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Mobilization of Industrial Capacity Building for Advanced Biofuels

Final Report

Mobilization of Industrial Capacity Building for Advanced Biofuels

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Mobilization of Industrial Capacity Building for Advanced Biofuels

Final Report

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Contents

Abbreviations

ACEA	European Automobile Manufacturer's Association
AD	Anaerobic Digestion
AFF	ART Fuels Forum
AGRI	Agriculture and Rural Development
ART	Alternative Renewable Transport
ASN	Additional Support Needed
AtJ	Alcohol to Jet
CAPEX	Capital Expenditures
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilization
CINEA	European Climate, Infrastructure and Environment Executive Agency
CLIMA	Climate Action
COP	Conference of the Parties
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CRL	Commercial Readiness Level
DA	Delegated Acts
DAC	Development Assistance Committee
DG	Directorate General
DR	Discount Rate
EASA	European Union Aviation Safety Agency
EBTP	European Biofuel Technology Platform
EC	European Commission
EE	Energy Efficiency
EIBI	European Industrial Bioenergy Initiative
EP	European Parliament
EPC	Engineering Procurement and Construction Companies
ESG	Environmental, Social and Governance
ETIP	European Technology & Innovation Platform
ETS	Emission Trading Scheme
EU	European Union
EUA	European Union Allowance
EUBCE	European Biomass Conference & Exhibition

EUSEW	EU Sustainable Energy Week
FAME	Fatty Acid Methyl Ester
FAO	Food and Agriculture Organization
FEUM	Fuel EU Maritime
FID	Final Investment Decision
FOAK	First-Of-A-Kind
FPBO	Pyrolysis Bio-Oil
FQD	Fuel Quality Directive
GHG	Greenhouse Gas
HDV	Heavy Duty Vehicle
HEFA	Hydrotreated Esters and Fatty Acids
HVO	Hydrotreated Vegetable Oil
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IEA	International Energy Agency
IFC	International Finance Corporation
ILUC	Indirect Land Use Change
IMO	International Maritime Organisation
IR	Inflation Rate
IRENA	International Renewable Energy Agency
IVC	Industrial Value Chain
JEC	JRC-Eucar-Concawe collaboration
LCoP	Levelized Cost of Production
LDV	Light Duty Vehicle
LNG	Liquified Natural Gas
M&E	Monitoring & Evaluation
MEP	Member(s) of the European Parliament
MOVE	Mobility and Transport
MS	Member State
NGO	Non-Governmental Organization
OPEX	Operational Expenditures
RCF	Recycled Carbon Fuels
RED	Renewable Energy Directive
RED	Renewable Energy Directive

REFEUA	ReFuelEU Aviation
RES	Renewable Energy Sources
RFNBO	Renewable Fuels of Non- Biological Origins
SGAB	Subgroup on Advanced Biofuels
SIA	Social Impact Assessment
STF	Sustainable Transport Forum
ToR	Terms of Reference
TR	Tax Rate
TRL	Technology Readiness Level
TTW	Tank To Wheel
UN	United Nations
WTO	World Trade Organization
WTT	Well To Tank
WTW	Well To Wheel

Abstract

The objective of the project **"Study on how to mobilize industrial capacity building for advanced biofuels"** is to identify and propose ways to realize the essential industrial value chains of advanced biofuels including the technical, financial, business and feedstock-related aspects, in order to reach the defined 2030, 2040 and 2050 EU targets. Presented results are rooted on estimation calculated previously[1]. The approach aimed to create a record of the essential industrial value chains of advanced biofuels, analyse the actual needs and bottlenecks of each industrial value chain, develop a business model for each industrial value chain, interview relevant industrial stakeholders and financial sources and collect inputs to validate the identified data and business models through external experts and propose a plan for financing and realizing the industrial value chains, collectively.

The project builds on the selection of the essential industrial value chains of advanced biofuels for the periods of 2025-2030 and 2030-2040 under technological and commercial maturity criteria. Business Model analyses for the essential IVCs indicate that financial support will be required to close the gap between the biofuels' Levelized Cost of Production (LCoP) and the market price of their fossil fuel counterparts, even when considering the impact of EU Allowances' additional costs. Two main financing supports are necessary: (a) **financing support to industrial units** that is proportional to produced quantities of biofuels in the form of Feed-in-Premium (FiP), which accounts for **3,849 – 7,499 mil.€/yr** in 2030 and (b) **financing support mobilizing farmers** that is proportional to produced feedstock quantities in the form of FiP, which accounts for **700 – 1,245 mil.€/yr** in 2030 and is not influencing the final price. The estimation of the respective financing support figures for 2040, when new technologies will be mature and penetrate in the market, is **11,586 – 17,852 mil.€/yr** for industrial units and **1,704 – 2,805 mil.€/yr** for farmers.

The European technology providers have the knowledge needed to build this industry expecting sufficient feedstock availability, as well as availability of equipment, processing materials, and skilled workforce, but there is a severe lack of experienced project developers for advanced biofuels, if indeed these facilities shall all be built in the next years.

The overall conclusion is that **biofuels have a vital role to play in reducing emissions in the transport sector** and that there is not one single solution or pathway that will provide 50% or more of the fuels needed to fulfil the targets, but rather a portfolio of essential pathways. Transesterification, hydrotreatment, anaerobic digestion, pyrolysis, gasification followed by synthesis to FT-liquids, methanol and methane will all be important. Only the full portfolio will allow the EU industry to draw on the full range of feedstocks (from lipids to agricultural and forestry residues to biogenic CO2 and green hydrogen). **Renewable hydrogen** can become an enabler for several benefits, such as higher process yields (in gasification) and additional emission reductions. However, its **production cost remains a major hindrance** and potentially a showstopper.

[1] "Study on development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels"

1. Introduction

This report is the Final Report of the project ***"*Study on how to mobilize industrial capacity building for advanced biofuels*"*** and follows the contract originally signed by **EXERGIA SA** (Leader) in Consortium with **Politecnico di Torino (POLITO)**, and **BEST - Bioenergy and Sustainable Technologies GmbH** (Consortium members), referred to henceforth as the "Consultant". This study **is initiated by DG RTD to contribute to the EU R&I strategy and support development on renewable fuels**. This report covers in principle the relevant requirements of the ToR, by providing the work accomplished in Tasks 1, 2, 3 and Task 4 (workshop).

The **outline of this report** is as follows: The present Chapter 1 introduces the project and its objectives and gives a high-level description of the project Tasks. The following Chapters are dedicated to each project Task i.e., in Chapters 2, 3, 4 and 5 the overview of the activities of Tasks 1, 2, 3 and 4 which collectively constitute the bulk of the project work. Specifically, Chapter 5 presents the work of Task 4, which is the organization of the validation workshop which took place in Brussels on October 24th.

1.1. The Project

The **scope** of this study is to build a roadmap of industrial value chains that can be realized in 2030, 2040 and 2050; each value chain will be supported by a feasibility study and (where necessary) a technology-to-market plan.

The present study will make use of the previous project, titled: **"Study on development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels"** No: CINEA/2022/OP/0004/SI2.884011, that was published on 07 February 2024 (https://op.europa.eu/en). It is noted that in the "previous study" (as it will be called in the following Sections of this document), three of the members of the present Consortium had participated and therefore there is good knowledge of the results and access to the full information.

The **general objective of this study** is to identify and propose ways to realize the essential industrial value chains of advanced biofuels including the technical, financial, business and feedstock-related aspects, in order to reach the defined 2030, mid-target for 2040 and 2050 EU targets.

This has been realized by **exploiting up-to-date industrial data and plans from relevant stakeholders** (industries, industrial associations) active in the renewable transport fuels sector, feedstock and equipment suppliers, industrial plant providers, financial institutions, public and private funding programmes, funds (i.e. pension funds), and private investors (i.e. individuals and/or organisations/enterprises).

Significant **specific project objectives** are the following:

- Create a record of the relevant industrial value chains of advanced biofuels that are necessary to progressively meet the targets for 2030, mid-target for 2040 and final targets to achieve climate neutrality in 2050.
- Analyse the actual needs of each industrial value chain in terms of 1) securing the feedstock, 2) supplying the equipment and process material, 3) identifying the operational skills, 4) finding the industrial plant developers and constructors.
- Develop a business model for each industrial value chain that will, among others, propose how to raise capital and identify investment opportunities, and forecast the financial return, based on the feasibility study and (where necessary) the technology-to-market plan.

- Interview relevant industrial stakeholders and financial sources and collect inputs to validate the identified business models.
- Propose a plan for financing and realizing the industrial value chains, collectively.
- Summarize the results in a report validated by relevant stakeholders and experts.

Below, a brief description of the project Tasks is provided.

Task 1: Record of industrial value chains of advanced biofuels and needs: The first Task within this project aimed at producing a record of essential advanced biofuels value chains necessary to meet the GHG emission targets in transport for 2030, 2040 and of climate neutrality in 2050. This Task focused on the identification of the essential Industrial Value Chains (IVCs) and the quantification of their needs as described in the ToR and represents the baseline for subsequent works.

Task 2: Business models of industrial value chains of advanced biofuels and needs: This Task elaborated business models and feasibility studies and, where necessary, technology-to-market plans for each value chain for 2030 and 2040. The findings have been validated by relevant industrial and financial stakeholders. This Task followed and enriched the knowledge in the area of business and economic feasibility of the selected essential industrial value chains, especially by conducting feasibility studies and where necessary technology-to-market plans.

Task 3: Proposal for a collective financing and realization plan: This Task concentrated on implementation issues by considering formulation of new collective plans and integrated projects of common interest to be supported by regional / national /EU funding programs. Task 3 provided elaboration on supporting opportunities concluding to a proposal for new collective plans related to integrated projects of common interest for the EU.

Task 4: Organization of a consultation workshop: A one-day consultation workshop, with the participation of external stakeholders and the involvement of subject matter thematic experts and panellists, was organized in Brussels on 24 October in order to discuss and validate the findings of the study.

A simplified schematic representation of the evolution of the work in the various tasks is shown in Figure 1-1.

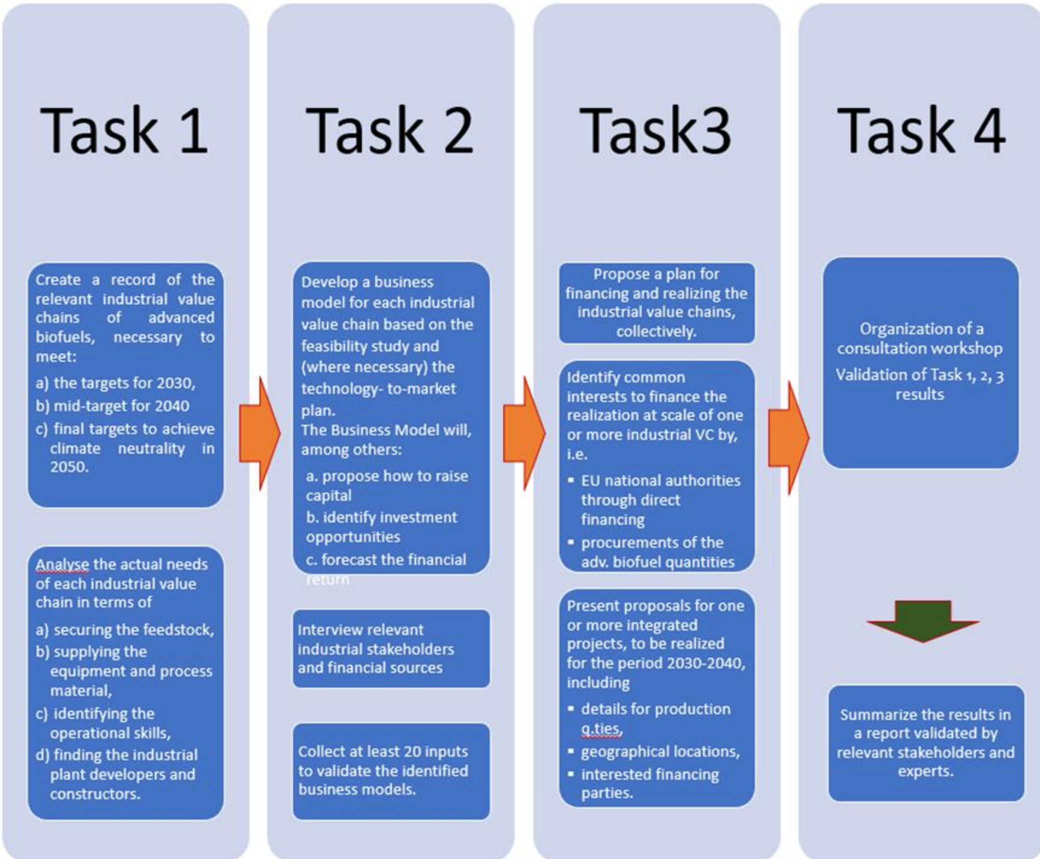

Figure 1-1 Structure of project Tasks

2. Record of industrial value chains of advanced biofuels and needs

2.1. Selection of essential industrial value chains

2.1.1. Definitions

Industrial Value Chain (IVC): An Industrial Value Chain of Advanced Biofuel is a combination of feedstock types and conversion technologies to one or more products. It is defined by its conversion technology and corresponds to an industrial project to build a production facility. Depending on the location of the facility, different feedstocks might be of interest, although a specific facility will likely specify the intended feedstocks in order to adapt the process technology. Also, an IVC may produce more than one product in the process, which might even go into different markets.

Fuels considered in this study are liquid and gaseous biofuels that are produced from feedstocks listed in Part A and part B of Annex IX of Directive 2023/2413, as well as RFNBOs if the CO2 used is biogenic. For the purpose of this study, the group of these fuels will be called “Advanced Biofuels.”

2.1.2. Identification of Industrial Value Chains

A list of industrial value chains was created using value chains from the previous study[2] as starting point. To this list, additional value chains from the industrial insights in chapter 3.5 "Technologies and innovations" from the previous tender study were added.

As requested in the Terms of Reference for this study, synergetic industrial value chains of advanced biofuels and renewable fuels of non-biological (so-called e-Fuel Biomass hybrids) were listed, where either hydrogen from electrolysis is used in a biofuel production pathway, or CO2 from a biofuel production pathway is used for e-Fuel production.

Algae as potential feedstock was added for the hydrothermal liquefaction, anaerobic digestion and hydrotreatment of lipids pathways.

The list of pathways was then cross-checked with other sources and missing important value chains were added. The following literature sources were used:

a. ETIP Bioenergy Value Chains https://www.etipbioenergy.eu/value-chains/

b. JRC 2023 reference: Motola V., Hurtig O.,Scarlat, N., Buffi M., Georgakaki A., Letout S. and Mountraki A, Clean Energy Technology Observatory: Advanced biofuels in the European Union - 2023 Status Report on Technology Development, Trends, Value Chains and Markets, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/672584, JRC135082.

c. JEC Well-to-Tank report v5 Prussi, M., Yugo, M., De Prada, L., Padella, M., Edwards, R., Lonza, L. JEC Well-to-Tank report v5, EUR 30269 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-19926-7, doi:10.2760/959137, JRC119036.

d. A. O'Connell, M. Prussi, M. Padella, A. Konti, L. Lonza, Sustainable Advanced Biofuels Technology Market Report 2018, EUR 29929 EN, European Commission, Luxembourg, 2019, ISBN 978-92-76-12585-3, doi:10.2760/487802, JRC118309

e. DBFZ 2023, Hauschild, S.; Costa de Paiva, G.; Neuling, U.; Zitscher, T.; Köchermann, J; Görsch, K. (2023): Production technologies for supplying renewable fuels. In: 10.48480/4xdx-xy05

After complementing the list of IVCs with additional sources, the feedstocks were categorized according to the categories defined for the stakeholder questionnaire in the previous study. Additional categories for e-biofuels feedstocks (i.e. biogenic CO2 and H2 from electrolysis) and intermediate bioenergy carriers were introduced.

Food and feed feedstocks were excluded from the feedstocks for these IVCs.

The final list of IVCs is provided in Table 2-1, and the feedstocks considered are depicted in Table 2-2.

[2] "Study on development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels" No: CINEA/2022/OP/0004/SI2.884011; https://op.europa.eu/en/publication-detail/-/publication/b1c97235-c4c3-11ee-95d9-01aa75ed71a1/language-en

Nr.	Value Chain	Fuel(s)
IVC1	Transesterification	FAME
IVC2	Hydrotreatment of Lipids	HVO, HEFA-SPK
IVC3	Lignin Boost with Fatty Acids and Co-processing in Refinery	Renewable diesel
IVC4	Sugar and Starch Fermentation to Ethanol	Ethanol, AtJ-SPK
IVC5	Fermentation of Lignocellulosic Materials to Ethanol	Advanced ethanol, AtJ-SPK
IVC6	AtJ / MtJ	AtJ-SPK, MTJ-SPK
IVC7	Biomethane from Anaerobic Digestion	Biomethane
IVC8a	Gasification and Methanol Synthesis	Methanol
IVC8b	Methane reforming and Methanol Synthesis	Methanol
IVC8c	Methanol Synthesis from biogenic CO2 and green H2	e-Methanol
IVC8d	Methanol from pulping	Methanol
IVC9a	Gasification and Methanation	Methane
IVC9b	Methanation from biogenic CO2 and green H2	e-Methane
IVC10	Gasification to Hydrogen	Hydrogen
IVC11a	Gasification and FT-Synthesis	FT-diesel, FT-SPK
IVC11b	FT-Synthesis from biogenic CO2 and green H2	e-FT-diesel, e-FT-SPK
IVC12	Gas Fermentation to Ethanol	Ethanol, AtJ-SPK
IVC13a	Pyrolysis and Co-processing in Refinery	partly biogenic Gasoline, Diesel, and Kerosene
IVC13b	Pyrolysis (and Thermo-Catalytic Reforming) and Upgrading (HDO)	Bio-Gasoline, Bio-Diesel, Bio-heavy fuel oil
IVC14	Hydrothermal Liquefaction and Upgrading in Refinery (FCC or HDO)	Bio-diesel, Bio-kerosene, Bio-heavy fuel oil

Table 2-1 List of Industrial Value Chains

Feedstock GROUP	Feedstock CATEGORY	DI code
Primary production of crops	Lignocrops and woody crops from unused and abandoned and from severely degraded lands	2101; 2103; 2104; 2106
Primary production of intermediate, cover crops	Oil crops from unused and abandoned and from severely degraded lands	2102; 2105
Primary production of intermediate, cover crops	Oil crops inter & cover cropping	2108
Primary production of intermediate, cover crops	Lignocrops inter & cover cropping	2107; 2109

Feedstock GROUP	Feedstock CATEGORY	DI code
Primary residues from forests	Primary forestry residues, , incl. low-grade stemwood	1200; 1220
Primary production of aquatic biomass	Microalgae	
Agricultural residues	Straw, maize stover, oil crop residues	2201; 2202; 2203
Agricultural residues	Prunings & damaged crops	2204; 2205
Agricultural residues	Manure	2301; 2302
Secondary residues of industry utilising agricultural products	Agroprocessing residues	4201; 4202; 4203; 4206; 4207; 4208; 4209; 4210; 4211; 4214
Secondary residues of industry utilising agricultural products	crude glycerine	4217
Secondary residues of industry utilising agricultural products	Maize cobs	4204
Secondary residues of industry utilising agricultural products	UCO	4216
Secondary residues from wood industries	POME, Tall oil pitch	413201
Secondary residues from wood industries	Secondary forest residues	4111; 4112; 4121; 4122; 4131; 4132
Biodegradable (industrial & municipal) waste	Brown grease, Animal fat	5106; 5107
Biodegradable (industrial & municipal) waste	Sewage sludge	5108
Biodegradable (industrial & municipal) waste	Biowastes	5101; 5102; 5104
Biodegradable (industrial & municipal) waste	Post consumer wood	5211; 5212
Intermediate Bioenergy carriers	Biocrude	
Intermediate Bioenergy carriers	FPBO	
Intermediate Bioenergy carriers	Lignin from Kraft pulp	
Intermediate Bioenergy carriers	Ethanol, Methanol	
Intermediate Bioenergy carriers	Biomethane	
Intermediate Bioenergy carriers	Cellulose pulp	
Intermediate Bioenergy carriers	Syngas	
e-biofuel feedstocks	Biogenic CO2 and green Hydrogen	

Table 2-2 Feedstock categorisation

2.1.3. Essential IVCs and Key performance indicators (KPIs)

The scope of the study called for identifying essential industrial value chains, and from these several should be selected for further analysis in Tasks 2 and 3 of the study. The study team concluded that, as s to be considered essential, the respective IVC should be able to contribute on an industrial scale to a specific sectorial target in the given year, meaning that:

- it is **eligible** under the criteria of the Renewable Energy Directive, in particular with respect to GHG emission reduction (KPI: **GHG saving in %);**
- it must have reached **commercial maturity, i.e. TRL 9** at least 5 years ahead of the year in question (KPIs: **TRL**, **CRL**);
- there must be sufficient **feedstock available** to support biofuel production in quantities of at least 10% of the sectorial target, i.e. road, shipping and aviation considered separately (KPI: **feedstock potential to contribute to sectorial target**);
- the expected **technology deployment** allows the production of quantities of at least 10% of the advanced biofuels target as per current EU legislation (RED, ReFuelEU Aviation, FuelEU Maritime; KPI: **expected technology deployment versus advanced biofuels target**).

The KPIs were developed based on results of the previous study and complemented with data from literature research.

The first KPI considered was the **potential GHG emission reduction** (%), as to check compliance with EU regulation. The previous study already provides information for most value chains. Data for additional value chains, especially for e-biofuels, was taken from the JEC WTTv5 dataset. According to RED, new installations for transport biofuel production need to demonstrate 65% GHG savings, and new installations for production of transport renewable fuels of non-biological origin need to demonstrate 70% GHG savings. IVCs that don´t meet these thresholds, would not produce eligible fuels under RED and can thus not be considered essential.

The next KPIs assessed were **TRL and CRL**, as defined in the JEC Well-to-Tank report v5[3], see Table 2-3.

The TRL of each IVC was assessed for 2024 and used to place it in the proper assessment timeframe as follows:

- **TRL 9** – the value chain has the potential to be essential in the 2025-2030 timeframe
- **TRL 7-8**– the value chain will be considered for the 2030-2040 timeframe
- **TRL 4-5-6** – the value chain will be considered for the 2040-2050 timeframe

The CRL provides additional information on the level of scale-up and multiplication of the value chain. The main source for the TRL/CRL assessment was the demo plants database at https://demoplants.best-research.eu/, which was set up by IEA Bioenergy Task 39 and is updated and maintained by the same group with support of experts from further IEA Bioenergy Tasks, the Advanced Motor Fuels TCP, and ETIP Bioenergy WG2 experts.

The next KPI, **feedstock potential to contribute to sectorial target**, is based on (a) feedstock availability and mobilization, and (b) sectorial target. For feedstock availability, data were drawn from the Annex 2 Report on Task 2 (pg. 29) of the previous study. This Annex includes data for feedstock availability per feedstock category in low, medium and high feedstock mobilization scenarios for 2030 and 2050. A linear development of feedstock availability between 2030 and

[3] Prussi, M., Yugo, M., De Prada, L., Padella, M., Edwards, R. And Lonza, L., JEC Well-to-Tank report v5, Publications Office of the European Union, Luxembourg, 2020, https://data.europa.eu/doi/10.2760/959137, JRC119036.

2050 was assumed for 2040. For the 2025-2030 timeframe, the values from the **medium mobilization scenario** were used, and values from the **high mobilization scenario** were used for the other timeframes.

<table>
<tr><th colspan="2">TRL</th><th colspan="2">CRL</th></tr>
<tr><td>1</td><td>Basic principles observed</td><td colspan="2">N/A</td></tr>
<tr><td>2</td><td>Technology concept formulated</td><td rowspan="6">1</td><td rowspan="6">Hypothetical commercial proposition</td></tr>
<tr><td>3</td><td>Experimental proof of concept</td></tr>
<tr><td>4</td><td>Technology validated in lab</td></tr>
<tr><td>5</td><td>Technology validated in relevant environment</td></tr>
<tr><td>6</td><td>Technology demonstrated in relevant environment</td></tr>
<tr><td>7</td><td>System prototype demonstration in operational environment</td></tr>
<tr><td>8</td><td>System complete and qualified</td><td>2</td><td>Commercial trial, small-scale</td></tr>
<tr><td rowspan="4">9</td><td rowspan="4">Actual system proven in operational environment</td><td>3</td><td>Commercial scale-up</td></tr>
<tr><td>4</td><td>Multiple commercial applications</td></tr>
<tr><td>5</td><td>Market competition driving widespread development</td></tr>
<tr><td>6</td><td>Bankable asset class</td></tr>
</table>

Table 2-3 TRL and CRL definition based on JEC Well-to-Tank report v5

The availability of intermediate bioenergy carriers was estimated as follows:

- Biocrude, FPBO; Ethanol, Methanol; Biomethane: technically possible production capacity (capped by feedstock availability) in 2030 as per previous study
- Crude glycerine: 10% of FAME according to previous study
- Lignin from Kraft pulp, Methanol from Kraft pulp: based on sulphate pulp production according to CEPI
- Syngas and Biogenic CO2: based on biomethane and ethanol production (previous study)
- Hydrogen from electrolysis: sufficient to utilize all biogenic CO2.

As to not account for any feedstock twice, feedstocks were distributed over the listed IVCs as shown below, and summed up for each IVC separately:

- lipids: (1, 2, 3)
- sugars: (4)
- straw: (5, 13a, 13b)
- wood: (8a, 9a, 10, 11a)
- wet feedstocks: (7, 14)
- biogenic CO2: (8c, 9b, 11b, 12).

Feedstock potential for each pathway was then multiplied with the average yield from main feedstock to product for each pathway. Yields were taken from the JEC-WTTv5 dataset.

Fuel volumes to fulfil the sectorial targets were taken from the results of Task 1 of the previous study (Annex 1 Report on Task 1, pg. 28, sectorial demands in the FF55-RED scenario), for the three sectors road, aviation and shipping separately (road: 22.4 Mtoe/y (2030); 24.3 Mtoe/y (2040) / shipping: 1.9 Mtoe/y (2030); 7.4 Mtoe/y (2040) / aviation: 2.2 Mtoe/y (2030); 10.5 Mtoe/y (2040)). Feedstock availability and volumes required to fulfil the sectorial target were then combined into the KPI "**feedstock potential to contribute to sectorial target**" as percentage.

Finally, for the expected technology deployment, technically possible **production capacities** as calculated from the Task 3 assessment of the previous study were used (Annex 3 Report on Task 3, pg. 45). Since the previous study did not provide values for 2040, these had to be estimated based on assumptions. Considering that the tentative GHG reduction targets of the EU for 2040 are 90% less than 1990 GHG emissions, ReFuel EU Aviation prescribes accelerating shares of SAF over time, and that advanced biofuels production technology development that is triggered by the 2030 targets now will increase the deployment of these technologies in the 2030 to 2040 period, it was assumed that the gap between the 2030 capacity and the 2050 capacity would be 75% filled by 2040. These production capacities were compared to the advanced biofuels policy-driven market demand as calculated in the previous study (27.1 Mtoe/y (2030); 64.5 Mtoe/y (2040)).

All IVCs were assessed towards these KPIs, and the result for the first two timeframes is depicted in Figure 2-1 and Figure 2-2. Where the contribution to market demand or the technically possible production capacity is below 10%, this is indicated as low (L), from 10 to 50% it is medium (M), and above 50% it is high (H). Values that meet the selection criteria for the respective timeframes are highlighted in green, as well as IVCs that meet all three selection criteria.

Out of the 20 IVCs identified and assessed, only 4 of them met all selection criteria for the 2025-2030 timeframe, and 13 IVCs met all selection criteria for the 2030-2040 timeframe.

As to streamline the work to be undertaken in Tasks 2 and 3 of this project, several essential IVCs for the timeframe 2030-2040 were clustered as follows.

IVC5, 6 and 12 were clustered as all targeting production of **advanced ethanol** after 2030, to be likely used in the production of AtJ-SPK for the aviation sector.

IVC7, 9a and 9b were clustered as all target production of **methane**, and many EU Member States are specifically interested in substituting natural gas imports. It is thus likely that regulatory frameworks will be developed that support bio- and e-methane production, independent from the value chain used for their production. However, the assessment of this cluster will consider the fact that feedstocks and technologies applied in these clustered value chains vary significantly, with consequences on the siting and scale of facilities.

IVC8a, 8b and 8c were clustered as all target production of **methanol**, a very suitable alternative fuel for the shipping sector. We observe that Maersk, the worlds´ largest ship operator, is driving and supporting the development of methanol production facilities, regardless of the technology used. Again, feedstocks and technologies applied in these value chains are very different and demand different siting and scale of facilities.

IVC13a and 13b were clustered since we expect that fast pyrolysis facilities will first feed into refineries for co-processing but later will rather be upgraded in stand-alone facilities. Co-processing is an easy starting point for increasing the share of renewables in a refinery´s fuel pool but is limited to 5-10% of fast **pyrolysis bio-oil** (FPBO) in conventional refineries. This limitation makes it impossible to meet higher targets for the share of advanced biofuels, which is why we expect that the upgrading of FPBO in stand-alone facilities will gain importance. Also, the stand-alone upgrading will offer the opportunity to produce fuel qualities that meet the requirements of the shipping sector even when not meeting those of the road sector.

Nr.	Value Chain	Fuel	Sector	TRL in 2024	Contribution to market demand	Production capacity
				1-9	2030	2030
1	Transesterification	FAME	Road-bio	9	M	M
2	Hydrotreatment of Lipids	HVO	Road-bio	9	M	M
2	Hydrotreatment of Lipids	HEFA	Aviation-bio	9	H	M
3	Lignin Boost of Fatty Acids and Co-processing in Refinery	Renewable diesel	Road-bio	6	M	L
4	Sugar and Starch Fermentation to Ethanol	Ethanol	Road-bio 2030	9	L	n.a.
4	Sugar and Starch Fermentation to Ethanol	ATJ-SPK	Aviation-bio 2040/2050	9		
5	Fermentation of Lignocellulosic Materials to Ethanol	Advanced ethanol	Road-bio 2030	8	M	M
5	Fermentation of Lignocellulosic Materials to Ethanol	ATJ-SPK	Aviation-bio 2040/2050	8		
6	ATJ / MTJ	ATJ-SPK	Aviation-bio	8	H	M
7	Biomethane from Anaerobic Digestion	Biomethane	Road-bio 2030	9	H	H
7	Biomethane from Anaerobic Digestion	Biomethane	Maritime-bio 2030/2040/2050	9	H	H
8a	Gasification and Methanolysis	Methanol	Maritime-bio	6-7	H	L
8b	Methane reforming and Methanolysis	Methanol	Maritime-bio	8	H	L
8c	Methanolysis from CO2 and H2	e-Methanol	Maritime-e	8	H	L
8d	Methanol from pulping	Methanol	Maritime-bio	9	L	L
9a	Gasification and Methanation	Methane	Road-bio 2030	8	H	H
9a	Gasification and Methanation	Methane	Maritime-bio 2040/2050	8		
9b	Methanation from CO2 and H2	e-Methane	Road-e 2030	9	H	L
9b	Methanation from CO2 and H2	e-Methane	Maritime-e 2040/2050	9		
10	Gasification to Hydrogen	Hydrogen	Road-bio 2040/2050	8		
11a	Gasification and FT-Synthesis	FT-diesel	Road-bio 2030	6-7	H	M
11a	Gasification and FT-Synthesis	FT-SPK	Aviation-bio 2040/2050	6-7		
11b	FT-Synthesis from CO2 and H2	e-FT-diesel	Road-e 2030	4-5	H	M
11b	FT-Synthesis from CO2 and H2	e-FT-SPK	Aviation-e 2040/2050	4-5		
12	Gas Fermentation to Ethanol	Ethanol	Road-bio 2030	9	M	L
12	Gas Fermentation to Ethanol	ATJ-SPK	Aviation-bio 2040/2050	9		
13a	Pyrolysis and Co-processing in Refinery	Gasoline+Diesel	Road-bio 2030	9	H	M
13a	Pyrolysis and Co-processing in Refinery	Bio-kerosene	Aviation-bio 2040/2050	9		
13b	Pyrolysis (and Thermo-Catalytic Reforming) and Upgrading (HDO)	Gasoline+Diesel	Road-bio 2030	6-7	H	M
13b	Pyrolysis (and Thermo-Catalytic Reforming) and Upgrading (HDO)	Bio-heavy fuel oil	Maritime-bio 2040/2050	6-7		
14	Hydrothermal Liquefaction and Upgrading in Refinery (FCC or HDO)	Diesel	Road-bio 2030	6	H	L
14	Hydrothermal Liquefaction and Upgrading in Refinery (FCC or HDO)	Bio-kerosene	Aviation-bio 2040/2050	6		
14	Hydrothermal Liquefaction and Upgrading in Refinery (FCC or HDO)	Bio-heavy fuel oil	Maritime-bio 2040/2050	6		

Low (L) < 10% < Medium (M) < 50% High (H) as compared to sectorial target / advanced biofuels target

Figure 2-1 KPI assessment for the 2025-2030 timeframe, based on domestic feedstock potential and domestic industrial production capacity

Nr.	Value Chain	Fuel	Sector	TRL in 2024	Contribution to market demand	Production capacity
				1-9	2040	2040
1	Transesterification	FAME	Road-bio	9	M	L
2	Hydrotreatment of Lipids	HVO	Road-bio	9	M	M
2	Hydrotreatment of Lipids	HEFA	Aviation-bio	9	H	M
3	Lignin Boost of Fatty Acids and Co-processing in Refinery	Renewable diesel	Road-bio	6	H	M
4	Sugar and Starch Fermentation to Ethanol	Ethanol	Road-bio 2030	9		
4	Sugar and Starch Fermentation to Ethanol	ATJ-SPK	Aviation-bio 2040/2050	9	L	n.a.
5	Fermentation of Lignocellulosic Materials to Ethanol	Advanced ethanol	Road-bio 2030	8		
5	Fermentation of Lignocellulosic Materials to Ethanol	ATJ-SPK	Aviation-bio 2040/2050	8	H	M
6	ATJ / MTJ	ATJ-SPK	Aviation-bio	8	H	M
7	Biomethane from Anaerobic Digestion	Biomethane	Road-bio 2030	9		
7	Biomethane from Anaerobic Digestion	Biomethane	Maritime-bio 2030/2040/2050	9	H	H
8a	Gasification and Methanolysis	Methanol	Maritime-bio	6-7	H	M
8b	Methane reforming and Methanolysis	Methanol	Maritime-bio	8	H	M
8c	Methanolysis from CO2 and H2	e-Methanol	Maritime-e	8	H	M
8d	Methanol from pulping	Methanol	Maritime-bio	9	L	M
9a	Gasification and Methanation	Methane	Road-bio 2030	8		
9a	Gasification and Methanation	Methane	Maritime-bio 2040/2050	8	H	H
9b	Methanation from CO2 and H2	e-Methane	Road-e 2030	9		
9b	Methanation from CO2 and H2	e-Methane	Maritime-e 2040/2050	9	H	M
10	Gasification to Hydrogen	Hydrogen	Road-bio 2040/2050	8	H	L
11a	Gasification and FT-Synthesis	FT-diesel	Road-bio 2030	6-7		
11a	Gasification and FT-Synthesis	FT-SPK	Aviation-bio 2040/2050	6-7	H	H
11b	FT-Synthesis from CO2 and H2	e-FT-diesel	Road-e 2030	4-5		
11b	FT-Synthesis from CO2 and H2	e-FT-SPK	Aviation-e 2040/2050	4-5	M	H
12	Gas Fermentation to Ethanol	Ethanol	Road-bio 2030	9		
12	Gas Fermentation to Ethanol	ATJ-SPK	Aviation-bio 2040/2050	9	M	M
13a	Pyrolysis and Co-processing in Refinery	Gasoline+Diesel	Road-bio 2030	9		
13a	Pyrolysis and Co-processing in Refinery	Bio-kerosene	Aviation-bio 2040/2050	9	H	M
13b	Pyrolysis (and Thermo-Catalytic Reforming) and Upgrading (HDO)	Gasoline+Diesel	Road-bio 2030	6-7		
13b	Pyrolysis (and Thermo-Catalytic Reforming) and Upgrading (HDO)	Bio-heavy fuel oil	Maritime-bio 2040/2050	6-7	H	M
14	Hydrothermal Liquefaction and Upgrading in Refinery (FCC or HDO)	Diesel	Road-bio 2030	6		
14	Hydrothermal Liquefaction and Upgrading in Refinery (FCC or HDO)	Bio-kerosene	Aviation-bio 2040/2050	6	H	L
14	Hydrothermal Liquefaction and Upgrading in Refinery (FCC or HDO)	Bio-heavy fuel oil	Maritime-bio 2040/2050	6	H	L

Low (L) < 10% < Medium (M) < 50% High (H) as compared to sectorial target / advanced biofuels target

Figure 2-2 KPI assessment for the 2030- 2040 timeframe

Based on the KPI assessment depicted on the previous pages, the final list of essential Industrial Value Chains was selected. It should be noted that the selection was made to narrow the number of IVCs to be further analysed in Tasks 2 and 3, and the definition of "essential" was made in a way to serve the purpose of this study. The KPIs used consider the use of RED Annex IX feedstocks only and the selection of "essential" IVCs was made based on Technology Readiness Level, feedstock availability, and preparedness to build industrial facilities; other factors that influence which technologies can or should be deployed include regionally available feedstock, feedstock supply chains and fuel supply chains, but were not considered for this selection. Also, future technological breakthroughs could quickly alter the picture. The list should thus be considered as a list of IVCs that were further analysed in this study, not as the only ones that could be important in the future. The list of selected IVCs is depicted in Table 2-4.

2025-2030	2030-2040
IVC1 - Transesterification for the production of FAME for the road or shipping sector	
IVC2 - Hydrotreatment of Lipids (either through co-processing or in stand-alone facilities) for the production of HVO for the road sector and HEFA for the aviation sector	**IVC2 - Hydrotreatment of Lipids** for the production of HVO for the road sector and HEFA for the aviation sector
	IVC5+12+6 - Production of advanced ethanol for the road sector or for further processing into AtJ-SPK for the aviation sector
IVC7 - Biomethane from AD for the production of biomethane for the road and shipping sectors	**IVC7+9a+9b - Biomethane from AD, and Gasification and Methanation**, **and Methanation from CO2 and H2**, for the production of bio- or e-methane for selling into the road and shipping sectors
	IVC8a+8b+8c - Gasification and Methanol Synthesis, Biomethane (from AD) reforming to methanol, and Methanol Synthesis from biogenic CO2 and H2 for the production of bio- or e-methanol for the shipping sector
	IVC11a a - Gasification and FT-Synthesis for the production of FT-SPK for the aviation sector
IVC13a - Pyrolysis and Co-processing in Refinery for the production of fuels with biogenic content for the road sector	**IVC13a+13b - Pyrolysis and Co-processing in Refinery or Upgrading** for the production of fuels with biogenic content for the aviation and shipping sectors

Table 2-4 List of selected (and clustered) essential Industrial Value Chains

Further value chains at lower TRL were identified, which could become important in the 2040-2050 timeframe. This was done through scanning the technologies investigated in recent and ongoing Horizon Europe research projects on renewable fuels, and through discussing a draft list with the experts of ETIP Bioenergy WG2.

IVC at TRL 4-6 / Variation of IVC at lower TRL	estimated TRL

Table 2-5 lists the resulting technologies and their estimated TRL.

IVC at TRL 4-6 / Variation of IVC at lower TRL	estimated TRL
Hydrotreatment of lipids, produced from algal lipids	3-5
Hydrotreatment of lipids, produced without additional hydrogen	3-5
Lignin boost of fatty acids and Co-processing in Refinery	6
Lignin depolymerisation	5
AtJ technology, using a combination of ethanol and methanol and including production of aromatics	3
AtJ technology, based on methanol	4-5
AtJ technology, consolidated alcohol deoxygenation and oligomerization (CADO) technology	7-9[4]
Biomethane from AD, using in situ or ex situ methanation for upgrading of biogas to biomethane	6-7
Biomethane from AD, providing energy to microbes through electrodes	5
Methanolysis from CO2 and H2	3-7
Gasification and Methanation, using heat integration to minimize auxiliary fuel needs	5-7
Gasification to Hydrogen, multiple process variations, e.g. integrating gas cleaning and conditioning into the reaction vessel	5-7
FT Synthesis from CO2 and H2	4-5
Gas fermentation, producing lipids instead of ethanol	4-6
Pyrolysis, providing energy through microwaves	5
Pyrolysis, providing energy through concentrated solar power	3-7
Hydrothermal treatment, at higher temperature and pressure to increase gaseous phase	4
Hydrothermal treatment, using ethanol or methanol as solvent instead of water	5
Gasification and chemical looping	5
Thermo-catalytic reforming	5
Dark fermentation to hydrogen	4-5
Dark fermentation to single cell oils	4-5
Aqueous phase reforming	5
READi Reactive Distillation Technology	4-5
Condensation of C5 sugars and hydrodeoxygenation	3-4
Sugar to lipid conversion	4-5

Table 2-5 List of value chains at lower Technology Readiness Level

[4] Not yet demonstrated at scale with RED Annex IX feedstocks

2.2. Needs of selected value chains

For each of the essential industrial value chains identified and selected above, information on the needs and potential related gaps in different categories was collected. These categories include classes of feedstock type, feedstock quantities, processing materials type and quantities; equipment for the conversion of feedstock into (crude) biofuel, equipment for upgrading intermediate products into finished biofuel; feedstock production skills, construction skills for conversion facility, operational skills for conversion facility.

The information was collected from literature (including the previous study), knowledge within the study team, and through contacting technology users with an online survey. All of this was done in close collaboration with the project teams of all project Tasks, as the aim was to reach out to each group of stakeholders only once, with a coordinated set of questions.

2.2.1. Data collection from literature and from within the study team

As a first step, a list of data and information that would be relevant for developing the business models under Task 2 was created and adapted according to feedback from the project team. The team decided not to pose open questions, but to seek validation of data and statements instead. Also, the team agreed that it would be useful to reach out to technology users, i.e. prospective biofuel producers such as oil companies, that would invest in building a production facility, instead of reaching out to technology developers, who might have an overly optimistic view of yields and costs. Nevertheless, in the course of this discussion and as a basis for later contacts to experts, a full matrix of experts for all value chains, transport sectors and types of organizations was set up by the project team.

From the full list of data and information needs identified, some (namely the classes of feedstock type applicable in each IVC and the yields from the main feedstock to the main product) had already been collated for the KPI assessment. Process schemes for each of the IVCs and a list of processing materials were created based on knowledge within the team and support from literature and directly provided as input to the work of Task 2. In addition, lists of skills required for (a) developing, conducting and managing projects, (b) building production facilities, (c) operating facilities, and (d) providing feedstock were created based on literature, among which the previous study and a report produced by several European Technology and Innovation Platforms on skills in the renewable energy sector[5].

All this information was brought together in a dataset including the following information for each essential IVC:

- List of industrial value chains (IVCs) and essential IVCs
- Feedstocks applicable per IVC
- Yield from main feedstock to main product
- Process scheme
- Processing materials
- Required skills

[5] “Skills in the Renewable Energy Sector - Visions from the European Technology and Innovation Platforms”, online accessible at: https://www.etipbioenergy.eu/wp-content/uploads/2024/07/2024_Report_Skills_in_the_renewable_energy_sector_Visions_from_the_ETIPs.pdf

2.2.2. Survey to technology users

For the remaining data and information, survey questions were created. It was decided to use an online survey tool (EU Survey), and to accompany the request for completing the survey with a background document providing the specific data for the IVC in question together with some background information on financial instruments. The teams of Task 2 and Task 3 were heavily involved in this process and defined their own questions and statements to be answered/validated.

The online survey served to solicit guided feedback from biofuel producers, for each of the IVCs separately. It asked experts to:

- validate data the project team uses to calculate generic business models,
- identify gaps in the supply of process equipment and materials,
- provide information on skilled workers and specialised companies needed, and
- validate support measures for advanced biofuels value chains.

The survey included four sections:

1. Technology
2. Equipment and Process Materials
3. Skilled Workers and Specialised Companies
4. Support Measures

2.2.3. Survey results

16 experts from 11 companies provided a total of 25 responses to the survey (several experts responded for more than one value chain).

The average scores (in a 1 to 5 range, where 5 is best) of questions validation were generally positive; the list below provides the quantitative results, per section:

- Technology-related Data Validation: average score of 2.7 - 3.9 points;
- Equipment and Processing Materials: average score of 4.2- 4.4 points;
- Information on Skilled Workers and Specialised Companies: average score of 3.5 - 4.5 points.

Feedback was quite detailed and useful and was used to update the dataset of Task 1 and the business models of Task 2, to expand the list of equipment and processing materials and the list of skills needed to build and operate advanced biofuels facilities and provided input to Task 3.

2.2.4. Equipment and key processing materials

Equipment

Feedback from the survey was used to update the list of equipment and processing materials.

Production facilities for advanced biofuels are built from a long list of equipment and devices, including:

- Chemical reactors

- Physical separators
- Heat exchangers
- Distillation columns
- Conveyors
- Processors and pumps
- Pipelines
- Fittings
- Safety devices
- Measuring devices
- Automation and control devices

Nr.	Value Chain	Processing materials
1	Transesterification	Methanol, acidic catalyst, alkalic catalyst
2	Hydrotreatment of Lipids	Hydrogen, catalysts, bleaching earths
3	Lignin Boost of Fatty Acids and Co-processing in Refinery	Fatty acids, hydrogen
4	Sugar and Starch Fermentation to Ethanol	Yeast, enzymes
5	Fermentation of Lignocellulosic Materials to Ethanol	Yeast, enzymes
6	AtJ / MtJ	Hydrogen catalysts
7	Biomethane from Anaerobic Digestion	
8a	Gasification and Methanol Synthesis	Gasification agent, steam, catalysts
8b	Methane reforming and Methanol Synthesis	Catalysts
8c	Methanol Synthesis from biogenic CO2 and H2	Steam, renewable electricity
8d	Methanol from pulping	Sulfuric acid
9a	Gasification and Methanation	Gasification agent, steam, catalysts
9b	Methanation from biogenic CO2 and H2	Renewable electricity
10	Gasification to Hydrogen	Gasification agent, steam
11a	Gasification and FT-Synthesis	Gasification agent, steam, catalysts, hydrogen
11b	FT-Synthesis from biogenic CO2 and H2	Hydrogen, catalysts
12	Gas Fermentation to Ethanol	
13a	Pyrolysis and Co-processing in Refinery	Vacuum gas oil, cracking catalyst
13b	Pyrolysis (and Thermo-Catalytic Reforming) and Upgrading (HDO)	Hydrogen, catalysts
14	Hydrothermal Liquefaction and Upgrading in Refinery (FCC or HDO)	Hydrogen, catalysts

Table 2-6 Processing materials required in each of the selected value chains

Lack of suitable equipment could slow down the implementation of production facilities. It would thus be relevant to identify bottlenecks.

The survey, however, did not reveal any major bottlenecks, although several respondents noted that despite supply of equipment being available from within Europe, it might be cheaper to purchase globally. Components usually sourced from outside Europe include catalysts and pressure equipment. A future supply gap in terms of components, for both from within and from outside Europe, would be expected in biomass pre-treatment (steam explosion), gasification and FT reactors, and upgrading equipment to upgrade biogas to biomethane.

Key processing materials

Processing materials used in advanced biofuels production processes include e.g. bed materials, catalysts, scrubbing materials, activated charcoal and enzymes. Processing materials required in each of the selected value chains are summarized in Table 2-6.

Processing materials are well available in Europe, only catalysts, reactor internals and instrumentations are usually imported. Supply with catalysts could be critical, since requiring nickel and molybdenum and potentially some specific additives. Also, low price renewable electricity is only available in specific locations in Europe.

2.2.5. Skilled workers and specialized companies

The list of skills and companies was updated based on the feedback from the survey.

Developing, conducting and managing projects for the erection of production facilities for renewable fuels production is very demanding and requires a team with skills and experience in the following areas:

- Technology
  - Process design and process scale-up
  - Technology commercialization
  - Biofuels product commercialization
  - Operating chemical plants and waste treatment plants
  - Process optimization
- Project promotion
  - Project management and execution
  - Construction planning and coordination
  - Civil engineering
  - Procurement
  - Permitting
  - Contracting
  - Regulatory affairs / markets
  - Certification
  - Risk Management
  - Health, Safety and Environment (HSE)
- Feedstock supply

- Feedstock market knowledge (biomass, H2 and CO2 markets)
- Stakeholder / Community Relations
- Land agreements
- Financing
  - Financing
  - Strategic Partnerships Development / Business Development

When it comes to **building the facility, workers skilled in the following areas** are needed:

- Mechanical engineering
- Chemical/process engineering
- Biotechnological engineering
- Craftsmen, e.g. welding, automation
- Civil / structural engineering
- Electrical engineering
- Material sciences for proper equipment material selection

Most of these workers will also be needed to **operate the facility**, with some additions:

- Trained operators, craftsmen and maintenance personnel in the areas of
  - Feedstock handling
  - Mechanical engineering
  - Chemical/process engineering
  - Biotechnological engineering
  - Electrical engineering & maintenance
  - Automation and control
  - Laboratory analysis
- Production management and coordination
- Logistics & supply chain management
- Data monitoring & process optimization
- Quality assurance
- Regulatory expert and sustainability management
- Sales / final product delivery
- Health, Safety & Environment (HSE) management
- Human resources

With respect to the sourcing and management of feedstock, the following areas of expertise were mentioned:

- Agricultural management, in particular for new crops such as cover crops
- Agricultural equipment development

- Forest management
- Waste management
- CO2 sourcing
- Power sourcing / knowledge of electricity market
- H2 sourcing
- Supply chain & logistics management
- Contract negotiation & stakeholder relations
- Sustainability assessment / certification

In general, availability of such skilled workforce is not considered problematic. The following gaps in the implementation chain were identified:

Availability of project developers for developing projects in Europe:

- It was noted that refiners seem to focus their efforts on HVO/HEFA production; for other technologies, it seems no strong action to be in place in the EU.
- It was noted that sometimes project developers for biomethane from anaerobic digestion aim at selling the projects to third parties, with the result that these projects could lack rigour in the business model.
- It was generally noted that the industry seems reluctant to invest in gasification technologies.

Availability of EPC companies:

- For the hydrotreatment technology, it was noted that relevant EPC companies exist, but with low availability due to present commitments in projects.
- For 2G ethanol it was noted that the focus needs to be on feedstock handling, pretreatment and hydrolysis.
- For the technologies around gasification, FT synthesis, and methanol synthesis it was noted that few EPC contractors are able to adequately address these challenging first-of-a-kind projects.

Qualified personnel:

- 2G ethanol facilities are expected to draw from 1G ethanol experience.
- AtJ and hydrotreatment technologies are expected to use personnel from traditional refineries or other chemical industry.
- Also, the gasification, FT synthesis, and methanol synthesis technologies are expected to use personnel from chemical industry, however availability could be challenging.

Knowledge to supply feedstocks:

- For the hydrotreatment technology the main challenge is to constantly ensure sufficient feedstock supply.
- For both the AtJ and the gasification technology, the issue mentioned is not the knowledge about the feedstocks, but the capability to organize at large scale:
  - the production of new lignocellulosic feedstock
  - the mobilization of more forest residues and the "cultivation" of more forest
  - the optimization of harvesting agricultural biomass and collecting the residues

- For fuels based on CO_2 and electrolytic H_2 it was mentioned that both the CO_2 and electrolytic H_2 markets are still under development.

Several respondents listed companies that act as project developers or are EPC companies. Project developers mentioned include:

- BP, ENI, Galp, Moeve, Neste, OMV, Orlen, Preem, Repsol, Shell, TotalEnergies, UPM (for hydrotreatment),
- Versalis (for 2G Ethanol)

EPC companies mentioned include:

- Genia, Heymo, Cobra, Biovic, IDEA (for anaerobic digestion)
- Técnicas Reunidas, Alfa Laval (for hydrotreatment).

3. Business models of industrial value chains of advanced biofuels and needs

3.1. Business Models inputs collection

The objective of this task was to define and collect the data and information needed to develop the Business Models for the essential Industrial Value Chains selected by Task 1. The project experts worked on the selection of both the type of information and the most fitting data sources. The selected macro-categories of information were:

- **Feedstock and intermediates**: considering topics such as type, seasonality, cost, type of contracts, storage requirements
- **Technology**: typical size of the plant, time from Final Investment Decision to production, typical product yield, eventual co-products, technological maturity
- **Environmental impact**: eventual emission thresholds, GHG emission levels of the final biofuel
- **Market**: Existing and planned plants, market size and demand, typical off-take schemes, eventual obligations and mandates in force and planned
- **Logistics**: highlighting possible bottlenecks in the value chain that could hinder IVC development
- **Regulatory framework**: eventual regulations in place implementing incentives, caps or penalties for non-compliance (and identifying the obliged parties)
- **IVC and production pathway economics**: such as CAPEX, OPEX, market price of final products and co-products

The required data was collected from a range of sources:

- The outcomes of the previous study “Development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels.”
- Literature research from publicly available sources. It should be noticed that many available data sources, including publicly available comprehensive assessments have been realized before COVID and Ukraine war and this may reflect in possible accuracy reductions. All economic values have been actualized to current currency value, considering historical conversion rate from currencies other than Euro and historical inflation rates dataset from

Eurostat.

- Internal expertise from project partners.
- Targeted interviews with experts.

Finally, as already mentioned above, a stakeholder's matrix was prepared in order to define who shall be contacted with the online survey, which shall serve to validate the data and information used to define the IVC business models and the related results and also identify potential gaps in the availability of equipment as well as potential gaps in the availability of skills (with indications on specific experts acting as contact points within the companies, associations, and institutions).

3.2. Deployment of the Industrial Value Chain Business Models evaluation tool

As already mentioned, of the 20 IVCs identified and assessed, 4 met all selection criteria for the 2025-2030 timeframe, and 13 met all criteria for the 2030-2040 timeframe.

Three out of four (first period IVCs) are present also in the second period, the exception being IVC1: FAME. This decision builds up on the results of the work carried out by Task 3 in the previous tender (see table 3-11 pag.37 of "Annex 3 report on Task 3"), that present a scenario where the same production capacity expected to be operational in 2030 for this IVC is expected to be operational also in 2050, without additional increments of installed capacity. This can be interpreted as the result of not having no further significative expansion of IVC1 after 2030, while maintaining operativity of the existing plants (plus, eventually possible turnover between older capacity being dismissed and new capacity being deployed, or older capacity being revamped to new standards).

Figure 3-1 summarizes the structure of all the selected Essential IVC, from feedstock types to process(es) to final biofuel products; the number in circles are used to identify each IVC in short and the colours are used to identify the clusters to which the conversion process are linked (blue: AtJ, purple: CH4, yellow: MeOH, light grey: pyrolysis). The white-coloured IVCs are not part of any cluster.

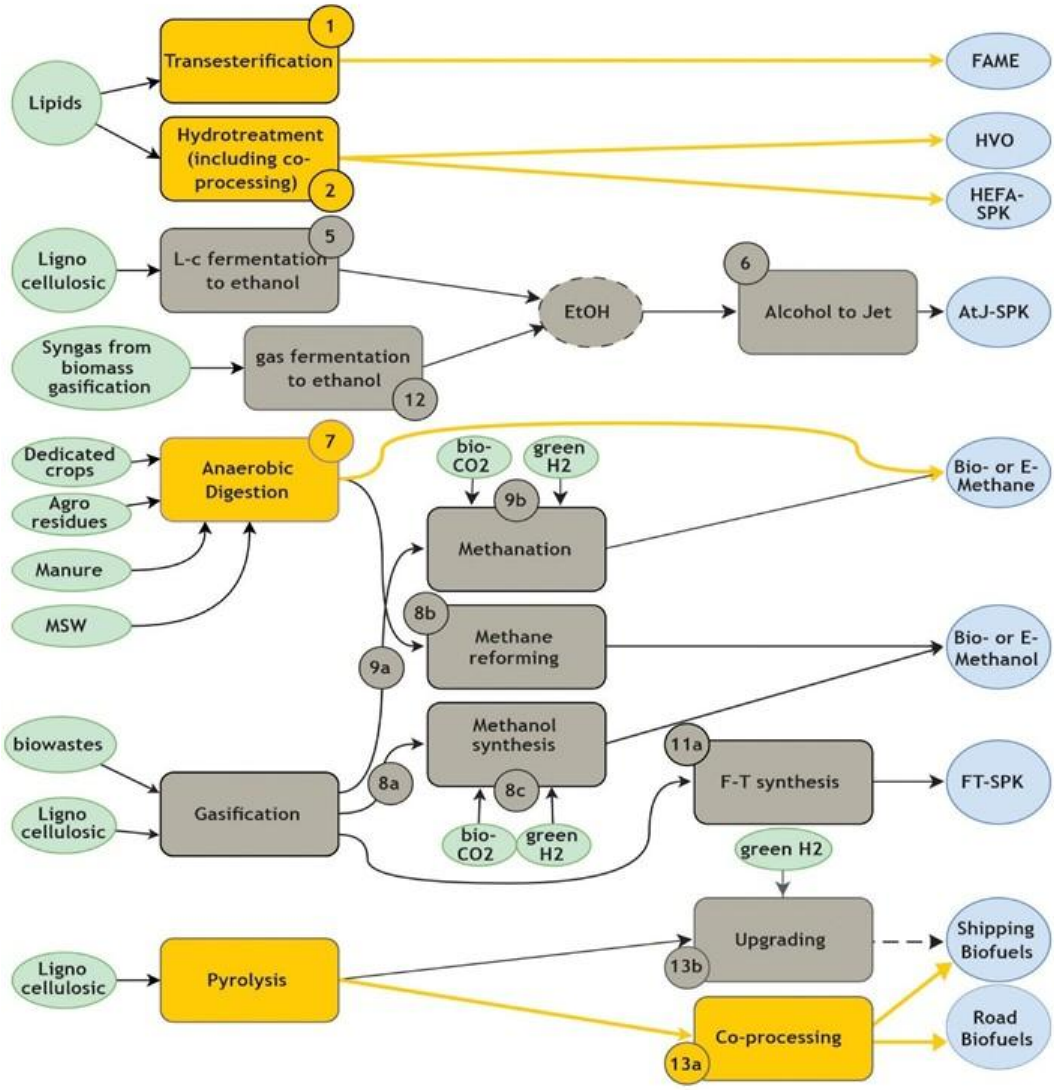

Figure 3-1 Simplified flowchart of the essential IVCs. 2025-2030 essential IVCs are colored in yellow and 2030-2040 essential IVCs in grey)

3.2.1. Business Model Structure

A dedicated Business Model for each IVC has been developed in the frame of the study. Each one of the Business Models, briefly describes a specific IVC in terms of feedstock used, conversion process, overall economics, environmental performance, market and technology perspective and expected risks. Each Business Model essentially considers three sections.

The **first section** provides a brief description of the value chain, complemented with a simplified value chain flow chart. The main IVC characteristics and features are then briefly reported in a dedicated table, listed under the categories here reported

- Feedstock type(s)
- Target sector(s)
- Main output(s)
- Co-product(s)
- Typical plant size
- Typical FID-to-operational time
- Typical yield
- Energy consumption
- Maturity level

The **second section** reports on the main data and assumptions used to carry out a Financial Analysis and provides with the following set of results:

- **Levelized Cost of Production (LCoP)**: two cases are considered: the base one with Tax Rate (TR) of 30% and Inflation Rate (IR) of 2%/yr and an additional one with TR and IR set at zero, for easier confrontation of the results with available literature.
- **Expected profitability** when considering counterfactual fossil market prices, calculated under current market and regulatory framework conditions, including EUA cost as well as penalties for non-compliance with existing regulations, when applicable (the following section is dedicated to the definition of the methodology used).
- **Sensitivity analysis** on the impact of CAPEX, OPEX and feedstock prices variation on LCoP.

The main assumptions used in the Financial Analysis are listed below:

- A discounted cashflow model was used.
- A 100% equity-based case was analysed in order to provide a consistent baseline for the comparison of the results between different IVCs and for the Task 3 activities.
- Financial parameters: in the base case the TR set at 30% and Discount Rate (DR) set at 8%. IR set at constant 2%/yr rate; a case with TR and IR set at zero is provided for easier confrontation of the results with available literature.
- A constant-rate ramp-up of plant capacity was considered across the ramp-up period.
- CAPEX, OPEX, plant lifetime data gathered from literature and expert opinions.
- Feedstock types, expected availabilities and projected prices are mostly provided by the outcomes of Task 1 and previous study Task 2 activities. The latter prepared an extended dataset of projected feedstocks availabilities and prices for 2030 and 2050, while the former defined the types of feedstocks to be used as inputs for each IVC. Finally, specific cases are complemented with focused literature research.

The **third and last section** of the business model is a qualitative assessment of the IVC, carried out by considering the following six macro-categories:

- **Input feedstock and logistics**: feedstock definition, upstream logistics status, infrastructure availability, hindrances and bottlenecks such as low density, storage requirements, sparse distribution, regulatory barriers, type of contracts / procurements
- **Technology and skills**: number of companies already operating along the IVC, existing commercial references and/or demo / pilot plants, availability of equipment and required skills for plant construction and operation (from feedstock management downward).

- **Market**: Potential contribution to expected demand, expected market(s) for co-product(s), expected type/structure of off-take agreements, potential market barriers.
- **Environmental impact**: Expected GHG emissions reduction. Specific values have been selected from two main sources: Annex V and Annex VI of the Renewable Energy Directive II (RED II) and JEC Well-to-Tank (WTT) v5 study[6]. The latter was selected due to its role as a comprehensive and scientifically robust compendium, offering detailed and consistent data on fuel pathways. Moreover, insights on potential for reduction of C Intensity are provided, highlighting facility level mitigation strategies, impacts from feedstock selection and optimization and use of integrated strategies among the others.
- **Risk and Barriers**: including expected impact and likelihood.
- **Tech-2-Market Plan**: only for second period IVCs, whenever their TRL is lower than commercial level; describing the IVC features to be developed in order to reach commercial maturity, as well as existing hindrances and barriers.

3.2.2. Fossil fuels price projections calculation under current market and policy framework

In order to be able to evaluate the expected IVC profitability, the projected LCoP should be compared against fossil fuel cost; thus, a methodology was defined to evaluate the price projections of the fossil alternatives to IVCs biofuels output. These fossil price projections are based on **current fossil fuel market price** and should include:

- **EUA** cost, as mandated by EU-ETS and EU-ETS2 (depending on the sector of use)
- **Penalties** for non-compliance with the targets set by EU regulations (in this document we are considering the penalties defined by FuelEU Maritime and ReFuelEU Aviation)

Thus, the sum of fossil fuel market price, EUA costs and penalties costs (where applicable) can be considered as the alternative price to be compared **to the biofuel price** (for the latter, the minimum price – net of eventual subsidies – could be considered equal to the Levelized Cost of Production). The period considered ranges from 2025 to 2060, to cover a 20-year lifetime of a plant deployed at the end of the second period, on year 2040.

The type of fossil fuels to be considered are different, depending on the IVC considered:

- HVO/HEFA: mix of Diesel, jet fuel, Naphtha, LPG (with variable shares depending on main output)
- FAME: Diesel
- Biomethane cluster: Methane
- Methanol Cluster: Methanol
- Fast Pyrolysis + Co-processing: same as HVO/HEFA
- Fast Pyrolysis + Upgrading: maritime fuel such as VLSFO
- Alcohol-to-Jet: Jet A1, Gasoline, Diesel
- Gasification + F-T: Jet A1

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[6] M. Prussi, M. Yugo, L. De Prada, M. Padella, R. Edwards, and L. Lonza, JEC Well-to-Tank report v5: Well-to-Wheels analysis of future automotive fuels and powertrains in the European context. Luxembourg: Publications Office of the European Union, 2020. [Online]. Available: https://doi.org/10.2760/959137

The methodology is composed by three steps:

- First, gather information on the current fossil fuels EU market prices, whenever possible averaged over the last 24 months and excluding taxes
- Successively, assess the regulatory framework defining additional costs, penalties for non-compliances with targets (and obliged parties) and eventual subsidies for biofuels use in different transport sectors.
- Finally, merge the results of the previous two steps and calculate the total fossil fuel costs projecti0ns. When necessary, the price is adjusted on an energy basis (in case the biofuel is not of the drop-in type and its LHV differs from the one of its direct fossil alternatives)

The results of the first step, provided a dataset with the current fossil fuels EU market prices (per ton of material), which are reported in the following list, with the main data sources provided within parentheses:

- Diesel: 990 €/t (Eurostat)
- Gasoline: 1,190 €/t (Eurostat)
- CH4: 900 €/t (Eurostat)
- Jet fuel: 770 €/t (EASA 2024 prices report, in good agreement with Argus Media)
- Maritime Fuel (VLSFO): 450-460 €/t
- Methanol: 315-625 €/t (Argus Media - Methanex)
- Naphtha: 600 €/t (Argus Media)
- LPG: 840 €/t (Eurostat)

The main regulatory framework considered to evaluate additional costs related to fossil CO2 emissions and possible non-compliance penalties comprises:

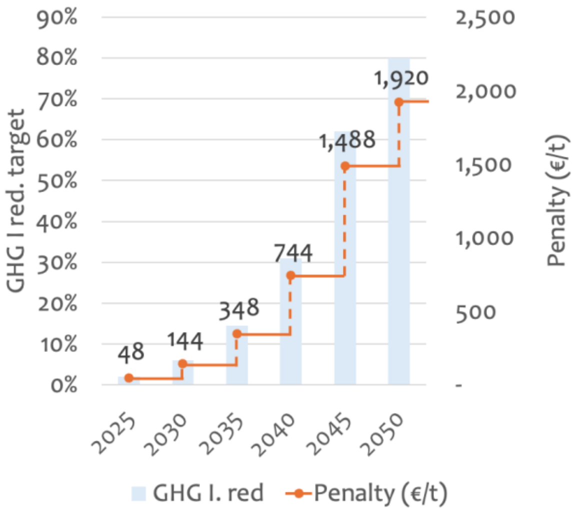
- **EU-ETS regulation:** covering the aviation sector; an average EUA price of 100 €/t_CO2[7]. It also defines possible economic support for covering part of purchase price differential between SAF and fossil Jet fuel, with 20M EUA dedicated to commercial aircraft operators, for an estimated value of 165-210 €/t_SAF[8]. Indeed, a variation of the expected EUA future cost would have an impact on the business viability of some IVCs (see the next section for more detailed information); anyway, the overall impact is quite reduced when compared with the one related to the penalties defined by REFEUA and FEUM.
- **EU-ETS2 regulation:** covering maritime and road sector; EUA price of 45 €/t_CO2 considered for period 2025-2030, then moving to 100€/t_CO2. The obliged party is identified in the fuel supplier (road) or the shipping company (maritime).
- **Fuel EU Maritime (FEUM):** defining non-compliance fees for not reaching the GHG reduction targets (as reported in Figure 3-2 a). The obliged party is identified in the Shipping company.
- **ReFuelEU Aviation (REFEUA):** defining non-compliance fees for not reaching the SAF volumes mandates (Figure 3-2 b). The obliged party is identified in both the fuel supplier and the airline operator, with different level of penalties. In this document the implemented methodology is the one referring to the airline operator since the main objective is to

[7] It should be noticed that the EUA price historically proven to be volatile (as an example, in the last two years it ranged between 55 €/t_CO2 and 105 €/t_CO2) and EUA projections reflect this volatility as well. Publicly available data for 2030 ranges between 70 and 160 €/t_CO2.
[8] Considering the average EUA price of 80- 100 €/t_CO2 and a total of 9.5 Mt of SAF demand over the considered period.

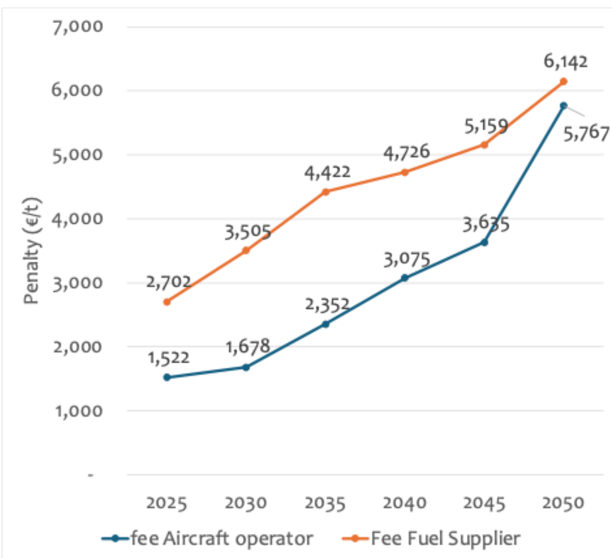
calculate the **updated fossil fuel market price**.

- **RED II – RED III:** define targets for overall energy consumption in transport sector; the definition of non-compliance penalties is to be provided at MS level, and it not considered in this study.

Figure 3-3 reports the results of the described methodology for all the considered fossil fuels counterparts in different end use sectors, showing the impact of EUA prices and non-compliance penalties. It can be noticed how aviation sector REFEUA-defined penalties could impact on total fossil price, especially in the second part of the considered timeframe.



(a)



(b)

Figure 3-2 Calculated non-compliance penalty levels for a) Maritime sector and b) Aviation sector, as respectively defined by FEUM and REFEUA

Figure 3-3 Price projections of considered fossil fuels counterpart of main biofuels outputs from the essential IVCs

3.2.3. Overall results from BM development activity

Figure 3-4, Figure 3-5 and Figure 3-6 provide a summary of some of the main characteristics and performance metrics of the investigated IVCs. The first two Figures show the IVC specifications regarding the assumed average commercial size for the conversion processes (in MW) and the specific CAPEX (in €/kW), while Figure 3-6 provides a summary of results focusing on the Levelized Cost of Production (LCoP) for the biofuels output of each IVC.

It can be noticed from Figure 3-5 that the lowest specific CAPEX is attributed to the most mature IVCs for 2025-2030, such as FAME (IVC1) and HVO/HEFA (IVC2). Instead, it has to be noticed that for the production pathways of the biogenic-CO2 and green H2 based methane (IVC9b) and methanol (IVC8c) the low specific CAPEX is due to the assumption made in their business model: there, the reported CAPEX only includes the methanation or the methanol synthesis section, respectively. The CAPEX (and OPEX) related to the green H2 production and storage sections are included in the Levelized Cost of the green H2 as applied in the financial analysis and thus are falling into the feedstock costs figure (as reported in Figure 3-6). This choice allows to explicit the calculated green H2 LCoP considered in the analysis. All the other IVC specific CAPEX are comprised in the 2.500 – 3.500 €/kW range, with the exception of the AtJ IVCs (IVC6 and IVC6a), that are expected to reach the quite higher values of 5.500 – 8.200 €/kW, that could seriously hinder business viability.

Research on existing sector literature and databases (I.e. the IEA Bioenergy Task 39[9]) has been carried out, complemented by experts' evaluations, in order to define a plausible average commercial scale of the conversion plants for the considered IVCs. Figure 3-4 reports on the lowest side of the range the biomethane production through A.D. (IVC7) and synthesis (IVC9b), with 5 MW output. Many IVCs are in the range of 75-150 MW, such as all the ones in the AtJ cluster and in the Pyrolysis cluster (IVC13a and IVC13b), as well as the methane and methanol production from syngas from gasification (respectively IVC9a and IVC8a). Increasing the size, gasification + F-T (IVC11a) and FAME (IVC1) are positioned around the 200 MW size, while HVO/HEFA (IVC2) so far is on the highest side of the range with more than 700 MW.

The LCoP values shown in Figure 3-6 align well with the existing publicly available literature[10] and are described on a singular basis in each IVC Business Model Financial Analysis result section. What should be stressed here is that all the fuel-related co-product revenues (i.e. when more than one fuel product is produced as an output of the process) were calculated by applying the fossil fuel price methodology described above, thus including EUA and penalties-related costs into the total price. This could lead to a rather high valorisation of the co-products revenues, and thus to an LCoP lower than the one from considering the sum of CAPEX, OPEX and feedstock shares.

The LCoP for the diesel-like biofuels ranges between the **119 €/MWh** of FAME and the **103 €/MWh** of HVO. Biomethane LCoP ranges between **98 €/MWh** of A.D from MSW (IVC7) and **154 €/MWh** of synthesis from biogenic CO2 and green H2 (IVC9b). The lower end of the range can be achieved when MSW is used as feedstock or in larger plant sizes. This conclusion is supported by industrial stakeholders' feedback: a LCoP calculated by using the provided inputs could reach 44 €/MWh – for a bigger plant (more than twice the size) processing MSW.

SAF LCoP has a wide range, depending on the technology and the period: from **154 €/MWh** of HEFA (IVC2), to the **225-320 €/MWh** of the AtJ (IVC6 and IVC6a), to the **160 €/MWh** of gasification + F-T (IVC11a) in the second period. Multiple feedback from stakeholders' consultation suggested to increase both CAPEX and OPEX for the AtJ and the gasification + F-

[9] https://demoplants.best-research.eu/

[10] All the literature references used for the characterization of the various IVCs can be found in Appendix 1 of this report. More detailed are provided in the accompanying relevant Annex of the study "Industrial Value Chains Business Models".

T IVCs. The impact on LCoP were consistent, especially for the gasification + F-T IVC, which new LCoP raised to 450 €/MWh; instead, the recalculated LCoP for AtJ increased to almost 380 €/MWh.

In the shipping sector, Methanol LCoP projections ranges between **121 €/MWh** of the gasification-based process (IVC8a) and **160 €/MWh** of synthesis from biogenic CO2 and green H2 (IVC9b) and biomethane reforming (IVC8b).

Table 3-3 reports the results of the LCoP projections – and on the CAPEX, OPEX and feedstock cost contributions to them – expressed in €/ton of main output.

Finally, Table 3-1 and Table 3-2 report the main findings from the IVC business models evaluation, summarized in the various considered parameters and KPIs. It can be noticed that, when considering a market scenario in which the biofuel products and co-products are sold at the same price of their fossil alternative plus the price of EUA (*EUA* case), **IVC2 HVO is the only IVC among the ones considered for the first period that come close to not needing additional financial support** in order to reach a calculated NPV higher than zero at the end of plant lifetime. In the second period, the modelling results show that **IVC9b-Methanation from biogenic CO_2 and green H_2 would not require additional support,** but **only in the case of the extremely low electrolysis-based H_2 costs of 2.3 €/kgH_2** as considered in the *H2 Low* scenarios. It should be noticed that such value was included in the analysis because it can indeed be found in available literature for 2030 and beyond, but it is still considered as overly optimistic by many experts.

When considering the case in which the biofuel products and co-products are sold at the same price of their fossil alternative plus the price of EUA and the cost of penalties as defined by REFEUA or FEUM, depending on sector of use (*EUA + penalty* case), several other IVCs don't need additional financial support in order to reach a calculated NPV higher than zero at the end of plant lifetime:

- **First period (2025-2030):** IVC1 FAME, IVC2 HVO/HEFA for both HVO and HEFA considered as main products and IVC7 CH4-AD in the case considering MSW as input feedstock.
- **Second period (2030-2040):** IVC6a Syngas EtOH to Jet, IVC8c MeOH from biogenic CO2 and green H2 (but only in the case considering lower H2 production costs), IVC9a Gasification to CH4, in the case considering MSW as input feedstock (and at a price stable in time), IVC9b MeOH from biogenic CO2 and green H2 (but only in the case considering lower H2 production costs), IVC11a Gasification to F-T. IVC8a Gasification to MeOH proves to be closer to parity, but still needs additional financial support.

A LCoP value lower than the expected fossil counterpart market price is a requirement for an IVC to be considered profitable without additional economic support; anyway, also adequate margins should be considered into the equation. Internal expertise suggests that usually margins range between 10 and 30%; a high degree of uncertainty is associated to this parameter, due to obvious commercial sensitiveness of this industrial data.

It can be noted that the impact of penalties additional costs proves to be substantial on the business cases; the comparison between the expected average fossil fuel counterpart price and the calculated LCoP (under the considered techno-economic conditions) is reported in Table 3-1 and Table 3-2, among the main KPIs defining the IVC results. Since the penalties are sector-related (namely aviation and maritime, without similar measures in place for road sector), it can be expected that they could stimulate a reduction in the offer toward the road sector, for all the biofuels that could be used in the maritime sector as well. A possible example for this situation can be found in biodiesel and biomethane, as well as for HPO.

A word of caution should be added when commenting some of the most positive results related to the existence of penalties embedded in the fossil fuel counterpart price. Indeed, this can be considered as the highest possible price that an obliged party could be willing to pay for a compliant biofuel; however, it can be well understood how, in a real-life scenario, the final market price would be set to a lower price, laying somewhere in the range between LCoP and the fossil fuel counterpart calculated price, thus reducing the financial KPIs such as IRR. Moreover, another word of caution should be added on the IVCs that consider the use of locally produced green H2: there is high uncertainty on the future development of green H2 prices, and the prices used for the calculation in the "Low H2" cases are rather optimistic, and should be considered as a best techno-economic scenario case.

On another note, several IVCs that emerged as requiring additional economic support from the model evaluation in the *EUA* case (where biofuel products and co-products are considered as sold at the same price of their fossil alternative plus the price of EUA) are however rather close to economic viability. As an example, the variability range attributed to the LCoP by the sensitivity analysis carried out on the following IVCs could intersect with the fossil fuel counterpart market price: IVC1 – FAME, IVC2 – HVO, IVC7 – Biomethane from AD (both cases), IVC13 – Pyrolysis and co-processing and IVC9a – Gasification to CH4. Thus, a +/- 30% variation (or less) in one or more among CAPEX, OPEX or feedstock price, could allow these IVCs to be profitable without additional financial support.

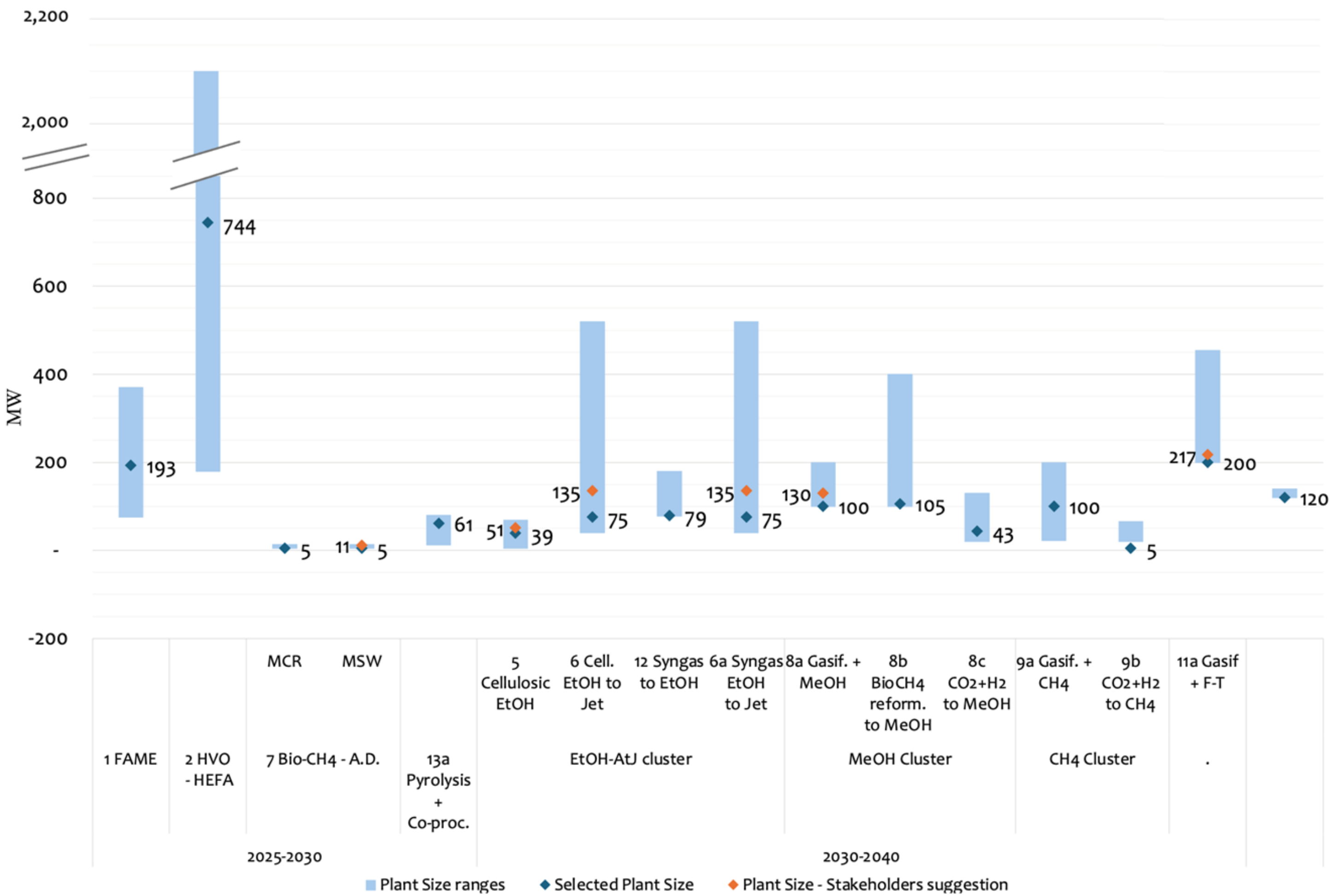


Figure 3-4 Overview of the considered average commercial size (light blue bars: total ranges from public literature; blue dots: value used in Financial Analysis; orange dots: suggested values from Stakeholders consultation) for all the essential IVCs

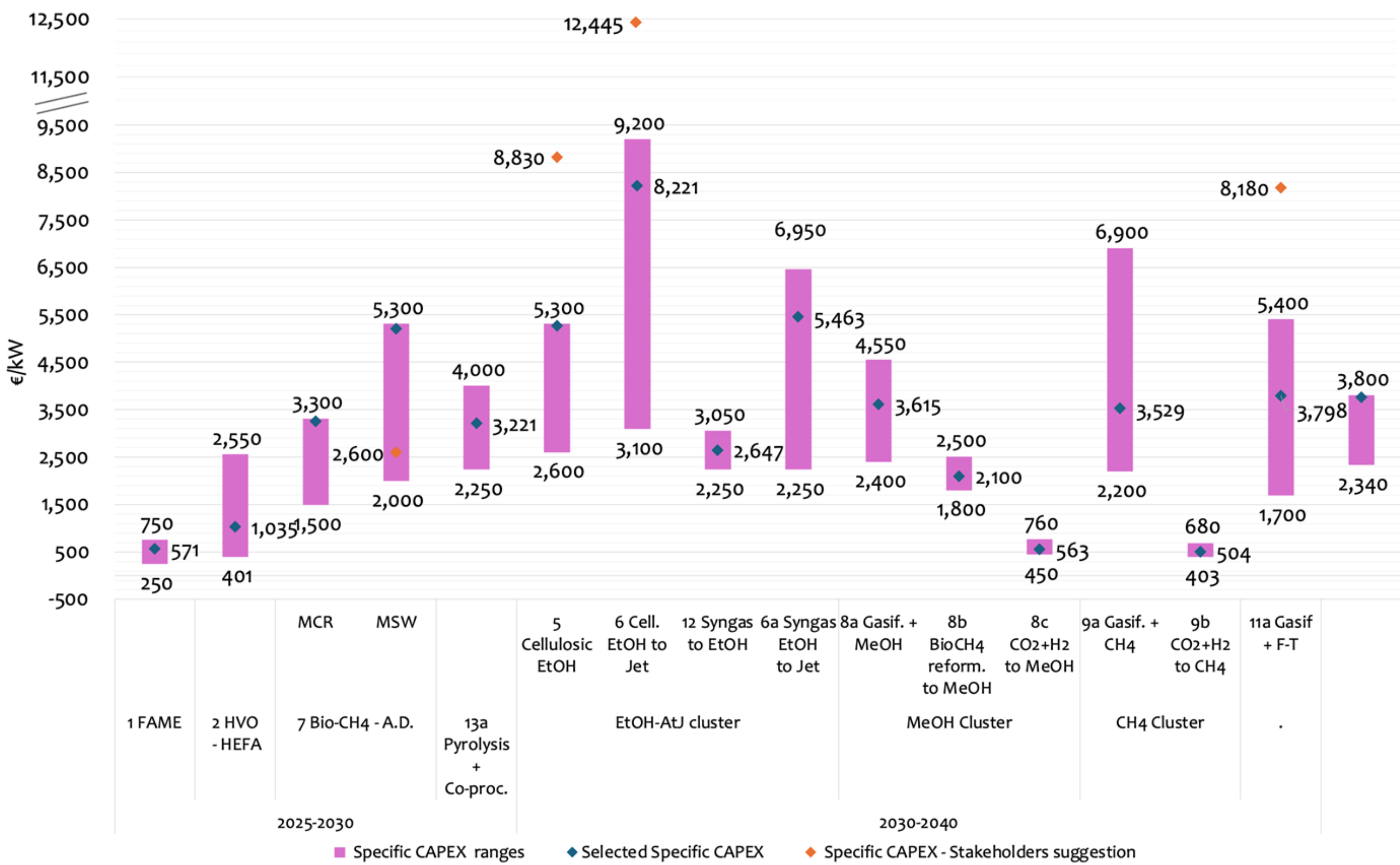


Figure 3-5 Overview of the specific CAPEX for all the essential IVCs (light purple bars: total ranges from public literature; blue dots: value used in Financial Analysis; orange dots: alternative CAPEX values as gathered from Stakeholders consultation, for all the cases when the stakeholders answer fell outside of the proposed ranges. These values have been used in the updated Financial Analyses calculations)

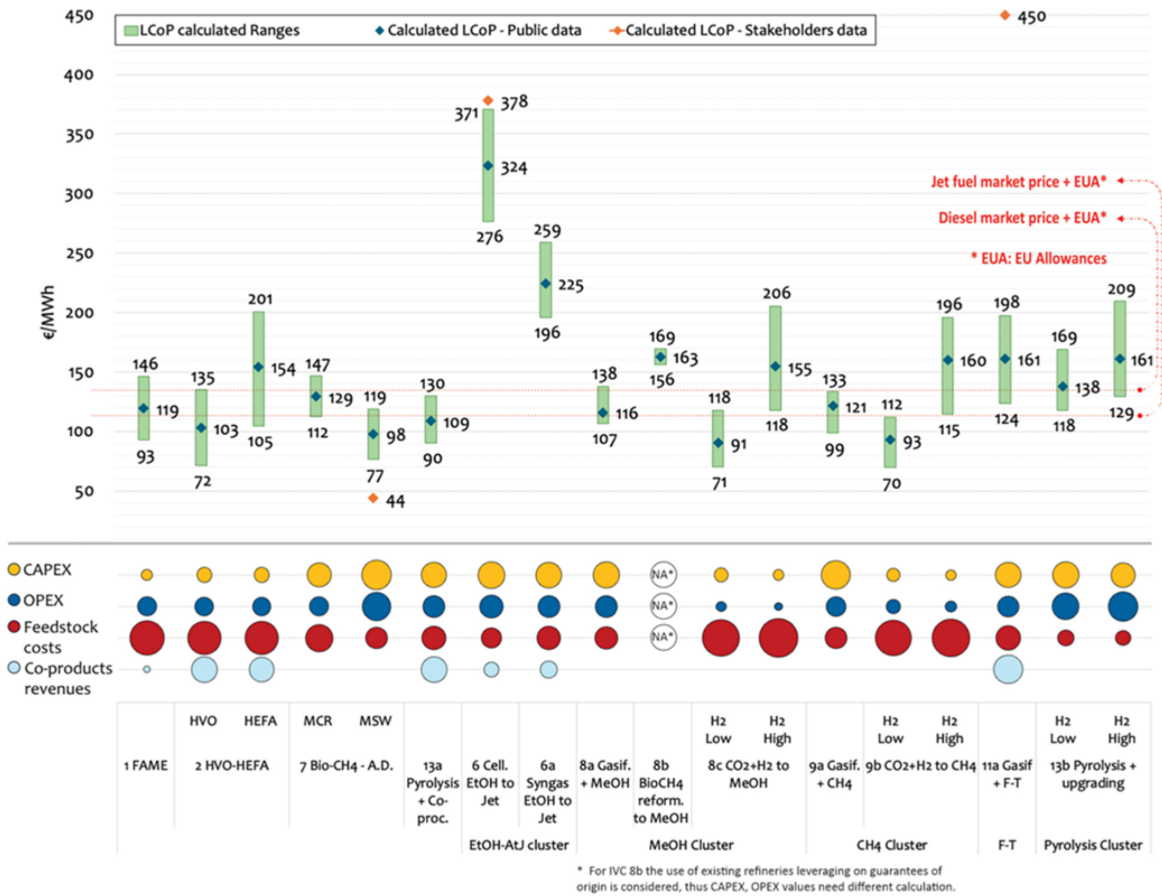


Figure 3-6 Overview of the composition of the LCoP for all the essential IVC[11]

[11] The upper part of the graph shows the calculated value from publicly available data (blue dot), the one from alternative data provided by industrial stakeholders (orange dot) and LCoP ranges from sensitivity analysis results (green bars). The lower section qualitatively reports the influence of CAPEX, OPEX, feedstock prices and coproduct revenues on the final LCoP values. The following H2 prices are considered in the analysis “H2 Low”: 2.3 €/kg, “H2 High”: 4.2 €/kg.

Nr.	Case	Main prod.	Size		Target Sectors	Feedstock type(s)	Specific CAPEX	CAPEX	Share OPEX/ CAPEX	LCOP [A]	Average biofuel market price[B]	Calculated average fossil price[C]	NPV[A]	IRR[A]
			kt/yr	MW			€/kW	M€	%	€/t	€/t	€/t	M€	%
IVC1 - FAME	N.A.	FAME	150	192	Road, Maritime	Lipidic waste (UCO)	571	110	13.2%	1,486	1,450	(E)[D]: 1,585	A. S. N.[E]	A. S. N.
												(E+P)[F]: 1,960	138.85	15.0%
IVC2 - HVO-HEFA	HVO	HVO	500[G]	743	Road, Aviation	Lipidic waste (UCO)	1,035	770	20.3%	1,623	1,750	(E): 1,585	A. S. N.	A. S. N.
												(E+P): N.A.*	N.A.	N.A.
	HEFA	HEFA	500[G]	743	Road, Aviation	Lipidic waste (UCO)	1,035	770	20.3%	2,325	2,380	(E): 1,353	A. S. N.	A. S. N.
												(E+P): 3,580	1,821	22.5%
IVC7 - Bio-CH4 - AD	M+C+R	CH4	2.9	5	Road	Manure, agro-residues, seq. crops	3,258	16.3	6.8%	2,145	1,275	(E): 1,509	A. S. N.	A. S. N.
												(E+P): 1,886	A. S. N.	A. S. N.
	MSW	CH4	2.9	5	Road	Municipal organic wastes	5,212	26.1	10.1%	1,637		(E): 1,509	A. S. N.	A. S. N.
												(E+P): 1,886	2.44	9.1%
IVC13a - Pyrolysis + Co-processing	N.A.	Ren. Diesel	38.7	61.1	Road	Ligno-cellulosic	3,221	196.8	8.8%	1,755	1,750[H]	(E): 1,585	A. S. N.	A. S. N.
												(E+P): N.A.	N.A.	N.A.

[A]: It should be noticed that an uncertainty range have always to be considered to account for all the expected variabilities i.e. in CAPEX, OPEX, upstream logistics and other parts of the IVC, that are expected to happen among different projects.
[B]: 2025 data evaluated on EU markets, averaged over 24 months whenever possible
[C]: The calculated average fossil price includes: inflation effects over the considered period, the ETS costs for EUA purchase (E case) and the additional penalties costs as defined by REFEUA and FEUM (E+P case).
[D]: E refers to the ETS case
[E]: A.S.N. (Additional Support Needed): the application of the fossil counterpart price to the product and co-product(s) requires some form of support, as the modelled value chain does not reach business viability (NPV=0 at the end of plant lifetime)
[F]: E+P refers to the case in which both ETS additional costs and penalties from REFEUA and FEUM
[G]: Total output pool
[H]: HVO price used as proxy
* It should be noticed that, if the use of HVO in maritime sector is considered, it would be possible to consider a scenario in which the price of the fossil counterpart includes also the penalties from FEUM regulation. This would allow to reach a positive NPV during plant lifetime.

Table 3-1 Summary of the main KPIs for the IVC considered in the first period (2025-2030)

Nr.	Case	Main product	Size		Target Sectors	Feedstock type(s)	Specific CAPEX	CAPEX	Share OPEX/ CAPEX	LCOP[A]	Average biofuel market price[B]	Calculated Average Fossil price[C]	NPV[A]	IRR[A]
			kt/yr	MW			€/kW	M€	%	€/t	€/t	€/t	M€	%
5 - Cellulosic EtOH	N.A.	EtOH	85	78.8	Road	Ligno-cellulosic	5,270	415.1	10.6%	1,903	1,000	(E)[D]: 2,030	A.S.N.[E]	A.S.N.
												N.A.	N.A.	N.A.
6 - Cell. EtOH to Jet	N.A.	SAF	50	74.9	Aviation	Ligno-cellulosic	8,221	615.8	8.5%	4,789	2,380[F]	(E): 1,462	A.S.N.	A.S.N.
												(E+P)[G]: 4,351	A.S.N.	A.S.N.
12 - Syngas to EtOH	N.A.	EtOH	85	78.8	Road	Ligno-cellulosic	2,647	208.5	16.0%	1,399	1,000	(E): 2,030	A.S.N.	A.S.N.
												N.A.	N.A.	N.A.
6a - Syngas EtOH to Jet	N.A.	SAF	50	74.9	Aviation	Ligno-cellulosic	5,463	409.2	11.8%	3,342	2,380[F]	(E): 1,462	A.S.N.	A.S.N.
												(E+P): 4,351	115.4	10.9%
9a – Gasific. + CH4	N.A.	CH4	57.8	100	Road, Shipping	Ligno-cellulosic	3,529	352.9	5.9%	1,923	1,275	(E): 1,697	A.S.N.	A.S.N.
												(E+P): 2,466	82.83	11.1%
9b - Biogenic CO2+H2 to CH4	H2 - Low	CH4	2.9	5	Road, Shipping	CO2, H2	504	2.5	8.0%	1,550		(E): 1,697	2.28	16.3%
												(E+P): 2,466	13.6	31.4%
	H2 - High									2,645		(E): 1,697	A.S.N.	A.S.N.
												(E+P): 2,466	A.S.N.	A.S.N.
8a - Gasification + MeOH	N.A.	MeOH	145	100	Shipping	Ligno-cellulosic	3,615	361.5	7.5%	824	935	(E): 1,003	A.S.N.	A.S.N.
												(E+P): 1,773	A.S.N.	A.S.N.
8b - CH4 reforming to MeOH	N.A.	MeOH	150	105	Shipping	Bio-CH4	2,100	220.5	N.A.*	870 - 940		(E): 1,003	A.S.N.	A.S.N.
												(E+P): 1,773	A.S.N.	A.S.N.
8c - Biogenic CO2+H2 to MeOH	H2 - Low	MeOH	62	43	Shipping	CO2, H2	563	24.1	7.5%	633		(E): 1,003	A.S.N.	A.S.N.
												(E+P): 1,773	55.97	17.8%
	H2 - High									1,091		(E): 1,003	A.S.N.	A.S.N.
												(E+P): 1,773	A.S.N.	A.S.N.
11a – Gasific. + F-T	N.A.	SAF	134	200	Aviation, Road	Ligno-cellulosic	3,798	759.7	7.5%	2,364	2,380	(E): 1,462	A.S.N.	A.S.N.
												(E+P): 4,351	659.1	16.3%
13b - Pyrolysis + upgrading	H2 - Low	HPO	79.2	120	Shipping	Ligno-cellulosic	3,766	452.5	7.5%	2,058	1,150[H]	(E): 1,003	A.S.N.	A.S.N.
												(E+P): 1,773	A.S.N.	A.S.N.
	H2 - High									2,405		(E): 1,003	A.S.N.	A.S.N.
												(E+P): 1,773	A.S.N.	A.S.N.

[A]: It should be noticed that an uncertainty range have always to be considered to account for all the expected variabilities i.e. in CAPEX, OPEX, upstream logistics and other parts of the IVC, that are expected to happen among different projects.
[B]: 2025 data evaluated on EU markets, averaged over 24 months whenever possible
[C]: The calculated average fossil price includes: inflation effects over the considered period, the ETS costs for EUA purchase (E case) and the additional penalties costs as defined by REFEUA and FEUM (E+P case). In the case of non-drop-in biofuels (i.e. ethanol), the fossil fuel price has to be adjusted to consider the difference in energy contents
[D]: E refers to the ETS case
[E]: A.S.N. (Additional Support Needed): the application of the fossil counterpart price to the product and co-product(s) requires some form of support, as it does not reach business viability (NPV=0 at the end of plant lifetime)
[F]: HEFA considered as proxy
[G]: E+P refers to the case in which both ETS additional costs and penalties from REFEUA and FEUM
[H]: Considered advanced biodiesel for maritime B100 as proxy
* IVC 8b considers the use of existing refineries, leveraging on guarantees of origin; thus, a different methodology is used for CAPEX and OPEX calculation

Table 3-2 Summary of the main KPIs for the IVCs considered in the second period (2030-2040)

IVC	Case	Main Output	CAPEX share (€/t)	OPEX share (€/t)	Feedstock mix share (€/t)	LCoP (€/t)
IVC1 - FAME	N.A.	FAME	83	267	903	1,226
IVC2 - HVO-HEFA	N.A.	HVO	269	405	1,342	1,218
	N.A.	HEFA	376	566	1,961	1,844
IVC7 - Bio-CH4 - A.D.	M+C+R Case	CH4	605	388	799	1,791
	MSW Case	CH4	965	913	- 525	1,354
IVC13a - Pyrolysis + Co-processing	N.A.	Renew. Diesel	805	582	711	1,283
IVC5 - Cellulosic EtOH	N.A.	EtOH	555	516	472	1,543
IVC6 - Cell. EtOH to Jet	N.A.	SAF	1,892	1,421	1,086	3,855
IVC12 - Syngas to EtOH	N.A.	EtOH	278	393	463	1,134
IVC6 - Syngas EtOH to Jet	N.A.	SAF	1,257	904	1,064	2,681
IVC9a - Gasification + CH4	N.A.	CH4	800	360	446	1,606
IVC9b – biogenic CO2+H2 to CH4	H2 Low	CH4	128	151	976	1,255
	H2 High	CH4	128	151	1,863	2,142
IVC8a - Gasification + MeOH	N.A.	MeOH	281	186	200	668
IVC8b - CH4 reforming to MeOH	N.A.	MeOH	N.A. *	N.A. *	N.A. *	936
IVC8c – biogenic CO2+H2 to MeOH	H2 Low	MeOH	57	29	427	513
	H2 High	MeOH	57	29	795	882
IVC11a - Gasification + F-T	N.A.	SAF	1,445	955	1,329	1,922
IVC13b - Pyrolysis + upgrading	H2 Low	HPO	685	706	251	1,642
	H2 High	HPO	685	981	251	1,917

*For IVC8b the use of existing refineries and the leveraging on Guarantees of Origin is considered; CAPEX, OPEX and feedstock cost impact on LCoP can't be calculated due to different methodology utilized for LCoP evaluation

Table 3-3 Contribution of CAPEX, OPEX and feedstock cost to the Levelized Costs of Production, in €/t (not considering inflation and taxes, for consistency with the other graphs in the section) for the main output of all the IVCs

3.3. Business Models outcomes validation through interviews with selected stakeholders

The industrial stakeholders' consultation activity gathered a total of 275 answers to specific questions related to the techno-economical part of the business model, from 17 single responders. All the questions where the responder attributed a 1 or 2 score to the Business Model results were revised and amendments proposed whenever required. Table 3-4 is dedicated to each specific point in the end of this chapter. In the followings, a brief paragraph is dedicated to each revised IVC, highlighting suggestions and remarks arisen from stakeholders' consultation.

IVC2 – HVO/HEFA

Slight modifications in the shares of output slates were suggested; moreover, it was stressed the importance of highlighting the variability of overall and single co-products yields, related to different plant configurations and optimization. Finally, the consultation reported that average CAPEX could be near to the upper range proposed. The suggestion was reported in the qualitative section of the Business Model, while the CAPEX remark should be already addressed by the sensitivity analysis results.

IVC5 – Fermentation of L-C materials to Ethanol / IVC6 – AtJ

A series of remarks were reported by the stakeholders' consultation, all of which were integrated in the qualitative part of the Business Model, whenever not already (at least partially) addressed by the sensitivity analysis:

- **Feedstock types**: a reference to Annex IX-A of 2018/2001 RED II was requested
- **Type of co-products and SAF yields**: biomethane from A.D of process residues was expected to be in the co-products, and higher SAF selectivity was pointed out as obtainable by the process.
- **CAPEX and OPEX too low**: even without complete consensus within the answers from the industrial stakeholders, the CAPEX was generally considered to be lower than reality, up to 50%. Only one answer on proposed OPEX value deemed it to be challenging.

A new Financial Analysis has been carried out with updated inputs as provided by the stakeholders. The results are presented in comparison with the others obtained by using publicly available data as follows.

IVC7 – Advanced biomethane from anaerobic digestion

The feedback from industry consultation suggested that a bigger sized plant could be modelled when considering the MSW case. This brings lower specific CAPEX and OPEX and longer construction and ramp-up times. A new Financial Analysis has been carried out with updated inputs as provided by the stakeholders. The results are presented in comparison with the others obtained by using publicly available data.

IVC8a - Gasification + MeOH

The feedback from industry consultation suggested that this process could exploit additional feedstocks, such as the organic fraction of municipal solid waste, and that methanol could indeed be used as a precursor for other fuels in addition to the maritime sector. We have integrated this information in our analysis, although we have maintained the focus on the proposed feedstock and target sectors. Additionally, some experts suggested that higher

CAPEX and OPEX could be expected compared to our central estimate. However, we believe that the sensitivity analysis that we have presented already account for this possible increase.

IVC8c – biogenic CO2+green H2 to MeOH

The feedback from industry consultation suggested that this process could exploit additional feedstocks, such as non-biogenic CO2 streams and CO2 from direct air capture (but it should be noticed that, in this case, the cost of capture would be different), and that methanol could indeed be used as a precursor for other fuels in addition to the maritime sector. We have integrated this information in our analysis, although we have maintained the focus on the proposed feedstock and target sectors. We have also verified the comments on the plant size and the CAPEX and OPEX levels, although they were mostly referred to existing and proposed plants that were not targeting biological CO2 streams.

IVC9b – biogenic CO2+green H2 to CH4

The feedback from industry consultation stressed the importance of clarifying that synthetic methane, to be classified as RFNBO, needs that hydrogen should be produced from water electrolysis supplied by renewable electricity. Although this assumption was already present in our analysis, we have further highlighted it to avoid any misleading interpretation (the same comment has also been applied to the IVC8c). The experts have also requested other minor clarifications for the feedstocks, that have been added to the document. They have also suggested that our estimate on the OPEX may be too high: we have reported this comment in the document for transparency.

IVC11a – Gasification and F-T

The industrial stakeholders suggested a slight revision of the process flow scheme in order to make it more alike to their experience, which was implemented. The complexity of the process was highlighted together with a lower maturity level that would require longer construction and ramp-up times and quite higher CAPEX, up to doubling the values proposed in the Business Model. Also, higher OPEX were envisaged, but without a complete alignment across stakeholders' responses. Finally, process flexibility in terms of output shares was highlighted by the stakeholders. All the suggestions were implemented in the qualitative sections of the Business Model, and a new Financial Analysis has been carried out with updated inputs as provided by the stakeholders. The results are presented in comparison with the others obtained by using publicly available data.

IVC13a – Pyrolysis and co-processing in refineries

A single comment was provided regarding the output slate composition. We agreed on a technical standpoint, and it was integrated in the process description part of the Business Model.

IVC13b – Pyrolysis and upgrading

A stakeholder suggested a specific distribution of products in the output pool that is seen as a base case; it was integrated in the process description. Finally, a suggestion to further leverage on the distributed nature of the IVC was proposed and integrated in the Business Model.

IVC	Questionnaire issue	Main Remarks	Proposed amendments
2	Output slate composition	Use ranges to identify main and co-products yields since they can differ due to specific plant design.	Added clarification in the qualitative description through the text
2	CAPEX	It can vary depending on plant configuration; in particular, toward the higher values.	None. We acknowledge the possible variation of the economic parameters; the proposed one is an average value of publicly available data, supported by experts' evaluation. The variability is then accounted by the sensitivity analysis.
2	Feedstock description and product slates	Slight changes requested on feedstock wording; highlight flexibility of product slates composition.	Added clarification in the qualitative description through the text
5, 6	CAPEX, OPEX	CAPEX and OPEX of EtOH plant are too low.	Added a clarification in the quantitative and qualitative section of the Business Model. A Financial Analysis with adjusted inputs, considering the values proposed by the stakeholders has been conducted and the results added to the Business Model.
6 - AtJ	Feedstock types	Redefine suitable feedstock definition, report on additional possible feedstocks and logistic issues.	Added "…including the types defined in Annex IX of Directive (EU) 2018/2001" to feedstock definition; possible additional feedstock and logistic issues mentioned in qualitative section
6 - AtJ	Co-products	Provide additional coverage to lignin, biomethane and bio-CO2 as feedstock for downstream e-fuel plant.	Lignin and CO2 are already considered in the Business Model, and IVC8c already consider the use of CO2 to produce Methanol. CH4 added in the qualitative description of the Business Model
5, 6	SAF yield	Higher yield of SAF from optimized plant.	Added in the qualitative description of the Business Model. A Financial Analysis with adjusted inputs, considering the values proposed by the stakeholders has been conducted and the results added to the BM
6	Feedstock types	Woody biomass more appropriate than straw.	None. Both are already cited in the qualitative part of Business Model
7	Construction and ramp-up times	Longer construction and ramp-up times expected.	Added a clarification in the quantitative and qualitative section of the Business Model. A Financial Analysis with this and the following adjusted inputs, considering the values proposed by the stakeholders has been conducted and the results added to the BM
7	Plant Size	Proposed bigger plant size for the MSW case.	
7	CAPEX, OPEX	Reduced values for specific CAPEX and OPEX were suggested for the MSW case.	
8a	Value Chain description	Methanol is not only for maritime but can be used in other value chains (e.g. SAF or gasoline).	This clarification has been added.
8a	Choice of ref. feedstock	Other feedstocks can be used (e.g. organic fraction of MSW).	This clarification has been added.

IVC	Questionnaire issue	Main Remarks	Proposed amendments
8a	Value Chain description	External hydrogen can increase the methanol yield in the water-gas-shift reaction.	This is true. In fact, this point has already been mentioned in the section “Technology and skills.”
8a	CAPEX	CAPEX is low.	Our values for CAPEX are based on values from different literature studies. The sensitivity analysis also includes the effect of up to +30% of CAPEX.
8a	OPEX	OPEX is low, it can be >10% of CAPEX.	Our values for OPEX are based on values from different literature studies. The sensitivity analysis also includes the effect of up to +30% of OPEX.
8c	Value Chain description	Methanol is not only for maritime but can be used in other value chains (e.g. SAF or gasoline).	This clarification has been added.
8c	Value Chain description	In addition to biogenic CO_2, non-biogenic and DAC can be used.	This clarification has been added. However, the analysis focuses on biogenic CO_2, due to future mandates that require no fossil CO_2 and to the fact that DAC will likely remain too energy intensive and costly.
8c	Feedstocks and products	Water is mentioned as product but not as feedstock.	Water has been removed from the description and heat added as a co-product.
8c	Yield ranges	Cross-check with other studies.	Done, the values are comparable.
8c	Plant size	The size is in the lower range compared to existing and announced projects.	We have acknowledged this aspect but also mentioned the fact that the low size is due to the need of coupling the system to a biogenic source of CO_2.
8c	OPEX	OPEX is too high. It should be 2-3% excluding feedstock, instead of 7.5%.	Our values for OPEX are based on values from different literature studies. We have included this comment in our qualitative analysis to stress that a lower value can be considered.
8c	CAPEX	Check CAPEX with other projects, which include the contribution of renewable electricity and DAC.	Our CAPEX does not include these contributions, as hydrogen and CO_2 are considered as input feedstocks.
8c	Value Chain description	The product is not classified as biomethanol, but rather as e-methanol.	According to other comments and value chains, we have named it synthetic (bio)methanol.
8c	Value Chain description	The description should specify the production pathway.	This clarification has been added.
8c	Value Chain description	Methanol is not only for maritime but can be used in other value chains (e.g. SAF or gasoline).	This clarification has been added.
8c	Value Chain description	In addition to biogenic CO_2, non-biogenic can be used until 2040.	This clarification has been added. However, the analysis focuses on biogenic CO_2, due to future mandates that require no fossil CO_2 after 2040.

IVC	Questionnaire issue	Main Remarks	Proposed amendments
8c	Value Chain description	The configuration should include the direct synthesis from CO2+H2 without including the water gas shift reactor.	We have modified the layout accordingly.
8c	Co-products	Another coproduct is off-gas.	We have modified the list accordingly.
8c	Construction time	Construction time from FID to commercial operations date is 3-4 years and ramp up is 1-2 years.	We have modified the figures accordingly.
8c	Plant size	Due to economy of scale, the average size should be higher (> 200 kt/y of methanol). However, it is true that aligning the availability of biogenic CO2 and electrolytic H2 with such production volumes remains a significant challenge.	The size of the plant is linked with the availability of CO2 streams. We mention the fact that economic viability is critical for lower sizes.
8c	CAPEX	The specific CAPEX (ISBL + OSBL) is 1,686-2,814 €/Kw depending on the capacity.	Our values for CAPEX are based on values from different literature studies. Please note that these values do not include the contribution of hydrogen generation, since green hydrogen is considered as feedstock in our model (with different values of price).
9b	Plant size	500 m3/h is too low for economic feasibility; the minimum size is 2000 m3/h.	We have added this clarification. Our reference size is based on the size of existing biomethane plants to maximize the applicability of the system. We mention the fact that economic viability is critical for lower sizes.
9b	OPEX	OPEX is too high. It should be 2-3%.	Our values for OPEX are based on values from different literature studies. We have included this comment in our qualitative analysis to stress that a lower value can be considered.
9b	Value chain description	E-methane however does not qualify as an advanced biofuel as it does not directly use biomass as an input.	We agree that this fuel is in fact an RFNBO. We have included this IVC in the analysis since the goals was to exploit available biogenic CO2 streams to maximize the synergies with other biofuel supply chains.
9b	Value chain description	The word synthetic refers to many different H2 colours. Labelling the product as synthetic biomethane might therefore result in wrong conclusions.	We have clearly specified that our analysis is focused on green hydrogen only.
9b	Value chain description	It could be worthwhile to clarify that this does not refer to biogas as an input but only to the CO2 that is emitted as part of biogas production.	This clarification has been added.

IVC	Questionnaire issue	Main Remarks	Proposed amendments
9b	Feedstocks	Other biogenic CO2 sources can be used and are present in Europe.	This is specified in the "feedstock types" section.
9b	Required time	Higher time when encompassing carbon capture and electrolyzers.	Not applicable in this case.
9b	Plant size	Specify assumptions for CO2 and H2 availability.	We have verified that all the main assumptions are reported. Additional details are available in the literature sources (e.g. https://doi.org/10.1016/j.renene.2015.07.066).
9b	OPEX	OPEX is too high. It should be 2-3%.	Our values for OPEX are based on values from different literature studies. We have included this comment in our qualitative analysis to stress that a lower value can be considered.
11a	Process description	Gasification and transport agents.	Process flowchart revised.
11a	Construction time	Should be at least 36-48 months.	Added clarification in the process description part of Business Model (currently considering 24 months); construction time does not include the first stages of engineering and permitting.
11a	CAPEX	Should be 50% - 100% higher.	Added clarification in qualitative part of Business Model. It is partially considered by the sensitivity analysis.
11a	OPEX/CAPEX ratio	Should be 50% - 100% higher.	Added clarification in qualitative part of Business Model. It is partially considered by the sensitivity analysis; another stakeholder validated the OPEX/CAPEX ratio proposed in the BM.
11a	Output slates	Modification of output slates, benefits of H2 injection.	Added clarification in qualitative part of Business Model.
11a	Output slates	Request to highlight output flexibility.	Added clarification in qualitative part of Business Model.
11a	Plant size, feedstock logistics	High requests for feedstock suggest scaling down the plant size.	Added clarification in qualitative part of Business Model.
13a	Output products	Change the type of output products listed.	Modified the process table accordingly.
13a	Plant size	Possible range of commercial plant sizes.	Added clarification in the qualitative description throught the text.
13b	Feedstock mix	Mix of feedstock not expected for a single plant, but output from different pyrolysis plants can be mixed.	Fits with the proposed distributed case; added clarification in qualitative part of Business Model.
13b	Output slates	May differ per case; proposed a base case.	Added clarification in qualitative part of Business Model.

Table 3-4 List of remarks from the industrial stakeholders consultation and proposed amendments, ordered by IVC type

4. Proposal for a collective financing and realization plan

The following analysis in this Section builds upon the results of Task 1 and Task 2 aiming at analysing the generated information towards the synthesis of a collective financing and realization plan for aggregated advanced biofuels value chains. Task 3 concentrates on diagnosis of present situation in financing and supporting of biofuels projects and the identification of a collective financing and realization plan, tailored to serve the needs of developing the advanced biofuels capacities. The objective of Task 3 is to provide a proposal for new collective plans for financing of aggregated industrial value chains in the EU, contributing thus to built-up the industrial capacity needed so as to meet the climate targets for 2040 and 2050.

4.1. Review of available funding programs and schemes

In this task we exploit the current opportunities of support and financing for projects of the advanced biofuels industry. Three main streams are distinguished:

- Support for **R&I projects** in the technological areas of advanced biofuels;
- Supporting initiatives for commercial projects deriving from **European Union** policies on energy transition and climate change measures;
- **EU Member States (MS)** supporting initiatives for commercial projects either in the context of EU policies and programs or independent national state measures aiming at economic development and support of industries related to energy transition.

The emphasis of this project is placed on the two streams of the commercial projects; in the following chapter however only a brief overview of the R&I programmes will be provided for completeness, and as an indication for which technologies are expected to have been developed towards the 2040 (mainly) frame.

Figure 4-1 presents a scheme with the most significant cases of financial and regulatory support coming from both (i.e. Supporting initiatives for commercial projects at EU and/or national level) of the above-mentioned sources. The red-line links indicate the flow of funds, either loans or grants, whereas the blue-line links indicate guarantees, communication, decisions and regulatory mandates influencing the supporting activities addressed to the advanced biofuels industry. Some of the EC initiatives and frameworks are directed to lower-income EU MS (e.g. Modernization Fund) or the less developed MS (e.g. European Regional Development Fund) not to all the MS. The dotted lines are used for the forthcoming Clean Industrial Deal which is expected to support the whole industry related to energy transition including the biofuels production sector.

The main financial branch of the EC initiatives are the two development banks, namely the **European Investment Bank (EIB)** and the **European Bank for Reconstruction and Development (EBRD).** They cooperate with private banks to offer attractive financing options and impose sustainability and climate change criteria. On the other hand, the main regulatory policy expressed with GHG emission reduction targets and other measures is expressed mainly by the Renewable Energy Directive (RED II/III) that is transposed to national legislations of the MS. The imposition of obligations and mandates creates the necessary demand for advanced biofuels.

The contribution of state funds to EU supporting programs occurs in some of the financing cases as indicated in Figure 4-1. Current supporting initiatives like REPowerEU, Just Transition Fund and Recovery and Resilience Facility (RRF) that terminate in 2026 and 2027 are not presented in the supporting and financing scheme, since the time horizon of our assessment is broader focusing to 2030 and reaching up to 2050 for industrial investments on advanced biofuels. Nevertheless, it is evident that the supporting framework for advanced biofuels is very complicated since alternative and complementary or overlapping opportunities have to be considered.

The **Multiannual Financial Framework (MFF)** is a source of funds for the European Regional Development Fund, the European Cohesion Fund (supports investments in the area of **environment** and trans-European networks in the area of **transport infrastructure**, TEN-T) and the European Social Fund (employment, social, education and skills policies, including structural reforms in these areas) among others. The procedure followed anticipates financing of programmes in shared responsibility between the European Commission and national and regional authorities in Member States. The Member States' administrations choose which projects to finance and take responsibility for day-to-day management.

Very recently on 16 July 2025, the European Commission presented its proposal for an ambitious and dynamic Multiannual Financial Framework amounting to almost EUR 2 trillion (or 1.26% of the EU's gross national income on average between 2028 and 2034). This framework will equip Europe with a long-term investment budget matching its ambitions over the coming decade.

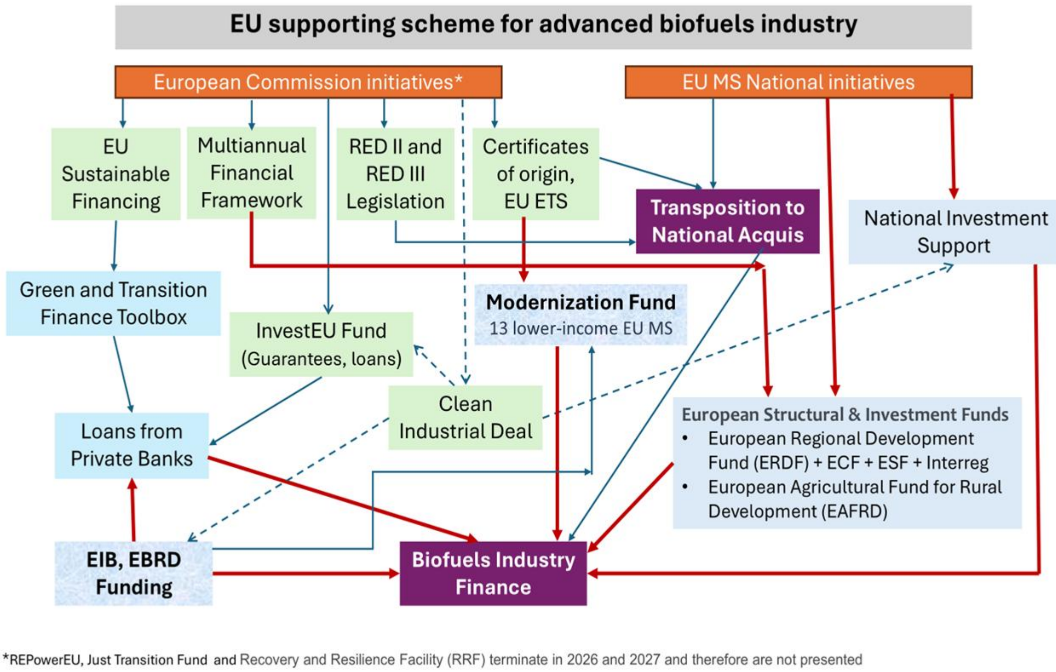


Figure 4-1 Present EU supporting and financing scheme for the advanced biofuels industry

4.2. Review of available Research and Innovation funding programs and schemes

4.2.1. Frame of the review

Since the time horizon of the analysis spans from 2030 to 2040 and 2050, outcomes of R&I programmes in the field is expected to directly contribute to the commercialization of technologies relevant to essential industrial value chains, as they have been selected in Task

1, for the longer run (i.e. 2040 and 2050). Considering the above, the aim of the present section is to provide a **high-level overview of the available funding within R&I programmes** that is potentially relevant to the development of advanced biofuel industry technologies. It is noted that the review considers R&I programmes both at the EU as well as national levels.

In Figure 4-2 the coverage of the TRL scale by the present EU supporting programs is indicated. In addition, the CRL is also indicated, and some of the characteristic EU supporting programs are illustrated. Evidently, even if a technology reaches TRL equal to 9, market up-take and widespread commercial deployment is not certain unless the appropriate progress is made in the CRL scale.

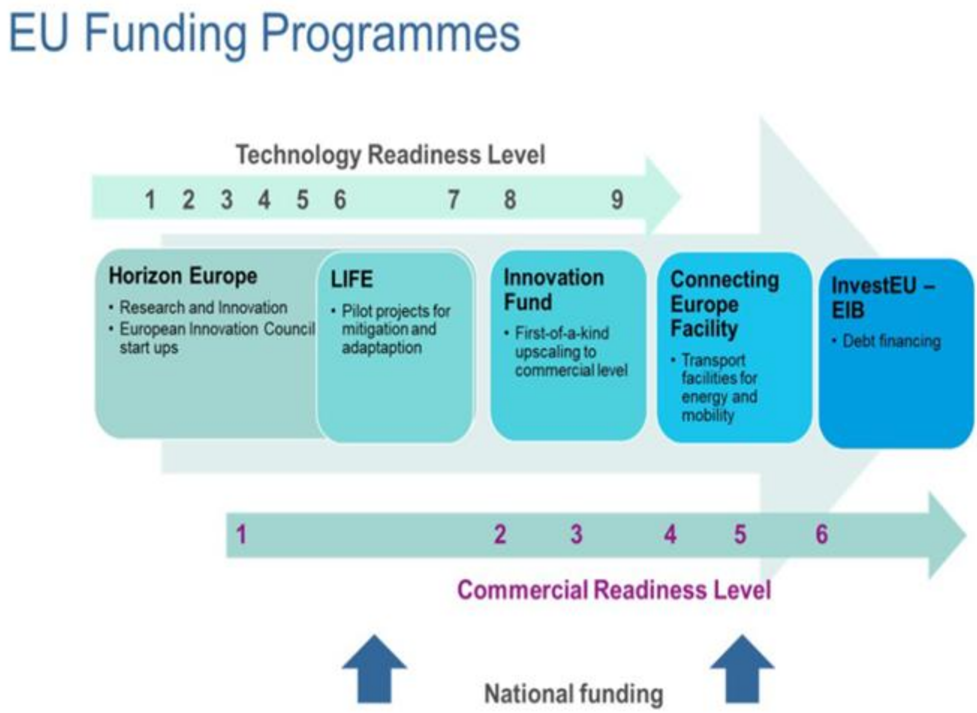


Figure 4-2 Coverage of the TRL and CRL scales by EU funding programmes[12]

4.2.2. Horizon Europe

Horizon Europe is the European Union's flagship research and innovation programme for 2021–2027, with a budget of over €95 billion. It aims to tackle climate change, boost the EU's global competitiveness, and support the green and digital transitions. The programme funds collaborative research across thematic areas such as health, climate, energy, mobility, digital technologies, and more, encouraging partnerships between academia, industry, and public institutions across EU member states and associated countries.

The main programme is divided into three main parts: (a) Pillar 1 supports excellence in science, (b) Pillar 2 focuses on solving global challenges through collaborative research & innovation, (c) Pillar 3 supports business growth and competitiveness. Figure 4-3 provides an overview of the Horizon Europe Programme, also indicating the allocated amounts to each pillar.

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[12] https://www.ieabioenergy.com/wp-content/uploads/2024/12/Keynote4_Georgiadou-EC.pdf

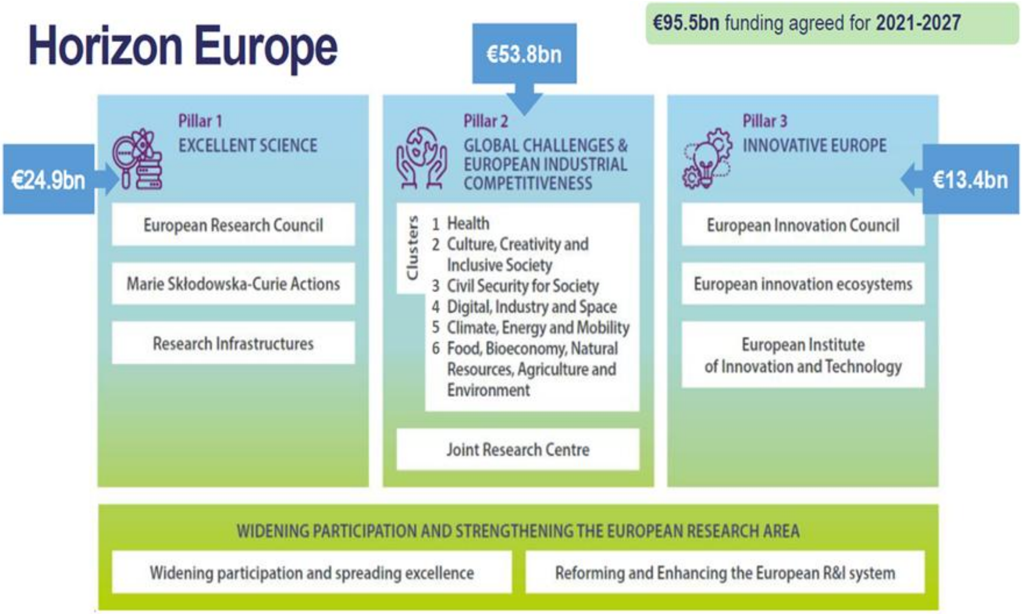

Figure 4-3 Overview of the Horizon Europe R&I programme

For the purposes of the present study, the presentation in this section focusses on (a) the overall possibilities for funding provided by Pillar 2, and (b) the support from the European Innovation Council (EIC), and in particular the EIC Accelerator programme, as this support programme is closer to the needs of industrial capacity development.

Within Pillar 2, **Cluster 5 is devoted to Climate, Energy and Mobility**, and is the one that is most related to the field of advanced biofuels. Cluster 5 enjoys €15,1 bn for the 2021 – 2027 period, including funds allocation to specific areas of focus such as Clean Energy Transition Partnership (CETP), Waterborne, Clean aviation (~€ 9 bn), and EU Missions Climate, Oceans, Cities, Soil (~€ 1,5 bn).

Cluster 5 is structured around six primary areas of intervention, often referred to as "Destinations". These Destinations aim to tackle critical issues related to climate change, energy security, and mobility solutions. Destination 3 “Sustainable, secure and competitive energy supply” appears to offer several **projects and topics related to advanced biofuels for transport**, particularly aimed at decarbonizing hard-to-electrify sectors like aviation and maritime.

A number of calls aim to address **development challenges at various stages of the TRL scale**. Depending also on the nature of the call, i.e. **Research and Innovation Action (RIA), Innovation Action (IA) or Coordinated Support Action (CSA)**, projects responding to the calls can (a) vary from establishing complete value chains from sustainable feedstocks to end use, to fostering international collaboration and disruptive innovation (e.g. through the use of algae, CO_2, and waste materials), and (b) seek to reduce CAPEX/OPEX (and improve economic viability in general), improve market uptake, perform life-cycle assessments and advance the EU’s climate and energy targets through support to individual and specific families of technologies (incl. integrated biorefinery concepts) and even though (partially) retrofitting existing industrial plants.

Among all sectors, **aviation** emerges as the one with the most visible technological results, with several technologies approaching or exceeding TRL 5–7 and progressing toward ASTM certification, especially for biomass-derived Sustainable Aviation Fuels (SAF). The **maritime**

(shipping) sector is also advancing with strong developments in pyrolysis-derived fuels and bio-methanol, with some projects already operating at TRL 7 and targeting ISO fuel standards. Several technologies are designed as cross-sectoral solutions, especially those producing bio-based intermediates compatible with conventional refinery infrastructure, allowing dual applications in both aviation and maritime fuels.

Within Pillar 3, the European Innovation Council (EIC) aims to identify, develop, and scale up breakthrough technologies and innovations in Europe. Its objective is to support high-risk, high-impact innovation, bridging the gap between research and commercialization. EIC features three programmes as presented below:

- **EIC Pathfinder**, which focuses on funding early-stage research on disruptive technologies (TRL 1-4, grants up to €3–4M)
- **EIC Transition,** providing support to allow moving research results toward innovation and commercialization (TRL 4–6, grants up to €2.5M)
- **EIC Accelerator,** targeting SMEs/start-ups developing and scaling market-ready innovations (TRL 5–9, grants up to €2.5M plus equity up to €10M).

The EIC Accelerator provides a unique combination of grant and investment funding and Business Acceleration Services. The provided support targets at the later stages of technology development as well as scale up.

Applicants to EIC Accelerator can submit proposals either on an open basis (i.e. open proposals with no predefined thematic priorities) or on the areas of emerging and strategic technologies of the EIC Accelerator Challenges. The Challenges are announced each year under the EIC Work programme. Considering the announced lists of EIC Accelerator Challenges from 2022 until today it appears that **advanced biofuels** have *potentially* been covered under several **EIC Accelerator Challenge calls**, especially where they intersect with **future mobility** and **circular bioeconomy / biotech**.

4.2.3. LIFE

The LIFE Programme[13] is the EU's funding instrument for the environment and climate action. In the latest LIFE programme (2021-2027) the Commission allocates €5.45 billion; approximately €3.5 billion will go to environmental projects and the remaining €1.9 billion will be allocated to those on climate action. LIFE considers the following new sub-programmes: nature and biodiversity, circular economy and quality of life, climate change mitigation and adaptation, and clean energy transition. LIFE calls for proposals are run on an annual basis and following the announcement of the specific priorities (and therefore specific evaluation criteria) under each sub-programme.

Funding is dispensed via competitive calls for proposals and typically offers co-financing (60%–95%) that ranges from **€0.5 to €3 million per project**. While it does not support capital expenditures (CAPEX), the programme focuses on "**soft measures**" like policy support, training, financing models, and stakeholder coordination—potentially benefiting advanced biofuels supply chains, especially in upstream feedstock development.

For **biofuel projects**, LIFE provides opportunities under its **Clean Energy Transition** and **Climate Change Mitigation** sub-programmes. These can fund:

- **Demonstration and deployment** of advanced biofuels technologies,
- **Integration of biofuels** into transport systems,

[13] https://cinea.ec.europa.eu/programmes/life_en

- Market uptake and capacity-building efforts,
- Support for renewable energy policy implementation.

4.2.4. Innovation Fund

The **EU Innovation Fund (IF)**[14] is one of the world's largest funding programs for the demonstration of innovative low-carbon technologies. Established under the framework of the **EU Emissions Trading System (ETS)**[15], the fund is a key instrument to deliver on the European Union's commitment to reach **climate neutrality by 2050**. Running from **2020 to 2030** (aligned with the EU's 2030 climate goals and the ETS phase 4), it supports the commercial demonstration of breakthrough technologies across several strategic sectors, aiming to accelerate the green transition of Europe's industrial base.

The IF focuses on highly innovative technologies and big flagship projects in EU Member States, Norway and Iceland that can bring on significant emission reductions. It is about sharing the risk with project promoters to help with the **demonstration of first-of-a-kind highly innovative projects**.

The Innovation Fund's financial backbone comes from the revenues generated by the auctioning of allowances under the EU ETS. Its total value is estimated at around **€40 billion**, although the actual amount varies in accordance with carbon prices; essentially IF funds increase with rising ETS revenues.

The fund launches **periodic calls for large- (those with CAPEX above EUR 7,5 million) and small-scale (those with CAPEX below EUR 7,5 million) projects**; these calls are structured to ensure sustained support over the project's lifecycle, including project development, construction, and operational phases.

The Fund offers support[16], in the form of grants, up to **60%** (in case of regular grants) and up to **100%** (in case of competitive bidding) of the relevant costs calculated according to the methodology indicated in each call for proposals (usually covering capital and operational costs minus revenues over the first ten years of operation). The grants are being disbursed in a flexible way based on project financing needs, considering the milestones achieved during the project lifetime. For regular grants, up to **40% of the grant** can be given based on pre-defined milestones before the whole project is fully up and running. For competitive bidding, on the other hand, the payments are scheduled only during the operational (reporting) period of the projects.

The Innovation Fund targets a broad array of sectors that are crucial to Europe's climate transition. By focusing on sectors with high emissions and technological transformation potential, the fund aims to create demonstrable models of decarbonization that can be scaled across the EU and beyond. These include:

- **Energy-intensive industries** (e.g., cement, steel, chemicals)
- Renewable energy generation
- Carbon capture, utilization, and storage (CCUS)
- Energy storage
- **Advanced transport fuels**, particularly sustainable aviation and marine fuels

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[14] https://cinea.ec.europa.eu/programmes/innovation-fund_en
[15] Established by Article 10a(8) of Directive 2003/87/EC of the European Parliament and of the Council
[16] https://climate.ec.europa.eu/eu-action/eu-funding-climate-action/innovation-fund/what-innovation-fund_enIVCapplication-process

To be eligible, projects must demonstrate high climate impact, meaning substantial greenhouse gas emissions reductions compared to conventional technologies. They must also be highly innovative, financially and technically mature, and possess strong potential for market replication.

This positioning makes the Innovation Fund uniquely supportive of technologies that are close to market but still need significant capital and de-risking to become commercially viable.

Following the IF project portfolio dashboard[17], 208 projects in total have received funding, but only a few are related to advanced biofuels for transport. Further, for high-quality projects that applied for funds to the IF but where not eventually funded, the IF includes a dedicated **Project Development Assistance (PDA)[18]** to help to accelerate the structuring and financing of such projects. The PDA is a non-repayable support mechanism designed to help promising but not yet fully mature low-carbon projects advance toward investment readiness.

4.2.5. Available R&I funding at national level

Besides funding at EU level, Member States may also provide additional funds through national R&I programmes. Each country has different targets for the penetration for renewable energy sources into the various send-use sectors, including transport. Primary sources for the analysis made in this section are the **National Energy and Climate Plans (NECPs)** of the 27 EU Member States, and the **available country reports by the IEA[19].**

Overall, EU countries place significant importance on research, innovation, and competitiveness in the energy sector. Several countries emphasize the need to increase public expenditure on energy research and allocate dedicated funding for energy-related R&D projects.

Specific research priorities frequently mentioned in relation to biofuels and bioenergy include the development and production of advanced biofuels and biomethane from various sources like agricultural waste, manure, and residues. Research into renewable fuels of non-biological origin (RFNBOs) and synthetic fuels, often linked to hydrogen production (Power-to-X technologies) and carbon capture/utilisation, is also a major focus for decarbonising hard-to-abate sectors like industry, aviation, and maritime transport.

Countries actively support research through various mechanisms, including national funding programmes, pilot and demonstration projects, and participation in European and international initiatives like Horizon Europe and the SET Plan. Collaboration between research institutions, universities, and industry is emphasized to translate research into real-world applications and commercialisation. Regional and cross-border cooperation in energy research is also considered important for tackling common challenges and leveraging resources.

Besides the above generic frame, there are no dedicated R&I programmes focusing explicitly on advanced biofuels. Each country, depending also on its position in terms of available feedstock sources, technological advancement, and market maturity, can appear to support to a greater or a lesser extent specific value chains.

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[17] https://cinea.ec.europa.eu/programmes/innovation-fund/innovation-fund-project-portfolio_en
[18] https://www.eib.org/en/products/mandates-partnerships/innovation-fund/index
[19] There are 21 out of the 27 EU Member States IEA reports. Moreover, not all reports have been conducted on the same year: Austria (2022), Belgium (2022), Czech Republic (2021), Denmark (2023), Estonia (2023), Finland (2023), France (2021), Germany (2025), Greece (2023), Hungary (2022), Ireland (2024), Italy (2023), Latvia (2024), Lithuania (2021), Luxembourg (2020), Netherlands (2024), Poland (2022), Portugal (2021), Slovakia (2024), Spain (2021), Sweden (2024).

4.2.6. Critical Observations

There is a wide palette of EU funded programmes that provide opportunities for R&I funding in fields pertinent to advanced biofuels spanning from basic research (TRL 1) to a fully developed product (TRL 9). The EU R&I funding programme has been built to directly respond to the challenges of the EU Green Deal and covers the full range of technologies and solutions needed to achieve carbon neutrality. This leads to a situation where the availability of specific calls for proposals targeting exclusively R&I areas of advanced biofuels are limited. Therefore, advanced biofuel R&I projects often have to compete with other RES technologies for funding.

Moreover, changes in the overall policy priorities due to the occurrence of external conditions, such as COVID-19 and the Ukraine-Russia war, often lead to the need to update R&I priorities as well – typically through the emergence of additional research funding opportunities in programmes not inherently bound to the typical EU R&I funding framework (e.g., and for shake of illustration, available funds in the RRF, or within the frame of NZIA, and not a new/additional part within the umbrella of the Horizon Europe). This fragmentation can often provide difficulties to the R&I community to identify the most appropriate opportunities that would allow the direction of fund in a concentrated path leading eventually to technology scale-up.

Nonetheless, the review of the identified relevant European research and innovation projects in the Horizon Europe programme reveals that the R&I community indeed develops innovative production methods, addressing key technical and economic barriers and demonstrating potential for costs reduction. In particular, focusing on the essential value chains that have been primarily selected by Tasks 1 and 2 of the present project for the 2030 – 2040 period, it is noted that significant results of R&I project are expected in the fields of feedstock base enhancement for thermochemical conversion routes, co-processing of bio-based feedstocks in a refinery context (that would potentially lead easier to a final product closer to the market), combination of bio-based and electricity-based routes, etc., while aviation and maritime appear to be the primary sectors of focus (being also the most pressing to decarbonize). At the same time, the work done with the support of the Innovation Fund also leads to tangible examples of facilities that can be viable even on the basis of market terms in the near future, setting thus a paradigm for further endeavours.

Where R&I funding at a national level is concerned, there is not a uniform approach by the Member States. In fact, national R&I programmes are typically open to all RES technologies and there are not specific calls for advanced biofuels. Also, countries with strong industrial focus on the deployment of particular technologies or feedstock type, often tend to prioritize these areas in their R&I programmes.

Considering the above, it can be argued that the currently available R&I funding opportunities that can cover development needs in the field of advanced biofuels, both at an EU and national level, is deemed as appropriate to support the deployment of the needed future Essential Industrial Value Chains, eventually providing the required preconditions to allow their timely commercialization and scale-up.

4.3. Supporting initiatives for commercial projects deriving from European Union policies

4.3.1. Frame of the analysis

This section provides a critical review of current EU-level support programs that can support the commercial deployment of advanced biofuel supply chains, and the relevance of current schemes that have supported the development of biofuel installations in the past. The focus is on the gap experienced for projects' commercial deployment, not research. The analysis is based on publicly available sources and prior EU and academic reports. The review has considered relevant EU financial support measures (i.e., CEF-Energy, CEF-Transport, the InvestEU program, the Modernization Fund, the Cohesion Fund/ERDF, the Just Transition Fund) as well as CAP programs that can support the feedstock supply side for advanced biofuels. There is particular mention of Feed-in-Tariffs, Feed-in-Premiums and Guarantee of Origin schemes, which have successfully supported renewable energy projects in the past at the national level using EU-level support. This is because they seem equally relevant to the development of advanced biofuels supply chains, both on the product pricing as well as the feedstock pricing level.

Over the past years the launch of significant national projects for the production of biofuels across Europe has been supported significantly by EU funds. These projects have been implemented within national borders and have successfully utilized EU funds as well as state support. NextGenerationEU funds has partially supported Plan France 2030 projects, and in Finland it has aided ca. 600 MEUR for the development of advanced biofuels projects through direct grants provided by the Ministry of Economic Affairs. In Austria, NextGenerationEU funds have been committed for commercial deployment of advanced biofuels processing, while in Italy NextGenerationEU contributes to a State Aid Scheme for Advanced Biofuels and Biomethane. Additional examples include Poland, Romania and Lithuania. InvestEU funds (via loans) have been used to develop biomethane projects in France (Pret Methanation Agricole).

4.3.2. Challenges in the deployment of Advanced Biofuels

EU-level funding opportunities will play a crucial role in the deployment of advanced biofuel supply chains. These initiatives are essential in bridging the gap from pilot-scale technology demonstrations to full commercial operations, particularly by addressing market risks and financing barriers. However, from the perspectives of advanced biofuel producers (project sponsors) and feedstock suppliers, significant gaps and challenges remain. The deployment of advanced biofuels projects is hindered by challenges linked to financial eligibility, fragmented regulation, technological maturity, market access, commercial demand and commoditization (Table 4-1). The findings below are also informed by the preliminary findings of the Task 2 analysis (business model development) and will be further enhanced once the stakeholder survey exercise under Task 1 is completed.

EU level financial support and specific instruments can help overcome these challenges, particularly the ones related to finance, bankability and commercialization. It is useful to distinguish between project developers (i.e., the processing / refining facility) and the feedstock supply chain and infrastructure (which may or may not be part of the project structure). From the developer's perspective, who faces high capital expenditures, streamlined access and clearer pathways to combine various sources of EU support (grants, loans, and credit enhancement) could potentially accelerate project deployment. Demand needs to be secured at a competitive price - and this can be supported by a combination of compliance / regulatory requirements as well as price support mechanisms. Equally important is the security of feedstock supply at a viable price. Feedstock suppliers (if not integrated in the project structure) would benefit from simpler and more uniform support measures that are the foundation of long-term supply chains. Price stability measures for feedstocks can potentially provide the necessary security that will encourage investment both on the feedstock and related infrastructure, as well as the processing / refining capacity.

Table 4-2 provides a mapping of challenges that hold back deployment as reported previously and the fundamental financial instruments that can be used to overcome these challenges. The Table represents a first hypothesis, and will be confirmed with structured interviews with developers, the investment community and financial institutions as part of the forthcoming campaign within Task 3 of the project.

This mapping shows that financial instruments such as grants, loans and interest-rate subsidies, credit support and institutional equity capital are useful for kick-starting CAPEX-intensive investments on the refining / processing side, by providing access to investment capital and de-risking financing decisions for private investors. On the other hand, price support mechanisms for both feedstocks and products, such as **Feed-in Tariffs** (**FiT**), **Feed-in Premia** (**FiP**), **Contracts for Difference** (**CfD**) and tax incentives are aimed at improving the economic and risk profile at the operational stage, as well as ensuring a sustainable and predictable supply of feedstock. Because the challenges faced by advanced biofuels projects span both capital as well as operational risk, it is postulated that both of these types of support are going to be essential.

Category	Challenge
Financial	**High Production Costs**, due to immaturity of production technologies, limited economies of scale, and high feedstock costs.
	Lack of Bankability and difficulty meeting criteria for non-recourse project financing (strong offtake commitments, long-term supply agreements, and robust business cases)
	Risk of First-Mover Disadvantage because of high early-stage production costs compared to future expectations as the market matures
	Lack of Higher-Risk Capital and delayed Final Investment Decisions committed to early-stage projects, which are CAPEX-heavy with uncertain returns
Technical	**Technology Risks** for some supply chains and technologies, pertaining both to construction as well as operations
	Feedstock Limitations: The availability of advanced bio-feedstocks (like cellulose and algae) is constrained, and their production at a commercial scale remains unproven
	Complexity of Integrated Projects that create interface and integration risks
Commercial	**Difficulties establishing Long-Term Offtake Agreements** in markets where buyers operate on short-term offtake and price contracts
	Supply Chain Gaps in underdeveloped supply chains for sustainable fuels, including infrastructure and transport
	Lack of commoditization in feedstocks and products makes it difficult to establish consistent pricing and contracts
	Competing decarbonisation strategies, including electrification of road transport, adds uncertainty about a clear market ahead
Regulatory	**Uncertainty in Regulation** and clarity on how the regulatory landscape will evolve, particularly concerning blending mandates and emissions trading adjustments.
	Complex and inconsistent national regulations hinder the development of cross-border projects
Skills	**Skill gaps exist across the supply chain**, particularly with financial lenders and project sponsors

Table 4-1 Most important challenges in the deployment of advanced biofuels supply chains[20]

[20] Financing sustainable liquid fuel projects in Europe: Identifying barriers and overcoming them, European Investment Bank, 2024.

EU Programs	Grants	Loans & subsidies	Credit support	Equity capital	FiT, FiP, CFD	Price Support	Tax incentives
Connecting Europe (CEF)	☑						
InvestEU		☑	☑	▨	▨		
Modernization Fund	☑	☑	☑	▨	▨		
Just Transition Fund	☑	☑	☑				
LIFE – Clean Energy	▨						
Cohesion Fund / ERDF	☑	☑	☑	☑	▨		
CAP - Basic Direct Pay	☑						
CAP - Eco-schemes	☑						
CAP - VCS	☑						
EAFRD - rural development	☑					▨	
EAFRD - financial instruments		☑	☑			▨	
FiT / FiP (national schemes)					▨		
Guarantees of Origin						▨	▨

☑: Common / core financial instrument

▨: Indirectly available or offered in blending facilities

Table 4-2 Mapping of EU programs to types of financial support

4.3.3. Project Developer Perspective

For project sponsors developing advanced biofuel processing / refining facilities, EU programs such as the **InvestEU**, the **Modernisation Fund**, the **Connecting Europe Facility (CEF)**, and the **European Regional Development Fund (ERDF)** can provide substantial financial support. The InvestEU, through its Sustainable Infrastructure Window, offers critical risk-sharing instruments, including loans, equity, and guarantees via intermediaries such as the European Investment Bank (EIB). This support is particularly beneficial for biofuel projects requiring substantial upfront capital investment and facing significant perceived market risk.

The instruments in Table 4-3 are available to private developers and investors via an array of EU programs whose scope spans energy, transport and agriculture. From a project developer's perspective, these instruments provide access to the type of support that can in theory unlock commercial deployment. EU support mechanisms are also promising for the feedstock supplier. Fully utilizing these instruments is difficult, though.

However, developers often find accessing these instruments complex, requiring substantial administrative capabilities and financial expertise. The indirect delivery through financial intermediaries sometimes obscures visibility, complicating developers' planning processes. Moreover, while the **Modernisation Fund** offers generous support for priority investments in renewables, its availability is limited to specific lower-income EU Member States, constraining the geographic applicability of its resources.

The **CEF-Energy** and the **CEF-Transport** explicitly target cross-border renewable energy infrastructure projects. While beneficial for mature biofuel distribution networks, direct support for the production facilities themselves is often limited. Projects must be designated as **Projects of Common Interest** (**PCIs**) or explicitly address cross-border dimensions, potentially excluding promising local or regional biofuel initiatives.

The **ERDF** and the **Cohesion Fund** offer broader accessibility, especially in less-developed regions. Their decentralized management through national and regional authorities, however, introduces variability and uncertainty. Developers face differing application processes and evaluation criteria across Member States, which may lead to uneven playing fields and challenges in scaling projects across borders.

Key challenges	Grants	Loans & subsidies	Credit support	Equity capital	FiT, FiP, CFD	Price Support	Tax incentives
High production cost					☑	☑	☑
Bankability	☑	☑	☑	☑	☑	☑	
First-mover disadvantage			☑		☑	☑	☑
Lack of high-risk capital	☑	☑	☑	☑			
Feedstock supply					☑	☑	☑
Feedstock price					☑	☑	☑
Short-term off-taker trading					☑	☑	
Product fungibility					☑	☑	

Table 4-3 Financial instruments with the potential to alleviate barriers to deployment

4.3.4. Feedstock Supplier Perspective

From the perspective of feedstock suppliers, particularly agricultural or forestry operators supplying lignocellulosic biomass, the **CAP Pillar I (Eco-schemes, Voluntary Coupled Support)** and the **Pillar II (EAFRD)** provide significant potential support. These instruments incentivize sustainable agricultural practices, cultivation of energy crops, and supply chain integration for biofuel feedstocks.

Eco-schemes and coupled support can effectively encourage sustainable cultivation practices, particularly cover crops or short-rotation coppice, aligning with biofuel supply requirements. However, the variable national implementation of these schemes often leads to inconsistency in support, which complicates the predictability of feedstock supply and hampers long-term contract reliability for project developers.

The **EAFRD Rural Development Grants and Financial Instruments** offer direct investment opportunities for feedstock processing infrastructure and equipment, vital for suppliers transitioning towards supplying biofuel markets. Yet, the requirement for significant co-financing and sometimes lengthy approval processes creates barriers for small to medium-sized agricultural enterprises, potentially limiting participation.

4.3.5. Challenges in the deployment of EU funds for Advanced Biofuels

Despite the existence of robust EU-level support mechanisms, several structural and practical issues hinder their full use for funding advanced biofuels installations and supply chains. First, the funding landscape is highly fragmented and administratively complex. Navigating programs such as the **InvestEU**, the **Modernisation Fund**, and the **ERDF** requires considerable financial and administrative capacity, which many mid-size project developers or feedstock suppliers lack. The involvement of financial intermediaries and the indirect nature of support also create uncertainty and increase transaction costs.[21]

Second, the **Modernisation Fund**, one of the most generous instruments for renewable energy investment, is only available in 13 lower-income EU Member States. This geographic limitation excludes major agricultural economies where significant advanced biofuel investments might otherwise take place. For example, a commercial-scale lignocellulosic project in France cannot access **Modernisation Fund** grants, despite strong alignment with EU climate goals;[22] on the other hand, this financing support source can be used in the weaker EU economies.

Similarly, price support instruments such as **Feed-in Premiums** (**FiPs**) and **Contracts for Difference** (**CfDs**) that primarily operate at national levels but can be augmented by EU funds (e.g., **Modernisation Fund**, **ERDF**), significantly reduce market price risk which is essential for developers securing project finance. Yet they are not consistently available for advanced biofuels across the EU. Most national schemes focus on electricity or gas, leaving liquid biofuels – particularly those derived from lignocellulosic biomass – without long-term off-take security or price guarantees. In addition, EU programs that blend with national support (e.g., **FiP** + **ERDF**) must comply with complex State Aid rules under the CEEAG[23]. For example, no **CfD**-style price guarantee is currently available in most EU countries for cellulosic ethanol or advanced biodiesel, thus limiting bankability.[24] It is worth considering that these instruments, needed for advanced biofuels at state level, would increase bankability.

On the feedstock side, while CAP measures such as Eco-schemes and Voluntary Coupled Support offer targeted incentives, they are often short-term, vary by Member State, and are updated frequently. This undermines planning certainty for farmers or cooperatives considering long-term investment in perennial energy crops or residue aggregation systems. Additionally, the co-financing requirements of Rural Development grants (often 30–70%) are too high for many small suppliers, especially in marginal or remote areas.[25] A forestry cooperative seeking equipment to process lignocellulosic residues may not have liquidity to meet co-financing thresholds.

Guarantees of Origin (**GOs**) for biofuels remain underdeveloped. Guarantees of Origin can add revenue streams, providing indirect support through enhanced marketability of biofuel outputs. However, GOs alone often lack sufficient market price certainty to independently attract large-scale private investments without additional support measures or guarantees. While helpful as an auxiliary revenue stream, GOs also lack market liquidity found in the electricity sector, reducing their effectiveness in making biofuel projects bankable.[26]

[21] European Court of Auditors, 2020; EIB (2021) "Financing sustainable liquid fuel projects in Europe"
[22] Modernisation Fund Regulation (EU) 2018/1999, Annex II
[23] EU Guidelines on State aid for climate, environmental protection and energy 2022 (CEEAG)
[24] Transport & Environment (2022); RED III Impact Assessment
[25] DG AGRI "Financial instruments in EAFRD" (2020)
[26] CE Delft (2022), "Evaluation of Guarantees of Origin Systems"

In addition, on 13 June 2023, the Commission issued non-binding recommendations[27] on how non-financial and financial companies can voluntarily use EU sustainable finance tools to seek or provide transition finance. The **EU's sustainable finance toolbox** not only supports companies with the highest sustainability records, but also companies with different starting points that have clear sustainability targets. It also allows smaller companies to raise finance for their transition in a proportionate way. Early evidence shows that the EU sustainable finance agenda is working on the ground and that sustainable finance tools are starting to facilitate investments into the transition to a climate neutral and sustainable economy. The EU sustainable finance framework will continue to be developed and refined to ensure its effectiveness in achieving its intended goals and in supporting the objectives of the European Green Deal.

4.3.6. Critical Observations

Despite substantial opportunities for EU-level financial support, significant barriers persist, notably administrative complexity, misalignment at the Member State level, and fragmented funding streams.

From the developer's perspective, streamlined access and clearer pathways to combine various EU supports (grants, guarantees, loans, price supports) could potentially accelerate biofuel deployment. Feedstock suppliers, especially smaller-scale operators, would benefit from enhanced clarity, uniformity, and simplification in accessing agricultural support measures, improving predictability and long-term sustainability of feedstock supply chains. An aligned and harmonized system of price stability and support schemes (**FiT**, **FiP**, **CfD**) could reduce operational and financial risk, enhance investor confidence, and expedite the deployment of commercial projects.

Moreover, considering the technical nature of advanced biofuel supply chains that involve low energy content feedstock, it is likely that few Member States will be able to individually provide necessary elements for successful projects, namely proximity to feedstock supply, economies of scale and (less importantly) proximity to a demand pool. We expect that it will be important that support measures are geared toward collective measures that encourage cross-border projects in alignment with EU's climate objectives.

EU-level funding provides valuable mechanisms to advance biofuel projects and feedstock production, but current challenges relating to complexity, geographical constraints, and fragmented administration hinder optimal deployment. Enhanced coordination, simplification of procedures, and improved alignment of mechanisms could significantly improve outcomes, better supporting the EU's ambitious climate and energy targets.

4.4. EU Member States (MS) supporting initiatives for commercial projects

The approach followed in collecting necessary data towards understanding the present situation of supporting measures aimed at the advanced biofuels value chains and the satisfaction of the EU targets for 2030 and the next decades comprised two main steps:

- Collection of relevant data in the recent **National Energy and Climate Plans** (**NECPs**), most of which were submitted to the European Commission by the end of 2024 or beginning of 2025 and the most recent IEA country profiles of the EU MS which are also members of the

[27] "A sustainable finance framework that works on the ground", COM (2023) 317, EC COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS, Strasbourg, 13.6.2023

IEA. This research revealed the most significant initiatives of MS in supporting the advanced biofuels value chains, either based absolutely on national programs or coordinating with the EU supporting, particularly with the EU renown financing schemes (presented in Chapter 5.4).

- Specific research on the most interesting cases of supporting measures and EU MS to investigate in more detail the relevant policies, objectives and implementation schemes. Most of the state initiatives were directed to fully commercial technologies at present, like anaerobic fermentation (biogas, biomethane), UCO (biodiesel), HVO (biokerosene, biodiesel). It is worth noting that the MS supporting policies do not consider specific measures addressed to forthcoming essential value chains in general. On the contrary, specific measures directed to particular transport sectors, e.g. aviation and maritime, have been identified.

4.4.1. Country data collection, treatment and analysis

Taking as a reference starting point advanced biofuels-related provisions included in **EU MS National Energy and Climate Plans** (**NECPs**) and combining this information with relevant analyses featuring in the most recent IEA country profiles, the data collection and treatment processes involved the following steps:

- Updating and/or completing the preliminary information pool (**NECP**, **AIE** profiles) with the latest publicly available intelligence regarding national support initiatives for accelerating biofuel industrialization among the 27 MS. This is expected to confirm, amend or enrich the list of countries which appear to be taking initiatives in favour of advanced biofuel industrialization.
- Structuring the collected data on a per country basis, identifying the type of biofuel concerned by the support scheme and the stage of the respective value chain the scheme refers to. This step is expected to allow observation of the main trends and areas of focus of the available national supporting schemes.
- For each national support scheme, retrieving the amount of the total allocated state budget and the respective validity period (if available)
- For each scheme, pinpointing the support mechanism type (e.g. investment subsidy, contracts for difference, etc.) and some essential application principles, in order to possibly draw some conclusions regarding the way and the extent to which those schemes address the underlying risks and projects
- For each mechanism, mapping the responsible entities and respective implementing bodies, to obtain an overview of the characteristics of the players actively involved in supporting the biofuel sector in the identified countries
- Reporting the outcomes of the aforementioned analysis steps and establishing links with broader transversal (umbrella) initiatives at EU level (policies, support frameworks, funding facilities, etc.).

Following the work described hereinabove, it stands out that among the 27 members states, there are roughly 1/3 of them that have effectively integrated in their respective energy and transport national strategies tangible and concrete measures in support of the advanced biofuels sector. The countries appearing to offer support mechanisms, at national level, capable of addressing the challenges and risks across the various stages of their respective biofuel industrial value chains are the following: Austria, Denmark, Finland, France, Germany, Italy, Lithuania, Poland, Romania, Sweden and the Netherlands. This list is far from being exhaustive and complete. It only reflects the countries for which our analysis, as of today, has indicated the existence of concrete support schemes whose scope and scale of action come across as commensurate with the corresponding challenges at stake.

Regarding the types of the biofuel and the stage of the respective value chain concerned, based on the provisions and descriptions of the identified support schemes, it appears that the latter may explicitly, both exclusively or inclusively, refer to maritime biofuels, aviation biofuels, biomethane, e-fuels or more broadly on advanced biofuels. When it comes to the stage of the value chain, there again our review revealed that most national schemes focus on addressing mainly the:

- High capital intensity for building the respective plants and installations thus referring to the "processing/conversion" stage across the respective value chains, with typical support mechanisms including investment subsidy grants via **Calls for Projects** (**CfPs**), investment allowances linked to corporate tax benefits, long-term financing solutions, etc.
- Uncertainty of revenue streams and sufficient off-takes over the lifetime of the project as well as over the latter's bankability due to price biofuel price fluctuations, with support mechanisms ranging from feed-in tariffs, contracts for difference and excise duty reliefs/rebates. Hence, this category of measures addresses the "market/commercialization" as well as the "distribution/supply" stages across the respective value chains.

As far as the total amount of each state aid is concerned, the identified schemes present a large disparity with annual budgets spanning from less than 50 MEUR to several hundreds of million euros. In this regard, MS that have been able to secure EU funding for part or the entire envelope of the allocated state budget, have been able to come up with multi-year supporting initiatives including direct grants to large scale industrial players (e.g. Austria, Finland, France, Italy, Romania, etc.) or pass them through to intra-regional level (NUTS 2) support mechanisms especially in the case of federal states or countries engaged in more decentralized energy and transport management patterns (e.g. Germany, the Netherlands, etc.).

Further, our review points out that **EU countries that have been historically at the forefront** of the advanced biofuel industry have been able to bring some innovation and sophistication in their national support mechanisms, especially the ones associated with rather moderate budget allocations (e.g. Finland, the Netherlands, France, etc.). Those countries have also been able to swiftly adjust and amend adequately the support initiatives against the feedback received from the relevant investor communities operating in the respective territories. Therefore, according to the country, the implementation mechanism of each support scheme reveals diverse refinement levels with grants offered based simply on eligible costs to feed-in tariffs, *premia* and price hedging instruments whose applicability criteria witness a larger structural depth with conditions such as decreasing subsidy intensity over time to prioritize cost-effective projects.

Last, as expected the responsible entities of the different schemes are governmental public authorities (ministries), responsible for the environment, and/or energy and/or finance. In most of those countries the implementing competence passes to the energy regulator or state-dependent funds or agencies responsible for deploying the country's environmental and energy transition policy (e.g. Lithuania, Poland, France, Finland, Sweden, Austria, etc.).

4.4.2. Observations from a regional perspective

From a geographic point of view, our review can be focused in 4 regions: the **Western Europe**, the **Northern Europe**, the **Central-Southern Europe** and the **Eastern Europe**.

In **Western Europe,** France, Germany and the Netherlands seem to take the lead when it comes to tackling transport decarbonization imperatives through the development acceleration of the biofuel industry. The biofuel industries in these countries benefit from relatively mature innovation ecosystems, which include public research institutions, private sector investment, and government-backed initiatives. These ecosystems support the development of next-generation biofuels, and the integration of biofuels into hard-to-electrify transport modes, such as aviation, maritime, and heavy-duty freight. Biofuel development is seen not only as a climate imperative but also as a strategic opportunity to enhance energy security by reducing dependency on imported fossil fuels, strengthening the agricultural sector by utilizing domestic feedstocks and stimulating green industrial development and job creation. France and Germany have framed biofuel expansion as part of a broader push for economic resilience and technological sovereignty in the context of global energy transition. Each of these MS has implemented advanced and adaptive policy instruments to support biofuel deployment:

- Germany operates a GHG quota system that incentivizes fuel suppliers to reduce lifecycle emissions rather than focusing solely on blending volume.
- France has introduced mandates promoting the use of advanced biofuels and imposes financial penalties for non-compliance with blending obligations.
- The Netherlands maintains a highly transparent and efficient renewable energy tracking and compliance system, facilitating reliable deployment of sustainable biofuels.

In this region, the biofuel types that seem to receive major support from the three countries include biomethane, aviation fuels and maritime fuels. The latter can be certainly linked to the contributions those countries reserve for the global EU aviation and maritime industry, to their economic maturities, last to the important shares those countries have in the EU natural gas supply system.

Ireland has the most structured blending targets, and Belgium has started to scale biomethane (first grid injections expected in 2025). Both countries endorse mildly advanced liquid biofuels, though for different reasons. Ireland, and Belgium are supporting moderately advanced liquid biofuels, though for different reasons.

Ireland has made progress on conventional biofuels, reaching 10.1% blending in 2024, but advanced biofuels remain niche, with low targets and full reliance on imported used oils. Over 40 biogas plants are operating, and the country aims[28] for 5.7 TWh of biomethane by 2030, though support schemes are still pending (no major fiscal instruments, investment de-risking mechanisms, or clear national scale-up strategy). PtX remains at the planning stage, with long-term potential linked to offshore wind.

Belgium is just beginning to scale biomethane, with first grid injections in 2025 and some EU-backed funding. However, it has no tangible advanced biofuel or PtX projects, and progress is slowed by regulatory hurdles and policy fragmentation. Progress in those two countries depends on stronger domestic incentives, infrastructure investment, and clearer long-term strategies.

Moving towards Northern Europe, Finland, Sweden and Denmark appear to be at the forefront of the advanced biofuel scene. It is worth mentioning here that all three countries have set ambitious national climate goals, many of which exceed EU targets:

- Sweden aims to achieve net-zero emissions by 2045.
- Finland targets carbon neutrality by 2035—one of the most ambitious globally.
- Denmark has a legally binding target to reduce emissions by 70% by 2030.

Finland and Sweden in particular, have vast forest resources, managed sustainably for decades. These forest forests supply residues, lignocellulosic materials, and black liquor – ideal feedstocks for advanced biofuels. Further, the Nordic model of circular bioeconomy allows these countries to use waste and by-products from forestry and agriculture, reducing feedstock emissions and enhancing sustainability. Those factors, along with the state-support mechanisms have helped emerge several globally recognized companies in the biofuels sector; Finland hosts currently the world's largest producer of renewable diesel and sustainable aviation fuel (SAF), Sweden players are investing heavily in biorefineries and drop-in fuel alternatives

[28] https://www.energyireland.ie/pathway-to-irelands-renewable-gas-network/

for aviation and heavy vehicles transport, whereas Denmark harbours a major developer of hydrogen and biofuel technologies, including Power-to-X (PtX) systems,

In particular, Denmark set a low 0.9% biofuel blending mandate in 2016 but has made little progress since, with no subsidy schemes or large-scale advanced biofuel production. The country prioritizes biogas and Power-to-X (PtX) to decarbonize aviation and shipping, leveraging strong wind power and biogenic CO_2 from around 150 biogas plants[29]. Denmark focuses on green hydrogen, synthetic fuels, and electrifying road transport.

Norway is advancing steadily but trails Sweden and Finland in advanced biofuels due to limited biomass and reliance on imports. However, Norway leads in PtX development, investing in green hydrogen, ammonia, and synthetic fuels for maritime and aviation sectors. Supported by strong mandates and funding agencies like Enova, Norway is building industrial-scale PtX capacity, with less focus on biomass-based biofuels than its neighbours.

As far as, far as Central-Southern Europe is concerned, Austria and Italy are ranked number one when it comes to supporting the acceleration of the industrialization of the biofuel industry.

Italy uses agricultural residues, municipal organic waste, and used cooking oil (UCO) to produce advanced biofuels. Home to one of the first major oil companies in Europe to convert traditional refineries into biorefineries (e.g., Venice and Gela plants). A pioneer in HVO and biomethane, with strong R&D capabilities in waste- and residue-based fuels, Italy supports a growing ecosystem of innovative SMEs and academic institutions working on second-generation biofuels and sustainable aviation fuels (SAF). Italy acts as a regional hub for advanced biofuels in Southern Europe, exporting know-how and fuel products.

Austria integrates forestry residues, animal fats, and waste oils, benefiting from its long-standing expertise in biomass management. The country hosts a well-established bioenergy sector, especially in solid and liquid biomass. In Austria, strong public-private partnerships in biofuel innovation, including projects focused on cellulosic ethanol, biodiesel from waste oils, and biogas upgrading. Public authorities have been emphasizing decentralized, regional biofuel production, which integrates well with Austria's rural economy and forestry sector. The country plays a coordination and demonstration role in Central Europe, particularly through cross-border projects and participation in EU Horizon research programs. In the **Central-Southern European** region, both Italy and Austria actively contribute to shaping European innovation platforms, industry alliances, and sustainability certification schemes.

In contrast, Spain, Czechia and Slovakia, trail behind these leaders in industrial biofuel scale-up. Spain shows moderate progress, with early-stage PtX pilot projects and growing biomethane infrastructure, but advanced biofuels remain a niche market largely dependent on conventional biofuels. While state interest in hydrogen and renewable fuels is rising, policy support and industrial investments are still limited compared to Italy and Austria.

Czechia and Slovakia are in earlier stages of development. Both countries have small but growing biogas sectors and some conventional biofuel production, but advanced biofuels and PtX projects are minimal. Their industrial capacity for biofuels is constrained by limited feedstock availability and weaker policy frameworks. Slovakia, in particular, relies heavily on imports.

Hungary shows growing interest in biogas and renewable fuels, supported by some government incentives, but advanced biofuels and PtX technologies remain in infancy. While Hungary possesses agricultural residues and some forestry biomass, industrial-scale production is scarce, and infrastructure for biomethane injection is still limited. Policy support is gradually evolving but has yet to translate into significant market development.

Croatia has a modest bioenergy sector, largely relying on conventional biofuels and biogas from agricultural and municipal waste. Its advanced biofuel industry is minimal, with limited commercial-scale projects or PtX initiatives. The country's biomass potential is constrained, and

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[29] https://ens.dk/en/energy-sources/biogas-denmark

policy frameworks remain underdeveloped, limiting investor confidence and industrial growth.

Slovenia benefits from forestry resources and a small but active biomass sector, with some investments in biogas and conventional biofuels. However, advanced biofuels and PtX projects are largely absent. The country faces challenges in scaling production due to limited feedstock availability and regulatory complexities, resulting in a slow industrialization pace.

Portugal is gradually shifting from early-stage initiatives to industrial maturity in advanced biofuels, biomethane, and PtX—supported by strong funding, state-led planning, and integration with EU objectives. The country hosts an investment of 270 000 t/yr HVO facility at Sines, using waste oils and green hydrogen (100 MW electrolysers). The project is backed by a 250 MEUR EIB loan and 180 MEUR public support. A Biomethane Action Plan (2024–2040) and the first biomethane/hydrogen auction (up to 150 GWh/yr biomethane) underscore relevant state support intentions. Last, a “Project of National Interest” was announced in 2022 aiming to produce up to 80 000 t/yr synthetic eSAF from biomass and captured CO_2.

As far as, the **Eastern Europe** is concerned, although **this region** has traditionally lagged Western and Northern countries in renewable fuel deployment, Romania, Poland and Lithuania are distinguishing themselves as regional leaders in the industrialization of advanced biofuels. This leadership reflects a proactive alignment with EU regulations, domestic energy diversification strategies, and a drive to modernize national fuel supply chains. Further, the war in Ukraine and related fossil fuel disruptions have prompted these countries to fast-track renewable fuel development as a means of reducing dependence on fossil imports. Biofuels - especially advanced and waste-based - are seen as tools for both climate action and energy independence. Poland stands out somewhat with a more established biogas sector and growing interest in hydrogen but still lacks large-scale advanced biofuel production. Its biofuel industry remains focused on conventional blends, and PtX initiatives are nascent.

In those countries, states have supported the modernization of existing refineries to produce advanced fuels, often with EU funding (e.g. Cohesion Funds, Modernization Fund). Poland and Romania are attracting significant foreign investment in advanced biorefineries and biomethane plants whereas Lithuania has developed a flexible regulatory environment to facilitate new biogas and advanced ethanol projects. All three countries are actively involved in EU-funded innovation projects (e.g. Horizon Europe, CEF, Innovation Fund) related to low-carbon fuels and circular bioeconomy solutions. Theay are also engaged in cross-border collaboration with Western EU partners and industry alliances (e.g. ART Fuels Forum, Bioenergy Europe) brings in technology, know-how, and financing.

Bulgaria has a small and underdeveloped biofuels sector, with limited domestic production of advanced biofuels and biomethane. Biogas use is mostly unrefined and used locally, and there are no major PtX projects underway. Policy support exists but remains fragmented and implementation is slow. **Latvia** has shown some progress in developing biogas infrastructure and implementing circular bioeconomy initiatives. However, the industrialization of advanced biofuels and biomethane injection into the grid is still minimal. PtX technologies are largely absent from current energy planning. **Estonia while it** is slightly ahead within the Baltic trio in terms of innovation and green technology ambition. While it has strong digital infrastructure and a proactive climate stance, Estonia’s biofuel sector remains limited in scale, albeit its good biomethane sector. Advanced biofuels and PtX are still in early conceptual or research stages, and the industrial base for biofuel production is small.

Greece remains at an early stage in clean fuel industrialization. It relies mainly on conventional biodiesel, with no large-scale advanced biofuel or biomethane production. Power-to-X and hydrogen projects are limited to pilots, and no national strategy is in place. Recently (July 2025) a new law (Law 5215/2025**)** was adopted regulating production and supply conditions for biomethane and other low carbon gaseous fuels. There is provision in the law for operational and capacity financial support, but the secondary legislation required has not been promulgated at present. Investment and relevant use of EU funds remain low compared to peers.

4.4.3. Observations from an industrialization progress perspective

In the light of our analysis at this stage, EU countries seem to match one of the three following groups when it comes to assessing their progress in industrializing advanced biofuel value chains:

- **Group 1**: MS characterised by policy frameworks with **strong commitments** to advanced biofuel industrial scaling, indicatively Finland, France, Italy, Germany, the Netherlands, Sweden, Portugal.
- **Group 2**: MS characterised by policy frameworks with **moderate commitments** to advanced biofuel industrial development, indicatively Austria, Denmark, Poland, Norway, Spain, Lithuania, Romania.
- **Group 3**: MS Countries characterised by policy frameworks with **fair commitments** to supporting advanced biofuel industrial development, including almost all the remaining EU countries

Evidently the focus was placed on the MS of Group 1 and Group 2.

MS of Group 1 (Finland, France, Italy, Germany, the Netherlands, Sweden, Portugal)

This group consists of countries characterized by an increased effort to support the advanced biofuel industry through dedicated aid programs, project de-risking mechanisms and institutional initiatives. Those sets of tools tend to focus on:

- scaling biofuel technologies which have already attained a certain maturity level and bolstering respective value chains
- facilitating research and development programs to improve techno economic performance of emerging technologies.

Most of those countries leverage available EU funding supports mechanisms as well as national resources (state budgets) and by combining them they come up with support frameworks that lower economic and financial risks to which investors are exposed at various stages of the biofuel value chains. Further, the countries of this group are inclined to proactive approaches when it comes to enabling regulatory and institutional provisions which accelerate pending FIDs and attract risk-averse or reluctant investors.

Some of these countries introduce direct investment grants or investment allowances, possible with caps and TRL criteria, to compensate the capital intensity of the processing/conversion biofuels plants (e.g. France, Italy the Netherlands, in principle) and secure satisfactory payback periods. Other countries opt for subsidizing tariffs and price hedging instruments, like Contracts for Difference (CfD) and feed-in *premia* (FIP) (Italy, Germany, in principle) to future-proof returns on investment against contingencies of a market that is yet to demonstrate the value it may reserve for early adopters. However, most of the countries in this group, tend to offer a mix of those support “packages” according to the type of the biofuel and the challenges the respective industry faces in the specific geography. Subsidy intensities vary and are defined according to various criteria and methods; from common ones like applying a ratio on to the amount of the eligible investment envelop, to more complex ones such as the use of subsidy decreasing formulas over time, in order to prioritize cost-effective projects. Further, some countries are open to voluntary agreements between the government and private sector players (e.g. Green Deals in the Netherlands) while other count equity investors in their territories willing to support advance biofuel project bearers (e.g. Impala subsidiary in France interested in bio-methane investments).

It is also worth noting that many of these countries have reflected and aligned part of their national “biofuel strategies” (most often included in their national energy and climate policies) with relevant EU policies hence embedding part of their public support in existing EU funding schemes - pass-through to Recovery and Resilience Fund (RRF, ending in December 2027) or Modernization Fund - and EU State-Aid Frameworks. Therefore, those countries have also been able to integrate relevant investment provisions in their multiannual energy system planning roadmaps. The respective aid amounts are considerable, and even if they usually concern not only biofuels but also hydrogen, renewable electricity and biogas combustion, the eligible investors have to queue unapologetically regardless of the originality level of the project they defend.

Advancing institutional reforms and ad-hoc adjustments along with introducing investment support policies do not solely explain the reasons for which advanced biofuel development has accelerated in these countries. As a matter of fact, those factors add up to a breeding ground which, in most cases, includes industrial production and/or distribution infrastructure already in place (Italy, the Netherlands, in principle), available and accessible feedstock (Poland, France, Germany, in principle), and governmental action or economic development policies closely linked to decarbonization and net-zero strategy commitments (Denmark, Sweden, Finland, in principle).

From the biofuel distribution, supply as well as the off-taking perspective, those countries apply blending mandates coupled with renewable energy certificates and tax incentives. GHG quotas have also been introduced in many countries which can transform potential earnings made from avoided carbon emissions into a valuable monetization upside for the biofuels end-users. Moving to the upstream, structural issues related to feedstock availability, demand inelasticity to feedstock price variations and the high opportunity cost of restricting the use of feedstock to a specific use, are tackled in various ways. For instance, France encourages agricultural cooperatives to supply consistent biomass streams under long-term contracts (feed-in tariff mechanisms) and incentivizes industrial symbiosis (e.g., energy from agricultural or municipal waste) to lower input costs and promote resource efficiency.

Last, a common trend of this group of countries is their propensity to observe the biofuel industry holistically, i.e. by intervening across various stages of the underlying value chains and to equally echo this holistic approach in the design of the various support mechanisms, almost on a case-by-case basis depending on the challenge they are called to address, the nature, scale, replicability and disruptiveness of each project.

MS of Group 2 (Austria, Denmark, Norway, Spain, Poland, Lithuania, Romania)

This group consists of countries who have made significant steps towards unlocking the potential of advanced biofuels in their respective territories, although the specific pathways and the pace of development vary considerably among them. Often starting by introducing regulations providing advanced biofuels blending mandates, those countries tend to institute excise duty exemptions or rebates and other tax incentives for advanced biofuels mainstreamers[30]. Moving to the upstream, most of the countries of this group have provided, at a modest pace, with a limited time span, and for a specific funding budget, investment subsidies which are usually backed by EU support funds (RRF and Modernization Fund) and little by their respective state budgets. Further many of these countries may offer corporate income tax reduction schemes to offset financial viability risks during the first years of operations.

It is noteworthy that countries in this group are often engaged in energy system reforms which spur transition from fossil fuels and enhance national security of supply, especially in the aftermath of the 2022 crisis. Further, many of the countries in this group have common borders with countries of the previous group, hence leveraging potential feedstock resources and

[30] A mapping of the existing tax incentives for liquid biofuels in EU-27, can be found in the very recent (July 2025) FuelsEurope Statistical Report 2025, which can be found here. Statistical results further corroborate the approach of MS Groups 1 and 2 (i.e. the ones putting the more effort into the promotion of advanced biofuels) on exploiting the tool of provision of appropriate tax incentives as a lever to boost market scale-up.

industrial infrastructure mutualization.

Overall, this MS group represents a dynamic set of countries with "moderate commitments" or significant, albeit sometimes nascent, steps towards advanced biofuel development. Their strategies involve a mix of policy instruments, a notable reliance on EU funding for investment, and a strong drive towards energy independence and climate action, often through a blend of biomass-based advanced biofuels and Power-to-X technologies. However, the depth of policy implementation and the scale of advanced biofuel industrialization (especially for biomass-based fuels) can vary significantly within the group, with some members still facing limitations in domestic support schemes or prioritizing other renewable fuel pathways.

MS of Group 3 (all other not included in Group1 and 2)

This group consists of countries which seem to lack schemes that could unfold and accelerate industrialization of the advanced biofuels value chains. Compliant with EU regulations regarding reduction of GHG emissions or minimum share of renewables in transport sector, almost all these countries have already introduced blending mandates, or GHG quotas to fuel suppliers, most probably coupled with tax incentives for biofuels and other low carbon fuels. This common approach in many MS countries indicates minimum effort and low State expenditure in complying with the EU policy in transport sector GHG emissions. While some foundational steps, such as the initial scaling of biomethane or early biogas initiatives, may be underway, the overall picture indicates that industrial-scale production of advanced biofuels remains scarce or limited. This is often coupled with policy frameworks described as underdeveloped, fragmented, or in gradual evolution, which collectively hinder significant market development and investor confidence in these crucial sectors. This approach often suggests a compliance-driven strategy towards EU regulations, focusing on mandates rather than a proactive national push for deeper industrial decarbonization through advanced biofuel value chains. Within this group, a significant reliance on conventional biofuels persists as the primary means of meeting blending mandate. Further challenges stem from constrained industrial capacity and limitations in feedstock availability, which impede the scaling up of advanced biofuel production. The adoption of Power-to-X (PtX) technologies is largely absent, or confined to early conceptual and research stages, with only limited pilot projects observed. Progress in the development of these advanced fuel sectors is frequently impeded by regulatory hurdles and a lack of policy cohesion. Consequently, there is an overarching trend of low investment and limited utilization of available EU funds for the comprehensive industrialization of clean fuels within these MS, particularly when compared to other more advanced European peer.

Collectively, these countries appear to be in earlier stages of development regarding renewable fuel deployment compared to other regions. To overcome these challenges and accelerate the industrialization of advanced biofuels, there is a critical need for stronger domestic incentives, substantial infrastructure investment, and the establishment of clearer, long-term national strategies.

4.5. Determination of integrated projects of common interest

4.5.1. Major challenges for advanced biofuels to be tackled by supporting schemes

In the previous Chapters the main issues affecting the development of Advanced Biofuels (AB) Industrial Value Chains (IVCs) were discussed, in parallel, the present situation of supporting schemes at both European and National/ EU Member States (MS) levels were analysed. Table 4-4 presents in brief the mapping of current supporting schemes addressing the identified main issues related to the investors of Advanced Biofuels.

Main issues affecting the development of Advanced Biofuels investments	Existing Supporting Scheme
Risk of **new technology yield** and development of competition within new market conditions of low carbon economy	Derisking finance tools, EIB, EBRD, InvestEU
Regulatory conditions creating demand	RED II/III, Fuel EU Maritime, ReFuelEU Aviation, EU/ETS, ETS2
Economic viability reflecting finance support and bankability of new investments	Grants, soft loans, sustainable financing, private banks, EIB, EBRD, national funds
Difficulties in **collecting and producing affordable feedstock** (e.g. agri- forest residues, eligible crops) and supply industrial units	**EAFRD** (weak provisions), lack of supportive coordinated agro-schemes and aggregators, eSCA
Regional dimension of industry development (most industries operate in western and northern Europe)	**Missing of specific supporting schemes** oriented to less developed regions with lower density of feedstock potential
National dimension of project establishment, thus not facilitating **collective and more efficiently sized projects**	**Missing of integrated supporting schemes** with interregional value chain of projects

Table 4-4 Existing supporting schemes and needs of Advanced Biofuels investments

The perception identified is that technological risks, main regulatory framework and economic viability issues are largely covered, although not properly in some cases, by relevant EU and MS initiatives. On the contrary, it is noted that:

- the CAP/EAFRD (Common Agricultural Policy/ European Agricultural Fund for Rural Development) provisions in supporting the collection and production of affordable feedstocks, which are requested by AB industry, and the implementation of eSCA (Emission Saving from Soil Carbon Accumulation) provisions are weak at present;
- the regional dimensions of the AB activities have not been adequately addressed through the existing supporting schemes;
- the collective more efficiently sized projects, which benefit from the economies of scale, are not supported by corresponding relevant integrated and interregional supporting schemes.

The stages of a typical value chain for the production of Advanced Biofuels for transport is shown in Figure 4-4. The main stages and market actors are distinguished:

- Production or collection of biomass feedstock carried out by **farmers or biomass residue collectors**;
- **Aggregators** dealing with certification of feedstock, training and cultivation support of farmers, processing of feedstock, logistics and transport of feedstock from production sites to industrial sites;
- **Industrial units or biofuels producers** undertaking the main conversion process of biomass feedstock to biofuels;
- **Marketers** who satisfy their demand for biofuels and comingle the produced biofuels with fossil fuels to eventually supply the end-users (final transport consumers).

For each category of value chain the key areas of potential support are mentioned. Along with the broad support levels that have been identified so far in the analysis, aiming to illustrate that different supporting approaches might be needed due to the different investment and operational conditions of each actor.

To cope with the above-mentioned weaknesses the concept of "**integrated projects**" is introduced; the concept is related to the whole of the IVCs and in parallel, anticipating combined financing support addressed to all the value chain stages. Thus, the integrated require specific financing support schemes.

The development of new "**collective plans"** for financing aggregated industrial value chains within the EU is guided by a set of core principles aimed at strengthening industrial capacity to meet the 2030 climate targets. These principles emphasize a holistic approach that builds upon the identified essential value chains from Task 1, with business models assessed in Task 2, and the needs analysis from Task 2, which considers volume data from the previous related study (Development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels[31]). The plans seek to mobilize both EU and Member State support tailored to the specific requirements of investors and producers across different segments of the value chain that might promote cooperations among EU countries. A key focus is on de-risking the entire value chain—considering geographic dispersion and size dimensions—by implementing targeted financial instruments and support mechanisms. Although such collective financing frameworks do not currently exist in their comprehensive form, they are conceptualized based on successful ideas from existing programs at both EU and national levels, including the IPCEI framework. These principles aim to facilitate investment, reduce barriers, and foster an integrated effort to develop resilient, sustainable, and competitive industrial ecosystems aligned with climate objectives.

The **main effort** in this project task is to identify the necessary MS and/or EU support to the farmers/feedstock producers, aggregators, industrial units and marketers of each part of the identified value chain, thus concentrating on the specific needs for support. The "**collective"** characteristic of the AB projects refers, in principle, to the need to de-risk the entire value chain, given that geographic (interregional) and unit size dimensions may come in depending on the value chain and the investors' interests.

[31] https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/development-outlook-necessary-means-build-industrial-capacity-drop-advanced-biofuels-2024-02-07_en

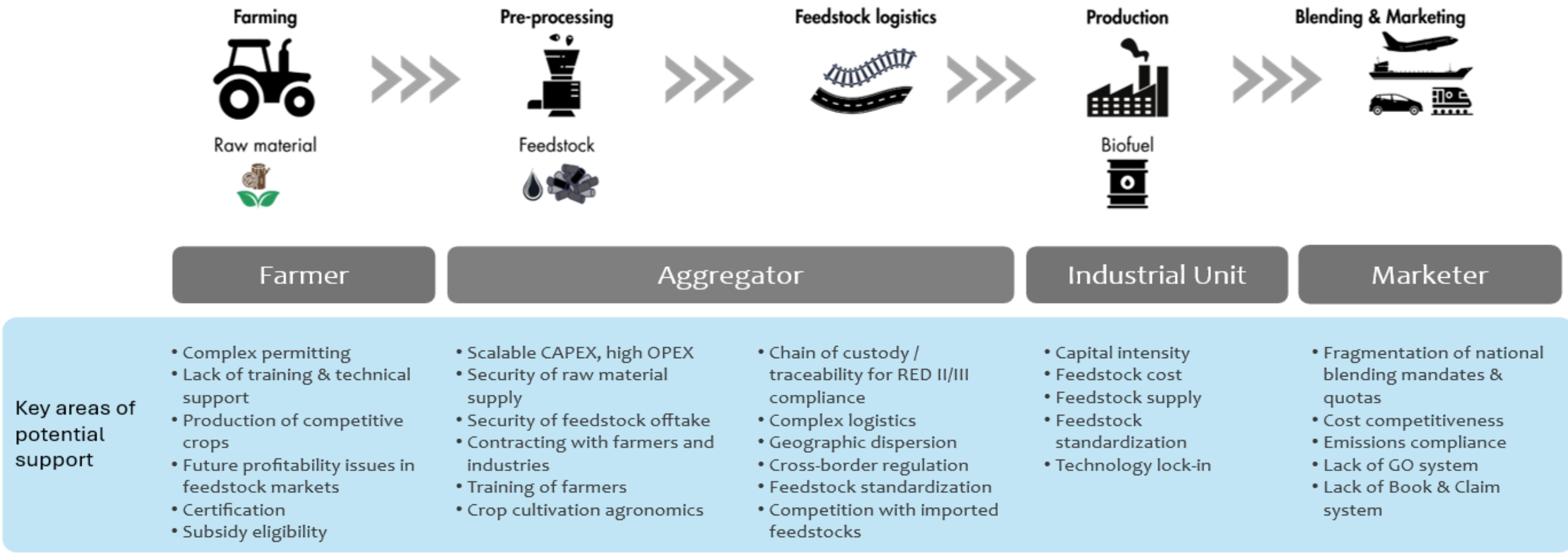

Figure 4-4 Typical value chain of Advanced Biofuels along with key areas of potential support for each actor

4.5.2. Criteria for selecting distinct value chains for collective financing/supporting plans

In the frame of the integrated projects and essential value chains, the selection of the **distinct value chains** is made in order to be able to examine in more detail the supporting needs and the required plan of financing support to the relevant investments and operational activities. Therefore, the study is directed to commercial and tangible integrated projects within the identified essential industrial value chains; the implementation of which implies the EU common interest to meet the necessary carbon reduction in the transport sector by 2030 and afterwards. The basic criteria in selecting the distinct value chains are:

1. Need to adopt **'down-to-earth'** project casers and value chains, as possible, for the development of realistic collective financing support and implementation plans.
2. Consideration of **relatively mature technologies in the period 2025-2030**, suitable for scale-up and having the greatest prospects to actually contribute to the volumes of advanced biofuels we need for the targets of 2030.
3. **Feedstock of focus**: a) **Lignocellulosic** feedstock (agriculture, gardening, forest, wood industry residues, etc.) would be important for Europe since there is a significant domestic (largely unexploited) potential; b) **Lipid** feedstocks (camelina, carinata, castor, etc.), especially oilseed crops, and particularly cover / intermediate crops, providing significant environmental and agronomic benefits, as well c) organic matter feedstocks for biomethane from a wide range including, food waste, sewage sludge, organic fractions of municipal waste, etc.
4. Coverage by the group of selected distinct IVCs of **demand of all main transport sectors**, namely aviation, maritime, road.
5. Consideration of **international markets,** subject to allowing competitive production of AB in the EU against potential imports of significantly cheaper products from abroad.
6. **Collective** interregional aspect in the analysis supported by the choice of technologies/value chains that can be efficiently developed in a decentralized way within Europe and in parallel linked to centralized industrial units e.g. many HVO oil producing plants and one centralized processing unit.

For the selection of distinct value chains, we need to consider the detailed analysis of Task 2 and develop **integrated** (i.e. referring to the entire value chain) **supporting schemes**, potentially considering specific ('fictitious', but realistic in terms of size and geography) projects of substantial impact. The **collective supporting plan** would allow for the identification and the exploitation of synergies among the various steps of the integrated industrial value chains.

Regarding the rest of the selected essential IVCs, many of the criteria are common especially in the period 2030-2040, i.e. feedstock which will be mainly lignocellulosic, sectors coverage mainly aviation & maritime, international and interregional (decentralized production) aspects. It is essential that the analysis for these value chains beyond 2030 could be also supported and developed in a similar way; the different elements which are not covered in the current analysis of distinct value chains relate, in principle, to the technological maturity and the bankability issues due to their innovative characteristics. The palette of financing support vehicles will be presented in the next Sections of this Chapter and might indicatively include:

- **MS national development and energy transition** programs applied to specific IVCs in the EU countries that might coordinate with pertinent EU supporting initiatives or policies;
- **Financing tools operated traditionally** under the EU policy measures and managed by the EC, EBRD, EIB, etc. or other institutions with European scope of activities;

- **Innovative supporting approaches** to be implemented in the context of interstate, green transition and security of supply at EU level (e.g. IPCEI, FiT, FiP, CfD, etc.).

4.5.3. Selection of Distinct IVCs to focus and develop financing plans

Keeping the nomenclature for essential IVCs of Task 1 and based on the above-mentioned criteria the following distinct IVCs have been selected:

- **IVC2:** Use **oil from eligible crops and hydrotreatment** for the production of liquid fuels for the aviation (Annex IX/A of RED II/III categorization) and road, as well as potential, maritime sector (Annex IX/B categorization). The challenges of supply with affordable feedstock production, support of aggregation of feedstock and support of centralized industry of rather big size should be tackled.
- **IVC8a: Biomass gasification and methanol synthesis** to produce bio-methanol from lignocellulosic biomass (residues, crops) aiming to supply maritime in principle, where various initiatives investigate this alternative to traditional fossil fuels. The challenges of supply with affordable feedstock production/collection, support for aggregation of feedstock, support for technological risk of industry and support at demand stage for methanol use should be tackled.
- **IVC7:** Use **of eligible crops for the production of advanced biomethane** via anaerobic digestion and upgrading of the produced biogas to biomethane able to fuel vehicles and ships (Annex IX/B of RED II/III categorization) as well as to be blended into the natural gas network. Other complementary feedstocks like organic matter from waste (manure, MSW, etc.), forest and agriculture residues are also considered in addition to lignocellulosic crops. The challenges of affordable feedstock production, support for improvements in the cooperation model and demand of gaseous fuels development are largely under consideration.
- **IVC13b: Pyrolysis and fuel upgrading for maritime sector,** via fast pyrolysis and FPO upgraded to Hydrotreated Pyrolysis Oil (HPO) that can be blended with diesel or HFO to be used mainly in maritime sector, and to a lesser extent to road transportation. The challenges of supply with affordable feedstock production/collection, support of aggregation of feedstock, support of technological risk of industry and support at demand stage for HPO use should be considered.

4.5.4. Support measures for farmers

Feedstock supply represents a significant risk factor for projects based on the hydrotreatment of lipids and lignocellulosic material processing according to the qualitative assessment of the respective IVCs. Considering the analysis of the selected IVCs (see Table 4-5) this section **focuses on regulatory and financial gaps that hold back the mobilization of biomass feedstock production.** Considering that IVC2 requires oilseeds, whereas IVCs 8a, 7 and 13b share lignocellulosic crops and residues, from the point of view of the farmers this section focuses on (a) oilseed production for IVC2 and (b) lignocellulosic feedstock production for the rest of the selected distinct IVCs.

Both for oil crops as well as lignocellulosic feedstock, we separate support measures as “administrative” and “financial.” **Administrative measures** involve changes in the member state interpretation of current regulations or the development of tools that can enable the supply chain of feedstocks with low administrative overhead costs for the supply chain. **Financial support measures** are actually options and focus on quantifiable financial incentives for farmers that would trigger the necessary feedstock production. Some of the necessary financial support measures are already satisfied by the existing EU and MS policies, however, the emphasis of this study is placed on **additional measures required to mobilize feedstock supply**.

Oil crops (IVC2)

Eligible crops for HVO and HEFA production under the RED II/III framework include crops grown on severely degraded land and intermediate crops (like catch crops and cover crops) grown not primarily for food, but as intermediate / cover / catch crops. Under certain conditions (e.g., short vegetation period, not triggering demand for additional land, maintaining soil organic matter) they are eligible. If channelled to the aviation sector, the produced biofuels may fall under RED Annex IV/Part A; for other transport sectors under Part B. Non-food oilseed crops, like Brassica carinata, are recognized as “intermediate crops” / cover crops in this context.

In order to develop the points in this study we will focus on Brassica carinata, indicatively chosen as an agronomically viable crop in the EU with scaling potential and for which sufficient information is available in the public domain. The next sections cover analysis and recommendations for administrative and financial support measures that can provide incentives for oilseed farmers and be engaged into cultivation and eventually to secure the supply of oil crop feedstock to IVC2.

Administrative and regulatory challenges and recommendations

The industry survey conducted in Task 1 of the present project has highlighted the need to **adopt clear operational rules for new Annex IX feedstocks** which constitute a key enabling factor for the development of the biofuels market through the integration of long-term agreements with suppliers. The feedback emphasized that regulatory measures should be undertaken at European level in the form of regulations which should be obligatory for the MS.

The main area of inconsistency that hinders the production of oil crops eligible for advanced biofuels production is between the Common Agricultural Policy (CAP) and RED II/III. Table 4-5 presents a comparison of policy areas and specific inconsistencies between the CAP and RED frameworks that affect the eligibility and support for oil crops used in advanced biofuels production. These frameworks do not align, causing missed opportunities and uncertainty for farmers growing advanced biofuel crops.

There is ample opportunity to lighten the regulatory and administrative burden for oilseeds farmers and give them access to additional economic benefits by further alignment of the CAP and REDII/III frameworks. Our recommendations are:

- Align CAP crop lists with RED Annex IX by clearly adding supported crops under CAP eco-schemes or AECMs
- Develop CAP schemes that reward carbon-efficient rotations, soil carbon increases, and biofuel-compatible cover or intermediate crops
- Integrate RED compliance data into CAP registries, and develop interoperable GIS, land history, and compliance platforms
- Create joint Monitoring Reporting and Verification (MRV) systems by harmonizing GHG methodologies across CAP (LULUCF), RED (LCA), and carbon markets (project-based MRV)

Besides the administrative initiatives above, carbon farming and sequestration can de-risk and enhance profitability of oilseed production in the EU. Carbon Removals & Carbon Farming (CRCF) Regulation,[32] creating the first EU-wide voluntary framework for certifying carbon removals, carbon farming and carbon storage in products across Europe. could be attractive for advanced oilseed crops (e.g. carinata, camelina, etc.) production, unlocking potential carbon benefits for farmers. The CRCF methodologies for permanent removals, currently covering

[32] Regulation EU/2024/3012

DACCS, BioCCS, and biochar, will be subject to public consultation and scrutiny by the co-legislators in the course of 2025 with a view to be formally adopted tentatively by Q1 2026. Carbon farming methodologies, covering planting of trees, peatland rewetting and restoration, and agricultural and agroforestry on mineral soils, are planned to go for public consultation by the end of 2025 and be formally adopted tentatively by Q2 2026.

Area	CAP Framework	RED II/III Framework	Gap / Inconsistency
Supported crops	CAP defines eligible crops for direct payments, eco-schemes, and GAEC compliance	RED defines Annex IX crops eligible for advanced biofuels	Many RED-eligible crops (e.g. carinata, camelina) are not listed as CAP-supported crops
Land eligibility	CAP rules (GAEC[33] 7–8) discourage monocultures, incentivize non-productive areas	RED allows biofuel crops on any land not deforested post-2008	Farmers using fallow or eco-area land for biofuels may lose CAP subsidies
Incentives for GHG reduction	CAP includes vague eco-schemes and Agri-Environment-Climate Measures	RED rewards GHG savings only at fuel supplier level	Farmers receive no reward for adopting low-GHG practices at present
Permitting and classification	CAP tracks crop types for compliance and subsidy	RED requires feedstock classification for sustainability audit	An oil crop may be unrecognized or misclassified in CAP registries
Audit systems	CAP checks land use, cross-compliance, GAEC	RED requires chain-of-custody (mass balance), sustainability documentation	No data-sharing or harmonized audit system; duplicate administrative burden
Support instruments	CAP offers area payments, eco-schemes, investment support (RDP)	RED provides demand pull via quotas, no direct farmer support	No coordinated financial pipeline for RED-eligible farmers under CAP

Table 4-5 Inconsistencies between RED II/III and CAP

Financial challenges and recommendations

For the farmer, the economic decision to include an oil crop as intermediate crop is complex. It is driven by the comparison between alternative strategies (over a 4-year cycle according to relevant studies[34]) in terms of potential revenue, working capital requirements, profit, administrative burden as well as regulatory and agronomical risk. Based on the present analysis, growing Brassica Carinata, as an example, has to be at least as competitive to the next-best alternative, e.g., following a rotation schedule with winter cereals or oilseeds, such as

[33] CAP's Good Agricultural and Environmental Conditions
[34] https://www.bike-biofuels.eu/wp-content/uploads/2023/07/Deliverable-D3.3_BIKE-2.pdf

rapeseed. In practice however and considering experience on the ground, the switch to Brassica Carinata must be significantly more beneficial to the farmer, considering the lack of familiarity with the crop, other agronomical risks, and administrative challenges mentioned above.

Across the EU, the optimal strategies are highly dependent on locality, both in terms of regulation and climate. In Germany, for example, a full winter cash crop (e.g. wheat or rapeseed) generally yields the highest net margin, followed by intermediate forage; even leaving land fallow can be surprisingly profitable due to high eco-scheme payments. Growing carinata in Germany appears least rewarding financially, given low yields and lack of incentives. In Italy on the other hand, a winter cash crop or Brassica carinata as an intermediate crop, can both be very profitable, leveraging the long growing season.[35]

Our research suggests that farmers would require financial support in order to switch to e.g. Brassica carinata and Camelina from their current strategies on pure economic terms. Such support should be localized and adapted to local regulatory (i.e., national CAP interpretations and eco-schemes) and climate conditions and beefed up to compensate for "early adoption" risks (e.g., higher agronomic risk and uncertain yields, or the need to coordinate with biofuel aggregators and producers).

In this nascent stage of Advanced Biofuels market development, **support should be targeted directly to the farmer** because there is no established market structure or transparency mechanism that would guarantee that benefits of carbon savings downstream would be transferred to farmers. At the same time, we recognize that CAP, which is the obvious vehicle for the delivery of such support, may be over-extended and cannot easily be leveraged further. We would also argue that farmers producing crops dedicated to biofuels should benefit from GHG emissions savings to keep their competitive advantage in terms of feedstock use.

Therefore, in the early stages our recommendation focuses on the following EU-level measures to ensure fast rollout, before "market-pull" mechanisms, such as blending mandates and carbon pricing, kick fully into place and establish a transparent marketplace for the entire biofuels supply chain[36]. The necessary financing support could be in the form of:

- **EU-or National-Funded Feedstock Premium**: A program offering a feed-in premium per ton of an eligible (e.g. carinata) seed delivered to biofuel producers. A centrally run call could invite proposals from cooperatives, agribusinesses, or regions to enrol farmers and guarantee them a premium (in terms of additional payments in €/t) for verified deliveries of sustainable and eligible oil crops to biofuel processing.

Such support should adhere to two principles:

1. **Non-competition to CAP and GAEC rules:** support schemes should not incentivize farmers to engage in practices outside GAEC standards. This can be ensured by requiring strict and documented adherence to GAEC standards for support eligibility.
2. **Localization:** support schemes should be tailored by member states to account for regional climactic conditions, crop economics and CAP implementation practices.

In conclusion, mobilizing farmers to provide secure and economically viable oilseed supply to HVO/HEFA value chains could be achieved with financing support schemes. This is a tried-and-tested method that worked in the early stages of renewable energy production.

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[35] Giovanna M. et al., Variety screening trial of Brassica carinata as a summer intermediate crop in Northern Italy, Industrial Crops and Products, Volume 233, 2025 (https://doi.org/10.1016/j.indcrop.2025.121427)

[36] Both mechanisms incentivize the creation and expansion of markets for low-carbon fuels and technologies. Blending mandates create direct demand by requiring the use of renewable fuels, while carbon pricing shifts market behaviour by increasing the cost of emitting greenhouse gases, thus favouring climate-friendly alternatives.

In addition, we recommend the **development of contract templates** with built-in compliance-safe calendars for harvest windows, minimum residue left, cover re-establishment etc. Such contracts can be developed in consultation with local authorities and auditors in order to reduce risks for the farmer. Contracts can delegate documentation and record-keeping to the aggregator, reducing administrative burden on the farmer. Finally, offtake contracts can delegate harvest and haul services to the aggregator, reducing work and capital expense for the farmer.

Lignocellulosic crops and agricultural residues (IVC8a, IVC7, IVC13b)

Of the lignocellulosic feedstock pool for IVCs 8a, 7 and 13b, only lignocellulosic energy crops (e.g., miscanthus, switchgrass) and agricultural residues (e.g., woody biomass, or harvested cover crops) involve agricultural farming. Nevertheless, regulatory bottlenecks and a small profitability gap stand in the way of scaling up.

Regulatory and administrative challenges and recommendations

On the regulatory side, unclear or unsupportive policies, administrative burdens, and lack of institutional guidance are issues that deter farmers from producing energy crops or supplying residues for biofuel. GAEC 6 (minimum soil cover) and GAEC 5 (erosion) are the main friction points when removing residues or harvesting cover/energy crops. Farmers have to follow both **CAP** and **RED III (EU Directive 2023/2413) sustainability criteria, the latter** explicitly strengthened the **cascading-use/waste-hierarchy** principles for woody biomass. For farmers, this mainly translates to **more documentation,** and therefore administrative work, demanded by buyers (voluntary scheme audits, land-status confirmations, proof residues/energy-crop status are Annex IX-A). It raises administrative effort at contract signature and periodic audit – especially for **woody residues** feeding pyrolysis or gasification. In summary, supplying energy crops and residues is a source of administrative burden for farmers.

As policy change is beyond the scope of this project and considering that logistics and certification are the largest cost items in the supply of lignocellulosic feedstocks (see next sections), we recommend initiatives that de-risk compliance and transfer the administrative onus to the aggregator.

Considering the above, the set of recommendations proposed for oil crops could be extended to lignocellulosic crops farming. In addition, a key support level is offtake contracting. We also recommend the development of contract templates**.**

Financial challenges and recommendations

Lignocellulosic Crops: For energy crops the farmer's decision hinges on comparative returns versus alternative strategies. Considering that Annex IX/A qualifies only catch crops for biofuel production, the alternative for Northern farmers is fallow land or a non-harvested cover which yields no direct income; therefore, any positive margin from harvesting the cover crop for energy is attractive, yet research shows that Northern farmers may need explicit financial incentives to shift land to dedicated energy cropping. According to survey with farmers in Poland[37], the most common reasons for the lack of interest in cultivating energy crops were the unprofitability of sales or production (32%) and uncertainty regarding continued sales or collection (25%). The results are echoed in Sweden, where farmers quoted low profitability, high-risk investments, and potential negative environmental consequences such as soil depletion as the most prominent barriers.[38]

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[37] Roszkowska, S., Szubska-Włodarczyk, N. What are the barriers to agricultural biomass market development? The case of Poland. *Environ Syst Decis* 42, 75–84 (2022). https://doi.org/10.1007/s10669-021-09831-1

[38] Hedda Thomson Ek, Jagdeep Singh, Josefin Winberg, Mark V. Brady, Yann Clough,

Our research however indicates that the economic gap even for Northern Europe is relatively small. In Northern Europe, a reasonable estimate for unprocessed energy crop biomass (e.g. chopped silage at farm gate) is on the order of €40–€60/t, based on German experience with biogas maize/catch crops. If administrative burdens and regulatory risks are mitigated (see previous section) then the economic gap can be covered by the biomass contract price so that the operation yields a modest (but purely additive) profit for the farmer.

In Southern Europe (e.g., Italy), the situation is more favourable, as climactic conditions allow farmers to add an extra harvest at higher yields, which is purely additional. As a result, lignocellulosic crops can in theory be integrated with minimal support. In Southern Europe, thanks to higher tonnage, unprocessed biomass can be cheaper than the north – Italian cover crop silage has been produced at €25–€35/t fresh.

In conclusion, the lignocellulosic crop production could potentially benefit from similar support mechanisms as oilseed feedstocks, but the level of support is expected to be lower.

Agricultural residues (e.g., straw): residues by definition involve no cost to produce. The economic gap that needs to be covered before a farmer participates in the value chain is (a) replenishment of soil nutrient and organic matter and (b) classical collection, storage and transport of the material to farmgate or torrefaction of feedstock using. The cost to replenish collected organic matter is estimated around €10–€15/t of straw equivalent. The bulk of the operational cost comes from logistics (wages, storage, baling, or torrefaction etc.). The German average supply cost for straw was around €58/t in 2020, and it is highly sensitive to storage requirements[39].

Our **key recommendation** pertaining to lignocellulosic residuals applies here: offtake contracts can assign collection, pre-processing haul and storage services to the aggregator, making it easier for the farmer/collector to enter the supply chain and reducing costs for the entire supply chain as the aggregator has greater economies of scale.

4.5.5. Support measures for aggregators

Aggregators and their role

Aggregators, regardless of value chain, assume the role of collecting biomass, pre-processing it to standardized feedstock (which may include crushing, baling or torrefaction), warehousing the feedstock and supplying to the producer's gate. Critically, Aggregators are also responsible for providing life cycle sustainability certification of the process up to the factory gate that ensures compliance with the RED II/III framework, as well training and agronomic support to farmers. Therefore, they are endorsed with a complicated multi-discipline management role enabling the link between the feedstock producers and the biofuels industrial units.

As independent agents, aggregator business models are similar to those of commodity trading houses. Added value and profitability comes from price risk management, scale, logistics efficiency, certification, and pre-processing. Risks come from regulation, price swings, and logistical failures. Financial needs involve major expenditures for collection, transportation and storage equipment (which may be on balance sheet or leased) as well as working capital for storage between harvest / collection (which can be seasonal) and supply to the industrial unit (which is continuous). From experience, margins for this business model are typically very tight,

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Farmers' motivations to cultivate biomass for energy and implications, Energy Policy, Volume 193, 2024, 114295, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2024.114295
[39] Karras, T., Thrän, D. The Costs of Straw in Germany: Development of Regional Straw Supply Costs between 2010 and 2020. *Waste Biomass Valor* **15**, 5369–5385 (2024). https://doi.org/10.1007/s12649-024-02528-x

and risks are disproportionate. An independent aggregator faces three types of risk, as elaborated below.

Supply-side risks

The dominant supply risk is security of supply, timing of supply and quality, i.e., not being able to secure enough feedstock at the right time, within specifications from an economic collection radius. This may be due to bad harvest, inclement weather during harvesting season, farmers switching to more profitable crops, selling to a competing aggregator or delivering feedstock outside of specifications and energy content. For lignocellulosic feedstocks, this means inconsistent moisture levels, high ash content (from soil contamination), or improper bale density. For oilseeds, it could be low oil content or impurities. The aggregator is responsible for delivering a uniform, on-spec product to the industrial unit, and failure to do so can lead to price penalties or rejection of the entire batch.

Most of these risks can be, in theory, transferred contractually to the farmer; however, the fragility and spa rsity of value chains at this early stage of development limits the aggregator's negotiating power to do so. Thus, we do not expect that aggregators, being the stronger part in this transaction, could transfer the risks to farmers and subsequently no need for relevant support to farmers will be required.

Logistics risks

Storage is a major challenge for aggregators. Stored biomass, especially lignocellulosic, can degrade if not managed correctly, unless it is pre-processed like torrefied which significantly reduces storage capital Oilseeds are more stable but still require specific conditions to prevent spoilage. Storage infrastructure represents a large capital expenditure if on balance sheet or large running costs if leased. Related to this is complexity in logistics: managing numerous collection points, optimizing transport routes, and scheduling deliveries is a complex, low-margin operation, although operational models exist. Fuel price volatility, truck shortages, and equipment breakdowns can severely impact profitability. Finally, operations entail processing / technology risk, as pre-processing equipment (e.g., dryers, chippers, pelletizers) is expensive and can be a single point of failure.

Market & demand-side risks

Margin squeeze may be a dominant risk for independent aggregators. In theory this is manageable contractually facing both farmers and biofuel producers; however, the terms of such contracts are not public. It is stipulated that the producer prefers pricing flexibility as the price of the biofuel depends on market and regulatory factors whereas upstream feedstock suppliers prefer price stability over the medium term (i.e., planting/growing season). While the details are unknown, there is potential for aggregators to assume such price risk. To the extent that aggregators operate in spot markets, the need to warehouse biomass during harvesting / collection seasons and deliver feedstock continually creates an additional price / margin risk, which could be alleviated by insurance schemes that can be purchased to stabilize the risks and volatilities or by creation of a bioenergy carriers hub system. Such risks are exacerbated by the fact that aggregators operate locally, within an economically viable radius of a single biofuel producer.

To mitigate these risks, **aggregators are often conglomerated with either farmers** (e.g., a farming cooperative) **or industrial units** (e.g., in joint ventures). Such schemes remove much of the risks inherent in aggregation of biomass into feedstock. Even so, aggregator operations may require support.

Support recommendations for aggregators

Aggregators' general financial needs both for CAPEX and OPEX can – and have been – covered by existing and mature financing programs. The EU and Member States have provided financial support that benefits feedstock aggregators, mostly by de-risking the supply chain investments and covering initial costs. More recently, some countries are using EU recovery or modernization funds to support advanced biofuel production capacity – which includes feedstock supply infrastructure. For instance, in 2024, the European Commission approved a €500 million state aid scheme in Romania, financed by the EU Modernisation Fund[40]. Several EU Member States have also implemented national support schemes that indirectly support feedstock aggregators. For example, Italy introduced a dedicated incentive for advanced biofuels starting in 2018, providing biofuel producers with tradable certificates (CICs) and premiums for advanced biomethane/biofuels over a 10-year period[41].

At this time, a major hurdle for aggregators remains the cost of RED certification and technical support to farmers. Currently, there are limited direct subsidies or financial aid earmarked specifically for covering these costs. Achieving and maintaining sustainability certification can be costly and complex, especially for smaller aggregators or farmer cooperatives. Conglomeration with larger biofuel producers can make these costs easier to absorb; but smaller aggregators might struggle. For example, and for EU voluntary sustainability schemes under RED, there is a proportional annual fee per ton of certified product, plus a fixed fee for the initial audit. Indicatively, the annual proportional fee is in the order of 0.08 to 0.10 € per tonne of certified product plus 100 to 500 € for issuing the certificate.

Although the existing financing framework involving the EU (EIB, EBRD included) development and commercial banks seems adequate, additional recommended support measures targeted specifically to aggregators might be:

- **Financial assistance or tax credits** to offset certification expenses in order to reduce the barrier to entry for farmer cooperatives (who can be also organized to undertake the role of the aggregator) and smaller aggregators.
- **Group certification** allowing an aggregator to certify a group of farmers or waste collectors under one certificate, reducing administrative burden and cost thus enabling smaller farms to participate in a certified supply chain.

4.5.6. Support measures for industrial units

Industrial biofuel production units are the most difficult to mobilize, mostly because of the large CAPEX requirements, uncertainty in feedstock availability, demand, profitability, and lack of clarity in the regulatory framework in a sufficiently long-term horizon. These factors translate into revenue instability and dubious business models that deter lenders and investors. The real challenge lies in the risk perception of the biofuel market, which remains strongly policy-driven and therefore exposed to a high degree of regulatory uncertainty. In these conditions it is difficult for projects to achieve real bankability.

Support measures consider demand creation (market pull) and financial push mechanisms: one without the other will not suffice. Mandated demand without support could lead to non-compliance or excessive costs; support without a mandate could lead to isolated projects with no market. The next sections outline the key bottlenecks and our recommendations.

[40] https://ec.europa.eu/commission/presscorner/detail/en/mex_24_5045
[41] https://www.ieabioenergy.com/wp-content/uploads/2018/10/CountryReport2018_Italy_final.pdf

Demand creation and market assurance

The survey conducted as part of Task 2 revealed the perceived lack of clear, long-term and gradually increasing deployment trajectories for biofuels across all transport sectors in Europe. RED III sets an EU-wide obligation for advanced biofuels in transport – 5.5% of energy by 2030 from advanced biofuels and e-fuels. This aggregate target is complemented by sector-specific mandates: the ReFuelEU Aviation regulation (agreed 2023) will require increasing percentages of Sustainable Aviation Fuel (incl. advanced biofuels) in jet fuel (e.g. at least 2% SAF by 2025, 6% by 2030, scaling up thereafter), and FuelEU Maritime will impose greenhouse gas intensity reductions on shipping fuels starting 2025, effectively pushing ships to use biofuels or e-fuels. In road transport, the RED framework provides visibility only until 2030, while uncertainty remains beyond that, further compounded by the ban on ICE vehicles from 2035.

The EU has created a guaranteed market floor through these measures, but it is structured around steep incremental targets. This schedule creates a situation where substantial investments are required at each policy-driven “jump” in demand, with limited to no market growth in the interim. This is misaligned with the investment cycles of capital-intensive industries, which require stable and progressive demand growth to ensure return on investment.

Additionally, there is doubt that these mandates are ambitious enough, long-lasting enough and enforced uniformly. The ECA’s recent audit found EU biofuel policy to date had an “unclear route” and needed more clarity and ambition for advanced biofuels[42]. The targets are a step forward, but monitoring implementation is key. Post-2030 targets will be needed soon to extend investors’ visibility and avoid a policy cliff-edge that could freeze investments around 2028-2030. This aligns with industry calls for long-term signals.

In sum, the EU has put in place a framework to mandate demand for advanced biofuels, which needs more operational definition before solving the demand uncertainty that blocks investment. A credible, enforced demand trajectory gives biofuel producers a clear business case. The key is to ensure these mandates are credible and accompanied by enforcement and incentives so that compliance is achieved not by paying fines but by actual fuel uptake.

To support demand certainty, we recommend the following regulatory and organizational measures:

- **Implement RED III advanced fuel target consistently across Member States**. Strictly enforce FuelEU Maritime and ReFuelEU Aviation so that fuel buyers are actively seeking advanced biofuels and respond to leakages or slack with tighter regulation or complementary incentives.
- **Schedule gradual mandated demand ramp-ups** so that it matches investment lifecycles without imposing steep capacity buildups or long periods of underutilization for first movers.
- **Commit to public initiatives that can support demand**. For example, cities and public transit authorities can commit to run municipal buses or waste trucks on biomethane or B100 biodiesel. The EU can incentivize such actions through the Clean Vehicles Directive, which mandates public fleet procurement include a share of clean vehicles/fuels. Likewise, policy can also facilitate offtake contracting by private entities, e.g., major airlines forming consortia to buy SAF from future plants (securing fuel supply for themselves and financing for the producer) in a PPA-style offtake agreement. EIB guarantees can further support such offtake contracts against buyer default and increase its bankability.
- Finally, **start the dialog and commit early to 2040 demand mandates** so that the industry can have much-needed long term visibility.

[42] https://renewable-carbon.eu/news/european-court-of-auditors-foggy-future-for-biofuels-in-the-eu/#:~:text=carbon,available%20on%20the%20ECA%20website

CAPEX De-risking: Grants, Guarantees and Low-Cost Finance

Strong support for initial capital investment is essential to launch advanced biofuel plants, given their high upfront costs and first-mover disadvantages. Several EU-level mechanisms can provide or enable CAPEX support, best provided by direct funding and financial de-risking. Grants (MS programs, JTF, etc.) cover a portion of construction costs, lowering the amount of capital that must be privately financed. Loan guarantees and concessional loans (InvestEU/EIB loans, national development banks, green funds) reduce the cost of debt and improve leverage. Equity investments (e.g. via InvestEU equity, or public-private funds like the CleanTech Invest Fund[43]) can also inject risk-bearing capital. These are front-loaded support mechanisms to get plants built. The existing framework requires little adaptation in order to support the deployment of industrial units.

The existing financing support initiatives might contribute to proper financing of advanced biofuels projects:

- **InvestEU and EIB Loans** – The InvestEU program provides an EU budget guarantee to de-risk investments by the European Investment Bank (EIB) and others. This is already being used to support advanced biofuel facilities. Loan guarantees and soft loans (e.g., for Cepsa[44]) effectively lower the cost of capital and improve debt terms for projects, making financing packages viable. InvestEU's Sustainable Infrastructure window and the EIB's climate lending mandate can be leveraged for advanced biomethanol plants and biomethane facilities. That said, InvestEU alone cannot finance deeply unprofitable projects. Risk capital must complement soft loans and guarantees to cover both risk and funding gaps.
- **Important Projects of Common European Interest (IPCEI)** – An IPCEI on advanced biofuels might allow Member States to collectively support a portfolio of large-scale projects beyond normal state aid limits. This mechanism could facilitate the *"large-scale deployment of advanced biofuels."*[45] Under an IPCEI, national governments can give substantial grants or equity co-investments for projects of strategic EU interest with European Commission approval. This tool is well-suited for integrated value-chains that involve multiple countries. While no biofuel-specific IPCEI has been executed to date, the Commission has indicated openness to IPCEI proposals in clean tech areas.
- **Connecting Europe Facility (CEF)** – The CEF is primarily aimed at cross-border infrastructure, but its *Alternative Fuels Infrastructure Facility* can support installations like fuelling/bunkering infrastructure for new fuels, but not production plant CAPEX directly. It can, however, cover the downstream infrastructure that carries fuels to market (e.g. port storage tanks for upgraded pyrolysis fuel or grid injection upgrades for biomethane). This reduces the overall investment burden on producers and helps ensure market access, indirectly improving project bankability.
- **Just Transition Fund (JTF)** – In regions undergoing fossil fuel phase-out JTF grants could co-finance advanced biofuel plants as alternative economic development, illustrating the regional development benefits. JTF grants would cover part of CAPEX in these regions (likely alongside other funds), with the dual benefit of emissions reduction and economic regeneration.
- **Development Banks** – In addition to EU-level instruments, many projects will blend support from national sources, e.g., grants from national renewable energy programs or loans from national development banks (KfW, Bpifrance, CDP, etc.).

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[43] https://www.eif.org/what_we_do/equity/cleantech-co-investment-facility/index.htm
[44] E.g., https://www.moeveglobal.com/en/press/the-eib-will-finance-cepsas-2g-biofuels-plant#:~:text=reducing%20EU%20dependence%20on%20fossil,2027
[45] https://www.btgworld.com/media/eohc12bl/industrial-capacity-for-drop-in-advanced-biofuels.pdf

However, as it happened in the phase of penetration of new producing more expensive energy technologies in the electricity and gas sectors, there is need of a **final price support policy in the form of Feed-in-Premiums (or other similar financing vehicles) on price so as to close the gap between fossil fuel price and advanced biofuel price** that is considerable at present even concerning the lower cost biofuels. This measure will result to significant de-risking and thus will promote investments on biofuels production units. Furthermore, this ensures market competitiveness and consumer acceptance while enabling industry development. Consumer acceptance is a major issue for the MS policy implementation, since it is not possible to support significant price increases in fuels, albeit their greener footprint.

Provision of biofuel **price Feed-in-Premiums** to support investments in industrial units; the reason is that these investors face the most significant financial challenges in the value chain.

4.5.7. Support measures for marketers

Across the EU, companies that blend, market and distribute advanced biofuels are essential to turning policy ambition into real decarbonisation. Yet their operations are shaped by fragmented rules, uneven infrastructure, and volatile economics. The challenges differ by fuel type, but a common thread is that administrative complexity and coordination, not technology, are the main barriers to scale.

Sustainable Aviation Fuel (SAF) faces the fastest-growing demand under the ReFuelEU Aviation regulation, which obliges suppliers to provide a rising share of low-carbon jet fuel. The policy is pushing volumes ahead of infrastructure readiness. Most airports in Europe still lack facilities for blending bio-based components with conventional jet fuel, so blending and quality control often take place far from where the fuel is used. This increases transport costs (new installations in tanks and blending facilities), working-capital needs, and the risk that sustainability certificates and physical deliveries do not match perfectly. The EU's new Union Database for Biofuels aims to fix traceability, but book-and-claim systems—where environmental credits can be traded independently of physical delivery—remain inconsistent between countries. Financially, the price gap between SAF and kerosene is still wide and volatile. Without stable support mechanisms or uniform credit systems, fuel marketers bear both price and credit risk, particularly when airlines are reluctant to sign long-term purchase contracts.

Renewable diesel (HVO) and HEFA fuels are more established but still face friction. These fuels could even replace conventional diesel up to 100%, yet many storage terminals and pipelines were designed for older biodiesel types and need costly adaptation. In colder climates, blending strategies must be adjusted to maintain performance, which adds operational complexity. Traceability is also demanding: each batch must prove it comes from sustainable waste or residue feedstocks to qualify for EU incentives. This proof travels through multiple audits and documentation layers, which are interpreted differently in each Member State. Changes in how countries apply double-counting or “advanced fuel” rules can suddenly make a previously compliant product ineligible, leaving suppliers with stranded stock. Financially, the prices of waste oils and fats fluctuate sharply, while sustainability certification ties up working capital—particularly for small distributors who wait months to reclaim taxes or prove compliance.

The deployment of marine biofuels, including biomethanol, require new installations for fuel transport and handling at a considerable scale. The FuelEU Maritime Regulation, setting mandatory greenhouse gas (GHG) intensity reduction targets for ships calling at EU ports, essentially calls for investments in dedicated marine fuel transport and handling infrastructure, such as storage tanks and safety systems for hazardous liquids like biomethanol, crucial for meeting operational and compliance requirements. Biomethanol, increasingly used in shipping and the chemical industry, faces more physical than regulatory barriers. It is a hazardous liquid that requires dedicated tanks, safety systems and trained personnel, yet only a handful of EU ports currently have such infrastructure. Regulations for low-carbon marine fuels are tightening, but standards for measuring greenhouse-gas savings differ between maritime and energy authorities. Suppliers must reconcile detailed production data with voyage-specific emissions reporting—an administrative burden that slows market growth. Price discovery is also limited: few buyers commit to long-term contracts because support schemes and tax treatment differ across Member States. This makes financing storage and logistics risky.

Biomethane—delivered either as compressed or liquefied gas or injected into the natural-gas grid—faces complex accounting rules rather than technical ones. Marketers must track three separate flows: the physical gas, the “green certificates” proving its renewable origin, and the credits used for transport-sector compliance. Because national registries are not yet fully linked, it can take weeks to align deliveries with certificates, exposing suppliers to price swings in renewable-gas credits. In addition, the credibility of emissions reductions depends on how methane leakage and digestate (the fertilizer by-product of biogas production) are measured and reported. Standards differ across the EU, creating uncertainty for investors. Smaller suppliers face the highest audit and collateral costs, as they must comply with energy-market rules while lacking the scale of large utilities.

Policy implications cut across all fuels. The EU’s advanced biofuel market is constrained less by technology than by administrative fragmentation. Harmonizing certification systems and carbon-credit accounting rules across Member States would reduce transaction costs and enable trade. By making sustainability certificates truly interoperable and compliance crediting predictable, the EU can allow blenders and marketers to compete on efficiency and innovation—rather than on the quirks of national regulation. Clear and consistent guidance on how to measure greenhouse-gas savings—whether for aviation, shipping or gas—would give suppliers confidence that their products will retain compliance value over time. Moreover, EU financial instruments could recognize the capital tied up in storage, transport and certification as eligible costs, not just focus on plant construction expenditures support.

It is also noted that marketer’s role is linked indirectly through the broader framework that governs alternative fuels infrastructure deployment, which includes refuelling stations and facilities necessary for delivering biofuels and other alternative fuels to end users. The AFIR (Regulation EU 2023/1804 on the deployment of alternative fuels infrastructure) emphasizes that deployment of publicly accessible alternative fuels infrastructure (including refuelling points) should primarily come from private market investment – in this sense, marketers who provide alternative fuels at the point of sale are critical in this private investment ecosystem[46]. Member States' national policy frameworks must describe support measures for the development of the alternative fuels market, including measures to encourage and facilitate infrastructure deployment and market uptake. Public support is allowed where market conditions require it to catalyse investments in infrastructure before a fully competitive market develops, which can apply to marketers' investments in blending and fuel delivery infrastructure. Overall, and considering the current AFIR framework, financing support to marketers could take the form of grants, tax incentives, preferential loans, and other funding mechanisms included in national policy frameworks, aligned with EU State aid rules. Therefore:

- **Administrative measures to facilitate harmonization** – Streamlining certification systems and carbon-credit accounting rules would reduce transaction costs and enable smoother trade between Member States. Addressing fragmented regulations is essential to lower administrative complexity. Administrative harmonization would allow companies to focus on innovation and efficiency rather than navigating regulatory barriers, thereby driving decarbonization at scale across sectors like aviation, maritime, and road transport
- **Financial support from available instruments** – Recognizing costs tied up in storage, transport, and certification within EU financial instruments would improve funding conditions

[46] See AFIR recital 15, 63 and Articles 14, 15.

and accelerate scaling of sustainable fuels like SAF, renewable diesel, biomethanol, and biomethane.

- **Measures at national level** – Financing for marketers can be mobilized through targeted support measures within national policy frameworks, leveraging direct and indirect incentives, grants, and public-private cooperation facilitated by the AFIR regulation.

4.5.8. Overview of required support

Following the analysis presented above, Figure 4-5 provides an overview of the financing and administrative support needs for the actors along a typical value chain of advanced biofuels. Based on the analysis, it is highlighted that farmers require EU or national feedstock price premiums and competitive tenders like Contracts for Difference for financial support, alongside administrative alignment with CAP crop lists and certification systems. Aggregators need financial assistance for certification and group certification allowances. Industrial units demand strong initial capital investment support, loan guarantees, and biofuel price premiums, coupled with consistent implementation of REDIII targets and demand ramp-ups. Marketers primarily need support for new storage and distribution facilities and harmonization of certification and carbon-credit accounting rules. Overall, this holistic overview connects financial mechanisms and regulatory frameworks essential for enabling actors at each stage to effectively contribute to the development of a sustainable drop-in biofuel market.

A targeted EU-level financing plan should prioritize (a) provision of EU- or national-funded feedstock price premiums to support farmers, and (b) provision of biofuel price premiums to support industrial units; the reason is that these actors face the most significant financial challenges in the value chain. Farmers need to be incentivized to initiate feedstock production, which is essential for establishing a stable supply base and ensuring the entire value chain is activated. Without adequate premiums, farmers may not find it economically viable to switch to or expand biofuel feedstock production. Industrial units require capital support to scale up biofuel production and maintain competitiveness, especially since bio-based fuels must achieve price parity with fossil fuels to attract buyers and compete in the market. Price parity is essential to avoid increasing costs perceived by the end user, thus maintaining market acceptance and support demand stimulation though the relevant policy targets and mandates. On the other hand, aggregators and marketers have generally better access to financing within the current EU framework, so targeting the start (feedstock) and production stages is crucial to overcoming investment barriers and securing the sustainable expansion of the biofuel sector.

The proposed approach is also proven to a large extent, as similar feed-in premium schemes have successfully supported other renewable technologies in Europe, such as photovoltaics (PVs), where feed-in premiums helped to reduce investor risks and incentivize capacity growth by providing a price floor above market rates. Leveraging this model in the area of sustainable advanced biofuels can help balance economic incentives, reduce financial risks, and foster a viable, competitive biofuel market aligned with EU climate goals.

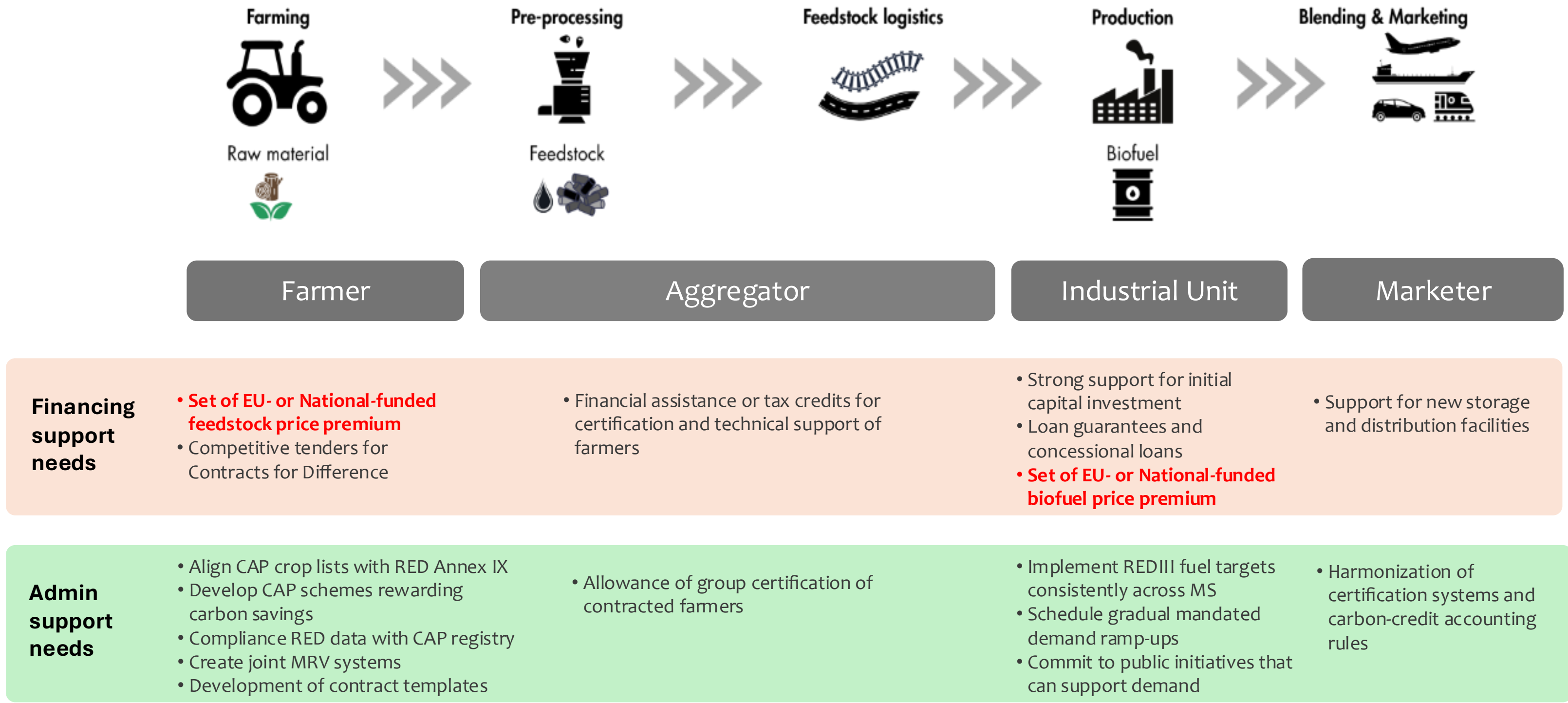

Figure 4-5 Overview of financing and administrative support needs for the actors along a typical value chain of Advanced Biofuels

4.6. Formulation of new collective plans for advanced biofuels value chain

This section reflects the requested analyses, which aims to synthesize the available information from the analysis of the work performed in Tasks 2 and 3 and to **formulate a collective plan for financing of integrated advanced biofuels value chain projects**. The collective plan approach will be applied to the 4 distinct integrated value chains, as these were selected following the analysis in the previous Sections.

The collective plans are addressed to the **whole EU as an area**, including the critical regional characteristics and efficient sizes at each value chain stage, for intervention and opening/ mobilization of the relevant markets of biomass feedstocks and advanced biofuels as final drop-in products for the three main transport sectors: road, aviation and maritime. On the other hand, the necessary financing support is considered to satisfy the needs of integrated value chains in compliance with the EU acquis.

4.6.1. Overall approach: target the reduction of the final price

A robust plan to finance advanced biofuels industrial value chains must prioritize the creation and opening of a nascent market of advanced biofuels, with a primary goal of accelerating market uptake by end users—ultimately displacing fossil fuel comparators. This approach means channelling financial support not just into isolated project nodes, but strategically targeting coordinated, cross-value-chain actions that lower entry barriers, de-risk investments, and catalyse technology deployment at commercial scale. Experience and analysis across the EU and internationally confirm that **the persistent cost gap with fossil fuels are critical deterrents that hinder the sector's** growth from pilots and isolated investments to meaningful industrial deployment.

Although, and as the analysis of Subtask 3.2 suggests, there are different support conditions at each stage of the value chain (e.g. high capital expenditures and uncertain market demand for the industrial unit of biofuels production, high operating expenditures for the aggregators, regulatory gaps for farmers, and so on), an integrated financial support mechanism should be designed considering the full value chain characteristics—encompassing feedstock production, aggregation logistics, conversion technologies, and downstream distribution—while deliberately avoiding interventions that cause price distortions, especially upstream in the feedstock market.

In addition to these considerations, it is important to note that the comprehensive support structure proposed for the advanced biofuels value chain is not currently available through any existing European or national programme. While mechanisms within frameworks such as the Common Agricultural Policy (CAP), InvestEU, or other sectoral funds can potentially offer partial or indirect financing for certain segments—such as R&D, rural development, or large-scale innovation—they are not designed to deliver targeted, cross-value-chain interventions that address the unique barriers to industrial market formation and broad-scale uptake of advanced biofuels. As highlighted in analysis of Subtask 3.1 and other recent policy and evaluation documents[47,48], gaps and fragmentation in support programmes persist, with current instruments often narrowly focused, oriented towards generic investment promotion and single-technology demonstration.

Direct or poorly targeted subsidies aimed solely at upstream segments risk inflating biomass prices, triggering competition with other sectors (and especially food and feed) and potentially

[47] European Court of Auditors, The EU's support for sustainable biofuels in transport: An unclear route ahead, Special Report, 2023
[48] EIB, Financing sustainable liquid fuel projects in Europe: Identifying barriers and overcoming them, 2024

reducing the system's overall sustainability and economic efficiency. Instead, support measures should combine instruments such as those presented in Subtask 3.2, including investment de-risking tools such as CfDs, FiT, etc. These latter tools have been extensively adopted in the first periods of penetration of renewable electricity and biomethane projects.

These should be complemented by dedicated project development assistance, transparent sustainability certification, and measures that enhance liquidity and reduce offtake risk throughout the value chain. Such a portfolio reduces market risks and gives investors reliable long-term frameworks, while keeping feedstock prices stable by not artificially boosting upstream demand or creating windfall profits for biomass growers. This balanced, value-chain-oriented financial support framework ensures the sector's growth is maximized efficiently, competitively, and sustainably.

The project's intervention area is intentionally set as additional to existing programme channels, avoiding overlap with their activities. Instead, it aims to test an **innovative, integrated approach** designed to address the specific market barriers hindering the commercial rollout of advanced biofuels. Its methods and scale extend beyond the reach of CAP, InvestEU, and comparable schemes. By doing so, the initiative complements rather than replicates current funding mechanisms, targeting unmet needs in market and value chain development while delivering strong added value for decarbonisation and the wider energy system.

4.6.2. Determination of the overall support needed per value chain

Task 2 has carried out a detailed assessment of the Levelized Cost of Production (LCoP) for the selected Integrated Value Chains (IVCs). This analysis included a comprehensive sensitivity assessment to evaluate how variations in key parameters—such as feedstock price, capital expenditure (CAPEX), and operational expenditure (OPEX)—affect overall production costs. Among these factors, feedstock price emerged as the most critical driver of cost fluctuations, highlighting its central role in determining the economic viability of advanced biofuel production.

Building on these findings, it is possible to estimate an indicative level of total financial support required across the entire value chain. This support level reflects the cumulative intervention needed to bridge the cost gap and make production competitive, and it can be allocated proportionally across different stages of the value chain as described above. Such an approach ensures that support measures are both targeted and balanced, addressing critical cost drivers while fostering efficiency and stability throughout the chain.

Table 4-6 provides an overview of the 4 selected distinctive IVCs to focus and develop collective financing plans, also presenting the key industrial and economic indicators for each one, as these have been determined in the analysis of Task 2. In particular,

- **Feedstock** refers to the biomass or biologically-derived material (oils and fats—such as vegetable oils, waste oils, or animal fats—lignocellulosic materials) used as the main input for producing biofuels. The annual input in tonnes of feedstock for a typical industrial unit converting this feedstock into biofuel, is also provided.
- **Output** indicates the amount of finished biofuel product produced by a typical industrial unit each year.
- **Sector** denotes the transport segment where the produced biofuel is primarily consumed.
- **CAPEX** stands for capital expenditure, representing the total upfront investment required to build a typical industrial facility converting the specific feedstock into the considered biofuel.
- **OPEX** is the operational expenditure, signifying the ongoing yearly costs of running and maintaining the industrial unit. OPEX values reported do not consider feedstock cost.
- **Feedstock Price (FP)** denotes the cost of securing the raw material needed for the

considered conversion process.

- **Levelized Cost of Production (LCoP)** – provided in Table 4-7 – is an indicator closely related to the eventual price per unit energy of product delivered, not including subsidies or profit margins.

Following the analysis of Subtask 3.2, for each of the considered IVCs **two main financing supports are considered**:

- **Financing farmers to mobilize them** to cultivate the necessary oil or lignocellulosic feedstock crops, or to incentivize them to shift their current cultivation to crops eligible for production of advanced biofuels.
- Needed overall support that is determined by considering what would be the required reduction in the LCoP so as the particular **biofuel to reach close to a parity with its relevant fossil fuel comparator**., This type of support is envisaged to be provided to the industrial units, which have to pay the farmers and/or aggregators the required amount of money so as to deliver the needed feedstock mix at the plant gate, and then to deliver biofuels to marketers at competitive prices.

Nr.	Industrial Value Chain	Feedstock type[49]	Feedstock Price	Product	Sector	Output of a typical unit	CAPEX and OPEX of a typical unit
IVC2	**Hydrotreatment (HVO/HEFA) of oil from eligible oil crops**	Oil crops An. qt 595 kt/yr	880 €/t (UCO)	HVO, HEFA Biodiesel	Aviation Road	500 kt/yr fuel pool capacity[50]	CAPEX 770 m€ OPEX 156 m€/yr
IVC8a	**Biomass gasification and methanol synthesis**	Lignocellulosic crops, residues An. qt 288 kt/yr	66 €/tn	Methanol	Maritime	145kt/yr (MeOH)	CAPEX 353 m€ OPEX 27 m€/yr
IVC7	**Eligible crops production of advanced biomethane**	Lignocellulosic Crops, agricultural residues, manure An. qt 13 ktn/yr	50 -70 €/tn	Biomethane	Road Maritime	4 mNm^3/yr	CAPEX 16.3 m€ OPEX 1.12 m€/yr
IVC13b	**Pyrolysis and upgrading for maritime sector**	Lignocellulosic crops, agricultural residues An. qt 93 ktn/yr	44 €/tn[51]	HPO	Maritime	25 kt/yr (FPBO) or 10 kt/yr (HPO)*	CAPEX 56.5 m€ OPEX 4.23 m€/yr

**Assumption: 8 decentralized FPBO units of 25 kt/yr serving 1 centralized HPO unit*

Table 4-6 Key industrial and economic indicators of the selected distinct IVCs

Estimation of financing support for farmers and aggregators

The need for financing support (€/tn of produced feedstock) addressed to farmers in the upstream part of the value chains (i.e. for farmers and aggregators) has been determined in approximation in Annex 1 as shown below:

[49] Calculated on the basis of a typical industrial unit overall output yield
[50] HVO+HEFA+Naphtha+LPG
[51] Agroprocessing residues

- Oil-crops: in the range of **25-40 €/t**
- Lignocellulosic crops: in the range of **11-18 €/t**

These figures reflect the average requirement for the EU farmers and is based on calculations of average prices and costs. The reality is that the central and southern EU farmers might need higher financing support due to the increased cost of production and the immaturity of the feedstock market, whereas in northern and western Europe there are already feedstock markets, but land is less productive for sustainable AB feedstocks. This situation might balance the needed financing support between north and south.

It is worth mentioning that this support is in addition to the relevant support through CAP and is necessary to mobilize the EU farmers either to take the decision to be involved in the feedstock production, as specified by the RED II/III, or shift from other crop cultivations. It should be considered as a mobilization support measure for farmers and not as a tool contributing to reduction of feedstock prices. Under such a financing support measure, we may assume that there will be increased number of farmers wishing to participate in contracts with industry and aggregators. This means that the price might slightly decrease and at least remain stable. This is a reasonable assumption we made in this study.

Estimation of financing support for industrial units

Task 2 has compared the LCoP of the biofuel of each considered ICV with the price of the relevant fossil fuel with which the concerned biofuel would “compete” in the market. Fossil fuel prices, also considered within the analysis of Task 2, are based on available market information and adjusted over the life of the project under the same inflation assumptions.

In this section the minimum support required by each IVC in focus, at the producer level is estimated. The feedstock cost at the producer’s gate is assumed as shown in Table 4-6 and any support required to achieve this feedstock cost is discussed in Annex 1.

The minimum necessary support for producers (industrial unit) on a levelized basis is shown in Table 4-7 and is calculated as the difference between the levelized cost of production and the corresponding fossil fuel price, in €/MWh.

We consider two market price scenarios for the produced biofuel, in line with the model developed in Task 2: (1) the biofuel is priced at parity with fossil fuels incorporating the carbon price and RED III penalties, and (2) biofuel is priced at parity with fossil fuels including carbon (EUA) but without penalties. The logic behind these assumptions is twofold: on one hand, we expect that biofuels are likely to be priced at parity to fossil fuels so that social and inflation costs are kept under control for the end consumer (which is a politically reasonable assumption). At the same time, we acknowledge that currently planned penalties are perceived by producers with some regulatory uncertainty, partially because of the political cost they entail. Considering the two scenarios bounds the biofuel price range and required support.

Considering the recommendation in Section 5.5, i.e., that FiP and other price support mechanisms are awarded with competitive bidding to prevent market distortion and overcompensation, it is reasonable to compare a production cost estimate for biofuel to the market price of the fossil equivalent. The support figure estimate includes no margin for the producer and provides a lower bound.

Even though the estimates are expressed in €/MWh it does not mean that they would be delivered as price support measures. They apply to the levelized cost of production which includes CAPEX and OPEX. Identifying the optimal split of the levelized support in the various instruments outlined in Section 1.6 (i.e., between CAPEX and OPEX) depends heavily on the specifics of the value chain and cannot be estimated constructively as a general case.

Table 4-7 provides a summary of levelized production cost (LCoP) comparisons for the considered IVCs against their fossil fuel counterparts, highlighting the degree of cost reduction needed to achieve parity at the level of final product, as well as the indicative financial support in €/MWh required for each pathway so as to achieve parity in the price of the final product.

Nr.	Industrial Value Chain description	LCoP (biofuel)	Fossil Fuel Comparator[52]	Reduction of LCoP	Indicative minimum support in monetary value
IVC2	**Hydrotreatment (HVO/HEFA) of oil from eligible oil crops**	138 (slate 1[53]) – 195 (slate 2[54]) €/MWh	131 (slate 1 equiv.) – 120 (slate 2 equiv.)[55] €/MWh	of the order of 5% (slate 1) - 40% (slate 2)	min. 7 €/MWh (slate 1) - 75 €/MWh (slate 2)
IVC8a	**Biomass gasification and methanol synthesis**	121.4 €/MWh	85 (VLSFO E) – 150 (VLSFO E+P) €/MWh	of the order of 30%	min. 36 €/MWh
IVC7	**Eligible crops production of advanced biomethane**	129.4 €/MWh	108 (CH4 E, road) – 135 (CH4 E+P, maritime) €/MWh	of the order of 16%	min. 21 €/MWh
IVC13b	**Pyrolysis and upgrading for maritime sector**	173 - 202[56] €/MWh	85 (VLSFO E) – 150 (VLSFO E+P) €/MWh	of the order of 50 – 60%[57]	min. 88 – 117 €/MWh [58]

Table 4-7 Levelized cost of production of biofuels and indicative minimum support per selected IVC

This amount constitutes the minimum support. It can be considered that the minimal level of financial support provided is based on the structure of competitive auctions, where support is determined by the minimum price bids submitted by eligible participants. In this approach, bidders compete to offer the lowest price at which they can deliver the required output, and support is granted to the lowest accepted bid. The competitive bidding mechanism ensures that public funding is allocated efficiently, aligning support levels with actual market conditions and cost structures rather than administratively determined or theoretical margins.

Results of Table 4-7 indicate that:

- The versatility of the final fuel pool in the hydrotreatment processes (IVC2) results into a different requirement for support. An HVO-focus product profile would require minimal support and actually this is further corroborated by the market analysis performed within the frame of the previous study59 where it was found that enough capacity of such industrial units is already planned for 2030 in Europe. On the other hand, sustainable fuel production

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52 ***E*** indicates consideration of EUA costs in the final price; ***P*** indicates consideration of the additional cost due to penalties of non-compliance with the REFuelEU Aviation or FuelEU Maritime Regulations (depending on the IVC) – see analysis of Task 2

53 Production profile resulting to mainly HVO: 66% HVO - 12% HEFA – 2% Naphtha – 6% LPG

54 Production profile resulting to mainly HEFA: 29% HVO - 46% HEFA – 4% Naphtha – 3% LPG

55 Based on the analysis of Task 2, road diesel is considered at 135 €/MWh, Jet fuel with EUA costs at 110 €/MWh and jet fuel with EUA cost and penalties at 300 €/MWh

56 Range depends on H2 cost for the upgrading

57 In case the fossil fuel price is considered including the penalties, a reduction of 13 – 25% in the LCoP is needed.

58 In case the fossil fuel price is considered including the penalties, the indicative support need is 23 – 52 €/MWh.

59 https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/development-outlook-necessary-means-build-industrial-capacity-drop-advanced-biofuels-2024-02-07_en

for the aviation market needs support of the order of 40% in terms of LCoP so as to match fossil jet fuel market competitiveness.

- Biomass gasification to methanol and maritime fuels (IVC8a) feature lower cost reduction margins, with indicative support levels of the order of 36 EUR/MWh for methanol – an overall need to reduce LCoP by ca. 30%. On the other hand, satisfying the maritime market with an alternative drop-in marine biofuel via gasification and upgrading (IVC13b) requires a cost reduction of more than 50% and a support of up to 117 EUR/MWh for maritime fuels). It is noted that the latter IVC cost is significantly dependent on the cost of hydrogen needed for the upgrading of bio-oil to marine biofuel. This is also the only case from those examined that the cost of the produced biofuel is more expensive than its fossil fuel comparator, even in the case penalties of non-compliance with the FuelEU Maritime Regulation are considered.
- The process of use of eligible crops for the production of advanced biomethane via anaerobic digestion and upgrading of the produced biogas to biomethane able to fuel vehicles and ships is already matured enough to require cost reduction in the order of 16% (ca. 21 €/MWh).

4.6.3. Regional examples towards deployment of financial support

Although most of the calculations in this study are based on average EU figures and conditions, the reality and the problems differ given the regional dimension of the EU area. For this reason, we consider that specific emphasis and differentiation should be considered at the stage of specific financing support measures are planned.

The International Energy Agency (IEA), through its Bioenergy Task 39, has undertaken extensive work to compile and continuously update a global database of advanced biofuel demonstration and production facilities, tracking developments since 2009. This comprehensive database catalogues a wide range of technologies –such as Alcohol-to-Jet, Fast Pyrolysis, Fermentation, Gasification, Hydrothermal Liquefaction, Hydrotreatment, etc.– across various facility types and development stages, providing essential details like project status, technology, location, feedstock, and capacity. Information is sourced via contributions from member country experts, partnerships, and verified public data, aiming to offer a current and critically reviewed resource that is used by policymakers, researchers, and industry stakeholders worldwide. The database essentially establishes a factual basis for assessing the status and progress of technology deployment and commercialization in the advanced biofuels industry, a sector vital to the EU decarbonization targets and the subsequent energy transition.

Considering projects related to the selected distinct IVCs for the development of the collective financing plans, a list of the available (operational) and planned (incl. those being under construction) industrial units can be extracted[60]. Figure 4-6 provides a map with the location of these units in Europe.

It is evident that almost all of the industrial projects and subsequently the relevant value chains are activated in countries of northern and central-western Europe. On the contrary, south-eastern and central-eastern regions of Europe are not favoured with installations of Advanced Biofuels industries. This reality has been already identified and results from two main reasons:

Financing and other support measures are adequate and encouraging enough in the countries of AB activity. Availability of necessary feedstock at affordable prices is easier and relevant

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[60] Selection criteria: TRL 8-9; Technology: Fast Pyrolysis, Fermentation, Gasification, Hydrotreatment; status: planned, under construction, operational; Raw material: agricultural residues, forest residue, lignocellulosic, oilcrops-oil and fats, organic residues and waste streams, sugar and starch crops; Output: bio-oil, biogas, diesel-type hydrocarbons, diesel with biogenic content, ethanol. FT liquids, gasoline-type fuels, methanol, pyrolysis oil, renewable diesel (HVO), SAF

mature markets exist in some of the northern and western European countries. The transportation cost of biomass feedstock is probably the most significant component in the total feedstock supply cost and for this reason the siting of industrial units should optimize this cost. So, in most cases we may not consider transportation of elaborated or raw biomass feedstock to long distances and therefore we need development of local value chains in the areas where we do not have AB production, but there are biofuels demand and feedstock potential. To this end, it is evident that we need higher "encouragement" through financing support, which is also accompanied by supporting infrastructure like bioenergy carriers' hubs, in the areas of lower or non-AB production activity.

Figure 4-6 Production facilities of distinct advanced biofuels in Europe

This support should be in principle driven to the first stage of the value chain that is the production and collection of necessary biomass feedstock, whereas we do not expect that the aggregators and industrial process activities will face regionality obstacles within the EU. However, it should be mentioned also that the rehabilitation of existing industrial facilities to being able to accept biogenic feedstock might favour the sites where these installations are established today. Therefore, industrial units based on **hydrotreatment of oil from crops** (i.e. IVC2) can be found in several regions across Europe, particularly in Italy, France, Spain, Sweden, the Netherlands, Finland, Austria, i.e. in countries with significant refining capacity, and are planned in other countries. These units utilize feedstocks such as oil crops, oils and fats, used cooking oils, and various waste oils to produce HVO (Hydrotreated Vegetable Oil) and sustainable aviation fuels (SAF) through hydrotreatment or, in some cases, co-processing technologies. These regions have leading roles in hydrotreatment technology deployment for biofuel production from crops and waste oils, and their facilities are either operational or in advanced planning stages according to the relevant IEA database.

On the other hand, industrial units converting **lignocellulosic crops and agricultural residues** are distributed across several regions in Europe, notably Austria, Norway, France, Sweden, Denmark, Finland, and the Netherlands. **Forestry residues** are specifically considered and prioritized in Finland, Sweden, Austria, Norway, and the Netherlands, where several commercial and demonstration-scale facilities process forest-derived biomass, indicating these countries as key areas of focus for forestry-based biorefineries.

Considering the above information, the map of Figure 4-7 can be developed specifying the regions with developed hydrotreatment of crops and regions with developed lignocellulosic crops treatment or both of them.

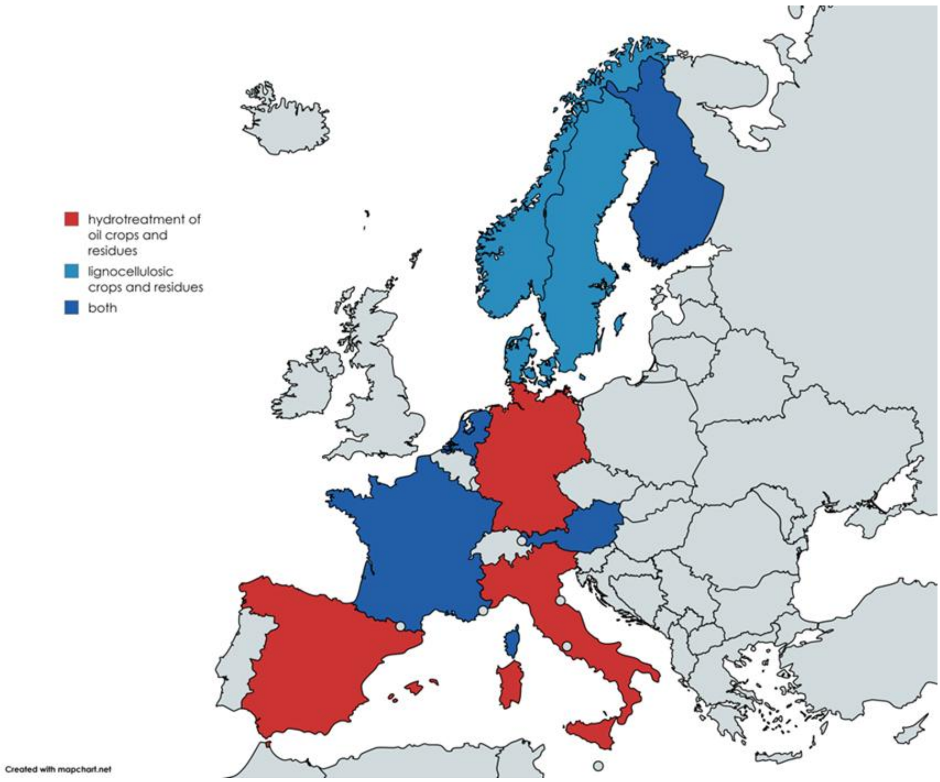

Figure 4-7 European map of developed lipid and lignocellulosic value chains

Hydrotreatment of oil crops mainly takes place in Spain, France, Italy, the Netherlands, and Finland because of a combined set of strategic industrial, infrastructural, and feedstock availability factors. In more detail:

- **Existing Refinery Infrastructure and Expertise:** These countries host major, modern oil refineries operated by companies like ENI (Italy), Total (France), Neste (Finland, Netherlands), and Repsol (Spain). These refiners have invested in adapting existing petroleum refining infrastructure to hydrotreating renewable oils (HEFA). The integration in existing refinery complexes lowers capital expenditure and operational complexity compared to building fully new standalone plants. For example, Neste's Porvoo refinery in Finland and Rotterdam refinery in the Netherlands are highly versatile and efficient, able to co-process renewable and fossil feedstocks within the same units. ENI's and Total's refineries similarly integrate hydrotreatment processes for oils from crops and waste streams.

- **Feedstock Availability:** Southwestern European countries such as Spain, France, and Italy have agricultural sectors that produce significant volumes of oil crops (e.g., rapeseed, sunflower) and generate large quantities of waste oils and animal fats. This local availability supports industrial units relying on these feedstocks. Northern countries such as Finland, despite less crop oil production, benefit from access to large volumes of waste oils, tall oils (a by-product of pulp and paper industries), and animal fats, partly due to strong forestry and biorefinery sectors. The Netherlands acts as a logistics hub, combining local feedstock availability with import capacity via port infrastructure.

Lignocellulosic crops and agricultural residues are mainly exploited as feedstock for biofuels in France, the Netherlands, Denmark, and Scandinavia because of specific factors related to biomass availability, infrastructure, policy incentives, and market demand, more specifically:

- **Abundant Availability of Biomass Feedstocks**: These regions have extensive agricultural and forestry sectors that generate large volumes of lignocellulosic biomass and agricultural residues. France has significant forest biomass alongside agricultural residues. Scandinavian countries (Sweden, Finland, Denmark) have strong forestry industries producing residues like sawdust, logging residues. The Netherlands benefits from both local agricultural residues and imported biomass, supported by advanced logistics and port infrastructure
- **Infrastructure and Existing Industrial Capacity**: Many biorefineries and conversion facilities are located here due to established industrial capacity for biomass handling and processing. For example, Scandinavian countries have mature wood processing industries and facilities enabling the use of forestry residues for biofuel production (ethanol, pyrolysis oils). The Netherlands serves as a hub for biomass import, storage, and conversion.

4.6.4. Collective plan

The previous study on "Development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels"[61] investigated the factors influencing the industrial growth of advanced and sustainable biofuels production, in the context of the relevant EU policy and regulatory framework and aiming at reaching the set EU targets. In that framework, the needed advanced biofuels capacities to meet the 2030 targets where determined, considering deployment of all identified industrial value chains[62].

Table 4-8 presents the quantities of advanced biofuels for transport sector, in Mtoe and their equivalent in TWh, needed in 2030 for each of the selected four distinct IVCs as were determined in the afore mentioned study. The aggregated quantities of the distinct four IVCs account for the 60% (14.4 Mtoe) of the foreseen quantities of advanced biofuels[63] needed in 2030. In addition to the selected IVCs, transesterification of lipidic feedstocks[64] resulting to Fatty Acid Methyl Ester (FAME) biodiesel (see IVC1 in Task 1 and 2 analysis) can contribute 6.54 Mtoe in 2030. These quantities have been determined in the frame of Task 4 of the previous

[61] https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/development-outlook-necessary-means-build-industrial-capacity-drop-advanced-biofuels-2024-02-07_en
[62] Identification of the industrial value chains was made on the basis of the consolidated actual data from industries and industry associations engaged in technology development, biofuel production, and distribution, as well as on the grounds of a survey targeted to significant industry players (see also analysis of Task 1 in this project)
[63] RED Annex IX Parts A and B
[64] Oil crops (cultivated as intermediate crops or on severely degraded land), as well as residual and/or waste lipids (UCO, brown grease, animal fats, tall oil pitch, POME, SBEO)

related study, considering (a) the total demand of biofuels in 2030 based on the current policies, and (b) the current and expected growth trends in the capacity of each industrial value chain/pathway[65].

It is noted here that deployment of IVC1 (FAME) does not need additional operational support, since following the analysis of the respective business models in Task 2, its LCOP is lower than that of the fossil fuel comparator (mostly diesel for road transport).

Considering the quantities of Table 4-8 and the monetary support determined in Table 4-7, it is possible to estimate the collective monetary support per IVC, aiming to produce the biofuels quantities needed to meet the climate targets of 2030. This support should be provided annually and according to the analysis presented earlier in this chapter, a suitable Feed-in-Premium (FiP) scheme seems to be the more appropriate means.

Table 4-9 presents indicative collective support expressed in million EUR for the selected distinct IVCs. This support should be considered that is implemented as a FiP at the level of final wholesale price of biofuels for the whole quantities of consumed biofuels. This FiP does not include potential additional fuel distribution costs which have not been considered in this study.

Industrial Value Chain	2030 advanced biofuels quantities	
	Mtoe/yr	TWh/yr
IVC2 Hydrotreatment (HVO/HEFA) of oil from eligible oil crops		
hydrotreatment of UCO and AF (animal fats)	1.58	18.38
hydrotreatment of intermediate crops	2.42	28.14
hydrotreatment of tall oil	0.21	2.44
Subtotal IVC2	*4.21*	*48.96*
IVC8a Biomass gasification and methanol synthesis		
gasification + methanol	1.37	15.93
IVC7 Eligible crops production of advanced biomethane		
Total anaerobic digestion (Annex IX A and B)	7.85	91.30
IVC13b Pyrolysis and upgrading for maritime sector		
Pyrolysis of agriculture residues	0.95	11.05

Table 4-8 Quantities of advanced biofuels, in Mtoe and in MWh, needed in 2030 in each of the selected four distinct IVCs

Hydrotreatment (focused on HEFA production for the aviation market) of oil crops requires the highest indicative minimum support of 3,672 million EUR. HVO production following the processes of IVC2 require considerably lower support as compared to the case of HEFA, approximated at 342 million EUR. Support for pyrolysis and upgrading for maritime biofuels depends on the cost of hydrogen needed in the process and estimated support can reach almost 1,300 million EUR. Biomass gasification/methanol synthesis require comparatively less support, while advanced biomethane lies in the mid-range.

[65] For further information, please see: https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/development-outlook-necessary-means-build-industrial-capacity-drop-advanced-biofuels-2024-02-07_en

Industrial Value Chain	Indicative collective minimum support in monetary value (mln.€/yr)	Indicative number of units
IVC2 Hydrotreatment (HVO/HEFA) of oil from eligible oil crops	from 343 (slate 1) to 3,672 (slate 2)[66]	11-15[67]
IVC8a Biomass gasification and methanol synthesis	580	20
IVC7 Eligible crops production of advanced biomethane	1,954	2,300
IVC13b Pyrolysis & upgrading for maritime sector	from 972 to 1,293 (range depends on the cost of H2 for the upgrading process)	40

Table 4-9 Indicative collective support in monetary value (million EUR/yr) for the selected IVCs for industrial units development, 2030

It is noted that, considering the broader macroeconomic picture, and considering that one way or another the climate targets for 2030 are met, meaning that the required biofuels quantities per IVC will be indeed consumed by the end-users, the estimated indicative collective support for each IVC does not constitute an additional amount of money; the current proposal is based on the fundamental requirement to have these fuels introduced to the market at a (levelized) price close to that of their fossil fuel comparator – in this sense, the gap between the market price of fossil and market price of drop-in bio-fuels is not covered by the demand (i.e. the end-users through a higher price of the final product in the market), but it is covered by a special and fit-for-purpose financing plan addressing the entire value chain. This approach facilitates the EU MS to implement the set RED policies, since significant increases in consumed fuels are not expected, as well the obliged marketers and consumers (airlines, ships, trucks, etc.) to adapt to fuels of lower GHG emissions.

Based on the annual quantities of biofuels required to reach the 2030 target, and considering the key characteristics (e.g. output production, feedstock quantities needs, etc.) of a typical plant for each IVC (see Table 4-6), it is possible to estimate the number of plants required so as to reach the total production output. It is noted that the analysis is based on mean /average figures following the business models studied in Task 2 and therefore results should be considered as providing a ballpark estimation of the needs (financing and/or number of industrial units). Therefore, it is estimated that the following number of industrial units should be operational in 2030 per IVC:

- IVC2: 11-15 industrial units for the production of HVO/HEFA for road and aviation
- IVC8a: 20 industrial units of biomass gasification and methanol synthesis, targeting maritime sector
- IVC7: ca. 2300 units of Anaerobic digestion units for the production of biomethane
- IVC13b: 40 industrial units of pyrolysis delivering upgraded HPO for the maritime sector

[66] Slate 1 and 2 refer to different industrial units configurations, see Table 4-7
[67] The range is due to the fact that the share of HVO and HEFA in the fuel pool of the relevant industrial units varies

The analysis of the aforementioned study[68] had identified that, based on the plans of the relevant industry, there will be enough capacity of HVO/HEFA industrial units (IVC2) to meet the required relevant demand in 2030; this assessment is also corroborated from the analysis of Task 2 of this project where 15 units existing and a few more planned, have been identified. However, recent developments regarding the scale back of relevant biofuels projects[69], indicate that still some support will be needed for facilities of IVC2 so as to create conditions that will help the avoidance of additional biofuel projects cancellation.

On the other hand, both the analysis of Task 2 (maturity of IVC) and the work in the previous study, indicate that there is indeed a gap between the existing and announced industrial units under IVCs 8a, 7 and 13b, and the relevant required quantities for the 2030 targets. In this regard, support to these IVCs would be crucial for the realization of the necessary investments.

Additional to the support needed for the industrial unit under the prism of achieving price parity with the corresponding fossil fuel comparators for each IVC, support will be needed in the upstream part as well. Section 4.6.2. presented the indicative support for the two types of feedstocks considered in this analysis, and considering the needs for fuels coming from each IVC (Table 4-8) and the specific characteristics of each one (Task 2 and Table 4-6), the collective support needed (i.e. to secure mobilization of the required feedstock quantities for the biofuels needed to achieve the policy targets) can be determined, see Table 4-10.

Industrial Value Chain	Indicative collective minimum support in monetary value (mln.€/yr)
IVC2 Hydrotreatment (HVO/HEFA) of oil from eligible oil crops	ca. 157 – 357
IVC8a Biomass gasification and methanol synthesis	ca. 63 – 103
IVC7 Eligible crops production of advanced biomethane	ca. 442 - 724
IVC13b Pyrolysis and upgrading for maritime sector	ca. 38 - 62

Table 4-10 Indicative collective support in monetary value (million EUR/yr) for the selected distinct IVCs for securing the mobilization of the upstream part, 2030

Overall, Table 4-11 provides the estimated indicative minimum collective annual support in monetary value (million EUR/yr) for the selected IVCs as a whole (i.e. under the integrated perspective and considering the entire value chain) in 2030. The table summarizes the derived information into two major level; at IVC level, i.e. considering the needs for support for each actor of each IVC separately, and at the collective plan, i.e. considering the quantities of fuels needed per IVC so as to reach the set EU policy targets of 2030. In particular, the support for farmers is expressed both in terms of EUR per ton of feedstock, as well as EUR per MWh of the final product of the each IVC. The operational support to the industrial unit is expressed in terms of EUR per MWh of the final product of the each IVC.

The total row indicates that the combined support needed across the four industrial value chains amounts to approximately 700–1,245 million EUR per year for securing upstream mobilization,

[68] https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/development-outlook-necessary-means-build-industrial-capacity-drop-advanced-biofuels-2024-02-07_en

[69] See for example recent announcements from BP (bp scales back biofuels ambitions, shelves Rotterdam project amid strategic shift) and Shell (Shell scraps plans for biofuels facility in Rotterdam)

3,849–7,499 million EUR per year for industrial unit development, and a total operational support requirement in the range of 4,548–8,744 million EUR per year. This illustrates the overall financial scale of the selected IVCs, showing that aggregated needs are substantial and span nearly an order of magnitude, reflecting both the variation in project configurations and the high capital intensity across the technologies.

Additional information on the support estimated for the selected IVCs for 2040 is provided in Annex 2.

Overall, the financing support for the production of biofuels includes the following components:

1. **Financing support mobilizing farmers** that is proportional to produced feedstock quantities in the form of FiP or production subsidy in €/tn and is absorbed at the stage of agricultural production not influencing the final price.
2. **Financing support to industrial units** that is proportional to produced quantities of biofuels in the form of FiP in €/MWh and significantly influences the final price to consumers.

The support to farmers, which accounts for approximately 15% of the total financing needs in the biofuel value chains, must be provided through the generation of additional financing streams, as these funds do not currently exist. This upstream support is essential to mobilize feedstock production and is typically delivered as feed-in premiums or production subsidies proportional to the quantity of feedstock produced, absorbed at the agricultural production stage without impacting the final biofuel price. On the other hand, support to industrial units, which represents about 85% of the total financing needs, **primarily constitutes a redistribution of existing financing flows**. Instead of consumers facing increased prices for the final biofuel product, this support—potentially funded through mechanisms such as carbon pricing revenues—helps maintain price parity between biofuels and fossil fuels at the point of sale. This ensures market competitiveness and consumer acceptance while enabling industry development.

Industrial Value Chain	IVC level			Collective plan		
	Support to farmers (€/t)	Support to farmers (€/MWh)	Operational support to the industrial unit (€/MWh)	Support for securing the mobilization of the upstream part (mln.€/yr)	Support for industrial units development (mln.€/yr)	Total support for the operation of the entire IVC (mln.€/yr)
IVC2 - Hydrotreatment (HVO/HEFA) of oil from eligible oil crops	25 – 40	3.2 – 7.9	min. 7 - 75	ca. 157 – 357	from 343 (slate 1) to 3,672 (slate 2)[70]	ca. 499 - 4,029
IVC8a - Biomass gasification and methanol synthesis	11 – 18	4.0 – 6.5	min. 36	ca. 63 – 103	580	ca. 643 - 683
IVC7 - Eligible crops production of advanced biomethane	11 – 18	4.8 – 7.9	min. 21	ca. 442 - 724	1,954	ca. 2,396 – 2,678
IVC13b - Pyrolysis and upgrading for maritime sector	11 – 18	3.4 – 5.6	min. 88 – 117[71]	ca. 38 - 62	from 972 to 1,293[72]	ca. 1,010 – 1,354
TOTAL[73]	-	-	-	**700 – 1,245**	**3,849 – 7,499**	**4,548 – 8,744**

Table 4-11 Indicative collective support in monetary value (mln.€/yr) for the selected distinct IVCs, 2030

[70] Slate 1 and 2 refer to different industrial units configurations, see also Table 4-7.
[71] In case the fossil fuel price is considered including the penalties, the indicative support need is 23 – 52 €/MWh. Please note that IVC13b is the only one of those selected where the produced biofuel is still more expensive even in the case of considering both EU ETS and compliance penalties costs for the fossil fuel.
[72] Range depends on the cost of H2 for the upgrading process.
[73] Total refers to the sum of the selected 4 IVCs.

The support identified for the four distinct IVCs can be effectively considered suitable for other selected essential IVCs of Task 1 not analysed in detail in the present Task 3, due to several key factors. First, the types of feedstocks covered—oil crops, lignocellulosic crops, and agricultural residues—are integral to virtually all biofuel value chains, making the upstream support measures widely applicable. These feedstock categories form the basis of diversified biofuel production pathways across the EU, ensuring relevance beyond the analysed cases. The proposed mobilization support to farmers to stimulate the shift towards biofuels feedstock cultivation is essential to initiate the upstream part the value chain irrespective of the conversion technology and the final fuel market a said IVC targets. Second, the operational support aiming to maintain price parity between final biofuels and fossil fuels aligns well with the technological and market realities of all other IVCs. This approach is essential not only for the four selected IVCs but also for the less mature (following the argumentation presented in section 5.5.3) as well as the expected post 2040 technologies, ensuring competitiveness without increasing the final consumer price. Furthermore, as detailed in the analysis, **the selected distinct IVCs collectively account for approximately 80% of the needed advanced biofuel volumes**[74] required to meet the EU 2030 targets, indicating that the associated support levels sufficiently cover a major portion of market needs toward the achievement of policy milestones.

In 2040, the needed quantities of advanced biofuels to meet the respective targets are almost 50% higher than the needs in 2030. Aligned with the analysis of Task 1 of the present work, these increased needs naturally bring more IVCs at the spotlight in the 2030 – 2040 period. Table 4-12 presents the quantities of advanced biofuels, in Mtoe and in MWh, needed in 2040, for the selected as essential IVCs in Task 1. The aggregated sum of the quantities presented in Table 4-13 accounts for approximately 65% of the needed quantities of advanced biofuels for the target year 2040. The remaining 35% would come from IVCs for which there is significant uncertainty with respect to their expected maturity level (see also respective analysis of Tasks 1 and 2).

Following the same approach as for the determination of the indicative collective support for the selected distinct IVCs in 2030, Table 4-13 provides the estimated indicative minimum collective annual support in monetary value (million EUR/yr) for the essential IVCs as a whole (i.e. under the integrated perspective and considering the entire value chain) in 2040. The table presents data at IVC level, i.e. considering the needs for support for each actor of each IVC separately, as well as at the collective plan level, i.e. considering the quantities of fuels needed per IVC so as to reach the set EU policy targets of 2040. In addition, the support for farmers for the mobilization of the required feedstock in each IVC, is also shown. The overall operational support to the industrial unit is expressed in terms of EUR per MWh of the final product of the each IVC.

The combined support needed for 2040 is approximately 1,704 – 2,805 mln.€/yr for securing upstream mobilization, 11,586 – 17,852 mln.€/yr for industrial unit development, and a total operational support requirement in the range of 13,290 – 20,526 mln.€/yr. This illustrates the overall financial scale of the essential IVCs for 2040. The significantly higher financing needs for the operational support of the industrial units in 2040 is due to the fact that the required advanced biofuels quantities to meet the target comes largely from expensive technologies featuring a high LCOP and thus are in need for greater support to reach parity with their fossil fuel comparator.

[74] Based on the analysis performed in the frame of Task 4 of the previous related study, considering (a) the total demand of biofuels in 2030 based on the current policies, and (b) the current and expected growth trends in the capacity of each industrial value chain/pathway , the four selected IVCs considered to receive support, are considered as critical ones for the additional reason that they collectively can provide approximately the 80% of the additional -based on the currently planned industrial capacity expansion- total quantities of advanced biofuels needed to reach the set 2030 policy targets. In particular, the four selected IVCs can provide 8.28 Mtoe/yr in 2030 out of the additional 10.6 needed based on the prevailing policy scenario.

Nr.	Industrial Value Chain	2040 advanced biofuels quantities	
		Mtoe/yr	TWh/yr (10^6 MWh/yr)
IVC2	**Hydrotreatment of lipids**	1.01	11.75
IVC5+ IVC6	**SAF production from Cellulosic Ethanol (EtOH-to-Jet)**	2.29	26.63
IVC12+ IVC6a	**SAF production from Syngas fermentation Ethanol (EtOH-to-Jet)**	0.29	3.37
IVC7	**Advanced biomethane from anaerobic digestion**	10.48	121.88
IVC9a	**Biomass Gasification and Methanation**	4.88	56.75
IVC9b	**Methanation from biogenic CO2 and H2**	0.69	8.02
IVC8a	**Biomass Gasification and Methanol Synthesis**	3.32	38.61
IVC8b	**Biomethane reforming into Methanol**	2.21	25.70
IVC8c	**Methanol Synthesis from biogenic CO2 and H2**	0.51	5.93
IVC11a	**gasification and F-T synthesis**	1.49	17.33
IVC13a	**Pyrolysis and co-processing for road sector**	1.53	17.79
IVC13b	**Pyrolysis and upgrading for road and maritime sector**	1.53	17.79

Table 4-12 Quantities of advanced biofuels, in Mtoe and in MWh, needed in 2040 for the selected as essential IVCs in Task 1

IVC #	Industrial Value Chain	IVC level			Collective plan		
		Support to farmers (€/t feedstock)	Support to farmers (€/MWh fuel)	Operational support to the industrial unit (€/MWh fuel)	Support for securing the mobilization of the upstream part (mln.€/yr)	Support for industrial units development (mln.€/yr)	Total support for the operation of the entire IVC (mln.€/yr)
IVC2	**Hydrotreatment of lipids**	25 – 40	3.2 – 7.3	7 - 75	27 - 61	59 - 628	85 - 689
IVC5+ IVC6	**SAF production from Cellulosic Ethanol (EtOH-to-Jet)**	11 – 18	9.4 – 15.4	102 – 281[75]	251 - 410	2,717-7,484[76]	2,967 – 7,894[77]
IVC12+ IVC6a	**SAF production from Syngas fermentation Ethanol (EtOH-to-Jet)**	11 – 18	6.8 – 11.1	81 - 172	23 - 37	273 - 580	296 - 617
IVC7	**Advanced biomethane from anaerobic digestion**	11 – 18	4.8 – 7.9	21.4	591 - 966	2,608	3,199 – 3,575
IVC9a	**Biomass Gasification and Methanation**	11 – 18	3.3 – 5.4	19	189 - 309	1,078	1,267 – 1,387
IVC9b	**Methanation from biogenic CO2 and H2**	N.A.[78]	N.A.	16	N.A.	128	128
IVC8a	**Biomass Gasification and Methanol Synthesis**	11 – 18	4.0 – 6.5	36.4	153 - 251	1,405	1,559 – 1,656
IVC8b	**Biomethane reforming into Methanol**	N.A.[79]	N.A.	1.4	N.A.	36	36
IVC8c	**Methanol Synthesis from biogenic CO2 and H2**	N.A.[80]	N.A.	31 – 49	N.A.	184 - 291	184 - 291

[75] Increased to 349 mln EUR considering the higher LCOP value provided by the stakeholders (see also Task 2 discussion).
[76] Increased to 9,281 mln EUR considering the higher LCOP value provided by the stakeholders (see also Task 2 discussion).
[77] Increased to 9,692 mln EUR considering the higher LCOP value provided by the stakeholders (see also Task 2 discussion).
[78] This specific technology exploits a flow of biogenic CO2 and clean hydrogen to produce (bio)methane (see also analysis of Task 2)
[79] Feedstock for Methane Reforming: While traditionally natural gas is the primary feedstock for methanol production, renewable methane sources such as biomethane (from anaerobic digestion of organic resources like agricultural waste, animal excrement, sewage sludge, and organic waste) and biogas can also be used (see also analysis of Task 2)
[80] In IVC8c, biomethanol is produced through the methanol synthesis of a flow of biogenic CO2 coupled with a flow of H2 (see also analysis of Task 2)

IVC #	Industrial Value Chain	IVC level			Collective plan		
		Support to farmers (€/t feedstock)	Support to farmers (€/MWh fuel)	Operational support to the industrial unit (€/MWh fuel)	Support for securing the mobilization of the upstream part (mln.€/yr)	Support for industrial units development (mln.€/yr)	Total support for the operation of the entire IVC (mln.€/yr)
IVC11a	**Gasification and F-T synthesis**	11 – 18	11.9 – 19.5	74	207 - 338	1,282	1,489
IVC13a	**Pyrolysis and co-processing for road sector**	11 – 18	11.4 – 18.7	14	203 - 333	249	452 - 582
IVC13b	**Pyrolysis and upgrading for road and maritime sector**	11 – 18	3.4 – 5.6	88 – 117	61 - 99	1,566 – 2,082	1,626 – 2,181
TOTAL		-	-	-	**1,704 – 2,805**	**11,586 – 17,852**[81]	**13,290 – 20,526**[82]

Table 4-13 Quantities of advanced biofuels, in Mtoe and in MWh, needed in 2040 for the essential IVCs in Task 1

[81] Increased to 19,650 mln EUR considering the higher LCOP value provided by the stakeholders in IVC5+IVC6 pathway (see also Task 2 discussion).
[82] Increased to 22,324 mln EUR considering the higher LCOP value provided by the stakeholders in IVC5+IVC6 pathway (see also Task 2 discussion).

4.7. Synthesis of Interviews on Financing Advanced Biofuels Value Chains

The survey addressed to financing experts in the context of this project was carried out in the first two weeks of October 2025. The invitation for interview was sent to 21 experts representing EU development banks, private banks and financing institutions related to biofuels projects. Seven experts responded positively and with them we executed the interviews, four experts responded negatively, and ten experts did not respond at all to the invitation albeit a reminder was sent.

The interview was based on a set of questions covering all the significant areas of financing; these areas are reflected in the section of Structured Findings below.

4.7.1. Key points

Through the four interviews, financial institutions and experts shared consistent views on the barriers and enablers for financing advanced biofuel value chains in Europe. Key barriers remain: (1) feedstock security, (2) offtake uncertainty due to limited long-term contracts and regulatory risk, and (3) technology risk for lignocellulosic and other low-TRL pathways. **Lenders view HEFA/HVO as the most mature and cost-effective option**, whereas lignocellulosic bioethanol, gasification, and pyrolysis are thought of as demonstration scale, requiring de-risking.

Integrated value chains are easier to finance. Bankability depends on proven technology and engineering, procurement and construction (EPC) integration, clear feedstock procurement strategies engaging cooperatives or aggregators, and credible long-term offtake agreements. Integration along the value chain is strongly preferred; projects that combine feedstock, production, and marketing under a single entity, with turn-key, lump sum basis construction contracts are far easier to finance. Inclusion of marketing in the integrated value chain is particularly important as it guarantees the market access to create offtake; however, requests for private sector financing by integrated parties is much less frequent in practice.

Ease of financing for separate segments of value chains varies. Commercial lenders will look at non-integrated upstream financing only after commercial operations date (COD) as a refinance option, and only if the aggregator has a strong compliance and operations track record. Under commercial lending, upstream financing for aggregators is often in the form of supply chain structures (pre-export finance, pre-payment finance, inventory-finance etc.). International and development institutions can also offer complementarity with secured KPI-based loans of up to 30-35%, provided the project sponsor has adequate balance sheet strength, a viable business model and internal capacity to support aggregation operations, i.e., the infrastructure and expertise to mobilize raw material producers. Fixed price long-term offtake agreements are a strong advantage but in reality, even upstream business models rely on spot prices or short-term price commitments. Individual production units are relatively easier to finance, even in project-finance structures, but require high confidence in technology, offtake and supply (typically over 120% of the plant capacity in firm supply agreements), and ideally ECA (financial guarantees) support. Unsecured financing of credible promoters is also preferred to project-finance structures that are seen as riskier and require higher due diligence standards in terms of operations and business viability.

Interviewees highlight that regulatory stability and credible mandates (e.g., RED III, SAF blending targets) are broadly trusted but insufficient: **investors doubt long-term political commitment to sustain** "**green premiums**." Upstream support for farmers and aggregators or book-and-claim systems that can increase price transparency and transfer added value upstream, could improve feedstock mobilization and make more regions viable for biomass sourcing. In all cases, the viability of the business model is critical before any bank (development or commercial) considers financing; in that, **deeper product price indexation would help with the evaluation of business models**.

Overall, the financial community supports biofuels' decarbonization role but seeks policy-anchored, commercially viable, and risk-mitigated structures before scaling investments. **The plethora of technologies, potential users and alternative supply chains proposed in the biofuel ecosystem are seen as providing more uncertainty about the dominant technology, more risk of leapfrogging, and less systematic resilience**.

4.7.2. Structured Findings

In compliance with the above-mentioned key points the following findings have been concluded from the interviews:

A. Institutional Perspective & Experience

- Institutions view advanced biofuels as part of their sustainable finance mandate but more complex than wind, solar, or hydrogen.
- International lenders favour corporate loans for large oil majors with proven HVO/HEFA assets; project finance is rare and high-risk for emerging technologies.
- Past financings confirm that integrated corporates can absorb risks; small SPV cannot without strong sponsor guarantees.

B. Technology & Project Risk

- HVO/HEFA: Most mature, cost-effective, and easy to integrate in refineries.
- Lignocellulosic ethanol, methanol, gasification, pyrolysis: High CAPEX, feedstock intensity, limited track record.
- Banks require track record and performance guarantees; no appetite for low-TRL technologies without public support.
- Valorisation of by-products (animal food, biogenic carbon, biomethane) improves bankability if backed by credible offtake.

C. Feedstock & Supply Chain Risk

- Feedstock procurement is central to bankability. Typically required at 120% of operational capacity in firm supply commitments.
- Convincing procurement strategy means early engagement with cooperatives, aggregators and binding contracts by financial close.
- Fragmented land ownership limits mobilization especially in CEE; feed-in premiums could activate untapped biomass.

D. Demand & Offtake Risk

- Offtake agreements are a bottleneck; banks require ≥10-year commitments.
- Regulatory risk—uncertainty over maintaining mandates—undermines confidence.
- Double-auction or CfD mechanisms could stabilize prices and ensure investor certainty.

E. Policy & Incentives

- RED III and SAF mandates provide a framework but insufficient certainty for 15-year lending horizons.

- EU-level feed-in premiums or CfDs could guarantee minimum revenues or feedstock prices.
- Upstream incentives for farmers/aggregators would mobilize biomass; stable RED III implementation remains key.

F. Financing Structures & Instruments

- Preferred models: corporate loans, project finance, blended finance, guarantees, first-loss facilities.
- EIB can finance up to 50% of project cost, sometimes subordinated, but pricing must reflect risk.
- Green bonds viable only for top-tier corporates (e.g., NESTE).

G. Barriers & Solutions

- Technology: Low TRL and cost gap vs. fossil require grants, first-loss capital, demo venture debt
- Feedstock: Fragmentation calls for aggregator contracts, farmer premiums and strong on-site presence and education
- Offtake: demand is driven by policy mandates. While there is confidence in the EU's resolution for support, the regulatory details are not clear in a long-enough timeframe
- Financing: High CAPEX for demands InvestEU guarantees and blended finance.
- Policy: Unclear long-term support → stable RED III and price mechanisms.

H. Emerging Models from Non-Traditional Actors

- Large corporates (e.g., Heineken) are funding low-carbon feedstocks to reduce scope 3 emissions.
- Book-and-claim systems can help create price and demand signal transparency and enable capital flows upstream
- Transparent carbon accounting and certification integrity are critical

I. Value Chain Segments Needing Most Innovation

- Feedstock producers and aggregators need the most financial innovation and policy support.
- Integration and EPC (Engineering, Procurement, Construction) consolidation reduce risk and financing complexity.

5. Organization of a consultation workshop

5.1. Scope of work

The goal of Task 4 is to organize a consultation workshop aiming at supporting the work of stakeholders and experts in discussion and adoption of activities and project outputs. More specifically, the workshop is foreseen to be held for one day in Brussels, and it will be organized by the Consultant with the cooperation of the Contracting Authority. The overall objective of the activity is to provide the floor for discussion and analysis of the data and findings presented in the Interim progress report Part I and draft Interim progress report Part II. Also, it aims at refining and validating the conclusions of the aforementioned reports. Finally, Task 4 has the specific objective of the workshop outcome to be used for the drafting of the final study report.

Developments mentioned in the previous technical tasks of the project will have to be considered during the workshop planning phase in order to ensure that the thematic areas of the discussions during the event will reflect the project reality and that will touch upon the most critical issues related to the ways to mobilize industrial capacity for advanced biofuels.

6. Concluding Remarks

The scope of this study is to formulate a **capacity development plan** for advanced biofuel industrial value chains (IVCs) that can be realized in 2030, 2040, and 2050, aiming to meet emission reduction targets in the transport sector. The analysis was carried out in three main tasks, and the results were validated through a workshop organized in Brussels on October 24, 2025.

A **dramatic increase in biofuels production capacities based on Annex IX feedstocks is required between now and 2030** – and/or a continuous update of the REDII Annex IX list, or a further revision of the RED framework, impacting on eligible feedstocks and sustainable agroforestry value chains for sustainable biofuel production to fulfil the targets of the Renewable Energy Directive (RED). There is no single value chain that could provide 50% or more of the sustainable fuels; instead, a portfolio of solutions will be needed, complementary to the other decarbonization routes for transport (as electrification, hydrogen, ammonia, etc.). Only a variety of technologies will allow drawing on the full range of feedstocks currently eligible and producing the full spectrum of transport fuels needed. This is the reason for the substantial number of industrial value chains considered and assessed in this study.

The full list of IVCs was narrowed by using key performance indicators (KPIs) and potential contribution to targets. We considered **these KPIs as main components** of the technology readiness (TRL) level of the conversion technology, the availability of suitable feedstock, and the preparedness of the technology providers to build industrial facilities. Out of the 20 IVCs identified and assessed, **only 4 IVCs met all selection criteria to be characterized as essential for the EU in the 2025–2030 timeframe**, and 13 IVCs met all selection criteria for the 2030–2040 period. Several essential IVCs were clustered. It remains however possible that, in the coming years/decades, innovation will further accelerate the development of lower TRL value chains, offering contributions from these additional pathways and emerging technologies.

The IVCs selected as essential for **2025–2030** are:

- **IVC1:** Transesterification for the production of FAME for the road or shipping sector.
- **IVC2:** Hydrotreatment of lipids (either through co-processing or in stand-alone facilities) for the production of HVO for the road sector and HEFA for the aviation sector.
- **IVC7:** Biomethane from anaerobic digestion (AD) for the production of biomethane for the road and shipping sectors.
- **IVC13a:** Pyrolysis and co-processing in refineries for the production of fuels with biogenic content for the road sector.

The IVCs selected as **essential for** the period **2030–2040** are:

- **IVC2:** Hydrotreatment of lipids (either through co-processing or in stand-alone facilities) for the production of HVO for the road sector (or maritime, if economics allow to do so) and HEFA for the aviation sector.
- **IVC5+12+6**: Production of advanced ethanol for the road sector or for further processing

into AtJ-SPK for the aviation sector

- **IVC7+9a+9b:** Biomethane from AD, gasification and methanation, and methanation from CO_2 and H_2.
- **IVC8a+8b+8c:** Gasification and methanol synthesis, biomethane [from AD] reforming to methanol, and methanol synthesis from biogenic CO_2 and H_2.
- **IVC11a:** Gasification and FT-synthesis.
- **IVC13a+13b:** Pyrolysis and co-processing in refinery or upgrading.

As already stated, further value chains at lower TRL were identified, which could become important in the 2040-2050 timeframe. Also, any of the other IVCs not selected as essential could become important, either regionally because of specific conditions or due to technological breakthroughs. For each of the essential industrial value chains identified and selected, information on the needs and potential related gaps were collected from literature as well as through a survey with technology users. In particular, the survey provided important insights.

The survey confirmed that, as already identified in the previous study, European technology providers have the knowledge and the personnel needed to build the advanced biofuels industry. **The industry does not anticipate a lack of suitable equipment to build advanced biofuel production facilities**. However, several industrial stakeholders noted that, although the supply of equipment is available within Europe, it might be cheaper to purchase globally. Components usually sourced from outside Europe include catalysts and pressure equipment. A future supply gap—both from within and outside Europe—is expected in biomass pre-treatment (steam explosion), gasification and FT reactors, and upgrading equipment for upgrading biogas to biomethane.

Processing materials are generally available in Europe; only catalysts, reactor internals, and instrumentation are usually imported. The supply of catalysts could become critical, as they require nickel, molybdenum, and potentially specific additives. In addition, low-cost renewable electricity is only available in specific locations in Europe.

In general, the availability of a **skilled workforce** in the EU is not considered a significant problem. Advanced biofuel industries expect to recruit personnel from conventional ethanol production facilities, traditional refineries, and other chemical industries.

Although the previous study showed that **sufficient feedstock can be made available** in Europe to support the production of advanced biofuels as needed to fulfil the targets, constantly ensuring sufficient feedstock supply can be challenging. This was mentioned in particular for sourcing waste lipids for hydrotreating. For the Alcohol-to-jet and all gasification-based pathways, the main challenge mentioned was to organize at large scale the production and the collection of biomass residues from agriculture and forestry or to develop new sustainable supply routes from intermediate crops or severely degraded land. Finally, for RFNBOs the lack of maturity of biogenic CO2 and green hydrogen markets was mentioned.

EPC companies capable of building production facilities are available in Europe, although they may not be accessible due to other projects. Only a few are capable of adequately addressing the challenges of first-of-a-kind projects integrating gasification with FT or methanol synthesis. The most important gap identified is the **lack of project developers** for advanced biofuels.

Survey responses indicated that refiners tend to focus mainly on HVO/HEFA production, while there is difficulty in collaborating with skilled and experienced project developers for other biofuel technologies in Europe. Project developers for biomethane from anaerobic digestion sometimes aim to sell projects to third parties, resulting in less rigorous business models. Moreover, the industry appears reluctant to invest in gasification technologies.

Generally, the European technology providers have the knowledge needed to support this industry. Our survey has revealed that we expect sufficient feedstock availability overall (not for waste lipids based on current RED II framework), as well as availability of equipment, processing materials and skilled workforce. But there are caveats for each of these. The reluctance to invest in the more costly pathways and the difficulties in committing experienced EPC companies make **the case for securing projects in short time very tough**.

Regarding the **support to R&I projects**, there exists a wide range of EU-funded programs that provide opportunities for research and innovation across all technology readiness levels (TRLs), from basic research (TRL 1) to fully developed products (TRL 9). These programs have been designed to directly address the challenges of the EU Green Deal and encompass the full spectrum of technologies and solutions required to achieve carbon neutrality. As a result, **advanced and renewable sustainable biofuel R&I projects often find themselves competing** with other renewable energy sources (RES) for funding.

Focusing on the **essential IVCs** for the 2030–2040 period, significant results from ongoing R&I projects are expected in areas such as expanding the feedstock base for thermochemical conversion routes, co-processing of bio-based feedstocks in refinery contexts, and the integration of bio-based and electricity-based pathways.

The **aviation and maritime sectors** appear to be the main areas of focus, as they represent the most urgent sectors to decarbonize. Notably, work supported by the Innovation Fund has led to tangible examples of facilities that could become viable under market conditions in the near future, thereby setting a precedent for further industrial endeavours.

The currently available **R&I funding opportunities**, both at EU and national levels, are considered appropriate to support the development needs of advanced biofuels. These programs are expected to enable the deployment of the future essential IVCs by providing the necessary preconditions for their timely commercialization and scale-up.

Regarding the **financial support of commercial projects** in the field of advanced biofuels, the **EU-level funding opportunities** play a crucial role in the deployment of advanced biofuel supply chains. These initiatives are essential to bridge the gap between pilot-scale technology demonstrations and full commercial operations, particularly by addressing market risks and financing barriers.

Existing EU and MS financial instruments—such as grants, loans, interest-rate subsidies, credit support, and institutional equity capital—are useful for kick-starting CAPEX-intensive investments on the refining and processing side. They provide access to investment capital and help de-risk financing decisions for private investors. For **project sponsors** developing advanced biofuel processing or refining facilities, EU programs such as **InvestEU**, the **Modernisation Fund**, the **Connecting Europe Facility (CEF)**, and the **European Regional Development Fund (ERDF)** can provide substantial financial support. However, developers often find accessing these instruments complex, as they require significant administrative capacity and financial expertise.

From the **feedstock suppliers' perspective**—particularly agricultural and forestry operators supplying lignocellulosic biomass—the **CAP Pillar I** (Eco-schemes, Voluntary Coupled Support) and **Pillar II** (EAFRD) provide significant potential support. These instruments incentivize sustainable agricultural practices, the cultivation of energy crops, and multiple feedstock supply chain integration. Feedstock suppliers, especially smaller-scale operators, would benefit from enhanced clarity, uniformity, and simplification in accessing agricultural support measures, thereby improving predictability and the long-term sustainability of feedstock supply chains.

Given the **technical nature of advanced biofuel supply chains**, which often rely on low-energy-content feedstocks, few Member States can individually provide all necessary conditions for successful projects—namely proximity to feedstock supply, economies of scale, and proximity to demand centres. Therefore, support measures should encourage **collective, cross-border projects** aligned with EU climate objectives.

Among the 27 Member States, approximately **one-third** has effectively integrated tangible and concrete measures in support of the advanced biofuels sector into their respective national energy and transport strategies. Regarding the **types of biofuels and stages of the value chain** targeted by MS support schemes, these may focus on maritime and aviation biofuels, biomethane, e-fuels, or more broadly on commercial-scale advanced biofuels technologies. The **scale of state aid** varies widely across Member States, with annual budgets ranging from less than €50 million to several hundred million euros. Member States that have successfully leveraged EU co-funding for part or all of their national budgets have been able to establish multi-year support initiatives, including direct grants to large industrial players.

Business Model analyses for the essential IVCs indicate that **financial support will be required to close the gap between the biofuels' Levelized Cost of Production (LCoP)** and the market price of their fossil fuel counterparts, even when considering the impact of EU Allowances' additional costs (as defined by the EU ETS).

The **required level of financial support** is, however, expected to vary between different essential IVCs. In the 2025–2030 period, IVC2 (Hydrotreatment of Lipids) is assessed to have a relatively lower financial support requirement compared with other IVCs in the same period. Nevertheless, this strongly depends on feedstock eligibility and price evolution, which in turn depend on EU policies (e.g., the feedstock list).

In the 2030–2040 period, the modelling results indicate that **IVC9b (Methanation from biogenic CO_2 and green H_2)** would probably not require additional support, but only in the case of an extremely low price of electrolysis-based hydrogen – namely, costs around 2.3 €/kg H_2.

In addition to IVC2 (Hydrotreatment), the other essential IVCs for the 2025–2030 period – namely IVC1 (Transesterification), IVC7 (Biomethane from Anaerobic Digestion, in both considered feedstock scenarios: crop residues, manure, sequential crops, and MSW), and IVC13 (Pyrolysis and Co-processing) – are assessed as not requiring significant additional financial support.

IVC9a (Gasification to Methane) – for the period 2030–2040 – could reach economic attractiveness with a reduction of up to 30% in CAPEX, OPEX, or feedstock price, as shown by sensitivity analyses.

Regarding **biofuel production costs**, the analyses show that the LCoP for biofuels substituting diesel would range between 103 €/MWh for HVO and 119 €/MWh for FAME.

SAF pathways exhibit a wide range of LCoPs: 154–320 €/MWh, with HEFA on the lower end and AtJ (Alcohol-to-Jet) still on the higher end – especially when using EU-based lignocellulosic ethanol.

Biomethane from Anaerobic Digestion is expected to have an LCoP between 98 and 130 €/MWh (even though lower estimates are found in the literature). The lower end of the range can be achieved when MSW is used as feedstock or in larger plant sizes.

Green hydrogen is indeed an enabler for higher process yields (e.g., in gasification) and additional emission reductions (e.g., when substituting grey hydrogen in a biorefinery). However, its production cost remains a major hindrance – and potentially a showstopper. This also represents a key barrier for all bio-synthetic pathways. Projected LCoPs for bio-synthetic methane span 91–155 €/MWh, and those for bio-synthetic methanol range between 93 and 160 €/MWh. It should be noted that even the lower end of these ranges assumes highly favourable hydrogen production prices[83].

Methanol production from biomass gasification is particularly affected by the high gasification CAPEX and OPEX, with a projected LCoP of around 120 €/MWh. When considering biomethane reforming, leveraging on Guarantee of Origin schemes to link decentralized

[83] The following H2 prices are considered in the analysis "H2 Low": 2.3 €/kg, "H2 High": 4.2 €/kg.

biomethane production with existing conversion plants, the projected LCoP grows up to around 160 €/MWh; the increase in production cost can be mainly connected to the expected biomethane price and to the additional cost of the Guarantees of Origin.

Fast Pyrolysis Biocrude Oil (FPBO) is already available as an intermediate fuel for co-processing, although its uptake remains limited by blending constraints. These technical limits could be overcome through FPBO upgrading to a higher-quality feedstock for biorefining. However, this alternative pathway still requires the use of additional green hydrogen, again posing financial challenges due to its current and projected high production costs.

The current **R&I funding opportunities**, both at EU and national levels, are considered appropriate to support the development needs of advanced biofuels and should continue to enable the deployment of the future essential IVCs by providing the necessary preconditions for their timely scale-up.

The development of new **collective financing plans** for aggregated industrial value chain projects within the EU is guided by core principles aimed at strengthening industrial capacity to meet the 2030 climate targets. These plans seek to mobilize both EU and MS support tailored to the specific needs of investors and producers across different segments of the value chain and promote cooperation among EU countries. A key focus is on **de-risking the entire value chain**—considering geographic dispersion and project size—through targeted financial instruments and support mechanisms.

Regarding **farmers**, the analysis highlights a set of administrative and regulatory challenges, including the need to align CAP with RED provisions on supported crops, registries, and sustainability certification. The development of **standardized contract templates** between farmers and aggregators—with built-in compliance safeguards for harvest windows, minimum residue retention, and cover crop re-establishment—would be beneficial. Such contracts should be developed in consultation with local authorities and auditors to reduce risks for farmers.

The role of **aggregators**—regardless of the value chain—is critical. Aggregators collect biomass, pre-process it into standardized feedstock, manage warehousing and logistics, ensure sustainability certification up to the factory gate, and provide training and agronomic support to farmers.

As seen in earlier stages of renewable energy market development, there is a need for **final price support policies**, such as Feed-in Premiums or similar financial mechanisms, to close the price gap between fossil fuels and advanced biofuels—a gap that remains significant even for the lower-cost biofuels.

Financing for marketers can be mobilized through targeted support measures within national policy frameworks, leveraging direct and indirect incentives, grants, and public–private partnerships, particularly under the **AFIR regulation.** Additionally, harmonization of certification systems and carbon-credit accounting rules would ease administrative burden.

The formulation of collective plans for advanced biofuels value chains addresses the **whole EU as an area**, including the critical regional characteristics and efficient sizes at each value chain stage, for intervention and opening/ mobilization of the relevant markets of biomass feedstocks and advanced biofuels as final drop-in products for the three main transport sectors: road, aviation and maritime. The main points are presented below.

Two main financing supports are considered as necessary: (a) **financing support to industrial units** that is proportional to produced quantities of biofuels in the form of FiP in €/MWh and influences significantly the final price to consumers and (b) **financing support mobilizing farmers** that is proportional to produced feedstock quantities in the form of FiP or production subsidy in €/tn and is absorbed at the stage of agricultural production not influencing the final price.

The support to EU farmers, which accounts in the order of **700 – 1,245 mil.€/yr** that is **approximately 15% of the total annual financing needs** in the biofuel value chains in 2030, must be provided through the generation of additional financing streams, as these funds do not currently exist. This upstream support is essential to mobilize feedstock production and is typically delivered as feed-in premiums or production subsidies.

The support to EU industrial units, which accounts for **3,849 – 7,499 mil.€/yr representing about 85% of the total annual financing needs in 2030**, primarily constitutes a redistribution of existing financing flows. Instead of consumers facing increased prices for the final biofuel product, this support—potentially funded through mechanisms such as carbon pricing revenues—helps maintain price parity between biofuels and fossil fuels at the point of sale. This ensures market competitiveness and consumer acceptance while enabling industry development and facilitating EU MS to implement the set RED policies.

Indicatively and under the calculations made for the technological reality of 2040, the combined financial support needed is estimated to approximately **1,704 – 2,805 mil.€/yr for securing upstream feedstock mobilization** and **11,586 – 17,852 mil.€/yr for industrial units development**. Thus, the overall operational support requirement is expected in the range of 13,290 – 20,526 mil.€/yr.

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Appendix 2 – Estimation of required monetary support

In this section, a ballpark estimation of the required support to farmers to be mobilized to shift their production towards feedstock appropriate to feed the selected IVC, is made. The estimation follows the overall frame of the approach followed in this work (see sections 4.5 and 4.6 in the main text) to determine the overall support of the IVC. Our methodology assumes the feedstock price at producer gate corresponds to the model assumptions in Task 2. It is clear that a lower feedstock price improves the economics of the production unit but increases the required upstream support for mobilization and vice-versa; but this is not considered in this analysis.

IVC2 Support requirements

In IVC2 the main feed is assumed to be Used Cooking Oil (UCO) at present and results in the production of HVO and HEFA biofuel for aviation and road transport applications. Brassica carinata and similar cover crops are economically more viable in Southern Europe, compared to Northern farms, because of its milder and longer winter season. The analysis below follows the economics of a medium-size farm (100-500 ha) in Italy as proxy for Southern Europe, assuming feedstock mobilization will begin from such regions where production is more viable.

Our model considers:

(a) farmer's economic decision between Brassica carinata and alternatives. For Italian farmers, growing oilseeds competes with three main alternatives: (1) leaving land fallow (2) winter wheat and (3) winter rapeseed. We estimate the profitability of land based on average values for Southern Europe, in order to establish the minimum profitability of Brassica carinata in order to be competitive to the farmer's alternatives:

- Fallow land produces nothing and incurs some costs in soil enrichment (ca. 50€/ha) but provides significant eco-scheme benefits (of the order of 110€/ha). This sets the floor to around **60€/ha** (110-50) for growing oilseeds.
- Winter wheat requires direct costs of around 1000€/ha but yields 5t/ha of product priced at around 220€/t; in sum yielding around **160€/ha** of product to the farmer including eco-schemes of 60€/ha.
- Winter rapeseed yields 2.5t/ha with similar production costs, and sells for ca. 475€/t, yielding around **250€/ha** in gross profit to the farmer including eco-schemes of 60€/ha. This level of productivity of land (250€/ha) is the bar that – on average – brassica carinata needs to overcome.

(b) Costs of harvesting, drying, haul from farmgate to crusher, certification to burden the aggregator. These are estimated based on literature review, around 194€/t of crop.

(c) Benefits from meal byproduct sales accrue to the aggregator. The transfer price of vegetable oil at industrial unit gate must be consistent with the model assumptions from Task 2, i.e., **520€/t** of oilseed are equivalent to 880 €/t for UCO[84].

[84] Oilseed crops yield around 43% oil and 57% meal. While there is no price benchmark for carinata or Camelina meal to our knowledge, an approximation based on rapeseed meal (ca. 250€/t in Southern Europe, see teseo.clal.it) is reasonable. The vegetable oil is assumed to be economically

(d) Based on the calculations in the relevant literature, the total aggregator cost is estimated to 194 €/t and the gross profit margin for the aggregator must be enough to incentivize entering the supply chain. While there is no direct way of estimating this, we assume a gross profit margin of around 15%.

Table A1-1 shows indicatively the economics of the upstream value chain for no support for the farmer. A transfer price of carinata crop of 250€/t secures a gross profit margin of 15% for the aggregator and an oil price of 380€/t. On the other hand this price achieves a land productivity comparable to that of winter wheat (160€/ha) but much lower than rapeseed (250€/ha) and does not provide an incentive to the farmer to grow Brassica carinata. The analysis in Table A1-1 is subject to a lot of uncertainty: land yield, a critical parameter, is assumed to be 2.0t/ha, i.e., a high value for Northern Italy and low estimate for the South according to the literature. Likewise, yield for winter wheat and rapeseed as well as total farming costs are average estimates subject to geographical uncertainty.

Sensitivity analyses on these parameters yields a reasonable and a conservative estimate of support to the farmers lies between **25 and 40€/t** of crop (see Figure A1-1). Clearly, no support might be needed in regions where land yield is high. The case for mobilization, however, should focus on more marginal and low yield lands, the involvement of their farmers should be encouraged towards increasing the availability of eligible feedstock.

FARMER		
Support to farmer	€/t	**0**
Yield	t/ha	2,00
Production (total cost)	€/ha	400
Transfer price to Aggregator	€/t	**250**
Eco-schemes	€/ha	60
LAND PROFITABILITY	**€/ha**	**160**
AGGREGATOR		
Transfer price from Farmer	€/t	**250**
Total aggregator costs	€/t	**194**
MEAL output per t of CROP		57%
OIL output per t of CROP		43%
MEAL PRICE per t of meal	€/t	250
MEAL SALES €/t of CROP	€/t	143
OIL SALES per ton of OIL	€/t	880
OIL SALES €/t of CROP	€/t	378
TOTAL COST €/t of CROP	€/t	**444**
TOTAL PROFIT per t of CROP	€/t	77
GROSS MARGIN		**15%**

Table A1-1: Economics of upstream feedstock (carinata) production in South Europe (Italy), indicative calculation

fungible to UCO, which has been used for the assessment in Task 2. These assumptions yield 0.43*880€/t+0.57*250€/t = 380 + 140 = 520€/t of carinata crop

Required Level of support (€/t) for farmer to achieve land productivity of 250€/ha

	Tranfer Px to AGGR €/t of CROP									
Yield t/ha	**210**	**220**	**230**	**240**	**250**	**260**	**270**	**280**	**290**	**300**
1,75	127	117	107	97	87	77	67	57	47	37
1,80	118	108	98	88	78	68	58	48	38	28
1,85	109	99	89	79	69	59	49	39	29	19
1,90	101	91	81	71	61	51	41	31	21	11
1,95	93	83	73	63	53	43	33	23	13	3
2,00	85	75	65	55	45	35	25	15	5	0
2,05	78	68	58	48	38	28	18	8	0	0
2,10	71	61	51	41	31	21	11	1	0	0
2,15	64	54	44	34	24	14	4	0	0	0
2,20	58	48	38	28	18	8	0	0	0	0
2,25	52	42	32	22	12	2	0	0	0	0
2,30	47	37	27	17	7	0	0	0	0	0
2,35	41	31	21	11	1	0	0	0	0	0

Aggregator gross margin, given support to the farmer as above

	210	**220**	**230**	**240**	**250**	**260**	**270**	**280**	**290**	**300**
1,75	19%	17%	15%	13%	11%	10%	8%	6%	4%	2%
1,80	20%	18%	16%	14%	12%	10%	8%	6%	5%	3%
1,85	21%	19%	17%	15%	13%	11%	9%	7%	5%	3%
1,90	21%	19%	17%	15%	14%	12%	10%	8%	6%	4%
1,95	22%	20%	18%	16%	14%	12%	10%	8%	6%	5%
2,00	22%	21%	19%	17%	15%	13%	11%	9%	7%	5%
2,05	23%	21%	19%	17%	15%	13%	11%	10%	8%	6%
2,10	24%	22%	20%	18%	16%	14%	12%	10%	8%	6%
2,15	24%	22%	20%	18%	16%	14%	13%	11%	9%	7%
2,20	25%	23%	21%	19%	17%	15%	13%	11%	9%	7%
2,25	25%	23%	21%	19%	17%	15%	13%	12%	10%	8%
2,30	25%	24%	22%	20%	18%	16%	14%	12%	10%	8%
2,35	26%	24%	22%	20%	18%	16%	14%	12%	11%	9%

Figure A1-1: Sensitivity analysis of the required level of support to achieve competitive land productivity (250€/ha) and gross profit margin of 15% for the aggregator

IVC8a Support requirements

IVC8a involves the gasification biomass for methanol synthesis for the maritime sector. As modelled in Task 2, the IVC requires a minimum of 36€/MWh of support at the final product level in order to be competitive to fossil fuels under a scenario of no-penalties applied to the fossil fuel price.

Feedstock (agricultural residues) represents ca. 29% of the LCoP for this value chain. The cost of the feedstock is broadly broken down between the farmer (22%) and aggregator (78%) according to estimates based on the literature[85]. The farmer's cost is mainly dependent on the

[85] Multiple sources:

- https://www.bioboost.eu/uploads/files/bioboost_d1.1-syncom_feedstock_cost-vers_1.0-final.pdf
- Impact of Harvesting Operations on Miscanthus Provision Costs, October 2016, Transactions of the ASAE. American Society of Agricultural Engineers 59(5):1031-1039 DOI:10.13031/trans.59.11178
- https://teagasc.ie/wp-content/uploads/media/website/publications/2011/Miscanthus_Best_Practice_Guidelines.pdf
- https://www.silvafennica.fi/article/1689
- Karras, T., Thrän, D. The Costs of Straw in Germany: Development of Regional Straw Supply Costs between 2010 and 2020. *Waste Biomass Valor* 15, 5369–5385 (2024). https://doi.org/10.1007/s12649-024-02528-x

cost of replenishment of the nutritional value of residue removed, and can be estimated around 10 €/t of residue[86,87]. The bulk of feedstock supply has to be supported, including:

- Baling (€15–20/t)
- Field collection & headland stacking (€8–16/t)
- Grinding at plant (€4.2/t)
- Transport & full-chain examples (12-20€/t depending on distance/payload)

These costs depend heavily on land morphology, feedstock characteristics (water content) and site selection (affecting distances), i.e., they are very project specific. There is not enough evidence to assess the viability of the farmer's and aggregator's business model. Considering the feedback from farmers in Northern Europe[88], it is likely that these economics are not profitable enough and require support beyond access to existing financial instruments (see Section 5.5). Assuming a 25% additional markup in farmer costs in the form of support would result in an additional requirement of ca. 17€/t of crop.

IVC7 Support requirements

IVC7 involves the production of biomethane from either a mix of eligible energy crops, agricultural residues, manure and MSW for the maritime and road (HDV) sector. Two cases are modelled in Task 2: (a) feedstock as a mix of dedicated crops, agricultural residues and manure, and (b) 100% utilization of MSW. The former case is not competitive to fossil fuels without support of at least 21 €/MWh while the latter can be competitive if penalties are applied to fossil fuels as scheduled. In case (a) feedstock (agricultural residues) represents ca. 44% of the LCoP. Aggregators contribute the most to the total cost of the feedstock mix as modelled in Task 2 (64%) versus farmers (36%)[89]. This is the contribution of energy crops to the feedstock mix (30% by model). Perennial crops such as willow and miscanthus are often viable on suitable sites – especially in Southern Europe or warmer/wetter zones – but are not obviously competitive for farmers against mainstream strategies in northern European regions without high yield potential, proximity to aggregation sites and contract advantages[90]. In short, they are

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[86]https://projectblue.blob.core.windows.net/media/Default/Imported%20Publication%20Thumbs/RB209/2023/NutManGuideRB209S4_230526_WEB.pdf
[87] https://www.indexmundi.com/commodities/?commodity=dap-fertilizer&currency=eur
[88] Roszkowska, S., Szubska-Włodarczyk, N. What are the barriers to agricultural biomass market development? The case of Poland. *Environ Syst Decis* 42, 75–84 (2022). https://doi.org/10.1007/s10669-021-09831-1
Hedda Thomson Ek, Jagdeep Singh, Josefin Winberg, Mark V. Brady, Yann Clough,
Farmers' motivations to cultivate biomass for energy and implications, Energy Policy, Volume 193, 2024, 114295, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2024.114295
[89] https://www.bioboost.eu/uploads/files/bioboost_d1.1-syncom_feedstock_cost-vers_1.0-final.pdf
https://www.silvafennica.fi/article/1689
[90] David Livingstone, Beatrice M. Smyth, Erin Sherry, Simon T. Murray, Aoife M. Foley, Gary A. Lyons, Christopher R. Johnston, Production pathways for profitability and valuing ecosystem services for willow coppice in intensive agricultural applications, Sustainable Production and Consumption,
Volume 36, 2023, Pages 281-291, ISSN 2352-5509, https://doi.org/10.1016/j.spc.2023.01.013.
Also:
- https://www.climatexchange.org.uk/wp-content/uploads/2025/01/CXC-Economic-Potential-of-Energy-Crops-in-Scotland-December-2023.pdf
- https://teagasc.ie/wp-content/uploads/media/website/publications/2011/Miscanthus_Best_Practice_Guidelines.pdf
- https://www.mdpi.com/1996-1073/15/1/131
- https://terravesta.com/news/miscanthus-continues-to-stack-up-for-growers/

expensive relative to other lignocellulosic sources, limit the choice of sites and require farmer support in the same way that oilseeds crops do. Configuring the value chain to rely less on dedicated crops would have a large impact on its viability.

A combination of (a) less reliance on dedicated crops (b) support for dedicated crops akin to oilseed crops and (c) support for aggregator business models could have a significant impact on the LCoP of this value chain.

Estimating support measures for farming and aggregation in IVC7, we assume incentives similarly to IVC8a (i.e., with a 25% markup on costs) and farmer incentives for dedicated energy crops similarly to IVC2. This yields an average support proposal of 15€/t for IVC7.

IVC13b Support requirements

IVC13b involves the production of fuels from a mix of eligible energy crops, agricultural residues, manure and MSW for the maritime and road (HDV) sector. The output, Hydrotreated Pyrolysis Oil (HPO) can be blended in road and maritime fuels.

The cost structure of the value chain is less sensitive to feedstock prices (20% of the LCoP); as a result any support upstream would have relatively lower impact on the viability of the value chain. To add to this, the additional requirements on feedstock standards (low moisture and small size) increase biomass treatment costs.

For consistency we estimate a 25% markup on feedstock prices as a potential support package in order to incentivize mobilization. Subject to reasonable estimates of the diverse feedstock mix for the value chain and the same calculations as for IVC7, we estimate this to be of the order of 18€/t.

- https://ahdb.org.uk/knowledge-library/is-it-better-to-incorporate-or-sell-straw

Appendix 3 – Additional information on the support estimated for the selected IVCs for 2040

No	Industrial Value Chain	Feedstock type[91]	Feedstock Price	Product	Sector	Output of a typical unit	CAPEX and OPEX of a typical unit
IVC2	**Hydrotreatment (HVO/HEFA) of oil from eligible oil crops**	Oil crops An. qt 595 kt/yr	880 €/t (UCO)	HVO, HEFA Biodiesel	Aviation Road	500 kt/yr fuel pool capacity[92]	CAPEX 770 m€ OPEX 156 m€/yr
IVC5+ IVC6	**SAF production from Cellulosic Ethanol (EtOH-to-Jet)**	Ligno-cellulosic biomass An. qt 378 kt/yr	69[93] €/t	SAF (mostly), Gasoline, Diesel[94]	Aviation (primarily), Road	50 kt/yr (SAF)	CAPEX 615.8 m€ OPEX (EtOH+SAF) 52.5 m€
IVC12+ IVC6a	**SAF production from Syngas fermentation Ethanol (EtOH-to-Jet)**	Ligno-cellulosic biomass, including agricultural and forestry residues to produce intermediate Syngas An. qt 272 kt/yr	69 €/t	SAF (mostly), Gasoline, Diesel[95]	Aviation (primarily), Road	50 kt/y (SAF)	CAPEX: 409.2 m€ OPEX (EtOH+SAF): 48.2 m€

91 Calculated on the basis of a typical industrial unit overall output yield
92 HVO+HEFA+Naphtha+LPG
93 As received, with 35% moisture content
94 SAF 74%, Gasoline 12%, Diesel 14%
95 SAF 74%, Gasoline 12%, Diesel 14%

No	Industrial Value Chain	Feedstock type[91]	Feedstock Price	Product	Sector	Output of a typical unit	CAPEX and OPEX of a typical unit
IVC7	**Eligible crops production of advanced biomethane**	Lignocellulosic Crops, agricultural residues, manure An. qt 13 ktn/yr	50 -70 €/tn	Biomethane	Road Maritime	4 mNm^3/yr	CAPEX 16.3 m€ OPEX 1.12 m€/yr
IVC9a	**Biomass Gasification and Methanation**	Ligno-cellulosic biomass, including agricultural and forestry residues An. qt 243 kt/yr	69 €/t	Biomethane	Road (primarily), Maritime	57.8kt/yr	CAPEX: 361.5 m€ OPEX: 20.8 m€/y
IVC9b	**Methanation from biogenic CO2 and H2**	biogenic CO2 and clean hydrogen An. qt 7.2 kt CO2 and 1.5 kt H2	CO2: 30 €/t H2: 2.3 – 4.2 €//kgH2	Biomethane	Road (primarily), Maritime	2.9 kt/y	CAPEX 2.5 m€ OPEX 0.2 m€/yr
IVC8a	**Biomass gasification and methanol synthesis**	Lignocellulosic crops, residues An. qt 288 kt/yr	66 €/tn	Methanol	Maritime	145kt/yr (MeOH)	CAPEX 353 m€ OPEX 27 m€/yr
IVC8b	**Biomethane reforming into Methanol**	Biomethane, 30–35 GJ per ton MeOH	N/A	Methanol	Maritime	150kt/yr (MeOH)	CAPEX 200 m€ OPEX 13.8 m€/yr
IVC8c	**Methanol Synthesis from biogenic CO2 and H2**	biogenic CO2 and clean hydrogen	CO2: 16 €/t H2: 2.3 – 4.2 €//kgH2	Methanol	Maritime	62kt/y (MeOH)	CAPEX 24.1 m€ OPEX 1.8 m€/yr

No	Industrial Value Chain	Feedstock type[91]	Feedstock Price	Product	Sector	Output of a typical unit	CAPEX and OPEX of a typical unit
IVC11a	**Gasification and F-T synthesis**	Lignocellulosic crops, residues An. qt 781 kt/yr	66 €/tn	FT SPK	Aviation	134 kt/yr	CAPEX 759.7 - 1,639[96] M€ OPEX 57.0 - 163.9M€/y
IVC13a	**Pyrolysis and co-processing for road sector**	Lignocellulosic crops, agricultural residues An. qt 312.5 ktn/yr	44 €/tn[97]	HVO	Road	25 kt/yr (FPBO) or 40 kt/yr (HVO)	CAPEX 196.8 m€ OPEX 17.4 m€/yr
IVC13b	**Pyrolysis and upgrading for maritime sector**	Lignocellulosic crops, agricultural residues An. qt 298 ktn/yr	44 €/tn[98]	HPO	Maritime	25 kt/yr (FPBO) or 10 kt/yr (HPO)*	CAPEX 452.5 m€ OPEX 33.8 m€/yr

**Assumption: 8 decentralized FPBO units of 25 kt/yr serving 1 centralized HPO unit*

Table A2-1 Key industrial and economic indicators of the selected distinct IVCs for 2040

96 Upper limit following the input received in the stakeholders consultation
97 Agroprocessing residues
98 Agroprocessing residues

No[99]	Industrial Value Chain	LCoP (biofuel)	Fossil Fuel Comparator[100]	Reduction of LCoP	Indicative minimum support in monetary value
IVC2	**Hydrotreatment (HVO/HEFA) of oil from eligible oil crops**	138 (slate 1[101]) – 195 (slate 2[102]) €/MWh	131 (slate 1 equiv.) – 120 (slate 2 equiv.)[103] €/MWh	of the order of 5% (slate 1) - 40% (slate 2)	min. 7 €/MWh (slate 1) - 75 €/MWh (slate 2)
IVC5+ IVC6	**SAF production from Cellulosic Ethanol (EtOH-to-Jet)**	257 (EtOH, Road) – 401[104] (SAF, aviation) €/MWh	155 (EtOH E, road) - 120 (kerosene E+P, aviation) €/MWh	of the order of 40% - 70%[105]	min. 102 €/MWh (road) - 281[106] €/MWh (aviation)
IVC12+ IVC6a	**SAF production from Syngas fermentation Ethanol (EtOH-to-Jet)**	189 EtOH, Road) – 280 (SAF, aviation) €/MWh	155 (EtOH E, road) - 120 (kerosene E+P, aviation) €/MWh	of the order of 43% - 57%	min. 81 €/MWh (road) - 172 €/MWh (aviation)
IVC7	**Eligible crops production of advanced biomethane**	129.4 €/MWh	108 (CH4 E, road) – 135 (CH4 E+P, maritime) €/MWh	of the order of 16%	min. 21.4 €/MWh

[99] Numbering follows Annex 4 of Interim Report Part I (Task 2 dataset)
[100] ***E*** indicates consideration of EUA costs in the final price, ***P*** indicates consideration of the additional cost due to penalties of non-compliance with the REFuelEU Aviation or FuelEU Maritime Regulations (depending on the IVC) – see analysis of Task 2
[101] Production profile resulting to mainly HVO: 66% HVO - 12% HEFA – 2% Naphtha – 6% LPG
[102] Production profile resulting to mainly HEFA: 29% HVO - 46% HEFA – 4% Naphtha – 3% LPG
[103] Based on the analysis of Task 2, road diesel is considered at 135 €/MWh, Jet fuel with EUA costs at 110 €/MWh and jet fuel with EUA cost and penalties at 300 €/MWh
[104] Stakeholders consultation input indicated higher costs for the alcohol-to-jet value chains, resulting to a higher LCOP of 468.5 €/MWh.
[105] Consideration of the higher LCOP of 468.5 €/MWh would results to a support need of the order of 74%.
[106] Consideration of the higher LCOP of 468.5 €/MWh would results to Indicative minimum support in monetary terms of 349 €/MWh for the aviation fuel case.

No[99]	Industrial Value Chain	LCoP (biofuel)	Fossil Fuel Comparator[100]	Reduction of LCoP	Indicative minimum support in monetary value
IVC9a	**Biomass Gasification and Methanation**	139 €/MWh	120 (CH4 E, road) - 175 (CH4 E+P, maritime) €/MWh	of the order of 14% (road[107])	min. 19 €/MWh (road)
IVC9b	**Methanation from biogenic CO2 and H2**	112 (low H2 cost) – 191 (high H2 cost)[108] €/MWh	120 (CH4 E, road) - 175 (CH4 E+P, maritime) €/MWh	of the order of 21% (road) and 8-16% (maritime)[109]	min. 31.5 €/MWh (road) and 16 - 23.5 €/MWh (maritime)
IVC8a	**Biomass gasification and methanol synthesis**	121.4 €/MWh	85 (VLSFO E) – 150 (VLSFO E+P)[110] €/MWh	of the order of 30%	min. 36 €/MWh
IVC8b	**Biomethane reforming into Methanol**	156.4 – 169.3 €/MWh[111]	155 €/MWh[112]	of the order of 1-8%	min. 1.4 – 14.3 €/MWh
IVC8c	**Methanol Synthesis from biogenic CO2 and H2**	116 (low H2 cost) – 199 (high H2 cost)[113] €/MWh	85 (VLSFO E) – 150 (VLSFO E+P) €/MWh	of the order of 25-27%	min. 31 – 49€/MWh

[107] The cost of fossil maritime fuel with the cost of EUA and penalties, exceeds the LCOP of the corresponding biofuel.
[108] Assumed low cost H2: 2.3; high cost H2: 4.2 €//kgH2
[109] Consideration of low H2 cost results into a lower biofuel LCOP than the corresponding fossil fuel comparator. Support for road has been estimated on the basis of a mean H2 cost (and therefore a mean LCOP), while support for maritime has been estimated as a range for the mean and high H2 cost (and corresponding biofuel LCOPs)
[110] The cost of fossil maritime fuel with the cost of EUA and penalties, exceeds the LCOP of the corresponding biofuel.
[111] Typical range for the total value of renewable methanol (GO + fossil) (see Task 2 for details).
[112] Average cost of fossil methanol.
[113] Assumed low cost H2: 2.3; high cost H2: 4.2 €//kgH2.

No[99]	Industrial Value Chain	LCoP (biofuel)	Fossil Fuel Comparator[100]	Reduction of LCoP	Indicative minimum support in monetary value
IVC11a	**Gasification and F-T synthesis**	194 €/MWh	120 (CH4 E, road) - 175 (CH4 E+P, maritime) €/MWh	of the order of 38%	min. 74 €/MWh
IVC13a	**Pyrolysis and co-processing for road sector**	149 (HVO, road) €/MWh	135 (diesel, road) €/MWh	of the order of 9%	min. 14 €/MWh
IVC13b	**Pyrolysis and upgrading for maritime sector**	173 (low H2 cost) - 202 (high H2 cost)[114]	85 (VLSFO E) – 150 (VLSFO E+P) €/MWh	of the order of 50 – 60%[115]	min. 88 – 117 €/MWh [116]

Table A2-2 Levelized cost of production of biofuels and indicative minimum support per selected IVC, 2040

[114] Range depends on cost of hydrogen for upgrading – Assumed low cost H2: 2.3; high cost H2: 4.2 €//kgH2.
[115] In case the fossil fuel price is considered including the penalties, a reduction of 13 – 25% in the LCoP is needed.
[116] In case the fossil fuel price is considered including the penalties, the indicative support need is 23 – 52 €/MWh.

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Biofuels have a vital role to play in reducing emissions in transport if an EU coordinated approach for capacity development of essential industrial value chains of advanced biofuels needed to achieve the EU targets for 2030,2040, and 2050, is employed. Two main categories of financing support are identified as necessary: (a) for industrial production development, linked to the volumes of biofuels produced and (b) for feedstock supply mobilization, linked to feedstock supply volumes. For 2030, the corresponding financing needs are estimated at €3,849 – 7,499 million per year for industrial installations and €700 – 1,245 million per year for farmers/collectors.

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