WDB Action programme

WDB Action programme

Executive summary

The Dutch aviation sector is a substantial contributor to greenhouse gas emissions, both domestically and internationally, as Schiphol airport functions as an important international hub. For this reason, the Netherlands has initiated the 'Sustainable Aviation Table', which brings the government and the Dutch aviation industry together to discuss the actions that need to be taken in order to establish a net zero emission industry in the long run. One of the working groups of the Sustainable Aviation Table is the working group on sustainable fuels, in Dutch known as the 'Werkgroep Duurzame Brandstoffen' (abbreviated to WDB).

The purpose of the WDB is to accelerate and positively stimulate movement towards the targets set for the production and uptake of SAF (sustainable aviation fuels) in the Netherlands. The WDB has committed itself to replacing 14% of its fossil kerosene with sustainable kerosene by 2030. Furthermore, the WDB strives for 100% fossil kerosene replacement with SAF by 2050. This target meets the sector's commitment to reduce its emissions in 2050 by at least 50% compared to those in 2005. Lastly, this coalition of government and industry seeks to achieve zero emissions from aviation by 2070.

Assuring the sustainable scale-up of the industry: a holistic approach

Social and environmental sustainability are key to a responsible scale-up of the industry. The SAF industry wants to set a good example by taking a holistic approach to sustainability. The Dutch aviation sector not only wants to prevent the possible negative consequences that may emerge from the production of alternative fuels, but the industry also wants to make sure that SAF becomes a force for good. The growth of the SAF industry will result in job creation, decent salaries and working conditions, regenerative agricultural systems, increased biodiversity, healthy soils and the circular use of waste and residues instead of mere CO_2 savings. Accordingly, the industry could achieve much more than just replacing fossil carbon and reducing aviation's carbon footprint, but only if it adheres to stringent sustainability criteria.

The Dutch aviation industry does not accept feed or food crops as a feedstock for SAF, except if that is possible from a sustainability perspective. Examples of these exceptions include feedstock for SAF produced by utilising and improving abandoned farmlands or using crops that produce starch for food/feed purposes, with the oil part then being used for energy purposes. Furthermore, the industry does not accept feedstocks that might have caused deforestation or other types of environmental damage. Therefore, the focus of the industry is on using wastes and residues as a feedstock or products that enhance and improve current land use practices. More details on the Dutch aviation industry's holistic approach to SAF can be found in chapter 4.

SAF technology pathways

Even though there are quite a number of interesting technologies that are capable of producing SAF, most technologies still require development time and large investments before they can achieve commercial scale. Even if these technologies achieve commercial scale, the first facilities are likely to be relatively small, resulting in rather expensive SAF volumes. As these technologies achieve scale, the price of SAF will reduce significantly.

For the short term, due to technology maturity, the first SAF production facilities will have to use the HEFA technology. For this reason, the first refinery in the Netherlands which will produce SAF on a constant basis and as its main product will be a HEFA facility (for example the DSL-01 project presented in chapter 6).

However, in order to achieve a sustainable scale-up of the industry, the feedstock basis for SAF needs to become more diversified. In order to do so, we need to invest in SAF technology pathways at a pre-commercial state (low – medium technology readiness level (TRL)) which are able to use different feedstocks than the HEFA pathway, and support SAF technologies which haven't reached commercial scale yet. As an example, chapter 6 includes some projects which are looking at the development of SAF technology pathways such as Power to Liquid (abbreviated to PtL, also commonly referred to as synthetic kerosene). Given the fact that developing these SAF technologies to a commercial scale will require major investments, interaction with the Dutch government is needed to de-risk these important technology developments. These policy needs of the sector are discussed in chapter 7.

Goals and actions

In order to realise the ambitions and goals set by the WDB and to facilitate existing and future SAF development projects, the WDB is targeting three tracks in which concrete actions have been formulated. The first track covers the opportunities and challenges for the next four years. The second track covers the potential growth strategy and the hurdles to be overcome to facilitate the SAF sector in the Netherlands in the medium term and the last track covers the actions that need to be established and the gaps that must be bridged in order to meet the Dutch aviation sector's long-term goals. The concrete actions associated with the goals listed below can be found in chapter 6.

Track 1 - Short term (2021-2024)

- The aim is to have at least 200,000 tonnes of SAF produced in the Netherlands via the HEFA technology in 2024.
- The first Alcohol-to-Jet (AtJ) SAF demonstration plant in the Netherlands should be under development.
- The first Power to Liquid (PtL) demonstration plant in the Netherlands, based on CO_2 Direct Air Capture (DAC) and/or industrial point sources, should be under development.
- Other feedstock opportunities for the HEFA pathway should be explored

Track 2 - Medium term (2024-2028)

- The aim is to have at least 500,000 tonnes of SAF produced in the Netherlands via the HEFA technology in 2026.
- The aim is to have the first AtJ facility up and running in the Netherlands. Additional R&D incentives must be in place in order to create a solid business case for these first demo facilities. The support of the government for the development of these novel SAF pathways is needed.
- The aim is to support international efforts in solving some of the R&D challenges of the SAF sector. For example, exploring the non-CO_2 effects of aviation and SAF in particular, ensuring that ASTM (technical certification scheme) allows for 100% SAF in the engine of a plane, ensuring the ASTM certification of new SAF technology pathways etcetera.
- The aim is to have a commercial PtL plant under construction or up and running before 2028. Alongside this aim, the sector will also try to support the renewable hydrogen and electricity sector in scaling-up that sector, as these inputs are needed for every SAF technology pathway.

Track 3 - Long term (2028 onwards)

- The aim is to have SAF production in the Netherlands of between 640.000-702.000 tonne annually to enable the 2030 SAF target of 14%.
- The WDB will work hard to further commercialise DAC or industrial point source technologies for SAF. The aim is to have at least two commercial PtL plants up and running before 2035.
- The aim is to have the first commercial AtJ facility up and running before 2030.
- The aim is to have replaced all fossil kerosene with SAF from 2050 onwards.
- Reach net zero emissions from NL aviation before 2070.

Policy interaction

Policy plays an important role in ensuring the increased use of SAF in the Netherlands. Therefore, the WDB is striving for a stable SAF policy climate and long-term support mechanisms to push this sector forward.

The Dutch government has taken an important step with its active plea for the implementation of a European SAF mandate. If a European SAF mandate is not successfully implemented before the end of 2025, the Dutch government will strive to implement a national blending obligation by 2023. A European SAF mandate is preferred, as this would ensure more of a level playing field than just a national mandate. To ensure that the SAF mandate achieves its desired effect, it is necessary that a smooth transition between the existing policy framework and any future framework is safeguarded. This includes the need for a smooth transition for the aviation sector from the current opt-in to the HBE (the Dutch bioticket) system to the introduction of an SAF mandate. If such transition is not safeguarded, then current investments in SAF facilities could be jeopardised or the desired SAF volumes might not be produced. This could also lead to the relocation of SAF production to other countries or SAF being exported abroad. Furthermore, it is crucial that the cost of non-compliance is higher than the cost of compliance, to ensure the successful integration of an SAF blend mandate.

Since all SAF pathways are needed to ensure a more sustainable aviation sector, additional financial incentives should be created for the lower TRL SAF technology pathways other than HEFA. This is because HEFA is currently the least costly SAF pathway and the other technology pathways will otherwise face difficulties reaching commercial scale.

Lastly, a domestic SAF market would not only mitigate the risks associated with SAF imports, such as the dependence on imported energy or unsustainable practices, but would also be highly beneficial for other reasons. The Netherlands has a relatively large aviation sector and plays a key role in the production and trade of kerosene. The combination of the existing chemical and refining industry, transport infrastructure, airports, seaports and knowledge institutions, provides the Netherlands with the elements needed to also play an important role in scaling the market for SAF. The Dutch government recognised this opportunity and therefore organised a High Level conference on synthetic SAF in February 2021 to provide this SAF technology pathway with the support it needs. The conference also featured a joint statement by various EU Member States, which is discussed further in chapter 7 on policy targets.

All in all, the Netherlands wants to become a frontrunner in the global SAF sector and intends do so by using its knowledge, infrastructure and public-private joint ventures to ensure that the actions listed in chapter 6 can become reality. The SAF sector is well aware of its responsibility to ensure the sustainable scale-up of the industry and realises that, if it adheres to its holistic approach to social and environmental sustainability, SAF will become a force for good.

1. Introduction: national and international policies promoting sustainable aviation

On 12 December 2015, 197 countries adopted the Paris Agreement. The Paris Agreement's goal is to keep the increase to the global average temperature to well below 2 °C; and to pursue efforts to limit the increase to 1.5 °C. The Paris Agreement targets the reduction of the domestic emissions of countries that signed the agreement. Emissions from international aviation are not covered by the Paris Agreement. The Civil Aviation Organisation (ICAO) is given the task to reduce the greenhouse gas emissions from the international aviation sector.

On 28 June 2019, the Netherlands presented its National Climate Agreement. More than 600 agreements are included in this document, all concerning the reduction of greenhouse gases throughout all Dutch sectors.

Some of these agreements relate to the reduction of greenhouse gases in the mobility sector. Since renewable energy volumes used in the international aviation market do not count towards the obligations set out in the Paris Agreement, and because international flights contribute to over 99% of all flights in the Netherlands, the Dutch aviation sector is not included in the mobility part of the Dutch National Climate Agreement. However, as the Dutch aviation sector is a substantial contributor to greenhouse gas emissions domestically and internationally, the Minister for Infrastructure and Water Management initiated the 'Sustainable Aviation Table', which brings the government and the Dutch aviation industry together to discuss how to reduce their carbon footprint.

On 27 March 2019, the Table presented a draft agreement, in which it had formulated long-term goals which sought to achieve the decarbonisation of the aviation industry. Working groups were set up to ensure that these targets would be achieved. These groups were to focus on certain aspects of the draft agreement and create action plans through which they outlined how to achieve the formulated targets. One of the working groups of the Sustainable Aviation Table is the working group on sustainable fuels, in Dutch known as the 'Werkgroep Duurzame Brandstoffen' (WDB in short). The next chapters will elaborate the purpose, goals, timeline and projects that this working group wants to expedite in the following decade(s).

Meanwhile, at international level, initiatives to decarbonise the aviation industry are also taking place. One of the international measures ICAO is imposing to ensure the decarbonisation of international aviation is the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). CORSIA addresses the increase in total CO_2 emissions from international aviation over 2019 levels. CORSIA's goal is to prevent the further increase in total CO_2 emissions from international aviation, even though the demand for air transport is expected to grow significantly.

In the CORSIA scheme, carbon neutral growth can be established in two ways: 1) if an airline emits more CO_2 compared to its baseline year (the baseline emissions are set at the airlines' emissions in 2019) it can compensate its emissions by buying carbon offsets; and 2) airlines can buy and use Sustainable Aviation Fuel (SAF) and low carbon aviation fuels (fuels which deliver a 10% greenhouse gas reduction on a lifecycle basis) in order to reduce their emissions.

In addition to CORSIA, there is another international framework in place that could ensure a more sustainable aviation sector by stimulating (in particular) the use of SAF. In December 2018, the European Union agreed upon the revision of the Renewable Energy Directive, the RED II.

In the RED II, an option for the aviation sector became available enabling renewable energy produced for the aviation sector and delivered to an EU Member State to count towards the renewable energy target for transport, as specified in the RED II. In every EU Member State, at least 14% of the total consumption of energy in the transportation sector must come from renewable sources. Even though this obligation was set for the road and rail sector, aviation can contribute to this target as well. This could provide financial benefits for SAF producers, as it partly bridges the price gap between SAF and fossil kerosene.

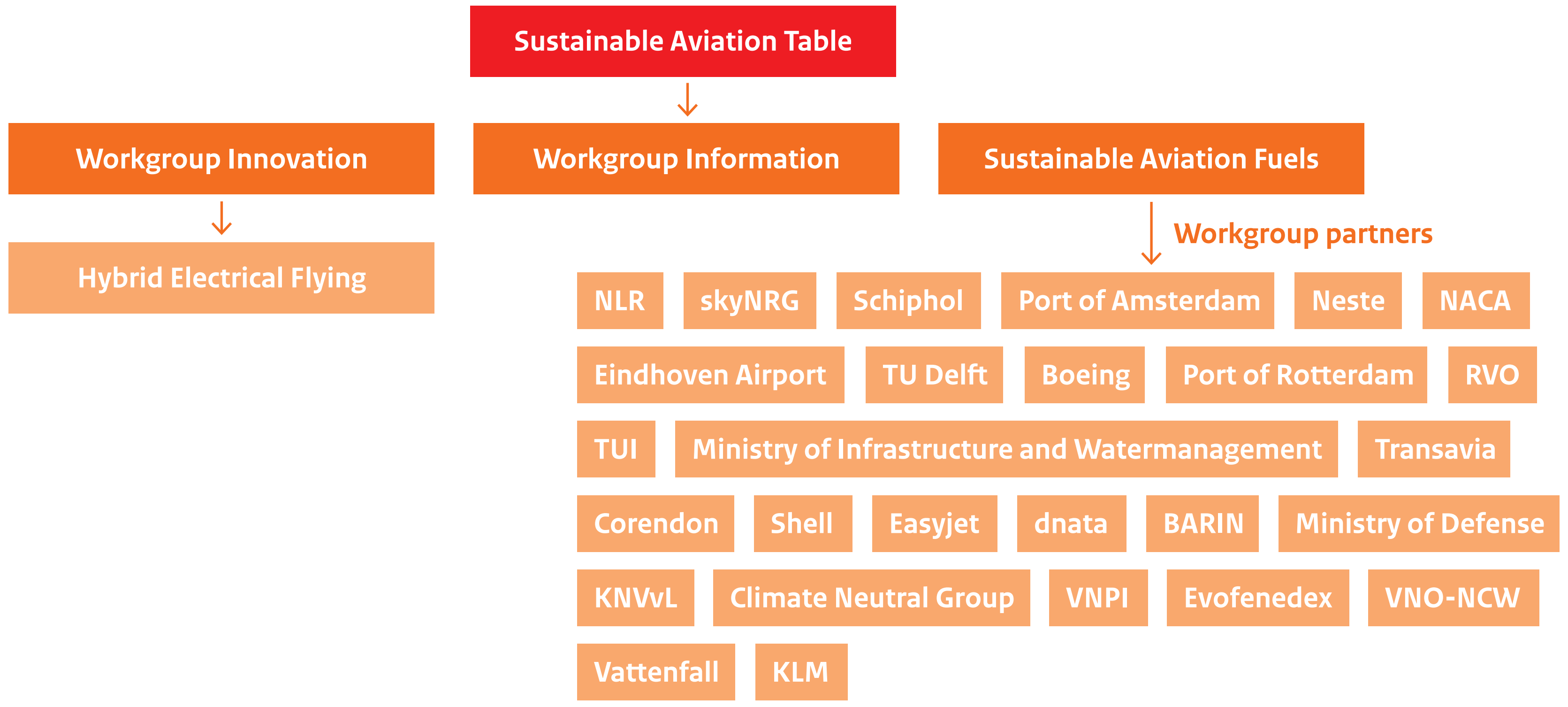


Figure 1. Sustainable Aviation Table governance

2. SAF development targets in the Netherlands

The purpose of the WDB is to accelerate and positively stimulate movement towards the targets set for the production and uptake of SAF in the Netherlands. These targets have been defined in the previously mentioned draft agreement on sustainable aviation which was agreed upon by the Sustainable Aviation Table.

The targets resulted from collaboration between industry representatives, knowledge institutes and the Dutch government. This coalition's goal is to replace 14% of its fossil kerosene with sustainable kerosene by 2030. This target is the guiding principle for the WDB's ambitions for 2030. Furthermore, the WDB strives toward 100% fossil kerosene replacement with SAF by 2050. This target will meet the sector's commitment to reduce its emissions in 2050 by at least 50% compared to those in 2005. Lastly, this coalition seeks to achieve zero emissions from aviation by 2070. Discussions about a blending obligation are also ongoing. As the Netherlands wants to become a frontrunner in the development of SAF, the Dutch government is urging the EU to implement a European SAF mandate, at the latest by 2025. If the EU fails to do so on time, then the Netherlands will aim to implement a national SAF mandate in 2023.

This action programme offers insight into ongoing developments and plans relating to SAF deployment in the Netherlands. The members of the WDB agreed to update this action programme every three years, to ensure that the latest developments in the Dutch SAF sector are included and so that targets can be adjusted if needed. Furthermore, the triennial updates will serve as a means to monitor the progress that the WDB has made on its SAF objectives.

3. The global SAF market - a deep dive

Production

The World Energy Paramount refinery in California continuously produces SAF on a commercial scale. World Energy produces between 5-15 kt SAF per year from bio-based waste oils and fats via the HEFA process. In October 2018, World Energy announced a $350 million investment to increase the annual capacity of the Paramount refinery to 900 kt of renewable fuel. Based on the design of the new refinery, World Energy expects to increase its SAF capacity to 450 kt per year. The industry expects to see an increase in SAF capacity in the next two to three years. Based on the announcements and the construction of new production facilities, not only will global SAF capacity expand, but so too will the commercialisation of first-of-a-kind production facilities that utilise different, innovative processes.

Neste has proven its ability to produce SAF and is already commercially engaged in producing and selling SAF to aviation customers. Total and other large renewable diesel producers are also able to produce SAF. Neste's SAF capacity is currently 100 kt/year. With Neste's Singapore refinery expansion on the way, and with possible additional investments in the Rotterdam refinery, Neste will have the capacity to produce some 1.5 million tonnes of SAF per year by 2023.

Since the main difference between renewable diesel and SAF produced via the HEFA process is the hydrocarbon chain length, many HEFA production facilities could potentially be used to produce SAF. However, when optimising to produce SAF, the choice of catalyst is important as it defines the spectrum of hydrocarbon chain lengths. Optimising for SAF will therefore result in a lower yield since more molecules will end up in the light (gasoline) fraction. Also, the separation of SAF from the heavy (diesel) and light (gasoline) fractions requires a fractionator, whereas a fractionator is not necessary when aiming for renewable diesel production. Therefore, not all currently operating HEFA plants are equipped with a fractionator. Adding a fractionator to an existing HEFA facility requires additional investment, which combined with a lower yield, results in a higher production costs for SAF compared to renewable diesel. Since the current value of renewable diesel is higher than that of SAF, almost all HEFA capacity is deployed to produce renewable diesel. Policies mandating the use of renewable fuels are the source of this economic benefit of diesel production over SAF. However, policy incentives are currently being developed to compensate this difference and to promote the production of SAF. Due to this competitive nature between the production of SAF and renewable diesel and the dependency on catalyst type for steering the process either to diesel or SAF, the production capacity of SAF in most HEFA plants is not publicly disclosed. With the extension of Neste's refinery in Singapore, Neste is determined to open up the SAF market and aims to produce 1 million tonnes of SAF by 2023. Furthermore, Total's la Mède refinery is also prepared to enter the SAF market when a solid business case can be made, introducing renewable diesel producers to the field of SAF.

In addition to the facilities currently operating, there are also numerous SAF production facilities under construction or that have been announced. These facilities use various SAF production techniques such as HEFA, Fisher-Tropsch (FT) and Alcohol-to-jet (AtJ). The figure below shows the current SAF production facilities, facilities under construction including the expansion of currently operating facilities, and announced SAF production capacity Not all announced or currently built production facilities have communicated their targets for renewable diesel and SAF production, therefore only the publicly disclosed targets are included.

The figure above indicates that current SAF production capacity is dependent on three renewable diesel producers: World Energy, Neste and GEVO. However, there are multiple initiatives to produce SAF currently under development by companies such as Fulcrum and Red Rock. These companies are using innovative production technologies and can produce both SAF and renewable diesel. Since they are developing their first commercial-scale production plants, the volumes are smaller for the first facilities utilising these technologies. It is expected that, over time, these production routes will become more competitive in producing SAF and could claim a larger share of the total renewable fuel pool.
The World Energy facility and the Neste facility in Singapore are expected to produce the largest quantity of SAF in the next few years based on the HEFA technology, which is currently the only SAF technology available on a commercial scale (more details on the SAF technology pathways can be found in chapter 5).
Renewable diesel producers could be incentivised to switch to SAF production when the business case for SAF improves, which could unlock significant production capacity. In 2017, Greenea published that the installed HEFA production capacity had reached 4,745 kt annually and that it expected global capacity to increase to 6,775 kt/year by 2022. If, for instance, policy incentivises the production of SAF over renewable diesel, and 10% of this global production capacity is steered towards the production of SAF, this could unlock additional SAF capacity of 677 kt/year. To put that in perspective, this additional volume of SAF would be enough to replace around 16.5% of the fossil kerosene consumption in the Netherlands (based on 2019/pre-COVID consumption data).

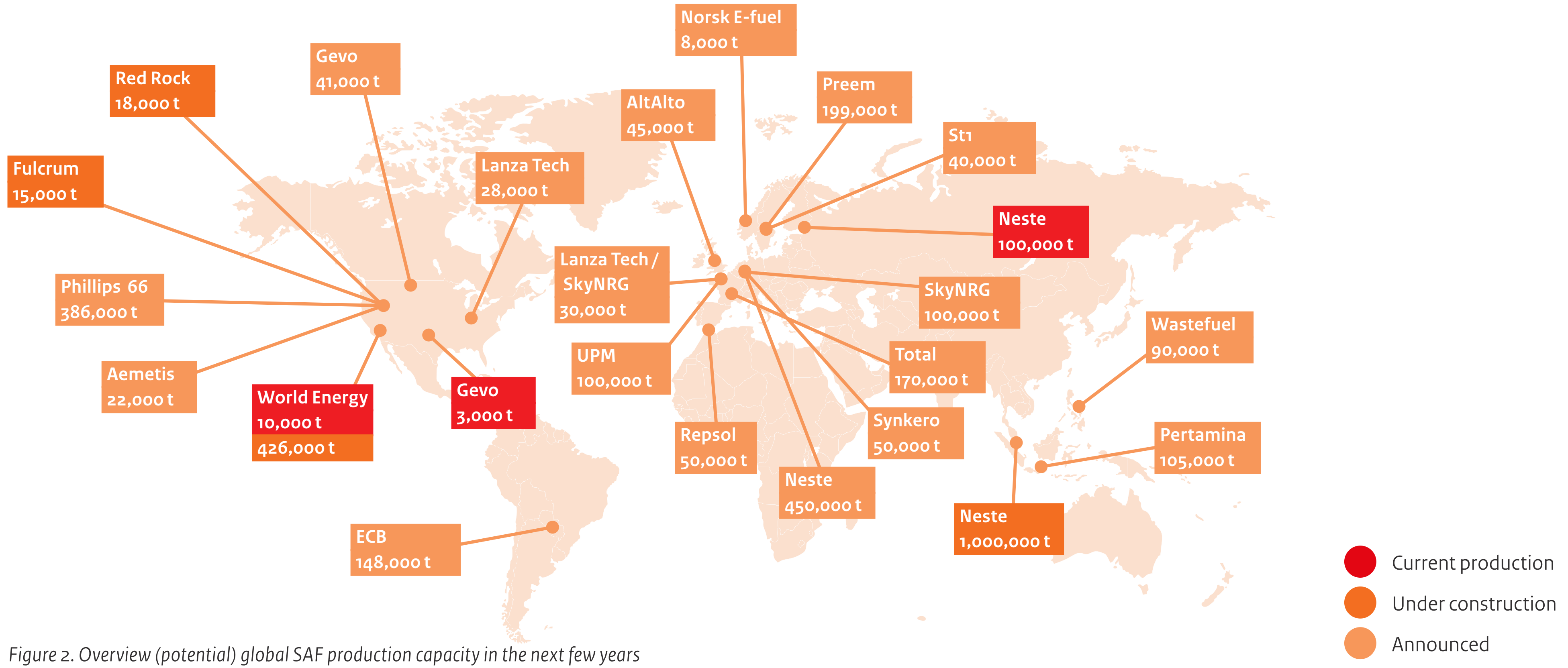
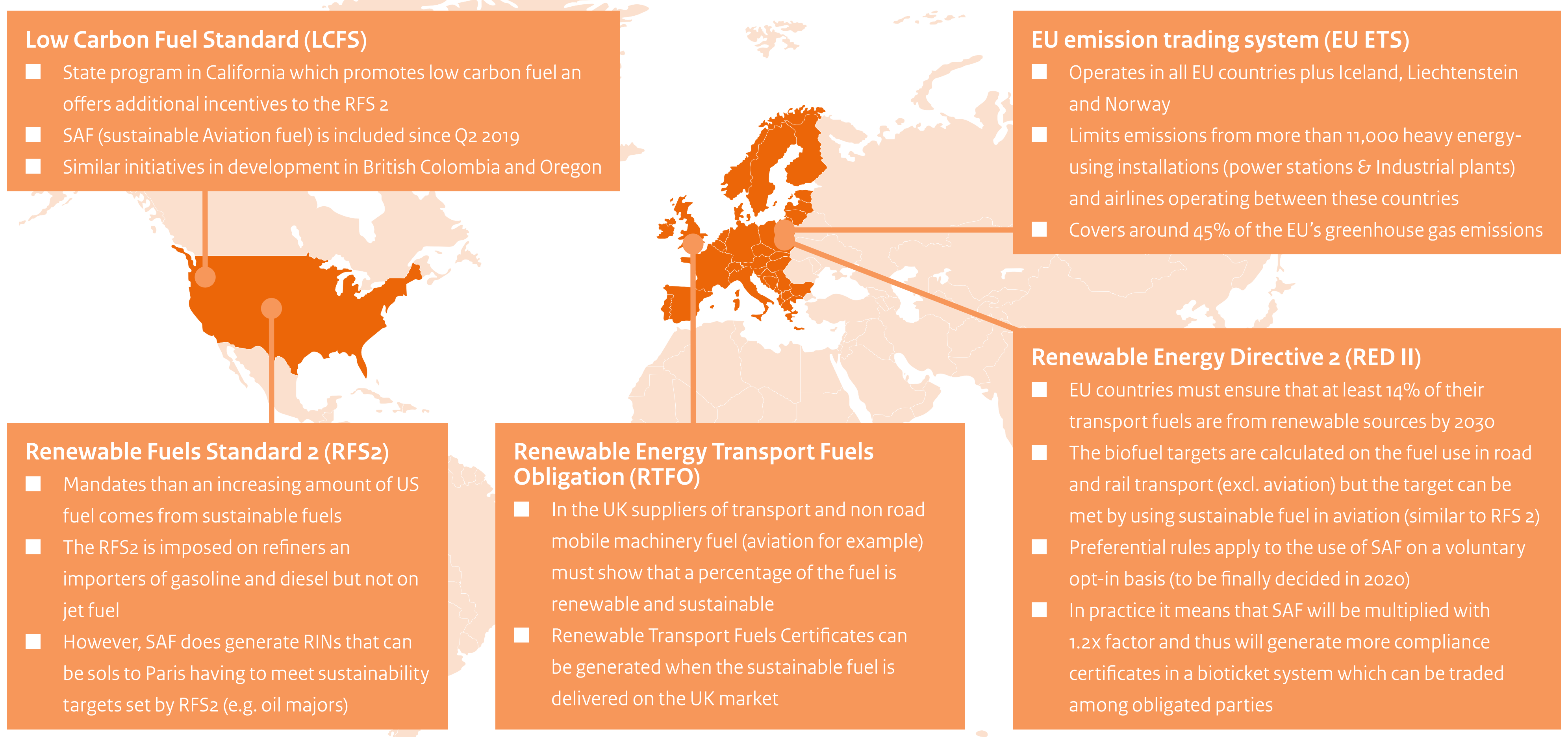


Figure 2. Overview (potential) global SAF production capacity in the next few years

International policies stimulating SAF

Policy is key in supporting the development of the SAF market, given the premium price of SAF over fossil jet fuel. Both the US and the EU have incentive schemes in place that support SAF demand through a voluntary opt-in. In these ‘opt-in’ systems, there is the possibility of governmental financial support if renewable energy for the aviation sector is delivered in the market within the policy framework targets. This is also why all production capacity mentioned in the previous paragraph is being developed in these regions - these policy incentives make sure that the price gap between fossil kerosene and sustainable kerosene is (at least partly) covered. Furthermore, there are some policy mechanisms, like the EU emissions trading system (EU ETS) a so-called cap-and-trade incentive, which allow airlines to generate emission credits when they emit less CO2. The value of such emission credits can offer some financial stimulation to offset the cost of SAF.

Next to these voluntary incentives, several countries are in the process of mandating the use of SAF or including a target for SAF. In the last year, multiple European countries started considering implementing a national SAF mandate for the use of SAF. A possible next step could be an EU-wide SAF mandate, part of the ongoing discussions on the Green Deal and part of the ReFuel Aviation Europe initiative, supported by an increasing number of stakeholders. An overview of the current mandate and target discussions and corresponding SAF volumes can be found below.



Low Carbon Fuel Standard (LCFS)

- State program in California which promotes low carbon fuel an offers additional incentives to the RFS 2
- SAF (sustainable Aviation fuel) is included since Q2 2019
- Similar initiatives in development in British Colombia and Oregon

EU emission trading system (EU ETS)

- Operates in all EU countries plus Iceland, Liechtenstein and Norway
- Limits emissions from more than 11,000 heavy energy-using installations (power stations & Industrial plants) and airlines operating between these countries
- Covers around 45% of the EU’s greenhouse gas emissions

Renewable Energy Directive 2 (RED II)

- EU countries must ensure that at least 14% of their transport fuels are from renewable sources by 2030
- The biofuel targets are calculated on the fuel use in road and rail transport (excl. aviation) but the target can be met by using sustainable fuel in aviation (similar to RFS 2)
- Preferential rules apply to the use of SAF on a voluntary opt-in basis (to be finally decided in 2020)
- In practice it means that SAF will be multiplied with 1.2x factor and thus will generate more compliance certificates in a bioticket system which can be traded among obligated parties

Renewable Fuels Standard 2 (RFS2)

- Mandates than an increasing amount of US fuel comes from sustainable fuels
- The RFS2 is imposed on refiners an importers of gasoline and diesel but not on jet fuel
- However, SAF does generate RINs that can be sols to Paris having to meet sustainability targets set by RFS2 (e.g. oil majors)

Renewable Energy Transport Fuels Obligation (RTFO)

- In the UK suppliers of transport and non road mobile machinery fuel (aviation for example) must show that a percentage of the fuel is renewable and sustainable
- Renewable Transport Fuels Certificates can be generated when the sustainable fuel is delivered on the UK market

Figure 3. Overview of SAF policy support mechanisms globally

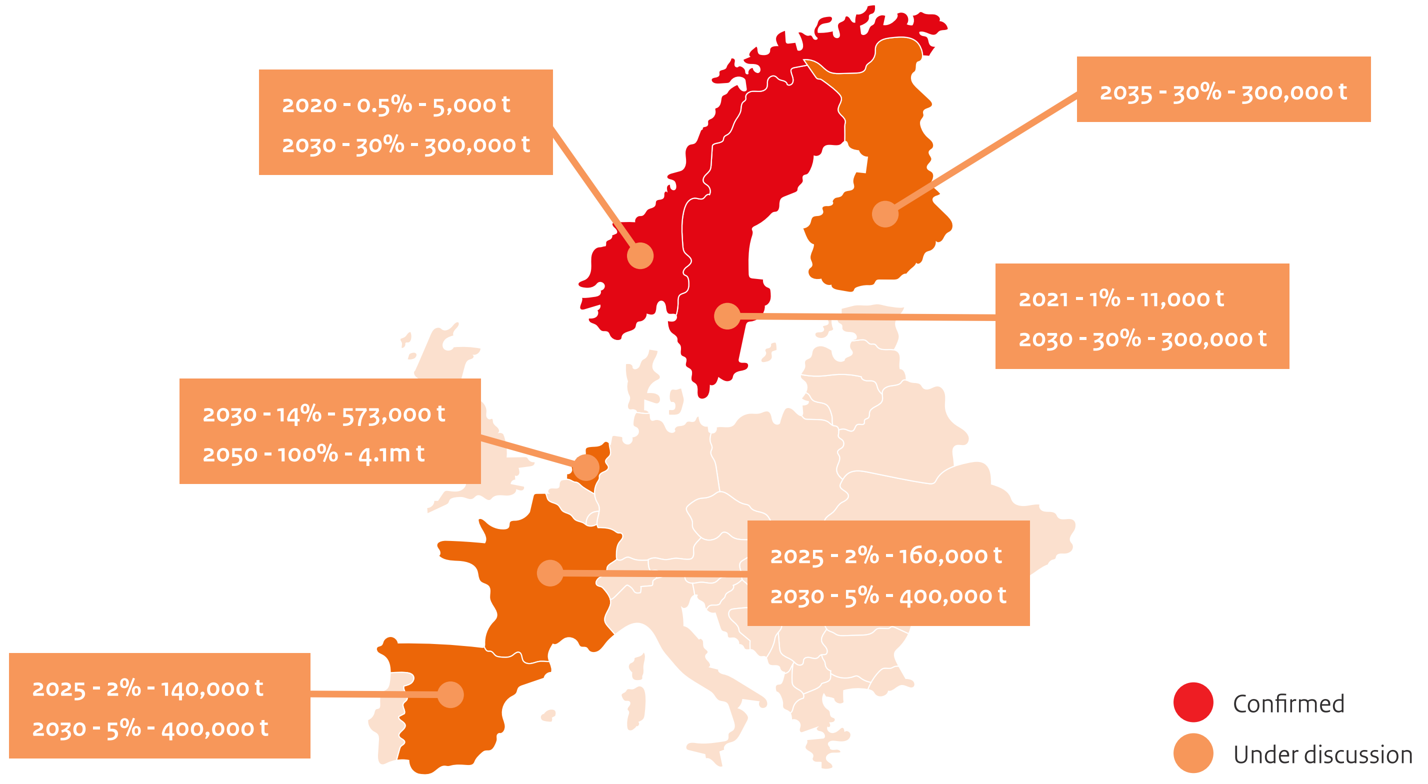


Figure 4. Overview of announced and implemented SAF blend mandates and targets in the EU

4. Our sustainability approach

Social and environmental sustainability are key to a responsible scale-up of the industry. The SAF industry wants to set a good example by taking a holistic approach to sustainability. Following this approach, the SAF sector is not only considering the carbon reduction associated with the production and use of SAF, but also the social and environmental benefits SAF can deliver. But before we dive into this holistic approach, the minimum requirements for producing SAF in Europe must be taken into consideration to understand the foundations of the sustainability criteria for SAF production and supply in Europe. These minimum requirements are formulated in the recast Renewable Energy Directive of 2018 (RED II).

The EU sustainability framework - the minimum requirements

When delivering SAF to the Dutch market, the sustainability criteria set out under the RED II set a minimum baseline from 2021 onwards. Within this framework, the use of certain feedstocks is promoted (the so-called advanced feedstocks) and the use of other feedstocks is limited (such as feed- or food crops). Furthermore, there is a minimum threshold for greenhouse gas emission reduction, varying from 50% to 70% depending on the year in which the SAF production facility went/ goes into production. Default values per fuel category are also given and system boundaries are being defined.

Topics such as land-use change are also covered under the RED II and new advanced fuel categories are being defined, such as Recycled Carbon Fuels[1] and Renewable Fuels of Non-Biological Origin[2]. The Commission will provide the EU Member States with a clear definition by December 2021 (latest).

Every individual EU Member State must integrate these sustainability rules (including the greenhouse gas criteria) into their own legislation. The Netherlands is currently in the process of integrating the RED II minimum requirements into its own legislation and minor differentiations from this framework may yet occur. However, the RED II sustainability criteria serve as a minimum for national transport legislation and as far as the Dutch aviation sector is concerned, the criteria are not stringent enough.

A holistic approach to sustainability

When it comes to social and environmental sustainability, aviation wants to take it one step further: it not only wants to prevent possible negative consequences that may emerge from the production of alternative fuels, but the industry also wants to make sure that SAF is a force for good, that the growth of the SAF industry will result in job creation, decent salaries and working conditions, regenerative agricultural systems, increased biodiversity, healthy soils and the circular use of waste and residues. As a result, the industry is already aiming for the highest sustainability standards for the production and use of SAF which guarantee this holistic approach to sustainability. The industry has aligned with the 12 themes of CORSIA by using certification systems that incorporate these themes. These criteria, also endorsed by the Roundtable on Sustainable Biomaterials (RSB) and the International Sustainability and Carbon Certification (ISCC) system, include the many social and environmental elements which should be considered when producing alternative fuels. They include criteria related to water management and access, local food security, rural and social development, improved air quality, no deforestation, carbon sink improvements, and (the most critical) those ensuring transparency. These principles are applied throughout the full supply chain and are aligned with the holistic approach taken by the UN's Sustainable Development Goals (SDGs).

Following this holistic but strict set of sustainability requirements, the Dutch aviation industry focusses on wastes and residues that achieve high CO_2-reductions and does not accept feed or food crops as a feedstock for SAF Only when it is sensible from a sustainability perspective, specific agricultural crops can be used. Examples include rotation or cover crops, crops from abandoned or degraded farmlands or extracted oils from starch-rich crops cultivated for food/feed purposes. Furthermore, the industry does not accept feedstocks that originate from land with a high biodiversity value or that have high ILUC-risks, thus preventing deforestation. The focus of the industry is on using waste and residues as its feedstock or products which enhance and improve current land use practices. In the following paragraphs examples are given of three different challenges which the Dutch SAF industry faces when scaling the industry:

1. **Waste and residues**. The Netherlands faces a challenge when it comes to the availability of sustainable biomass waste and residues. As a small country, it is likely that our SAF industry will need to look beyond its borders to be able to collect enough waste and residues to fulfil its feedstock demand. As the emissions from transporting feedstocks often do not exceed 5% of the total lifecycle emissions of a fuel (even if the feedstocks are shipped from other continents), the Dutch aviation sector is not bound by its national production of residues.

2. **Supply chain complexity.** Taking a holistic approach to the sustainability of feedstock production, it might be more sustainable to grow a certain cover crop in Uruguay than in the Netherlands: in the Netherlands this crop might require many more (chemical) inputs to reach the same yield as in Uruguay. For that reason, locally sourced feedstocks are not always the most sustainable option. Therefore, the most sustainable feedstock option for SAF needs to be determined on a case-by-case basis. Still, a challenge for non-locally sourced feedstocks is that distance creates longer supply chains. With longer supply chains, more entities are involved. With this complexity of entities involved in the supply chain, transparency decreases and monitoring good practices becomes more difficult. For that reason, the sustainability criteria that are discussed in the last paragraphs should always go hand-in-hand with monitoring and transparency requirements to guarantee social and environmental sustainability, especially when the supply chains become more complex.

3. **Renewable energy and CO_2.** There is a technology route called Power-to-Liquid (PtL, further described in the next chapter), which uses electricity to produce SAF. In order to produce SAF using this technology pathway, Dutch grid electricity is needed. Producing SAF via this pathway could make sense once the grid is almost fully decarbonised or if SAF production can be directly coupled to a renewable power plant. Until this is the case, our sector needs to consider the most effective and efficient use of the limited availability of renewable electricity in the Netherlands. We should ask ourselves whether it makes sense, at this point in the energy transition, to use scarcely available renewable power to produce SAF with relatively low system conversion efficiency, or whether we should use this directly in homes and electric vehicles with higher efficiency. In the meantime, we should ensure that the renewable energy and hydrogen used for this pathway is additional to existing supply.

Lastly, it is of uttermost importance to understand that in order to scale the SAF sector successfully, other related sectors also need to scale successfully. For example, without renewable electricity being abundantly available in the Netherlands, this SAF technology does not make sense here (or direct supplies from additional renewable energy facilities need to be directly connected to the SAF production facility), and without a solid renewable hydrogen network in the Netherlands that part of the inputs for SAF will remain an issue in the greenhouse gas performance of the fuel.

To conclude, all the requirements mentioned above create the basic requirements for SAF production and supply in the Netherlands and need to be prioritised when scaling this industry. Sustainability is situational and therefore the sustainability of a feedstock should be determined on a case-by-case basis. Ensuring a diversified sustainable feedstock portfolio should become a priority, as should expediting the decarbonisation of the energy sector. There is a huge challenge in front of us in terms of decarbonising the aviation sector. Care should be taken to ensure positive environmental and social conditions and to address the needs of other sectors to decarbonise as well. But if these elements can be assured, the Dutch aviation sector will contribute to a better situation, both socially and environmentally, than the one we started off with.

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[1] E.g. SAF made from non-recyclable fossil waste.

[2] E.g SAF made from renewable hydrogen in combination with CO_2 from the air, or captured from industrial point-sources of CO_2.

5. SAF technology pathways and their potential

This chapter will provide you with an overview of the technologies capable of producing SAF and the development status thereof. Some technologies are commercially available today and will be able to produce SAF on a larger commercial scale within the next 5 years. Others still have to follow a long path of development, making them a potentially interesting technology pathway for the long term.

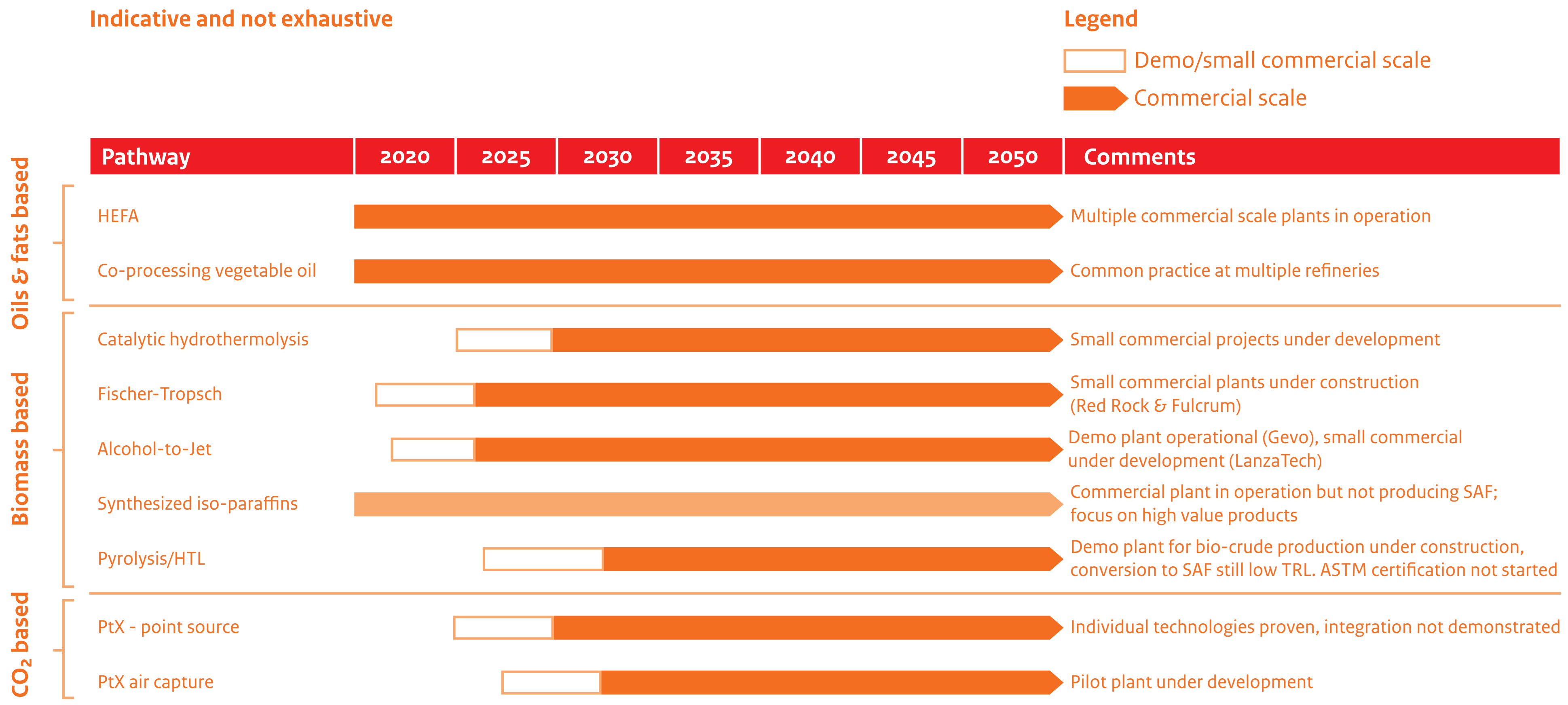


Figure 5. Projected SAF pathway developments

Production pathway	Production cost (per metric tonne in USD[3])	Estimated CO_2 savings[4]
Fossil kerosene (Jet A1)	\$350 - \$700	-
Commercially ready biofuels (i.e. oils and fat based HEFA)	\$1,200 - \$2,000	50% - 85%
Near commercially ready biofuels (i.e. FT and AtJ)	\$2,000 - \$3,000	60% - 100%
CO2 based (point source and DAC)	\$5,000 - \$10,000	50% - 100%

[3] Current production cost – based on figures of the International Energy Agency (2019)- these are likely to change over time

[4] Savings differ per specific supply chain and are predominately depended on feedstock

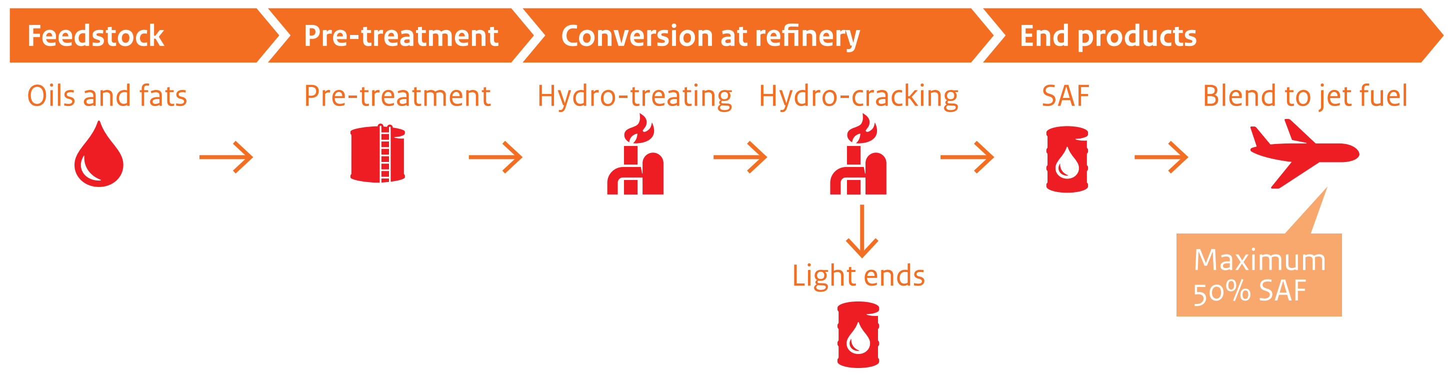
Figure 6. Current jet fuel production cost and GHG reduction overview

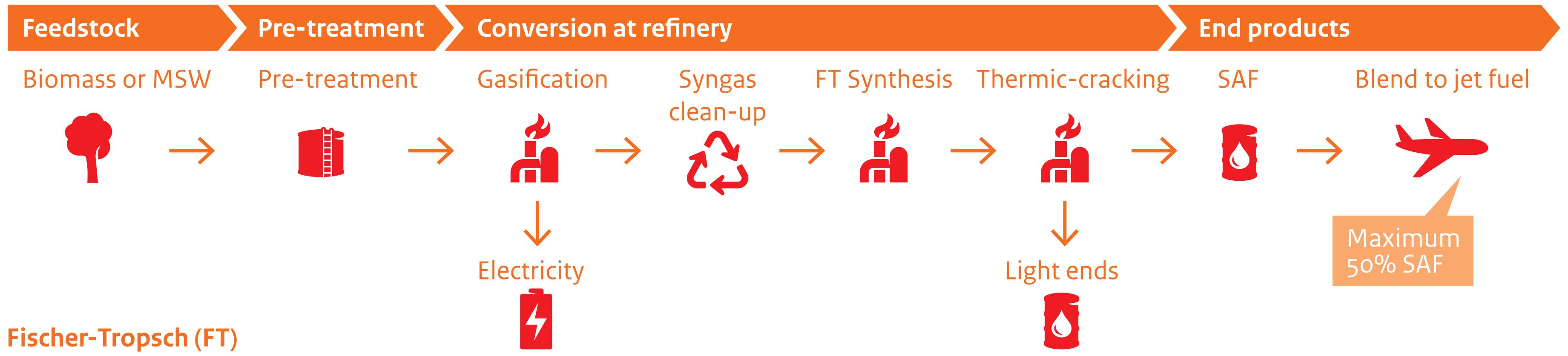
HEFA (Hydro-processed Esters and Fatty Acids)

The HEFA technology is currently the only technology which is successfully proven on a commercial scale (100,000+ tonnes production per year). The vast majority of the SAF currently produced uses the HEFA technology and is produced by World Energy in California (on a constant basis) and Neste in Europe. At the moment, production facilities for HEFA are predominantly used to produce renewable diesel for road transport.

Renewable diesel is produced on a large global scale due to favourable economics and existing demand through obligations under RED II. Nevertheless, the HEFA technology has been approved since 2011 for use in commercial aviation and has also been used since then. HEFA converts oils and fats to hydrocarbons via deoxygenation with hydrogen and cracking. Common feedstocks include vegetable oils, waste oils as used cooking oil and (inedible) animal fats. The aviation sector does not have a short-term alternative for producing drop-in fuels and this has been identified in the Dutch National Climate Agreement as a prioritised sector for the use of sustainable biomass.

The commercial technology readiness level of HEFA, urges for a regulatory framework that secures the uptake of SAF and provides investment security, as well as an active private-public partnership in scaling up SAF production and deployment within the next 5 to 10 years. This joint action should include a review of sustainable feedstock definitions in order to expand the sustainable feedstock portfolio for SAF and support for the development of other pre-commercial technologies. The definition of sustainable feedstock extends to the holistic sustainability approach to novel feedstocks such as the use of cover crops.





Fischer-Tropsch (FT)

Alcohol to Jet (AtJ)

The Alcohol-to-Jet (AtJ) technology has been in development for more than a decade. The technology has been proven on a demonstration scale. Two small commercial plants are in development. Gevo plans to upgrade its existing facility and LanzaTech is developing a small commercial facility. Production of cellulosic ethanol by fermentation or gas fermentation has been proven on a commercial scale.

As stated, AtJ converts sugars (from cellulosic materials or syngas) to jet through an alcohol intermediate. The feedstock options include organic waste, agriculture residues, municipal solid waste and industrial gases. Developing the AtJ technology through favourable policy is therefore also a key measure in diversifying the SAF feedstock options and scaling up production.

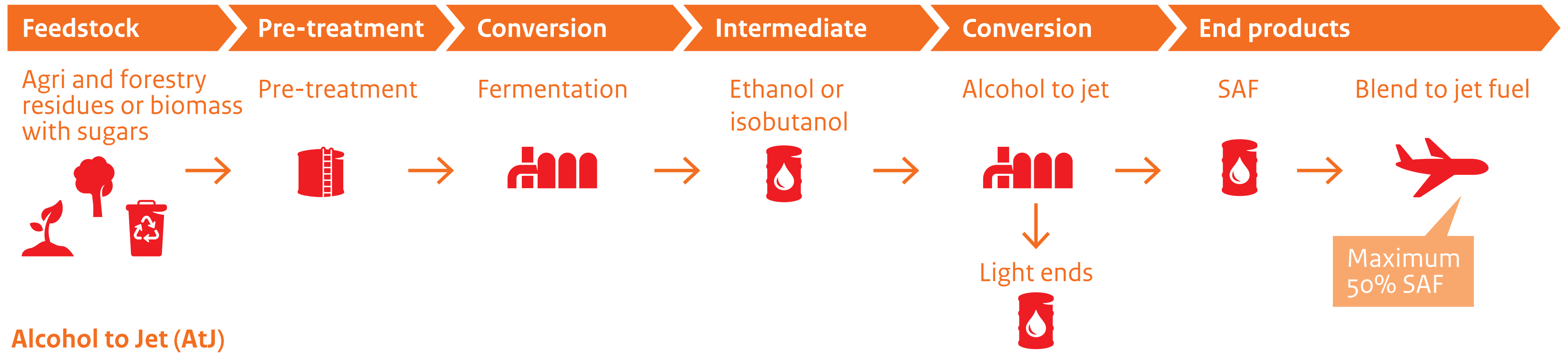
Fischer-Tropsch (FT)

Fischer-Tropsch (FT) is a proven technology for producing jet fuel from fossil-based feedstocks. Sasol has been producing FT-based fuel since 1955 from coal, while Shell uses FT in its Pearl GTL plant in Qatar based on natural gas. The technology converts any carbon-rich material into syngas which is then catalytically converted into fuel. The potential of FT is significant. The feedstock options comprise almost any carbon-rich material. Specifically, biomass, municipal solid waste, industrial gasses, biogas and landfill gas are interesting feedstocks for producing SAF. Especially from a sustainability point of view when these feedstocks are combined with renewable hydrogen to produce SAF.

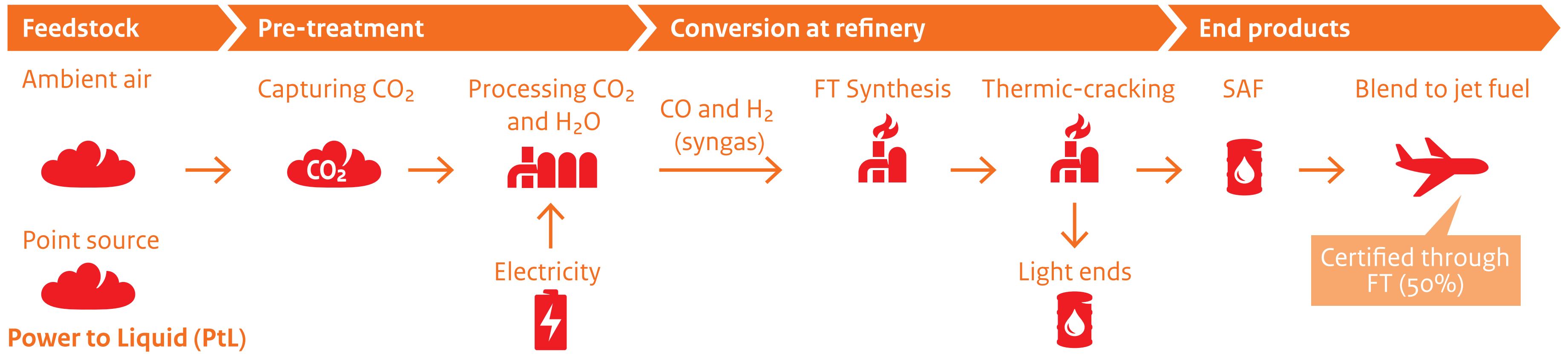
The PtL pathway relies on FT as the core conversion technology, discussed in more detail in the next paragraph. Given that FT is already proven and at scale commercially speaking, its deployment for SAF production with advanced (carbon and hydrogen) feedstock is considered feasible in this decade.

Power to Liquid (PtL)

A promising, but not yet mature, technology is Power-to-Liquid (PtL). This pathway has gained significant attention over the past years. One of the key advantages of this pathway is the fact that CO_2 can be used as a feedstock. With this pathway CO_2 is converted into CO, which together with hydrogen forms a very pure and clean syngas which can consequently be upgraded by means of FT to jet fuel, as described in the last paragraph. Although the scaling possibilities are endless when developing PtL on CO_2 from Direct Air Capture (DAC), we see significant challenges in respect of the electricity needed for this pathway and the currently limited technology readiness level.
For PtL to succeed, there is a need for an abundance of (continuous/full load) sustainable electricity at very competitive prices (<30 EUR/MWh), which is not expected in North-Western Europe for the next decade. Also, the technology is not yet mature and needs significant scaling before commercial plants can be developed for PtL. At the same time, PtL is essential for us to reach 100% SAF uptake by 2050. We therefore see a clear need and role for favourable policies around pilot/demonstration projects to develop this pathway parallel to more commercial pathways. Still, the use of recycled feedstocks and renewable hydrogen offers unique opportunities, in the Netherlands, for kick starting a large and affordable production capacity in low-carbon synthetic aviation fuels, and a platform for phasing in circular carbon and green hydrogen in the decades thereafter.



Alcohol to Jet (AtJ)



Power to Liquid (PtL)

Process overview of air capture through the Fischer-Tropsch process

Technology summary

Even though there are a number of interesting technologies which are capable of producing SAF (other SAF technologies can be found in Annex I), most technologies still require development time and large investments before they can achieve commercial scale. Even if these technologies then achieve commercial scale, the first facilities are likely to be relatively small, resulting in expensive SAF volumes.

An overview is presented below which shows the different SAF technologies and some important criteria which indicate the current status of each technology pathway. In the last chapter you have seen an SAF technology overview of the general SAF technology pathways. In the following table you will be able to see them specified per category.

The table below indicates, per specific SAF technology pathway, the current development status of this pathway per criterion. As one can see, major developmental steps need to be taken to achieve a green mark by every step.

The first criterion entails whether a technology pathway has already been approved by ASTM International (formerly known as the American Society for Testing and Materials). ASTM provides global standards for many products, including kerosene. The ASTM sets the technical criteria that kerosene must meet, such as having a low freezing point. These tests need to be performed for each new SAF technology pathway. It is only when a sustainable kerosene has been tested thoroughly and has been proven to have all the specific ASTM criteria set for kerosene, that the SAF is allowed to be used in aeroplanes.

The second criterion relates to the Technology Readiness Level (TRL). A low TRL (1-4) indicates that the technology has only been studied/tested in laboratory settings, a higher TRL level (4-8) indicates that the technology is in the demonstration phase (producing some volumes). A high TRL (8-9) indicates that the technology is available on a commercial scale.

The RED II category considers the feedstocks which can be used in each SAF technology and whether these are encouraged or discouraged under the RED II.

Finally, the costs (€) category considers whether the SAF technology can currently be deployed at low or high prices per tonne of SAF.

The information in this overview provides the Dutch SAF sector with the challenges and opportunities for scaling up this industry. For the short term, due to technology maturity, the first SAF production facilities will have to use the HEFA technology. For this reason, the first refinery in the Netherlands which will produce SAF on a constant basis and as its main product, will be a HEFA facility (for example the DSL-01 project presented in chapter 6).

But, in order to achieve sustainability through feedstock diversification, we need to invest in the other technologies now, to make them viable options in the (near) future as well. Therefore, chapter 6 includes some projects which are looking at other SAF technology pathways such as Power to Liquid. However, as developing these SAF technologies to a commercial scale will require major investments, interaction with the Dutch government is needed to de-risk these important technology developments. These policy needs of the sector are discussed in chapter 7.

Technology	Feedstock	ASTM	TRL	RED 2	€
HEFA	Virgin veg oils	🟢	🟢	🟠	🟠
	Waste oils	🟢	🟢	🟢	🟠
Fischer Tropsch	Biomass/MSW	🟢	🟠	🟠	🟠
Power to Liquid	Through FT	🟢	🔴	🟢	🔴
	Through MtJ	🔴	🔴	🟢	🔴
Alcohol-to-jet	1st gen alcohol	🟢	🟠	🔴	🟠
	2nd gen alcohol	🟢	🟠	🟢	🔴
Co-processing	Veg/waste oils	🟢	🟢	🟠	🟢
	FT - Crude	🟢	🟠	🟢	🟠
Synthesized iso-paraffins		🟢	🟠	🔴	🔴
Catalytic hydrothermolysis		🟢	🟠	🟠	🟠
Iso-butene to jet		🟠	🔴	🟠	🟠
Pyrolysis		🔴	🔴	🟢	🟢

	ASTM	TRL	RED 2	€
🟢	Approved	Commercial	Feedstock largely stimulated (green) or discouraged (red) under de RED 2	More (red), as (orange) or less (green) expensive compared to other SAF tracks
🟠	In process	Demonstration		
🔴	Process on hold	Lab/Pilot		

Figure 7. Current status of SAF technology

6. Goals and actions for SAF deployment in the Netherlands

In order realise the ambitions and goals set by the WDB and to facilitate existing and future SAF development projects, the WDB is targeting three tracks in which concrete actions have been formulated. The first track covers the opportunities and challenges for the next four years. The second track covers the potential growth strategy and the hurdles to be overcome to facilitate the SAF sector in the Netherlands in the medium term and the last track covers the actions which should be established and the gaps which must be bridged in order to meet the Dutch aviation sector's long term goals. The most important actions per track are mentioned below.

Track 1 - Short term (2021-2024)

For the short term, the goals and actions of the Dutch aviation industry are listed below.

Goals

- The aim is to have at least 200,000 tonnes of SAF produced in the Netherlands via the HEFA technology in 2024.
- The first Alcohol-to-Jet SAF demonstration plant in the Netherlands should be under development.
- The first Power to Liquid demonstration plant in the Netherlands, based on CO_2 Direct Air Capture (DAC) or biogenic/ industrial point sources, should be under development.
- Other feedstock opportunities for the HEFA pathway should be explored to meet international growing demand for biobased fuels, materials and chemicals

Actions

- It is crucial that the feedstock base for the HEFA technology is enlarged. WDB's aim is to contribute to the development of at least two sustainable feedstock alternatives next to tallow and used cooking oils (UCO), such as cover crops, before 2024. The WDB will contact knowledge institutes and companies active in this field to investigate the potential sustainable feedstock alternatives for this SAF pathway. Sustainability criteria for these feedstocks will be based upon the social and environmental criteria from the RED II, CORSIA and third-party certificate schemes such as RSB and ISCC. The WDB will contribute to a wider EU vision on using/reusing marginal and degraded soils. Amongst other things, these soils can be used for the development of nature and the cultivation of bio-based raw materials without displacing food crops or causing deforestation (for an overview of the sustainability criteria we refer to chapter 4).
- Europe's first dedicated SAF production facility, the DSL-01 built by SkyNRG, based on the HEFA technology, should be up and running in the Netherlands in 2024. More details can be found on this in the project overview.
- Neste is conducting a feasibility study for a potential 450 ktonne/a SAF production capability as part of its existing Rotterdam refinery capacity by 2023. You can find more information regarding this project and the feasibility study that is being conducted below.
- The Zenid project will deliver a design for a pilot plant capable of producing 1,000 l/day from CO_2 captured from ambient air and water. The aim is to have an SAF pilot plant based on direct air capture before 2024. More details are available in the project overview.
- A techno-economic feasibility study of PtL production in the port of Amsterdam will be performed. This study will lead to a go/no-go decision for a pilot facility in 2021. More details are available in the project overview.

Track 2- Medium term (2024-2028)

For the midterm, the goals and actions of the Dutch aviation industry are listed below.

Goals

- The aim is to have at least 500,000 tonnes of SAF produced in the Netherlands via the HEFA technology by 2026.
- The aim is to have the first Alcohol-to-Jet facility up and running in the Netherlands. Additional R&D incentives need to be in place in order to create a solid business case for these first demo facilities. The support of the government for the development of these novel SAF pathways is needed.
- The aim is to support international efforts in solving some of the R&D challenges facing the SAF sector. For example, exploring the non-CO_2 effects of aviation and SAF in particular, ensuring that ASTM allows 100% SAF in the engine of a plane, ensuring the ASTM certification of new SAF technology pathways etcetera.
- The Synkero project aims to develop a commercial facility that is able to use industrial CO_2 from various sources and convert it into SAF using the Fischer-Tropsch process. The commercial plant should be realised by 2027. More details can be found on this in the project overview..

Actions

- The WDB acknowledges that a sustainable scale up of the SAF industry goes hand in hand with the development of some other sectors. The scale up of this industry can only become successful if significant additional renewable power capacity is built and added to the Dutch grid and if sufficient load hours and sufficiently low renewable power prices can be guaranteed. In addition, the production of renewable hydrogen needs to become commercialised. Therefore, the WDB will try to support the development of the renewable hydrogen sector by trying to include its efforts in our SAF projects and we aim to be actively involved in the industry's work to create workable policy incentives to kick-start these developments which are crucial to a sustainable scale-up of the Dutch SAF industry.
- Consortia, similar to Synkero (see projects), will be the driving forces behind the first Alcohol-to-Jet and Power-to-Liquid facilities in the Netherlands. However, in order to continue working on these goals, the first steps in the short-term track should be supported and successfully concluded.
- Once more SAF technologies become available on a commercial scale, a bigger feedstock base will become accessible as well. The industry will ensure a sustainable scale-up of the utilisation of sustainable resources for SAF production, based on the criteria set in chapter 4.

Track 3- Long term (2028 onwards)

For the long term, the goals and actions of the Dutch aviation industry are listed below.

Goals

- Based on current estimates[5], the aim is to produce between 640.000 and 702.000 tonne SAF annually from 2030 onwards, through which the Dutch aviation sector will achieve its 14% target. As the Dutch aviation sector has to reduce its 2030 emissions to the 2005 emission level, and as the fossil kerosene consumption of 2005 corresponds with 155 PJ, producing between 640.000-702.000 tonnes SAF in 2030 is estimated to contribute to achieving between 61-67% of the 2030 PJ target, respectively, in the high growth scenario and between 43%- 47% of the 2030 PJ target in the high growth scenario.
- The WDB will work hard to commercialise DAC and industrial point source capturetechnologies for SAF. Accordingly, the aim is to have at least two commercial PtL plants up and running before 2035.
- The aim is to have the first commercial Alcohol-to-Jet (AtJ) facility up and running before 2030.
- The aim is to replace all fossil kerosene with SAF from 2050 onwards.
- Reach net zero emissions from NL aviation before 2070.

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[5] Based on the most recent growth projections of the Dutch aviation sector (Uitbeijerse, G.C.M. (2020), CO_2-emissie van de luchtvaart op de lange termijn, Den Haag: PBL). Page 14 of this report include the low growth scenario where it is expected that the Dutch aviation sector will consume 199 PJ kerosine in 2030, which equals 4,57 mln tonnes of kerosine, and a high growth scenario where 218 PJ is consumed which equals around 5,01 mln tonnes kerosene lifted in the Netherlands. Yet, these growth projections do not include all the environmental gains achieved by other measures such as fleet renewal etc. Therefore, we need to evaluate and further sharpen the projections in the upcoming years to see whether the imposed measures and actions match the potentially revised projections.

The SAF projects in the Netherlands

The number one aim for the aviation industry, for the long-term goal, is to develop multiple commercial facilities based on different SAF technologies and sustainable feedstocks, which produce SAF as their main product. To reach this goal, individual leadership and collaboration between the different stakeholders within the SAF sector will be needed. Furthermore, new production capacity plans will be developed on an ongoing basis and new sustainable feedstock opportunities explored.

Developing Europe's 1st dedicated SAF production facility: DSL-01

SkyNRG is currently developing Europe's first dedicated SAF production facility in the north of the Netherlands. The project is approaching the end of the engineering phase.
When in full operation (2024), the DSL-01 plant will produce 100,000 tonnes of SAF yearly plus 35,000 tonnes of by-products (LPG and naphtha).

This SAF will stand out as the greenest SAF on the market due to the fact that DSL-01 will boast a zero NO_x and SO_x emission profile, and will have the expected lifecycle CO_2 reduction of 85% compared to fossil kerosene. Additionally, DSL-01 will exclusively use green H_2 as feedstock from a custom-designed electrolyser operation (50MW).
The DSL-01 project was initiated by SkyNRG in 2017. KLM, SHV Energy and Royal Schiphol Group were the founding partners and enabled the development by participating in the round A financing. KLM is the designated offtake of a minimum of 75% of the 100,000 tonnes of SAF produced annually, which will be supplied to its home hub at Amsterdam Airport Schiphol.

Project partners: SkyNRG, KLM, Royal Schiphol Group, Shell Aviation, SHV Energy, Haldor Topsoe, Nouryon, NOM

Neste Rotterdam

Neste is in a feasibility study phase to be able to add 450 ktonne/a SAF production capability as part of its existing Rotterdam refinery capacity by 2023. Engineering studies on the next world scale capacity expansion steps are ongoing for several sites globally, including current and selected new locations. The company is targeting investment decision capability on the next world scale production capacity by the end of 2021 and production start-up in 2025.

Project partners: Neste

Zenid Rotterdam (SAF from ambient air)

The project delivered a design for a demonstration plant capable of producing 1,000 – 4,000 l/day from CO_2 and H_2O captured from ambient air. The project uses a combination of innovative technologies. First CO_2 is captured directly from air through Climeworks technology. The CO_2 is together with water (H_2O) converted into syngas (a mixture of CO and H_2) by the co-electrolysis technology of Sunfire. Subsequently this syngas is converted into a wax like intermediate through the Fischer-Tropsch process (Ineratec), which is then upgraded towards SAF. Due to system integration energy supply and production costs are relatively low.

On the 8th of February 2021 the project announced a next step with the creation of the Zenid project entity and MoU's with Uniper, aimed to be the operator of the plant, and RTHA/RHIA for regional support. The consortium will review the initial feasibility study and will work towards site selection and fund raising for the actual construction of the demonstration plant.

Project partners: Climeworks, SkyNRG, Uniper, Rotterdam the Hague Airport (part of Royal Schiphol Group), RHIA, EDL, Sunfire, Ineratec and Urban Crossovers

Synkero Amsterdam (SAF from industrial CO_2)

This project originates from initial discussions in 2016. The project partners developed a business plan in 2020 to show the financial and technological feasibility of a commercial PtL facility in the North Sea Canal area. During the high level SAF event on 8 February, project partners announced a follow-up cooperation. Synkero B.V. has been founded and will act as a development entity with the goal to develop a synthetic SAF facility based on renewable hydrogen and CO_2 from various (point)sources. The plant should be built in the North Sea Canal area and aims at being operational in 2027. In addition, the work currently going on (until the realisation of the facility) will focus on creating the necessary conditions (policy inclusion of RFNBOs/RCFs, sustainable electricity, allocation of CO_2) for e-fuels to succeed.

Project partners: SkyNRG, KLM, Port of Amsterdam, Schiphol, and others in support

Techno-economic feasibility study of synthetic jet fuel

A techno-economic feasibility study of synthetic jet fuel production in the port of Amsterdam: the study will compare the direct production route using the Fischer-Tropsch process to the route using methanol conversion against techno-economic parameters and will also study the fit with the location of Vattenfall and VTTI in Amsterdam. A first conclusion is expected in Q2-2021 and should result in a go/no-go decision on the project.

Project partners: VTTI and Vattenfall

In addition to all these publicly announced projects, there are more SAF related projects 'in the making' which unfortunately cannot be shared with the public yet.

7. Policy targets

Policy plays an important role in ensuring the increased use of SAF in the Netherlands. Therefore, the WDB is striving for a stable SAF policy climate and preferably some long-term support mechanisms to push this sector forward. Accordingly, in this chapter we discuss some crucial policy proposals which could help the aviation industry kick-start the SAF ramp-up.

One of the policies that has already been presented, is the 'Duurzaamheidskader biogrondstoffen' or the sustainable biomass framework in English. This framework seeks to ensure the sustainable use of biomass in the Netherlands. The policy seeks to achieve this by: decreased use of biomass in low-grade applications such as electricity or heat production; a transition-focused use in sectors in which there are few to no alternatives in the medium term such as aviation and shipping; and increased use of biomass for high-grade applications like the biochemical sector. For the aviation sector, this means that biomass will remain an important source for the production of SAF as long as alternatives - such as synthetic fuels or electric aircrafts – are not yet economically viable on a large scale and cannot fully replace fossil-based kerosene. The sustainable biomass framework also seeks to increase the available amount of biomass by broadening the available feedstock base. This action program is aligned with the aforementioned framework and also seeks to sustainably use biomass and broaden the feedstock base.

Furthermore, the Dutch government has taken an important step with its active plea for the implementation of a European SAF blend mandate. If a European blending mandate is not successfully implemented in time, then the Dutch government will strive to implement a national blending obligation by 2023. A European SAF mandate is preferred as it would ensure more of a level playing field as opposed to just a national mandate. To ensure that the SAF mandate achieves its desired effect, it is necessary that a smooth transition between the existing policy framework and any future framework is safeguarded. This includes the need for a smooth transition from the current opt-in (for aviation) to the HBE-system (the Dutch system incentivizing renewable energy in transport) to the introduction of a separate SAF blend mandate. If such transition is not safeguarded, then current investments into SAF facilities could be jeopardised or the desired SAF volumes might not be produced. Furthermore, it could also lead to SAF production being relocated outside the Netherlands or SAF being exported abroad. In addition to its plea for the implementation of a European SAF mandate, the Dutch government took the lead in a joint statement on SAF with Denmark, Finland, France, Germany, Luxembourg, Spain and Sweden, in which these Member States clearly stated their support for the European Commission's aim of boosting the supply of and demand for SAF in the EU. The aforementioned states called upon the European Commission to further stimulate and incentivise the uptake of SAFs, including PtL/ synthetic fuels through funding programmes under the existing financial framework. They also welcomed the ReFuelEU Aviation initiative as a starting point for further EU coordination to ensure an integral and effective long-term agenda on sustainable aviation. The statement was published during a digital High Level conference on synthetic SAF, which was organised by the Netherlands and which offered the opportunity for the industry to show that PtL aviation fuels are technically viable.

The WDB embraces the sustainability criteria for SAF discussed in chapter 4. Without a guaranteed, strong sustainability framework, social and environmental sustainability will be at risk. This should form the basis for a SAF policy mechanism. Another criterion for the policy mechanism is that it should be clear and long lasting (at least 15 years). This stability is needed to provide investment security for different technology pathways that are currently under development.

Since all SAF pathways are needed to reach net-zero emissions in aviation, additional financial incentives should be made available for SAF technology pathways other than HEFA. This is because HEFA is currently the least costly SAF pathway and the other technology pathways will otherwise face difficulties reaching commercial scale. These other pathways can be incentivised by creating a sub-target for these other types of SAF (AtJ, FT combinations etc) or by creating Contract-for-Difference type of calls by the EU or national Member States, which in particular target and support these lower TRL SAF pathways to commercial scale by taking away the financial risks attached to such innovative endeavours.

In addition to the importance of stimulating all SAF pathways and creating extra incentives for lower TRL technologies to reach commercial scale, it is crucial that compliance with the mandate is secured to assure investment security. The costs of non-compliance should be higher than the cost of compliance, to the mandate.

Besides expediting the development of the different SAF technologies, it is also essential to stimulate the deployment of the sustainable resources needed for the production of SAF (such as renewable electricity and green hydrogen). Without a proper and sustainable scale up of these industries, the SAF industry will face difficulties achieving its climate targets.
A delegated act of the European Commission enters into force Q1 of 2022 which will set out the requirements on renewable electricity for the production of RFNBOs (e.g. green hydrogen for synthetic kerosene). To avoid the risk of losing projects on green hydrogen and synthetic kerosene, because of them not being able to comply with or become competitive due to these requirements, it is argued that the use of Power Purchase Agreements (PPAs) with a renewable electricity plant in combination with Guarantees of Origin (GoOs) should be allowed as sufficient evidence to prove that the RFNBO is exclusively produced from green electricity sources. The Dutch aviation industry advises that 'additionality' should be arranged nationally and at an energy system-wide level, of course considering the most useful utilisation of renewable energy from the climate perspective and stimulating actual additional production when utilised for SAF. Furthermore, the industry foresees difficulties in scaling the PtL pathways - taking the additionality principle into account - if the use of PPAs and GoOs is not allowed.
With regard to sustainability, the WDB prefers a system beyond the current 'list approach' of the Renewable Energy Directive II (RED II), which is too limited. To further broaden the feedstock base for the production of SAF, it is necessary to look at sustainable feedstock options beyond the list provided by the RED II. The WDB advises the Dutch government to take an active role in safeguarding potentially sustainable feedstocks and allowing the usage of these feedstocks if their use will result in the social and environmental benefits described in chapter 4.

Lastly, R&D support for the pre-commercial SAF technologies (TRL <9) is needed and policy mechanisms that can de-risk first-of-a-kind commercial SAF facilities are needed as well to kick-start the industry.

8. Challenges and opportunities

If actions are taken in the Netherlands, as advised under track 1 to 3, it will be on its way to supply the SAF demand with its own production facilities. To guarantee the successful deployment of the goals and actions under the three SAF tracks, it is of vital importance that the aviation industry and the Dutch government work together. Stable (long-term) policy incentives are needed to ensure that the SAF industry can scale up its production capacity in the Netherlands.

Furthermore, another lesson which can be learned is that, if the Dutch aviation industry wants to produce its SAF cost-effectively using the HEFA technology, it should focus on feedstock diversification in order to meet international growing demand for bio-based fuels, materials and chemicals and to secure a competitive market for sustainable feedstocks. Therefore, SAF technology diversification and feedstock diversification/enlargement per SAF technology pathway should be the main priorities for the Dutch SAF sector while growing this industry.

It is essential that opportunities for SAF production are deployed to the fullest extent possible. Otherwise, a future in which the Netherlands needs to import its SAF volumes could be possible. High rates of importing SAF could potentially lead to unsustainable practices and high SAF import prices. To prevent such a situation and to promote security of the supply of sustainably produced SAF in the Netherlands, it is recommended that SAF production capacity is created and scaled in NL to fulfil (the majority of) the Dutch aviation sector's SAF demand nationally.

A domestic SAF market would not only mitigate the risks associated with SAF imports, but could also be highly beneficial for other reasons. The Netherlands has a relatively large aviation sector and plays a key role in the production of - and trade in - kerosene. The combination of the existing chemical and refining industry, infrastructure (pipelines), airports, seaports and knowledge institutions, provides the Netherlands with the elements needed to also play an important role in scaling the market for SAF. All in all, the Netherlands could become a frontrunner in SAF terms as we have:

- a high-level knowledge infrastructure for the required technologies, both for design and scale up, as well as the requisite personnel qualifications
- high-level knowledge on the sustainability of feedstocks and production
- large and efficient ports able to handle large volumes of feedstock imports and SAF exports
- the aim to create a stable policy climate for the next 15-20 years.

The establishment of a domestic SAF sector will bring benefits including:

- Economic growth (employment and investments)
  - › The domestic production of SAF could provide for the creation of jobs, directly and indirectly, through activities like construction, infrastructure, maintenance, insurance, logistics, import (harbour), storage, etc.
  - › The use of sustainable feedstocks will provide employment in sustainable biomass production and handling which is substantially higher than in other forms of renewable energy (IRENA (2018))
  - › Large investments could be attracted to the Netherlands if the Netherlands becomes a front runner in the production and consumption of SAF
- Energy security
  - › The deployment of an SAF industry in the Netherlands could be seen as an opportunity to become less reliant on fossil kerosene imports
- Social development
  - › If chosen to operate via a global supply chain, certain types of biomass produced for SAFs could bring important social benefits for poorer countries which have abundant land available but which face high unemployment rates. Sustainable sourcing of biomass for SAF production could stimulate the primary biomass producer sector (farmers, forestry) and bring several advantages such as local poverty alleviation through employment; improved sustainable agriculture and the accompanying improved food security; local energy production for own social development; and clean water as a side effect when managed well. Criteria for such benefits could be designed in collaboration with the strong agronomics and agriculture knowledge sector; NL could safeguard such benefits.
- Knowledge and innovation hub for sustainable practices and development of new technology pathways.

** review see https://www.econstor.eu/bitstream/10419/125639/1/WWWforEurope_Policy_Paper_012.pdf*

Annex I- Other SAF technology pathways

Co-processing

This production pathway is different from the previously described pathways since it does not produce a neat SAF that requires blending with conventional jet fuel. Instead, this pathway allows for the co-processing of biogenic feedstocks in existing refinery units along with petroleum-based feedstocks. The ASTM D1655 (standard specification for aviation turbine fuel) has been amended to include this pathway as being suitable for jet fuel production.

Currently, the biogenic feedstocks are limited to (vegetable) oils and fats. However, in theory, multiple biogenic feedstocks could be co-processed, including pyrolysis oils and FT wax. Several refineries (e.g. Repsol) have been co-processing oils and fats for years to meet the mandates for biofuels in road transport. Since this was not a certified pathway for jet fuel production, the biogenic feedstock had to be introduced to refinery units that did not produce jet fuel.

The specific approach to co-processing (and the investments needed to enable this) will vary for each refinery. In general, two approaches can be distinguished. The biogenic feedstock can be introduced to the Fluid Catalytic Cracker (FCC) or the Hydrodesulphuriser (HDS). The FCC is primarily a gasoline producing unit; the HDS is a diesel unit.

Catalytic hydrothermolysis (CHJ)

Applied Research Associates (ARA) along with its partner Chevron-Lummus Global (CLG) have developed a process that converts oils, fats, and greases into renewable diesel, jet fuel, and naphtha. They specifically target low-quality waste oils such as unrefined yellow and brown grease, which differentiate them from the existing HEFA facilities using oils and fats. Tapping into different feedstocks makes sense in order to stimulate competitive feedstock markets which will lead to the cost effective production of SAF.

The process consists of three stages. It starts with a clean-up step, which splits the oils and fats into separate building blocks (free fatty acids). These free fatty acids are then mixed with water and passed to the catalytic hydrothermolysis reactor where a bio-crude is formed at very high temperature and pressure. This bio-crude contains a wide range of molecules in the jet and diesel boiling range. The final hydrotreating step saturates the molecules before the different fractions are separated in the distillation column. Typically, this process yields jet fuel, diesel, and naphtha.

Synthesized iso-paraffins (SIP)

The Synthesized Iso-Paraffin jet fuel pathway is a one-step biological conversion that converts sugars into hydrocarbons. There are multiple companies at the research and development phase, but Amyris is the only company that has taken production to a commercial scale. The feedstock can be any sugar, including starch, sucrose, or lignocellulosic sugars derived from woody biomass, but the initial focus is on cane sugar. The sugars are fed to a micro-organism (yeast) that is genetically engineered to produce a hydrocarbon molecule called farnesene. This is a branched and unsaturated hydrocarbon (containing double bonds) consisting of 15 carbon atoms. Farnesene is a versatile platform molecule with multiple high-value applications, including a precursor to an anti-malarial, and it also has cosmetic and industrial applications. To produce a jet fuel blending component, the farnesene must undergo a final hydrotreating step to produce farnesane, a saturated C15 molecule.

Farnesane was approved as jet fuel blend stock in 2014 and is known as Synthesized Iso-Paraffinic (SIP) jet fuel. Amyris entered to a joint venture with Total to market SIP jet fuel. However, the uptake thus far has been limited to a few flights, as Amyris has focused on higher-value applications in the pharmaceutical and cosmetics industries.

Pyrolysis & HTL

Both pathways first convert biomass into bio-crude oil, which is similar to conventional crude oil, and needs a final refining step to produce SAF. First, the feedstock is ground into small particles which are then heated very rapidly to +/-500°C, this liquefies the biomass and yields bio-crude oil. Unlike fossil crude oil, this bio-crude contains oxygen and thus has a lower energy density (and may be acidic). The second step is to refine the bio-crude oil. This process is very similar to refining crude oil and could potentially take place in a traditional oil refinery.

The production of bio-crude is at commercial scale for pyrolysis oil production and almost at demonstration scale for HTL. However, upgrading these oils to SAF and the potential integration in existing refineries needs significant development and is probably at pilot level. Also note that the ASTM certification track has not started yet.