

# Fueling the future

How can Europe scale up  
SAF production?

EY global SAF study

March 25, 2024

Prepared for





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**- Dr Axel Kraft**  
SAF expert, Fraunhofer UMSICHT

To download the full SAF study please press here [LINK](#)

# Agenda



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# 01

Introduction to the study

# Europe is one of the regions that might struggle to fulfill growing SAF mandates. There is a lack of efficient financing tools to scale up mega projects and make them bankable



In **several global regions**, such as the EU, UK, and USA, **robust policy frameworks** are in place, mandating the use of **SAF** to **drive** the **decarbonization** of aviation. These regulations set blending targets, incentives, and compliance mechanisms, ensuring a structured transition toward lower-emission air travel



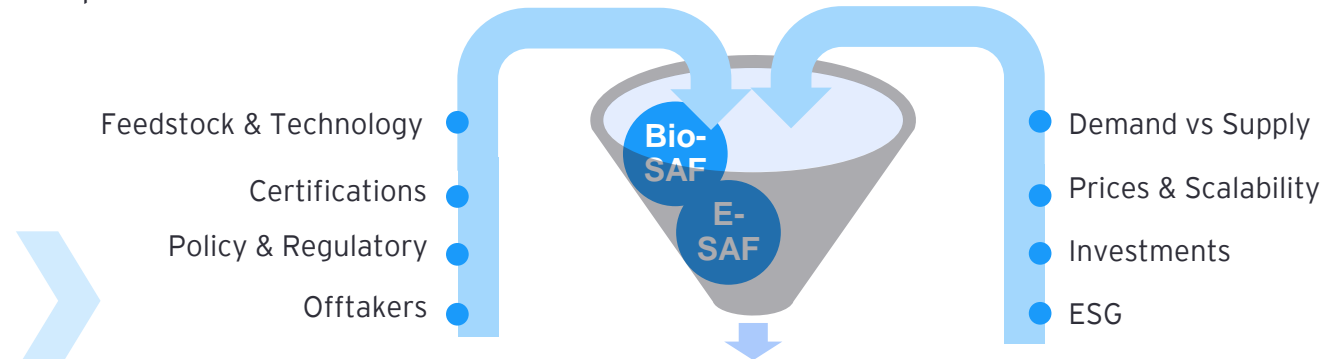
SAF producers **face high production costs**, **limited economies of scale**, and **expensive feedstocks**, making production financially challenging. As a result, SAF is currently **2-5 times** more **expensive** than **conventional jet** fuel, hindering widespread adoption



SAF projects, particularly e-Fuels, require **substantial investments**, ranging from **\$260 million** to **\$3 billion per facility**. These high capital costs are essential to scale production and meet the growing global demand for SAF by **2050**



**Airlines** operate on **thin profit margins** and are **reluctant** to **commit** to **SAF** due to its high costs and the lack of cost pass-through mechanisms. The **low willingness** to **pay** for a **premium** fuel further slows adoption, making large-scale investment and **long-term contracts** challenging









**How to ensure the bankability of SAF projects & secure future investments?**








# 02

SAF technology significance  
and certification landscape

# There are currently eleven certified production pathways for SAF, with additional pathways under development and awaiting certification (1/2)






Conversion process ASTM terminology	Feedstock supply chain	Blend Ratio Components	Certification year	Operator/ Licensor *TRL 7-9
ASTM D7566		Blending of alternative fuels		
Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene (FT-SPK) - Annex A1	Coal, natural gas, biomass, polymers	50% normal paraffin, isoparaffin	2009	
Hydroprocessed esters and fatty acids (HEFA) - Annex A2	Plant oil, related used cooking oils, waste and animal fats	50% normal paraffin, isoparaffin	2011	
Synthesized iso-paraffines from hydroprocessed fermented sugar (SIP) - Annex 3	Biomass from sugar processing	10% isoparaffin	2014	
Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene plus aromatics (FT-SKP/A) - Annex A4	Coal, natural gas, biomass, polymers	50% normal paraffin, cycloparaffin, isoparaffin and aromatics	2015	
Alcohol-to-jet-synthetic paraffinic kerosene (ATJ-SPK) - Annex A5	Synthesis gas and biomass biochemically converted to ethanol or iso-butanol	50% normal paraffin, isoparaffin	2016	
Catalytic hydrothermolysis jet (CHJ) - Annex A6	Plant oils, animal fats, waste fats and related free fatty acids	50% normal paraffin, cycloparaffin, isoparaffin and aromatics	2020	

# There are currently eleven certified production pathways for SAF, with additional pathways under development and awaiting certification (2/2)

Conversion process ASTM terminology	Feedstock supply chain	Blend Ratio Components	Certifica- tion year	Operator/ Licensor *TRL 7-9
<b>ASTM D7566</b>		<b>Blending of alternative fuels</b>		
Synthesized paraffinic kerosene from hydro-processed hydrocarbons, esters and fatty acids (HC-HEFAs) - Annex A7	Terpenes of algae <i>Botryococcus braunii</i>	10% normal paraffin, cycloparaffin, isoparaffin	2018	 IHI   POWER SERVICES CORP.
Alcohol-to-jet synthetic paraffinic kerosene with aromatics (ATJ-SKA) - Annex A8	Synthesis gas and biomass biochemically converted to C2-to-C5-alkohols	50% normal paraffin, cycloparaffin, isoparaffin and aromatics	2023	 Swedish Biofuels™  LanzaTech
<b>ASTM D1655</b>		<b>Co-processing in a refinery</b>		
Co-processing of Fischer-Tropsch hydrocarbons in conventional refinery (co-processed SAF)	Fischer-Tropsch hydrocarbons with fossil hydrocarbons	5%	2020	 Fulcrum BIOENERGY
Co-processing of esters and fatty acids in conventional refinery (co-processed SAF)	Hydrocarbons from fats and oils with fossil hydrocarbons and crude oil fractions	5% (future may bring 30%)	2020	
Co-processing of esters and fatty acids in conventional refinery (co-processed SAF)	Hydrocarbons from hydroprocessed fats and oils with fossil hydrocarbons (max.24% of feed)	10%	2023	<b>TOPSOE</b>

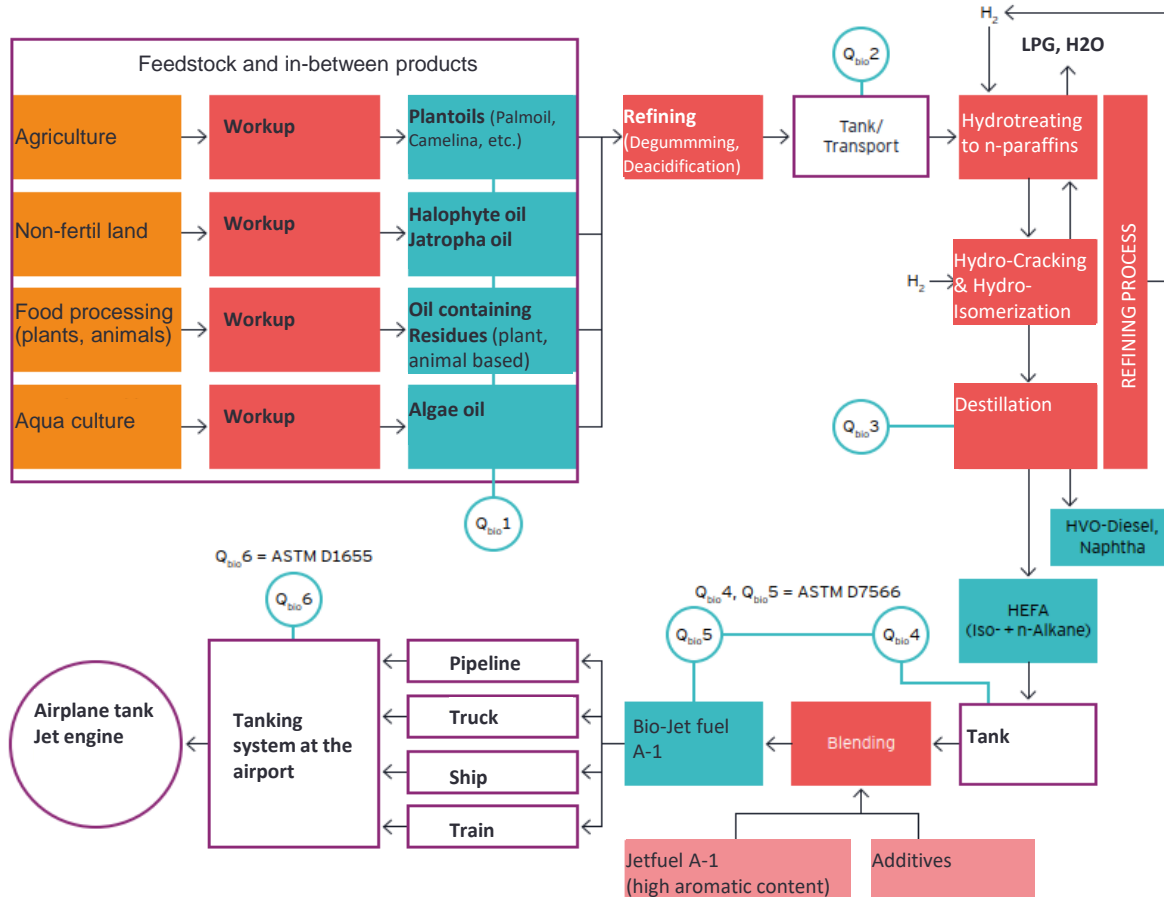


# Several additional production pathways are currently in the final stages of the certification approval process

In the pipeline (not exhaustive) Conversion process, terminology	Feedstock supply chain	Blend Ratio Components	Certifica- tion year	Operator/ Licensor
Synthesized aromatic kerosene (SAK)	Derived from plant sugars	-	-	
Pyrolysis of non-recyclable plastics (ReOil)	Plastics	-	-	
Methanol-to-jet (Methanol from syngas)	Methanol and ethanol	-	-	
Cycloalkanes and aromatics (via Deoxygenation and Oligomerization)	Ethanol	-	-	
Cycloalkanes (75%) and paraffins (fermentation to Isoprene as intermediate)	Sugar and «waste biomass»	-	-	

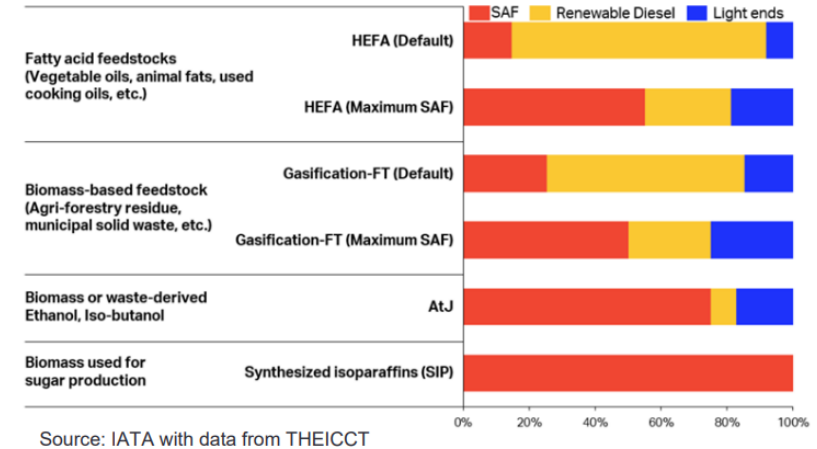
# Currently, HEFA-SPK is the most widely recognized and utilized production pathway in Europe

## HEFA route



● Source  
● Processes  
● Product  
○ Logistic

## Different SAF pathways with feedstock\*

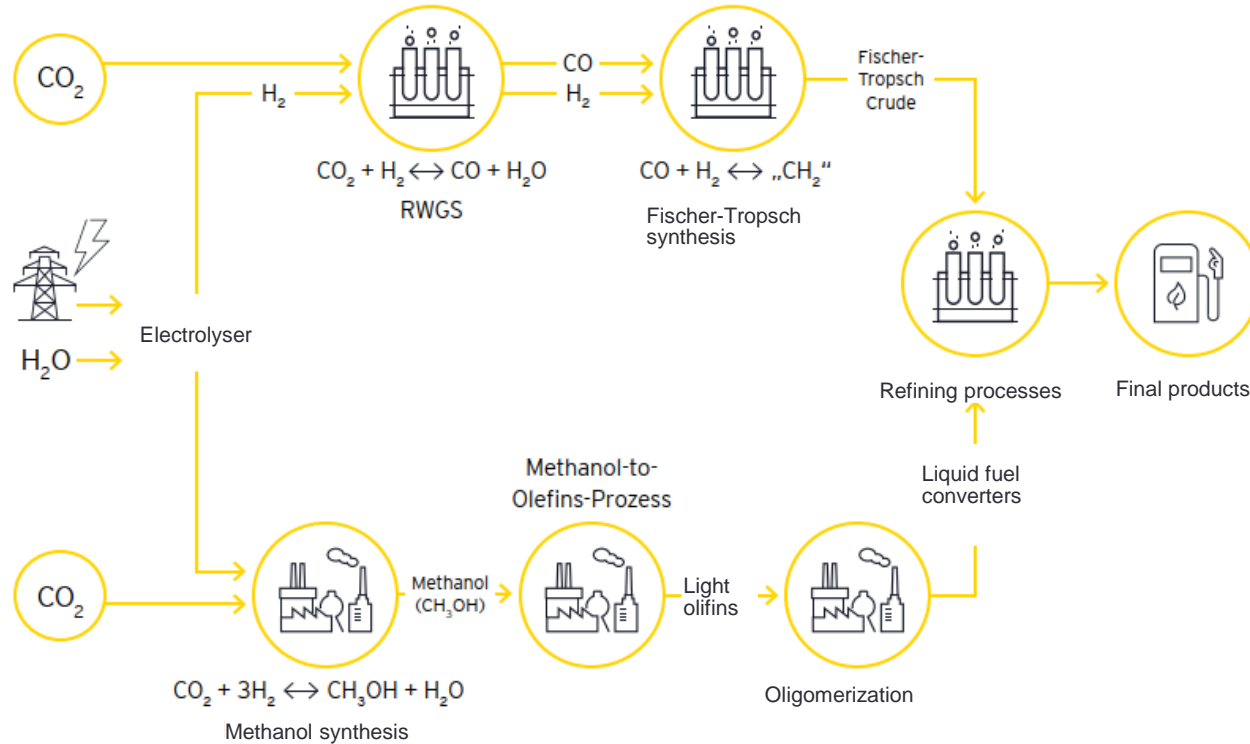


Own calculation / literature data	ATJ-SPK (%)	Diesel (%)	Naphtha (%)
Ethanol based	70%	20%	10%
Isobutanol based	70%	0%	30%
Average	70%	10%	20%

\* Source: IATA with data from THEICCT

Meanwhile, there are two pathways for producing E-SAF: (RWGS-)FT and Methanol-to-Jet (MtJ). While MtJ is still undergoing certification, (RWGS-)FT is already approved

### E-SAF production pathways



### Routes overview

**RWGS-FT:** In a 2-step process (CO<sub>2</sub>) and H<sub>2</sub> are converted into a hydrocarbon mixture including synthetic jet fuel called "e-kerosene or e-SAF"

- ▶ **Step 1:** Reverse Water Gas Shift (RWGS): CO<sub>2</sub> and H<sub>2</sub> are catalytically converted to syngas, a mixture of steam, carbon monoxide (CO) and H<sub>2</sub> serving as intermediate
- ▶ **Step 2:** Fischer-Tropsch (FT) Synthesis: CO from RWGS combines with H<sub>2</sub> over another catalyst to form a complex mixture of hydrocarbon chains, including e-kerosene/e-SAF

### Methanol-to-jet (MtJ)

- ▶ **Step 1:** generates Methanol from CO<sub>2</sub> and H<sub>2</sub> over the intermediate step of syngas like in RWGS-FT
- ▶ **Step 2:** Methanol reacts over various catalysts to a complex hydrocarbon mixture including jet fuel. Other alcohols, like Ethanol from fermentation processes, can optionally be co-fed too



# 03

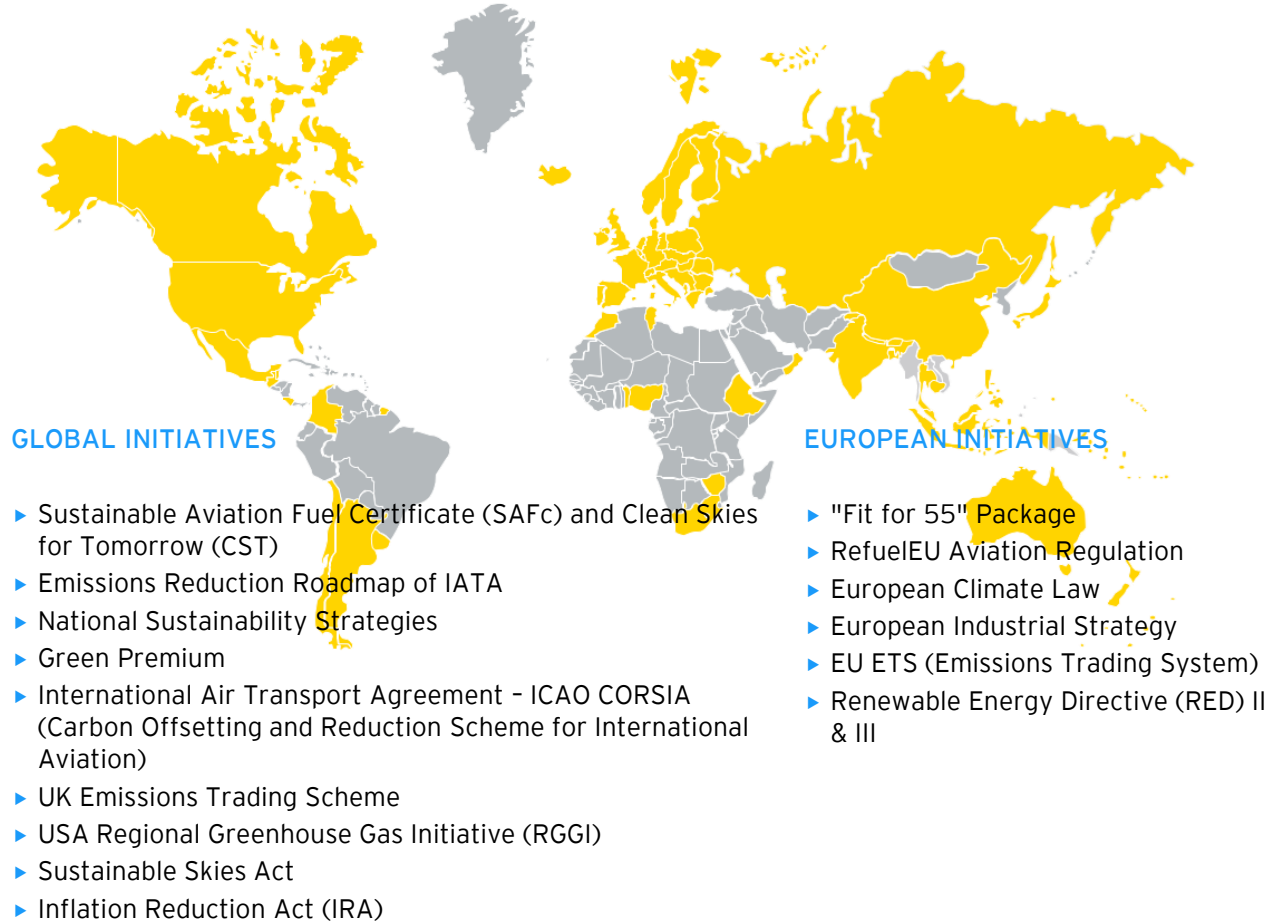
SAF demand vs production

# At the global scale, SAF demand is primarily driven by policies and regulations aligned with the Paris Agreement, with around 75 countries committing to its goals

NON-EXHAUSTIVE

## Established sustainable strategies under the Paris Agreement

## Key insights

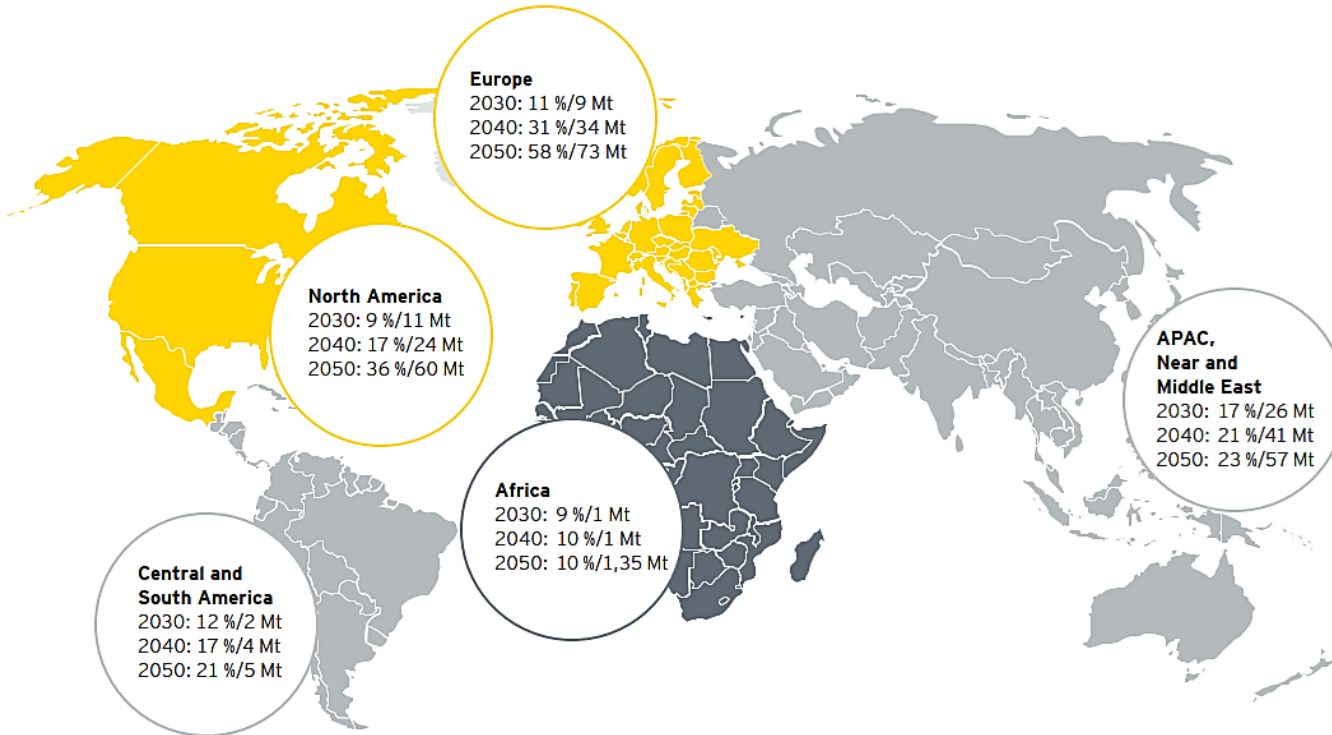


- ▶ 75 countries have developed **long-term strategies under the Paris Agreement** to reduce GHG emissions
- ▶ The 2019 EU Green Deal aims to transform the EU economy to achieve **climate neutrality by 2050**, with support for **low-carbon aviation** and **SAF** promotion
- ▶ The RefuelEU Aviation Regulation **mandates a minimum SAF share** from **2025**, gradually increasing to **>70% SAF** by 2050. By then, SAF should account for **>50%** of the fuel at **EU airports**, supported by direct flights and incentives in the **EU trading system**
- ▶ Nevertheless, there is a **lack of clarity in ReFuelEU regulations**, as airlines have limited control over SAF supply. Suppliers independently decide when, where, and how to meet their blending obligations

Source: Climatewatch, Communication of Long-term Strategy - Explore Long-Term Strategies (LTS), January 2024

# SAF as a key solution for aviation decarbonization: Global demand is projected to reach 49 Mt by 2030 and 196 Mt by 2050 with a CAGR of 7%

## SAF demand (in %) of total jet fuel demand<sup>1</sup>



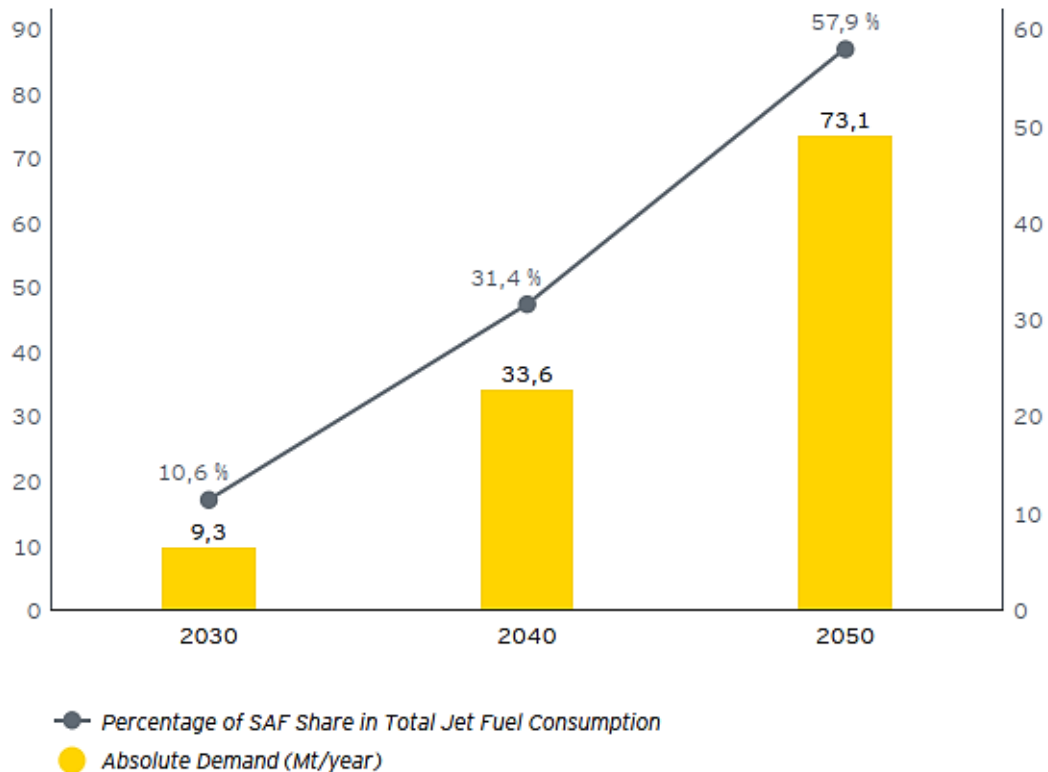
## Key insights

- ▶ By 2030, the **global SAF supply** will reach **49 Mt**. By 2050 this will reach **196 Mt**. **CAGR** is **7 %**
- ▶ The **EU** is the **one** of the **global regions**, that established **long-term SAF quotes**. Nevertheless, countries like **Canada, India, and Japan (10% SAF by 2030)** push SAF adoption by setting usage targets, but long-term goals remain undefined for many regions
- ▶ Looking at global demand, it is notable that:
  - As per **2030 APAC** and **Middle East** will be one of the biggest offtaker of SAF (**26 Mt**)
  - The second one is the **North America - 11 Mt, 2030**
  - However, in **2050 Europe** will be a **leading market** with **73 Mt** of demand (60% of kerosene demand by 2050), **11% CAGR**
  - **North America** - 60 Mt by 2050, 9% CAGR
  - **APAC/Middle East** - 57 Mt by 2050, 4% CAGR
  - **Latin America & Africa** will remain to keep the lowest demand (5 & 1.35 Mt by 2050, respectively), 4% CAGR

1. Absolute SAF Volumes, considering SAF mandates and net zero  
Source: EY Forecast, as of January 2025

# Europe is projected to become one of the largest aviation markets globally, with a forecasts indicating 73 Mt by 2050, to support its decarbonization goals

## Projected SAF demand in Europe<sup>1</sup>



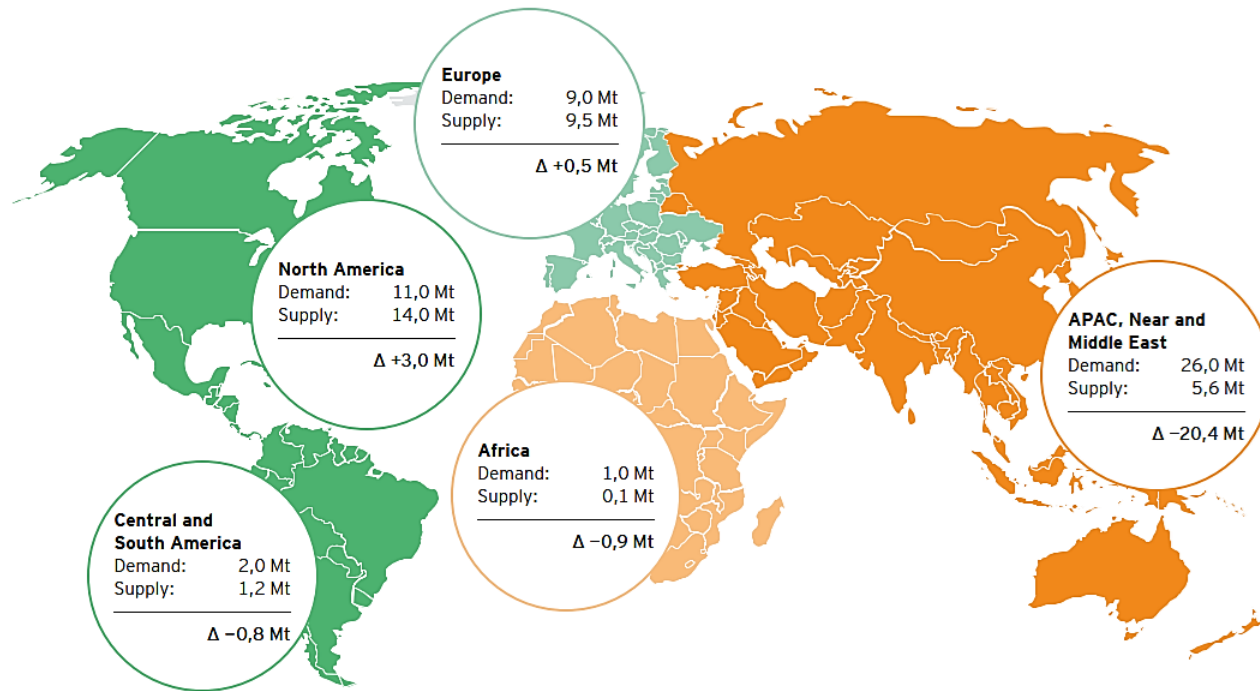
## Key insights

- ▶ The demand is primarily driven by regulations, including decarbonization strategies and incentives, as well as mandatory quotas. Key EU policies shaping demand include [ReFuelEU](#), [EU ETS](#), and [RED II & III](#)
- ▶ SAF share in [Europe's kerosene](#) consumption was **0.2%** in **2023**
- ▶ Our projections indicate a **rise** to **11%** by **2030** and **31,4%** by **2040**. By **2050** and under EU reforms, **SAF demand** is projected to reach **73 Mt** accounting for **~60%** of **total kerosene consumption** and aligning with airline CO<sub>2</sub> reduction targets worldwide
- ▶ The projected **CAGR 11%** from **2030** to **2050** makes Europe the **fastest-growing SAF market**, surpassing [North America](#) (60 Mt by 2050)
- ▶ As large-scale **e-SAF production** becomes **efficient** (approx. 2035 - 2040), **biofuel demand** is expected to **decline**

1. In this context, the European region includes not only the EU but also the United Kingdom, Norway, and Turkey, as these countries have established national SAF targets  
Source: EY Forecast, as of January 2025

# Despite planned global SAF projects, maximum production is expected to reach only 30.4 Mt by 2030, leaving a gap of 18.6 Mt compared to expected demand

## Potential gas considering maximum SAF production capacities by 2030<sup>1</sup>



## Key insights

- ▶ The **current SAF production** is **fully utilized globally**
- ▶ Starting from **2030 APAC/ Near and Middle East** will have a **gap of 20,4 Mt**
- ▶ Potentially, **Europe and North America should not** have **issues** with **SAF supply** in **2030** (as per planned projects). However, especially **Europe might not meet this goal** since number of **projects are still not at FEED stage**
- ▶ **Africa and Central/South America** will have approximately the same gap of **0,9 Mt** between **demand** and **supply**
- ▶ With current **production capacity growth**, the forecasted **demand** of **104 Mt** in **2040** and **196 Mt** in **2050** **may not be met**. **No further information** how **SAF projects** will be developed after **2040 - 2050**, making long-term supply predictions uncertain



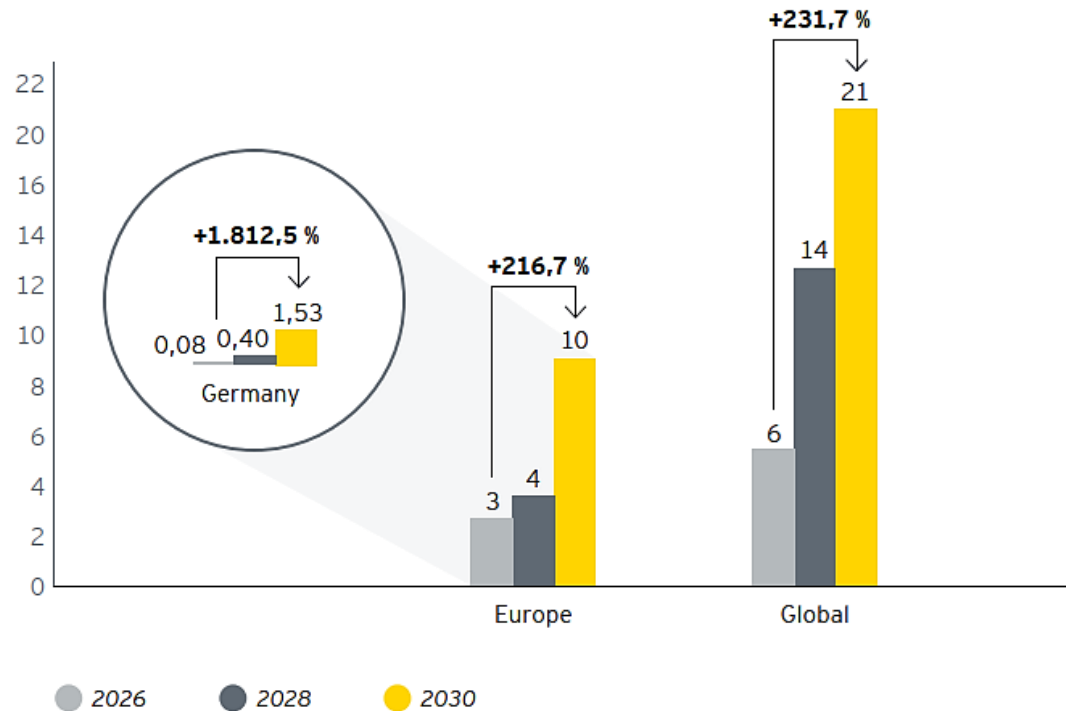
The **limiting factor** for **widespread SAF adoption** is **availability** of the **feedstock** (bio-SAF), **not scalable technology** (e-SAF) and finally **too high investments**

1. The supply represents the maximum possible production capacity (an optimistic representation)  
Source: EY, as of January 2025



# Europe is the second-fastest growing SAF supply market after North America, with projected production reaching 19.4% of global capacity by 2030

Comparison of expected potential SAF production by 2030 (Mt)



Source: Argus, SAF capacity map, as of January 2025

Key insights

- ▶ The European SAF production market is expected to grow at 218% between 2026 and 2030
- ▶ In **Europe**, the projects include both **bio-** and **e-SAF**. In **Germany** most of projects cover the **FT route**
- ▶ The following key challenges of SAF production in Europe:



Limited **agricultural land** and a **shortage of biomass** resources in Europe constrain production



**Renewable energy availability** and **costs**



The World Economic Forum (WEF) anticipates that SAF imports will play a significant role, with increased collaboration within Europe and internationally needed to meet demand



First scalable e-SAF plant in Norway, aiming to produce 80,000 tons, 2026



(Velocys, British Airways, Shell)  
A SAF plant in the UK to convert waste into SAF, with a production of 500,000 tons, 2027



# 04

Production costs vs.  
willingness to pay

# SAF is 1,5-6 times more expensive than conventional kerosene due to feedstock availability and their cost, technology scalability, and green energy prices for e-SAF

## Minimum Selling Price (MSP) Breakdown

- ▶ **Conventional Kerosene: ~\$820/ton** (July 2024)<sup>1</sup>
- ▶ **Bio-SAF Mix (Bio-SAF, Bio-HVO, Bio-Naphtha): ~\$2,680/ton**
- ▶ **E-SAF: ~\$4,900/ton\*\***



SAF is currently **1.5 to 6 times more expensive** than conventional kerosene<sup>2</sup>

## Current Challenges in SAF Adoption



SAF supply is **still unclear** and **number of projects must get investments** to increase **significantly** for **aviation decarbonization**

The significant price gap between SAF and conventional kerosene is a **major challenge** for large-scale adoption



## Price evolution factors by 2050



**Bio-SAF** price will **increase** due to **resource scarcity** by **mid-2030s**

**E-SAF** price will **decrease** with **technological advancements** and **lower energy costs**



## Global investment needs for SAF Infrastructure

- ▶ Required Investments: **\$1.00-1.45 trillion** by **2050**
- ▶ Annual Investment: **~\$48 billion per year** until **2050**



Comparison factors: Equivalent to **6% of annual fossil fuel investments<sup>3</sup>**

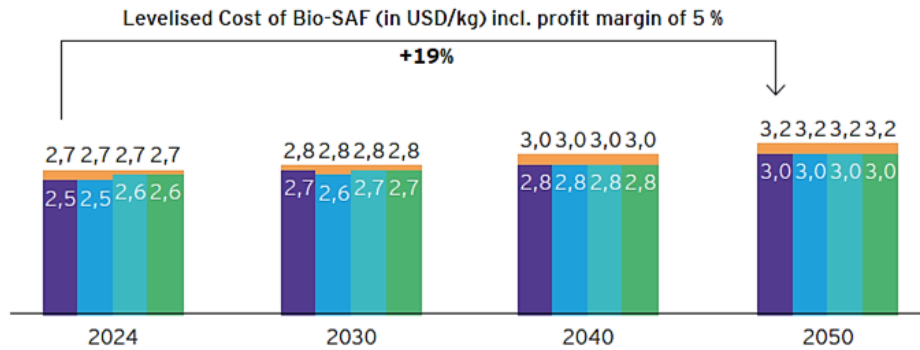
1. IATA: Jet Fuel Price Monitor; 2. EASA Eco: Current landscape and future of SAF industry; 3. Albrecht, Uwe et al.: Zukünftige Kraftstoffe für Verbrennungsmotoren und Gasturbinen, October 2013

Other sources: EY analysis

\*\* Projections

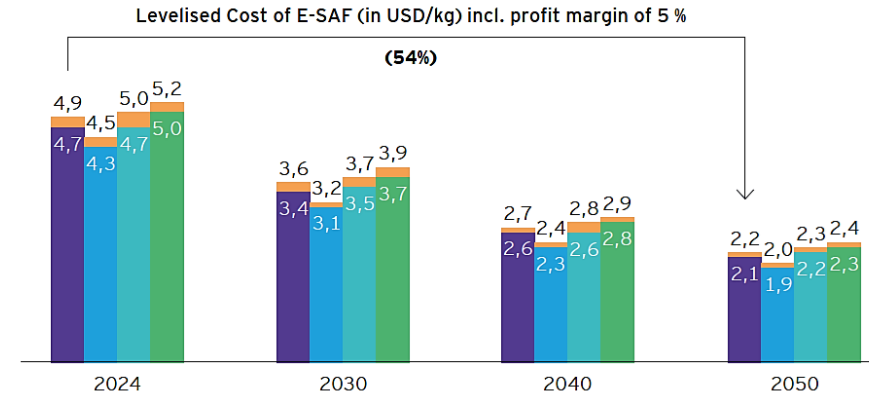
# Our price forecast suggests that by 2040, bio- and e-SAF prices may align, driven by rising bio feedstock costs, availability, and e-SAF technology scalability

## Development of Bio-SAF Levelized Cost<sup>1</sup>



- ▶ In 2024, bio-SAF costs were ~\$2,530/ton and lower than in the USA and APAC due to cheaper feedstock price and energy
- ▶ Bio-SAF is currently cheaper than E-SAF due to its technological maturity and integration into existing HVO-diesel production infrastructure
- ▶ Future cost increases are expected due to feedstock scarcity, availability issues (e.g., caused by natural disasters, crop failures, or land-use conflicts), regulatory constraints, and rising demand from other industries (e.g., food, shipping, chemicals).
- ▶ HEFA-SAF demand and costs will likely rise faster than other SAF types, as its production generates valuable co-products (HVO-diesel, propane, naphtha) that improve financial viability

## Development of E-SAF Levelized Cost<sup>2</sup>



- ▶ Technological advancements and scaling of E-SAF production will lead to decreasing production costs and lower CapEx for related facilities
- ▶ The anticipated progress in GH<sub>2</sub> technology will also contribute to a reduction in e-SAF LCO, along with decreasing costs for renewables energy, which is crucial for production due to its high energy demands
- ▶ Between 2024 and 2050, the LCO for Bio-SAF will increase by approximately 19%, while the LCO for E-SAF will decrease by 54%.
- ▶ Investors and customers are expected to favor Bio-SAF until the mid-2030s, after which E-SAF investments will likely to become attractive

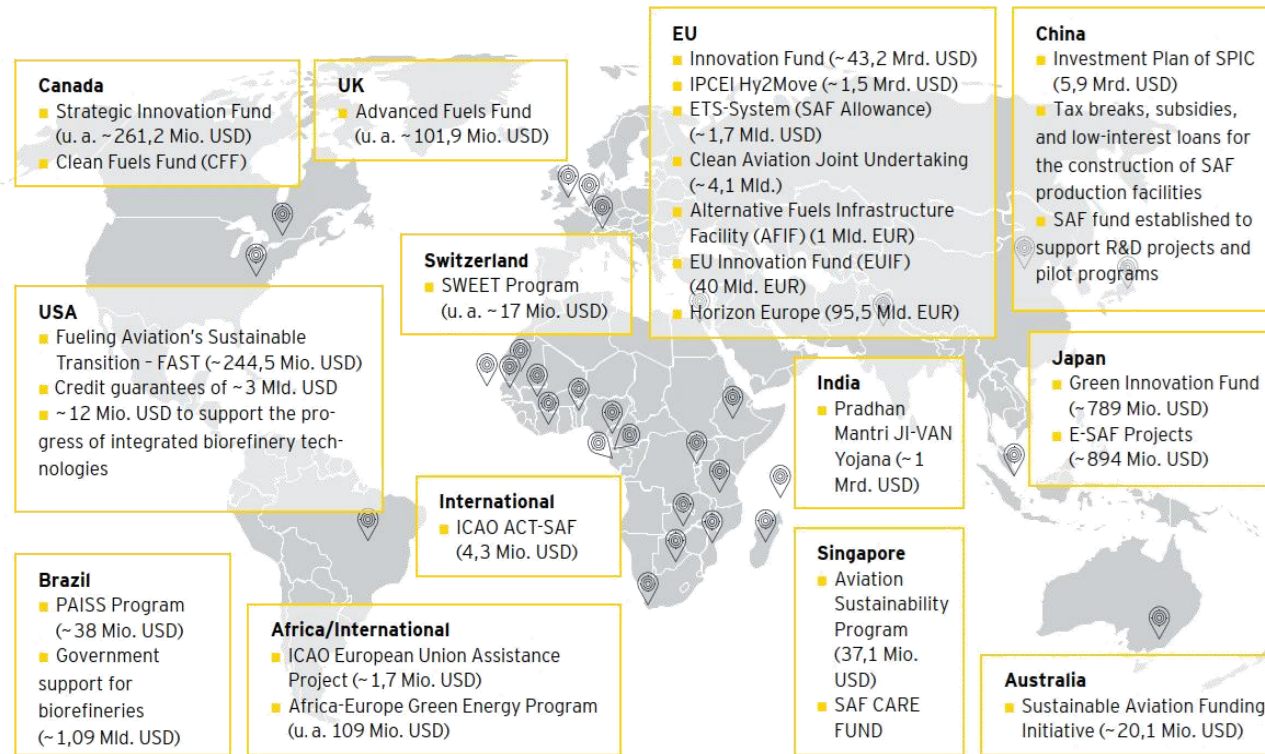
● Profit margin
 ● Global
 ● EU
 ● USA
 ● APAC

<sup>1</sup> LCO for Bio-SAF was calculated based on the HEFA route (Process Route 1) using GH<sub>2</sub>

<sup>2</sup> LCO for E-SAF was calculated based on the methanol route

# A large number and volumes of initiatives and government funding projects for SAF, e-fuels, and biofuels worldwide create positive sentiment towards SAF development<sup>1</sup>

## Selection of global government support projects for SAF, e-fuels, and biofuels



## Key insights

- ▶ Initial projects require both **CapEx** and **OpEx funding** to prevent **first-mover disadvantages** for producers and airlines
- ▶ **Government support** plays a **key role** in **scaling SAF** production and mitigating investment risks. **Subsidies** help cover **high-risk pre-financing, loan costs**
- ▶ **APAC countries show growing support:** Several nations have significant SAF funding initiatives in place.
- ▶ **Latin America is still behind:** Only a limited number of SAF funding programs exist in the region
- ▶ **Africa faces the biggest funding gap:** SAF projects rely mostly on international programs like ICAO European Union Assistance Program and ICAO Act SAF
- ▶ **Foreign aid is crucial in Africa:** Biofuel and bio-based raw material development depends on financial support from external governments, development banks, and state-owned enterprises

# Additionally, private investments in SAF continue to rise globally, fueled by growing demand and the strong market benefits enabled by political support



## FUTURE-PROOF INVESTMENT

- ▶ SAF portfolios help institutional investors meet sustainability targets, support green energy transition & reaching net-zero goals
- ▶ Geographical diversification, allowing investors to enter new markets
- ▶ Alignment with emerging nature-based financial instruments like the Global Biodiversity Framework & TNFD
- ▶ Increase viability, long-term investments and bankability



## PORTFOLIO STABILITY

- ▶ SAF investment reduces overall portfolio volatility, as returns are not correlated with stocks or bonds
- ▶ SAF projects provide steady cash flows, which are preferred by institutional investors
- ▶ Improved regulatory frameworks and risks mitigation measures by governments enhance investment security
- ▶ Enhance an organization's CSR profile, as supporting sustainable technologies can boost brand reputation

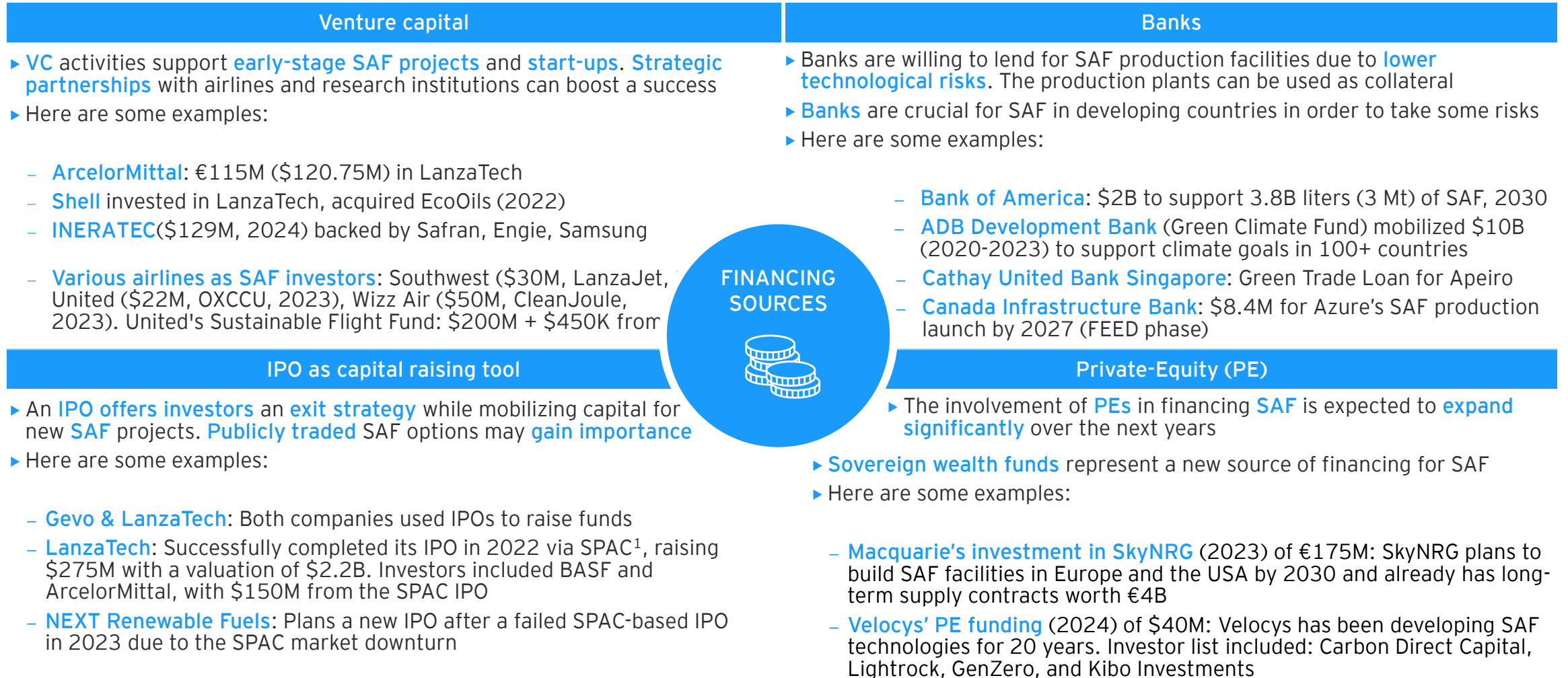


## PUBLIC-PRIVATE COLLABORATION

- ▶ Private and governments' involvement in SAF presents strategic partnerships & long-term investment opportunities
- ▶ Investors can co-invest with national & multinational development banks (e.g., World Bank) and access more favorable financing options than private capital markets<sup>1</sup>

<sup>1</sup> ATAG: Accelerating Adoption of Sustainable Aviation Fuel: Financing and Related Issues, March 2023

# Combining multiple funding sources enables SAF projects to scale from development to industrial production while enhancing bankability



<sup>1</sup> SPAC = Special Purpose Acquisition Company

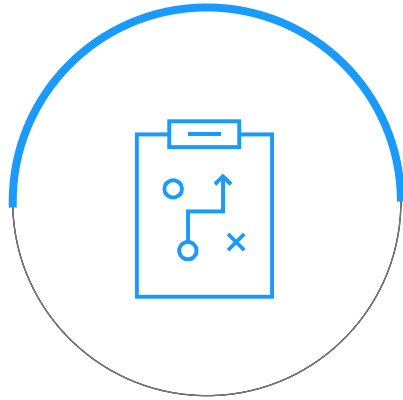


# 05

Barriers and hurdles to market expansion



# Globally, only a few SAF projects have secured investments, with most being pilot initiatives or funded by major O&G players



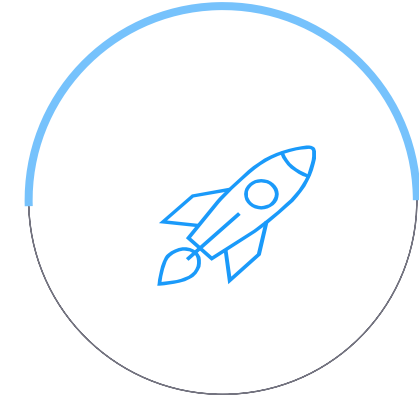
## FIRST-MOVER DISADVANTAGES

- ▶ The production of green H<sub>2</sub> (as a key feedstock) is still expensive (e-Fuels relevance)
- ▶ Lack of long-term feedstock supply, e.g. CO<sub>2</sub> source, power grid connection
- ▶ Collaborations with developing countries require strong risk mitigation measures
- ▶ Long planning and permitting durations, e.g. for renewables
- ▶ Uncertainties in the business plan (guarantees for volumes and prices)



## ECONOMIC INDICATORS & BANKABILITY

- ▶ High upfront investments and lack of fit-for-purpose financing models
- ▶ ESG risks need to be clarified for investors (especially when a project is in a developing country)
- ▶ Investors require assurances about the uptake (preferably for a long time e.g., 10-15 years)
- ▶ Lack of long-term planning horizon, e.g. yearly SAF allowances (needed for e-SAF plants)



## TECHNOLOGY

- ▶ Complexity of international and national regulatory and policies pose significant challenges for (international) companies especially when it comes to technology allowance and SAF quality
- ▶ Lack of access to grid infrastructure or refining, blending and supply infrastructure



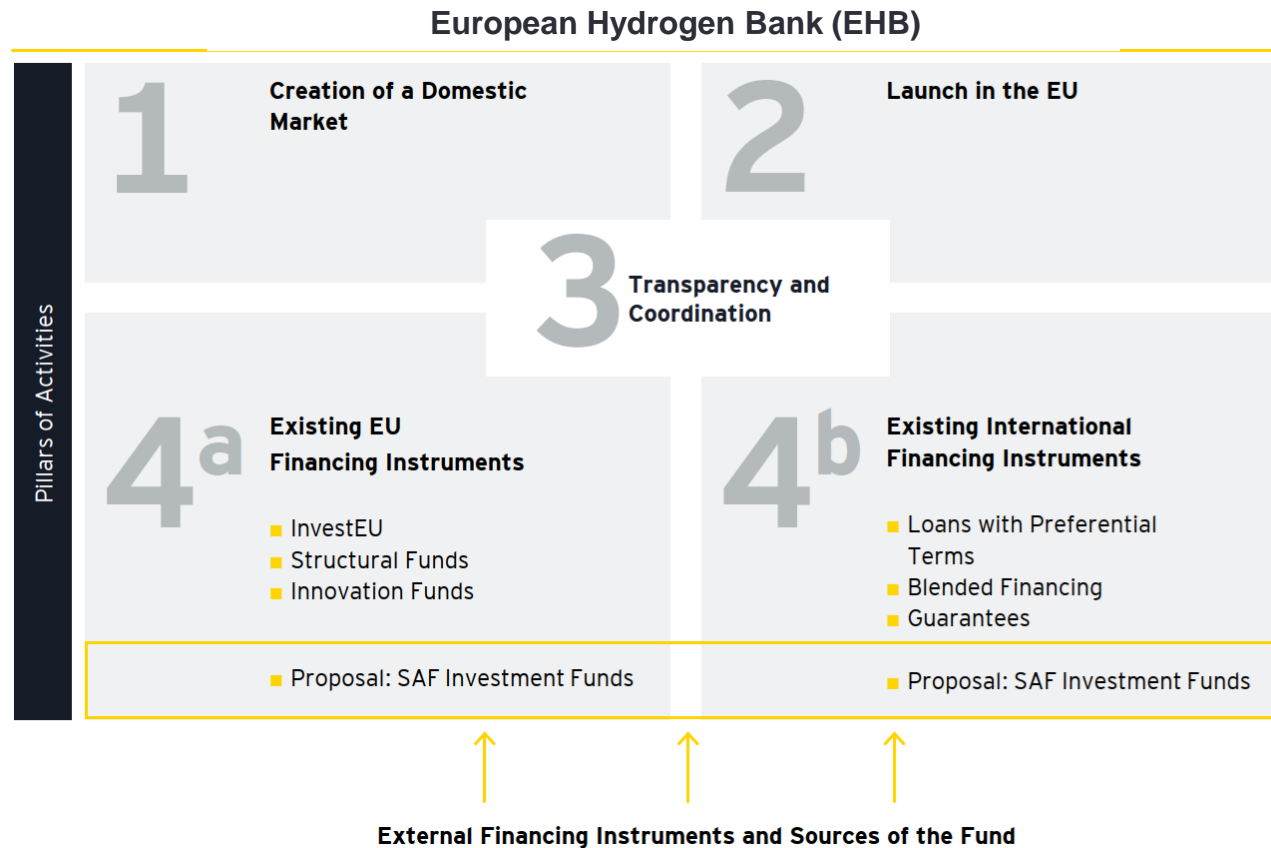
# 06

How to solve the current challenges?

Concrete instruments to accelerate SAF adoption

# To enhance SAF financing in EU, a dedicated fund can be established under e.g. EHB, pooling various revenues from penalties / other fin. sources

## Structure of EHB and proposed SAF investment fund

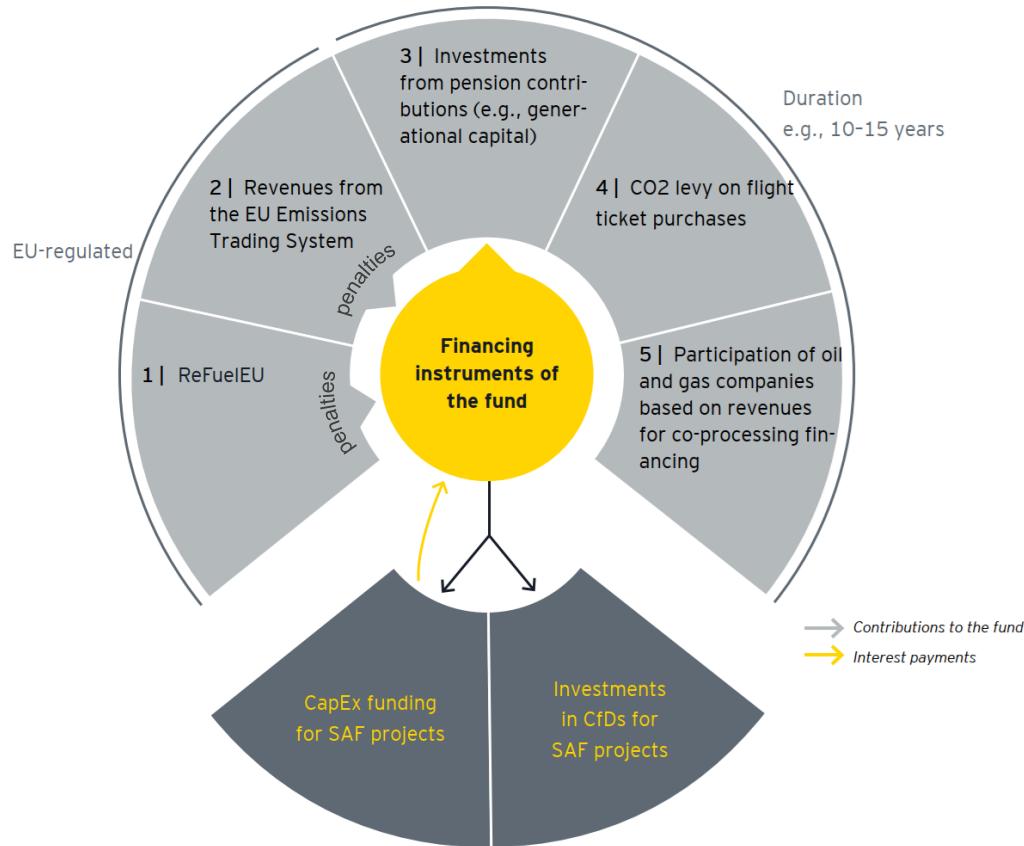


## Key insights

- ▶ The EU already offers various funding sources to support the decarbonization of aviation, including grants for innovative production pathways, H2Global, and others. Additionally, penalties for non-compliance with the ReFuelEU Aviation Regulation are collected at a national level in each EU country. These funds should ideally be reinvested in scaling SAF production, but each country retains the authority to decide how to allocate them
- ▶ A new fund can be developed separately under the EU or being a part of the EHB. This fund should focus only on a future SAF projects, potentially benefiting EU and global aviation. It should support both Bio- and E-SAF projects
- ▶ The EHB currently has four pillars of activities, and a dedicated SAF investment fund could be added as a fourth pillar (under 4a and 4b)
- ▶ **Role of the fund:** Align and prioritize financial resources to strategically invest in SAF projects at the European level
- ▶ **Key functions:** Financing SAF projects (from development to operation stages) covering infrastructure and supporting R&D for new SAF production technologies

# This approach will accelerate SAF project scaling, drive market growth, and enhance industry adoption

## EY model combining various financial sources to scale up SAF production



## Key insights

### ► EY proposes to include:

- **Collection of penalties from ReFuelEU and ETS for aviation sector:** Each member state determines and collects penalty amounts, adhering to a minimum threshold. A central authority within each country could be responsible for collecting and allocating these funds to ensure effective reinvestment.
- **Integrate new sources like:**
  - **Pension contributions** (e.g. Germany's Generation Capital initiative for pension funds): Pension funds from EU countries investing in capital markets could serve as a new funding source for SAF projects
  - **CO2 levy on flight tickets** (potential levy: €5 for EU flights, €10-15 for international flights): Similar to existing voluntary airline contributions, a fixed fee would minimize administrative burden.
  - **Tax on co-processing revenues** (tax on SAF made alongside fossil fuels in refineries): depends on national tax laws and regulations. Companies must ensure correct tax calculation and compliance while exploring potential incentives for sustainable practices



# 07

Q&A session

## EY | Building a better working world

EY exists to build a better working world, helping to create long-term value for clients, people and society and build trust in the capital markets.

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Working across assurance, consulting, law, strategy, tax and transactions, EY teams ask better questions to find new answers for the complex issues facing our world today.



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