

Study on the potential effectiveness of a renewable energy obligation for aviation in the Netherlands

Final report

E4tech (UK) Ltd and studio Gear Up
for Ministerie van Infrastructuur en Waterstaat

December 2019

E4tech (UK) Ltd

83 Victoria Street
London SW1H 0HW
United Kingdom

Tel: +44 20 3008 6140
Fax: +44 20 7078 6180

Incorporated in England and Wales

Company no. 4142898

Registered address:

133-137 Alexandra Road,
Wimbledon, London SW19 7JY
United Kingdom

www.e4tech.com

Contents

Glossary	1
1 Executive Summary	2
2 Managementsamenvatting	6
3 Introduction.....	11
3.1 Context.....	11
3.2 Objectives of this study.....	12
4 Legal framework	13
4.1 International	14
4.2 EU.....	17
4.3 National.....	22
4.4 Conclusions	24
5 Choice of policy mechanism	25
5.1 Aims of the policy	25
5.2 Supply-side measures	26
5.3 Demand-side measures	27
5.4 A blending obligation	31
5.5 Conclusions	47
6 Supplying a SAF obligation	48
7 Sustainability requirements	67
7.1 Introduction	67
7.2 Crop-based fuels	68
7.3 Waste oils-based fuels	71
7.4 Advanced fuels.....	71
7.5 Sustainability criteria and certification	74
7.6 Reducing the risk of fraud	80
8 Promoting SAF production in the Netherlands	82
8.1 Planned SAF production in the Netherlands.....	82
8.2 Policy choices to support production in the Netherlands	83
8.3 Economic opportunities from SAF production	85
9 Economic impacts.....	87
9.1 Direct economic impacts of an obligation	87
9.2 Impact on competitiveness of airlines and airports	93
9.3 Costs to government.....	97
10 SAF supply logistics	98
10.1 Introduction	98
10.2 Current and future supply logistics	98
11 Conclusions	100
Appendix A	104

Glossary

2DS	2-Degree Scenario
APR	Aqueous Phase Reforming
AtJ	Alcohol to jet
B2DS	Below 2-Degrees Scenario
CAAFI	Commercial Aviation Alternative Fuels Initiative
CORSIA	Carbon offsetting and reduction scheme for international aviation
DSHC	Direct sugars to hydrocarbons
ETS	Emission Trading Scheme
FAME	Fatty acid methyl esters
FT	Fischer-Tropsch
GHG	Greenhouse gas
HDO	Hydro-deoxygenation
HEFA	Hydro-processed esters and fatty acids
HFP	High Freeze Point
HTL	Hydrothermal liquefaction
HVO	Hydrotreated vegetable oil
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
IEA	International Energy Agency
ILUC	Indirect Land Use Change
LCFS	Low-Carbon Fuel Standard
MSW	Municipal solid waste
NDC	Nationally Determined Contribution
PtL	Power-to-liquids
PV	Photovoltaic
RED	Renewable Energy Directive
RTFO	Renewable Transport Fuel Obligation
SAF	Sustainable aviation fuel
SIP	Synthetic iso-paraffinic kerosene
SPK	Synthetic paraffinic kerosene

1 Executive Summary

Reducing emissions from aviation is an important policy aim for the Netherlands

The need to tackle climate change will require deep emissions reduction in all sectors of the economy including air travel. As aviation is an international sector, international approaches to emissions reduction are preferable, to avoid emissions leakage¹, and ensure a level playing field between different countries and airlines. The International Civil Aviation Organization (ICAO) is developing the agreement for the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), which will aim to encourage sustainable aviation fuels as well as obliging participating parties to reduce emissions through offsetting. However, if this does not provide a strong enough driver for sustainable aviation fuel uptake, additional measures will be required at European and/or national level.

For the Netherlands, international aviation is an important sector of the economy, as the share of aviation traffic and fuel consumption within the transport sector is high compared with other EU Member States. For the Netherlands it is particularly important to find innovative solutions to address the climate impacts of international aviation, whilst not undermining the important economic contribution from the aviation sector. In February 2019, a Draft Sustainable Aviation Agreement was adopted at the Sustainable Aviation Roundtable, which committed to a target of at least 14% of the aviation fuel bunkered in the Netherlands in 2030 being sustainable.

This study assesses the potential effectiveness of a renewable energy obligation for aviation

Following this Agreement, the Ministry of Infrastructure and Water Management commissioned this study to assess the potential effectiveness of a renewable energy obligation for aviation in the Netherlands. The report considers whether the introduction of an annual renewable energy obligation for aviation would be an effective way to stimulate the production and consumption of sustainable aviation fuel (SAF), with a view to achieving the objective of a minimum of 14% sustainable aviation fuel in the Netherlands by 2030. It also discusses the preconditions for and risks of introducing an obligation. To assess this, we have undertaken analysis and stakeholder interviews, covering six key areas: legal framework, choice of policy mechanism, supply options, sustainability, promoting production in the Netherlands, economic impacts and logistics.

Sustainable aviation fuel policy is evolving rapidly at international, EU and national level. EU policy places some restrictions on the fuels that could be supported under EU or Dutch policies

Review of international, EU and national policies shows that:

- Interaction of **international policies** and regional and national policies related to SAF are still under discussion, but do not appear to present a barrier to a SAF obligation in the Netherlands.
- **European policy** requires that obligations or financial support for biofuels follow the sustainability criteria set out in the Renewable Energy Directive (RED II), even if the fuels are not counted towards RED II targets. State Aid rules are also important: these limit the options for support of food and feed crop-based biofuels, and allow additional support alongside an obligation only for fuels with high costs and where competitive impacts can be avoided.

¹ Increase of emissions in other sectors or geographies

Compared with other policy measures, a blending obligation in the Netherlands would provide the highest level of assurance that a 14% target would be met

- An EU-wide obligation would reduce competitive distortion and carbon leakage, however it is likely to be challenging to secure MS-wide agreement and therefore unlikely to be implemented in the short-term. As a result, this report focuses on the design of a Netherlands SAF obligation.
- A blending obligation provides the highest level of assurance that the 14% target will be met, and is also the only option possible if food and feed crop-based biofuels were to be supported. Practically, there are no substantial barriers to implementing a blending obligation. However, additional policies to mitigate cost impacts would be limited to certain fuels by State Aid rules.
- Supply or demand side policy support could be used as well as, or instead of an obligation. A payment for SAF use could be constructed to give reasonable level of confidence of the target being met, with an advantage of this option being the ability to split the costs of compliance between industry and government if desired.

The obligation would be likely to be met through SAF derived from oils, as other routes are at an earlier stage of commercialisation, and have higher costs

- There are many routes to produce SAF, six of which are already certified for blending with fossil jet fuel, generally at up to 50%. However, only hydroprocessing of oils/fats (HEFA) is at commercial stage today. SAF can be supplied to airports through existing infrastructure, with minimal additional handling costs.
- Overall, the HEFA route is the most feasible option to meet the obligation, but could have feedstock constraints if demand grows fast in other markets. For example, if a 14% obligation in the Netherlands, equivalent to around 700kt of SAF in 2030, was supplied entirely through HEFA from waste oils and fats alone, this would require around 18% of the EU potential resource, for which there is also growing demand from the road transport sector.
- For routes from lignocellulosic feedstocks and for power to liquids, even supplying all of 2030 SAF demand in the Netherlands would lead to feedstock requirements that are very small compared with the EU resource potential. However, these are at the demonstration/early commercial stage, and so there is more uncertainty over their contribution by 2030.

Decisions are needed on the sustainability of feedstocks and support to advanced biofuels and power to liquids, which will have a large effect on the design of an obligation, and interact with policy in other sectors

Ensuring the sustainability of SAF is very important to all stakeholders, in terms of preventing use of unsustainable fuels in the near term, and encouraging greater levels of SAF supply in the future.

- The extent to which biofuels based on food and feed crops could contribute towards SAF supply is a key option for policy, with widely differing views amongst stakeholders. This will need to be agreed in conjunction with Netherlands policymaking on biofuels in other sectors
- Waste oils are considered as the main near-term route to SAF, but have limited resources. Whether or not to limit their use should be agreed alongside policymaking in other sectors.
- Incentivising advanced biofuels and renewable electricity (through a sub-target, additional support, or preferably both) is widely supported to increase the sustainable feedstock base and so the potential for SAF supply.

All biofuels will need to meet RED II sustainability criteria, which cover areas including GHG savings, land use, biodiversity, and forest carbon stocks. Clarification of detailed rules for factors such as co-processing, Annex IX feedstocks and additionality of renewable electricity is needed as soon as possible to enable investment.

Although an obligation could not favour production in the Netherlands, an obligation would be likely to further promote interest in SAF production

- There are planned SAF plants in the Netherlands today, and interest in further production in the 2020s. Planned and potential production volumes could be used to inform the levels of interim targets to ensure that it is at least possible to supply a high proportion of demand from production in the Netherlands.
- Supplying 14% SAF in the Netherlands in 2030 via new HEFA plants would require additional investment of €230 and €730 million, with the potential for around 300 additional permanent jobs.

High SAF costs and prices will mean economic impacts on airlines, in particular those with a hub in the Netherlands, depending on the scope of fuels considered, and the level of the target

- Expected prices for SAF are high: around 4-5 times the prices of fossil jet. This is a result of both high production costs of SAF and very low levels of global supply today. Prices are not expected to decrease to 2030. A kerosene blend containing 14% SAF is anticipated to cost between €178/tonne and €276/tonne more than fossil kerosene, as a result of these high SAF prices. If all of these costs are passed on to passengers, this represents an increased cost per passenger per flight of around €7 for short-haul flights and around €33 for long-haul flights.
- The costs imposed by an obligation will result in lower passenger numbers due to demand reduction, mode-shifting, and use of alternative routes. This has an economic impact on all actors in the NL aviation sector, but particularly airlines with hubs in the Netherlands.
- Options to reduce these distortions are a) to advocate for policy with a wider geographic scope b) reduce the level of the obligation, which would also reduce the climate benefits or c) reduce the costs to passengers, for example through subsidising the additional costs of SAF blending.
- Detailed economic impact assessment will be needed once policy options are narrowed down further, to compare the expected costs versus expected benefits in terms of GHGs and reduction of other air pollutants.
- The additional costs of SAF blending could also lead to carbon leakage: increased emissions as a result of airlines tankering (carrying more fuel than is needed to avoid uplifting fuel in the Netherlands) or from passengers using alternative (potentially longer) routes on which SAF is not used. This could be mitigated through the same approaches as for economic impacts.

Overall, an obligation would be an effective way to stimulate consumption of SAF in the Netherlands

- An obligation for SAF in the Netherlands would be likely to result in the target of 14% sustainable aviation fuels in 2030 being met, provided that the obligation resulted in a price comparable to that in other similar markets. Nevertheless, a rapid increase in demand for SAF in other countries or for feedstocks and fuels from the road transport sector could lead to price increases and shortage of supply. An obligation would also be likely to support and stimulate production in the Netherlands, although this would not be guaranteed by this type of policy.

- To support future SAF routes, such as advanced biofuels and power to liquids, an obligation is needed to give market certainty to investors. However, an obligation alone would not provide sufficient support, and so additional policy measures are needed to help to commercialise these technologies and enable cost reductions.
- An obligation is also an effective way to support near term SAF routes, through promoting action across the industry, stimulating production, and encouraging competition between suppliers. Providing a direct payment for SAF use, for example through a scheme analogous to SDE++, would have the benefit of being able to split costs between industry and government, and so reduce economic impacts, but would not bring the same advantages in terms of competition and wider market creation, though it could stimulate production in the Netherlands. Government would also need to consider carefully the level of public contribution made. Adequately designed and with additional support measures, an obligation would also support longer term SAF routes not commercial today, as well as their deployment in the Netherlands.
- Successful introduction and operation of an obligation relies on balancing the demand, set by the level and timing of the obligation, with the supply, set by the scope of the target (e.g. inclusion of food and feed crop based fuels), sustainability requirements, and any additional support for the obligated fuels. Decisions made on each one of these factors discussed above will affect the others, meaning that their combined impacts will need to be assessed, and re-assessed if decisions change.

Key areas for agreement if an obligation is to be introduced

- Extent to which biofuels based on food and feed crops should contribute towards SAF supply and treatment of fuels from low ILUC crops
- Extent to which waste oils feedstocks should contribute towards SAF supply
- Form and level of support for advanced biofuels and power to liquids
- Degree of economic impact on airlines
- Level and timing of targets
- Compliance mechanism
- Chain of custody in pipelines across multiple countries
- Approach to encouraging an EU-wide policy in parallel with introduction of an obligation in the Netherlands

2 Managementsamenvatting

Het verminderen van emissies door de luchtvaart is een belangrijk beleidsdoel voor Nederland

De noodzaak om klimaatverandering tegen te gaan, vereist het terugdringen van de broeikasgasemissies in alle sectoren van de economie, inclusief de luchtvaart. Aangezien de luchtvaart een internationale sector is, heeft een internationale benadering voor het terugdringen van de emissies de voorkeur: het voorkomt 'carbon emission leakage'² en waarborgt een gelijk speelveld tussen verschillende landen en luchtvaartmaatschappijen. De International Civil Aviation Organisatie (ICAO) ontwikkelt momenteel het Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). Dit schema beoogt het gebruik van duurzame vliegtuigbrandstoffen³ aan te moedigen. CORSIA verplicht deelnemende partijen daarnaast om emissies te verminderen door middel van compensatie. Mocht dit schema het gebruik van SAF niet voldoende vergroten dan zullen aanvullende maatregelen op Europees en/of nationaal niveau nodig zijn.

De internationale luchtvaart is een belangrijke economische sector voor Nederland, gezien het relatief grote aandeel van het luchtvaartverkeer en bijbehorende brandstofverbruik in de Nederlandse transportsector, vergeleken met andere EU-lidstaten. Voor Nederland is het daarom belangrijk om innovatieve oplossingen te vinden voor de klimaateffecten van de internationale luchtvaart, zonder daarbij de economische bijdrage van de luchtvaartsector te ondermijnen. In februari 2019 werd in de RondeTafel Duurzame Luchtvaart een Ontwerp-Akkoord Duurzame Luchtvaart aangenomen, waarbij men zich committeerde aan een doelstelling dat in 2030 ten minste 14% van de in Nederland gebunkerde vliegtuigbrandstof van duurzame oorsprong is.

Deze studie beoordeelt de potentiële effectiviteit van een verplichting voor een aandeel hernieuwbare energie in de Nederlandse luchtvaart

In navolging van dit Ontwerp-Akkoord heeft het ministerie van Infrastructuur en Waterstaat opdracht gegeven tot deze studie om de mogelijke effectiviteit van een verplichting tot hernieuwbare energie voor de luchtvaart in Nederland te beoordelen. Het rapport onderzoekt of invoering van een jaarlijkse verplichting voor inzet van hernieuwbare energie in de Nederlandse luchtvaart een effectieve manier zou zijn om de productie en het gebruik van duurzame vliegtuigbrandstof (SAF) te stimuleren, met als beoogd doel het bereiken van inzet van ten minste 14% duurzame vliegtuigbrandstof in Nederland in 2030. Het rapport gaat ook in op de voorwaarden en risico's van het invoeren van een dergelijke verplichting. Om dit te beoordelen, hebben we analyses uitgevoerd en interviews gehouden met belanghebbenden, op de volgende zes belangrijke issues : de wettelijk kaders, keuze van beleidsinstrumenten, opties voor aanbod van de duurzame brandstoffen, duurzaamheid, bevordering van de productie in Nederland, economische effecten en logistieke aspecten.

Beleid op duurzame vliegtuigbrandstof ontwikkelt snel, zowel op internationaal, EU- als nationaal niveau. Het huidige EU-beleid legt enkele beperkingen op aan de brandstoffen die zouden kunnen worden ondersteund in EU- of Nederlands kader

² 'Emission leakage' is het effect waarbij door beleidsmaatregelen economische activiteiten verplaatst worden naar een andere land of regio. In het 'vertrekkende' land zijn er dan minder emissies, maar omdat ze elders alsnog plaatsvinden is er netto geen effect.

³ (In dit rapport wordt ook de term Sustainable Aviation Fuels (SAF) gebruikt). De term duurzame vliegtuigbrandstof (SAF) betreft de ongemengde brandstof van biobrandstof of van power-to-liquid. Als SAF wordt gemengd met conventionele kerosine spreekt dit rapport over een SAF-mengsel.

De evaluatie van het internationale, Europese en nationale beleid laat zien dat:

- De onderlinge afstemming tussen **internationaal beleidsmaatregelen** en regionaal en nationaal beleidsmaatregelen met betrekking tot duurzame vliegtuigbrandstoffen is nog steeds gaande, maar lijkt vooralsnog geen belemmering te vormen voor een verplichting voor een aandeel duurzame vliegtuigbrandstoffen in Nederland.
- **Het Europese beleid** vereist dat een verplichtingsmaatregel of financiële steun aan biobrandstoffen in overeenstemming zijn met de duurzaamheidscriteria van de Richtlijn Hernieuwbare Energie (RED II), zelfs als de brandstoffen niet kunnen worden meegeteld voor de RED II doelen. De regels voor staatssteun zijn eveneens belangrijk: deze beperken de mogelijkheden voor steun voor biobrandstoffen op basis van voedsel/veevoergewassen. De regels maken ook extra steun mogelijk in aanvulling op een verplichting, wanneer de steun betrekking heeft op brandstoffen met hoge kosten en waarbij concurrentie-effecten kunnen worden vermeden.

Vergeleken met andere beleidsmaatregelen, zou een bijmengverplichting in Nederland de hoogste mate van zekerheid bieden dat het beoogde 14%-doel wordt bereikt

- Een EU-brede verplichting zou de concurrentievervalsing en 'carbon leakage' verminderen, maar het bereiken van overeenstemming in de gehele EU hierover en implementatie van een verplichting op EU-niveau achten we daarom onwaarschijnlijk op de korte termijn. Daarom richt dit rapport zich op het ontwerp van een Nederlandse SAF-verplichting.
- Een bijmengverplichting biedt de hoogste mate van zekerheid dat het doel van 14% wordt gerealiseerd. Het is ook de enige mogelijke optie als biobrandstoffen op basis van voedsel/veevoergewassen zouden worden ondersteund. Praktisch gezien zijn er geen substantiële belemmeringen voor de implementatie van een bijmengverplichting. Aanvullend beleid om de kosteneffecten te beperken, zou vanwege de staatssteunregels beperkt zijn tot bepaalde brandstoffen.
- Beleidsondersteuning ter stimulering de vraag- of aanbodzijde kan eveneens worden overwogen naast of in plaats van een verplichting. Een vergoeding voor het gebruik van duurzame vliegtuigbrandstof zou kunnen worden vastgesteld om een redelijke mate van vertrouwen te geven dat de doelstelling wordt bereikt. Een voordeel van deze optie is de mogelijkheid om de nalevingskosten desgewenst te verdelen tussen bedrijfsleven en overheid.

De verplichting zal meest waarschijnlijk worden ingevuld met duurzame vliegtuigbrandstoffen gemaakt van plantaardige oliën en dierlijke vetten. Routes op basis van andere grondstoffen bevinden zich in een eerder stadium van de commercialisatie en hebben vooralsnog hogere kosten

- Er zijn verschillende routes om duurzame vliegtuigbrandstoffen te produceren. Zes routes zijn al gecertificeerd voor het bijmengen met fossiele vliegtuigbrandstof, tot een aandeel van ten hoogste 50%. Momenteel heeft alleen de productieroute waarbij oliën/vetten met waterstof worden opgewerkt tot SAF (HEFA) het commerciële stadium bereikt. Duurzame vliegtuigbrandstof kan aan luchthavens worden geleverd via de bestaande infrastructuur, met minimale extra afhandelingskosten.
- De HEFA-route is, algemeen gesproken, momenteel de meest haalbare optie om de verplichting te realiseren, maar er moet rekening worden gehouden met beschikbaarheid van de grondstoffen als ook de vraag voor biobrandstoffen op basis van deze grondstoffen op

andere markten toeneemt. Als bijvoorbeeld de verplichting van 14% duurzame vliegtuigbrandstof in Nederlands luchtvaart – overeenkomend met circa 700 duizend ton SAF in 2030 - volledig ingevuld zou worden met HEFA gemaakt van afvaloliën en -vetten, is hiervoor ongeveer 18% van de in de EU beschikbare hoeveelheid van deze grondstoffen nodig. En daarbij moet opgemerkt dat er ook een groeiende. Vraag is naar deze grondstoffen voor biobrandstoffen in het wegvervoer.

- Voor productieroutes gebaseerd op lignocellulosehoudende grondstoffen en de power-to-liquid-routes ligt het beschikbaarheidsvraagstuk anders. Voor een volledige invulling van de 14%-SAF-doelstelling in Nederland in 2030 op basis van deze opties is slechts een beperkt aandeel van het grondstofpotentieel in de EU vereist. Deze twee opties bevinden zich echter nog in de demonstratie en vroege commerciële fase en er bestaat dus nog meer onzekerheid over hun te verwachten bijdrage in 2030.

Voor verdere ontwikkeling is besluitvorming nodig over de duurzaamheidsaspecten van grondstoffen en de steun aan geavanceerde biobrandstoffen en power-to-liquid is nodig. De besluiten zullen bepalend zijn voor de inrichting van een verplichtingsmaatregel en voor de samenwerking met het beleid in andere sectoren

Het waarborgen van de duurzaamheid van SAF is van groot belang voor alle belanghebbenden, om het gebruik van niet-duurzame brandstoffen in de toekomst te vermijden en om een groter aanbod van SAF in de toekomst te stimuleren.

- De mate waarin biobrandstoffen op basis van voedsel/voedergewassen kunnen bijdragen aan de levering van SAF is een belangrijke beleidskeuze. Hierover hebben betrokken partijen sterk uiteenlopende standpunten. Deze beleidskeuze zal in samenhang met het Nederlandse biobrandstoffenbeleid in andere sectoren moeten worden genomen.
- Afvalgebaseerde oliën en vetten worden beschouwd als de belangrijkste kortetermijnroute naar duurzame vliegtuigbrandstoffen, maar deze grondstoffen kennen een beperkte beschikbaarheid. Of het gebruik ervan al dan niet moet worden beperkt, vereist afstemming met beleidsvorming in andere sectoren.
- Er bestaat brede steun voor het stimuleren van geavanceerde biobrandstoffen en hernieuwbare elektriciteit (door middel van een subdoel, extra steun, of bij voorkeur beide) vanwege de grotere beschikbare duurzame grondstoffenbasis. Dat leidt tot een groter volumepotentieel van duurzame vliegtuigbrandstof.

Alle biobrandstoffen moeten voldoen aan de RED II-duurzaamheidscriteria. Deze criteria betreffen o.a. de vermindering van well-to-wheel broeikasgasuitstoot, landgebruik, biodiversiteit en koolstofvoorraden in bossen en natuurgebieden. Verdere verduidelijking van specifieke afspraken over bijv. co-processing, de grondstoffen vermeld in Annex IX van de Richtlijn en de additionaliteit van hernieuwbare elektriciteit zijn vereist om investeringen in productiefaciliteiten mogelijk te maken.

Hoewel een verplichting de productie van duurzame vliegtuigbrandstof in Nederland niet noodzakelijkerwijs begunstigt, is het waarschijnlijk wel dat een dergelijke verplichting de belangstelling voor de meer productie van SAF aanwakkeren

- Er zijn momenteel enkele SAF-fabrieken gepland in Nederland en er bestaat interesse voor verdere productie na 2020. Informatie over geplande en potentiële productievolumes kan de

basis vormen voor het vaststellen van tussentijdse doelstellingen, om zo de mogelijkheid te creëren dat een groot deel van de vraag afkomstig is van in Nederland geproduceerde SAF.

- Levering van 14% SAF in Nederland in 2030 via nieuwe HEFA-centrales zou extra investeringen van ca. 230 - 730 miljoen euro vereisen, met het potentieel van ongeveer 300 extra vaste banen.

Hoge SAF-kosten en -prijzen zullen economische gevolgen hebben voor luchtvaartmaatschappijen, met name voor hen met een hub in Nederland. De mate van impact is afhankelijk van het portfolio van ingezette duurzame vliegtuigbrandstoffen en de hoogte van de verplichting.

- De verwachte prijzen voor SAF zijn hoog: ongeveer 4-5 keer de prijzen van fossiele brandstoffen. Dit is het gevolg van zowel hoge productiekosten van SAF als het zeer lage niveau van het huidige mondiale aanbod. Er wordt niet verwacht dat de prijzen richting 2030 zullen dalen. Een kerosinemengsel met 14% SAF zal naar verwachting tussen 178 €/ton en 276 €/ton meer kosten dan fossiele kerosine, als gevolg van deze hoge SAF-prijzen. Als al deze kosten aan de passagiers worden doorberekend, betekent dit een stijging van de kosten per passagier per vlucht van ongeveer € 7 voor kortereafstandsvluchten en ongeveer € 33 voor langeafstandsvluchten.
- De kosten die een verplichting met zich meebrengt, zullen leiden tot een lager aantal passagiers als gevolg van vraagafname, een verschuiving naar andere vervoerswijzen en het gebruik van alternatieve routes. Dit heeft een economische impact op alle spelers in de Nederlandse luchtvaartsector, maar vooral op luchtvaartmaatschappijen met hubs in Nederland.
- Mogelijkheden om deze verstoringen te beperken zijn: a) pleiten voor een beleid met een ruimer geografisch bereik, b) verlaging van het verplichtingspercentage, wat ook lagere klimaatvoordelen tot gevolg heeft, of c) verlaging van de kosten voor de passagiers, bijvoorbeeld door subsidiëring van de extra kosten van de duurzame vliegtuigbrandstof.
- Zodra er keuzes wordt gemaakt voor bepaalde beleidsopties, zal een gedetailleerde economische 'impact assessment' nodig zijn om de verwachte kosten af te zetten tegen de verwachte baten (in termen van reductie van broeikasgasreductie en vermindering van emissies van andere luchtverontreinigende stoffen).
- De additionele kosten van het mengen van SAF kunnen ook leiden tot 'carbon leakage': hogere emissies als gevolg van het tanken door luchtvaartmaatschappijen elders (en die dan meer brandstof vervoeren dan nodig is om te voorkomen dat er brandstof moet worden getankt in Nederland) of als gevolg van passagiers die alternatieve (potentieel langere) routes gebruiken waarop SAF niet wordt gebruikt. Dit kan worden beperkt door dezelfde aanpak als voor de economische effecten (zie eerdere bulletpoint op deze pagina).

Algemeen gesteld zou een verplichting een effectieve manier zijn om het verbruik van SAF in Nederland te stimuleren.

- Een verplichting voor gebruik van SAF in Nederland zal er waarschijnlijk toe leiden dat de doelstelling van 14% duurzame vliegtuigbrandstoffen in 2030 wordt gehaald, op voorwaarde dat de verplichting leidt tot een prijs die vergelijkbaar is met die in andere relevante markten. Niettemin kan een snelle groei van de vraag naar SAF in andere landen of groei van inzet van grondstoffen en brandstoffen in wegtransport leiden tot prijsstijgingen en tekorten aan

aanbodzijde van SAF. Verwacht wordt dat een verplichting ook de productie in Nederland kan ondersteunen en stimuleren, alhoewel dit niet gegarandeerd kan worden met een verplichting.

- Een verplichting is noodzakelijk om investeerders voldoende markt zekerheid te bieden voor het ontwikkelen van toekomstige SAF-productieroutes, gebaseerd op geavanceerde biobrandstoffen en power-to-liquid. Een verplichting alleen zou echter niet voldoende steun bieden en daarom zijn aanvullende beleidsmaatregelen nodig om deze technologieën te helpen commercialiseren en de kostenreductie mogelijk te maken.
- Een verplichting is ook een doeltreffend instrument om SAF-routes die al commercieel stadium hebben bereikt te ondersteunen. De maatregel raakt de hele sector, stimuleert de productie en moedigt de concurrentie tussen leveranciers aan. Een rechtstreekse betaling voor het gebruik van SAF, bijvoorbeeld via een regeling analoog aan de SDE++-regeling, zou het voordeel hebben dat de kosten kunnen worden verdeeld tussen het bedrijfsleven en de overheid. Op die manier kunnen de economische gevolgen worden verminderd. Daar staat tegenover dat het niet dezelfde voordelen opleveren in termen van concurrentie en bredere marktcreatie. Een dergelijke maatregel kan wel de productie in Nederland stimuleren. De overheid moet wel een zorgvuldige afweging maken over de mate van een publieke bijdrage. Een verplichting, die goed is opgezet en met aanvullende ondersteunende maatregelen, zou ook de SAF-routes die nu nog niet commercieel zijn, en de inzet van de SAF van deze routes in Nederland ten goede komen.
- Een succesvolle invoering en werking van een verplichting hangt af van het vinden van het juiste evenwicht tussen de vraag - die wordt bepaald door het niveau en de timing van de verplichting - en het aanbod - dat wordt bepaald door de reikwijdte van de doelstelling (bijvoorbeeld, het opnemen van brandstoffen op basis van voedsel/voedergewassen), duurzaamheidseisen en eventuele aanvullende steun voor de verplichte brandstoffen. Besluiten op elk van de hierboven besproken issues, zullen gevolgen hebben voor de andere issues. Dit houdt in dat de gecombineerde effecten ervan eveneens moeten worden beoordeeld en herbeoordeeld moeten worden als besluiten veranderen.

Belangrijkste onderwerpen waarover overeenstemming moet worden bereikt als een verplichting wordt ingevoerd

- Mate waarin biobrandstoffen op basis van voedsel/voedergewassen mogen bijdragen aan de levering van SAF en de wijze waarop de bijdrage van nieuwe gewassen (zoals tussengewassen en bodembedekkende gewassen) wordt beschouwd
- Mate waarin afval- en reststroomgebaseerde biobrandstoffen kunnen bijdragen aan de levering van SAF
- Vorm en mate van steun voor geavanceerde biobrandstoffen en power-to-liquid
- Mate van economische impact op luchtvaartmaatschappijen
- Niveau en timing van de doelstellingen
- Nalevingsmechanisme
- 'Chain of Custody' in een brandstofpijpleidingensysteem dat zich over meerdere landen uitstrekt
- Aanpak om een EU-breed beleid te stimuleren, parallel aan de invoering van een verplichting in Nederland

3 Introduction

3.1 Context

The need to tackle climate change will require very deep emissions reduction in all sectors of the economy including air travel. For example, International Energy Agency (IEA) scenarios⁴ show this being achieved in 2 degree and below 2 degree scenarios through significant reductions in aviation final energy consumption with lower growth in air mobility demand (by shifting to high speed rail), significant efficiency improvements, and adoption of sustainable aviation fuels. The IEA notes that reducing global aviation emissions in line with the Below 2 degree scenario carbon budget could not be achieved through offsets from other sectors alone, without a direct reduction of CO₂ emissions from the aviation sector.

As aviation is an international sector, international approaches to emissions reduction are preferable, to avoid emissions leakage⁵, and ensure a level playing field between different countries and airlines. The International Civil Aviation Organization (ICAO) is developing the agreement for Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), which will aim to encourage sustainable aviation fuels as well as obliging participating parties to reduce emissions through offsetting. Participation in CORSIA will begin through a pilot phase (2021 – 2023) and first phase (2024 to 2026) on a voluntary basis. The second phase (2027-2035) will apply to all states that have an individual share of international aviation activities above 0.5%⁶. The Netherlands will be required to participate in the second phase, and intends to participate voluntarily in the earlier phases. Airlines can comply with CORSIA through a number of measures: reducing fuel burn, for example through more efficient aircraft and operations; ensuring that the fuel they do burn has lower CO₂ emissions, for example through supplying sustainable aviation fuel; and through a market-based offsetting mechanism.

Supply of sustainable aviation fuels is therefore a key part of how airlines could meet their obligations under the CORSIA agreement. However, if (as expected) this does not provide a strong enough driver for sustainable aviation fuel (SAF) uptake, additional measures will be required at European and/or national level. The Dutch Minister of Infrastructure and Water Management, Van Nieuwenhuizen, stated in a letter of 27 March 2019, that a European approach would be preferred, to avoid conflicts and competition with other countries, emissions leakage, and a reduced driver for investment. However, action at a national level may be required where this is not feasible, or in order for a country to take a lead in stimulating the sector. Whichever approach is taken, care will be needed to determine the rules for each scheme to avoid double counting of climate benefits, while ensuring that measures are collectively strong enough to drive uptake.

For the Netherlands, international aviation is an important sector of the economy: the share of aviation traffic and corresponding fuel consumption within the transport sector as a whole is high compared to other EU Member States (MSs). Therefore for the Netherlands it is particularly important to find innovative solutions to address the climate impacts of international aviation whilst not undermining the important economic contribution from the aviation sector. The Minister's letter also highlights the potential opportunities for the Netherlands from sustainable aviation fuel production, as a result of

⁴ IEA, Energy Technology Perspectives, 2017

⁵ Increase of emissions in other sectors or geographies

⁶ ICAO, Available from: https://www.icao.int/environmental-protection/Pages/A39_CORSIA_FAQ2.aspx

the current infrastructure, chemical industry, and knowledge institutions. On 21st February 2019, a Draft Sustainable Aviation Agreement was adopted at the Sustainable Aviation Roundtable, made up of the Ministry of Infrastructure and Water Management (*Min IenW*) as well as stakeholders from the sectors, academics and NGOs. This group provided specific aviation measures to the Mobility sector Roundtable, one of the five sector tables determining measures for the Climate Agreement⁷. The group committed to a target of at least 14% of the aviation fuel bunkered in the Netherlands in 2030 being sustainable, including sustainable advanced biofuels, synthetic kerosene based on green electricity/green hydrogen, green hydrogen for combustion engines or a fuel cell (hybrid electric).

3.2 Objectives of this study

Following the Draft Sustainable Aviation Agreement, the Ministry of Infrastructure and Water Management (*IenW*) commissioned this study to assess the potential effectiveness of a renewable energy obligation for aviation in the Netherlands.

The overall questions for this study are:

- Would the introduction of an annual renewable energy obligation for aviation be an effective way to stimulate the production and consumption of sustainable aviation fuel (SAF), with a view to achieving the objective of a minimum of 14% sustainable aviation fuel in the Netherlands by 2030?
- What are the preconditions for introduction of this commitment for aviation in the short/medium term?
- What are the risks of introducing this type of obligation?

In order to answer these questions, the project team has undertaken analysis and stakeholder interviews, covering six key areas:

- The legal framework for an obligation - whether there are any requirements for, or obstacles to, particular policy options for SAF at an EU or NL level
- The choice of policy mechanism – what policy mechanisms could encourage SAF consumption, and what options exist for introduction of an obligation?
- Supply options - how an obligation of 14% renewable energy in obligation in 2030 would be likely to be supplied
- Sustainability – how an obligation could ensure sustainable fuel supply, and promote increasing sustainability
- Promoting SAF production in the Netherlands – how this could be achieved
- Economic impacts – how the costs of supplying SAF would affect airlines, fuel suppliers, airports and passengers, and the economic opportunities from SAF production
- Sustainable aviation fuel supply logistics – whether there are barriers to increasing supply of SAF into aviation fuel supply chains

⁷ Climate Agreement <https://www.klimaataakkoord.nl/documenten/publicaties/2019/06/28/national-climate-agreement-the-netherlands>

4 Legal framework

Summary

Review of international, EU and national policies shows that:

- Interaction of **international policies** and regional and national policies related to SAF are still under discussion. However, aside from a restriction on placing taxes on fuels, international policies do not appear to present a barrier to a SAF obligation in the Netherlands, or place particular requirements on the form of the obligation.
- **European policy** requires that obligations or financial support for biofuels follow the sustainability criteria set out in the Renewable Energy Directive (REDII), even if the fuels are not counted towards REDII targets. State Aid rules are also important: these may limit the options for support of food and feed crop-based biofuels, and allow additional support alongside an obligation only for fuels with high costs and where competitive impacts can be avoided.
- There are existing **policies in the Netherlands** to support supply of renewable fuels, including SAF. Although there will be interactions between markets for renewable fuels in different sectors, the policies themselves do not restrict the options for SAF policy.

This section considers the legal framework related to SAF, at international, EU and national level, in order to determine whether there are any requirements for, or obstacles to, particular policy options for SAF at an EU or NL level. It is also important to consider how a policy mechanism for SAF would interact with other existing mechanisms, in terms of how SAF use or emissions saved would be accounted for.

Questions to be answered in this section include:

- Is it legally possible to set a blending obligation at EU or at national level? Would there be obstacles to this from ICAO, from EU law, or from national laws?
- Are there restrictions on how the target could be set, for example on the type of policy mechanism used, who the obligated parties might be, or what the metric for measurement could be?
- What would interactions be with other mechanisms that promote renewable energy use or GHG reduction in aviation? For example, what could be claimed by Member States and airlines (renewable energy use, GHG reductions) under which framework (e.g. the recast Renewable Energy Directive (RED II), EU emissions trading scheme, EU Effort Sharing Regulation, Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA))

4.1 International

CORSIA

The International Civil Aviation Authority (ICAO) is a UN specialised agency, and one of its environmental goals, agreed in 2004, is to “limit or reduce the impact of aviation greenhouse gas emissions on the global climate”.⁸ In 2016 ICAO adopted the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), which aims to stabilise net CO₂ emissions from international civil aviation at 2020 levels⁹. This is the first global system aiming to address CO₂ emissions from aviation. Participation in CORSIA will begin through a pilot phase (2021 – 2023) and first phase (2024 to 2026) on a voluntary basis. The second phase (2027-2035) will apply to all states that have an individual share of international aviation activities above 0.5%¹⁰. Airlines can comply with CORSIA through a number of measures: reducing fuel use, for example through more efficient aircraft and operations; ensuring that the fuel used has lower CO₂ emissions, for example through supplying sustainable aviation fuel; and through a market-based offsetting mechanism.

Emissions reduction can be claimed from the use of CORSIA Eligible Fuels that meet CORSIA Sustainability Criteria, certified by an approved Sustainability Certification Scheme. The saving claimed will be the actual GHG saving from the eligible fuel used, rather than a fixed GHG saving for all eligible fuels, meaning that fuels with higher GHG savings are incentivised. Eligible fuels can be a sustainable aviation fuel (biofuel, other renewable or waste-based), or a lower carbon aviation fuel (fossil based). CORSIA sustainability criteria have been agreed for the pilot phase¹¹. Eligible fuels should have at least 10% GHG savings, including an ILUC factor, and that there should be no deforestation after 1 January 2008¹². A further ten themes not approved for the pilot phase remain under discussion for later phases: water, water rights, soil, air, conservation, waste, human rights, land rights, local development and food security¹³. Final sustainability requirements will be agreed by the end of the pilot phase. It is therefore not yet known whether the final CORSIA rules alone will be strong enough to guarantee the sustainability of SAFs. Interviewees highlighted that many airlines will voluntarily go beyond these rules in the SAF that they use, and advocate for more stringent standards (see section 7.5).

Does CORSIA preclude other policy mechanisms that promote the use of SAF?

ICAO’s agreement on CORSIA¹⁴ includes several statements aiming for CORSIA to be the only market-based measure for CO₂ emissions in aviation.

- Introduction: “Recognizing that MBMs [market based mechanisms] should not be duplicative and international aviation CO₂ emissions should be accounted for only once”

⁸ ICAO, Available from: <https://www.icao.int/environmental-protection/Pages/default.aspx>

⁹ CORSIA (2018) Available from: https://www.iata.org/pressroom/facts_figures/fact_sheets/Documents/corsia-fact-sheet.pdf

¹⁰ ICAO, Available from: https://www.icao.int/environmental-protection/Pages/A39_CORSIA_FAQ2.aspx

¹¹ CORSIA Eligible Fuels, ICAO, accessed July 2019 <https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx>

¹² Sustainability of CORSIA Eligible Fuels, ICAO, 2019

<https://www.icao.int/Meetings/SAFStocktaking/Documents/ICAO%20SAF%20Stocktaking%202019%20-%20AI4-4%20Bruno%20Silva.pdf> and T&E, 2019 <https://www.euractiv.com/section/aviation/opinion/aviation-risks-undercutting-eus-new-renewables-rules/>

¹³ European Commission (2018) Union reply to the State letters sent by ICAO to the Member States on the CORSIA package, Available from: <http://data.consilium.europa.eu/doc/document/ST-6137-2018-ADD-3-REV-1/en/pdf>

¹⁴ ICAO 2016 Resolution A39-3: Consolidated statement of continuing ICAO policies and practices related to environmental protection – Global Market-based Measure (MBM) scheme https://www.icao.int/environmental-protection/Documents/Resolution_A39_3.pdf

- Introduction: “Emphasizing that the decision to develop a global MBM scheme for international aviation reflects the strong support of Member States for a global solution for the international aviation industry, as opposed to a possible patchwork of State and regional MBMs”
- Article 19: “Determines that the CORSIA or any other scheme decided by the Assembly is to be the market-based measure applying to CO₂ emissions from international aviation”

A study on the SAF obligation in Sweden concluded that a GHG reduction obligation on fuel suppliers rather than airlines would not constitute a market-based mechanism for CO₂ emissions on international aviation as referred to in the agreement¹⁵. A similar view has been taken in development of the Spanish target: that a Spanish policy promoting renewable energy use (rather than CO₂) by fuel suppliers (rather than airlines) would not be a market-based measure for CO₂ emissions. Nevertheless, there is ongoing debate at ICAO on the interaction between CORSIA and inclusion of aviation in the EU ETS, and on the potential for interaction with other policies which could be considered market-based measures. In this study, we have assumed that CORSIA would not present a barrier to an EU or NL policy mechanism on fuels, and would not preclude this mechanism from acting on either airlines or fuel suppliers, given that it would be a policy on fuels, rather than on all CO₂ emissions from aviation.

How would SAF use promoted by another policy mechanism interact with CORSIA targets?

CORSIA Standards and Recommended Practices (SARP) Annex 16 Volume IV ¹⁶ states that: “an aeroplane operator should provide a declaration of all other GHG schemes it participates in where the emission reductions from the use of CORSIA eligible fuels may be claimed, and a declaration that it has not made claims for the same batches of eligible fuels under these other schemes”. This is intended to avoid counting the emissions savings towards more than one target – although this is not necessarily a problem as long as emissions are only counted once, as explained below. Currently, emissions savings from opt-in of SAF to the Netherlands’ Energy for Transport system cannot be counted towards CORSIA or EU ETS (see section 4.3), although this need not be the case under a new policy.

This requirement intends that GHG savings claimed under CORSIA should not be claimed towards compliance with other GHG targets. However:

- The investigation into the Swedish obligation concluded that emissions reductions from use of SAF for refuelling in Sweden should be allowed to count towards compliance with the obligation by fuel suppliers, and also be taken into account towards EU ETS by airlines¹⁷. The report does not explicitly state what the view is on CORSIA, but points out the difference between CORSIA and a national obligation on fuel suppliers, and suggests that it would be unreasonable for airlines not to be allowed to differentiate between fossil jet and SAF.
- This does not necessarily preclude the renewable energy use being claimed towards compliance with a renewable energy target (such as RED II targets and/or a national renewable energy in aviation target), a view taken in discussion on the Spanish policy. As long

¹⁵ SOU 2019 Biojet för flyget, p184, Available from:

<https://www.regeringen.se/493238/contentassets/6d591e58fd9b4cad8171af2cd7e59f6f/biojet-for-flyget-sou-201911>

¹⁶ Annex 16 Volume IV 2.3.3.2 First Edition of Annex 16 — Environmental Protection, Volume IV — Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

¹⁷ SOU 2019 p184 Biojet för flyget, p206, Available from:

<https://www.regeringen.se/493238/contentassets/6d591e58fd9b4cad8171af2cd7e59f6f/biojet-for-flyget-sou-201911>

as the associated GHG savings from international aviation are not claimed in the national inventory this is not seen as a problem

- It is arguable that it should be possible to define an obligation for SAF use using GHG savings as the metric for compliance, as long as the resulting savings from SAF use in international aviation are not counted towards national targets

How would reporting under CORSIA fit with reporting under other schemes?

Under CORSIA international emissions are reported to the State by airlines on an annual basis, in an Emissions Report, including use of CORSIA eligible fuels¹⁸, their origin, feedstock and greenhouse gas savings¹⁹. CORSIA does not require reporting of physical supply of eligible fuel, given that supply chains are co-mingled. Reporting is based on purchasing and blending records. The European Commission has created a dedicated monitoring plan template for the monitoring of emissions for both CORSIA and EU-ETS²⁰. This means that it would be most efficient for any new policy mechanism to follow the same approach as used here to simplify reporting.

International aviation agreements: ICAO and bilateral agreements

The Chicago Convention (1944) prohibits the taxation of fuel on already on-board aircraft. ICAO has policies and guidance material on taxes defined in Assembly Resolution A37-20, Appendix E, as well as in the ICAO's Policies on Taxation in the Field of International Air Transport²¹. This text states that no taxes or similar duties should be levied on fuels. Bilateral agreements, for example the EU–US Air Transport Agreement²², reflect this text. However VAT and other taxes on fuels in some countries do exist,²³ which ICAO is concerned about. There are also many other types of duty and fee not related to fuels, on both domestic and international flights, which vary by country²⁴, including a Dutch flight tax for passengers and freight from 2021 which is under discussion²⁵.

The European Court of Justice has ruled that inclusion of aviation in the EU ETS does not constitute a tax on fuel under this rule, but that a CO₂ tax on fuel would do²⁶. Analysis of SAF policy for Sweden concluded that an obligation on aviation fuel does not constitute a tax, as it does not involve transfer of funds to the state. However, as obligations generally include a penalty for non-compliance, to be paid by the obligated party (such as a fuel supplier), there is a question over whether this would be considered a tax. The Swedish analysis concludes that as the system providing revenue to the state is not a decisive factor in whether the instrument constitutes a tax, the GHG reduction obligation on aviation fuel in Sweden would not constitute a tax. It also considers how policy affecting fuel would be

¹⁸ ICAO (2019) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), Frequently Asked Questions (FAQs), Section 3.78, Available from: https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_FAQs_September%202019_FINAL.PDF

¹⁹ Template of CORSIA eligible fuels supplementary information to the Emissions Report (from aeroplane operator to State) <https://www.icao.int/environmental-protection/CORSIA/Pages/Templates.aspx>

²⁰ NEA 2019 CORSIA obligations 2019-2020 <https://www.emissionsauthority.nl/topics/corsia>

²¹ ICAO (1994) ICAO'S policies on taxation in the field of international air transport, Available from: https://www.icao.int/publications/Documents/8632_2ed_en.pdf

²² European Commission (2007) Available from: <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32007D0339&from=EN#d1e797-4-1>

²³ ICAO (2013) Available from: https://www.icao.int/Meetings/atconf6/Documents/WorkingPapers/ATConf6-wp010_en.pdf

²⁴ ICAO (2013) Available from: https://www.icao.int/Meetings/atconf6/Documents/WorkingPapers/ATConf6-wp010_en.pdf

²⁵ NL government, Dutch flight tax, Available from: <https://www.rijksoverheid.nl/documenten/kamerstukken/2019/05/14/nader-rapport-wijziging-van-de-wet-belastingen-op-milieugrondslag-wet-vliegbelasting> ; documents available from:

<https://www.rijksoverheid.nl/documenten/kamerstukken/2019/09/20/nota-naar-aanleiding-van-het-verslag-wet-vliegbelasting>

²⁶ SOU (2019) Biojet för flyget p182, Available from:

<https://www.regeringen.se/493238/contentassets/6d591e58fd9b4cad8171af2cd7e59f6f/biojet-for-flyget-sou-201911>

considered under Article 15 of the EU-US agreement, which states that adverse effects of environmental policies should be minimised. The report concludes that a policy which acts on fuel suppliers rather than airlines, and which is not discriminatory between national and non-national airlines, is unlikely to be an issue. However it was concluded that this may be a point for discussion within the framework of the agreement. Similarly, discussions on a Spanish policy currently consider that a SAF obligation would not constitute a tax, and in any case would fall on the fuel supplier rather than an airline.

Whilst the views of those who have considered this are generally that an obligation would not be considered a tax, there is no precedent on this. There is also no clear view on whether this would vary depending on whether it was placed on fuel suppliers or airlines, whether or not the penalty for non-compliance was financial, and how this penalty income was used (for example, if redistributed to organisations that did comply, as was previously done in the UK Renewable Transport Fuel Obligation).

WTO

The Netherlands and the EU as a whole are members of the World Trade Organization (WTO). WTO agreements limit members' ability to subsidise fuels, and also introduce policies which will have an impact on trade, for example if these measures are considered to be discriminatory between fuel-producing countries. For example, there are ongoing disputes over the treatment of palm oil under EU policy²⁷.

The Swedish investigation (section 9.5.2) states that (translated) "proposals are designed in a non-discriminatory manner and in compliance with the RED. It must be assumed that Union law is compatible with the agreements". On this basis, it appears that if the policy is designed not to be discriminatory (e.g. not requiring fuel from EU/NL), and is similar to how biofuels policies implementing the RED have been used to date in road transport, the likelihood of WTO challenge is low.

4.2 EU

Renewable Energy Directive

The recast of the Renewable Energy Directive to 2030, or RED II²⁸, allows for Member States to take renewable fuel and recycled carbon fuels used in aviation to count towards their targets for the supply of renewable energy in the transport sector. This includes biofuels and renewable fuels of non-biological origin (RFNBOs, including when used as intermediate products for the production of conventional fuels), and may include recycled carbon fuels. Use of these fuels is not counted towards the denominator, which includes fuel use in road and rail only, but is counted towards the numerator (Article 27). For the purposes of this calculation fuels supplied in the aviation sector shall be considered to be 1.2 times their energy content with the exception of fuels produced from food and feed crops. This article means that there is no obligation for Member States to use SAF, but that if MSs do so, the SAF use can be counted towards RED II targets, providing that they meet sustainability requirements.

²⁷ Bernama, 2019 Malaysia to file complaint against EU's palm biofuel policy with WTO by November
<https://www.theedgemarkets.com/article/malaysia-file-complaint-against-uss-palm-biofuel-policy-wto-november>

²⁸ Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources <http://data.europa.eu/eli/dir/2018/2001/oj>

Renewable fuels (biofuels and RFNBOs), but not recycled carbon fuels²⁹, can also be counted towards MSs overall renewable energy targets in Article 3 of RED II (see more below).

Sustainability requirements in RED II apply to fuels that are used to count towards overall renewable energy shares of MSs (at least 32% in 2030, Article 3), towards the target for transport (at least 14% in 2030, Article 25), towards other renewable energy obligations, or that are eligible for financial support for their consumption. Requirements cover soil, biodiversity, use of high carbon stock land and peatland, sustainable forestry, changes in forest carbon stock, and minimum lifecycle greenhouse gas savings. Sustainability requirements are discussed in more detail in Chapter 7.

RED II sets other requirements which could interact with SAF policy, which only apply to fuels used to meet the Article 3 and Article 25 targets:

- A cap on contribution to the targets by biofuels produced from food or feed crops set at 1% higher than a MS's 2020 contribution for these biofuels, or at 7% contribution, whichever is lowest (Article 26).
- A cap on contribution to the targets by high indirect land use change (ILUC) biofuels with the limit set at an MS's 2019 contribution level for these fuels, unless they are certified as having low indirect land-use change risk. This limit is set to be decreased from 2023 to 2030 to a 0% contribution level.
- A cap on contribution to the targets by biofuels produced from feedstock listed in Part B of Annex IX (waste cooking oils and animal fats) of 1.7 %. However, Member States may modify this limit, taking into account the availability of feedstock, providing this is justified and subject to approval by the Commission
- A sub target for advanced biofuels produced from a list given in Annex IXa (lignocellulosic energy crops, wastes and residues) of at least 0.2 % in 2022, at least 1 % in 2025 and at least 3.5 % in 2030 (after MSs count these fuels at twice their energy content towards the targets)
- MSs can count fuels from feedstocks in Annex IX (a and b) at twice their energy content

How does SAF use count towards RED II targets?

This is still under discussion. RED II covers energy consumed in the EU, so use of SAF in domestic and intra-EU flights should be able to be counted towards RED II renewable energy targets, but renewable energy use in international flights outside the EU may not be counted. . As Article 25 clearly aims at promoting renewable energy use in transport and in aviation, it is expected that SAF use will be counted towards these targets, with a 1.2x multiplier(for non food and feed crop based fuels). In the Netherlands, all SAF use is currently counted towards the RED Article 25 target. It may also be possible for SAF use to count towards Article 3 targets. This is not currently done in the Netherlands.

²⁹ European Commission (2018) (89) of Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources, Available from: <http://data.europa.eu/eli/dir/2018/2001/oj>

Would claiming towards RED II targets preclude claiming GHG emissions savings under another scheme?

Emission reduction obligations and renewables policies are separate, and so should not be considered to be in conflict. As a result, claiming SAF use towards RED II targets would not preclude the GHG emissions savings being claimed under another scheme. There is precedent for this with the co-existence of the RED and Article 7a of the Fuel Quality Directive, which sets a GHG emission reduction obligation on fuel suppliers to road vehicles, non-road mobile machinery, agricultural and forestry tractors, and recreational craft when not at sea. By 31 December 2020 fuel suppliers must reduce GHG emissions by 6% compared with the 2010 fuel baseline standard. Recently it has become stated that in view of the European Commission this obligation is assumed to extend to the years after 2020, i.e. into implementation of RED II, although no official decision has been made on this.

Would RED II sustainability requirements apply to a SAF obligation?

Sustainability requirements in RED II in Article 29 apply to fuels that are used to count towards Article 3, Article 25, towards other renewable energy obligations, or that are eligible for financial support for their consumption. Therefore any policy supporting SAF that was either a renewable energy obligation or a form of financial support for consumption would need to include these requirements. This would include an obligation for SAF in the Netherlands, even if this was not used to count towards any RED II targets.

In addition, the sustainability criteria of any new policy could not go beyond those requirements:

- Article 29 (12): “For the purposes referred to in points (a), (b) and (c) of the first subparagraph of paragraph 1 of this Article, and without prejudice to Articles 25 and 26, Member States shall not refuse to take into account, on other sustainability grounds, biofuels and bioliquids obtained in compliance with this Article. This paragraph shall be without prejudice to public support granted under support schemes approved before 24 December 2018.”

This means that a new policy could not require any higher sustainability standards, such as those set out under specific sustainability certification schemes (see section 7.5).

However, this only applies to the sustainability requirements in Article 29. A different approach is taken to other requirements:

- Article 25 allows MSs to “exempt, or distinguish between, different fuel suppliers and different energy carriers when setting the obligation on the fuel suppliers, ensuring that the varying degrees of maturity and the cost of different technologies are taken into account”.
- Article 26 states that MS can “set a lower limit and may distinguish, for the purposes of Article 29(1), between different biofuels, bioliquids and biomass fuels produced from food and feed crops, taking into account best available evidence on indirect land-use change impact. Member States may, for example, set a lower limit for the share of biofuels, bioliquids and biomass fuels produced from oil crops.”
- Article 27 allows MS to modify the limit on Annex IX, Part B feedstocks “where justified, [...], taking into account the availability of feedstock. Any such modification shall be subject to approval by the Commission”.

As a result, a new SAF policy could differentiate between these fuel types, including setting lower/higher targets/caps than those given in RED II, when approved by the Commission.

The requirements of Article 25, 26 and 27 on crop caps, advanced biofuels, Annex IX, Part B biofuels and high ILUC fuels only apply to fuels used to meet the Article 3 and Article 25 targets. It would be possible to use SAF without meeting these requirements if the SAF used is not counted towards those targets. Nevertheless, sustainability requirements in Article 29 would still need to be met if the SAF use was supported by an obligation or financial support.

EU Emissions Trading Scheme (EU ETS)

Emissions from flights with take-off and landing within the EEA are included in the EU ETS with certain exceptions. International aviation with take-off or landing outside the EEA are exempted until December 2023, when their inclusion will be reviewed on the basis of the progress with implementation of CORSIA. Under the EU ETS biofuels meeting RED sustainability criteria are counted as having zero GHG emissions. This currently provides a small benefit to use of SAF in Europe, as the EU ETS credit price is low (€28/tCO₂ in July 2019³⁰). Debate is ongoing over the potential for this to conflict with the CORSIA provision on being the only global market-based measure applying to CO₂ emissions from international flights.

As well as requirements to meet sustainability criteria, the EU ETS also requires that biofuels reported under the EU ETS have not been accounted for in other GHG regulation systems. This can be done through verified purchase records³¹ or a guarantee of origin system in line with the RED.

The investigation into the Swedish obligation concluded that emissions reductions from use of SAF for refuelling in Sweden should be allowed to count towards compliance with the obligation by fuel suppliers, and also be taken into account towards EU ETS by airlines³².

Currently, SAF use in the Netherlands under the opt-in system is not counted towards EU ETS, but future treatment is under discussion, and so this does not set a condition for this study. Several interviewees stated that they did not see a barrier to obligated SAF use also being used for EU ETS compliance as long as the proof of sustainability is available to the airline, and that GHG savings are not double counted with national GHG savings. This would mean multiple policy support mechanisms being used to cover the costs of SAF use, but again, interviewees considered that there was no legal barrier to this, if agreed upon by NL policymakers.

Overall, it is important that international emissions savings resulting from SAF policies follow whatever approach is finally agreed between CORSIA and EU ETS.

³⁰ Sandbag carbon price viewer, Available from: <https://sandbag.org.uk/carbon-price-viewer/>

³¹ European Commission (2018) The Monitoring and Reporting Regulation –General guidance for Aircraft Operators, Section 5.5 https://ec.europa.eu/clima/sites/clima/files/ets/monitoring/docs/gd2_guidance_aircraft_en.pdf

³² SOU (2019) Biojet för flyget p206, Available from : <https://www.regeringen.se/493238/contentassets/6d591e58fd9b4cad8171af2cd7e59f6f/biojet-for-flyget-sou-201911>

State Aid

Policies which involve transfer of state resources to industry need to comply with EU law on State Aid, under article 107–109 of the Treaty on the Functioning of the European Union (TFEU)³³. This can be in the form of grants, loans, guarantees, investment, waived tax revenues or exemption from fines³⁴. It is possible for some types of support to be exempted from State Aid rules. This can be done through General Block Exemption Regulations (GBERs), which provide a list of specific conditions under which Member States may launch a funding scheme without being required to complete the full notification procedure. This is possible for promotion of renewable energy sources³⁵. Provided the block exemption conditions are met, the organisation is only required to notify the Commission retrospectively. For biofuels, these conditions exclude support for food-based biofuels, and biofuels which are subject to a supply or blending obligation except in certain cases (see below). If the conditions are not met, the organisation must apply for an individual exemption using the full notification procedure which can take at least 3-6 months.

Investigation into SAF policy in Sweden³⁶ looks further into the cases in which support for fuel production is allowed under State Aid rules if an obligation is also present, citing precedent from cases in Finland and Italy. It concludes that this is acceptable if:

- The production cost of fuels from the plant is so high that it would not be competitive under the obligation, compared with either price of fuels that would be supplied, or with a penalty price, and
- The aid would not give rise to significant undue adverse effects on the competition by outcompeting fuels that had not received the support. This would be demonstrated by showing that the plant's production capacity was small compared with the market demand, and/or that the level of support had been set to avoid such effects. For example, this would mean that the support should not cover the whole difference between the production cost and the fossil jet price, but instead the difference between the production cost and the buy-out or market price, subject to maximum levels of support under State Aid.

Further legal analysis of this topic will be needed to ensure that the policy mechanism(s) proposed to support SAF are likely to meet State Aid requirements, and assess whether the full notification procedure would be required.

Restrictions on trade

Article 34 of TFEU prohibits quantitative restrictions on trade between Member States, but as stated in Article 63 this does not preclude restrictions justified on the grounds of “the protection of health and life of humans, animals or plants”, as long as these do not “constitute a means of arbitrary discrimination or a disguised restriction on trade between Member States”. This means that market-

³³ 2012 Consolidated version of the Treaty on the Functioning of the European Union https://eur-lex.europa.eu/eli/treaty/tfeu_2012/oj

³⁴ C/2016/2946 Commission Notice on the notion of State aid as referred to in Article 107(1) of the Treaty on the Functioning of the European Union <https://publications.europa.eu/en/publication-detail/-/publication/fc2abdd-4d75-11e6-89bd-01aa75ed71a1/language-en>

³⁵ Article 41, Commission Regulation (EU) No 651/2014 of 17 June 2014 declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the Treaty, <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32014R0651&from=EN#d1e6306-1-1>

³⁶ SOU 2019 Biojet för flyget, Section 10.2, Available from : <https://www.regeringen.se/493238/contentassets/6d591e58fd9b4cad8171af2cd7e59f6f/biojet-for-flyget-sou-201911>

based policies such as an obligation cannot preferentially support domestic production. The measures should also be proportionate to the policy aim.

4.3 National

Climate policy

A 95% reduction target set for 2050 has been incorporated into the bill for the Dutch Climate Act (Klimaatwet). Only emissions within the Netherlands, such as airport operations, are covered by this target³⁷. As a result, this will not present a conflict with fuels used in international flights.

Energy for Transport system

The first biofuel mandate in the Netherlands was introduced in 2007. This was an obligation on fuel suppliers to supply at least 4% of their fuel, on an energy basis, from biomass by 2010. In 2011 the mandate was raised to 4.25%³⁸. As a consequence of the ILUC Directive, in 2018, the Dutch government updated national obligations on biofuels. The new mandate for the transport sector aims to achieve 16.4% of the energy use from biofuels by 2020³⁹, including double counting. The delivery of biofuels to the Dutch transport market generates tradable renewable fuel units, HBEs (Hernieuwbare Brandstof Eenheden), which allow suppliers to demonstrate that they have met their biofuel obligations. One HBE represents 1 gigajoule of renewable energy that has been delivered to the Netherlands transport market. HBEs are divided into three types depending on the feedstock that has been used to produce the biofuel⁴⁰

- HBE Advanced - advanced biofuels (Annex IX Part a of RED)
- HBE Conventional - biofuels produced from agricultural and energy crops. The contribution from food and feed crop based biofuels is limited to 3% in 2018, rising to 5% by 2020.
- HBE Other – Annex IX part b feedstocks (waste cooking oils and animal fats), renewable electricity, and other types of biofuels not in the categories above

A sub-target is applied to advanced biofuels starting at 0.6% in 2018 rising to 0.8% in 2019 and 1% in 2020 (including double counting). Liquid or gaseous renewable fuels of non-biological origin (RFNBOs) are currently in HBE Advanced, and so count towards the sub-target for 2020. From 2022 onwards RFNBOs will be counted as HBE Other, and will not count towards the advanced sub-target⁴¹.

HBE Advanced and HBE Other may double count towards the targets if a double counting declaration is provided by the fuel supplier. This will be continued for Annex IX until RED II is implemented. From January 2018 onwards, the obligated parties need to demonstrate that the feedstock used for obtaining double counting status has not been intentionally modified so as to become eligible for double counting.

³⁷ CE Delft (2019) Biobrandstoffen in de Nederlandse luchtvaart

³⁸ Dutch Emissions Authority, Available from : <https://www.emissieautoriteit.nl/onderwerpen/algemeen-ev-2018/ontwikkelingen-ev-2018>

³⁹ Overheid.nl (2018), Besluit energie Vervoer, Available from: <https://wetten.overheid.nl/BWBR0040922/2018-07-01>

⁴⁰ Dutch Emissions Authority, Available from : <https://www.emissionsauthority.nl/topics/general---energy-for-transport/renewable-energy-units>

⁴¹ Source: Duurzame Mobiliteit. This is included in the proposal for the new version of chapter 9.7 in the Environment act that implements REDII in Dutch legislation, which will be distributed for public consultation

Obligated volumes are of petrol and diesel supplied to road, rail, non road mobile machinery, agricultural and forestry tractors and recreational craft when not at sea⁴². Companies that have delivered less than 500,000 litres of petrol or diesel on an annual basis are not obligated. The total amount of fuel (including bio-components) that a company has delivered to transport destinations in the Netherlands that are subject to an obligation, is known as the 'taxed delivery for final consumption' (Lte: *levering tot eindverbruik*). Companies register these fuel deliveries in the Energy for Transport Registry. Obligated parties are those companies that have a license for an excise duty warehouse (accijnsgoederenplaats) for mineral oils or are registered addresses for mineral oil importers⁴³. There were 38 obligated suppliers in 2018⁴⁴.

Fuels for the aviation sector are not currently obligated, but fuel suppliers supplying qualifying sustainable aviation fuels can opt-in and benefit from the HBE trading scheme. To do this, the SAF supplier registers the delivered biokerosene in the Registry and provides the proof of sustainability to the NEa, who issue HBEs for the SAF⁴⁵. The SAF supplier then sells the HBEs to obligated fuel suppliers, and sells and supplies the SAF to the aviation market. The SAF is sold as normal fuel, without proof of sustainability, i.e. the sustainability claim no longer applies to the SAF and cannot be further tracked through the system. This decision was made in order to avoid the need for the chain of custody requirements of the RED to be met further down the supply chain, and to avoid double claiming by other parties ... Because of this, the end-user cannot claim the use of SAF, and so under EU ETS the consumed SAF are considered as fossil fuels. The Netherlands is working on implementation of RED II, including on whether the opt-in will be maintained post-2022. The chain of custody approach used for a new SAF policy would not need to match that used under the opt-in.

Climate Agreement

The 2019 Climate Agreement⁴⁶ agreed that there will be an additional amount of maximum 27 PJ of renewable fuels used in the road transport sector by 2030, in addition to the estimated 33 PJ of biofuels in all transport set out in the 2017 National Energy Outlook for 2030. For inland shipping another 5 PJ of sustainable energy carriers (including hybrid electric, hydrogen and sustainable biofuels) has been agreed upon in the Green Deal for Maritime shipping, inland shipping and ports.

The HBE system is being used as a way to account for renewable energy use in the road transport sector, which is also translated into GHG savings for the purposes of the Climate Agreement, within the national GHG budget. Given this, continuing to support SAF through an opt-in to this system is under review, as SAF use could not contribute towards these targets. The Climate Agreement also announced plans for a sustainability framework for biomass used in all applications, to be developed by March 2020⁴⁷.

⁴² Dutch Emissions Authority, Available from: <https://www.emissionsauthority.nl/topics/obligations---energy-for-transport/annual-obligation>

⁴³ NL Government, Staatscourant van het Koninkrijk der Nederlanden, Article 3, Available from : <https://zoek.officielebekendmakingen.nl/stcrt-2018-34392.html>

⁴⁴ Dutch Emissions Authority, Available from : <https://www.emissieautoriteit.nl/onderwerpen/rapportages-ev-2018/documenten/publicatie/2019/07/03/rapportage-energie-voor-vervoer-in-nederland-2018>

⁴⁵ SkyNRG, Available from : <https://skynrg.com/wp-content/uploads/2019/03/Publications-The-voluntary-RED-opt-in-for-aviation-biofuels.pdf>

⁴⁶ NL Government (2019) Climate Agreement, Available from : https://platformduurzamebiobrandstoffen.nl/wp-content/uploads/2019/10/2019_NL-GOV_NationalClimateAgreementTheNetherlands_190628.pdf

⁴⁷ Uitwerking afspraken Klimaatakkoord over duurzame biomassa https://www.tweedekamer.nl/kamerstukken/brieven_regering/detail?id=2019Z14515&did=2019D29767

4.4 Conclusions

Review of international, EU and national policies shows that:

- Interaction of **international policies** and regional and national policies related to SAF are still under discussion. However, aside from a restriction on placing taxes on fuels, international policies do not appear to present a barrier to a SAF obligation in the Netherlands, or place particular requirements on the form of the obligation.
- **European policy** requires that obligations or financial support for biofuels follow the sustainability criteria set out in the Renewable Energy Directive (RED II), even if the fuels are not counted towards RED II targets. State Aid rules are also important: these limit the options for support of crop-based biofuels, and allow additional support alongside an obligation only for fuels with high costs and where competitive impacts can be avoided.
- There are existing **policies and agreements in the Netherlands** to support supply of renewable fuels, including SAF. Although there will be interactions between markets for renewable fuels in different sectors, existing policies and agreements do not restrict the options for a new SAF policy. .

5 Choice of policy mechanism

Summary

- An EU-wide obligation would reduce competitive distortion and carbon leakage, however is likely to be challenging to implement and unlikely to be implemented in the short-term. As a result, this chapter focuses on the design of a Netherlands SAF obligation.
- A blending obligation provides the highest level of assurance that the 14% target will be met, and is also the only option possible if food and feed crop-based biofuels are to be supported. Alternatively, direct financial support for SAF use would provide a reasonable level of assurance that a 14% blend of SAF in aviation can be achieved.
- Practically, there are no substantial barriers to implementing a blending obligation. However under an obligation, additional policies to mitigate cost impacts would be limited to certain fuels due to State Aid rules.
- Supply or demand side policy support could be used as well as, or instead of an obligation. A payment for SAF use could be constructed to give reasonable level of confidence of the target being met, with an advantage of this option being the ability to split the costs of compliance between industry and government if desired.

5.1 Aims of the policy

The high-level aim of the policy mechanism under consideration is to meet the target of at least 14% sustainable aviation fuel used in the Netherlands by 2030. We have defined a number of other aims that the policy should also fulfil:

- Be cost-effective
- Ensure high standards of sustainability
- Promote increasing sustainability and GHG savings
- Reduce the risk of indirect environmental impacts such as carbon leakage
- Reduce the risk of negative economic and social impacts for the Netherlands
- Support the production of renewable aviation fuel in the Netherlands

These are considered in this chapter, on the type of policy mechanism, but also in Chapters 6,7,8 and 9 which consider in more detail supply options, sustainability, production in the Netherlands and economic impacts.

Policies for supporting the uptake of renewable aviation fuel can broadly be categorised as either ‘supply side’ or ‘demand side’ measures. Supply side policies are those that aim to support the production of sustainable aviation fuel, and demand side policies are those that aim to create demand for sustainable aviation fuel. Note that the range of options for providing a payment for production is discussed under demand side policies.

The cost of producing SAF is currently several times higher than the cost of producing fossil kerosene, and it is anticipated to remain more expensive over the coming decades (see section 9). Many, though not all, airlines are unwilling to pay more for SAF than fossil kerosene. Consequently demand for SAF is limited. Therefore the main focus of this section is on policies which can stimulate demand for SAF

(section 5.3), and in particular on a blending obligation (section 5.4). Supply-side policies which could be complementary to these measures are briefly described in section 5.2.

5.2 Supply-side measures

There are a number of supply-side measures which could be implemented in order to increase the production of SAF, and these are reviewed in Table 1. Some supply-side support measures are already in place or will shortly be introduced, although not all of these will necessarily support SAF. Examples include €30M for pilot and demonstration projects accelerating CO₂ emissions reductions, Invest-NL,⁴⁸ the Demonstration scheme for climate technologies and innovations in transport (DKTI)⁴⁹, and a potential €50bn investment fund to support economic growth⁵⁰. The draft Sustainable Aviation Agreement (2019) highlights that a new guarantee facility for SAF producers would be desirable, and expresses the wish to carry out two multi-year demonstration projects in the period up to 2025, for each of which a contribution of €25 - €35 million is requested. .

None of these measures provide a high level of assurance that a 14% blend level will be achieved, therefore they are not considered in detail in this study, but could be complementary to a blending obligation as discussed in section 5.4.12. An important advantage of these supply-side measures, compared to a blending obligation, is that they can be specifically targeted towards producers of SAF based in the Netherlands, although this does not guarantee that the SAF would be sold into the NL market. In addition, there are other possible measures not listed below which could support technologies at earlier stages, such as RD&D funding, or parts of the supply chain, such as waste policy or support for energy crop cultivation. Successful commercialisation of new technologies is likely to require a combination of these approaches in addition to support for the final product (through an obligation or payments).

⁴⁸ PWC (2019) Available from: <https://www.pwc.nl/en/insights-and-publications/tax-news/pwc-special-budget-day/sustainability-business-and-innovation.html>

⁴⁹ MKSubsidy, Available from: <https://www.mksubsidy.com/subsidies/demonstration-scheme-climate-technologies-and-innovations-in-transport-dkti/>

⁵⁰ Rabobank (2019) Dutch Investment Fund, Available from: <https://economics.rabobank.com/publications/2019/august/dutch-investment-fund/> Accessed 8/11/2019

Table 1 Policy measures which could be used to stimulate supply of SAF

Policy measure	Explanation	Example of where this has been used in other country / sector
Demonstration plant funding – loans or grants	Low cost loans or grants can help to finance plants which are seen as risky by other investors. Even if the grant / loan is a small percentage of the total project finance it can demonstrate government support and therefore help developers to secure other investment.	UK Future Fuels for Flight and Freight (F4C) competition
Plant financing guarantees	Government loan guarantees can enable plants to access finance from conventional lenders which would otherwise consider the project too risky.	USDA Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program
Prize	Funding is awarded once a goal has been reached or a challenge has been overcome	Virgin Earth Challenge

5.3 Demand-side measures

Currently there is low demand for sustainable aviation fuel because its production cost is substantially higher than fossil kerosene. Demand-side measures aim to increase demand for renewable aviation fuel, by either **requiring** a certain amount of SAF to be blended into fossil kerosene, or by providing a **cost incentive** to blend SAF into kerosene. Table 2 reviews the key policy measures for stimulating demand for SAF, and assesses their likelihood of meeting the 14% target.

Table 2 Policy measures which could be used to stimulate demand for SAF

Policy measure	Explanation	Likelihood of meeting the 14% target
Carbon pricing	A fee is charged for every tonne of CO ₂ emitted by the aircraft. Renewable aviation fuels pay zero / a reduced fee to reflect lower CO ₂ emissions than fossil kerosene. Analogous to the EUETS.	Could provide sufficient cost incentive to make SAF cost competitive with fossil kerosene if the fee is high enough. As other measures could also be used to reduce aircraft CO ₂ emissions this does not ensure that the SAF target will be met.
Tax exemptions – passenger or flight tax	A tax per passenger or per flight is imposed on airlines, which is waived or reduced if the flight uses SAF (such a tax does not yet exist in the NL but is under consideration).	Could provide sufficient cost incentive to make SAF cost competitive with fossil kerosene if the differential in the tax is high enough. Airline is incentivised to use SAF but there is no requirement for SAF

		use, so low assurance that 14% target will be met.
Differentiated airport fees	Airport fees are reduced / waived if the flight uses SAF	Could provide sufficient cost incentive to make SAF cost competitive with fossil kerosene if the differential in the fees is high enough. The airline is incentivised to use SAF but there is no requirement for SAF use, so low assurance that 14% target will be met.
Payment for SAF use	A payment is provided for every unit of SAF that is used. There are several possible options for the design of the policy: funding could be through an industry levy or through general taxation; distribution could be either on the basis of per unit of fuel supplied or as part of a pre-agreed arrangement. These options are described in more detail below.	If the price provided is high enough it will cover the cost differential between SAF and kerosene. The support scheme could be designed so that a reasonable level of assurance is provided that the 14% target would be met.
Public procurement	Aviation fuel procured directly by the government (e.g. by the military) is renewable.	Public procurement, for example through a scheme similar to SkyNRG's Board Now programme ⁵¹ or KLM's Corporate Biofuel Programme, could guarantee that a certain volume of renewable fuel is used in aviation. However the volumes of fuel procured directly by the government are low compared to fuel used in commercial flights, and the 14% target from the Sustainable Aviation Roundtable only applies to civil aviation.
Cap on fossil jet uplift in NL	Fossil jet uplift is limited to a fixed level, with SAF exempt from the cap	Uncertain whether 14% target would be met as relies on projections of industry fuel consumptions, and would be highly complex to administer
Blending obligation	An actor along the kerosene supply chain (e.g. fuel supplier or user) is required to blend in a certain quantity of SAF.	Provides the highest level of assurance that a 14% blend of SAF in aviation kerosene will be met.

The term 'support for SAF use' in Table 2 is used to generally refer to schemes which pay the SAF user directly for every unit (e.g. tonne or litre or MJ) of fuel that they use. In order to ensure that the scheme

⁵¹ SkyNRG (2019) Board now leads the way towards sustainable flying, Available from: <https://skynrg.com/press-releases/board-now-leads-the-way-towards-sustainable-flying/>

increased the volume of SAF used in the NL, the payment would need to be to the user or supplier of SAF, rather than the producer. This concept covers a number of policy design options:

- Different ways of funding the payment:
 - Industry levy, such as a passenger or flight tax (e.g. SDE+ is funded in this way)
 - General taxation
- Options for distribution:
 - A payment is provided to every unit of SAF used in NL (e.g. feed-in-tariff for renewable electricity)
 - A pre-agreed arrangement with the government determines the price and volume of fuel to be supplied. (e.g. as is done in SDE+ and in the Contracts for difference scheme used to support renewable electricity in the UK)
- Different way to set the basis of the payment:
 - Fixed payment per unit of fuel supplied
 - Fixed payment per unit of fuel supplied, differentiated according to fuel types or production process
 - Payment is given based on the differential between the wholesale kerosene price and a 'strike price'. The strike price could be set in a number of different ways, e.g. set by the government, agreed bilaterally between government and SAF producers, or agreed competitively through a reverse auction.

Currently, this type of support is given for electricity, gas and heat under the SDE+ scheme, (Stimulerend Duurzame Energieproductie), an operating grant for renewable energy producers that covers the difference between the cost and the market price for a fixed number of years. The Dutch Climate Agreement supports supply side measures for advanced biofuels, and will reserve 200 million euros, which it intends to use to increase the production and innovation of sustainable advanced biofuels and renewable synthetic biofuels. The government will assess which instruments are most suitable and will not commit these funds before 2020. This includes the SDE++ (Stimulation of Sustainable Energy Transition) scheme, which is in development⁵², within which technologies will compete based on their GHG savings rather than energy generated. It has not yet been decided which technologies will fall under the SDE++, but inclusion of advanced biofuels is under discussion. According to the Climate Agreement, supported production would be in addition to RED II requirements.

Note that there are barriers to inclusion of SAF under the SDE++ scheme: the SDE++ scheme was conceived to deliver GHG savings to the Netherlands, which would not be possible for SAF. In addition, there are already questions in the Netherlands about giving support to advanced biofuels production that is already incentivised by an obligation, on the grounds that additional GHG savings are not being made. As a result of these factors, if this approach were to be used, a separate scheme for SAF could be preferable. This would also provide the option to tailor the policy specifically to the SAF industry. However, given that many companies producing SAF may also be producing road transport fuels, and therefore be interested in both schemes, a combined scheme or very close alignment may be needed to enable bidders to bid into both in order to make a viable business case, and may be easier to manage for government.

⁵² Stek, January 2019, Broadening subsidy scheme for renewable energy: from SDE+ to SDE++
<https://webcache.googleusercontent.com/search?q=cache:oHPpF4i7YLMJ:https://www.lexology.com/library/detail.aspx%3Fg%3D0a524002-d2ac-4026-8706-8915e96e8f6d+&cd=1&hl=en&ct=clnk&gl=uk&client=firefox-b-d>

5.3.1 Comparison of blending obligation and direct payment for SAF use

The assessment in Table 2 identifies a blending obligation and a direct payment for SAF use as the two demand-side measures most likely to meet the 14% target. Both measures are commonly used to increase the use of renewable energy within a particular sector. For example:

- the HBE scheme in the Netherlands and the Renewable Fuel Standard (RFS) in the USA are both examples of blending obligations for the road transport sector.
- The UK's Contracts for Difference scheme, and the Netherlands' SDE + are direct payment schemes for renewable power. The Renewable Heat Incentive (RHI) in the UK provides a direct payment for every unit of biomethane injected into the gas grid for use in heating.

These two measures are compared in more detail in Table 3, with further discussion below of some potential challenges to implementing these measures to support SAF use in NL.

Table 3 Comparison of blending obligation with direct payment for SAF use

	Blending obligation	Direct payment for SAF use
Types of fuels which could be included in measure	Can apply to all types of SAF. However any other policy mechanisms, when introduced alongside a blending obligation, are limited in the types of fuels that can be supported (see 5.4.12).	Support may not be given to food-based biofuels, but any other fuel types can be supported in the absence of a blending obligation.
Sustainability	Sustainability requirements in RED II in Article 29 apply to fuels under a blending obligation, or financial support for their consumption. Some interviewees were concerned that an obligation would encourage import of unsustainable fuels - however there is no reason this should be the case if sustainability criteria are applied to fuel from any source.	
Strength of signal to SAF industry, i.e. driver for capacity growth	Clear bankable signal of a future market to all industry players. This has been demonstrated through increased interest in advanced biofuels since agreement of advanced biofuel targets in RED II.	Depends on scheme design, but generally weaker than an obligation. Multiple rounds, with fixed volumes, announced at the outset, needed to give future market confidence, and attract new entrants to the sector.
Bearer of cost impact	Costs are borne by the industry. Likely that most costs are passed on to customers, but strategy for doing this is determined by airlines. Measures could be introduced to mitigate cost impacts, but as these could not support waste-based HEFA, limited potential to reduce costs to industry in the near term.	Costs can be spread across both industry and government. If an industry levy were used it could be designed to minimise impacts on the most price-sensitive customers. If government funded will need to justify level of support compared with other sectors
Level of cost impact	Initial high price of fuel as volumes are low. Continuous competitive market will drive down prices as new players enter,	Initial high price of fuel as volumes are low. If costs are fixed at these levels for early funding rounds,

	but limited by prices available in the road sector, and may be counteracted by increasing feedstock costs in the future (see section 9.1.1)	overall costs likely to be higher than with an obligation.
Support for NL production	Under state aid rules could not preferentially support NL-based production.	Potential to preferentially support NL-based production (but would need mechanism to ensure use in NL)
Ease of implementation	Target levels need to reflect realistic assumptions for the speed of capacity growth in response to the mandate, including new entrants, so that the obligated parties are able to source required quantities	May be limited number of bidders in early rounds and so limited competition. Difficulty in fixing appropriate level of support for fuels with high and variable feedstock costs (compared with when this measure is used in electricity sector)

Of the policy measures reviewed in Table 2 and Table 3, the **blending obligation** is the option that provides the highest level of assurance that a 14% SAF blend in kerosene used in the Netherlands will be achieved. It provides the clearest signal to the industry, and a driver for continuous cost reduction. It is also the only option possible if the decision is made to support food and feed crop-based biofuels (see section 7.2), as State Aid rules prohibit any financial support for food and feed based biofuels.

Nevertheless, some of the other policy measures could reduce the price differential between kerosene and SAF, and hence could be considered as ways to partially **finance a blending obligation**. Alternatively such policy measures could be used instead of a blending obligation if crops were excluded, but without a blending obligation, the level of assurance of meeting the 14% target would be lower. Therefore in sections 5.4.1 to 5.4.10 we will consider the specific policy design aspects of a blending obligation. All of the other supply-side or demand-side measures could be used alongside a blending obligation, although there are limitations on the fuels which can be supported, which are not present if these measures are used without a blending obligation. This is discussed in section 5.4.12.

5.4 A blending obligation

The options for the design of a renewable aviation fuel blending obligation in policy are discussed in section 5.4.2 to section 5.4.13. Each option is assessed in terms of a number of key metrics. Only those metrics from the following list which are most relevant or which are differentiators are considered for each option:

- Legal position
- Economic efficiency
- Wider impacts (positive or negative)
- Flexibility for businesses
- Ease of implementation for government
- Potential to encourage technology innovation
- Potential to ensure production is in NL
- Ability to ensure sustainability
- Likelihood of meeting the target

- Risk of emissions leakage
- Certainty for investors

5.4.1 Potential response to a renewable aviation fuel blending obligation

A renewable aviation fuel blending obligation will raise the cost that an airline must pay for fuel, and this is likely to be transferred on to passengers (see section 9). There are a number of possible responses from airlines, passengers and markets to these higher costs. These are described in Table 4, along with a qualitative assessment of whether they are likely to result in GHGs decreasing or increasing (carbon leakage)⁵³. The economic impact for different stakeholders of these potential responses to a blending obligation are considered in section 9. Where policy design choices considered in section 5.4.2 to section 5.4.13 may impact the likelihood of these responses occurring, this has been taken into account.

Table 4 Potential responses to a blending obligation

Response	Explanation	Impact on overall GHGs
Demand reduction	As higher fuel costs are passed onto passengers, some passengers choose not to travel	GHGs decrease
Mode-switching	As higher fuel costs are passed onto passengers, some passengers choose to travel by other modes of transport instead. These generally have lower GHGs per km than flying	GHGs decrease
Tankering	Fuel tankering is the practice of carrying more fuel than is required for one flight in order to reduce or avoid refuelling at a destination airport. Fuel tankering is already a widespread practice within the industry to minimise refuelling costs (it is estimated that in the EU fuel tankering is performed on 15% of flights and partial tankering on a further 15% of flights). ⁵⁴ Increasing fuel costs at some airports could increase the amount of fuel tankered.	GHGs increase (due to avoidance of SAF use and impact of carrying additional fuel)
Alternative routes	Instead of flying through airports where a SAF obligation is imposed on the kerosene, passengers may travel on routes through alternative airports, leading to more of these flights operating over time. This is particularly applicable in the case of transfer flights, where an alternative stopover airport could be used with minimal impact on the passenger.	GHGs increase (due to avoidance of SAF use and potentially longer flight distances)

5.4.2 Geographic scope of obligation

Only a global policy could avoid any carbon leakage, by applying to the whole aviation sector. This was the rationale behind the development of CORSIA. In the longer term, a stronger global policy to support

⁵³ Carbon leakage refers to the situation that may occur if, for reasons of costs related to climate policies, businesses transfer activities to regions outside the jurisdiction of the policy, resulting in an increase in their total emissions (Adapted from European Commission (https://ec.europa.eu/clima/policies/ets/allowances/leakage_en))

⁵⁴ EUROCONTROL Aviation intelligence unit (2019) Fuel tankering in European skies: economic benefits and environmental impact, Available from: <https://www.eurocontrol.int/publication/fuel-tankering-european-skies-economic-benefits-and-environmental-impact>

SAF, either through tightening of CORSIA requirements or an alternative policy mechanism is seen as preferable by many industry players. However, given the time taken to agree the CORSIA agreement, the speed at which it will be implemented, and the challenges of securing global agreement on aspects of the policy such as sustainability, a revised or new global policy is not likely to 2030. As a result, a global obligation is not considered further here. This section considers whether a blending obligation should be imposed either on fuel used in the Netherlands or across the whole EU, termed the geographic scope of the obligation.

The geographic scope of an obligation has an important impact on the likelihood of demand shifting to alternative routes, and tankering. Both of these responses to an obligation have negative GHG impacts (section 5.4.1), and shifting demand to alternative routes can impact on the competitiveness of airlines based within the geographical scope of the obligation (section 9.2).

These impacts are likely to be different depending on the geographic profile of the flight. Flights are broadly classified as origin and destination (O&D) for passengers flying directly between two points, or transfer flights for passengers taking a connecting flight. For clarity and consistency, the use of these terms within this study are given in Table 5. Transfer flights which have a stopover outside of the EU are not specifically considered in this study, they are assumed to be impacted in the same way as Extra-EU O&D flights.

Table 5 Terminology used within this study

Departure region		Stopover region		Arrival region	How referred to in this study
EU	→	N/A	→	EU	Intra-EU O&D flight
EU	→	N/A	→	RoW	Extra-EU O&D flight
RoW	→	N/A	→	EU	Extra-EU O&D flight
EU	→	EU	→	EU	Intra-EU transfer flight
EU	→	EU	→	RoW	Extra-EU transfer flight
RoW	→	EU	→	EU	Extra-EU transfer flight
RoW	→	EU	→	RoW	Extra-EU transfer flight

Advantages of an EU-level obligation

An EU-level obligation would reduce the risk of passengers travelling through alternative routes where a blending obligation is not in place. This risk would be substantially reduced for O&D passengers, and partially reduced for transfer passengers.

- O&D passengers: under national obligations, intra-EU and extra-EU O&D passengers may be able to travel by other transport modes into neighbouring EU MSs which do not have an obligation to make a similar journey (e.g. instead of flying from Amsterdam to Istanbul a passenger can travel by train from Amsterdam to Brussels and then fly from Brussels to Istanbul). Under an EU policy there would be very little opportunity for passengers to do this.
- Transfer passengers: under national obligations, intra-EU and extra-EU transfer flight passengers may be able to use another hub airport in a non-obligated MS (e.g. instead of flying from Exeter to Amsterdam to Mumbai a passenger could fly from Exeter to Paris to Mumbai). These transfer passengers are particularly sensitive to price increases as it does not matter to them where the transfer occurs, so they can search for the lowest-cost option. Under an EU-

wide obligation the transfer could be shifted entirely outside of the geographic scope of the obligation in order to avoid the obligation, for example to the Middle-East or to countries near to the EU which do not implement an obligation e.g. Switzerland.

An EU-level obligation would also reduce the likelihood of fuel tankering. Under an EU-level obligation, airlines would not be able to avoid compliance costs by tankering fuel on intra-EU flights. There may still be some tankering on extra-EU flights.

Options for an EU-level obligation

There are two main regulatory options for an EU-level obligation:

1. An EU-level directive requiring SAF targets **within each MS**, which is implemented by Member State legislation, similar to the Renewable Energy Directive (RED). Whilst the key principles are harmonised at EU level, MSs can transpose the Directive in different ways. This can result in differences between MSs in exactly how the policy is implemented, as is currently the case with implementation of the RED⁵⁵. Alternatively, a Regulation could be introduced requiring MSs to set individual mandates, meaning no option for national interpretation.
2. Introduction of an **EU-wide obligation** with compliance possible anywhere in the EU, with all rules harmonised between MS, such as the EU ETS. Intra-EU flights are already covered under the EU-ETS, but the cost of compliance with the EU ETS is not sufficient to overcome the higher cost of SAF compared to kerosene, so the EU ETS is not driving any SAF use in aircraft. Therefore in order for such a scheme to result in SAF supply it would likely have to be specific to the aviation sector and have a higher cost of compliance than under the EU ETS.

An EU-wide obligation, rather than separate national obligations, would reduce the risk of having a 'patchwork' of different schemes across different MSs which could have different targets, sustainability criteria and administrative requirements. The transposition of the RED, which has resulted in different administrative schemes in each MSs with varying rules on feedstocks, the level of the target and sub-targets for specific fuels, illustrates that option 1 will not necessarily result in complete coherence between MSs. However, an EU-wide obligation allowing trading between MSs may not ensure the target for 14% SAF use in the Netherlands is achieved.

Is an EU-level obligation feasible?

Whilst the majority of interviewees agreed that an EU-level obligation would be preferable to one imposed by a single MS, EU-level policy options are at an early stage of discussion by the Commission with further details anticipated in the Green Deal on the 11th December. Despite interest in a EU level option, it may take several years for an EU-level policy to be agreed and implemented. The main potential barriers to an EU-level obligation are considered to be:

- The challenge of securing agreement from all EU MSs
- The required level of SAF supply, unless the level of the obligation were very low

⁵⁵ ePURE (2018) European Renewable Ethanol: overview of biofuel policies and markets across the EU-28, Available from: <https://epure.org/media/1758/180903-def-rep-overview-of-biofuel-policies-and-markets-across-the-eu-28.pdf>

- The potential for international disputes or legal challenge, which some interviewees considered may be greater if action were taken at EU level than in individual MSs, drawing parallels with the discussions over perceived conflict between CORSIA and the EUETS

The Netherlands could therefore focus on supporting an EU-level obligation. However this is unlikely to be introduced before 2025 and indeed may not be introduced at all. An interim EU-wide measure covering key hub airports only could be administratively easier to introduce, but would still require agreement between Member States.

Conclusion:

An EU-wide obligation would likely entail a lower risk of tankering and flights shifting to alternative routes compared to a NL obligation, however is likely to be challenging to implement and unlikely to happen in the short-term. Even if an EU-wide obligation were implemented, it does not provide strong assurance that the 2030 target for SAF in NL aviation will be met. Therefore the rest of this section focuses on the design of a Netherlands SAF obligation. The introduction of an obligation in the Netherlands does not preclude the Netherlands from later taking part in an EU-wide obligation, although might entail some changes in order to harmonise the two schemes. With this in mind, it would be advisable to match the requirements of a Dutch SAF obligation with schemes introduced by other MSs.

5.4.3 Obligated fuel

The target laid out in the Draft sustainable aviation agreement applies to all fuel uplifted in the Netherlands for civil aviation, regardless of whether it is used for commercial or private use. Concerns were voiced by some interviewees about the requirement for SAF to be physically supplied in the Netherlands as it may cause unnecessary cost and CO₂ impacts from importing fuel, compared to just using the same volume of aviation fuel in its country of production. However to meet the target laid out in the draft sustainable aviation agreement the obligation would need to be imposed on fuel physically supplied in NL, and would need to require the SAF to be physically supplied in NL or through pipelines that supply NL if a book and claim system is allowed. The agreement also aimed to stimulate production in the Netherlands.

Some interviewees also suggested that the obligation should only be imposed on fuel used for O&D flights, in order to avoid imposing competitive disadvantage on transfer flight operators. Transfer passengers are considerably more price sensitive than O&D passengers, and for this reason many studies exclude the possibility of imposing additional costs on transfer passengers. SEO (2018)⁵⁶ consider two scenarios where a flight tax was limited only to O&D passengers, and a third scenario where it is applied to both O&D and transfer passengers depending on the maximum take-off weight (MTOW) of the aircraft. Under the third scenario where the tax is applied to both O&D and transfer passengers, the total number of O&D passengers decreases by 2% whereas the total number of transfer passengers decreases by 5%.

Limiting the obligation to fuel only used by O&D passengers would be administratively complicated as flights would contain both transfer and O&D passengers and the fuel use would have to be apportioned

⁵⁶ SEO (2018) Effecten van een nationale vliegbelasting, Available from: http://www.seo.nl/uploads/media/2018-99_Effecten_van_een_nationale_vliegbelasting_in_2025.pdf

between them. Limiting an obligation only to intra-EU flights was proposed as a more straightforward option to avoid imposing costs on transfer passengers, but this would also place many inter-continental O&D flights outside the obligation. Moreover if the obligation was only limited to fuel used by O&D passengers, it would have to be higher than 14% in order to ensure that the overall target of 14% SAF in aviation fuel is met. Therefore the obligation is assumed to be imposed on all fuel uplifted in NL.

It may be appropriate to exempt from the obligation fuel used for some specific purposes in order to not pass on additional costs to these parties, or because the aircraft used are not compatible with SAF. Under CORSIA, humanitarian, medical, and firefighting flights are exempt, as well as aircraft with a maximum take-off weight (MTOW) of less than 5.7tonnes.⁵⁷

‘State flights’, which include “aircraft used in military, customs, and police services” and specific flights carrying official government representatives are also exempt from CORSIA, as ICAO only covers civil aviation. As the draft sustainable aviation agreement target of 14% only applies to civil aviation,⁵⁸ the blending obligation could exclude fuel used on state flights if required.

5.4.4 Obligated parties

Airlines typically buy fuel through a contract with a fuel supplier. Currently at Schiphol airport, fuel supply can only occur via companies within the AFS consortium: Air BP, Air TOTAL, Chevron Aviation, Shell Aviation, Q8 Aviation, Statoil Aviation, Vitol Aviation, and KLM.⁵⁹ KLM is the only airline within the AFS consortium, therefore KLM can purchase and deliver their own fuels, whereas other airlines have to purchase fuel through one of the eight companies in the AFS consortium. Other Dutch airports are typically supplied by only one fuel supplier, and whilst supply by other companies is in theory possible, interviewees suggested that this would be unlikely.

The two principal options for imposing an obligation are either on the **airline** or on the **supplier of the fuel**.

Two other options not considered further are:

- Airports - Airports do not buy and sell fuel themselves directly. If an obligation were imposed at airports, they would have to pass it on directly to the fuel suppliers or the airlines in order to comply with the obligation.
- Airport fuel handlers - Aircraft Fuel Supply BV (AFS) is a consortium of companies including seven fuel suppliers to Schiphol and KLM airlines. AFS manages the refuelling infrastructure for Schiphol but does not directly buy and sell fuel.

In this section we discuss the main factors that affect the suitability of airlines and fuel suppliers to be the obligated party, and how other schemes have defined the obligated party, to conclude on whether airlines or fuel suppliers should be the obligated party in the case of a NL blending obligation.

Number of obligated parties:

⁵⁷ CORSIA (2019) The second edition of the Environmental Technical Manual (Doc 9501), Volume IV — Procedures for demonstrating compliance with the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) (Available from: <https://www.icao.int/environmental-protection/CORSIA/Pages/ETM-V-IV.aspx>)

⁵⁸ Aviation Roundtable (2019) Draft sustainable aviation agreement

⁵⁹ CAPA Centre for Aviation (Available from: <https://centreforaviation.com/data/profiles/airports/amsterdam-schiphol-airport-ams>)

Obligating a fuel supplier would impact less than 10 companies. Most of these companies already supply the road transport sector and therefore have experience of fuel obligation schemes, albeit in different business units from their aviation fuel supply business unit.

Over 100 airlines fly in and out of Schiphol airport, therefore **obligating airlines** would result in significantly more obligated parties than obligating fuel suppliers.⁶⁰ If this number of obligated parties is likely to prove an administrative challenge for the government it would be possible to introduce an exemption for airlines which uplift less than a certain volume of fuel (or fly few flights from the Netherlands) so that the number of obligated parties would be limited whilst still covering the vast majority of fuel uplifted in the Netherlands. This exemption would also prevent the obligation falling on airlines which make emergency or unplanned landings at Schiphol. However, the exemption would increase competitive distortion between obligated and non-obligated airlines.

Point of obligation:

If the obligation is imposed on airlines the most likely control point for measuring the volume of obligated fuel is the point at which refuelling takes place, at the wing of the aircraft. The amount of fuel taken on by the aircraft is recorded in order to charge the airline for the fuel delivered. These records could be used to verify the volumes of obligated fuel reported by each airline. A challenge to this approach perceived by some interviewees is that once the fuel enters the airport supplies are co-mingled,. However this is not a barrier, as the contract between the airline and the fuel supplier would specify the volume of SAF purchased by the airline, so this could be used to verify how much SAF the airline has purchased, even if that volume of SAF has not physically been delivered to their planes. Moreover, airlines will be required to collect information on the volume of fuel that they use in order to report under CORSIA. An obligation on airlines should use this information if possible in order to avoid duplicating work for the airlines. The information that must be transferred by the airlines to the European Commission for the monitoring of emissions under both CORSIA and the EU-ETS using the dedicated monitoring plan template could be used to verify the fuel volumes reported to the Dutch government under a NL blending obligation.

If the obligation were imposed on fuel suppliers, the control point could also be the point of refuelling, using the contract between airline and fuel supplier to determine the volume of fuel from each supplier. If the obligation were imposed on fuel suppliers there could also be other options for the control point, further back in the supply chain. Under the obligation scheme proposed for Sweden, the obligation is imposed at the point of taxation of the fuel known as a 'tax warehouse', which for jet fuel corresponds to registration for a tax exemption. Under the HBE scheme, the obligation is imposed at the taxation point of the fuel. Interviewees considered that a control point at the plane would also be most suitable.

Using a control point at the plane would require sustainability certification to be obtained for the pipelines serving airports. As mass-balance of renewable fuel is allowed under the HBE scheme this is not anticipated to be a substantial challenge within the Netherlands, but could be more challenging for pipeline systems which run between multiple countries.

Cost:

⁶⁰ Schiphol, Available from: <https://www.schiphol.nl/en/airlines/>

There was concern from some interviewees that if the fuel suppliers were obligated then airlines might face a substantial increase in the price they would have to pay for fuel. Interviewees suggested that if the obligation was on the airlines themselves then they could either purchase SAF from fuel suppliers, or purchase SAF directly from SAF producers, and therefore would not be so vulnerable to high prices imposed by fuel suppliers. Several other interviewees disagreed with this view, on the grounds that in a short market, high SAF prices would be as a result of the SAF producers' ability to charge large margins. These high prices would be passed on to the airlines irrespective of whether the obligation was on a fuel supplier or airline. Airlines also have the ability to choose between different fuel suppliers, who will compete to supply at the lowest price. Moreover, it is not clear whether airlines which are not part of the AFS consortium would in practice be able to source SAF directly, so even if the obligation is on the airlines they may still be forced to purchase blended SAF from fuel suppliers. Therefore whilst there is a perception from airlines that they would be able to meet the obligation in a lower-cost way if the obligation were placed directly on airlines, there is limited evidence to suggest this would be the case.

Sustainability:

Airlines were concerned that if the fuel suppliers were obligated, the airlines may not have control over the type of SAF provided, particularly if the sustainability characteristics required by the obligation were not as stringent as their own internal sustainability standards. This could be mitigated if the airlines specify in their request for tender that the fuel they purchase must only contain SAF that meets certain sustainability characteristics. Fuel suppliers would be likely to charge a premium for SAF meeting more stringent sustainability requirements than the minimum set by the policy, but this would be true whether or not the airline or fuel supplier were obligated. Depending on the chain of custody rules, supplying SAF meeting different sustainability criteria to different airlines may be practically difficult and therefore expensive.

Obligated party under other schemes:

- The HBE system obligates fuel suppliers
- The proposal for a blending obligation in Sweden suggests it should be implemented at the point of tax liability (which in the case of jet fuel is a tax deferral), which normally falls on the fuel supplier
- The proposed blending obligation in Spain would be imposed on the fuel supplier
- The Norwegian obligation will be imposed on the fuel supplier

Overall:

Whether the obligation is imposed on either the fuel supplier or the airline, the cost burden ultimately falls on the airline. There are not substantial challenges associated with either approach. An obligation on fuel suppliers would maintain consistency with the proposals of other European countries, therefore could facilitate easier integration of a Dutch blending obligation with a future EU-wide blending option.

5.4.5 Links with the HBE system

The Netherlands has allowed renewable fuel used in the aviation sector to be eligible for HBEs since 2015⁶¹. Suppliers of aviation fuel are not obligated but they can receive HBEs for the supply of SAF. However today the volumes of renewable aviation fuel supplied remain low.

When imposing an obligation on the aviation sector this could either be done by bringing aviation fuel within the HBE scheme, or by creating a separate aviation fuel obligation scheme. If aviation fuel is brought within the HBE scheme this could be done in three different ways:

- (a) Target of 14% is set, including road and aviation fuel in the denominator (currently only road fuel is in the denominator). Obligation can be met using either road or aviation fuel;
- (b) Target of 14% is set, including road and aviation fuel in the denominator. Obligation can be met using either road or aviation fuel, aviation fuel counts multiple times towards targets (e.g. 1.2x multiplier introduced in RED II).
- (c) Target of 14% is set, including road and aviation fuel in the denominator. A sub-target is set for how much of the renewable fuel must come from SAF.

Under option (a), although the obligation is on the total volume of road + aviation fuel, the obligation can be met in the cheapest way possible. Given that SAF is typically more expensive to produce than road transport fuel, this is unlikely to result in significant supply of SAF into the market. Option (b) is more likely to result in SAF being supplied into the aviation sector, but also provides no guarantee of this. Moreover, both options (a) and (b) present a risk towards achieving the 2019 Climate Agreement targets which apply only to the road transport sector (see section 4.3) or the target for 14% SAF in the aviation. This is because the obligation could be met using either road or aviation fuel, and so either sector could be under-supplied with renewable fuel and therefore not meet the target. This would also create uncertainty for investment. Therefore, this section focusses on option (c) for integration of an aviation obligation within the HBE scheme, or a fourth option (d) of creating an entirely new scheme. Both of these options effectively create a separate target for the aviation sector, either within the existing HBE scheme (option c) or outside of the existing HBE scheme (option d).

Both option (c) for integration of an aviation obligation within the existing HBE scheme, and the option (d) of creating an entirely new aviation obligation scheme have equal likelihood of meeting the 14% target, and ensure that SAF is actually supplied into the aviation sector. Including aviation within the existing HBE scheme may have some reduction of administrative burden for government and for fuel suppliers to the aviation sector who are also fuel suppliers to the road transport sector. However, aspects of the aviation obligation may be different to the current set-up of the HBE scheme, in terms of which party is obligated, sustainability requirements etc. which may be challenging to implement under the existing HBE scheme.

5.4.6 Metric for the obligation

An obligation could either be imposed in terms of an energy or volume percentage of total fuel supplied/purchased; or in terms of a GHG saving that must be achieved on average across all fuel supplied/purchased. A GHG reduction requirement could in theory be met through a number of other measures, such as new aircraft designs and improved air traffic management, but it is assumed here

⁶¹ SKYNRG, Available from: <https://skynrg.com/wp-content/uploads/2019/03/Publications-The-voluntary-RED-opt-in-for-aviation-biofuels.pdf>

that only the fuels are within scope. Examples exist of both types of schemes. For example, most countries in the EU, including NL, require a blend percentage by energy or by volume of renewable fuel in the road transport sector. The USA Renewable Fuel Standard also requires a minimum blend by volume of renewable fuel, and the Norwegian SAF obligation will be defined as a percentage blend by volume. Germany requires a percentage GHG reduction for fuels used in the road transport sector, and the California Low Carbon Fuel Standard also operates on the principle of a GHG reduction target. An analysis of the potential for a SAF mandate in Sweden recommends that a GHG-based reduction should be required.⁶² This approach is recommended in the Swedish study instead of a volume or energy based blending target because:

- It is considered to be ‘more equitable from a climate perspective’ to directly incentivise GHG reductions, rather than having a volume or energy based blending target, by providing higher incentives for fuels produced from certain feedstocks (e.g. wastes and residues) in order to promote those with the lowest GHG intensities.
- It puts a value on lower emissions in the fuel production process, which is particularly advantageous for Swedish producers which tend to have low process emissions
- Promotes lower emissions in sectors other than the transport sector

The key trade-offs between these two options are detailed in Table 6. Overall, the GHG-based obligation provides a direct incentive for lower GHG emissions per tonne of SAF, but the volume or energy based obligation provides a higher certainty of the 14% target being met and is similar to the existing HBE scheme.

⁶² Statens Offentliga Utredningar (2019) Biojet för flyget, Betänkande av Utredningen om styrmedel för att främja användning av biobränsle för flyget

Table 6 Comparison of volume or energy based obligation vs. GHG-based obligation

	Energy / volume-based obligation	GHG-based obligation
Sustainability impact	A threshold would be required to ensure that each tonne or MJ of fuel made sufficient GHG savings. This would need to be consistent with Article 29 of the REDII (see section 7.5.1). However once fuels had met this GHG saving threshold there would be no extra incentive to make better GHG savings.	A GHG based obligation would incentivise every additional unit of GHG savings made. A GHG threshold would still be required in order to ensure compliance with Article 29 of the REDII (see section 7.5.1).
Ability to increase sustainability over time	The thresholds for GHG savings cannot be increased over time because compliance with Article 29 of the REDII is required (see section 7.5.1).	In theory a GHG-based target incentivises improved GHG performance over time as there is a direct financial incentive to reduce GHG emissions. This could either be achieved by driving GHG emissions reductions within an existing supply chain, or incentivising new fuels with very low GHG emissions. However if the majority of countries in the EU do not have a GHG based target then fuels with a high GHG saving will go to these countries, whereas fuels which only just meet the threshold will go to other countries, so overall there may be no net improvement in GHG saving of renewable fuels.
Likelihood of achieving target	Obligation can be set at 14% in 2030 so target will be met unless obligated parties can pay a buy-out price instead.	The policy administrator would need to estimate the likely GHG saving that can be achieved by SAF in order to estimate what level the GHG-based target should be set at to ensure a 14% blend. Therefore with this method less certainty that a 14% target would be met.
Strength of signal to SAF industry	Industry can anticipate future market volumes and likely value of their products to a certain extent	More difficult for prospective SAF producers to anticipate GHG savings of fuel supplied into the market
Encouraging technology innovation	Encourages innovation to reduce GHG emissions to meet thresholds, but once this is achieved no additional benefit from improving emissions further (though there is a benefit in CORSIA)	Encourages innovation over time to improve GHG performance as this links directly to higher fuel price in the market

5.4.7 Timing and level of obligation

An obligation should aim for 14% SAF in NL aviation fuel in 2030, as laid out by the Aviation Roundtable. Three additional questions should be considered:

- a) The length of time over which the obligation is set beyond 2030
- b) Whether interim targets are imposed between the date of introduction of the obligation and 2030. If interim targets are imposed, the level at which they should be set.

Long-term certainty in the continuation of the obligation, and the level at which it will be maintained is very important in order to provide certainty to investors in plant facilities. Investment decisions being made today will only bring plants online in the mid-2020's, therefore commitment to an obligation only to 2030 provides demand certainty over only at best the first 7 years' of a plant's life. It will therefore have an important positive impact on the certainty provided to investors if the obligation is extended beyond 2030, and would also be in line with the 2050 goal of 100% SAF use in aviation in the Netherlands.⁶³ Previous reports have noted 15 years as a recommended time-scale over which policy certainty should be provided.⁶⁴

Interim targets could be set between the date of introduction of the obligation and 2030, gradually increasing the level of obligation up to 14% in 2030. This would provide several advantages:

- Higher and earlier GHG savings through earlier use of SAF
- Provide operational experience with the administrative and IT system so that there are less likely to be technical issues in 2030
- Start to build up supply chains by creating demand in the years prior to 2030
- Reduce risk of 'one-off' actions that meet 2030 target but do not build up sustainable supply chains of SAF – e.g. HVO plants in 2030 could increase production of HEFA at the expense of road transport fuel.
- Reduce risk of very high prices as a result of shortage of supply during periods of rapid increase in demand

Interviewees were in general supportive of interim targets for giving clarity on the path to 14%, stating that it adds credibility to the 2030 obligation and helps to develop demand certainty and de-risk investment. However more than one interviewee highlighted the fact that interim targets put in place before the first SAF production in the Netherlands (anticipated 2022) would result in supply being met through imports. Current planned plants in NL are likely to be able supply around 2.4% of total kerosene demand in 2022, and future plants anticipated in the Smart and Sustainable Aviation Action Plan could provide 4.4% - 5.6% of total kerosene demand in 2025.⁶⁵ Interim targets at this level could therefore be met from NL supply.

In addition, it was highlighted that interim targets would likely be met through HEFA, so if interim targets are introduced it should be ensured that these do not preclude the development of technologies at lower TRL which could prove more sustainable in the long-term, for example through measures discussed in section 7.4.

⁶³ Aviation Roundtable (2019) Draft Sustainable Aviation Agreement

⁶⁴ CE Delft (2017) Overheidsmaatregelen biokerosene, Available from: <https://www.ce.nl/publicaties/1980/overheidsmaatregelen-biokerosene>

⁶⁵ Dutch aviation stakeholders, 2018, "Smart and Sustainable – Action Plan for Air Transport in the Netherlands", https://www.klmtakescare.com/sites/default/files/Smart%20and%20Sustainable_final.pdf

Overall there are several advantages to imposing interim targets between the date of introduction of the obligation and 2030. It should however be ensured that in the years preceding 2030 interim targets should be set at an appropriate level to provide certainty as supply-chains are built up, without unduly burdening the industry whilst SAF is still available only in relatively limited quantities.

5.4.8 Trading of certificates

Setting up a trading mechanism for the certificates that can be used to meet the obligation enables some obligated parties to physically supply less than their obligated amount of SAF whilst others over-supply so that overall the obligation is met. This is currently allowed under the HBE scheme and under most renewable fuel obligation schemes currently operated in European MSs, so the administrative requirements from doing so are well understood. Allowing trading allows the target to be met in the lowest-cost way across all obligated parties, whilst if trading is not allowed then overall cost of compliance with the 14% target is higher. Trading does not impact the overall likelihood of meeting the target. A traded mechanism could facilitate some fuel suppliers or airlines committing to off-take agreements for volumes of fuel greater than the amount of fuel needed to fulfil their obligation. Such off-take agreements have been important in supporting first-of-a kind SAF plants to-date.

Even if a traded mechanism was not put in place, the timescale over which an obligated party could meet the obligation could still allow some flexibility in supply. For example the obligated party could supply different volumes at different points in time as long as over a given period (e.g. a year) they have supplied the required SAF volume.

It should be clearly defined whether an obligated party is able to meet its obligation with SAF supplied at any airport in the NL rather than at the airport where the obligation occurs. Generally under mass balance principles, without a traded mechanism, this would not be allowed. A traded mechanism would allow this to take place. This could lead to SAF supply at Schiphol but not at smaller regional airports, which would not be a problem as long as overall targets were met.

If trading was allowed, certificates would need to be generated which could be traded between obligated parties. Under the HBE scheme, credits are generated by the SAF supplier. The HBE must be sold on by the SAF supplier to obligated parties, because no party in the kerosene supply chain is obligated. In contrast, under an aviation obligation, either the fuel supplier or the airline would be obligated, therefore the certificate could be generated at the control point for the obligation.

There are many examples from other countries of operating a traded certificate mechanism for meeting an obligation, including those based on a volume or energy based obligation, for example the UK Renewable Transport Fuel Obligation⁶⁶, Italian CICs and US RINs; and those based on a GHG reduction obligation, including the UK GHG Mechanism⁶⁷ and in California's Low Carbon Fuel Standard⁶⁸

Overall, a traded mechanism was favoured by the majority of interviewees. It offers advantages in terms of flexibility of meeting the obligation, and is not challenging to implement.

⁶⁶ Department for Transport (2019) Renewable Transport Fuel Obligation (RTFO) guidance: 2019 ; Available from: <https://www.gov.uk/government/publications/renewable-transport-fuel-obligation-rtfo-guidance-2019> (Accessed 18/11/2019)

⁶⁷ Department for Transport (2019) Manage motor fuel greenhouse gas emissions, Available from: <https://www.gov.uk/guidance/manage-motor-fuel-greenhouse-gas-emissions>

⁶⁸ Ricardo (2018) California Low Carbon Fuel Standard Rethinking Decarbonisation Incentives – Policy Case Studies; Available from: <https://es.catapult.org.uk/wp-content/uploads/2018/10/California-LCFS-Case-Study-FINAL.pdf> (Accessed 18/11/2019)

5.4.9 Eligible fuel pathways

The requirement from the Sustainable Aviation Roundtable is for 14% sustainable aviation fuel. Therefore biofuels and power-to-liquids (PtL) are both eligible fuels. Hydrogen and electricity produced from renewable sources are also eligible. As hydrogen and electricity are not currently used in commercial aviation, and are anticipated to contribute only a very minor proportion of energy use in aviation, specific policy relating to these fuels is not considered further in this study. Recycled carbon fuels are assumed to be not eligible.

5.4.10 Buy-out price

Many existing renewable fuel blending mandates, such as the UK RTFO, have a buy-out price. The buy-out price can be paid if the obligated party does not supply the required amount of fuel, effectively providing an upper limit on the price that will be paid for SAF. The implications of a buy-out price for different stakeholders is explored below, along with how a buy-out price could be set.

Implications of a buy-out price for consumers:

A buy-out price caps the overall cost of the scheme to the consumer because if obligated parties are unable to supply the required volumes then they will pay the buy-out price.

Implications of a buy-out price for SAF producers:

A buy-out price caps the cost that the market is willing to pay for SAF, so SAF produced at a cost above the buy-out price is unlikely to be sold in the Netherlands. This may hamper the development of production processes at an early TRL which currently have high production costs. However this can be mitigated through the provision of additional support to early-TRL processes, as discussed in section 7.4.

A buy-out price also provides some additional certainty to investors in SAF production as it informs them of the upper limit on the support they will receive for SAF. However the key information for investors to understand whether a new plant is viable is likely to be the lower limit on the level of support they will receive. The lower limit of accessible support is determined by the volume and price of the supply of different fuels into the market, hence is not impacted by a buy-out price.

Implications of a buy-out price for obligated parties:

A buy-out price reduces risk to the obligated party that under a situation of limited SAF supply some obligated parties may be forced to pay very high costs for SAF and hence may be at a competitive disadvantage. There is currently very low production capacity for SAF so all purchases are through bilateral contract, and even traded HVO prices are not publicly available. A buy-out price could therefore be an effective mechanism to reduce risk to the obligated parties.

Design of the buy-out price:

The buy-out price should be high enough that it is more advantageous to the obligated party to provide SAF rather than to pay the buy-out price; however it should be low enough so that it provides protection to the consumer and industry that if there are supply problems or unforeseen circumstances. The buy-out should also be at a similar level to that of nearby alternative markets.

A buy-out price under the Swedish obligation, which requires a certain percentage GHG reduction, has been proposed at 6 SEK / kg CO₂eq. The price per tonne of SAF is therefore dependent on the GHG intensity of the SAF. The implied buy-out price per tonne of SAF under a number of different scenarios is shown in Table 7. This effectively caps the cost of compliance at roughly the trading price of HEFA (see section 9).

Table 7 Estimated buy-out price from a SEK6/kgCO₂eq. penalty under a number of different scenarios for fuel GHG intensity (assuming 0.09394 EUR/SEK)

Assumed GHG intensity of SAF (gCO ₂ eq./MJ)	Assumed GHG intensity of kerosene (gCO ₂ eq./MJ)	GHG intensity reduction made by switching from kerosene to SAF (gCO ₂ eq./MJ)	GHG intensity reduction made by switching from kerosene to SAF (kgCO ₂ eq./tonne _{fuel})	Implied buy-out price per tonne of SAF (EUR / tonne SAF)
16	89	73	3142	1771
9	89	80	3443	1940

Proceeds from the buy-out price could be used: (a) to mitigate the cost of compliance for compliant parties, for example by direct payment on the basis of volumes of SAF supplied; (b) or it could be used to indirectly reduce the costs of the industry e.g. by funding demonstration plants. However if the buy-out price is set at the correct level then the revenue received should not be high so the proceeds from the buy-out price would not contribute substantially to mitigating the costs of compliance.

5.4.11 Enforcement mechanism

In order to ensure that the obligation is met, there must be a penalty for non-compliance. Two main options exist for ensuring that the obligation is met – however neither of these would be needed if a buy out was in place:

- A penalty price could be imposed for non-compliance. This effectively has the same impact as the buy-out price by capping the overall cost of compliance, however interviewees suggested the perception of a ‘penalty price’ means they would be less willing to pay it. It is also possible to set a penalty on top of the obligation i.e. if a party does not comply they would need to pay the penalty and supply the obligated volume in the next period. The points noted in section 5.4.10 should be considered when setting the level of the penalty price.
- There could be legal penalties for non-compliance. This enforcement mechanism is currently used under the HBE scheme. It does not place a cap on the overall cost of the scheme to the consumer.

Under the HBE system NEa as the competent authority can use information from the Tax Authority for supervision and verification. This information is not available for kerosene, so for a SAF obligation an alternative method of verification for enforcement purposes may need to be defined.

5.4.12 Mitigation of cost impacts

An obligation imposed on either airlines or fuel suppliers would likely be passed on directly to consumers to some extent, and potentially in different ways (see chapter 9.1.4). Measures paid for from general taxation could be put in place in order to offset the cost to the consumer. Such measures

do not reduce the overall cost of compliance with the mechanism, but would simply spread the cost across the general population (via taxation) rather than just across the aviation industry. Reducing the cost to the industry by financing an obligation through general taxation would reduce the severity of the potential response to a blending obligation. This would mitigate the negative economic impacts of these responses, which are discussed in section 9. A reduction in tankering and travelling via alternative routes would have a positive impact on GHGs, whilst lower levels of mode shifting and demand reduction would have a negative impact on GHGs.

Of the potential policy mechanisms described in Table 2, the following mechanisms could be used to offset the cost of compliance with a blending obligation.

- Supply side policies, as described in section 5.2:
 - Demonstration plant funding
 - Plant financing guarantees
 - Prizes
- Demand side policies, as described in section 5.3:
 - Tax exemption
 - Differentiated airport fees
 - Government support or payment for SAF used

As explained in section 4.2, State Aid rules exclude support for food-based biofuels, and biofuels which are subject to a supply or blending obligation, unless a) the production cost of fuels from the plant is so high that it would not be competitive under the obligation, compared with either price of fuels that would be supplied, or with a penalty price and b) that the aid would not give rise to significant undue adverse effects on the competition by outcompeting fuels that had not received the support. This would be demonstrated by showing that the plant's production capacity was small compared with the market demand, and/or that the level of support had been set to avoid such effects. Therefore it could be possible to introduce additional supply or demand side support for non-food SAF routes with high production costs. This would rely on showing that they met the conditions above. The criterion on their production volume being small compared with market demand may be difficult to meet, particularly in early years of an obligation, as one plant capacity for some routes could be a significant proportion of NL demand. However, it is unlikely that financial support could be given to HEFA, given that this is expected to supply the majority of the demand under this obligation. Since financial support cannot be given to HEFA plants, yet HEFA is expected to meet the majority of the SAF demand, it follows that there is limited scope to mitigate the cost impact of a blending obligation on the industry. Price support measures for SAF, including HEFA, could only be carried out if a blending obligation were not also in place.

5.4.13 Integration with other renewable energy support schemes

Airlines and others supported enabling airlines to claim use of SAF under any new NL policy towards CORSIA and EU ETS, provided that the GHG savings from the NL policy are not counted towards NL's national GHG accounts. As all NL flights are international, there are no plans to count these GHG savings towards national accounts, and so this is not a barrier. This would require a chain of custody for fuel and proof of sustainability to the aircraft, for example on a mass-balance basis, which is different from the approach used in the current opt-in. However, no interviewees saw insurmountable

barriers towards this. One action needed would be to decide on chain of custody rules in mixed pipelines, in particular the CEPS pipeline once this is approved for SAF transport.

As explained in section 4.2, counting of SAF use promoted by the new policy towards RED II targets is still under discussion.

5.5 Conclusions

If food and feed crop based biofuels are to be used in aviation in the Netherlands, a blending obligation is the only policy option, as State Aid rules prevent any financial support for food and feed based biofuels. Whatever the decision made on acceptable feedstocks, an obligation provides the highest level of certainty that a desired blend level will be met. However, this is not guaranteed if a buy-out or penalty price is used. An EU-wide obligation would reduce competitive distortion and carbon leakage, however is likely to be challenging to implement and unlikely to be implemented in the short-term.

If an obligation were introduced, there are several options in the design of the policy. The obligated party could feasibly be either the fuel supplier or the airline. An obligation on fuel suppliers would maintain consistency with the proposals of other European countries. An obligation could either be imposed on a volume or energy basis, or on the basis of a required GHG reduction. A volume or energy based obligation provides a higher certainty of the 14% target being met, but the GHG-based obligation provides a direct incentive for lower GHG emissions per tonne of SAF. A long-term and stable policy is important for investor certainty, and introducing interim targets in addition to the 2030 target would likely be beneficial in building up SAF supply-chains.

Under an obligation, provision of support through additional policies to mitigate cost impacts would be limited to certain fuels, again due to State Aid rules. Additional support for the main fuel expected to supply the obligation would be difficult to justify. Support would be possible for routes with higher costs than those expected to supply the majority of the obligation, and which have either small production volumes OR where the level of support given is limited. This support could be in the form of supply side policies (e.g. capital grants) or demand side policies (e.g. SDE++-like system).

If food and feed crop based biofuels are to be excluded from the policy mechanism, supply or demand side policies could be used instead of an obligation, rather than alongside one. In this case, it would need to be established for each fuel pathway whether an obligation or an alternative mechanism (such as one analogous to SDE++) would be more likely to create certainty for investors, promote long term sustainable supply, promote competition, and reduce costs to the industry.

6 Supplying a SAF obligation

Summary

This section presents the development status of SAF routes and analyses possible supply scenarios to meet a 14% SAF obligation in the Netherlands and across Europe.

- There are **10 known conversion routes** to produce SAF. The SAF produced by 6 of these routes is already certified for blends with fossil jet fuel, generally at up to 50%. Only hydroprocessing of oils/fats (HEFA) is at the commercial stage and Alcohol-to-Jet (AtJ) is close to commercialisation. Based on central scenarios of future total aviation fuel demand, a 14% obligation by 2030 would require around **700 kt/yr of SAF in the Netherlands**, before considering any impact of increased cost on demand. If the same 14% obligation level was applied across the whole EU this would correspond to 6,600 kt/yr of SAF.
- If a 14% obligation in the Netherlands was supplied entirely through **HEFA** the total amount of feedstock required would be 880 kt/yr of oils/fats for the jet fuel portion, though the total demand from the plants as a whole could be much higher, as road transport fuel is also produced. If waste oils and fats alone were used, this would require around 18% of the EU potential resource, for which there is growing demand from the road transport sector. To meet the 700 kt/yr SAF demand 1 or 2 additional HEFA plants would be required depending on the plant capacity. Overall, this route is the most feasible option to meet the obligation, but could have feedstock constraints if demand grows fast in other markets.
- For **routes from lignocellulosic feedstocks and power to liquids**, even supplying all of 2030 SAF demand in the Netherlands would lead to feedstock requirements that are very small compared with the EU resource potential. However, these are at the demonstration / early commercial stage, and so there is more uncertainty over their contribution by 2030.
- Scenarios for the **mix of SAF routes supplying 14% of EU aviation fuel demand by 2030**, assuming successful commercialisation of advanced routes show 60-70% supply from HEFA, 15-18% from AtJ, 5-10% from gasification and FT, and 5-7% from pyrolysis, with small contributions from other routes. This would require huge growth in capacity of all routes, a significant share of global waste oils and fats supply, and a global market willing to pay for the associated road transport fuel produced.

6.1.1 Supply routes for SAF to 2030

There are currently 6 certified production routes for SAF, a number of routes in the certification process and several other routes that are not in the certification process yet, but that could reach approval by 2030. The technical and commercial status of all these routes is presented and summarised in Table 8.

Table 8 Summary of SAF routes development status

Route	Certification ⁶⁹	Technology status	Global volumes of jet fuel produced in 2018 (kt/y)
Hydroprocessing oils/fats	HEFA-SPK up to 50% blend	Commercial (TRL 8)	17
Co-processing oils/fats	D1655, up to 5% co-feed	Commercial (TRL 8-9)	No commercial production
Alcohols to Jet	ATJ-SPK up to 50% blend	Demonstration (TRL 6-7)	0.3
Biomass Gasification + FT	FT-SPK up to 50% blend	Demonstration (TRL 6)	No commercial production
Biomass Gasification + FT with Aromatics	FT-SPK/A up to 50% blend	Demonstration (TRL 6)	No commercial production
Direct sugars to hydrocarbons	HFS-SIP up to 10% blend	Prototype (TRL 5) for lignocellulosic sugars, pre-commercial (TRL 7) for conventional sugars	No commercial production
Pyrolysis + upgrading	On going ^a	Demonstration (TRL 6)	No commercial production
Hydrothermal liquefaction	Pre-qualification stage	Demonstration (TRL 5-6)	No commercial production
Aqueous phase reforming	Ongoing (HDO-SPK)	Prototype (TRL 4-5) for lignocellulosic sugars, demonstration (TRL 5-6) for conventional sugars	No commercial production
Power to Liquids + FT	FT-SPK up to 50% blend ^b	Demonstration (TRL 5-6)	No commercial production
a) IH ² catalytic process developed by Shell is undergoing certification			
b) PtL FT jet fuel can be certified as FT-SPK as long as the FT synthesis is based on iron or cobalt catalysts ⁷⁰			

Hydroprocessing of oils and fats (HEFA)

Hydroprocessing of oils and fats is the most mature SAF pathway (currently at technology readiness level (TRL) 8) and the fuel produced through this pathway is certified by ASTM as HEFA-SPK. The production process is the same as for Hydrotreated Vegetable Oil (HVO), a fuel commonly used in the road transport sector, but uses a narrower hydrocarbon cut and includes a more severe isomerisation step that lowers the fuel freezing point. Because of its maturity and simplicity compared to other routes, HEFA is the only type of SAF commercially used today. The main limitation of this route is availability of the waste or vegetable oil feedstocks required. Used cooking oil (UCO) and tallow represent a relatively small resource globally, and the availability of virgin vegetable oil for fuel is constrained by competition with other markets and sustainability concerns. As a result, biofuels from waste oils and vegetable oils have limits to their contribution towards RED II targets (see section 4.2). Novel crops are being investigated in terms of potential and sustainability, such as camelina, carinata and oil-bearing algae. Lastly, larger volumes of SAF could be potentially supplied if High Freeze Point HEFA (HFP-HEFA) was approved as an aviation fuel. HFP-HEFA is very similar to diesel HVO and would require less upgrading compared to HEFA, meaning a lower degree of plant modification than for HEFA. Therefore if HFP-HEFA was approved, HVO capacity could be quickly converted to HEFA provided market drivers were sufficiently strong. However some interviewees considered that given that modification is required, HFP-HEFA may not give much cost or supply capacity benefit compared with HEFA.

⁶⁹ CAAFI, Fuel qualification – Current status, accessed on Oct 2019, http://www.caafi.org/focus_areas/fuel_qualification.html

⁷⁰ D7566 specification, Annex1, article A1.4.1.1

Co-processed oils and fats

SAF can also be produced through co-processing oils and fats at oil refineries with the advantage of exploiting already existing facilities and fuel distribution networks. The integration of lipid co-processing into the refining process is commonly done in a hydrotreater. Typical percentages of co-feed are between 5% and 10% of the total feedstock, although up to 30% co-processing has been achieved in special circumstances. Co-processing of renewable lipids (free fatty acids and fatty acid esters found in oils derived from plants and animal fats) to produce jet fuel is limited to 5% by the ASTM conventional jet fuel standard (D1655). Co-processing vegetable oils may require some equipment and plant set-up modifications, which are minimal below 5% but can become significant above this threshold⁷¹.

Alcohol to Jet (AtJ)

The Alcohol to Jet (AtJ) process turns alcohols into jet fuel. The alcohol used can be produced through conventional processes involving fermentation of sugar or starch crops, such as sugarcane, corn and wheat, or through advanced routes from lignocellulosic feedstocks, such as woody and grassy feedstocks, and wastes. ATJ-SPK bioblends up to 50%v/v have been certified by ASTM since 2016 and the technology is currently at TRL 6-7. The AtJ route offers logistical flexibility because the alcohol catalysis plant does not need to be co-located with alcohol production, and alcohols can be conveniently transported and stored. An issue to consider in relation to this route is the opportunity cost of using the alcohols directly in transport applications (e.g. road and marine) as opposed to converting them to jet fuel, at the cost of additional capital expenditure, efficiency loss and potentially loss of revenue from policy support.

Gasification with Fischer-Tropsch synthesis

The gasification with Fischer-Tropsch synthesis (Gasification+FT) process transforms lignocellulosic biomass or solid waste into road and aviation fuels, such as naphtha, gasoline, diesel and jet fuel, as well as other valuable co-products. The jet fuel produced through the Gasification+FT route was the first to be certified in 2009 under the name of FT-SPK. This type of SAF can be blended with fossil kerosene up to 50%. While a commercially mature route for coal and natural gas-to-liquid routes, the bio-based route is only now approaching TRL 7-8. Challenges faced by this route are the economic viability of scaling down processes to scales suitable for biomass and waste-based systems, the design of processes and catalysts well suited to relatively small-scale systems and the overall efficiency of integrated systems. An option for this route could be co-process the waxes that are produced as a process intermediate at oil refineries, rather than upgrading them in a dedicated plant, to reduce capital requirements. This route is currently being certified by ASTM.

Direct sugars to hydrocarbons (DSHC)

Genetically modified microorganisms can be used to convert sugars into hydrocarbons or lipids. These routes are known as Direct Sugars to Hydrocarbons (DSHC) routes. There are three main routes under development whose products can be further processed into jet fuel: heterotrophic algae or yeast converting sugars into lipids within their cells; genetically modified yeasts which consume sugars and excrete long-chain liquid alkenes (e.g. farnesene); genetically modified bacteria consuming sugars and

⁷¹ Concawe, 2019, "Refinery 2050: Conceptual Assessment", PDF page 32, https://www.concawe.eu/wp-content/uploads/Rpt_19-9.pdf

excreting short-chain gaseous alkenes (e.g. isobutene). Currently biological routes almost exclusively use conventional sugar feedstocks, although pilot projects are testing cellulosic sugars. DSHC routes using conventional sugar feedstocks are at TRL 7-8, while the same processes based on cellulosic feedstocks are at TRL 5. A specific route based on the production of farnesane from sugar is certified as Hydroprocessing of Fermented Sugars - Synthetic Iso-Paraffinic fuels (HFS-SIP) and can be blended with fossil kerosene up to a maximum of 10%. The complexity and low efficiency of converting lignocellulosic sugars into fuels through DSHC translates into high feedstock cost and high energy consumption, which makes DSHC an expensive SAF route.

Pyrolysis and upgrading

Pyrolysis transforms lignocellulosic biomass or solid waste into an intermediate bio-crude oil, which can then be upgraded to road and aviation fuels. The fast pyrolysis to bio-crude oil process is at TRL 8, with several first commercial facilities selling the pyrolysis oil for heating applications. However, refinery upgrading of pyrolysis oils to a finished fuel product is only at the early demonstration stage (TRL 6), with batch production in limited trial runs. Therefore, the overall route from pyrolysis to jet fuel is at maximum TRL 6. KiOR had embarked on the ASTM certification process for bio-kerosene from fast pyrolysis but the company filed for bankruptcy. Now, Shell's catalytic pyrolysis process (IH²) is in Testing Phase 1 of the ASTM's D4054 qualification procedure. At date there is no commercial process for upgrading pyrolysis oil to finished fuel in dedicated plants. However, research into materials and catalysts for such systems is ongoing.

Hydrothermal Liquefaction (HTL)

Hydrothermal liquefaction (HTL) is a process where biomass and water are heated at very high pressures to produce a bio-crude. The near/super-critical water acts as a reactant and catalyst to depolymerise the biomass. The bio-crude produced can then be upgraded similarly to the pyrolysis route. The higher molecular weight distribution makes HTL oil more suitable for diesel production, but gasoline and jet are possible adding hydrocracking steps. HTL is well suited to process very wet biomass (sewage sludge, manure, micro and macro algae), as well as some lignocellulosic feedstocks. Bio-crude production of HTL oils is currently at TRL 5-6 with small scale demonstration activities ongoing. Dedicated upgrading to jet fuel is at lab-scale (TRL 3-4). This route has not entered the ASTM certification procedure and is still in pre-certification stage.

Aqueous Phase Reforming (APR)

The Aqueous Phase Reforming (APR) process catalytically converts biomass-derived oxygenates (such as sugars, sugar alcohols and polyols) into a hydrocarbon mixture that can be separated into a slate of various fuels, including kerosene. APR using conventional sugars is at TRL 5-6 as a result of pilot scale plants operated by Virent. APR derived bio-crude using lignocellulosic sugars has been produced and upgraded to bio-kerosene at lab scale (TRL 3-4). Aviation kerosene produced via APR is in Phase 2 of the ASTM certification procedure and referred as Hydro-deoxygenated Synthetic Kerosene (HDO-SK). Unlike other reforming processes, APR operates in wet conditions which reduces the costs of dewatering certain feedstocks like sugars. However, this process has low selectivity to liquid hydrocarbons (high gaseous yields) and short catalyst lifetime. These two characteristics makes APR expensive from a capital and operational cost standpoint.

Power-to-Liquids with Fischer-Tropsch synthesis

The Power-to-Liquid with Fischer-Tropsch (PtL FT) route produces liquid fuels by catalytically combining a carbon source with hydrogen produced via electrolysis using renewable electricity. This pathway requires three “feedstocks”: electricity, water and a concentrated source of CO₂. The maturity of the PtL FT route depends on the maturity of single components and the design configuration chosen, with some systems being demonstrated at small scale (TRL 5-6). CO₂ from concentrated sources like biogas upgrading, ethanol production or beer brewing, or CO₂ waste streams from industrial processes are commercially available, but other sources, such as direct air capture, are at an earlier stage of development and commercialisation (TRL 6-7). A reverse water gas shift is then needed to convert the CO₂ to CO for reaction with hydrogen in the FT synthesis process. Hydrogen production via electrolysis is a mature technology, though with high costs due to input electricity prices, and high capital costs especially if utilisation is low. Nevertheless, electrolysis has significant further cost reduction potential⁷². FT synthesis is a well-established process at large scale (for gas and coal), but at the demonstration stage for small scale applications (TRL 6-7). FT-SPK produced through PtL is certified under ASTM as long as the FT synthesis is based on iron or cobalt catalysts⁷³. Operating costs for this route can be very high depending on the cost of electricity. Specific capital costs are currently high as the technology is at the early demonstration stage, and the potential to reduce these through scale remains to be demonstrated. Despite being at very early stage with just a handful of active developers, PtL is a pathway attracting widespread interest as a result of its potential to produce fuels with very low GHG emissions, which could be subject to fewer feedstock constraints and sustainability issues than bio-based fuels.

6.1.2 Supplying NL demand to 2030

The **projected jet fuel demand** in the Netherlands in 2030 ranges from 4,100 to 5,400 kt/yr depending on assumptions on traffic volumes, oil prices and macro-economic drivers⁷⁴. Therefore, an obligation requiring 14% of jet fuel to be SAF would correspond to a SAF demand of 580 to 760 kt/yr, if the obligation caused no impact on overall aviation fuel demand as a result of higher prices. For the purposes of this analysis, we have assumed a demand based on PBL’s National Climate and Energy Outlook for 2030 (KEV2019), published November 2019 central scenario of 5,000 kt/yr, which gives a SAF demand of 700 kt/yr. This includes no impact of demand response to price, given that this will vary depending on how the costs of SAF are covered by the industry and government.

The 580 - 760 kt/y range for SAF is aligned with publicly available studies such as the “Smart and Sustainable” action plan (2018)⁷⁵ and CE Delft (2018)⁷⁶. Smart and Sustainable’s SAF demand estimate is based on lower total aviation fuel consumption (4.1 Mt/y in 2030) due to expected energy efficiency improvements. Thus, the 14% SAF demand in this case equals to 574 kt/y, which matches the lower

⁷² E4tech at al 2018 Industrialisation of water electrolysis in Germany: Opportunities and challenges for sustainable hydrogen for transport, electricity and heat <http://www.e4tech.com/the-electrolyser-industry-is-ready-to-scale-to-gigawatts/>

⁷³ Dutch aviation stakeholders, 2018, “Smart and Sustainable – Action Plan for Air Transport in the Netherlands”,

https://www.klmtakescare.com/sites/default/files/Smart%20and%20Sustainable_final.pdf

⁷⁴ Planbureau voor de Leefomgeving (PBL), 2019, “Klimaat- en Energieverkenning (KEV) 2019”, <https://www.pbl.nl/publicaties/klimaat-en-energieverkenning-2019>

⁷⁵ Dutch aviation stakeholders, 2018, “Smart and Sustainable – Action Plan for Air Transport in the Netherlands”,

https://www.klmtakescare.com/sites/default/files/Smart%20and%20Sustainable_final.pdf

⁷⁶ CE Delft, 2018, “Beoordeling Slim én Duurzaam”,

https://d1rkab7tlqy5f1.cloudfront.net/LR/Actueel/News/2018/Q4/CE_Delft_7S95_Beoordeling_Slim_en_Duurzaam_DEF.PDF

bound figure of the latest KEV2019 projections. For comparison, the Dutch consumption of road biodiesel (FAME and HVO) in 2017 was 427 kt/yr⁷⁷.

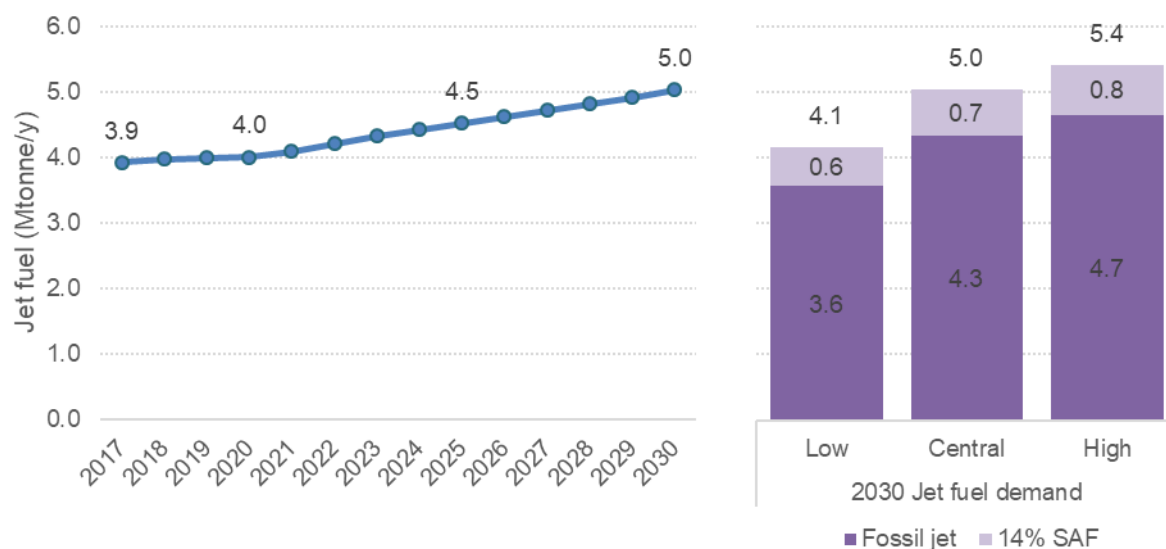


Figure 1 Historical and projected jet fuel consumption in the Netherlands and corresponding SAF volumes in 2030 at 14% of this figure (Source: KEV, 2019)

Considering the current status of the SAF industry, the technological advancement of the routes and the given time horizon, **HEFA will most likely be the predominant production route to 2030**. However, this demand for SAF could be supplied through a **wide range of possible mixes of fuels**, as the demand is relatively small compared to the potential global plant capacity from these routes by 2030. The mix will depend on the success of each route, and the level of policy support for each route in the Netherlands compared with other markets. As a result, rather than making an assumption about the future supply mix in the Netherlands, this section considers the supply-chain implications if **each of these pathways met the total SAF demand alone**, in terms of the feedstock volume and number of plants required.

The fuel product slate of the conversion routes in scope can vary significantly depending on the plant configuration. To address this uncertainty, two scenarios are used for each route:

- an “aviation optimised” scenario, where plants are set up to maximise their jet fuel output, i.e. are built specifically to meet SAF demand
- a “road optimised” scenario in which road transport fuel (i.e. gasoline and diesel) output is maximised. Here producers are primarily aiming to supply the growing road transport market, but building plants with capacity to supply a small proportion of HEFA to give them an option for an alternative market. This is likely where the level of SAF demand and price achievable remains uncertain. Importantly, in both scenarios, the number of plants is sized to meet the aviation fuel demand in the Netherlands. The road fuel produced at the same time could supply NL and other markets – and markets would be required for these products. In a road optimised scenario, the total amount of feedstock required for the plants in which SAF is

⁷⁷ CBS, 2019, online statistics on liquid biofuels for transport – sum of FAME and HVO
<https://opendata.cbs.nl/statline/#/CBS/en/dataset/71456eng/table?ts=1571415839627>

produced is higher than in the aviation optimised case. However, the feedstock allocated to SAF is the same in the two cases.

The full list of product slates assumed for each pathway in the two scenarios is provided in Appendix A.

The **feedstock and number of plants requirement for each route to supply the whole 14% demand alone** are summarised in Table 9 (aviation optimised scenario) and Table 10 (road optimised scenario) and are discussed in more detail in the following paragraphs.

Table 9 Feedstock and plant requirements for each route alone to supply 14% SAF in the Netherlands, in an aviation fuel optimised scenario

Route/scenario	Feedstock example	Total feedstock required	Feedstock allocated to jet fuel	Plants required
Hydropro. oils	Vegetable oils	1262 kt/y	883 kt/y	3
Gasification+FT	Forestry residues	91 PJ/y	46 PJ/y	16
Pyrolysis	Forestry residues	85 PJ/y	51 PJ/y	18
ATJ	Agricultural residues	82 PJ/y	74 PJ/y	5
DSHC	Agricultural residues	89 PJ/y	89 PJ/y	16
PtL FT	Electricity	44 TWh _e /y	22 TWh _e /y	16

Table 10 Feedstock and plant requirements for each route alone to supply 14% SAF in the Netherlands, in a road fuel optimised scenario

Route/scenario	Feedstock example	Total feedstock required	Feedstock allocated to jet fuel	Plants required
Hydropro. oils	Vegetable oils	6310 kt/y	883 kt/y	14
Gasification+FT	Forestry residues	760 PJ/y	46 PJ/y	133
Pyrolysis	Forestry residues	256 PJ/y	51 PJ/y	54
ATJ	Agricultural residues	295 PJ/y	74 PJ/y	20
DSHC	Agricultural residues	-	-	-
PtL FT	Electricity	109 TWh _e /y	22 TWh _e /y	41

HEFA

If the 14% SAF volume was entirely supplied by HEFA, then 883 kt/yr of feedstock would be required to produce the HEFA alone. However, the jet output fraction of a plant hydroprocessing oils and fats is estimated to be 70% of the total fuel output in an aviation optimised scenario, but only 14% in a road optimised scenario. This means that the total feedstock required for the plants producing HEFA and HVO would be 1.3 to 6.3 Mt/y depending on the product slate (Appendix A).

The feedstock for these plants could come from a mixture of vegetable oils and waste oils and fats, such as used cooking oil and tallow. The feedstock which would be considered to have been used to produce HEFA would depend on the demands of the aviation market, which would be set by a combination of the NL SAF policy sustainability criteria, and the requirements of airlines. However, as

most interviewees supported use of waste oils as the main feedstocks for HEFA production, a comparison with the potential for these feedstocks is important.

The Netherlands potential for waste cooking oils is about 60 kt/yr⁷⁸, while the EU has an estimated potential of 1.9 Mt/y of UCO and 2.8 Mt/y of tallow⁷⁹. If the 883 kt/yr feedstock for HEFA alone was entirely sourced in the EU, it would absorb about 18% of the EU estimated potential for UCO and tallow, or the entirety of the UCO volume traded on the market at the moment. If all of the feedstock for hydrotreating plants were sourced from the EU in an aviation optimised scenario, it would absorb about 28% of the EU estimated UCO and tallow potential⁸⁰. Sourcing this level of UCO and tallow to supply the whole feedstock demand for these plants, as well as supplying road biodiesel (FAME) plants and HVO-only plants, would be extremely challenging, given the competition with other countries and other sectors. This would mean that imports from outside Europe would be needed, and that there would be a strong driver for sourcing of other types of oils and fats, if they can be shown to be sustainable. Also note that the projected amount of biofuel corresponding to the RED II Annex IX B cap at EU level is equal to 5.2 Mt/yr HVO in 2030⁸¹. Given the scale of HVO/HEFA demand, this is likely to result in a competition between FAME and HVO/HEFA plants in supplying fuels under this cap. As a result of the many competing demands for waste oils, from the road transport sector and the growing SAF sector, many interviewees considered that supplying 14% NL demand in 2030 by waste oil derived HEFA alone would be very challenging, meaning that either crop-based biofuels would need to be allowed, or advanced routes supported, or both.

In an aviation optimised case, the 700 kt/y of HEFA would be associated with 1 Mt/y total fuel production, which corresponds to the current HVO capacity in the Netherlands⁷⁷ (Figure 3). At EU level there is currently 3 Mt/y operational HVO capacity and another 2 Mt/y is planned to be commissioned by 2023⁸². Thus, the required HEFA in the Netherlands corresponds to 20% of the total 2023 EU HVO/HEFA capacity. Although this level of capacity deployment appears ambitious it could still be achieved by 2030 in an aviation optimised scenario. This scenario would require 3 oil/fats hydroprocessing plants if each plant had a total fuel production capacity of 350 kt/yr.

In a road optimised scenario, the 700 kt/y of HEFA would be associated with 5 Mt/y total fuel production because jet fuel makes up only 14% of the total fuel output (Figure 3). This fuel volume is equivalent to the total operational and planned HVO capacity in Europe. This would imply that the majority of HVO plants planned in the EU would need to include capability to produce HEFA, plus additional non-EU supply or EU aviation-optimised plants, just to provide sufficient SAF for the Netherlands obligation.

⁷⁸ Greenea, 2016, "Analysis of the current development of household UCO collection systems in the EU", PDF page 17, https://theicct.org/sites/default/files/publications/Greenea%20Report%20Household%20UCO%20Collection%20in%20the%20EU_ICCT_20160629.pdf

⁷⁹ Ecofys, 2018, "Technical assistance in realisation of the 2018 report on biofuels sustainability", table 8, PDF page 59, https://ec.europa.eu/energy/sites/ener/files/documents/technical_assistance_in_realisation_of_the_2018_report_on_biomass_sustainability-final_report.pdf

⁸⁰ Ecofys, 2018, "Technical assistance in realisation of the 2018 report on biofuels sustainability", table 8, PDF page 59, https://ec.europa.eu/energy/sites/ener/files/documents/technical_assistance_in_realisation_of_the_2018_report_on_biomass_sustainability-final_report.pdf

⁸¹ Annex IX B cap: 1.7% (energy). Total transport energy demand in the EU in 2030: 320 Mtoe. Assumes all of this is HVO for the purposes of the energy content used in this calculation: in reality it will be a split between HVO and FAME. Source: European Commission, 2019, Results of the EUCO3232.5 scenario on Member States, PDF page 6, https://ec.europa.eu/energy/sites/ener/files/technical_note_on_the_euco3232_final_14062019.pdf

⁸² E4tech advanced biofuel producer database updated to Oct 2019

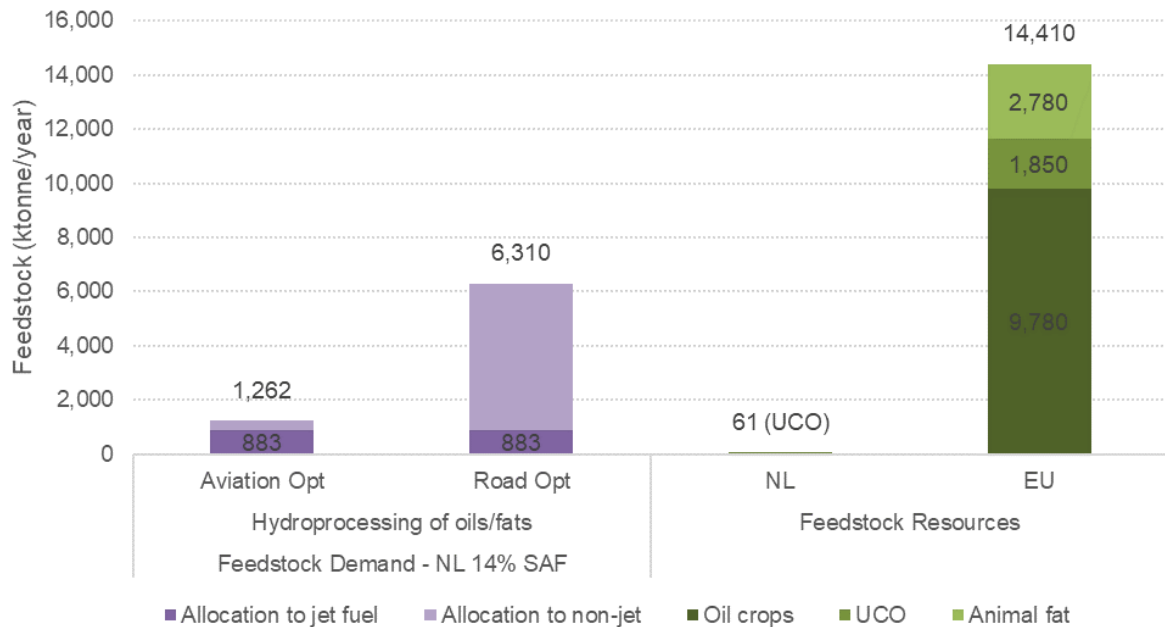


Figure 2 Feedstock requirements to supply 14% SAF in the Netherlands entirely through HEFA. (Feedstock data sources: Ecofys (2018), Greenea (2016), OECD FAO (2019))

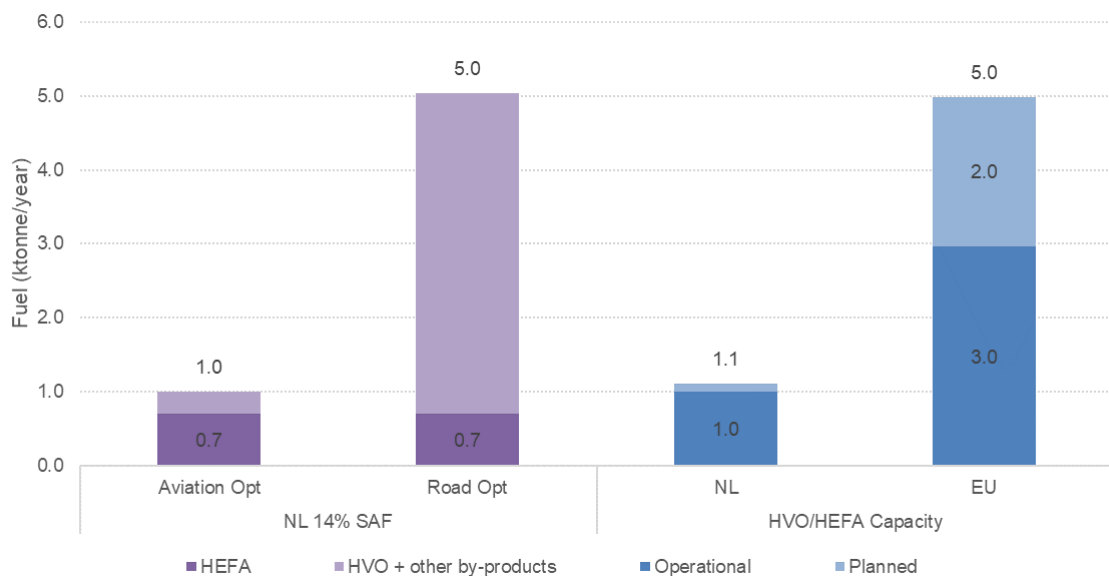


Figure 3 Comparison between HEFA/HVO supply volumes in a 14% SAF scenario in the Netherlands and HEFA/HVO capacity in the Netherlands and Europe. (Known planned capacity as of October 2019)

Lignocellulosic routes

The SAF volume could also be supplied by routes based on lignocellulosic/waste feedstocks such as Gasification+FT and Pyrolysis. In this case a broad range of biomass feedstocks can be used. These feedstocks can be broadly categorised into four groups: forestry residues, agricultural residues (e.g.

straws), energy crops (e.g. miscanthus, willow, poplar) and municipal solid wastes⁸³. Due to the heterogeneity of these types of biomass an analysis based on the feedstock energy content is more suitable than a mass-based one.

In aviation optimised scenarios, both Gasification+FT and Pyrolysis would require about 90 PJ/y equivalent of lignocellulosic feedstock of which 50% and 60% are allocated to SAF, respectively (Figure 4). This can be compared with an estimated 140 PJ/y of domestic biomass resources projected to be available in 2030⁸⁴. These resources represent the amount of lignocellulosic biomass potentially available for energy use considering agreed sustainability standards for agricultural forestry and land management⁸⁵. The feedstock demand associated with a 14% SAF obligation supplied by lignocellulosic routes would absorb the equivalent of 65% of these domestic resources. However, this demand is very small in the context of EU lignocellulosic feedstock potential, which is estimated to be over 20,000 PJ in 2030. In terms of plants, supplying 14% SAF by Gasification+FT would require 16 plants with a nameplate capacity of 90 kt/y, while Pyrolysis would need 18 plants with a nameplate capacity of 65 kt/y.

In road optimised scenarios, the total feedstock demand would be 760 PJ/y for Gasification+FT and 256 PJ/y for Pyrolysis. Both demands are higher than the Netherlands biomass feedstock potential but only about 4% and 1% of the European potential, respectively. However, of the total feedstock demand only around 50 PJ/y are allocated to jet fuel in both cases.

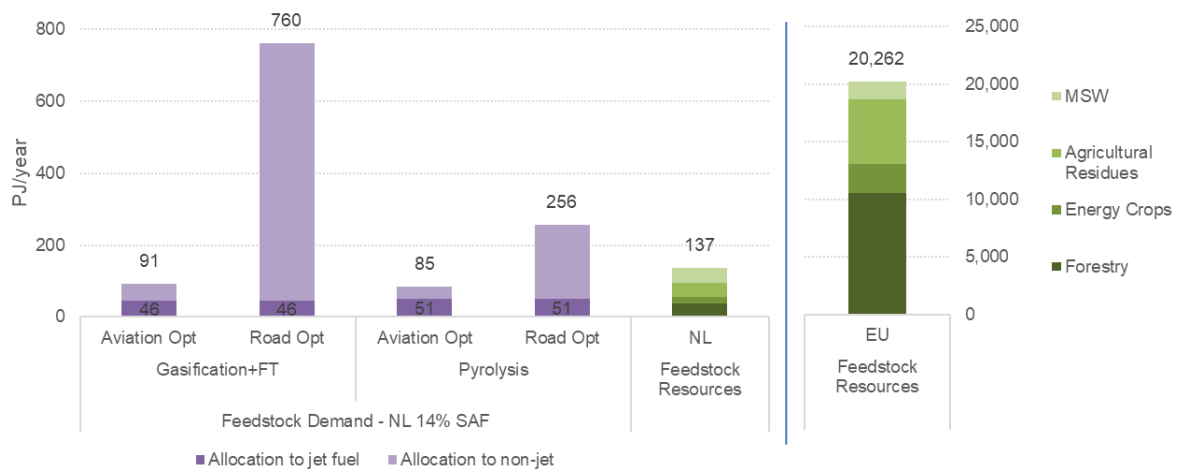


Figure 4 Feedstock requirements to supply 14% SAF in the Netherlands through Gasification with FT or Pyrolysis and upgrading. Feedstock demand volumes refer to supplying the fuel through each route individually. EU feedstock resources are plotted on a different scale. (Feedstock data source: S2BIOM database (2019))

AtJ and DSHC are two other routes that could supply SAF from lignocellulosic feedstocks. Although currently most AtJ and DSHC plants are based on conventional sugars, these routes could be based on

⁸³ Municipal solid wastes are grouped with lignocellulosic feedstocks because they share similar conversion technology. However, municipal solid wastes generally have different chemical composition and properties compared to woody biomass.

⁸⁴ E4tech analysis based on data from S2BIOM database, <https://s2biom.wenr.wur.nl/web/guest/data-downloads>

⁸⁵ Referred as “base potential” in the source.

sugars obtained from lignocellulosic residues. MSW is not considered as potential feedstock for these two routes because it would require unfeasible pre-treatment before being processed.

In aviation optimised scenarios, 100 PJ/yr would be needed for SAF production, through AtJ and DSHC routes as shown in Figure 5. These two routes can produce very high fractions of jet fuel (90-100%), therefore almost the entire feedstock required is allocated to SAF. Supplying 14% SAF through AtJ would require 5 plants with a nameplate capacity of 140 kt/y. DSHC plants are assumed to have typically smaller size (on average 40 kt/y) therefore about 16 plants would need to be built in the Netherlands by 2030.

A road optimised production of SAF through AtJ would require nearly 300PJ feedstock, much higher than the Netherlands resource but very small in the context of EU biomass potential. For this route, it could be possible to produce ethanol elsewhere, and import it to the Netherlands for conversion to SAF. Whereas if DSHC was designed for non-aviation purposes such as road transport fuels or even pharmaceuticals production then no kerosene would be produced by this process⁸⁶. Thus, no feedstock requirement is associated with the road optimised scenario for the DSHC route.

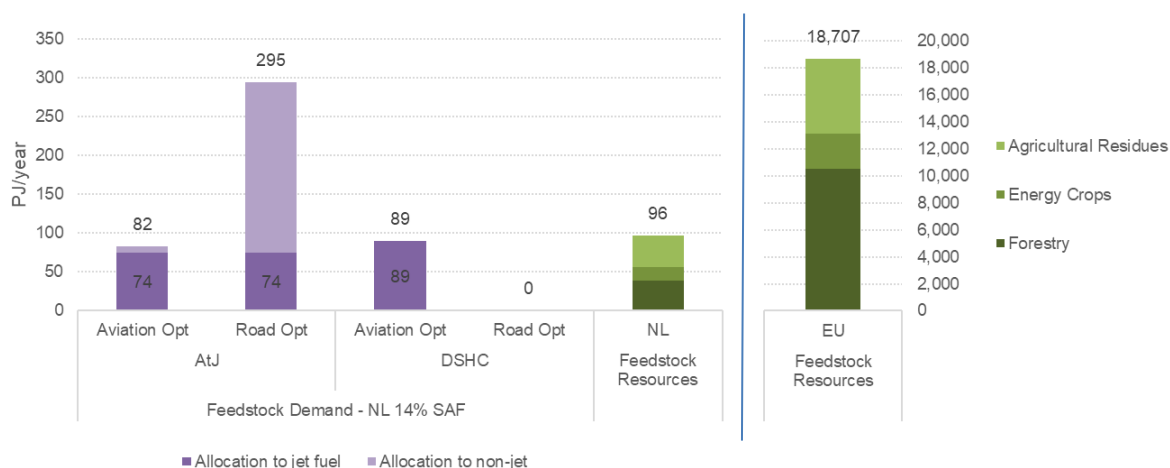


Figure 5 Feedstock requirements to supply 14% SAF in the Netherlands through Alcohol-to-Jet or Direct Sugars to Hydrocarbons. Feedstock demand volumes refer to supplying the fuel through each route individually. EU feedstock resources are plotted on a different scale. (Feedstock data source: S2BIOM database (2019))

Power-to-Liquids

Supplying 14% SAF in the Netherlands through PtL FT would require about 44 TWh/y of electricity in an aviation optimised scenario. Half of this electricity is allocated to SAF production and the rest to other FT co-products. As a comparison, the gross electricity consumption in the Netherlands was 122 TWh/y in 2018, of which 18 TWh was generated from renewable sources⁸⁷. Therefore, meeting the 14% SAF obligation would imply adding an additional 36% of generation by 2030, assuming that this electricity needed to be additional and not displace other uses. If the production of this additional electricity came from wind energy, the aviation optimised scenario would be equivalent to installing

⁸⁶ IRENA, 2017, Biofuels for Aviation, https://www.irena.org/documentdownloads/publications/irena_biofuels_for_aviation_2017.pdf

⁸⁷ Netherlands Statistics, 2019, Hernieuwbare energie in Nederland 2018, <https://www.cbs.nl/nl-nl/publicatie/2019/40/hernieuwbare-energie-in-nederland-2018>

about 1,430 off-shore turbines with a rated capacity of 10 MW, operating with 35% average capacity factor. A road optimised scenario would require 109 TWh/y of electricity to supply 700 kt/y SAF by PtL FT, but this would at the same time generate 2,830 kt of PtL fuels for road.

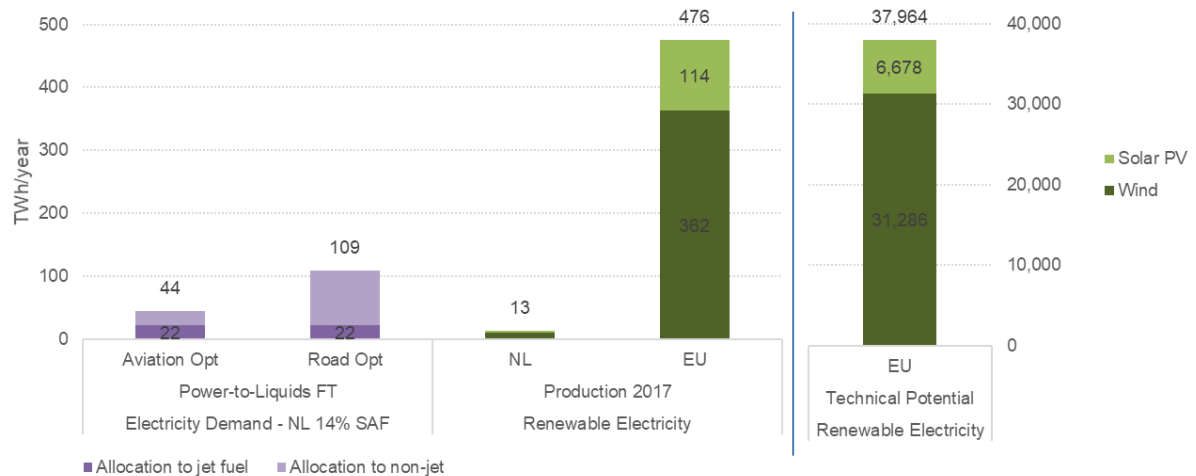


Figure 6 Electricity requirements to supply 14% SAF in the Netherlands entirely through Power-to-Liquids FT. EU feedstock resources are plotted on a different scale. (Sources: IEA (2019), Shell Global Energy Resource database (2018))

6.1.3 Supplying EU demand to 2030

As aviation is an international sector, international approaches to emissions reduction are preferable, to avoid emissions leakage, and ensure a level playing field between different countries and airlines. For this reason, there are ongoing discussions at European level about introducing a SAF obligation across the whole EU. This section explores the feasibility of supplying a 14% SAF if an EU-level obligation were put in place, if the level were set to match the level agreed upon in the Netherlands.

By 2030, the overall projected jet fuel consumption in Europe ranges from 29 Mt/y to 76 Mt/y depending on the level of policy commitment, degree of technology improvement and expected air transport demand (Figure 7). In this analysis two different sets of aviation demand scenarios were compared: EASA 2019⁸⁸ and IEA ETP 2017⁸⁹ scenarios.

- IEA ETP scenarios** simulate the evolution of the energy industry under different policy scenarios. The Reference Technology Scenario (RTS) takes into account today's commitments by countries to limit emissions and improve energy efficiency, including the NDCs pledged under the Paris Agreement. The 2-Degree Scenario (2DS) lays out an energy system pathway consistent with limiting the average global temperature increase to 2°C by 2100. In the Below 2-Degree Scenario (B2DS) technology improvements and deployment are pushed to their maximum practicable limits across the energy system in order to achieve net-zero emissions by 2060 at global level. The B2DS depicts a radical transformation of the aviation sector. In this scenario, by 2060, air transport energy efficiency improves by 68% compared to 2017 levels;

⁸⁸ EASA, 2019, "European Aviation Environmental Report 2019", https://www.easa.europa.eu/eaer/system/files/usr_uploaded/219473_EASA_EAER_2019_WEB_HI-RES_190311.pdf

⁸⁹ IEA, 2017, "Energy Technology Perspectives", <https://webstore.iea.org/energy-technology-perspectives-2017>

70% of the total aviation fuel consumption is supplied by advanced biofuels; a substantial transport demand shifts from aviation to high speed rail.

- **EASA scenarios** are built based on an aviation industry perspective. EASA's projections consist of 6 scenarios created combining 3 different levels of air transport traffic and 2 possible technology improvement pathways. "Frozen Technology" scenarios assume that no improvements will be applied to new aircraft after 2017. In "Advanced Technology" scenarios the aircraft energy efficiency is assumed to improve by 1.6% per year until 2040.

The two sets of scenarios clearly reflect two different perspectives on the evolution of the aviation sector. IEA foresees considerable energy demand reduction in Europe, whereas EASA's projections are representative of a business-as-usual development. Nonetheless, the two sets of scenarios show one overlapping trajectory. The EASA Advanced Technology Low Traffic trajectory closely matches the IEA RTS trajectory from 2030 to 2040. This pathway shows a declining jet fuel consumption in the next two decades which would reach 47 Mt/y in 2030. Since this pathway represents the intersection between EASA and IEA projections it was taken as reference in this analysis. If a 14% EU-level mandate was set in place by 2030, with no demand reduction due to SAF price, this would correspond to a SAF demand of 6.6 Mt/y.

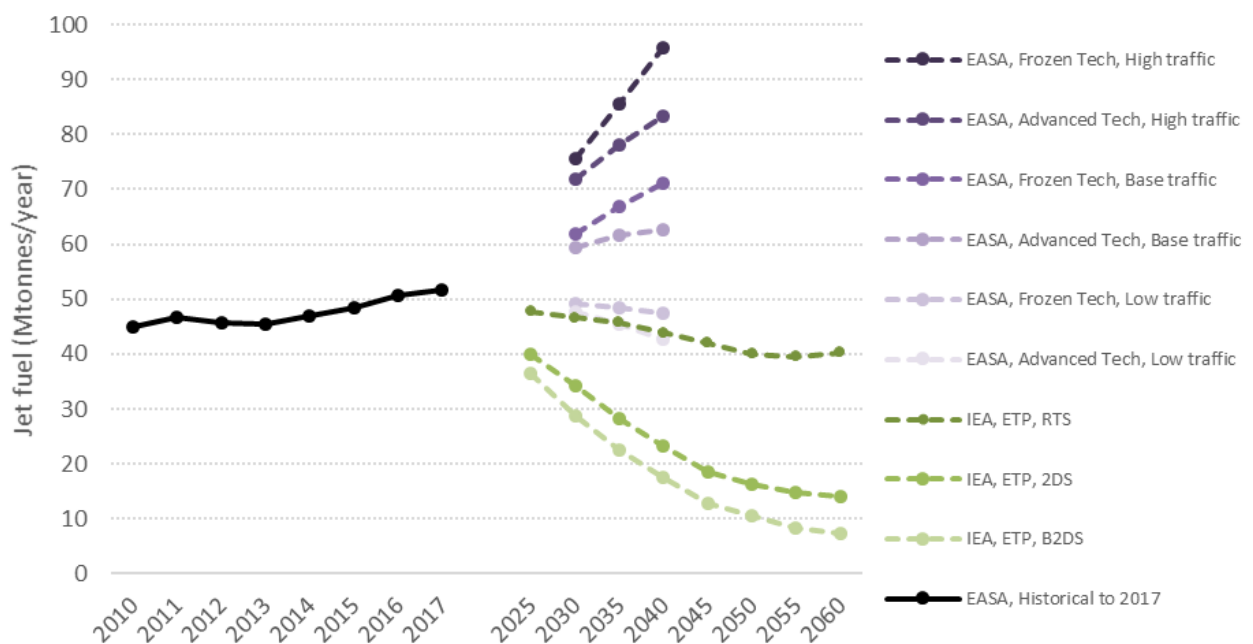


Figure 7 Historical and projected jet fuel consumption in Europe according to multiple scenarios
(Sources: EASA, 2019 and IEA, ETP, 2017)

As for the Netherlands case, this volume of SAF could be supplied through multiple conversion routes, based on different feedstocks. Whilst many interviewees considered that the current status and lowest production costs of HEFA meant that the market would be largely supplied by HEFA, others considered that alternative routes could have potential by 2030, if they were supported by policy and successful in commercialisation. Additionally, HEFA price might increase in the future due to limited resources of UCO and tallow. This short market could drive more investments in development of the other SAF routes.

Anticipating the exact mix of these routes is challenging considering that many of these routes are at an early stage of development and the SAF market is still at an early stage. Nonetheless, some insights can be drawn by estimating the potential SAF capacity ramp-up in the case of a supportive policy environment for all routes, based on the current players and typical project development timelines. E4tech has developed and maintains a ramp-up model of advanced biofuel producers that is used to estimate the potential SAF industry capacity to 2030 at global level. This shows the number of plants that could be built using different routes – although in practice the mix used to supply the SAF market will depend on the relative success and cost of different routes, and the prices available for their products in competing markets. Using this model, the global mix of SAF capacity by 2030 is dominated by HEFA (Figure 8). The second largest potential supply route is AtJ which - by definition - has a higher jet fuel slate and is a more advanced technology compared to other non-HEFA routes.

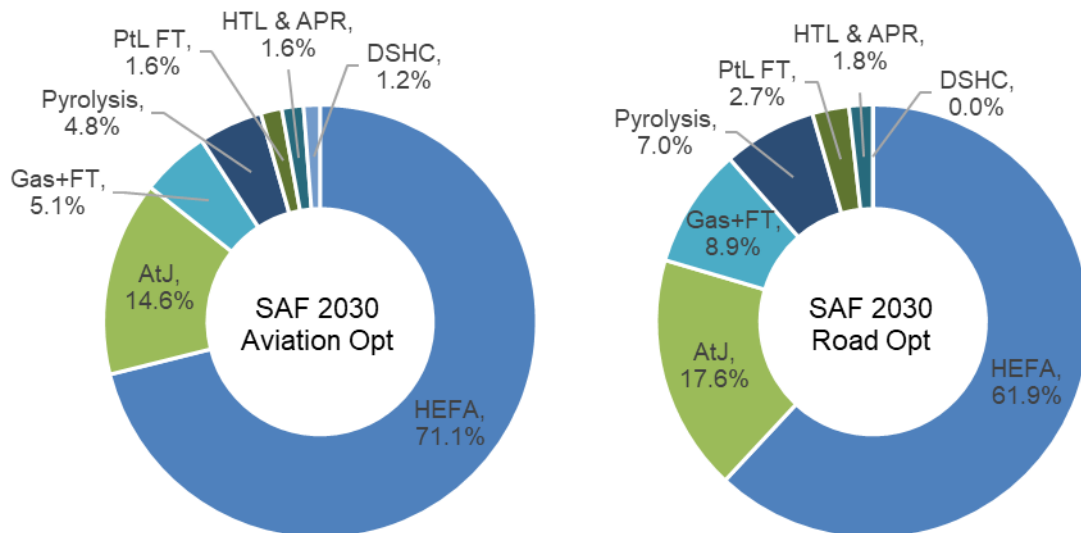


Figure 8 Global mix of SAF production pathways by 2030

Here we assume that the EU market would be supplied by the same mix of pathways as the potential global capacity mix shown above, on the basis that SAF is likely to be a traded product similar to road transport biofuels. From this we estimate the amount of feedstock required by each route applying the same approach as in the Netherlands case. An important distinction must be highlighted here. At Netherlands level, feedstock requirements are illustrative of extreme cases where each route supplies the entirety of SAF volume individually. On the other hand, a supply mix was assumed for the EU analysis. The different approach is justified by the fact that on a single country level a small number of large plants (especially in case of HEFA and AtJ) is more likely to cover the entire national SAF demand.

Scaling up to the regional level, this scenario is less probable due to larger demand, higher number of players increasing competition and a larger pool of heterogenous feedstocks.

The feedstock and number of plants requirement for an EU-level 14% SAF obligation are summarised in Table 11 (aviation optimised scenario) and Table 12 (road optimised scenario) and will be discussed in more detail in the following paragraphs. Note as before that the **scenarios are sized to meet aviation fuel demand** – the associated road transport fuel production varies considerably.

Table 11 Summary of feedstock and plant requirements to supply 14% SAF in the EU through a mix of routes, in an aviation fuel optimised scenario

Route	SAF (Mt/y)	Feedstock example	Total feedstock required	Feedstock allocated to jet fuel	Plants required
Hydropro. oils	4.7	Vegetable oils	8.4 Mt/y	5.9 Mt/y	19
Gasification+FT	0.3	Forestry residues	44 PJ/y	22 PJ/y	8
Pyrolysis	0.3	Forestry residues	38 PJ/y	23 PJ/y	8
AtJ	1	Agricultural residues	112 PJ/y	100 PJ/y	7
DSHC	0.1	Agricultural residues	13 PJ/y	13 PJ/y	2
PtL FT	0.1	Electricity	6 TWhe/y	3 TWhe/y	2
Total	6.5	Mix	542 PJ/y	389 PJ/y	46

Table 12 Summary of feedstock and plant requirements to supply 14% SAF in the EU through a mix of routes, in a road fuel optimised scenario

Route	SAF (Mt/y)	Feedstock example	Total feedstock required	Feedstock allocated to jet fuel	Plants required
Hydropro. oils	4.1	Vegetable oils	36.6 Mt/y	5.1 Mt/y	84
Gasification+FT	0.6	Forestry residues	636 PJ/y	38 PJ/y	111
Pyrolysis	0.5	Forestry residues	167 PJ/y	33 PJ/y	35
AtJ	1.2	Agricultural residues	486 PJ/y	122 PJ/y	33
DSHC	0.0	Agricultural residues	-	-	-
PtL FT	0.2	Electricity	28 TWhe/y	6 TWhe/y	10
Total	6.5	Mix	2748 PJ/y	403 PJ/y	273

HEFA

In an aviation optimised case, HEFA covers 71% of total SAF required, which equals 4.7 Mt/y. Supplying 4.7 Mt/y of HEFA to European airports would be associated with 6.7 Mt/y total fuel production from oils/fats hydroprocessing. This fuel volume is higher than the sum of the operational and planned HVO capacity in Europe and corresponds to 67% of the operational and planned global capacity⁸² (Figure 9). This shows that the level of HEFA supply required to meet a 14% EU-level obligation is high, considering that the operational HVO capacity is currently producing very small quantities of HEFA. Nevertheless,

introducing an EU-level obligation would create an incentive for new plants and for HEFA production (to the extent possible) from existing plants.

If plants were designed to maximise road transport fuel, then 4.1 Mt/y of HEFA would be produced by 2030 and this would be associated with 29 Mt/y total fuel production. Reaching this level of HEFA/HVO production by 2030 appears extremely unrealistic considering the current operational and planned capacity of around 10 Mt/yr and typical project development timelines. However, importantly it also achieves a significant production of road transport fuel, which would make a significant contribution to EU and non-EU biofuels targets.

Under the aviation optimised scenario, 4.7 Mt/y out of the total 6.6 Mt/y would be supplied by HEFA. Producing this amount of HEFA requires 8.4 Mt/y of oils and fats of which 70% are allocated to jet fuel and the rest to HVO and other by-products. The total feedstock required by this route is roughly equal to the current biodiesel production from oil crops in Europe, as illustrated in Figure 10. UCO and animal fat resources potentially available across Europe are estimated to be around 4.6 Mt/y, which would cover only 56% of the feedstock required. Globally 34 Mt UCO and 10 Mt of animal fats are potentially available annually. However, Europe competes with other countries and regions for the exploitation of these resources, across sectors including road transport and oleochemicals. As a result, producers are actively seeking new feedstock options, including oils from crops with lower land impacts, and other sources of waste oils and fats. The availability and sustainability of these feedstocks will need to be assessed to determine their inclusion in RED II Annex IXb (see section 7.3).

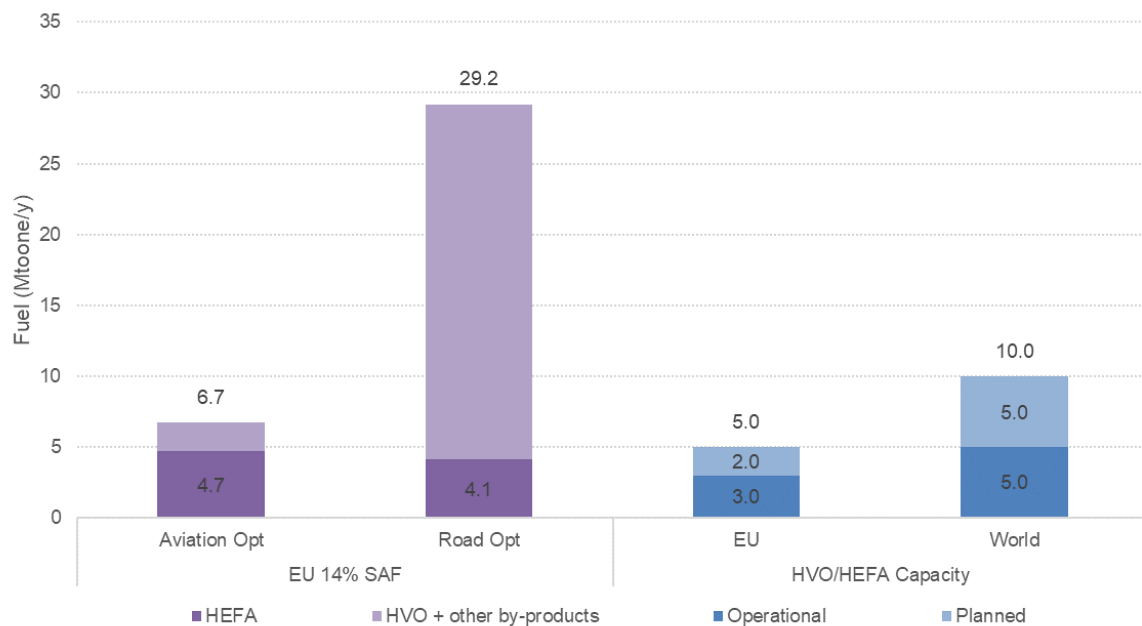


Figure 9 Comparison between HEFA/HVO supply volumes in an EU-level 14% SAF scenario and HEFA/HVO capacity in Europe and globally. (Known planned capacity as of October 2019)

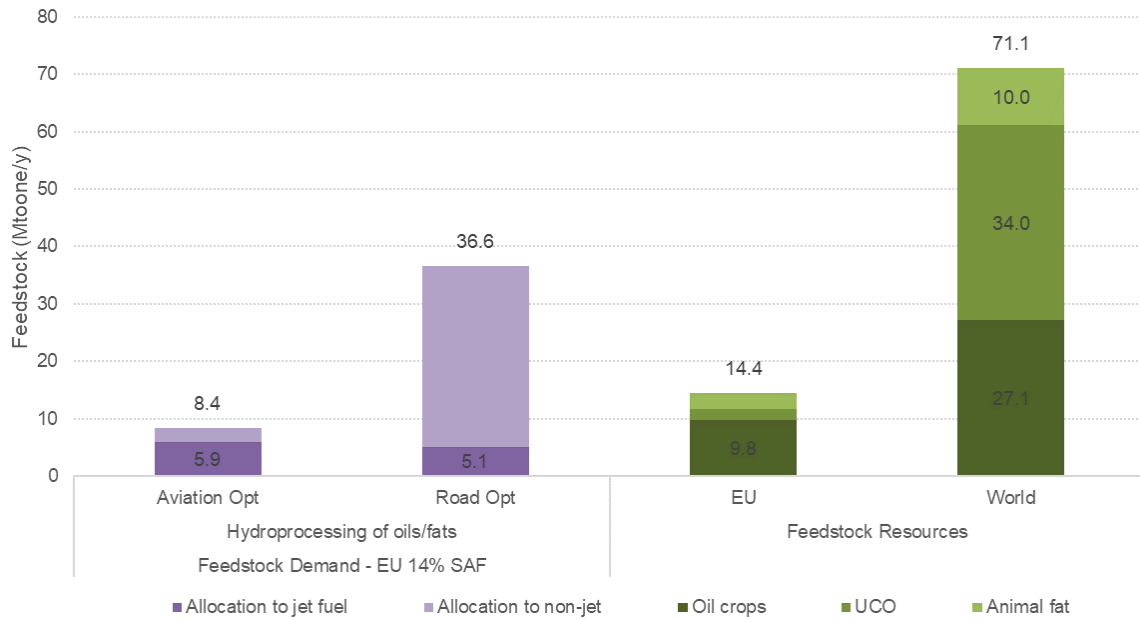


Figure 10 Comparison between feedstock requirements and resource potentials for HEFA in an EU-level 14% SAF scenario. (Feedstock data sources: Ecofys (2018), OECD FAO (2019))

Lignocellulosic routes

If successfully commercialised, the conversion routes based on lignocellulosic feedstock combined altogether could supply between 27% and 35% of the 6.6 Mt/y SAF required to meet a 14% SAF obligation. Among these routes, the main contribution is from AtJ, which would provide 1 - 1.2 Mt/y SAF by 2030 depending on the scenario. In an aviation optimised scenario this level of production corresponds to 7 AtJ plants with a nameplate capacity of 145 kt/y. The second major contribution comes from Gasification+FT, which would provide 0.3 Mt/y SAF in an aviation optimised scenario and 0.6 Mt/y SAF in a road optimised scenario (note that these figures are not the same because these routes has a different contribution to the total under different scenarios). In the first case, producing 0.3 Mt/y SAF would require 8 Gasification+FT plants with a nameplate capacity of 90 kt/y.

Both in an aviation and road optimised scenario the lignocellulosic feedstock required to supply 14% SAF could be largely sourced within the EU. As shown in Figure 11, lignocellulosic resources in Europe are 3 to 4 orders of magnitude higher than the amount required to satisfy the SAF demand covered by lignocellulosic routes. In principle, the EU lignocellulosic resources would be sufficient to supply the entirety of the 14% SAF demand.

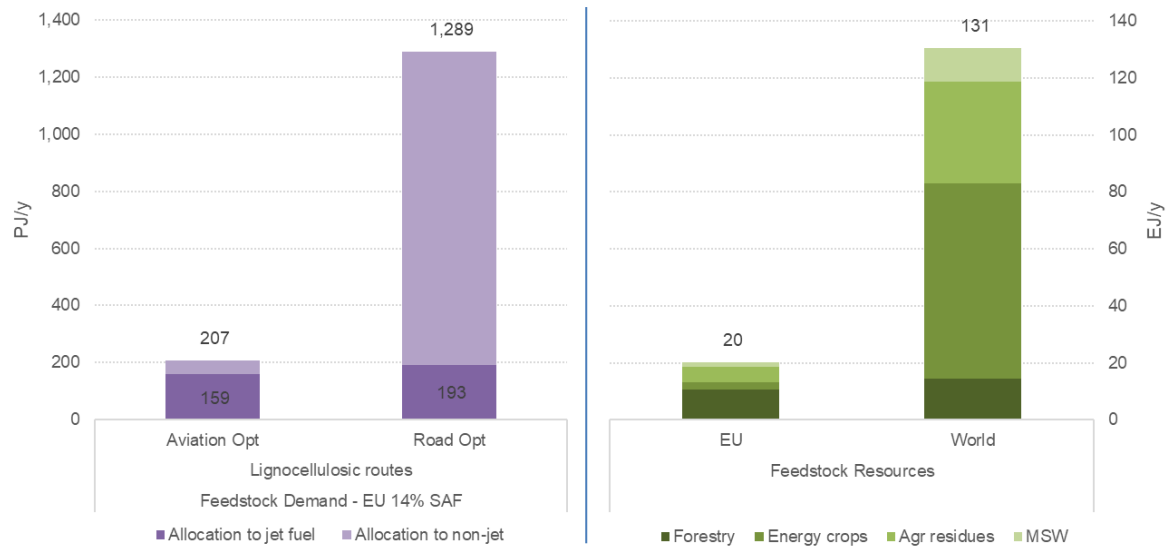


Figure 11 Comparison between feedstock requirements and resource potentials for lignocellulosic routes in an EU-level 14% SAF scenario. Lignocellulosic routes (i.e. Gasification+FT, Pyrolysis, AtJ, DSHC) are grouped together in this chart. EU and global feedstock resources are plotted on a different scale. (Feedstock data source: S2BIOM database (2019), Ricardo Bioenergy Resource model (2017), Gregg & Smith (2010))

Power-to-Liquids

By 2030 the penetration of PtL in the SAF supply mix is likely to be low given its current stage of development. Our modelling estimates a contribution of 1.6%, or 100 kt/y of SAF under this set of assumptions. The corresponding electricity required to produce this volume of SAF and FT co-products ranges between 6 and 28 TWh/y, depending on the product slate configuration (Figure 12). These electricity volumes would have very limited impact on the EU power system representing only 1% - 6% of the current EU electricity generation from wind and solar PV sources. Furthermore, the total EU-wide technical potential from wind and solar PV is two orders of magnitude higher than its current exploitation, therefore there is a large margin to accommodate additional electricity generation capacity dedicated to PtL. This PtL penetration estimate may be conservative, as it is based on its current early stage of development, and limited number of players today. A strong driver for PtL, such as policy support and lower cost renewable electricity could attract more players to the sector faster, bringing a faster ramp up in capacity.

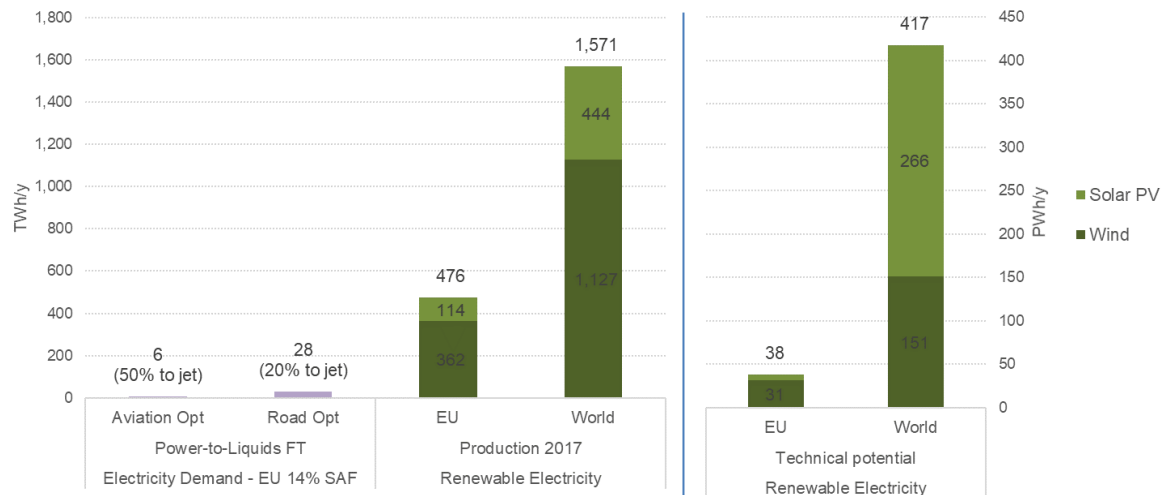


Figure 12 Comparison between feedstock requirements and resource potentials for Power-to-Liquids in an EU-wide 14% SAF scenario. EU and global feedstock resources are plotted on a different scale. (Sources: IEA (2019), Shell Global Energy Resource database (2018))

In conclusion, an EU-wide 14% SAF obligation would be challenging. Assuming successful commercialisation of advanced SAF routes, 14% of EU aviation fuel demand could be supplied by 2030 through a mix of SAF routes: 60-70% from HEFA, 15-18% from AtJ, 5-10% from gasification and FT, and 5-7% from pyrolysis, with small contributions from other routes. This would require huge growth in capacity of all routes, a significant share of global waste oils and fats supply, and a global market willing to pay for the associated road transport fuel produced.

7 Sustainability requirements

Summary

Ensuring the sustainability of SAF used in the Netherlands is very important to all stakeholders, both in terms of preventing use of unsustainable fuels in the near term, and encouraging greater levels of supply of sustainable fuels in the future.

- The extent to which biofuels based on food and feed crops could contribute towards SAF supply is a key option for policy, with widely differing views amongst stakeholders. This will need to be agreed in conjunction with Netherlands policymaking on biofuels in other sectors
- Waste oils are considered as the main near-term route to SAF, but have limited resources. Again, whether or not to limit their use should be agreed alongside policymaking in other sectors
- Incentivising advanced biofuels and renewable electricity (through a sub-target, additional support, or both) is widely supported to increase the sustainable feedstock base and so the potential for SAF supply
- All biofuels will need to meet RED II sustainability criteria from Article 29, which include GHG savings, land use, biodiversity, forest carbon stocks etc. These may not match the requirements of the CORSIA scheme. Clarification of detailed rules for factors such as co-processing, Annex IX feedstocks and additionality of renewable electricity is needed as soon as possible to enable investment.
- No inherent risks of fraud related to SAF use in aviation were identified, however increased demand and prices and new supply chain players could increase fraud risks.

7.1 Introduction

All statements made to date about the supply of SAF in the Netherlands have emphasised the importance of sustainability. In addition, ensuring the sustainability of renewable fuels in road transport has been an important ongoing theme in Dutch and EU level policy for the past 15 years.

- In the “Smart and sustainable plan” of 2018, the Dutch aviation sector set an ambition of 14% SAF, produced in the Netherlands, with a requirement for use of feedstock that is not produced at the expense of food supply for humans and animals and / or causes environmental damage, such as deforestation. The group was in favour of sustainability certification based on what they consider to be the strictest criteria, namely those of the Roundtable on Sustainable Biomaterials (RSB)⁷⁵.
- The Draft Agreement on Sustainable Aviation mentions “sustainable raw materials”
- The Dutch Climate agreement states “In relation to the use of renewable fuels, sustainability is a precondition both in quantitative and qualitative terms”. More detail on specific conditions within this policy is given below.

All interviewees for this project stated that the sustainability of SAF used in the Netherlands was very important to them. However, definitions of what types of SAF were sustainable varied between

interviewees. Some also noted that other players in the industry may have fewer concerns in this area, and prioritise compliance with policy at the lowest possible cost.

7.2 Crop-based fuels

The extent to which biofuels based on food and feed crops could contribute towards SAF supply is a key option for policy, with widely differing views amongst stakeholders. This decision affects the sustainability and costs of biofuels supplied throughout the lifetime of the policy.

The Dutch Climate Agreement states:

“Many biofuels are already produced from waste and residues. The increase in biofuels must be brought about largely from sustainable residual substances (including cascading). This is in line with the government’s objective regarding the highest quality use of biomass as well as with the development of the circular economy. For that reason, the parties have agreed that, in relation to achieving this renewable energy target for transport (including the 27 PJ), no additional biofuels from food and feed crops in excess of the 2020 levels should be used in the Netherlands. This will be embedded in national regulations with the implementation of RED II. This will go toward advancing the realisation of growth through sustainable advanced biofuels, produced from waste and residues.

At this time, no biofuels produced from agricultural crops (other than food and feed crops) with a low ILUC risk that meet the requirements of the regulatory framework of RED I and RED II are being used in the Netherlands. In 2020, the parties will make agreements on the future commitments and the sustainability framework in force and will not commit to the additional use of the foregoing crops during this period.”

This decision shows that there is no support for use of food and feed based biofuels at levels above those used in road transport in 2020 in order to meet the Climate Agreement targets. This implies that there may not be support for increased use of these fuels to meet other targets, such as a SAF obligation. This would mean that the 2020 level could be considered a limit on Netherlands food and feed crop biofuel use across all sectors including aviation and shipping.

Aviation industry views on the use of food and feed crop-based biofuels in aviation vary, as shown by interviews: many airlines do not support the use of biofuels derived from palm oil or palm oil products, as a result of environmental concerns and reputation risk. These airlines would prefer to use waste and residue-derived fuels, though have not entirely ruled out use of non-palm food and feed crops. Other airlines have lower concerns on use of food and feed crops, being more sensitive to fuel price, whilst some airlines from countries with high levels of food and feed crop production may actively support use of these crops, for example palm oil in Malaysia⁹⁰. Fuel suppliers’ views also vary: several stated that they would prefer a long term framework with performance-based criteria, such as a need to prove avoidance of impacts on land and food, to a list-based approach to acceptable feedstocks, on the grounds that this would enable innovation in feedstock sourcing.

⁹⁰ Malay Mail Jan 2019 Three major airlines join ‘Love MY Palm Oil’ campaign
<https://www.malaymail.com/news/malaysia/2019/01/22/three-major-airlines-join-love-my-palm-oil-campaign/1715306>

Note that when discussing food and feed crop-based biofuels, interviewees focused on discussing oil crops, in particular those such as palm with high ILUC impacts, and so views on use of crop-derived ethanol for AtJ routes may differ. For example, using CORSIA LCA values, AtJ from sugarcane ethanol has lifecycle emissions, including ILUC impacts, at a similar level to AtJ from agricultural residues or grassy energy crops⁹¹, and therefore exclusion or restriction based on the feedstock being edible may not be justifiable on the basis of relative GHG savings.

In addition, some interviewees considered that there could be promising options for biofuels based on crops which could demonstrate their lack of impact on land and food, for example cover and rotation crops. Crops under consideration are both edible and non-edible, and so these need to be defined based on their impacts rather than edibility. These crops are defined in RED II Art 2 (40) as not counting as food and feed crops (“excluding [...] intermediate crops, such as catch crops and cover crops, provided that the use of such intermediate crops does not trigger demand for additional land”). However, this does not mean that all of these crop types are in Annex IX. In some situations cover crops are also defined as counting as ‘non-food cellulosic material’ in RED II Art 2 (42), and are therefore included in Annex IX Part A. However, RED II gives no further detail on the process for assessing the impact of these crops on demand for land, and so further clarification is needed. When the RED II Annex IX is reviewed every two years, new feedstocks may be added. Feedstocks that can be processed only with advanced technologies shall be added to Part A, while those that can be processed into biofuels, or biogas for transport, with mature technologies shall be added to Part B. Overall, the treatment of these crops would need to be made clear within any NL SAF policy.

In Norway, only SAF produced from feedstocks in Annex IX, Part A and B of RED II are acceptable, ie. excluding food crops⁹². In Sweden, the proposed policy does not appear to restrict food and feed crop biofuels although notes the restrictions in RED II on high ILUC biofuels⁹³. For other proposed mandates, treatment of food and feed crops is not yet known.

The table below compares options for an obligation in the Netherlands, based on several criteria. Note that the CORSIA approach of assessing fuels based on their GHG emissions including ILUC factors, which has the impact of not incentivising some food crop based biofuels, has not been considered here, as Article 29 of RED II requires that RED GHG methodology is used, i.e. that ILUC factors are not included.

⁹¹ ICAO 2018 “CORSIA Default Life Cycle Emissions Values For CORSIA Eligible Fuels” <https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx>

⁹² Norwegian amendment, May 2019, <https://lovdata.no/dokument/LTI/forskrift/2019-04-30-555>

⁹³ SOU 2019 Biojet för flyget <https://www.regeringen.se/493238/contentassets/6d591e58fd9b4cad8171af2cd7e59f6f/biojet-for-flyget-sou-201911>

Table 13 Comparison of potential approaches to crop-based biofuels

	RED II	RED II plus palm ban	Exclude all food and feed based crops
Approach	Follow RED II approach: capped contribution from food and feed crops, and high ILUC rules	Follow RED II approach, but exclude palm and palm products	Define SAF policy to exclude food and feed crops
Impacts on:			
Sustainability	Increased risk of impacts from food and feed crops as a result of increased overall demand, unless cap is split with road	Increased risk of impacts from non-palm food and feed crops as a result of increased overall demand, unless cap is split with road	Zero risk from food and feed crops. Increases pressure on UCO and tallow sourcing until other routes commercialised
Supply	Baseline – no impact	Reduced supply in the near term as palm is commonly used in HVO plants	Could be impacts on NL SAF supply if global UCO and tallow demand increases rapidly. Limits mid term potential for AtJ route
Acceptability to industry	Perceived unfairness between airlines with internal commitments to avoid palm and those with none.	Unacceptable for some airlines in producing countries. More acceptable for airlines with internal commitments to avoid palm. Perceived unfairness versus road transport sector.	Unacceptable for some airlines in producing countries. Less acceptable for airlines and fuel suppliers prioritising cost, though considered essential by others. Perceived unfairness versus road transport sector.
Road transport policy	Would require the crop biofuel volume in the road transport sector to be split with the aviation (and potentially marine) sector (revising HBE targets), or the total acceptable volume increased (with sustainability impacts above)		No impact

Note that it would also be important to determine the treatment of co-products and residues from food and feed crop production. Whilst some of these are listed as advanced feedstocks in RED II Annex IX Part A, others are considered to be valuable co-products of food/feed production, which may lead to increased demand for the primary food/feed product. As a result, under current policy in several

countries including the Netherlands some of these have been considered not to be wastes, and so have been excluded from double counting towards policy targets⁹⁴.

7.3 Waste oils-based fuels

HEFA derived from used cooking oil and tallow is widely expected to be a major contributor to SAF targets, as a result of the commercial status of the route today, and lower sustainability concerns than virgin vegetable oils. Nevertheless, limited long term feedstock availability for this route has led to a cap on contribution to RED II targets by biofuels produced from feedstock listed in Part B of Annex IX (waste cooking oils and animal fats) of 1.7 %. Member States may modify this limit, taking into account the availability of feedstock, providing this is justified and subject to approval by the Commission.

When a cap for the Netherlands is agreed as part of RED II implementation, it will be important to define whether the cap represents the maximum amount of these feedstocks the Netherlands considers acceptable to use in all fuels together (including road, aviation and shipping), or whether this is a road cap alone, and further feedstock could be used in aviation and/or shipping. In that case, it will need to be agreed what volume would be acceptable in these sectors. It is also important to agree whether this cap will only apply for 2030, or be included in interim years' targets.

Increased use of waste oils in the Netherlands in response to SAF policy is likely to lead to:

- increased demand for waste oil feedstocks, which will increase the incentive to collect/recover them. Some interviewees considered that there was considerable further potential for sustainable recovery of waste oil feedstocks, and that the scope of sustainable waste oil based feedstocks extended to many types of material aside from used cooking oil and tallow. Each of these would need to be assessed against sustainability criteria.
- Shifting of waste oil feedstock to NL SAF supply from the road transport sector. Use of Annex IX, Part B feedstock is incentivised in many EU MSs by double counting towards RED targets, rather than by any more binding supply obligation. As a result, if the price available to waste oil suppliers from HEFA plants is higher than for FAME/HVO plants for road, then supply will shift partly. The replacement for this supply could vary depending on the market: potentially through more food and feed crop based biofuels (up to capped values in the EU, but potentially higher elsewhere), or other compliance options (advanced biofuels, RFNBOs, renewable electricity in transport).
- Increased interest in sourcing oil feedstocks from other sources, such as oils from catch crops and cover crops, to supply demands in all fuels sectors.

7.4 Advanced fuels

The 14% target in the Draft Agreement on Sustainable Aviation is not intended to be an end point, but instead part of a trajectory towards decarbonised aviation in 2050, which could include higher levels of SAF supply. Given the limited availability of waste and residue feedstocks for HEFA, and the much larger availability of feedstocks for advanced biofuels and renewable electricity for PtL, successful commercialisation of these routes will be very important to enable continued scale up for SAF use in the NL and globally. However, these pathways to SAF are estimated to have higher production costs

⁹⁴ NEa Grondstoffen in het REV - april 2019 <https://www.emissieautoriteit.nl/documenten/publicatie/2019/04/29/grondstoffen-in-het-rev--april-2019>

than HEFA, and are at an earlier stage of commercialisation today. As a result, plans in the aviation and road sectors recognise the need for additional effort and/or support for these fuels in order to make sure that they become available:

- The Draft Agreement on Sustainable Aviation advocates cross sectoral effort to scale up production of SAF from biomass and wastes through a Sustainable Aviation Knowledge Initiative. This would include an integrated analysis and feasibility study for AtJ, pyrolysis and HTL, and the start of a demonstration plant for preferred routes in 2020-2025.
- The HBE system includes a sub target for advanced biofuels (RED Annex IX, Part A). The Dutch Climate Agreement includes, other measures, such as the Stimulation of Sustainable Energy Production scheme (SDE++) which it intends to increase the production and innovation of sustainable advanced biofuels and renewable synthetic fuels.

Several options have been suggested to provide support to advanced biofuels and/or PtL compared with HEFA from crops or waste and residues:

- **Sub target** – this approach is used for advanced biofuels in RED II, and in the HBE system in NL.
 - The advantage of a sub target is that it provides a clear market demand for advanced biofuels, which can be used to underpin an investment case for advanced SAF projects. Some interviewees considered that a sub-target, rather than other support types alone, is essential to provide this investment case, and attract new players and investment to the sector. The example was cited of the advanced biofuels sub target under RED II, which are reported to be stimulating interest from new players – though there has not yet been enough time to see the impacts of this interest in practice. A sub-target is also economically efficient, in that the market will decide how best to invest to meet the target.
 - However, some interviewees were opposed to sub-targets, given that advanced SAF routes are not proven today at scale. They felt that this would expose the industry to unacceptable levels of risk, to risk of a high cost if a buy-out or penalty were in place, and risk of the overall target not being met. This has been a common criticism of targets for cellulosic biofuels for road in the US, but could be mitigated by a later introduction date for the advanced sub-target, giving the sector time to scale-up production.
 - A sub target imposes additional costs on the sector, and so would increase the economic impacts compared with those shown here, if advanced SAF routes have higher prices, unless additional measures are used to reduce costs (see below).
 - Setting a sub-target that is challenging, yet achievable can be complex as it relies on an assessment of the likely available volumes of the desired fuels. If the sub-target has a buy out price it would need to be set at a higher level than any buy out price for the main obligation (as seen with the development fuels sub target under the UK RTFO), to reflect the higher costs of advanced SAF routes. This can also be challenging, as advanced routes themselves have a wide range of costs - a sub target set at a level to encourage FT and AtJ may incentivise very little PtL - meaning that earlier stage routes would require additional demand or supply side support, as set out below, or a separate sub-target specifically for PtL which could have a different buy-out price and date of introduction.

- **Additional supply or demand side support** – additional supply or demand side support as described in Chapter 4, such as capital grants, operating grants (similar to the SDE++ scheme) or usage payment (similar to a feed-in tariff). These would be financed by government, industry, or a combination of both.
 - The advantage of this approach is that players with plans for advanced fuels production are supported, without the industry having the risk of being obligated to supply fuels that are not yet available
 - A disadvantage of this approach is that funding is required for this support, either from government (general taxation) or from the industry (e.g. via flight or passenger taxes), or a combination of both. Support from general taxation would limit the economic impacts on NL airlines, as would levying taxes on certain flights only (such as excluding transfer passengers) to mitigate impacts on NL hub carriers.
 - Another disadvantage is that in most of these options the additional support is limited to a small number of successful bidders, and so does not provide a wider signal to the market that advanced fuels will be required. In addition, SAF production companies cannot build a business case based on support for one plant; they need to show a path to scale up which relies on being competitive in a future, larger market. This could rely on future rounds of support in NL or elsewhere.
- **Sub target with additional supply or demand side support** - this option combines the market certainty for investors of a sub target with mitigation of cost impacts for airlines, for example a contract for difference payment for the additional cost of advanced biofuels compared to HEFA, alongside an advanced fuel sub-target. This type of approach is used/under consideration in the road transport sector in the Netherlands and several other MSs, such as the UK. Several interviewees considered that this option was essential to ensure commercialisation of advanced routes.
- **Higher buy out price** – setting a higher buy out price could in theory allow sale of fuels with higher production costs. However lower production costs for HEFA could allow HEFA to undercut advanced fuel suppliers, meaning less certainty for investors.
- **Higher targets** – setting high SAF targets increases the demand for all SAF routes. However, the maturity and cost of the HEFA route make it likely that HEFA could grow faster to meet this demand. This also does not provide certainty to investors.

Selection of which fuels to include in the additional support could be done in several ways:

- **List based** – for example as in Annex IX, Part A, based on feedstock impacts and conversion technology readiness. Some interviewees suggested additional support should be for PtL only, as a result of sustainability risks for all biofuels – albeit without specifying how the sustainability of PtL should be ensured.
- **Performance based** – based on a list of criteria which could include technology readiness of the feedstock or conversion technology, sustainability performance, production cost differential versus fossil jet or versus HEFA. Some interviewees felt that this approach would be more likely to stimulate innovation than a list-based approach. Some also consider that this approach could be more stable over time than a list-based – although this is not necessarily the case as sustainability impacts, in particular indirect ones, can change over time in ways that are not predictable. This approach would entail additional costs for the government, as

the administrator of the scheme would need to assess applications for support against these criteria. This would be relatively straightforward if only a small number of plants were being assessed, but difficult for fuels on a batch basis (as has been seen for approval of double counting waste and residue feedstocks).

- **Based on GHG savings** – some interviewees supported additional support based on the fuel's GHG savings alone. This approach would not be a viable way to support advanced fuels, many of which may not have higher per tonne GHG savings than HEFA from wastes and residues. The advantage of advanced fuels is their ability to lead to greater total GHG savings through much higher sustainable supply volumes in the long term. This approach also does not take into account non GHG sustainability risks or technology development status, many of which cannot be quantified.

7.5 Sustainability criteria and certification

Several frameworks exist to evaluate risks to sustainability and compliance with sustainability criteria and indicators, primarily from public policies and voluntary standards.

The level of required sustainability performance varies significantly between different frameworks. In theory, sustainability should entail all three fundamental pillars in the Brundtland definition, namely economic, social and environmental. Concretely, this means that SAF production should not only preserve highly biodiverse areas, but also water resources, soil health, air quality, human rights, economic conditions in local communities, etc.

It is therefore important to distinguish between voluntary standards aiming to comprehensively address sustainability issues of SAF (e.g. RSB and ISCC) from policy frameworks focusing on the most pressing environmental or social issues only. As an example of the latter, the Renewable Energy Directive, both in its current (2009/28/EC) text and upcoming recast (2018/2001/EU) only addresses environmental impacts of biofuels, RFNBOs and recycled carbon fuels in relation to land-use and life-cycle greenhouse gas emissions.

7.5.1 EU Renewable Energy Directive (2018/2001/EU)

Article 29 of EU RED II includes land-use criteria, which prohibit the use of feedstocks produced through the conversion or degradation of protected areas, areas of high biodiversity value or lands with high carbon value (e.g. wetlands, peatlands, forests). In the specific case of forest biomass, additional criteria apply to ensure the legality of harvesting operations, the regeneration of harvested areas and the maintenance of soil and long-term forest productivity.

Depending on the date of beginning of operations in production plants, the life-cycle greenhouse gas savings to be achieved by biofuels used in transport are 50%, 60% and 65% for installations starting operations on or before 5 October 2015, 31 December 2020 and after 1 January 2021 respectively. The GHG calculation approach in RED II is based on a classic LCA approach using a “Well-to-Tank” scope, i.e. the engine efficiency and combustion emissions are not taken into account (release of biogenic CO₂ is assumed to have zero contribution to global warming potential). Direct land-use change of biomass production is included in the calculation, but not indirect land-use change (ILUC). ILUC is however taken into account through a phase-out process, which should progressively reduce the share of feedstock considered as carrying “high ILUC risk”.

Other impact categories such as soil health, water depletion, land rights or food security are not included as compulsory requirements in EU RED II.

Note that Article 25 states that the GHG savings from RFNBOs shall be at least 70 % from 1 January 2021. As this is in Article 25 rather than Article 29, this would apply to fuels used to contribute towards RED II targets, but need not necessarily be applied to policies that were not used to comply towards this target. By 31 December 2021, the Commission will adopt a delegated act to specify the methodology for assessing GHG savings from RFNBOs (which will ensure that the credit for avoided emissions is not given for CO₂ the capture of which has already received an emission credit under other provisions of law) and a methodology for operators can use to prove that the electricity used in RFNBO production is fully renewable (Art. 27) .

Two countries with SAF obligations planned appear to be adopting RED sustainability criteria. In its document entitled “Biojet for Aviation” (SOU 2019:11)⁹⁵, Sweden describes the sustainability criteria for biofuels, in line with the EU RED, which are currently implemented in the Sustainability Act (2010:598). Similarly, Norway is implementing sustainability criteria and default GHG values from EU RED⁹⁶ in its *Regulation on restrictions on the use of hazardous chemicals and other products (product regulations) - Chapter 3. Requirements for biofuels and sustainability criteria for biofuels and liquid biofuels*.

7.5.2 CORSIA

The recently approved sustainability requirements in CORSIA have a comparable scope to those in EU RED II, since they also focus exclusively on land-use impacts and GHG savings. Sustainability criteria in CORSIA include:

- An obligation to emit at least 10% less greenhouse gas compared to a baseline for aviation fuels on a life-cycle basis;
- The exclusion of use of biomass from converted or degraded primary forest, wetlands or peatlands. Note: as in RED II, the cut-off date for land conversion is set as January 1, 2008.

The GHG calculation methodology also follows a classic attributional LCA approach, in line with EU RED II. However, notable differences exist between EU RED II and CORSIA⁹⁷:

- The scope of GHG calculations in CORSIA includes engine efficiency and combustion emissions, which makes the scope “Well-to-Wheel” (vs “Well-to-Tank” in RED II).
- CORSIA allows attribution of zero emissions from cultivation and no ILUC emissions to waste, residues and by-products, which cover a wide range of feedstocks, including crude tall oil (CTO), Palm Fatty Acid Distillates (PFAD) and technical corn oil (TCO), which is not the case in RED II;.
- Indirect (or “induced” as per CORSIA’s terminology) Land-Use Change is included in the GHG calculations, following a consequential LCA approach.
- Required minimum GHG savings are much lower in CORSIA than in RED II (10% vs 50-65%).

⁹⁵ SOU (2019) Biojet för flyget, Available from :

<https://www.regeringen.se/493238/contentassets/6d591e58fd9b4cad8171af2cd7e59f6f/biojet-for-flyget-sou-201911>

⁹⁶ Lovdata, Available from: https://lovdata.no/dokument/SF/forskrift/2004-06-01-922/KAPITTEL_4#KAPITTEL_4

⁹⁷ ICAO (<https://www.icao.int/environmental-protection/CORSIA/Documents/ICAO%20document%2005%20-%20Sustainability%20Criteria.pdf>)

Therefore, complying with EU RED II would theoretically ensure compliance with CORSIA's land-use restrictions, but CORSIA requires different GHG accounting, which may result in different policy treatment of the fuel.

Under CORSIA, the required level of assurance is defined as "reasonable" (as per ISAE 3000⁹⁸), which is a stronger level than "limited"⁹⁹. While the framework for assessing voluntary schemes against RED II is not known, the previous framework (used under RED I) only required a "limited" level of assurance. If voluntary schemes undergoing EC recognition against RED II are only required to ensure a "limited" level of assurance CORSIA would therefore ensure a stronger level of assurance. Consequently, certificates and claims of compliance under CORSIA could be considered more robust than under RED II.

7.5.3 Voluntary standards and certification schemes

A large number of EU-approved voluntary standards and certification schemes are currently available to fuel producers and retailers in order to demonstrate compliance with EU RED II. A significant share of these schemes were developed and implemented only for legal compliance with EU RED and therefore are limited to the same land-use and GHG criteria as in EU RED. This is for example the case for 2BSvs, Red Tractor or Red Cert. There are, however, standards which address sustainability issues of biofuels more comprehensively at environmental, social and economic levels. Several of these schemes are "roundtables", with a higher degree of inclusiveness and transparency. Examples include the Roundtable on Sustainable Biomaterials (RSB), Bonsucro, and the Roundtable for Responsible Soy (RTRS).

In addition, it is important to note that important variations exist between certification schemes regarding the compliance evaluation process, also known as "assurance". Relevant aspects include the procedure for training, accrediting and monitoring auditors and certification bodies, the audit process itself (e.g. the number of sites to be included in a sample for physical visit in the case of a multi-site scope), the compliance/non-compliance decision process, the issuance, renewal or suspension of certificates, and rules about the use of compliance claims. Following numerous criticisms, the European Commission issued several communications and improved EU RED II to ensure that a minimum level of assurance could be guaranteed among all EU-approved schemes. However, the protocol used by the European Commission for recognition of voluntary schemes only requires a "limited" level of assurance (as per ISAE 3000), which is lower than a "reasonable" level, as required by most roundtables and CORSIA (see previous section).

In 2013, the WWF issued an important publication¹⁰⁰, which compared a selection of EU-approved schemes against a set of benchmark criteria, with the aim to evaluate their comprehensiveness in addressing biofuel sustainability issues, ensuring a robust assurance system and implementing a transparent and inclusive governance process. The following tables show that large discrepancies exist between schemes focusing on EU RED compliance and schemes with a broader scope. While several schemes further improved on content and implementation after the publication of the WWF report,

⁹⁸ ISAE, Available from: <https://www.ifac.org/system/files/downloads/b012-2010-iaasb-handbook-isae-3000.pdf>

⁹⁹ ICAO document "CORSIA Eligibility Framework and Requirements for Sustainability Certification Schemes" 2019

¹⁰⁰ WWF (2013), Searching for Sustainability, Available from:

http://awsassets.panda.org/downloads/wwf_searching_for_sustainability_2013_2.pdf

the clear contrast between schemes aiming to implement a comprehensive set of criteria and those limited to EU RED compliance remain relevant.

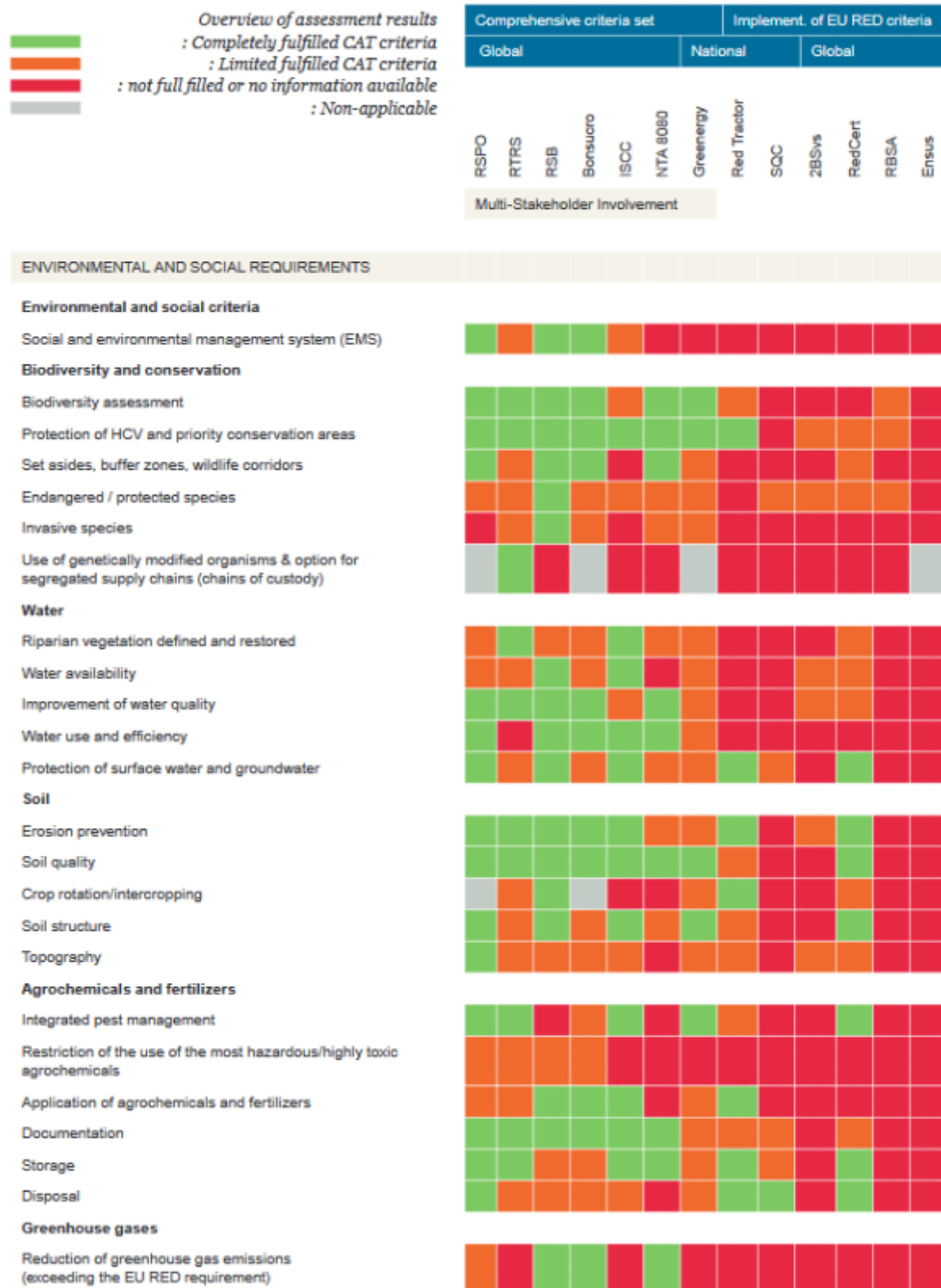


Figure 13 Comparison of environmental criteria in EU-approved schemes (Source: WWF)

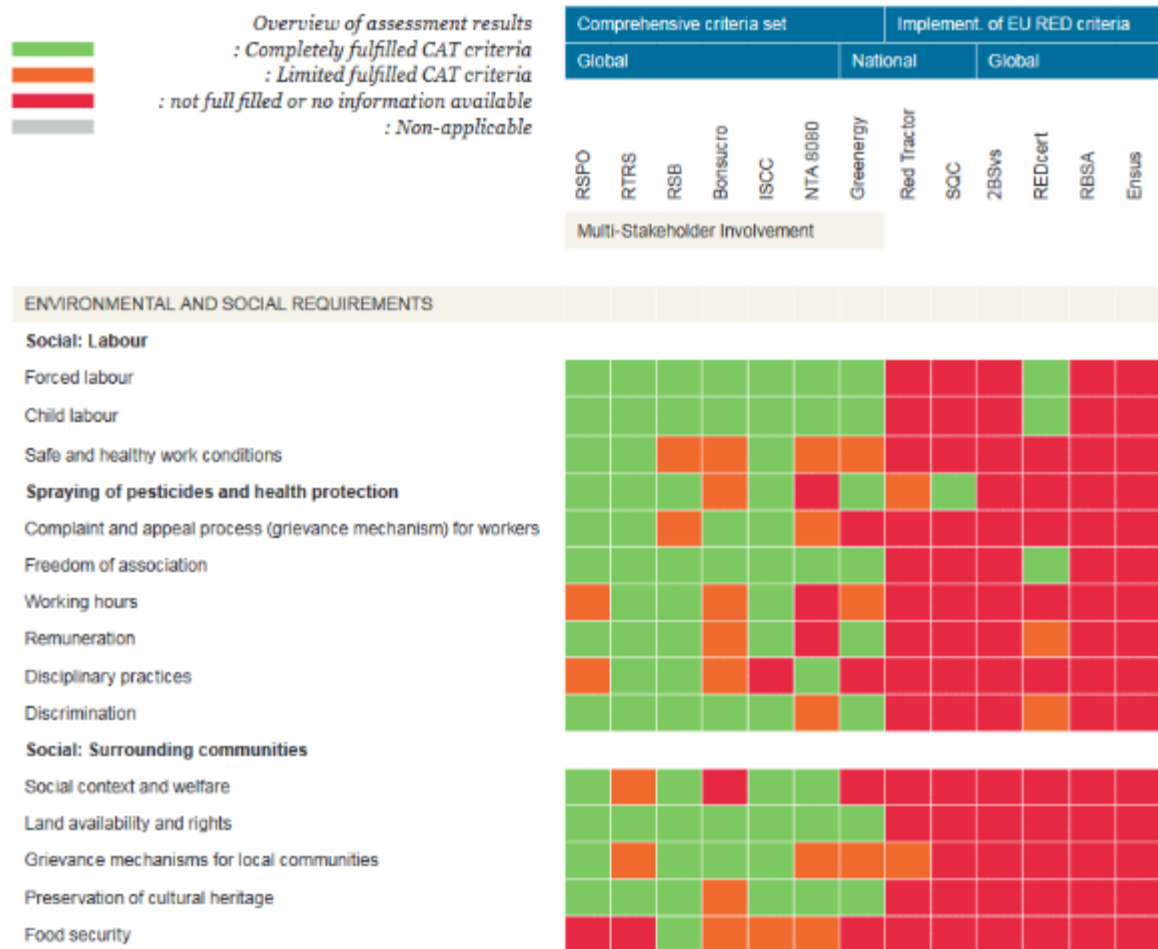


Figure 14 Comparison of socio-economic criteria in EU-approved schemes (Source: WWF)

Similar results were observed in following publications by FAO¹⁰¹, the International Union for Conservation of Nature (IUCN)¹⁰² and the Natural Resource Defense Council (NRDC¹⁰³). In its 2017 aviation scorecard¹⁰⁴, NRDC confirmed its recommendations for airlines to commit to source RSB-certified aviation biofuels only.

The recognition of RSB by several influential social and environmental organisations as one of the most credible biofuel certification schemes is seen by the aviation industry as a solid safety net to ensure alternative fuels deliver on sustainability promises and are traceable across the supply chain, as illustrated by the pledge taken by the members of the Sustainable Aviation Fuel Users Group (SAFUG)¹⁰⁵. Some interviewees were concerned that adoption of the REDII sustainability criteria by an NL obligation would result in the bulk of fuel supplied in NL meeting a lower standard of sustainability than they themselves would require, such as RSB or ISCC+ certification, meaning that they would need to pay more than other airlines if they required their fuel suppliers to supply fuel meeting their more stringent standards.

¹⁰¹ FAO, Available from: <http://www.fao.org/bioenergy/31594-044649dd008dd73d7fa09345453123875.pdf>

¹⁰² IUCN, Available from: https://cmsdata.iucn.org/downloads/betting_on_best_quality.pdf

¹⁰³ NRDC (2014), Available from: <https://www.nrdc.org/sites/default/files/biofuels-sustainability-certification-FS.pdf>

¹⁰⁴ NRDC (2017) Available from: <https://www.nrdc.org/sites/default/files/aviation-biofuels-sustainability-scorecard-2017.pdf>

¹⁰⁵ SAFUG, Available from: <http://www.safug.org/safug-pledge/>

7.5.4 Conclusions

The previous sections demonstrate that the level of sustainability of aviation fuels may vary greatly depending on which framework is used to evaluate compliance. An obligation or any other form of financial support in NL would need to follow the RED II requirements, but could not go beyond them as explained in section 4.2. However, as set out in the table below, this would not be sufficient for some airlines (who could voluntarily go beyond the RED II standards), and would not necessarily mean that fuels incentivised by these policies would meet CORSIA requirements, which are still in development.

Table 14 Overview of main differences in requirements for aviation fuels between EU RED, CORSIA and comprehensive voluntary schemes

	EU RED II (incl. voluntary schemes limited to RED compliance)	CORSIA (incl. recognised certification schemes¹⁰⁶)	Comprehensive voluntary schemes (e.g. RSB, ISCC, Bonsucro)
Feedstock restrictions	Cap on crop-based feedstocks. Phase-out high-iLUC feedstocks.	No feedstock restriction. CORSIA's definitions of waste residues and by-products include a much wider range of feedstocks (e.g. CTO, PFADs)	Some schemes are feedstock-specific, e.g. RSPO (palm only), RTRS (soy + corn), Bonsucro (sugar). RSB, ISCC and Better Biomass can be used with any feedstock.
Biodiversity	No-go areas include grasslands and forests with high biodiversity, primary forests, and protected areas.	No-go areas limited to primary forests.	Any area with high biodiversity or conservation values. Protection of ecosystem services and functions.
High Carbon Land	Forests, wetlands and peatlands	Wetlands and peatlands	Any area with high carbon stock.
Minimum GHG Threshold	50-65%	10%	Variable (at min. aligned with EU RED)
iLUC	Not included in GHG calculations. Risk-based approach.	Included in GHG calculations (not for waste, residues and by-products).	Not included in GHG calculations. Low iLUC certification (RSB).
Other environmental criteria	Soil quality taken into account for agricultural residues and forest biomass.	None. Ongoing work from CAEP on other criteria.	Water depletion and contamination, soil health, air quality, use of GMOs, waste management.
Socio-economic criteria	None	None	Working conditions Food security

¹⁰⁶ No certification schemes are currently recognised under the CORSIA mechanism. Therefore, several elements in the table are unknown.

			Land/Water rights Local communities Smallholders
Chain-of-Custody	Mass Balance only	Mass Balance only	Segregation Mass Balance Book & Claim
Assurance level (As per ISAE 3000)	Limited	Reasonable	Reasonable
Governance	Limited number of stakeholders and inclusiveness. EC requires transparency over constituencies to avoid conflicts of interest.	CORSIA requires certification schemes to have a process in place for stakeholder engagement and a complaint procedure.	Generally multi-stakeholder and consensus-based. Actively seeking inputs from NGOs, civil society and academics to balance inputs from private sector.

7.6 Reducing the risk of fraud

Because feedstocks included in EU RED II Annex IX generally benefit from specific policy incentives (e.g. sub-target, double-counting), a risk exists that false claims be made regarding the origin or nature of feedstocks. Under the existing RED, several cases of fraud in biofuel used for road transport have been reported. An ongoing investigation in the Netherlands aims to determine whether conventional feedstock (e.g. palm oil) was traded as waste/residue (e.g. UCO¹⁰⁷), thus unduly benefiting from economic incentives in the country of retail. While the European Commission has implemented additional measures regarding the origin of waste and residue in the context of biofuel certification schemes¹⁰⁸, fraud risks remain important, especially for waste and residues derived from complex supply chains.

Fraud risks can be described according to 1) the **elements incentivising fraud** (e.g. policy support, price premiums, etc) and 2) the elements **enhancing the opportunity for fraud** (e.g. operators' size, local regulation, group certification, etc.).

- **Elements incentivising fraud** relate to the profit to be gained from fraud. They stem from a combination of policy incentives (e.g. sub-targets) and market patterns (e.g. feedstock market prices, available supply, etc.) leading to significant profits to be gained from intentional fraud, e.g. by substituting feedstocks. Specific national mandates on aviation fuels may add to the elements incentivising fraud if implemented through economic incentives further increasing potential profits for fraudulent operators.
- **Elements enhancing fraud** relate to the ease of fraud. They are mostly related to the type and complexity of supply chains, the size of economic operators, the type of chain-of-custody system used, etc. Aviation fuel supply chains are particularly complex given the large number

¹⁰⁷ DutchNews (24 May 2019) Available from: <https://www.dutchnews.nl/news/2019/05/dutch-company-embroiled-in-biodiesel-scandal-earning-millions-vk/>

¹⁰⁸ European Commission (2014) Note To The Voluntary Schemes That Have Been Recognised By The Commission For Demonstrating Compliance With The Sustainability Criteria For Biofuels, Available from: https://ec.europa.eu/energy/sites/ener/files/documents/2014_letter_wastes_residues.pdf

of economic operators involved (fuel producers, fuel retailers, airports, airlines), which may also aggravate the risk of fraud.

Concretely, the different types of fraud can be defined as follows:

- Fraud over feedstock types and sustainability characteristics. A risk exists that different feedstocks get fraudulently mixed in a given batch of certified raw material used for jet fuel production. Due to their inconsistent composition in fatty acids, used cooking oil and other waste oil are particularly vulnerable as detecting the presence of other virgin vegetable oil (e.g. palm oil) would require advanced chemical analysis. Whenever feedstocks from different origins are fraudulently mixed in a batch of certified raw material, their origin, production processes and potential social/environmental impacts cannot be known, thus leading to uncertainty over sustainability characteristics as well.
- Fraud over biofuel contents in blend. The exact amount of biofuels mixed with jet fuels in a blend may be difficult to track, especially in the case of drop-in aviation fuels produced through co-processing. To overcome this, clear rules on mass balance through the supply chain are required, including in pipelines (across different countries) and in co-processing.
- Fraud over final country of consumption. The business model of fuel trading and related transactions being extremely complex and dynamic, a risk exists that a batch of SAF expected to be consumed in the Netherlands is eventually traded again to a different country. This can be overcome by using the point at which fuel is uplifted into the aircraft as the point of control.
- Fraud over claims. Biofuel producers sourcing both compliant and non-compliant feedstocks use a mass balance system, which allows compliance claims over a limited volume of outgoing fuels. Eligible volumes of compliant fuels correspond to the volumes of compliant feedstock entering the process. Whenever some volumes of compliant biofuels remain unsold at the end of the mass balance accounting period (generally 3 months), the corresponding claims can be carried over onto the following accounting period. Operations involving continuous production (as opposed to batch processing) are at risk of incorrect accounting of eligible volumes and associated claims, thus leading to the risk of operators claiming higher volumes of compliant fuels than actually allowed.
- Fraud over false certificates. Reports of false certificates are frequent among the most widely used certification schemes, such as ISCC109. Thus, a risk exists that the certificate attached to a batch of feedstock/fuel is false or expired.

Fraud risks in SAF can be efficiently reduced by implementing strict rules on traceability by imposing, for example, the possibility for auditors to trace waste oil and fats up to the generators (e.g. industrial fryers) or requiring chemical analysis over a sample of raw material/biofuel batches from countries considered sensitive. Robust and consistent assurance schemes are another meaningful safeguard to reduce the risk of fraud, including the proper training, accreditation and monitoring of assurance providers (auditors, certification bodies and accreditation bodies).

¹⁰⁹ ISCC (2019) Fake certificates, Available from: <https://www.iscc-system.org/certificates/fake-certificates/>

8 Promoting SAF production in the Netherlands

Summary

- There are planned SAF plants in the Netherlands today, and interest in further production in the 2020s. Planned and potential production volumes could be used to inform the levels of interim targets to ensure that it is at least possible to supply a high proportion of demand from production in the Netherlands.
- Supplying 14% SAF in the Netherlands in 2030 via new HEFA plants would require additional investment of €230 and €730 million, with the potential for around 300 additional permanent jobs.

Whilst it is not possible for an obligation to favour fuels produced from one country over those from another, it is important to consider when designing a policy whether players in the Netherlands will be in a position to respond to the new demand, and whether there are options for the obligation design, or for supporting supply side policies, that could promote production in the Netherlands.

8.1 Planned SAF production in the Netherlands

There are several SAF projects planned or under consideration in the Netherlands:

- **SkyNRG** in collaboration with KLM, SHV Energy and Schiphol Group, announced a project to build the first SAF plant in Europe in May 2019. This greenfield plant, called DSL-01, is planned to start commissioning in 2022 with an output capacity of 100 kt/y of SAF and 15 kt/y of bioLPG as a by-product. The type of SAF produced will be HEFA, and KLM has already committed to a 75 kt/y off-take agreement over 10 years¹¹⁰.
- A consortium led by **EDL Anlagenbau Gesellschaft** mbH is planning the realisation of a PtL FT pilot plant at Rotterdam The Hague Airport, which aims at producing SAF from electricity, water and CO₂ directly captured from air. The plant will combine electrolysis technology provided by Sunfire, Direct Air Capture technology by Climeworks and Fischer-Tropsch synthesis by Ineratec. Once completed the plant will produce 1,000 litres of SAF per day which could potentially be sold to Transavia. The airline has already committed itself to this project and intends to reduce its CO₂ emissions through SAF use¹¹¹.
- **Neste** is considering HEFA production in Rotterdam alongside their HVO plant. This would require investment of more than €100 million, a lower figure than if a plant were built at a separate location¹¹². Neste has also established its global renewable aviation business in Amsterdam (Hoofddorp).

¹¹⁰ SkyNRG, May 2019, Press Release, <https://skynrg.com/press-releases/klm-skynrg-and-shv-energy-announce-project-first-european-plant-for-sustainable-aviation-fuel/>

¹¹¹ EDL, May 2019, Press Release, http://www.edl.poerner.de/en/news-edl/edl-pressemeldung/news/erneuerbarer-flugtreibstoff-aus-luft/?tx_news_pi1%5Bcontroller%5D=News&tx_news_pi1%5Baction%5D=detail&cHash=045386c0c780f08a79fecb233e4c5aec

¹¹² Fd April 2019 'Maasvlakte in beeld voor fabriek voor duurzame kerosine' <https://fd.nl/ondernemen/1295586/maasvlakte-in-beeld-voor-fabriek-voor-duurzame-kerosine#> and October 2019 'Finse producent van biokerosine nestelt zich bij Schiphol' https://fd.nl/ondernemen/1319534/finse-pionier-met-biokerosine-nestelt-zich-nabij-schiphol?_ga=2.111083525.1404910842.1573041266-188964628.1573041266#

In addition, the Netherlands has several advantages as a location for SAF production, which could lead to interest from more players in the future. However, interviewees considered that this would rely on supportive policy in the Netherlands, such as an obligation, as there are many other locations with similar benefits.

- The Netherlands is a key oil product trading hub with 50% of European fossil kerosene traded in the country⁷⁵. Future biorefineries built in the Netherlands could benefit from a well-developed distribution infrastructure and logistic network to sell their products domestically or to other countries. Conventional ethanol plants currently operating in the country could also help supporting the development of a Dutch SAF industry for the AtJ route.
- The Netherlands has high density of crude oil refineries. There are 6 operational refineries located in the country, mainly concentrated around Rotterdam, with a combined throughput of 60 million tonnes of crude oil per annum¹¹³. Most of these refineries produce some fossil jet fuel, but none of them is co-processing vegetable oil at commercial volumes. In other countries, oil refineries are already co-processing biomass feedstocks in commercial quantities. If all Dutch oil refineries dedicated to fuel production started co-processing 5% vegetable oil, about 2 Mt/y of vegetable oil demand would be created. The exact volume of SAF produced from this feedstock is not straightforward to determine, because this will depend on specific plant product slates and on how the renewability is allocated to multiple products. However, considering the absolute volume of vegetable oil feedstock required it can be concluded that a significant amount of SAF could potentially be generated in the Netherlands without building additional capacity.

8.2 Policy choices to support production in the Netherlands

Based on the plants planned or under consideration above, the potential evolution of SAF capacity in the Netherlands to 2030 is shown below (

¹¹³ Concawe, Refineries map, NL 2017, accessed Oct 2019, <https://www.concawe.eu/refineries-map/>

Table 15), with a corresponding percentage of the Dutch aviation fuel demand (no demand response effects included). Whilst there is no guarantee that fuel produced in the Netherlands will be sold in the Netherlands, this gives an indication of the maximum potential supply from Netherlands. Post 2026, the potential is considered unlimited by plant capacity, since if a policy were introduced in 2020, the time taken to plan, construct and commission a HEFA plant is between 4 and 5 years (and faster for low levels of co-processing), while for thermochemical routes it takes between 5 and 6 years.

Table 15 Potential evolution of SAF capacity in the Netherlands

Year	SAF supply (kt/y)	Supply basis	% of Dutch aviation demand ⁷⁴	Associated road transport fuel production (kt/y)
2022	100	SkyNRG	2.4% (of 4.2 Mt)	30 (aviation optim.)
2025	200-250	SkyNRG plus additional HEFA plants (based on industry estimates in the Smart and Sustainable plan) plus demos of advanced routes	4.4% - 5.6% (of 4.5 Mt)	60 – 75 (aviation optimised scenario)
Post 2026	Unlimited	Plants that could be planned from 2020 onwards	-	-

This information could be used to consult on the basis for targets for interim years, as discussed in section 5.4.7. Whilst demand side policy cannot preferentially support production in the Netherlands, additional supply side support could be given for plants in the Netherlands where this is permissible under State Aid rules, i.e. for non-food SAF routes with high production costs (see section 5.2). It is also important to note that the way in which RED II is implemented, which is likely to vary between MSs as seen from REDI and policy announced to date, will affect the most likely locations for sustainable fuel production, including SAF.

8.3 Economic opportunities from SAF production

If the 14% SAF obligation were met through domestic fuel production, the economic and employment opportunities for the Netherlands would largely depend on the mix of SAF routes. However, by 2030, most interviewees expected that the predominant production route will be most likely HEFA.

Supplying 14% jet fuel in the Netherlands through HEFA is projected to require 700 kt/y by 2030. The SkyNRG plant is expected to come online in 2022 with 100 kt/y of HEFA production. Assuming the entirety of this volume was sold on the domestic market, there would be 600 kt/y of HEFA left to supply. This could be supplied by new HVO plant capacity, and/or by co-processing at Dutch refineries, or by advanced routes. In a scenario where the fuel output was optimised for jet fuel production, supplying the remaining 600 kt/y of HEFA would require 2 dedicated plants with a nameplate capacity of 350 kt/y (of total fuel). This capacity is an average across current and planned HVO plants globally.

According to techno-economic studies, a commercial greenfield HEFA plant with a nameplate capacity of 350 kt/y has a unit capital cost between €320 and €1040 per tonne of liquid fuel produced¹¹⁴. Therefore, the total capital required ranges between €230 and €730 million, which is in line with the estimate given in the “Smart and Sustainable” plan⁷⁵. This uncertainty range is given by the fact the unit capital cost varies depending on the plant size, nth of a kind/first of a kind deployment and level of integration with pre-existing facilities (i.e. greenfield vs brownfield). For example, building a single 700 kt/y HEFA plant could reduce the total investment by about 25%, at parity of other conditions¹¹⁴.

¹¹⁴ Calculation based on de Jong (2015). Total investment cost of HEFA plant 200 – 644 MEUR(2013) scaled to 350 kt/y capacity using scaling factor 0.6. Costs adjusted using 2018 CEPCI. Source: de Jong, 2015, “The feasibility of short-term production strategies for renewable jet fuels...”, <http://doi.wiley.com/10.1002/bbb.1613>

Neste Rotterdam plant's capital expenditure falls within the uncertainty range, with a unit cost of €670 per tonne of fuel¹¹⁵.

Additionally, SAF production has associated volumes of road transport biofuel production. A HEFA plant designed to produce mainly jet fuel could generate up to 30% road transport fuels. These co-products would increase the export potential for the Netherlands, to a growing EU market driven by REDII.

Building 2 extra plants in the Netherlands could provide about 300 new permanent jobs. This is based on the assumption that the workforce required by this type of plants is to large extent inelastic to plant capacity and equal to 150 employees per facility¹¹⁶.

¹¹⁵ Total expenditure for Neste's Rotterdam plant is €670 million and it produces 1 Mt/y of renewable products (800 kt/y of HVO + other products). Source: <https://www.neste.com/neste-oil-builds-europes-largest-renewable-diesel-plant-rotterdam>

¹¹⁶ Both Neste's Rotterdam plant (1,000 kt/y) and World Energy's Paramount refinery (128 kt/y) have 150 employees.

9 Economic impacts

Summary

- A kerosene blend containing 14% SAF is anticipated to cost between €178/tonne and €276/tonne more than fossil kerosene, as a result of high SAF costs and prices.
- If all of these costs are passed on to passengers, this represents an increased cost per passenger per flight of around €7 for short-haul flights and around €33 for long-haul flights.
- The costs imposed by an obligation result in lower passenger numbers due to demand reduction, mode-shifting, and use of alternative routes.
- This has an economic impact on all actors in NL aviation sector, in particular airlines with hubs in the Netherlands.
- Detailed economic impact assessment will be needed once policy options are narrowed down further, to compare the expected costs versus expected benefits in terms of GHG and the reduction of other air pollutants.

9.1 Direct economic impacts of an obligation

9.1.1 Incremental costs of SAF

The incremental costs per tonne of sustainable aviation fuels compared with fossil jet are the root of the majority of the economic impacts of a SAF obligation, with other costs arising from the administration of an obligation. These incremental costs are made up of the incremental price of SAF compared with fossil jet, plus any additional costs of handling. The incremental costs of handling are expected to be very low once SAF is handled in co-mingled logistics systems, of the order of €10/t, compared with hundreds of euros per tonne with a segregated supply chain. As this figure is very low compared with the variability in SAF production cost, we have not considered this in the costs below. Production costs of SAF are estimated to be between 2 and 8 times the price of fossil jet, with a wide variation between SAF routes.

Table 16 below shows production costs for different routes from two sources for NOAK plants built today. Interviewees were generally in agreement with these costs, although some were more optimistic over the costs of some routes, such as FT from municipal solid waste, and pyrolysis oil routes.

Table 16 Production cost of SAF from different conversion routes (€/tonne)

Route	de Jong (2017), as used in CE Delft (2019)	ICCT (2019) ¹¹⁷
HEFA	1,200	1,100 (UCO) – 1,350 (soy)
Gasification+FT	1,800 – 2,600	1,700 (from MSW feedstock) to 2,300 (energy crops)
DSHC	5,000 – 6,500	4,800
AtJ	2,200 – 3,500	2,050 (from sugar cane) to 3,050 (energy crops)
Pyrolysis	1,200 – 1,900	-
HTL	900 – 1,200	-
PtL FT		3,000

However, the price of SAF in the market will not be determined only by the production cost. The price will as a minimum include necessary margins for SAF producers and fuel suppliers, and in cases where the market is short, could include large margins for fuel suppliers:

- If there are **high levels of supply of SAF** compared with demand from other countries with obligations, the price for each SAF type will be set by the market prices for the fuels in the road transport sector, as this is a larger market than the aviation sector, plus some additional costs to cover the higher costs of SAF production compared with road transport biofuels production. The market price for SAF in NL will depend on the marginal compliance option, but this is most likely to be HEFA in this case.
- If there are **low levels of supply of SAF** compared with demand from other countries with obligations, the SAF price could be much higher. Large margins could be made by the players at the point of constraint. Currently this is the SAF supplier, given the low global production capacity, but in the future could increasingly be the feedstock supplier for waste oils feedstocks, as pressure grows on these resources. The price would be limited by either
 - the buy out price, or penalty price for non compliance with the obligation,
 - If there is no buy out/penalty price, the price could in theory increase indefinitely. However, given that the HVO capacity globally is likely to be very high compared with the level of HEFA demand in obligated countries, a very high SAF price will create a strong driver for production of HEFA or HEFA+ (once certified) from this capacity. This could be done in the near term through secondary processing at a third party site, or in the medium term through developers of new plants including steps required to produce HEFA. This would limit the time period over which much higher prices would be seen. Note that the period of higher prices would be longer depending on the shortfall in the market, which could be large if large obligations (such as an EU-wide obligation are introduced at high levels.

Overall, it seems unlikely that the price would rise high enough to make supply of any routes viable that were significantly more expensive than the HEFA price. Given the large margin that may be made in the HEFA supply chain, given its production costs, it may be easy for HEFA suppliers to undercut suppliers of other fuels even if they can reach these levels. If other routes cannot supply at near this

¹¹⁷ Pavlenko N. et al. (ICCT), 2019, "The cost of supporting alternative jet fuels in the European Union", https://theicct.org/sites/default/files/publications/Alternative_jet_fuels_cost_EU_20190320.pdf

price in the near term, additional support may be needed to help bring their costs down, given the limited feedstock availability for HEFA (see section 7.4). This would be less important if the price of HEFA were to rise significantly as a result of feedstock competition.

Currently, there is limited information on HEFA prices, given the early stage of development of the market. Interviewees stated that HEFA prices in Sweden were expected to be close to fossil jet fuel plus the buy-out price, or a total of around €2500/t¹¹⁸. We have used this as the higher bound case. The lower bound estimate can be made based on the production cost of SAF, plus margins currently made by HVO producers¹¹⁹.

Table 17 SAF price assumptions

Assumption	Value	Unit	Reference
Price of fossil kerosene	530	€/tonne	
SAF price (high)	2500	€/tonne	Estimated from maximum value of Swedish buy out plus kerosene price
SAF price (low)	1800	€/tonne	Estimated from HEFA production cost + margin for HVO producers today
SAF price (average)	2150	€/tonne	Average of high and low figure

The additional cost of SAF compared with fossil kerosene is €1270/tonne under the low SAF price scenario, and €1970/tonne under the high SAF price scenario.

For increasing blends of SAF in kerosene, the estimated fuel price and incremental additional cost compared to fossil kerosene are shown in Table 18 below.

Table 18 Estimated additional fuel price under various SAF blend scenarios

% _{mass} SAF in blend	Estimated blended fuel price (€/tonne)		Additional cost compared to fossil jet (€/tonne)	
	High SAF price	Low SAF price	High SAF price	Low SAF price
7%	668	619	138	89
14%	806	708	276	178

9.1.2 Costs to fuel suppliers

Fuel suppliers would be likely to pass all of the additional cost of SAF onto the airline, plus a small additional margin to cover their additional costs of sourcing, sustainability assurance etc, plus administration related to complying with the obligation if they were the obligated party (estimated by interviewees to be less than the costs of employing one full time equivalent person). Fuel suppliers estimated that any additional costs related to logistics, such as the need for new or repurposed tanks for blending, and additional testing against fuel specifications, would be low on a per tonne basis. Fuel suppliers could make higher margins if they had access to SAF in a short market (for example through having invested in supply chains themselves or made offtake agreements), but this would be a portion of the supply margins already estimated above. Competition between the multiple fuel suppliers at

¹¹⁸ Sweden buy-out 6 SEK/kgCO_{2eq}. Source: SOU, 2019, "Biojet för flyget", PDF p201,

<https://www.regeringen.se/493238/contentassets/6d591e58fd9b4cad8171af2cd7e59f6f/biojet-for-flyget-sou-201911>

¹¹⁹ 600 USD/t sale margin. Source: Neste, Annual Report 2018, <https://www.neste.com/corporate-info/news-inspiration/material-uploads/annual-reports>

Schiphol, would in theory counteract the suppliers' ability to gain margins above these market prices. Given the competitive nature of the aviation fuels market, fuel suppliers interviewed stated that they would not choose to cross subsidise the additional cost of SAF in the Netherlands from sales of fossil jet in other markets, or from sales of other fuels.

9.1.3 Costs to airlines

Based on the assumptions on the estimated additional fuel cost per tonne and two illustrative flights¹²⁰, an estimation can be made of the additional cost of fuel per flight:

- Short-haul flight from Amsterdam to Rome on Boeing 737- flight distance 1,300 km, 160 passengers, 5 tonnes fuel burnt
- Long-haul flight from Amsterdam to New York on Boeing 777- flight distance 5,800 km, 310 passengers, 47 tonnes fuel burnt

Costs presented in Table 19 are additional to fuel costs of €2,663 for a short-haul flight and €25,009 for a long-haul flight under the assumptions noted above.

Table 19 Estimated additional fuel costs per flight, under 2 representative SAF blend scenarios

% SAF blend	Additional fuel cost for a short-haul flight (€)		Additional fuel cost for a long-haul flight (€)	
	High SAF price	Low SAF price	High SAF price	Low SAF price
7%	667	421	6,268	3,956
14%	1,335	842	12,536	7,911

For an airline buying 250 ktonnes/year of fuel in the Netherlands (equivalent to 5% of estimated 2030 kerosene use in the Netherlands) the total additional cost under the 14% SAF blend scenario would be between €42M and €67M. This corresponds to an additional cost between 27% and 44% compared to not having a 14% obligation.

9.1.4 Costs to passengers

Airlines could pass on their costs in several ways:

- Pass on full additional cost to the flights which refuel in the Netherlands
- Spread additional cost across all customers globally
- Intermediate situation where a higher portion of the incremental cost is passed on to passengers on flights refuelling in the Netherlands than elsewhere, but not the full cost.

Interviewees stated that airlines would be likely to do a combination of a) and c), as well as absorbing some costs from their margins. The choice will depend on the airline's key competitors on each route, and whether they are subject to the same obligation.

Based on the fuel cost assumptions above, the additional cost of a flight ticket under a scenario where the full cost of meeting the obligation is passed onto passengers on that flight can be estimated, for the two flights described above. Assuming that the total cost of meeting the obligation across the flight

¹²⁰ Aircraft information from Source: ICCT, 2018, Transatlantic Airline Fuel Efficiency Ranking 2017, https://theicct.org/sites/default/files/publications/Transatlantic_Fuel_Efficiency_Ranking_20180912.pdf

is passed on equally to all passengers, the additional cost per passenger per flight is illustrated in Figure 15.

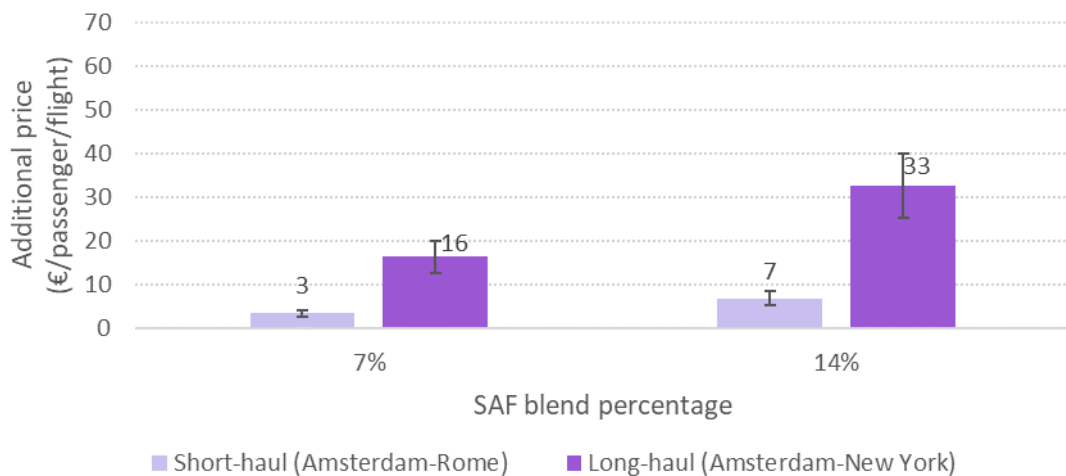


Figure 15 Additional flight price per passenger in case of SAF cost fully passed-on. Bars illustrate use of average SAF price, uncertainty intervals refer to high and low SAF price

Under the 14% SAF blend scenario this represents an increase on the short-haul ticket price of between 3% and 4% (assuming a return ticket price of €200¹²¹) and increase on the long-haul ticket price of between 6% and 10% (assuming a return ticket price of €400¹²¹). The additional cost paid on a return ticket is the same as on a one-way ticket because the SAF blend is assumed to be uplifted only once. This provides an approximation only, as the additional cost may not be spread equally between passengers, for example between those flying business and economy class (low-cost passenger segments are more price sensitive than those flying business class¹²²). It would also be possible for airlines to try to pass some of the costs onto particular passengers e.g. through schemes allowing corporate customers to pay for SAF use to cover the demand from their business flights. However, these customers may be unlikely to want to pay extra for SAF supply if this was already mandated, and so would be supplied in any case. This also assumes that no portion of the additional SAF cost is borne by freight carried on passenger flights.

Scenario (b) represents the other extreme: airlines spread the additional cost across all of their global operations. If refuelling in NL was 5% of the airline's fuel use, then in theory only 5% of the cost in Figure 15 would be passed on to consumers. This equates to a price increase on the short-haul ticket of €0.26 - €0.42 / person.flight and a price increase on the long-haul ticket of €1.26 - €2.00 / person.flight (assuming passengers/tonne fuel is constant). Airlines that have a high proportion of their total fuel uplift in NL will have a much more limited ability to spread costs amongst other passengers. Note that there may be additional costs from obligations in other countries and from CORSIA.

¹²¹ This is an indicative price for a round-trip Amsterdam-New York in end of January 2020, booked 2 months in advance. Prices have been taken from <https://www.skyscanner.net/>. Prices can vary significantly depending on airline, booking date, flight date, flight time, economy vs business class.

¹²² CE Delft (2017) Overheidsmaatregelen biokerosene, Available from: <https://www.ce.nl/publicaties/1980/overheidsmaatregelen-biokerosene>

There would also be impacts on the cost of air freight, which would vary for belly freight (in passenger aircraft, where costs could be shared with passengers) and cargo-only aircraft.

9.1.5 Costs to airports and airport fuel suppliers

Given that SAF blending cannot occur within the boundary of an airport, there are not anticipated to be any additional direct costs to the airport of complying with a blending obligation. Indirect impacts from reduced demand are discussed in section 9.2.

9.2 Impact on competitiveness of airlines and airports

The potential responses of passengers or airlines to the costs imposed by a blending obligation were described in section 5.4.1:

- Demand reduction
- Mode switching
- Tankering
- Use of alternative routes

In addition to environmental impacts, these responses could have important economic impacts for stakeholders in the aviation sector.

The extent to which these responses occur depends on the level of the cost impact, with higher costs leading to greater impact. Moreover, the response of a passenger or freighting company to a fixed increase in ticket price (demand elasticity) is affected by many factors, including: whether the trip is for business or leisure; whether the trip is short-haul or long-haul; whether the elasticity is considered at the level of the airline or the whole market; passenger income.¹²³ Detailed economic modelling of the industry-wide response to higher fuel costs is outside the scope of this study. In subsequent sections the impact of these responses on competitiveness of each sector is discussed, and ways in which these impacts could be mitigated are considered.

¹²³ IATA (2008) Air Travel Demand, AITA Economics Briefing Number 9, Available from: https://www.iata.org/whatwedo/documents/economics/air_travel_demand.pdf

Table 20 Possible consequences of a blending mandate for different stakeholders

	Alternative transport modes	Airports	Fuel suppliers	Airlines
Demand reduction	No impact	Loss of revenue	Loss of revenue	Loss of revenue
Mode-switching	Gain in revenue	Loss of revenue	Loss of revenue	Loss of revenue
Tankering	No impact	No impact	Loss of revenue for fuel suppliers within the obligated region. Overall more fuel has to be purchased as more fuel is burned when tankering	By avoiding the obligation, tankering reduces cost for airline
Use of alternative routes	No impact	Loss of revenue unless slots can be filled by other flights	Loss of revenue for fuel suppliers within the obligated region.	Impact on competitiveness of different airlines, as variable ability to fly alternative routes.

9.2.1 Modes: competition between modes for passenger and freight transport

The introduction of a blending obligation, financed by the passenger or freighting company, would increase the cost of flights and therefore cause some passengers/freight to take alternative modes of transport. This would increase revenues to operators of overland transport in the NL.

CE Delft (2018) modelled the impacts of a flight tax on passenger demand. Their modelled scenario 3A, with a flight tax which ranges from €7/passenger on a short-haul flight to €40/passenger for a long-haul flight most closely correlates with the cost increases anticipated from a 14% blending obligation (Figure 15). Under scenario 3A passenger numbers in 2030 are lower than in the reference scenario by between 1.6 million (under tight restrictions on overall airport capacity) and 1.9 million (where overall airport capacity is assumed to be higher), which is a decrease of 1%-2% compared to the baseline scenario. Of this decrease in passenger numbers, between 35% and 37% is due to passengers not travelling at all, between 17% and 20% is due to passengers instead travelling overland, and between 43% and 47% is due to passengers travelling through foreign airports instead. This results in an increase in passengers travelling by land of between 280,000 and 370,000 per year. Given that currently the Dutch railways transports over 1.3M passengers per day, this is not a substantial increase in passenger numbers.¹²⁴

¹²⁴ NL Times (2019) Dutch railway handles 1.3M passengers per day, Available from: <https://nltimes.nl/2019/07/04/dutch-railway-handles-13-million-travelers-per-working-day> (Accessed on 5th november 2019)

9.2.2 Airlines: competition between airlines with a hub in the Netherlands and those without

Whilst all airlines will suffer revenue loss from demand reduction or mode shifting, airlines with a hub in the Netherlands have a reduced ability to tanker fuel, to compete with alternative routes, to spread compliance costs across passengers who do not fly through NL, or to shift more efficient aircraft to routes through NL, which may place these airlines at a competitive disadvantage.

Two studies have assessed the decrease in passenger demand if costs were increased by a flight tax in the Netherlands, which is analogous to an increase in costs from a SAF obligation. This decrease is a combination of demand reduction, mode shifting and use of alternative routes.

- CE Delft (2017) examine the impact of imposing a cost of 8€/passenger on a flight from Amsterdam to elsewhere in Europe and 31€/passenger on an intercontinental flight on passenger numbers compared to a reference scenario with no additional costs. This per person charge is similar to that anticipated under a 14% blending obligation (Figure 15) and it therefore provides an indication of the level of demand decrease that might be anticipated under such a mandate. In the study, the cost is only imposed on O&D passengers, and is anticipated to cause a decrease of O&D passenger demand of 7% for European destinations and 4% for intercontinental destinations in 2030, compared with a scenario without this passenger charge.
- SEO (2018)¹²⁵ considers two scenarios where the flight tax is limited only to O&D passengers, and a third scenario where it is applied to both O&D and transfer passengers depending on the maximum take-off weight of the aircraft. Where the tax is applied to both O&D and transfer passengers, the total number of O&D passengers decreases by 2% whereas the total number of transfer passengers decreases by 5% compared to a reference scenario without the cost, showing that transfer passengers are much more sensitive to prices.

A further study (CE Delft, 2018) gives additional information on where demand is being shifted to:

- Under CE Delft (2018) scenario 3A (described in 9.2.1) of the total decrease in passenger numbers due to higher costs, between 35 % and 37% is due to passengers not travelling at all, between 17% and 20% is due to passengers instead travelling overland, and between 43% and 47% is due to passengers instead travelling through foreign airports instead. It is anticipated that the impact of passengers travelling through foreign airports instead of through NL would disproportionately affect Dutch airlines.
- Importantly it should also be noted that in CE Delft's scenario 3A, freight and transfer passengers are exempt from the tax. It is easier for transfer passengers to fly by alternative routes than O&D passengers, as the location of the transfer airport is relatively unimportant. Therefore a blending obligation which impacts both O&D and transfer passengers will likely result both in a greater drop in passenger numbers (relative to a scenario with no additional costs); and of this reduction in total passenger numbers a greater proportion will choose to travel via alternative routes rather than mode-shifting. Hence the relative impact on airlines headquartered in NL will be greater than that given by CE Delft (2018).

¹²⁵ SEO (2018) Effecten van een nationale vliegbelasting, Available from: http://www.seo.nl/uploads/media/2018-99_Effecten_van_een_nationale_vliegbelasting_in_2025.pdf

Based on the evidence reviewed, imposing higher costs on passengers as a result of a blending obligation will result in a reduction of passenger numbers. This will have negative economic impacts for all airlines operating through the NL. The impact on airlines with a hub in the NL will be proportionately greater than for other airlines, because some passengers will choose alternative routes not via the Netherlands, served by other airlines. Once the policy design has been narrowed further, detailed economic analysis is recommended to assess the likely impact of remaining options on airlines, and in particular the extent to which airlines with a hub in NL will be disadvantaged compared to other airlines.

9.2.3 Airports: competition between Schiphol and other hubs

Under a blending obligation, Dutch airports could lose revenue in the case of demand reduction, mode shifting, or flights being made via other airports.

In 2018 Schiphol airport reached the capacity ceiling of 500,000 flight movements.¹²⁶ In addition the opening of Lelystad Airport which was expected in 2019 has been delayed. Given the existing capacity constraints on Schiphol airport, higher costs are not anticipated to impact the volume of traffic through Schiphol in the short-term. However, demand growth over the medium term could be slower with a blending obligation than in a scenario without a blending obligation. Estimates of the decrease in the total number of passengers in the case of higher flight costs, compared to a reference scenario without higher flight costs, are reviewed in section 9.2.2. In the case of flights being made via alternative routes, this loss of revenue would come at the expense of increased revenue for airports outside of the Netherlands.

In addition, the obligation may also impact Netherlands' regional airports differently from Schiphol. Previous modelling on the impacts of a passenger tax on the NL aviation sector¹²⁷ concludes that across all scenarios modelled the reduction in passenger demand at regional airports is significantly more severe than the reduction in passenger demand at Schiphol due to the high percentage of low-cost and non-business passengers at regional airports, who are more sensitive to price increases. In one scenario for example, Schiphol experiences a decrease in O&D passengers of 4.8% whilst the number of passengers at regional airports falls by 9%.¹²⁸ On the other hand, regional airports do not carry any transfer passengers, and it is known that transfer passengers are more price sensitive than O&D passengers. Other previous work¹²⁹ suggests that with a tax which applies to both O&D and transfer passengers, Schiphol experiences a 2% drop in O&D passengers and a 5% drop in transfer passengers (relative to a reference scenario), resulting in overall a 3% drop in passengers. Other Dutch airports experience only a 2% drop in passengers relative to a reference scenario because they only carry O&D passengers. Therefore it seems likely that under a blending obligation Schiphol would experience a greater economic impact relative to other airports in NL, but once the policy design has been finalised full economic analysis would confirm this.

¹²⁶ KLM (2018) Annual report, Available from: https://annualreports.klm.com/KLM_Annual_Report_2018.pdf

¹²⁷ CE Delft (2017) Overheidsmaatregelen biokerosene, Available from: <https://www.ce.nl/publicaties/1980/overheidsmaatregelen-biokerosine>

¹²⁸ This fall is relative to a reference scenario without any policy measures so does not represent an absolute decrease in passenger numbers but a slow-down in growth. Under the reference scenario the passenger numbers are anticipated to increase 2.7% annually, so that a decrease of 5.4% vs. the reference scenario reflects the loss of 2 years' growth.

¹²⁹ SEO (2018) Effecten van een nationale vliegbelasting, Available from: http://www.seo.nl/uploads/media/2018-99_Effecten_van_een_nationale_vliegbelasting_in_2025.pdf

9.3 Costs to government

9.3.1 Direct costs to government

The direct cost to government of an obligation scheme is the cost of administering the scheme. In 2018 there were 38 obligated suppliers under the HBE scheme. Under an aviation obligation, if this was imposed on fuel suppliers there would be a smaller number of obligated parties (up to 10), and if it was imposed on airlines there would be around 100 obligated parties (depending on the exact rules and any exemptions allowed). Therefore the administrative burden for government would be lower for an aviation obligation compared to the HBE system if fuel suppliers were obligated, and may be slightly higher if airlines are obligated. It has been estimated that the cost of implementing the previous air passenger tax in the Netherlands from 2008 to 2009 was less than €₂₀₀₉0.5M¹³⁰ (accounting for inflation corresponds to around €0.6M today). Integration with the existing HBE scheme, and administration by the same implementing organisation could further reduce costs from administering the aviation obligation.

9.3.2 Indirect costs to government

There may also be indirect costs from loss of tax income. Costs to government could also be incurred indirectly through economic impacts on state owned parts of airlines and airports including Schiphol, KLM and the Air-France KLM holding company¹³¹. If a policy is set up to partially cover the costs of a blending obligation, or support particular routes, which is funded through general taxation (see section 5.4.12) then this would impose further costs on government. However other benefits, including from SAF production in the NL, may offset these costs.

In a study analysing the impacts of a flight tax, Dutch GDP is found to increase under all 10 variants of the flight tax which were investigated¹³². This is partly because part of the tax is paid by non-residents and non-resident companies (which would also be the case if SAF costs were passed on to passengers), and because spending in the Netherlands increases as some Dutch people choose not to travel and instead spend money in NL. The impact on Dutch GDP also depends on how much of the SAF production occurs in NL, and the impact on prices from freight cost increases.

¹³⁰ CE Delft (2018) Economische-en Duurzaamheidseffecten Vliegbelasting, Available from: <https://www.ce.nl/publicaties/2132/economische-en-duurzaamheidseffecten-vliegbelasting>

¹³¹ Council for the Environment and Infrastructure (2019) Aviation policy, a new approach path, Available from: <https://en.rli.nl/publications/2019/advice/aviation-policy>

¹³² CE Delft (2018) Economische-en Duurzaamheidseffecten Vliegbelasting, Available from: <https://www.ce.nl/publicaties/2132/economische-en-duurzaamheidseffecten-vliegbelasting>

10 SAF supply logistics

Summary

- If an obligation were introduced, SAF would be blended with fossil jet fuel, and supplied to airports through existing infrastructure, with minimal additional costs.
- Barriers to this are expected to be overcome in the near term.

10.1 Introduction

A central strategy from the earliest stages of the development and deployment of sustainable aviation fuels has been that the fuels have to comply completely with the existing quality and safety standards that are used in the aviation sector. This requirement ensures that following the blending process of sustainable aviation fuels with conventional Jet A1 fuel, the downstream processes and infrastructure can in principle process such blends without further modifications in logistics and supply.

This approach was followed because:

- Aircraft engines and fuel systems have a very long lifetime, and so combining with existing specification is needed to enable ramp up in the near and medium term
- Safety of operation is a core requirement in the aviation sector. Forcing sustainable aviation fuels to perform equally to existing Jet A1-fuels and to follow all internally accepted standards was necessary for them to be accepted by airlines.
- The emphasis on the drop-in quality of sustainable aviation fuels means that no additional infrastructural and logistical costs are added to the use of sustainable aviation fuels. This allows sustainable aviation fuel producers to focus on the cost competitiveness of the fuels itself rather than on the total fuel supply system.

10.2 Current and future supply logistics

Most sustainable aviation fuel supply is still based on batch operations. Until 2016, SAF was usually distributed via trucks or rail to separate storage facilities from which aircraft were supplied. This is because supply volumes were small and irregular. Since 2016, SAF distribution has been integrated to a larger extent in existing jet fuel infrastructure and supply of SAF via the airport's common hydrant system used for fossil jet has become standard practice, demonstrated in several airports globally. No interviewees reported any issues related to safety or reliability of SAF delivery in these operations.

All interviewees considered that in a future situation with obligatory SAF blending, SAF would be supplied through existing jet fuel infrastructure, i.e. via pipelines and airport hydrant systems where available. This would require SAF to be blended with jet at the production location or an intermediate point such as on import, and from then it would be transported using existing pipelines to airports. At smaller airports delivery may be by truck. Note that SAF cannot be blended at an airport, as unblended SAF is not allowed in airport fuel systems.

Two current barriers to be overcome in achieving this cited by interviewees were:

- The existing Rotterdam-Schiphol pipeline is the Central European Pipeline System (CEPS), which is a NATO pipeline system, operated by the Defensie Pijpleiding Organisatie (DPO). This pipeline system runs through 5 countries (NL, BE, LU, FR, DE, with the US also a member of the system) and currently does not allow synthetic components in the system as it also serves military airfields. All member countries unanimously need to approve synthetic components in the system to allow for blended SAF at Jet-A1 specifications in the system. This is currently not the case with, Germany being against this change. One interviewee estimated that approval from Germany would be given by the end of 2020.
- The fossil jet fuel produced from refineries varies over time in its specification. This variation means that at some times it is only possible to blend SAF up to a lower percentage (e.g. 20-30%) rather than the 50% to which it has been approved. This is a barrier to SAF producers and blenders in economic terms, as it means they need to buy more fossil jet to blend. Several interviewees considered that this issue would be overcome if an obligation were introduced through cooperation between the fossil jet and SAF industries.

11 Conclusions

Would the introduction of an annual renewable energy obligation for aviation be an effective way to stimulate the production and consumption of sustainable aviation fuel (SAF), with a view to achieving the objective of a minimum of 14% sustainable aviation fuel in the Netherlands by 2030?

- An obligation for SAF in the Netherlands would be an effective way to stimulate consumption of sustainable aviation fuels, and would be likely to result in use of 14% sustainable aviation fuels in 2030. Obligations have been shown to be an effective way to deliver renewable fuel use in the road transport sector in many European Member States, and interviewees from the aviation industry confirmed that an obligation would drive uptake in the aviation sector.
- Given that 14% of projected Dutch demand for aviation fuel is a relatively small volume in the context of projected global renewable fuel supply and demand, it would be likely to be met provided that the obligation resulted in a price comparable to that in other similar markets. Nevertheless, a rapid increase in demand for SAF in other countries (for example through mandates in countries with high aviation fuel demand) or for feedstocks and fuels from the road transport sector (from all Member States as REDII is implemented) could lead to price increases and shortage of supply.
- An obligation would also be likely to support and stimulate production in the Netherlands, although this would not be guaranteed by this type of policy. There are planned SAF projects in the Netherlands today, with other players interested in siting plants, and airlines keen to support local supply chains to supply aviation demand. In addition to an obligation, support mechanisms could be used to support SAF plants in the Netherlands based on higher costs routes that could broaden the sustainable feedstock base for SAF.

Would an obligation be an effective way to support future SAF routes?

- Given the limited availability of waste and residue feedstocks for HEFA, and the much larger global availability of feedstocks for advanced biofuels and renewable electricity for power to liquids, successful commercialisation of these routes will be very important to enable continued scale up for SAF use in the NL and globally. However, these pathways are estimated to have higher production costs than oils-based SAF routes, and are at an earlier stage of commercialisation today. As such, they are likely to supply very little of a 2030 obligation unless supported further.
- These fuels require either a sub-target within an obligation, or additional support via supply or demand side policy, or preferably a combination of the two, as is common for road transport biofuels. These fuels could also be incentivised through an obligation only for these fuels, rather than as a sub-target within an obligation with a broader scope. A sub-target or dedicated obligation has a higher risks of a shortage of supply, given that these routes are at an early stage of commercialisation. As these plants will take several years to be planned and built, with very few underway today, an obligation could start in the mid 2020s.

Would an obligation be an effective way to support near term SAF routes?

Any type of support for SAF in the near term will have **benefits** in terms of:

- near term GHG savings

- further readying the supply chain for SAF use, such as putting appropriate chain of custody systems in place across pipelines
- sending a signal to the industry that SAF supply is required, which could drive investment in production capacity, and action in feedstock sourcing

There are also **risks** related to near term support:

- There have been concerns that supporting use of SAF would merely divert feedstocks and fuels from use in the road transport sector, with increased processing emissions. However, diversion from the road sector will lead to increased use of other renewable fuels to meet road sector policy targets. Provided that sustainability requirements, including caps on food and feed crops, are maintained in the road sector this should not lead to negative impacts.
- There is widespread interest in use of waste oils and fats in aviation, and some concern over limited resources for these feedstocks, leading to a risk of high prices and/or targets not being met. This implies a need to design policy such that targets can be realistically met and the sector does not become over-reliant on these feedstocks in the longer term, for example through encouraging alternative options such as new sustainable feedstock types and advanced biofuels

Assuming that the benefits are judged to outweigh the risks, options for supporting SAF in the near term would be a blending obligation, or direct payment for SAF use.

A blending obligation would:

- pass the costs of SAF use on to the airlines, and so on to passengers. This would have economic impacts on airlines, together with potential for carbon leakage through tankering and passengers taking alternative routes. However, it would mean that the costs were borne by those causing the impacts, rather than by tax payers in the Netherlands, or road-fuel users (as in the case of the opt-in).
- encourage continuous competition, which would bring down prices from today's high levels as new entrants enter the market, albeit limited by prices available for similar fuels in the road sector, and potentially counteracted by increasing feedstock costs in the future.
- raise awareness in the whole aviation industry (airlines and fuel suppliers) of the need for action, which could prompt those that have not been active to date to focus on their strategies for decarbonisation, and potentially to invest in SAF supply chains. Optional support policies are unlikely to create this level of interest, particularly amongst large players where renewable feedstock/fuel supply would be a small share of their business.

Providing a direct payment for SAF use, for example through a scheme analogous to SDE++, would have the benefit of being able to split costs between industry and government, and so reduce economic impacts, but would not bring the same advantages in terms of competition and wider market creation. Government would also need to consider carefully the public contribution made: to what level this could be justified for technologies that are already commercialised, lack of public funding for production of similar fuels for the road transport sector, and the high margins being made as a result of low capacity. However if the direct payment were set too low, SAF would not compete with use of the same feedstocks and conversion plants in the road transport sector.

What are the preconditions for introduction of a blending obligation for aviation?

- Successful introduction and operation of an obligation relies on balancing the demand, set by the level and timing of the obligation, with the supply, set by the scope of the target, sustainability requirements, and any additional support for the obligated fuels. Some of these factors interact with other policy areas, such as targets for decarbonisation and renewable fuels in other sectors. Decisions made on each one of these factors will affect the others, meaning that their combined impacts will need to be assessed, and re-assessed if decisions change. Key factors for which decisions are needed are described below.
- Some interviewees considered that a potential barrier to the introduction of a blending obligation is the currently limited SAF production capacity. However, as long as this capacity, and a realistic pathway for this to increase, is taken into account in the policy design this should not present a barrier to the success of a blending mandate.
- The extent to which biofuels based on food and feed crops could contribute towards SAF supply is a key consideration for policy, with widely differing views amongst stakeholders. This will need to be agreed in conjunction with Netherlands policymaking on biofuels in other sectors. Excluding food and feed crop-based fuels would reduce supply options, lead to risks related to limited waste oils supply, and may provoke challenge from some airlines. Including these fuels would increase the risk of impacts on food and feed markets, conflict with sustainability requirements of some airlines, and require careful alignment with biofuel policymaking in other sectors. Further assessment is needed of the potential for, and impacts of crops with low land use impacts.
- The economic impacts of obligating SAF blending could lead to competitive distortion between airlines, in particular on those with a hub in the Netherlands. The only ways to reduce these distortions are a) to develop a policy with a wider geographic scope, through pushing for European level policy or a stronger driver for SAF within CORSIA, b) reduce the level of the obligation, which would also reduce the climate benefits or c) reduce the costs to passengers, for example through subsidising the additional costs of SAF blending from general taxation (only possible for non-food and feed crop based SAF). The Dutch government will need to decide what level of economic impact is acceptable in order to achieve the policy goal of GHG reduction.

Key areas for agreement if an obligation is to be introduced

- Extent to which biofuels based on food and feed crops should contribute towards SAF supply and treatment of fuels from low ILUC crops
- Extent to which waste oils feedstocks should contribute towards SAF supply
- Form and level of support for advanced biofuels and power to liquids
- Degree of economic impact on airlines
- Level and timing of targets
- Compliance mechanism
- Chain of custody in pipelines across multiple countries
- Approach to encouraging an EU-wide policy in parallel with introduction of an obligation in the Netherlands

What are the risks of introducing this type of obligation?

- Policymaking for SAF is at a relatively early stage globally, with ongoing debate over the interaction between CORSIA, the EUETS, Member State level policies and the potential for EU policy. Whilst no barriers to an obligation appear to exist, there is a small remaining risk of potential challenge to an obligation in the Netherlands depending on the approach taken.
- The sustainability risks around an obligation will depend on the feedstocks allowed under the obligation. Waste oils provide a near term sustainable route to SAF, though their limited potential leads to concerns about price rises and supply volumes particularly if demand increase in other markets. Food and feed crop-based biofuels will be used to supply SAF unless this is specifically excluded in the policy, as whilst some airlines have policies to avoid these feedstocks, others will use the cheapest fuels available. Advanced biofuels from lignocellulosic feedstocks and liquid fuel from renewable electricity are widely seen as having lower sustainability risks and much higher sustainable resource potential.
- Expected prices for SAF are high: around 4-5 times the prices of fossil jet. This is a result of both high production costs of SAF (2-3 times jet at the low end, up to 8 times for routes in development) and very low levels of global supply today. These prices are not expected to decrease to 2030: whilst the prices of today's oil-derived routes may come down with new players entering the market, pressure on feedstocks is likely to increase. Production costs of some advanced routes will come down, meaning they can enter the market, but not to the extent that they would bring prices down. The resulting additional fuel cost will lead to economic impacts on airlines, which may need to be managed through policy design (as above). It would also be possible to limit the potential costs through setting a buy-out price for the policy, which would limit costs at the expense of achieving some GHG savings.
- The additional costs of SAF blending could also lead to carbon leakage: increased emissions as a result of airlines tankering (carrying more fuel than is needed to avoid uplifting fuel in the Netherlands) or from passengers using alternative (potentially longer) routes on which SAF is not used. This could be mitigated through the same approaches as for the economic impacts above, in particular through EU or stronger global policy.

Appendix A

All of the technology routes considered in this study can produce a number of different fuel types. In this study two cases are considered: where the percentage of jet output is maximised, and where the percentage of other fuels is maximised. The percentage of jet fuel (as a percentage of total fuel output from the plant) in each of these two scenarios is shown in Table 21.

Table 21 High and low jet fuel slate

Route	Jet % when pathway optimised to produce jet	Jet % when pathway optimised to produce other fuels
Hydroprocessing of oils/fats	70%	14%
Gasification with Fischer-Tropsch	50%	6%
Pyrolysis with catalytic upgrading	60%	20%
Alcohol catalysis (AtJ)	90%	25%
Aerobic fermentation (DSHC)	100%	0%
APR with catalytic upgrading	60%	20%
HTL with catalytic upgrading	60%	20%
PtL with FT catalysis	50%	20%