Financing sustainable liquid fuel projects in Europe

Identifying barriers and overcoming them

European Investment Bank

European Commission

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Acknowledgements

This report is based on a comprehensive study conducted by the European Investment Bank (EIB) on financing conditions for sustainable liquid fuel projects in Europe to identify barriers preventing such projects from accessing financing and propose solutions to overcome them. The study involved consultations with 34 companies across the value chain, from technology providers to financial investors, and included discussions with EU institutions and industry experts. Key findings highlight the investment barriers and potential solutions. The report aims to facilitate the growth of the European sustainable liquid fuel market by providing multilateral lenders and policy makers with an overview of limitations faced by the sector and recommendations for overcoming identified barriers.

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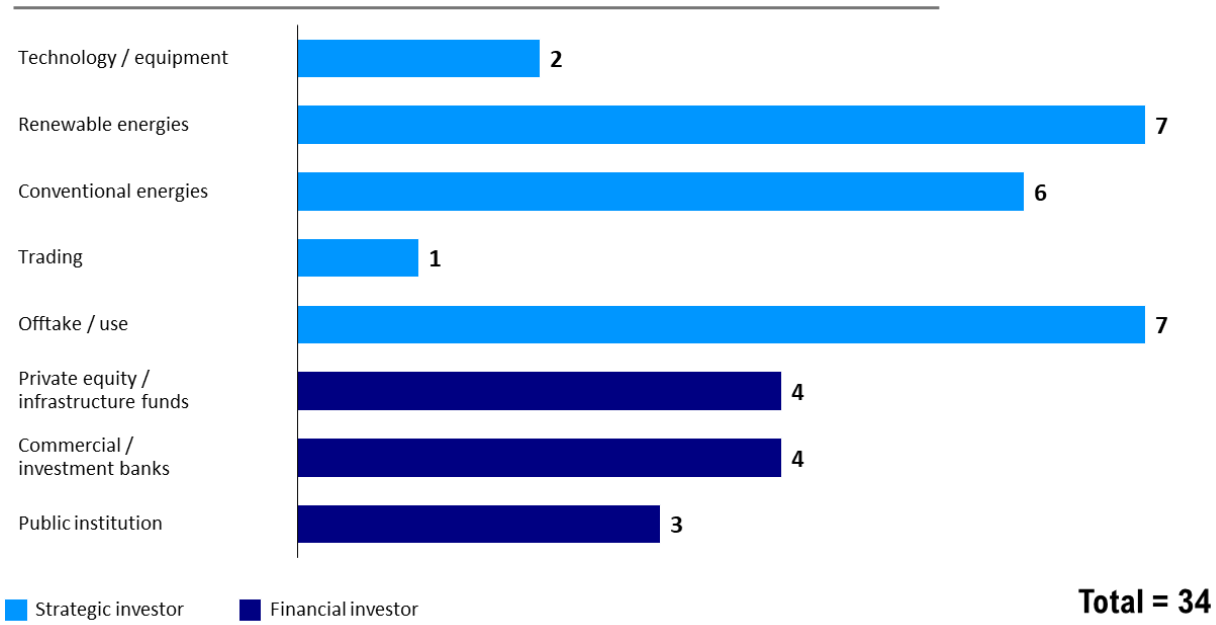
1 Introduction and methodology

This report summarises the key findings from a market consultation about financing sustainable liquid fuel production in Europe.

The European Investment Bank (EIB) undertook a study on access-to-finance conditions for European sustainable liquid fuel projects to gain insight into the drivers of this nascent market. The study provides an overview of the status of the industry (including the current European regulatory framework), identifies the main strategic and financial investors active in the market and their related strategies and projects, and outlines perceived barriers to investment in production. Potential tools and solutions for overcoming these barriers were also discussed with study participants. The aim of the study was to inform the EIB about this emerging industry and provide ideas for the development of financial products that could support the sector.

The study consulted 34 companies involved in the sustainable liquid fuel market selected from a longlist of more than 100 companies active in the industry. Discussions were also held with other European Union institutions and industry experts. Outcomes from these discussions were analysed in two workshops with EIB staff and selected market players. The study participants covered various roles along the entire sustainable liquid fuel value chain, including strategic and financial investors. The strategic investors were technology providers, energy producers, mid-stream handlers and buyers, and the financial investors included commercial and public banks, private equity and debt providers and other indirect market participants (Figure 1).

Figure 1: Value chain distribution of consulted market participants (number of interviewees)



Prior to a consultation, participants were sent a semi-structured digital questionnaire tailored to their investor profile (strategic or purely financial). Both investor types completed questions on their sustainable liquid fuel strategy, current or planned project investments in the domain, perceived barriers to market uptake and recommendations on how to unlock further investments in the market. Interviewees provided open answers, scores from one to ten or a selection of preferred options depending on the question.

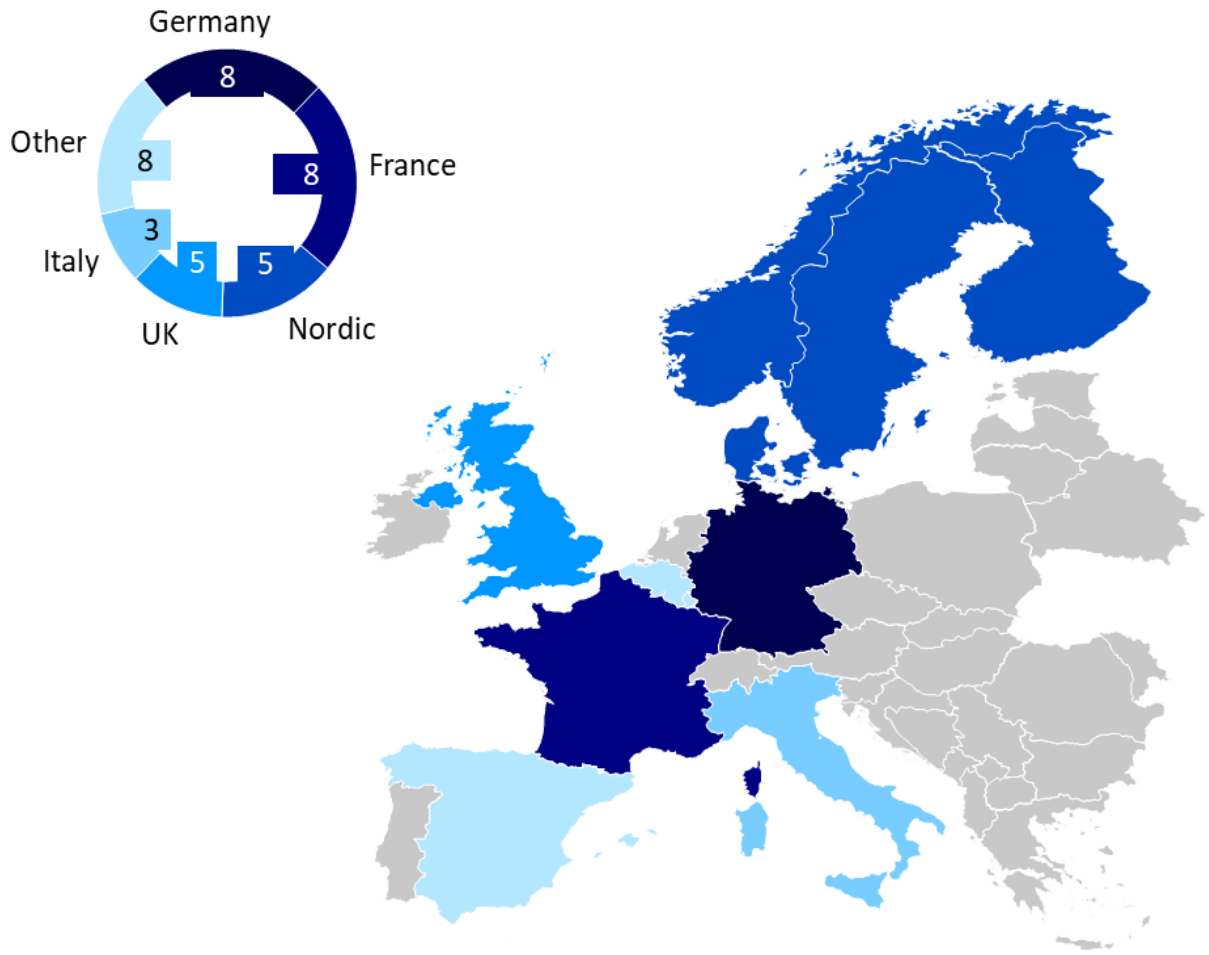
Factual statements and numbers (for example, expected demand for sustainable liquid fuels) in this report are based on publicly available information. Where applicable, the information was updated or modified to reflect

policy updates up to February 2024, different geographical scopes in the European Union, the latest public announcements from those involved in the market, and market developments up to February 2024, as interpreted by external market experts.

The completed questionnaires were discussed with the respective respondents in one-hour virtual interviews, which provided further details on the interviewees' responses and their perceptions of the sustainable liquid fuel market. Data gathered from the questionnaires and interviews were used for a qualitative analysis of the characteristics of European sustainable liquid fuel projects, the challenges they face and the strategic preferences of participants. This analysis provided a basis on which to formulate recommendations for European policymakers as well as concerning financial instruments for the EIB Group and the European Commission.

A summary of the findings from these market consultations is reported below, along with the analysis and recommendations derived from the findings.

Figure 2: Geographical distribution of interviewees in the study



2 Sustainable liquid fuels — technology, regulation and market background

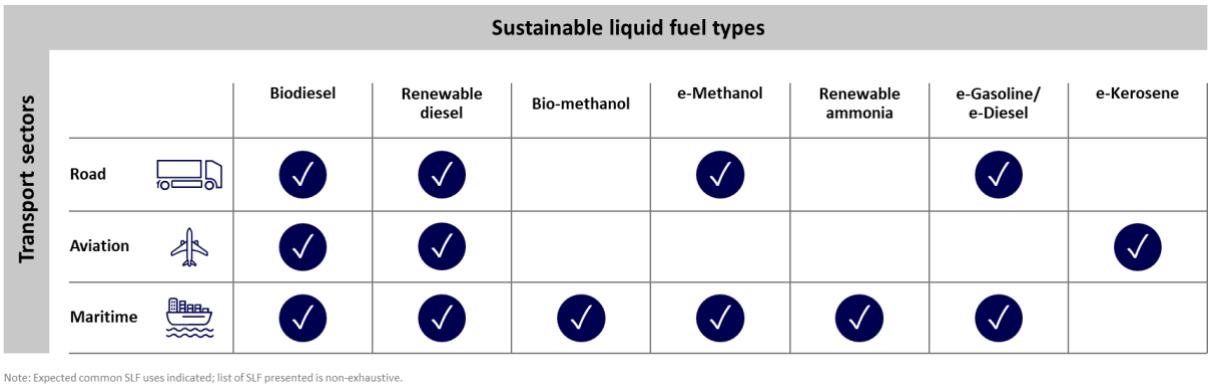
Definition of sustainable liquid fuels

Sustainable liquid fuels are sustainable, low-carbon liquid fuels that can directly replace conventional, fossil-based transport fuels such as diesel, kerosene, gasoline and bunker fuel. They also include products that are currently not commonly used as transport fuels, such as methanol and ammonia in shipping.

Sustainable liquid fuels are defined by three characteristics:

- **Sustainable:** They display significantly lower greenhouse gas emission intensity compared with their fossil counterparts. The emissions intensity of a sustainable liquid fuel depends on the initial feedstock and technological pathway used in its production. This study concentrates on fuels with a sufficiently low emission intensity to be covered by key EU decarbonisation regulations.
- **Liquid:** They are liquid at or close to ambient temperatures. In this way, they differ from gaseous sustainable fuels, such as green hydrogen or bio-liquified natural gas. The liquid nature of sustainable liquid fuels provides significant advantages in handling, transport and distribution.
- **Fuels:** They are fuels and thus energy carriers that can be used in transport applications. This study focuses on sustainable liquid fuels used in road, maritime and aviation-based modes of transport (Figure 3).

Figure 3: Key sustainable liquid fuels and applicable transport sectors



Source: Desk research, Roland Berger.

Sustainable liquid fuel production pathways

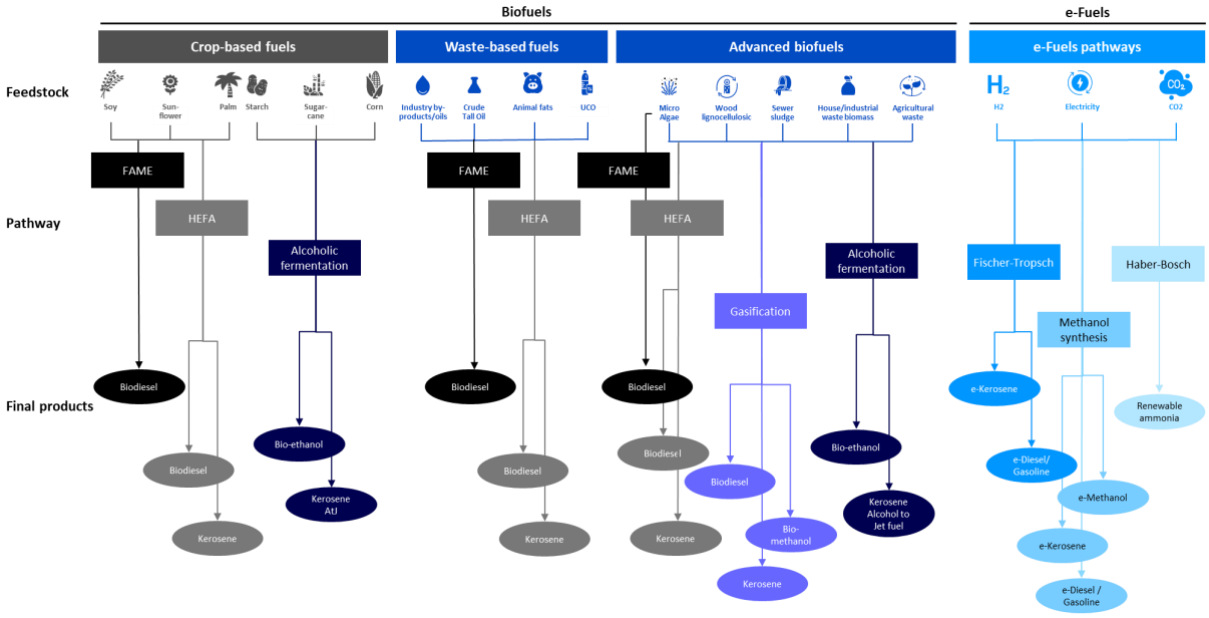
Sustainable liquid fuel production pathways can generally be grouped into two categories — bio and synthetic (electricity-based) pathways — depending on the respective feedstock.

- **Biofuels** differ in their sustainability level depending on the type of feedstock used. Fuels are commonly divided into crop-based fuels (sugar or oil crops), advanced biofuels (for example, lignocellulose and algae) and waste-based fuels (used cooking oils and animal fats). The current dominant pathway (in terms of production cost and technological maturity) is transesterification, or fatty acid methyl ester (FAME), for which the most common feedstocks are derived from crops. However, these crops directly compete with food crops for arable land and water, meaning they negatively impact biodiversity and have considerable disadvantages in terms of sustainability criteria.
- **Electrofuels (or e-fuels)** are derived from green hydrogen in an intermediate phase and from renewable electricity in a primary phase. Most e-fuels are produced by thermally reacting hydrogen and carbon dioxide

into syngas (a mixture of hydrogen and carbon monoxide) and then further processing the syngas into hydrocarbon fuels. A theoretically unlimited supply of renewable electricity and ambient carbon dioxide means e-fuels have vast scalability potential. Green ammonia, in contrast to other e-fuels, does not require carbon dioxide as a feedstock but instead uses ambient nitrogen.

Although there are numerous sustainable liquid fuel production pathways, this study focuses on seven that have promising short- and medium-term commercial and decarbonisation potential (Figure 4).

Figure 4: Most common sustainable liquid fuel pathways by feedstock and end product



Source: Desk research, Roland Berger.

Transesterification (FAME) is the most used production pathway for sustainable liquid fuels. First-generation feedstocks such as oil crops (for example, rape, palm or soy) or animal fats are the main feedstocks for this pathway. The reliance of FAME on food- or feed-based feedstocks creates indirect land use change risk. In the FAME process, oils are extracted from feedstocks and refined before being transesterified, where higher weight oils and fats react with short-chain alcohol in the presence of a catalyst and produce lower weight esters. After further upgrading, a fuel is derived with the characteristics of diesel, allowing it to be blended with conventional fuel and used in diesel engines. However, FAME diesel can only be blended with conventional fuels up to a certain percentage because its chemical properties differ significantly from those of conventional diesel. This limitation and the reliance of FAME on first-generation feedstocks mean this technological pathway is unlikely to experience significant growth in the future.

In **hydroprocessed esters and fatty acids (HEFA)** pathways, oils are treated with hydrogen to produce hydrocarbons, which are subsequently cracked and fractioned into jet fuel or renewable diesel. HEFA fuels are commercially mature and currently the cheapest option for producing sustainable aviation fuel. The most common HEFA feedstocks are plant-based oils and waste cooking oils. Technologies using other advanced feedstocks such as algae are still at an early stage of development.

Alcoholic fermentation is used to produce ethanol, which can be added to conventional gasoline up to a certain percentage (10-15%) and burned in conventional engines. Alcoholic fermentation is often based on starch, sugar and lignocellulosic (for example, straw) feedstocks that are fermented into ethanol. Although alcoholic fermentation is a mature technology, the use of advanced (lignocellulosic) feedstocks requires a prior step (degradation of the feedstock into sugars) involving technology that is still immature.

The **alcohol-to-jet** process converts ethanol or other alcohols to jet fuel. In this process, alcohols are dehydrated, oligomerised and hydrogenated. Like HEFA, alcohol-to-jet is an option for converting bio-feedstocks into jet fuel.

The **Fischer-Tropsch** process applies a series of catalysed reactions to convert carbon monoxide and hydrogen (syngas) into various liquid hydrocarbons such as kerosene, diesel or gasoline. Fischer-Tropsch is the key pathway for producing most e-fuels using green hydrogen (via electrolysis) and carbon dioxide as the main inputs. However, although the Fischer-Tropsch process to derive fuels from syngas is technologically advanced, the production of e-syngas from hydrogen and carbon dioxide (via reverse water gas shift and co-electrolysis) has not yet been deployed at commercial scale.

Methanol synthesis is the process for deriving methanol from syngas. The conversion process called catalytic synthesis is a mature technology. However, the syngas used in the process can either be from a fossil or renewable origin. The technological maturity of renewable methanol production therefore depends on the technological maturity of the renewable syngas production pathway. Renewable syngas can be either produced from biological feedstock, via gasification or via green hydrogen and carbon dioxide. The mode of transport most likely to employ green methanol is expected to be shipping, but green methanol can also be used as an intermediate step in the production of sustainable aviation fuel.

Ammonia synthesis via the Haber-Bosch pathway is the key process for deriving ammonia from hydrogen and nitrogen. These inputs are reacted via a catalyst, high pressure and high temperatures to produce ammonia. The synthesis process does not differ between fossil-based ammonia or the green variety, but the latter relies on green hydrogen (via electrolysis) and green nitrogen (via air separation). Green ammonia is expected to be adopted by the maritime sector as a clean fuel, but its use requires several adaptions to ship engines and storage and distribution infrastructure.

Other pathways for processing lipids and sugar-based feedstocks into hydrocarbon fuels include **hydrothermolysis**, **pyrolysis** and **hydroprocessing of fermented sugars**. However, these pathways were not widely discussed in the consultations in this study as they are still technologically immature and have limited use in the market.

Sustainable liquid fuels are vital for decarbonising hard-to-abate modes of transport

The physical and chemical properties of sustainable liquid fuels lead the interviewees in this study to expect them to have a key role in decarbonising hard-to-abate transport sectors. For road, maritime and aviation transport, sustainable liquid fuels can be a zero- or low-carbon alternative to current fossil fuels. They are already widely used in the road sector in the form of ethanol produced from first-generation feedstocks, which is then blended with gasoline. However, despite this use in road transport, the interviewees expect future demand to be primarily driven by the aviation and maritime sectors, due to strong regulatory support and voluntary uptake. Sustainable liquid fuels offer the following three advantages as a tool for decarbonising hard-to-abate modes of transport:

- **direct replacement of fossil fuels in conventional engines;**
- **ability to use existing mid-stream infrastructure;**
- **lack of viable technological decarbonisation alternatives for aviation and maritime shipping in the short and medium term.**

Sustainable liquid fuels have identical or very similar chemical properties to their fossil fuel equivalents.[1] In practical terms, this means that several sustainable liquid fuels can replace fossil fuels entirely or can substitute a significant portion of the underlying fossil fuel (as with sustainable diesel, benzene and kerosene). This ease of substitution presents potential buyers with a practical advantage compared with other decarbonisation solutions that require a substantial replacement or upgrade of assets and support infrastructure. Renewable diesel for example can be used in conventional diesel engines, and sustainable kerosene can be dropped into jet fuel up to a certain blending share without needing major modifications to plane engines. Some sustainable liquid fuels, such as methanol or ammonia, do require modifications and/or replacement of assets and infrastructure.

[1] Excluding FAME diesel.

However, even those fuels require relatively limited adaption compared with electrification or the use of gaseous fuels. The ease of substitution decreases the overall investment and cost requirements for the decarbonisation of hard-to-abate transport sectors.

The chemical comparability of sustainable liquid fuels to their fossil counterparts means that industry knowledge for handling, transportation and storage is well established and limited innovation is needed for logistics and mid-stream infrastructure (particularly compared with gaseous fuels). They can also use existing trading networks. However, successful adoption will require adjustments to existing business models and the development of new ones, particularly since cost and revenue drivers for most sustainable liquid fuels differ significantly from those of conventional fuels.

Most sustainable liquid fuels have volumetric[2] and gravimetric[3] energy densities that are similar to their fossil fuel alternatives. Certain types (for example, methanol and ammonia) may have energy densities below their fossil fuel alternatives (bunker fuel), but these are nonetheless higher than those of alternatives such as gaseous or battery-based energy carriers.

Sustainable liquid fuels are vital for meeting EU decarbonisation targets and achieving carbon neutrality by 2050

In the European Green Deal and the recent Fit-for-55 initiative, the European Union set itself bold decarbonisation targets of reducing emissions by 55% by 2030[4] and achieving carbon neutrality by 2050. To meet these ambitious climate targets, the European Union aims to decarbonise its transport sector, which is a primary source of emissions.

As a result, the European Union has introduced sector-specific goals and objectives for decarbonisation. First, key modes of transport will be included in the EU Emissions Trading System (EU ETS) from 2024. In addition, under the revised Renewable Energy Directive (RED III), the European Union wants to reduce the greenhouse gas emission intensity of transport by 14.5%, or alternatively, increase the share of renewable energies in final energy consumption to at least 29% (for example, via e-mobility) by 2030. RED III also introduces target blending quotas for advanced biofuels, which directly affect demand for sustainable liquid fuels.

These objectives will be achieved through policies accelerating the uptake of sustainable liquid fuels, for example, the recently adopted ReFuelEU Aviation initiative, which includes blending mandates for sustainable fuels in aviation. Such mandates will reach 6% by 2030 and gradually increase to 70% by 2050, with a significant share allocated to e-fuels (35% in 2050). For the maritime sector, FuelEU Maritime requires shipping companies to reduce their greenhouse gas emission intensity by up to 6% in 2030 and 80% by 2050.

Under these regulations, demand for sustainable liquid fuels is expected to grow strongly by 2030 and beyond. Due to widespread use in the road transport sector, total demand in the European Union was approximately 17 million tonnes of oil equivalents (mtoe) in 2022, and this could grow to 21 mtoe in 2030 and 34 mtoe by 2035 (Figure 5).

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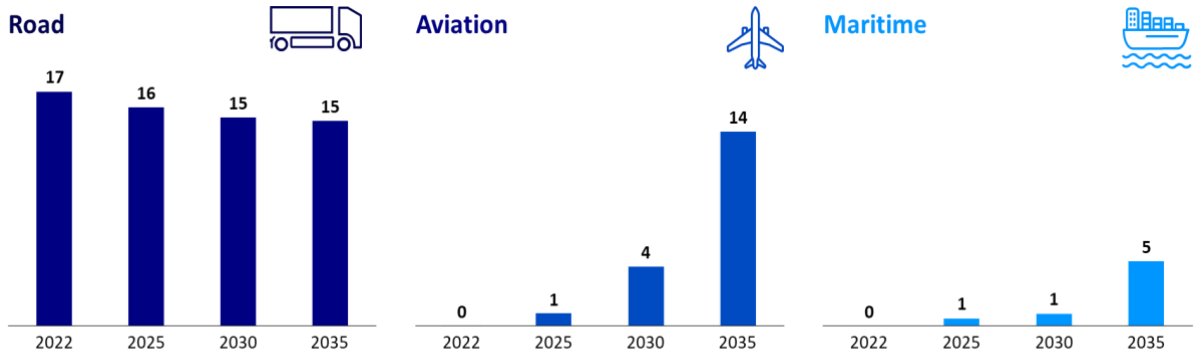
[2] Volumetric energy density is the amount of stored energy per unit of volume. Liquid fuels are significantly denser than gaseous energy carriers such as hydrogen. They can therefore be stored in smaller tanks yielding the same energy output.

[3] Gravimetric density is the amount of stored energy per unit of mass. Liquid fuels are significantly lighter than alternative energy carrier technologies such as battery storage, especially over long distances or for powering heavy vehicles (for example, ships or aeroplanes).

[4] Compared to 1990 levels.

Figure 5: Expected EU sustainable liquid fuel demand by sector, 2022-2035 (million tonnes of oil equivalent)



Note: Aviation includes EU-27 international and domestic air traffic; maritime includes EU international and domestic shipping, covering all reported monitoring, reporting and verifying (MRV) emission and fuel data, for example 100% of emissions and fuels on voyages between EU ports, 100% at-berth and 100% of voyages between an EU port and one outside the European Union ("Full MRV Scope").

Source: Calculation by Roland Berger; assumption from public sources such as the European Commission, Concawe, Transport & Environment, SkyNRG, IEA and IRENA.

The expected growth of sustainable liquid fuels differs by mode of transport. Driven by strict blending mandates and, to a lesser extent, by voluntary commitments from airlines, the aviation sector is expected to become a major buyer of sustainable liquid fuels, accounting for approximately 40% or 14 mtoe by 2035. Biodiesel and bioethanol demand in road transport is expected to stagnate or decline owing to increased electrification in the sector. In the maritime sector, demand for sustainable liquid fuels is expected to increase significantly after 2030 when greenhouse gas intensity reduction targets ramp up, potentially resulting in demand of up to 5 mtoe by 2035. Decarbonisation needs in the maritime sector are expected to be met by e-fuel-based methanol, renewable ammonia and potentially bio-liquified natural gas.

Significant investments are needed by 2035 to realise the ambitious EU decarbonisation targets

Achieving decarbonisation targets and complying with underlying policies will require considerable expansion of industrial-sized sustainable liquid fuel production capacities. By 2035, investments of over €50 billion will be needed in novel production facilities (biofuels and e-fuels). For e-fuels, additional investments in hydrogen production, carbon capture and renewable electricity are required, bringing the cumulative amount needed until 2035 to between €200 billion and €300 billion.

The current sustainable liquid fuel project pipeline is not sufficient to meet expected demand

Strong policy support is driving interest in the development of sustainable liquid fuel production projects and, as a result, the European project pipeline is growing. According to public project announcements, at least 20 industrial-scale sustainable aviation fuel production facilities will be operating in Europe by 2026. At the same time, about 20 commercial sustainable methanol plants and ten renewable ammonia plants exist in Europe or are at an advanced stage of development. Most new project announcements are based on e-fuel pathways, as was also reflected in the interviews carried out in this study.

However, the complexity of large and ultra-large energy infrastructure projects and their typical failure rates mean the current project pipeline is likely to be insufficient for the sustainable liquid fuel demand expected by 2030. Furthermore, existing projects are mostly at an early stage, with little to no capital committed and no final investment decisions made.

The development and construction phases of industrial-sized projects typically last five to seven years. Urgent expansion of the sustainable liquid fuel project pipeline is therefore needed to provide sufficient supply and meet the EU decarbonisation targets for 2030. To expand the pipeline of viable projects, projects under development need to be matured through holistic de-risking mechanisms to rapidly achieve financial investment decisions.

In the current stage of the market, there are regulatory and market challenges that hinder investments in sustainable liquid fuel projects and the development of an abundant project pipeline. Targeted public support can make it easier for projects to receive financing and accelerate market uptake. In this context, the report analyses the current involvement of industrial, financial and other sustainable liquid fuel sector companies interviewed and underlines their view of current financing barriers. Based on these views, the study develops detailed recommendations for European public institutions on how to effectively allocate public support for projects in this domain.

3 Summary of market consultations

Market consultations began by investigating the strategic position of companies involved in the sustainable liquid fuel ecosystem. Companies were interviewed about their products, production technologies, offtake segments (which purchase the output from the production plants) and perceived role in potential investments. Interviewees were also asked to describe their current European project pipeline expected to reach a final investment decision by 2026.

3.1 Sustainable liquid fuel market and project characteristics

The first part of the market consultation resulted in six main findings about the state of the sustainable liquid fuel market.

Finding 1: The sustainable liquid fuel market is at an early stage with mostly demonstration projects deployed. Interest in industrial-scale sustainable liquid fuel projects is rapidly increasing, leading to growing project pipelines.

The market for sustainable liquid fuels — especially for aviation and maritime uses — is still developing, and there are few commercial-scale plants in operation apart from on the FAME, HEFA and, to a certain extent, biomass fermentation pathways (based on first-generation feedstocks). Most advanced biofuel pathways and all e-fuels production technologies are limited to pre-commercial deployments. However, the market is transitioning from these small-scale pilot plants to large-scale advanced production technology plants.

The study confirmed that there was increasing interest in sustainable liquid fuels among market participants from various backgrounds and industries, driven by the regulatory background of the market. The EU target of carbon neutrality by 2050, along with intermediate goals in the Fit-for-55 package, make it clear that regulatory backing for sustainable technologies will be maintained. Sector-specific regulations (ReFuelEU Aviation in particular) establish a pathway for uptake in the transport sector. Although some participants expressed concerns that sector-specific sustainable liquid fuel targets could be weakened if supplies do not keep up with demand, producers generally see opportunities in becoming leading suppliers of these fuels.

Regulatory-driven uptake affects many market participants. Buyers (for example, airlines or shipping companies) will be required to increase the share of sustainable liquid fuels in their fuel mix in the future. Technology providers or original equipment manufacturers need to advance their production technologies to a technology readiness level that allows for industrial-scale deployment. Fuel traders see opportunities in bundling supply and demand and becoming intermediary brokers. Furthermore, financial investors are expecting financial gains from the regulatory-driven uptake. This strong interest has led to a growing project pipeline of industrial-scale projects that remain at an early stage of preparation.

Most interviewees indicated that they are involved in at least one sustainable liquid fuel project, and almost 50% are involved in two or more projects. Nearly all interviewees will invest in this area in the near term, with more than two-thirds aiming to participate in three or more projects within the next 36 months.

Finding 2: Various participants are developing industrial-scale sustainable liquid fuel projects. Independent project developers are crucial participants but have difficulties in accessing financing.

The prospects of the sustainable liquid fuel market are promising, even though its exact characteristics are yet to be defined. Participants from various backgrounds are interested in entering the marketplace, but it is not yet

clear which type of investor (strategic and/or financial) is best suited to benefit from future development. Market participants differ in their strategic approaches and their financing capacity and support requirements.

Types of strategic investor in the sustainable liquid fuel market

Key participants in the current sustainable liquid fuel market include:

- **Oil and gas majors:** As sustainable aviation fuel blending mandates under ReFuelEU Aviation apply directly to fuel suppliers, incumbents such as oil and gas companies need to offer sustainable liquid fuels by 2025, when the first blending quotas come into effect. Oil and gas companies have vast experience in handling and supplying conventional fuels and developing large-scale production projects, and have the financial capacity and sophistication to fund these developments up to a final investment decision (often from their own balance sheets). However, these incumbents may be restricted in their capability and willingness to move quickly, balancing their established business activities with emerging opportunities in sustainable liquid fuels.
- **Energy and utilities:** Low-carbon energy producers in particular see the sustainable liquid fuel market — especially the e-fuels pathways — as a good strategic fit for their existing business lines. Electricity is a core component of renewable hydrogen, which is a precursor for e-fuels. Although demand for low-carbon electricity is high, trading on the spot market is complex and uncertain. Sustainable liquid fuel production could become a predictable and long-term source of offtake demand, making it an interesting sector for investment by energy providers.
- **Independent project developers:** Historically, independent project developers have taken the lead in introducing novel technologies, including in the wind and solar industry. Such project developers are typically more willing than incumbents to use innovative technologies. Similarly, this study found that independent project developers are critical in developing early-stage sustainable liquid fuel projects and introducing innovative technologies.
- **Original equipment manufacturers for key sustainable liquid fuel technologies:** Although FAME and HEFA (from first-generation sources) are technologically mature, other sustainable liquid fuel production technologies require further development and still need to be proven at a commercial scale. Some technology providers are participating in sustainable liquid fuel production projects to demonstrate the readiness of their technology. However, high capital requirements mean these projects are mostly undertaken at a demonstration scale and not at an industrial scale.
- **Sustainable liquid fuel end users:** Users such as airlines and shipping companies are affected by decarbonisation regulations and are therefore interested in sustainable liquid fuel production projects. Large shipping operators increasingly invest in this kind of production project to secure access to low-carbon fuels and gain first-hand experience in their handling and use. Airlines have also shown interest in these projects, but their involvement is mostly limited to either a buying role — with short-term and small-volume commitments so as to benefit from future price decreases — or selective minority stakes in production projects, owing to the balance sheet and liquidity constraints prevalent in the airline sector.
- **Others:** Other participants in the sustainable liquid fuel sector include chemical companies and forestry and paper companies. These firms are either active in the production of fossil-based equivalents to sustainable liquid fuels (for example, ammonia and methanol) and want to decarbonise their business model, or have favourable access to feedstocks required for sustainable liquid fuel production (for example, bio-feedstocks from paper and forestry businesses).

Differences in funding requirements

Strategic investors differ in their financing needs. Large incumbent participants such as oil and gas companies and energy firms are capable of financing development, and sometimes construction, of large or even ultra-large sustainable liquid fuel projects on their balance sheet. They can also provide sufficient levels of collateral, equity or debt service undertakings for unlocking project finance debt.

In contrast, independent project developers (and technology providers) are significantly smaller and experience greater balance sheet constraints. Such developers require external development capital to bring their projects

to maturity. They also need to access financing for construction relating to their sustainable liquid fuel projects once a final investment decision is made.

Policymakers should consider these variations in funding requirements, based on strategic investor profiles, when formulating mechanisms for supporting the sustainable liquid fuel sector and improving access to finance.

Finding 3: Interest in sustainable fuel liquids varies by pathway and offtake segment. Aviation is currently the most relevant sector as it benefits from clear regulatory mandates.

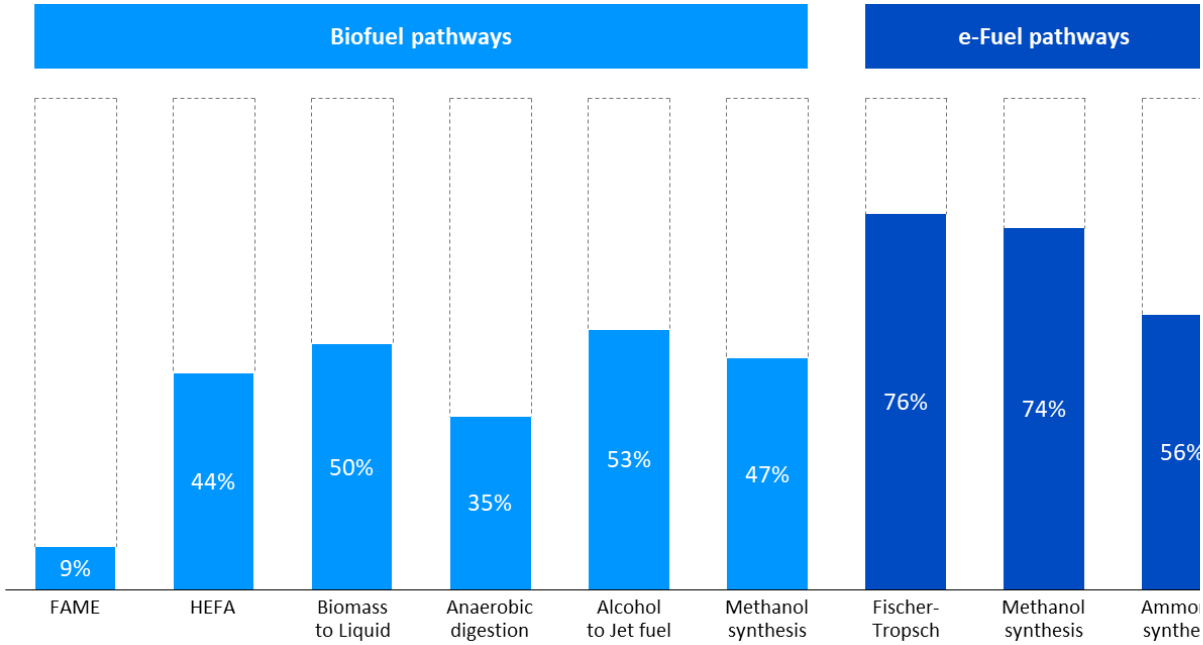
Still in its infancy, the sustainable liquid fuel market may evolve in different ways. Various fuel production pathways covering three different modes of transport (road, maritime and aviation) are being developed. Although some pathways are commercially more advanced than others, the related technological landscape is not yet defined. The market participants consulted in this study highlighted certain emerging trends in the market, including in production pathways, fuel types and offtake segments.

Fuel types and production pathways

The companies interviewed in this study had a slight preference for e-fuels over biofuels (Figure 6), with reasons being favourable market momentum for e-fuels, accelerated political momentum, expected shortages in bio-feedstocks, and scalability potential of e-fuels. All biofuel pathways are equally interesting to the interviewees, except for FAME, which has limitations related to sustainability (primarily linked to land use), blending percentages, and number of applicable sectors (since FAME is unable to produce a kerosene substitute). For e-fuel pathways, the Fischer-Tropsch route is the preferred choice, followed by methanol synthesis. The production of renewable ammonia is being pursued mostly by incumbent chemical companies and independent project developers.

The early stage of the market means most participants remain technology-agnostic. Participants will expand or narrow their business activities (adding or removing fuel types and technology pathways in their project portfolio) depending on future technological and regulatory developments.

Figure 6: Preferred production pathways (% of interviewees in the study)



Source: Market consultations, Roland Berger.

Offtake segments

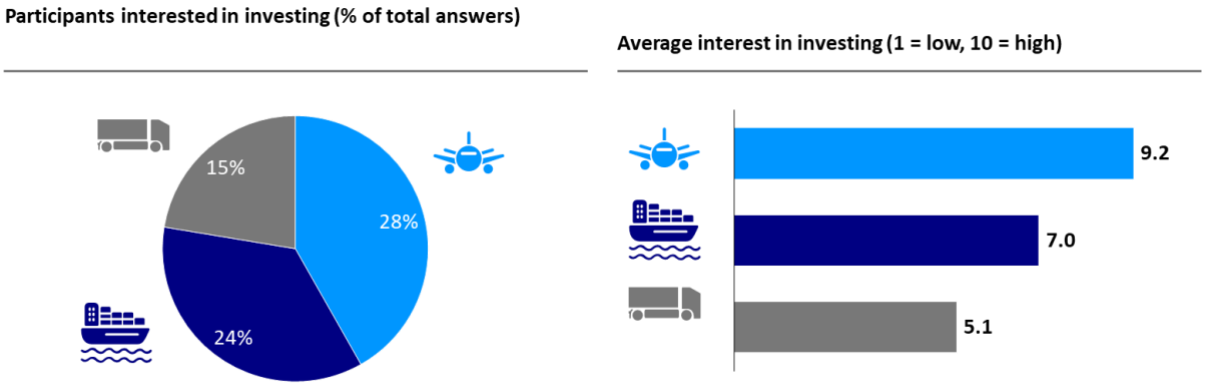
Companies consulted in this study view aviation as the most attractive offtake sector (Figure 7), owing to a strong regulatory framework that is expected to create substantial long-term demand. Under ReFuelEU Aviation, sustainable aviation fuel blending mandates apply from 2025 and will increase substantially up to 2050. However, some interviewees highlighted the regulatory risk that blending mandates could be softened in the future if sustainable liquid fuel supply is unable to keep up with demand.

Decarbonisation of the maritime sector is also supported by the regulatory framework, in particular the FuelEU Maritime regulation. Unlike ReFuelEU Aviation, which contains blending mandates,[5] FuelEU Maritime introduces emission intensity reduction targets. Such intensity reductions can be achieved through the use of sustainable liquid fuels and by using technologies to improve fuel efficiency (for example, sails, improved hull design and improved antifouling coating), particularly during the initial years of the regulation when reduction targets are modest. However, once reduction targets increase substantially from 2035, the alternative methods for reducing emission intensity will become insufficient, thereby requiring significant uptake of sustainable liquid fuels.

The road sector is the largest consumer of sustainable liquid fuels, driven by well-established blending mandates for biodiesel and bioethanol. However, interviewees are less interested in producing sustainable liquid fuels for road vehicles than for other modes of transport. This is because electrification is expected to be the most viable decarbonisation alternative for most road transport uses, while future sustainable liquid fuel demand will likely stem from other modes of transport that have fewer options for decarbonising. Furthermore, policymakers in Europe have no plans to introduce higher blending mandates for road transport (such mandates would drive demand for sustainable liquid fuels).

Finding 4: Planned industrial-scale projects are mostly captive and self-contained, covering multiple value chain steps.

Figure 7: Target offtake segments by interviewees consulted



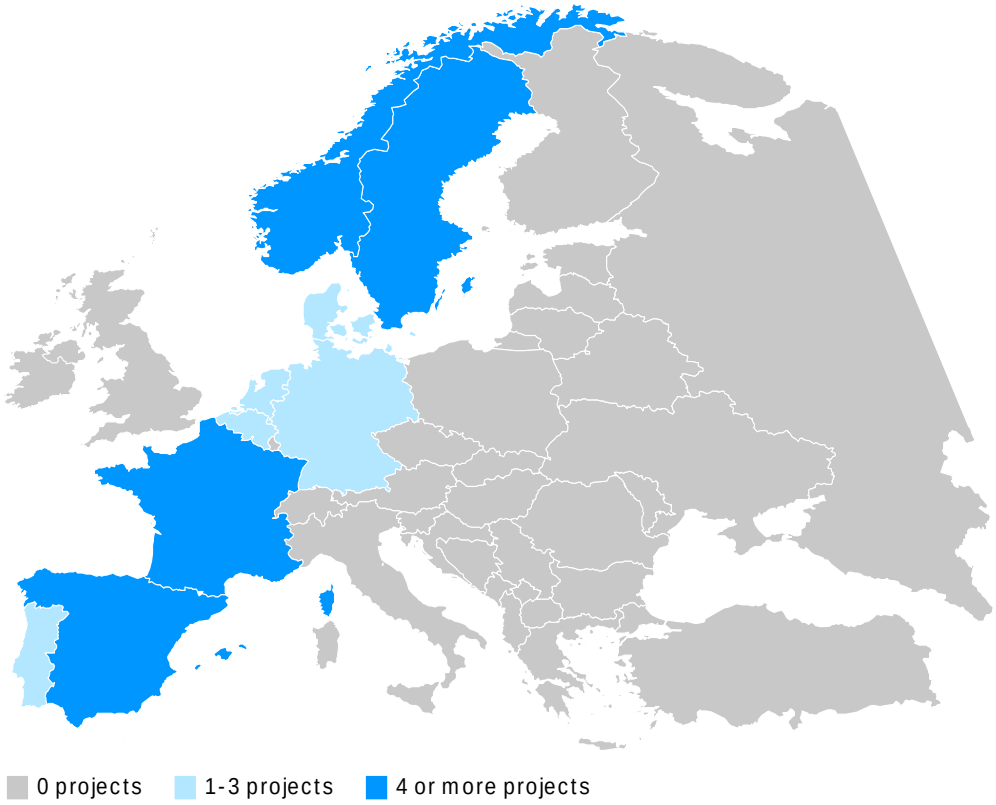
Projects under development are mostly captive and self-contained, integrating the production of feedstocks (electricity, hydrogen, carbon dioxide and bio-feedstocks) and the production and storage of sustainable liquid fuels. In the current nascent sustainable liquid fuel market, such inputs are not commoditised and are therefore easily accessible in large volumes and at competitive prices. Such vertical integration, which incorporates the production of precursors into the project design, is necessary for securing a stable and predictable supply of inputs. However, this vertical integration adds to the complexity and risk, and increases the capital required to build a project.

[5] Although FuelEU Maritime does introduce conditional blending mandates.

Finding 5: Location is a pivotal success factor for sustainable liquid fuel projects as proximity to abundant and low-cost feedstocks is crucial to project economics.

As sustainable liquid fuel production plants are vertically integrated units, a key factor in optimising project economics is the proximity of the production plants to abundant and low-cost inputs, for example, electricity, hydrogen and/or bio-feedstocks. Most companies consulted in this study are planning projects in locations that provide such ideal conditions (Figure 8). For e-fuel projects, Scandinavia and the Iberian Peninsula are the most sought-after locations, owing to the availability of abundant, reliable and cheap low-carbon electricity. Scandinavia offers abundant hydroelectric resources, whereas Spain and Portugal provide favourable conditions for solar and, to a certain extent, wind energy. For biofuels, production plants are often strategically located in areas with access to feedstock from forestry and agricultural biomass. Beyond Europe, participants frequently mentioned South America and North Africa, and occasionally Australia, as attractive locations for e-fuel production or at least production of key feedstocks (for example, green hydrogen or renewable electricity).

Figure 8: Number of active or planned sustainable liquid fuel production projects developed by study interviewees in each country



Source: Market consultations, Roland Berger.

Finding 6: Industrial-scale projects have high capital requirements, straining the financing capacity of developers and thereby impeding final investment decisions.

Achieving economies of scale is vital for reducing the unit costs of sustainable liquid fuel production facilities. Industrial-scale projects of this kind are capital intensive, often needing investments of hundreds of millions or even billions of euros. Although the scale of investment varies by fuel type, production pathway, overall project setup and value chain coverage, most interviewees expect their projects to need investments significantly over

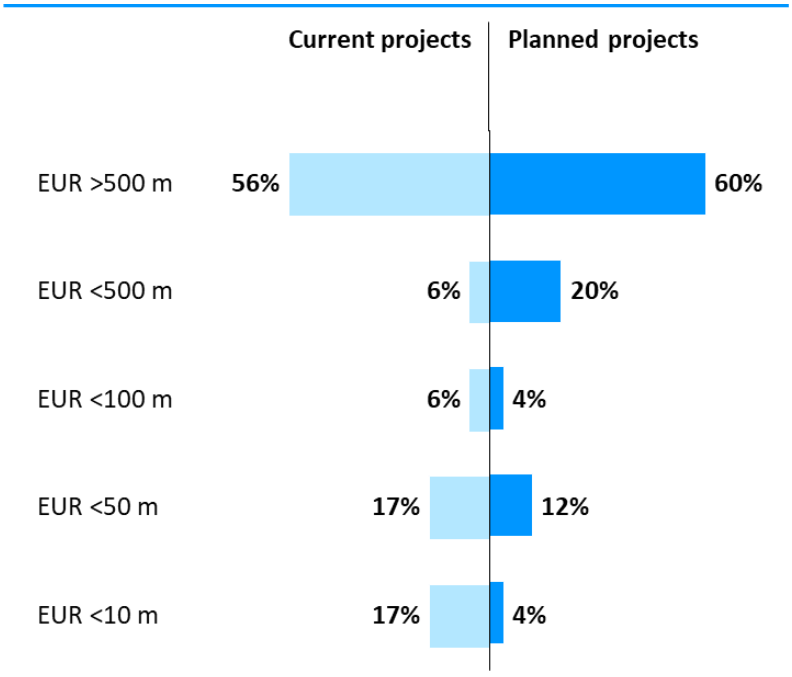
€100 million. More than 85% of respondents indicated investment requirements of more than €100 million, almost 60% reported that their projects would need more than €500 million in capital spending, and approximately 40% stated that their investments would be in excess of €1 billion (Figure 9).

"Our typical investment size is over €1 billion. Some of our projects even require investments significantly exceeding that to ensure sufficient production capacity."

Renewable energy player

Prior to implementation, significant expenditure is also needed to bring projects to a sufficient level of maturity for a final investment decision. Such expenditure includes (pre-)feasibility studies, front-end engineering design studies and business development activities. These essential development expenses are correlated with the overall size of the underlying project and are frequently in the range of tens of millions or hundreds of millions of euros.

Figure 9: Average investment size of current and planned projects (% responses)



Source: Market consultations, Roland Berger.

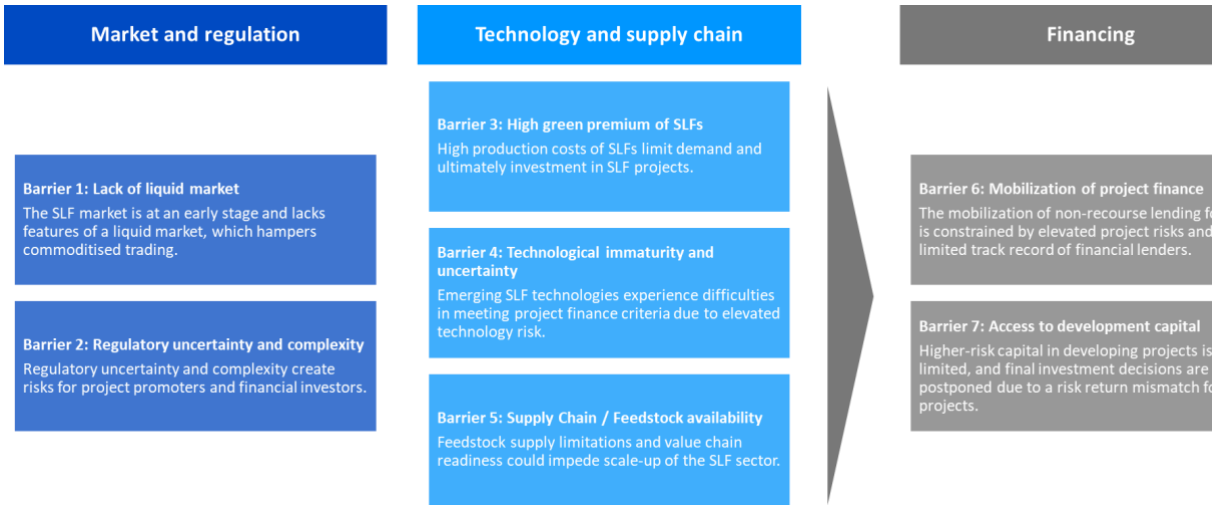
The European pipeline of large-scale sustainable liquid fuel projects is at an early stage of development. Except for selected FAME, HEFA or ethanol (first-generation) production plants, very few final investment decisions for industrial-scale sustainable liquid fuel plants have been reached in the European Union. There are numerous reasons for this absence of final investment decisions. Most project promoters highlighted the fact that sustainable liquid fuels are significantly more expensive than their fossil-based counterparts, making it difficult to develop business cases that justify the initial large capital investments. Strict regulatory conditions were frequently mentioned as adding complexity to finding viable project locations and producing and sourcing eligible feedstocks. In addition, the current challenging global economic conditions, high inflation, high interest rates and uncertain economic outlook make committing large amounts of capital increasingly difficult. As a result, many planned final investment decisions have been postponed. Interviewees often mentioned that projects with target dates for final investment decisions in 2025 or 2026 and commercial operations in 2028 or 2029 have experienced or will likely experience delays.

3.2 Barriers in the sustainable liquid fuel market

During the market consultations, interviewees mentioned several risks and barriers that are hindering initial investments in large-scale sustainable liquid fuel deployments. If left unaddressed, these barriers will delay or prevent the European Union from reaching its decarbonisation targets for the transport sector.

The main concerns of market participants can be arranged into three categories: market and regulation, technology and supply chain, and financing (Figure 10).

Figure 10: Key perceived market challenges



Although the first two groups of barriers are exogenous, they directly contribute to the third group of financing-related barriers. Financial investors displayed a general willingness to invest once exogenous project risks are mitigated. Access to finance was frequently cited by strategic investors (but not financial investors) as an additional barrier alongside the other challenges. For this reason, financing barriers are discussed in detail as an individual topic (see Chapter 4). Furthermore, access to finance is the market barrier in which the EIB can best intervene.

Barrier 1: The sustainable liquid fuels market is at an early stage and lacks the features of a liquid market, hampering commoditised trading.

The first-generation biofuel sustainable liquid fuel market for road transport is well established, but the market for other modes of transport is at an earlier stage, with demand and supply centred around single early adopters and initial demonstration plants. Experience with sustainable liquid fuel trading is limited, supply chains have not been formed and intermediaries with respective sustainable liquid fuel business models are missing from the market. As typically seen in early-stage markets, the interviewees in this study noted that the following issues are hampering production, trading and consumption of sustainable liquid fuels in the aviation and maritime sectors:

- There are no merchant or spot markets for sustainable liquid fuels, meaning fuel producers must secure bankable, long-term offtake agreements to receive financing for their projects.
- Long-term visibility on offtake volumes and prices for sustainable liquid fuel producers is limited, making committing capital and executing projects difficult due to increased project risk.
- Offtake volumes are small, geographically dispersed and disconnected from sustainable liquid fuel production centres.

- Supply chains are underdeveloped and the physical distance to the nearest production sites can be substantial, hindering the physical trade of sustainable liquid fuels even when demand and supply are matched.
- There are no uniform standards for maximum fuel blending capabilities and fuel properties (especially carbon dioxide intensity), restricting comparability, uniform pricing and the commoditisation of fuels.
- Access to fuelling infrastructure at ports and airports is unequal, especially for small-scale producers, because oil and gas companies often hold exclusive rights of use.

"Buyers are cautious in signing long-term offtake agreements because they are uncertain in which direction the market will develop."

Sustainable liquid fuel producer

Overcoming these early market barriers is challenging because traditional market players (fuel traders, airlines and shipping companies) are used to operating in fully commoditised markets with product standardisation, liquid demand and supply, and functioning supply chains. Many sustainable liquid fuel promoters have experienced difficulties in concluding long-term offtake agreements owing to the aviation and maritime sectors being accustomed to trading based on spot prices. Sustainable liquid fuel buyers have yet to adapt to the emerging market and develop appropriate hedging strategies against volatile prices and market developments before engaging in long-term contracts.

"We believe that we need to bundle sustainable liquid fuel demand enough to structure the market and start commoditising sustainable liquid fuels."

Fuel trader

Barrier 2: Regulatory uncertainty and complexity create risks for project promoters and financial investors.

Interviewees were very supportive of EU regulation of the sustainable liquid fuel industry and acknowledged the leading position of the European Union in this field and in tackling global climate change. However, there are areas where greater clarity is needed, with almost all interviewees mentioning that a simple and harmonised regulatory framework is essential for sustainable liquid fuel market development.

Uncertainty and the implications of regulatory developments

Although EU decarbonisation objectives are understood and supported, many investors are unclear about the European Union's long-term regulatory treatment of sustainable liquid fuels and how the evolution of the regulatory framework might affect projects based on existing regulations. For projects in development, developers want greater clarity and protection against future regulatory changes. For investors, such clarity about the future is necessary for them to commit capital today. In addition, interviewees questioned whether the strict regulatory regime, especially increasing sustainable aviation fuel blending mandates, will be maintained if the market lacks sustainable liquid fuel supply due to underinvestment in production capacity. In their view, this would most certainly lead to weak offtake prices and stranded assets for early movers. Other common themes about the regulatory framework are summarised below. The points raised by developers and investors make planning for and investing in sustainable liquid fuel projects challenging at present.

- **Renewable Energy Directive II/III:** Interviewees are concerned that the combination of targets for renewable fuels of non-biological origin and advanced biofuels could create unnecessary competition. In addition,

investors frequently mentioned a lack of long-term prospects for current investments because RED III has no renewable energy and fuel targets beyond 2030.

- **ReFuelEU Aviation:** This regulation is welcomed by market players since long-term blending mandates create visible future demand. However, investors doubt that current ambitious blending mandates will be maintained in the future if imminent supply-side constraints are not addressed. In addition, a framework is needed to support the tradability of sustainable aviation fuels, especially for demand centres that are not physically connected to a sustainable aviation fuel supply.
- **FuelEU Maritime:** There is a lack of clarity on demand from the shipping sector as the regulation focuses on targets for reducing emission intensities and only includes initial, conditional sustainable liquid fuel blending quotas.
- **Energy Taxation Directive:** This directive currently includes many exemptions and reduced tax rates for aviation and maritime fuels, encouraging the use of fossil fuels. Development of a revised Energy Taxation Directive that taxes fuels based on their energy content and environmental performance is ongoing but urgently needed to level the playing field for sustainable fuels.

"Production projects have a horizon of more than 15 to 20 years. RED has been reviewed in approximately five-year cycles and will be revised again. We can't build on that."

Logistics company

Complexity of regulation

The interviewees in this study frequently raised concerns about increasing regulatory complexity. The current regulatory regime requires significant internal resources and external advisory support for compliance. Numerous interviewees demonstrated a lack of knowledge of and even misunderstood existing regulations (for example, penalty schemes, eligibility criteria and delegated acts). Interviewees highlighted the following as examples of current regulatory complexity:

- There are numerous relevant regulations (such as RED II/III, various delegated acts, ReFuelEU Aviation, FuelEU Maritime, ETS and Energy Taxation Directive) with partial cross-referencing.
- EU legislative procedures are complex and lengthy, and there are no visible timelines for the adoption of critical regulation.
- EU legislation is not harmonised. For example, different bio-feedstock eligibility criteria apply for ReFuelEU Aviation, FuelEU Maritime and RED III, and long-term targets for ReFuelEU Aviation and FuelEU Maritime are provided but RED III lacks targets beyond 2030.
- There are potential differences in the national implementation of key directives. Keeping abreast of the regulatory environment in individual EU Member States can be challenging.

"The regulator seems to underestimate the complexity of its regulation and its impact on those involved in the market. Companies must hire whole departments to keep up with complexity and development of regulation."

Sustainable liquid fuel buyer

Strict definitions for renewable fuels of non-biological origin

For renewable fuels of non-biological origin, the definitions of what constitutes renewable hydrogen and under which conditions carbon dioxide is considered as avoided are critical issues for the interviewees in this study. These issues were recently defined by two delegated acts, the Delegated Act on a methodology for renewable fuels on non-biological origin and the Methodology Delegated Act. However, interviewees active in e-fuel

production believe the rules are too strict, especially the criteria defining renewable hydrogen (additionality, temporal and geographical correlation criteria for renewable electricity production) and the approaches for calculating greenhouse gas emissions for captured carbon dioxide. Interviewees expressed concerns that the strict regulations could hamper market uptake during the early stages of market development.

Lack of global regulatory harmonisation

The study participants reported concerns about a lack of regulatory harmonisation with key global markets beyond the European Union, particularly sectors that operate globally such as aviation and shipping. For example, European airlines are concerned that ambitious EU regulations could cause economic disadvantages compared with their international competitors, which are less impacted by European policies. The interviewees want greater coordination of European regulations and policies with other key jurisdictions, such as the United States, and international associations, such as the International Maritime Organization and the International Air Transportation Association, which will ensure equality for European companies.

Barrier 3: High production costs for sustainable liquid fuels limit demand and ultimately investment in sustainable liquid fuel projects.

The most imposing barrier to investments in sustainable liquid fuels is their high production costs, which are currently several times greater than those of fossil-based fuels. Without adequate support mechanisms, the green premium is too high for investors to make a positive business case. This barrier is particularly relevant for e-fuels but also applies to all sustainable liquid fuel technological pathways. The underlying causes of the higher costs compared with conventional fuels include limited economies of scale, immaturity of production technologies, high production and feedstock costs, underdeveloped supply chains for mid-stream transport, and inadequate carbon pricing.

Interviewees indicated that the gradual introduction of blending mandates combined with adequate penalty schemes for non-compliance will mitigate the cost gap for regulated demand volumes. However, regulated demand is expected to increase slowly in the near future, reducing the financial incentive for companies to enter the sustainable liquid fuel market.

"The only solution to unlock the sustainable liquid fuel economy is to reduce the cost gap."

Shipping company

Lack of economies of scale

At the current stage of technological immaturity and low demand, most sustainable liquid fuels are produced in limited quantities (except first-generation biofuels for road transport). As a result, there is considerable potential for economies of scale and endogenous efficiency gains to decrease costs over time and reduce the green premium. However, this will only be achieved with the systematisation and scale-up of production processes and capacities. As previously stated, high production costs hinder the incentives for investors to finance the very large-scale deployments that could initiate a virtuous cycle of market development.

High production and feedstock costs

The interviewees expect sustainable liquid fuels (e-fuels and, to a lesser extent, biofuels) to remain more expensive than conventional fuels, even in the longer term. Production costs for e-fuels can mostly be attributed to the cost of renewable electricity. Interviewees expressed doubts that the cost reductions in renewable electricity prices over the past decade will continue to the extent that e-fuels become cost competitive. They also reported that production costs for renewable electricity vary substantially within Europe, and that locations with favourable conditions are limited, questioning claims about the unlimited scalability of e-fuels. Some interviewees believed that green hydrogen production, which is required for e-fuel production, will be located beyond Europe in the future, potentially in geographical regions with competitive renewable electricity costs,

such as South America, North Africa, Australia and the Middle East. Investors also emphasised that the Delegated Act on Renewable Hydrogen and its requirements for additionality, temporal and geographical correlation further limits the economic potential for e-fuel production in Europe.

Feedstock accounts for the largest share of biofuel production costs. In the consultations, concerns were raised about feedstock supply shortages leading to higher feedstock and production costs in the medium term. There are two reasons for these supply issues. First, biofuels are expected to meet most of the regulated blending mandates in the initial phase of the sustainable liquid fuel market, as they are more technologically mature (second-generation plants) and have lower production costs than e-fuels. This increase in biofuel production will create significant demand for, and eventually exhaust, the finite sources of bio-feedstock. Second, the strict bio-feedstock sustainability criteria imposed by the European Union have increased demand for advanced feedstocks. These feedstocks are currently limited to industrial by-products, such as used cooking oil and animal fats, which are in short supply. Technology for the commercial-scale processing of more abundant and advanced feedstocks is still being developed.

"It's difficult to make a positive business case as sustainable liquid fuels remain relatively expensive. Also, there is hesitation to be the first deployer as first projects will be the most expensive."

Sustainable liquid fuel investor

Adequate carbon dioxide pricing

By 2024, all major modes of transport (road, aviation and maritime) will be covered by the EU Emissions Trading System. However, many interviewees in this study pointed out that the current price of carbon emissions is not sufficient to cover the cost premium of lower- and zero-carbon technologies. As a result, the EU Emissions Trading System will only slightly reduce the price differential between sustainable liquid fuels and fossil fuels. Although carbon prices are expected to increase in the future — partly through the reduction in availability of free emission allowances by the European Union — interviewees were unsure whether these projected prices would achieve cost parity for most sustainable liquid fuels by 2035 or even later. The interviewees want an adequate monetisation of carbon emission savings, which will substantially reduce the price differential between sustainable liquid fuels and fossil equivalents, providing a financial incentive for the large-scale deployment of carbon-reducing technologies.

"Current prices for carbon emissions under EU Emissions Trading System do not reflect the cost premium for technologies that reduce carbon emissions in the transport sector."

Fuel producer

Public support mechanisms aiming to reduce the cost gap are pivotal in making it easier for sustainable liquid fuel promoters to access finance. Such mechanisms could create sufficient long-term visibility and financial incentives for promoters to take final investment decisions for their projects. They could also unlock project finance as they reduce the market risk for lenders. The market consultation found that these mechanisms should target supply and demand. Supply-side mechanisms are needed to create adequate financial incentives for early movers to commit the initial investments for scale-up and long-term cost reductions. Demand-side mechanisms are needed to provide investors with sufficient offtake visibility to commit to and undertake their projects.

Barrier 4: Emerging sustainable liquid fuel technologies experience difficulties in meeting project finance criteria due to high technology risk.

Financial investors and lenders frequently mentioned the technology risk of sustainable liquid fuel production as a key barrier to investment. Current commercially available production pathways (HEFA, FAME and alcoholic fermentation) primarily produce biodiesel and bioethanol for road transport. Existing deployments are mostly based on food feedstocks (first-generation sources), which will largely be phased out in the European Union by 2030. HEFA and alcoholic fermentation pathways can produce advanced biofuels from selected feedstocks (agricultural and industrial waste, used cooking oil and animal fats). However, the scalability of these production technologies is limited by feedstock supply constraints. Numerous pathways are being developed for processing additional advanced and waste-based feedstocks (including using green electricity) to produce various fuels. Such novel technologies are vital for meeting the expected demand for sustainable liquid fuels but have not yet been deployed at commercial scale. The technologies are also still not bankable due to the lack of industrial-scale projects mitigating concerns related to construction, operation and performance risks and further mitigating technology risk for lenders and investors.

Uncertainty of future technological landscape and market-winning products

The financial investors and lenders interviewed remain uncertain about the future technological landscape and which technological pathways will prevail:

- **Aviation**: The technological landscape of sustainable aviation fuel production is evolving rapidly. Financial investors and lenders expressed difficulties in remaining up to date on the latest technological trends and assessing the most promising pathways. These difficulties raise concerns about today's investment choices becoming tomorrow's stranded assets, thereby hindering commitment from investors.
- **Maritime**: Interviewees were unsure about the most feasible fuel for the shipping sector from a technological and economic perspective. This uncertainty is reflected in current vessel order books — liquified natural gas new builds represent the largest share of alternative fuel technologies, but recent orders include both ammonia- and methanol-ready ships. It is therefore not yet clear which of the two green shipping fuels will be preferred by the market. Certain financial investors and project finance lenders reported that this uncertainty is contributing to increased obsolescence risk when considering maritime sustainable liquid fuel projects. Meanwhile, some shipping company representatives interviewed for this study predict that various maritime sustainable liquid fuels will co-exist because of the inability of a single technology to meet future demand from the entire European shipping sector.
- **Road**: Road transport is currently the largest sector for sustainable liquid fuels due to the established blending mandates for biodiesel and bioethanol. However, most market participants question their continued prominence in this domain, believing that electrification will be the preferred decarbonisation option for most road vehicles.

Lack of technology maturity for key sustainable liquid fuel technologies

In the aviation and maritime sectors, commercially available propulsion technologies that use sustainable fuels depend on either the HEFA (kerosene) or anaerobic digestion (bio-liquified natural gas) technological pathways. Novel sustainable liquid fuel production pathways, especially for producing e-fuels, are still at a pre-commercial or even a technological demonstration phase. Feedback from the market consultations suggests that lenders perceive the risk of these technologies as being too high to provide non-recourse financing to projects. Risk mitigation mechanisms or instruments would therefore be needed to reduce the project risk profiles for lenders and enable them to access such financing.

Multi-project and multi-technology risks

The early stage of the sustainable liquid fuel market means most projects under development are captive and self-contained, incorporating various steps of the value chain for production. This is particularly true for e-fuel

projects, which frequently combine renewable electricity generation, carbon capture, hydrogen production and fuel synthesis.

Such project integration is typical in developing markets and non-commoditised sectors because it ensures the availability of intermediate inputs and production processes for the desired end products. However, the integration of multiple steps and technologies, even when they are mature, presents interface risks for the project arising from interactions and the interdependence of production steps — an issue in an earlier step can negatively impact downstream production steps. Such interface risks can also arise where value chain steps are assigned to separate projects, causing the delay or underperformance of one project to negatively affect the performance of projects further down the value chain. These risks are particularly relevant to non-commoditised markets where inputs cannot be easily sourced from alternative external providers. Lenders must therefore develop methodologies for managing interface risk in addition to developing appropriate financing structures.

"Combining technologies is an issue in terms of complexity, efficiency and scalability."

Commercial lender

Lenders' lack of knowledge about emerging sustainable liquid fuel technologies

Interviewees mentioned that most lenders do not understand the underlying technology fundamentals of sustainable fuels, often hindering their willingness to finance projects. Developing in-house expertise and knowledge is essential for lenders to navigate and understand new sectors, identify the most promising use cases (fuels and sectors), perform technology assessments for robust project opportunities, and structure alternative finance products that are better suited to emerging sustainable liquid fuel technologies than traditional project finance.

"Many financial investors lack knowledge about technological aspects of sustainable liquid fuels. There is a need to inform them to increase their confidence and willingness to invest."

Sustainable liquid fuel research centre

Barrier 5: Feedstock supply limitations and value chain readiness could impede scale-up of the sustainable liquid fuel sector.

Feedstock is a key factor in the cost-efficient production of sustainable liquid fuels. For this reason, promoters develop their projects in proximity to low-cost and abundant supplies of electricity, carbon dioxide and/or bio-feedstock. However, the limited number of optimal production sites mean feedstock availability is a concern for the market participants (e-fuel and biofuel) interviewed in this study.

Feedstock availability for biofuel production

The restricted scalability of bio-feedstocks used in the commercial production of advanced and waste-based biofuels has raised concerns among interviewees about feedstock shortages once fuel blending mandates increase significantly after 2030. Numerous advanced biofuel technologies are in development and could potentially unlock additional advanced bio-feedstocks such as cellulose or algae. However, these technologies are not yet sufficiently developed for large-scale deployment. Technological advancements are pivotal in addressing the bio-feedstock challenge and scale-up of sustainable liquid fuels. Interviewees suggested the need for continued innovation and research and development and called for action in the form of increased grant and research funding support.

Hydrogen and carbon dioxide availability for e-fuel production

Key steps in the e-fuel production process are the supply and/or production of inputs such as renewable hydrogen and carbon dioxide.

Despite the current abundance of large sources of carbon dioxide emissions, they are expected to become increasingly scarce for the production of e-fuels. This is mainly due to two recent Delegated Acts on Renewable Hydrogen, which from 2041 restrict industrial carbon dioxide from being used in the production of e-fuels (renewable fuels of non-biological origin). Since the economic life of e-fuel production assets is typically in the range of 20 to 30 years, project developers need to identify alternative carbon dioxide sources now, or otherwise be willing to accept that their projects will have a shorter economic life as it becomes a stranded asset when the stricter standards come into force. This creates a major barrier for promoters as alternative supply routes are either expected to be limited in their scalability (biogenic carbon dioxide) or depend on costly and still immature technologies (ambient carbon dioxide via direct air capture), adding another layer of complexity to their projects.

Hydrogen is another pivotal input for the production of e-fuels. Cost-efficient production of renewable hydrogen depends on access to cheap and abundant sources of renewable electricity. As previously stated, interviewees stressed that the reduction in cost of renewable electricity may not continue in the future. Other interviewees reported that that renewable electricity production costs vary substantially within Europe, with only a few locations providing the optimal conditions to produce competitive green hydrogen at scale. Such locations are typically disconnected from large sustainable liquid fuel demand centres. There is also uncertainty about importing green hydrogen from low-cost production centres beyond Europe because new long-distance transport infrastructure is needed in addition to the production facilities.

All interviewees agreed that a massive expansion in capacity for renewable energy generation is needed to meet the European e-fuel sub-mandates under ReFuelEU Aviation. Current installation rates of such capacity are insufficient and could become a major bottleneck for the large-scale roll-out of e-fuels.

"Additionality criteria currently limit e-fuel production to Scandinavia and the Iberian Peninsula. That won't be enough."

Sustainable liquid fuel investor

Supply chain coordination for e-fuels

The geographical mismatch between future supply centres of cheap and abundant renewable electricity and demand centres of e-fuels means market participants require infrastructure development connecting these centres. For future supply chains, interviewees see their development occurring in two phases:

- **Short-term:** Sustainable liquid fuel production at optimal locations within Europe (Scandinavia and the Iberian Peninsula) linked to European demand centres.
- **Mid-term:** Hydrogen production centres, with optimal supplies of renewable electricity, located beyond the European Union (for example in Latin America, North Africa or the Middle East) connected to European sustainable liquid fuel demand centres.

Both options require large-scale mid-stream infrastructure to connect the supply and demand centres. Interviewees mentioned that this infrastructure remained in an early stage of development, introducing further uncertainty for investors in sustainable liquid fuel production. Increased clarity and financial support would accelerate the development and construction of mid-stream infrastructure. Comparable concerns were voiced about biofuels, but to a lesser extent than for e-fuels.

Barrier 6: Mobilisation of non-recourse lending for sustainable liquid fuels is constrained by high project risks and the limited track record of financial lenders.

According to the interviewees, numerous large-scale plants costing hundreds of millions of euros are required by 2030 to meet EU decarbonisation targets. Due to these capital requirements, the construction of such plants will ultimately depend on non-recourse project financing from commercial lenders.

International project finance lenders typically require large-scale sustainable liquid fuel production projects to have certain risk mitigants in place to be considered bankable, including:

- a robust business case, based on achievable sustainable liquid fuel market prices and production costs, demonstrating that any debt can be repaid under a defined base case and various stress scenarios;
- strong, long-term offtake commitments for a significant share of production capacity;
- long-term supply agreements for key feedstocks (bio-based feedstock, renewable electricity or carbon dioxide);
- an appropriate contracting and construction strategy (engineering, procurement and construction; equipment suppliers; and operations and maintenance services) that provides an adequate risk allocation structure for mitigating construction, commissioning and operational risks.

Under current market conditions, many project promoters struggle to implement a risk mitigation strategy that meets the bankability requirements of non-recourse lenders. This in turn hinders such lenders in providing sustainable liquid fuel projects with non-recourse financing.

"One of our biggest challenges is to de-risk projects enough for senior lenders to provide project financing."

Sustainable liquid fuel project developer

In the market consultations, interviewees identified several main risks affecting non-recourse financing for sustainable liquid fuel projects.

Market risks

- The production costs of sustainable liquid fuels are several times higher than those of fossil fuels and significantly higher than the willingness-to-pay of unregulated demand. Project promoters and lenders expect a considerable cost gap to persist in the long term, making it difficult to build a positive business case for production volumes in excess of regulated demand.
- The inclusion of key transport sectors in the EU Emissions Trading System is unlikely to decrease the cost gap sufficiently in the medium term.
- Current levels of high inflation, rising interest rates and increased electricity prices across Europe have negatively affected project returns for promoters and investors.

Commercial agreements

- Project promoters struggle to secure sufficient offtake volumes at appropriate prices to reassure lenders that the project can repay its financing.
- There is a maturity mismatch between the commitment of buyers and the requirement of lenders for long-term non-recourse financing. The market consultations showed that buyers are hesitant to commit for periods over two to three years, whereas the loan period for financing the construction of such projects is considerably longer. Two reasons for the brevity of offtake commitments are that buyers are used to trading on spot prices in fully commoditised markets, and expect marked decreases in sustainable liquid fuel production costs over the coming years as economies of scale and increased production efficiencies are achieved. These expectations reduce their willingness to lock-in current (higher) prices.
- Even if long-term offtake agreements were possible, some early-stage buyers, such as airlines, are not considered sufficiently creditworthy by lenders.

Technology risks

- Various sustainable liquid fuel production technologies are still in development or have not yet been deployed at scale, increasing the perceived level of technology risk for lenders.
- For the maritime sector, the future sustainable liquid fuel of choice (ammonia, methanol or bio-liquified natural gas) is not yet known, posing obsolescence risks for production plants that select the losing alternative. However, some interviewees suggest that numerous fuels may co-exist to supply the volumes needed to meet the EU decarbonisation targets for shipping.

Contracting

- Many sustainable liquid fuel technologies are being developed by highly innovative small and medium enterprises that will supply crucial equipment to projects. Lenders expressed concerns that these technology providers either cannot provide performance guarantees or, if provided, do not have the balance sheets to support them. In the absence of such guarantees, prohibitively expensive reserve accounts or bespoke insurance coverage may be required by lenders to secure financing.

Creditworthiness of project sponsors

- Project promoters themselves may be deemed uncreditworthy by lenders. In particular, independent project developers can have a weak credit profile in the eyes of lenders and therefore are unable to provide bankable debt service undertakings or other forms of guarantees prior to project completion.

Alongside high project-level risks, lenders themselves are ill-equipped to provide non-recourse financing to sustainable liquid fuel projects, owing to a lack of knowledge about the technical aspects of sustainable fuels, hindering their ability to rigorously assess technology and performance risks.

The above obstacles impede initial investments in sustainable liquid fuel production. Investors want adequate risk distribution mechanisms, where risks are shared between public and private players and between strategic and financial investors. Investors also mentioned direct risk-sharing instruments (for example, subordinated loans or guarantees) and supply- and demand-side mechanisms to reduce project risks for lenders. Risk

mitigation strategies and mechanisms will be crucial for unlocking private financing for sustainable liquid fuel production.

"Bankability requires robust risk-return profiles. Loan repayments need to be assured even in stress scenarios. Current sustainable liquid fuel projects do not fulfil our bankability criteria to qualify for project finance."

Commercial lender

Barrier 7: Higher-risk capital in developing projects is limited, and final investment decisions are being postponed due to a risk-return mismatch for sustainable liquid fuel projects.

Bringing a sustainable liquid fuel project from the origination stage to the operational phase is expensive and high risk

Bringing sustainable liquid fuel projects through the various stages of development — inception, feasibility, (pre-)front-end engineering design, and final investment decision — requires financing in the range of tens or even hundreds of millions of euros. However, the risk of failure or abandonment in the development phase is high for such projects. A successful project typically needs to pass several quality gates before a final investment decision is made. Projects are abandoned by their promoters if they do not meet certain technical and economic feasibility requirements, resulting in the loss of all the capital invested. Therefore, access to adequate levels of risk capital is necessary for advancing projects from conception to construction.

Independent project developers are pivotal in commercialising sustainable liquid fuels, but are constrained by their own funds

Historical experience with solar and wind energy has shown that independent project developers are instrumental in early-stage adoption and roll-out of new technologies, and the market consultations in this study support this finding. In contrast to large energy incumbents who can finance the development of such projects on balance sheet, independent developers lack their own funds (excluding external financing) to bring a project to fruition. These developers largely depend on the willingness and ability of private equity, venture capital or other higher risk capital providers to invest in their early-stage projects.

Higher risk capital for the development of early-stage sustainable liquid fuel projects is scarce

Providers of private equity and infrastructure funds are increasingly interested in the sustainable liquid fuel sector and could be a source of project development capital for independent developers. However, under current market conditions, the involvement of these providers, and the quantity of development capital available, is limited. Among providers of EU funds, a few are specialised in clean technology and have sufficient knowledge to invest in sustainable liquid fuels, but even these investors are hesitant to undertake such investments. In the consultations carried out, these investors frequently referred to barriers that hamper their increased involvement in the sector, including high capital requirements for the development of large-scale projects, limited cost competitiveness, regulatory uncertainty and technology risk.

In addition, large energy incumbents, despite the financial resources at their disposal, are hesitating to develop innovative sustainable liquid fuel projects owing to the perceived risks. Incumbents must strike the right balance between higher-risk activities in the emerging sustainable liquid fuel sector and lower risk activities in their established businesses, meaning that although they are increasing their participation in the sector, their involvement is limited at present. As a result, the current project pipeline and overall speed of development will not meet the EU decarbonisation targets for 2030.

“At the current stage of the market, more medium-scale investments are necessary to help first projects reach commercial stages. Raising sufficient funds to execute engineering studies is especially difficult.”

Infrastructure fund provider

Overall risk-return profiles make final investment decisions difficult even if projects are mature

Projects that have attracted sufficient capital and reached a final investment decision may fail due to poor shareholder returns. The promoters interviewed for this study often mentioned that justifying investment in a sustainable liquid fuel project was challenging in light of the high project risks and modest returns. In addition, the promoters raised the issue of early-stage production facilities becoming uncompetitive in the medium to long term, as the sustainable liquid fuel market matures and production costs decline. The perceived first mover disadvantage is also a significant obstacle for initial equity investments. The challenging risk-return profiles are causing many final investment decisions to be postponed or abandoned.

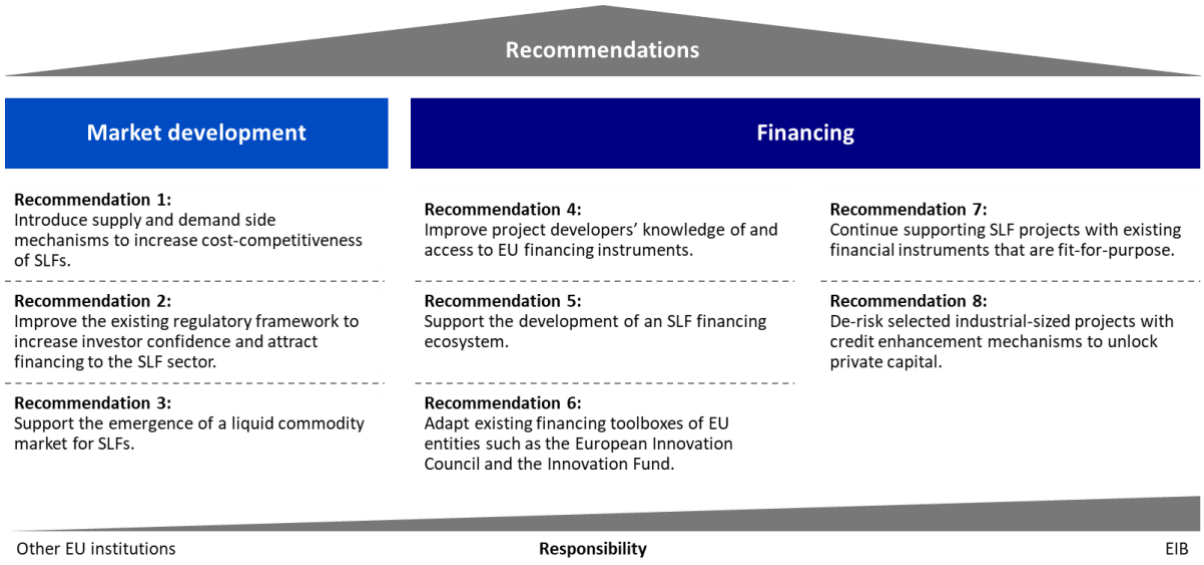
"Current projects lack economic competitiveness. In addition, strict regulatory hurdles from European legislators, rising interest rates and overall cloudy economic outlooks put project economics and feasibility to the test. Hence, most financial investment decisions have been delayed."

Biofuel producer

4 Recommendations for overcoming barriers and facilitating access to finance in the sustainable liquid fuels market

The market consultations and in-depth analysis of the findings in this study led to the development of eight recommendations for achieving sufficient investments in sustainable liquid fuel production and creating a liquid commoditised market. The recommendations are summarised in Figure 11 and described below.

Figure 11: Recommendations for overcoming barriers and facilitating access to finance for the sustainable liquid fuels sector



To put the recommendations into context, two parameters should be considered: the role and mandate of the EIB, and the link between access to finance for independent developers and attaining the EU decarbonisation targets.

The role and mandate of the EIB: Governed by all EU Member States, the EIB is the world's largest multilateral lender and largest provider of climate finance. It has selected financing products that enable it to finance high-risk projects such as sustainable liquid fuels.

In formulating recommendations for improving access-to-finance conditions, the study considered the current investment focus of the EIB and its operating principles, which are stipulated in the EIB Statute and other Treaty provisions. These conditions set the context in which the EIB can act.

In 2022, EIB Group financing reached €72 billion, €21 billion of which backed projects in sustainable energy and natural resources. The EIB has also entered the sustainable liquid fuel industry by financing mature technologies, such as the recent financing of a 255 kilotonne per year biofuels production facility in Spain that uses HEFA technology.

The EIB has a well-developed toolbox making it possible to finance capital-intensive projects with a mature risk-return profile. It can offer project developers attractive pricing conditions, reflecting its advantageous funding conditions on the market. To continue supporting such projects with favourable conditions, the EIB relies on low funding costs and hence must maintain its strong credit rating.

The EIB has also developed financing instruments (for example, thematic project finance) to support high-impact projects while protecting its credit rating. Adapting these instruments to the evolving needs of sustainable liquid fuel project developers, in addition to promoting a strong financing ecosystem (including with other EU institutions), has the potential to accelerate private sector investments in sustainable liquid fuels and encourage market uptake.

Relevance of access to finance for independent developers: The bold EU decarbonisation targets require a ramp-up of novel sustainable liquid fuel production technologies. Supporting earlier stage projects from independent developers could help to meet these targets.

The European Union has set itself the most ambitious decarbonisation targets in the world, including in the transport sector. These targets require a marked increase in sustainable liquid fuel production capacity when compared with the rates achieved historically for other technologies (for example, liquified natural gas). However, most production pathways for sustainable fuels are still at an early stage (for example, e-fuels) with interviewees describing high levels of project risk (market, technical and operational), and hence a struggle to secure external financing and by extension a hesitation to commit their own capital. The accelerated decarbonisation timeline needs public sector support for an enhanced flow of financing to sustainable liquid fuel projects.

Access to capital is particularly difficult for independent project developers. Internally, such developers lack the strong balance sheets — typical of major energy firms — for financing projects on balance sheet. These developers also face challenges in obtaining external financing due to high project risks and the inability to provide strong guarantees. However, independent developers have historically introduced new technologies to the energy and power sectors and are expected to play a similar role for sustainable liquid fuels. Without independent developers, the emergence of solar and wind energies and their early penetration of energy markets would have been more gradual. Independent developers are the participants most likely to disrupt established markets, promote early-stage projects and push innovation by introducing new technologies and processes. They are also expected to have a key role in maturing the sustainable liquid fuel market by proving the viability of new technological pathways.

In light of its ambitious decarbonisation targets, the European Union should support smaller and innovative producers to accelerate the roll-out of new sustainable liquid fuel production technologies and mature the market.

4.1 Recommendations on market development and regulation

Recommendation 1: Introduce supply- and demand-side mechanisms to increase the cost competitiveness of sustainable liquid fuels.

The current status of the market means making a positive business case for industrial sustainable liquid fuel production projects remains difficult for strategic investors. The production costs of these projects are several times greater than those of fossil fuel equivalents, thereby limiting the willingness of buyers to commit to purchasing sizeable volumes for extended periods. Including aviation and shipping in the EU Emissions Trading System is a first step towards closing the gap between sustainable liquid fuels and conventional fuels. However, projected EU Emissions Trading System prices will probably reach levels that are insufficient to close this gap. Even in the medium to long term, those interviewed for this study expect a significant cost gap to persist.

In market consultations, investors frequently expressed their concerns about the low returns offered by sustainable liquid fuel projects due to the persistent cost gap and high upfront capital spending requirements. These concerns are particularly relevant for first-of-a-kind industrial-scale deployments that typically have the highest costs. Historically, in the renewables sector, production facilities built early-on become uncompetitive in the medium to long term as new facilities come online with lower costs of production due to greater economies of scale and efficiencies. As a result, the market consultations revealed that there is a perceived first mover

disadvantage in the sustainable liquid fuel sector, particularly for e-fuel pathways. In the early stage of the market, additional support could close the cost gap and increase financial incentives and predictability for first or early movers.

The study recommends focusing support for sustainable liquid fuels on supply- and demand-side mechanisms that incentivise the roll-out of the first industrial-scale production projects. These initial deployments demonstrate the feasibility of various technologies, accelerate the development of the market and produce greater efficiencies via learning curves. The market consultations highlighted expectations that reduced production costs will initiate a virtuous cycle of larger deployments of production capacity and further cost reductions, which, over time, reduces the need for public support schemes.

Public support schemes for sustainable liquid fuels should seek the lowest achievable production costs via mechanisms such as periodic auctions. Interviewees believed that the achievable production cost should not be determined for a single sustainable fuel because future demand may be met by more than one. Such mechanisms should rather be based on modes of transport, with the market determining the most appropriate and competitive sustainable liquid fuel or combination of them.

Numerous mechanisms could reduce the cost gap for sustainable liquid fuels and promote their large-scale roll-out, including the following.

Contracts for difference

Of the various support mechanisms mentioned during the market consultations, (carbon) contracts for difference were repeatedly identified by participants as being among the most efficient mechanisms for incentivising investment in sustainable liquid fuel technologies. Under a contract for difference, a contracting authority (typically a public institution) awards a pre-defined fixed price (strike price) to a project for the energy produced. When the market price is below the strike price, the contracting authority pays the difference in price to the project. When the market price is greater than the strike price, the project refunds the difference to the contracting authority. Contracts for difference can overcome the first mover disadvantage for a less-established technology by providing projects with price certainty, regardless of how the market evolves (for example, production costs decline as technology matures). This certainty facilitates investor decisions in deploying the first industrial-scale plants.

An additional advantage of contracts for difference is that they can follow a technology-agnostic approach. In broad terms, the contracting authority specifies the amount of funding available under a contract for difference scheme and the transport sector to be supplied, while the market determines the optimal production pathway for that sustainable liquid fuel supply via an auction mechanism. Contracts for difference can also be geared to target upstream inputs, such as green hydrogen or renewable electricity for non-biological fuels.[6]

A contracts for difference scheme for sustainable liquid fuels could be funded by allocating a portion of shipping and aviation EU Emissions Trading System revenues for incentivising private investments in the production of fuels for the respective transport sector. However, given the volumes needed in the coming years (especially in aviation) and the current price differential between sustainable liquid fuels and conventional fuels, a contracts for difference scheme would likely only cover a limited number of projects. Nevertheless, even a limited contracts for difference scheme could positively affect the creation of a European sustainable liquid fuel market by allowing the first large-scale projects to be rapidly deployed and initiating the virtuous cycle expected by those interviewed for this study.

Tax incentives

The American Inflation Reduction Act, which was frequently mentioned by interviewees, is a scheme that increases the cost competitiveness of renewable fuels. Producers of renewables — including renewable fuels,

[6] The European Hydrogen Bank, introduced by the European Commission in early 2023, uses a comparable model. It aims to accelerate the roll-out of green hydrogen in the European Union by targeting the production of 10 million tonnes by 2030. The first pilot auctions are underway, backed by €800 million from the Innovation Fund. In November 2023, the European Union announced the launch of a second auction worth €2.2 billion in spring 2024. As hydrogen is a key feedstock for e-fuels, this could already have a positive effect on sustainable liquid fuels.

hydrogen or captured carbon dioxide — can claim tax reductions based on the amount and sustainability of the fuels produced. Tax credits can be investment tax credits or production tax credits. Investment tax credits can total 40% of the investment costs in renewable production assets, whereas production tax credits are calculated based on the product and amount produced.

An advantage of tax credits is the low complexity and direct effect of support for producers, compared with other support schemes. Tax credits are typically not linked to complex application systems or eligibility criteria but rather are directly linked to producers' core businesses. Production tax credits contribute directly to reducing the cost gap. In the early market stages before significant cost reductions are achieved, tax credits could accelerate the economic viability of sustainable liquid fuels.

Another advantage of tax incentives is the comprehensiveness of their scope. Conventional incentive schemes often target certain types of players, whereas tax credits are available to any producer of a certain product.

The Inflation Reduction Act tax incentives were frequently mentioned by interviewees for their flexibility. The level of support offered is directly linked to the sustainability of the underlying fuel. Production credits for sustainable aviation fuel range from $1.25 to $1.75 per gallon, depending on the actual emission reductions of the fuel. A minimum 50% emission reduction is required for the lower boundary. For each additional percentage point, tax credits rise by $0.01 per gallon. This sliding support allows producers to find the optimal technological pathway without benefiting producers focused on the least sustainable fuels.

The introduction of tax credits via the Inflation Reduction Act has incentivised several sustainable liquid fuel producers to pursue production projects in the United States instead of Europe. As a result, large-scale projects in the United States are close to final investment decisions due to the tax credits boosting their economic viability. Introducing similar incentive schemes in Europe could convince project promoters to undertake such investments and reverse the migration of sustainable liquid fuel projects to the United States.

Increased fossil fuel surcharges

Increased prices for carbon emissions reduces the price differential between sustainable liquid fuels and their fossil fuel equivalents. This increased cost for carbon emissions can be achieved by expanding and strengthening the current EU Emissions Trading System. By reducing the number of free emission allowances, regulators can steer EU Emissions Trading System prices upwards and close the gap between sustainable liquid fuels and fossil fuel equivalents.

Another instrument that was frequently discussed in the consultations is a fossil fuel surcharge, which would be redistributed to sustainable liquid fuel producers to subsidise their production. Such a charge could be designed in a similar manner to the German renewable energy surcharge (Erneuerbare-Energien-Gesetz Umlage) used for accelerating the development of renewable energy sources.

A similar scheme could also be implemented in the transport sectors, with passengers and shippers of goods using fossil fuels in their transport paying a surcharge, which is then redistributed to sustainable fuel production. A competitive bidding process would ensure that only the most efficient producers and production pathways benefit from the redistributed proceeds.

The EU decarbonisation framework encapsulated in the European Green Deal and Fit-for-55 initiative underscores the commitment of the European Union to achieving climate neutrality by 2050. A highlight of the Fit-for-55 package is the introduction of two critical regulations aimed at increasing the uptake of sustainable liquid fuels in aviation and shipping: ReFuelEU Aviation and FuelEU Maritime. The mandatory blending quotas for sustainable aviation fuel are particularly lauded by market participants as an important catalyst in generating demand for the fuel.

In the market consultations, the European Union was acknowledged as leading the global efforts in limiting climate change, but interviewees stressed that regulatory improvements could further these efforts. The study recommends the following three areas where the current EU regulatory framework for sustainable liquid fuels could be improved to unlock additional investments in related projects:

- reduction of uncertainty;

- reduction of complexity;
- the exemption of new or existing sustainable liquid fuel projects from regulatory limitations that could lead to bottlenecks in the future.

Reducing uncertainty for investments

The possibility of improving regulation predictability was raised in the interviews, specifically regarding unfinished or missing regulations, frequent revision cycles and the implementation of EU directives into national laws of Member States. The early phase of the sustainable liquid fuel market means current demand is primarily driven by regulation. Regulators should therefore provide greater certainty and predictability to facilitate long-term investments. Steps taken to this end could include:

- introducing ambitious and binding blending mandates in all transport sectors, similar to ReFuelEU Aviation, especially for the maritime sector;
- harmonising long-term decarbonisation targets with those of industry associations (for example, the International Maritime Organization and the International Civil Aviation Organization);
- including long-term targets under RED III (beyond 2030), similar to ReFuelEU Aviation and FuelEU Maritime;
- finalising key regulations such as the revised Energy Taxation Directive and RED III (entered into force on 20 November 2023 after the market consultation);
- harmonising and streamlining feedstock eligibility for biofuel production as well as their caps and double counting towards renewable energy targets across all relevant EU regulations (ReFuelEU Aviation, FuelEU Maritime and RED III);
- swiftly implementing EU directives into national law;
- establishing a European clearing house, especially for sustainable aviation fuels, to accelerate and streamline the fuel approval process.

Reducing the complexity of current regulations

The market consultation revealed a lack of knowledge and some misunderstanding of existing regulations (for example, penalty schemes, eligibility criteria under RED II and delegated acts). In addition, investors expressed concerns about the resources and effort required in reviewing and understanding existing regulations and keeping abreast of proposed and adopted revisions. Improving understanding and accessibility of the regulatory framework is a complex but critical task to increase investor confidence and enable capital commitments to be made.

Reducing the complexity of the regulatory framework should be tackled at European and national levels. At a European level, regulations could be streamlined by reducing cross-referencing across different regulations and simplifying sustainability criteria, penalty schemes for non-compliance and calculations for carbon dioxide emissions, and aligning them across all relevant EU directives. At a national level, Member States should take a common approach in implementing EU directives into national law.

Finally, increasing visibility and access to relevant regulations is recommended. This could be done, for example, through a digital platform that allows users to identify and filter relevant laws by fuel type, market player and transport sector.

Grandfathering regulatory limitations that could lead to bottlenecks

Over the past 12 months, EU institutions have adopted and published numerous directives, regulations and delegated acts that stipulate the use of renewable and low-carbon fuels in transport. These include ReFuelEU Aviation (October 2023), FuelEU Maritime (July 2023), the Alternative Fuel Infrastructure Regulation (July 2023) and the Delegated Acts on Renewable Hydrogen (June 2023). The interviewees in this study welcome the introduction of the new regulations, which will ensure alignment of EU policies with its climate goals through the setting of ambitious targets and strict sustainability criteria, and are confident that this will contribute to removing the previously mentioned uncertainties for investors.

However, interviewees expressed concerns that the regulations might be too strict, especially for fuel feedstocks and power-to-liquid production pathways in this early stage of the market, and could stall overall market uptake. Most frequently mentioned were the two delegated acts outlining rules on the EU definition of renewable hydrogen and the methodology for assessing greenhouse gas emission savings from renewable fuels of non-biological origin. The expected scarcity in the supply of inputs for sustainable liquid fuel production, such as renewable electricity or carbon dioxide from biological sources and/or novel technologies, and the resulting shortage of sustainable liquid fuels, which could hinder market uptake, indicate that a more long-term approach should be taken in ensuring the levels of fuel feedstocks are sufficient, especially in the early stage of the market.

The following suggestions for addressing this issue were mentioned in the consultations:

- Introduce grandfathering clauses to count industrial carbon dioxide for the production of e-fuels as avoided beyond 2041 for production plants that start operating in the coming years.
- Continuously monitor capacity expansion and availability of renewable electricity and adjust additionality, temporal and geographical correlation principles for the production of renewable hydrogen if bottlenecks arise.
- Lower sustainability criteria (for example, 60% emission savings) for biofuels in the early stage of the market and strengthen these criteria once novel biofuel pathways become commercially available and unlock additional sources of bio-feedstock.

Recommendation 3: Support the emergence of a liquid commodity market for sustainable liquid

This study found that the sustainable liquid fuel industry is still in its infancy and has various weaknesses including limited long-term visibility on supply and demand, disconnected production and offtake centres, limited product standardisation and underdeveloped supply chains. For the European Union to meet its decarbonisation targets for the transport sector, a liquid market is needed allowing price transparency and the seamless trade of large volumes of sustainable fuels, enhancing predictability in the offtake of production. Based on the market consultations, there are a number of mechanisms could support the emergence of such a liquid market.

Book-and-claim mechanisms

The book-and-claim mechanism is a common practice in which a sustainability claim of a consumer is separated from the physical delivery of goods. Such mechanisms are very efficient as they overcome distribution bottlenecks and deficient supply chains while reducing overall costs and emissions by optimising existing supply chains.

Book-and-claim mechanisms are particularly valuable for the aviation and shipping sectors, which will experience continuous growth in sustainable liquid fuel demand. The mechanisms would allow airlines and/or shipping companies who have paid the sustainable liquid fuel premium to claim the volumes as part of their fulfilment of blending mandates without having to physically use the fuels. Instead, the fuels are used by other buyers close to the production facility. A book-and-claim system can also achieve efficiencies in production by allowing supply and demand centres to cluster in a single location, thereby enabling larger facilities at sites with the most favourable conditions for production.

The European Commission is understood to be assessing possibilities for improving the tradability of sustainable aviation fuels, including with book-and-claim mechanisms, and will prepare a feasibility report by 2024.

Regional sustainable liquid fuel demand clusters, potentially built around existing hydrogen clusters

To overcome underdeveloped supply chains and infrastructure, especially for e-fuels, public entities could support the formation of demand clusters for sustainable liquid fuels and/or their key feedstocks (for example, hydrogen and carbon dioxide) around key regional demand centres (for example, ports and industrial zones).

These clusters could improve the overall economics behind projects by optimising the use and expansion of required supply chain infrastructure and by aggregating various buyers of sustainable liquid fuels, hydrogen and carbon dioxide. This could even extend beyond the transport sector and include industrial consumers of hydrogen, methanol and ammonia.

Support could be through collaborative initiatives and matchmaking platforms for various participants along the value chain. An example is the Hydrogen Valley platform, which is a global collaboration platform implemented by the Clean Hydrogen Joint Undertaking and Mission Innovation, aiming to connect regional hydrogen clusters into an integrated hydrogen ecosystem.

Market maker mechanisms and/or demand and supply aggregators

Finally, investors expressed the need for publicly backed market makers or intermediaries who provide liquidity by buying and selling sustainable liquid fuels, while markets and supply remain restricted to individual projects. Depending on the design of the market maker instruments, several barriers could be mitigated, including:

- volume mismatch through aggregation of small-scale demand and matching with producer volumes;
- maturity mismatch between long-term purchase agreements with producers and short-term sale agreements with buyers;
- limited long-term visibility for producers on offtake volumes and prices;
- counterparty credit risks (especially for aviation offtake) for producers and project developers.

Market maker mechanisms could also be combined with other mechanisms such as contracts for difference, allowing the market maker to enter into long-term purchase agreements and short-term sale agreements, even if a cost gap persists. In such cases, price differences will be compensated by public grants. The combination of long-term purchase agreements and public backing could provide the security needed for project developers and lenders to unlock large-scale investments and may have a catalytic effect on the whole industry. Although still at an early stage, the German H2Global instrument was mentioned frequently in the market consultations and could be rolled out for sustainable liquid fuels in Europe. Another less stringent mechanism is AggregateEU, which is the demand aggregation and joint purchasing mechanism of the European Commission and contributes to the security of supply for liquified natural gas.

4.2 Recommendations on improving access to finance

Recommendation 4: Improve project developers' knowledge of and access to EU financing instruments.

The market consultations suggested that in the near term sustainable liquid fuel production projects will continue experiencing high levels of risk, impeding funding from commercial lenders. Most projects will therefore require some form of blended finance to mitigate perceived project risks. In the consultations, investors lacked basic knowledge about available EU financing instruments and saw the application processes for such instruments as lengthy and cumbersome. The study recommends the following three actions for improving market players' knowledge of and access to EU financing instruments:

- developing a digital information platform for navigating through existing financial instruments that are relevant to sustainable liquid fuel projects;
- promoting financial advisory services and expanding their coverage;
- promoting the offer of project development assistance.

Digital information platform on EU financing

Discussions with the EIB and other EU institutions revealed that there are numerous financing instruments available, covering various value chain steps and development stages of sustainable liquid fuel projects.

However, the interviewees in this study were unaware of such instruments or displayed little knowledge of them. There seems to be a significant disconnect between the informational campaigns carried out by EU institutions about their project assistance programmes and sources of funding, and the knowledge that project promoters have about these programmes and instruments.

Knowledge about financing opportunities available from EU institutions could be improved by establishing a dedicated digital financing platform, structured according to the needs of promoters and the stages and statuses of projects as they move through the project lifecycle. The platform could serve as the first landing point for project promoters and therefore should collate key information on relevant financing instruments available from EU institutions. The platform could also be equipped to suggest applicable financing instruments for a specific project, based on selected criteria. In addition, depending on the instruments indicated, the platform could provide the contact details of information officers at respective EU institutions who could further assist the interested party in understanding and accessing the appropriate instrument or support programmes.

Promoting financial advisory services and expanding their coverage

The lack of knowledge and difficulties with the application processes of public support instruments reported by investors indicates the need for support in navigating and applying for EU financing instruments. EIB Advisory already offers support to project promoters that are interested in accessing public and private sources of financing, including public grants.

A vital step in rectifying the knowledge gap is to increase promotional efforts of the advisory services of the EIB, thereby increasing awareness and demand for them among project promoters. The range of advisory services could be expanded to cover the entire project lifecycle up to final investment decisions. A special focus should be placed on:

- identifying appropriate financing instruments within EU institutions (the EIB, the European Investment Fund (EIF), the European Innovation Council, and the European Climate, Infrastructure, and Environment Executive Agency (CINEA));
- coordinating between or within EU institutions (for example, key points of contact);
- identifying and selecting private equity providers and lenders for blended finance solutions;
- facilitating blended financing solutions with commercial investors.

Promoting project development assistance

Once appropriate EU financing instruments are identified, targeted project development assistance — financial and technical — could help project promoters to receive EU financing, for example, by accelerating project maturity and/or ensuring compliance with the financing requirements of grantors. For project development assistance, the EIB can use its experience from providing such services under the Innovation Fund, the NER 300 programme and more recently under InvestEU. Lessons learnt from these project development assistance services, especially in the field of clean energy topics, could be used for further development of sustainable liquid fuel projects. By providing such services, the maturity and de-risking of these projects could be accelerated and EU financing unlocked.

Recommendation 5: Support the development of a sustainable liquid fuel ecosystem.

The market consultations show that the environment for participants in the sustainable fuels sector is developing rapidly but remains immature. Several deficiencies were identified during the consultations. Project promoters can lack understanding of available public financing instruments, and do not have a clear overview of the private financing landscape and the type of investors and lenders willing to provide capital at various stages of a project's development. Investors and lenders may not understand the technological fundamentals of sustainable fuels (especially ammonia and methanol in shipping), and hence struggle with assessing risks and opportunities. In addition, traditional fuel traders and buyers have so far limited their exposure to trading sustainable fuels (especially e-fuels). As a result, cooperation between these various parties is challenging. To resolve this difficulty, several collaborative efforts, such as the Renewable and Low-Carbon Fuels Value Chain Industrial Alliance promoted by the European Commission's Directorate-General for Mobility and Transport, have been undertaken with the aim of facilitating knowledge sharing, identifying financing opportunities and promoting the development of a strong sustainable liquid fuel project pipeline.

The study recommends reinforcing these collaborative efforts to promote the development of a dynamic sustainable liquid fuel ecosystem, with priority given to the following four actions:

Collaboration across the sustainable liquid fuel value chain

Initiatives such as the Renewable and Low-Carbon Fuels Value Chain Industrial Alliance should be continued and expanded. Such efforts could further the connections between project developers, investors and lenders and incorporate best practices and lessons learnt from projects that have begun operating (as the sector evolves). Furthermore, cooperation with similar initiatives from other sectors should be encouraged (for example, the Clean Hydrogen Partnership).

Blended finance instruments

Given the high levels of risk, initial sustainable liquid fuel projects will likely require blended finance instruments to secure financing. The deployment of such instruments could be supported by launching initiatives that increase awareness of the instruments, their availability and access to them. The European Union and the EIB are already offering blended instruments in a partnership with Breakthrough Energy. Under this partnership, the EU seeks to mobilise up to €820 million for demonstration and large first-of-its-kind projects in the field of clean hydrogen, sustainable aviation fuel and direct air capture. The partnership could be a model for a systemic roll-out with other financial players and grant providers, with the respective scopes expanded to cover sustainable fuels for the maritime sector.

Matchmaking between financial players and project promoters

One objective of the Renewable and Low-Carbon Fuels Value Chain Industrial Alliance is to increase access to public and private finance. As a result, the alliance is planning matchmaking sessions between its members. Additional matchmaking efforts should be undertaken in collaboration with the EU institutions. Such efforts could include dedicated matchmaking platforms as implemented with the Smart Cities Marketplace by the European Commission, where Investor Networks were created to connect financiers with cities and project developers.

Project de-risking through knowledge sharing

EU institutions (European Commission Directorates-General, the EIB, the EIF and CINEA) have accumulated considerable knowledge on techno-economic aspects of sustainable liquid fuels and on the development of fuel projects. This expertise should be distilled into lessons learnt and best practices for the sustainable liquid fuel sector, which should then be shared with market players. Two thematic focus areas could be developed, aimed at reducing knowledge gaps among selected audiences:

- **Sustainable liquid fuel project de-risking architecture** for project promoters to facilitate limited recourse financing, including best practices on commercial structuring, designing bankable supply and offtake term sheets, risk allocation in contract negotiations and counterpart credit risk mitigation strategies.
- **Sustainable liquid fuel technologies and technology assessment** for financial institutions to increase their expertise on the underlying technological aspects of sustainable fuels and enhance their technical assessments of such projects.

Support could be provided via dedicated project development services for market participants and through recurring knowledge seminars and workshops, organised with industry experts. For example, under the European Commission's Smart Cities Marketplace Initiative, workshop-based finance masterclasses are offered to city administrations and smart city project developers to support the bankability of their projects.

Recommendation 6: Adapt existing financing toolboxes of EU entities such as the European Innovation Council and the Innovation Fund.

The sustainable liquid fuel ecosystem is highly innovative from a technology perspective but immature from a market perspective. Significant funding is needed for accelerating innovation, commercialising promising technologies and ultimately scaling up production capacity. European institutions offer various funding schemes covering a broad range of technology readiness levels for innovative technologies, products and business models. The study recommends continuing these funding frameworks, improving access to them for sustainable liquid fuel innovators and project developers, and where necessary modifying the instruments.

European Innovation Council

Equipped with a total budget of €10 billion, the European Innovation Council was established under the EU Horizon Europe programme to support game-changing innovations throughout their lifecycle from early-stage research to proof of concept, and the financing and scale-up of startups and small and medium businesses. European Innovation Council funding is structured in three schemes (Pathfinder, Transition and Accelerator) and comes as a combination of grants (between €2.5 million and €4 million) and equity (up to €15 million). The European Innovation Council funding opportunities are not for supporting the uptake of industrial-scale sustainable liquid fuel production facilities, but are suitable for supporting innovators and startups developing novel production pathways. The study recommends making European Innovation Council funding available to deep-tech and early-stage startups in the sustainable liquid fuel field.

EU Innovation Fund

Funded by revenues from the EU Emissions Trading System, the Innovation Fund aims to create financial incentives for companies to invest in the demonstration of innovative, low-carbon technologies. The Innovation Fund is well established, with interviewees in this study highlighting its effectiveness in incentivising investments in low-carbon technologies. Initially, two distinct budgets were available from the Innovation Fund — one for large-scale projects and one for small-scale projects (capital expenditure of up to €7.5 million) — implicitly channelling most grants to large developers with sufficient capabilities and resources. Sustainable liquid fuel projects, especially those from independent project developers, were thus scarcely supported in past funding calls. Interviewees in this study demanded a greater focus on sustainable liquid fuel production and for the inclusion of medium-sized projects with capital expenditure of up to €100 million.

In November 2023, the latest call for proposals opened, with a dedicated budget of €4 billion. For the first time, the call includes a dedicated middle tranche for projects in the capital expenditure range of €20 million to €100 million, along with two additional compartments for small- and large-scale projects. Funding is provided as non-repayable grants and can cover up to 60% of a project's relevant cost (capital spending and operating expenses). Following the recent revision of the EU Emissions Trading System, the call is now open to all three transport sectors (aviation, maritime and road). This new call will improve financing conditions for pioneer projects aiming to commercialise novel technologies prior to industrial scale-up.

The study recommends monitoring the effect of the latest call on sustainable liquid fuel project funding. If the number of supported projects and developers (including small independent developers) remains low, barriers to their success should be investigated. The Innovation Fund could then enhance its focus on promising production pathways by considering the status of the sustainable liquid fuel industry (for example, carbon dioxide abatement costs and overall maturity) when determining eligibility and award criteria. Finally, to improve the success rate of innovative project developers and small and medium businesses being awarded Innovation Fund grants, the study recommends maintaining and tailoring the EIB project development assistance programme to small-scale companies who often lack the track record, experience and capabilities to obtain EU grants.

Recommendation 7: Continue supporting sustainable liquid fuel projects with existing financial instruments that are fit-for-purpose.

The EIB currently offers financing instruments that are suitable for supporting higher-risk sustainable liquid fuel technologies and projects that are not bankable for commercial lenders.

EIB thematic impact finance

With the support of the European Commission (via risk guarantees), the EIB offers thematic venture debt and project financing of up to €75 million to innovative technologies and projects in selected sectors. These instruments target startups and/or established companies that are showcasing commercial-scale demonstration or scale-up of innovative technologies in five climate action focus areas including energy and low-carbon fuels. In total, up to €1 billion is earmarked for thematic finance, a substantial portion of which has already been allocated.

The study found that the sustainable liquid fuel project pipeline must be strengthened and brought to maturity to meet the EU decarbonisation targets, with independent project developers likely playing a pivotal role in such efforts. The study therefore recommends committing additional financial resources to thematic impact finance and allocating a significant share to sustainable liquid fuel projects, especially in the current early phase of the market where project risks (including technology) remain high.

The study showed that various sustainable liquid fuel production pathways are transitioning from a technology demonstration phase towards the phase of industrial- and commercial-scale plants. Industrial-scale projects are complex and capital-intensive, requiring investments of hundreds of millions to billions of euros. However, despite the transition from demonstration to commercial plants, project risks remain high, preventing such projects from easily accessing private financing. Therefore, thematic finance can have a crucial role even at this stage of the sector's development. However, the current loan size for EIB thematic finance is inadequate for these larger-scale projects and should be increased to around €200 million to €300 million. Such amounts will enable the EIB to have a material impact on the financing of the first large-scale innovative sustainable liquid fuel production facilities, which are vital for initiating the rapid development of the sector. Continuous monitoring and, if necessary, adjustments to eligibility and ticket size should be considered to keep thematic finance fit-for-purpose in this sector.

European Investment Fund — funds-of-funds

Part of the EIB Group, the EIF provides equity finance to small and medium European enterprises by taking significant minority stakes in privately managed funds. This seed capital has a catalytic effect by attracting commitments from private investors. The EIF has invested in over 200 funds across various sectors and locations.

These funds could be a source of equity for innovators and independent project developers. This study recommends two sequential steps in the development of the funds. First, the EIF should invest in funds that incorporate sustainable liquid fuels as a key investment theme within their broader fund strategy. Subsequently, when the sector has further matured, dedicated sustainable liquid fuel funds should be established. To do this, the EIF would work together with European private equity and infrastructure funds that are specialised in clean technology and potentially already have a track record in these fuels. Investment could focus on the following three areas:

- early-stage sustainable liquid fuel innovators aiming to develop innovative production pathways for liquid fuels and/or required feedstocks (hydrogen production, carbon capture);
- project developers of sustainable bio- and/or e-fuel production facilities;
- project developers of renewable energy projects (solar photovoltaics, on- and offshore wind) to increase the required renewable capacity for e-fuel production.

Recommendation 8: De-risk selected industrial-sized projects with credit enhancement mechanisms to unlock private capital.

As described above, sustainable liquid fuel projects are subject to various risks that impede project developers from attracting limited recourse project finance and hinder the roll-out of first-of-a-kind large-scale projects. As previously mentioned, such deployments are critical for financial investors gaining experience, accelerating long-term learning curve synergies and unlocking additional private capital. Given the current risk profile of sustainable liquid fuel projects, a holistic de-risking architecture is needed for commercial lenders to commit capital.

During the market consultations, financial investors highlighted credit enhancement mechanisms as a key element in improving the risk-return profiles of large-scale, first-of-a-kind sustainable liquid fuel projects. The study recommends developing new risk mitigation instruments to unlock greater volumes of private financing. Such instruments could include first-loss guarantees and/or subordinated loans, issued by the EIB and with the support of the European Commission.

First-loss guarantees

A first-loss guarantee is a mechanism whereby a third party (for example, the EIB, the European Commission or national promotional banks) compensates lenders up to a certain percentage of the underlying loan in the event of a borrower default. The issuer of the guarantee receives remuneration in return. The advantage of these instruments for the public is twofold. First, it is financially efficient for the guarantor if the amount of capital needed for covering the provisions is lower than the actual guaranteed amount. Second, guarantees are powerful mechanisms for unlocking private financing because they reduce the risk exposure for lenders to a range of risks, thereby making (previously unbankable) projects bankable.

Subordinated loans

Subordinated loans provided by the EIB could mobilise private financing by altering the risk-reward relationship for senior lenders. In a blended financing structure, a subordinated loan provided by the EIB is repaid only after the senior debt has been serviced, thereby reducing the probability of default for senior lenders. In the market consultations, financial investors frequently mentioned that public participation in projects sends a strong market signal and can crowd in private investment by increasing investors' willingness to provide financing. The EIB would likely require support from the European Commission in the provision of subordinated loans to higher-risk sustainable liquid fuel projects.

For first-loss guarantees and subordinated loans, determining the required level of public support is a challenging but crucial task. Public support that is too low will be insufficient to stimulate investments, whereas public support that is too generous will enable lenders to generate excess profits in relation to the underlying risk of the project, thereby wasting public resources.

Credit enhancements should be used judiciously and selectively to de-risk first-of-a-kind large-scale projects that are necessary for gaining experience and achieving learning curve synergies. Once such deployments have been successfully rolled out and the virtuous cycle of sustainable liquid fuel technology cost reduction has begun, public support instruments should be phased out.

5 Concluding remarks and next steps

The ambitious EU decarbonisation targets for the transport sector are expected to significantly increase demand for sustainable liquid fuels in the next decade. Driven partly by EU policy support, investors have identified these fuels as an attractive market segment and are exploring investment opportunities. This increased interest has led to a growing but still limited project pipeline. A large majority of the interviewees consulted for this study are already investing in or are planning to invest in sustainable liquid fuel projects.

Despite its initial rapid development, the nascent sustainable liquid fuel market still faces challenges that are impeding further investment. As a result, almost all large-scale European projects in this domain lack the capital commitment for proceeding with deployment. Non-existent markets, weak project economics, regulatory uncertainties and technology risks are slowing project development and posing significant barriers to the large-scale mobilisation of project financing, meaning initial large-scale deployments are scarce or non-existent. However, such deployments are vital for providing the operational experience necessary to achieve the efficiency gains and cost reductions that will accelerate the roll-out of production capacity.

To support and accelerate the development of the European sustainable liquid fuel sector, this report outlines proposed regulatory improvements, financial instruments and market development efforts to be undertaken by the EIB Group and EU institutions.

A rapid ramp-up of production capacity is needed to meet the bold EU decarbonisation targets and timelines, and this study found that support from policymakers will be crucial in achieving this. Reducing the risk profile of projects, increasing their competitiveness compared with conventional fuels and strengthening the regulatory framework are important steps in improving access to finance in the sustainable liquid fuel sector. Consultations with companies involved in this market found that supply- and demand-side mechanisms are particularly effective in improving the risk-return profiles of projects of this kind.

To fully mobilise private financing and initiate the development of a sustainable liquid fuel market, the de-risking of selected first-of-a-kind large-scale projects is required. New risk mitigation instruments provided by public entities could facilitate the participation of private lenders in financing these initial projects. The EIB also has existing financing products that, if tailored to large-scale sustainable liquid fuel projects, could play a crucial role in financing them. Furthermore, the study found that the emergence of a sustainable liquid fuel financing ecosystem should be promoted by the EIB in collaboration with other EU institutions.

Finally, EIB Advisory should continue coordinating with EU policymakers and market participants in observing the development of the sustainable liquid fuel sector, identifying barriers and working together on actions to overcome such barriers. Ultimately, these efforts will accelerate the uptake of these fuels within the European Union and contribute to the decarbonisation of the European transport sector.

Market participants interested in products and services offered by the EIB are invited to visit the EIB website (http://www.eib.org/en/products/) or to contact EIB Advisory.

6 Annex

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6.2 List of abbreviations

Acronym	Definition
CINEA	European Climate, Infrastructure, and Environment Executive Agency
EIB	European Investment Bank
EIF	European Investment Fund
EU	European Union
FAME	Fatty Acid Methyl Ester
HEFA	Hydroprocessed Esters and Fatty Acids
mtoe	Million tonnes of oil equivalents
RED II	Renewable Energy Directive II
RED III	Renewable Energy Directive III

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