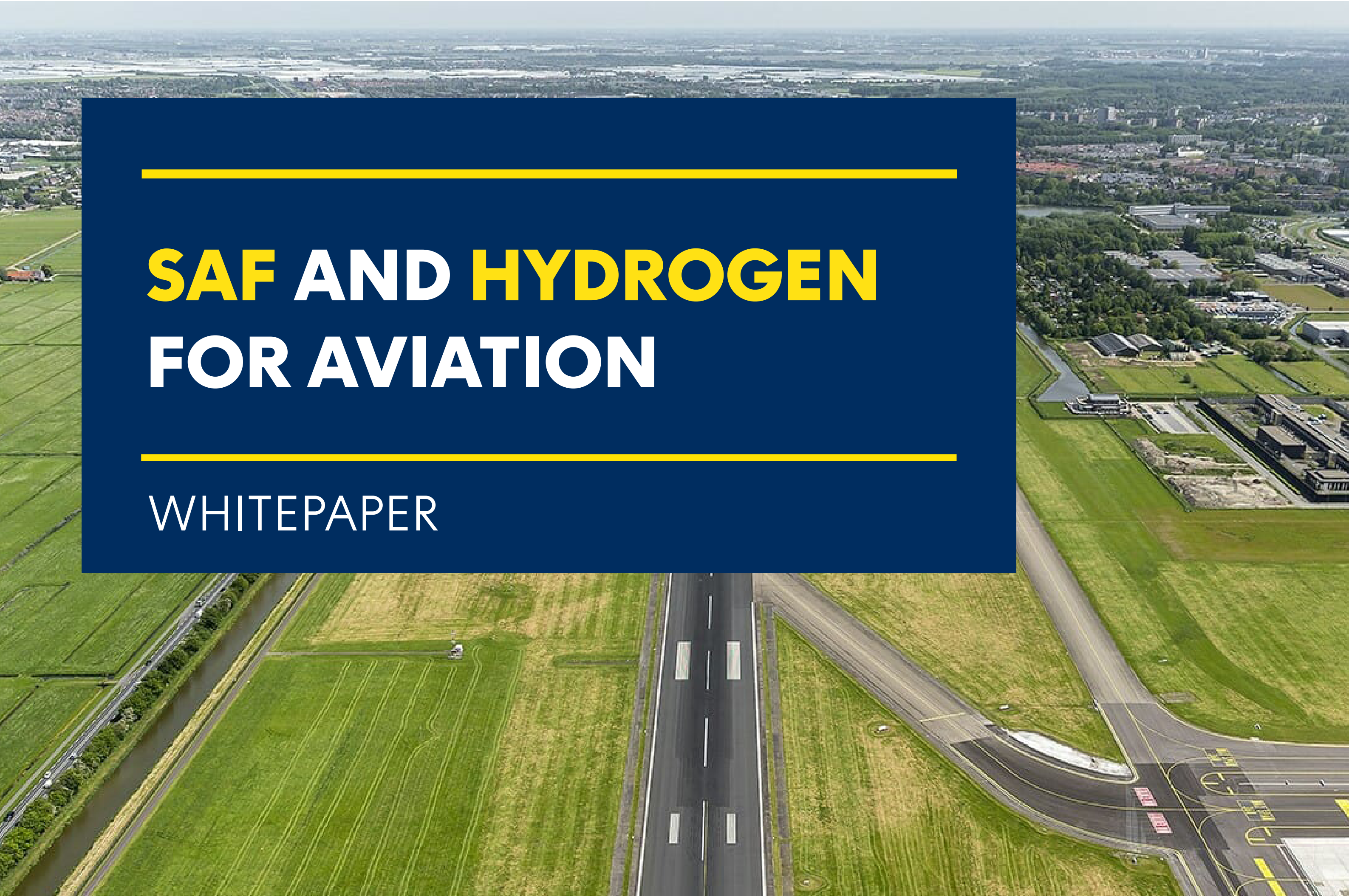
Port of Rotterdam

Rotterdam The Hague Airport



# SAF AND HYDROGEN FOR AVIATION

WHITEPAPER

Aviation is one of the sources of greenhouse gas emissions, thereby affecting global climate. Despite the fact that aircraft have become more fuel-efficient in recent decades, global aviation emissions are still rising due to the growing demand for air travel. Direct emissions from aviation accounted for 3.8% of total $CO_2$ emissions in the EU in 2017 , while not taking into account non-$CO_2$ effects such as: contrail formation, nitrogen oxides, water vapour, sulphate and soots. These non-$CO_2$ effects also contribute to global warming, but the exact impact on the climate is still unknown.

Making aviation less dependent on fossil fuels can be achieved through multiple complementary methods, such as the use of Sustainable Aviation Fuels (SAF) and the development of innovative aircraft and engine technologies such as battery-electric and hydrogen-powered aircraft. These developments require the setup of complete new value chains and supply chains in order to assure the delivery of SAF and hydrogen at airports. Developments in different parts of the SAF and hydrogen value chain are emerging in the Rotterdam region with Port of Rotterdam and Rotterdam The Hague Airport (RTHA) as active players. Both organizations are joining forces in establishing a coherent supply chain for alternative fuels such as SAF and hydrogen.

### Sustainable Aviation Fuels (SAF)

SAF are one of the few currently available options for mitigating international aviation emissions. The use of these fuels also cuts emissions of soot and ultrafine particles if used in larger blending concentrations. SAF can reduce $CO_2$ emissions by 80% in its life cycle compared to current kerosene (JET-A1). This has a positive impact on the climate worldwide, while potentially also enhancing local air quality at the airport. The advantage of this fuel is that it can be used as a drop-in fuel in existing aircraft and corresponding fuel infrastructure.

The ReFuelEU Aviation Regulation mandates a gradual incorporation of SAF into all fuels provided to aircraft operators at airports within the EU. The minimum share gradually increases from 2% by 2025 and 6% by 2030 to 70% by 2050. RTHA accelerates this effort by setting itself a minimum extra target of 8% until 2030 to meet the more ambitious goal of the current Dutch aviation sector of 14% by 2030. It does so to provide a strong and stable demand, which is necessary for scaling up the production, supply and use of SAF.

Two main types of SAF are defined in EU-blending mandates – bio SAF and synthetic SAF (also known as eFuels). Bio SAF is made from non-fossil resources, such as plant sources and used cooking oil. eFuels are produced by using green hydrogen, carbon dioxide ($CO_2$) and green electricity. Both bio and synthetic sources are needed in order to meet future SAF demand. However, raw materials needed to produce bio SAF are limited in quantity. eFuels are therefore expected to play a significant role in filling the eventual SAF gap . A sub obligation of the RefuelEU regulation is that a minimum percentage of blended SAF must contain eFuels. This percentage will gradually increase from 1.2% in 2030 to 35% in 2050 .

### SAF and eFuel developments in the Port of Rotterdam

There are already several refineries in the port of Rotterdam that produce biofuels, namely Viterra (biodiesel), Alco (bioethanol), Neste (HVO) and Koole (SAF) with a combined production capacity of 2.5Mt. This makes Rotterdam the largest biofuels cluster in Europe. Two major new refineries are currently under construction. Neste and Shell are both building new biofuel plants at the Port to produce SAF, with a total capacity of more than 2Mt.

In addition to the Neste and Shell projects, Koole is investing in a second distillation unit for the production of SAF. With these 3 projects, the current production capacity of biofuels could more than double to 5.1Mt in the coming years. Swiss VARO Energy has announced that it wants to build a SAF refinery on the Gunvor site, BP has announced that it is considering an investment in a SAF refinery, and the Finnish UPM wants to realize a biorefinery in the port area that will mainly produce SAF.

Currently, around 24% of the European demand of kerosine is being supplied via Rotterdam. The port aims to play the same supply role for the European and Dutch demand for SAF. It is therefore important to extend the current bio SAF production in Rotterdam with $CO_2$ based SAF, or eFuel, production. Especially since the biobased feedstock needed for bio SAF is limited and due to the RefuelEU targets on the increased production and use of eFuels within aviation. Being a hydrogen (import) port makes Rotterdam a strategic location for the production of these eFuels as well. Although there is no company producing this product yet, the port is working on multiple developments in the field of eFuels.

### Hydrogen

Green hydrogen is seen as a sustainable alternative for short and medium haul JET-A1 powered flights as it eliminates $CO_2$ emissions. Hydrogen can be combusted in a jet engine to power the aircraft or used to power electric engines by making use of fuel-cell technology. The latter form allows for zero-emission propulsion (including the elimination of non-$CO_2$ emissions such as NOx and particles – excluding contrails). The applicable range of future hydrogen-powered aircraft is estimated at 1000 – 2000 nm (roughly 1800 – 3700 km) by Airbus which corresponds to most of intra-European air traffic . The Destination 2050 roadmap projects that hydrogen-powered flights could decarbonise approximately 20% of total $CO_2$ emissions from European flights by 2050.

The use of hydrogen in aviation is however still in an early development phase. Aircraft developers, such as Airbus with its ZEROe programme, are planning to introduce new hydrogen-powered aircraft in the future. Other companies such as ZeroAvia, H2FLY, Universal Hydrogen and Conscious Aerospace focus on converting existing aircraft into hydrogen-powered aircraft by developing hydrogen propulsion systems.

Adjustments at airports are needed as well on top of the developments in the field of hydrogen-propulsion systems. Hydrogen infrastructure and supply is a prerequisite to facilitate and scale the adoption of hydrogen-powered aircraft. As many airports are not yet familiar with hydrogen, airports most likely need to start from scratch when setting up new value chains with stakeholders to allow the provision of hydrogen at their airports. This includes hydrogen production, supply, (local) storage and airport operations.

### Hydrogen developments in the Port of Rotterdam

The Port of Rotterdam Authority and its partners are working on a hydrogen system. The use of low carbon hydrogen in industry and transport contributes to the goal of becoming a $CO_2$ neutral port. Currently, half of all hydrogen projects in the Netherlands are taking place in Rotterdam. The Rotterdam hydrogen system consists of several components. At this moment, a hydrogen transport pipeline is constructed to form the backbone of Rotterdam's hydrogen infrastructure. In the future, the pipeline will be connected to the national and international hydrogen network and provide a connection to industrial clusters.

On the Maasvlakte, a specific land area is reserved for electrolysers that will convert green electricity from offshore wind farms into green hydrogen using electrolysis. The first 200 MW electrolyser, Holland

Hydrogen I is being built right now by Shell. According to current expectations, the production of green hydrogen in Rotterdam will rise from 115 kt in 2025 to 195 kt by 2030. By 2050, demand for this relatively clean energy carrier is expected to increase to 20 Mt, of which around 18 Mt will be imported. Therefore the port of Rotterdam is currently also involved in dozens of projects with the aim of setting up imports via Rotterdam. There are various ways of transporting hydrogen by 'packing' it to another molecule, such as ammonia, methanol or a Liquid Organic Hydrogen Carrier (LOHC). Rotterdam is able to import all different carriers.

## Hydrogen projects at Rotterdam The Hague Airport

RTHA is well-positioned to play a role in accelerating hydrogen-powered aviation through the combination of the following aspects:

- The ability to test, integrate and scale new technologies given the size of the airport
- Flight profiles (intra-European / regional) that fit well in the foreseen future range profiles of hydrogen-powered aircraft
- Presence in 'Europe's Hydrogen Hub' - a hydrogen-minded region with Europe's biggest energy importer the Port of Rotterdam just around the corner

Several hydrogen projects are in progress at the airport in order to build-up knowledge on the introduction of hydrogen at airports. Each of these projects falls under the umbrella of the Dutch$H_2$ Aviation Hub hydrogen programme that the airport launched in 2022. This programme has been established to facilitate cooperation between partners on the hydrogen value chain at the airport, from production to operational deployment at the airport.

RTHA is focused on developing the hydrogen supply chain and the necessary infrastructure for hydrogen storage and refuelling, plus airport operations tailored to hydrogen, such as local storage and refuelling. Current projects include amongst others the realization of a small-scale liquid hydrogen storage facility, the realization of a hydrogen refuelling station and hydrogen refuelling projects with partners such as ZeroAvia and AeroDelft. More projects are expected in the future.

## Hydrogen and SAF supply chain to the airport

The supply of SAF and (liquid) hydrogen to airports differ a lot in their form. As SAF is blended with JET-A1 fuel, relatively little adjustments need to be made on the side of the airport. JET-A1 fuel is currently


*Figure 1. Hydrogen developments in the port of Rotterdam and the supply to Rotterdam The Hague Airport*

provided to RTHA via trailers, while other airports such as Amsterdam Airport Schiphol are connected through pipelines with the Rotterdam port area. Main adjustments for this greener fuel can therefore be expected on the production side and the supply of raw materials that are needed to produce SAF, whether its feedstock for biofuel or hydrogen for eFuels.
The supply of (liquid) hydrogen however has a big impact on airports. Current airport infrastructure and operations are centred around more well-known JET-A1 operations.

The type of hydrogen supply and infrastructure heavily depends on the hydrogen demand of the airport and the airport's proximity to hydrogen production and/or import clusters. One can imagine that this differs significantly between a regional airport such as RTHA versus a major international hub such as Amsterdam Airport Schiphol. A visualization of the hydrogen developments in the region and the supply in the airport can be seen in figure 1.

A visualization of the (liquid) hydrogen and SAF supply chain for RTHA can be seen in figure 2.

RTHA has the advantage that it can benefit from the (liquid) hydrogen developments in the Rotterdam region, such as the hydrogen production and import, liquefaction and transport opportunities.

## About the collaboration

The Port of Rotterdam and Rotterdam The Hague Airport recognize the need for value chain development for alternative aviation fuels – both for hydrogen and sustainable aviation fuels (SAF). Setting up a coherent supply chain for the delivery of these fuels is part of the collaboration between the two organizations.
By using their knowledge and expertise, they aim to set an example on how to build a coherent supply chain together with multiple partners and take care of the required port, airport and refuelling infrastructure

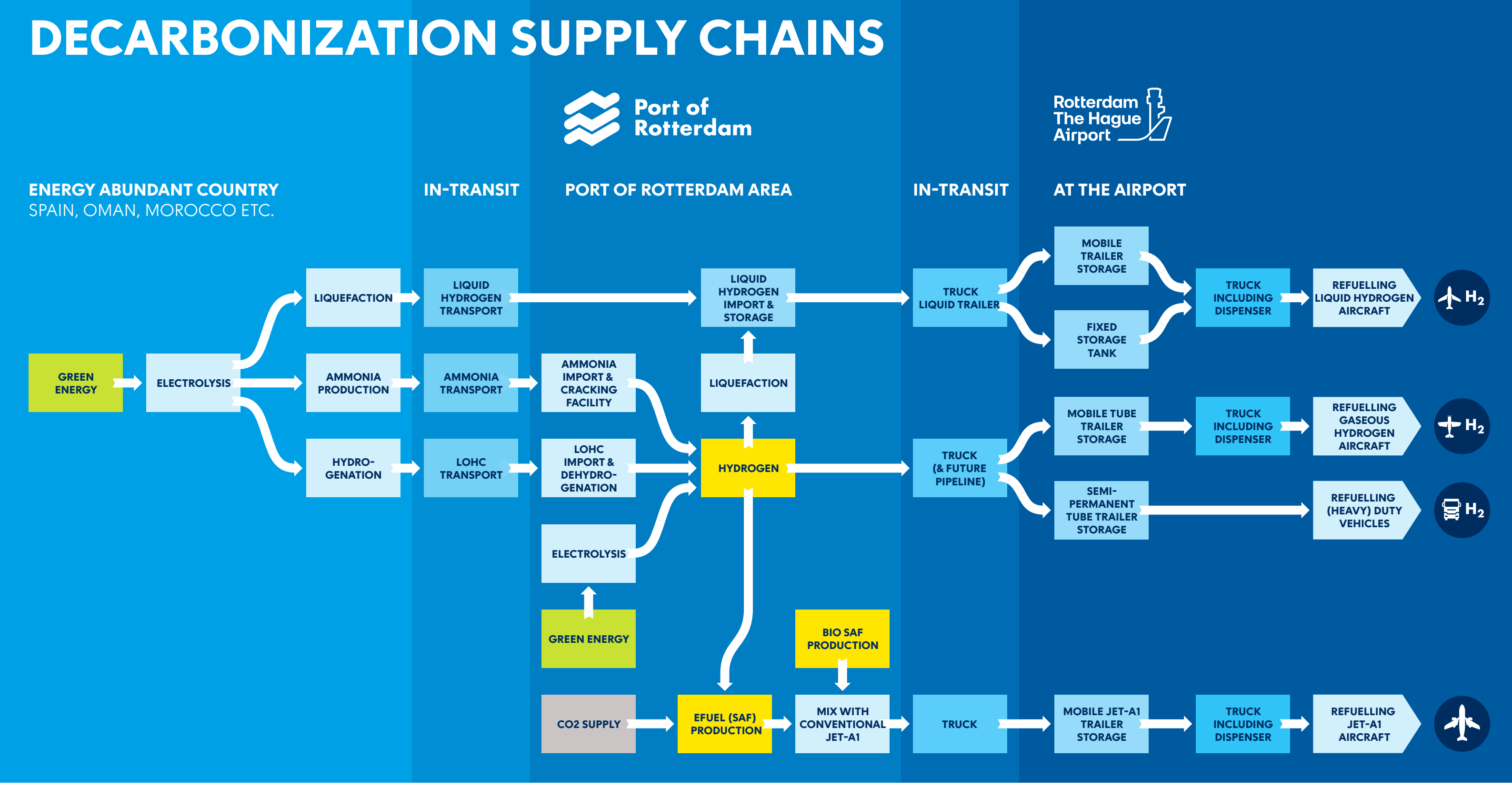



*Figure 2. Visualization of the SAF and hydrogen supply chains to Rotterdam The Hague Airport through the port of Rotterdam*

over the next few years. The port and airport will work together on topics like safety, certification, demand and supply but will also aim to setup pilot projects in the coming years to test different aspects that need to be in place in order to use alternative fuels. The link with the Royal Schiphol Group and Amsterdam Schiphol Airport will be made in a later phase to extend the focus to a broader region and a hub airport with higher expected volume (and associated potential $CO_2$ reduction) and (partially) different supply chain needs.

## Call to action

The realization of the value chains for these alternative fuels require collaboration throughout the chain. Multiple actors are needed in order to realize this. Potential participants that would like to contribute to the establishment of this value chain and/or demonstrators are invited to contact Port of Rotterdam or Rotterdam The Hague Airport via the contact details below if interested.

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## About Rotterdam The Hague Airport

RTHA is a regional airport located in The Netherlands and part of the Royal Schiphol Group. The airport facilitated around 56.000 aircraft movements and 2.2 million passengers in 2023. Around 16.000 of these aircraft movements are categorized as 'commercial traffic', mostly carried out with narrowbody aircraft like the Boeing 737, Airbus A319/320 and the Embraer 190. The airport serves destinations like London City, Malaga, Faro, Lisbon and Barcelona by main carrier Transavia, British Airways and TUI, amongst others. RTHA and the other airports of the Schiphol Group have dedicated itself to achieving $CO_2$-neutral aviation by 2050. Key strategies for achieving this goal include transitioning to more sustainable forms of fuel, such as battery-electric, SAF and liquid hydrogen. The airport is ACA-level 5 accredited - the highest level in the Airport Carbon Accreditation programme by Airports Council International (ACI). With this Level 5 accreditation, RTHA has proved to have reduced its scope 1 and 2 emissions by more than 90% since 2010 and is committed to achieving net zero in scope 3 emissions by 2050 or sooner — and serves as an innovation platform within the Schiphol Group for the integration of hydrogen-powered aviation at airports.

## About the Port of Rotterdam

The port of Rotterdam is a cornerstone of the Dutch and European transport and economic systems. In addition to the significant economic and social value the port holds in the Rotterdam-Rijnmond region, it also benefits the logistics sector and businesses that import and export in the rest of the Netherlands and Europe through employment, added value, revenue and business locations. The Port of Rotterdam is the largest port in Europe. The port authority manages, operates and develops the Rotterdam port and industrial area and is responsible for ensuring safe and expedient shipping services and for creating an environmentally-friendly, inclusive and safe port. The Port of Rotterdam Authority collaborates with companies in the port and the government on a future-proof port with net zero $CO_2$ emissions. That demands a change from an energy system based on fossil energy to a circular economy.
Port area: 12,500 ha of port area (land and water, of which over 6,000 ha is industrial sites). Length of the port area: over 40 km. Cargo throughput: approximately 438 million tons of freight a year. Shipping: approximately 28,000 seagoing vessels and 90,000 inland vessels annually.