Barriers to Advanced Biofuels

Addressing Policy and Finance Barriers

TNO Public ⟩ TNO 2025 P12633
February 2026

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TNO 2025 P12633 – February 2026

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Classification report	TNO Public
Title	TNO Public
Report text	TNO Public
Appendices	TNO Public
Number of pages	114 (excl. front and back cover)
Number of appendices	10
Sponsor	Ministry of Climate Policy and Green Growth

Summary

Background and Objectives

The Netherlands aims to become climate-neutral by 2050, with advanced biofuels playing a key role in reducing greenhouse gas (GHG) emissions from hard-to-abate sectors such as aviation and maritime transport. These biofuels, produced from lignocellulosic waste and residues, hold significant potential in Europe but remain scarcely utilised. Beyond the transport sector, advanced biofuels can also support the development of bio-based chemicals, e-fuels, and contribute to negative emissions, all of which are critical for long-term climate goals.

However, despite ambitious European and national targets, the market share of advanced biofuels remains very low. Most projects are still at the demonstration stage, and only a few initiatives are progressing towards Final Investment Decisions (FID). This gap between policy ambition and market reality is due to a series of technical, financial, and regulatory barriers.

This study addresses the main obstacles hindering the large-scale deployment of advanced biofuels projects, focusing specifically on policy and finance barriers, and proposing practical solutions tailored to Dutch conditions. This research was financed with subsidy from the Ministry of Climate and Green Growth in the context of the Knowledge for Energy Policy Research Program.

Methodology

The study combined:

- A literature review**, with a focus on policy and finance.**
- Expert interviews **with stakeholders from research, industry, government, and finance.**
- Conducted a comparative analysis of selected EU and non-EU countries, assessing their regulatory frameworks, fiscal incentives, and the deployment status of advanced biofuels to derive **cross-country lessons learned**.
- A workshop **to validate findings and co-create recommendations.**

The scope covers advanced biofuels, particularly from lignocellulosic waste and residues, covering the following innovative technology pathways:

- Biomass gasification followed by Fischer–Tropsch synthesis
- Biomass gasification followed by methanol synthesis
- Biomass pyrolysis followed by upgrading to fuel quality
- Hydrothermal liquefaction (HTL)
- Lignocellulosic ethanol production, followed by alcohol-to-jet conversion

Key Findings

Across Europe and globally, **policy instability has been one of the strongest barriers to scaling advanced biofuels**. Frequent revisions to the Renewable Energy Directive (RED), shifting sub-targets (for advanced biofuels), and inconsistent implementation across Member States have created uncertainty for investors. In addition, international experience shows that changing definitions of what counts as “advanced” has hindered lignocellulosic biomass-based projects. Evidence across countries shows that long-term policy stability matters more than financial incentives: predictable mandates, sub-mandates, and GHG-intensity systems are

essential to secure investment. However, without clear protection of advanced categories, these high-risk biofuel value chains struggle to compete against cheaper, mature biofuels, and investment progress is lost.

The Dutch government could engage with the European Commission **to keep the advanced feedstock list in the Renewable Energy Directive stable.** This can be approached either by maintaining a separate priority list for lignocellulosic biomass or by halting further expansion of feedstocks so that the investment in lignocellulosic conversion routes is not further undermined.

While biomass supply is not seen as the main barrier, current availability is based on a narrow range of resources. **Supply chains** for many REDIII eligible feedstocks **remain underdeveloped**, and securing long-term biomass-supply contracts, which are critical for de-risking investments and securing financing, is challenging. Frequent changes to the list of eligible feedstocks create uncertainty and may discourage investment in harder-to-process materials. To address this, the Dutch government could advocate for stable feedstock eligibility at the EU level and support the development of infrastructure and logistics that enable feedstock to become a tradable commodity. European collaboration will be essential as much of the biomass potential is located outside the Netherlands.

Strong, long-term demand signals are indispensable. For the Netherlands, stable demand for advanced biofuels will require government-backed offtake mechanisms, pooled procurement, and alignment with the FuelEU Maritime and ReFuelEU Aviation Regulations. However, strong and stable demand may not necessarily pull the domestic development of advanced biofuels in the Netherlands or Europe. Instead, the demand may be filled by imports. Therefore, c**ompetition with other regions will need to be managed carefully**.

First-of-a-kind (FOAK) plants are essential stepping stones toward profitable next-of-a-kind (NOAK) projects, and they rarely achieve commercial success on their own. Constructing a commercial-scale plant requires hundreds of millions of euros and is accompanied by numerous risks across the value chain and unvalidated operational performance. This weighs heavily on investment decisions. The lack of track-record and lack of predictable and credible cash flows for the FOAK plants make investors cautious. However, these plants are required as the proof point that advanced biofuel technologies can scale, operate reliably, and deliver needed quantities. Independent developers who are often the source of innovation face even greater difficulties as they lack strong financial reserves and credit ratings.

Existing EU-wide financial support remains fragmented and risk-averse, largely providing support for proven technologies rather than innovative pathways. Advanced biofuels from lignocellulosic feedstocks have not scaled, while value chains based on relatively easier to process feedstocks, such as HVO/HEFA and biomethane dominate due to lower risk. Recent developments, such as the Sustainable Transport Investment Plan (STIP) put more weight on e-fuels and do not explicitly target advanced biofuels.

Focused de-risking mechanisms for a limited number of FOAK plants can help these projects reach financial close and, over time, scale without continued support. A combination of support mechanisms like government-backed guarantees, concessional public financing, ramp-up support can reduce lender risk and improve liquidity during early operations. Using these tools together to cover residual risks that the market cannot absorb will allow high-risk technologies to move from early demonstration toward full commercial deployment.

Government support must ensure market competitiveness beyond FOAK phase by adapting existing instruments and progressively shifting from national schemes to collaborative, cross-border mechanisms that expand investment opportunities and strengthen competition between projects. Once FOAK learning is established, government support will be needed to maintain the competitiveness of these advanced value chains. This will be a transition period from FOAK to a better functioning market for advanced biofuels. Existing instrument, such as SDE++ can provide cost-effective revenue certainty over an extended period of time. This will act as a safety net until the market matures. However, adjustments in this instrument will be needed to include aviation and maritime sectors and account for feedstock price volatility.

Additional innovative market mechanisms such as double-sided auctions, could enhance offtake certainty, stabilise revenues and attract investment. For this option, a joint auction approach with other EU countries is recommended to increase liquidity, foster competition on both sides, and share budget. This option will require a longer implementation timeline. Until then, using the existing support scheme which is connected to Emission Reduction Unit (ERE) system (the successor to the HBE system used until the end of 2025) is essential. The Netherlands can quickly pilot by combining SDE++ (supply side cost gap funding) with demand side compliance, then expand with partner countries to expand investment opportunities in advanced biofuel projects.

International experience shows that **industrial clustering improves project feasibility**: co-location, shared utilities, and reduced feedstock risks have been key success factors in countries like Brazil. The Netherlands can apply these lessons by **integrating advanced biorefineries into its established refinery and chemical clusters.**
While building bio-based processes near regions with abundant biomass and renewable energy is cost-effective, the Netherlands can leverage its existing petrochemical industry and logistics infrastructure by positioning biofuel refineries as strategic assets for both transport decarbonisation and industrial transformation, particularly the chemical industry. A national action plan for renewable fuels with a dedicated focus on advanced biofuels can support this, ideally coordinated with neighbouring Member States. As advanced biorefineries for fuels will be an important stepping stone for the chemical industry, this action plan could integrate the action agenda for biomaterials (Actieagenda Biogrondstoffen) and the Vision on Sustainable Carbon in the Chemical Industry.

Overall, the comparative evidence shows that **advanced biofuels scale only when four elements align: long-term policy stability, reduced early-stage risk, secure feedstock access, and strong market demand**. For the Netherlands, these factors need to be shaped to fit local conditions. The country has limited domestic biomass, but is uniquely well positioned through its ports, logistics hubs, and industrial clusters. The country already handles significant wood chips and pellet imports and can use this infrastructure for the development of advanced biofuels. To accelerate progress, the Netherlands can focus on the pathways that best fit its industry, and supporting a few selected pathways will accelerate scale up and avoid fragmented or inefficient investment. Supporting multiple smaller FOAK plants, instead of one large flagship, will help spread risk and speed up learning.

In conclusion, to close the gap between ambition and reality, the Netherlands needs a stable and supportive ecosystem that reduces risks and enables technology scale-up. If current conditions persist, the country risks becoming dependent on imports and missing opportunities to strengthen its industrial base and reach national ambitions.

Recommendations for The Netherlands

Adopt a Two-Track Policy Approach Until Value Chains Mature

To accelerate deployment while ensuring long-term stability, implement two complementary policy tracks:

- **Track 1: Long-term, stable GHG-based obligations** to create demand, give investors confidence and drive continued innovation across the market.
- **Track 2: Temporary, targeted support for a small number of FOAK projects** to de-risk the most promising advanced pathways.

Both tracks should run in parallel until the supply of advanced biofuels scales and costs fall.

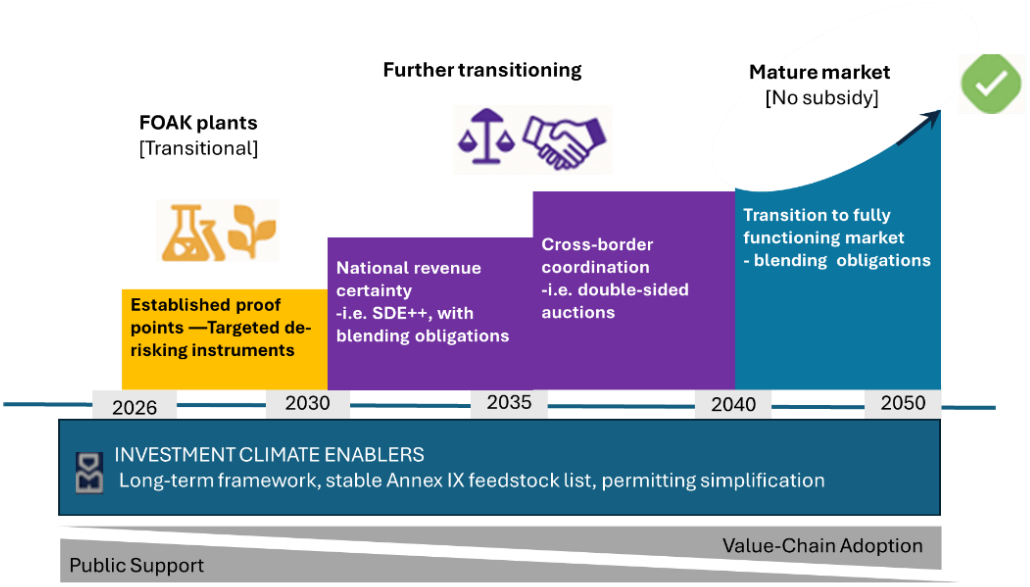

Figure S.1: Illustration of the recommended policy support framework

Track 1: Keep strong GHG reduction goals and clear sub-mandates (10–15 years)

- Maintain ambitious, stable GHG-intensity obligations, like the annual obligation for fuel suppliers to blend in renewable fuels.
- Keep binding sub-mandates for advanced biofuels, ensuring they also support new lignocellulosic and waste-based value chains that can later supply aviation, maritime, and chemicals. Avoid adding more sub-mandates; instead ensure existing ones genuinely drive innovation.
- Keep stability in Annex IX feedstock lists to protect investments in difficult-to-process feedstocks.

Track 2: Provide temporary, targeted de-risking for a few strategic FOAK projects
Identify a small number of pathways tailored to Dutch strengths: early studies highlight syngas-based routes and renewable methanol (bio + e-methanol).

For these priority pathways:

- Apply targeted, time-limited risk sharing instruments (e.g., loan guarantees, targeted grants) to enable successful FOAK commercial-scale plants, followed by early NOAK capacity.

- Focus on a limited number of key projects but ensure they reach breakeven so future plants can rely mainly on market mechanisms.
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Use existing instruments to ensure revenue stability after FOAK success
- Use SDE++ together with GHG-intensity obligations to provide stable revenues for 15 years.
- Expand SDE++ eligibility to include SAF and maritime fuels.
- Update feedstock cost assumptions using indexed or periodic benchmarks.
- Apply learnings from targeted enhancements listed above, then expand through cross-border auctions or EU-level platforms.
- Work with the European Commission to ensure (lignocellulosic) advanced biofuels are explicitly included in the Sustainable Transport Investment Plan (STIP) that was adopted in 2025 to unlock investments and scale up production of renewable and low-carbon fuels.

Rely on market mechanisms once the sector is fully mature
After scale-up and cost reduction, the GHG system should drive further deployment without extra support.

Coordinate instruments, budgets, and cross-sectoral needs
- Align support for advanced biofuels with the chemical industry's decarbonisation trajectory, since these value chains will be the stepping stones for a fossil free chemical industry.
- In addition, advanced biofuels can supply biogenic CO_2 for renewable fuels of non-biogenic origin (e-fuels) or for chemicals. Support integrated clusters where advanced biofuel, e-fuel, and chemical producers co-locate and share biomass preprocessing, hydrogen, CO_2 streams, and logistics infrastructure.

Improve wider enabling conditions
Simplify permitting. Ensure infrastructure access. Support feedstock markets and regional hubs. Promote links with the production of e-fuels and chemicals.

Contents

Abbreviations

Abbreviation	Full Term
AF	Animal Fats
CAPEX	Capital Expenditure
CfD	Contract for Difference
CIC	Certificato di Immissione in Consumo
CO_2	Carbon Dioxide
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
DEI+	Demonstration Energy & Climate Innovation
DOE	Department of Energy
DSCR	Debt Service Coverage Ratio
ECA	Export Credit Agency / European Court of Auditors
EIB	European Investment Bank
EPC	Engineering, Procurement, and Construction
EU	European Union
EU ETS	European Union Emissions Trading System
FEED	Front-End Engineering Design
FID	Final Investment Decision
FOAK	First-of-a-Kind
GHG	Greenhouse Gas
GSE	Gestore dei Servizi Energetici
HEFA	Hydroprocessed Esters and Fatty Acids
HVO	Hydrotreated Vegetable Oil
ICAO	International Civil Aviation Organization
IEA	International Energy Agency
ILUC	Indirect Land-Use Change
IPCEI	Important Projects of Common European Interest
IRA	Inflation Reduction Act
IRICC	Incentive for Carbon Intensity Reduction in Fuels
LNG	Liquefied Natural Gas
MS	Member State
NEA	Nederlandse Emissieautoriteit
NGO	Non-Governmental Organization
NOW	Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditure
PBL	Planbureau voor de Leefomgeving
R&D	Research and Development
RFS	Renewable Fuel Standard
RED/RED II/RED III	Renewable Energy Directive (II/III)
RFNBO	Renewable Fuels of Non-Biological Origin
ROM	Regionale Ontwikkelingsmaatschappij
RVO	Rijksdienst voor Ondernemend Nederland
SAF	Sustainable Aviation Fuel

Abbreviation	Full Term
SDE++	Stimulation of Sustainable Energy Production and Climate Transition
SEA	Swedish Energy Agency
SME	Small and Medium-sized Enterprise
SPV	Special Purpose Vehicle
STIP	Sustainable Transport Investment Plan
TRL	Technology Readiness Level
UCO	Used Cooking Oil
USDA	United States Department of Agriculture
VGF	Viability Gap Funding

1 Introduction

1.1 Background

The transition to a climate-neutral energy system and industry requires a rapid scale-up of advanced biofuels. From 2030 onwards, demand is expected to grow significantly due to policies such as the EU's Renewable Energy Directive (RED III), and sector-specific regulations such as FuelEU Maritime, and ReFuelEU Aviation. These policies set stringent greenhouse gas (GHG) emission reduction targets and binding sub-mandates for use of advanced biofuels. Recent studies for the Netherlands ((PBL, 2024), (Scheepers, et al., 2024), (Uslu, et al., 2025) confirm the critical role of advanced biofuels in the transport sector, enabling negative emissions, and providing biogenic CO_2 for the production of synthetic fuels and feedstocks such as synthetic methanol. In addition, value chains like biomass gasification and biomass pyrolysis are seen as strategically important for both transport fuels and chemical feedstocks.

Even with rising demand, advanced biofuels still make up less than 1% of transport energy use. Most projects remain at the demonstration stage, and only a few commercial plants exist worldwide. Major barriers—technical, policy, feedstock, and financial—continue to slow large-scale deployment. Although these challenges are known, effective solutions and actionable policy interventions are still lacking.

1.2 Goal and Approach

The main goal of the project is to support the ministry of Climate Policy and Green Growth (Ministry of KGG) in identifying and understanding the barriers for the market development of advanced fuels in the Netherlands and explore ways to overcome them. The key focus is on policy and finance related barriers with the goal of creating clear, practical solutions tailored to Dutch conditions.

To achieve this, we address the following questions:
- Why have no commercial advanced biofuel projects been developed in recent years? What is preventing the industry from scaling up?
- What practical solutions can remove these barriers in the Netherlands or the EU, and how can the Dutch government support the market?

To answer these questions, the study uses the following approach:
- Review existing literature and policy documents.
- Conduct expert interviews with stakeholders across the value chain (interview list is in Appendix A).
- Assess policy and financial barriers and identify possible solutions.
- Organize a stakeholder workshop to validate findings and co-create actionable recommendations (Participant list is in Appendix A).

In total 24 semi-structured interviews were conducted for this study. These interviews were designed to capture diverse perspectives on barriers to the deployment of advanced biofuels and potential solutions the Dutch Government could pursue. Semi-structured interviews were chosen as they allow for consistency across key topics while providing flexibility to explore stakeholder-specific concerns in depth. This is an approach that ensures both comparability and richness of input.

The interviewees represented a balanced mix of research institutions, industry actors, government bodies, and financiers (see Figure 1.1). This diversity is critical: industry stakeholders bring practical implementation challenges, financiers highlight investment risks and enablers, and government representatives provide policy context. Together, these viewpoints create a comprehensive understanding of systemic barriers and inform actionable strategies. A workshop was also organised to discuss barriers and potential solutions.

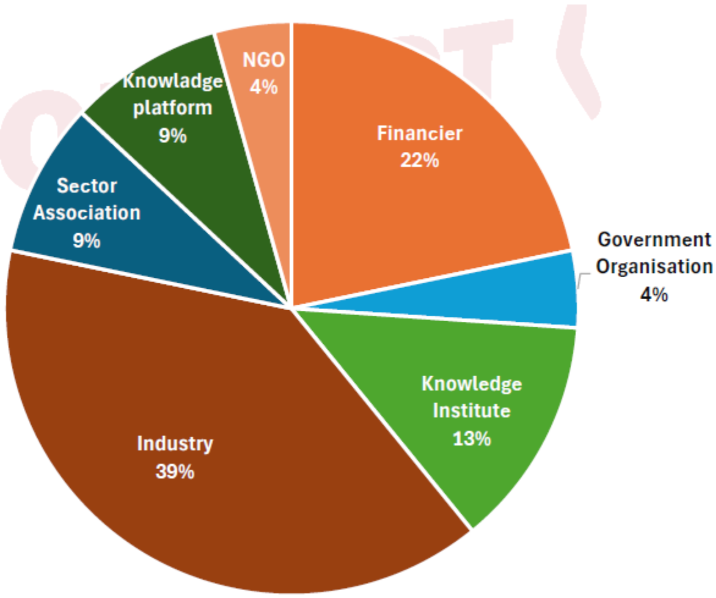


Figure 1.1: Illustration of the interviewed stakeholders

1.3 Definitions and Scope

In the EU, advanced biofuels are defined politically, based on the feedstock categories listed in Annex IX of the Renewable Energy Directive (RED II/III). Article 2 of RED II specifies that advanced biofuels are those produced from the feedstocks listed in Part A of Annex IX. These are primarily waste and residue streams of biogenic origin. In 2024, the list was updated through Commission Delegated Directive (EU) 2024/1405, adding additional eligible feedstocks. The full, updated list is provided in Appendix B. There are also eligible feedstocks categorised as Part B. Part B consists of used cooking oils (UCO), animal fats (AF), and expanded to damaged crops not fit for food and feeds use, crops grown on severely degraded land, and intermediate crops, such as catch crops and cover crops.

Biofuels can be produced via multiple conversion technologies at varying stages of market maturity. Conventional production routes such as ethanol from sugary crops, biodiesel (HVO/FAME) from vegetable oils, and HEFA-based sustainable aviation fuel (SAF) from fatty feedstocks and liquefied natural gas (LNG) from organic waste and residues, are already commercial. These routes, however, are not the focus of this study.

Instead, this study concentrates on novel and less mature production routes that are critical for unlocking the larger potential of lignocellulosic feedstocks, but which have not yet been deployed at commercial scale.

These include:
- Biomass gasification followed by Fischer–Tropsch synthesis
- Biomass gasification followed by methanol synthesis
- Biomass pyrolysis followed by upgrading to fuel quality
- Hydrothermal liquefaction (HTL)
- Lignocellulosic ethanol production
- Alcohol-to-jet conversion.

1.4 Reading Guide

This report is structured to provide a comprehensive overview of the barriers and opportunities for advanced biofuels, with a focus on policy and finance. Below is a guide to help you navigate the chapters:
- Chapter 2 Briefly highlights the status of biofuel technologies and summarizes the main barriers identified in the literature.
- Chapter 3 Introduces the discussions and insights gathered during stakeholder interviews, capturing diverse perspectives from across the value chain.
- Chapter 4 Introduces the key financial instruments in the EU affecting advanced biofuels.
- Chapter 5 Provides the key findings of an in-depth analysis of current policies related to advanced biofuels. The focus is on EU-level policies and key financial instruments, followed by a review of policy implementation in other regions such as the US, Brazil, and India. Detailed country analysis can be found in Appendix F.
- Chapter 6 Focuses on the financing landscape for advanced biofuels and explores how projects can be moved towards bankability. This chapter details potential government support mechanisms to mitigate risks across the value chain and improve stability of cash flows.
- Chapter 7 Presents the overall conclusions and policy recommendations based on the findings of the study.

2 Status of Advanced Biofuels and Identified Barriers

Advanced biofuels are widely recognised as a key value chain in achieving the EU's climate and energy targets. Policy frameworks such as the Renewable Energy Directive (RED II/III), FuelEU Maritime, and ReFuelEU Aviation Regulations are introduced to drive the demand in Europe. Beyond Europe, global policy initiatives are also pushing for (advanced) biofuel uptake. The International Maritime Organization (IMO) has introduced increasingly stringent GHG reduction targets for international shipping, creating demand for low-carbon marine fuels. Similarly, the International Civil Aviation Organization (ICAO), through its CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) framework, is encouraging the use of sustainable aviation fuels (SAF) to mitigate emissions from international aviation. Together, these initiatives underline the growing international momentum behind advanced biofuels.

Despite these policy signals, the contribution of advanced biofuels to transport energy demand remains marginal, with most production limited to pilot and demonstration projects. Commercial-scale plants are still scarce, and progress has been uneven across technologies and countries. Figure 2.1 illustrates the estimated capacities of various production facilities in Europe. It also shows the estimated production amounts by 2023. As can be seen, the contribution from novel production routes (HTL, Pyrolysis, Gasification, ATJ, Advanced Ethanol) is minor to non-existing.

It is necessary to highlight that while the Renewable Energy Directive introduces a cap to biofuels produced from Annex IX Part B list, ReFuelEU Aviation regulation does not introduce any limitations to biofuels from this list. Neither ICAO nor IMO directly reference Annex IX Part A list. Instead, all feedstocks that meet sustainability criteria and avoid indirect land-use change are considered eligible.

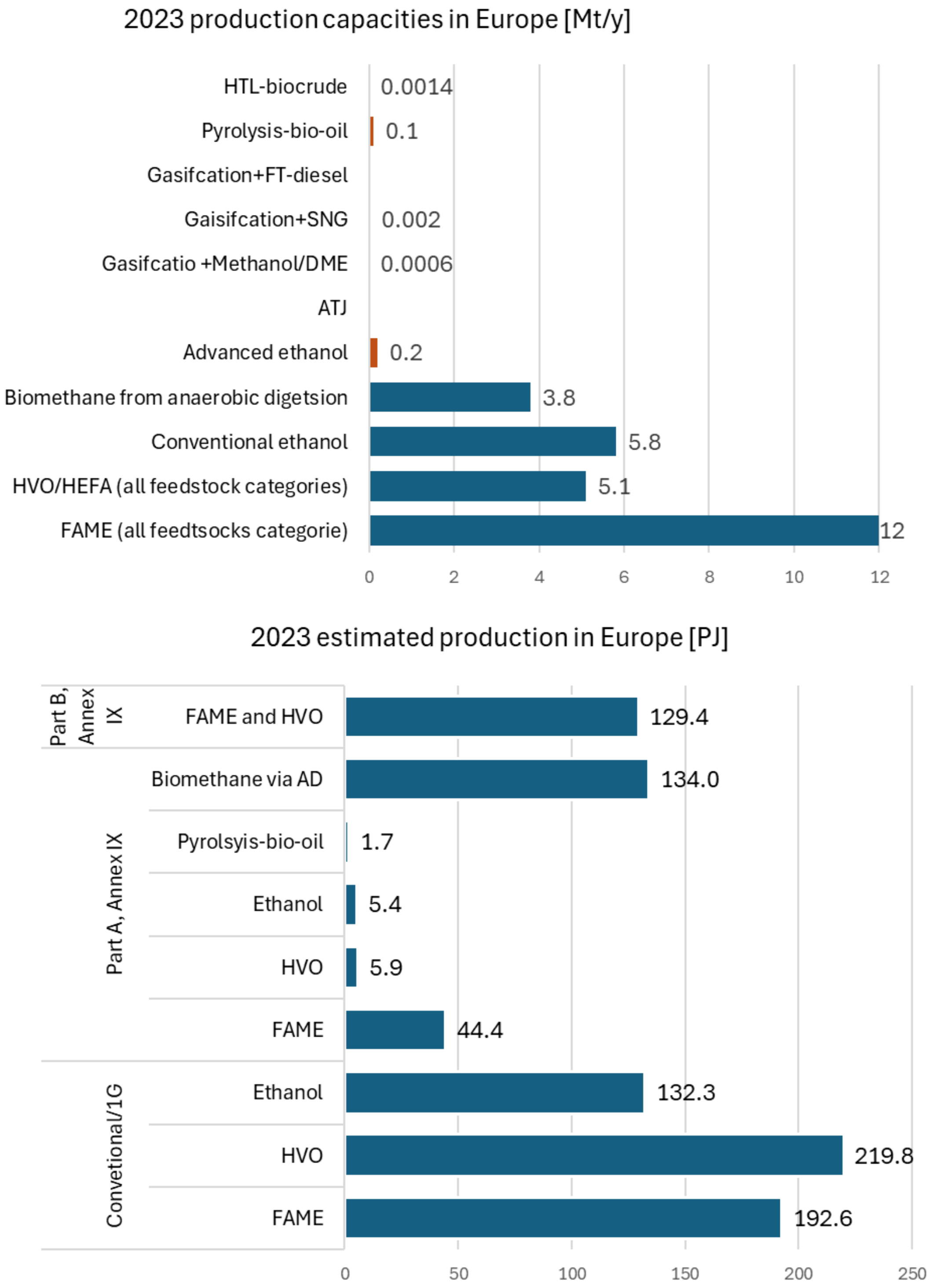


Figure 2.1: Estimated biofuels production capacities (Mt/y) and production amounts (PJ) in Europe [EC, 2024]

Various previous projects and studies have identified key barriers to advanced biofuels with a focus on the complete value chains. Below table recaps the identified barriers based on (Uslu, et al., 2018); (IEA, 2023); (Calliope Panoutsou, et al., 2021); (IRENA, 2019).

Table 2.1: Recap of key barriers according to literature

Step within the value chains	Description of the barrier
Feedstock Supply Limitations	⟩ Scaling sustainable biomass supply is urgent, requiring the mobilization of diverse feedstocks like forestry and agricultural residues and waste streams. Current supply chains rely on limited resources like wood chips, pellets, and fats.
Technological Development	⟩ Advanced biofuel conversion technologies are mostly pre-commercial or early commercial stages. Scaling requires intensive R&D to enhance efficiency, improve yields, and reduce costs. ⟩ Early-stage market challenges, like the absence of spot markets, small and dispersed production sites, and underdeveloped supply chains, create hurdles in securing long-term offtake agreements and financing.
Policy and Regulatory Uncertainty Creating Demand Uncertainty	⟩ Frequent legislative changes (e.g., RED II to RED III transitions) and complex regulatory frameworks deter investment. Variability in implementation across EU Member States adds complexity and creates uneven opportunities. ⟩ Policy and regulatory ambiguity creating demand uncertainty. While REDIII recognises advanced biofuels (from annex IX part A list), it makes the demand for these biofuels conditional to RFNBOs. ⟩ Neither RefuleEU not FuelEU Regulations provide direct demand for advanced biofuels.
High Costs and Investment Needs	⟩ Production costs for renewable fuels are significantly higher than fossil fuels due to immature technologies, high feedstock prices, and insufficient economies of scale. ⟩ High upfront capital expenditures (CAPEX) and a lack of first-of-a-kind commercial plants deter investment.
Project Financing Risks	⟩ The renewable fuels market faces a dilemma of unproven technologies and perceived investment risks. Without large-scale plants, progress stalls, perpetuating the cycle of limited investments. ⟩ Investors and buyers are hesitant to commit to long-term contracts due to cost uncertainty and the expectation of future price reductions as production scales.

The barriers outlined below and examined in detail in the following chapters are common across all value chains considered in this study. Table 2.2 presents the Technology Readiness Levels (TRLs) for these pathways. TRLs provide a simple and standardized metric for assessing the maturity of a technology, ranging from early-stage concepts to fully commercial systems. As shown, none of the value chains have yet reached commercial maturity, and each present both technological and integration-related risks. Table 2.3 summarises the key technology challenges and the current research focus for these pathways (JRC, 2024).

Table 2.2: Technology Readiness Levels [derived from JRC, 2024)

TRL level	5	6	7	8	9	10	11
Value chain	PROTOTYPE		DEMONSTRATION		EARLY ADOPTION		MATURE
Lignocellulosic biomass to ethanol			■	■			
Lignocellulosic biomass to alcohol to jet		■					
HTL biocrude production	■	■					
Pyrolysis of biomass to pyrolysis oil				■	■		
Fast pyrolysis & thermos-catalytic reforming to drop-in fuels		■	■				
Biomass gasification to syngas			■	■			
Lignocellulosic biomass to FT fuels		■	■				
Biomethanol synthesis				■			

Table 2.3: Key Technological Barriers Across Advanced Biomass-to-Fuel Pathways

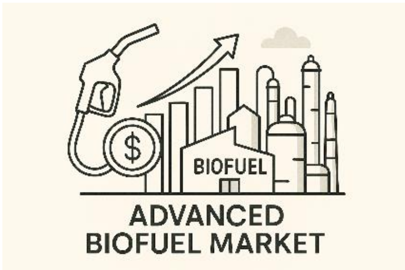
Pathway	Technological barriers
Lignocellulosic biomass to ethanol	Lignocellulosic biomass is composed of three major fractions: cellulose (C6 sugar polymers), hemicellulose (C5 sugar polymers), and lignin (aromatic polymer structures). The tightly bound and heterogeneous nature of these components makes lignocellulosic feedstocks inherently resistant to breakdown. As a result, a pre-treatment step is required before enzymatic saccharification to open the structure and allow separation of cellulose and hemicellulose from lignin. Once separated, saccharification can proceed through enzymatic hydrolysis using cellulases and hemicelluloses to release fermentable sugars. While the resulting C6 sugars can be efficiently fermented by conventional yeasts, the fermentation of C5 sugars requires engineered or specialized microorganisms, and these processes are not yet as mature. Lignin, which cannot be fermented, is typically recovered and used as a fuel to supply process heat or electricity. Despite extensive research and pilot-scale deployment, several technical barriers continue to hinder the commercial-scale production of lignocellulosic ethanol. Key challenges include the development of efficient and cost-effective pre-treatment methods, reducing enzyme costs while improving enzymatic activity, and achieving robust and reliable fermentation of pentose (C5) sugars. These constraints collectively limit process efficiency and increase production costs, slowing down widespread commercialization.

Pathway	Technological barriers
Fast Pyrolysis to drop-in fuels	Biomass pyrolysis has been demonstrated at small-scale and several large pilot plants or demo projects are in operation although current production capacity is limited (IRENA, 2016). Although pyrolysis is a well-researched thermochemical pathway, the resulting bio-oil presents significant challenges for downstream upgrading. Raw pyrolysis oil is highly oxygenated, acidic, thermally unstable, and chemically heterogeneous, making it unsuitable as a direct fuel without extensive treatment. Achieving consistent, high-quality bio-oil requires advances in reactor design, feedstock preprocessing, and process control to reduce variability. To produce drop-in fuels compatible with existing engine and refinery infrastructure, pyrolysis oil must undergo upgrading processes such as hydrodeoxygenation, catalytic cracking, or co-processing in standard refinery units. Upgrading technologies remain energy-intensive and catalyst-dependent, and the development of robust catalysts that can withstand impurities and high oxygen content is still ongoing. In addition, the hydrogen demand for hydrodeoxygenation is substantial, affecting both process efficiency and economics.
HTL to drop-in fuels	This process can handle a wide variety of feedstocks, including algae, sewage sludge, and agricultural residues, without the need for drying, making it a promising route for flexible, low-cost biofuel production. However, despite successful pilot-scale demonstrations, several technical challenges continue to hinder commercial deployment. Bio-crude quality depends on the feedstock type and operating conditions such as temperature, solvent type, and catalyst and residence time. Production of renewable hydrocarbons via HTL is progressing currently at laboratory (TRL of 4) or pilot stage (TRL of 5-6), while some projects appear to be closer to commercialisation.
Biomass gasification	Biomass gasification has been widely studied, leading to the development of several gasifier reactor configurations. Owing to the operation of demonstration plants biomass gasification is generally considered to have reached Technology Readiness Level (TRL) 8. Current research efforts concentrate on the “raw gas” produced during gasification, which requires significant cleaning and conditioning prior to conversion into fuels. The most substantial technological advancements are expected in this stage of the process.
Biomass gasification followed by Fischer-Tropsch (FT) synthesis	Fischer-Tropsch is an established technology, and many components of the system are already proven and operational for decades in coal-to-liquid or gas-to-liquid plants. Applying FT to biomass-derived syngas requires further development, particularly in designing reactors that can be effectively scaled. Achieving economic viability generally requires large plants to benefit from economies of scale, both for gasification and for the catalytic systems. However, scaling up is often difficult for biomass-based operations because of feedstock supply and logistics constraints. Additionally, efficient pressurized biomass gasification remains an active area of investigation.
Biomethanol synthesis	The raw syngas leaving the gasification step needs to be cleaned and conditioned to meet the quality level required by the methanol synthesis step. Syngas cleaning involves the removal of certain impurities, tar removal/cracking, particulate matter removal, and sulphur, nitrogen and chlorine species removal. The syngas is subsequently conditioned through several steps to reach the optimal composition for methanol synthesis, for example by removing CO_2 or adding hydrogen.

3 Barriers to Advanced Biofuels

Barriers are grouped under three core heading, namely demand creation, conversion technology status and financing, and feedstock supply and classification.

3.1 Demand-Side Uncertainty



Interviewees pointed out that market risks are closely linked to the demand for (advanced) biofuels. European mandates under REDIII, ReFuelEU Aviation and FuelEU Maritime Regulations were generally seen as effective in creating demand for biofuels. However, these mandates are all relatively new and have not yet established a track record that would build trust in long-term demand and price stability. This is accommodated by policy ambiguity surrounding the implementation of REDIII, ReFuelEU Aviation, and FuelEU Maritime regulations.

Market pull via implementation of Renewable Energy Directive and related barriers
EU biofuel policy has undergone frequent and significant changes over the past two decades. It evolved from voluntary biofuels targets to broad renewable energy targets to complex frameworks that distinguish between conventional and advanced biofuels. The Directive has defined eligible feedstocks in different lists and set caps and sub-targets, with the goal to limit unintended socio-economic and environmental impacts from using certain feedstocks for biofuel production. This evolving policy landscape (summarized in detail in Appendix C) has created uncertainty for investors and project developers, often slowing the scale-up of advanced biofuels.

REDII (2018/2001/EU) introduced a dedicated target for advanced biofuels produced from feedstocks listed in Part A of Annex IX. According to this, biofuels (including biogas) should make up at least 0,2% in 2022, at least 1% in 2025 and at least 3,5% of transport energy demand in 2030. This was intended to stimulate the deployment of next-generation biofuels from sustainable waste and residue feedstocks. The amended Directive, REDIII (EU/2023/2413), altered this and introduced a combined binding sub-target for advanced biofuels and RFNBOs, to reach at 5.5% of transport energy by 2030. In addition, this sub-target is set conditional to RFNBOs, for which a minimum of 1% should be met by RFNBOs. The inclusion of RFNBO in the target creates both complexity and uncertainty for the demand for advanced biofuels.

While RED III set binding renewable energy target for transport (of 29%), or alterative, GHG based compliance (of at least 14.5%), these targets can also be met using renewable electricity in transport. Direct electrification of road transport offers significant efficiency gains, reducing overall energy demand compared to liquid fuels. Given the targets are expressed as a percentage of total transport energy, lower energy demand due to electrification indirectly reduces the volume of renewable fuels required, including advanced biofuels. Additional incentives for electrification, such as multiple counting, amplify this effect. For example, the Netherlands previously applied a 4× multiplier for renewable electricity in road transport, and under RED III implementation, a new bonus for renewable electricity supplied to electric vehicles further strengthens this approach. These mechanisms can substantially lower projected demand for advanced biofuels, influencing investor confidence and long-term project viability.

The limited time frame of the Renewable Energy Directive has also been criticized by stakeholders, for instance REDIII targets only run until 2030, creating uncertainty about the continuation after that period. This issue has been recognised by some of the EU countries.

- France has proposed a draft IRICC (Incitation à la Reduction de l'Intensité Carbone des Carburants) decree that sets annual renewable energy obligations for different fuel types, such as diesel, gasoline, gas fuels, maritime, and aviation, from 2026 to 2035. It also includes yearly sub-targets for advanced biofuels (Annex IX A) and RFNBOs, extending the country's transport compliance framework beyond the EU's 2030 deadline[1].
- In December 2025, the German Federal Government (Bundeskabinett) approved the Second Act on the Further Development of the GHG-Reduction Quota (THG-Quote), extending transport compliance to 2040. This act increases the overall GHG reduction quota from 10.6% in 2025 up to 59% by 2040 and introduces a dedicated RFNBO quota that provides long-term certainty beyond 2030[2].
- In the Netherlands, Tweede Kamer (House of Representatives) passed a motion (Groningen & Veltman) on 29 September 2025, requesting the government to extend the RED III investment horizon to 2035, specifically for the fuel transition obligation (brandstoftransitieverplichting). This is to enhance investment certainty and align with neighbouring countries. Implementation remains under assessment, and legislative action is expected by early 2026[3].

ReFuelEU and FuelEU regulations

While REDIII sets targets until 2030, ReFuelEU Aviation (2023/2405; in force January 2025) and FuelEU Maritime (92023/1805: in force January 2025) regulations cover a longer time horizon. However, the targets set in these regulations ramp-up in a stepwise increase leading to sudden jumps in demand. For example, the minimum SAF share increases from 6% in 2030–2034 to 20% in 2035, while the GHG intensity reduction under FuelEU Maritime rises from 6% in 2030 to 14.5% in 2035. Figure 3.1 and Figure 3.2 show the stepwise increases introduced in these regulations.

Neither ReFuelEU nor FuelEU includes a dedicated sub-mandate for advanced biofuels. Both biofuel categories from waste & residues listed in in Part A of Annex IX and those from Part B are eligible fuels under ReFuelEU. This enables compliance primarily through HEFA fuels in aviation, which are cheaper and widely available. As a result, investment in lignocellulosic pathways will be postponed. Studies (SkyNRG, 2025) indicate HEFA will dominate SAF supply until 2030-2035 with advanced biofuels and RFNBO becoming essential thereafter. However, long lead times and market uncertainty make financing these projects challenging, highlighting the need to begin planning conversion facilities now.

[1] See 20250512_-_projet_arrete_iricc.pdf
[2] See BMUKN: Klimafreundlicher tanken, neue Nachfrage für grünen Wasserstoff: Bundesregierung beschließt Gesetzesnovelle zur Treibhausgasminderungs-Quote | Pressemitteilung
[3] See Kamerstuk 36766, nr. 12 | Overheid.nl > Officiële bekendmakingen

FuelEU Maritime Rergulation sets binding limits on GHG intensity (well-to-wake) for ships that are ≥ 5000 GT[4]. This follows a technology-neutral approach; thus, ships could choose low-GHG fuel options including biofuels, e-fuels, liquefied natural gas (LNG), hydrogen, or ammonia. This regulation does not specifically require advanced biofuels from lignocellulosic feedstocks[5]. There has been some warning signs that this technology-neutral design may favour LNG over renewable alternatives, particularly in reaching relatively low GHG intensity limits introduced up to 2030 (Transport&Environment, 2022); (Uslu, 2024), followed by bio-LNG production based on anaerobic digestion of gashouse feedstocks (Transport&Environment, 2023); (Wood Mackensie, 2025);(Wood Mackensie, 2025).

The complexity of feedstock eligibility across EU and Dutch law

Feedstock rules differ by instrument and by Member State implementation. Under the Renewable Energy Directive (RED III) there are two lists of eligible waste- and residue-based materials; Annex IX Part A (advanced) and Annex IX Part B (used cooking oils and certain animal fats), with sub-targets for fuels from List A and caps on fuels from List B. Sectoral regulations then build on RED's sustainability criteria in different ways.

- ReFuelEU Aviation counts biofuels from Annex IX A and B and allows a limited share of other biofuels not listed in Annex IX if they meet RED sustainability rules (subject to an overall 3% cap).
- FuelEU Maritime is performance-based: it does not prescribe feedstock lists but requires biofuels to meet well-to-wake GHG-intensity limits and RED sustainability.
- Finally, national implementation can further steer the mix: in the Netherlands' RED III transport scheme (from 2026), Annex IX-B feedstocks are capped in inland transport and shipping and excluded for the maritime transport of the national obligation. The policy goal is to prioritise scarce IX-B (UCO/animal fats) for sectors where they deliver most benefit and avoid locking maritime into limited waste-oil pools, thereby accelerating Annex IX-A and RFNBO scale-up in shipping.

Table 3.1 summarises which feedstocks are eligible under which policy.

Table 3.1: Feedstock eligibility according to REDIII, ReFuelEU and FuelEU Regulations

Feedstock List	REDIII	FuelEU Maritime	ReFuelEU	Implementation in the Netherlands from 2026 onwards[6]
Annex IX, Part A	All feedstocks eligible, promotes as part of the dub-mandate	All feedstock eligible, no target or cap	All feedstock eligible, no target or cap	Eligible in all sectors

4 It covers 100% of the emissions for voyages within the EU/EEA (including at berth) and 50% of the emissions for arrival or departures to non-EU ports.

5 Biofuels from food and feed crops are disqualified by attaining a GHG intensity performance comparable to fossil fuels. At the same time, it allows 1G biofuels if they are under Annex IX.

6 Caps refer to GHG intensity reduction obligations (ERE's)

Feedstock List	REDIII	FuelEU Maritime	ReFuelEU	Implementation in the Netherlands from 2026 onwards[6]
Annex IX, Part B	All feedstock eligible but are capped.	All feedstock eligible, no target of cap	All feedstock eligible, no target or cap	Land (excl. inland shipping): IX-B capped (4.3%). Inland: IX-B capped (11.07%). Maritime: IX-B excluded from counting under NL's transport scheme.
Food and feed crops	Capped to 2020 levels, with a max of 7%	Eligible, but due to high GHG emission intensity same as fossil	Not eligible	Inland: Caped to max 1.2% Maritime: Not allowed Inland Shipping: Not allowed Aviation: Not allowed
Other biomass feedstocks	Not eligible	Not eligible	Category 3 animal fats with a cap of max.3%	Biofuels made from animal fat Category 3 will receive a reduced ERE yield (factor = 0.5) under the new RED3 system

On the future market development, stakeholders generally agree that current mandates up to 2030 can be met with existing biofuel production routes (HVO/FAME/HEFA). Between 2030 and 2035, a tipping point is expected where feedstock limitations for conventional routes will make novel technologies necessary. Views differ on the exact timing of this tipping point. It was noted that while Annex IX, list B feedstocks (e.g., used cooking oil) are limited, some feedstocks from Annex IX, List A (e.g. palm oil effluent, intermediate crops or crops grown on severely degraded land used for the production of aviation biofuels) can still be used in conventional production facilities. This will potentially delay the need for novel routes. At the same time, questions were raised about the real availability and sustainability of such feedstocks, suggesting the tipping point may come earlier if supply constraints are taken into account. This will require robust monitoring, reporting and evaluation of feedstock sustainability.

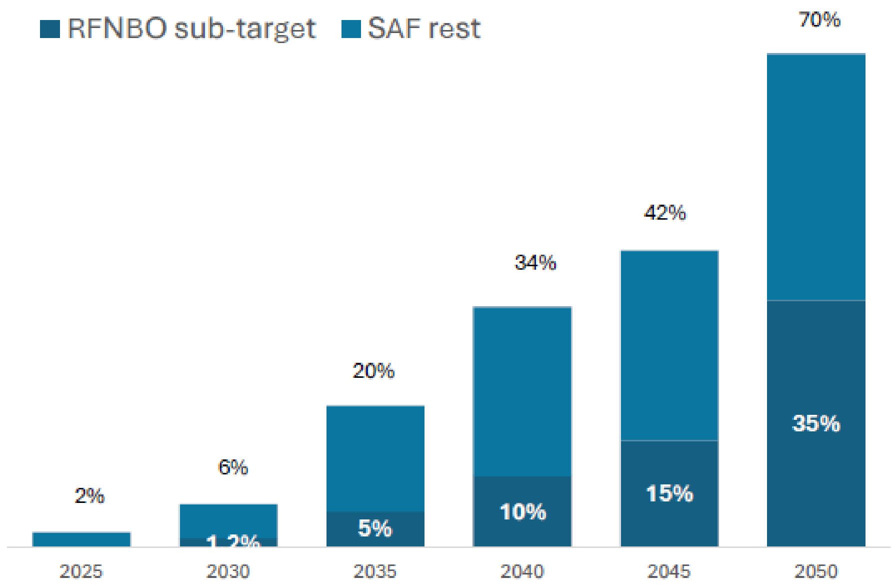


Figure 3.1: SAF obligations (vol.) according to ReFuelEU Aviation regulation

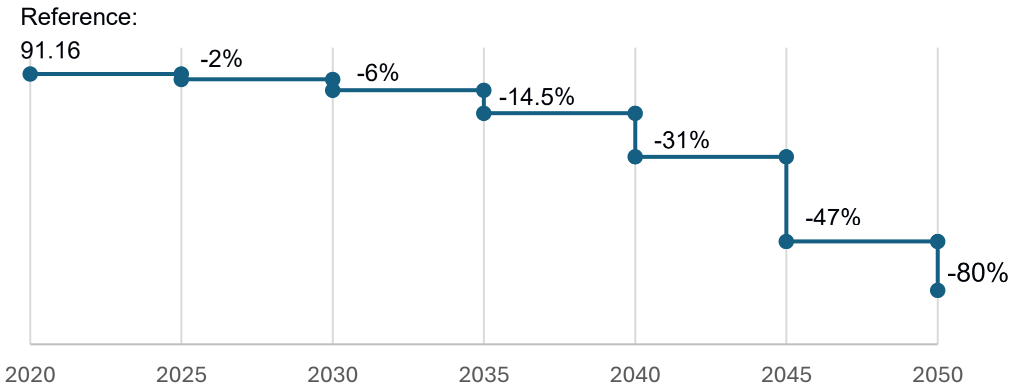


Figure 3.2: GHG intensity reduction targets within FuelEU Maritime regulation

Competition with other regions

Competition from other producers from outside the EU was also highlighted as a barrier to domestic production of advanced biofuels. Prior to the February 2025 anti-dumping duties, Chinese HVO was being imported into Europe and oversupply from these imports put downward pressure on EU HVO prices and reduced margins for local producers, contributing to delayed investment decisions (Greenea, 2025). This pricing pressure also impacted European HEFA-based SAF projects. Similar risks of international price competition were mentioned for advanced biofuels, creating uncertainty for project developers and financiers.

Co-processing regulatory framework complexity

Under the June 2023 EU Delegated Regulation (EU 2023/1640), Member States can employ the mass-balance approach to quantify biogenic shares in co-processed fuels. However, if C^{14} testing is not the primary method, it must still be used regularly to verify and calibrate the accuracy of that method. In the Netherlands, however, it is mandatory that operators ("inboekers") substantiate the biogenic content of co-processed biofuels (HVO, HEFA, other co-processed fuels) via physical sampling and C^{14} analysis (NEa, 2023).This approach is perceived as an administrative burden, and stakeholders warn it creates the risk that small fractions of biogenic content remain invisible, resulting in higher feedstock costs without corresponding benefits.

EU ETS will trigger cheapest emission reduction options

The EU Emissions Trading System (EU ETS) is one of the key mechanisms of the EU to cut GHG emissions. It started covering aviation in 2012, but only for flights inside the European Economic Area (EEA) and to the UK and Switzerland. Flights outside the EEA were left out because of international rules and the CORSIA system. This meant most aviation emissions were not included. Airlines also received many free allowances, which reduced costs for them but made the system less effective in cutting emissions. As a consequence, it did not attract investments in cleaner alternatives, including advanced biofuels.

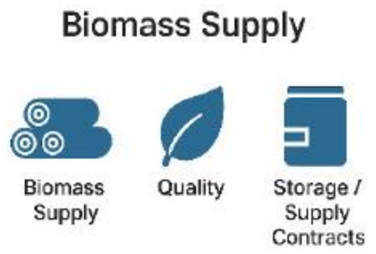
The revision of EU ETS and its expansion to include shipping from 2024 onwards can narrow the cost gap between conventional fuels and low-carbon alternatives. However, the extent of this effect will depend on the level and stability of carbon pricing. In addition, advanced biofuel plants require hundreds of millions in upfront investment, long lead-times, and face uncertain yields. The ETS does not provide direct capital support; it offers an operational cost signal. Thus, EU ETS alone is unlikely to be sufficient to scale up advanced lignocellulosic biofuels or trigger major investments in high-CAPEX, high-risk value chains.

Table 3.2: Observed strengths and weaknesses of EU-wide instruments

EU Regulatory Instrument	Strengths	Weaknesses/Risks/Gaps
RED/REDII/REDIII	⟩ Creates an EU-wide demand signal for advanced biofuels by privileging Annex IX feedstocks and tightening sustainability/traceability requirements. ⟩ Provides a legal basis for national implementation measures (quotas, blending obligations) and for harmonised sustainability criteria across Member States.	⟩ Some Annex IX definitions and Part A vs Part B distinctions (and how multipliers/double-counting apply) remain complex and leave discretion to Member States, creating investor uncertainty. ⟩ Sustainability verification and enforcement capacity varies across Member States; audit findings flag oversight weaknesses (ECA, 2023). ⟩ No EU-level guaranteed revenue mechanism or offtake support tied to RED targets — mandates signal demand but do not directly de-risk investment in first-of-a-kind conversion plants (NOW, 2024).
ReFuelEU Aviation	⟩ Sets binding sector targets for SAF up to 2050, thus market certainty ⟩ Same rues across all MSs	⟩ Current EU/industry production projections and project pipelines indicate limited regional supply through 2030, creating a demand–supply mismatch. (T&E; IATA) highlighting constrained SAF availability relative to mandated shares and the risk of imports raising lifecycle emissions. ⟩ No EU-level SAF revenue support mandates to accompany blending obligation.

EU Regulatory Instrument	Strengths	Weaknesses/Risks/Gaps
		⟩ Definitions are not always the same with RED, i.e. advanced biofuels dedicated to list A or also covering list B
FuelEU Maritime Regulation	⟩ Technology-neutral GHG-intensity reduction targets with a long-time frame (up to 2050) ⟩ Incentivises fuels with low life cycle emissions	⟩ The possibility of pooling and trading of compliance may distort domestic production incentives
EU- ETS	⟩ Puts a carbon price on fossil fuels, reducing the cost price gap between fossil fuels and biofuels	⟩ Carbon price alone may be insufficient to close the cost gap, particularly for early advanced biofuel projects ⟩ ETS revenues are not automatically earmarked for advanced biofuel revenue support. It provides a signal but not direct project de-risking ⟩ FuelEU's GHG targets and ETS shipping obligations both put a price or limit on emissions; coordination is required to avoid double charging or contradictory incentives (e.g., paying for allowances vs. meeting intensity targets).

3.2 Biomass Supply Uncertainty



Feedstock supply was generally not perceived as an insurmountable barrier by the stakeholders, even if biomass availability in the Netherlands is limited. Some stakeholders noted that the classification of feedstocks as “advanced” is determined by the Annex IX feedstock list. This list also includes feedstocks that do not necessitate novel conversion routes.

Recent additions to this annex, particularly sugary and fatty feedstocks that can be processed in existing biofuel facilities have influenced the projected demand for advanced biofuels technologies. Concerns were raised that further additions of easier-to-process feedstocks could create a risk for projects aiming to process abundant but more difficult to process feedstocks.

Some of the feedstocks under annex IX, list A, that can be converted to biofuels using existing, commercial facilities are listed in Table 3.1. It is necessary to note that this list was not provided by the stakeholders, but the authors own interpretation. The full list can be found in Appendix A.

Table 3.3: Some of the feedstock listed in Annex IX, List A, that are easier to process in current commercial plants

	Selected types
Feedstock easier to process in current commercial plants	g) Palm oil mill effluents as lipid/fatty residue suitable for biodiesel/HVO/HEFA after treatment h) Tall oil pitch, lipid rich by product, that can be treated via HVO/HEFA. i) Crude glycerine by product of biodiesel, can be fermented into ethanol via 1G ethanol plants ® Fuel oils from alcoholic distillation, as alcohol-rich stream, can be used in ethanol blending
	(s) Raw methanol from kraft pulping is an alcohol-rich by-product stream, can be purified to fuel-grade methanol with relatively straightforward upgrading
	Wet organic waste streams suitable for anaerobic digestion c) Biowaste from private households (separately collected) d) Biomass fraction of industrial waste (food & agro-food residues) f) Animal manure and sewage sludge

The second issue highlighted by the stakeholders relates to the misalignment of timelines for feedstock sourcing contracts and feedstock sourcing agreements required by lenders. A lender will typically require feedstock sourcing agreements to be in place before the final investment decision (FID) and the agreement to cover the period of the loan, introducing challenges for accessing financing. Yet current common practice is that biomass sourcing agreements are made for shorter periods (1-3 years) and agreements are not made many years before the start of production.

3.3 Conversion Technology and Commercialisation Risks for FOAK Advanced Biofuel Plants

Interviewees noted that all conversion technologies within this study scope still involve technological risks at the level of first-of-a-kind (FOAK) commercial plants. Technologies that are not yet mature, such as lignocellulosic biomass based biochemical and thermochemical routes, were highlighted as carrying particular uncertainties. Even for technologies considered almost mature (TRL 9), such as lignocellulosic ethanol projects[7], risks remain when scale-up is required, when various conversion technologies are linked for the first time, or when technology still needs to be proven for the biomass feedstock of choice. Some examples are:

1. Gasification technology itself is a mature technology, but experience with biomass (and waste) gasification is limited.

[7] It is necessary to note that there were different reactions to the technology status of lignocellulosic ethanol among interviewers

2. Fischer Tropsch and methanol synthesis are proven technologies, but the link with biomass gasification is new. Both Fischer Tropsch and methanol synthesis will also require scaling down for biofuels projects compared to the coal gasification and natural gas-based projects that are currently operational.
3. Biomass pyrolysis is mature, but upgrading to fuel quality is not yet a mature process and there is limited experience with linking the two.

With some recent first-of-a-kind (FOAK) plants failing or only operating for a short period (e.g., Clariant lignocellulosic ethanol plant in Romania and the Fulcrum gasification and Fischer Tropsch BioEnergy plant in the US) investors have become more hesitant to invest.

The main obstacle for the realisation of FOAK commercial scale novel advanced biofuels production plants is the combination of high investment costs and high risks. In order to reach commercially viable scale of production, the plants need to be at a certain scale, and investments run up to several hundred million euros to more than a billion euros. Appendix I introduces the financing landscape for advanced biofuels projects.

For the purposes of this study, specific focus is placed on the move from TRL7-8 demonstration to commercialization. This phase carries significant investment requirements and high risk, creating challenges for investing in scaling advanced biofuels projects.

3.4 Funding Bottleneck for Scaling Advanced Biofuel Projects

Securing large-scale, low-cost finance for FOAK projects is one of the most significant challenges in scaling innovative technologies. Lenders and investors are concerned about whether the facility will perform as expected, whether construction will be completed on time and within budget, and whether the product will have a stable market that enable consistent revenue streams from projects. To manage these risks, financial institutions typically require strong contractual guarantees, additional liquidity buffers, and long-term offtake agreements. While these measures aim to reduce risk, they often create new barriers that complicate project development. This chapter examines these barriers during the construction phase, the ramp-up phase, and the role of offtake certainty.

3.4.1 Risks During the Construction Phase

Scaling up from a demonstration plant to a full commercial facility introduces significant technical and system uncertainties. Technical uncertainties relate to design completeness and accuracy such as scale-up errors in translating demo plant design to commercial size, need for engineering design rework, and delays in manufacturing or shipping critical components, as well as risks related to technology integration and interfacing across balance of plant. System-level uncertainties at this stage involve broader project execution and external factors such as schedule risk (delays due to permitting, weather, labour shortages, or supply chain disruptions), cost over runs due to inflation in material costs, unexpected site conditions, or design changes, and currency fluctuations for imported equipment. Permitting delays (i.e. environmental approvals or safety certifications taking longer than planned) are particularly highlighted by stakeholders as major barriers. long permitting times, difficulties linked to nitrogen emissions and deposition rules, and challenges with access to utilities, space, and skilled labour.

These execution risks inflate the risk profile of the investment and creates caution from investors. Commercial scale facilities require large capital investments. To protect their investment, lenders demand guarantees from engineering, procurement, and construction (EPC) contractors and original equipment manufacturers (OEMs). These guarantees typically include commitments that the facility will be completed on time, within budget, and will meet agreed performance standards. For example, EPC contractors are often required to provide a lump-sum turnkey guarantee, which ensures delivery of a fully operational plant that meets specified output and efficiency targets. They may also be asked to provide a completion guarantee covering delays or cost overruns. Similarly, OEMs are expected to provide equipment performance guarantees and, in some cases, take a small equity stake in the project to demonstrate commitment.

Although these guarantees reduce lender risk, they create significant financial exposure for EPCs and OEMs. The liabilities associated with these guarantees can far exceed the profit margin of the project. While margins for FOAK projects are higher than for conventional projects, they remain insufficient to incentivise covering these risks. Consequently, EPCs and OEMs may refuse to provide guarantees, or negotiations may become lengthy and complex, delaying financial close. In some cases, technology insurance can substitute for EPC guarantees, but premiums are prohibitively expensive. These factors make the financing process slow and uncertain.

Attracting loans requires visibility and stability of cash flows. This requires clear and robust risk allocation. Project developers and contractors (OEMs and EPCs) can take on higher risks, but that affects their risk/return ratio and may negatively impact their business case, making them reluctant to invest or participate in projects. Investors that can take on a higher risk, like InvestNL or Polestar Capital, can absorb some risk but typically provide smaller investments (max ~€50 million). These investment sizes are insufficient to resolve the issue. Alternatively, insurance can cover part of the risk, but this is costly for project developers. However, complete de-risking is often not possible. Even in seemingly low-risk pathways such as Shell’s HEFA, engineering choices had to be made that ultimately did not succeed. This illustrates that residual technical and execution risks remain, even for mature technologies.

Another structural challenge is that lessons learned from FOAK projects are rarely shared due to commercial confidentiality. As a result, potentially the same mistakes are repeated leading to inefficiencies and wasted public funds.

3.4.1.1 Risks During the Ramp-Up Phase

Risk do not disappear once construction is complete. The ramp-up phase, when the facility begins operations and gradually reaches full production, is typically unpredictable. FOAK projects often experience extended optimization periods due to unexpected technical bottlenecks or process inefficiencies. If ramp-up takes longer than expected, revenue generation is delayed, creating liquidity stress for the developer and increasing the risk of loan repayment delays.

3.4.1.2 Offtake Uncertainty

Predictable revenue streams are essential for securing financing. Lenders require assurance that the facility’s output will be sold at stable prices over a long period. For FOAK projects, this typically means signing binding contracts with creditworthy buyers for six years or more, covering the entire production volume. This is particularly important for products without established commodity markets, such as advanced biofuels.

These agreements often rely on strong regulatory mandates that require buyers to purchase renewable fuels. If these mandates are unclear or subject to change as discussed in Section 3.1, lender confidence declines. Price volatility is another concern. To mitigate this, contracts could adopt cost-plus pricing structures, allowing feedstock cost fluctuations to be passed through to the buyer. This approach stabilizes operating margins and improves cash flow predictability. However, securing such agreements are challenging.

4 Assessment of Key EU Financial Instruments for Advanced Biofuels

The European Union has established a broad suite of financial instruments that collectively span the innovation deployment continuum from early-stage research to FOAK support, guarantees, and emerging market-creation mechanisms. These instruments provide an important foundation for advancing clean energy technologies. However, for advanced biofuels from lignocellulosic feedstocks, there remains a structural misalignment between what these tools are designed to achieve and the pace and scale of deployment implied by RED III, ReFuelEU Aviation, and FuelEU Maritime.

Below, each type of instrument is assessed in terms of what it already contributes, what is expected of it, and where gaps remain.

Grant-based instruments do not sufficiently prioritise FOAK advanced biofuel scale-up
The Innovation Fund represents one of the EU's strongest instruments to bring high-impact, low-carbon technologies to commercial scale, including advanced biofuels from residues and wastes. However, the actual allocation of Innovation Fund grants shows that the programme favours high-TRL, lower-risk technologies, particularly hydrogen, CCS, and biomethane upgrading. Only one lignocellulosic FOAK biorefinery (BioOstrand in Sweden) has been supported to date, representing a marginal share of total awards. Selection criteria that emphasise technological maturity, rapid deployment, and robust financial structures tend to disfavour gasification-FT, hydrothermal liquefaction, or advanced thermochemical pathways, which inherently carry higher technical and commercial risk. As such, while the Innovation Fund is a robust and well-established mechanism, it has not yet become the catalyst for FOAK lignocellulosic biofuel plants that policy goals would suggest. Distribution of the projects funded by innovation fund that relates to heavy industry is introduced in Appendix D. In addition, the biofuel projects under this program can be found in this appendix.

Research and demonstration grant under Horizon Europe have not closed the commercial gap
The Horizon Europe programme remains the backbone of EU research and innovation support, and it has made significant contributions to developing and validating advanced biofuel technologies across the last decade, particularly under Cluster 5, which is expected to move technologies from TRL 5–6 toward TRL 7–8 by supporting large integrated demonstrations that validate full value chains. In principle, this should prepare advanced biofuel technologies for subsequent support under Innovation Fund or InvestEU.

While the 2026–2027 Work Programme introduces stronger emphasis on large-scale demonstrations, Horizon Europe has not yet ensured finance readiness, meaning that many projects complete technical pilots but are not prepared for investor due diligence.

Guarantee and blended-finance instruments have been deployed, but they do not adequately provide targeted risk-sharing for advanced biofuels

The InvestEU Programme is intended to mobilise large volumes of public and private financing through EU-backed guarantees, particularly for high-risk infrastructure. In theory, this tool should reduce lender exposure to construction risk, feedstock variability, and uncertain revenue streams for FOAK advanced biofuel plants.

In practice, InvestEU does not include a dedicated guarantee facility for advanced biofuels. As a result, although InvestEU is a strong financial instrument in general, it currently mobilises little capital for advanced biofuel projects. Project developers continue to face significant difficulties in obtaining debt financing, as commercial banks view lignocellulosic biorefineries as high-risk assets with uncertain margins and complex supply chains. Although InvestEU mobilises substantial capital for the green transition, it has mainly funded more mature or politically prioritised technologies, including hydrogen, biomethane infrastructure, and CCS.

Recent market creation and revenue stability tools (STIP) focus primarily on e-fuels

The Sustainable Transport Investment Plan (STIP) is a major new initiative that consolidates EU funding streams (See Figure I.2) and aims to support large-scale production of sustainable fuels for aviation and maritime sectors. It is expected to create stable revenue frameworks, stimulate demand, and reduce market risk for new fuel producers.

Although the quantitative targets highlight a major role for biofuels, the concrete investment actions in STIP focus primarily on e-SAF and hydrogen-based fuels. This creates an imbalance in technology signals at a time when both biofuel and e-fuel pathways are needed to meet near-term and medium-term targets. Definitions and implementation pathways for advanced biofuels from lignocellulosic feedstocks remain unclear. The Commission also plans an “eSAF Early Movers Coalition” to mobilise at least €500 million and is exploring double-sided auction mechanisms to reduce price risk. This is an approach inspired by the H2Global model.

No comparable auction, offtake guarantee, or price-stabilisation mechanism has been defined for lignocellulosic pathways. The absence of a dedicated biofuel revenue mechanism places advanced biofuels at a structural disadvantage compared with e-fuels.

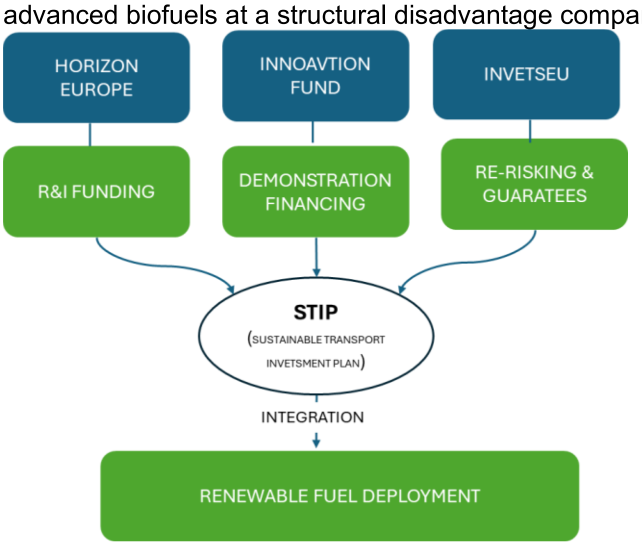


Figure 4.1: Illustration of the newly designed STIP

In conclusion, the EU’s financial ecosystem is not fully aligned with the deployment needs of advanced biofuels. While the Union has a mature set of research, grant, guarantee, and market-oriented funds, these instruments are largely calibrated toward low-risk, high-TRL, or politically salient technologies. For advanced biofuels, which require integrated value-chain demonstrations, risk-sharing guarantees, revenue stabilisation, and long-term offtake, the current arrangements remain insufficient.

Table 4.1: Comparative assessment of existing finance instruments

Instrument	Expected role for advanced biofuels	Current reality	Core gap
Innovation Fund	Fund FOAK commercial plants; bridge between demo and market	Very limited advanced biofuel projects from lignocellulosic feedstocks (e.g. Ostrand); several small -scale biogas plants; multiple e-SAF selections in recent calls	High-TRL, risk-avers attitude; limited support for FOAK for lignocellulosic fuels; K
Horizon Europe	Move TRL 5–6→7–8; validate full value chains	Strong demo ambition in 2026–27; weaker attention to finance-readiness/offtake	No earmarked blended finance for FOAK lignocellulosic pathways; last-mile risk remains
InvetsEU	Mobilise large guarantees for clean fuel plants	Horizontal tool; no dedicated advanced biofuels window	No ring-fenced guarantee/CfD for FOAK biofuel plants; lender risk not fully addressed
STIP	Accelerate fuels for aviation/maritime; fix revenue risk	Large funding mobilisation; core focus on e-fuels	Biofuels not explicitly prioritised; unclear book-and-claim / ETS alignment; auction design still pending

5 Policy Support for Advanced Biofuels: A Review of Selected EU Member States and Key International Producers

5.1 Regulatory and Fiscal Instruments in Selected Member States

This chapter examines how selected Member States, namely Germany, Italy, Sweden, France, Finland, and the Netherlands have implemented the Renewable Energy Directive (RED II/III), with a particular focus on advanced biofuels. It also reviews the fiscal instruments these countries use to stimulate biofuel deployment.

These countries were chosen for their relatively higher deployment of advanced biofuels (see Figure 5.1) and their relevance in stakeholder interviews. The analysis provides key findings and lessons learned from their approaches, aiming to provide actionable insights for Dutch policy as the Netherlands seeks to accelerate advanced biofuel deployment. Detailed country overviews are provided in the Appendix for reference.

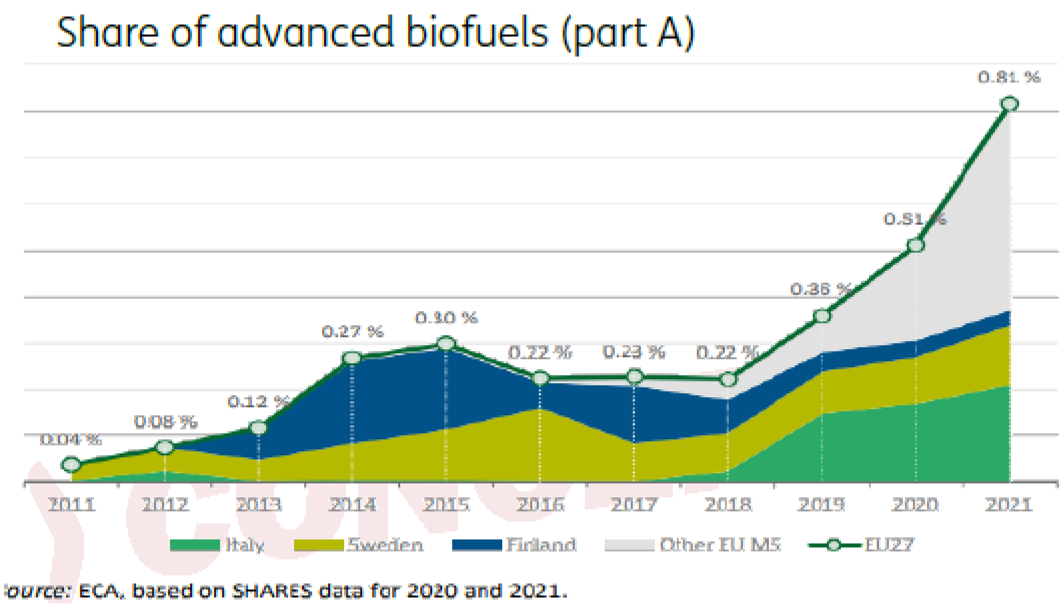


Figure 5.1: Share of advanced biofuels in the EU, with a breakdown to member states with relatively larger shares (derived from (ECA, 2023))

Table 5.1 provides an overview of the regulatory and financial instruments applied in the four selected countries. The key observations are listed below. For more detailed information on the evolution of biofuels in each Member State and specifics of the policy instruments, please refer to Appendix F.

Mandates and sub-mandates drive low-cost biofuels, but on their own they are insufficient to scale lignocellulosic advanced biofuels, especially under policy volatility

Across all countries, renewable energy obligations, whether energy-based or GHG-intensity-based, are the primary instrument currently in action. A gradual shift toward GHG-intensity frameworks is observed (Germany and Sweden already use them; France and the Netherlands are transitioning in 2026).

However, these obligations alone mainly drive mature, low-cost biofuels, such as waste oils, animal fats, or biomethane. Without a dedicated sub-mandates or targeted incentives, renewable energy mandates are supplied by the cheapest compliant options rather than emerging advanced technologies. Thus, these policies have not led to significant investment in higher-risk, innovative advanced biofuel value chains.

- In the Netherlands, the annual obligation and double counting mechanisms led to a rapid increase in the use of waste-based biofuels (e.g., palm oil mill effluent, used cooking oil, bleaching earth), but lignocellulosic ethanol and other advanced biofuels from lignocellulosic feedstock remain marginal.
- Germany's advanced sub-mandate ("Unterquote") increased the share of advanced biofuels, but the growth was concentrated in industrial biowaste and biomethane, not in new biofuel technologies. The certificate price signal from the GHG quota system helped, but without additional support, advanced biofuels did not scale.
- In Sweden, the relative share of advanced biofuels from Part A list has been small. This had to do with the fact that country had no sub-mandate. Instead, high blends were tax exempt (HVO100, B100, E85) resulting in larger use of biofuels from feedstocks within Part B. Neither tax exemptions, nor GHG intensity reduction obligations stimulate investment in new advanced biofuel plants from lignocellulosic feedstocks. Instead, the country has

experienced a growing supply of other eligible biofuels (that are neither part of Annex IX, nor food and feed crop based). This is due to the technology neutral GHG intensity reduction quota and having no dedicated sub-quota. In Sweden, despite a long-standing reduction obligations and tax relief for high blends, there was no significant scale-up of advanced liquid biofuels. Tax exemptions for high blends improved operating margins but did not finance new advanced biofuel plants.

- Sweden's freeze and subsequent reduction of its GHG reduction obligation caused a sharp decrease in total biofuel use.
- Finland introduced a rising sub-mandate for advanced biofuels, which may have enabled the tipping point of using low hanging fruits to be reached and other innovations to be supported by the market. However, when fuel prices spiked, the government reduced the obligation, and supply of advanced biofuels fell.

Obligations create demand but do not mitigate the financing and technology risks of FOAK lignocellulosic plants. When combined with policy instability, such as abrupt obligation cuts, and exposure to volatile feedstock and energy prices, the investment environment becomes too uncertain for capital-intensive advanced biofuels to progress.

Figure 5.2 illustrate the total biofuels supplied to these four markets, based on their feedstock category. Country specific details can be found in the Appendix.

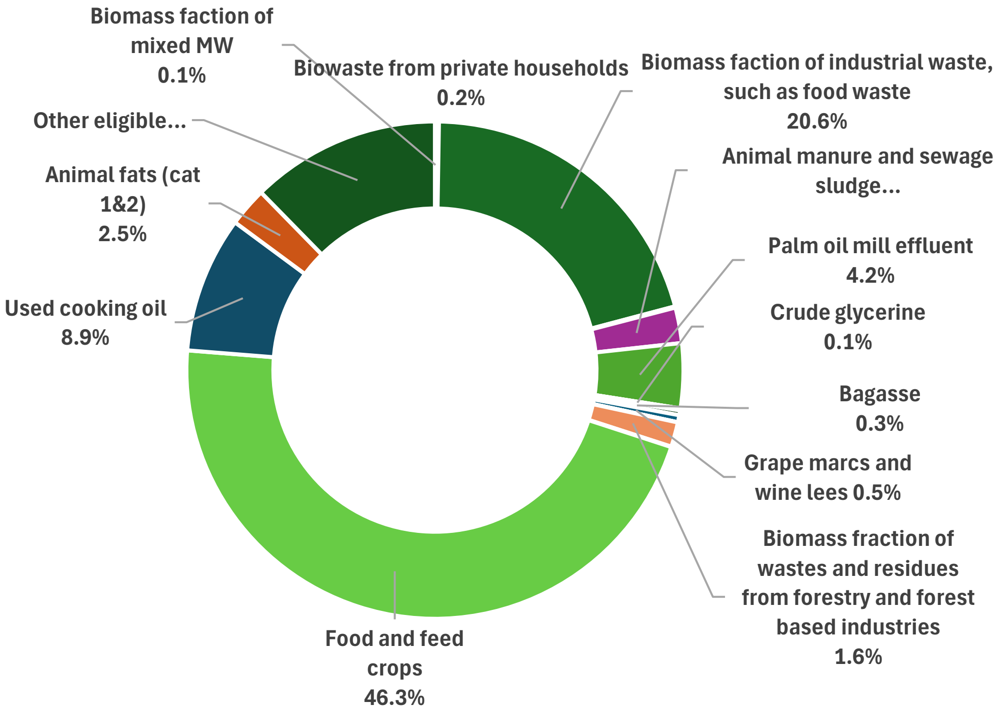


Figure 5.2: Biofuel supply in selected four countries in 2024, broken down to feedstock types [Derived from EC SHARE Database]

Other monetary rewards linked to carbon intensity and certificates can accelerate market uptake

Financial incentives that reward lower-carbon fuels (e.g., premiums, tax relief, certificates) can accelerate deployment, but only if they are paired with support for capital investment.

- Italy is a good example for an integrated package. The biomethane policy in this country combines a quota, premium certificates (CIC), and generous capital grants (PNRR), resulting in rapid growth of biomethane production.

Still, even here, lignocellulosic liquid fuels did not scale, showing that operating incentives alone are insufficient. Monetary rewards improve operating economics, but without capital support, they do not overcome the high up-front costs and risks of building new advanced biofuel facilities.

Double counting and multipliers raise compliance figures but don't guarantee real decarbonization

Allowing certain biofuels to count double or applying multipliers can help meet targets on paper but does not ensure new physical capacity or genuine decarbonization. Up until now, these measures have not pushed advanced biofuels from lignocellulosic feedstocks. Only when the targets are high double counting may incentivise these fuels.

- All studied countries used double counting at some point in time to boost compliance with advanced biofuel targets, but this did not translate into significant new investment in advanced biofuels.
- The shift to GHG-based accounting is intended to provide a more accurate signal for decarbonization, but this alone did not drive investment in high-risk technologies.

Table 5.1: Recent implementation of renewable energy directive in selected member states

	Italy	Sweden	Finland	Germany	France	The Netherlands
Type of obligation	Energy based	Since 2018 GHG reduction obligation	Energy based mandates since 2019	Since 2015, GHG reduction obligation	Energy based. Shifting to GHG reduction from 2026 onwards.	Energy based. Shifting to GHG reduction 2026 onwards
Share of renewable energy/GHG reduction obligation	10% in 2022 11.7% in 2025	7.8% for gasoline, 30.5% for diesel between 2022 and 2023. However, in 2024, it was lowered and frozen to 6% for the time period 2024-2026 and abolished the quote from 2027.	12% in 2022-2023 (was previously higher) 16.5 % in 2025 (was previously higher) 22.5% in 2027 30% in 2029 and afterwards. this is lifted up to 34% in 2023 but revised downward in 2024 to 13.5% from 28%	7% in 2022 10.5% in 2025 and 25% in 2030.	8.6%bioethanol and 8 % biodiesel between 2023-2027	Renewable energy in road transport to be 28.4% in 2024 and 29.4% in 2025
Sub-target advanced biofuels	2.5% advanced biomethane, 0.6% other advanced biofuels in 2022 3.5% advanced biomethane, 3% bioethanol, 0.05% other advanced biofuels in 2025	No specific target	4%% in 2026 gradually increasing to 10% from 2030 onwards.	0.2%in 2022 0.7% in 2025 2.6%in 2030, increasing to 9% in 2040.	Introduced in 2022. 1.2% for bioethanol increasing to 3.8% from 2028 onwards and 0.4% for biodiesel, increasing to 2.8% from 2028 onwards	3.6% by 2025, including double counting.

	Italy	Sweden	Finland	Germany	France	The Netherlands
Double counting to advanced biofuels	Yes			Double counting is allowed for advanced biofuels beyond the minimum sub-mandate (except for Palm Oil Mill Effluents or empty palm fruit brunches). However, the double counting is likely to be fully erased.	Yes, with double counting for biofuels from Annex IX., except tall oil and tall oil pitch.	Yes, double counting from Annex IX feedstock-based biofuels. However, it is to be excluded with the GHG quotas.
Tax relief	Excise duty relief to HVO; tax relief to quantifying biodiesel (from annex IX)	High blends are exempt from tax (these high blends are excluded from mandates).	Biofuels from wastes and residues are fully exempt from CO2 tax	No	Tax relief available to all renewable supply options to meet the set targets	No
Specific capex subsidy for FOAKs	No	No		No	Biomethane investment scheme.	No

	Italy	Sweden	Finland	Germany	France	The Netherlands
Other available instruments	R&D support, no specific focus on advanced biofuels	Direct investment grants to climate projects, including biogas/biomethane production; biofuel projects from lignocellulosic feedstock as well	For R&D. one example BtL pilot plant (12MW gasification) received funding	RD&D funding. In general, there has been a decrease in funding projects related to biofuels	State aid scheme in the form of direct grant. However, covers biomass and renewable hydrogen in energy and transport. No specific support to advanced biofuels.	CAPEX fund for pilot and demonstration projects. No earmarked amounts for advanced biofuel projects.
	Capital grants to convert existing traditional refineries	Grants for feasibility studies, research and pilot and demonstration project for industrial green transition is available. So far, no specific advanced biofuel project				SDE++ operational subsidy
	Capital grant + feed-in tariff for biomethane					

5.2 Experiences in Other Regions

Stakeholders identified the United States, Brazil, and India as important countries to review for advanced biofuel policies. These countries were highlighted for their strong renewable energy programs.

Appendix E presents a country-by-country policy analysis and shows the development of their biofuel sectors from 2015 to 2024, including key feedstocks used for these biofuels. Drawing on the experiences from these countries, several high-level insights emerge. The main insights are summarised below.

The main insight from all countries is that long-term policy certainty matters more than high financial incentives. When rules change often or are unclear, investors lose confidence. Emerging advanced pathways struggle when they compete in the same policy category as mature, low-risk options. Without clear separation, established fuels capture most of the market and slow the growth of newer technologies.

In the United States, the Renewable Fuel Standard (RFS) was designed to support cellulosic biofuels through a separate D3/D7 target. However, shifting definitions of “cellulosic biofuel” created instability. Renewable natural gas (RNG) from landfills, wastewater, manure, and food waste could qualify for the D3 category, and it quickly dominated because it was easier and less risky than lignocellulosic fuels. The “advanced biofuel” category was also broad, covering almost any fuel except corn ethanol with a life cycle GHG reduction of 50% and higher. This regulatory uncertainty weakened investment, even with incentives such as the biodiesel blender credit and the Clean Fuel Production Tax Credit under the IRA.

Brazil has supported ethanol through mandates and stable policies for almost fifty years. RenovaBio provides LCA-based certification and CBIO trading with 10-year targets, yet targets have been periodically revised and CBIO prices volatile, which reduces predictability for newer pathways (e.g., 2G ethanol). The Fuel of the Future Law (14.993/2024) introduces national programs for SAF and renewable diesel, but long-term certainty for advanced projects is still not fully guaranteed.

India has a clear structure for biofuels: the National Policy on Biofuels, the PM JI-VAN scheme for 2G ethanol (viability gap funding), and the SATAT program for compressed biogas with guaranteed offtake by oil companies. These tools show strong intent, but rules on feedstocks and administered prices change often. In 2024, stricter limits on using sugar and rice for ethanol, combined with lower crop output, reduced expected blending levels. New 2G projects depend on annual procurement and pricing decisions, and investors wait each year for updated terms unless longer-term guidance is provided.

FOAK/NOAK project viability depends on strong risk-reduction measures and industrial integration

A second key lesson is that FOAK and early NOAK pathways require far more than production subsidies. They require mechanisms that reduce risk across the entire project value chain and development cycle, including CAPEX, commissioning, feedstock logistics, and early years of operation.

- The U.S. DOE provides loan guarantees and USDA programs, yet several projects still failed because the risk profile remained too high for conventional lenders.

- India's Viability Gap Funding (VGF) reduces capital cost burden. It does not compensate developers if their plant underperforms, if yields are lower than expected, or if technology fails.
- The Brazilian Development Bank (BNDES) provided low-interest, long-tenor loans that helped lowering financing costs for 2G ethanol plants. This allowed industrial players such as Raízen to commit to multiple commercial scale 2G ethanol plants, with a pipeline extending to 2031. At the same time, these plants were co-located with existing 1G sugar facilities. This co-location could reduce utilities costs, eases feedstock logistics, and enables shared operations. These factors significantly improve bankability.

Feedstock security and supply chain strategies are key

Feedstock availability, price stability, and logistics are a central determinant of whether advanced biofuels scale. The case studies illustrate that feedstock is the most underestimated risk in advanced biofuel project development.

- Brazil's success with 2G ethanol relates to the concentrated availability of bagasse at sugarcane mills. The feedstock is already on-site, transport costs are minimal, and its supply is tied to the 1G ethanol.
- In the U.S., agricultural residues proved more expensive and logistically complex than early techno-economic assessments assumed, contributing to project difficulties.

Market pulls through offtake stability and strategic technology prioritization

Successful scaling requires not just production incentives but also demand certainty. Long-term offtake agreements were decisive in Brazil and India, enabling producers to secure financing with predictable cash-flows.

- In Brazil, Raizen secured off-take agreements with the US, Japan and Europe.
- India organises advanced biofuel (mainly 2G ethanol) offtake through government-administered prices and binding long-term offtake agreements between state-run Oil Marketing Companies (OMCs) and dedicated 2G ethanol plants.
- Conversely, U.S. cellulosic ethanol developers struggled partly due to the absence of guaranteed buyers.

Table 5.2: Recap advanced biofuel policy landscape in the US, Brazil and India

Country	Policy Type	Policy Name	Promotes Advanced Biofuels Specifically	Fiscal Incentives / Support	Disadvantages / Policy Gaps
UNITED STATES	Blending mandate	Renewable Fuel Standard (RFS)	Intended to, but mostly met with RNG	RIN credits (incl. cellulosic fuels)	EPA waivers; RNG substitute cellulosic ethanol targets; weak innovation signal
	IRA Tax credit	Biodiesel Blender Credit (40A)	No	$1/gal	Favours HEFA/biodiesel; no additional support for lignocellulosic fuels
	IRA SAF-specific credit	SAF Credit (40B)	Limited; HEFA dominates	$1.25–1.75/gal	Very short duration (2023–2024); not sufficient to cover FOAK pathways
	Tech-neutral production credit	45Z Clean Fuel Production Credit to any transportation fuels produced within the US	Potentially, short window limits FOAK	CI-based credit (2025–2027) ≥ 50%	Only 2025–2027; relatively lower CI favouring RNG and crop-ethanol retrofits to absorb value
	Advanced biofuel credit	Second-Generation Producer Credit	Yes	Up to $1.01/gal (expired end 2024)	Expired; policy uncertainty
	Grants/loans	USDA/DOE Programs	Yes	Grants + loan guarantees	Insufficient to overcome FOAK risk; several project failures
BRAZIL	Blending mandates/CI credit mandates	Ethanol (27%) & Biodiesel (B14→B15)/ RenovaBio	Mostly no (supports 1G)	CBio credits; Tax differentiation for ethanol	Supports 1G; no dedicated 2G quota
	Fuel diversification law	Fuel of the Future Law (2024)	Yes	Mandates + diversification policy (incl. SAF trajectory)	Early-stage implementation; operational rules evolving; no focus on FOAKs
	SAF mandate	SAF Blending Mandate (1% in 2027 → 10% in 2037)	Yes, also covers 1G ethanol-based Jet but	Demand creation (no direct fiscal tools yet)	No direct fiscal support: technology pathway preferences unclear
	Public development bank loans	National BNDES Credit Lines	Yes	Loans	Strongly reliant on sugarcane/bagasse context

Country	Policy Type	Policy Name	Promotes Advanced Biofuels Specifically	Fiscal Incentives / Support	Disadvantages / Policy Gaps
	Tax incentives	Federal/state tax breaks (2021–2023)	Partially	Exemptions/reductions	Benefits mainly 1G fuels; uneven advanced prioritisation
INDIA	National biofuel strategy	National Policy on Biofuels (2018)	Partially	Tax rebates; GST exemptions; customs duty reductions	Strong 1G focus; limited real 2G output
	Blending programme	Ethanol Blending Programme (EBP)	No	Administered ethanol prices	Blend rates met with 1G; no 2G-specific demand
	CAPEX support for 2G	JI-VAN Yojana (2019)	Yes	Viability Gap Funding for 6 commercial + 4 demo plants	High CAPEX; commissioning delays
	Bioenergy support programme	National Bioenergy Programme (2021–2026)	Yes	Capital subsidies; tax incentives; low-interest loans	Fragmented implementation; limited scale-up so far
	SAF roadmap	SAF blending milestones (1% 2027 → 5% 2030)	Yes	Indirect demand creation	No fiscal incentives yet; market very small
	Offtake support	OMC Long-Term Offtake Agreements	Yes	Fixed-price purchase guarantees	Administered pricing may be too low for 2G economics

6 Analysis of financing for advanced biofuels projects

Large-scale advanced biofuels projects have high capital requirements and are associated with significant risks along the value chain. This combination leads to challenges for these projects to access financing. This chapter explores the financing landscape for advanced biofuels projects, the main funding bottleneck for scaling these projects, requirements for moving these projects towards bankability, and potential government support mechanisms for de-risking projects and mobilising private sector financing.

Further description of key terms, like corporate finance, project finance, strategic developer, and independent developer, along with an overview of the financing landscape can be found in Appendix J.

6.1 Moving Advanced Biofuels Projects Towards Bankability

Chapter 3 introduces the barriers recognised by the stakeholders as feedstock supply risk, conversion facility risks,and market risks, which translates itself to offtake certainty risks and policy & regulatory framework risks. Securing reliable, homogenous feedstock appears challenging due to unorganized supply chains (particularly for some the feedstock categories listed in Annex IX of REDII), price volatility, and the limited track record and creditworthiness of smaller suppliers. Scaling up conversion facilities from demonstration to commercial size introduces uncertainty in technology performance, potential delays, and cost overruns, which can strain liquidity during prolonged ramp-up periods. Offtake agreements remain uncertain as markets are still developing, leading to reluctance from buyers to commit to long-term contracts, especially for lignocellulosic fuels. Finally, policy changes and permitting delays can undermine project economics and accessibility to financing. This often leads to complex risk allocation negotiations that create barriers to financial close.

Figure 6.1 summarises the main risks associated with advanced biofuel projects per development stage

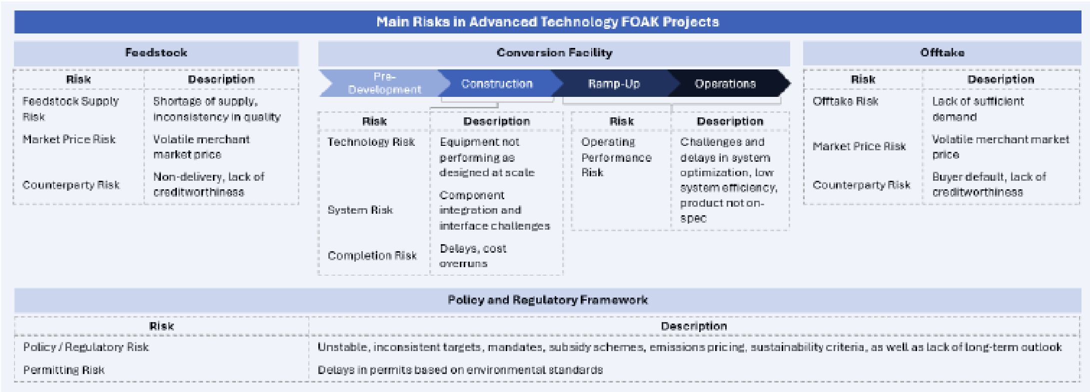


Figure 6.1: Overview of main risks areas across value chain

The pathway to improve the bankability of the business case for advanced biofuel projects is characterized by a complex, interdependent risk allocation structure. Bankability depends on predictable and credible repayment capacity. This can only be achieved through systematic and transparent risk allocation to the parties best positioned to manage each exposure. Project developers, project sponsors, Engineering Procurement Construction (EPC) contractors, Original Equipment Manufacturers (OEMs), Export Credit Agencies (ECAs), feedstock suppliers, offtakers, financiers, and government must each assume a defined share of responsibility through equity participation, completion and performance guarantees, long-term contracts, and subsidies, as shown in Figure 6.4.

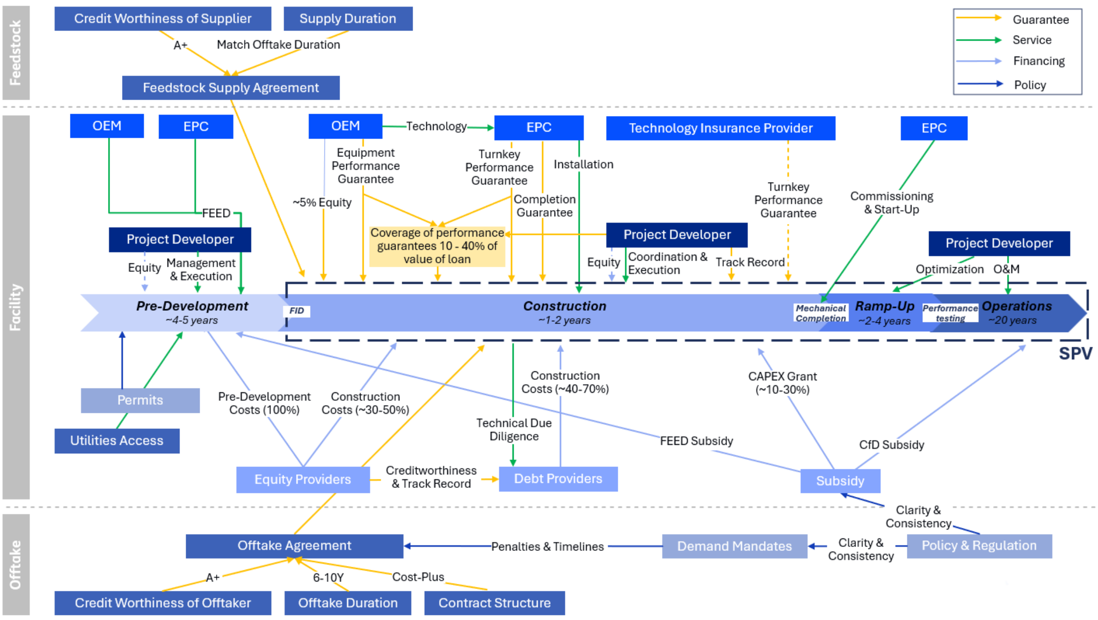


Figure 6.2: Blueprint for structuring risks across the value chain

This section will zoom in on the risk allocation requirements across the three main risk categories of i) feedstock supply, ii) technology risk of conversion facility, and iii) offtake certainty.

6.1.1 Risk Mitigation: Feedstock Supply

To mitigate feedstock availability and pricing uncertainty, feedstock supply should be secured through long-term feedstock supply agreements where possible. This should preferably mirror offtake durations to ensure stable production volumes and therefore stable returns (typically preferred for ~≥ 6 years). Supply contracts should be secured with creditworthy counterparties where possible to mitigate counterparty risk, decrease project-on-project risks, avoid disruptions, and ensure supply continuity over the full loan horizon. Robust, diverse feedstock sourcing strategies may need to be considered in cases where feedstock supply chains are still in early development to reduce dependency on a single supplier or region.

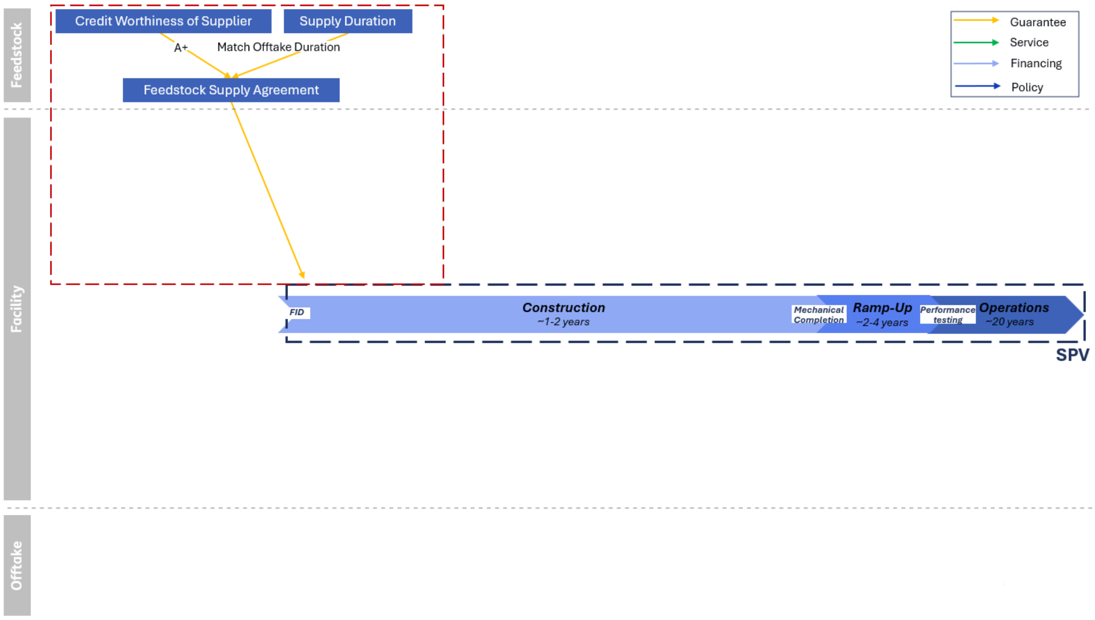


Figure 6.3: Risk allocation structures for mitigating feedstock supply risk

6.1.2 Risk Mitigation: Conversion Process

Risk mitigation at the facility level is explored across the construction phase and the ramp-up phase.

Construction Phase

The construction phase is accompanied by significant technology and system risks for scaling demonstration plants to large-scale commercial facilities. Commercial lenders therefore often seek lump-sum turnkey guarantees and completion guarantees from the EPC as well as equipment performance guarantees from the OEM. These guarantees are accompanied by pre-agreed financial penalties for underperformance or late completion, thereby protecting the project's lenders and owners.

- **Equipment performance guarantee from OEM** – Guarantee that specialised equipment operates as designed. The lender may also require for the OEM to provide a small equity stake in the project Special Purpose Vehicle (SPV) to incentivise delivery.

- **Lump-sum turnkey performance guarantee from EPC** – Guarantee that the facility is in ready to operate condition at pre-agreed output, efficiency, and quality standards when all equipment is installed and connected. This includes a warranty period where the EPC is responsible for correcting design or equipment defects during. If a turkey performance guarantee cannot be provided by the EPC, a technology insurance provider may potentially be used to fulfil this role, but this is likely accompanied by high premiums.

- **Completion guarantees from EPC** – construction is completed within the agreed timeframe and budget, where additional cost overruns are borne by the EPC

From a lender's perspective, these instruments can assist with increasing the certainty of debt repayment in projects that lack established performance track records. The lender may require that the performance guarantee package, particularly from the EPC, covers around ~10-40% of the total value of the loan provided (indicative number, varying case by case with technology, counterparties, and policy support). This could in turn create substantial risk for the EPC, where the liabilities they are asked to cover could significantly exceed the margin the EPC can earn in the project. The margin that an EPC can earn from a FOAK project may be relatively high compared to conventional projects, given the risks involved, but this margin may still be significantly lower than the exposure it has outstanding on the guarantees. This leads to these guarantees becoming difficult to provide, given the opportunity costs.

The loan guarantee package will therefore typically also include guarantees from the OEM and contingency funding from the project developer or sponsor, alongside the EPC guarantees. The allocation of risks to parties best able to manage and absorb them may lead to complex, time-intensive negotiations, and often, no conclusion, as the risks for each party seemingly outweigh the benefits. This can be particularly extreme for FOAK projects, as they lack references and suitable benchmarks, which may extend project timelines significantly.

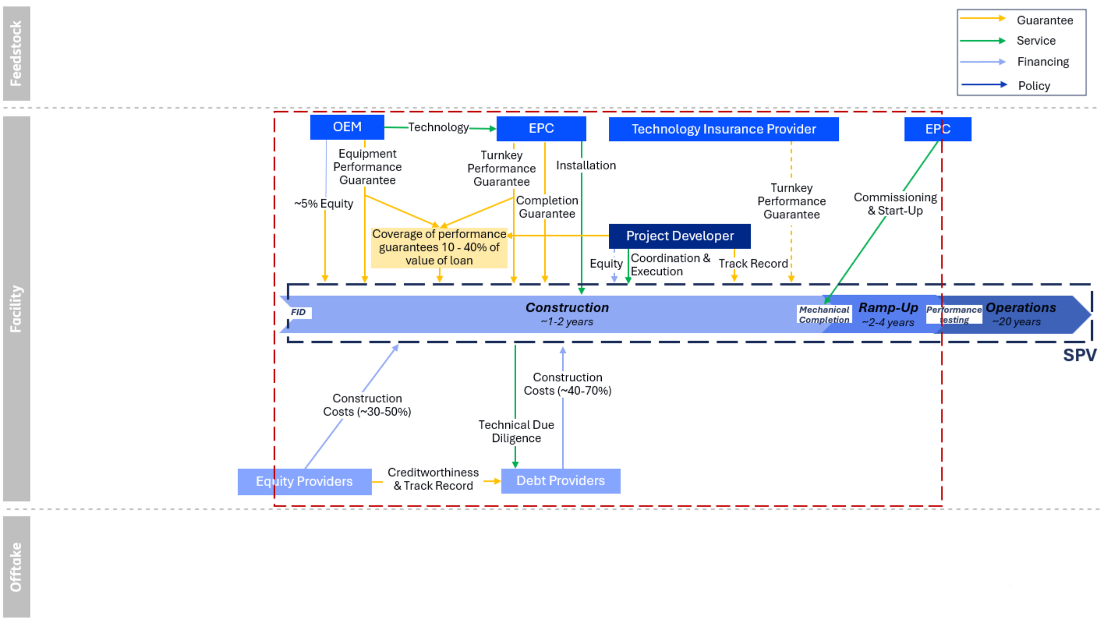


Figure 6.4: Risk allocation structures for mitigating construction phase risks

Ramp-Up Phase

After the facility has reached mechanical completion and commissioning and start-up has taken place, risks remain around ramping-up the facility to reach desired full load hours and produce on-spec products at predictable operating cost within the desired timeframe. Projects could face a prolonged optimization and ramp-up period due to operational bottlenecks or unforeseen process inefficiencies. Extended facility ramp-up and optimisation often lead to liquidity stress for the project developer and hinder debt repayment capacity for the lender. Given that the duration and extent of the ramp-up phase is unpredictable, project developers must plan for ramp-up liquidity buffers during project design.

From a financial standpoint, developers and lenders recognize that ramp-up variability is an inherent part of the commercialization process. This stage should therefore be financed intentionally by aiming to secure dedicated ramp-up liquidity before Final Investment Decision (FID), modelling conservative ramp-up trajectories in financial projections, and negotiating for acceptance of temporary pressure on financial metrics such as debt service coverage ratios (DSCR) or internal rate of return (IRR). This can also include pursuing milestone-based capital injections from public or private parties, where available, in the form of equity, grants, or specialized loans to ensure financial stability.

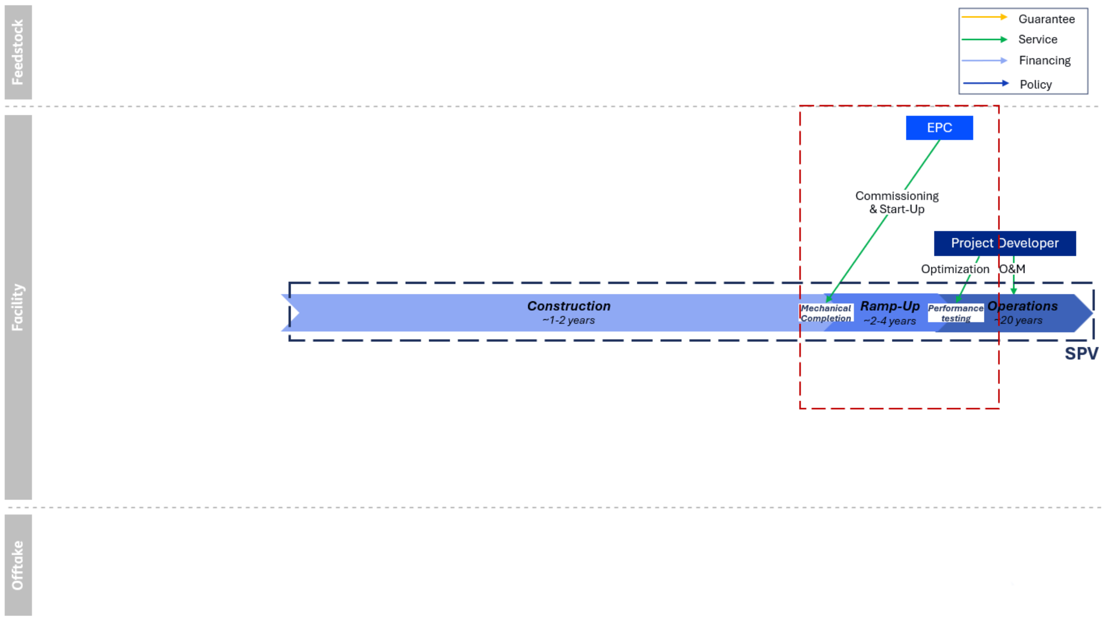


Figure 6.5: Mechanisms for mitigating ramp-up phase risks

6.1.3 Risk Mitigation: Offtake Certainty

Lenders base financing decisions primarily on the predictability of future cash flows and therefore require binding, long-term agreements, typically six years or more and signed with highly creditworthy offtakers. Offtake agreements should cover the full output volume, especially for products that do not yet have established commodity merchant markets to absorb volumes, like second generation ethanol. Offtake agreements are typically underpinned by demand mandates and accompanying penalties for non-compliance. Mandates require consistent regulation with a clear time horizon and stringent penalties to be effective in creating sufficient market uptake. Cost-plus offtake structures that include mechanisms to allow for feedstock price fluctuations to be passed through to the offtaker further enhance predictability of revenues and reduce exposure to input cost volatility. This mechanism stabilizes operating margins and shields the project from feedstock price volatility, thereby reinforcing the reliability of projected cash flows.

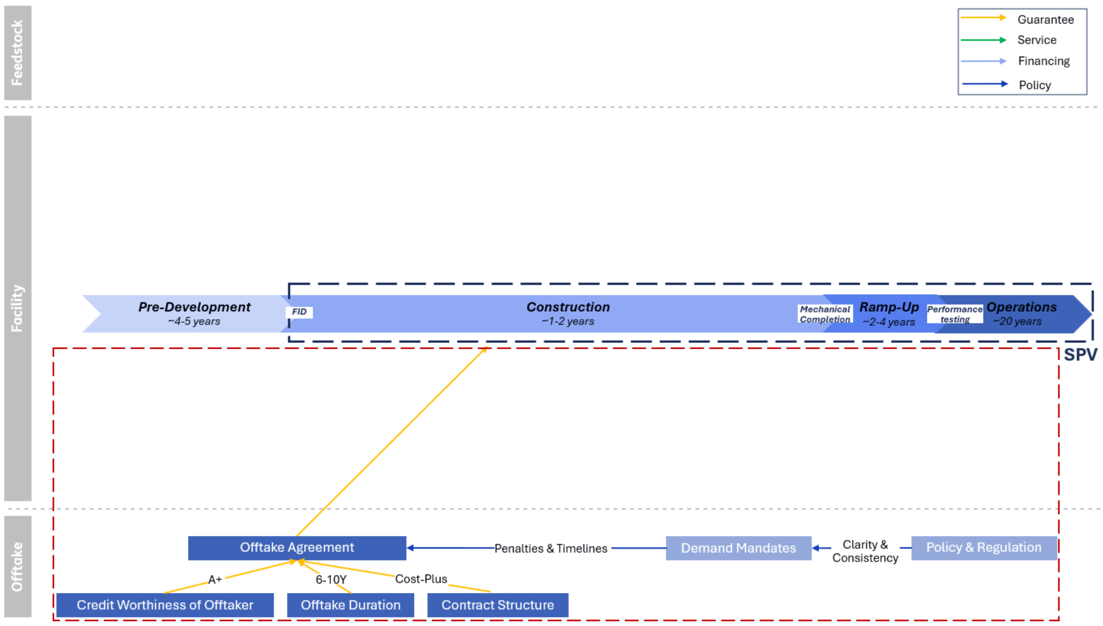


Figure 6.6: Risk allocation structures for mitigating offtake risks

6.1.4 Interdependent Risk Allocation for Improving Bankability

A critical factor for unlocking financing for (FOAK) advanced biofuel projects is creating predictable and credible cash flow streams. The pathway to arrive at a bankable business case for constructing advanced biofuel projects is therefore characterized by this interdependent, complex risk allocation structure. Risks need to be systematically and transparently allocated to the parties best positioned to manage each exposure. Project developers, EPC contractors, OEMs, feedstock suppliers, offtakers, and lenders must each assume a defined share of responsibility through equity participation, completion and performance guarantees, or long-term commercial agreements. In addition to robust project derisking, lender confidence is typically also improved through the participation of credible counterparties with a strong track record, particularly in the case of the equity sponsor. Lenders also prefer governance structures within the SPV that allow lenders to intervene within existing contract frameworks should the project no longer perform as planned.

These projects typically struggle to meet these criteria, specifically when it comes to risk allocation. Risk distribution negotiations can often lead to a risk allocation stalemate where parties along the value chain are not able to agree on how to best allocate these risks, specifically at the facility-level for distributing technology and system performance risk. Without mechanisms to enable risk sharing and strengthen bankability, projects may remain in the planning phase.

Bridging the bankability gap requires targeted government intervention and public funding instruments to play a complementary role by closing residual risk gaps that market parties cannot feasibly absorb. The next section will explore potential government support mechanisms that may help to improve bankability of advanced biofuels projects.

6.2 Potential Support Mechanisms for Mobilizing Investments for Advanced Biofuels Projects

This section explores potential support mechanisms targeting the main risk areas across the conversion facility and offtake based on analysis from the interviews. The challenge of improving the feasibility of risk allocation across parties for achieving a bankable project, particularly for independent project developers seeking project finance debt, is a key focus.

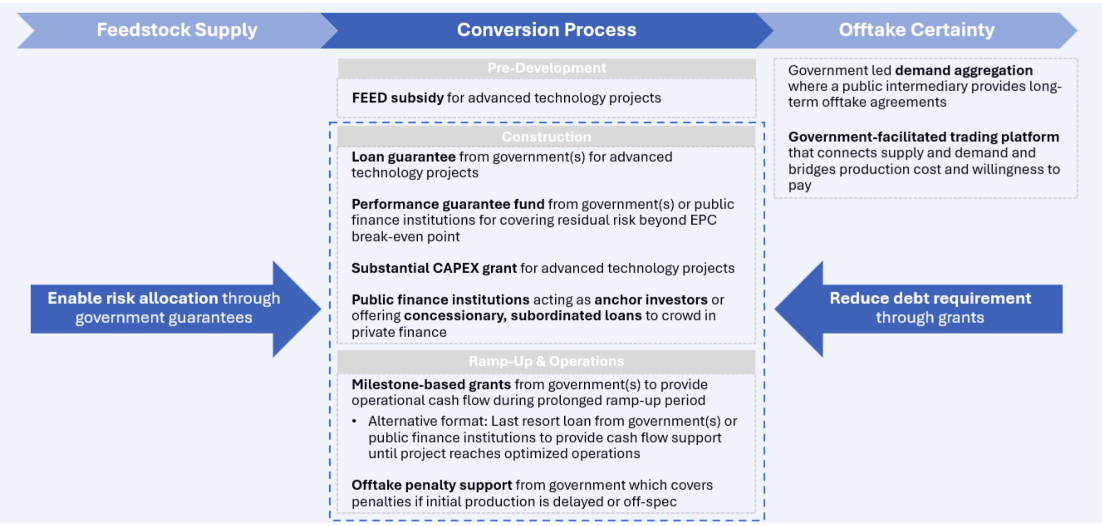


Figure 6.7: Overview of potential government support mechanisms for improving bankability

6.2.1 Conversion Process

The conversion process includes pre-development, construction, and ramp-up and operations phases. Risk allocation is particularly challenging across the construction phase for reaching FID.

Predevelopment Phase

As discussed in Appendix J advanced biofuel projects face significant early-stage financing risks, particularly for independent project developers with limited financial reserves at their disposal. The FEED phase represents an important cost item, which can be in the range of €50 million depending on facility size and complexity.

Construction Phase

1. Loan Guarantee Programme

A government loan guarantee to the project SPV has substantial potential for improving a project's bankability. With this guarantee, the government commits to repaying a portion of the loan if the project is not able to make debt repayments. This derisking instrument provides lenders with collateral on the repayment of their loan against the series of risks across the value chain.

A government loan guarantee is not a direct subsidy but a contingent liability where funding for the program is earmarked. The government only makes a payment if the project is not able to fulfil its debt obligations. Since not all projects will fail, the real amount the government disburses may be a fraction of the total guaranteed amount. This feature makes loan guarantees a potentially efficient use of public funds, as they can leverage large volumes of private capital while maintaining limited budgetary exposure for government, thereby creating a multiplier effect on public money. According to the OECD, guarantees are the most effective instrument for mobilizing private finance (Garbacz W., 2021). The provision of loan guarantees may also reduce the extent of the guarantees required by the lender from the EPC and OEM.

The effectiveness of loan guarantees depends upon the portion of the loan it covers and the requirements to access the loan guarantee program. Loan guarantees will need to cover a substantial portion of the lender's loan to be an effective derisking mechanism, otherwise the lender is left with significant risk exposure themselves. Access to loan guarantee programs should be less stringent than the bankability requirements of the commercial lender to allow projects to gain access to lower cost debt financing.

Loan guarantee funds could also be structured to be partially cost covering, where project developers could pay a premium to have access to the loan guarantee fund. Within this structure, private investors may be incentivized to invest in the fund as there is a potential for return on investment, provided that government investment in the fund accepts a first loss position. Required premiums should not be so substantial that this makes the business case infeasible.

The US DOE's loan programs office (LPO) provides significant loan guarantees to derisk clean energy projects, including advanced biofuels projects, moving beyond the demonstration phase (US DOE, 2010). The LPO developed a formula to determine the cost per guarantee, as shown in Figure 6.10. "For each applicant, LPO determines a credit subsidy cost, which is the expected cost to the government of its loan guarantees considering the time value of money; potential risk factors, such as default; and the estimated recovery rate" (RFF, 2025). The DOE loan programs office expects to create a significant multiplier on this cost of the guarantee. "In the near term, $3.6 billion in credit subsidy funding was appropriated in the IRA, expected to cover the subsidy costs for up to $40 billion in loan authority" (RFF, 2025).

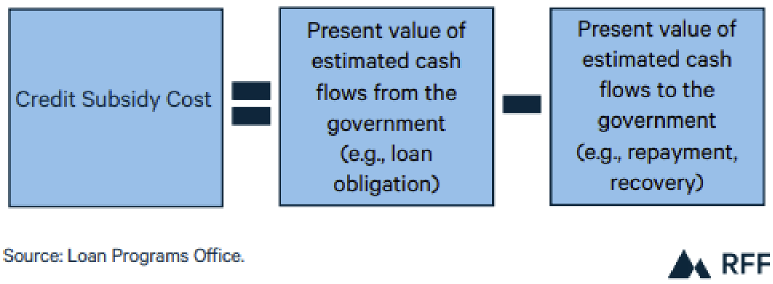


Figure 6.8: US DOE LPO methodology for determining cost of loan guarantee

The DOE loan program recently provided a $1.67 billion loan guarantee to Montana Renewables LLC. This loan guarantee was provided for the expansion of a renewable fuels facility to produce SAF, renewable diesel, and renewable naphtha. This foreseen capacity of the plant after expansion will amount to 315 million gallons per year of biofuels, primarily SAF (DOE, 2025).

Atradius, an export credit agency (ECA) in the Netherlands supported by the Ministry of Finance, offers credit insurance for project loans. They have previously engaged on large industrial infrastructure projects, like roads, and offshore wind. This scope may be expanded to include biofuels projects like SAF, where the ECA will provide loan guarantees up to 80% of the value of the loan (according to EU state aid rules) to local projects provided that either the feedstock is imported, or the product is exported.

2. Technology Performance Guarantee Fund covering residual risk

To mitigate technology performance risk for advanced biofuels projects seeking project finance debt, EPCs are required to provide performance guarantees covering a substantial portion of the total loan exposure. This may exceed their project margins, leading to challenges in fully covering and allocating this risk. A Technology Performance Guarantee Fund from government or public finance institutions aimed at covering the residual risk beyond the EPC breakeven point could address this constraint to enable feasible risk allocation.

Under this structure, the EPC provides the required performance guarantees to the value of their expected margin on the project, and the technology performance guarantee fund covers the remaining requirement from lender. This fund can allow for the EPC to feasibly participate in risk allocation without facing excessive losses going beyond their margin while providing lenders the required coverage on performance obligations. Within this fund structure,

- The EPC should remain responsible for the initial layer of exposure to the value of its expected project margin and accept a first loss position to ensure that the EPC remains incentivized to deliver.
- The government-backed fund can then provide a backstop guarantee to cover residual risks beyond the EPC's break-even point.
- The Technology Performance Guarantee Fund could be designed as a blended public–private financial instrument, where EPCs could pay a premium based on project size and risk level to gain access to the fund, thereby helping to make the fund partially cost-recovering.

The liabilities accompanied by providing performance guarantees are typically priced into contracts to offset excessive financial losses, which likely leads to an increase in overall project costs. Public instruments, like a Technology Performance Guarantee Fund, can reduce the need for extensive performance guarantees and may therefore also contribute to lower project costs.

This instrument specifically targets technology risk and does not address other risks along the value chain, like feedstock supply and offtake uncertainty. It is therefore less comprehensive than a loan guarantee but will require a smaller capital expenditure. Thus, in a market environment where feedstock supply and secure offtake are not considered to be key barriers, the Technology Performance Guarantee Fund could unlock access to financing for FOAK projects while minimising potential public expenditure. This allows for benchmarks and learnings to be established for EPCs and OEMs for NOAK projects.

In an uncertain market environment where feedstock supply and offtake are significant concern areas for the lender, a loan guarantee will provide more comprehensive derisking.

There is no example of this instrument being implemented yet. The concept was developed based on insights gathered during the interview discussions.

3. CAPEX Grants

Large CAPEX subsidies can directly reduce upfront investments costs and the need for difficult to access debt, as well as potentially lower the cost of capital across the projects financing structure. As described in the Policy Analysis above and in Appendix, the DEI+ CAPEX subsidy scheme is available in the Netherlands for advanced biofuels projects, amongst others. This provides a CAPEX subsidy of up to €30 million for pilot and demonstration projects, not for FOAK commercial plants.

4. Public Finance Institutions Acting as Anchor Investors or Offering Concessionary Financing

Public finance institutions, such as the European Investment Bank (EIB), InvestNL, and other national or regional development banks and ROMs, can play an active role in mobilizing private capital by taking a first-mover or risk-tolerant position in the capital structure. By acting as an anchor investor, a public financial institution sends a strong market signal regarding the validity of the project, providing assurance to commercial lenders and institutional investors. Additionally, public financial institutions can offer concessionary loans with lower interest rates and longer repayment periods and subordinated, meaning first-loss, positions to the senior debt provided by banks. By taking a subordinated position, the public institution absorbs a larger share of potential losses in the event of project underperformance, improving the overall bankability of the project.

The EIB provides loans that may cover up to 50% of total investment costs. These loans can take the form of senior or subordinated debt, with or without collateral, depending on project risk and structure. Conditions such as tenor (the total length of the loan), grace period (a period at the start of the loan when the borrower does not have to make principal repayments), and pricing are tailored to each project's economic life and credit profile (EIB, 2024). For advanced biofuels projects, the EIB primarily provides direct loans to large corporates, namely strategic developers, with full recourse to the borrower's balance sheet, i.e., corporate finance. Repayment is therefore based on the company's overall financial strength rather than project-specific revenues. To date, most EIB-supported biofuel projects have been HVO and HEFA SAF facilities led by established strategic developer, no lignocellulosic pathways have received EIB financing. The EIB often participates as part of a lending syndicate, a group of multiple lenders, and it operates on equal terms as other financial institutions, thereby still maintaining a low-risk position. EIB participation in biofuels projects enhances credibility, attracts co-lenders, and signals alignment with EU sustainability objectives. However, for independent developers, project risks are still typically too high to access project finance debt, highlighting the need for more lenient requirements from public finance institutions or dedicated de-risking instruments to enable broader participation in the advanced biofuels sector.

Example advanced biofuel projects that received financing from EIB :

- Repsol 250kt advanced biofuels plant using lipid-based feedstock in Spain - received a €120m loan (EIB, 2022)
- Cepsa 500kt SAF and HVO plant using UCO and agricultural waste in Spain - received a €285m loan, backed by InvestEU program (EIB, 2024)
- Galp 270kt SAF and HVO plant using vegetable oils and residual fats in Portugal - received a €250m loan (EIB, 2025)
- ENI conversion of conventional refinery into a 500kt biorefinery to produce HVO from UCO and agrifood waste in Italy - received a €500m loan (EIB, 2025)

The InvestEU program provides a guarantee backing the investments of implementing partners, like EIB and InvestNL, for projects that align with EU priorities. This derisks the investments made by partnered finance institutions (European Commission, sd). However, despite the InvestEU backing lowering the investment risk for public finance institutions like EIB, investments are still only made in low-risk, HEFA and HVO based projects.
The EIB currently also operates a venture debt instrument under InvestEU backing, designed to provide debt for high-risk, smaller projects, often in the demonstration phase (EIB, 2019). The InvestEU program provides a guarantee backing the investments of implementing partners, like EIB and InvestNL, for projects that align with EU priorities. This derisks the investments made by partnered finance institutions (European Commission, sd). The EIB

venture debt instrument has already been applied to a small e-fuels project in the EU, but not yet for large-scale advanced biofuel projects. For technology developers, such financing can bridge the gap between pilot and demonstration stages. Extending this instrument to also include commercialisation of FOAK advanced biofuel projects could help to de-risk early projects and crowd in private investors.

InvestNL in the Netherlands is a publicly funded Venture Capital financier providing equity, quasi-equity, a hybrid form of finance combining features of both debt and equity such as convertible loans, and debt in the range of €5 million to €50 million for early-stage technology development (Invest NL, sd). This follows a blended finance approach, where InvestNL, takes on higher-risk positions to encourage mobilization of private capital. For the large-scale commercialization of advanced biofuels facilities, the ticket size of InvestNL is not well aligned with the capital needs of these projects, where total investment requirements often exceed €100 million.

Despite providing valuable support, the maximum investment ticket size of InvestNL and ROMs is insufficient for capital-intensive initiatives such as the commercialisation of advanced biofuels projects and the EIB's requirement for maintaining a high credit rating limits it's risk appetite for providing large-scale financing for these projects. This creates a public financing gap for high risk, high investment requirement advanced biofuel projects deploying novel technologies, like gasification and second-generation ethanol. A dedicated state investment bank aimed at providing larger equity investments or longer-term patient debt with a higher risk tolerance could potentially bridge this financing gap and crowd in private investors.

Ramp-Up Phase

During the ramp-up and plant optimisation phase, lower than expected revenues may be experienced while fixed costs remain high. As a result, the project could face challenges in fulfilling its debt coverage ratio or experience liquidity shortages. If investors or parent companies lack financial endurance, the plant may become stranded before technical proof is achieved. Additional working capital and cash buffers are therefore typically required during the ramp-up phase.

1. Milestone-Based Grants

Governments could introduce milestone-based grants aimed at providing liquidity support at operational milestones, like mechanical completion or first full cycle production run. Such grants would enable developers to manage unforeseen costs and maintain financial stability while the facility gradually ramps up to desired capacity.

2. Liquidity Facility

"Liquidity Facility" provided by governments or public finance institutions could be considered as an alternative support instrument to grants when liquidity challenges are experienced during a prolonged ramp-up periods when operational milestones, like achieving a certain capacity utilisation, have not yet been achieved within the planned timeframe. This type of loan should allow for flexible repayment schedules, potentially coupled with below market interest rates, to offer short-term liquidity until the project reaches optimized operations and cash flows stabilize. This instrument may require a lower public capital outlay than milestone-based grants, while still reducing the risk of project failure due to severe financial constraints.

3. Offtake Penalty Support

Offtake penalty support could be a complementary measure, in which government temporarily provides financial support for covering penalty payments incurred from delayed or off-spec product deliveries associated with offtake agreements during the ramp-up phase. Offtake contracts often include strict performance and quality clauses that trigger financial penalties if the project is not able to fulfil the product delivery requirements. Through providing assistance with absorbing these penalties, governments can prevent projects from experiencing detrimental early-stage liquidity stress.

6.2.2 Offtake Certainty

A demand aggregation approach, where government or a public intermediary provides the required long-term offtake agreements to project developers and takes on the roll and associated risk of selling the product on to the market will assist with enabling offtake certainty. This could also take the form of a government-facilitated trading platform, where a public intermediary connects supply-side producers with demand-side offtakers and bridges the production cost and willingness to pay through SDE++ or CfD mechanisms.

6.3 Potential Pathways Forward

Government interventions applied across different value chain segments may support strategic developers and independent developers differently. Interventions related to feedstock supply and offtake certainty will support both strategic and independent developers, while loan guarantees and other mechanisms targeting technology risk at the conversion facility level will specifically support independent developers needing to derisk their projects to gain access to project finance debt. The deployment of selected support mechanisms can therefore be tailored to the type of projects, and the type of project developers' government aims to provide growth opportunities for.

6.3.1 Improving Market Certainty

Reducing market uncertainty through stimulating feedstock supply and enabling long-term offtake certainty through ambitious demand mandates, demand aggregation, or government-facilitated trading platforms may create a more feasible local market environment for project developers. Initiatives focussed primarily in these areas will support both strategic and independent developers but may be most beneficial to strategic developers if not also deployed alongside public funding mechanisms aimed at mitigating technology risk. Support mechanisms related to feedstock supply and long-term offtake may provide strategic developers with sufficient certainty to justify capital investment in production capacity. Provided that strategic developers focus mostly on conventional technologies closely aligned with their existing assets and business, support only in these areas could lead to majority of projects in the short-term being developed based on conventional lipid-based technologies until pressure on the lipid feedstock supply rises.

This approach may allow for mandates to be fulfilled with limited public funding needs but will likely favour mature or conventional technologies which present lower risk profiles and proven performance. While this approach may drive deployment of advanced biofuel projects, it risks concentrating investment in conventional technologies, potentially slowing innovation and limiting the diversification of advanced feedstock utilization pathways.

6.3.2 Supporting Independent Developers Through Public Funding Mechanisms

Government support could also be leveraged to support the debt funding gap experienced by independent developers through deploying targeted public funding mechanisms that strengthen the business case for advanced technology lignocellulosic projects. These mechanisms should focus on creating credible and predictable cash flows. This could include guarantee funds aimed at improving feasibility of risk allocation or substantial grants to reduce debt requirements or provide cash flows during the ramp-up phase. This approach should be focussed on assisting independent developers that have many, but not yet all, elements of a bankable business case to access project finance debt and reach FID.

Supporting independent developers may expand the use of harder-to-process feedstocks for advanced biofuels projects, including lignocellulosic residues and municipal solid waste. This approach may require higher levels of public investment to de-risk projects and mobilize private capital. By focusing on independent developers, this approach may support technological innovation and diversification but depends on the government's ambitions for direct financial involvement and long-term commitment to de-risking early projects.

The approach followed depends on government appetite for involvement in, and deploying public capital for, advanced biofuel projects. Currently, lignocellulosic feedstock-based projects pursued by independent developers cannot easily access debt and therefore rely more heavily on equity and grants. If it is desired for advanced technology projects to roll-out on a large-scale in the short term, then enabling access to large investment size, low-cost debt will be key. Providing substantial liquidity support and risk coverage for the initial FOAK advanced technology projects would establish operational proof points, reduce technology risk perceptions, lessen the "unproven" reputation of these projects, and pave the way for commercial debt participation in subsequent projects. Reaching bankability will likely require strong projects with many elements of a bankable business case already in place, equity sponsors with a track record that inspire confidence and trust from lenders, robust risk allocation that converts uncertainty into predictable cash flows, and public funding instruments that play a complementary role in covering residual risks that market parties cannot feasibly absorb. Public funding is not a substitute for private investment, but a catalyst that can make it possible.

Table 6.1 recaps the support mechanisms that can be implemented to support FOAK plants.

Table 6.1: Summary of various support mechanisms for construction and ramp-up phases with potential ''pros'' and ''cons''

Instrument	Description	''Pros''	''Cons''
Construction Phase			
Loan Guarantee Programme	- Government-backed guarantee on portion of project loan	- Low direct public capital needs if projects perform well - Provides comprehensive risk reduction across all elements in project value chain - Track-record of strong ability to crowd in private finance (effective use of earmarked public funds)	- Government carries contingent liability, which can be very substantial if projects do not perform well - For FOAK projects, it requires a guarantee to cover significant portion of the loan (thereby increasing government exposure to potential liabilities) - For FOAK projects, access requirements need to be flexible to align with the high-risk nature of these projects (thereby increasing likelihood of public expenditure) - Must follow EU State Aid rules

Instrument	Description	''Pros''	''Cons''
Technology Performance Guarantee Fund	- Government fund covering *residual* technology performance risk that EPCs cannot absorb	- Low(er) direct public capital needs if projects perform well - Specifically targets FOAK technology risk to enable feasible risk allocation and provision of required performance guarantees - Therefore, requires smaller volume of earmarked funds (efficient use of earmarked public funds)	- Government carries contingent liability - Less comprehensive risk reduction as only technology risk is compensated for, other risks along value chain remain and need to be addressed if significant - Complex to define ''residual'' risk and maintain fair playing field amongst EPCs, will require case-by-case evaluation - Must follow EU State Aid rules
Large CAPEX Grants	- Direct subsidies from government that reduce upfront investment cost	- Familiar and simple to use, already deployed for similar sectors/projects - Reduces investment requirement for capex-intensive projects	- Significant upfront public expenditure required - For high capital requirement projects, only effective if grant is substantial
Concessionary Financing from Public Finance Institutions	- Direct loans (or equity contributions) from public finance institutions on flexible terms	- Provides access to low-cost financing that projects typically struggle to access from commercial parties, thereby filling debt gaps - Financing is repaid if project is successful - Sends strong signal endorsing validity of project to private financiers	- Requires upfront public expenditure via public finance institution - Risk profile of FOAK projects still typically exceed that which is currently accepted by public finance institutions (like EIB) - Access requirements need to be tailored to be more flexible and risk tolerant for FOAK projects - Requires for public finance institution to accept more risk within financing structure than commercial parties (subordinated position) to substantially reduce risk for commercial lenders
Ramp-Up Phase			
Milestone-Based Grants	- Direct grants provided from government when projects reach specific operational milestones	- Provides liquidity runway to cover early cost overruns and support projects during prolonged ramp-up, thereby enabling project to repay debt and equity returns (and avoiding need for capital expenditure form other supporting instruments, like loan guarantees) - Prevents projects from directly failing based on ad hoc, short-term financial pressure - Attempts to prevent high capital expenditure of construction phase from being stranded	- Requires upfront public expenditure - Challenging to set clear access criteria, judge whether long-term technical outlook is positive, and monitor eligibility - Ramp-up phase is unpredictable for FOAK projects, therefore complex to determine i) at which milestone the grant may be most effective and ii) the size of the grant - Requires case-by-case evaluation to avoid excessive spending and sunk cost resulting from deep-rooted technological challenges

Instrument	Description	"Pros"	"Cons"
Liquidity Facility	- Temporary loan from government or public finance institutions during prolonged ramp-up period	Same points listed above, additionally: - Financing is repaid if project is successful (potentially lower public expenditure than grant)	- Requires upfront public expenditure via public finance institution - For loan to be effective and support project continuation, repayment terms need to be flexible and interest rates low - Challenging to set clear access criteria, judge whether long-term technical outlook is positive, and monitor eligibility - Ramp-up phase is unpredictable for FOAK projects, therefore complex to determine when loan should be stopped - Requires intensive evaluation to avoid loan defaults based on deep-rooted technological challenges
Offtake Penalty Support	- Government temporarily covers penalties from missed or off-spec product deliveries during prolonged ramp-up	- Protects project from early financial stress stemming from penalties associated with strict offtake contracts - Reduces risk of offtake contract termination	- Requires upfront public expenditure - Challenging to set clear access criteria, judge whether long-term technical outlook is positive, and monitor eligibility - Ramp-up phase is unpredictable for FOAK projects, therefore complex to determine when support should be stopped - Requires case-by-case evaluation to avoid excessive spending and sunk cost resulting from deep-rooted technological challenges

6.4 Section Discussions

For the large-scale deployment of advanced biofuels projects, it is essential that projects become "bankable", meaning they can access large, low-cost financing, typically from banks and institutional investors. This requires credible and predictable cash flows, thereby requiring strong risk management and reliable project partners. Independent developers, who are often the source of innovation, are at a disadvantage as they cannot easily access this kind of financing and must rely on expensive equity or government grants. This presents a challenge for scaling innovative projects. Improving access to project-based debt for independent developers requires for risks and uncertainties to be translated into predictable cash flows through robust risk allocation across the value chain – feedstock supply, project construction, project ramp-up, offtake certainty. This will require multiple contracts and equity stakes from parties along the value chain, namely feedstock providers, OEMs, EPC contractors, equity sponsors, and offtakers. Accepting such risks and liabilities is often not completely feasible for market parties, leading to a risk allocation stalemate and the project stalling.

Targeted government intervention and public financing mechanisms can assist with overcoming the stalemate by accepting residual risks market parties cannot absorb and by creating market certainty for advanced biofuel products. Uncertainty in government policy,

changing regulations, and unclear subsidy schemes make it harder for investors to commit to these projects. While current public support programs are helpful, they are often not large enough or flexible enough to meet the needs of FOAK projects using new technologies.
To address these challenges, the Dutch government could consider the main policy recommendations below:

1. **Guarantee instruments**

- **Deploy Government Loan Guarantees:** Set-up government-backed loan guarantee schemes for advanced biofuels projects, especially those based on novel technologies using lignocellulosic feedstocks. Loan guarantees are one of the most effective instruments for mobilising private sector capital. Loan guarantees comprehensively reduce risk for the lender across the value chain. Any challenge across the value chain that leads to the project defaulting on loan repayments is covered by the loan guarantee. These guarantees should cover a significant portion of the project loan and have flexible requirements that align with the FOAK nature of projects, making it less risky for banks to provide debt and enabling more projects to reach financial close.
- **Create a Technology Performance Guarantee Fund covering the residual risk beyond the EPC breakeven point:** Establish a public-private fund aimed at enabling the provision of the required performance guarantees for new biofuel technologies from key stakeholders, like EPCs and OEMs. This fund should cover the risks and liabilities that contractors and equipment suppliers cannot reasonably take on themselves, thereby enabling EPCs and potentially OEMs to feasibly and more economically provide the performance guarantees required by lenders. This instrument specifically targets technology risk and does not address other risks along the value chain, like feedstock supply and offtake uncertainty. It is therefore less comprehensive than a loan guarantee but will require a smaller public expenditure.

Both instruments enable lender risk to be reduced without upfront public expenditure, either directly in the case of a loan guarantee or indirectly through enabling the provision of the required performance guarantees from the relevant stakeholders. This assists with accessing conventional project financing structures by protecting the lender but does not necessarily ensure the success of the project.

Liquidity challenges during the ramp-up phase remains a concern for project developers. A guarantee instrument should therefore be accompanied by a ramp-up liquidity instrument to reduce lender risk while also addressing a crucial funding gap experienced by project developers.

2. **Driect financial support**

- **Increase Availability of Capital Grants:** Raise the maximum amount of capital expenditure (CAPEX) grants for advanced biofuels projects, specifically for the construction of FOAK plants. This will reduce the requirement for difficult to access debt. The application process for subsidy schemes should be flexible and responsive to the needs of FOAK projects.
- **Expand Availability of Concessionary Public Financing:** Expand the mandate and funding availability of public finance institutions, namely InvestNL, to enable provision of larger, long-term investments for high-risk, high-impact advanced biofuels projects. This could take the form of concessionary debt provision, thereby providing patient capital with lower interest rates, for the construction phase or through participation in guarantee schemes or liquidity facility loans. A new state investment bank or low-cost equity investments from government could also be considered for fulfilling such purposes.

- **Provide Milestone-Based Grants or Liquidity Facility Loans**: Introduce grants that provide targeted support for prolonged facility ramp-up. These can be made available when projects reach key milestones, such as mechanical completion. This provides financial support during the project optimisation phase where cash flows are not yet at full capacity. This could also take the form of last-resort loans with flexible repayment terms from a public finance institute, like InvestNL, to help projects manage unexpected costs during the ramp-up phase.

It will be beneficial to deploy all three direct financial support mechanisms discussed in parallel as they cover different gaps and risk areas. Capital grants reduce the size of private financing required during the capital-intensive construction phase, thereby reducing risk for the lender. Concessionary public financing provides patient, low-cost investment for the construction of the project beyond that which is not covered by the capital grant in the case of market debt remaining too expensive for FOAK projects, thereby filling debt gaps. Milestone-based grants or liquidity facility loans provide liquidity buffers during the unpredictable ramp-up phase. These options all require upfront public expenditure.

The instruments discussed under points 1 and 2 can be complementary or deployed in isolation depending on the specifics of how the instruments are set up and how comprehensive the support package is, with the exception that ramp-up support will also be required under path-way 1. For example, if the loan guarantee does not cover a significant portion of the loan, then a capex subsidy will also be beneficial to lower the size of the private financing requirement of the project, thereby further lowering investor risk.

Market creation mechanisms also remain essential contributors to the success of the above instruments. To minimise the public expenditure from the loan guarantee fund, offtake for the product should be secured through market creation mechanisms and mandates as discussed in point 3 below.

3. Improve Market Creation and Certainty

- Organize Offtake Aggregation**:** Establish a public intermediary or platform to coordinate the demand for advanced biofuels. This body should offer long-term offtake contracts to reduce market uncertainty, thereby providing visibility on project revenues and making projects more attractive to investors.
- In addition to long-term offtake contracting, the Netherlands could maintain the SDE++ scheme as a stable revenue-support mechanism for advanced renewable fuels. SDE++ provides a predictable operational top-up based on CO_2 reduction performance, supporting project revenue streams and strengthening bankability once the plant is operational.
- Tailor Support to Developer Type**:** Design support measures to fit the needs of different project developers. Use market certainty tools, like provision of long-term contracts and demand mandates, to help large, established companies, and focus public funding and risk-sharing instruments on independent developers to encourage innovation and diversification.
- Ensure Stable and Predictable Policy Frameworks**:** Commit to maintaining clear, long-term policies and subsidy schemes for advanced biofuels to provide certainty across investment horizons. Avoid frequent changes in regulations or support mechanisms, so that investors and developers can plan with confidence.

7 Overall Conclusions and Recommendations

Across all countries examined within the EU and beyond, the consistent message is that **stable and predictable policy matters more than financial incentives** when it comes to scaling advanced biofuels. Mandates and sub-mandates and the shift toward GHG-intensity system help create market demand and thereby support revenue stability. However, current experiences indicate that such frameworks alone are not enough to bring forward high-risk, capital-intensive lignocellulosic pathways. When advanced biofuels must compete directly with mature, low-risk biofuels in the same category, the cheaper fuel dominates. For the Netherlands, which is transitioning to a GHG-based system in 2026, this highlights the importance of ensuring that advanced categories remain clearly differentiated and protected from being captured by low-cost existing biofuels. It is also important to keep Annex IX feedstock lists stable. Frequent changes can undermine investments in complex, hard-to-process feedstocks. This concern can be communicated to the European Commission to support long-term policy stability.

A second insight is about early project risk. FOAK plants often fail not because incentives are weak, but because the overall risk is too high. High CAPEX, commissioning problems, technology uncertainty, and feedstock issues make these projects difficult for normal lenders. Various financial instruments have been discussed above to help de-risk FOAK plants. To scale advanced biofuels, projects need to become bankable. This requires predictable cash flows and clear risk sharing across the value chain. Independent developers find this difficult, as they rely on expensive equity and have limited access to low-cost debt. This often leads to a risk-allocation stalemate.

Targeted government intervention can unlock financing for these projects by taking on residual risks and creating market certainty. Current support helps, but FOAK projects often need larger and more flexible tools. A mix of guarantee instruments, capital grants, concessionary public financing, and ramp-up support can help projects reach financial close and navigate the early operational phase. Using these tools together reduces lender risk, improves liquidity during ramp-up, and enables FOAK technologies to progress toward commercial scale.

Third, international success stories highlight the **value of system-level integration and industrial clustering**. Brazil's success with 2G ethanol came from systematic co-location with existing 1G sugar mill. This reduced feedstock risk (advantage of bagasse in Brazil), allowed shared utilities, and improved economics. For the Netherlands, this means supporting industrial clustering, when possible, integrating with existing refinery and chemical parks.

Fourth, strong, long-term demand signals are indispensable. Countries that scaled advanced biofuels made sure producers had long-term buyers. Brazil used export contracts. India used fixed 2G ethanol offtake agreements with state oil companies. For the Netherlands, stable demand for advanced biofuels will require government-backed offtake mechanisms, pooled procurement, and alignment with the FuelEU Maritimeand ReFuelEU Aviation Regulations. At the same time, strong and stable demand may not necessarily stimulate domestic advanced biofuel projects in the Netherlands or Europe. Competition with other regions will need to be tackled carefully.

Overall, the comparative evidence shows that advanced biofuels scale only when four elements align: long-term policy stability, reduced early-stage technology risk, secure feedstock access, and strong market demand.

For the Netherlands, these factors need to be shaped to fit local conditions. The country has limited domestic biomass, but is uniquely well positioned through its ports, logistics hubs, and industrial clusters. The country already handles significant wood chips and pellet imports and can use this infrastructure for the development of advanced biofuels. To accelerate progress, the Netherlands can focus on the pathways that best fit its industry, and supporting a few selected pathways will accelerate scale-up and avoid fragmented or inefficient investment. Supporting multiple smaller FOAK plants, instead of one large flagship, will help spread risk and speed up learning.

Recommendations for The Netherlands

Adopt a Two-Track Policy Approach Until Value Chains Mature

To accelerate deployment while ensuring long-term stability, implement two complementary policy tracks:

- **Track 1: Long-term, stable GHG-based obligations** to create demand, give investors confidence and drive continued innovation across the market.
- **Track 2: Temporary, targeted support for a small number of FOAK projects** to de-risk the most promising advanced pathways.

Both tracks should run in parallel until the supply of advanced biofuels scales and costs fall.

Track 1: Keep strong GHG reduction goals and clear sub-mandates (10–15 years)

- Maintain ambitious, stable GHG-intensity obligations, like the annual obligation for fuel suppliers to blend in renewable fuels.
- Keep binding sub-mandates for advanced biofuels, ensuring they also support new lignocellulosic and waste-based value chains that can later supply aviation, maritime, and chemicals. Avoid adding more sub-mandates; instead ensure existing ones genuinely drive innovation.
- Keep stability in Annex IX feedstock lists to protect investments in difficult-to-process feedstocks.

Track 2: Provide temporary, targeted de-risking for a few strategic FOAK projects

Identify a small number of pathways tailored to Dutch strengths: early studies highlight syngas-based routes and renewable methanol (bio + e-methanol).

For these priority pathways:

- Apply targeted, time-limited risk sharing instruments (e.g., loan guarantees, targeted grants) to enable successful FOAK commercial-scale plants, followed by early NOAK capacity.
- Focus on a limited number of key projects but ensure they reach breakeven so future plants can rely mainly on market mechanisms.

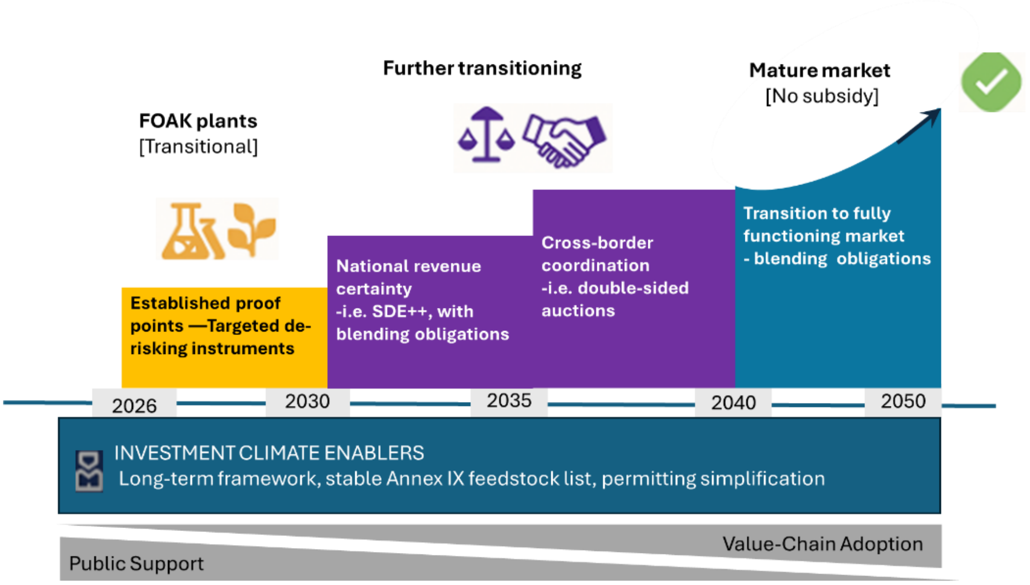


Figure S.1: Illustration of the recommended policy support framework

Use existing instruments to ensure revenue stability after FOAK success
- Use SDE++ together with GHG-intensity obligations to provide stable revenues for 15 years.
- Expand SDE++ eligibility to include SAF and maritime fuels.
- Update feedstock cost assumptions using indexed or periodic benchmarks.
- Apply learnings from targeted enhancements listed above, then expand through cross-border auctions or EU-level platforms.
- Work with the European Commission to ensure (lignocellulosic) advanced biofuels are explicitly included in the Sustainable Transport Investment Plan (STIP) that was adopted in 2025 to unlock investments and scale up production of renewable and low-carbon fuels.

Rely on market mechanisms once the sector is fully mature
After scale-up and cost reduction, the GHG system should drive further deployment without extra support.

Coordinate instruments, budgets, and cross-sectoral needs
- Align support for advanced biofuels with the chemical industry's decarbonisation trajectory, since these value chains will be the stepping stones for a fossil free chemical industry.
- In addition, advanced biofuels can supply biogenic CO_2 for renewable fuels of non-biogenic origin (e-fuels) or for chemicals. Develop integrated clusters where advanced biofuel, e-fuel, and chemical producers co-locate and share biomass preprocessing, hydrogen, CO_2 streams, and logistics infrastructure.

Improve wider enabling conditions
Simplify permitting. Ensure infrastructure access. Support feedstock markets and regional hubs. Promote links with the production of e-fuels and chemicals.

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Appendix A

Interview list and participation to the workshop

List of interviewees	
Stakeholder	**Stakeholder grouping**
Innovation Quarter (South Holland)	Finance
Invest NL	Finance
Polestar Capital	Finance
European Investment Bank (EIB)	Finance
ING	Finance
Atradius	Finance
PBL	Government organisation
Copernicus	Knowledge institute
TU Delft	Knowledge institute
Universiteit Utrecht	Knowledge institute
TNO	Knowledge institute
Alco Energy (BE/NL)	Industry
BtG-BtL (NL)	Industry
Clariant (CH)	Industry
GIDARA (NL)	Industry
Nesté (FI/NL)	Industry
Perpetual Next (NL)	Industry
SkyNRG (NL)	Industry
UPM (FI)	Industry
Zeeland refinery (NL) - Total (FR)	Industry
ISPT	Knowledge platform
Platform hernieuwbare brandstoffen (PHB)	Knowledge platform
Nederlandse Vereniging voor Duurzame Biobrandstoffen	Sector association
NVDE	Sector association
Transport and Environment (T&E)	NGO

List of workshop attendees	
Organisation	**Number of attendees**
Finance	1
Finance	2
Finance	4
RVO	2
GIDARA Energy	1
Neste	1
Perpetual Next	1
Via Solutis	1
TNO	5
Utrecht University	1
Platform Hernieuwbare Brandstoffen	1
VEMOBIN	1
Polestar Capital	1
BTG- BTL	1
SkyNRG	1
Alco Energy	1
TU Delft	1
Utrecht University	2
Platform Hernieuwbare Brandstoffen	2
Transport and Environment Association	1

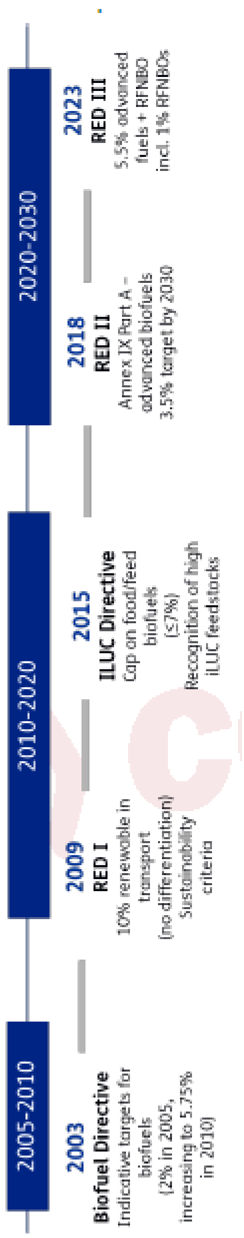
Appendix B

Annex IX List A and B from DIRECTIVE (EU) 2018/2001 with additions of 2024 (EU) 2024/1405

Part A. Feedstocks for the production of biogas for transport and advanced biofuels, the contribution of which towards the minimum shares referred to in the first and fourth subparagraphs of Article 25(1) may be considered to be twice their energy content:
(a) Algae if cultivated on land in ponds or photobioreactors;
(b) Biomass fraction of mixed municipal waste, but not separated household waste subject to recycling targets under point (a) of Article 11(2) of Directive 2008/98/EC;
(c) Biowaste as defined in point (4) of Article 3 of Directive 2008/98/EC from private households subject to separate collection as defined in point (11) of Article 3 of that Directive;
(d) Biomass fraction of industrial waste not fit for use in the food or feed chain, including material from retail and wholesale and the agro-food and fish and aquaculture industry, and excluding feedstocks listed in part B of this Annex;
(e) Straw;
(f) Animal manure and sewage sludge;
(g) Palm oil mill effluent and empty palm fruit bunches;
(h) Tall oil pitch;
(i) Crude glycerine;
(j) Bagasse;
(k) Grape marcs and wine lees;
(l) Nut shells; (m) Husks;
(n) Cobs cleaned of kernels of corn;
(o) Biomass fraction of wastes and residues from forestry and forest-based industries, namely, bark, branches, precommercial thinnings, leaves, needles, treetops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil;
(p) Other non-food cellulosic material;
(q) Other lignocellulosic material except saw logs and veneer logs.
‘(r) Fusel oils from alcoholic distillation;
(s) Raw methanol from kraft pulping stemming from the production of wood pulp;
(t) Intermediate crops, such as catch crops and cover crops that are grown in areas where due to a short vegetation period the production of food and feed crops is limited to one harvest and provided their use does not trigger demand for additional land, and provided the soil organic matter content is maintained, where used for the production of biofuel for the aviation sector;
(u) Crops grown on severely degraded land, except food and feed crops, where used for the production of biofuel for the aviation sector;
(v) Cyanobacteria

Part B. Feedstocks for the production of biofuels and biogas for transport, the contribution of which towards the minimum share established in the first subparagraph of Article 25(1) shall be limited and may be considered to be twice their energy content:
(a) Used cooking oil;
(b) Animal fats classified as categories 1 and 2 in accordance with Regulation (EC) No 1069/2009
(c) Damaged crops that are not fit for use in the food or feed chain, excluding substances that have been intentionally modified or contaminated in order to meet this definition;
(d) Municipal wastewater and derivatives other than sewage sludge;
(e) Crops grown on severely degraded land excluding food and feed crops and feedstocks listed in Part A of this Annex, where not used for the production of biofuel for the aviation sector;
(f) Intermediate crops, such as catch crops and cover crops, and excluding feedstocks listed in Part A of this Annex, that are grown in areas where due to a short vegetation period the production of food and feed crops is limited to one harvest and provided their use does not trigger demand for additional land and provided the soil organic matter content is maintained, where not used for the production of biofuel for the aviation sector.'.

Appendix C
Evolution of (advanced) biofuel policy in Europe



Biofuel policies in the EU have evolved significantly over time, creating uncertainty that has often hindered the development of advanced biofuels. Initially, the 2003 Biofuels Directive introduced indicative targets for biofuels in transport: 2% by 2005 and 5.75% by 2010. This was later replaced by the Renewable Energy Directive (RED I) in 2009, which set a binding 10% renewable energy target in transport by 2020. At that stage, there was no distinction between conventional and advanced biofuels, although harmonized sustainability criteria were introduced.

Concerns over the food-versus-fuel debate and indirect land-use change (ILUC) led to the ILUC Directive in 2015, which capped the share of food- and feed-based biofuels (often called first-generation or conventional biofuels) and identified high-ILUC-risk feedstocks.

In 2018, the RED II revision was adopted for the 2021–2030 period. For the first time, eligible feedstocks for advanced biofuels were listed in Annex IX, divided into Part A (agricultural and forestry residues, and other organic waste fractions) and Part B (used cooking oil and animal fats). RED II introduced a 3.5% sub-target for advanced biofuels by 2030, alongside an overall 14% renewable energy target in transport. This directive also introduced a specific limit for biofuels from Part B. Advanced biofuels could be double counted toward compliance.

Most recently, in 2023, RED III was adopted. It increased the binding renewable energy target in transport to 29%, alternatively, a 14.5% reduction in GHG intensity of transport fuels—Member States could choose between these options. Furthermore, it included a combined 5.5% sub-target for advanced biofuels and RFNBOs (Renewable Fuels of Non-Biological Origin), including a minimum 1% RFNBO sub-target. Double counting provisions remain applicable within the energy-based obligations.

While these directives set the overall framework, implementation at the Member States level has varied significantly.

Appendix D

Review of key EU-wide financing instruments

EU Innovation Fund

The EU Innovation Fund supports low-carbon technologies, financed through revenues from the EU ETS. It supports innovative projects that can significantly reduce GHG emissions, focusing on sectors like energy-intensive industries, carbon capture and utilisation, carbon capture and storage, innovative renewable energy generation and energy storage. With the revision of the ETS Directive, net-zero mobility and buildings are also included. For advanced biofuels Innovation Fund provides funds for first-of-a-kind commercial scale plants and breakthrough technologies, with the ambition to bridge the gap between demonstration and market deployment.

The 2025 Annual Knowledge Sharing Report of the innovation fund (EC, 2025) introduces the insights related to the funded projects. By the end of 2024, the Fund project portfolio consisted of 120 ongoing projects and 36 projects reaching financial close. Figure D.1 illustrates the funded projects within the energy-intensive industries. It appears that there are two biofuels and biorefinery related projects in Spain, one in Sweden and two in the Netherlands. Thus, only 4% the total projects (or 10% of the energy-intensive industry related projects) are related to biofuels and biorefineries. Among the granted projects, only the one in Sweden is a first-of-a-kind commercial plant and the Innovation Fund grant provided for this plant comprises approximately 2% of the total funding granted under this Fund[8].

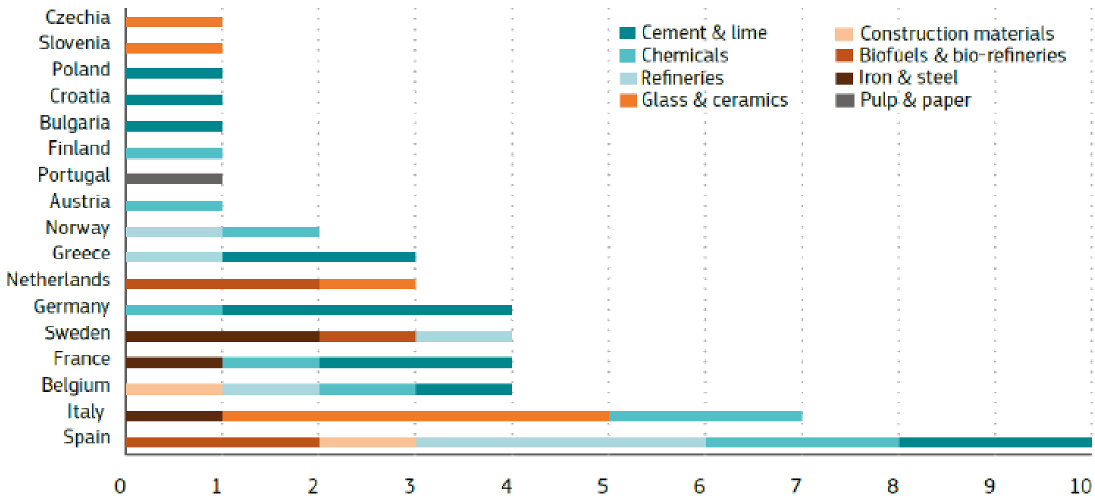


Figure D.1: Funded projects within the energy intensive industry

[8] The total commitment amounted to EUR 7.1 billion (EC,2025)

Biofuel projects funded under Innovation Fund

The Netherlands[9]

- FirstBio2Shipping (Innovation Fund grant 4.3 million €)
  This project aims converting biogas to bio-LNG for shipping sector. While biogas production via anaerobic digestion is already commercial, this project focuses on direct integration of a new cryogenic liquefaction technology to process biogas and convert it into LNG.
- Sol: Sugar Oil as sustainable marine fuels (innovation Fund grant: 4 million €)
  Aims to increase the technical maturity of conversion of cellulose to crude sugar oil by means of dilute acid hydrolysis and emulsification of this sugar oil with heavy fuel oil, and scale up this production from1 kt per annum to 5 kt.

Spain[10]

- W4W project (project cost 7.3 million €; Innovation Fund grant2.6 million €)
  This project aims at biomethane production from landfill gas using an innovative technology.
- LuGaZ3 (Innovation Fund grand: 4.5 million€)
  Focuses on biogas and biofertilisers production using local manure and gari-food residues.

Sweden[11]

- BioOstrand: Biorefinery Ostrand (Innovation Fund:166.7 million €)
  This is the first commercial scale biorefinery producing SAF and naphtha from solid forestry residues. The project will combine solid biomass gasification and Fischer-Tropsch synthesis, with an electrolyser utilising renewable electricity. The expected entry into operations is 30 June 2029.

Among the new projects that are invited to enter grant agreement preparation (under Innovation Fund call of 2024), the majority relate to biogas and biomethane production using organic waste[12]. Only, one of them, Neste SCOOP project in Finland, relates to advanced biofuel production. This project aims to develop a new co-processing technology for crude tall oil, a byproduct from pulp mills, into renewable fuels and chemicals.

These observations illustrate the very limited contribution of this funding scheme to scaling up advanced biofuels in Europe. The Fund appears to favour large-scale, proven technologies with high technology readiness (TRL 7–8). Technologies such as gasification and hydrothermal liquefaction are either early commercial scale and/or with high technical risk and uncertain economics. This makes them less competitive compared with mature CCS or hydrogen projects.

Horizon 2020/Horizon Europe (Cluster 5)

Horizon 2020 has been the main funding source supporting advanced biofuels up to 2020. This programme is followed by the Horizon Europe programme.

The latest Horizon Europe Cluster 5 call text for 2026–2027 (version May 2025) places strong emphasis on accelerating the deployment of sustainable fuels for hard-to-abate sectors such as aviation, maritime transport, and heavy-duty mobility. It prioritizes large-scale

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10 4d94fc84-4ea2-4404-bee2-01d7a27d4c3c en; 101157027.pdf
11 101132801.pdf
12 Biomethane production from organic waste in Norway, greenfield biogas production in France, biomethanol production from organic waste in Denmark.

demonstration projects that validate complete value chains—from feedstock sourcing and conversion technologies to upgrading and end-use integration. The ambition is to move technologies from pilot scale (TRL 5–6) to first-of-a-kind industrial deployment at TRL 7–8. This represents a significant change from the previous programmes, which funded pilot-level topics (such as CL5-2024-D3-02-01/06 with 50% funding) and focused more on early-stage technology validation without explicit commercialization or finance-readiness requirements.

Invest EU (2021-2027)

InvestEU is the European Union's flagship investment programme (2021–2027), designed to mobilize at least €372 billion in public and private capital—backed by a €26.2 billion EU budget guarantee—to support EU policy goals such as the green and digital transitions, innovation, competitiveness, and cohesion. It is organized into four policy windows—Sustainable Infrastructure, Research, Innovation & Digitalisation, SMEs, and Social Investment & Skills—with dedicated support for green-energy projects, including advanced biofuels and renewable fuels.

While this instrument appears to be a strong horizontal guarantee instrument, there is no dedicated window or ring-fenced risk-sharing for advanced biofuels FOAK plants.

Sustainable Transport Investment Plan (STIP)

The Sustainable Transport Investment Plan (STIP) is a new EU-plan, adopted on 5 November 2025, to speed up clean fuels for aviation and maritime sectors. It will offer €2.9 billion between 2025 and 2027 from Horizon Europe (~€133m), the Innovation Fund (€153m e-aviation; €293m maritime), InvestEU (~€2bn), and the European Hydrogen Bank (€300m for SAF/SMF hydrogen production). The goal is to produce about 20 million tonnes of sustainable fuels by 2035. This includes 13.2 million tonnes of (advanced) biofuels and 6.8 million tonnes of e-fuels to meet ReFuelEU Aviation and FuelEU Maritime mandates. Figure D.2 illustrates the design of the STIP.

While the volumes mentioned for biofuels appear larger, the key actions to boost investments appear to focus mainly on e-SAF production. Moreover, there is no clear definition of these biofuels nor a reflection on advanced biofuels from lignocellulosic feedstocks.

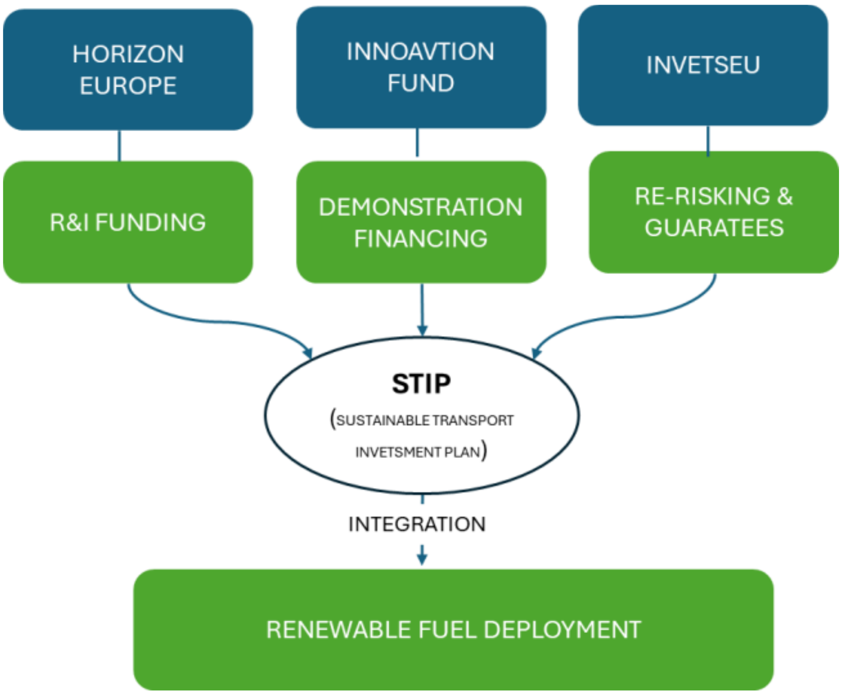


Figure D.2: Illustration of the newly designed STIP

Additionally, the commission indicates launching a pilot project “eSAF Early Movers Coalition’ with committed member states will be launched by the end of 2025. It aims to bring together at least 500 million €. The Commission also indicates a need for intermediary mechanisms in the EU that connect fuel producers and suppliers. Such a system will give price certainty and de-risk investment. This appears to be a double-sided auction for e-SAF, which is a market design where both buyers and sellers submit bids/offers, and a market intermediary matches them to determine transactions. The fuel producers and suppliers submit offers indicating the minimum price they need to produce and supply SAF. Consumers, thus airlines, submit bids indicating the maximum price they are willing to pay for SAF. The intermediary then clears the market by matching bids and offers, using a uniform clearing price or pay-as-bid approach (see Figure 4.6). The EU H2Gloabl initiative uses a similar double-auction model, with long term purchase agreements with producers and short-term sales to consumers to accelerate green hydrogen projects. There is a recommendation to design such an auction for renewable fuels for the maritime sector (Beroske, et al., 2025).

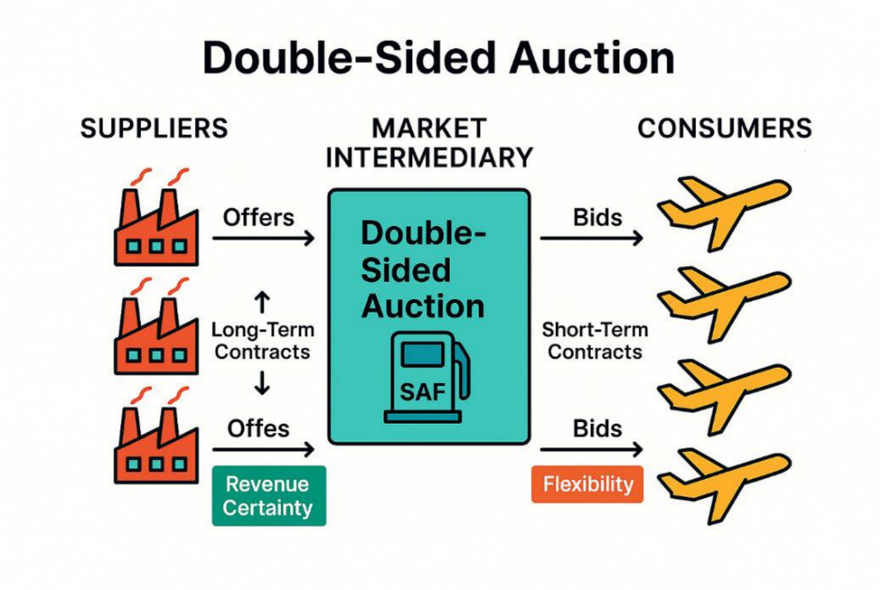


Figure D. D.3: Simplified illustration of a double-sided auction mechanism

The STIP design leans heavily towards e-fuels. There is no explicit investment plan or dedicated risk-sharing for advanced biofuels. In their response, IATA refers to this and highlights that the plan still underestimates biofuels' regional feedstock potential and overly prioritises e-SAF[7].

Like e-fuels, advanced biofuels face high upfront costs and uncertain demand. A regional auction could aggregate demand from airlines, shipping firms, and fuel suppliers. Different than e-fuels, advanced biofuels rely on varied feedstocks, which differ by country. This may further complicate such a mechanism. In addition, the limited advanced biofuel production facility at scale may create issues. The feedstock complexity can be addressed by standardisation of feedstock commodities. In addition, regional clusters and logistics hubs can address this issue.

Appendix E
Innovation Fund – list of projects invited to grant agreement preparation

Project	Type	Category	Sector	Location	Technology pathways	Status
ANTHEMIS	IF24Call – General large-scale	Energy-intensive industries	Cement & lime	Belgium	Carbon capture for storage	Invited to grant agreement preparation
AirvaultGoCO2	IF24Call – General large-scale	Energy-intensive industries	Cement & lime	France	Carbon capture and utilisation	Invited to grant agreement preparation
APOLLOCO2-LT	IF24Call – General large-scale	Industrial carbon management	Other	Greece	Carbon capture for storage	Invited to grant agreement preparation
CARBON HUB CPT01	IF24Call – General large-scale	Energy-intensive industries	Cement & lime	Romania	Carbon capture for storage	Invited to grant agreement preparation
DEZiR	IF24Call – General large-scale	Energy-intensive industries	Refineries	France	Sustainable Aviation Fuel (e-SAF)	Invited to grant agreement preparation
DREAM	IF24Call – General large-scale	Energy-intensive industries	Cement & lime	Italy	Carbon capture for storage	Invited to grant agreement preparation
ENDOR	IF24Call – General large-scale	Energy-intensive industries	Refineries	Denmark	Sustainable Aviation Fuel (eSAF)	Invited to grant agreement preparation
LUXIA	IF24Call – General large-scale	Energy-intensive industries	Chemicals	Spain	Renewable hydrogen, green ammonia and e-methanol production	Invited to grant agreement preparation
ReSTart	IF24Call – General large-scale	Energy-intensive industries	Refineries	France	Sustainable Aviation Fuel (eSAF)	Invited to grant agreement preparation

Project	Type	Category	Sector	Location	Technology pathways	Status
VAIA	IF24Call – General large-scale	Energy-intensive industries	Cement & lime	France	Carbon capture for storage	Invited to grant agreement preparation
BIOVIND	IF24Call – General medium-scale	Energy-intensive industries	Refineries	Norway	Biomethane and biofertiliser production from organic waste	Invited to grant agreement preparation
GREENFIELD BIOGAZ	IF24Call – General medium-scale	Energy-intensive industries	Refineries	France	Biogas production	Invited to grant agreement preparation
Leopard	IF24Call – General medium-scale	Energy-intensive industries	Cement & lime	Belgium	Carbon capture technology	Invited to grant agreement preparation
MECACLAY	IF24Call – General medium-scale	Energy-intensive industries	Cement & lime	Lithuania	Product substitution with supplementary cementitious materials	Invited to grant agreement preparation
OTO	IF24Call – General medium-scale	Energy-intensive industries	Glass, ceramics & construction material	Spain	Low-carbon plasterboard production line	Invited to grant agreement preparation
PP2XH	IF24Call – General medium-scale	Energy-intensive industries	Refineries	Estonia	Low carbon e-methanol for the maritime shipping industry and green hydrogen for land transport applications	Invited to grant agreement preparation
RECLAIM	IF24Call – General medium-scale	Energy-intensive industries	Refineries	Denmark	Circular economy: green methanol, biomethane, and digestate fertilizer	Invited to grant agreement preparation
ReNova ChemPET	IF24Call – General medium-scale	Energy-intensive industries	Other	Italy	Chemical recycling	Invited to grant agreement preparation
SCOOP	IF24Call – General medium-scale	Energy-intensive industries	Refineries	Finland	Biofuels production	Invited to grant agreement preparation
SCW Steel CleanUp	IF24Call – General medium-scale	Energy-intensive industries	Cement & lime	Sweden	Chemical recycling of steel slags	Invited to grant agreement preparation

Project	Type	Category	Sector	Location	Technology pathways	Status
Thermolysis	IF24Call – General medium-scale	Energy-intensive industries	Chemicals	Greece	Chemical recycling of end-of-life tyres	Invited to grant agreement preparation
VIPER	IF24Call – General medium-scale	Energy-intensive industries	Iron & steel	Norway	Circular economy: biorefinery	Invited to grant agreement preparation
W2BIOFUEL	IF24Call – General medium-scale	Energy-intensive industries	Refineries	France	Biofuels production	Invited to grant agreement preparation
INSPIRE-PV	IF24Call – General small-scale	Energy-intensive industries	Non-ferrous Metals	Spain	Chemical recycling for photovoltaic panels	Invited to grant agreement preparation
LCSCM	IF24Call – General small-scale	Energy-intensive industries	Cement & lime	France	Substitute products: low-carbon supplementary cementitious material	Invited to grant agreement preparation
Reprocover5.0	IF24Call – General small-scale	Energy-intensive industries	Cement & lime	Belgium	Circular economy for thermoset waste	Invited to grant agreement preparation
H2PEARL	IF24Call - Manufacturing	Energy-intensive industries	Manufacturing of components for EII	Germany	PEM electrolyser stacks	Invited to grant agreement preparation
ASTRA PP	IF24Call - Pilots	Energy-intensive industries	Chemicals	Belgium	Chemical recycling for polypropylene (PP) waste	Invited to grant agreement preparation
DEMONSTR8	IF24Call - Pilots	Energy-intensive industries	Non-ferrous Metals	France	Battery recycling	Invited to grant agreement preparation
HuCCSar	IF24Call - Pilots	Industrial carbon management	Other	Poland	Carbon transport and storage	Invited to grant agreement preparation
RjukanLH2	IF24Call - Pilots	Energy-intensive industries	Hydrogen	Norway	Hydrogen powered shortsea container vessels	Invited to grant agreement preparation
SLALOM 2.0	IF24Call - Pilots	Energy-intensive industries	Refineries	Norway	Ethanol to produce sustainable aviation fuels (SAF)	Invited to grant agreement preparation
TAKE KAIR	IF24Call - Pilots	Energy-intensive industries	Refineries	France	Sustainable Aviation Fuels (e-SAF)	Invited to grant agreement preparation

Project	Type	Category	Sector	Location	Technology pathways	Status
ROSE	IF24Auction - renewable hydrogen	Energy-intensive industries	Hydrogen		Electrolytic renewable hydrogen production	Invited to grant agreement preparation
H2CEF	IF24Auction - renewable hydrogen	Energy-intensive industries	Hydrogen		Electrolytic renewable hydrogen production	Invited to grant agreement preparation
Tharsis-ELY-1	IF24Auction - renewable hydrogen	Energy-intensive industries	Hydrogen		Electrolytic renewable hydrogen production	Invited to grant agreement preparation
NOON	IF24Auction - renewable hydrogen	Energy-intensive industries	Hydrogen		Electrolytic renewable hydrogen production	Invited to grant agreement preparation
GH2Move-VLC	IF24Auction - renewable hydrogen	Energy-intensive industries	Hydrogen		Electrolytic renewable hydrogen production	Invited to grant agreement preparation
ARANDAH2	IF24Auction - renewable hydrogen	Energy-intensive industries	Hydrogen		Electrolytic renewable hydrogen production	Invited to grant agreement preparation
Arteixo H2V	IF24Aucti on - renewable hydrogen	Energy-intensive industries	Hydrogen		Electrolytic renewable hydrogen production	Invited to grant agreement preparation
GreenWHV ELY	IF24Aucti on - renewable hydrogen	Energy-intensive industries	Hydrogen		Electrolytic renewable hydrogen production	Invited to grant agreement preparation
ATLAS	IF24Aucti on - renewable hydrogen	Energy-intensive industries	Hydrogen		Electrolytic renewable hydrogen production	Invited to grant agreement preparation
H2BRISA	IF24Aucti on - renewable hydrogen	Energy-intensive industries	Hydrogen		Electrolytic renewable hydrogen production	Invited to grant agreement preparation
SolWinHy Cadiz	IF24Aucti on - renewable hydrogen	Energy-intensive industries	Hydrogen	Spain	Electrolytic renewable hydrogen production	Invited to grant agreement preparation
H2LZ	IF24Aucti on - renewable hydrogen	Energy-intensive industries	Hydrogen	Spain	Electrolytic renewable hydrogen production	Invited to grant agreement preparation

Project	Type	Category	Sector	Location	Technology pathways	Status
TORDESILLAS H2	IF24Aucti on - renewable hydrogen	Energy-intensive industries	Hydrogen	Spain	Electrolytic renewable hydrogen production	Invited to grant agreement preparation
RjukanH2	IF24Aucti on - renewable hydrogen – maritime topic	Energy-intensive industries	Hydrogen	Norway	Electrolytic renewable hydrogen production	Invited to grant agreement preparation
Gen2-LH2	IF24Auction - renewable hydrogen – maritime topic	Energy-intensive industries	Hydrogen	Norway	Electrolytic renewable hydrogen production	Invited to grant agreement preparation

Appendix F
Assessment of national regulations and incentives on (advanced) biofuel

F.1 Sweden

Initially, biofuels were promoted through extensive tax exemptions (CO_2 and energy tax) in Sweden. A major policy shift occurred in 2018 with the introduction of the GHG reduction mandate (Reduktionsplikten), replacing tax exemptions with binding annual reduction targets for fuel suppliers (IEA Bioenergy Country Report Sweden, 2024).The GHG reduction target set for gasoline was 7.8% and for diesel 30.5% between 2022 and 2023. The tax exemption was revised to only apply to pure biofuels such as HVO100 (100% HVO) and B100 (100% FAME) as well as hight proportion blends such as E85. This tax exemption scheme has recently been approved by the European Commission to run until the end of 2026 (IEA Bioenergy Country Report Sweden, 2024).

In January 2024, the reduction obligation for petrol and diesel was lowered from 7.6% and 30.5 % respectively to 6 % for both fuels. This led to a sharp decrease in the total use of biofuels compared to 2023 (SEA, Swedish Energy Agency, 2025).However, the delivered quantities of high-blended and pure biofuels increased between the years. This was duet to the tax exemption.

Figure F.1 shows the biofuel supply to the Swedish market between 2015 and 2024. The majority of the biofuels relate to diesel substitution, reaching over 80% of the total biofuels in 2024. These refer to mainly HVO and FAME. The second largest biofuel type was biogas in this country. In general, biofuels from Part A list feedstocks appear to be quite limited. Other biofuels, while eligible under REDII, but not from the feedstock list of Annex IX and from non-food crops appear to play a major role in Sweden. Figure F.2 further introduces the type of feedstocks used for these biofuels in 2024. As can be seen, feedstock categories relate to biofuels production based on the currently commercial facilities. The largest feedstock categories within Part A relate to the biomass faction of industrial waste followed by animal manure and sewage sludge. While Sweden is one of the largest producers of tall oil-based biofuels in Europe contribution of these biofuels within the total biofuel supply is a small fraction.

Recently, the Swedish parliament adopted a proposition, which raises the GHG reduction obligation from 6% to 10% from 1 July 2025 through 2030 (SEA, 2025). This reduction obligation can be met by blending biofuels or purchasing electricity credits.

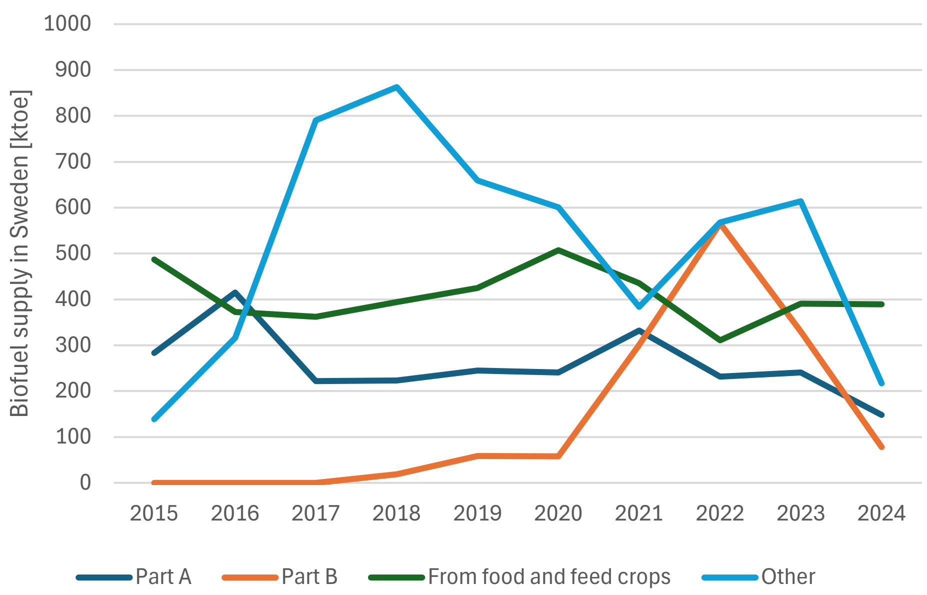


Figure F.1: Biofuel supply to the Swedish market between 2021-2024 [Data derived from the EC SHARE database}

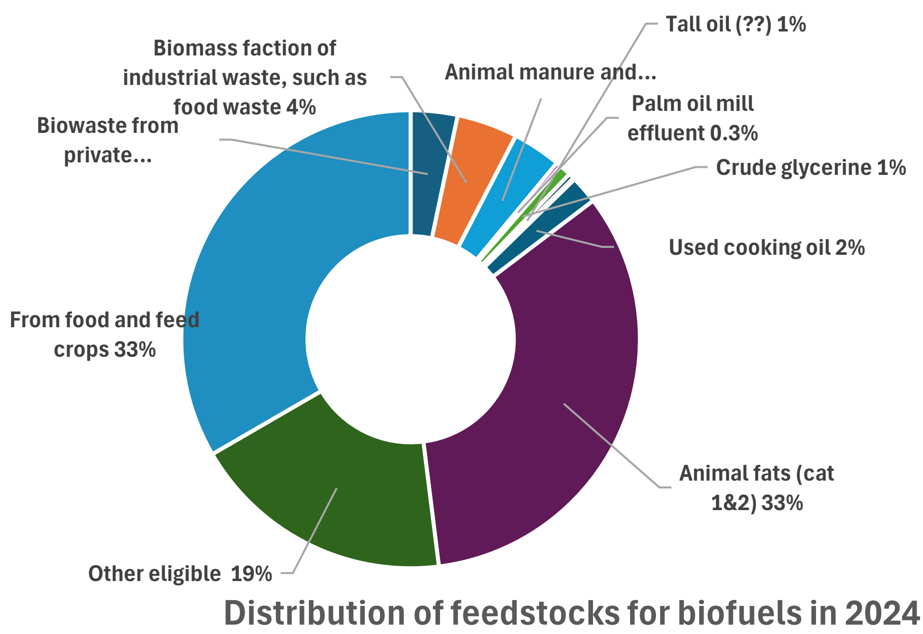


Figure F.2: Distribution of feedstocks for biofuels supplied to Swedish market in 2024 [Data derived from the EC SHARE database}

Fiscal measures in Sweden

- Since July 2018, a reduction obligation applies for petrol and diesel, and therefore biofuels used as low blends in petrol and diesel do not receive any tax exemption.

- High blends (E85, ED95, HVO100, FAME100) are explicitly excluded from mandate accounting and are incentivised through tax reduction (SEA, 2025); (USDA, 2025). The tax exemption scheme has recently been approved by the European Commission to run until the end of 2026[13].
- Direct investment grants are provided to climate projects as part of "Klimatklivet[14]"(the Climate Leap: these grants are for biogas/biomethane production and stations and biogas filling stations (IEA, Country Report Sweden, 2025). Updated on 2 September 2025, the webpage confirms that investment grants are available for:
  - Projects producing solid or liquid biofuels from forest residues. Eligible actions include both new installations and upgrades of existing facilities—demonstrating a broadened scope to support advanced fuel pathways
- To support Sweden's industrial green transition, the Swedish government launched "Industriklivet" (Industrial Leap). It provides grants for feasibility studies, research, pilot and demonstration projects and investments in various areas. The majority of the projects that have been granted funding relate to research and environmental studies. There is a very limited number of demonstration projects and none of them appear to be on advanced biofuels (See The Industrial Leap)

Overall assessment: Sweden's policy imposed a general GHG reduction obligation but did not include a specific submandate or quota for advanced biofuels. This overall GHG reduction obligation was not sufficient to mobilise supply of advanced biofuels from lignocellulosic feedstocks using innovations. Reductions and freeze in the GHG obligation to 6% (2024–2026) cut total biofuel use and revealed the fragility of demand-only policies.

Sweden's tax exemptions for pure/high blends (HVO100, B100, E85) helped operational economics and *kept some high-blend volumes growing*, but tax relief did not address the high CAPEX and technology risk nor helped market roll out of advanced biofuels from lignocellulosic feedstocks.

F.2 Finland

Before 2020, waste and residue-based advanced biofuels were double counted, helping meet 2020 target. There was no specific sub-target for advanced biofuels. In 2019, the biofuels obligation was revised, and the pathway toward 2030 was set. The biofuel target for 2030 was set to 30%, without double counting. The direct impact of this policy can be observed in Figure F.3, as biofuels from part A reduced significantly and other biofuels increased. This sharp increase relates to mandates being set as actual energy accounting.

Finland revised its national blending mandates in 2019 and introduced a long-term target: 30% share of renewable energy in transport by 2029 and afterwards. However, due to fuel price volatility, the obligation has been revised downward, with the 2024 target reduced to 13.5% from the previously planned 28%, and further adjustments expected through 2027 (IEA Bioenergy Country Report Finland, 2024).

The blending mandates were increased in 2022. With that, Finland aims for biofuels to make up 34% of road transport fuels by 2030.

[13] Skattebefrielse för rena och höginblandade biodrivmedel till och med 2026 - Regeringen.se
[14] Klimatklivet

This country introduced a sub-mandate for biofuels from Part A: 2% for 2021-2023, reaching at 10% in 2030 ((Finlex, 2019). In 2021 amendment, this target is expanded to also RFNBO in line with the REDIII. Even when RFNBOs can satisfy parts of the mandate, Finland requires a minimum share coming specifically from Annex A advanced biofuels/biogas, increasing over time ((Finlex, Finlex, 2021).

Similar to Sweden, Finland temporarily reduced its 2022 and 2023 biofuel blending obligations due to high fuel prices. This could explain the reduction of other biofuels in Figure F.4 A flexibility mechanism was introduced from 2025, allowing distributors to meet parts of the quota through alternative carbon reduction actions (e.g., biochar).

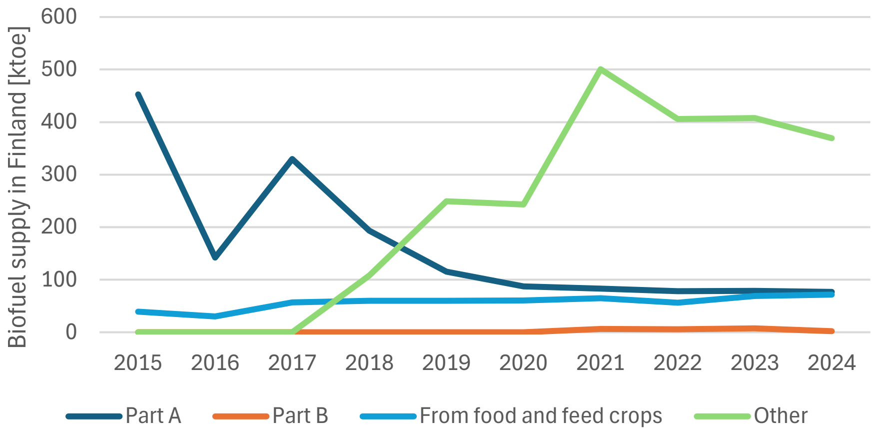


Figure F.3: Biofuel supply in Finland [extracted from EC, SHARE Database]

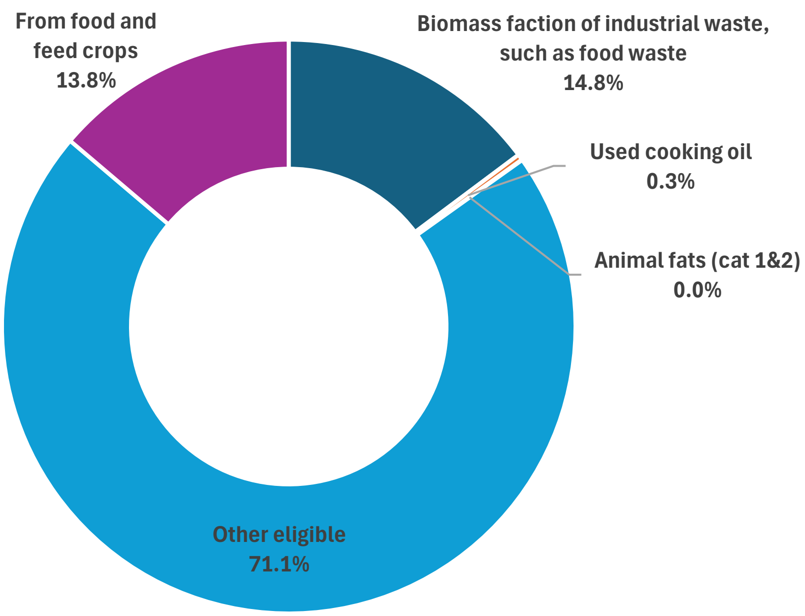


Figure F.4: Distribution of biofuels according to feedstock category in 22024 [extracted from EC SHARE Database]

Current fiscal measures:

Finland implemented tax reliefs on biofuels and structural adjustments to the energy tax system to enhance competitiveness—specifically, reduced excise duties for sustainable biofuels. While for the compliant biofuels lower taxes are implemented (half the CO2 tac rate), biofuels from wastes and lignocellulosic residues are fully exempt from the CO2 tax in Finland ((Finlex, Finlex, 2022).

There have been national funding programmes in Finland (Business Finland, formerly Teke), providing grants/loans for research, development and piloting, including Co-Innovation (companies + research orgs), Research to Business, and funding for leading-company ecosystems (e.g., Neste Veturi). One example of historical demonstration is the NSE Biofuels (Neste–Stora Enso) Varkaus BtL demo (12 MW gasifier) plant that received Tekes R&D and Ministry investment support indicating the state-backed demonstrations. The Varkaus pilot proved unit operations at 12 MW and generated critical knowledge, but technical risk (particularly on syngas cleaning and FT catalyst life), capex intensity, and the rise of proven HEFA/HVO routes made a near-term FID on a 500 MW BtL plant infeasible.

The Finnish government decided in 2024 to adopt a tax subsidy for large industrial investments to support clean transition in industry. This was based on the temporary state aid framework adopted by the European commission in 2023. The minimum size of eligible investments would be €50 million, and the tax subsidy would be maximum 20% of the investment costs and would be capped at € 150 million per company. Biofuel projects are among the eligible projects to use this subsidy. The company making the investment would receive the tax subsidy as a concession from corporate income tax ((Finnish government, 2024).

In June 2025, the Government's Ministerial Finance Committee endorsed aid for three large demonstrations: renewable methanol (Kokkola), LBG (Kurikka), and bioethanol (Pori), totalling €49.5m, with formal decisions prepared by TEM.

Overall assessment: Finland's pathway removed double counting and added a rising Part A sub-mandate, but cuts to obligations in 2024–2027 dampened supply. Emerging large-industrial tax subsidies (≥€50m) are promising but not tailored to the risl profile of advanced liquid biofuels (gasification/FT, ATJ, lignocellulosic ethanol).

F.3 Italy

The supply of advanced biofuels appears to grow significantly, particularly since 2018 (see Figure F.5). This could be explained by the Interministerial Decree of 2 March 2018, promoting the use of biomethane and other advanced biofuels, and the biomethane quota introduced in this country, in addition to sub-targets for bioethanol and biofuels other than biomethane. Advanced biomethane producers can sell their product to the national energy agency (GSE) at market price minus 5% and receive a premium of €375 per Biofuel Certificate (CIC) for every 5 GCal produced. Similar incentives apply to other advanced biofuels supplied to obligated fuel retailers. Incentives for advanced biomethane and biofuels were available for plants operating or converted between 2018 and 2023, with a cap of 1.1 billion m^3 per year for biomethane. These measures aimed to boost advanced biofuel use in transport in the country (IEA Bioenergy Country Report Italy, 2024).

Among the countries studied, Italy has the highest share of biofuels from List A relative to its total biofuel energy supply. In absolute terms, Italy's total biofuel energy is the second largest, after Germany. Figure F.6 shows the biofuel supply based on the feedstock types in 2024. A wide range of feedstocks is used to produce biomethane that is injected in the gas grid and accounted towards transport in this country. This is in line with the significant push for biomethane through dedicated quota obligation, tariffs and capex grands. Approximately 17% of the biofuels delivered to transport in Italy correspond to gaseous biofuels in 2024.Feedstocks such as UCO, animal fats, agro-industry residues are converted into HVO diesel in several of the Eni biorefineries in Italy.

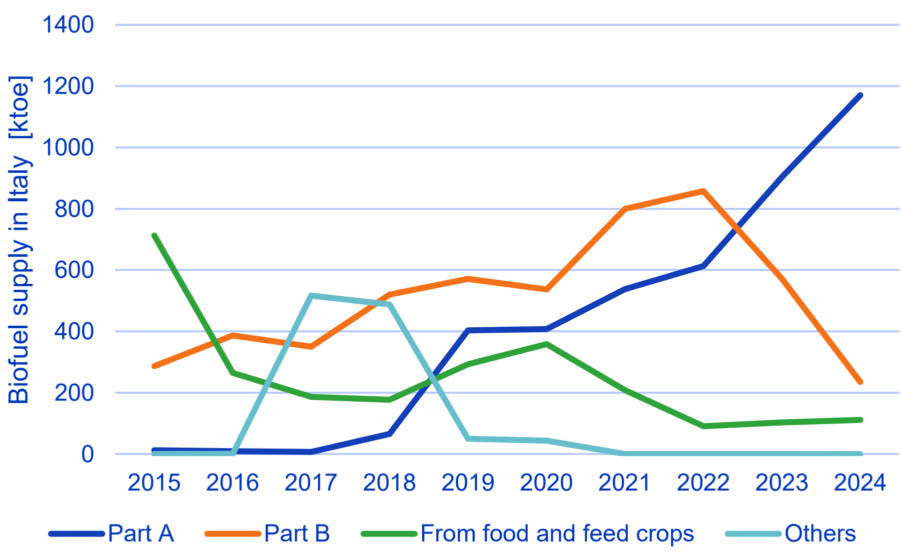


Figure F.5: Biofuel supply in Italy

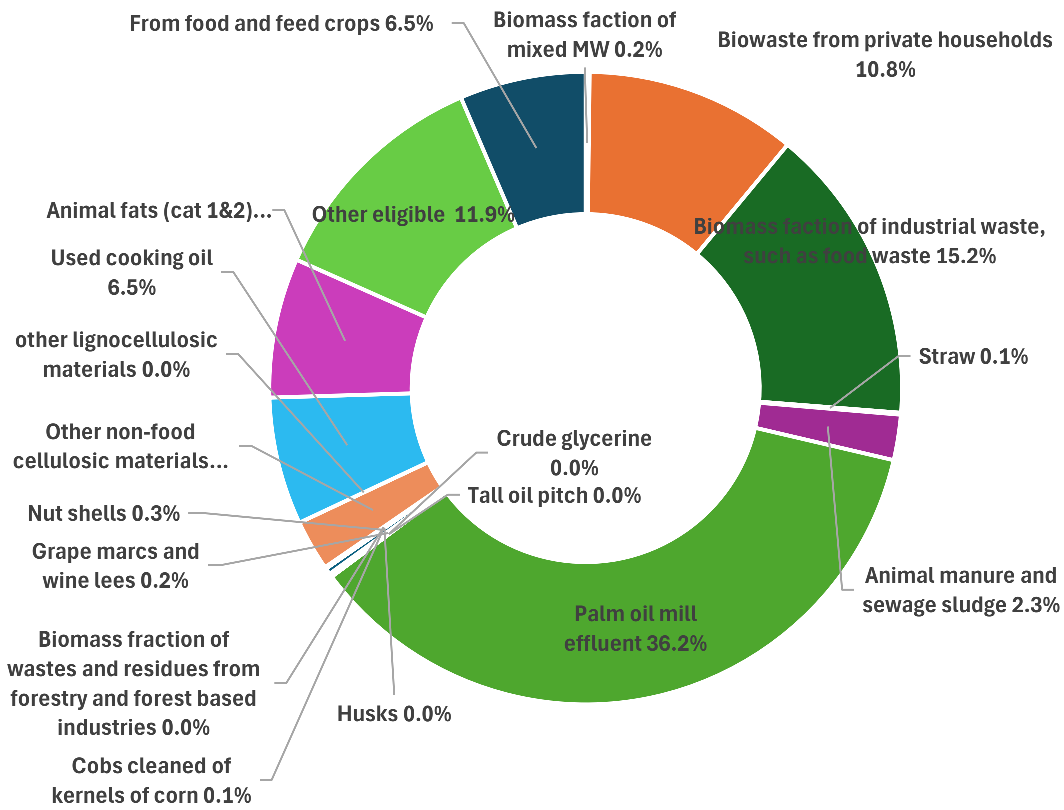


Figure F.6: Biofuel distribution according to feedstock types in 2024 in Italy

Fiscal measures and tax relief:

- Law No. 111/2023 (Tax Reform Delegation) extended the excise duty relief previously reserved for commercial diesel to HVO (Hydrotreated Vegetable Oil).
- Decree-Law of 17 June 2025, No. 84 extends the tax relief to qualifying biodiesel (from Annen IX based feedstocks) ((UNEM, 2025).
- The Italian Ministry of Environment and Energy Security (MASE) MASE Decree of 5 August 2024 aims to incentivize the total or partial conversion of existing traditional refineries to increase the national production of sustainable liquid biofuels to be used in pure form. It provides a capital grant of up to €30 million per company/project (MASE, 2024).
- The National Recovery and Resilience Plan (PNRR) biomethane (DM 15/09/2022) provides up to 40% capital grants plus a feed-in tariff for biomethane production for 15 years (new plants & conversions). This is a strong deployment signal for advanced gaseous biofuels in transport. Biomethane quantities eligible for incentives remain capped at 1.1 billion m³/year. In 2025, an update to the decree allocated €1.73 billion for biomethane projects under PNRR Mission 2((Reteambiente, 2026).
- MASE has further announced R&D support for 2025, primarily focusing on energy transition, sustainability, and technology innovation through the Mision Innovation 2 framework. These are useful for innovation, but not a deployment instrument. [quifinanza.it], [first.art-er.it]

Overall assessment: Italy’s biomethane policy combines quota + guaranteed price (CIC) and CAPEX grants/feed-in tariffs (PNRR), plus refinery conversion grants and HVO excise relief. This integrated design reduced investment and offtake risk, delivering rapid capacity build-out and a high Annex IX Part A share. Nevertheless, even with this combination, there are not any FOAK plans.

F.4 Germany

Germany has applied GHG reduction quota for transport since 2015. With this switch, the earlier double counting for advanced biofuels from waste and residues was discontinued.

Germany has steadily raised the GHG reduction obligation, reaching 7% in 2022 and 10.5% in 2025. In addition to the main GHG reduction target, Germany introduced a minimum share (“Unterquote”) for advanced biofuels produced from the Annex IX Part A feedstocks. This advanced sub-target must be met in addition to the THG quota. Germany allowed a form of “double counting” (a multiplier) for advanced fuels supplied beyond the minimum sub-target.

Germany’s 2030 target is set at 25% GHG reduction, and earlier documentation showed the advanced biofuels sub-mandate rising to ~2.6% by 2030.

December 10, 2025, the German Cabinet approved a draft law, the Second Law for the Further Development of the GHG Reduction Quota, to implement the EU’s RED III and ReFuelEU Aviation into national law. The draft sets a long-term trajectory to reduce fuel GHG emissions by 59% by 2040, and the legislation is expected to enter into force in 2026.

The German cabinet draft law indicates higher ambition for advanced biofuels: 3.5% in 2030, rising to ~9% by 2040. In addition, a separate obligation path for RFNBO is introduced: 0.5% in 2026, 1.2% in 2030 and 8% by 2040. The use of RFNBO will be incentivise by a multiplier. This is set at 3x from 2024 onwards, 2.5x from 2037, And 1x by 2040 ((Global, 2025; IEA Bioenergy Country Report Germany, 2024).

Figure F.7 illustrates the biofuel supply in Germany between 2015-2024. Supply of biofuels from Part A appears very limited up to 2020. Beyond it continuously increases, which can be explained with the sub-mandates for advanced biofuels. This can also partially be explained by double counting that has been implemented to biofuels from wastes and residues that exceed the quota obligation. Figure F.8 shows the distribution of biofuel types based on the feedstock categories in 2024. Biomass fraction of industrial waste such as food industry waste appears as the largest supply category in Germany, which could be attributed to biomethane use in transport.

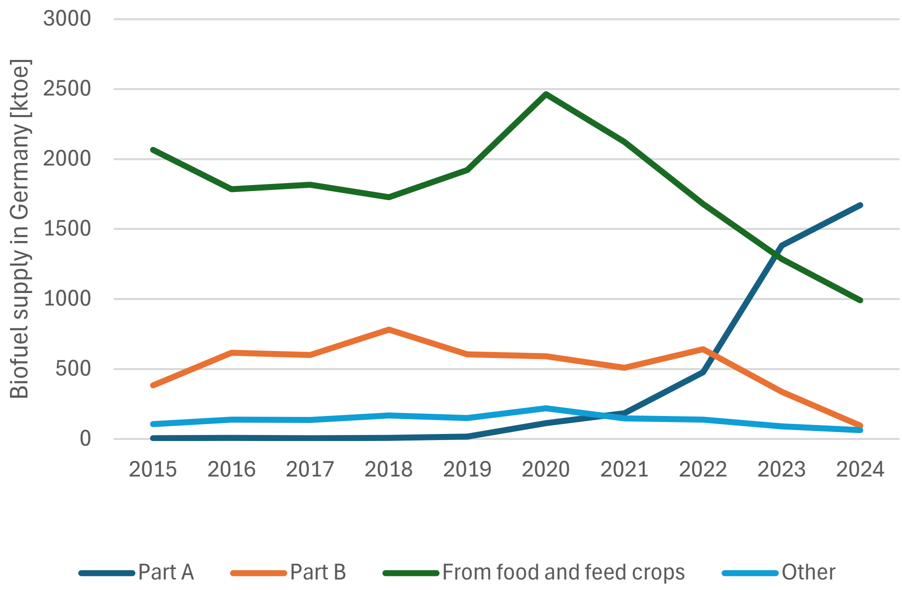


Figure F.7: Biofuel supply Germany [extracted from EC Share Database]

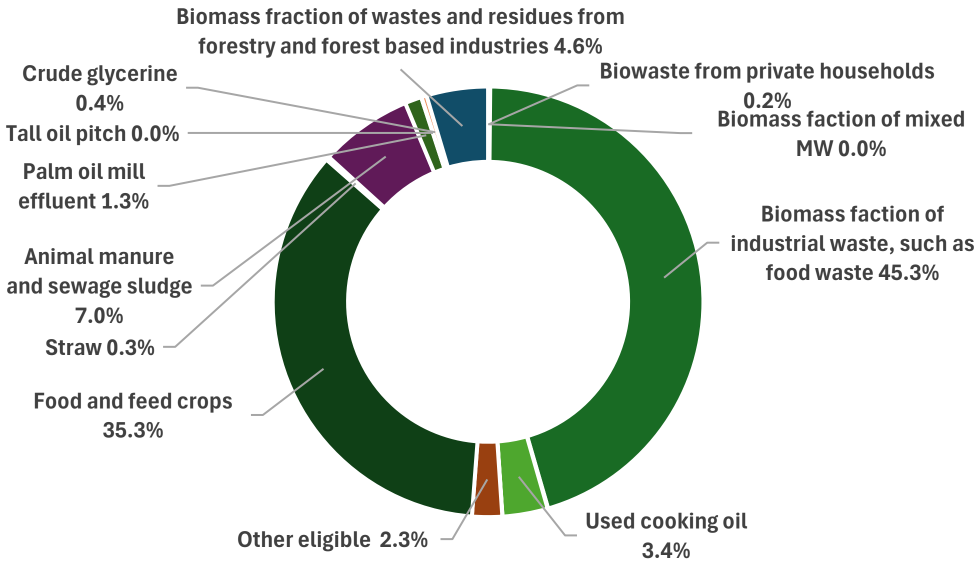


Figure F.8: Biofuel categories according to feedstock types delivered to the German market in 2024 [derived from EC SHARE Database}

Fiscal incentives:
- Currently, there are no fiscal incentives (e.g. Tax reductions) for biofuels in Germany, except for biomethane.
- Advanced biofuels are indirectly[15] promoted though higher GHG quota certificate prices within the GHG reduction quota system.
- Various RD&D funding programs emphasize advanced biofuels and e-fuels across the whole value chains. These programs aim to strengthen Germany's role as a technology developer. However, there has been a decrease in funded projects related to biofuels ((Ekbom, 2023)

Overall assessment: Germany's THG quota and advanced sub-mandate increased biofuel supply from Part A after 2020, notably industrial biowaste/biomethane. Yet, advanced liquid routes have not scaled indicating reliance on certificate price signals leaves FOAK investments exposed to market volatility.

F.5 France

To accelerate decarbonization, France introduced the Incentive Tax on Biocarbon Incorporation (TIRUERT) tax system in 2022, which encourages fuel suppliers to incorporate renewable energy, including advanced biofuels and electricity. Suppliers who blend renewable energy into petrol and diesel could receive a tax relief if they meet the set target (9.9% petrol and 9.2% diesel) (IEA Bioenergy Country Report France, 2024).

Since 2019 the share of energy that can be taken into account towards France's mandate is limited to a maximum of ((USDA, Report Name: Biofuel Mandates in the EU by Member State - 2025, 2025):
- 7% for conventional biofuels including biofuels produced from palm oil fatty acid distillates.
- 0.9% for used cooking oil and animal fats.
- 0.6% for tall oil and tall oil pitch.
- 0.2% for sugar plant residues and starch residues extracted from starch-rich plants (0.4% from 2020).
- Palm oil is excluded since 1 January 2020.
- Soybean oil is excluded since 1 January 2022

An advanced biofuels mandate was introduced in 2022. This included double counting.

Figure F.9 shows the biofuel supply in France, broken down to the different types. Food and feed crop-based biofuels have been the major supply option. The reduction in these biofuels in 2019 relates to the limitations introduced that year. Contribution of biofuels from both List IX A and B remain limited. This may be because tax exemption has not differentiated biofuel supply based on feedstock categories, and sub-targets have been relatively low (1.2% for bioethanol and 0.4% for biodiesel between 2023-2027).

Figure F.10 illustrates the feedstocks used for biofuels. Food and feed crops comprise the largest share in the overall biofuel supply. This is followed by feedstocks that can be digested to biogas/biomethane and then used cooking oil used for FAME and HVO production.

[15] Biodiesel and vegetable oil use in agriculture receives some tax relief. The use of biofuels is also indirectly affected by the current preferential treatment of fossil gas fuels, such as CNG, LNG and liquified petroleum gas (LPG), as well as their biogenic substitutes, like biomethane. A reduced tax rate will apply to gaseous hydrocarbons until December 31, 2026.

In May 2025, public consultation was launched to replace TIRUET with IRICC (Incentive for Carbon intensity Reduction in Fuels)"[16] to implement REDIII. IRICC transforms support from the TIRUERT tax cut into a wider, GHG reduction focused incentive system. This proposal introduces two separate requirements for transport fuels (Argus, 2025).

- The first is for GHG emissions reduction requirements, broken down by transport sectors (road, aviation, maritime), and LPG and natural gas fuels. Within, there are sub-targets for RFNBO in aviation and maritime.
- The second is a renewable fuel requirement by energy content, which is broken down by fuel type (diesel, gasoline, LPG and natural gas fuels and marine fuel).

The proposal includes different sub-mandates for advanced biofuels and renewable hydrogen/RFNBO. The advanced biofuels sub-mandate start with 0.7% in 2026, rising to 1.95% in 2030 and 2.6% in 2035 (Argus, 2025).

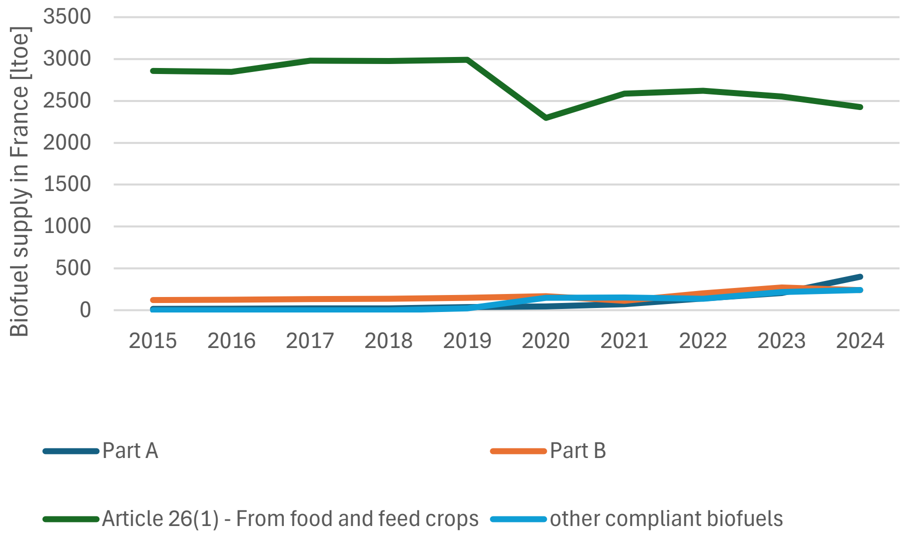


Figure F.9: Biofuel supply in France

[16] See [Lancement de la consultation sur le projet de mécanisme incitant à la réduction de l'intensité carbone des carburants (IRICC) | ministère de l'Économie des Finances et de la Souveraineté industrielle et énergétique]

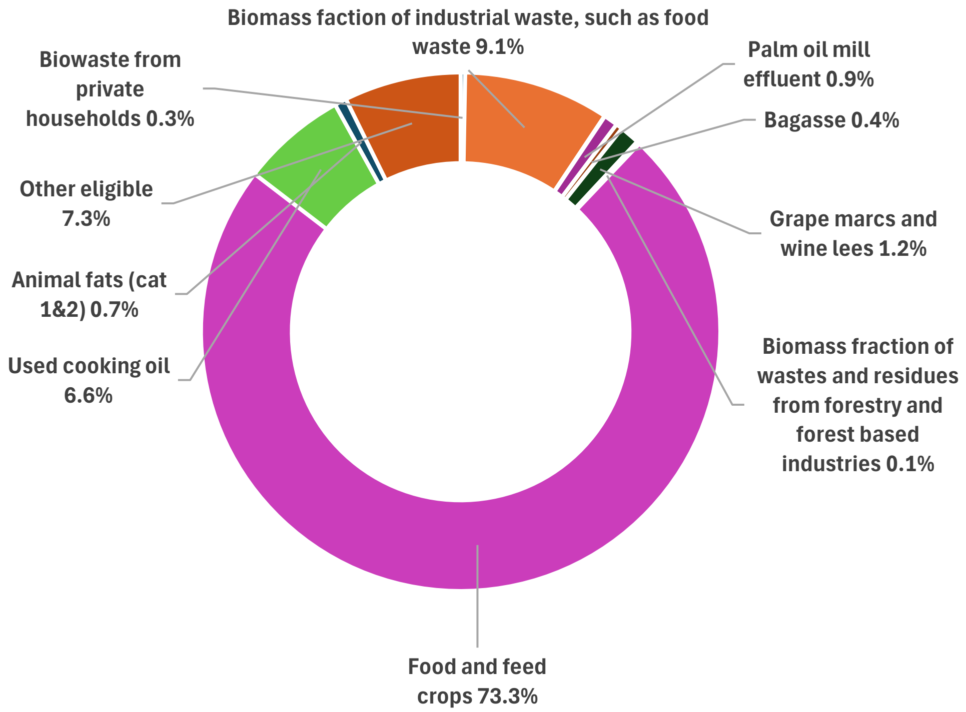


Figure F.10: Distribution of biofuel supply based on the feedstock categories in 2024

Fiscal incentives:

- Formerly the TGAP, TIRUERT is a tax advantage system tied to renewable energy in transport. Operators who meet the blending quotas could reduce their tax obligation. This includes using biofuels or renewable hydrogen. Advanced biofuels benefit from double counting in the incentive tax, effectively doubling the excise relief compared to conventional blends.
- France launched a €900 million state aid scheme, approved under EU Temporary Crisis & Transition Framework, to support biomass and renewable hydrogen in energy and transport. Under this measure, the aid will take the form of direct grants, covering part of the eligible investment costs.
- A €1.5 billion biomethane investment scheme, approved by the European Commission, uses 15-year contracts for difference to support sustainable biomethane production for injection into the gas grid. The schemes align with decarbonizing the gas grid and enabling use in transport via gaseous fuel but does not target liquid alternative fuels.

Appendix G
GHG intensity reduction obligations for transport sector

The Ministry of Infrastructure and Water Management (IenW) expanded the obligation for fuel suppliers to include deliveries of fuels to multiple transport sectors. This means that the obligation for fuel suppliers applies to companies that supply fuel to the following sectors:

- Land (road vehicles, rail vehicles, mobile machinery, and stationary installations).
- Inland shipping (inland vessels).
- Maritime shipping (sea-going vessels).

Following table introduces the GHG intensity reduction obligations for each transport sector, with details on the role of various renewable fuel options (NEA, 2025)[17]

Table G.1: Obligations for inland transport, excluding inland shipping (road transport, non-road machinery and aril transport)

	2026	2027	2028	2029	2030
Total	14.4%	16.4%	22.8%	24.8%	27.1%
	Use of ERE from other sectors is not permitted in this sector.				
ERE-Conventional (supply of biofuels from food and feed feedstocks)	Max. 1.2%				
ERE-IX-B (supply of biofuels from waste oils and fats from Annex IX-B of RED)	Max 4.3%				
ERE-Advanced (supply of biofuels from waste streams listed in Annex IX-A of RED)	Min. 3.1%	Min. 4.5%	Min. 5.9%	Min. 7.3%	Min 8.8%
ERE-renewable fuels* (supply of RFNBO) (E-fuels, hydrogen)	Min. 0.05%	Min 0.06%	Min. 0.36%	Min 0.77%	Min. 1.07%
ERE-electricity (supply of electricity to transport)	No minimum/maximum supply of ERE-electricity				
ERE-other (supply of biofuels from other feedstocks than above mentioned)	No minimum/maximum supply of ERE-other				
** The sub-target for RFNBOs can also be fulfilled with units from the refinery route (RAREs). The sub-target for RFNBOs will be increased by 2 PJ at the national level due to a commitment made during the legislative process. At a later stage, it will become clear how this will be translated into annual reduction targets for the*					

[17] Brandstoftransitieverplichting | Nederlandse Emissieautoriteit

RFNBO sub-target in each sector. What is already clear is that the increased RFNBO target cannot be fully met with RAREs.

Table G.2: Obligation for maritime shipping

	2026	2027	2028	2029	2030
Total Of which form other sectors than inland shipping	3.6% max. 1.1%	4.8% max. 1.5%	5.9% max. 1.8%	7.1% max. 2.2%	8.2% max. 2.5%
	Use of ERE from other sectors is not permitted in this sector.				
ERE-Conventional (supply of biofuels from food and feed feedstocks)	Use of ERE-conventional is not permitted				
ERE-IX-B (supply of biofuels from waste oils and fats from Annex IX-B of RED)	Use of ERE-IX-B is not permitted				
ERE-Advanced (supply of biofuels from waste streams listed in Annex IX-A of RED)	No minimum limit				
ERE-renewable fuels* (supply of RFNBO) (E-fuels, hydrogen)		Min 0.02%	Min. 0.08%	Min 0.16%	Min. 0.32%
ERE-electricity (supply of electricity to transport)	No minimum/maximum supply of ERE-electricity No use of ERE-electricity from other sectors is permitted				
ERE-other (supply of biofuels from other feedstocks than above mentioned)	No minimum/maximum supply of ERE-other				
** The sub-target for RFNBOs can also be fulfilled with units from the refinery route (RAREs). The sub-target for RFNBOs will be increased by 2 PJ at the national level due to a commitment made during the legislative process. At a later stage, it will become clear how this will be translated into annual reduction targets for the RFNBO sub-target in each sector. What is already clear is that the increased RFNBO target cannot be fully met with RAREs.*					

Table G.3: Obligations for inland shipping

	2026	2027	2028	2029	2030
Total Of which form other sectors than inland shipping	3.8% max. 0.8%	5.1% max. 1.0%	7.6% max. 1.5%	10.2% max. 2.0%	14.5% max. 2.9%
ERE-Conventional (supply of biofuels from food and feed feedstocks)	Use of ERE-conventional is not permitted				
ERE-IX-B (supply of biofuels from waste oils and fats from Annex IX-B of RED)	Max. 11.1%				
ERE-Advanced (supply of biofuels from waste streams listed in Annex IX-A of RED)	No minimum limit				
ERE-renewable fuels* (supply of RFNBO) (E-fuels, hydrogen)	Min. 0.02%	Min 0.04%	Min. 0.09%	Min 0.17%	Min. 0.34%
ERE-electricity (supply of electricity to transport)	No minimum/maximum supply of ERE-electricity No use of ERE-electricity from other sectors is permitted				
ERE-other (supply of biofuels from other feedstocks than above mentioned)	No minimum/maximum supply of ERE-other				

** The sub-target for RFNBOs can also be fulfilled with units from the refinery route (RAREs). The sub-target for RFNBOs will be increased by 2 PJ at the national level due to a commitment made during the legislative process. At a later stage, it will become clear how this will be translated into annual reduction targets for the RFNBO sub-target in each sector. What is already clear is that the increased RFNBO target cannot be fully met with RAREs.*

Appendix H
Policy assessment: US, Brazil and India

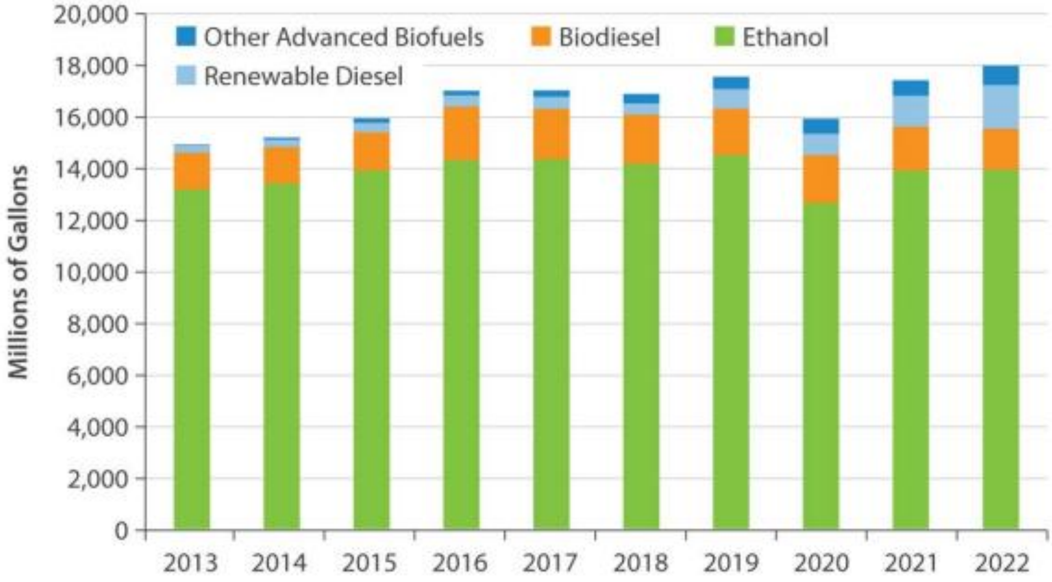
The US (IEA Bioenergy Country Report USA, 2024)
The United States supports biofuels through a mix of financial incentives, standards, and research programs. The most important law is the Renewable Fuel Standard (RFS), which requires fuel suppliers to blend renewable fuels into gasoline and diesel. It sets specific volume-based quotas for advanced biofuels like cellulosic ethanol and biodiesel, based on lifecycle greenhouse gas emissions.

Figure H.1 illustrates the U.S. biofuel consumption between 2013 and 2022. In this graph, the "other advanced biofuels" category covers among many other options, also cellulosic ethanol. Within this category, renewable natural gas (RNG) was the dominant fuel. RNG qualifies as a cellulosic biofuel under the Renewable Fuel Standard and has been the main contributor to this fuel category ((Moriarty, 2024)((ERA, 2023). In 2022, 4% of domestic ethanol production was from cellulosic biomass((Moriarty, 2024); (RFA, 2023) (RFA, 2023). The 4% cellulosic biomass was derived entirely from add-on processes at existing conventional ethanol plants that extract the nonedible corn kernel fibre, which is designated as a cellulosic feedstock under the RFS.

Thus, the impact of RFS in bringing innovations into the market has been limited. Even with high expectations, cellulosic biofuels have not scaled up commercialy. Actual production has often been below the targets. When supply or infrastructure was not enough, the Environmental Protection Agency (EPA) used waivers to lower the targets. This sometimes reduced the pressure to innovate.

(Brown, 2019) examined why the biofuels mandate failed and found that the main reasons were an unfavourable financial climate and policies that increased uncertainty for producers. Pioneering plants struggled with poor returns and low technological readiness. In addition, inconsistent policy enforcement and resistance from obligated blenders caused RIN price swings. These issues, combined with government actions[18] that unintentionally increased investment risk and market challenges such as low oil prices, discouraged the development of cellulosic biofuel capacity.

[18] Instead of liquid cellulosic biofuels, the cellulosic component of the RFS2 mandate has been either waived or partially met by liquid natural gas (LNG) or compressed natural gas (CNG) production. These gases are produced from captured gas from landfills, municipal wastewater treatment facilities, and agricultural livestock manure



Data for advanced biofuels were obtained from the EPA’s Public Renewable Fuel Standard data and were based on volume. Other advanced biofuels include biogas, butanol cellulosic diesel, cellulosic gasoline, cellulosic heating oil, naphtha, renewable heating oil, renewable natural gas, and sustainable aviation fuel. This dataset includes small volumes of imported advanced biofuels.

Figure H.1: US biofuel consumption (NREL,XX; original source: ethanol, biodiesel, renewable diesel: EIA (2023a; 2023b; 2023c); other advanced biofuels: EPA (2023a))

The Inflation Reduction Act (IRA), passed in 2022, is an incentive-based policy that works alongside the RFS. It provides tax credits, grants, and funding to make producing and using low-carbon fuels cheaper.

- Phase 1: IRA kept the Biodiesel Blender Tax Credit (BCT, 40A) at $1/gal through Dec. 31, 2024. In parallel, it created a separate SAF credit (§40B) for 2023–2024, paying $1.25–$1.75/gal based on lifecycle GHG reductions (≥50%). It was not permitted to stack 40B with the BTC on the same gallon. These Phase-1 incentives were transitional to Phase 2(45Z). In practice, this extension favoured SAF from HEFA, supporting existing hydrotreaters and established supply chains. This was because they could easily achieve the CI target.
- During this Phase 1, the cellulosic ethanol targets were mainly met with RNG as explained above.
- Phase 2 covers the 2025-2027 period.
- The IRAs technology-neutral Clean Fuel Production Credit (45Z) started in 2025 and is planned to end by end of 2027. This leaves a narrow window for final investment decisions and financing FOAK lignocellulosic projects, which typically need long lead times.
- This 45Z credit is tied to lifecycle carbon intensity (CI) of at least 50%. HEFA via fats/oils and crop-based ethanol retrofits could capture this incentive faster than a FOAK lignocellulosic project. Especially, Renewable Natural Gas is recognised as advanced fuel and can substitute the cellulosic ethanol mandate. Through CO2 capture and/or climate-smart agriculture the CI can be quickly improved, thus competing for the same value.

- As stated, RFS market has shifted towards RNG, not cellulosic ethanol: In practice, the cellulosic (D3) RIN pool under the RFS has been met largely by renewable natural gas (RNG), not by cellulosic ethanol or BtL liquids.
- The separate second-generation biofuel credit (up to $1.01/gal) expired at the end of 2024; efforts to extend it highlighted the gap and uncertainty as §45Z details lagged.

Other tax credits include:

- Second-generation biofuel producer credit (up to $1.01 per gallon for cellulosic biofuels). IRA extended this to 2024, it then expired.
- Alternative Fuel Excise Tax Credit ($0.50 per gallon for qualifying fuels). This applied to certain alternative fuels, such as CNG/LNG, LPG. Thus, it was more relevant for RNG than cellulosic biofuels.

In addition to production and blending support, the USDA and DOE run programs to expand feedstock production, build biorefineries, and fund advanced biofuel research. Grants/loans (USDA/DOE) help demonstrations and pre-FIDs but have been insufficient to overcome techno-economic, feedstock contracting, and offtake risks.

Brazil
Brazil has a long history of promoting biofuels. The country first introduced mandatory ethanol blending into gasoline in the 1970s, eventually reaching a 27% blend rate by 2015. Brazil expanded its policy framework in 2017 with the launch of RenovaBio (Law No. 13,576/2017), a national program designed to reduce the carbon intensity of transport fuels. RenovaBio is structured around annual decarbonization targets, certification of biofuels based on lifecycle emissions, and the creation of CBio credits, which provide financial incentives for low-carbon fuel production. Each year, targets are set for the following year as well as for a ten-year horizon. The policy covers a broad range of fuels, including cellulosic ethanol, sugarcane and corn ethanol, biodiesel, HDRD, HEFA-type SAF, and biomethane (IEA Bioenergy Country Report Germany, 2024) .

Brazil has also developed a biodiesel sector and is now the world's third-largest single-country biodiesel market after the United States and Indonesia (USDA, Biofuels Annual–Brazil, 2024). The biodiesel program began in 2005 under the National Program for the Production and Use of Biodiesel (PNPB), which set mandatory blending requirements. The national blend rises from B14 to B15 in March 2025.

Despite Brazil's strong innovation ecosystem, second-generation (2G) ethanol has not yet entered a large expansion phase. Current policies continue to prioritize scaling first-generation production to meet near-term decarbonization needs. However, the policy landscape is evolving. In 2024, the Fuel of the Future Law provided a significant update, setting clear targets for advanced biofuels. It introduced a Sustainable Aviation Fuel (SAF) blending mandate, which will start at 1% in 2027 and increase to 10% by 2037. This law also promotes the integration of green diesel and biomethane into natural gas networks. These measures indicate that Brazil is beginning to move beyond first-generation fuels toward more advanced alternatives.

Figure H.2 shows the biofuel consumption in the country. National consumption patterns show ethanol's central role. Sugarcane remains the dominant feedstock for ethanol, with corn growing in importance. In biodiesel, around 69% of 2023 output came from soybean oil, followed by recycled grease (16%), with tallow, palm oil, and other fats making up the remainder. As of August 2024, Brazil still had no commercial-scale hydrogenated renewable diesel (HDRD) production (USDA, Biofuels Annual-Brazil, 2024).

This figure also shows the cellulosic ethanol (2G) production in the country, which remains relatively small but growing. This ethanol is derived mainly from bagasse, the fibrous residue left after sugarcane is crushed. Most of this production is exported to markets with strong incentives for low-carbon fuels. For 2024, national cellulosic ethanol output is estimated at 51 million litres. Raízen remains Brazil's main 2G producer: its first commercial plant, operating since 2014, has a capacity of 82 million litres per year, and the second plant opened in 2024, bringing total capacity to 164 million litres annually. Between 2024 and 2025, the company plans to add four more plants—each with 82 million litres of capacity—reaching 328 million litres by 2025/26. Looking ahead, Raízen aims to operate 20 plants by 2031 with a combined annual capacity of 1.6 billion litres (Hydroprocessing, 2024). This expansion is driven by strong international demand for low-carbon, waste-based biofuels, especially from Europe, but also from Japan and the United States (Hydroprocessing, 2024).

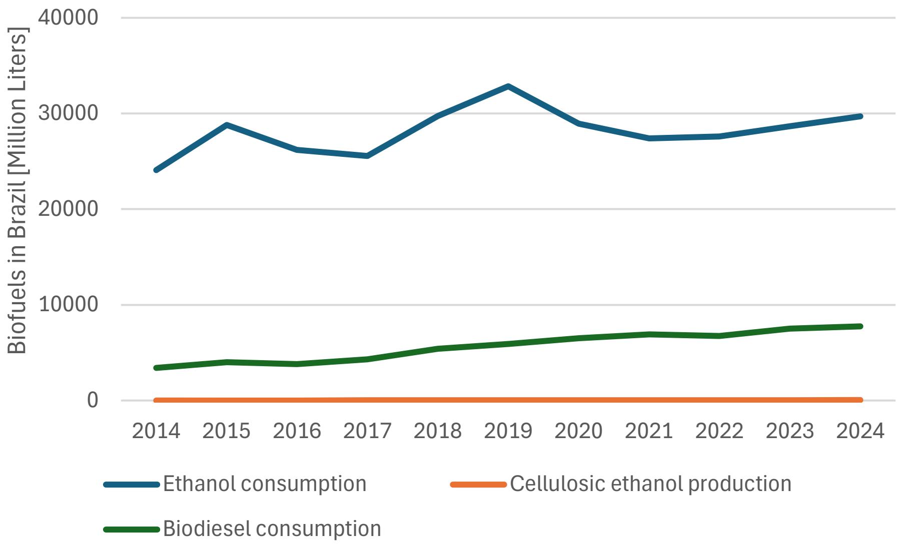


Figure H.2: Biofuel supply in Brazil

Brazil's fuel and biofuel sectors have benefited from extensive fiscal incentives, including subsidies, tax reductions, and exemptions. In 2021–2023, the government granted tax breaks across the fuel sector, with specific exemptions for biodiesel producers and consumers of ethanol. Although federal taxes were restored in 2023, ethanol still benefits from lower rates than gasoline. Beyond taxation, significant public financing is provided through Brazilian Development Bank (BNDES) credit lines, which support biofuel production, logistics, innovation, and environmental performance improvements, including for advanced biofuels.

Raízen did not receive direct public grants; however, it did secure substantial subsidized public loans that significantly reduced financing costs for its capital-intensive 2G ethanol plants. In 2025, BNDES approved a R$1 billion loan for Raízen's new second-generation ethanol plant. This was offered at interest rates below Brazil's benchmark Selic rate ((Valorinternational, 2025). The success of this project is closely related to the abundant supply of sugarcane bagasse concentrated in mills with integrated logistics, the co-location of 2G facilities with existing first-generation ethanol plants, and the ability to establish multi-year purchase agreements with major buyers in Europe and the United States. In Europe, for example, companies such as Shell have entered long-term offtake contracts (Raizen, 2022).

Raízen’s long-standing expertise in pre-treatment and process technologies further strengthened its ability to scale cellulosic ethanol production successfully.

India

India’s biofuel policy includes the 2018 National Policy on Biofuels and the ethanol blending with Petrol Program. The goal has been to raise the national blending from E5 in the past to E20 in 2025. In India, Oil Marketing Companies are responsible for producing ethanol and supplying blended fuel. The policy allows use of sugarcane juice, molasses, damaged food grains, surplus rice and corn. In addition, India has a 5% biodiesel target by 2020.

Figure H.3 shows the biofuel consumption in India. Ethanol consumption grew rapidly between 2016 and 2025. In 2025, the average blend rate was 19.3%, just short of the E20 target. Biodiesel remains small, with a national average blend rate of 0.7%, which is far from the 5% goal in the country.

Figure H.4 introduces the feedstock composition used for biofuels production in India. Sugarcane, corn, rice and molasses are the main feedstock categories, followed by UCO. None of these are lignocellulosic based.

India has widened support for advanced biofuels through the updated JI-VAN Yojana (2019), scheme and the National Bioenergy Programme (2021–2026), which provide financial support for building commercial-scale biorefineries for second-generation (2G) ethanol and biogas/CBG. A major tool is Viability Gap Funding (VGF), introduced in 2018 and extended to 2028–29. VGF offers fixed funding per project and has supported six commercial-scale and four demo-scale cellulosic ethanol plants.
Measures consist of (Advancebiofuel, 2025):

- Capital Subsidy: Up to 30% of project cost for biofuel plants, with extra benefits for advanced biofuels and waste-to-energy projects.
- Tax Incentives: GST exemptions, income tax rebates, and reduced customs duties for biofuel equipment. Carbon credits and green energy certificates reward low-carbon production.
- Low-Interest Loans: Government-backed loans and guarantees for biofuel producers, plus special financing for farmers and cooperatives supplying feedstock.

To ensure market stability, public sector oil companies sign long-term offtake agreements to buy ethanol from producers. India also uses administered pricing, meaning ethanol procurement prices are fixed by the government.

On aviation, India has set SAF blending milestones for international flights (1% in 2027, 2% in 2028, 5% by 2030) and is encouraging pilot projects with industry partners.

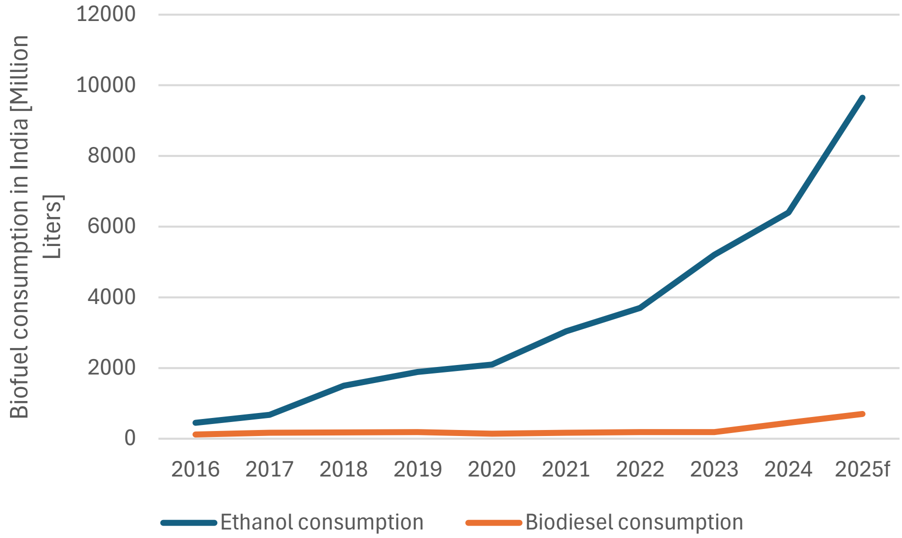


Figure H.3: Biofuel consumption in India (USDA, Biofuel Annual- India, 2025)

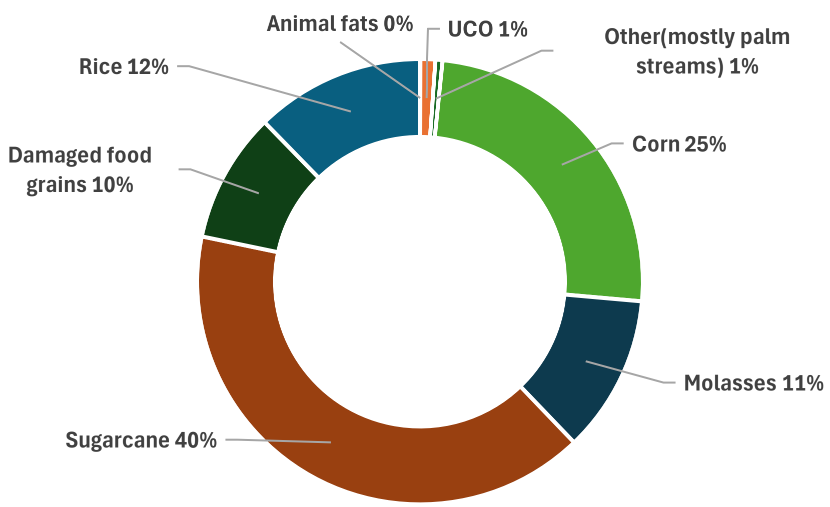


Figure H.4: Feedstock composition used for biofuels production in India (USDA, Biofuel Annual- India, 2025)

Appendix I
Review of key EU-wide financing instruments

EU Innovation Fund

The EU Innovation Fund supports low-carbon technologies, financed through revenues from the EU ETS. It supports innovative projects that can significantly reduce GHG emissions, focusing on sectors like energy-intensive industries, carbon capture and utilisation, carbon capture and storage, innovative renewable energy generation and energy storage. With the revision of the ETS Directive net-zero mobility and buildings are also included. For advanced biofuels Innovation Fund provides funds for first-of-a-kind commercial scale plants and breakthrough technologies, with the ambition to bridge the gap between demonstration and market deployment.

The 2025 annual knowledge sharing report of the innovation fund (EC, 2025) introduces the insights related to the funded projects. By the end of 2024, the Fund project portfolio consisted of 120 ongoing projects and 36 projects reaching financial close. Figure I.1 illustrates the funded projects within the energy-intensive industries. It appears that there are two biofuels and biorefinery related projects in Spain, one in Sweden and two in the Netherlands. Thus, only 4% the total projects (or 10% of the energy-intensive industry related projects) related to biofuels and biorefineries. Among the granted projects, only the one in Sweden is a first-of-a-kind commercial plant and the Innovation Fund grand provided for this plant comprises approximately 2% of the total funding granted under this Fund[19].

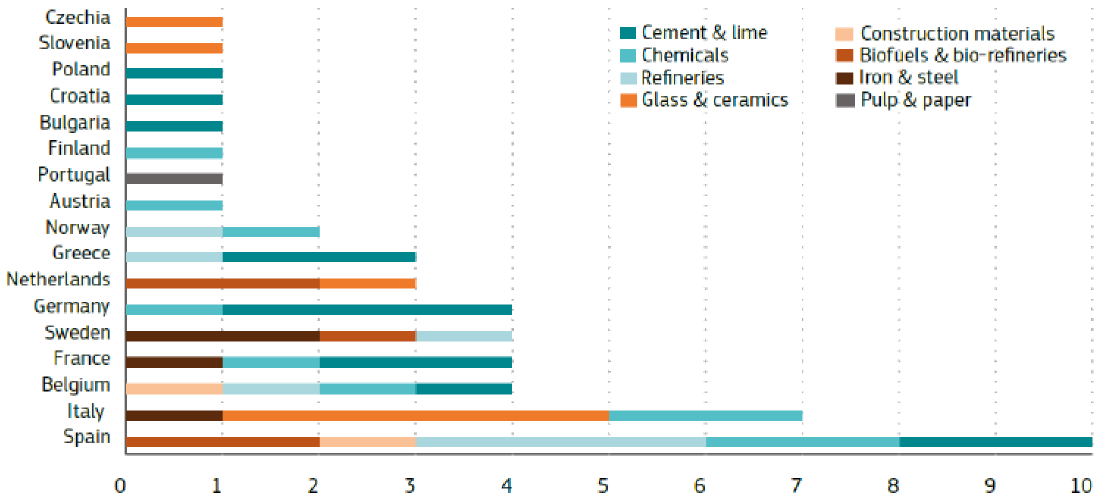


Figure I.1: Funded projects within the energy intensive industry

[19] The total commitment amounted to EUR 7.1 billion (EC,2025)

Biofuel projects funded under Innovation Fund

The Netherlands[20]

- FirstBio2Shipping (Innovation Fund grant 4.3 million €)
  This project aims converting biogas to bio-LNG for shipping sector. While biogas production via anaerobic digestion is already commercial, this project focuses on direct integration of a new cryogenic liquefaction technology to process biogas and convert it into LNG.
- Sol: Sugar Oil as sustainable marine fuels (innovation Fund grant: 4 million €)
  Aims to increase the technical maturity of conversion of cellulose to crude sugar oil by means of dilute acid hydrolysis and emulsification of this sugar oil with heavy fuel oil, and scale up this production from1 kt per annum to 5 kt.

Spain[21]

- W4W project (project cost 7.3 million €; Innovation Fund grant2.6 million €)
  This project aims at biomethane production from landfill gas using an innovative technology.
- LuGaZ3 (Innovation Fund grand: 4.5 million€)
  Focuses on biogas and biofertilisers production using local manure and gari-food residues.

Sweden[22]

- BioOstrand: Biorefinery Ostrand (Innovation Fund:166.7 million €)
  This is the first commercial scale biorefinery producing SAF and naphtha from solid forestry residues. The project will combine solid biomass gasification and Fischer-Tropsch synthesis, with an electrolyser utilising renewable electricity. The expected entry into operations is 30 June 2029.

Among the new projects that are invited to grant agreement preparation (under Innovation Fund call of 2024), majority relate to biogas and biomethane production using organic waste[23]. Only, one of them— Neste SCOOP project in Finland– relates to advanced biofuel production. This project aims to develop a new co-processing technology for crude tall oil, a byproduct from pulp mills, into renewable fuels and chemicals.

These illustrate the very limited contribution of this funding scheme to scaling up advanced biofuels in Europe. The Fund appears to favour large-scale, proven technologies with high technology readiness (TRL 7–8). Technologies such as gasification, hydrothermal liquefaction are either early commercial scale and/or with high technical risk and uncertain economics. This makes them less competitive against mature CCS or hydrogen projects.

Horizon 2020/Horizon Europe (Cluster 5)

Horizon 2020 has been the main funding source supporting advanced biofuels up to 2020. This programme is followed by Horizon Europe programme.

The latest Horizon Europe Cluster 5 call text for 2026–2027 (version May 2025) places strong emphasis on accelerating the deployment of sustainable fuels for hard-to-abate sectors such as aviation, maritime transport, and heavy-duty mobility. It prioritizes large-scale demonstration projects that validate complete value chains—from feedstock sourcing and

[20] 101103462.pdf
[21] 4d94fc84-4ea2-4404-bee2-01d7a27d4c3c en; 101157027.pdf
[22] 101132801.pdf
[23] Biomethane production from organic waste in Norway, greenfield biogas production in France, biomethanol production from organic waste in Denmark.

conversion technologies to upgrading and end-use integration. The ambition is to move technologies from pilot scale (TRL 5–6) to first-of-a-kind industrial deployment at TRL 7–8. This represents a significant change from the previous programmes, which funded pilot-level topics (such as CL5-2024-D3-02-01/06 with 50% funding) and focused more on early-stage technology validation without explicit commercialization or finance-readiness requirements.

Invest EU (2021-2027)

InvestEU is the European Union’s flagship investment programme (2021–2027), designed to mobilize at least €372 billion in public and private capital—backed by a €26.2 billion EU budget guarantee—to support EU policy goals such as the green and digital transitions, innovation, competitiveness, and cohesion. It is organized into four policy windows—Sustainable Infrastructure, Research, Innovation & Digitalisation, SMEs, and Social Investment & Skills—with dedicated support for green-energy projects, including advanced biofuels and renewable fuels.

While this instrument appears a strong horizontal guaranteed instrument, there is no dedicated window or ring-fences risk-sharing for advanced biofuels FOAK plants.

Sustainable Transport Investment Plan (STIP)

The Sustainable Transport Investment Plan (STIP) is a new EU-plan, adopted on 5 November 2025, to speed up clean fuels for aviation and maritime sectors. It will offer €2.9 billion between 2025 and 2027 from Horizon Europe (~€133m), the Innovation Fund (€153m e-aviation; €293m maritime), InvestEU (~€2bn), and the European Hydrogen Bank (€300m for SAF/SMF hydrogen production). The goal is to produce about 20 million tonnes of sustainable fuels by 2035. This includes 13.2 million tonnes of (advanced) biofuels and 6.8 million tonnes of e-fuels to meet ReFuelEU Aviation and FuelEU Maritime mandates. Figure I.2 illustrates the design of the STIP.

While the volumes mentioned for biofuels appear larger, the key actions to boost investments appear to focus mainly on e-SAF production. Moreover, there is no clear definition of these biofuels nor a reflection to the advanced biofuels from lignocellulosic feedstocks

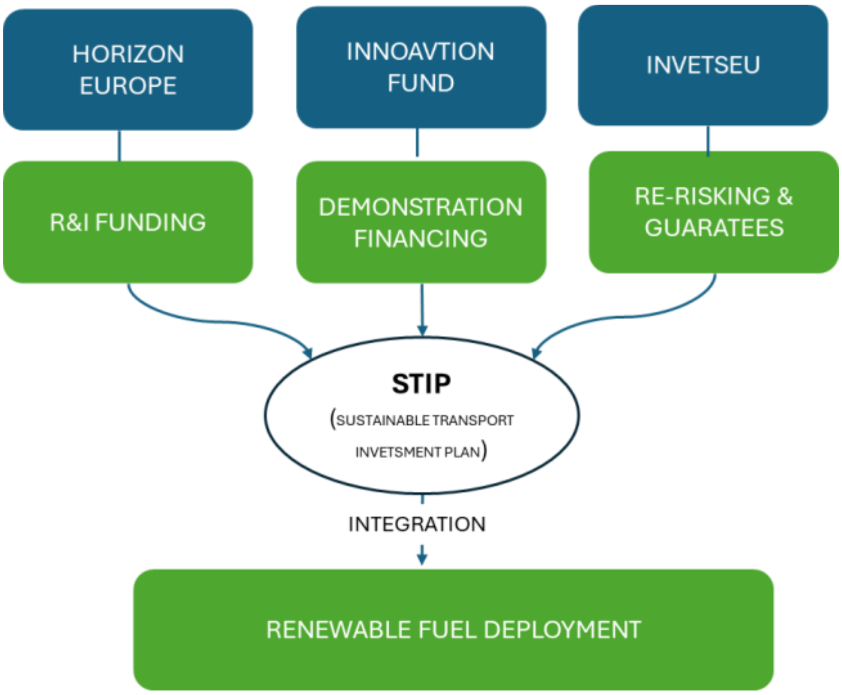


Figure I.2: Illustration of the newly designed STIP

Additionally, the commission indicates launching a pilot project “eSAF Early Movers Coalition’ with committed member states will be launched by the end of 2025. It aims to bring together at least 500 million €. The Commission also indicates a need for intermediary mechanisms in the EU that connects fuel producers and suppliers. Such a system will give price certainty and de-risk investment. This appears to be ta double-sided auction for e-SAF, which is a market design where both buyers and sellers submit bids/offers, and a market intermediary matches them to determine transactions. The fuel producers and suppliers submit offers indicating the minimum price they need to produce and supply SAF. Consumers, thus airlines, submit bids indicating the maximum price they are willing to pay for SAF. The intermediary then clears the market by matching bids and offers, using a uniform clearing price or pay-as-bid approach (see Figure 4.6). The EU H2Gloabl initiative uses a similar double-auction model, with long term purchase agreements with producers and short-term sales to consumers to accelerate green hydrogen projects. There is a recommendation to design such an auction for renewable fuels for the maritime sector (Beroske, et al., 2025).

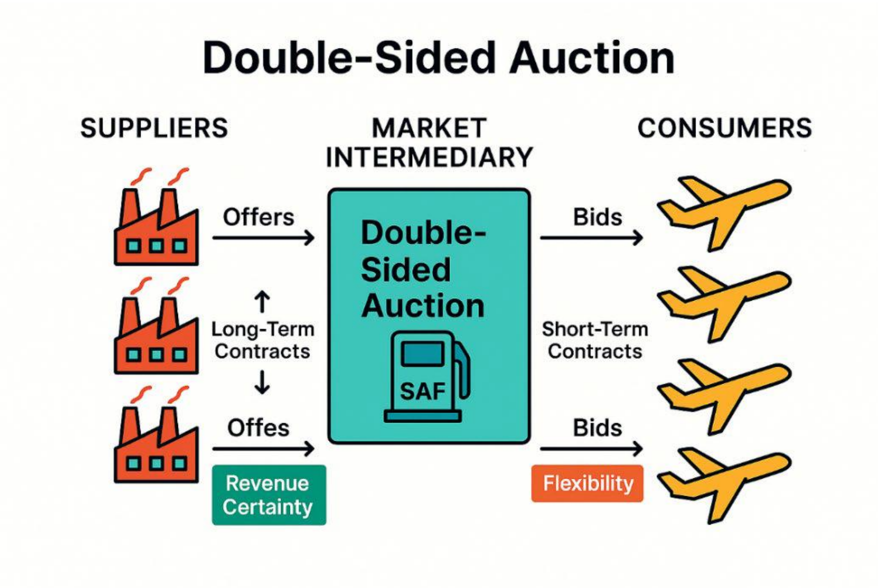


Figure I.3: Simplified illustration of a double-sided auction mechanism

The STIP design leans heavily towards e-fuels. There is no explicit investment plan or earmarked risk-sharing for advanced biofuels. In their response, IATA refers to this and highlights that the plan still underestimates biofuels' regional feedstock potential and overly prioritises e-SAF[7].

Like e-fuels, advanced biofuels face high upfront costs and uncertain demand. A regional auction could aggregate demand from airlines, shipping firms, and fuel suppliers. Different than the e-fuels advanced biofuels rely on varied feedstocks, which differ by country. This may further complicate such a mechanism. In addition, the risk of limited advanced biofuel production facility at scale may create some issues. The feedstock complexity can be addressed by standardisation of feedstock commodities. In addition, regional clusters and logistics hubs can help solving this issue.

Appendix J
Financing landscape for advanced biofuels projects

Large-scale infrastructure projects, as with advanced biofuels projects in the Netherlands, are typically financed through three main funding streams i) equity, ii) debt, and iii) government subsidies and grants.

The type of funding and financier most suitable for a project evolves based on the stage of technology development and as the commercialization stage is neared, also based on the stage of project development and the type of project developer. Early-stage technology faces high technical and scale-up risk with limited revenue potential. In contrast, technologies applied in commercial scale projects typically face reduced technology uncertainty and offer opportunity for revenue generation.

As presented in Figure J.4, financing advanced biofuel projects involves complex capital stacks that evolve over time with technology maturity and scale.

- In the early R&D and piloting stages (TRL 1–6), projects rely almost entirely on public grants and subsidies, high risk private capital (such as angel investors, venture capital), and high-risk public capital regional development funds (ROMs) as revenue visibility is low and technology risk remains high. Debt financing is typically inaccessible at this stage.
- During the demonstration phase (TRL 7–8), investment requirements increase sharply. Improving commercial visibility begins to attract private equity infrastructure funds, strategic corporate investors, and impact-oriented debt providers. Public institutions like InvestNL, ROMs, or the European Investment Bank (EIB) may be involved in co-financing demonstration projects to share risk.
- At commercial scale (TRL 9), financing shifts to large-scale institutional capital and project finance structures. Projects are typically funded through a mix of equity (from private equity infrastructure funds, pension funds, and large asset managers) and debt (from commercial banks and credit funds). Debt structures can include senior loans and credit funds providing a wider variety of debt instruments, including mezzanine and junior debt.

Figure J.4: Overview of debt and equity financiers per TRL category

7.1.1 Financing characteristics across technology stages

⟩ Early Research & Development: TRL 1-3, €50k–€1m

During early-stage R&D and proof-of-concept development there is limited visibility on technology success potential and future revenue streams. The funding available in this stage is mainly philanthropic grants, public and private research grants, and R&D-geared equity. Equity investment may come from angel investors or ROMs that aim to stimulate local economic growth and innovation. Debt funding will generally not be accessible during this stage due to the absence of revenue streams and the high-risk profile associated with R&D.

⟩ Piloting: TRL 4–6, €1m–€10m

Capital requirements grow and substantial technology uncertainty remains in the piloting stage where the technology is continuously tested within an integrated system. Equity investors, given their high-risk appetite, will remain the principal investors at this stage. Alongside angel investors and ROMs, venture capital will likely become active to target high-risk/high-reward opportunities in promising technology companies. Public-funded venture capital entities, namely InvestNL in the Netherlands, may provide equity funding for initiatives key to innovation and supply chain development in the local system. Debt funding will still be limited in this stage because of high risk and uncertain cash flows.

⟩ Demonstration: TRL 7–8, €10m–€50m

In the demonstration stage for larger-scale testing and proof of commercial readiness, investment requirements grow, risks remain high, but visibility on potential revenue streams improves. Equity investors expand to include private equity funds. Strategic investments from large, incumbent energy companies seeking early positioning in new markets may also be observed. ROMs and state-funded venture capital funds may co-invest alongside other investors to reduce investment risk for commercial parties. Debt funding may start becoming available from specialised debt providers able to take on risk-bearing investments, typically with a higher return outlook. This may include impact-oriented private debt funds, venture debt providers, or specialised debt funds.

- **Commercialization: TRL 9, €50m+**

At full commercial scale, projects require large-scale financing in the range of €50 million – >€1 billion. For the purposes of this study, specific focus is placed on the move from TRL7-8 demonstration to TRL9 commercialization. For many advanced biofuel value chains, such as gasification followed by downstream synthesis or lignocellulosic ethanol production, this transition will result in first-of-a-kind (FOAK) commercial-scale projects. This phase carries significant investment requirements and high risk, creating challenges for investing in scaling advanced biofuels projects.

The development of a commercial-scale facility can be segmented into three phases – pre-development, construction, and ramp-up and operations.

- **Pre-development**: Includes initial preparation activities like site identification, feasibility studies, front-end-engineering-design (FEED) studies, permitting applications, and generally concludes with Final Investment Decision (FID).
- **Construction**: Includes activities like site preparation, installation and connecting of mechanical and electrical equipment, commissioning and start-up, and generally concludes with mechanical completion and handover.
- **Ramp-up and operations**: Includes performance testing and optimization in the initial stages until the facility is running at the desired full load hours. In the later stages, this phase revolves more around general plant maintenance.

The financing strategies for each of these stages will vary based on the type of project developer, where project developers in this study, as aligned with a recent study by the EIB (EIB, 2024), are categorised as either strategic or independent. These different financing strategies are illustrated in figure 6.2. Strategic developers are larger incumbent and corporate players (like oil and gas majors and large energy companies), and independent developers are smaller companies and newer entrants to the biofuels market.

Strategic developers are more likely to focus on conventional technologies (like HEFA and FAME) that align with their current business offering and existing assets. These technologies are typically associated with lower risk and already proven at scale. Strategic developers often use their operational cash flows or raise corporate finance to develop these projects.

Independent developers focusing on novel, advanced technologies are faced with higher risks for developing FOAK facilities. FOAK advanced biofuel projects are characterized by high capital intensity, uncertain cash flows, and unproven operating performance. These projects typically require a project finance approach, which is accompanied by complex, and often unfeasible, risk allocation requirements to improve certainty on cash flows and reduce project risk. Consequently, this leads to challenges in accessing financing at scale.

Corporate Finance - Debt on a corporate level relies on the company balance sheet for repayment, thereby based on existing financial capacity and company assets which can be used as collateral for the loan. Corporate finance includes loans from large lenders or green bonds issued by the project developer. Corporate level debt is more applicable to established, strategic developers who already have strong balance sheets.

Project Finance - Debt on a project level relies only on the cash flows of the project for repayment. This is therefore non-recourse or limited recourse, as only the project assets can be used as collateral for the loan. Project finance is considered ''off balance sheet'', as collateral is ringfenced to the project, thereby protecting the company's financial reserves and assets. A project finance approach requires a Special Purpose Vehicle (SPV) structure to separate the project's assets, cash flows, and collateral from the parent company. The SPV acts as a standalone legal ''container'' for the project. Financing, contracts, and guarantees are all conducted at the SPV level for project finance. Project finance is mainly provided by large lenders and is more applicable to independent developers without established balance sheets.

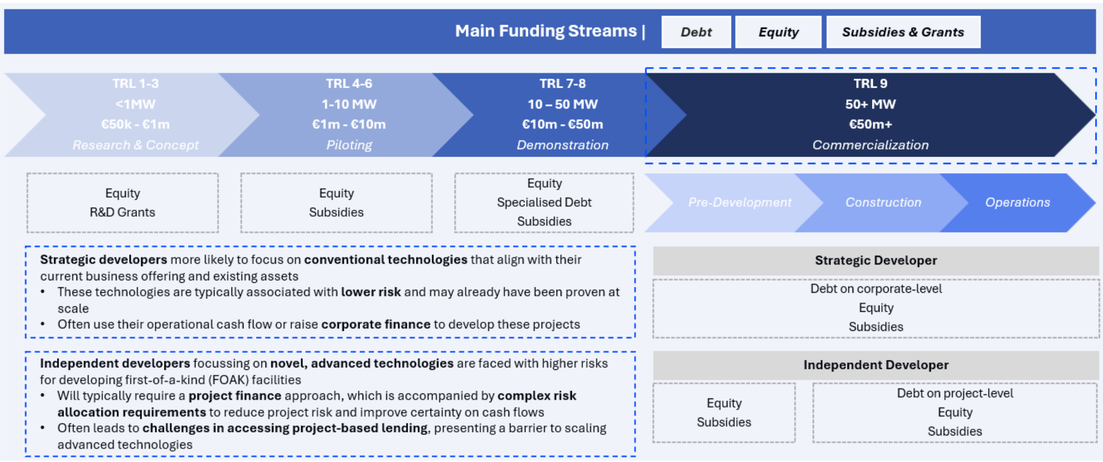


Figure J.5: Overview of financing strategies for different types of project developers

7.1.1.1 Financing for commercial plants

Pre-Development Phase

Pre-development stage activities are essential to the development of the project, but do not yet generate any cash flow. The funding required for this phase can be significant for advanced biofuels projects, where FEED studies can be in the range of €50m. Obtaining external financing at this stage is challenging, as investors are required to provide upfront capital when the project is still highly uncertain. Moreover, pre-development capital is spent on studies and permit applications, rather than physical assets. This results in little or no collateral for investors or lenders to fall back on in the event of project failure.

Pre-development funding is primarily raised on a corporate/company level. Strategic developers finance pre-development activities from their balance sheet via corporate finance loans or corporate bonds, as well as from existing cash flows. Independent developers do not have significant operational cash flows or strong balance sheets that allow for access to corporate finance. This creates the need to attract external financiers for this phase. They are often required to sell stakes in their company to obtain equity financing for this phase. The pre-development phase typically ends when the Final Investment Decision (FID) is taken.

This marks the point at which project developers, project sponsors, and financiers commit to funding and constructing the facility.

Construction and Operations Phases
Commercial-scale advanced biofuel projects require significant capital for the purchase and installation of equipment. Project developers may seek large-scale and lower cost financing for the construction phase. Alongside equity, debt from commercial and public lenders often plays a role in this phase.

Equity remains important, typically involving larger players like infrastructure private equity funds, institutional players, namely asset managers and pension funds, and strategic corporate investors. Debt can be approached on a corporate or project level. Corporate level debt is more applicable to established, strategic developers who already have strong balance sheets. Debt on a project level is more applicable to independent developers and relies only on the cash flows of the project for repayment. Under conventional a project finance structure, commercial banks and private credit funds play a central role, often supplying up to 50–70% of total capital requirements for mature, proven projects.

Given that many technologies applied for advanced biofuels projects are largely unproven, accessing conventional project finance is challenging.

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