the economic risks that may lead to the failure of some facilities to be established.

### Task 4 – Synthesis of industrial capacity outlook

Task 4 commences by providing insights and analysis of the industries' perspectives on their future development. It then outlines strategic research and innovation policy directions and a roadmap for industrial development, drawing from the findings of Tasks 1 through 3. A gap analysis, contrasting the demand for and supply of drop-in advanced biofuels, offers evidence for the required expansion of industries within the renewable fuels sector. This analysis is based on industry plans to meet renewable fuels demand spurred by policy measures and on recommendations for strategic research directions for novel and improved technologies.

The gap analysis focused on three selected cases:

- The “**High Scenario**”, representing the peak advanced biofuels demand by 2030 within the context of the Fit for 55 package. This scenario assumes a substantial Effort Sharing Regulation (ESR) contribution from transport, increased transport activity, and limited technology deployment.

- The “**Low Scenario**”, resulting in the minimal advanced biofuels demand by 2030, which derives from the RePower EU context, aiming to reduce EU's natural gas consumption and diversify energy sources.

- The **Central Scenario**, aligning with the Fit for 55 principles and incorporating the provisional agreement on RED III[22].

Comparisons were made between the advanced biofuels demand for 2030 and 2050 as estimated in Task 1, and the current and projected advanced biofuels production capacities as foreseen in Task 3's analysis and external expert consultations. Additionally, potential

[21] Potential additional time to obtain permits and taking the investment decision, is not considered.
[22] Assuming compliance met through the GHG intensity target. It is noted that the study has been completed before the final adoption of the RED III by the Parliament

gaps between this demand and the supply capabilities identified in Task 2 were scrutinized to determine how these could be bridged by additional capacity. Table 2 outlines the gaps for the three scenarios, with the lowest and highest biofuels demand for transport and the central scenario. Both the central and high biofuels demand scenarios exhibit a considerable gap for 2030, but by 2050, no gaps are projected due to the anticipated growth in capacity.

| Year | Scenario | Demand (D) | Production 2023 (P) | Growth foreseen by experts (F) | gap (D-P-F) |
|---|---|---|---|---|---|
| 2030 | High scenario | 42.8 | 17.8 | 9.6 | 15.4 |
| | Central scenario | 38.1 | 17.8 | 9.6 | 10.6 |
| | Low scenario | 23.4 | 17.8 | 9.6 | -4.0 |
| 2050 | High scenario | 46.4 | 17.8 | 30.7 | -2.1 |
| | Central scenario | 46.7 | 17.8 | 30.7 | -1.8 |
| | Low scenario | 45.3 | 17.8 | 30.7 | -3.2 |

Table 2 Gap between demand and current production plus additionally foreseen capacity for Low, Central, and High scenarios, 2030-2050 (Mtoe/year)

In the central scenario for 2030, a significant gap of 10.6 Mtoe/yr is identified between the transport demand of 38.1 Mtoe/yr and the 2023 production of 17.8 Mtoe/yr, plus an anticipated increase of 9.6 Mtoe/yr by 2030. Consequently, a robust effort is essential to enhance the production capacity of advanced biofuels and to mobilize the necessary sustainable biomass feedstock, particularly that of lignocellulosic origin.

It is posited that beyond the growth predicted by experts until 2030, there will be no further increase in technologies based on "lipids" due to feedstock limitations. Therefore, other technologies such as anaerobic digestion, lignin boost of fatty acids, advanced ethanol, gasification plus methanol, gasification plus SNG, gasification plus FT, pyrolysis, and HTL are anticipated to contribute to closing the 10.6 Mtoe gap. Additionally, Alcohol to Jet (ATJ) growth is not expected to continue beyond 2030, as supply is not projected to increase past set targets. However, this is speculative and may not accurately reflect future developments.

Interviews with 12 advanced biofuels producers/technology providers focused on *"what factors are most critical to the capacity development of advanced biofuels?"*. This central open-ended question guided the interviews, followed by more detailed discussions on a comprehensive list of critical factors. Regulatory issues, particularly comments on specific EU regulations such as RED III and ReFuel Aviation, were commonly addressed during the interviews, alongside capital access and perceived investor risks. While there is recognition and appreciation for the EU's framework supporting advanced biofuels in maritime and aviation, regulatory uncertainty and complexity were frequently cited as significant concerns by respondents.

### Task 5 – Analysis of socio-economic impact, GHG emissions and costs

Task 5 analyses the socio-economic and environmental impacts of deploying drop-in advanced biofuels in transport, focusing on their contribution to hard-to-abate sectors such as aviation, maritime, and road heavy-duty vehicles. The analysis is framed within the Fit for 55 policy context, as per the findings from the preceding tasks, and looks at the central scenario for 2030 and 2050.

Market prices for biofuels have been projected based on expert opinions for 2030, resulting in a range of values for the different production pathways. The total turnover from biofuels consumption in the EU by 2030 is estimated to be between 41 and 120 billion euros, varying with the demand scenario and market prices. The largest share comes from transesterification pathways (41%-43% of the total), followed by hydrotreatment (35%-38%), ethanol (12%-17%), and biomethane from anaerobic digestion (A.D.) at around 3%. These contributions include both conventional biofuels and those produced using RED II Annex IX feedstocks. Some scenarios indicate that biofuel imports could account for a substantial portion, up to one-third, of the total biofuels' turnover. The sector's contribution to GDP, evaluated as the added value of the biofuels sector, could range from 12 to 35 billion euros, equivalent to 0.07% - 0.2% of the projected 2030 EU-27 total GDP.

In terms of **total emissions**, the lowest value occurs in the Low Scenario (refer to Figure 4), attributed not only to significant emissions avoidance through the deployment of electricity but also to an overall reduction in the energy demand of the transport sector. The High Scenario shows the greatest emission savings, primarily due to the higher uptake of alternative fuels and the assumption that GHG emissions for e-fuels and hydrogen are considered zero, irrespective of the production chain (which could partially use grid electricity from renewable sources). Similar observations apply to **GHG intensity reduction**.

The employment impact assessment predicts a **significant increase in net employment** across all scenarios, as biofuel production in the EU grows. This trend is more pronounced in scenarios with policies aimed at intensive decarbonization of the transport sector, especially in the 2020-2030 period, when the implementation of alternative EU policies has a varied impact on employment. The most significant employment increase is expected between 2030 and 2040, coinciding with the implementation of new biofuel technologies. Approximately 70% of the overall employment growth in the Central Scenario is anticipated during this decade, with similar trends observed in the other two scenarios. Figure 5 shows the projected rise in direct and indirect employment in the EU due to the growth of advanced biofuels.

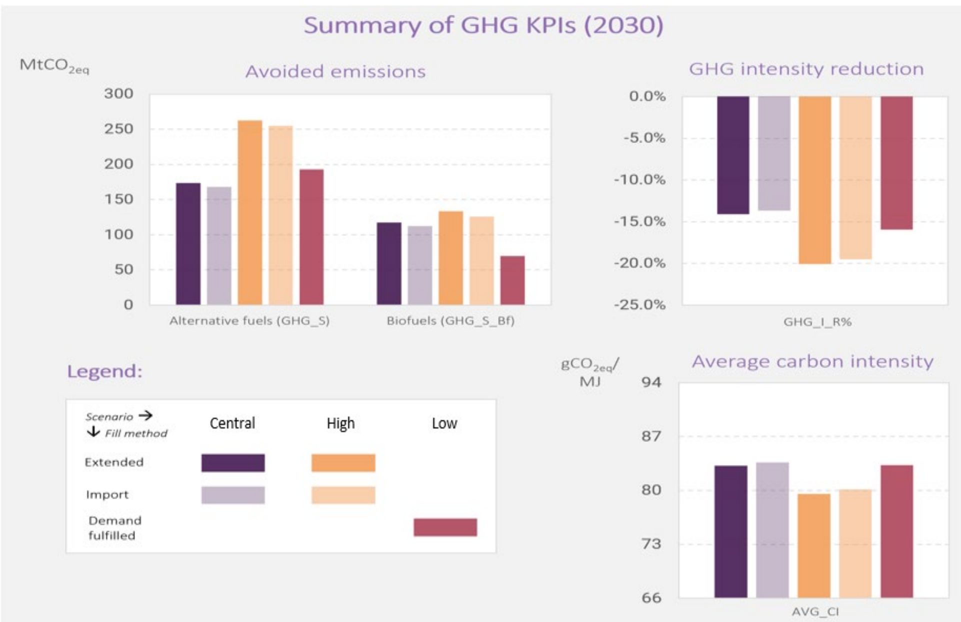

Figure 4 Summary of GHG KPIs in the different scenarios

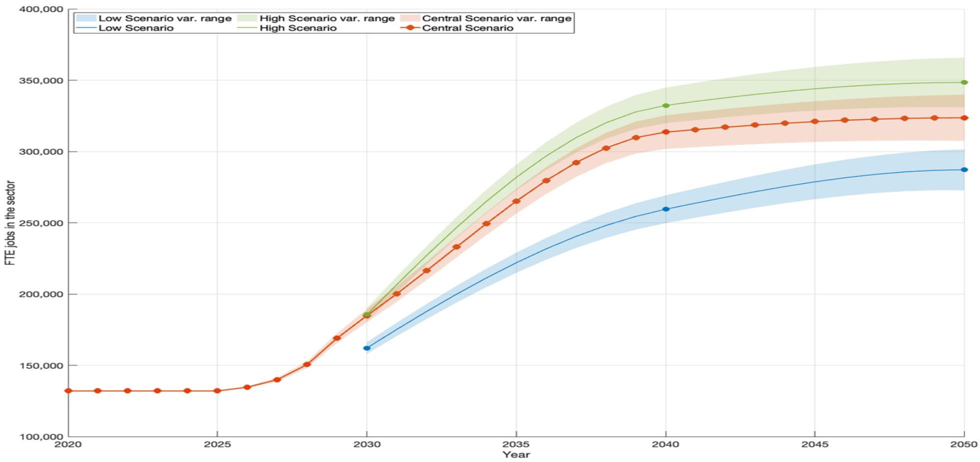


Figure 5 Comparative evolution of employment in FTE for the three selected scenarios

## Task 6 –Workshop organization

A **consultation workshop** was held in Brussels on September 26, 2023, adopting a participatory and interactive format to foster dialogue among various stakeholders. The event brought together representatives from the European Commission, the consortium, and key industrial and research entities involved in the advanced drop-in biofuels value chain. The primary aim of this workshop was to validate the plausibility of the project's assumptions, scenarios, methodologies, results, and conclusions.

The workshop's structure reflected the five core tasks of the project, featuring the active involvement of dedicated Thematic Experts. This setup facilitated focused discussions and in-depth exploration of each task. The insights and feedback gathered from the participants during the workshop were meticulously compiled. This valuable input was then thoroughly analyzed and integrated into the final Project report, ensuring that the report reflected a broad spectrum of perspectives and expert opinions.

# Conclusions and Messages

The final conclusions of the project underscore the **critical role of biofuels in reducing emissions in the transport sector**, aligning with the objectives of the Fit for 55 package and climate neutrality goals. This role is expected to escalate as advanced biofuels become increasingly available, bolstered by the full-scale commercialization of technologies, processes, and value chains driven by ambitious policies and sectoral targets.

### Demand

Model-based scenarios suggest a significant increase in biofuels demand in transport if advancements in electric vehicle battery technology, alternative fuels infrastructure, electrolyzers, and direct air capture technologies lag behind expectations by 2030. In such cases, **biofuel demand could rise by up to 2.5 times compared to 2021 levels** (reaching up to 42.8 Mtoe in 2030 compared to 16.5 Mtoe in 2021).

Projections indicate **advanced biofuels will constitute about half of all biofuel demand**, **translating to over one-third of all renewable energy consumed in transport by 2030**. Under certain conditions, demand for advanced biofuels might even surpass these estimates, highlighting the strategic importance of the biofuel industry for the EU in achieving timely emissions reductions.

**Feedstock potential**

The project estimates that total biomass potential available for energy markets in the EU-27 and accession countries ranges from **310 to 836 million dry tonnes (132 - 353 Mtoe/yr) for 2030,** and **294 - 892 million tonnes (128 - 382 Mtoe/yr) for 2050**.

The most significant biomass types, with the largest potential to be further mobilized are primary residues from arable crops, manure and stemwood and primary forestry residues. Towards **2050** the **dedicated lignocellulosic crops** and **oil crops produced on unused degraded lands and as cover & intercrop** in combination with food production also become more important. Therefore, one of the **few options to mobilize more biomass**, is significantly increasing the biomass production on unused, degraded lands and from inter- and cover crops.

**To effectively increase biomass production, significant R&I support is needed**. This includes enhancing the conversion of biomass to biofuels, improving resource efficiency and circularity, and developing novel technologies and biomass resources. Moreover, the implementation of agricultural protocols and practices for biomass mobilization is essential beyond 2030 and crucial in the path to 2050.

**Industry assessment**

Under current market conditions, industry estimates suggest that **capacity expansion for advanced biofuels and biogas could reach 23.6 Mtoe/yr by 2030** satisfying demand of all other sectors in addition to transport. Biomethane is anticipated to be the most significant contributor, though there is uncertainty regarding its availability for transport and the fleet's readiness for high biomethane usage. Lignocellulosic materials are expected to contribute 1.6 Mtoe/y, while advanced ethanol technology deployment may be limited until 2030. Technically, capacity expansion could be expedited, with numerous technology providers nearing the commercialization of their technologies and ready to support multiple projects.

With the impending implementation of the revised Renewable Energy Directive, along with ReFuelEU Aviation and FuelEU Maritime, both the aviation and shipping sectors are expected to increasingly demand biofuels, potentially redirecting them from the road sector. This shift creates no-regret investment opportunities in HEFA (Hydrotreated Esters and Fatty Acids) currently and potentially in advanced ethanol (ATJ - Alcohol to Jet) production after 2030, despite a projected decrease in market demand for gasoline substitutes. From this perspective, **the industry has expressed readiness to invest and meet, at least, the relevant EU demand.**

**Development challenges**

The project highlights the necessity of a substantial effort to enhance the production capacity of advanced biofuels and to mobilize the required sustainable biomass feedstock, particularly lignocellulosic biomass. This escalation is essential to bridge the gap between the anticipated demand for advanced biofuels, crucial for meeting the EU's climate targets for 2030 and 2050, and the current production capacities, as well as those forecasted by experts. The present production capacity for advanced biofuels and biogas, standing at 4.6 Mtoe/yr, is projected to potentially increase sixfold, reaching around 27.4 Mtoe/yr by 2030.

To ramp up advanced biofuels capacity the **EU industry needs:** (1) predictive advanced biofuels targets that remain consistent over an extended period, thereby minimizing regulatory uncertainty and complexity, (2) access to capital for demonstration projects with a higher technological risk profile, and (3) financial support for technological development of advanced biofuels technologies capable of utilizing a wide array of available sustainable feedstocks.

**Potential synergies between RFNBOs and advanced biofuels** technologies development should be identified and utilized for the benefit of both pathways. For example, both pathways partly use similar technologies, such as methanol and FT synthesis; and biogenic $CO_2$ emissions of advanced biofuels production could be used as input for RFNBO production.

**Socioeconomic impacts**

Throughout the various scenarios examined in the project, **the adoption of advanced biofuels is projected to yield considerable GHG savings**, which are directly proportional to the volumes used. A conservative analysis, taking into account the availability of sustainable feedstock, posits that advanced biofuels can make a substantial contribution to meeting environmental targets for transport. Depending on the scenario, emissions avoided by biofuels could range from **70 to 126 MtCO2eq/yr in 2030**. Of this, biofuels from Annex IX Part A feedstock could account for **27 – 65 MtCO2eq/yr**, and biofuels from Annex IX Part B feedstock for **10 – 15 MtCO2eq/yr**. By 2050, the emissions avoidance could exceed **151 MtCO2eq/yr**. Furthermore, the adoption of alternative fuels, including biofuels, e-fuels, and electricity, has the potential to **reduce the carbon intensity (gCO2eq/MJ) of the transport fuel mix by 20% as early as 2030**.

The deployment of advanced biofuels is associated with a significant positive impact, in terms of **direct and indirect employment**. It is estimated that **over 53,000 new jobs could be generated by 2030**, with the potential for this number to increase to **over 190,000 by 2050** in the central scenario, which would represent about **0.1% of the total EU jobs as of 2022**. When compared to other renewable energy technologies, advanced biofuels are found to have a higher employment rate per unit of energy, attributed to the extensive value-chain involved in their production.

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Biofuels are crucial for reducing emissions in the transport sector, contributing significantly to the objectives of the Fit for 55 package and climate neutrality goals. This role is anticipated to grow in the future as advanced biofuels become increasingly accessible. This expansion will be driven by the full commercial-scale development of technologies, processes, and value chains, supported by ambitious policies and sector-specific targets that will encourage their deployment.

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