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European Union Aviation Safety Agency

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Welcome to the 11th webinar of the series on

Sustainability - EU/SEA CCCA CORSIA Project

The webinar will start @ 15h Bangkok/Jakarta/Hanoi Time
16h Singapore/Manila Time
10h Brussels/Cologne Time

1977-2022
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Sustainable Aviation Fuels 2030:
« Market Outlook on Demand & Supply »

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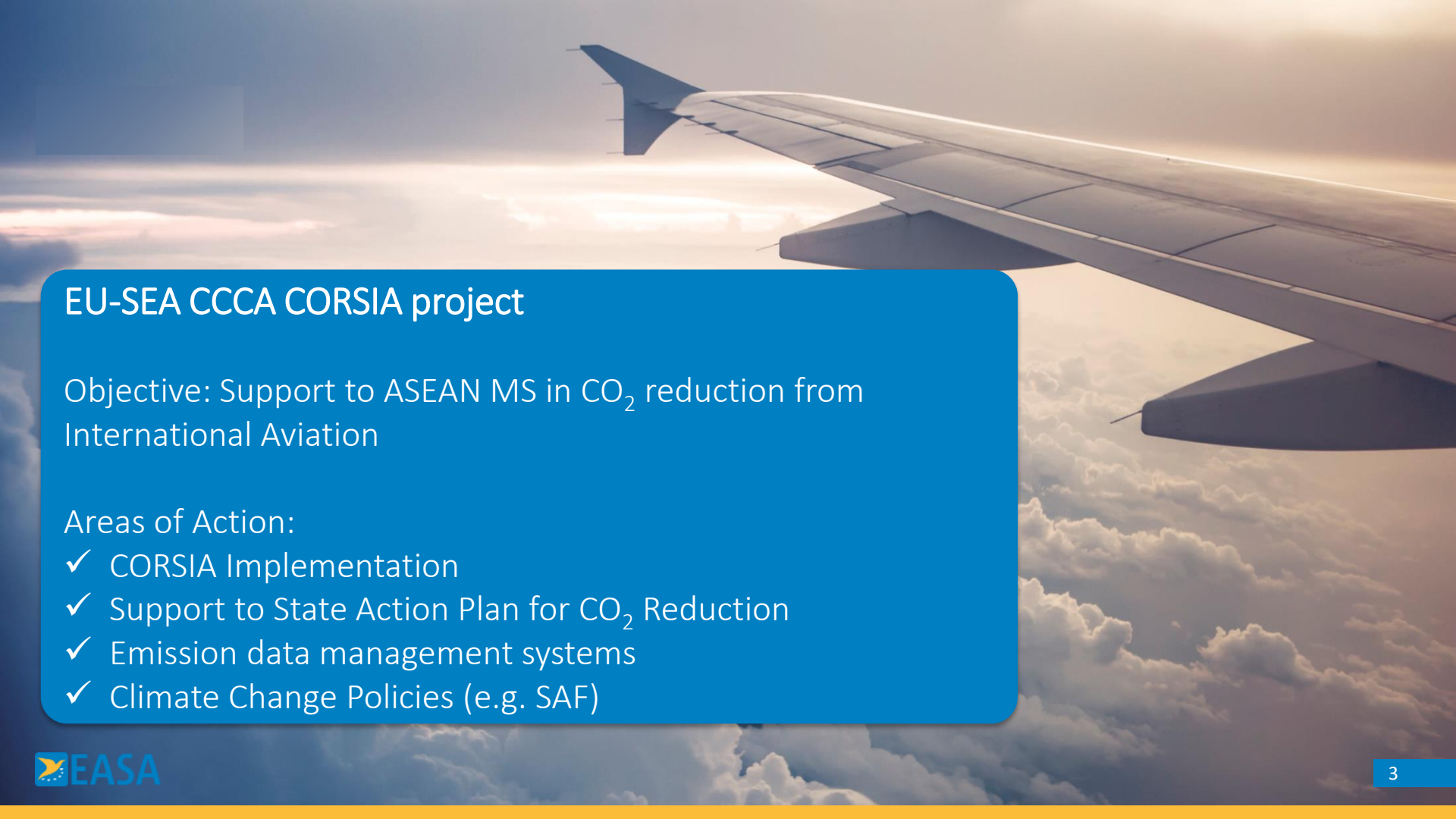

EU-SEA CCCA CORSIA project

Objective: Support to ASEAN MS in CO_2 reduction from International Aviation

Areas of Action:

- ✓ CORSIA Implementation
- ✓ Support to State Action Plan for CO_2 Reduction
- ✓ Emission data management systems
- ✓ Climate Change Policies (e.g. SAF)

Some practicalities & moderators

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→ **Q&A** after the speaker

→ Use Q&A section (Slido)

→ Vote up/down questions

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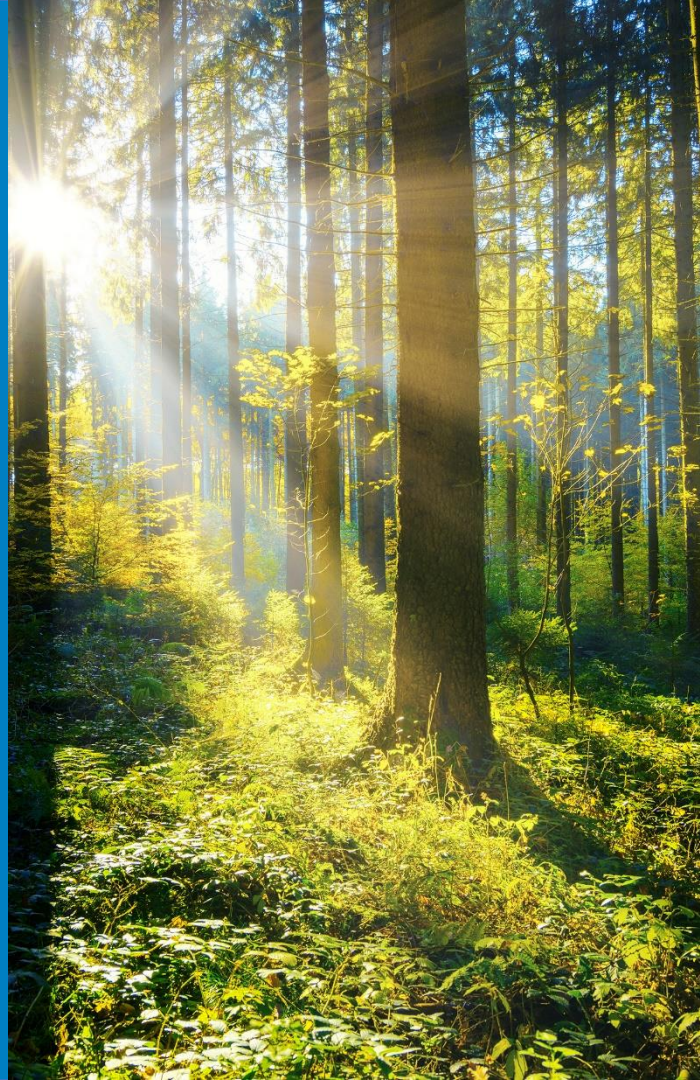
Webinar 11:

Sustainable Aviation Fuels 2030 – Market Outlook on Demand & Supply

What are the current market dynamics worldwide? How does the most realistic future demand and supply scenario look like? What about the availability of SAF in 2030 based on current announced production capacities? What kind of technologies, feedstocks and players drive the market?



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Our key speakers for today!

Dr. Chiara Boscagli

@ cboscagli@cbr-partner.de

CBR Consult & Invest GmbH

Senior Project Manager

Extensive track record in scientific research, engineering and in the chemical and fuels industry sector related to the green transition to renewable products and production processes

Consulting Focus @ CBR Consult & Invest GmbH

- *Project management lead in the fields of renewable liquids and gases hydrogen, Power-to-X, sustainable fuels (SAF) and green chemicals*
- *Expert in catalysis in industrial reactions and processes, reactors, biomass conversion technologies and other renewables*

Education

Promotion in Chemistry, Karlsruhe Institute of Technology (KIT), Germany

- *Thesis: "Hydrotreatment of pyrolysis-oils over nickel-based catalysts“*
- MSc und BSc *in Chemistry, University of Florence, Italy*

Our key speakers for today!

Christoph Behrendt-Rieken

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CBR Consult & Invest GmbH

Managing Partner

More than 15 years experience in the chemical process industry, large production infrastructure projects and technology development with focus on green transition of various industries via ClimateTech related innovation (renewable fuel, green chemistry, sustainability, environmental management systems, environmental certification, etc.)

Consulting Focus @ CBR Consult & Invest GmbH

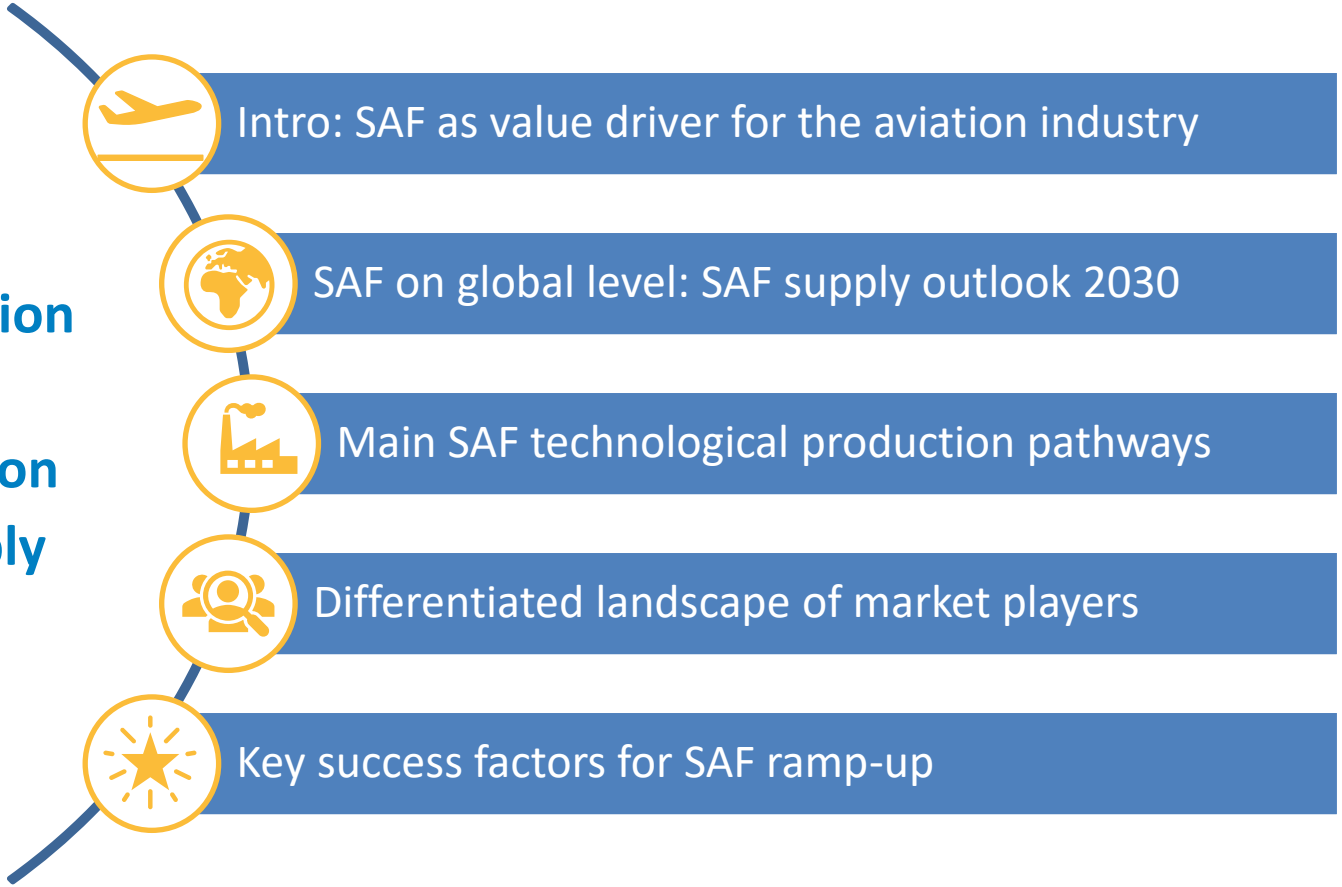
- *Commercial project development and deal advisory (due diligences, etc.) of green energy, fuel and chemicals investments and production plant projects*
- *Renewable fuel and chemical regulatory, commercial and technology expertise*

Education

- *EMBA -Executive Master of Business Administration-, Kellogg School of Management at Northwestern University / WHU Otto Beisheim School of Management*
- *Diploma -International Business Studies-, University of Paderborn, Germany / École Supérieure de Commerce de Reims, Grande École / NEOMA Business School, France*

Agenda

Sustainable Aviation Fuels 2030: Market Outlook on Demand & Supply



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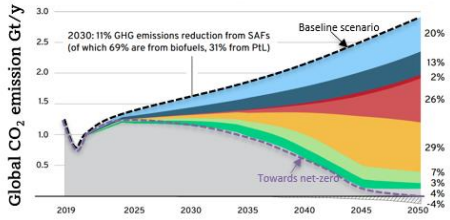
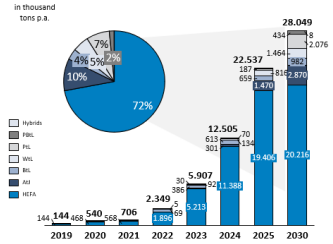
Source: CBR, 2023

Guiding questions today



What are the current market dynamics for SAF worldwide?



How does the future SAF supply scenario look like in 2030?

1. HEFA
2. Power-to-Liquid
3. Waste-to-Liquid
4. Biomass-to-Liquid
5. Alcohol-to-Jet
6. Hybrid fuels, e.g. PBtL

Which technologies and related feedstocks drive the market?

Who are the frontrunners in SAF technology development and production?

SAF roadmaps

Direct supply line

Policies

...

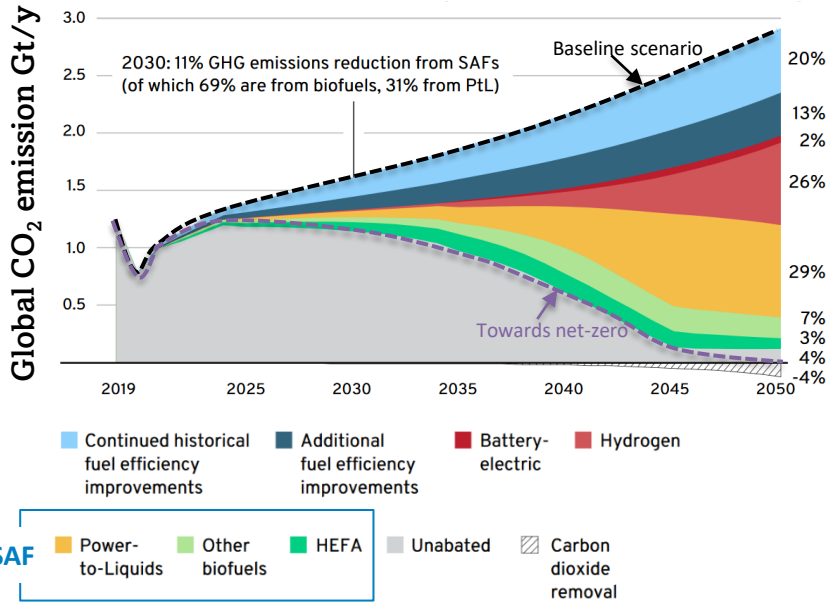
- Feedstock Innovation
- Conversion Technology Innovation
- Building Supply Chains
- Policy and Valuation Analysis
- Enabling End Use

What are key success factors in increasing SAF availability and use?

Source: CBR, 2023

Low-carbon substitutes for fossil jet kerosene, are critical to decarbonising aviation as hard-to-abate sector.

- **Global CO_2 emissions from aviation** exceeded **1 billion tons** in 2019, accounting for **>2%** of total anthropogenic CO_2 emissions.
- **SAF** is a **key contributor** to **reduce CO_2 emissions** in the decades to come **coexisting** with **more disruptive technologies**.

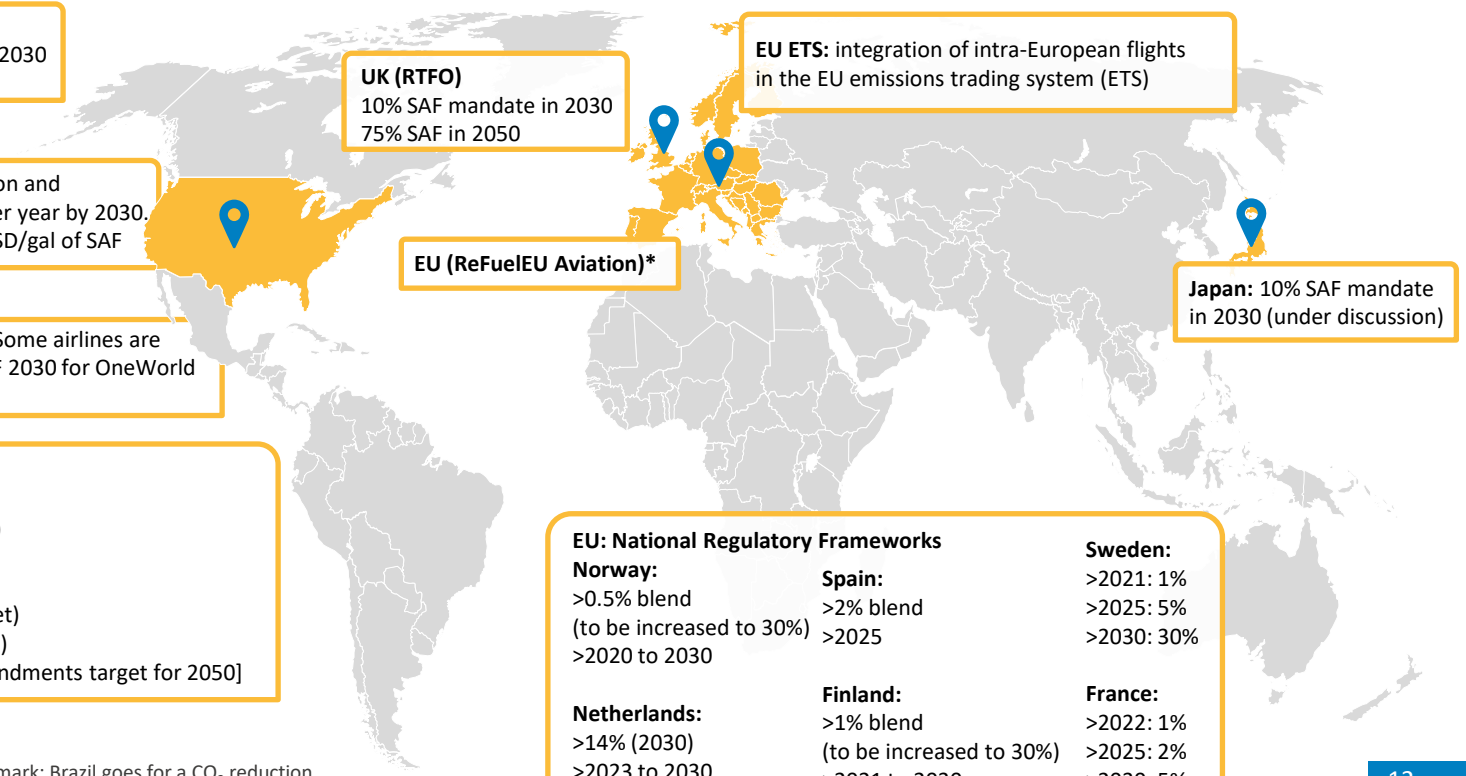


	GHG reduction	Regional flight	Short haul	Medium/ long haul
Batteries	100%	✓		
Hydrogen	100%	✓	✓	
Sustainable aviation fuel (SAF)	70-99%	✓	✓	✓

- Global jet-fuel demand in 2019: **~360 million tons**
- **Batteries and hydrogen are limited** to shorter flights
- **SAF** shows an intrinsic advantage by having similar properties to jet-fuel, offering a **drop-in compatibility** with the available fleet technology, and being suitable **for long-distance travel.**
- Different studies predict scenarios for 2050, where SAF global demand could be between **300-500 million tons**.

Source: Mission Possible Partnership, Making net-zero aviation possible - An industry-backed, 1.5°C-aligned transition strategy, here the Optimistic Renewable Electricity scenario, WEF, 2022; CBR, 2023

To accelerate SAF ramp-up, various regulatory initiatives have been implemented, especially in the U.S. and Europe.



USA
20% GHG emission reduction in 2030
3 billion gallons SAF by 20230

Sustainable Skies Act: Production and consumption of 3 bill. gallons per year by 2030. Tax credit between 1.25-1.75 USD/gal of SAF

Self commitments by Airlines: Some airlines are committing to use SAF (10% SAF 2030 for OneWorld alliance e.g.)

***EU (ReFuelEU Aviation)**
2% SAF in 2025
5% SAF in 2030 (incl. 0.7% eJet)
20% SAF in 2035 (incl. 5% eJet)
32% SAF in 2040 (incl. 8% eJet)
38% SAF in 20455 (incl. 11% eJet)
63% SAF in 2050 (incl. 28% eJet)
[100% SAF EU parliament amendments target for 2050]

UK (RTFO)
10% SAF mandate in 2030
75% SAF in 2050

EU ETS: integration of intra-European flights in the EU emissions trading system (ETS)

EU (ReFuelEU Aviation)*

Japan: 10% SAF mandate in 2030 (under discussion)

EU: National Regulatory Frameworks

Norway:
>0.5% blend
(to be increased to 30%)
>2020 to 2030

Netherlands:
>14% (2030)
>2023 to 2030

Spain:
>2% blend
>2025

Finland:
>1% blend
(to be increased to 30%)
>2021 to 2030

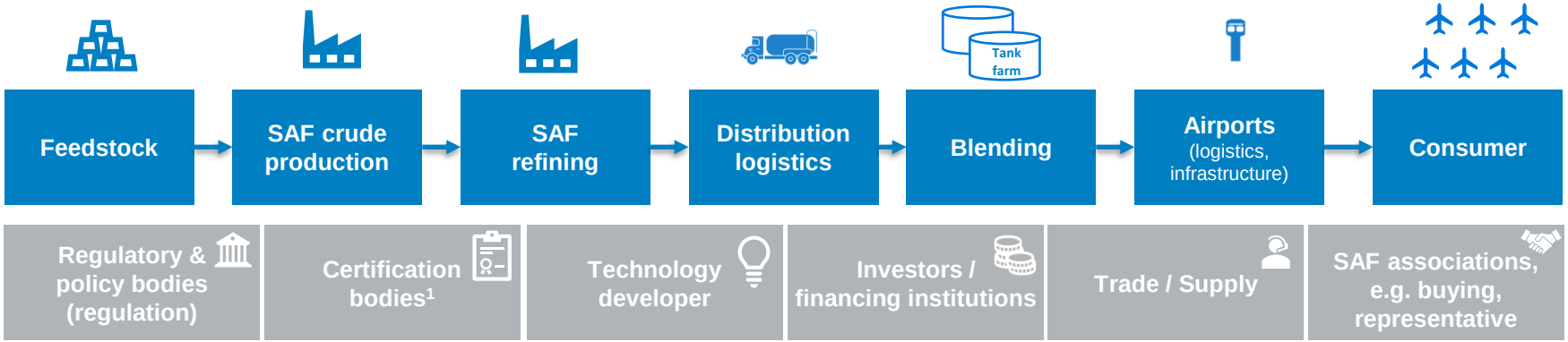
Sweden:
>2021: 1%
>2025: 5%
>2030: 30%

France:
>2022: 1%
>2025: 2%
>2030: 5%

Source: CBR, 2023; Remark: Brazil goes for a CO_2 reduction mandate incentivizing a CO_2 market and SAF quality/blend

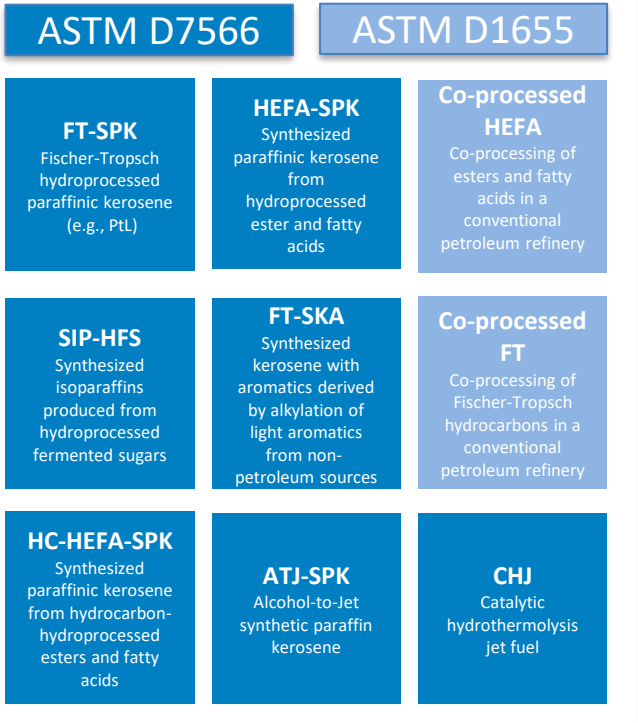
A long way towards net-zero aviation with SAF as major contributor between opportunities and challenges

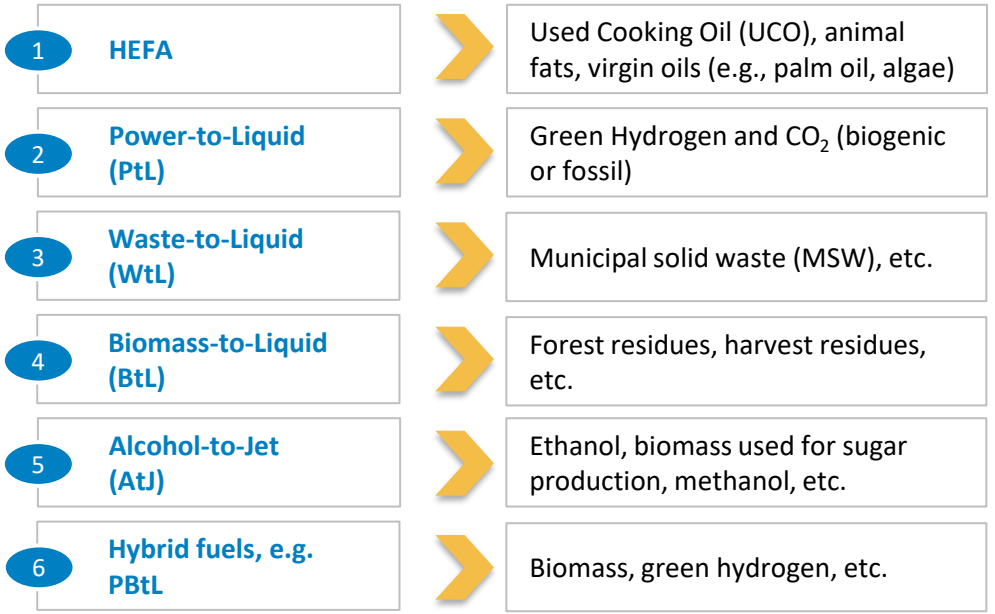
- Awareness about the **importance** of **SAF** in the **net-zero target 2050** has increased in the last years.
- The production in **2019** was only **~24 million liters**, up to ~100 million liters in 2021 to **~300 million liters** in **2022**.
- Over **450,000 flights** had already used SAF and more than **50 airlines** have it **tested** in their **SAF supply chains**.
- However, **SAF production** in **2022** was only **0.1%-0.15%** of **total aviation fuel demand** and a **great commitment** is **needed** to reach **450 billion liters** in **2050**.
- Only **one single production technology cannot be the solution** to face the ambitious target, but a strategic combination of them should be adopted and SAF integrated in the supply chain.



Source: CBR, 2023

Nine ASTM certified SAF types, six main pathways and a variety of feedstocks are available for SAF production.





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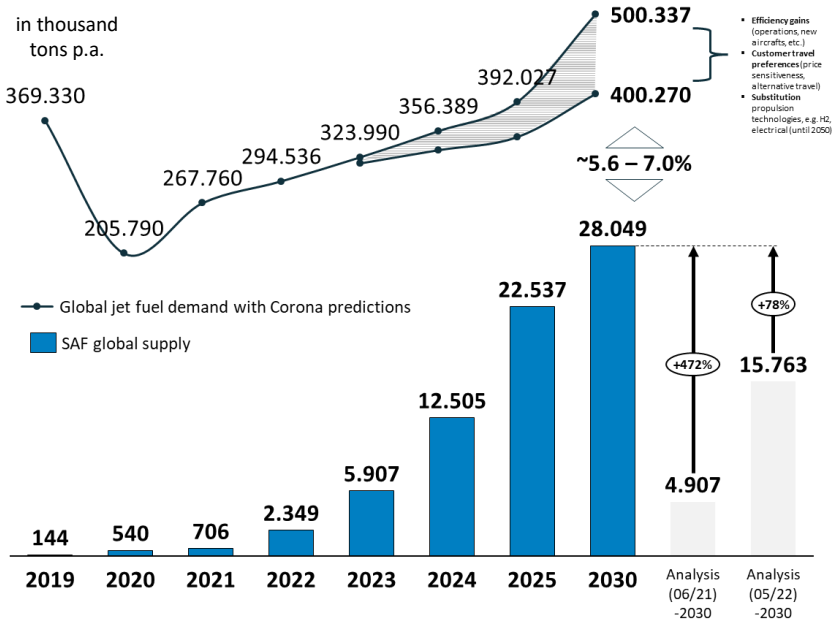
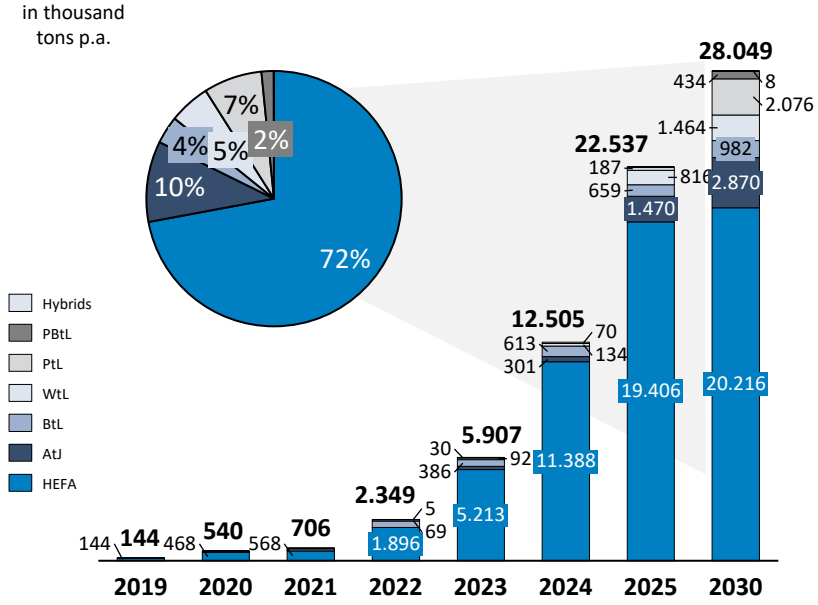
UCO: Used Cooking Oil; HEFA: Hydrotreated Esters and Fatty acids; MSW: Municipal Solid Waste; MtK: Methanol-to-Kerosene; PBtL: Power-and-Biomass-to-Liquid;
[1] Sustainable Aviation Fuel as level for GHG emission reduction besides Hydrogen and electrification alternatives; Source: ICAO; CBR, 2023

Global SAF supply only covers ~5.6% up to 7.0% of expected demand in 2030 with HEFA as predominant SAF pathway.



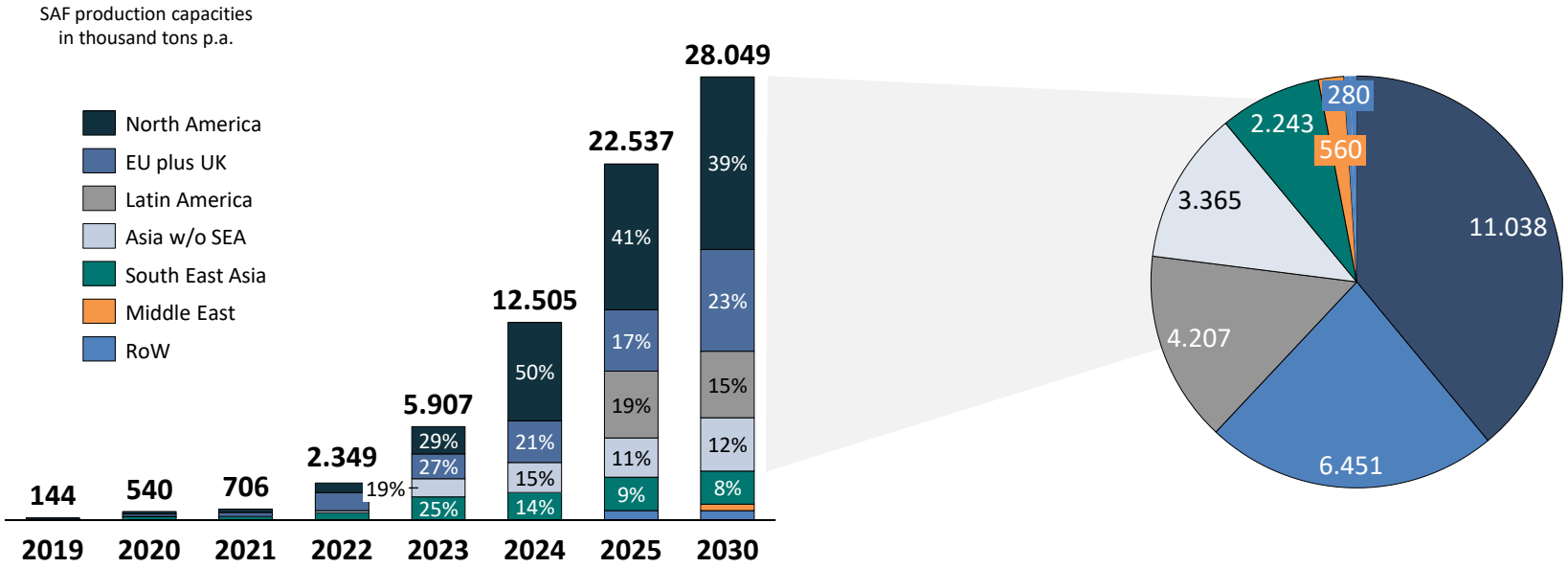


SAF production capacity only **covering ~5.6% up to 7.0% of global demand** in **2030** depending on consumption

HEFA is the recognized commercial pathway, as reflected in its **market share today** and in **2030.**

Source: BloombergNEF; Statista; Reuters/FGE ; Corporate announcements by respective companies, ; IEA; CBR, 2023;
Remarks: Predicted SAF production capacity based on operating plants and announced projects becoming operational until 2030.

Europe has played a frontrunner role in SAF production while North America (NA) takes the lead in terms of SAF production capacity.



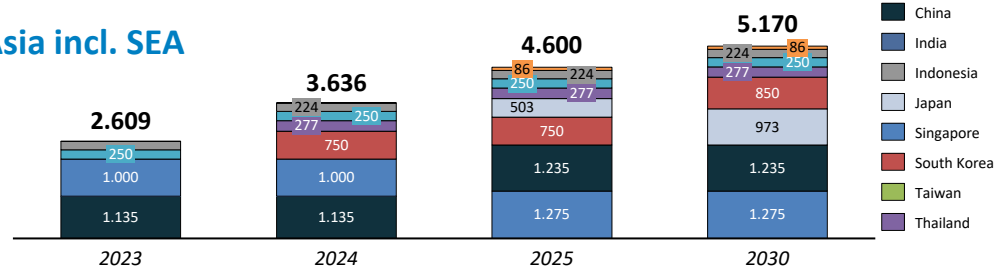
More than **60%** of **SAF production capacity** in **2030** is planned to be established in **North America** and **EU**.

All **figures** are subject to **constant review**, as new projects will be **announced** and some projects could have significant **delays** or **not materialize**.

Source: Corporate announcements by respective companies; CBR, 2023;
Remarks: Predicted SAF production capacity based on operating plants and announced projects becoming operational until 2030

Regional SAF capacity build-up is driven by various single projects looking for ideal set-ups in terms of feedstocks, policies, etc.

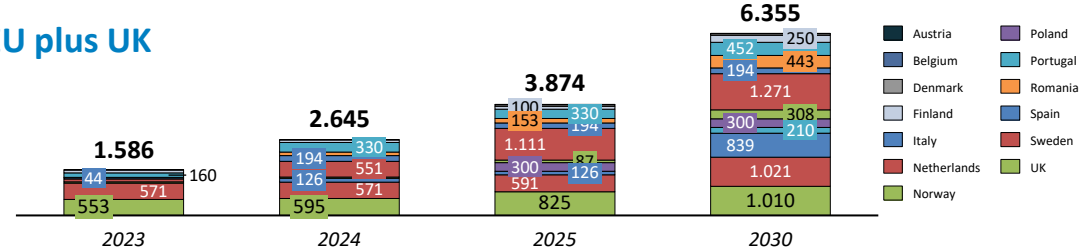
Asia incl. SEA



SAF capacity ramp-up in **Asia** incl. **SEA** represent **~20%** in **2030**. This is highly driven by NESTE's and Pertamina's refinery projects, starting in 2023.

Major projects: **Oriental Energy (China), Neste (Singapore)**

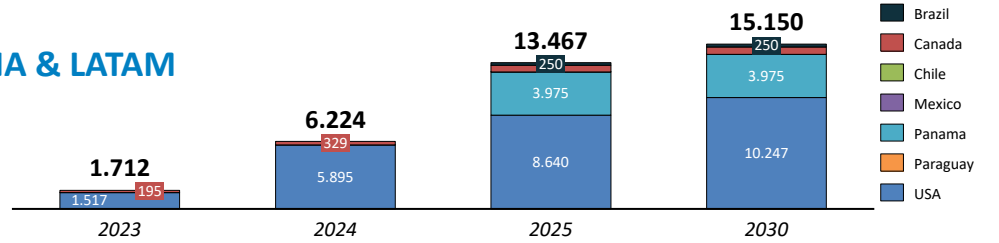
EU plus UK



EU plus UK will contribute to **more than 20%** of worldwide **production capacity** in **2030**. The Nordics have favorable conditions for PtL & PBtl.

Major projects: **Shell (Netherlands), Neste (Netherlands)**

NA & LATAM



NA & LATAM will represent **over 50%** of **global SAF capacity**, driven by **favorable regulations** and abundance of **renewable feedstocks**.

Major projects: **Grön Fuels (U.S.), SGP Bioenergy (Panama)**

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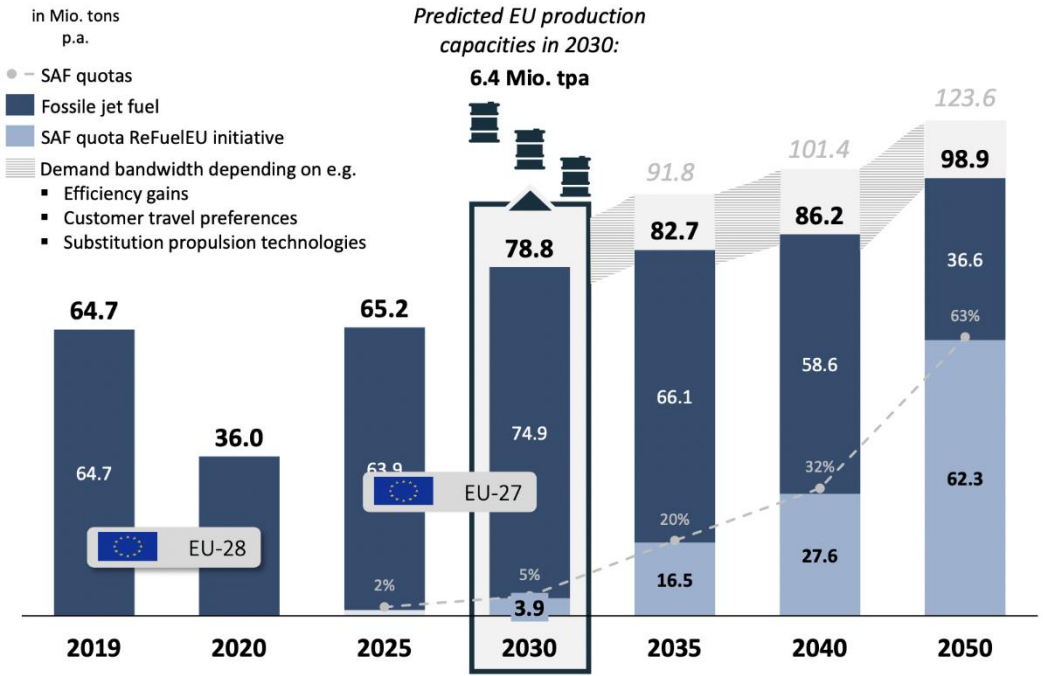
Source: Corporate announcements by respective companies; CBR, 2023;
Remarks: Predicted SAF production capacity based on operating plants and announced projects becoming operational until 2030

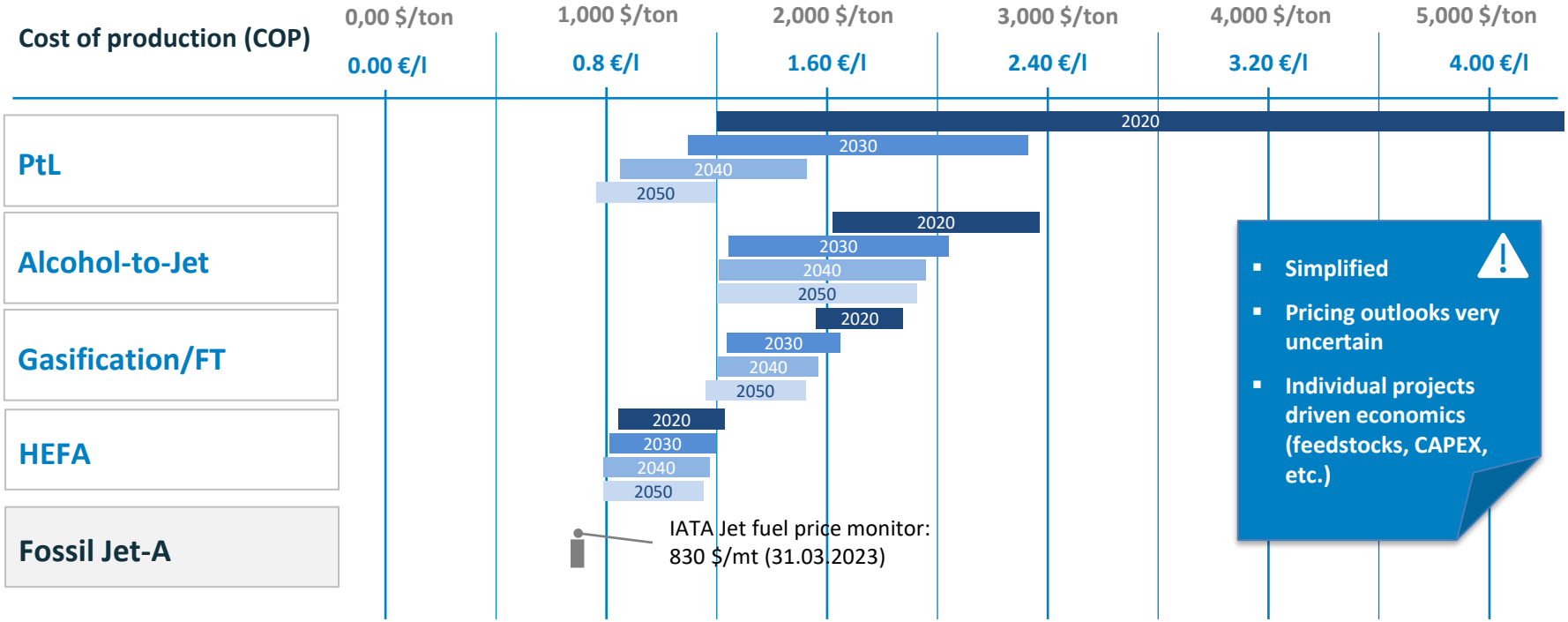
EU example – Market pull effects are induced by the introduction of SAF quotas with obligations for fuel suppliers and airlines.



- The **SAF market** and **technology adoption** driving the **production capacity ramp-up** is **strongly influenced by regulation.**
- The announced **ReFuelEU Aviation initiative in 2020** (part of the EU Green Deal framework) intends to reduce the environmental footprint of the EU aviation sector.
- Quotas **from 5-6% SAF in 2030 up to 63% in 2050** will be established. It is still a draft regulation on European level.
- It indicates a level of **pull demand** for **SAF in general** and **specific types**, here **PtL,** in the future.

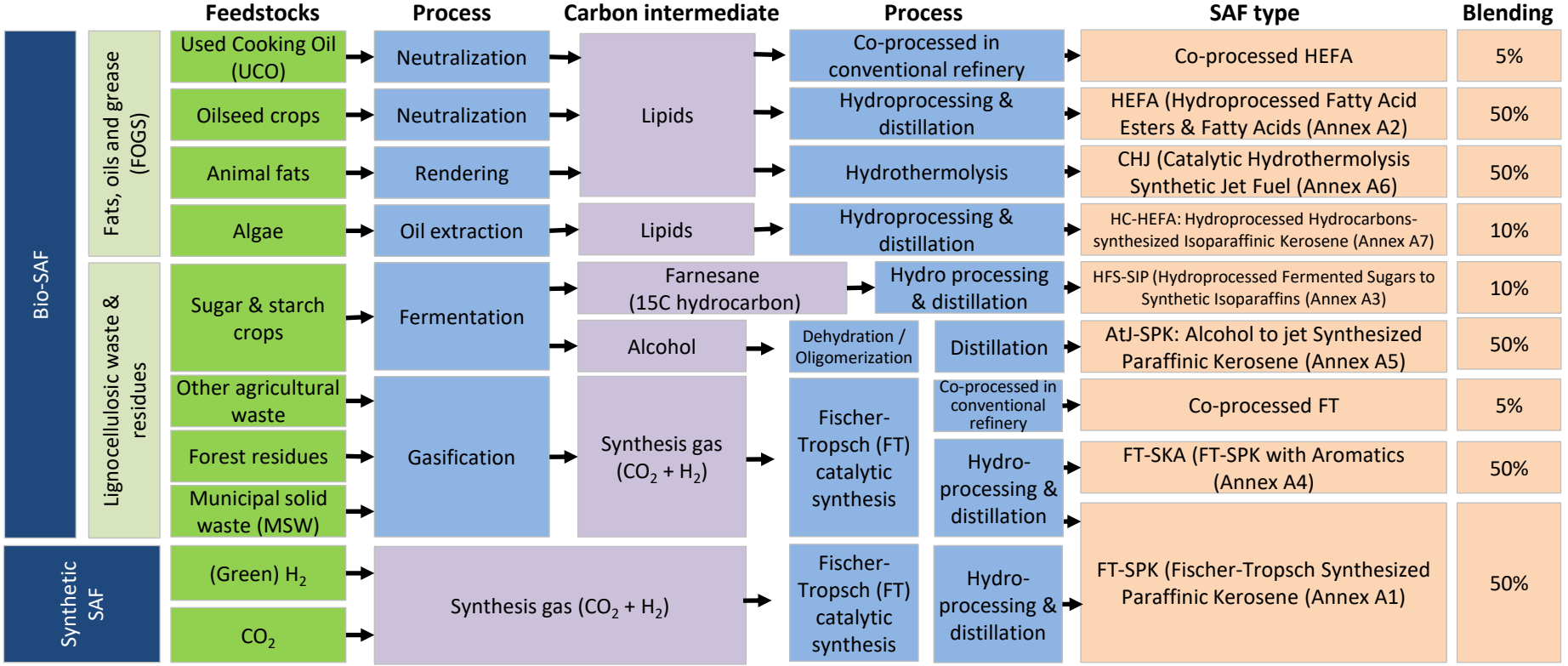
Source: BloombergNEF; Statista; Reuters/FGE; Sustainable Aviation Fuel – ReFuelEU Aviation, European Commission; Corporate announcements; CBR assumptions, 2023;
Remarks: Predicted SAF production capacity based on operating plants and announced projects becoming operational until 2030

Intransparent SAF pricing driven by specific cost of production with lowest specific capital requirement and conversion costs for HEFA.



COP: Cost of production; Source: WEF; CBR, 2022;
Remark: Currently no SAF market price due to single project-specific offtake agreements reflecting the immature SAF market, here project-based cost of production ranges for different SAF pathways and SAF project locations; exchange rate:1 EUR / 1.07 USD

High variety of SAF production routes in terms of feedstocks and technologies applied leading to different eligible blending rates



Source: Barclays Research, 2022; CBR, 2023

Pros and cons of the major six SAF production pathways

			Pros	Cons
1	HEFA	Competitive factors: **Feedstock access** and **large-scale refinery infrastructure**.	State of the art technology Low specific CAPEX Low cost of production	Limited oils / fatty acids supply Depending on feedstock
2	Power-to-Liquid	Competitive factors: **Access** to **renewable energy** (Green Hydrogen) and CO_2.	Hardly any restrictions Low GHG emissions	TRL6: not yet commercialized High specific CAPEX High cost of production
3	Waste-to-Liquid	Competitive factors: **MSW sourcing** and **pre-treatment capabilities**.	Wide range of feedstock Low GHG emissions Feedstock / process dependent	TRL7: not yet commercialized High specific CAPEX
4	Biomass-to-Liquid	Competitive factors: Abundant, reliable **biomass feedstock**, e.g. forest residues.	Wide range of feedstock Low cost of production Depending on feedstock	TRL6: not yet commercialized High specific CAPEX
5	Alcohol-to-Jet	Competitive factors: **Sustainable Ethanol access** and **technological integration**.	Low specific CAPEX Several feedstock available Depending on feedstock	TRL7: not yet commercialized Depending on feedstock
6	Hybrid fuels, e.g. PBtL	Competitive factors: **Technology proof**, **feedstock access** (e.g. biogas) and **funding** for roll-out.	Abundant feedstock Low cost of production	TRL4 (TRL8-9 indv. processes) High specific CAPEX Feedstock / process dependent

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Source: CBR, 2023

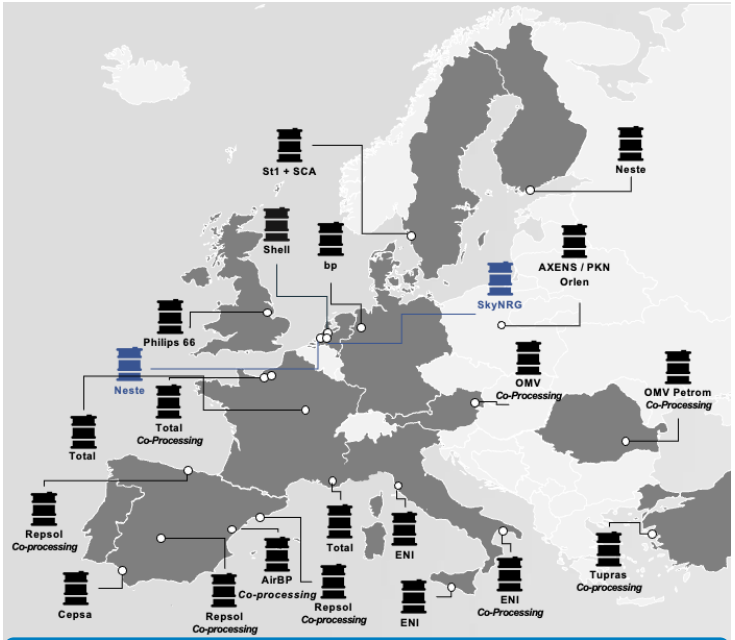
CAPEX
Cost of Production
Feedstock Availability
GHG Emission Savings
Technical Maturity
ASTM Certification(all ✓)

EU example – Comparison of selected SAF-landscape (HEFA vs. PtL/PBtL) shows differentiated roles of refineries in SAF market

Fossil refinery sites

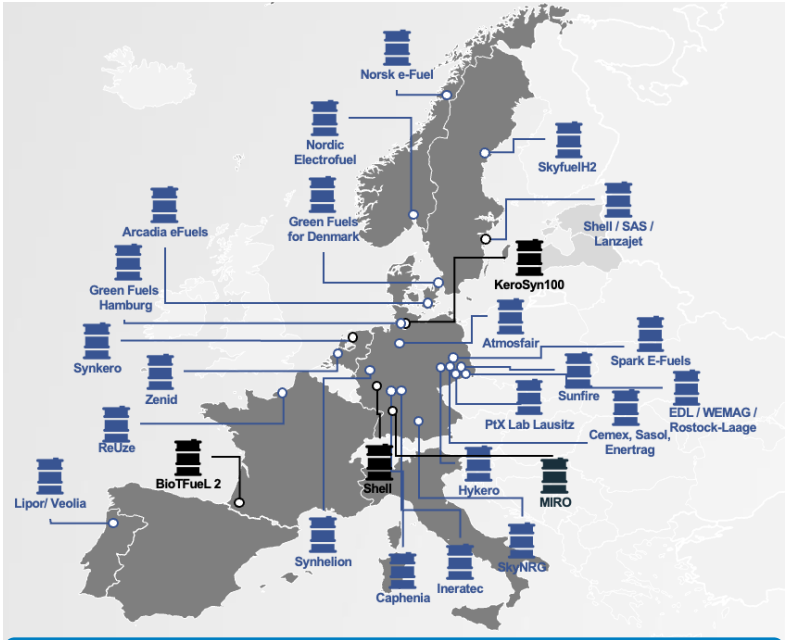
Other sites (non-fossil refinery sites)

Source: CBR analysis (status 03/2023)



Selected **HEFA (incl. co-processing)** plant projects

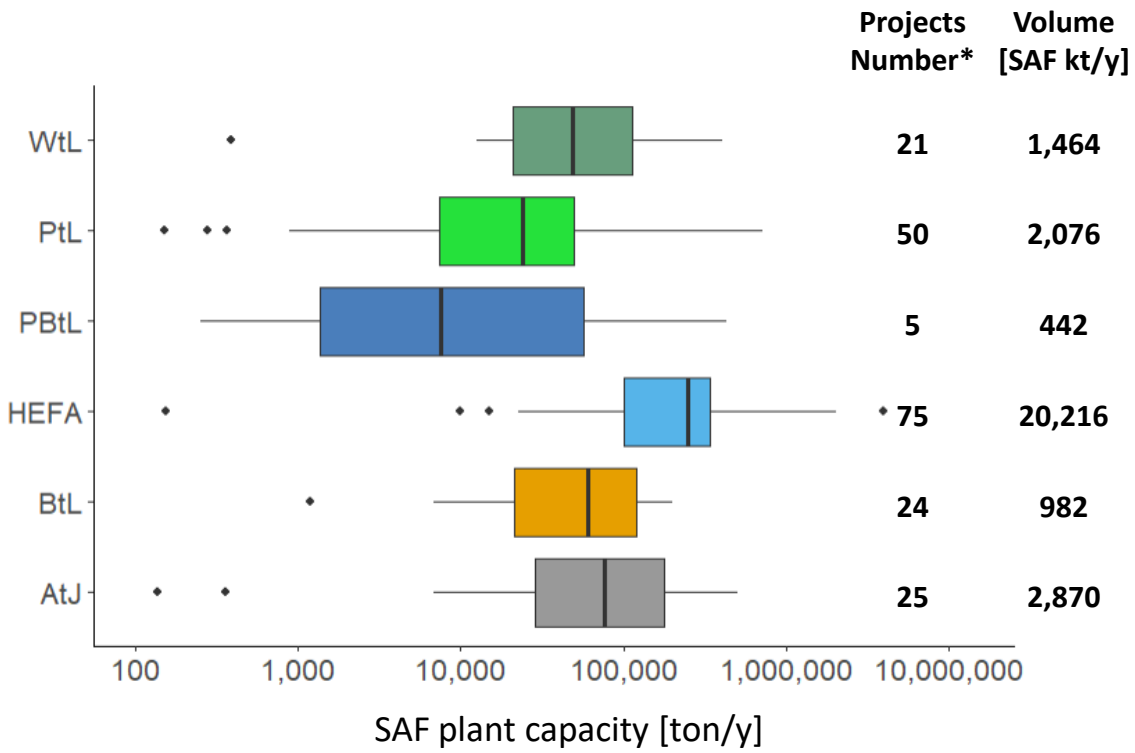
- Pre-dominantly driven by **oil majors**
- Often realized at **fossil refineries**
- Currently **dominant SAF pathway**



Selected **PtL** (incl. PBtL) plant projects

- Pre-dominantly driven by **new players**
- Realized at other **sites** (e.g., at favourable conditions for feedstock and power sourcing, i.e., regions with **abundant renewable power** at **low costs**)

Technology readiness of specific SAF production pathways results in different plant capacities and available SAF volumes



HEFA

- Most advance with **75 projects** and providing the **highest SAF volume**
- **Biggest plant** announced: **7.5 million t/y** of renewable diesel and SAF (50:50) by SGP Bioenergy (Panama)
- **Average** capacity: **270,000 t/y**
- **Median** capacity:**125,000 t/y**

PtL

- **50 PtL projects** have been announced to **start before 2030** and this number will rise in the future.
- **Average** capacity: **41,000 t/y**
- **Median** capacity: **24,000 t/y**

Source: CBR, 2023;
Remark: Based on operating or announced projects to enter in operation before 2030.

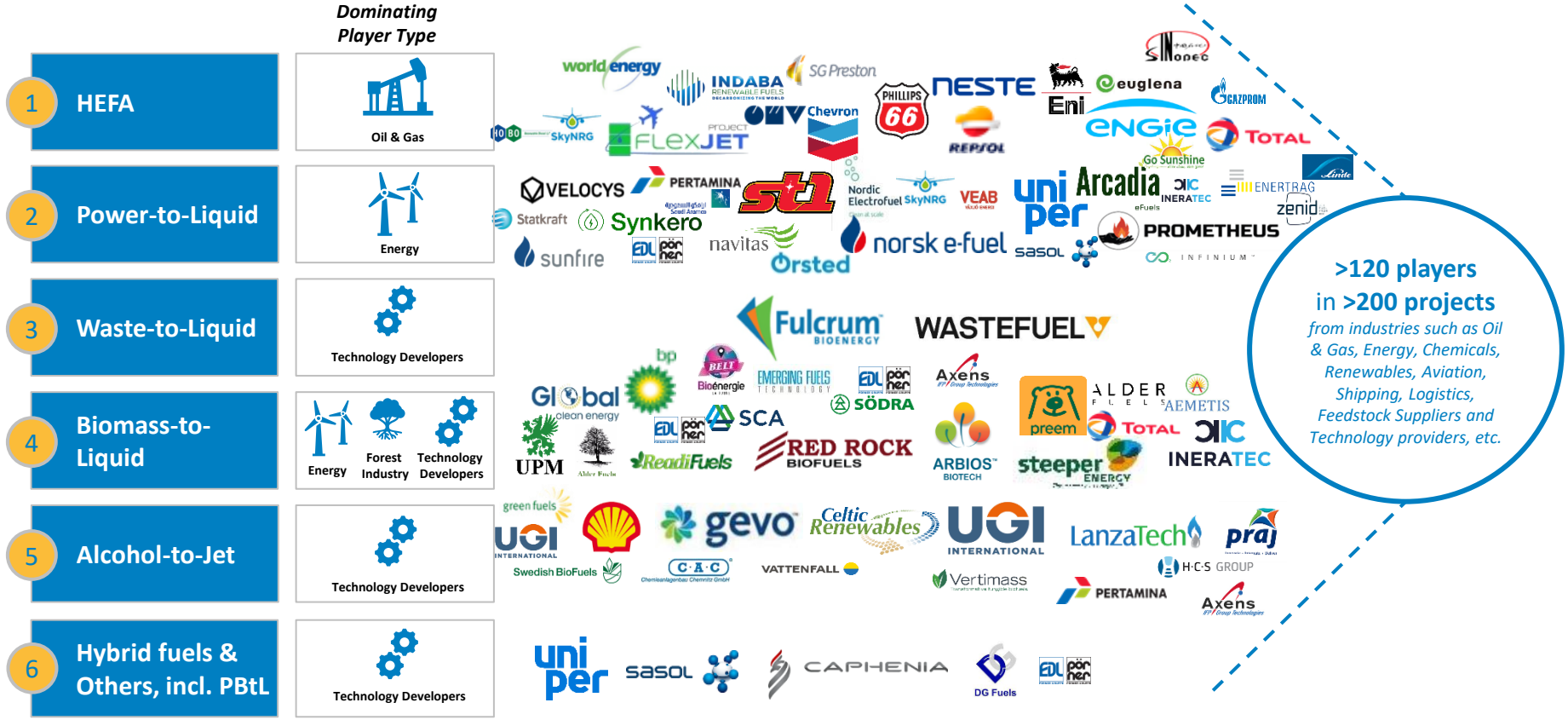
Potential fast expansion of the SAF landscape: HVO facilities converted to SAF and co-processing

- **HVO refineries** produce mainly **green diesel**.
- **Road transport electrification** will reduce its demand and **free feedstock volume** (limited vegetable oils, UCO, animal fats) which can be allocated for SAF production.
- Their chemical composition is similar and **HVO facilities** can be easily **optimised to deliver more SAF**.
- New SAF volumes could materialize relatively **quickly** by shifting the production towards **higher SAF percentage in renewable diesel plants** or by opting for **co-processing in existing crude oil refineries.**

Current and planned HVO production units

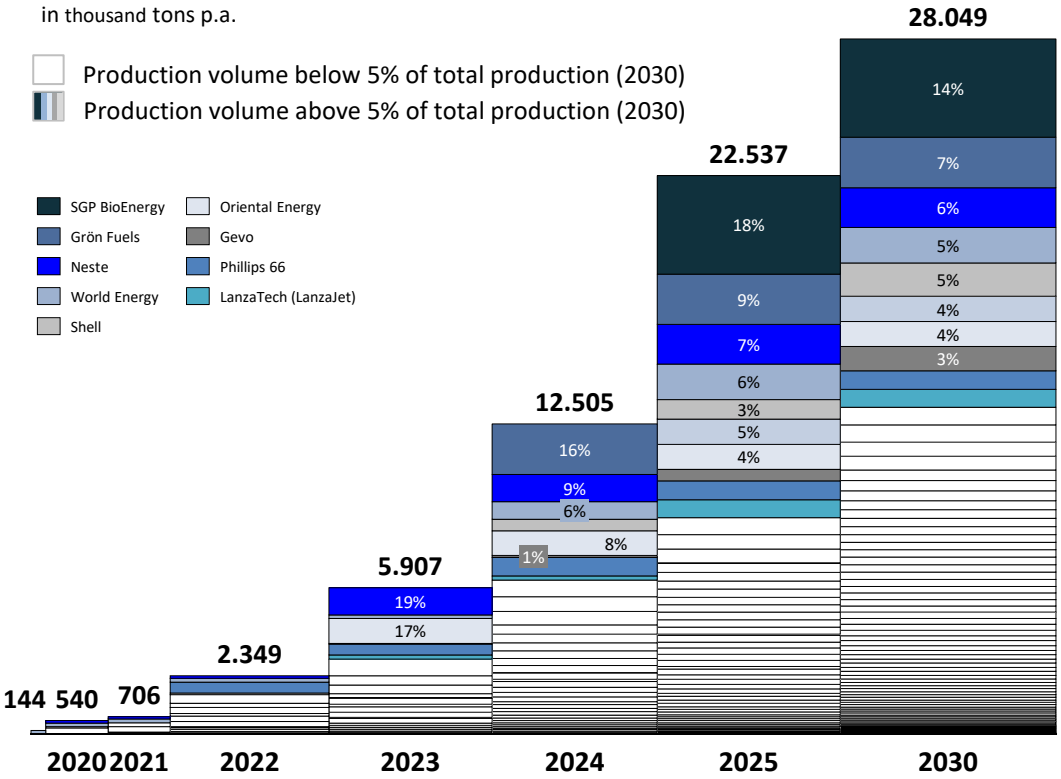
Source: Greenea; CBR, 2023; HVO = Hydrotreated Vegetable Oil

Over 120 players in +200 projects from various industries (illustrative)



Overview non-exhaustive; players can be active across several routes.

Minority of producers represents the majority of SAF production in 2030.



- **SPG BioEnergy** and **Grön Fuels** are the dominating players in 2030 followed by **Neste** and **World Energy** accounting for **over 30% market share** from a **today's perspective**.
- **Production figures** are relatively **volatile** as many new projects start, while other projects encounter significant delays or do not materialize.
- **Time lags linked to plants going on stream**, leave competitors with time to catch up on the first mover advantage.

Source: CBR, 2023;
Remark: Based on operating or announced projects to enter in operation until 2030.

Increasing number of airlines with voluntarily even more ambitious targets than the regulations with varying depth of engagement

Member of public-private consortium	Objective to reduce GHG emission	SAF sourcing & usage strategy	Part of the core corporate strategy	Purchasing program of SAF credits	Advocating for policy incentives	Supporting research	Investment in production plants	Committed funds for offtakes & R&D	Dedicated Fund	Equity stake in SAF production company

Selected example to show the variety

1

British Airways has an offtake agreement with Philips66. The airline's parent company (IAG), is investing $400 million over the next 20 years.

- Customers can choose from a range of carbon products, incl. carbon removals and SAF
- Partnership with Velocys to build a plant in Humberside will convert household and commercial waste into SAF
- Has applied for funding for a SAF plant
- SAF fund with Travel Places

2

German cargo operator **Deutsche Post DHL (DPDHL)** have committed to using at least 30% SAF by 2030, independent of mandates by regulation.

DHL Express has announced two of the largest ever SAF deals with **bp** and **Neste** amounting to more than **800 million liters**.

DPDHL launched its **GoGreen Plus** service enabling customers to **address Scope 3 emissions (SBTi)** from shipping through the use of SAF.

3

Singapore Airlines signed the **Global SAF Declaration** committing to promote the acceleration of the development, production, and consumption of Sustainable Aviation Fuel.

SIA is also **exploring mechanisms to introduce SAF credits to corporates (together with CIX) Partnership with government** in pilot program on using SAF.

Key success factors for SAF ramp-up – Elaboration of SAF roadmaps involving all key stakeholders along the regional SAF value chain

SAF roadmap objectives

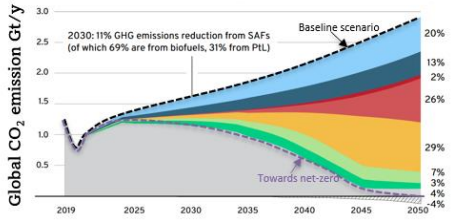
1. Expansion of SAF supply and use
2. Reduction of SAF cost
3. Enhancement of SAF sustainability

SAF roadmap building blocks

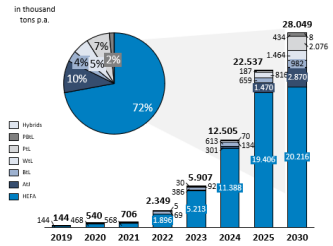
- Feedstock Innovation
- Conversion Technology Innovation
- Building Supply Chains (DSL)
- Policy and Valuation Analysis
- Enabling End Use

Source: aligned to the SAF Grand Challenge Roadmap by the U.S. Department of Energy, U.S. Department of Transportation, and U.S. Department of Agriculture, in collaboration with the U.S. Environmental Protection Agency; DSL: Direct Supply Line

Key messages – Sustainable Aviation Fuels 2030



Only the **combination of different technologies** will define the success for **net-zero aviation**.



As of today, **global SAF capacity** only covers **~5.6-7.0%** of demand in 2030, with **HEFA** as main supply.

1. **HEFA**
2. **Power-to-Liquid**
3. **Waste-to-Liquid**
4. **Biomass-to-Liquid**
5. **Alcohol-to-Jet**
6. **Hybrid fuels, e.g. PBtL**

Six pathways are **characterized by** different **technology, feedstock**, etc. with their **own pros and cons**.

Over 120 players in **>200 projects** from **various industries** & **different capabilities** defining the **pathway**.

SAF roadmaps

Direct supply line

Policies

...

- Feedstock Innovation
- Conversion Technology Innovation
- Building Supply Chains
- Policy and Valuation Analysis
- Enabling End Use

Required **SAF roadmaps** & **policies** for ramp-up, but need to be tailored to **regional-specific conditions**.

Source: CBR, 2023

Questions and Answers

EASA
European Union Aviation Safety Agency

Thanks for joining!
… stay tuned for additional sessions:

 # 12 @ 19.04.2023

CORSIA Eligible Fuels
Feedstocks categories and steps for including new types of feedstocks

 # 13 @ 27.04.2023

SAF Feedstocks and Regulation
Which general kinds of feedstock exist to produce SAF? What is their availability - today and in the future?

15h Bangkok / Jakarta / Hanoi Time
16h Singapore / Manila Time
10h Brussels / Cologne Time

EASA
European Union Aviation Safety Agency

More than 45 years ASEAN -EU relations


Shared ambitions


Shared challenges


Shared opportunities

Thank you for your attention

easa.europa.eu/connect

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