

CLEANTECH REALITY CHECK



AVIATION

E-SAF in Europe: Waiting for take-off

• What is e-SAF ?

Electro-fuel Sustainable Aviation Fuel (e-SAF) is a type of synthetic aviation fuel produced from clean hydrogen and captured CO₂ that reduces emissions by at least 90% compared to fossil jet fuel. By 2050, the ReFuelEU Aviation regulation mandates a 35% e-SAF share on the total EU aviation fuel demand. The scale-up of e-SAF is imperative to the decarbonisation of aviation, as the only alternative for low-carbon, long-haul flight is bio-SAF which is constrained by the limited availability of sustainable biomass.

• Key take-aways

- e-SAF projects are struggling to reach Final Investment Decision (FID), with none having achieved FID globally to date, and only two projects in post/engineering design stage.
- By 2030/31, the ReFuelEU Aviation regulation mandates ~600 kilotonnes per annum (ktpa) of e-SAF in Europe, but only a capacity of ~300 ktpa is currently on track to be operational by 2030.
- The primary barriers to deployment include investor concerns over regulatory uncertainty, along with insufficient public funding support and limited bankable offtake agreements and adequate mitigation mechanisms of first-of-a-kind project risk.

AVIATION



E-SAF: WAITING FOR TAKE-OFF

STRATEGIC IMPORTANCE FOR EUROPE

- European e-SAF production offers a **once-in-a-century opportunity to reduce the EU's dependence on aviation fuel imports**, increase energy security (e.g. in cases of future conflicts), and accelerate the growth of an emerging domestic industry, as many e-SAF startups currently originate in Europe.
- It also offers the opportunity to **restructure value chains**, by exporting key equipment and IP to regions with **cheaper and more abundant renewable electricity** that will produce **e-SAF at larger scales** and by importing those fuels back to the EU.
- If Europe scales e-SAF now, it could access a global e-SAF market of EUR 350+ billion per annum by 2050.

CURRENT PROGRESS OF LARGE-SCALE E-SAF PROJECTS (25+ KTPA E-SAF CAPACITY) IN THE EU

OFF-TRACK



ON-TRACK

Status: OFF-TRACK e-SAF projects are not getting to FIDs due to **perceived regulatory uncertainty from investors** (despite the legally binding nature of ReFuelEU Aviation), a **lack of adequate public support for first-of-a-kind plants, bankable offtake agreements, and adequate mitigation mechanisms of first-of-a-kind project risk.**

0 large-scale projects have **reached Final Investment Decision (FID)** anywhere in the world

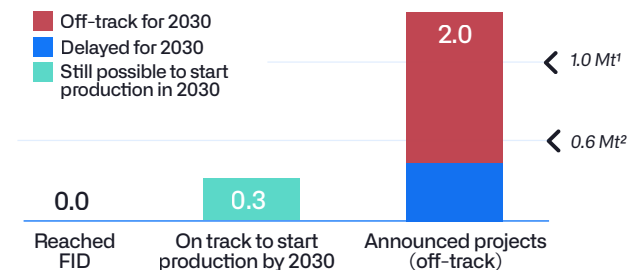
2 projects are current in or post Front-End Engineering Design (FEED) stage, preparing for FID

TWO-THIRDS OF GLOBAL E-SAF PIPELINE IS IN EUROPE, BUT PLANTS NOT ON TRACK TO MEET 2030 EU MANDATE

- Europe is home to **two-thirds** of the global e-SAF pipeline (~2.3 out of 3 million tonnes (Mt)).
- Projects need to **enter FEED phase within the next few months** to be able to start production in 2030.
- From the 30+ announced projects, **only a handful of projects could still meet that timeline¹.**

Announced e-SAF production capacity in the EU by 2030, in Mt

– excl. pilot projects <25ktpa



¹: 2032-34 ReFuelEU Aviation mandate

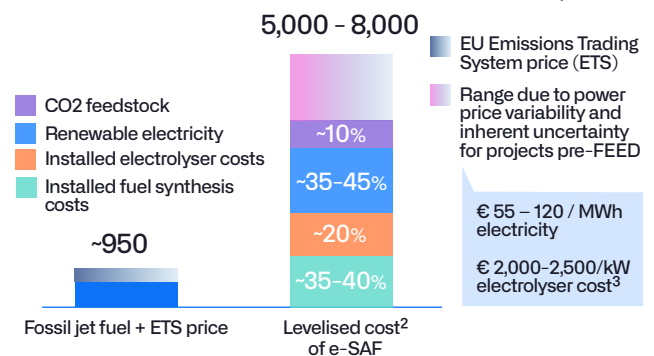
²: 2030/31 ReFuelEU Aviation mandate

E-SAF'S >5-8X GREEN PREMIUM MAKES IT UNCOMPETITIVE AGAINST CONVENTIONAL JET FUEL TODAY

- e-SAF production is electricity-intensive and involves high project-on-project risks for a first-of-a-kind plant.
- By maturing the technology (and thereby reducing the risks) and through innovation across the e-SAF production process, e-SAF costs could **come down by 40-50%** in the long run.
- However, e-SAF will not enter the market without the penalties foreseen within ReFuelEU Aviation.

Levelised cost² of e-fuel compared to price of fossil jet fuel + ETS

in EUR per tonne



¹ FEED (Front-End Engineering Design): 12+ months, getting to offtake contracts and financial close: 6+ months, Construction: 36 months, commissioning: 2-3 months, start-up phase: 15+ months.

² Only includes CAPEX and OPEX of the project itself and does not include e.g. pre-development costs, taxes, etc. hence the actual price of e-SAF required is expected to be higher than the stated costs.

³ Includes all expenses to start producing hydrogen e.g. installation (EPC, labour), site preparation (civil works, construction), auxiliary systems (e.g. balance of plant equipment like water purification systems, compressors, cooling systems), etc.

Sources: Project SkyPower (2024): Accelerating the take-off for e-SAF in Europe – Insights Report; Analysis by Systemiq undertaken for Breakthrough Energy and Cleantech for Europe.



😊 ENABLERS – WHAT IS GOING WELL

LONG-TERM DEMAND SIGNAL

ReFuelEU Aviation promotes the use of e-SAF, with an average 1.2% mandate in 2030–31, increasing to 35% by 2050. The regulation includes high penalties (at least 2x the green premium) and no buy-out option due to make-up obligation. SAF allowances¹ could provide revenue certainty in the long run: the number of allowances dedicated to e-SAF increases and is provided on a 10-year basis.

EU INDUSTRIAL LEADERSHIP

Two-thirds of the global e-SAF project pipeline is in Europe (2.3 Mtpa – equivalent to 5% of the expected 48 Mt of aviation fuel demand in the EU by 2030). For 10+ years, R&D support and the prospect of a strong demand signal with ReFuelEU Aviation has made the EU a tech leader, with pilot plants in operation or under construction.

HIGH LONG-TERM INTEREST FROM BANKS AND EQUITY

Banks and equity express high long-term interest to provide finance of EUR 1–2 billion for a ~50 ktpa e-SAF plant, due to long-term offtake security provided by ReFuelEU Aviation. Hence, enough capital is ready to be deployed to cover the total CAPEX need of EUR 15–25 billion to fulfil the 2030 e-SAF mandate, once e-SAF projects are sufficiently de-risked.

☹️ BARRIERS – WHAT IS NOT GOING WELL

REGULATORY UNCERTAINTY

ReFuelEU Aviation provides a solid regulatory framework. While the EU's e-SAF mandates are clear and legally binding since 2024, perceived regulatory uncertainty forms a barrier to FID, e.g. because Member States have not yet provided clarity on penalty systems. Reducing ambition levels would be incompatible with the EU's 2040 climate targets.

LACK OF BANKABLE OFFTAKE CONTRACTS (10+ YEAR, E.G. TAKE-OR-PAY)

from fuel suppliers (Oil & Gas companies) and airlines. So far, O&G majors have not yet contracted e-SAF from producers, despite being the obligated party as suppliers – nor have they invested into e-SAF projects themselves. Due to the technological performance and supply risks of first-of-a-kind e-SAF projects, airlines are hesitant to enter long-term offtake contracts – in particular if their competitors are not taking the same step, as production costs of future e-SAF plants could decrease and expose them to a first mover disadvantage.

INADEQUATE PUBLIC FUNDING

Many EU funding instruments (e.g. EU Innovation Fund, EU Hydrogen Bank, SAF Allowances) are currently inaccessible to e-SAF projects (in the light of competition with lower-hanging fruit-sectors, or bio-SAF) and are not capitalised adequately.

📅 ACTION AGENDA – WHAT NEEDS TO BE DONE

1 Build a business case for e-SAF:

Establish an adequate mix of incentives and penalties to create a business case for e-SAF by implementing EU policies at member state levels and ensure that European companies using e-SAF benefit from a global level playing field and are not punished for being first movers.

2 Provide sufficient and adequate public funding for the first wave of e-SAF projects:

Provide sufficient public funding in the short-term, e.g. in form of a dedicated e-SAF call within the EU Innovation Fund or the EU Hydrogen Bank (ticket sizes of EUR 400–600 million to close competitiveness gap with the US) – and in form of development expenditure support (ticket size of EUR 10–15 million per project for FEED studies). In the long-term, increase number of SAF Allowances dedicated to e-SAF and change to 10-year allocations.

3 Stimulate accessible and affordable loans:

from the European/national investment banks, and loan guarantees from InvestEU and export credit agencies (backing commercial debt.)

¹ ETS allowances for uptake of SAF – herein referred to as SAF Allowances

Sources: Project SkyPower (2024): Accelerating the take-off for e-SAF in Europe – Insights Report; Analysis by Systemiq undertaken for Breakthrough Energy and Cleantech for Europe.

“The scale-up of e-SAF production in Europe presents a pivotal opportunity to achieve energy independence in Europe. The EU must harness its experience from past clean energy breakthroughs and seize this moment to become a leader in e-SAF.”

Amy Hebert, CEO Arcadia e-Fuels



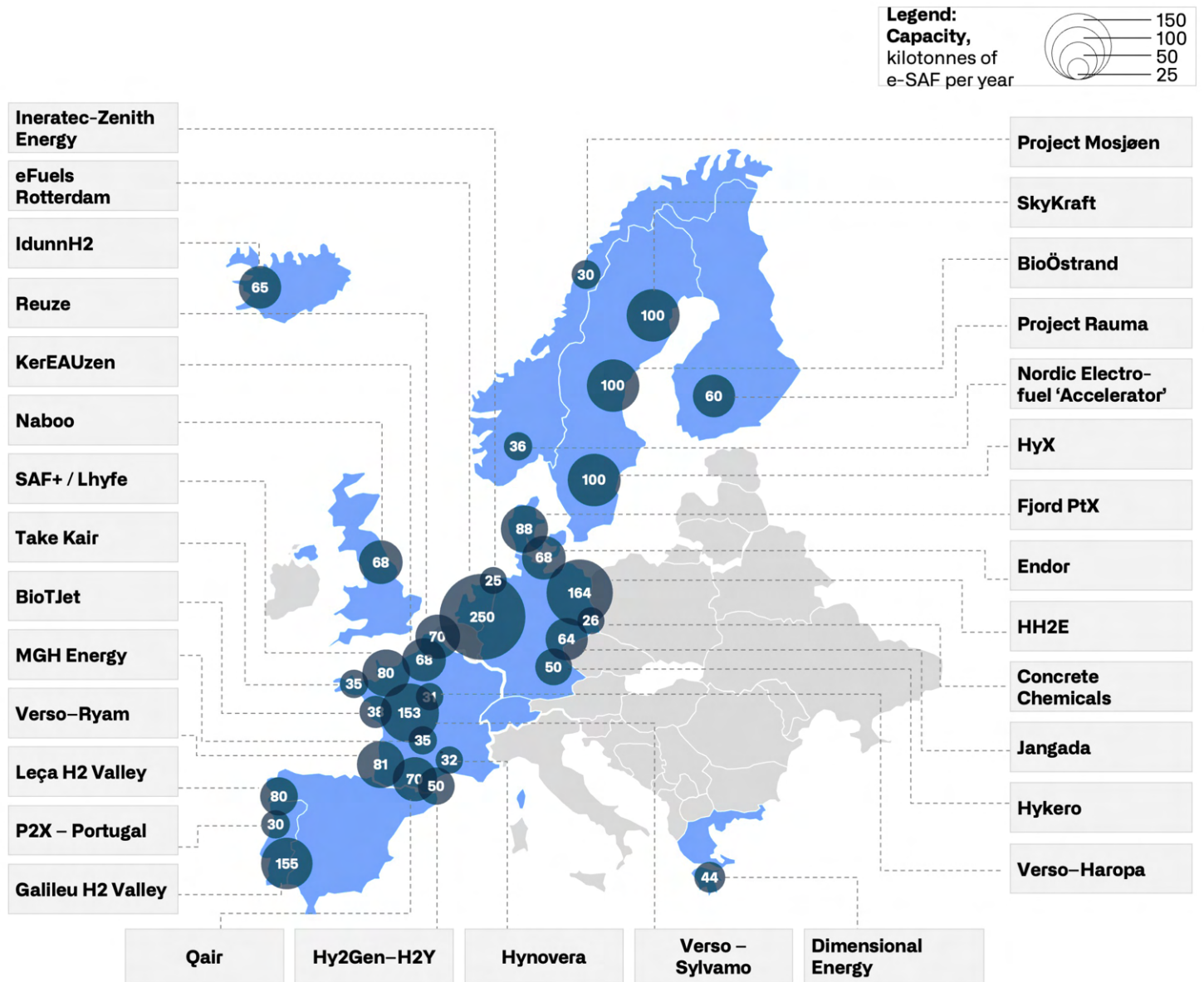
AVIATION



E-SAF: WAITING FOR TAKE-OFF

AROUND 30 ANNOUNCED LARGE-SCALE E-SAF PLANTS (~2.3 MTPA) IN EUROPE

(as of October 2024)



Notes: All projects plan to use biogenic CO₂. Some projects also plan to use point source CO₂ from cement or steel production. Map excludes projects <25 ktpa e-SAF capacity
Source: Systemiq, T&E, MPP (2024), based on public announcements and press search.