

May 2022 Update

A MARKET OUTLOOK ON SAF

United States: 1st SAF Market Analysis

Europe: ReFuelEU update, introducing
draft UK mandate





FOREWORD

All stakeholders will need to do their part to sustainably scale the SAF sector.

At SkyNRG, we have led initiatives in voluntary markets for Sustainable Aviation Fuel (SAF) for more than a decade, creating awareness and momentum across the aviation industry. Today, we are finding that the United States is approaching a tipping point in SAF capacity deployment which is enabling significant growth opportunities to meet existing and future demand for SAF. Simultaneously, we see discussions on the EU SAF mandate making significant progress in the EU Parliament and the United Kingdom is currently laying the groundwork for a UK SAF mandate.

With President Biden's SAF Grand Challenge announcement to reach 3 billion gallons of SAF production capacity by 2030, and long-term SAF incentive frameworks being developed in Europe, along with voluntary demand from airlines and airplane manufacturers, it is clear that this is the beginning of a new sustainable era in aviation. In this new era, it is SkyNRG's mission to build up SAF capacity for aviation to meet its 2050 net-zero commitment.

To understand the SAF market and, consequently, develop our own North American growth strategy, SkyNRG decided to assess how Biden's U.S. SAF production goal will affect the future of SAF. We created a U.S. SAF supply/demand forecast scenario that is built on market data, peer-reviewed literature, think-tank analyses, industry scenarios, and our own industry-leading knowledge. In this SAF Market Outlook you will also find an update to European supply and demand figures until 2050, introducing UK demand and supply forecasts for the first time.

To meet the SAF demand set out in this Outlook in a sustainable way, all stakeholders will need to do their part: corporates, airlines, airplane manufacturers, fuel producers, governments and even the individual travellers. We invite all stakeholders to participate in the mobilization of resources to scale the SAF sector. Your thoughts, opinions, insight, and resources are extremely valuable, so thank you in advance for your interest. Every six to twelve months, SkyNRG will review all SAF advancements, update our analysis, and continue to share it with industry.



John Plaza,
*Chief Investment Officer,
Head of Capacity Development North America*

EXECUTIVE SUMMARY

Just after the publication of the ReFuelEU Aviation proposal by the European Commission came a proposal for a UK SAF mandate, as well as the SAF Grand Challenge launched by the United States. These initiatives mark important steps towards further growing the global SAF market.

In light of these developments, SkyNRG has updated their previous A Market Outlook on SAF – Summary Report (July 2021), and has assessed the the feasibility of meeting the targeted SAF volumes until 2050 in both Europe and the United States.

UNITED STATES

- For the United States, SkyNRG concludes that meeting the 3 billion gallon (8.6 Mt) SAF target by 2030 is conditional upon rapid feedstock and technology diversification.
- Currently, SAF announcements in the US rely predominantly on fats, oils and greases (FOGs) and corn ethanol, with an optimistic perspective on the availability of FOGs.
- A significant pipeline of renewable diesel projects in the US will prohibit new SAF announcements from accessing FOG feedstocks.
- SkyNRG expects that with current policies a significant share of the 2030 production target would be filled with SAF from corn ethanol. The remainder would have to be filled SAF from wastes and residues converted via the Alcohol-to-Jet (AtJ) and Gasification + Fischer-Tropsch (G + FT) pathways.
- Power-to-Liquids (PtL) SAF is not expected to play a significant near term role in meeting US SAF supply due to absent incentives, despite its vast potential. Opportunities to export for the EU market remain present.
- For 2050, SkyNRG concludes that even with a stable jet fuel demand after returning to pre-Covid levels, the 100% SAF target will be extremely challenging.
- Using conservative assumptions, we expect the US can develop around 250+ SAF facilities by 2050 , which could yield roughly 50 Mt (18 bgal) SAF, falling short of the required 75 Mt (27 bgal) under constant jet fuel demand.
- To meet the 100% SAF goal, the US will need to double down on valorizing cellulosic waste feedstocks, develop novel sustainable biomass supply chains and accelerate green hydrogen deployment for Power-to-Liquids.

1. Based on an average plant size of 200,000 metric tonnes, averaged across different technology pathways.





EUROPE

- For Europe, we conclude that up to 2027, supply can match demand, provided that currently announced production capacity materializes and some renewable diesel facilities will make additional investments to produce SAF.
- Until 2030, European supply is 2 Mt short of meeting projected mandate demand. More announcements are needed and/or imports of SAF will have to be considered to meet expected mandates in the EU and UK.
- Based on announced projects worldwide, we expect that potentially 2 Mt of SAF could find its way to the European market, meaning additional European capacity would not be needed to meet mandates volumes in 2030.
- If Europe were to prioritize energy independence, capacity increases would have to come from more European renewable diesel plants switching to SAF or new announcements based on cellulosic waste (AtJ/G+FT) or renewable power (PtL) inputs.
- Long-term, Europe will have to develop 200+ SAF facilities to meet a demand of 40 Mt by 2050 under constant jet fuel volumes. Most of these facilities would be based on AtJ, G + FT and PtL technology.

A Market Outlook on SAF - Summary Report (May 2022) is a condensed version of a larger SAF supply/demand analysis performed by SkyNRG. The full analysis, A Market Outlook on SAF - Background Analysis (May 2022) is [available on our website](#).



INTRODUCTION

To assess progress to date in meeting 2030 SAF goals in the United States and Europe, SkyNRG has investigated short-term supply possibilities based on 115+ entries of existing renewable fuel capacity and global SAF capacity announcements. We assessed each entry on its technical ability to produce SAF adhering to relevant sustainability criteria, theoretical maximum share of SAF in product output, and the likelihood of the announced plant to materialize on time.

To develop projections on SAF supply until 2050, SkyNRG developed a capacity growth model using a rich assumption base around feedstock and technology that has been validated through discussions with technology developers and key SAF literature. For more details on the methodology and assumptions, please refer to *A Market Outlook on SAF - Background Analysis (May 2022)* on the [SkyNRG website](#).

The first section covers the SAF Grand Challenge in the United States, progress made towards achieving stated goals and an outlook towards 2050. The second section provides an update on how SAF announcements stack up against the EU SAF mandate (ReFuelEU) and the draft UK mandate. This section also provides a long-term SAF supply outlook in Europe.

1. UNITED STATES



UNITED STATES IS PIVOTING INTO A GLOBAL LEADER ON SAF

Under its *Sustainable Aviation Fuel (SAF) Grand Challenge*, the Biden Administration has proposed to scale US production of SAF to 3 billion gallons by 2030. By 2050, the US proposes to have substituted 100% of its jet fuel demand by SAF. Because the SAF Grand Challenge is a production target, imports of SAF are not considered in the US market analysis.

Production in the US is expected to be driven by three policy mechanisms. These include:

1. Renewable Fuel Standard (RFS)
2. Low-Carbon Fuel Standards (LCFS) such as in California and Oregon
3. A proposed federal SAF Tax Credit that is designed to incentivize low carbon SAF

All three of these incentives are complementary, and when stacked together, can significantly reduce the cost of SAF for the aviation industry.

Table 1. US Renewable Fuel Standard

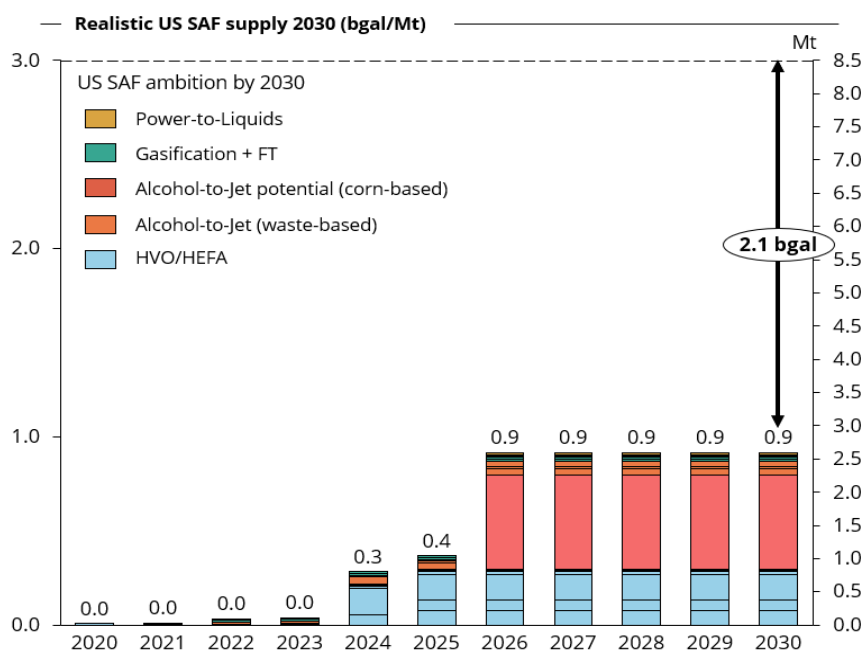
The RFS, which makes up for most of the financial incentive, currently only allows the use of biogenic feedstocks. This means that for any production of SAF to be qualified for participating in the RFS program, the feedstocks must come from biogenic sources such as vegetable and waste oils, cellulosic residues or corn. This contrasts with European SAF mandates, where food/feed crops are not eligible over concerns of indirect land-use change effects and associated negative GHG impacts.

This also means that the RFS currently does not incentivize renewable fuels of non-biological origin like Power-to-Liquids (PtL), despite the US' abundant and cheap renewable power resources. This creates a misalignment of policy and coordination of the global SAF industry due different policy metrics and guidelines for the sector in the US versus the EU.



HOW WILL THE US FILL ITS 3 BILLION GALLON GOAL?

Based on an analysis of all announced renewable fuel projects² in the US today, SkyNRG estimates that about 0.9 bgal (2.5 Mt) of SAF capacity is expected to be online by 2030. This means that the US is about 2.1 bgal (6 Mt) short of meeting the 2030 production goal. This takes into account all projects that have announced to produce SAF as part of their total product output.



HVO/HEFA

HEFA is the most prominent technology in terms of SAF announcements in both Europe and the US. Demand for vegetable oils and waste oils has created an extremely tight feedstock situation globally, but especially in the US, as the country holds most of the world's renewable diesel announcements totalling about 8 bgal (23 Mt) announced capacity. All of these plants require vegetable and/or waste oils.

This puts a huge strain on domestically available vegetable oil and conventional waste oil feedstock for SAF. SkyNRG finds that renewable diesel announcements in the US would demand roughly triple the waste and vegetable oil available in the US. As a result of this situation, we do not expect significant additional SAF announcements using HEFA technology in the US beyond what has already been committed. An exception to this would be projects using imported vegetable oils. If SAF is prioritized in the coming years, downsizing/cancellations of renewable diesel announcements and/or feedstock diversion from FAME biodiesel plants seems inevitable.

2. Renewable fuel projects in this analysis are defined as projects producing renewable diesel and/or SAF.

Alcohol-to-Jet (1st gen)

The US ethanol sector is in an oversupply situation today. We see the sector moving towards redirecting part of the corn ethanol capacity for SAF production. This volume could potentially supply up to a third of the SAF needed by 2030.

However, a forthcoming SAF Tax Credit could stir up the level playing field for corn ethanol SAF. The SAF Tax Credit would likely lend its sustainability criteria from the RFS, which sets a GHG reduction threshold of 50%. Average GHG intensity of corn ethanol going into the LCFS in 2019 was 35% lower compared to gasoline³, meaning that there is need to achieve significant additional on-farm GHG savings and/or add carbon capture and storage to be eligible for incentives.

Although demand for ethanol in other countries could rise strongly (e.g. from India's ethanol blending target), it seems likely that outputs will flow towards markets with the highest incentives. Based on the incentives for crop-based AtJ could enjoy in the US, and an expected reduction in US ethanol demand by 2030⁴, we estimate that at least 1.8 billion gallons of corn ethanol capacity could be steered towards SAF production, leading to 1 billion gallons of SAF capacity by 2030.

Alcohol-to-Jet / Gasification + Fischer Tropsch (2nd gen)

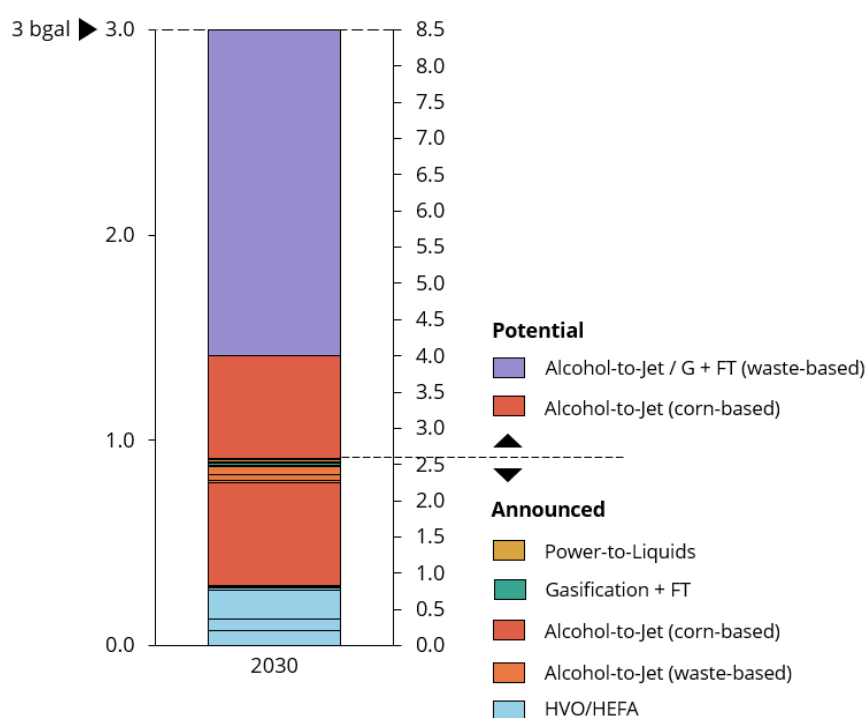
The pool of cellulosic feedstocks in the United States is enormous. Using EPA's feedstock assessments⁵, we estimate that if all were converted into SAF through AtJ/G+FT technology, supply could reach 22 – 26 bgal (63 – 75 Mt) by 2040 using only domestic resources.

However, as other sectors also look to decarbonize their energy supply and feedstock, these resources will increasingly face competition. Still, given the large technical potential and the ability of the aviation sector to valorize these feedstocks, we consider it plausible that the remainder of the SAF target (1.6 bgal/4.5 Mt, representing 6-7% of the technical potential) could be filled using 2nd gen feedstocks in combination with AtJ/G+FT.

Power-to-Liquids

Because existing renewable fuel policies in the United States do not incentivize Power-to-Liquids, we do not expect this pathway to materially contribute to the US' 2030 production goal, despite the US Midwest being one of the high potential global hotspots for low-cost PtL production.

If incentives were rapidly put in place that recognize the long-term decarbonization needs of the sector, we expect that by 2050 Power-to-Liquids SAF could meet roughly a third of US SAF demand under constant jet fuel demand (75 Mt/27 bgal).



3. Source: USDA (2020), The California Low Carbon Fuel Standard: Incentivizing Greenhouse Gas Mitigation in the Ethanol Industry

4. OECD-FAO (2021), OECD-FAO Agricultural Outlook 2021-2030

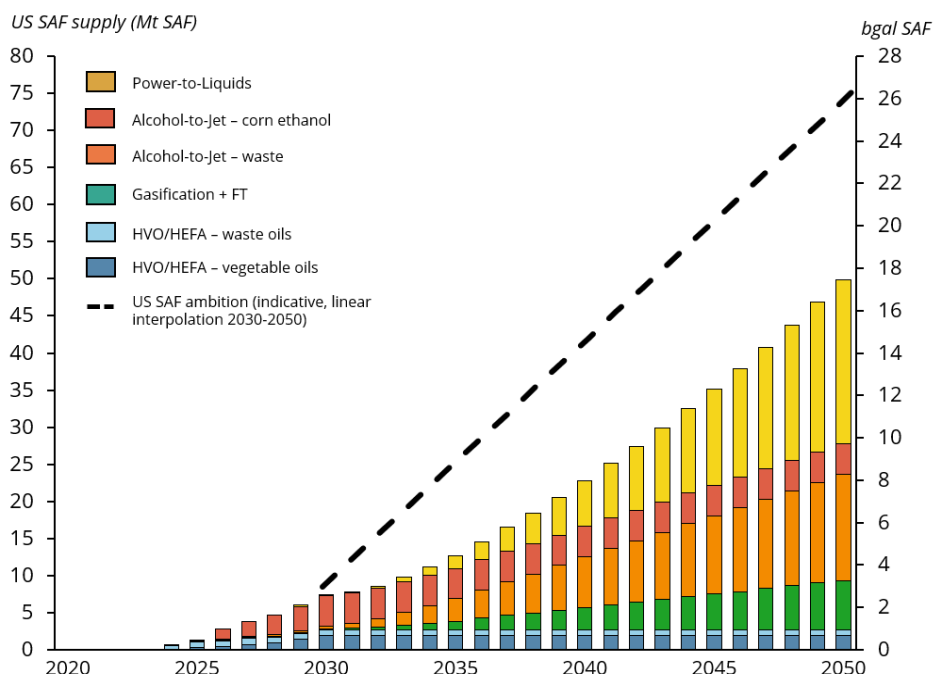
5. EPA (2016), 2016 Billion Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy

POST-2030 SAF GOALS ASK FOR MAJOR FEEDSTOCK AND TECHNOLOGY DIVERSIFICATION

Looking ahead at the levels of SAF needed post-2050, a shift in feedstock-technology focus is essential. While most announcements today in the US in terms of size are based on corn ethanol and vegetable oils, towards 2050 major volumes would need to come from cellulosic wastes and Power-to-Liquids facilities.

By 2050, we expect that with the currently existing technology and feedstock portfolio, 250+ SAF facilities could be developed in the US with a total output of 50 Mt (18 bgal). However, if US jet fuel demand restores to pre-Covid levels and optimistically stays constant until 2050, a supply of 75 Mt (27 bgal) would be required to ensure the aviation sector is supplied with 100% US-based SAF. This illustrates that besides SAF, other developments like electric flying and hydrogen-powered aviation will have to be explored to substitute all conventional jet fuel by 2050.

To accommodate this major sector transformation and scaling, different feedstock supply chain models would have to be developed. This could include hub-and-spoke supply chains, where cellulosics are converted into 2nd gen ethanol at decentralized locations but centrally upgraded to jet fuel in large refineries. Another example is the production of green hydrogen, where by using GW-scale electrolyzers and hydrogen storage large Power-to-Liquids facilities could be developed. Such developments are however all contingent on policy incentives that are aligned with this need for technology diversification and upscaling, as well as flanking measures that ensure that the availability of key inputs like renewable power is accelerated.



2. EUROPE (EU-27 + UK)



On July 14th, 2021, the European Commission (EC) proposed an EU-wide blending mandate on sustainable aviation fuel (SAF), as well as uplifting obligations for airlines. EU Parliament and Council discussions are in full force and adoption is expected by 2023. In the UK, the government held several consultation rounds to receive stakeholder input on a SAF mandate.

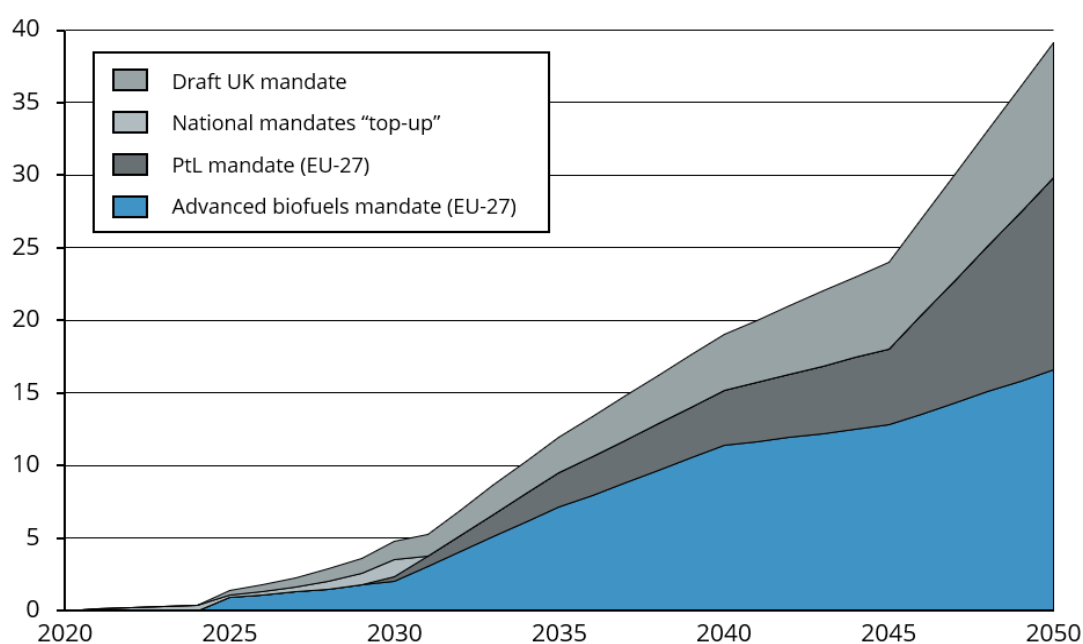
As outlined in *A Market Outlook on SAF – Summary Report (July 2021)*, the ReFuelEU proposal consists of a 2% blending obligation for SAF in 2025, increasing to 5% in 2030, 32% by 2040, and 63% in 2050, with a specific sub-mandate for Power-to-Liquids fuels (0.7% in 2030, 8% by 2040, 28% by 2050). Preceding these proposals, several European countries already implemented or proposed a national blending mandate, going beyond the ReFuelEU targets. Discussions in the EU Parliament and Council until adoption is expected later in 2022 will center around the height of the proposed blending targets, addressing competitive distortion, flanking measures to incentivize SAF production via revolving funds and the need for a cap on the use of waste oil feedstock, in line with the RED II framework.



A NATIONAL SAF MANDATE IS UNDER DISCUSSION IN THE UK, WHICH WOULD SIGNIFICANTLY GROW THE EUROPEAN MANDATED MARKET

The UK is currently in the process of formulating a SAF mandate. In an analysis that was published by the UK Department for Transport during a public consultation round, several scenarios were presented that all follow a ramp-up similar to the ReFuelEU proposal. Based on discussions with UK aviation stakeholders, it is most likely the blending mandate would start at 2.5% in 2025 (0.3 Mt), increasing to 10% by 2030 (1.2 Mt), 31% by 2040 (3.9 Mt) and 75% by 2050 (9.3 Mt).

To meet the aggregate demand from EU and UK mandates and the additional demand expected from national mandates, a SAF supply of 4.7 Mt in 2030 and 39.1 Mt in 2050 is needed⁶.



Please note: Graph does not include voluntary SAF commitments from airlines and corporates

6. Assuming a post-Covid return of EU-27 and UK jet fuel demand by 2024 to 2019 volumes and a stable demand of 47.4 Mt (EU) and 12.4 Mt (UK) until 2050, respectively. Source: Eurostat

ADDITIONAL ANNOUNCEMENTS FROM NON-HEFA PATHWAYS REQUIRED TO MEET 2030 TARGETS

Provided that all currently announced renewable fuel capacity will materialize, we consider it realistic that up until 2027, the mandated amount of SAF in EU27+UK can be fulfilled with Europe-based SAF production by currently announced plants. From 2023 until 2027, more SAF could be produced than is mandated. We assume that these supplies will flow to the rapidly growing voluntary market. This implies that total demand in 2030 would be that of the European mandates plus any contracted volume under the voluntary market, which could exceed 1 Mt based on projected oversupply in the mid-2020s.

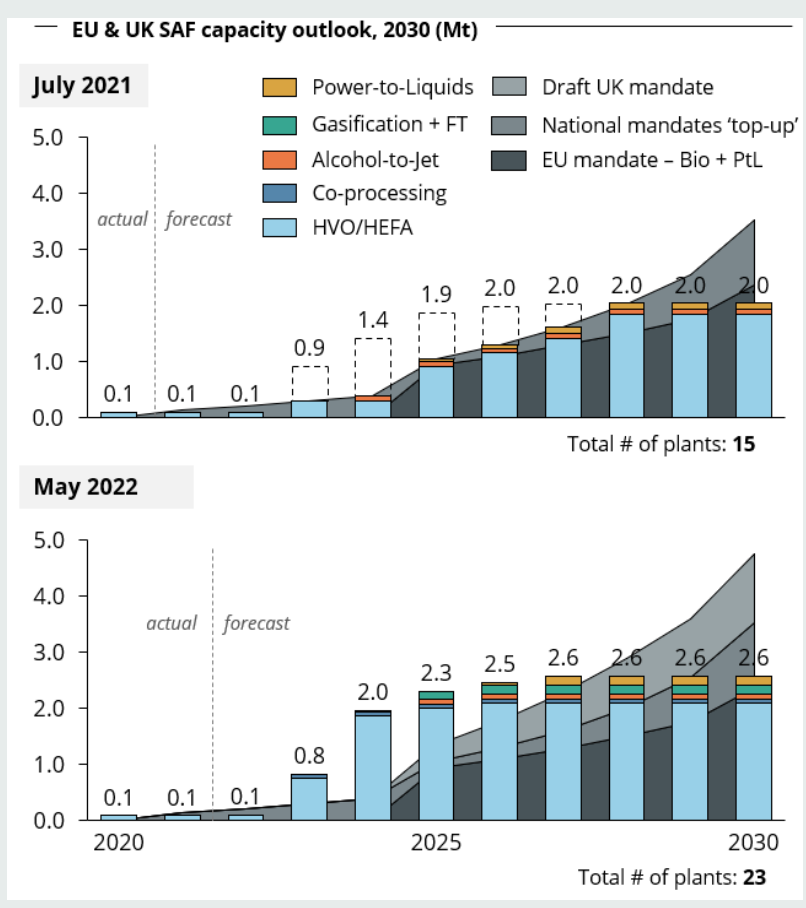
Post-2028, the increasing mandated SAF demand would have to be met with yet-to-be-announced SAF capacity, ‘capacity switches’ from announced renewable diesel production, or by importing SAF from outside of the EU27/UK. By 2025, at least 2.2 Mt of RED II-compliant SAF could technically come to EU27/UK from Asia, although most likely demand centers in Asia-Pacific would also grow in coming years.

In terms of additional announcements, we see a waste oil market that is becoming increasingly tight as renewable diesel and SAF plants come online in the coming years. If energy independence is prioritized by European policymakers, the additional post-2028 demand would need to be met with mostly Europe-based production capacity. Given feedstock supply constraints, these announcements would likely have to come from non-waste oil pathways.

Depending on how the EU mandate discussions develop, an amendment proposing a cap on waste oils could also be adopted to prevent these feedstocks flowing from the road sector to aviation⁷. This would increase Europe’s reliance on cellulosic wastes and Power-to-Liquids.

Table 2: Comparison of 2030 Outlook

- Compared to *A Market Outlook on SAF – Summary Report (July 2021)* there is a 0.6 Mt increase in total SAF announcements in 2030. This is partly due to the addition of plant announcements in the UK, but is mostly explained by additional announcements.
- The majority of the currently announced EU plants use HEFA technology, making it the dominant SAF production pathway up to 2030. In the UK, this is different with most plants targeting a municipal solid waste-based production pathway.
- We notice an increase in announced capacity using either the Alcohol-to-Jet (AtJ), Fischer-Tropsch (FT) or Power-to-Liquids (PtL) technology. These demonstration plants will remain important proof points for further deployment of these technologies and further ramp-up of SAF production.



7. Euractiv (2022), Lawmaker proposes raising EU green jet fuel target to 100% by 2050

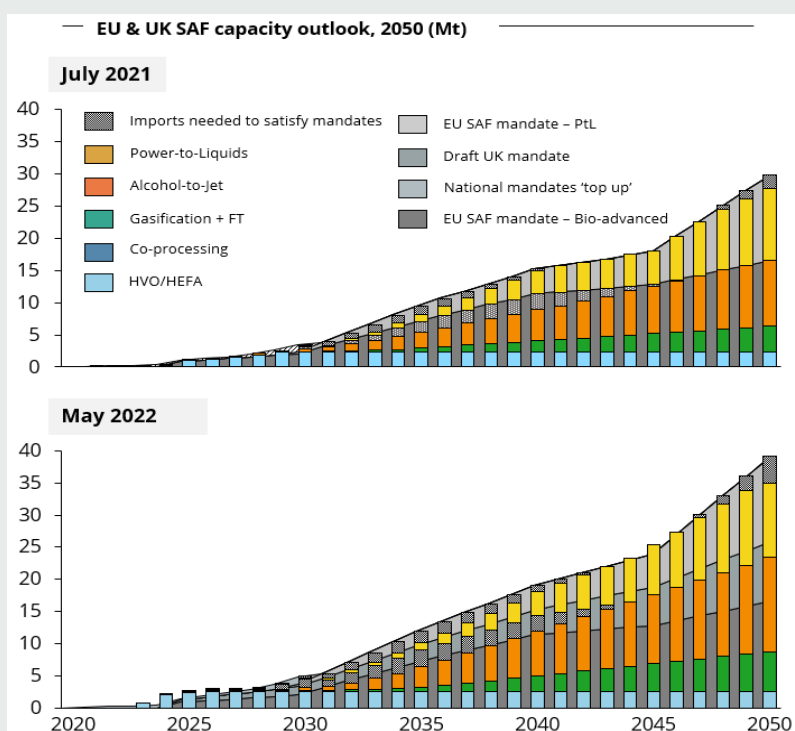
POST-2030 TARGETS ARE IN DANGER IF WE FAIL TO ALIGN INCENTIVES WITH NEED FOR TECHNOLOGY DIVERSIFICATION

Using SkyNRG's capacity growth model, we see that the HEFA pathways is essential to scale the SAF sector in the near-term. However, we see this deployment curve flattening by 2030, due to the limited availability of waste oil feedstocks, which will only increase as other regions also introduce SAF incentives in coming years.

After 2030, targets accelerate rapidly, already growing to 20% SAF by 2035, from 5% in 2030. This will mostly have to be met by SAFs produced from cellulosic feedstocks like agricultural residues, forestry residues, as well as Power-to-Liquids. To ensure that the sector is in time for the pace acceleration in deployment between 2030 and 2035, demo facilities converting cellulosic wastes and renewable power with CO₂ into SAF should start yesterday.

As the EUSAF mandate works on a least-cost basis, diversification of feedstock-technology combinations is not incentivized. With the current design, fuel suppliers are more likely to import HEFA-SAF, than to buy EU-based SAFs based on Annex IX-A feedstocks, which are mostly cellulose. A cap on waste oils (Annex IX-B), in line with the RED II transport framework, could generate the needed market push in time.

Table 3: Comparison of 2050 Outlook



- Due to progressing mandate discussions in the EU and the UK, mandated demand for SAF in Europe is projected to be 40 Mt in 2050.
- Due to limited availability of waste oil feedstocks, dependence on Alcohol-to-Jet, Gasification / Fischer-Tropsch and Power-to-Liquids is increased.
- In the updated analysis, supply is no longer cut off at the mandated levels, but supplied until feedstock and other deployment constraints are reached as there will also be significant demand for



WE INVITE ALL STAKEHOLDERS TO ENGAGE IN ACCELERATING SAF PRODUCTION AND UPTAKE

We conducted this analysis to inform our business strategy. We chose to share these insights to enable other organizations to learn and potentially direct resources into growing the SAF industry. Our intention is to keep monitoring developments and update this analysis to provide our view on the state of the SAF market. We will issue an updated *Market Outlook on SAF* every six to twelve months. We would like to invite all stakeholders, inside and outside the SAF supply chain, to provide us with your viewpoint and explore how to join forces to scale the SAF industry and decarbonize



Since 2009, SkyNRG has been building up SAF capacity and production for the industry to meet its 2050 net zero commitment

SkyNRG has supplied SAF to over 40 airlines 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 of our operations. Learn more at www.skynrg.com.