SKYNRG

SUSTAINABLE AVIATION FUEL MARKET OUTLOOK 2023

May 2023

FOREWORD

"NOW THAT KEY LEGISLATION IS IN PLACE, IT IS TIME TO DIRECT FINANCING TO THE RIGHT PATHWAYS THROUGH WHICH WE CAN ACCELERATE THE SAF INDUSTRY"

We are at the beginning of an exciting new era of sustainability in aviation. Policies for Sustainable Aviation Fuel (SAF) production and use in the EU, the US and the UK are accelerating the development of SAF production capacity by reducing the uncertainty on the demand and supply side. At the same time, we see a growing number of new SAF projects being announced to meet existing and future demand from mandates and voluntary commitments made by frontrunners in the aviation sector. Corporates and individual travellers are also contributing to maturing the SAF industry through programs such as those initiated by SkyNRG.

This report covers the current state and trends of the SAF market in the European Union, the UK and the US by assessing announcements of SAF projects and modelling SAF capacity until 2050. We originally produced this report for our own needs, to understand and map these market developments. We then decided our market outlook should be made available to anyone wanting to understand the SAF industry. We are pleased that it continues to establish itself as a reference publication and a leading source of market information in the industry.

Our analysis reveals that Europe and the United States can reach their 2030 goals if sufficient new capacity is announced and materializes, but there is still much to do. Together these markets offer USD 650 billion ESG-related CAPEX investment opportunities by 2050 and more if we include upstream supply chains and service providers.

The industry now needs solid partnerships to realise the increase in production capacity required to reach net zero. These include partners who commit to meaningful SAF offtakes, investors that recognize the importance of SAF in their portfolio and are willing to fund projects, and visionary leaders and governments who recognize and can address the investment hurdles that remain.

This market outlook is a summary of extensive research, modelling, analysis and discussions with industry stakeholders. Every year, we review SAF advancements, update our analysis, and continue to share it with the industry. We would like to thank the team in SkyNRG who were involved in making this report and everyone who is working hard to help aviation reach its goal of being net zero by 2050. Please get in touch with us if you want to explore how SkyNRG can support you on your journey to more sustainable aviation.

Philippe Lacamp
Chief Executive Officer

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EXECUTIVE SUMMARY

On the 25th of April, the **European Council and Parliament reached a provisional deal on ReFuelEU**, a landmark piece of legislation aiming to establish harmonized targets to increase demand and supply of sustainable aviation fuel (SAF) across the EU-bloc. Binding targets are expected to accelerate investment into SAF and bring the aviation sector on a trajectory that is aligned with the Paris Agreement.

The UK in turn, is advancing its discussions on a national SAF mandate equivalent to 10% of jet fuel by 2030, and is targeting to have five UK production plants under construction by 2025. To avoid displacing feedstock from road to aviation, the UK intends to install a waste oil cap.

In the United States, guidance on federal tax credits is being developed while State governments (WA, IL) are introducing stackable tax incentives that are expected to kickstart the SAF industry in the US.

Blending mandates and production goals worldwide are expected to trigger at least 12.8 million metric tonnes (Mt), or 4.5 billion gallons (Bgal), of SAF demand and supply by 2030. Voluntary commitments from corporates, airlines and freight forwarders are expected to further drive up demand.

As legislation in the EU, UK and the US crystalizes, patterns in future trade flows based on eligible feedstocks can be predicted. As a result of how policies are designed, we expect waste oil-based SAF generally to be most attractive in the EU, SAF based on advanced feedstocks (e.g., agricultural residues) and MSW in the UK market, e-SAF in the EU and the UK whereas agricultural commodity-based SAF (e.g., soybean oil) is likely to be most attractive in the US.

A wave of announcements in renewable diesel projects, mainly from the US, will further increase pressure on global waste and vegetable oil markets. If all renewable diesel announcements become operational, this could prove to strain available feedstock supply for HEFA and the feasibility of reaching 2030 goals in the US and Europe, or risk significantly impacting agricultural commodity markets globally.

Markets with blending mandates (EU, UK) and production goals (US) in place or under development today could have approximately 120 Mt (42 Bgal) of SAF production capacity in place by 2050. If SAF is the main product, an estimated production capacity of 78 Mt of renewable co-products such as diesel and naphtha would also be in place, thereby contributing to the decarbonization of road, marine and chemical sectors.

EUROPEAN UNION AND UK

1.

Mandated demand in both markets is expected to reach 4.2 Mt (1.5 Bgal) by 2030, excluding demand from voluntary commitments.

2.

SAF projects expected to reach operation are estimated to supply up to 3.3 Mt (1.2 Bgal) SAF by 2030, 0.6 Mt (0.2 Bgal) more compared to the analysis of last year. Announcements are predominantly HEFA-based (80%), with some facilities coming online post-2025 opting for more advanced pathways such as Alcohol-to-Jet (AtJ), Fischer-Tropsch (FT) and e-SAF. Various facilities are delayed compared to our previous outlook, leading to a slower ramp-up of SAF production in Europe.

3.

SAF supply is expected to meet mandated demand until 2030, with a supply gap of 0.9–2.1 Mt (0.3–0.7 Bgal) remaining until 2030 targets, depending on the growth in jet fuel consumption. Note however, that the voluntary market could potentially absorb production capacity in excess of what is needed to meet mandates.

4.

Supply gap to meeting 2030 targets can be closed by new announcements of projects currently in feasibility stage and imports of SAF from the US and Asia-Pacific. EU SAF projects with a total production capacity of ~1.5 Mt (0.5 Bgal) are currently in feasibility stage, while SAF capacity of ReFuelEU-eligible SAF capacity outside of Europe could provide ~7 Mt SAF to EU and UK markets by 2030.

5.

To reach a European SAF production capacity of 40 Mt (14 Bgal) by 2050 around 150 SAF refineries would have to be deployed, representing 250 billion EUR in CAPEX investment. Investment would be required mostly in the conversion of cellulosic/MSW feedstocks into SAF and clean hydrogen/CO_2 into e-SAF.

6.

SAF requirements based on European mandates until 2050 can be met with European SAF production capacity if jet fuel demand remains at pre-Covid levels (40 Mt, 14 Bgal). Growth in jet fuel consumption could drive up SAF needs to 69 Mt (24 Bgal), which would add further pressure on SAF capacity deployment and/or imports.

UNITED STATES

1.

Aspirational production of SAF in the United States is 3 Bgal (8.5 Mt) by 2030 and 27–35 Bgal (77–100 Mt) by 2050. Getting on track to meeting these 2050 goals requires a more stable and long-term policy climate for SAF that delivers investment certainty.

2.

Based on current announcements, SAF supply could reach 2.2 Bgal (6.2 Mt) by 2030, based on current announcements. Announcements are predominantly HEFA (66%) and corn ethanol-ATJ based (27%).

3.

Waste and vegetable oil markets in the US are under pressure. The success of HEFA-based SAF projects is contingent on the US: evaluating scale of renewable diesel announcements to free up feedstock, or risk impacting global agricultural commodity markets by significantly expanding soybean oil production.

4.

SAF based on corn ethanol and cellulosic waste feedstocks could close the gap to meeting the US goal of 3 Bgal (8.5 Mt) SAF production by 2030. Attractive state and federal policies drive investments in cellulosic SAF while corn ethanol incentive eligibility still hinges on the selected greenhouse gas (GHG) methodology.

5.

By 2050, the US could have enough domestically based SAF capacity in place to substitute its pre-Covid jet fuel demand of 27 Bgal (77 Mt) with SAF. This is contingent on the rapid deployment of SAF refineries based around use of green H_2 and cellulosic feedstocks. Growing jet fuel demand beyond pre-Covid levels would increase competition for feedstock and may further challenge the feasibility of meeting the 2050 production goal.

6.

To reach a domestic SAF production capacity of 27 Bgal (77 Mt), the US would have to deploy around 250 SAF refineries by 2050, representing a cumulative CAPEX investment of 400 billion USD.

EUROPEAN UNION AND UK

European Council and Parliament reach provisional deal on ReFuelEU

European Council and Parliament negotiators agreed on a set of harmonized rules to increase the uptake of sustainable aviation fuel (SAF) across the EU. Binding targets will mandate fuel suppliers to make a minimum share of SAF available at EU airports. Sub-targets are in place for synthetic aviation fuels[1] to ensure that these fuels can play a major role in decarbonising air transport in the longer term.

The deal includes a broader definition of SAF compared to the initial Commission proposal, namely: i) SAF produced from advanced feedstocks defined in Renewable Energy Directive (RED) Annex IX[2], ii) SAF produced from other RED-eligible feedstocks, and iii) synthetic aviation fuels that are considered renewable fuels of non-biological origin (RFNBOs).[3]

As a carve-out to the above, food and feed-based aviation biofuels and biofuels made from palm- or soy-derivatives will not be eligible for the mandate.

[1] In this report hereafter referred to as e-SAF.

[2] Annex IX defines feedstock eligible for the RED II, and is currently being updated. It includes agricultural wastes, household waste and waste oils, among others. A proposed update to Annex IX also includes crops grown on degraded land and intermediate crops.

[3] These are, e.g., e-SAF and green hydrogen produced in accordance with RED II Delegated Act Art. 27 and 28.

Minimum shares of SAF are considered compliant when supplied with recycled carbon fuels (RCFs).[4] Synthetic aviation fuel minimum shares can also be supplied with 'low-carbon aviation fuels', a new term introduced to refer to hydrogen or synthetic aviation fuels made from nuclear power. This widening of the scope of eligible feedstocks is expected to alleviate some pressure on waste oils to satisfy short- to medium-term targets, but could take away market share from synthetic aviation fuels made from green hydrogen.

Fuel suppliers will have the flexibility to average fuel supplies across EU airports they supply with the minimum share of SAF until 2035.[5] Non-compliance with the minimum shares will be fined with a penalty of double the difference between the price of conventional jet fuel and SAF while maintaining an obligation to supply the minimum share in the following year.

Minimum shares of SAF and synthetic aviation fuel required in the EU

	2025	2030	2032	2035	2040	2045	2050
SAF	2%	6%	6%	20%	34%	42%	70%
Synthetic aviation fuel	-	1.2%	2%	5%	15%	20%	35%

UK government is considering a SAF mandate of 10% by 2030, including a cap on waste oil use

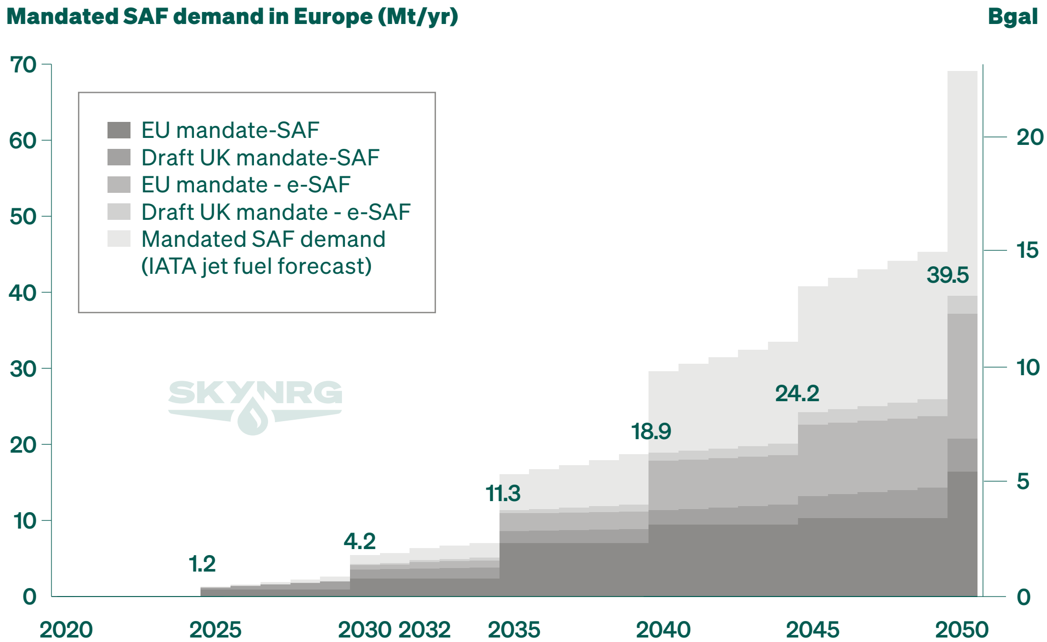
In 2022, the UK launched its *Jet Zero Strategy*, aiming to achieve a net zero aviation sector by 2050 by focusing policy across six measures: system efficiencies, SAF, zero emission flight, market-based measures and removals, consumer demand and non-CO_2 impacts. The UK government is planning to introduce a SAF mandate to trigger SAF demand and enable a domestic SAF industry. To this end, it is currently running a second industry consultation with the aim of beginning the legislative process early 2024.

A previous consultation round confirmed that the UK wants to go ahead with a 10% SAF target by 2030. The UK's Jet Zero Strategy further suggests that a 50% SAF pathway by 2050 is the most likely trajectory for the UK. The government also intends to install a cap on how much SAF can be made from waste oils to prevent oils being displaced from the road transport sector to aviation. The government is considering a cap of either zero, or one that increases to ~250,000 tonnes of SAF by 2040. Buy-out prices are intended to give fuel suppliers the option to discharge their SAF blending obligation in case they are unable to source SAF on the market, while also protecting consumers from disproportionally high costs. Buy-out prices are proposed at 2,657 GBP/tonne SAF and 3,525 GBP/tonne e-SAF. Especially the e-SAF buy-out price is considered to be too low to trigger demand from fuel suppliers by 2030.

[4] These are low-carbon fuels (minimum 70% GHG reduction) that have their energy content coming from fossil waste, e.g., refinery or steel mill waste gases.

[5] This introduces some uncertainty around the level of blending that can be expected per member state, as fuel suppliers are allowed to choose at which EU airport they want to fulfil their obligation.

Mandated SAF demand in the EU and UK are expected to reach > 40 Mt by 2050[6]



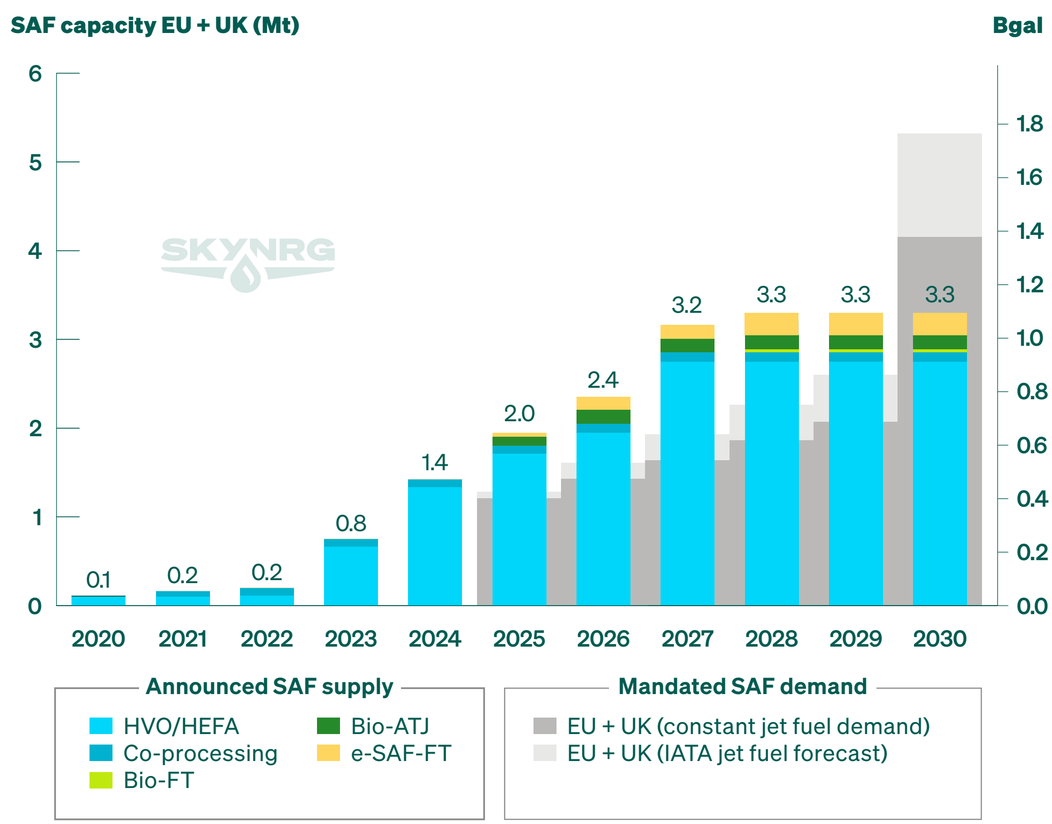
[6] Base case jet fuel demand in the EU assumes that jet fuel demand rebounds to pre-Covid levels by 2025 (46.9 Mt, 15.5 Bgal) and aircraft efficiency gains offset any increase in jet fuel demand until 2050. IATA forecast sees jet fuel demand grow by 72% between 2019 – 2050 to 80.4 Mt (26.6 Bgal). Yet undefined targets for the synthetic aviation fuel sub-target are adjusted pro-rata based on the Council and Parliament proposals.

Announced accumulative SAF production capacity has increased compared to last year, from 2.6 to 3.3/year Mt (0.9 to 1.2 Bgal) by 2030

Based on our assessment of European SAF announcements in the public domain today, we expect that 3.3 Mt/year (1.2 Bgal) will reach commercial operation by 2030. This is an increase of 0.6 Mt/year (0.2 Bgal) compared to our assessment a year ago. However, we observe that multiple projects have experienced delays,[7] in part due to policy uncertainty postponing final investment decisions. This has decreased announced SAF capacity in the coming years and 'pushed' capacity coming online more towards 2030, with some identified developers updating their announced SAF capacity as their project progresses.

A major share of the announced HEFA capacity is driven by two SAF announcements: Neste Rotterdam (1.2 Mt, 0.4 Bgal) and Shell Pernis (0.4 Mt, 0.14 Bgal), both in the Netherlands. This means that 60% of the announced HEFA capacity in Europe is contingent on the success of these two projects. Future SAF capacity in Europe could further be impacted by the success of less technologically mature pathways, such as alcohol-to-jet (ATJ), gasification in combination with Fischer-Tropsch (G+FT) and e-SAF, which together represent about 0.45 Mt (0.16 Bgal) of announced SAF production capacity. We expect that the UK will become an important market for advanced biofuels, which are not specifically mandated in the EU, while some member states may introduce e-SAF targets/incentives prior to 2030 to kickstart supply.

More announcements or imports are needed to close 'supply gap' in 2030[8]



[7] In our previous analysis, we identified 2 Mt (0.7 Bgal) SAF capacity announced in 2024 vs. 1.4 Mt (0.5 Bgal) in this analysis.

[8] Note that the EU mandate has minimum shares of SAF defined for 2025 and 2030, remaining constant for the years in-between. This causes a significant step-change from 2029 to 2030.

More SAF capacity or imports are needed to close the ‘supply gap’ to meet European mandates

Mandated demand from EU and UK is expected to be 4.2–5.4 Mt (1.5–1.9 Bgal), the difference being caused by uncertainties in European jet fuel demand by 2030.

In previous analyses, SkyNRG had assumed that part of the gap between announcements and mandated demand could be filled by renewable diesel (RD) producers investing in ‘capacity switching’, i.e, changing the configuration of a RD plant to produce more SAF. Developments around the implementation of ‘Fit for 55’, specifically around RED III and the inclusion of road transport under EU ETS suggests that the demand for renewable fuels in Europe will increase dramatically. We therefore assume that renewable diesel producers will not switch capacity to SAF to meet 2030 targets.

We consider it more likely that new SAF capacity projects will be announced, or that SAF is imported from outside the EU to satisfy minimum SAF shares in 2030. Currently, about 1.5 Mt (0.5 Bgal) of SAF production capacity is in ‘feasibility’ stage. If these projects progress to making a final investment decision, European mandates could be fulfilled with SAF capacity located in Europe. Furthermore, there is approximately 7 Mt (2.5 Bgal) of SAF capacity announced globally that is estimated to be fully or partially compliant with ReFuelEU. This SAF supply is considered to find the markets with the highest incentives, so in the case that there is an under-supply in European markets, imported SAF is likely to be used for compliance purposes.

An uncertainty of this analysis is demand from voluntary commitments by corporates, airlines or freight forwarders. Most of the SAF production capacity in operation today is already spoken for, in the absence of active mandates. With various organizations having SAF commitments that significantly exceed the European mandates, it is likely that SAF demand in Europe is higher than what is mandated. In addition, a number of EU member states are considering stimulating SAF supply beyond the minimum levels under ReFuelEU, including the Netherlands, Sweden, Finland and Germany. Policy tools other than blending mandates will be needed for those member states wanting to go further compared to the minimum shares as the EU will not allow higher national mandates, in order to protect the EU level-playing field.

European mandated demand until 2050 can be met with European SAF capacity if growth in liquid jet fuel demand is limited

We estimate that European SAF capacity could grow to 40 Mt (14 Bgal) by 2050 if deployment of pathways using cellulosic materials and MSW (AtJ, Gas+FT) and green hydrogen (e-SAF) accelerate rapidly. In our analysis, we constrain SAF growth by the maximum pace of deployment[9] and feedstock availability of biomass, MSW and renewable power for green hydrogen production.

[9] Based on historical deployment of corn ethanol facilities in the US.

A key sensitivity for European SAF supply is feedstock availability, but more important is the share of that feedstock pool that can be used for SAF production. This is determined by the willingness to pay for feedstock compared to other end-uses such as maritime, road transport and chemicals production, which is again driven by the stringency of mandates and overall jet fuel demand. Our sensitivity analysis shows that if aviation can claim only 10% of total feedstock (vs. 20% assumed), potential SAF capacity in Europe would decrease by 11 Mt.

If jet fuel demand increases, mandated demand in Europe could significantly outgrow available supply (~70 Mt [24 Bgal] demand vs. 40 Mt [14 Bgal] capacity), either leading to greater dependency on imports, and/or greater pressure on feedstock to produce more SAF and thus higher feedstock prices, and/or demand reduction due to price elasticity effects or government intervention.

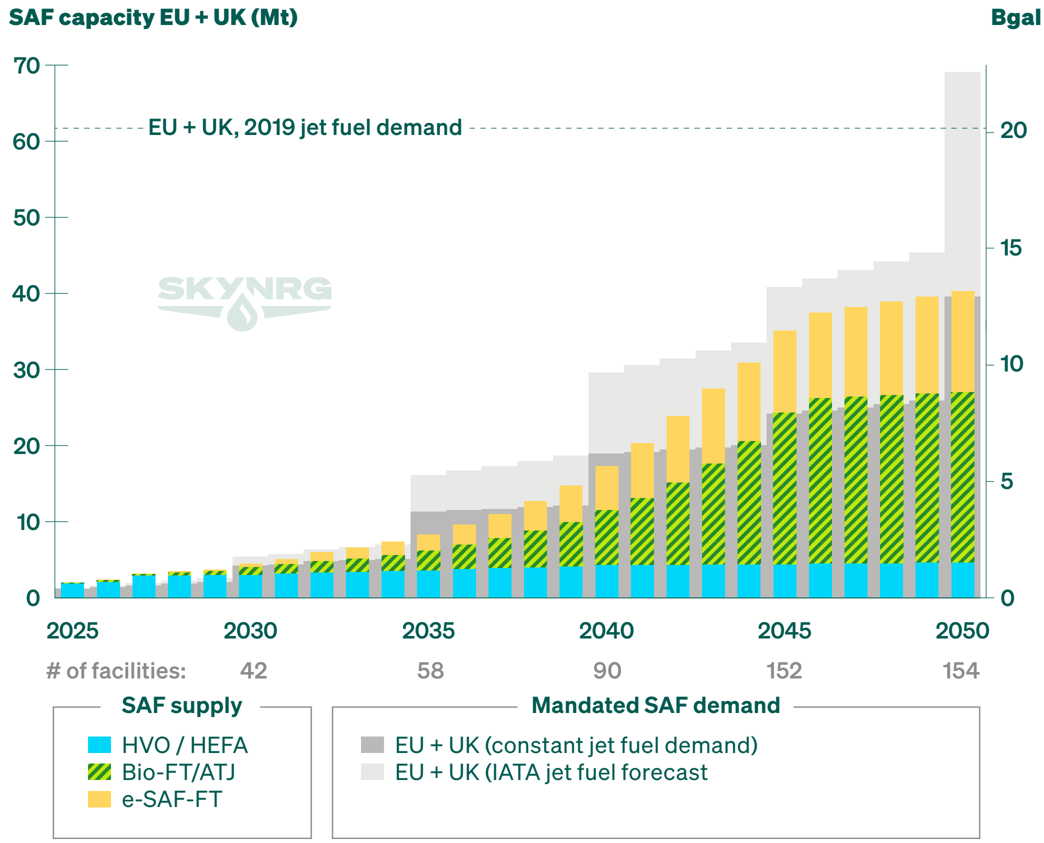
Reaching 40 Mt (14 Bgal) of European SAF production capacity by 2050 means deploying around 150 SAF refineries

To reach a European SAF production capacity of 40 Mt (14 Bgal), by 2050, approximately 150 dedicated SAF refineries would have to be deployed. While these refineries could be optimized for maximum SAF production, product slates cannot be geared to output 100% SAF regardless of the technology. With the technology mix modelled in our analysis, around 28 Mt of renewable co-products like renewable diesel and naphtha are produced that can contribute to reducing GHG emissions in road transport, maritime and production of bulk chemicals.

Capital expenditures required to develop 150 SAF refineries represents a cumulative investment of ~250 billion USD, or average annual CAPEX of 10 billion USD between 2025 – 2050. This is roughly equivalent to 2% of global annual upstream oil and gas CAPEX in 2019.[10]

[10] IEA (2022)

European SAF capacity vs. mandated SAF demand until 2050



SkyNRG SAF Database and Capacity Growth Model

2030 Outlook

A — Total renewable fuel supply

- We identified **announced renewable fuel capacity** based on existing SAF announcements:
  - Using key sources such as press releases
  - Only including facilities that could produce SAF (e.g. excluding biodiesel plants)

B — Realistic SAF supply

- We excluded **renewable fuel facilities that are considered unlikely to produce SAF:**
  - facilities in a feasibility phase;
  - facilities that are unlikely to materialize (on time)
  - facilities unlikely to produce SAF
- We estimated the **realistic SAF output for each facility** using tech/supplier specific SAF yields

C — Feedstock/capacity checks

- We applied two sense-checks to the realistic SAF scenario:
  - **feedstock:** assess waste oil availability when considering demand from other sectors
  - **renewable fuel capacity**: assess demand from road transport and marine policy to verify potential renewable diesel 'capacity switches'

2050 Outlook

- Few SAF plants are announced today that start after 2029.
- To forecast SAF supply until 2050 we developed a capacity growth model, applying the s-curve principle to estimate maximum SAF refinery deployment based on an initial state of SAF announcements in 2028.
- SAF deployment is constrained by feedstock availability, sourced from S2BIOM (Europe) and the Billion Ton Study (US).
- Finally, we run a sensitivity analysis to discover the most impactful drivers in this base case.

Federal and state tax credits under development for SAF are expected to kickstart a domestic SAF industry

To implement the US *Inflation Reduction Act* (IRA) that was signed by President Biden in August 2022, the US Department of the Treasury is currently drafting guidance for the roll-out of various federal tax incentives that will drive SAF production in the US. The IRA is expected to help the US achieve its ambitious *SAF Grand Challenge* goals of producing 3 Bgal SAF by 2030 and replacing 100% of jet fuel demand with US-produced SAF by 2050.

As part of the IRA, a Sustainable Aviation Fuel Blender's Tax Credit (BTC) can be claimed between 2022-2025, where SAF blended in the US can enjoy a tax credit of up to 1.75 USD per gallon. The Clean Fuel Production Tax Credit will apply from 2025-2027, which is a performance-based incentive based on the carbon intensity of the fuel with a similar maximum credit as the SAF BTC but only applicable to US-produced SAF. The IRA is further looking to implement the Hydrogen Producer Tax Credit, eligible for clean hydrogen production facilities[11] operational before 2033 and with a maximum rate of 3 USD/kg hydrogen for 10 years.

Various states are also looking to make the production of SAF more attractive by introducing additional stackable incentives. Most recently, the state of Washington and Illinois passed legislation providing a SAF tax credit of up to 2 USD and 1.50 USD per gallon, respectively.

These incentives will undoubtedly make the production of SAF more attractive in the US and supports the SAF Grand Challenge goal of producing 3 billion gallons (8.5 Mt) of SAF by 2030. However, given the limited duration of these SAF-specific incentives,

[11] Treasury and IRS are developing guidance that constitutes what can be considered 'clean' hydrogen. Credit is likely to be given based on carbon intensity, possibly allowing natural gas-based hydrogen. Criteria may also require hourly matching of supply and demand for renewable power in green hydrogen systems.

critics say it mainly benefits those projects that are already built or in construction, and that a more stable long-term policy environment is required to develop pathways that are needed to reach goals set for 2050.

SAF Grand Challenge can be reached, but requires support for new investments as well as evaluating renewable diesel projects, or risk distortion of global waste/vegetable oil markets

Based on our assessment of United States SAF capacity announcements in the public domain today, approximately 2 Bgal (5.8 Mt) of SAF capacity could reach commercial operation by 2030. This is an increase of 1.3 Bgal (3.7 Mt) compared to last year's outlook, primarily because we adopted a different approach around HEFA feedstock constraints up to 2030. We now assume all projects meeting our success criteria materialize, while highlighting feedstock dependencies for these projects to succeed.

Due to a recent wave of renewable diesel announcements in the US (~6 Bgal (19 Mt) by 2030), waste and vegetable markets are expected to be even further strained than they are today, given that available waste and vegetable oils in the US were already fully consumed in 2022, driving up prices and imports.[12] If the US is to satisfy lipid-based feedstock demand for all renewable diesel projects, one or more of the following scenarios would have to materialize:

- Curbing exports of whole soybeans to yet-to-be developed crushing facilities to increase soybean oil production. This would affect the US trade balance as well as impacting global soybean meal trade flows.[13]

- Large-scale government support for novel non-edible oilseed crops suitable for conversion into fuel. Appropriate safeguards would have to be in place to avoid indirect land use change effects.

- Increasing soybean acreage by 40 million acres from 87 million acres today to meet soybean oil needs. This would impact corn and wheat markets as soy would have to largely expand on existing cropland.[12,13] This could in turn have consequences for corn ethanol availability.

- Evaluating the pace and scale of renewable diesel announcements on the basis of feedstock availability and/or mothball biodiesel facilities to free up feedstock.

We consider the latter scenario the most feasible to meet 2030 goals, meaning that the success of HEFA announcements in the US is contingent on feedstock becoming available from road transport. With ambitious goals at the federal level around electric vehicles and with several states implementing zero-emission truck sales requirements, it is possible that additional feedstock is freed up for SAF. However, incentives currently favoring the production of biodiesel and renewable diesel over SAF would also need to shift for HEFA capacity announcements to be successful.

[12] Cerulogy (2022)

[13] DTNPF (2012)

We further identify that two announcements (Gevo/ADM and DG Fuels) are responsible for about 35% of announced US SAF capacity. These projects make use of the corn ethanol-ATJ and cellulosic-FT pathways, respectively, and make up almost all of the non-HEFA-based SAF announcements. The deployment of non-HEFA pathways in the US is therefore contingent on the success of these projects.

If all announcements materialize in the US, corn ethanol-ATJ and cellulosic-FT/ATJ could close the production gap by 2030

The US Department of Energy estimates that about 2.85 Bgal (10.8 billion liters) of corn ethanol could become available for exports by 2030 due to overcapacity relative to domestic road fuel demand. We assume that US-produced ethanol is likely supplied to the market where it can generate the highest profits. If this turns out to be the SAF market, around 1.5 Bgal (4.3 Mt) of corn ethanol-ATJ SAF could be produced by 2030. However, the ability of the corn ethanol-based pathway to meet the 50% GHG reduction threshold required to claim federal incentives is going to be dependent on the final GHG methodology agreed to (GREET or CORSIA).

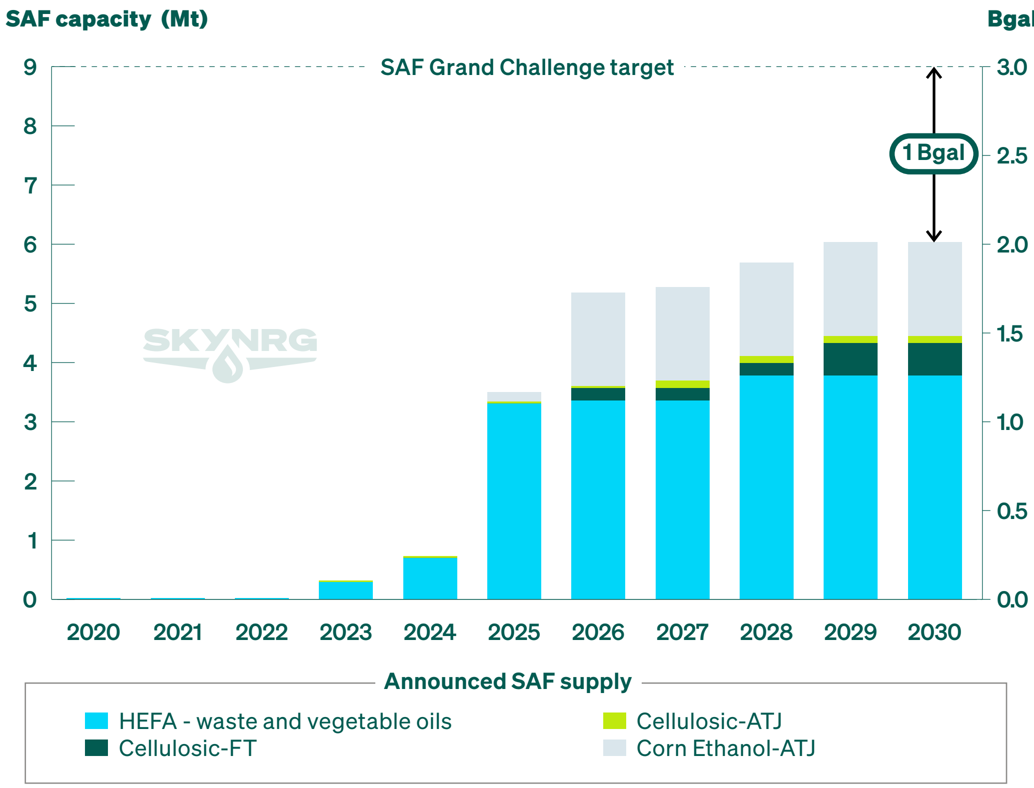
Based on attractive incentives for cellulosic/MSW-based fuels in the US, we estimate that up to 0.5 Bgal (1.4 Mt) SAF could be produced via this pathway by 2030. Scaling this pathway can be accelerated when using waste bio-intermediates such as renewable natural gas (RNG) derived from manure or agricultural residues. Deployment of bio-intermediate pathways in early years is mostly constrained by deployment pace, permitting of new facilities and federal policy adaptation to bio-intermediate routes rather than feedstock constraints. The Hydrogen Production Tax Credit may further trigger some e-SAF production in the US, depending on final guidance from the IRS.

Announced renewable diesel capacity in the US exceeds expected demand from low-carbon fuel standards in North America by approximately 2.8 Bgal (9.0 Mt).[14] If these projects manage to secure feedstock, we expect a significant share of this 'overcapacity' could be exported to European markets due to RED III and EU ETS ramping up targets for road transport.[15] We therefore consider it unlikely that the Grand Challenge is met by renewable diesel projects switching part of their slate to SAF.

[14] 5.8 Bgal announcements vs. 4 Bgal expected demand by 2030 from CA, OR, WA, BC LCFS and Canada CFS.

[15] studio GearUp (2021)

SAF Grand Challenge aspirational goal for 2030 seems within reach, provided that all announcements materialize, and new projects are announced in coming years



By 2050, the US could have enough SAF capacity in place domestically to substitute its pre-Covid jet fuel demand of ~27 bgal with SAF

Compared to Europe, the US is less constrained by cellulosic and MSW feedstocks, as well as renewable power potential. For the US to have 27 Bgal (77 Mt) of SAF capacity in place, the US would have to allocate corn ethanol overcapacity to SAF production, a significant share of cellulosic and MSW feedstocks ensure that the growth[16] of e-SAF would be unconstrained.[17] These assumptions are considered to be on the optimistic side, which tells us that already satisfying pre-Covid jet fuel demand with 100% SAF will be a major challenge for the US. If jet fuel demand grows in line with the Department of Energy and IATA's projections (+30%), SAF demand could grow to 35 Bgal (100 Mt) and thereby further challenging the feasibility of the target.

Because cellulosic/MSW feedstock availability is estimated to be significantly higher in the US compared to Europe,[18] our sensitivity analysis shows that feedstock constraints are not expected to limit the deployment of cellulosic/MSW-SAF until 2050. However,

[16] In this outlook, we illustrate the potential by allocating 30% of cellulosic and MSW feedstock in the US to aviation. The rest would be requires by other end-use sectors like road transport, marine and chemicals.

[17] The e-SAF pathway therefore follows the maximum rate of deployment, based on the highest rates of deployment seen in the US corn ethanol industry between 2000-2010.

[18] ~1,330 Mt vs. 680 Mt.

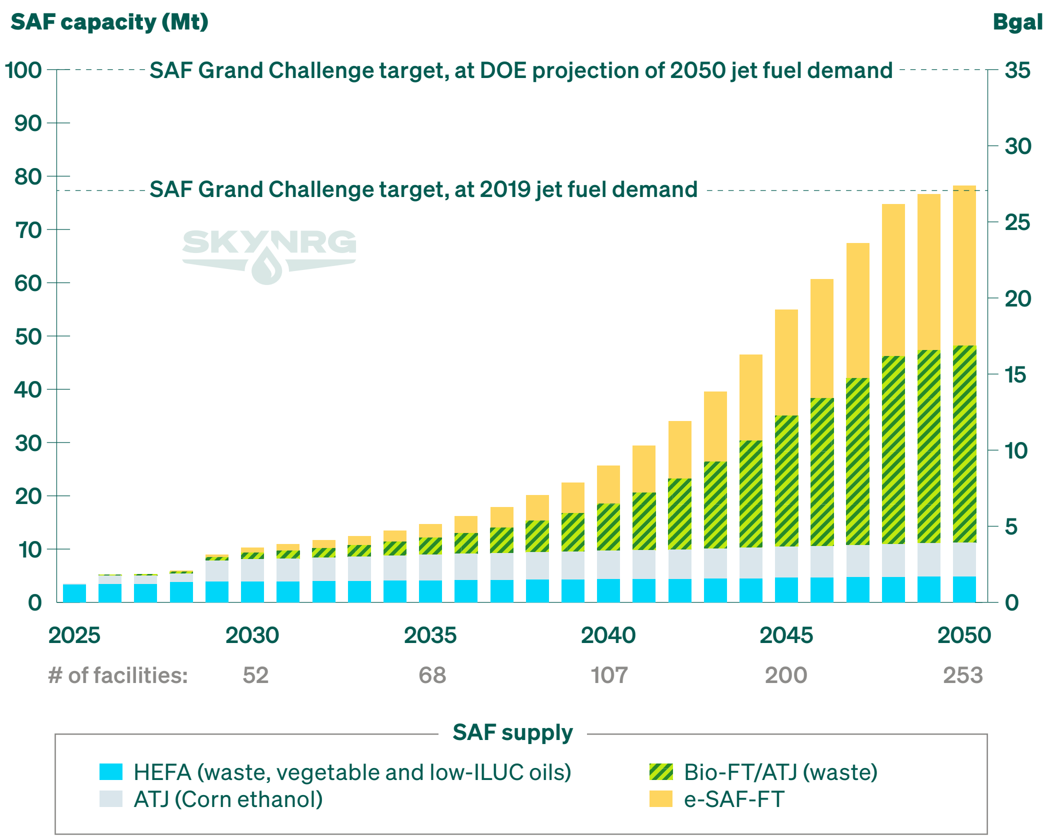
a large part of the US potential is made up of energy crops and coppice grown on conventional crop or forest land. For this to materialize, the US may have to re-evaluate (within planetary boundaries, and governed by sustainability standards and principles) corn and wheat production levels to allow for more acreage to be dedicated to energy crops. Only when US feedstock potential is cut by half, the feedstock constraint starts to be restrictive, suggesting results are less sensitive to feedstock constraints compared to our European analysis.

To reach a domestic SAF production capacity of 27 Bgal (77 Mt), the US would have to deploy around 250 SAF refineries by 2050

To reach a US SAF production capacity of 27 Bgal (77 Mt), around 250 dedicated SAF refineries would have to be deployed until 2050. Based on the technology mix used in our analysis, approximately 50 Mt of renewable co-products like renewable diesel and naphtha are produced that can contribute to reducing GHG emissions in the marine and road transport sectors, and in production of bulk chemicals.

Capital expenditures required to develop 250 SAF refineries represents a cumulative investment of ~400 billion USD, or average annual CAPEX of 16 billion USD between 2025 – 2050. This is roughly equivalent to 3% of global annual upstream oil and gas CAPEX in 2019.[19]

SAF production capacity in the US could just be sufficient to meet 2050 goals, provided that jet fuel demand remains stable or alternative propulsion technologies can cover demand increase



[19] IEA (2022)

ABBREVIATIONS

ATJ	Alcohol-to-Jet
BTC	Blender's Tax Credit
CAPEX	Capital Expenditures
e-SAF	SAF produced using green electricity
EU	Europe or European Union
EU ETS	EU Emissions Trading System
EUR	Euro
FT	Fischer-Tropsch
gal, Bgal	gallon, billion gallon
GHG	Greenhouse Gas
HEFA	Hydrotreated Esters and Fatty Acids
IATA	International Air Transport Association
IL	Illinois
IRA	Inflation Reduction Act
IRS	Internal Revenue Service
MSW	Municipal Solid Waste
mt, Mt	metric ton, Mega ton (= 1,000,000 mt)
RCF	Recycled Carbon Fuel
RED	Renewable Energy Directive
RFNBO	Renewable Fuel of Non-Biological Origin
RSB	Roundtable on Sustainable Biomaterials
SAF	Sustainable Aviation Fuel
UK	United Kingdom
US	United States
USD	US Dollar
WA	Washington State

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About SkyNRG
Since 2009, SkyNRG has been a global leader in Sustainable Aviation Fuels (SAF). The company is dedicated to increase SAF demand and production capacity for the industry to meet its 2050 net zero commitment. SkyNRG has supplied SAF to over 40+ airlines and 70+ corporates across the world and is now developing dedicated SAF production facilities to support the transition from fossil jet fuel to sustainable aviation fuel. SkyNRG does not compromise when it comes to sustainability; we are a globally recognized Certified B Corp©, our operations are certified by the Roundtable on Sustainable Biomaterials (RSB), and we are advised by an independent Sustainability Board, as well as a worldwide NGO network to ensure we make the right sustainability decisions across all our operations. To find out more, visit skynrg.com.

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