SkyNRG

Background Analysis

SAF Market Outlook

SkyNRG's Perspective on the ReFuelEU Aviation initiative Proposal

July 2021

Disclaimer

This report is provided for information purposes only and should not be relied upon as legal, strategic, commercial, financial or other professional advice. While the information contained herein is taken from sources believed to be reliable, SkyNRG does not represent or warrant that it is accurate or complete and neither SkyNRG, nor its employees, shall have any liability arising from or relating to the use of this publication or its contents.

Executive summary

Introduction

- This EU SAF market outlook has 3 components:
  - Quantitative analysis of EU SAF supply for the 2020-2030 period, based on industry announcements
  - Quantitative analysis of EU SAF supply for the 2030-2050 period, based on the modelled deployment potential of new capacity
  - Qualitative analysis on different factors that could influence the future EU SAF supply

SAF supply 2020-2030

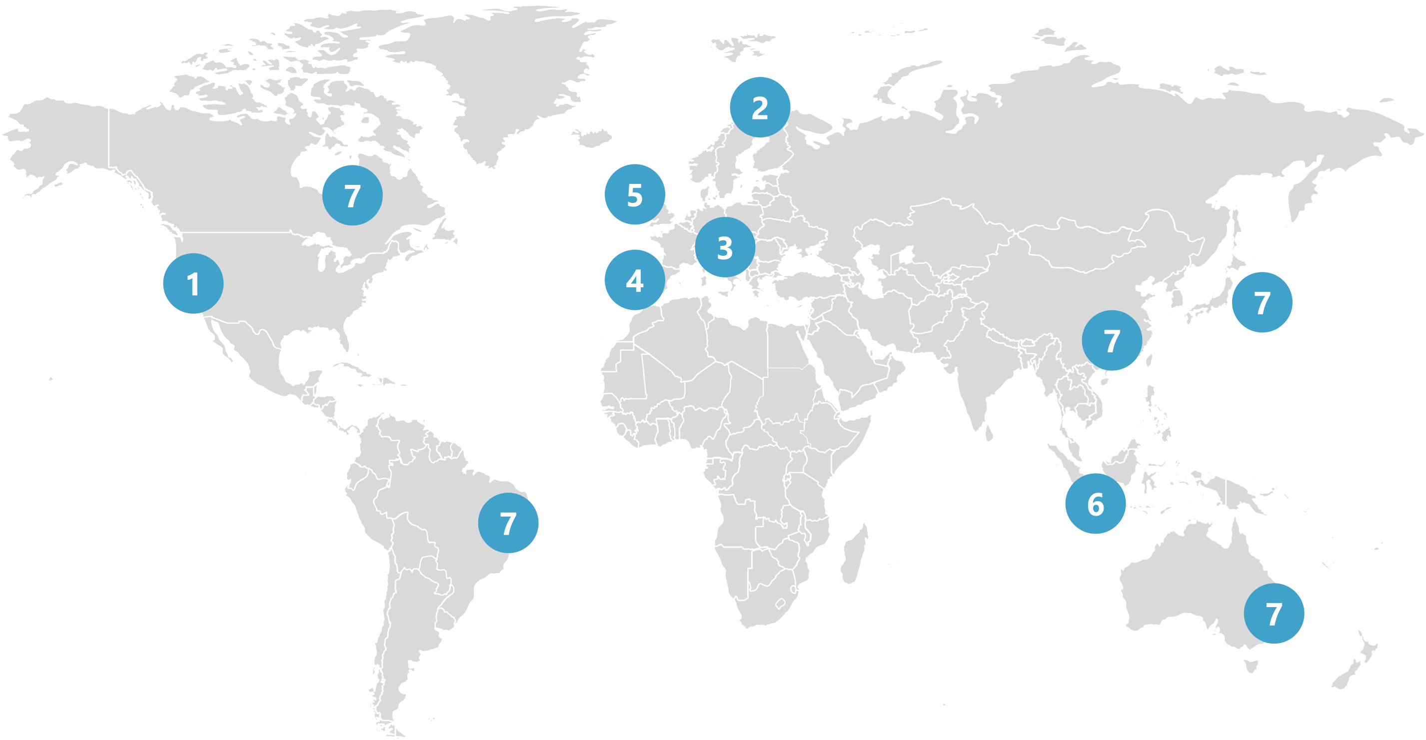
- Up to 2030, SAF supply can match mandated volumes, provided current announcements of new capacity and switches from renewable diesel to SAF materialize, and if additional production capacity is developed or SAF is imported from outside the EU
- There will be a heavy reliance on waste oils and fats as feedstock and on the HEFA and co-processing technology pathways to convert these

SAF supply 2030-2050

- Rapid deployment of new technologies (FT, AtJ, PtL) is required to realize mandated volumes beyond 2030
- It is unlikely that the targeted volumes will be met without imports of SAF or intermediate products for SAF production

Government incentive schemes will largely drive SAF demand in the coming decades

SAF incentives in various jurisdictions – anticipated or installed

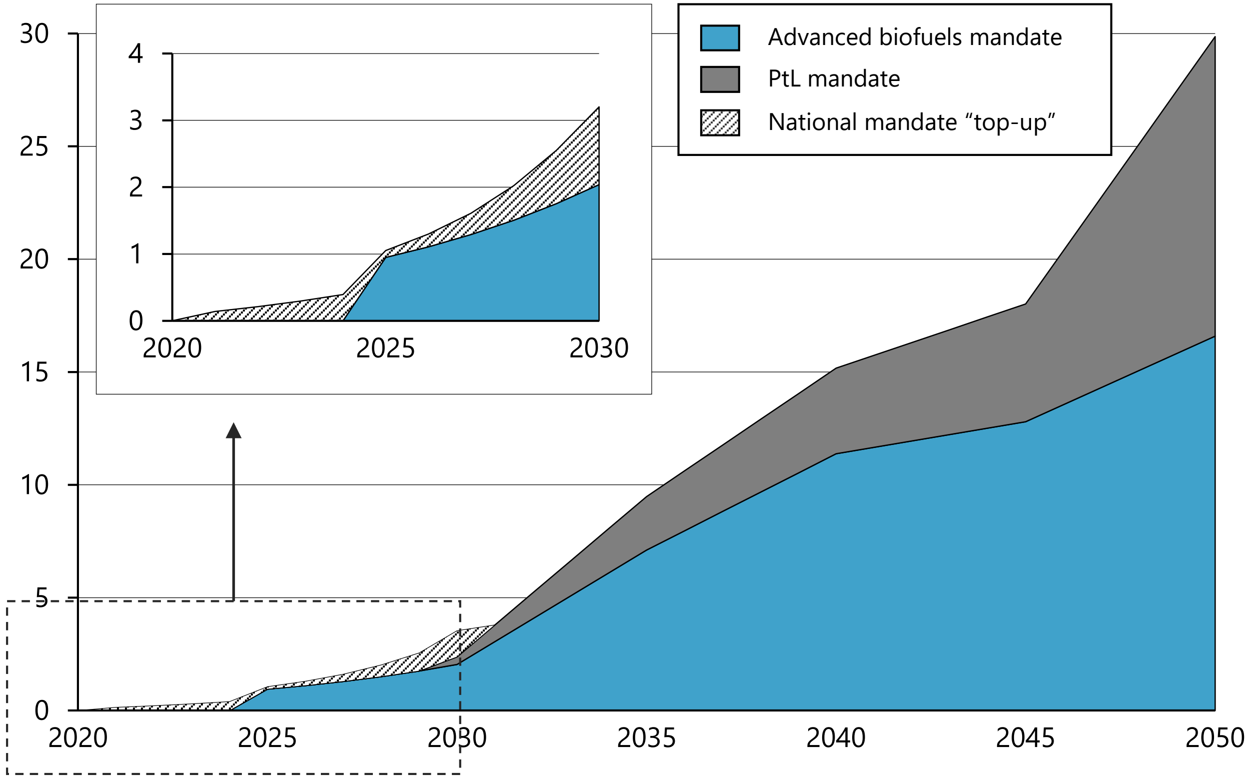


1. SAF is recognized under the US RFS and California's LCFS, which cover a significant part of the price gap
2. Norway and Sweden have enforced a SAF mandate starting at 1% since 2020 and 2021, respectively, both steeply increasing to 30% in 2030
3. The EU provides incentives for SAF under RED II. As a next step, the European Commission has proposed a SAF mandate of 2% in 2025, growing to 63% in 2050
4. Several members states (e.g., Netherlands, France, Germany, Finland, Spain) are planning to install SAF obligations beyond the EU mandate
5. The UK is investigating a SAF mandate starting in 2025
6. Indonesia has a SAF mandate in place of 3% in 2020, increasing to 5% in 2025
7. Canada, Japan, China, Australia and Brazil are exploring options to stimulate SAF

SkyNRG

The EU is leading the pack, with an anticipated SAF mandate of ~30 Mt SAF in 2050

SAF mandates in the EU (Mt SAF)[1]



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

Assumptions

- EU implements a SAF mandate of 2% in 2025, moving to 5% in 2030, 32% in 2040, and 63% in 2050, with split sub-targets for Bio-advanced SAF and Power-to-Liquid (PtL) SAF
- Countries implementing/discussing a more ambitious mandate than the EU (e.g. Sweden) stick to those targets, creating a national mandate "top-up"
- EU jet fuel demand will recover to pre-COVID volumes in 2024, after which it remains constant at 47.4 Mt

Key takeaways

- The RefuelEU mandate for Bio-advanced SAFs increases steeply from 2.0 Mt in 2030 to 11.4 Mt in 2040
- The mandate for PtL SAFs accelerates after 2045 to 13.3 Mt in 2050
- Total anticipated mandated volumes are 1 Mt in 2025, 3.5 Mt in 2030 and 30 Mt in 2050

[1] *Based on: EC, Proposal for a Regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport, 2021 (link), communication on national mandates*

To assess the feasibility of reaching the mandated volumes, we project SAF supply based on announcements and a capacity growth model

A. EU SAF supply based on industry announcements

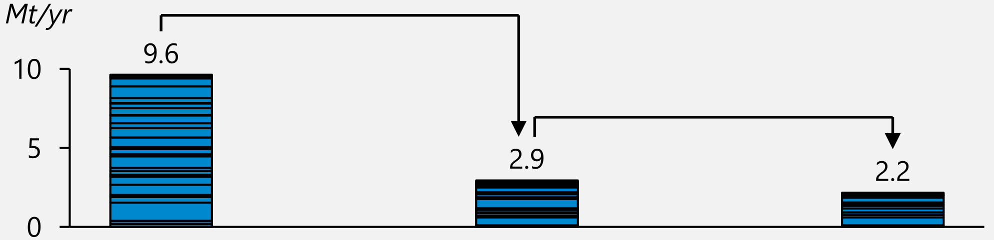
- Projection based on SAF supply from industry announcements for new capacity or fuel switches from renewable diesel to SAF
- We adjust for two factors (see below):
  - Maximum SAF production in the product slate
  - Market conditions, including competing demand for feedstocks and biofuels from other sectors
- Other key assumptions include:
  - No SAF is imported or exported to/from Europe
  - All SAF adheres to EU RED-II sustainability standards

+

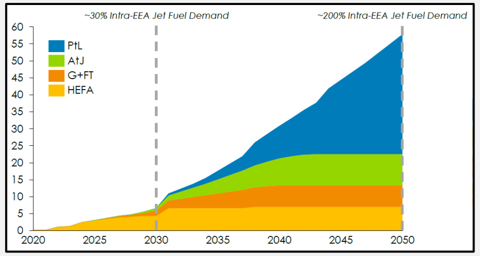
B. Projection of long-term capacity growth

- On top of existing announcements, we run a capacity growth model, which projects newly deployed SAF capacity
- This method builds upon the approach developed by McKinsey and ETC under the World Economic Forum Clean Skies for Tomorrow initiative.[1] The model projects capacity deployment based on:
  - Technology-specific initiation rates and lead times
  - Average plant outputs and product slates
- We have enriched the McKinsey/ETC analysis based on external sources, stakeholder discussions and industry knowledge

Example for 2027

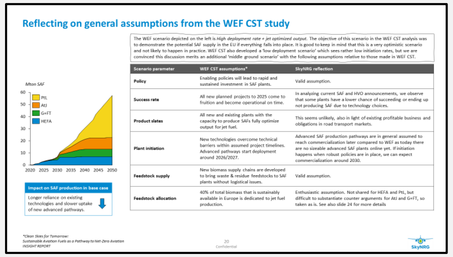


1. Quantify installed biofuel capacity
2. Quantify technical max SAF production
3. Adjust for market conditions



McKinsey/ETC analysis

+



Enriched assumption base

[1] *ECT, Guidelines for a Sustainable Aviation Fuel Blending Mandate in Europe, 2021 (link)*

SkyNRG

Supply Analysis

Industry Announcements

Supply/demand analysis for EU: multi-step approach

Step 1

Industry announcements

- The analysis is based on known data points. We start global and zoom in on Europe
- Plant announcements until June 2021 are included to develop a database of 75+ plants. Relevant information is based on desk research, discussions with stakeholders and industry knowledge
- The following steps are taken to derive realistic SAF EU production and import, finally this is compared with the mandated SAF demand

1 MAX CAPACITY	2 MAX TECH	3 MAX MARKET	4 REALISTIC MARKET
Maximum advanced renewable fuel capacity from installed and announced plants in the EU (mainly HVO)	Technical maximum SAF production capacity by taking into account tech. constraints (yields per licensor etc.)	Maximum SAF output adjusted for market conditions	Check is performed on competition with road sector for feedstock and production capacity to ensure realistic SAF production in EU

Step 2

Capacity growth model

- Few SAF plants are announced today that start after 2027
- To forecast SAF supply till 2050, we developed a capacity growth model, using tested metrics under the WEF Clean Skies for Tomorrow initiative which were chosen after thorough consultation with academics and industry
- Based on in-house knowledge and stakeholder engagement we enriched the analysis to create our own base case for EU SAF supply
- Finally, we run a sensitivity analysis on to discover what are the most impactful drivers in this base case

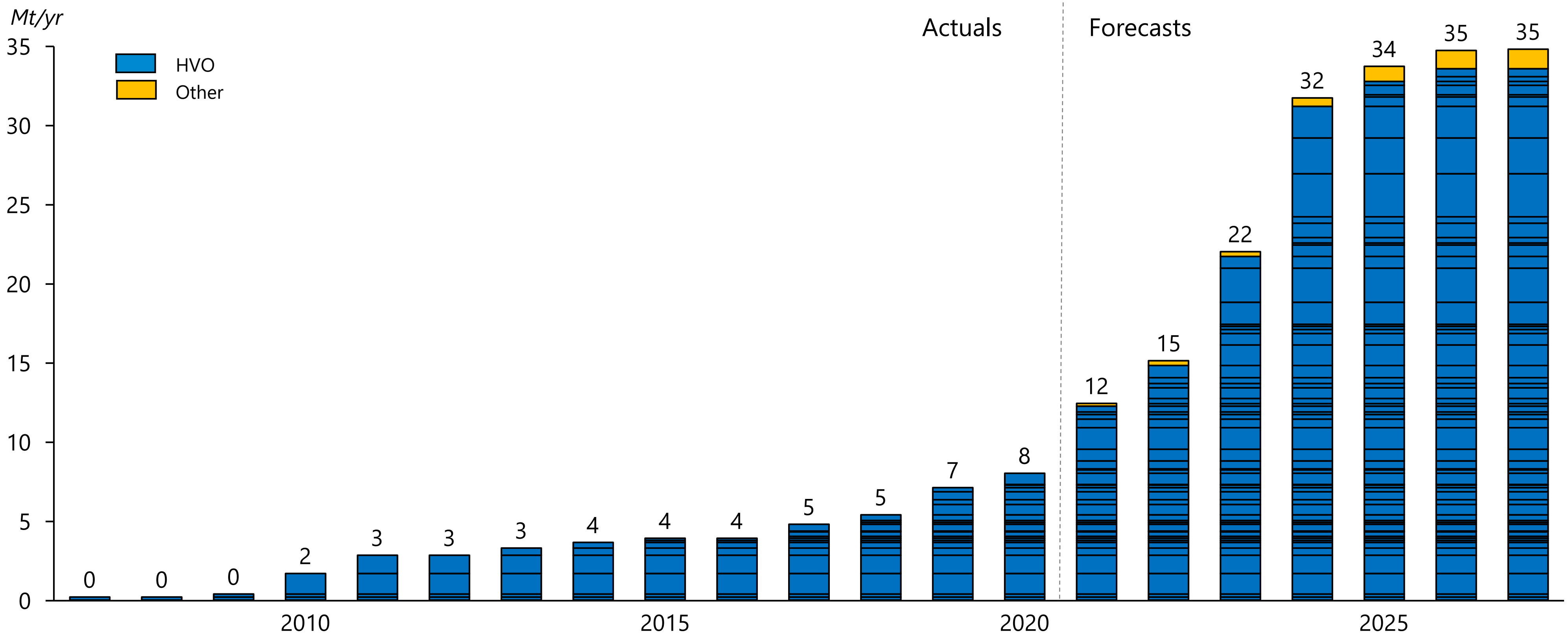
[1] *WEF CST, Guidelines for a Sustainable Aviation Fuel Blending Mandate in Europe, 2021 (link)*

SkyNRG

Globally, significant HVO capacity is already operational; if all announcements materialize, capacity could grow at least by a factor 4 until 2027

1 MAX CAPACITY
2 MAX TECH
3 MAX MARKET
4 REAL MARKET

Global capacity with potential to produce advanced renewable fuel, including SAF

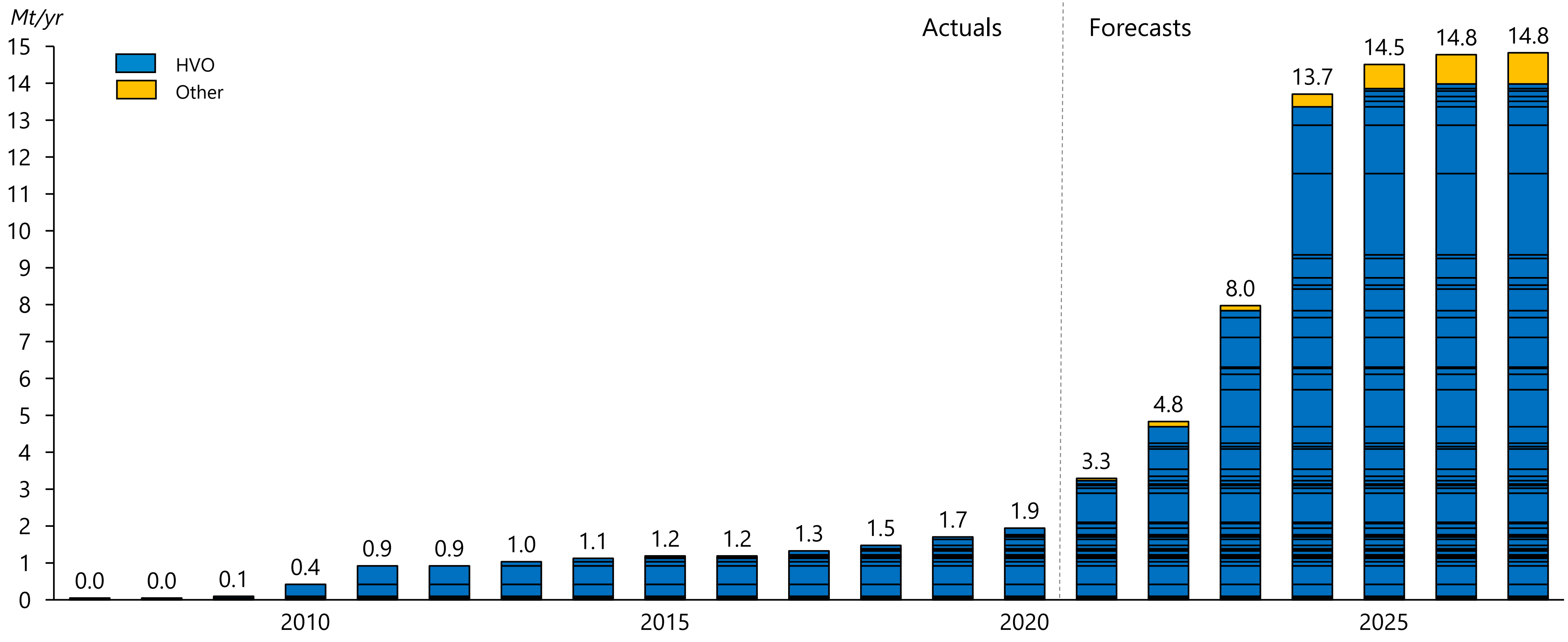


SkyNRG

Assuming every plant (installed and announced) will maximize SAF output, there is a maximum technological output potential of ±15M ton in 2027

1 MAX CAPACITY
2 MAX TECH
3 MAX MARKET
4 REAL MARKET

Maximum SAF output – Global capacity based

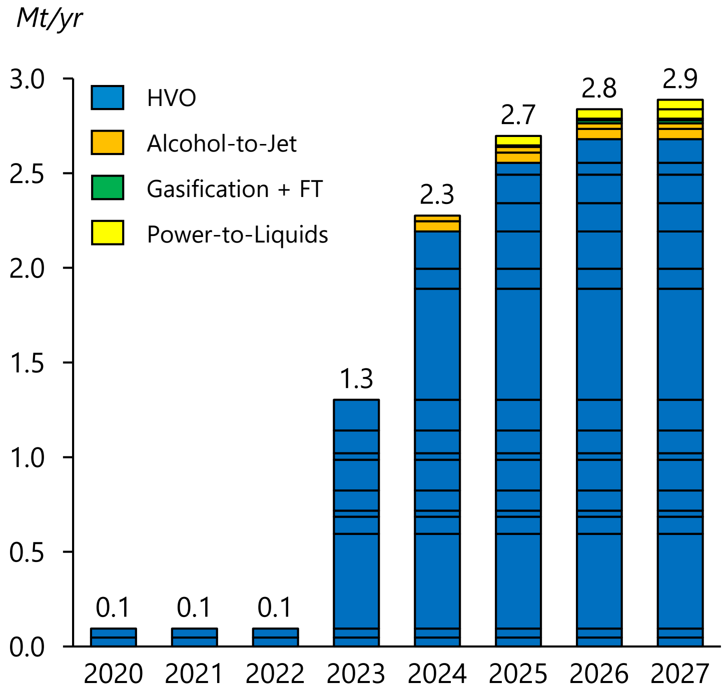


SkyNRG

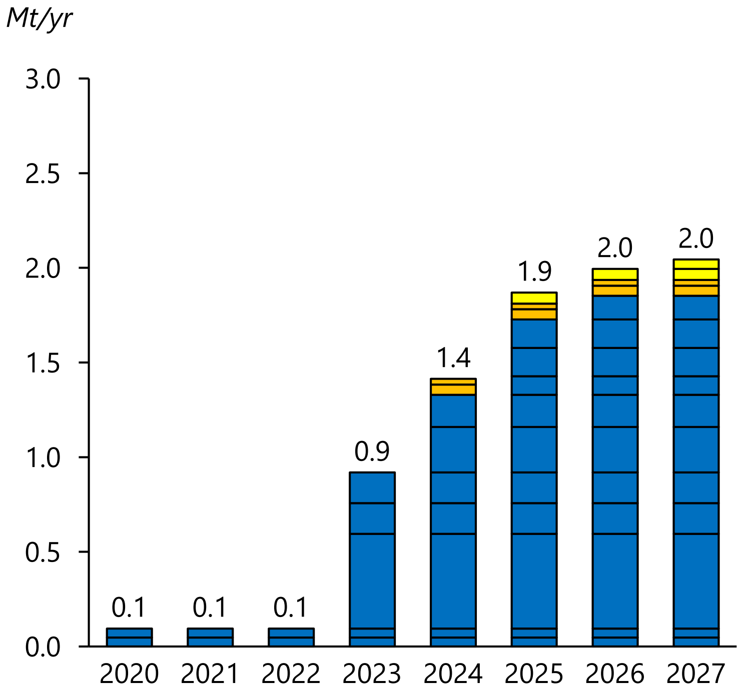
Two leading assumptions get us from the MAX TECH scenario (in EU) to the MAX MARKET scenario

1. Some plants that are currently producing renewable diesel and make good profit will likely not invest in SAF or switch to 100% SAF

2. It is not likely all announcements will materialize (on time). Correction is made based on current level of development, discussions with developers and industry knowledge



MAX TECH

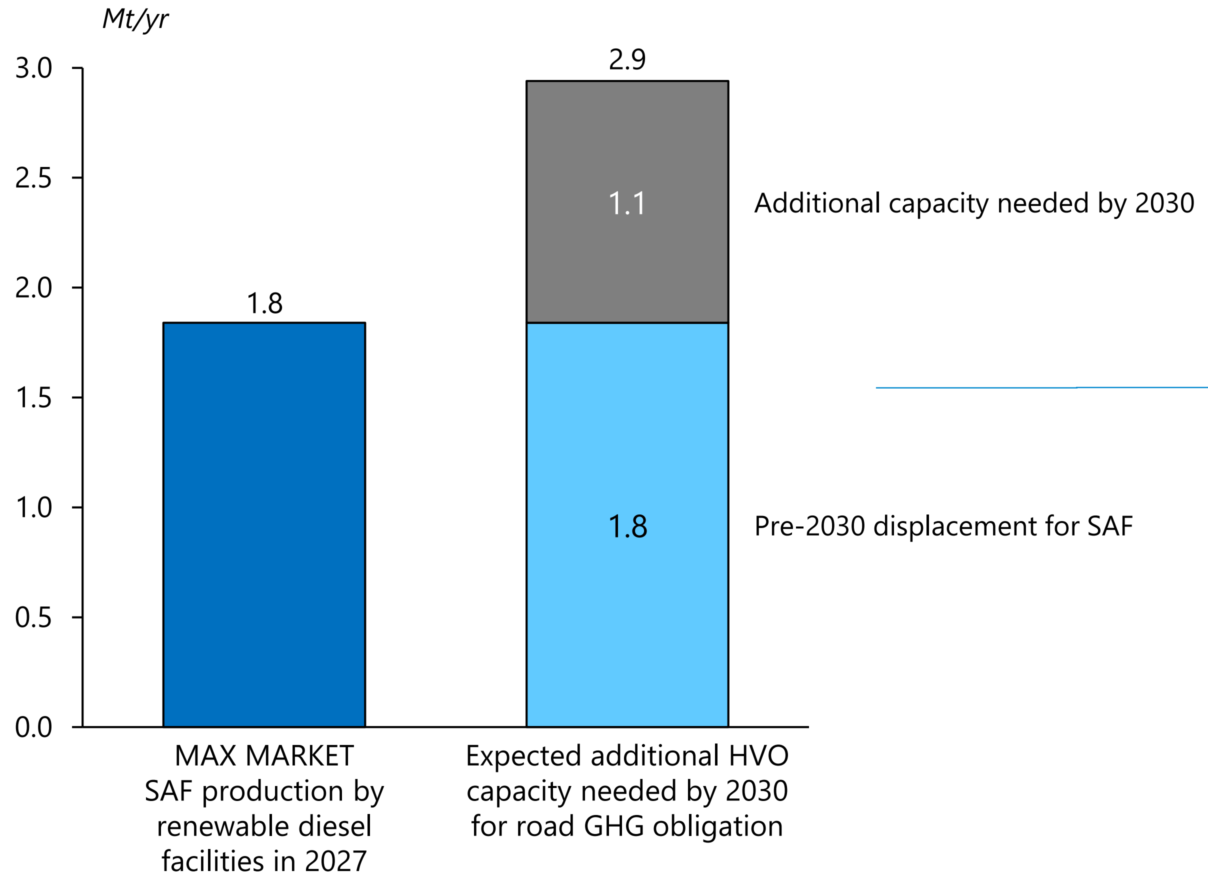


MAX MARKET

SkyNRG

Final step: cross check on HVO capacity needs for SAF production

① MAX CAPACITY
② MAX TECH
③ MAX MARKET
④ REAL MARKET



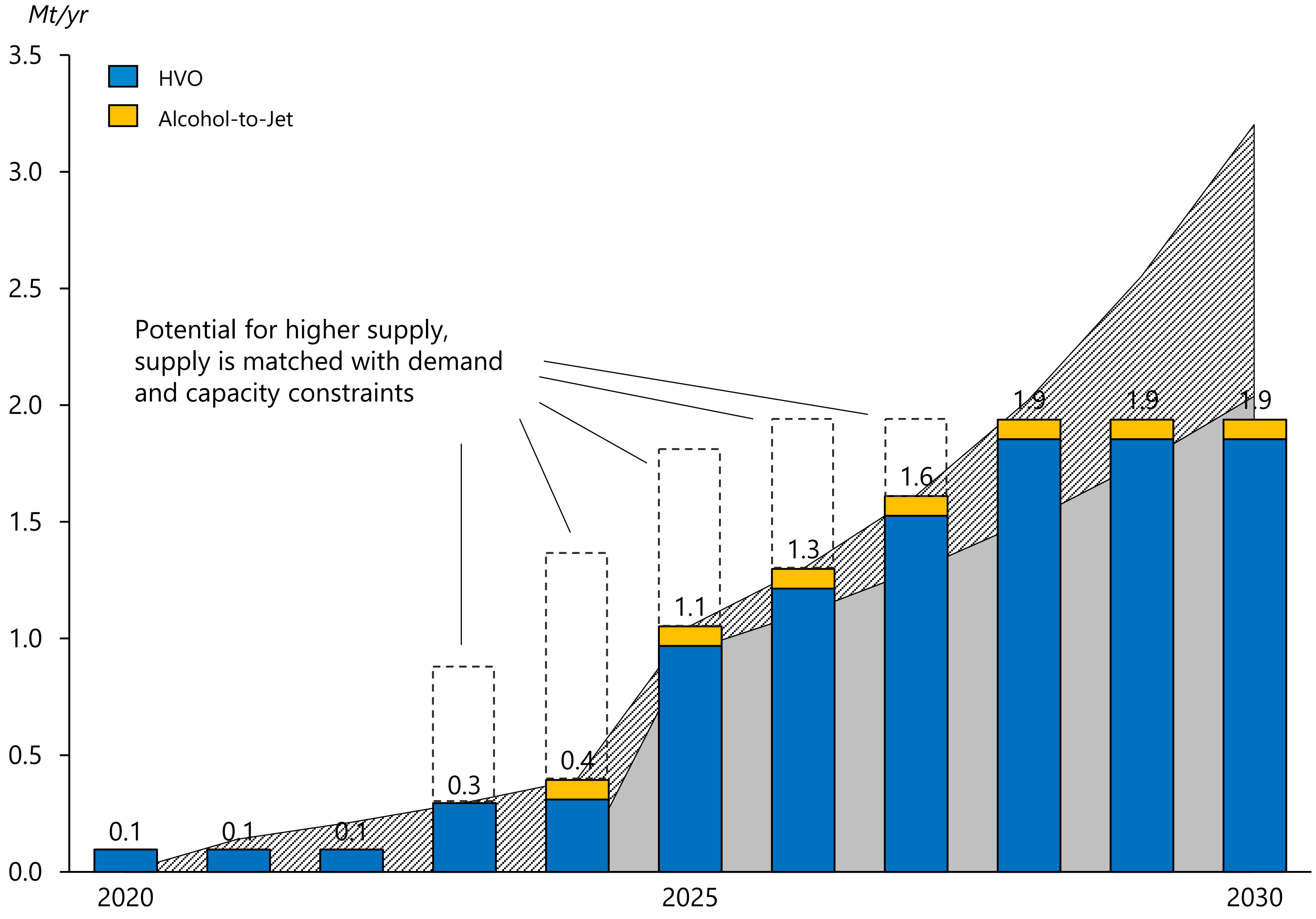
MAX MARKET TO REAL MARKET?

- With the B7 biodiesel blending limit having been reached in 2020,[1] drop-in alternatives seem needed to achieve the recently announced 16% GHG reduction target by 2030, even though the recently released RED II revision proposal includes a B10 blending limit.
- The RED II revision Impact Assessment foresees that the policy proposal will lead to the uptake of an average blend of 10% FAME biodiesel and 10% HVO.
- This would represent around 18 Mt of HVO diesel in 2030 which can be produced with 19 Mt of HVO capacity.
- Based on SkyNRG's analysis of announcements, we expect that most of the current HVO producers will continue using vegetable oils until 2030, about 2.5 Mt, which cannot be double counted under the RED II. If the remaining 16.5 Mt *can* be double counted or achieves equally higher GHG savings,[2] this means the waste-based capacity should be ±8.3 Mt, adding up to a total of 10.8 Mt HVO capacity to satisfy the GHG targets under the road sector.
- Renewable diesel already contributes to 1.9% of total diesel demand (2.7 Mt),[3] and dedicated HVO capacity in Europe was over 3 Mt up to 2020, which will increase to 9.7 Mt in 2030 based on current announcements, including co-processing (split: 7.4 Mt HVO & 2.3 Mt co-processing).
- This means that based on current announcements and policy framework, the road transport sector would just need to develop around 1.1 Mt of additional HVO capacity until 2030 to satisfy their road transport targets. Now diverting 1.8 Mt of production capacity to SAF means the road transport sector would have to develop an additional 2.9 Mt of capacity dedicated to the road sector
- Based on this cross-check, we conclude that it is ambitious, but realistic that the capacity in the MAX MARKET scenario could indeed be used for SAF production, with the road transport sector still having sufficient capacity to fulfil their industry GHG obligations.

[1] *Greenea, Who are tomorrow's waste-based biofuels buyers?, 2019 (link)*
[2] *Depending on how the RED II revision plays out. Double-counting is likely removed, meaning waste-based feedstocks would have to achieve double the GHG savings compared to food/feed-based fuels to satisfy the projection for road with the mentioned production capacities.*
[3] *USDA, Biofuels Annual, 2020 (link)*

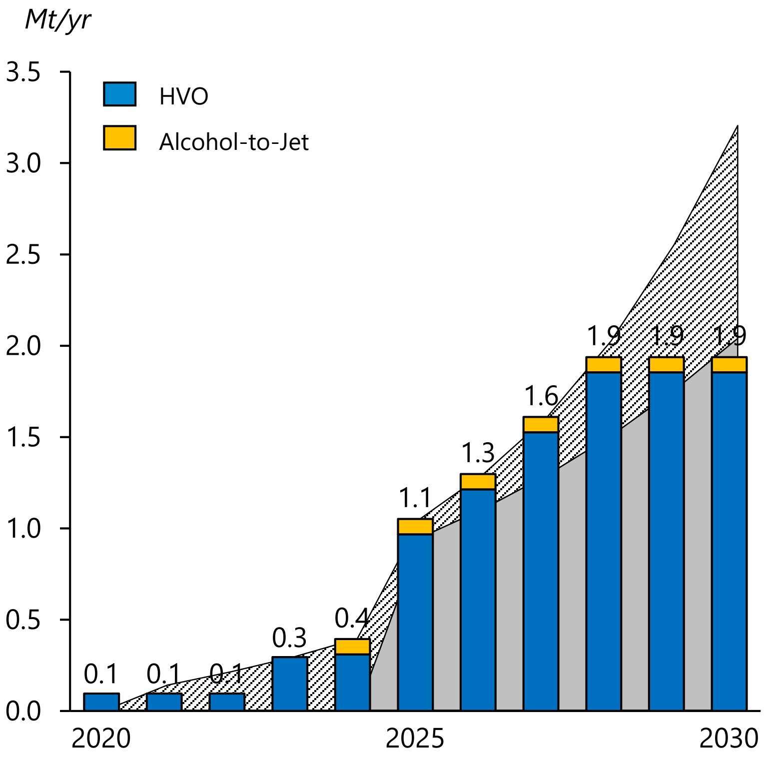
SkyNRG

Based on the REAL market scenario, there will likely be sufficient EU based SAF production to fill the EU SAF demand until 2027

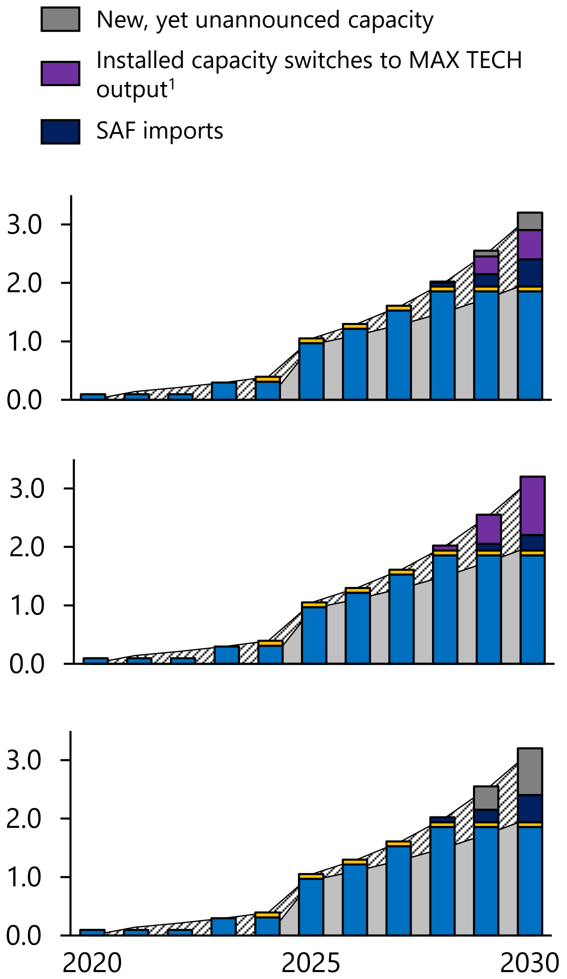


To reach 2030 volumes, there is need for (a combination of) imports, capacity switches and/or new capacity

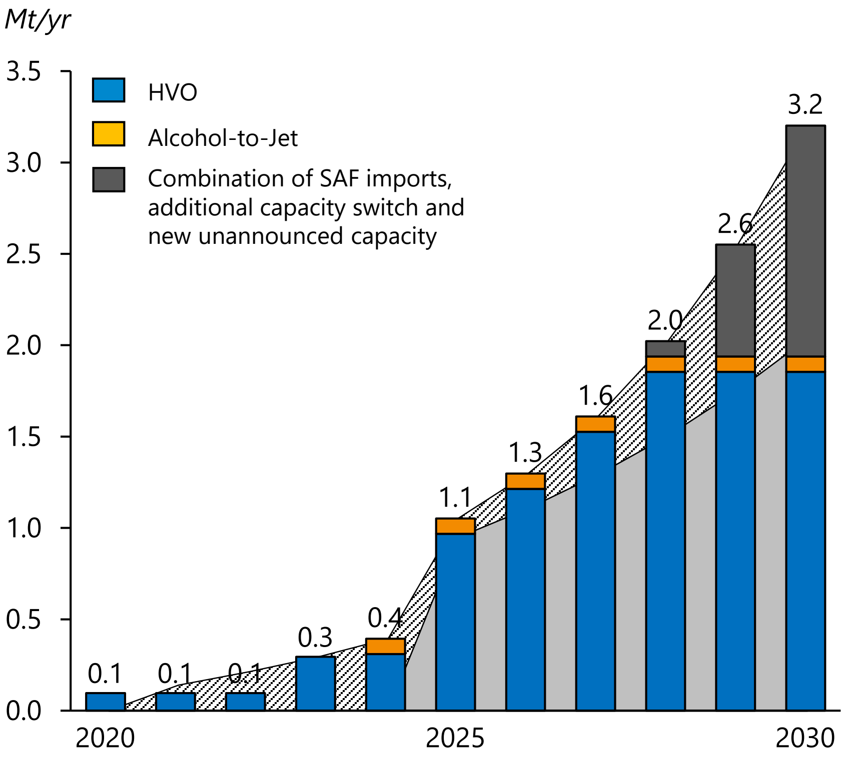
SAF supply scenario
(based on existing announcements and market constraints)



Various combinations of options possible to fill the gap



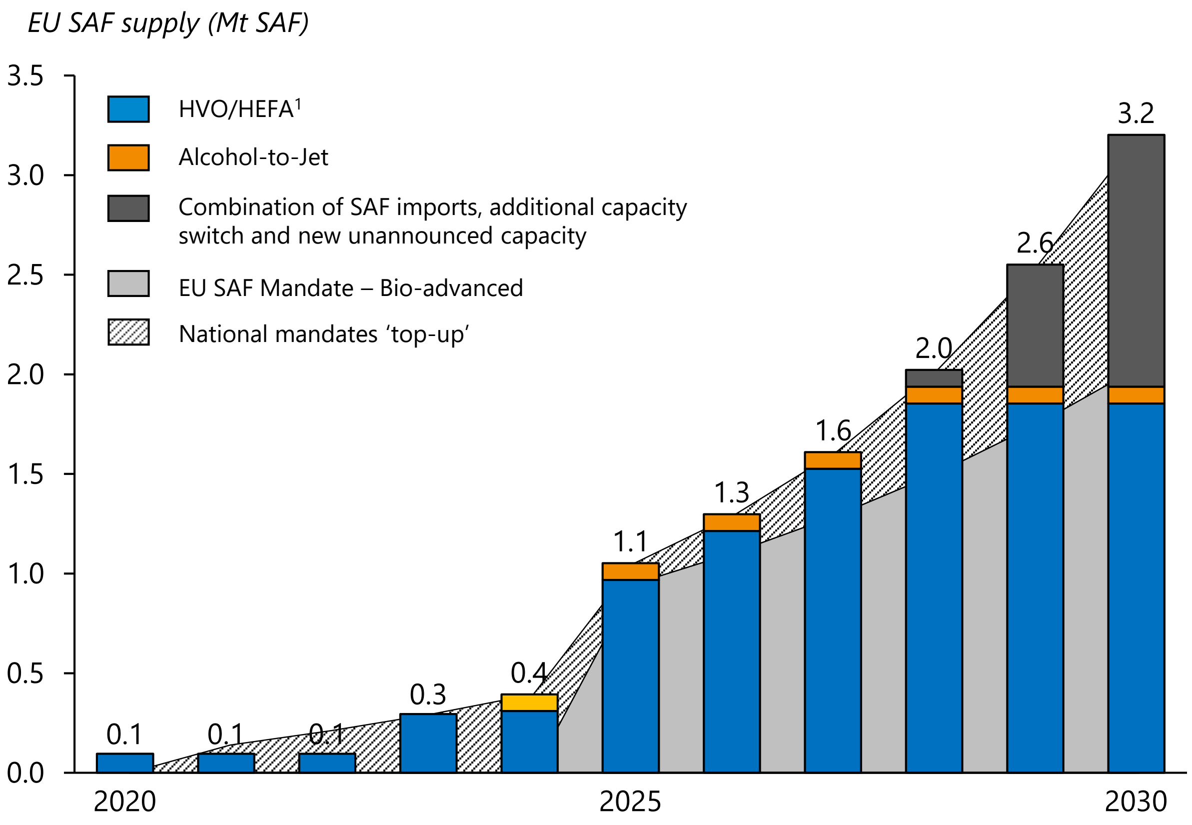
SAF supply scenario
(including options to fill the gap)



[1] *Unlikely due to market conditions and constraints, but not impossible*

SkyNRG

Concluding: up to 2030, supply can match demand provided plant announcements and capacity switches materialize



Key pre-conditions

- All promising announcements for development of new SAF facilities do indeed materialize
- Renewable diesel facilities make a significant switch to SAF production (nearly 2 Mt of SAF production is expected from renewable diesel facilities in 2027)

Key takeaways

- Announced plants and expected capacity switches seem sufficient to fill in the EU SAF targets up to 2027, including the individual member state "top-up"
- Beyond 2027, there are no additional announcements yet. There is potential to grow SAF volumes with a combination of SAF imports, existing renewable diesel plants investing and switching to SAF production, and new capacity that is currently not yet announced
- The dominant feedstock for SAF will be waste oils. This will require significant waste oil imports
- It is not to be expected that (demo scale) Alcohol-to-Jet (AtJ) and Fischer-Tropsch (FT) pathways will yield molecules before 2024

[1] The HVO/HEFA capacity increase includes both announced new plants and announced/expected renewable diesel capacity switching to SAF production

SkyNRG

SkyNRG

Supply Analysis

Capacity Growth
Model

Supply/demand analysis for EU: multi-step approach

Step 1

Industry announcements

- The analysis is based on known data points. We start global and zoom in on Europe
- Plant announcements until June 2021 are included to develop a database of 75+ plants. Relevant information is based on desk research, discussions with stakeholders and industry knowledge
- The following steps are taken to derive realistic SAF EU production and import, finally this is compared with the mandated SAF demand

1 MAX CAPACITY	2 MAX TECH	3 MAX MARKET	4 REALISTIC MARKET
Maximum advanced renewable fuel capacity from installed and announced plants in the EU (mainly HVO)	Technical maximum SAF production capacity by taking into account tech. constraints (yields per licensor etc.)	Maximum SAF output adjusted for market conditions	Check is performed on competition with road sector for feedstock and production capacity to ensure realistic SAF production in EU

Step 2

Capacity growth model

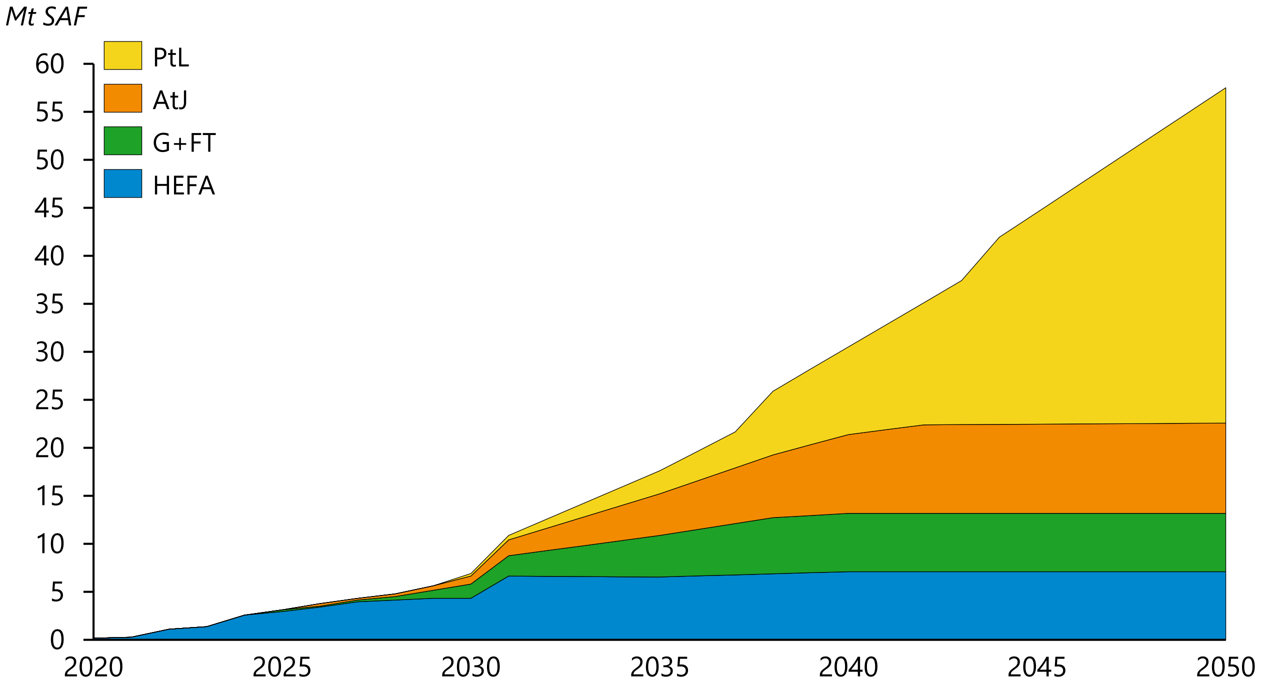
- Few SAF plants are announced today that start after 2027
- To forecast SAF supply till 2050, we developed a capacity growth model, using tested metrics under the WEF Clean Skies for Tomorrow initiative which were chosen after thorough consultation with academics and industry
- Based on in-house knowledge and stakeholder engagement we enriched the analysis to create our own base case for EU SAF supply
- Finally, we run a sensitivity analysis on to discover what are the most impactful drivers in this base case

[1] *WEF CST, Guidelines for a Sustainable Aviation Fuel Blending Mandate in Europe, 2021 (link)*

SkyNRG

For the 2028-2050 period, we estimate SAF supply taking the Clean Skies for Tomorrow model as basis, challenging assumptions and creating our own base case

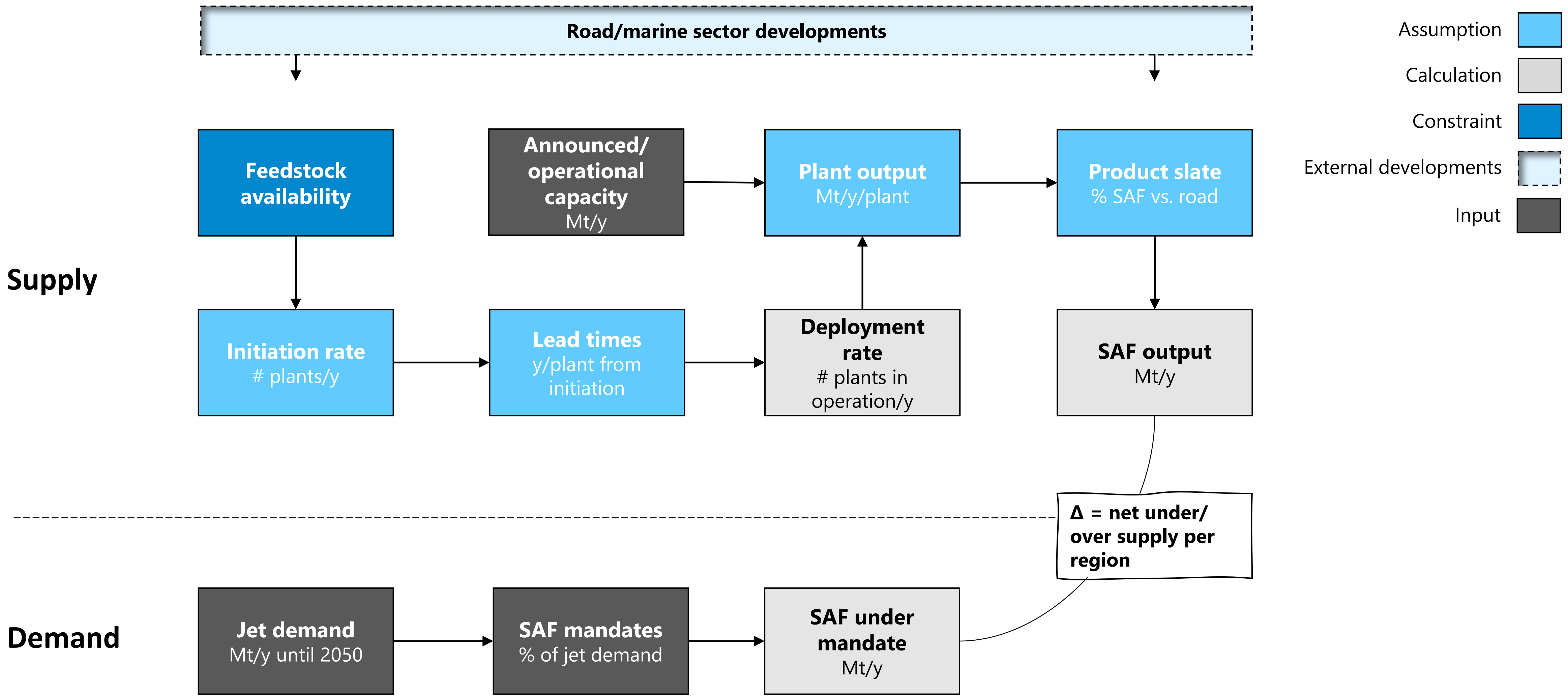
- The Clean Skies for Tomorrow initiative delivered a tested model with assumptions that were developed with input from academics and industry. To not reinvent the wheel, we decided to use the principles of this model and the fact base that was developed as a basis for the SkyNRG analysis.
- The WEF CST analysis included 3 scenarios to model the potential SAF supply in Europe.[1] We rebuilt scenario 2, which assumes that there will be significant deployment of SAF capacity in Europe as a result of favorable policies and plants will optimize their output towards SAF, but no biomass is imported.
- The result of this rebuild, before any modifications, is shown in the figure below. The reasoning behind the modifications and results of this assessment are detailed in the next slides. We furthermore outline how those assumptions were adapted to arrive at the SkyNRG base case.



Total modelled SAF output, incl. announced plants, adapted from World Economic Forum Clean Skies for Tomorrow initiative. NB: aim of this study was to show the maximum potential supply of SAF as input to EU mandate discussions.

[1] *WEF CST, Guidelines for a Sustainable Aviation Fuel Blending Mandate in Europe, 2021 (link)*

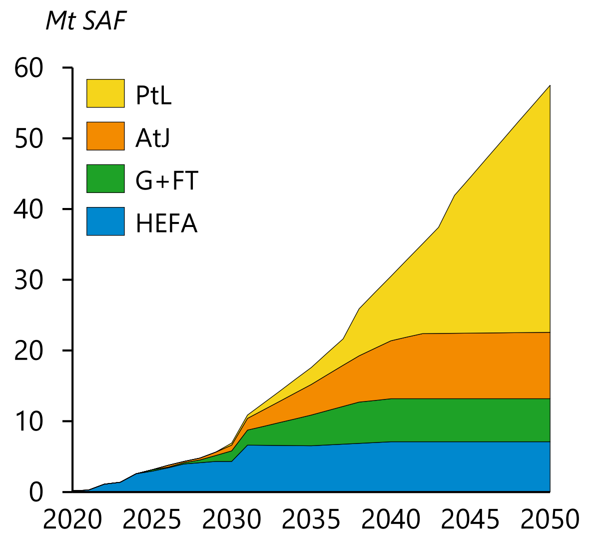
To be able to make our own base case, we developed a capacity growth model



SkyNRG

SkyNRG reviewed WEF CST assumptions to arrive at a SkyNRG 'base case'

The WEF scenario depicted on the left is *High deployment rate + jet optimized output*. The objective of this scenario in the WEF CST analysis was to demonstrate the potential SAF supply in the EU if everything falls into place. It is good to keep in mind that this is a very optimistic scenario and not likely to happen in practice. WEF CST also developed a 'low deployment scenario' which sees rather low initiation rates, but we are convinced this discussion merits an additional 'middle ground scenario' with the following assumptions relative to those made in WEF CST.

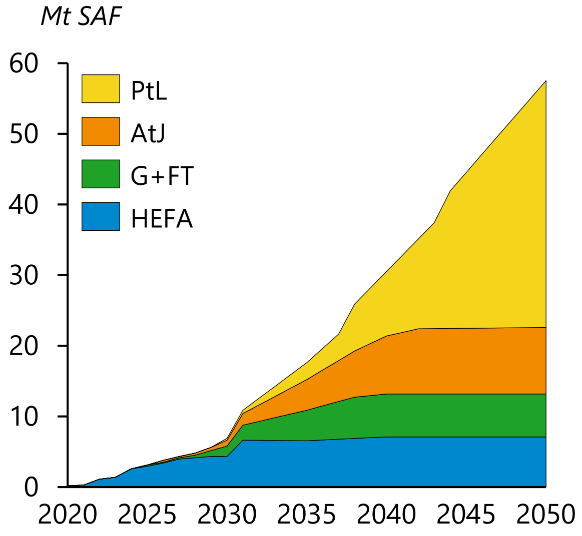


Impact on SAF production in base case

Longer reliance on existing technologies and slower uptake of new advanced pathways.

Scenario parameter	WEF CST assumptions[1]	SkyNRG reflection
Policy	Enabling policies will lead to rapid and sustained investment in SAF plants.	Valid assumption.
Success rate	All new planned projects to 2025 come to fruition and become operational on time.	In analyzing current SAF and HVO announcements, we observe that some plants have a lower chance of succeeding or ending up not producing SAF due to technology choices.
Product slates	All new and existing plants with the capacity to produce SAFs fully optimize output for jet fuel.	This seems unlikely, also in light of existing profitable business and obligations in road transport markets.
Plant initiation	New technologies overcome technical barriers within assumed project timelines. Advanced pathways start deployment around 2026/2027.	Advanced SAF production pathways are in general assumed to reach commercialization later compared to WEF, as today there are no sizeable advanced SAF plants online yet. If initiation happens when robust policies are in place, we can expect commercialization around 2030.
Feedstock supply	New biomass supply chains are developed to bring waste & residue feedstocks to SAF plants without logistical issues.	Valid assumption.
Feedstock allocation	40% of total biomass that is sustainably available in Europe is dedicated to jet fuel production.	Enthusiastic assumption. Not shared for HEFA and PtL, but difficult to substantiate counter arguments for AtJ and G+FT, so taken as is. See also page 25 for more details.

[1] *ETC, Guidelines for a Sustainable Aviation Fuel Blending Mandate in Europe, 2021 (link)*



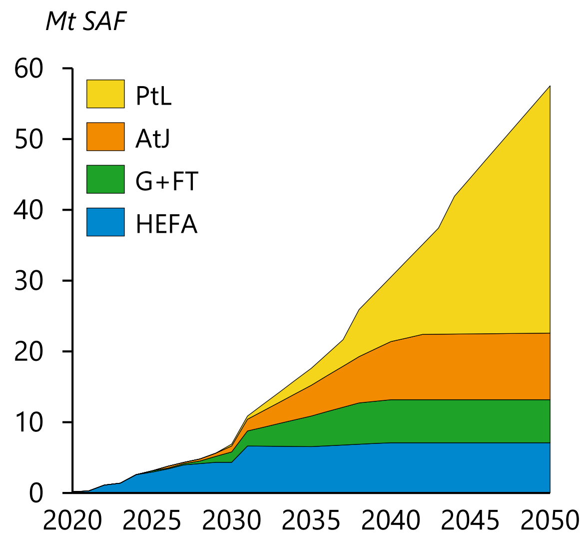
Impact on SAF production in base case

Fewer HEFA plants are initiated until 2025, when feedstock constraint is reached

Scenario parameter	WEF CST assumptions[1]	SkyNRG reflection
Feedstock availability	No imports are assumed. They take 20 Mt of oils and fats are available globally, and that 40% of this pool (i.e. 8 Mt) can be allocated to SAF in Europe. Breakdown: ▸ 2.4 Mt of waste oils and residues, includes used cooking oil, animal fat, fish oil, tall oil and other waste and residue lipids. ▸ 2.8 Mt of oil from oil trees on degraded land. 1% of the amount of degraded land is assumed to be practically available for oilseed bearing trees. ▸ 2.8 Mt of oil from oil-cover crops. It is assumed that 25% of the total amount of arable land is practically available for cover crops. This amount is allocated on a 20/80 division between oilseed bearing and cellulosic cover crops, respectively.	**Waste oils and fats** ▸ Currently, 60% of all waste oils processed for advanced fuel production in Europe are imported.[2] We therefore suggest an approach in which a maximum amount of the global pool of waste oils is allocated to SAF production in Europe → 4 Mt of waste oils for EU SAF production (see page 25 for additional detail) **Oil trees on degraded land** ▸ Currently, there is no indication that biomass from degraded lands will enter the RED-II definition of advanced fuel soon. We choose not to include these volumes **Cover crops** ▸ Currently being assessed for use as advanced biofuel feedstock under the RED-II. No existing (EU) supply chains. Mobilizing large quantities of these feedstocks in the short term seems unrealistic. We choose not to include the volume in the base case, but in the scenario analysis
Initiation rate	A low number of plants is initiated until 2025. After 2025 no plants are initiated due to feedstock constraints.	Due to tighter feedstock availability compared to WEF as elaborated above, a lower number of plants is announced until 2025, after which feedstock constraints are reached.
Lead time	3 years	Based on SkyNRG's experience with HEFA technology, we suggest to include an average lead time of 4 years from initiation until commercial operation.
Plant output	0.5 Mt middle distillate output	Not invalid assumption, although quite sizeable. This means 0.7 Mt feedstock input. Based on expert interviews, we assume a 50/50 split diesel/jet and a 70% conversion feedstock to jet, which yields 0.35 Mt feedstock for SAF and results in 0.25 Mt SAF output per plant.

[1] *ETC, Guidelines for a Sustainable Aviation Fuel Blending Mandate in Europe, 2021 (link)*
[2] *Greenea, Which investments will see the light in the biofuel industry?, 2021 (link)*

SkyNRG



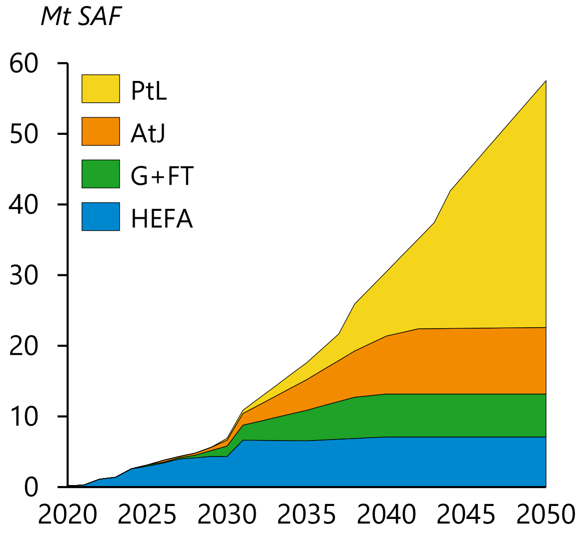
Impact on SAF production in base case

Slightly slower deployment due to lower SAF output per G+FT plant

Scenario parameter	WEF CST assumptions[1]	SkyNRG reflection
Feedstock availability	It is assumed that 40% of a total of 640 Mt cellulosic material and MSW can be allocated to SAF production in Europe (i.e. 256 Mt). This feedstock pool is shared with AtJ (except for MSW, which is allocated to G+FT) and is broken down as follows: ▸ 36 Mt of cellulosic cover crops. Amount of arable land under temporary crops is based on FAOstat, 25% of this land is assumed to be practically available for cover crops; assumed split of 20/80 between oilseed bearing and cellulosic cover crops; ▸ 49 Mt of agricultural residues; ▸ 64 Mt of forestry residues; ▸ 41 Mt of wood-processing waste; ▸ 132 Mt of MSW. Availability is based on World Bank number for pure organic waste plus 20% of total plastic waste, assumed to be non-reusable.	▸ Cellulosic material will be in high demand in the coming decades for both the chemicals and (road) fuels sectors. This means that allocating 40% to SAF production is likely very optimistic. ▸ More realistic would be to assume a lower share, but at the same time also consider which feedstocks could be realistically imported to Europe. ▸ Regarding the individual potentials, there are also some remarks to be made. See page 36. ▸ SkyNRG assumes that MSW is split equally over AtJ and G+FT, as both technologies can process it. ▸ All in all, we have insufficient robust analysis at the moment to assume different numbers compared to WEF, so more analysis on this feedstock pool is needed. ▸ We adopt the WEF numbers for the base-case
Initiation rate	Increases from 0 plants/year in 2020 to a maximum of 5 in 2028 and decreases again after 2035 due to feedstock constraints.	Valid assumption, although initiation rate is lower in SkyNRG case due to exclusion of UK from scope.
Lead time	6 years for a 1st commercial plant, 4 years for an nth commercial plant.	Valid assumption.
Plant output	0.15 Mt	Valid assumption.
Product slate	SAF is 60% of the total output pre-2030 and 70% post-2030	Through discussions between SkyNRG and FT technology developers, we could validate that these percentages are indeed the maximum SAF output for FT. Realistically however, based on project announcements and likely continuing incentives to produce renewable diesel, we assume a pre-2030 SAF output of 35% and post-2030 of 50%.

[1] *ETC, Guidelines for a Sustainable Aviation Fuel Blending Mandate in Europe, 2021 (link)*

SkyNRG



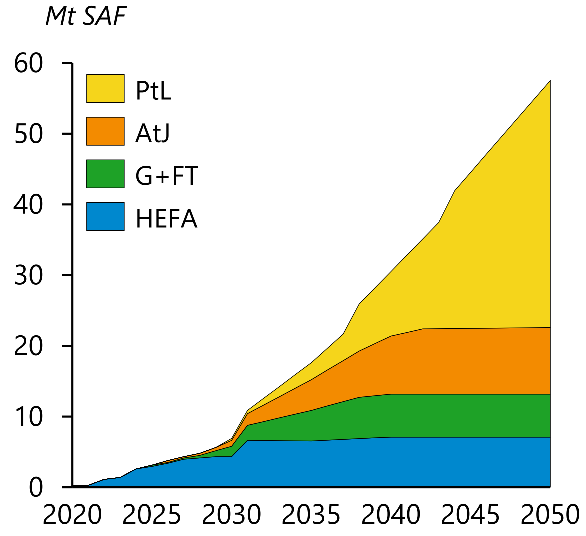
Impact on SAF production in base case

Slightly higher supply due to higher SAF output per plant

Scenario parameter	WEF CST assumptions[1]	SkyNRG reflection
Feedstock availability	Feedstock pool is shared 50/50 with G+FT, except for MSW. Refer to previous page for assumptions and discussion.	WEF feedstock focus is 100% Europe, no imports. In the case of AtJ it is very likely there will be imports of (cellulosic) ethanol/alcohols, increasing the potential for deployment of this pathway in Europe. In addition, SkyNRG assumes this pathway can also take in MSW, meaning we model with a 50/50 split of the feedstock.
Initiation rate	Increases from 0 plants/year in 2023 to a maximum of 5 in 2031, and decreases again after 2038 due to feedstock constraints	Valid assumption, although initiation rate is lower in SkyNRG case due to exclusion of UK from scope.
Lead time	5 years for a 1st commercial plant, 4 years for an nth commercial plant.	Valid assumption.
Plant output	0.2 Mt	Operating in an integrated supply chain (including alcohol production) 0.2 Mt SAF/year is high, but not unrealistic. If an AtJ facility is operated in a hub-and-spoke supply chain where cellulosic ethanol is imported from other regions, up to 1 Mt/year is thought to be feasible. For our base case, however, we adopt the WEF assumption.
Product slate	SAF is 77% of the total output, both pre- and post-2030	Conservative assumption. Based on discussions and publications from technology providers we know that AtJ technologies are capable of producing a higher jet cut. We still take the WEF assumption for the base case, leaving upside potential in the scenarios

[1] *ETC, Guidelines for a Sustainable Aviation Fuel Blending Mandate in Europe, 2021 (link)*

SkyNRG



Impact on SAF production in base case

Lower deployment, due to feedstock constraint and lower plant output

Scenario parameter	WEF CST assumptions[1]	SkyNRG reflection
Feedstock availability	No limitations included	Based on the projected amount of available renewable electricity in most of the EU's low-carbon 2050 scenarios, we believe including a constraint on which share of this amount can be used for SAF production would be realistic (i.e. 600 TWh). See page 25 for more detail.
Initiation rate	Starts to ramp up after 2025 to 10 plants/year by 2045. Capped at 10 plants, compared to 10 plants/year for the other advanced routes in total.	Valid assumption, as the syngas production step requires different types of equipment compared to the advanced fuel routes. However, the FT step is also done in the Gasification route and might therefore face limitations in the supply chain. Also in reality, the initiation rate is constrained by the renewable power additions that can be done, which links to the maximum plant output as well. Initiation rate is lower in the SkyNRG case due to exclusion of UK from scope.
Lead time	4 years	Valid assumption.
Plant output	0.4 Mt	Based on SkyNRG's discussions with technology providers, we estimate that a total plant output of 0.4 Mt would require a hydrogen input of about 164 thousand tonnes. To produce this amount of hydrogen, an installed renewable power capacity of about 2 GW offshore wind or 5.5 GW of solar PV in Spain are required. Especially in combination with the initiation rates assumed, this is considered unrealistic. We therefore suggest to set the maximum plant output at 0.2 Mt, while noting that this is already ambitious.
Product slate	Same as Gasification + FT	Same as Gasification + FT

[1] *ETC, Guidelines for a Sustainable Aviation Fuel Blending Mandate in Europe, 2021 (link)*

SkyNRG

Details on feedstock assumptions

Oils and fats

- We consider it more realistic to draw from the global feedstock pool of 40 Mt feedstock (McKinsey analysis).
- We consider that the EU can likely claim a maximum of a third of the global pool for all economic sectors by 2030, which it currently already does for UCO. This means the EU could claim about 13 Mt waste oil feedstock.
- In practice a significant share (at least 8 Mt) of the global waste oil potential will be already be required to satisfy EU road transport targets.
- When we subtract this feedstock demand for road transport, we arrive at 4 Mt of waste oils and fats available to the EU SAF sector until 2030, which is more optimistic than the 2.4 Mt waste oils ETC uses, but conservative compared to total 8 Mt waste oils and fats from ETC.
- Mobilizing new biomass supply chains can take longer than 5 years, especially if it concerns feedstocks from species for which novel incentives have yet to be developed such as cover crops and oil trees on degraded land, or feedstocks that are not yet allowed under the RED II. While appreciating there is a significant upside potential, suggest to include this in our sensitivity analysis and not include these estimates in a realistic potential.
- Cover crops: see next box

Cellulosic & MSW feedstock

- ETC assumes that 25% of the total arable land can be used for cover cropping. Of which 20% will be then used for oil seed crops and 80% for energy crops.
- SkyNRG is currently not in a position to confirm or challenge this assumption.
- Based on current legislation, it seems appropriate to take the volumes along in the scenario analysis, not in the base case
- To get a better understanding of the actual potential of cover crops (oil & energy), we have started initial discussions with academics on this topic. SkyNRG will work to further validate this in the coming months.
- A sizeable part of the potential (33 Mt) comes from non-reusable plastic waste.
- Based on current legislation, it does not seem appropriate to take the volumes along in the base case nor the scenarios
- It seems realistic that certain primary feedstocks (e.g. wood pellets) or intermediates (e.g. ethanol) will be produced outside of Europe (close to feedstock source) and could be imported for processing into final SAF products in European facilities.
- It is included in the scenario analysis and SkyNRG will investigate this non-EU potential further in the coming months

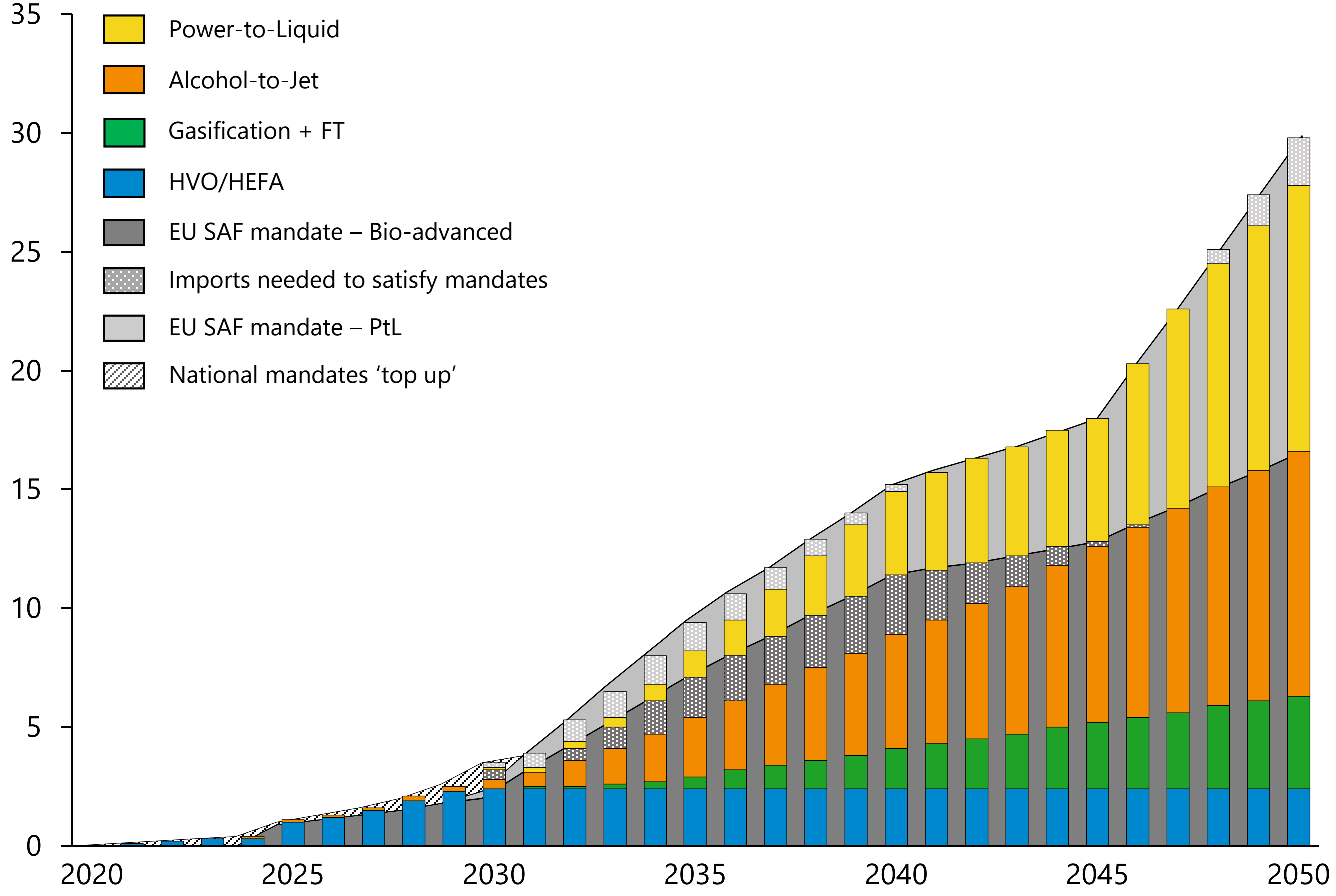
Renewable electricity

- Although PtL SAF or the H_2 intermediate could well be imported from regions with better geographical conditions (i.e. cheaper renewable electricity), it is considered realistic to include a feedstock constraint for PtL production in the EU.
- The 35 Mt of PtL SAF assumed in this pathway would require a renewable power input of around 1100 TWh (only considering the power demand to produce the hydrogen), which represents around 16% of the gross electricity production assumed in the most ambitious scenario from the EU's 2050 low-carbon roadmap (1.5TECH).[1]
- It seems unlikely that such a significant share of the EU's power production would be allocated just to SAF production.
- We therefore suggest to include a constraint in line with the EU 2050 vision, where the power production allocated to PtL SAF production in their maximum technology scenario equals around 600 TWh. We include this constraint in our scenario, which represents just under 10% of the gross power production in the EC's 1.5TECH scenario.
- This results in lower amounts of PtL-SAF vs. ETC.

[1] *European Commission, A Clean Planet for all, 2018 (link)*

SkyNRG base case for SAF supply till 2050

EU SAF supply (Mt SAF)



Key boundary conditions in this analysis

- Upscaling of plants is limited by global feedstock availability in case of HEFA, and EU feedstock availability for other pathways
- Steepness of the growth in mandated SAF volumes impacts the rate of plant initiation
- A maximum of 10 advanced biofuel plants are realized per year, with a maximum of 10 for PtL
- Imports amount to a maximum of 30% of the mandated supply
- Product slates of FT and HEFA technologies are not fully jet-optimized due to expected fuel demand from road sector

Key takeaways

- About 300 SAF plants will be required to fulfil the EU mandate by 2050 (vs. ~25 EU plants currently announced)
- Pathways depending on cellulosic (waste and residue) feedstock will become essential to achieving mandated volumes
- Rapid deployment of new technologies (FT, AtJ, PtL) and feedstock mobilization required to supply mandated volumes post 2030
- Imports are needed to achieve mandated volumes, especially in the rapid mandated increase between 2030-2040

SkyNRG

SkyNRG

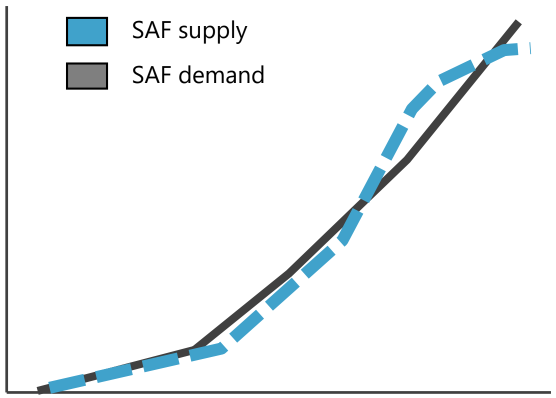
Qualitative Supply Scenario Analysis

To get a feeling for the drivers impacting supply/demand dynamics, we have made a qualitative scenario analysis

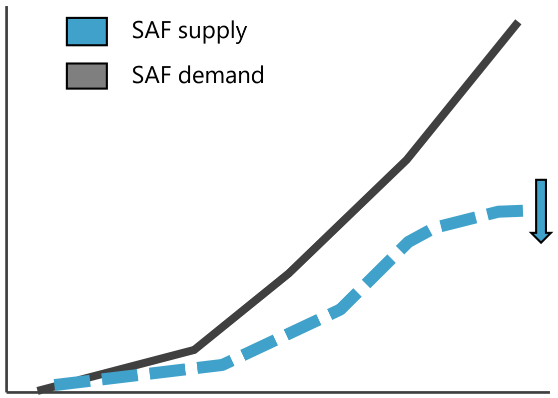
Qualitative scenarios: explanation

- Various drivers can have an impact on the (EU) SAF supply and demand
- We have not quantified these drivers and scenarios
- We have focused on the HIGH & MEDIUM impact scenarios
- In the next pages we perform a qualitative scenario on some of the main drivers
- Compared to the SkyNRG base case, we (conceptually) indicate
  - The effect on SAF supply and demand (arrows)
  - The level of impact (low, medium, high)
  - The likeliness of the scenario occurring (low, medium, high)

Example

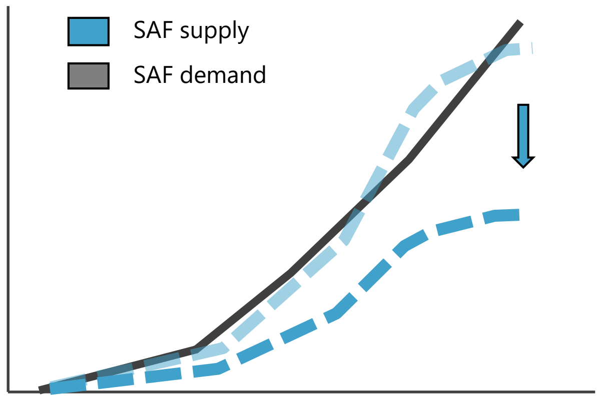


SkyNRG base case



Scenario results

As shown



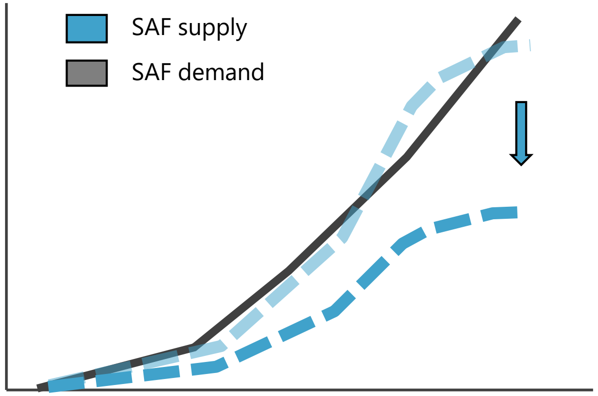
SkyNRG

Qualitative scenarios: supply-side changes

Demand side stimulation outside of EU

Increased demand outside of EU will likely have the following effects:

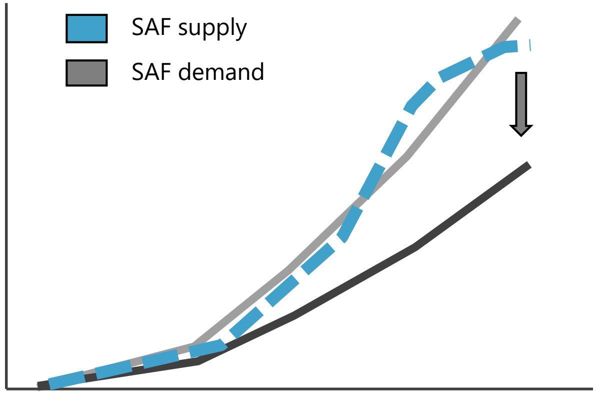
- Less import of SAF into EU possible (minor negative impact on meeting SAF targets)
- Less import of feedstock into EU (massive negative impact on meeting SAF targets)
- Potential export from EU to other regions, if economics are better (potential negative impact on meeting SAF targets)
- Conclusion: If any of non-EU region implements (demand-side) SAF policies, it will be more difficult to meet the targets and an under-supply situation is more likely



Impact: HIGH
Likeliness: HIGH

More rapid developments in hydrogen/electric powered aircraft

- First possible introduction of electric aviation (2025) and hydrogen fuel cell (2030)
- Main focus: commuter and regional flights
- Together max 4 percent of industry CO_2, so will have very limited impact on jet fuel volumes
- Introduction of electric and hydrogen aircraft for short haul flights are expected from 2040 onwards
- More rapid development scenario: introduction and scaling from 2030 onwards. This will have an effect on jet fuel consumption, and related absolute SAF volumes under the mandate (positive impact on meeting SAF targets)
- Pace of developments will not only depend on aircraft introduction, but needs significant investment in renewable electricity and airport infrastructure as well



Impact: MEDIUM
Likeliness: LOW

Conservative post-COVID recovery aviation sector

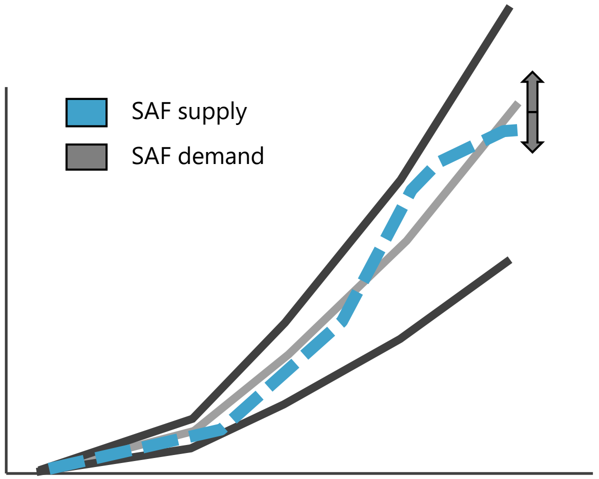
a

- Current assumption is the IATA Covid recovery projection
- In a conservative post-covid recovery, the (European) jet fuel demand will be (structurally?) lower
- As the SAF mandate is defined as percentage of jet fuel demand, the absolute SAF volume needed will decrease as well (positive impact on meeting SAF targets)

More rapid post-COVID recovery aviation sector

b

- Will result in higher jet fuel demand and related needed SAF volumes (negative impact on meeting SAF targets)



a Impact: HIGH
Likeliness: MEDIUM

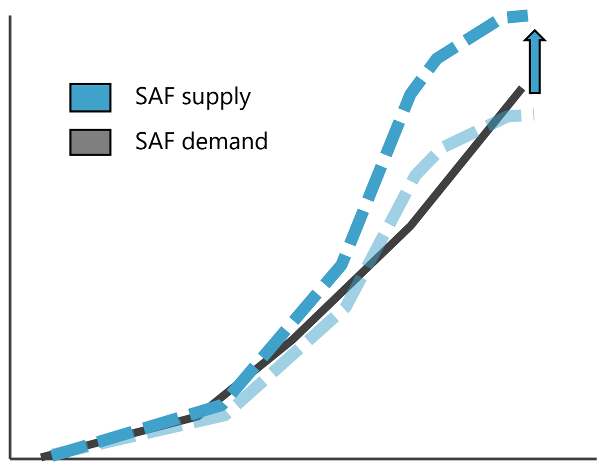
b Impact: MEDIUM
Likeliness: LOW

SkyNRG

Qualitative scenarios: demand-side changes

More rapid capacity deployment

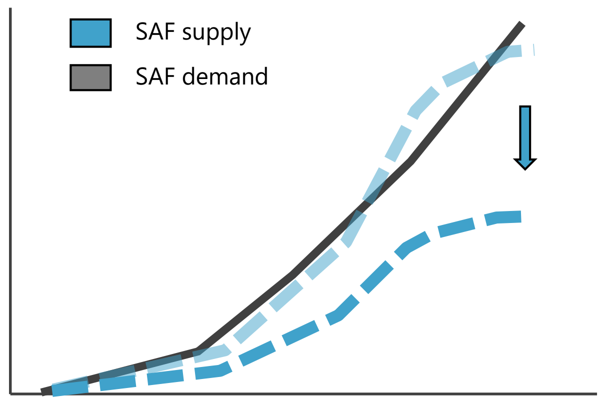
- More rapid capacity deployment in Europe would lead to more SAF (positive impact on meeting SAF targets)
- More rapid capacity deployment outside Europe could lead to more SAF (positive impact on meeting SAF targets), but could also lead to increased political confidence and higher blending mandates outside of Europe (negative impact on meeting SAF targets)
- Although the capacity deployment assumptions are already optimistic, in the basis we think that more SAF capacity is a positive development



Impact: MEDIUM
Likeliness: LOW

New and/or increased demand in other sectors

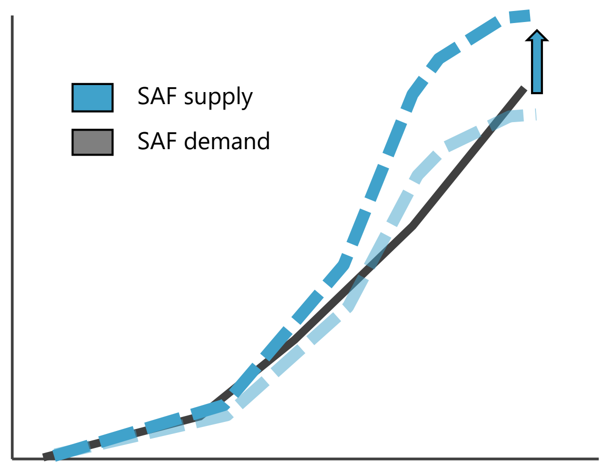
- Introduction of obligations for renewable energy in new sectors (e.g. marine, chemicals) or an increased obligation in existing sectors (e.g. road transport, electricity) will increase the pressure on the feedstock base for SAF production (i.e. bio-based material and renewable electricity)
- Although there can be synergies between these markets from a production capacity point of view (e.g. multiple product slate, lower cost of production), the overall opinion is that this will reduce the SAF capacity potential and related volumes



Impact: HIGH
Likeliness: HIGH

More rapid electrification of road transport

- Increased deployment of electric (and hydrogen) vehicles will reduce the overall volume for road transport fossil fuels, which will lead to a reduced volume of sustainable fuels in that sector
- This means less pressure on feedstock and more (existing) capacity can be switched to bio-advanced SAF production (positive impact on meeting SAF targets)
- And increased demand in electricity and hydrogen in road transport will also mean more pressure on feedstock (and capacity) for the PtL SAF volumes

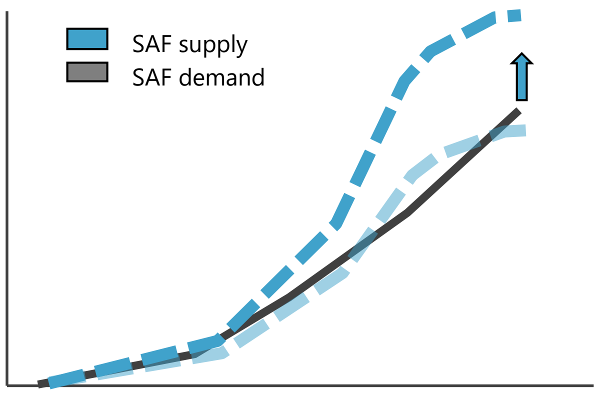


Impact: MEDIUM
Likeliness: MEDIUM

Qualitative scenarios: feedstock & technology assumptions

Allowing crops under the RED-II for bio-advanced SAF

- It is not unlikely this will happen. Maybe already in the RED-II delegated acts, maybe in the 2025 revision, maybe per 2030
- Allowing cover crops (oil seeds and cellulosic biomass) can have a positive impact on feedstock availability for HEFA, G+FT and AtJ pathways
- However, economics of cover crop products are not competitive with main crops. And new biomass supply chains need to be deployed as well
- Availability of feedstock will increase, but there will likely also be a price increase compared to waste & residue based SAF volumes



Impact: HIGH
Likeliness: MEDIUM

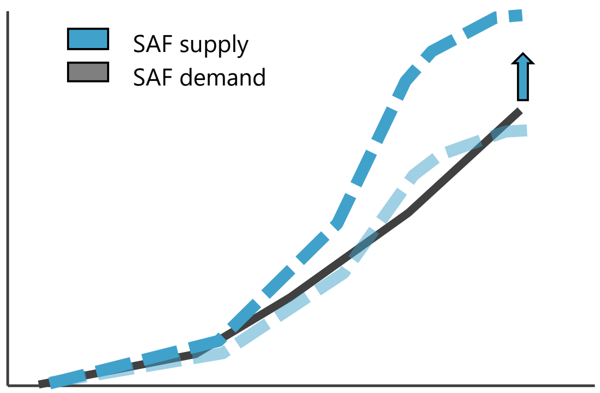
Large scale import of green hydrogen

- Production of green hydrogen needs renewable electricity and benefits from economies of scale
- The EU is not the most logical production region, from a cost and renewable electricity availability perspective
- Scaling up in other regions can increase SAF PtL supply

Allowing blue (and yellow) hydrogen

- Production of natural gas based hydrogen with CCS (blue), or with nuclear electricity (yellow) can accelerate and increase the PtL availability dramatically, and it will reduce cost strongly
- Currently not favored in Europe due to sustainability issues

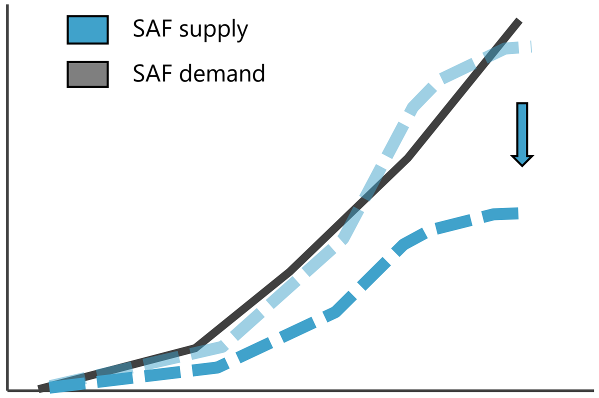
Overall: increased hydrogen availability means a positive impact on meeting the SAF PtL targets



Impact: MEDIUM
Likeliness: MEDIUM

Slower technology development

- Will result in lower deployment rates of SAF capacity (EU and global) and will have a direct effect on available SAF volumes
- Not relevant for HVO/HEFA pathway, as this technology is already at commercial scale (limiting factor is feedstock)
- Very relevant for AtJ and G+FT pathways, as there are currently no demo-scale facilities for these technologies in operation yet, let alone commercial scale facilities
- Less relevant for PtL pathway, as the technology development of the different conversion building blocks is already more advanced than for the AtJ and G+FT pathways. And the actual feedstocks (CO_2 + H_2) are less challenging from a processing standpoint

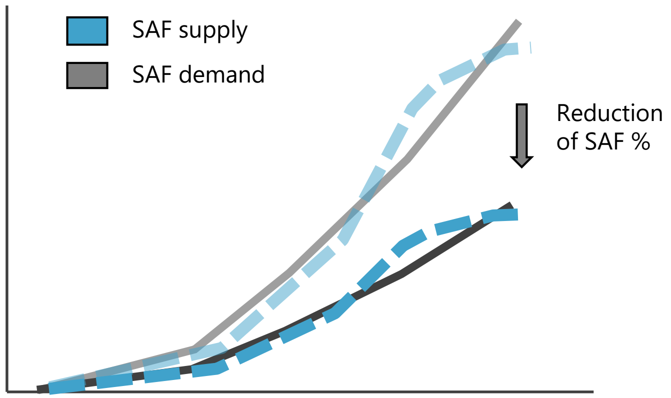


Impact: MEDIUM
Likeliness: MEDIUM

Qualitative scenarios: government interventions

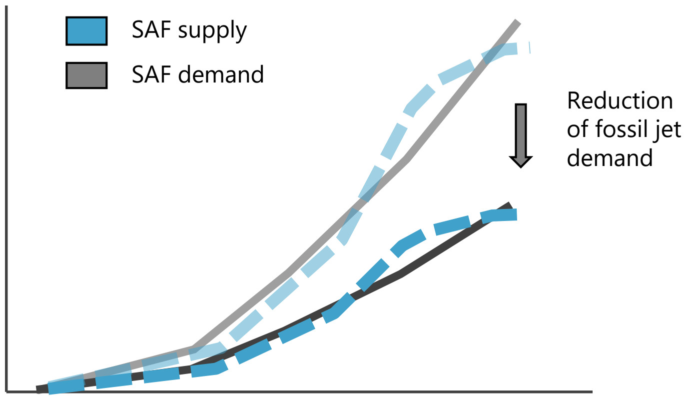
Supply does not match demand - #1

- Government interferes to better synchronize supply/demand
- Government downgrades mandates to match supply
- This will result in the aviation sector not meeting its climate targets



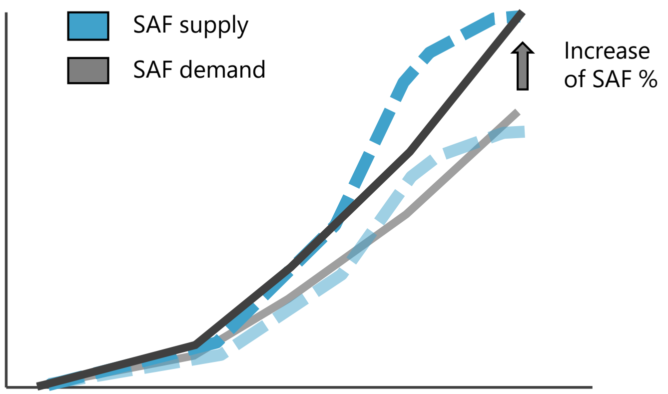
Supply does not match demand - #2

- Government interferes to better synchronize supply/demand
- Government will impose demand side reductions on the use of fossil jet fuel:
  - Flight restrictions
  - Increased taxes
  - CO2 ceiling
  - Cap on fossil jet fuel use
- Economic impact for (European) aviation sector, but climate targets will be met



Supply exceeds demand

- Market outperforms on government ambitions
- This leads to an over-supply situation
- In this scenario, it can be argued that the mandated target volumes will be increased as the EU has a clear net-zero ambition



SkyNRG

Scenario summary
Conclusion: we do not see any reason to adjust the base case, at this moment

Scenario	Impact (on meeting SAF targets)	Likeliness	Result
Demand side stimulation outside of EU	HIGH – negative	HIGH	9 (negative)
More rapid developments in hydrogen/electric powered aircraft	MEDIUM – positive	LOW	2 (positive)
Conservative post-COVID recovery aviation sector	HIGH – positive	MEDIUM	6 (positive)
More rapid post-COVID recovery aviation sector	MEDIUM – negative	LOW	2 (negative)
More rapid capacity deployment	MEDIUM – positive	LOW	2 (positive)
New and/or increased demand in other sectors	HIGH – negative	HIGH	9 (negative)
More rapid electrification of road transport	MEDIUM – positive	MEDIUM	4 (positive)
Allowing crops under the RED-II for bio-advanced SAF	HIGH – positive	MEDIUM	6 (positive)
Increased hydrogen sources	MEDIUM – positive	MEDIUM	4 (positive)
Slower technology development	MEDIUM - negative	MEDIUM	4 (negative)

High (3)
Medium (2)
Low (1)

x

High (3)
Medium (2)
Low (1)

=

Scoring of scenarios that have a **positive effect** on meeting the EU SAF targets

24

Scoring of scenarios that have a **negative effect** on meeting the EU SAF targets

24

SkyNRG

Concluding Remarks

Concluding remarks & additional information

Concluding remarks

- We have performed this study for internal purposes, as part of our own strategy outlook
- We have decided to make the (high level) content of the study available to the general public
- We realize there can be significant debate on the assumptions underlying the analysis
- However, the purpose of making this information available is to share SkyNRG's insights on SAF market dynamics free for everybody to use as they like, not to have a debate on it

Additional notes

- SkyNRG monitors all SAF developments on a continuous basis and aims to issue an updated market outlook every 6 months
- To pre-empt questions: yes, we have also performed an in-depth cost assessment till 2050 based on these supply/demand scenarios. However, this information is not made available at this stage

ABOUT SkyNRG

SkyNRG is the pioneer and a global leader in sustainable aviation fuel with the industry's most extensive dedicated sustainable aviation fuel team.

SkyNRG scales up SAF demand and supply globally. Having supplied over 30 airlines on almost all continents, it is SkyNRG's mission to make SAF the new global standard, driven by sustainable practices throughout the supply chain. To ensure SkyNRG makes the right decisions regarding the sustainability of its operations, projects and products, SkyNRG is structurally advised by an independent Sustainability Board, which includes representatives from WWF International, the European Climate Foundation, Solidaridad Network and the University of Groningen.

Also, SkyNRG's operations are certified by the Roundtable on Sustainable Biomaterials (RSB), the highest possible certification standard for sustainable fuels.

Contact

Paradijsplein 1
1093 NJ, Amsterdam
The Netherlands

+31 20 470 70 20

www.skynrg.com
info@skynrg.com

@skynrg
@skynrg