Opportunity Green

# SASHA Hydrogen Derived Fuels for Aviation and Maritime Study

Literature Review of Production Pathways and Policies for Net Zero Aviation and Marine Fuels


Source: Orbon Alija / Getty Images

# Contents



# Acknowledgements


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# Basis of Preparation

## Introduction

Arup was appointed by Opportunity Green to perform a literature review on Hydrogen Derived Fuels for Aviation and Maritime, along with a high-level review of the jobs and skills required to enable the Fuel Transition (the "Project").

Arup has developed this report for Opportunity Green-ahead of the launch of the Skies and Seas Hydrogen-fuels Accelerator (SASHA) Coalition. The SASHA Coalition is focused on raising the awareness of the use of green hydrogen and carbon-dioxide derived from direct air capture in the UK and EU, for the production of synthetic fuels for the use in the aviation and shipping sectors.

The report summarise the key policy and regulation supporting the decarbonisation of these industries as of May 2023.

## About Arup

Dedicated to sustainable development, Arup is a collective of designers, planners, engineers, consultants and technical specialists offering a broad range of professional services globally.

Our energy experts are focused on accelerating decarbonisation and supporting clients with their transition to net zero. Working across the industry in urban energy, networks, renewables, nuclear, hydrogen and industrial decarbonisation; we're helping to meet the growing demand for clean energy and embedding digital innovation to enable better outcomes. Whether it's investment or strategic advice, energy system integration, or the detailed design of complex infrastructure, we're creating a more sustainable, resilient, and equitable energy future.

Glossary of Terms

**Abbreviation**

| | |
|---|---|
| ANSP | Air Navigation Service Provider |
| APAC | Asia Pacific Countries |
| ATJ | Alcohol-to-Jet |
| BNEF | Bloomberg New Energy Finance |
| CCS | Carbon Capture Storage |
| CCUS | Carbon Capture Utilisation and Storage |
| CfD | Contract for Difference |
| CHJ | Catalytic Hydrothermolysis Jet Fuel |
| CII | Carbon Intensity Indicator |
| CMB | Compagnie Maritime Belge |
| CMDC | Clean Maritime Demonstration Competition |
| $CO_2$ | Carbon-Dioxide |
| COMAH | Control Of Major Accident Hazards |
| CORSIA | Carbon Offsetting and Reduction Scheme for International Aviation |
| DAC | Direct Air Capture |
| DECA | Domestic Emission Control Area |
| DfE | Department for Education |
| DNV | Det Norske Veritas |
| EASA | European Union Aviation Safety Agency |
| EC | European Commission |
| EEA | European Economic Area |
| ETS | Emissions Trading System |
| EU | European Union |
| FOAK | First-of-a-Kind |
| FOC | Flags of Convenience |
| FOG | Fat, Oil, and Grease |
| FQD | Fuel Quality Directive |
| FT | Fischer-Tropsch |
| FT-SKA | Fischer-Tropsch Synthetic Kerosene with Aromatics |
| GDP | Gross Domestic Product |
| GE | General Electric |
| GHG | Greenhouse Gases |
| Gt | Gigatonnes |
| GVA | Gross Value Added |
| GW | Gigawatt |
| H&S | Health and Safety |
| HEFA | Hydro-processed Esters and Fatty Acids |
| HFO | Heavy Fuel Oil |
| HGV | Heavy Goods Vehicles |
| HRS | Hydrogen Refuelling Station |
| HSE | Health and Safety Executive |
| HSFO | High sulphur Fuel Oil |
| ICAO | International Civil Aviation Organization |
| IEA | International Energy Agency |
| IEEX | Energy efficiency existing ship Index |
| IMO | International Maritime Organization |
| IPCEI | Important Projects of Common European Interest |
| IRA | Inflation Reduction Act |
| IRENA | International Renewable Energy Agency |
| LNG | Liquified Natural Gas |

# Glossary of Terms

## Abbreviation

| | |
|---|---|
| LPG | Liquefied Petroleum Gas |
| MARPOL | International Convention for the Prevention of Pollution from Ships |
| MGO | Marine Gas Oil |
| MSW | Municipal Solid Waste |
| Mt | Million tonnes |
| $NO_X$ | Nitrous oxide |
| NSA | Norwegian Shipowners Association |
| PtL | Power to Liquids |
| R&D | Research and Development |
| RED | Renewable Energy Directive |
| RFNBO | Renewable Fuels of Non-Biological Origin |
| RFS | Renewable Fuel Standard |
| RLF | Renewable Liquid Fuel |
| RTFO | Renewable Transport Fuel Obligation |
| SAF | Sustainable Aviation Fuels |
| SASHA | Skies and Seas Hydrogen-fuels Accelerator |
| SMR | Steam Methane Reforming |
| $SO_X$ | Sulphur oxides |
| SSA | Swedish Shipowners Association |
| STEM | Science, Technology, Engineering and Mathematics |
| TRL | Technology Readiness Level |
| UK | United Kingdom |
| UK SHORE | UK Shipping Office for Reducing Emissions |
| UN | United Nations |
| UNFCCC | United Nations Framework Convention on Climate Change |
| US | United States of America |
| VLSFO | Very Low Sulphur Fuel Oil |
| ZEBRA | Zero Emission Bus Regional Areas |
| ZERFT | Zero Emission Road Freight Trials |

Section 1

# Executive Summary

Section 1: Executive Summary

# Hydrogen will play a key role in the production of sustainable fuels for decarbonisation of the aviation and shipping sectors.

This report focuses on the need for green hydrogen to produce sustainable fuels in the aviation and shipping sectors. This report reviews the following:

- The range of sustainable fuels likely to replace traditional fuels for use in these sectors, and how hydrogen is crucial in the production of these.
- An overview of the current market, including the outlook for the decarbonisation of these sectors, co-benefits and other sectors that are predicted to use green hydrogen and carbon-dioxide ($CO_2$) from direct air capture (DAC).
- The current policy landscape, focusing on UK and European policy to support the development and uptake of sustainable aviation and shipping fuels, and policy supporting hydrogen production development.

## Sustainable Fuels – Aviation

- Hydrogen is a feedstock for all sustainable aviation fuel (SAF) pathways considered.
- Hydrogen can be used to make a number of hydrocarbon based fuels for aviation. These fuels can be easily integrated with traditional airport and airplane infrastructure.
- There are feedstock constraints for a number of these production pathways. It is therefore likely that multiple pathways will be required to decarbonise the aviation industry.
- The use of liquid hydrogen and electrification of airplanes is also being considered as a route to decarbonisation. These options are likely to be limited to certain applications and they require extensive changes to airport and airplane infrastructure.

## Sustainable Fuels – Shipping

- There are multiple sustainable fuel pathways for the shipping sector, all requiring hydrogen to a greater or lesser extent. Very few of the fuels are available at scale and it is likely that multiple fuels will be required, depending on the application and market conditions.
- All sustainable fuels require modifications to (or new) port, storage and bunkering infrastructure to some extent. Sustainable fuels present carbon-reduction potential but gas boil-off or slip could threaten their greenhouse gas reduction potential over the lifecycle.
- Different fuels are likely to be most suited to different shipping applications, as some require significant storage space that reduces their potential for long-haul shipping.

## Key sustainability considerations for synthetic fuel production

- To ensure the fuels are sustainable and meet relevant policy requirements, the energy used in their production must be from renewable sources.
- Carbon-dioxide used in the production, must also be from a sustainable source, such as DAC.
- Synthetic fuels will have significant land requirements. The use of brownfield sites is preferred over greenfield whilst impact on terrestrial carbon stocks and biodiversity must also be considered.

## Decarbonisation Outlook – Aviation

- The aviation sector accounts for ~12% of global transport emissions and as air travel demand continues to grow significantly, the sector is expected to become a main contributor to emissions.
- Governments and operators are pursuing operational and technology efficiency improvements in aircraft technology alongside exploring sustainable fuels and alternative technologies.
- It is estimated global demand for sustainable aviation fuel could increase up to c.303,000 b/d by 2030, an increase of 13-fold from current production.
- SAF demand growth is underpinned by government-imposed mandates and airline net zero commitments and self-imposed SAF targets.
- Synthetic fuels have the potential to become the leading SAF production process. Whilst this is reflected by private and public sector support, supply potential is dependent on sufficient feedstock availability (e.g. renewable energy, electrolysis, sustainable $CO_2$).

## Section 1: Executive Summary

# Sustainable aviation fuel demand growth is underpinned by government-imposed mandates and airline net zero commitments and self-imposed targets. Decarbonisation in the shipping industry is supported by increasing numbers of national-level and association-level emissions reduction targets.

### Decarbonisation Outlook – Shipping

- Global demand for sustainable shipping fuels is expected to grow exponentially, following increasing numbers of regulations and targets to reduce GHG emissions in the sector. The share of sustainable fuels in shipping needs to grow substantially from the current level of less than 1% to be able to meet the sector's 2050 decarbonisation goals.
- Hydrogen derived synthetic fuels (especially ammonia and methanol) are likely to account for the majority of demand growth. Synthetic shipping fuels are a low risk-of-regret application for hydrogen. Effective policy incentives in the 2020s will help to develop supply chains, so uptake of these fuels is expected to accelerate in the 2030s.

### Co-Benefits

- The sustainable fuel transition offers benefits of increased job creation and the opportunity to implement Just Transition plans.
- Switching to sustainable fuels should also result in lower air pollution, particularly around airports and ports. Alongside positive climate change impacts, reduced pollution around offtakers is likely to result in better health levels in surrounding areas and less damage to forests and crops.

### Competition for Green Hydrogen

- Hydrogen will play a role in decarbonising a wide range of sectors including, transport, heavy industry, electricity and possibly in buildings. In addition to these direct uses, hydrogen may act as energy storage.
- This high demand will result in competition for the hydrogen as the market develops.

### Competition for $CO_2$

- There are a number of industries that currently use $CO_2$ and multiple industries that are likely to use sustainable $CO_2$ to decarbonise. These include, fertilisers, chemical and polymer production and building materials.
- This high demand for $CO_2$ from renewable sources such as DAC will result in competition for $CO_2$as the market develops.

### Hydrogen Policy

- 17 EU Member States have published hydrogen strategies, aiming for >€55bn in public funding and >80GW installed capacity by 2030.
- In 2022, the UK government doubled its low-carbon hydrogen production capacity target to reach up to 10GW by 2030. More countries are expected to follow, following EU funding and climate ambitions.
- The increase of hydrogen consumption in the transport sector is a key pillar across strategy targets, however there is variability within funding allocations for different transport modes.

### Sustainable Aviation Fuels Policy

- The regulatory landscape for the aviation industry in the EU is integral in supporting the development of the SAF industry in the region. The EU Fit for 55 package includes a proposed SAF blending mandate, with a sub-target for e-fuels.
- Under the ReFuelEU Aviation Initiative, the European Commission aims to gradually increase SAF shares in the fuel mix from ~0.05% today, to 2% in 2025, 6% in 2030 and 70% in 2050. There is also a sub-mandate for synthetic fuels to account for 1.2% of total SAF share by 2030 and 35% by 2050.
- The UK government's Jet Zero Strategy introduces a SAF mandate to target at least 10% SAF in UK aviation fuel mix by 2030 and up to 75% by 2050. A synthetic fuel sub-target will also be introduced to encourage production.

### Sustainable Shipping Fuels Policy

- The regulatory environment for the shipping industry decarbonisation in Europe has been slower to develop, relative to other sectors, however there is an increasing number of national-level and association-level emissions reduction targets. There is also a global net zero GHG emissions reduction by 2050 target set out by the IMO, with intermediate targets aiming for 20% but striving for 30% by 2030 and 70%, striving for 80% by 2040 (as agreed in July 2023).
- The FuelEU Maritime initiative imposes constraints on greenhouse gas intensity of onboard energy used by ships and promotes the adoption of sustainable fuels. The framework aims to increase the share of renewable fuels (including decarbonised hydrogen and its derived fuels).
- Similarly, the UK Shipping Office for Reducing Emissions (UK SHORE) has released a consultation to gather stakeholder views on potential intervention pathways, with a focus on sustainable fuels.

# The transition to sustainable fuels provides an opportunity to create inclusive economic growth through good quality jobs, addressing the gender imbalance and benefitting developing countries through decentralised production.

This report provides an overview of the skills and jobs required to enable decarbonisation pathways for aviation and shipping to be realised, considering future and currents skills gaps through the lens of the Just Transition and the impact on developing countries.

There is a significant opportunity to create a secure, equitable low carbon economy through the transition with jobs across the skills range. International and national policy support is required to enable a Just Transition and avoid creating an inequitable low carbon economy where vulnerable populations are not adequately supported.

### Current Skills Gaps

- The supply chains for sustainable fuels will create significant new jobs and allow for upskilling and skills transfer. The current skills gap centres around the ageing workforce and lack of incoming workers across the value chain - particularly in terms of younger workers.
- These skills gaps provide an opportunity to catalyse the training and skills required for the energy transition across the full range of skill levels.

### Future Skills Gap & Job Opportunities - Aviation

- Technical training and education are key to developing the skills needed for the future fuel transition in aviation, with over 20,000 jobs expected in UK SAF production alone.
- Research indicates over 90% of the knowledge and qualifications in hydrogen-related job descriptions are already covered by many educational institutions.

### Future Skills Gap & Job Opportunities - Shipping

- The shipping industry is likely to require similar skills to aviation in the production of sustainable fuels, with variations at distribution level. Particularly at ports, specialised training for fuel handlers and emergency service responders would be required.
- As an example, shipping company Maersk has signed an agreement with the Spanish government to develop large-scale production of green fuel in Spain – this project alone will create 85,000 jobs.
- Currently it is unclear from literature the number of jobs that will be created and the skill requirements for the shipping industry across the supply chain. Further work is recommended in this area.
- There will be no shortage of jobs for seafarers in the next decade. It is estimated that by 2050, there will be 310,000 seafarers working on ships with alternative fuels and technologies.

### Future Skills Gap & Job Opportunities - Aviation & Shipping

- The energy and fuel transition provides an opportunity to create inclusive, fair growth across industries - particularly if the gender imbalance is addressed and upskilling occurs across all ages and stages of education.
- Job security and quality should be a focus, particularly in the shift from construction to operation of production hubs. The UK and EU have already begun to move forward on upskilling the workforce with institutions investing in green skills education.
- Future jobs in sustainable fuels are likely to utilise similar skills as those used in the existing fuel supply chain but require significant upskilling, which is an underappreciated barrier to decarbonisation.
- Alongside the direct job creation in the fuel supply chain, indirect and induced job creation is likely to be significant to support the supply chain – particularly in a decentralised production model.
- The transition will provide an ecosystem of direct and indirect jobs at different skills levels across all stages of the fuel supply chain and production lifecycle.

### Jobs and Skills in Developing Countries

- Decentralised production gives an opportunity for the creation of production hubs in developing countries, often near areas with good renewable potential. This if done right, provides opportunities for inclusive economic growth through formal, skilled work and education - provided that investment from international companies is focused on local skills development and creation of good quality jobs.
- The benefits of sustainable fuel production can be realised domestically if governments ensure local communities are protected through policies and regulations.

Section 1: Executive Summary

# The transition to sustainable fuels provides an opportunity to create inclusive economic growth through good quality jobs, addressing the gender imbalance and benefitting developing countries through decentralised production.

## Benefits of a Just Transition

- A Just and Equitable Transition is a 1.5°C-aligned transition which implements the "polluter pays" principle and which leaves no country behind by particularly supporting climate vulnerable States with adaptation and mitigation, ensuring all States are supported to access the benefits of the transition. A Just Transition looks different for each worker, company and country, requiring individual solutions with supporting government policies.
- The transition provides an opportunity to deliver high quality jobs and reduce public health disparities around airports and ports through Just Transition plans. Collaboration will be required between all stakeholders to avoid the negative effects of displacement and redundancy. Each community will require a different solution that uses established principles that are adjusted to suit the local context. In the Just Transition, the 'how' is as important as the 'what'.

**Source: Unsplash**

Section 2

# Introduction

Section 2: Introduction

# Opportunity Green has set up the Skies and Seas Hydrogen fuels Accelerator (SASHA) coalition, with the focus of highlighting to government the need for prioritising green hydrogen and carbon-dioxide from direct air capture (DAC) for sustainable fuels in the aviation and shipping sectors.

## Opportunity Green and the SASHA Coalition

### Overview of Opportunity Green

- Opportunity Green uses legal, economic and policy knowledge to solve climate change. It does this by amplifying diverse voices, forming ambitious collaborations and motivating decision makers to drive forward just climate action.
- Opportunity Green is building a coalition of industry leaders, called the Skies and Seas Hydrogen fuels Accelerator (SASHA) Coalition. Its ambition is to demonstrate to governments that the aviation and shipping sectors require significant support and access to technology in order to decarbonise.
- In addition, Opportunity Green supports climate vulnerable countries, including less developed countries and Small Island Developing States, through research, consultation and facilitation services.
- Opportunity Green also works to find innovative legal pathways through legal strategy, analysis and advisory work to reduce emissions. Where these do not exist, it works with industry and governments to help create new pathways towards reducing emissions.

### Overview of SASHA coalition

- Opportunity Green recognises that sustainable fuels are the key for sectors with no other viable options, especially aviation and shipping, to successfully decarbonise and need to undergo rapid scaling with the aid of EU and UK policy. There are multiple applications for sustainable fuels, including buildings, road transport, electricity generation, aviation and shipping. At the moment, EU and UK policy is focusing on green hydrogen and carbon-dioxide from Direct Air Capture (DAC) as a possibility for sectors that have multiple options for decarbonisation, such as buildings and road transport. However, Opportunity Green believes it would be better to prioritise these fuels in sectors such as aviation and shipping, where few alternatives exist, if any.
- Opportunity Green is tackling the challenge by creating the Skies and Seas Hydrogen fuels Accelerator (SASHA) Coalition. The SASHA Coalition will be made up of aviation and shipping industry leaders. The aim of the Coalition is to persuade the UK government and the European Commission to prioritise green hydrogen and carbon-dioxide from DAC for use in these sectors. The Coalition's strength will be underpinned by strong industry insight and evidence-based analysis to aid the UK and EU in designing policy measures that will enable fast deployment of these technologies and decarbonisation of these sectors.


**Overview of SASHA Coalition**

## Section 2: Introduction

# This report will provide an overview of the aviation and shipping pathways to reach net zero, and outline the key policy and market considerations for decarbonisation.

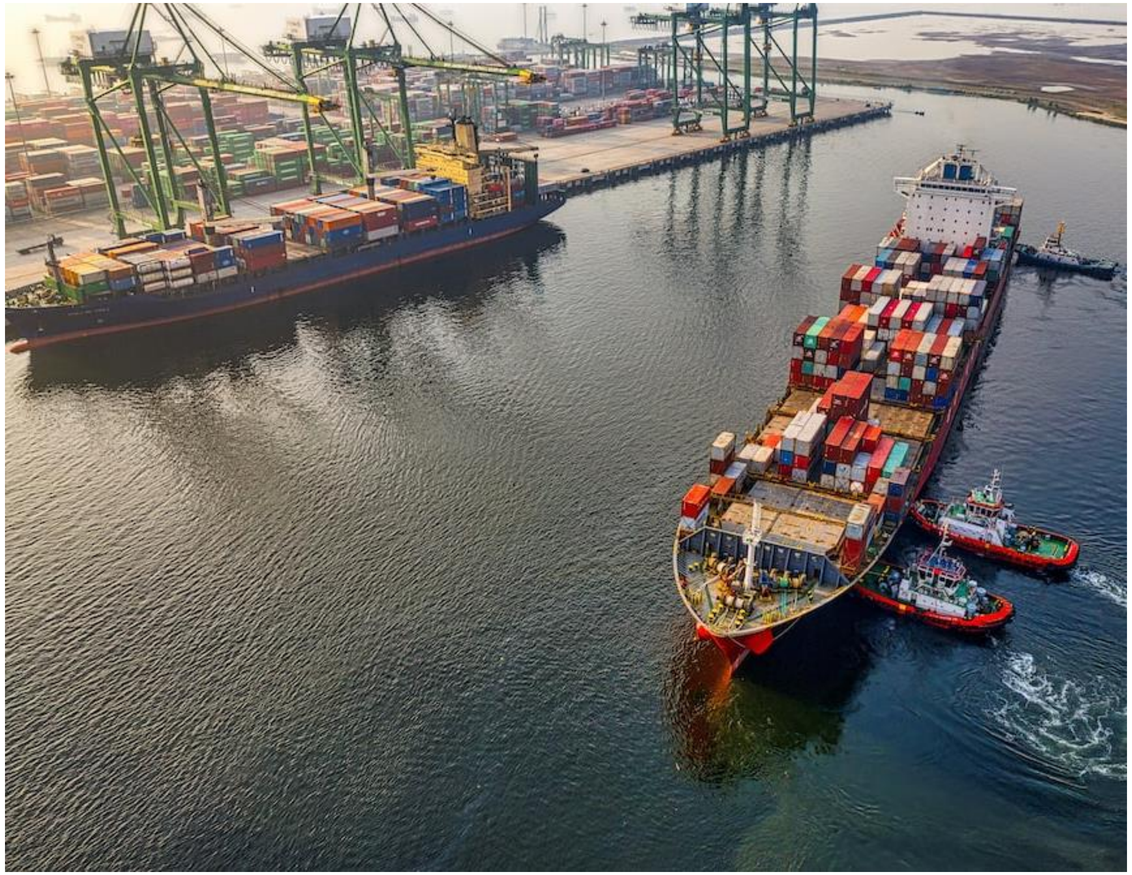
## Purpose

### Overview of the challenge and opportunity

- As energy transition policy and regulations are developing across the UK and EU, governments are examining the possibility of utilising green hydrogen and carbon-dioxide from DAC across multiple sectors, creating the potential for policy to prioritise their use in sectors where there are other more efficient ways to decarbonise. Possible fuel options include hydrogen, ammonia and methanol for shipping as well as hydrogen and synthetic kerosene for aviation, as aviation and shipping are harder to abate.
- The SASHA Coalition aims to highlight the demand in the aviation and shipping sectors for green hydrogen and carbon-dioxide from DAC in order to influence policy in favour of these sectors. The Coalition has the opportunity to encourage urgent policy coherence and support mechanisms to promote the supply of green hydrogen and carbon-dioxide from DAC. With ambitious targets and government support, this will improve the business case and enable investment into decarbonising infrastructure.

### Research purpose and objectives

- Opportunity Green has commissioned Arup for a research project. The findings from this will inform the prioritisation of green hydrogen and carbon-dioxide from DAC for aviation and shipping, feeding into the development of the SASHA Coalition.
- This first part consists of a literature review and the consolidation of Arup experience to provide a brief overview of the most likely fuel production pathways to reach net zero in the aviation and shipping sectors, outlining the key policy and market considerations for decarbonisation.
- The second part focuses on analysing skills and jobs that will be needed to enable the decarbonisation pathways to be realised – with input from select coalition members so that the analysis incorporates the latest industry insights.



**Source: Unsplash**

Section 3

# Sustainable Fuels

Section 3: Sustainable Fuels

# Aviation and shipping are considered hard to abate sectors. The following pages detail the possible pathways for decarbonisation and highlight the critical role green hydrogen will have in achieving this.

## Introduction

This section provides an overview of the current sustainable fuel production pathways for aviation and shipping. The diagram opposite shows a high level overview of the possible routes for the fuel production, which are elaborated upon in the following pages. The following categories are shown:

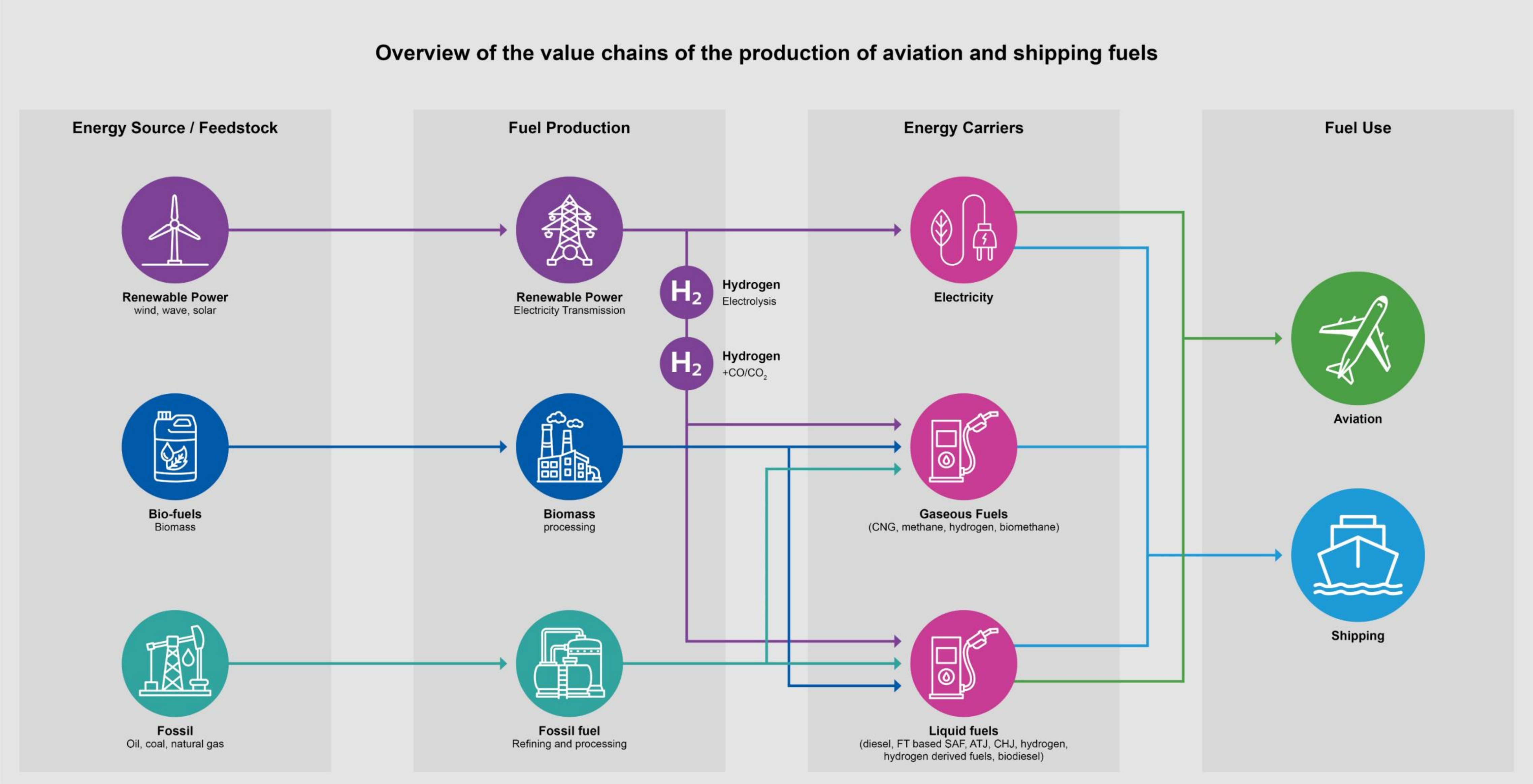
- The current fossil fuel based routes, producing traditional liquid and gaseous fuels.
- Biofuel routes, using a range of feedstocks such as biomass, lipids, vegetable oil and sugar grain.
- Renewable power, that can be used as a fuel, or to produce green hydrogen. The green hydrogen and its derivatives can be used to make multiple fuels such as ammonia, methanol and combined with Carbon-Dioxide ($CO_2$) or Carbon Monoxide (CO) to produce hydrocarbon fuels. The pathways utilising green hydrogen is shown using the bold green arrows.

The following section is split into sustainable aviation fuels (SAF) and sustainable shipping fuels. For each industry the full value chain from the feedstock/energy source to the onboard infrastructure has been considered.

Throughout this report we have used the following nomenclature.

- SAF – to encompass all Sustainable Aviation Fuels pathways.
- Sustainable Shipping Fuels – to encompass all Sustainable Shipping Fuels pathways.
- Synthetic Fuels – focusing on synthetic, electrolytic hydrogen derived sustainable fuels (i.e. Power-to-Liquids).

**Source: Getty Images**



Overview of the value chains of the production of aviation and shipping fuels
Energy Source / Feedstock
Fuel Production
Energy Carriers
Fuel Use
Renewable Power
wind, wave, solar
Renewable Power
Electricity Transmission
Hydrogen
Electrolysis
Hydrogen
+CO/CO2
Electricity
Aviation
Bio-fuels
Biomass
Biomass
processing
Gaseous Fuels
(CNG, methane, hydrogen, biomethane)
Shipping
Fossil
Oil, coal, natural gas
Fossil fuel
Refining and processing
Liquid fuels
(diesel, FT based SAF, ATJ, CHJ, hydrogen, hydrogen derived fuels, biodiesel)

## Section 3: Sustainable Fuels

Feedstock origins and inputs are crucial to the lifecycle carbon-neutrality of a synthetic fuel. Policy regulations stipulate sustainability requirements that hydrogen production must meet. Production of synthetic fuels and biofuels requires significant land, which must be considered.

### Key sustainability considerations for synthetic fuels

There are a number of factors that need to be considered for the fuels to be considered sustainable. The following section highlight some of the most prominent.

#### Consider effects over the lifecycle of the fuel

- The supply chains for the different types of sustainable fuels vary considerably. Greenhouse gases (GHG) can be emitted – and negated - in differing proportions at each stage in the chain, through feedstock sourcing, fuel production, transport, storage and use. Hence, it is important to view the net emissions on a 'lifecycle' basis, accounting for the full supply chain, to ensure an accurate comparison.

#### Renewable electricity

- Electricity is required to produce synthetic fuels across both aviation and shipping. Synthetic fuels can be produced using non-renewable sources such as the burning of fossil fuels. To ensure synthetic fuels reduce lifecycle greenhouse gas emissions to their fullest extent, renewable energy must be used in production. Producing synthetic fuels using surplus or untapped renewable energy prevents negative externalities.

#### Sustainable $CO_2$

- For fuels to be carbon-neutral over their lifecycle, carbon dioxide used in their production should be taken from a sustainable source, such as direct air capture (DAC). This can be a costly and energy-intensive process – and DAC has seen limited roll-out at commercial scale.

#### Fuels derived from biomass

- Biofuel feedstocks significantly influence the carbon emission reduction potential. Although first generation (food-derived) biofuels, such as sugarcane or corn, present an emission reduction, they tend to be less impactful.
- Second generation feedstocks (non-food derived), such as lignocellulosic plants, agricultural residues and other waste materials, are likely to provide a larger carbon emissions reduction. Third generation biofuels refer to algal biomass which can have very high yields and can be produced vertically. However, controlling the conditions for growth requires high temperatures and very large volumes of water – resulting in high capital costs and water scarcity issues.
- Biomass production can be harmful to the environment if biomass crops replace fertile land for crops or virgin countryside/forests. Repurposing land for crop production could also be detrimental to food security.

#### Indirect land use

- Increased production of synthetic fuels requires increased production of electricity or feedstocks which can require significant land areas, particularly in the case of biomass for biofuels. The use of brownfield sites must be maximised and biodiversity effects taken into account. Changing the land use, particularly from greenfield sites, affects the terrestrial carbon stocks, biodiversity and the possible reflectivity of the Earth's surface. Relocation of communities and cultural heritage impacts are also potential negative effects.

#### Policy regulations

- The European RED II and the UK's Low-Carbon Hydrogen Standard and Renewable Transport Fuel Obligation (RTFO) have provision to ensure that the production of biofuels, hydrogen and other synthetic fuels meets sustainability requirements. Further details can be found in Section 5 looking at Policy Landscapes.

**Solar panels replacing forest (Source: Unsplash)**

Section 3: Sustainable Fuels

# There are 7 sustainable aviation fuel pathways considered in this report. Green hydrogen is used in all of these routes. It is predicted multiple pathways will be required to successfully decarbonise the aviation industry.

## SAF Pathways

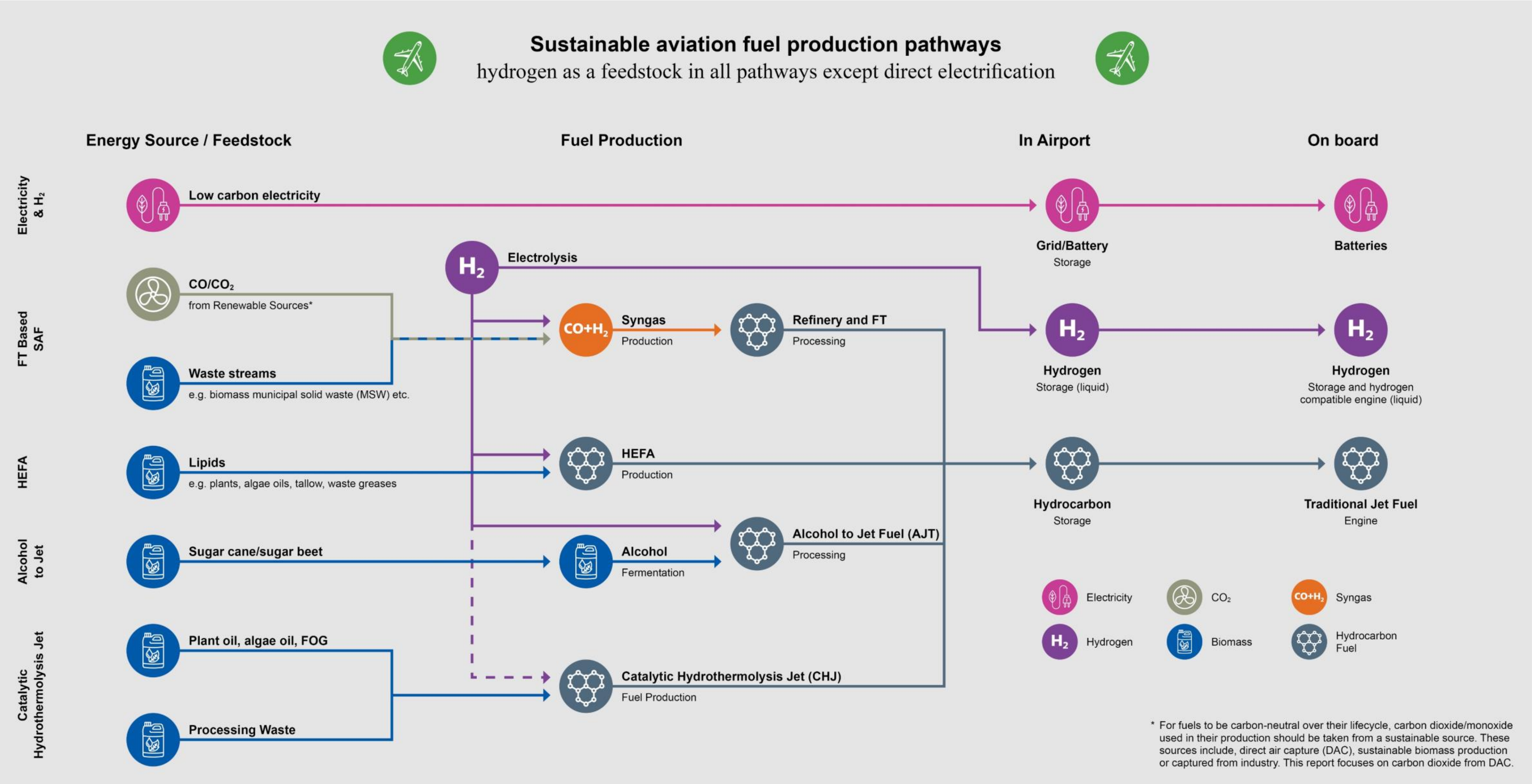
- SAF, which can be produced from multiple feedstocks, is viewed as a priority near-term solution towards the decarbonisation of the aviation industry.
- A challenge for exploring sustainable fuels as an alternative to fossil kerosene is achieving the same fuel energy density. For example, though the energy density of bio-derived fuels is similar to kerosene, hydrogen's volumetric energy density is an order of magnitude lower. An overview of sustainable fuel routes for aviation fuels is shown on the next page.
- The HEFA route is produced through the refining of virgin and waste oils. This route is currently the only SAF production technology at commercial scale and is deemed as the most viable short-term solution. However, constraints in the global supply chain of sustainable bio-derived feedstocks represents a challenge to scale up. Several alternative pathways are approved by the ICAO but require technological developments.

The below list* of 7 pathways are described in the following pages:

1. Fischer-Tropsch (FT) produced from renewable/green hydrogen and captured carbon (-monoxide);
2. Fischer-Tropsch Synthetic Kerosene with Aromatics (FT-SKA) produced from waste streams e.g., biomass, municipal solid waste (MSW) etc;
3. HEFA (Hydro-processed Esters and Fatty Acids) produced from lipids e.g. plants, algae oils, tallow, waste greases;
4. Alcohol-to-Jet fuels (ATJ), produced from sugar cane/sugar beet;
5. Catalytic Hydrothermolysis Jet fuel (CHJ), produced from plant oil, algae oil and processing waste,
6. Green Hydrogen (produced via electrolysis using renewable energy)
7. Electrification (produced from renewable resources e.g. wind, solar, hydro)

* Not an exhaustive list


Main aviation routes (Source: Open Flights)


Sustainable aviation fuel production pathways
hydrogen as a feedstock in all pathways except direct electrification
Energy Source / Feedstock
Fuel Production
In Airport
On board
Electricity & $H_2$
FT Based SAF
HEFA
Alcohol to Jet
Catalytic Hydrothermolysis Jet
Low carbon electricity
Grid/Battery
Storage
Batteries
Electrolysis
$CO/CO_2$
from Renewable Sources*
Waste streams
e.g. biomass municipal solid waste (MSW) etc.
Syngas
Production
Refinery and FT
Processing
Hydrogen
Storage (liquid)
Hydrogen
Storage and hydrogen compatible engine (liquid)
Lipids
e.g. plants, algae oils, tallow, waste greases
HEFA
Production
Hydrocarbon
Storage
Traditional Jet Fuel
Engine
Sugar cane/sugar beet
Alcohol
Fermentation
Alcohol to Jet Fuel (AJT)
Processing
Plant oil, algae oil, FOG
Processing Waste
Catalytic Hydrothermolysis Jet (CHJ)
Fuel Production
Electricity
$CO_2$
Syngas
Hydrogen
Biomass
Hydrocarbon Fuel
* For fuels to be carbon-neutral over their lifecycle, carbon dioxide/monoxide used in their production should be taken from a sustainable source. These sources include, direct air capture (DAC), sustainable biomass production or captured from industry. This report focuses on carbon dioxide from DAC.

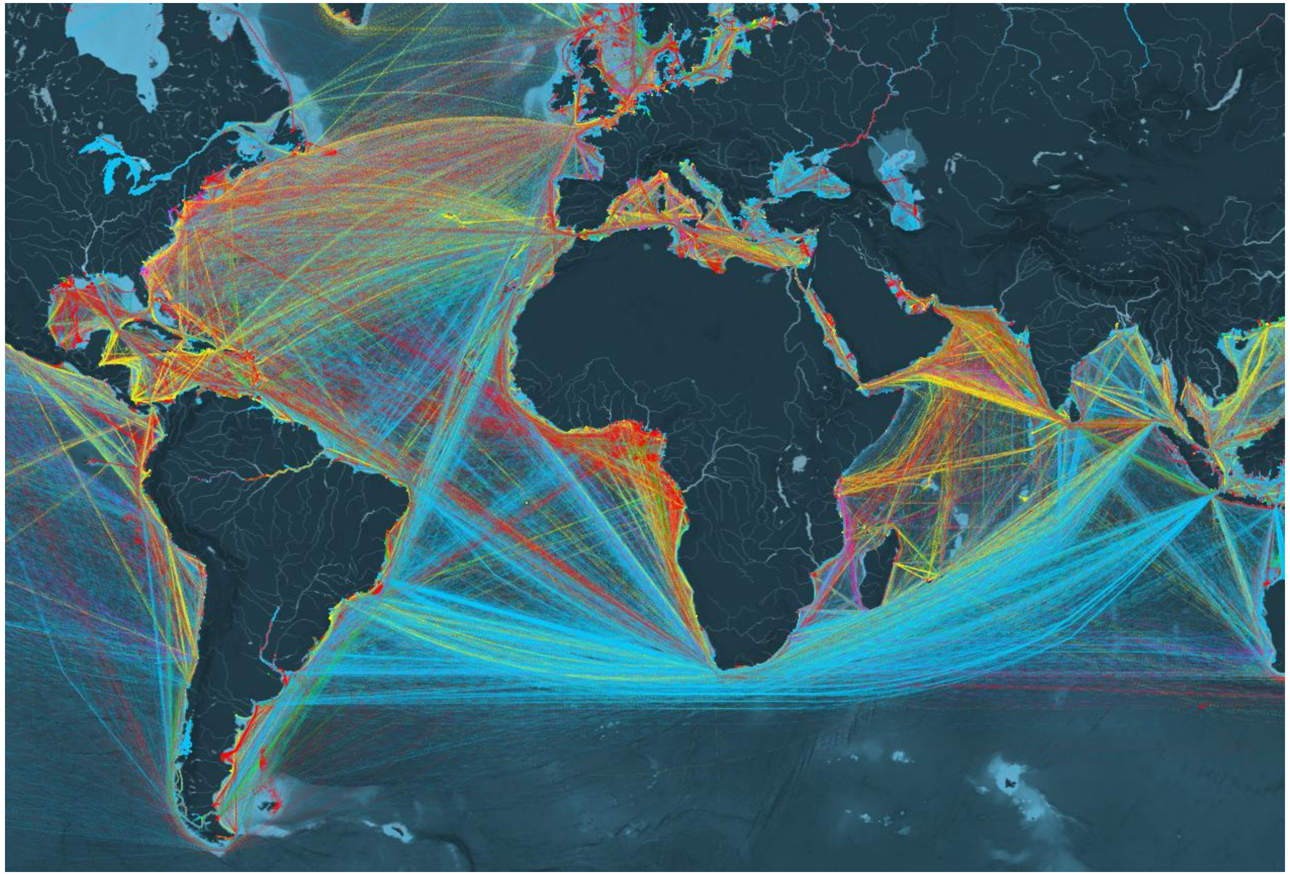
# There are multiple sustainable fuels – most of which require hydrogen in the production pathway. Few of these fuels are available at scale and pathways may require interim solutions whilst barriers to commercial use are resolved.

## Shipping Pathways

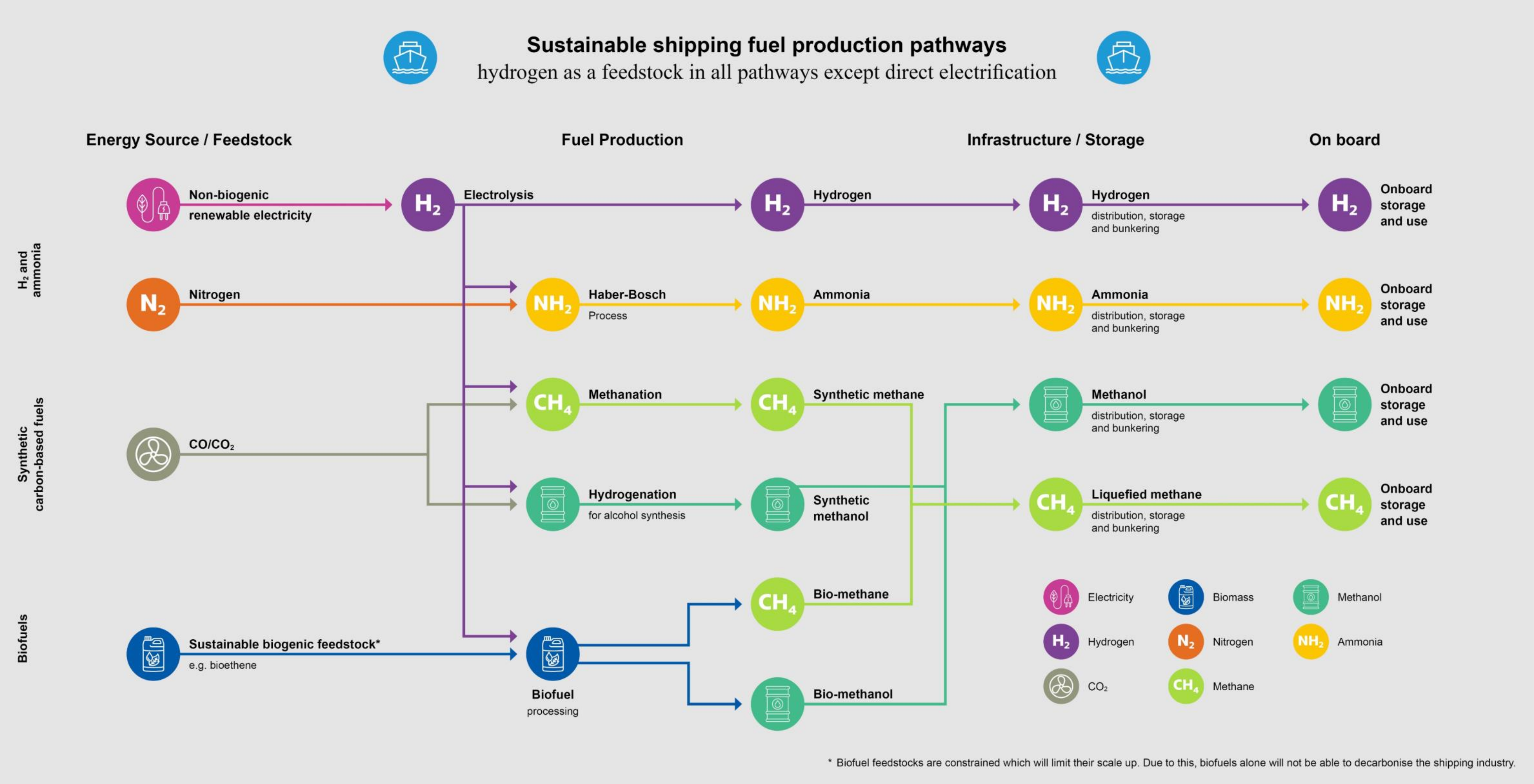
- Currently, the shipping industry uses Heavy Fuel Oil (HFO) and Marine Gas Oil (MGO) as the main fuels, with liquefied natural gas (LNG) playing a minor role.
- All sustainable fuel pathways have opportunities and barriers. Ambitious decarbonisation targets with supporting policy incentives focussed on scalable solutions are required to ensure that the opportunities are captured and the barriers overcome.
- Currently sustainable fuels cost significantly more than fossil fuels. Policy incentives and regulations are required to scale up supply chains and bring down costs through demand certainty and economies of scale. Multiple solutions are required to decarbonise shipping by 2050 including synthetic fuels, which have the potential for significant scale up.
- Biofuels will have a role to play in some locations but the global supply of sustainable feedstocks is limited, so biofuels will play a minor role in the decarbonisation of shipping.
- The following fuel pathways*, produced with sustainable feedstocks, are explored in the following pages:

1. Hydrogen
2. Ammonia
3. Synthetic methane
4. Methanol
5. Biomethane
6. Biomethanol

* Not an exhaustive list



**Main shipping corridors and routes (Source: Shipmap)**



Sustainable shipping fuel production pathways
hydrogen as a feedstock in all pathways except direct electrification
Energy Source / Feedstock
Fuel Production
Infrastructure / Storage
On board
H2 and ammonia
Synthetic carbon-based fuels
Biofuels
Non-biogenic renewable electricity
H2
Electrolysis
Hydrogen
Hydrogen
distribution, storage and bunkering
Onboard storage and use
N2
Nitrogen
NH3
Haber-Bosch
Process
Ammonia
Ammonia
distribution, storage and bunkering
Onboard storage and use
CH4
Methanation
Synthetic methane
Methanol
distribution, storage and bunkering
Onboard storage and use
CO/CO2
Hydrogenation
for alcohol synthesis
Synthetic methanol
Liquefied methane
distribution, storage and bunkering
Onboard storage and use
Bio-methane
Sustainable biogenic feedstock*
e.g. bioethene
Biofuel
processing
Bio-methanol
Electricity
Biomass
Methanol
Hydrogen
Nitrogen
Ammonia
CO2
Methane
* Biofuel feedstocks are constrained which will limit their scale up. Due to this, biofuels alone will not be able to decarbonise the shipping industry.

Section 3: Sustainable Fuels

# To produce synthetic fuels, the availability of significant quantities of green hydrogen and $CO_2$ will be critical to decarbonising the hard to abate aviation and shipping sectors.

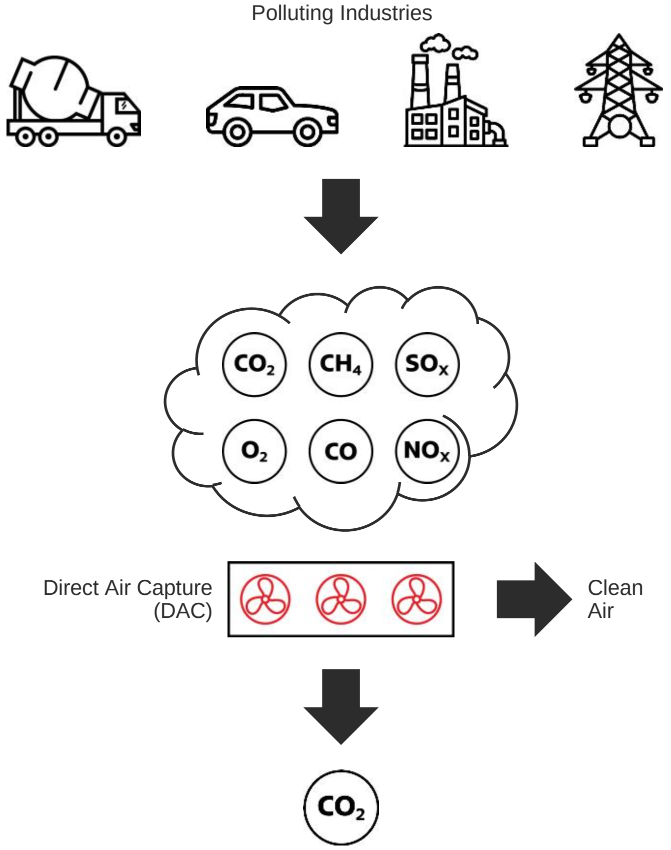
## Hydrogen

### All routes need Hydrogen

- As highlighted on the flow charts on the previous pages green hydrogen produced via electrolysis is integral to the decarbonisation of the aviation and shipping industries.
- Both aviation and shipping industries are considered hard to abate sectors and without access to green hydrogen the industries will not develop. It is expected that there will not be a "one solution fits all" fuel to answer to the problem.
- With respect to aviation, green hydrogen is used in all of the pathways (other than electrification). As a result, no matter which production pathway progresses to commercial operation, green hydrogen will be required to meet the demand.
- With respect to shipping, green hydrogen is required in all of the pathways other than the biofuel pathways. The next page explains the predicted balance of hydrogen derived fuels and biofuels in decarbonising the shipping sector.

### DAC

- Carbon-dioxide is required in all FT related pathways for aviation, and in the hydrogenation pathways for shipping. Currently there are limited non-fossil fuel sources of $CO_2$.
- Potential developing non-fossil fuel sources include CCUS and direct air capture (DAC).
- DAC extracts $CO_2$ directly from the atmosphere. Capturing $CO_2$ from the air is more energy-intensive and therefore more expensive than capturing it from a point source. This is because the $CO_2$ in the atmosphere is much more dilute.
- There are currently 18 small-scale direct air capture plants operating worldwide, capturing almost 0.01 Mt $CO_2$ /year, In the Net Zero Emissions by 2050 Scenario, direct air capture is scaled up to capture almost 60 Mt $CO_2$ /year by 2030 (IEA).
- DAC technology will be essential to make the sustainable aviation and shipping fuels fully sustainable in the long-term. Though there is considerable uncertainty around the process efficiency, the scale up possibilities and the capital investment costs.




DAC Process (Source: Geoengineering Monitor)

# Biofuels from sustainable waste feedstocks will have a minor but important role in the decarbonisation of shipping, especially as synthetic fuel supply chains scale up.

## Biofuels in shipping

### Biofuels and Synthetic Fuels

- There are many varying estimates of biofuel and synthetic fuel uptakes. All fuels, including biofuels, require hydrogen to a greater or lesser extent. Biofuels require hydrogen for desulphurisation on smaller scales than other sustainable fuels. Most estimates place a combination of e-ammonia, biofuels and hydrogen fuels will dominate the shipping sector.

### Biomethane

- Biomethane is produced from biomass through a process of gasification or fermentation. Biomass feedstocks can cover sludge, maize, manure and plant matter amongst others.
- Most production pathways use mature technologies, although significant scaling of plants and further improvements in technology are required for commercialisation – particularly for gasification.
- Biomethane can use the same bunkering infrastructure as LNG, making it compatible with some existing infrastructure.

### Biomethanol

- Biomethanol is produced using waste biomass, such as black liquor and plant matter, forming biomethanol via gasification processes. Gasification is a mature production technology with numerous commercial plants in operation.
- Biomethanol can utilise existing engine and fuelling systems, dependant on the metallurgy.
- The low calorific value of the feedstocks results in high quantities required.
- Significant scaling of the biomethanol plants will also be required.

### Safety and Environment - Biomethane

- Biomethane is a highly flammable but non-toxic fuel. Biomethane's similarity to LNG means safety handling practices are already well established.
- Methane is a highly potent GHG so any fugitive emissions could counteract the emissions reduction benefit over the course of its lifecycle. If fugitive emissions could be prevented, biomethane would be GHG-negative through the use of waste matter.

### Safety and Environment - Biomethanol

- Biomethanol has significant safety challenges due to high toxicity issues when in contact with skin or inhaled, and a very low flash point.
- There are numerous handling requirements already in place for methanol due to its existing usage, with easy handling due to its liquid state at ambient temperatures. Biomethanol is widely considered a $CO_2$-neutral fuel, although $NO_x$ emissions could cause issues.

## Section 3: Sustainable Fuels

# The following pages highlight the changes required at airport, port, on airplanes and on ships as a result of decarbonisation and changing from traditional fuels to sustainable fuels.

### Infrastructure changes required

The following pages highlight the changes to the value chain required to move from traditional fuels, to sustainable fuels.

For aviation we have considered the implication of:

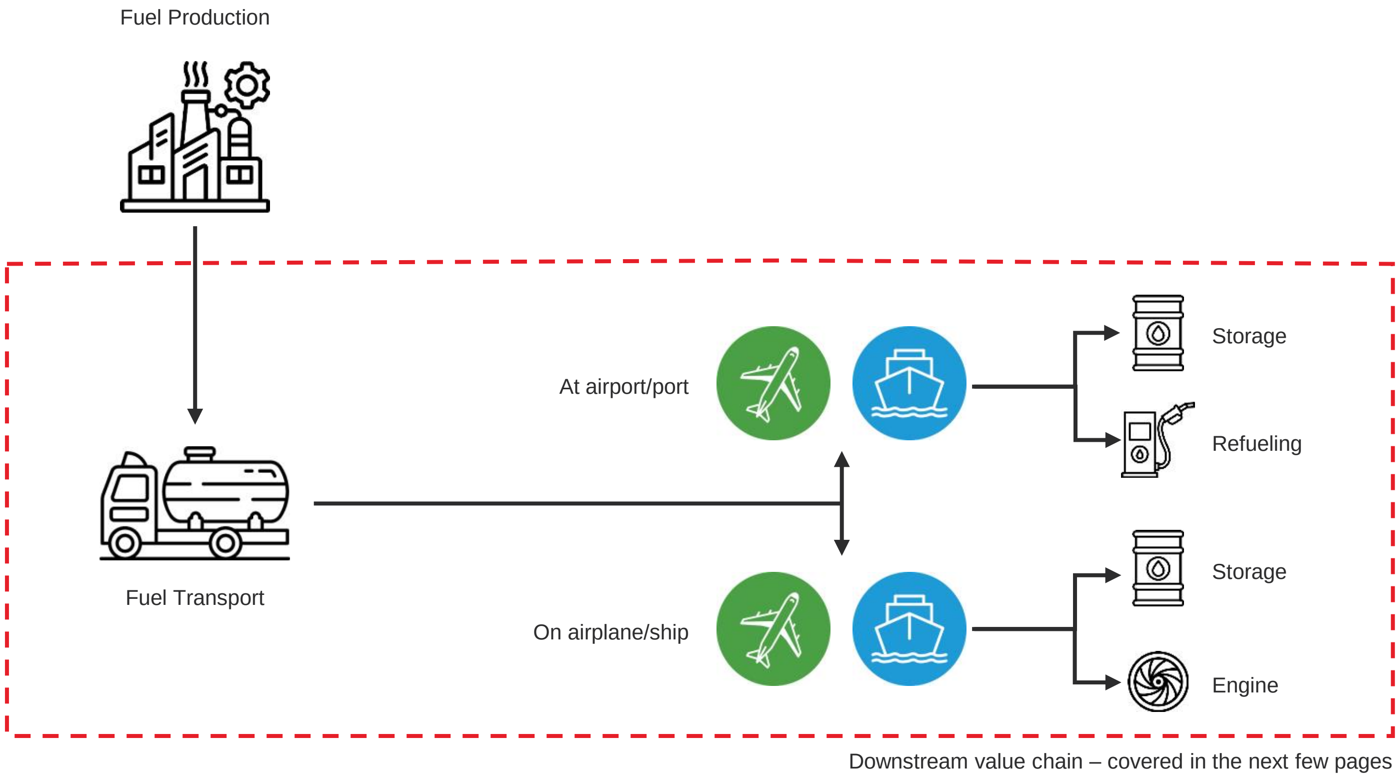
- Hydrocarbon based jet fuels
- Hydrogen jet fuels
- Electrification of aircraft

Highlighting the changes and the safety implications of each fuel types, at both the airport and onboard the airplanes.

For shipping we have considered the implication of:

- Hydrogen
- Ammonia
- Methane
- Methanol

Highlighting the changes and the safety implications of each fuel types, at both the port and onboard the ships.




**Sustainable fuel value chain**

# The use of hydrogen and electrification would require substantial infrastructure changes at the airport and in the transportation of the fuel to the airport. Hydrogen has different HSE challenges to jet fuel however is considered different but no worse.

## At airport – aviation

### Hydrocarbon storage

- The hydrocarbon fuels from the FT E-Crude, FT-SKA, HEFA, ATJ and CHJ pathways can be used in the same infrastructure, including fuel tanks and pipelines. The safety implications of these hydrocarbon based fuels remain the same.

### Hydrogen storage

The hydrogen fuel pathway will require a change to the storage facilities at the airport and require new transportation infrastructure from production site to airport. The hydrogen must be compressed or stored as a cryogenic liquid, with safe storage and refuelling recognised as critical steps.

The storage of hydrogen is considered no safer or more dangerous than traditional hydrocarbon fuels. There are a number of ways in which this differs – summarised below:

- The hydrogen molecule is smaller than the hydrocarbon molecule and in therefore “leakier”. This risk is well understood and can be designed against.
- In the event of a hydrogen leak from storage the diffusion process of liquid hydrogen after it overflows occurs in two parts: the pool formation process of liquid hydrogen on the ground and the expansion and dilution process of low-temperature hydrogen clouds in the atmospheric environment. Whilst jet fuel will remain a liquid.
- Hydrogen disperses a lot more quickly than hydrocarbons and has a much higher ignition temperature. Making fuel leaks less risky.
- Hydrogen burns with an invisible flame, compared to the traditional blue flame of a jet fuel. The invisible nature of the flame is more hazardous as it cannot be as easily avoided.
- Hydrogen is stored as a liquid at incredibly low temperatures. This is done using a cryogenic storage which is dual skinned and uses a vacuum. This dual skin lessens the chance of a leak from the storage tank.
- Hydrogen like hydrocarbons will have to comply to COMAH regulations for storage above 5 tonnes.

### Electricity storage

- The electric pathway will require a change to the storage facilities at the airport as well as possible grid upgrades. This would likely require significant infrastructure upgrades at airports to support electric aircraft.
- The airplane would require a charging system that is capable of re-charging the battery pack or fuel cell in a reasonable amount of time.
- Lithium ion batteries are currently the most advanced battery to be used in aviation. These are the same type of batteries used in the automotive industry, and therefore proven.
- The main risk of this battery type is the possibility of spontaneous combustion as a result of damage or manufacturing error – though this risk can be minimised through regular testing.
- Solid states batteries are currently under development and could offer a possible alternative, with less risk.


Plane Refueling (Source: Unsplash)

## Section 3: Sustainable Fuels – Aviation

The FT E-Crude, FT-SKA, HEFA, ATJ and CHJ pathways all produce a hydrocarbon fuel. This fuel can be used in the same airplane infrastructure as traditional fuels. The hydrogen and electrical pathways will require considerable changes to airplanes.

### Onboard – aviation

#### Hydrocarbons onboard

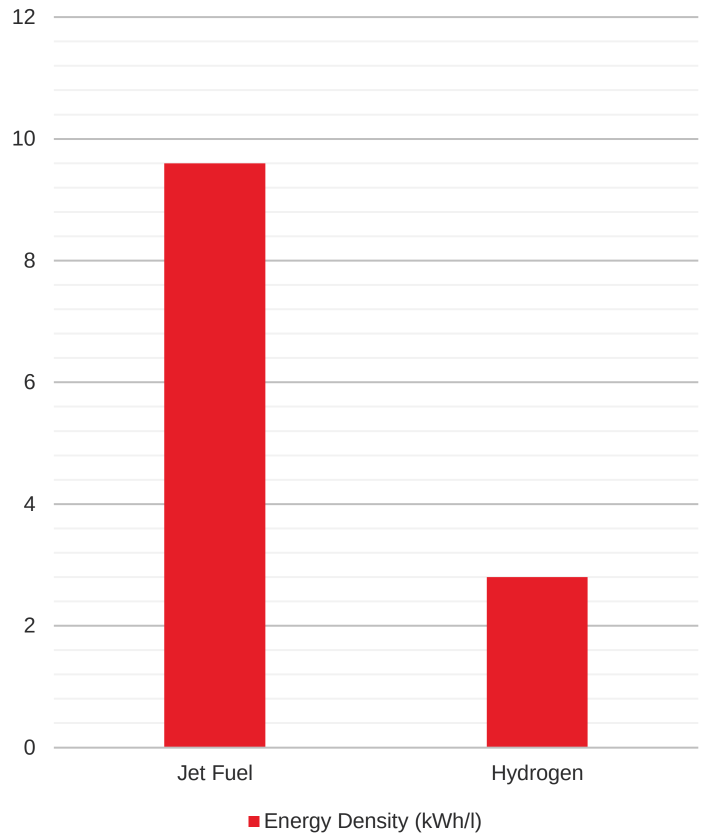
- The FT E-Crude, FT-SKA, HEFA and Alcohol-to-Jet and CHJ fuels all produce hydrocarbon based fuels, which are currently blended with traditional Jet Fuels before use. The resultant fuels are chemically similar to traditional jet fuel so the fuel can be used within the current Jet Fuel engine on airplanes.
- As a result of the hydrocarbon based fuel the contrails of the airplane will stay consistent. Resulting in the release of water, carbon-dioxide as well as other contaminated and incomplete hydrocarbon combustion. Contrails are formed when hot exhaust gases from an aircraft mix with the cold, moist air in the upper atmosphere, causing the water vapor in the air to condense and freeze into ice crystals. These in turn can form high altitude clouds, which act is insulation of heat, resulting in a global warming effect. The amount and persistence of contrails depend on various factors such as temperature, humidity, and the composition of the exhaust gases. It is important to note there is a high level of uncertainty in the understanding of the overall warming effect of contrails.

#### Hydrogen onboard

- Converting an airplane to run on hydrogen fuel requires significant modifications to the propulsion and fuel systems, as well as the safety system.
- The use of hydrogen as a jet fuel replacement will require the replacement of the airplane's engine and fuel storage.
- Hydrogen fuel has a much lower energy density compared to conventional jet fuel, so the aircraft needs to store a larger volume of fuel to achieve the same range.
- The current outlook is that hydrogen-powered aircraft will help contribute to emission reductions, but due to the energy density of the hydrogen, will be best suited for commuter, regional, short-range, and medium-range flights.
- The resultant contrails of the airplane from the combustion of hydrogen will be oxygen and water. However, the volume of water produced and the effect of the high temperature and pressures required for the reaction will still result in the water vapour in the air condensing and forming a cloud which, results in a global warming effect. The extent of this effect needs to be better understood.

#### Electricity onboard

- Converting an airplane to run on electricity would require a significant redesign of the propulsion system, including the power source, motor, and control systems. The airplane would require a new power source, such as a battery, to provide the electricity to power the aircraft. These batteries would need to be large and lightweight to store the required amount of energy for the flight. Currently a significant amount of research and development is required to develop batteries that are capable of storing enough energy to power an airplane.
- The use of electricity would result in no exhaust products and therefore no contrail effect.




**Energy Density of Jet Fuel vs. Hydrogen (Source: Department of Energy)**

### Section 3: Sustainable Fuels – Shipping

All sustainable fuels require more storage than existing maritime fuels, such as HFO. In many cases, existing infrastructure would not support the sustainable fuels and would require considerable changes. Boil-off or slip poses a threat to their efficacy as sustainable or carbon-neutral fuels.

## At port – Shipping

### Hydrogen

- Liquified hydrogen has a low boiling point, and is stored at very low temperatures in cryogenic vessels. These vessels are super-insulated, although boil-off is unavoidable (at a rate of 0.3-0.5% per day depending on the conditions). To minimise storage space, liquified hydrogen has to be stored in a compressed form, although it still takes up around five times more volume than fuel oil. To reduce heat ingress and boil-off, the fuel requires storage in cylindrical tanks, increasing volume.
- There is no existing infrastructure at ports to support the storage, transport or bunkering of hydrogen.

### Ammonia

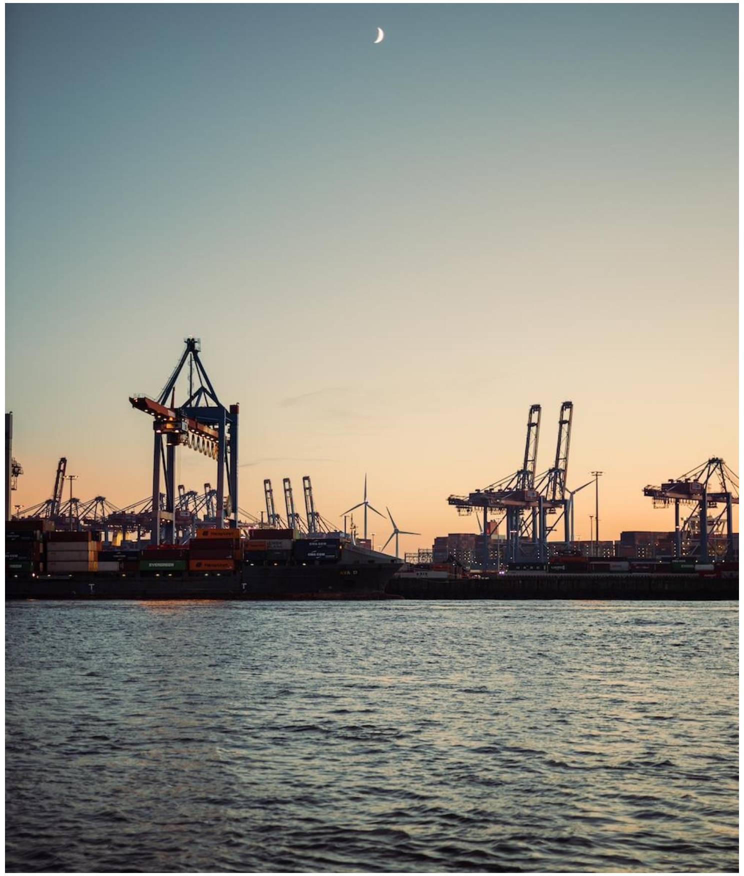
- Ammonia is highly toxic and requires careful handling, although its use in agriculture has resulted in understanding and regulation surrounding ammonia handling.
- Larger storage capacities are required and ammonia fuel is incompatible with current bunkering infrastructure. It is estimated that ammonia-fuelled vessels would require three times the bunkering that fuel oils currently do. Ammonia may also require significant scrubbing systems, particularly as ammonia is so harmful to aquatic life.
- Ammonia is more efficient on a volumetric basis than liquified hydrogen and is widely considered a possible long-term solution for deep-sea shipping.

### Methane

- As methane has a low boiling point and exists as gas at ambient temperatures and pressures, there is a possibility of fugitive emissions so cryogenic storage is required.
- As methane is so similar to LNG, any existing LNG storage or infrastructure can be used with few modifications. LNG is already used as a shipping fuel so infrastructure may already exist to handle methane.
- Methane slip is a possible issue so strict controls on methane handling is required so the GHG benefits are not reversed.

### Methanol

- As methanol is a liquid at ambient pressure and temperatures, storage, handling and transportation of this fuel is less complex as it does not require extreme temperatures to keep it in a liquid state.
- Methanol has a low volumetric density and heating value so storage takes up over twice as much space of traditional marine fuels, resulting in increased storage or more frequent refuelling. However, it is still more energy dense than hydrogen and ammonia.
- Only minor modifications to existing storage and bunkering facilities are required, with a low cost of conversion for existing engines.



**Hamburg Port (Source: Unsplash)**

Section 3: Sustainable Fuels – Shipping

# All sustainable fuels present flammability and toxicity risks, not dissimilar to existing shipping fuels. Hydrogen is likely to be more effective on limited distance routes. Cryogenic temperatures are often required for onboard storage and engine adjustments or replacements are likely to be necessary.

## Onboard – Shipping

### Hydrogen

- Low volumetric density of liquified hydrogen (7% of HFO) makes it difficult to use in deep-sea shipping as it requires so much storage. Though could be suitable for fixed routes covering limited distances.
- Hydrogen can be used as a blended fuel but the costs of effecting storage makes it unfeasible for a blended shipping fuel.
- The use of liquified hydrogen as a standalone fuel would require a complete refit of engine systems so would not be suitable as a drop-in fuel.
- Hydrogen is almost three times lighter than HFO, although onboard storage still requires specialised infrastructure due to the cryogenic temperatures required and flammability risks.

### Ammonia

- Ammonia provides higher energy density by volume than hydrogen and a much higher boiling temperature, which means it does not require large volumes or cryogenic storage onboard – although it must be stored above deck.
- High ignition energy through a pilot fuel or another source is required to initially ignite the ammonia. It is incompatible with various industrial materials such as copper, brass, acids and halogens.
- Diesel cycle is generally believed to be the best engines to support ammonia but research is ongoing. Control of nitrous oxide and ammonia slip is easiest at higher temperature combustion – although this generates higher $NO_x$ levels. Dual-fuel engines would be able to support up to 50% ammonia mixing.
- As ammonia is highly toxic, safety and training regulations would need to be in place for safe handling of the fuel onboard, although most experts agree that it should not be a constraint for ammonia use as its wide industrial uses have resulted in established H&S processes.

### Methane

- A low temperature (at cryogenic temperatures) is required to liquify methane for storage, creating additional challenges for onboard use.
- Liquified methane has a higher volumetric and energy density than ammonia and methanol, resulting in lower storage volumes and the potential for use in long-distance shipping.

### Methanol

- Methanol can be used as a blend in adapted or multi-fuel engines. Alternatively, 100% methanol fuel can be used in direct-methanol fuel cells or in methanol engines.
- Methanol fuel requires around twice the storage volume as that of traditional fuel oils due to a lower energy density but fewer safety concerns make it easier to handle compared to other sustainable fuels.
- Methanol can be stored in multiple arrangements onboard, making it more versatile. Fire detection systems would be required onboard but the additional monitoring systems that other sustainable fuels require are not necessary for methanol fuel.
- When combusted or leaked, methanol can leak formaldehyde, which is extremely toxic so engine adjustments would have to be made.


Ship in Croatia (Source: Unsplash)

Section 4

# Market Overview

Section 4: Market Overview

# International regulations and efforts from the public and private sector will be required to drive decarbonisation pathways in the aviation and shipping sectors.

## Decarbonisation of the Aviation and Shipping Industry

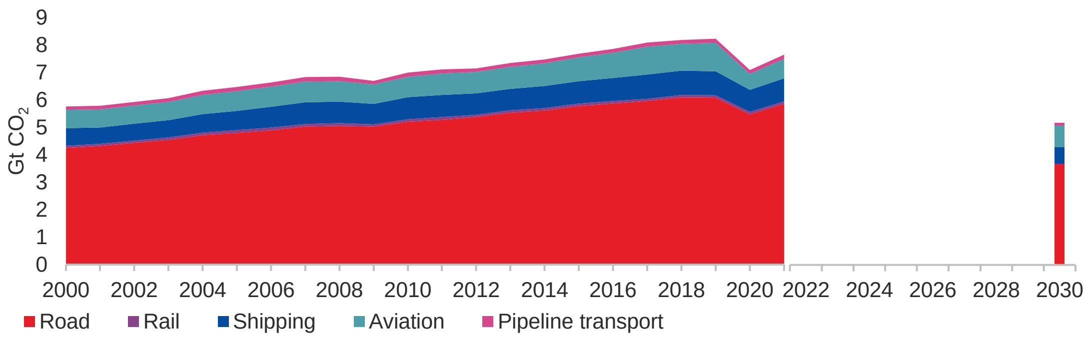
### Aviation

- Globally, international aviation accounted for ~9% of total transport emissions in 2021.
- In 2022, the EU estimated emissions from aviation accounted for ~14.4% of total transport sector emissions (the second highest source after road transport). The UK government estimated domestic and international aviation accounted for 8% of UK $CO_2$ equivalent emissions (2019).
- In addition to $CO_2$ emissions, the aviation sector also impacts climate through the release of nitrogen oxides, water vapour, sulphate and soot particles. Non-$CO_2$ emissions are estimated to account for ~2/3 of total aviation emissions, with contrails accounting for the majority of the share.
- Without intervention, the aviation sector will become one of the main contributors of emissions. Asia Pacific is expected to account for the majority of emissions in the trajectory, in line with increasing wealth per capita and low cost airlines.
- Governments and operators are pursuing efficiency improvements in aircraft technology alongside exploring sustainable fuels and alternative technologies.

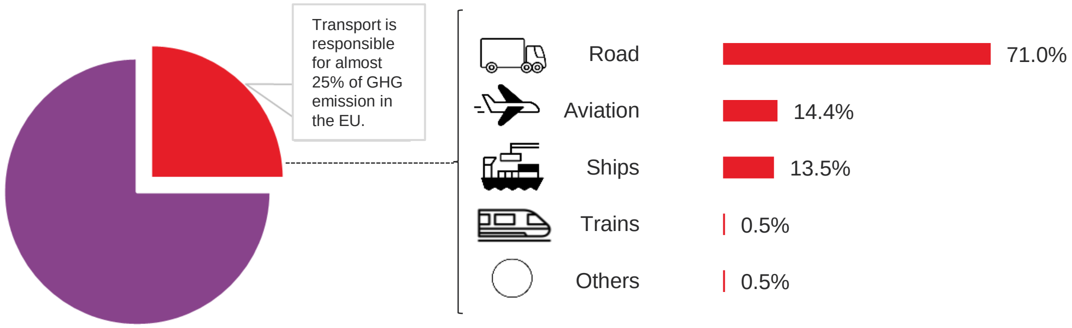
### Shipping

- Globally, international shipping accounted for ~2% of $CO_2$ emissions in 2021.
- Additionally, estimates suggest the 28% increase of LNG use as a global marine fuel (2012-18) resulted in a 150% increase in methane emissions in that time frame1.
- In 2022, the EU estimated emissions from the shipping sector accounted for ~13.5% of total emissions in the transport sector.
- Scale up of sustainable fuels in the shipping sector will be a key pathway in decarbonisation efforts, however greater policy ambition is needed to steer maritime shipping on track to a pathway to Net Zero.
- Indirect use of hydrogen and carbon-dioxide for the production of e-fuels (such as methanol and ammonia) will be critical, given they can provide significant emissions reductions with little to no engine modification.
- Validation of engine designs, safety measures and availability of required feedstock (hydrogen, $CO_2$) at competitive prices are major barriers that must be overcome to unlock sustainable fuel potential.

# International regulations and efforts from the public and private sector will be required to drive decarbonisation pathways in the aviation and shipping sectors.




**Global $CO_2$ emissions from transport by sub-sector in Net Zero Scenario (Source: IEA)**




**EU Greenhouse Gas Emissions (Source: EC. 1 – International Council of Clean Transport (ICCT))**

# Sustainable fuel blends can result in significant emissions savings and present a viable decarbonisation pathway, given current technology capabilities and supporting policy incentives.

## Decarbonisation Pathways in the Aviation and Shipping Sectors

| Decarbonisation Pathways | Aviation Sector | Abatement Potential[1] | Shipping Sector | Abatement Potential |
|---|---|---|---|---|
| Efficiency Improvements | • Technical: Replace old aircraft fleet with next-generation aircrafts and / or retrofit existing fleet components, such as lighter frame technologies and more efficient engines.<br>• Operational: Improve load factors per flight and optimize flying patterns (air traffic) and routes to reduce emissions per passenger-kilometer. | Low / High depending on method used | • Technical: IMO mandates (EEXI and CII) outline compliance guidance on energy efficiency requirements across vessels. Improvements may include vessel component retrofits (i.e. propulsion systems) and superstructure design and size optimization.<br>• Operational: Improvement measures may include limiting engine loads and reducing speeds and retrofitting vessels with energy-energy technologies. | Low / High depending on method used |
| Direct use of hydrogen | • Hydrogen-combustion aircrafts to eliminate emissions currently face technological and cost barriers. Unlikely to be overcome without significant policy intervention. | High | • Hydrogen-combustion vessels via fuel cells and direct use in internal combustion engines is in early-stage development and likely to be a use-case for short sailings in long-term. | Low |
| Sustainable Fuels | • Blends of sustainable aviation fuels in aviation fuel mix expected to gradually rise. SAFs can offer up to 50-80% lower emissions compared to fossil-derived fuels. | High | • Hydrogen-based fuels can achieve low- or zero-emission shipping. They are the main potential decarbonation option for the large-scale shipping, however, currently remain more expensive than traditional fuels. | High |
| Biofuels | • Current commercial sustainable fuel production pathway however, uncertainty around sufficient feedstock and land availability may pose future supply limitations. | Low | • Current commercial sustainable fuel production pathway however, uncertainty around sufficient feedstock and land availability may pose future supply limitations. | Low |

1 – The abatement potential (Low – High scale) rating is based on a judgment of two factors: (1) unit basis (i.e. how much the pathway reduces $CO_2$ per journey) and (2) how scalable / achievable the pathway is overall. For example, operational efficiency improvements are likely to have a lower $CO_2$ reduction impact per journey than use of SAFs, however the ability to produce at a quantity that can meet whole sector demand may hinder this. Additionally, high costs and scalability uncertainty on sustainable fuels today may push some operators towards operational efficiency improvements in the near-term, which are likely to represent the lowest cost option.

## Section 4: Market Overview

# SAF's key advantage over other leading alternatives, such as hydrogen & electric, is that its use does not require any alterations to the existing fleet of aircrafts and is already in use by various aircraft operators.

## Recent market developments for decarbonised fuels

### Electric Aircraft Developments

- BNEF tracked ~1,140 zero-emission aircraft orders in 2021, comprising ~900 electric (battery-electric and hybrid-electric) and ~240 hydrogen fuel cell airplanes.
- The most popular category is commercial regional and regional airplanes flying short distances.
- Aircraft operators are increasingly investing in these technologies. For example, IcelandAir recently signed a letter of intent to purchase an unknown number of hybrid-electric aircrafts.
- Airports, on the other hand, have been slower to deploy installation of charger infrastructure for electric aircrafts.

### Hydrogen Aircraft Developments

- While progress is ongoing to develop the underlying technology of hydrogen airplanes, direct use is expected to be limited in range and restricted to short distance aircraft use.
- Aircraft operator activity includes:
  - Lufthansa Technik launched the Hydrogen Aviation Lab in Germany.
  - Airbus are developing a hydrogen fuel cell engine and a liquid hydrogen tank. Both will be installed in the Airbus A380 demonstrator.
- Despite interest in technology advancement, the transition to hydrogen and electric aircraft faces significant challenges:
  - Significant capital expenditure required in overhaul of existing aircraft fleet.
  - Unclear whether green hydrogen production will ramp up to meet global aviation industry demand.
  - Technology limitations (i.e. battery technology is not suitable for long-haul flights, at present).

### SAF Developments

- In 2022, SAF startups raised $630 million, with e-fuel producers Sunfire and Twelve raising $353 million between them.
- A distinctive advantage of SAF is the use in aircrafts without requiring any alterations to the fleet, making it the most attractive option for reducing $CO_2$ emissions in the short-term.
- The view that SAF is better placed to decarbonise than its alternatives is shared by investors, as evidenced by a significantly higher deal count for SAFs compared with its alternatives in the past 24 months.

| Fuel | Market View | Pros & Cons |
|---|---|---|
| SAF[1] | • No alterations required to existing aircraft fleet<br>• Offers significantly lower emission when compared to conventional kerosene | ✓ High interest – increasing demand, new market entrants<br>✗ High fuel price, requires policy support<br>✗ Current supply is low |
| Hydrogen[2] | • Long-term sufficient green hydrogen supply is a concern<br>• Technical challenges around purpose-built hydrogen aircrafts | ✓ High emissions savings<br>✗ High fuel price<br>✗ Supply uncertainty<br>✗ Technology limitations |
| Electric | • Considerable reduction in $CO_2$ emissions if sufficient renewable energy is sourced<br>• Significant technical challenges, continued improvements in battery technology and investments are needed. | ✓ High emissions savings dependent on electricity source<br>✗ Supply uncertainty<br>✗ Technology limitations |

Low Carbon options in aviation

[1] – In this context, SAF refers to the synthetic, hydrogen-derived sustainable fuels production pathway (PtL).
[2] – Direct use of hydrogen can be as a power source, either fed into a jet engine (larger aircraft) or used to power a fuel cell to generate electricity for a propeller (smaller aircraft).

# Global demand for all sustainable aviation fuels is likely to grow 13x from 2023 levels to c.303,000 b/d in 2030, with demand driven by European governments and airline targets. The synthetic fuel pathway has the potential to become the main supply source if sufficient feedstock capacity emerges.

## Global SAF Demand

- Global demand for all sustainable aviation fuels (synthetic and biofuels) is likely to increase from c.22,000 b/d in 2023 to c.303,000 b/d in 2030, an increase of 13-fold.
- The increase in demand for SAF is underpinned by two factors:
  - Government-imposed mandates (discussed in more detail in the Policy Landscape section)
  - Airline net zero commitments and self-imposed SAF targets (discussed in more detail in subsequent pages).

### Unlocking SAF Capacity

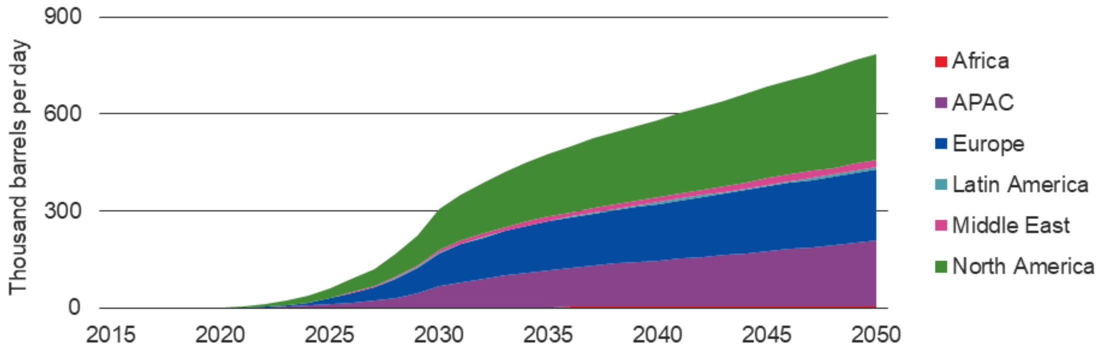
- ReFuelEU estimates the HEFA and ATJ pathways will account for ~70% of SAF supply in Europe. However, synthetic fuels are expected to overtake both in the remainder of the forecast.
- Synthetic fuels have the potential to become the leading production process, as reflected by private and public sector support. However, supply potential is dependent on feedstock availability and competition from other uses (i.e. renewable fuels for road transport).

### Current capacity outlook dominated by other pathways

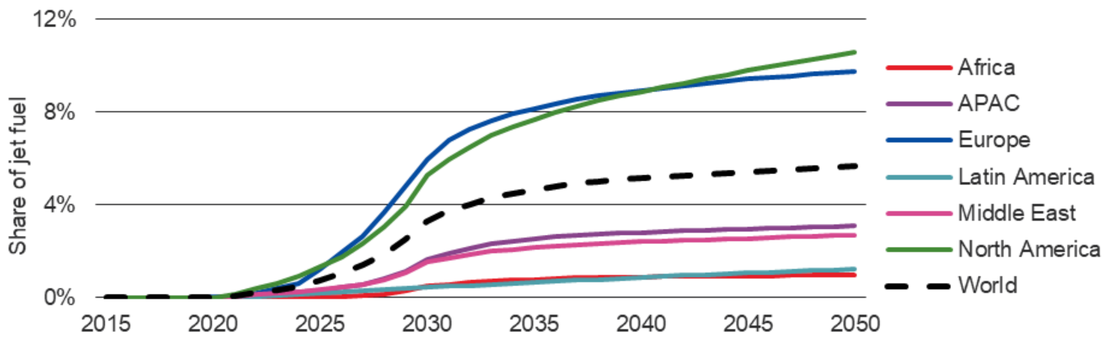
- BNEF estimates there are ~103 global renewable fuel projects which are expected to come online from 2023. 77 of these will have capability to produce renewable jet fuel, however only 17 state they will use synthetic fuel technology.

### Uncertainty of sufficient feedstock availability

- Waste oil and crop feedstock availability for biofuels may become a constraint in the medium-term (crop residues can be used to improve agricultural soil quality).
- As the synthetic fuel technology nears commercialisation, projects will shift focus towards securing feedstock supply.
- Conversion of capacity is dependent on the availability of required renewable energy, electrolysis and carbon capture capacity alongside refinery infrastructure.




**SAF Consumption by Region (Energy Transition Scenario) (Source: Bloomberg NEF (Energy Transition Scenario))**

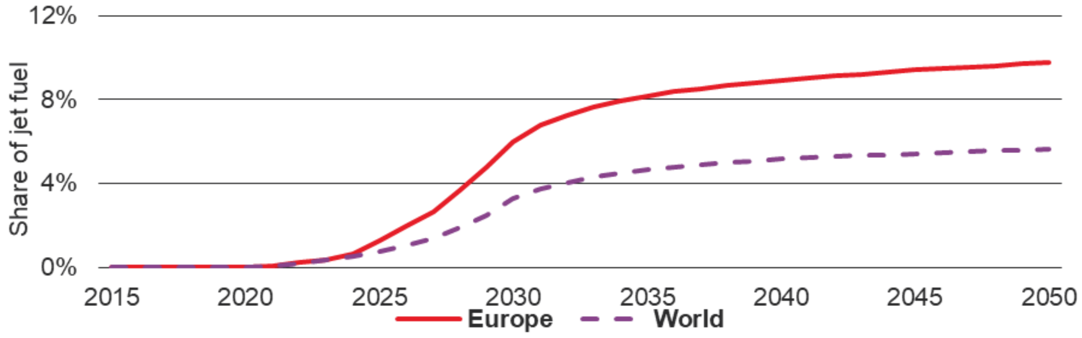



**SAF Blend Rates by Region (Share of Jet Fuel) (Energy Transition Scenario) (Source: Bloomberg NEF (Energy Transition Scenario))**

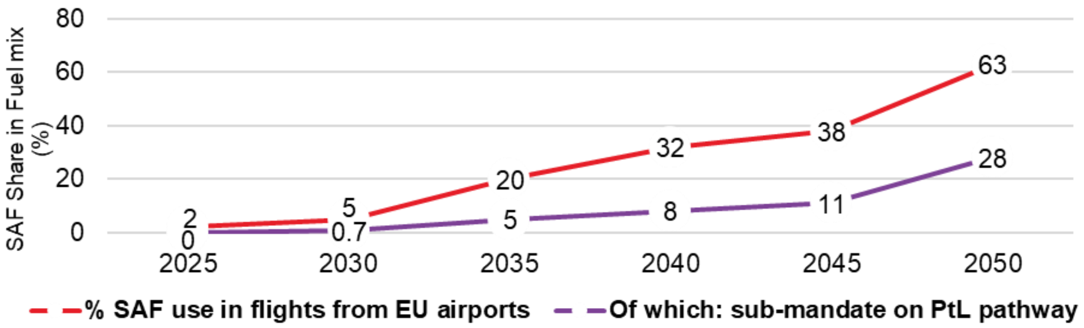
# Global demand for all sustainable aviation fuels is likely to grow 13x from 2023 levels to c.303,000 b/d in 2030, with demand driven by European governments and airline targets. The synthetic fuel pathway has the potential to become the main supply source if sufficient feedstock capacity emerges.

## Europe SAF Demand

- Globally, total SAF's share of overall jet fuel demand is likely to grow from c.0.4% in 2023 to c.3% in 2030.
- Meanwhile, in Europe, total SAF's share of overall jet fuel is likely to grow from c.0.4% in 2023 to c.5% in 2030.
- The faster uptake of SAF in Europe in comparison to global trends is mostly driven by government-imposed mandates.
  - The ReFuel EU SAF targets aim to have account at least 2% SAFs in fuel mix by 2025, gradually increasing to 6% by 2030 and 70% by 2050. This includes a sub-mandate for synthetic fuels to account for 35% of share by 2050.
  - The UK Jet Zero Strategy aims to drive at least 10% SAF in UK aviation fuel mix by 2030 and up to 75% by 2050.
- Some airlines have also published their own targets and strategies of SAF use in their fuel mix.
- These are strong incentives for airline operators to purchase increasing quantities of sustainable aviation fuel. If production capacity does not grow at pace, this could result in an under-supply of SAFs in the short-term.
- Greater European demand for SAF, coupled with likely under-supply, are strong tailwinds for SAF producers.
- Additionally, feedstock constraints (for waste sources) for more established production methods, such as HEFA and other bio-based solutions, can also drive demand for synthetic fuels in the long-term.
- The focus of the Market Overview and Policy Landscape sections is on synthetic, hydrogen-derived sustainable fuels (i.e. PtL pathway).
- It must be noted the majority of policy incentives currently do not differentiate between hydrogen and $CO_2$ production pathways for eligible SAFs.
- Establishing effective policy incentives in the 2020s will help to develop supply chains, so the uptake of these fuels is expected to accelerate in the 2030s.




EU v Global SAF Blend Rates by Region (Share of Jet Fuel) (Energy Transition Scenario) (Source: Bloomberg NEF (Energy Transition Scenario))




SAF Blend Rates by Region (Share of Jet Fuel) (Energy Transition Scenario) (Source: Bloomberg NEF (Energy Transition Scenario))

Airlines are key offtake partners of SAF supply, evidenced by a growing number of offtake agreements and discussions in hydrogen 2022. The trend is likely to persist in view of airlines' own SAF targets and upcoming EU and UK regulations prescribing SAF usage by aircraft operators.

## European Airlines that have set SAF Targets by 2030

| Airline | SAF Target |
|---|---|
| AIRFRANCE KLM GROUP | 5-10% |
| AIRFRANCE KLM GROUP | 10% |
| IAG International Airlines Group | 10% |
| FINNAIR | 10% |
| Virgin Atlantic | 10% |
| Ryanair | 13% |
| SAS | 17% |
| norwegian | 16-28% |
| Deutsche Post | 30% |

Note – SAF target refers to the blend, or the mix of SAF with traditional jet fuel. It is unclear, as yet, whether the SAF target will be applied on an average annual basis across all flights (per carrier), or per flight. All targets expected to be reached before or by 2030.

## Overview of SAF offtake discussions in hydrogen 2022

| Airline | Fuel provider | Duration | Quantity |
|---|---|---|---|
| AIRFRANCE KLM GROUP | NESTE | 2023-2030 | 1.25 billion litres of SAF |
| AIRFRANCE KLM GROUP | TotalEnergies | 2023-2032 | 1 billion litres of SAF |
| IAG International Airlines Group | AEMETIS | 2025-2031 | 98 million litres of SAF |
| wizzair.com | OMV Group | 2023-2030 | 231.25 million litres of SAF |
| Ryanair | OMV Group | 2023-2030 | 200 million litres of SAF |
| Ryanair | Shell ENERGY | 2025-2030 | 460 million litres of SAF |
| Lufthansa | OMV Group | 2023-2030 | 1 billion litres of SAF |
| Lufthansa | Shell ENERGY | 2024-2030 | 2.25 billion litres of SAF |
| Aer Lingus | gevo | 2026-2030 | 121.25 million litres of SAF |

**Source: Bloomberg NEF, ICAO**

# Neste is a dominant player in SAF production, however Arcadia, Norsk and SkyNRG are also significant players who are exploring the synthetic fuel production pathway.

## Key Market Players

SAF supply currently remains at below 0.05% total EU aviation fuel demand. To reach blend targets imposed by the ReFuelEU mandate, significant growth in production capacity is required. The market is responding with a growing number of projects under construction and offtake agreements.

### Pure SAF – projects in development (synthetic fuels)

- Currently, in the e-fuel space, Norsk has 2 projects in development in Norway. Other key players include Arcadia and P2X, both of which have projects with capacity of 100 million litres in development. Reuze, Atmosfair, SkyNRG, and Synhelion are other players with projects in development.

### Pure SAF – projects in developments (HEFA and ATJ)

- Neste is the largest SAF producer in the world, with an annual production capacity of 125 million litres. They are one of the oldest players in the SAF market to use the HEFA pathway, and currently have 2 projects in development.
- Preem, based in Sweden, also have 2 projects under development. SkyNRG has projects in development that use both the HEFA and ATJ pathways, and LanzaTech has 2 projects in development using the ATJ pathway.
- Velocys is leading a project to build the UK's first commercial SAF facility in collaboration with British Airways, called Altalto Immingham, located in Lincolnshire.

### Oil & gas companies with projects in development

- Shell and Repsol have 1 project each under development using the synthetic fuel pathway. There are currently 5 projects under development using HEFA that involve oil and gas companies, including ENI, Shell, TotalEnergies, and Repsol.

### Currently producing

SAF players currently producing include, amongst others:

- ENI – through the biorefineries in Italy (~8,000 b/d nameplate capacity).
- OMV Group - in Schwechat in Austria (~400 b/d nameplate capacity).
- Repsol – at Petronor Industrial Complex, Puertollano, and Tarragona (~650 b/d nameplate capacity).
- Neste – Porvoo in Finland (~900 b/d nameplate capacity).
- Phillips 66 – Humber in the UK (~2,000 b/d nameplate capacity).
- BP – Castellon refinery in Spain and Lingen refinery in Germany.

| Company | Pathway | Offtake agreements (2022) |
|---|---|---|
| Nordic Electrofuel | FT | 1 |
| norsk e-fuel | FT | Unknown |
| Arcadia | FT | Unknown |
| Shell Energy | Various | 2 |
| SkyNRG | Various | Unknown |
| gevo | HEFA | 5 |
| AEMETIS | HEFA | 4 |
| NESTE | HEFA | 4 |
| OMV Group | HEFA | 4 |
| Phillips 66 | HEFA | 2 |
| TotalEnergies | HEFA | 1 |

SAF players in Europe, and number of offtake discussions in 2022 (Source: BNEF, various public sources)

# The share of sustainable fuels in shipping needs to grow substantially from the current level of less than 1% to be able to meet the sector's 2050 decarbonisation goals.

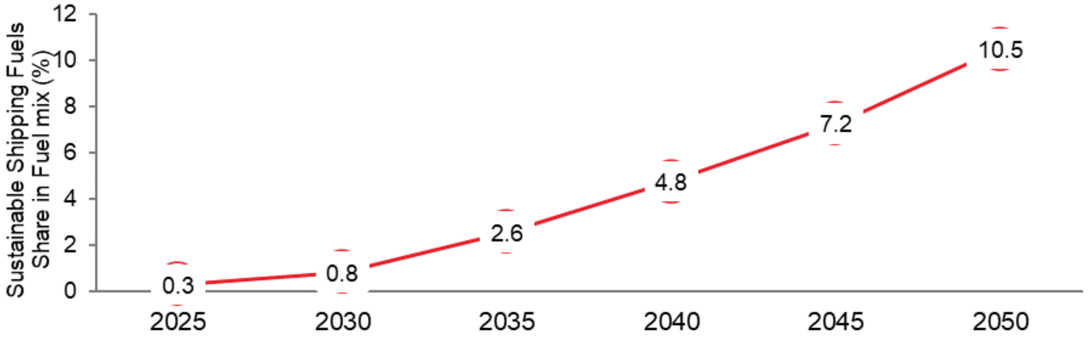
## Global Sustainable Shipping Fuel Demand

### Overall Demand

- BNEF estimates total consumption of marine fuels accounts for around 5% of global oil demand. Total marine fuel consumption is expected to continue to grow until 2030, and then will begin to decline to around 5.2 million b/d in 2050.
- Europe is forecast to be the biggest contributor to global carbon emissions reduction in shipping. Regional emissions are estimated to fall from 2025 and decline to 50% of 2008 levels by 2050. This could establish Europe as a potential demand hub for alternative shipping fuels.
- As the energy transition continues to accelerate in other sectors, shipping has been highlighted as hard to abate. This is partly due to the challenges the sector faces to trying to displace fossil-based marine fuels. These challenges can be attributed to the economies of shipping (including vessel lifespans and ownership costs of hydrogen-based fuelled ships) and the uncertain regulatory outlook and slow pace of change.
- LNG-fuelled vessels are being pegged as the ‘transition ships, with similar operational costs to natural gas and oil. However, LNG use can result in significant methane slip and leakage emissions and comparable or even higher $CO_2$e GHG emissions (depending on vessel types).

### Sustainable Shipping Fuels Demand

- Global demand for sustainable shipping fuels needs to grow exponentially from the current level of less than 1% to be able to meet the sector's 2050 decarbonisation goals.
- Hydrogen derived synthetic fuels (especially ammonia and methanol) are likely to account for the majority of demand growth.
- Synthetic shipping fuels are a low risk-of-regret application for hydrogen. Effective policy incentives in the 2020s will help to develop supply chains. Due to the long lifespan of vessels, the majority of this growth is expected to occur post-2030.
- This will be from large containership companies supporting the early adoption of green fuels, including ammonia and methanol.




Sustainable Shipping Fuels Growth Scenario (Source: Bloomberg NEF, Marine Demand Outlook 2022)

# Companies will be crucial in decarbonising the shipping industry. Despite this, key market players have predominantly focused ion LNG vessels and invested little in low- and no-carbon vessels to date.

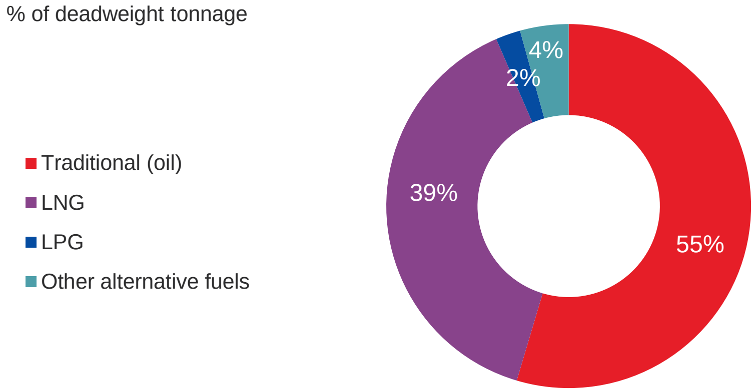
## New-build vessel orderbooks

### LNG-fuelled Vessels

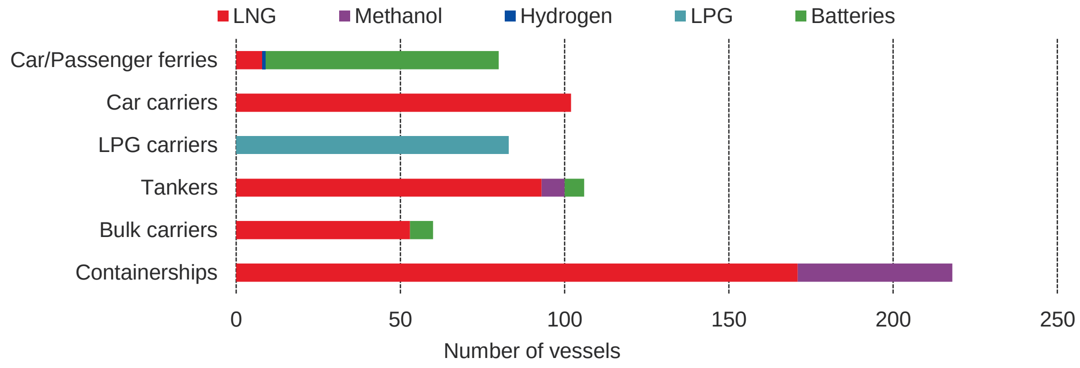
- There has been a significant increase in the new-build capacity of LNG-fuelled ships. This now accounts for approximately 40% of the orderbook tonnage, around a 25-percentage point increase from 2019.
- The majority of this is concentrated in containerships, tankers, and bulk carrier vessels.
- Mediterranean Shipping Company (MSC) and Seaspan are the currently the key players with the largest LNG orders.

### Hydrogen-based Fuels

- While hydrogen-based fuelled ship orders have increased, the uptake has been slower than that of LNG. They currently make up around 4% of the total orderbook.
- However, uptake is expected to increase over the coming years and increasingly stringent targets for decarbonising the shipping industry are implemented.
- Methanol has recently gained increasing traction within the industry. There are currently 25 methanol container ships on order to be delivered by 2026. Maersk is currently leading orders on methanol-fuelled vessels.
- The majority of the orders has been from containership companies. This is partly due to increasing demands from their customers. The likes of Amazon and Unilever have committed to only using zero-emission ships to transport their cargo from 2040.
- There are currently only nine ammonia-fuelled vessels on order for before 2026. Of the top five shipping companies, only Cosco Shipping has invested in ammonia vessels.
- Industry participants have suggested the key drivers behind the slow-uptake in zero-emission ship orders are underpinned by high costs, uncertain fuel supply, lack of port infrastructure, and a weak regulatory direction.




**New-build orderbook by fuel type (Source: Bloomberg NEF)**



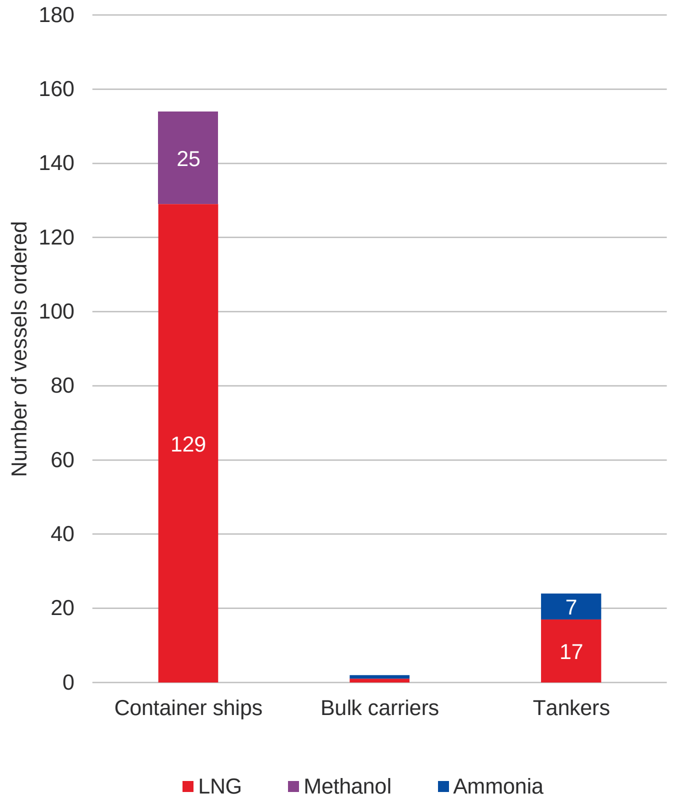

**Alternative fuel vessels on order (Source: Bloomberg NEF)**

Section 4: Market Overview

# Companies will be crucial in decarbonising the shipping industry. Despite this, key market players have invested little in low- and no-carbon vessels to date.

## Top 5 largest shipping companies alternatively fuelled vessels orderbook

| Company | HQ | Sector | Million DWT | Net zero target | Orderbook |
|---|---|---|---|---|---|
| COSCO SHIPPING | | Container, bulk carrier, tanker | 90 | 2060 | Ammonia: 1<br>LNG: 1 |
| MAERSK | | Container | 29 | 2040 | Methanol: 19 |
| msc | | Container | 26 | 2050 | LNG: 76 |
| seaspan | | Container | 22 | IMO target | LNG: 29 |
| 招商局集團有限公司 CHINA MERCHANTS GROUP LIMITED | | Tanker | 20 | By 2050, 75% lower-carbon intensity | None |




**Alternatively fuelled vessel orders by the largest shipping companies for delivery between 2022 and 2026 (Source: Bloomberg NEF)**

# Sustainable fuel production is likely to create new jobs and local economy benefits through an influx of income and creation of indirect jobs. Just Transition plans allow for social justice through the consideration of human rights and poverty in the transition to a green economy.

## Co-benefits to the decarbonisation pathways

### Job Creation

- Producing aviation and shipping fuels near airports and ports also creates local economy benefits through job creation. There would be increased requirements for skilled labour to operate production and distribution centres. This influx of permanent skilled labour into communities would boost the local economy. In addition to the skilled workers required for production centres, there will be extensive opportunities for workforce mobility. One example will be existing aviation and shipping workers that can be upskilled and trained in handling new technology systems and fuels.
- There will be significant creation of jobs, particularly when moving to decentralised production. Direct job creation will focus on workers taking part in the production, transportation or storage facilities. There will be secondary impacts on the local economy and an increased requirement for transport, housing and retail, amongst others – creating indirect jobs.

### Just Transition

- Just Transition refers to the need to consider social justice, human rights and poverty in the shift to renewable and regenerative industries. It encompasses workers, employers and governments working together to support workers in the transition to new jobs through retention, redeployment, reskilling, upskilling, and, when desirable, early retirement.
- The creation of green economy jobs will help support vulnerable communities as it will encourage investment in public services such as; infrastructure, public services, hospitals, and many others.
- The integration of flexible transition plans into infrastructure planning, ports and airports can gain a competitive advantage and future-proof their activities.
- The creation of new industries utilising novel technologies also allows for the implementation of circular economy principles through waste production reuse in the form of biofuels or to provide by-products for secondary use.


Just Transition components (Source: City of Longmont)

# Air pollution is a significant issue for aviation and shipping. Sustainable fuels are likely to reduce GHG emissions and pollution around airports and ports. Ecological impacts of fuel spills and negative health impacts are likely to be reduced through the adoption of sustainable fuels.

## Co-benefits to the decarbonisation pathways

### Air Pollution

- Aviation and shipping are responsible for significant greenhouse gas and air pollution contributions. The European Environment Agency reported that aviation and shipping produce 14.4% and 13.5%, respectively, of all greenhouse gas emissions from transport in the EU. Ships and airplanes emit a number of air pollutants into the atmosphere, mainly sulphur oxides, nitrogen oxides, particulate matter, carbon-dioxide and carbon monoxide. These air pollutants exacerbate the effects of climate change by warming the earth's atmosphere.
- Sustainable fuels emit fewer pollutants, including $CO_2$ and $SO_x$ into the atmosphere, as long as careful handling is carried out.
- Within the aviation sector, contrails are formed when hot exhaust gases from an aircraft mix with the cold, moist air, causing the water vapor in the air to condense and freeze into ice crystals. These in turn can form high altitude clouds, which act is insulation of heat. This heat, though not fully agreed on in literature, is believed to result in a global warming effect. The sustainable hydrocarbon based alternate fuels are expected to still result in these same contrails, while there is wide uncertainty on the effect of a pure hydrogen fuel on the contrails.

### Pollution around Airports and Ports

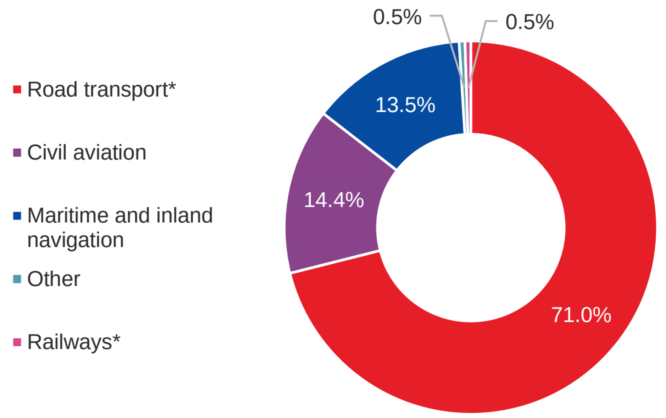
- The use of sustainable fuels and electrifying ports would reduce the air quality impacts from idling ships and port operations.
- Air pollution around airports comes from a combination of aircrafts and surface traffic. Nitrogen dioxide is the main pollutant of concern around airports, as it contributes to the production of ozone in the lower atmosphere, leading to warming. Despite reducing GHG emissions, the use of sustainable fuels would not eliminate all emissions and requires careful evaluation of its impacts.

### Ecological Impacts

- Existing fuel oils can have a significant negative impact on the ecology and environment through spills. In particular, these fuels show high impacts on invertebrates and birds and impacts on other ecology, such as fish and marine mammals.
- Ammonia has a high spill risk impact on fish but a much lower impact on invertebrates and birds. Hydrogen and methanol fuels, however, do not have this impact on aquatic life, creating a very low spill risk to ecology.
- Nitrogen oxides, often emitted from existing aircraft and airports, can also negatively impact plant diversity in the surrounding areas.

### Health Impacts

- Public Health England has found that the health and social care costs of air pollution in England could reach £5.3 billion by 2035. GHG emissions can cause health problems and diseases such as asthmas, bronchitis, emphysema, and cancer. Increasing level of ground-level ozone via nitrous oxides has direct effects on human health, and damage to forests and crops – which could create food scarcity. Switching to sustainable fuels would significantly reduce the GHG emissions from the aviation and shipping industry and help lessen the impact.




**Share of EU transport GHG emissions by mode, 2018 (Source: EEA)**

# Hydrogen is marked to play a critical role in a wide range of energy challenges, with uses across the transport industry, in heavy industries and for use in homes. Because of these wide-ranging possibilities, there could be heavy competition for the green hydrogen as the industry develops.

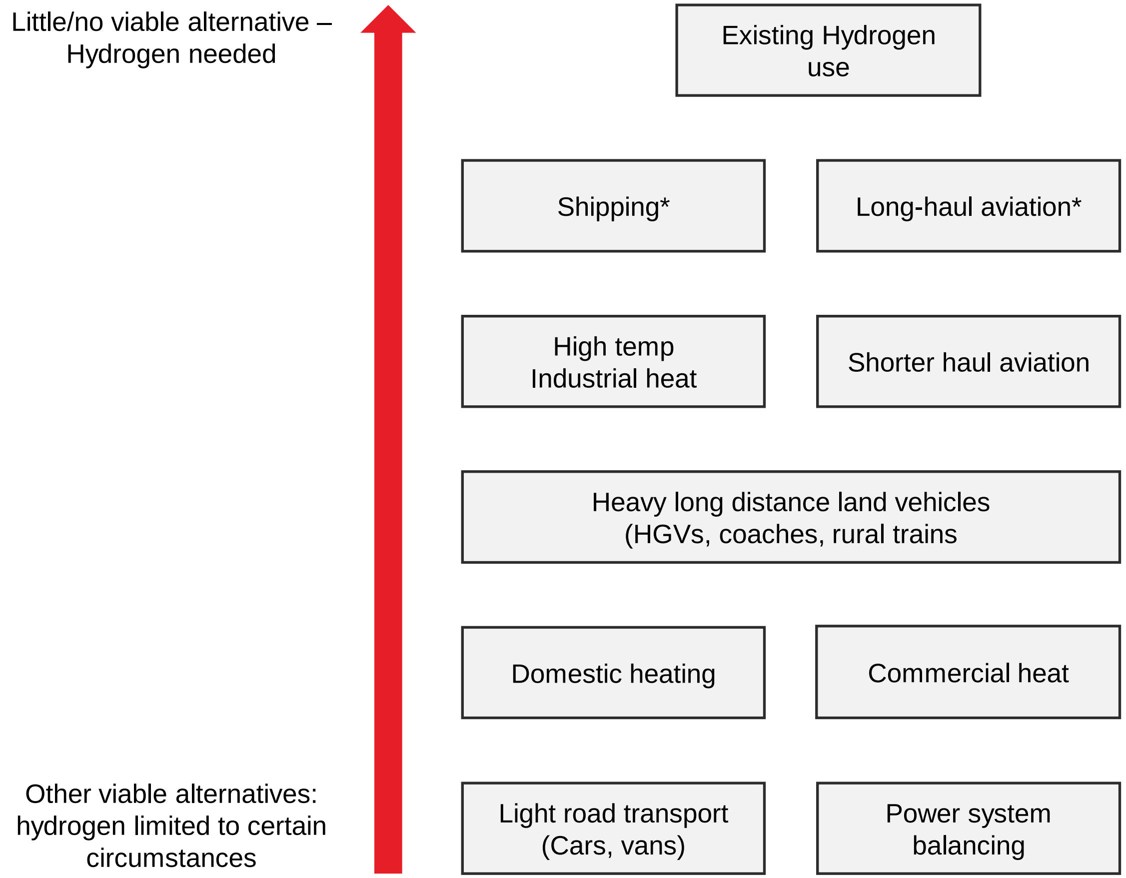
## Other sectors using green hydrogen to decarbonise

Hydrogen can help tackle various critical energy challenges and help strengthen energy security.

It can be used across a range:

- Transport: In addition to the production of aviation and shipping fuels, hydrogen can be used directly in fuel cell vehicles use where its rapid refuelling time and higher efficiency density give it an advantage over batteries. This is likely to be mostly limited for larger vehicles that need a longer range.
- Industry: Hydrogen (largely derived from fossil fuels) is already used in many industrial processes (refining) and as a feedstock fertilizer manufacture (i.e, ammonia and methanol production). Substituting this with green hydrogen is one of the easiest decarbonisation interventions. Additionally, hydrogen can be used in temperature industrial processes for example glassmaking and pottery. A move to hydrogen offers a big opportunity to decarbonise. Hydrogen is likely to play a key role in steel manufacturing.
- Gas Networks: Governments in Europe are investigating whether it makes sense to blend hydrogen into existing gas networks or repurpose them to operate with 100% hydrogen.

Hydrogen can enable renewables to provide an even greater contribution. It has the potential to help with variable output from renewables. Hydrogen is one of the options for storing energy from renewables and looks poised to become a lowest cost option for storing large quantities of electricity over days, weeks or months.




**Likely global usage of hydrogen (Source: Arup analysis Liberich associates, Bloomberg)**

Hydrogen is marked to play a critical role in a wide range of energy challenges, with uses across the transport industry, in heavy industries and for use in homes. Because of these wide-ranging possibilities, there could be heavy competition for the green hydrogen as the industry develops.

## Other sectors using DAC to decarbonise

Direct Air Capture (DAC) is used to capture $CO_2$ from the atmosphere. There are a number of existing industries that already use $CO_2$ as a feedstock. As these industries try to decarbonise, they may look to use $CO_2$ from DAC. Globally, approximately 230 million tonnes (Mt) $CO_2$ are used every year.

- Fertiliser: industry is currently, the largest consumer, using 130 Mt/year $CO_2$.
- Oil and gas: consumes 70 to 80 Mt $CO_2$ for enhanced oil recovery.
- Other: commercial applications include food and beverage production, metal fabrication, cooling, fire suppression and stimulating plant growth in greenhouses.

Additionally, there are a number of emerging technologies that will require $CO_2$ for decarbonisation. These routes will require non-fossil based $CO_2$, with DAC being a key option. These uses, in addition to aviation and shipping application are predicted to include:

- Chemical and polymer production: $CO_2$ to replace fossil fuels as a raw material.
- Building materials: using $CO_2$ via less energy-intensive pathways.
- Biological process enhancement.

DAC technologies are still relatively new (TRL 4-7 depending on the technology) but are improving rapidly. DAC offers a number of advantages compared to point source capture:

- Air offers an almost an abundant source of sustainable $CO_2$ that is available anywhere on earth.
- DAC has the potential to unleash decentralized carbon removals at scale.
- Capture projects need transportation and storage to the end users of $CO_2$ to come online to meet the export demand. As a result, these projects require collaboration between partner organizations that typically aren't used to working together.

The table opposite shows other sources of renewable and non-renewable $CO_2$ that may be used as to aid decarbonisation.

| Source or technology | $CO_2$ concentration in exhaust or gas stream (%) | $CO_2$ concentration after treatment (%) | |
|---|---|---|---|
| Biomass to ethanol | Up to 100 | Up to 100 | Renewable $CO_2$ |
| Biomass combustion | 3-8 | | |
| Biomass gasification | 20-90 | | |
| Biogas | 40-50 | | |
| BECCS/BECCU | Close to 100 | | |
| DAC* | 0.042 | | |
| | | | |
| Coal power plant | 12-14 | Up to 100 | Non-renewable $CO_2$ |
| Coal power plant with oxy-combustion | Close to 100 | | |
| Natural gas power plant | 3-5 | | |
| Iron and steel plant | 20-30 | | |
| Cement plant | 15-30 | | |
| Natural gas purification | 2-65 | | |
| Ammonia synthesis | Up to 100 | | |

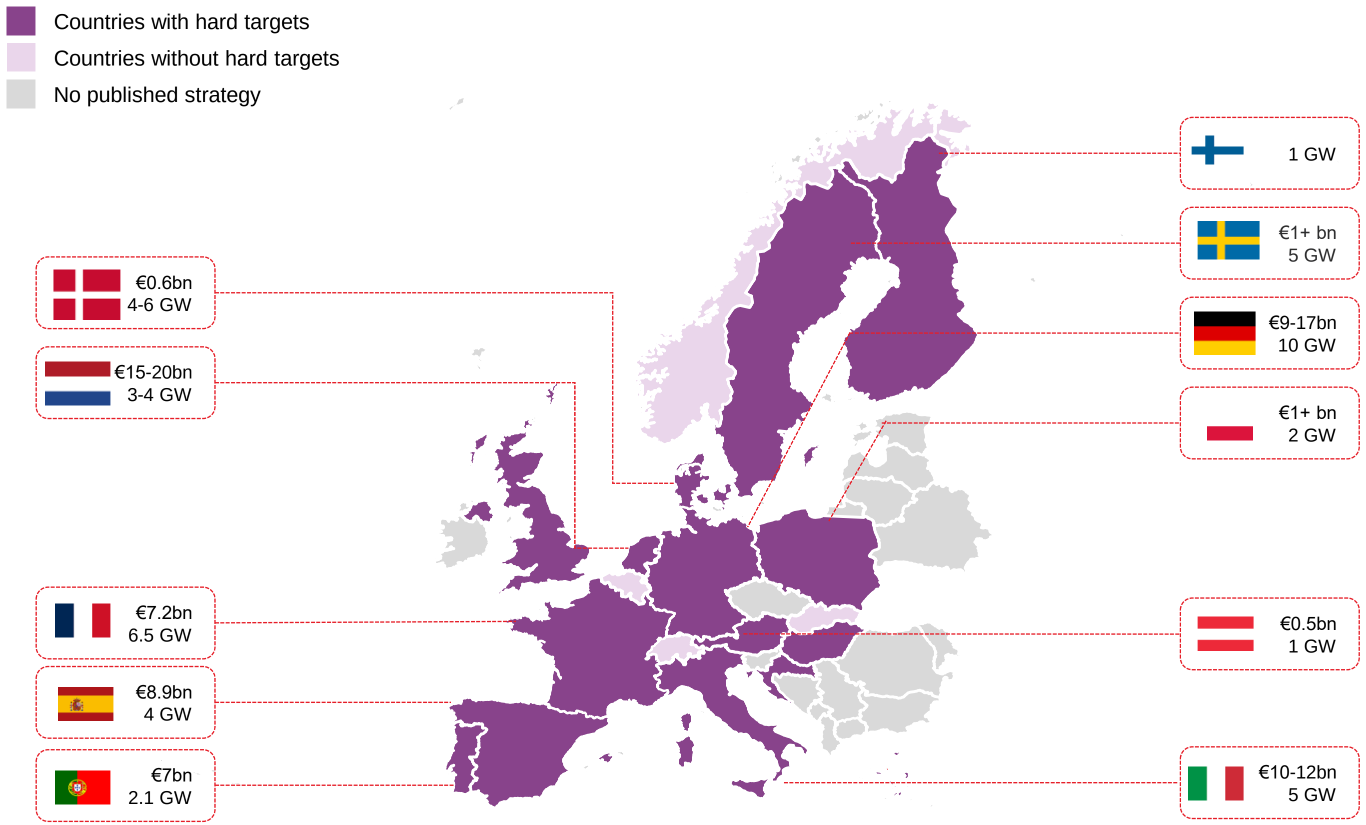
**Selection of renewable and non-renewable sources of $CO_2$ (Source: IRENA)**

Section 5

# Policy Landscape

# 17 EU Member States have communicated hydrogen strategies, aiming for >€55bn in public funding and >80GW installed capacity by 2030. More countries are expected to follow, following EU funding and climate ambitions.

## EU Government Hydrogen Strategies Funding and Installed Production Capacity Targets




| EU Government Initiatives for Hydrogen in Transport | |
|---|---|
| France | Focus on developing the use of decarbonised fuels for heavy-duty mobility, with goal to abate more than 6 Mt of $CO_2$ emissions in 2030 (27% of budget). |
| Germany | Promote the use of direct use of green hydrogen in aircraft engines and encourages the development of concepts for hybrid-electric flying. |
| Spain | Aim to have 150-200 fuel cell buses in 2030, 5,000-7,500 light and heavy-duty fuel cell vehicles in 2030, 100-150 public access hydrogen stations by 2030. |
| Portugal | Gradual increase of hydrogen consumption in the road transport sector up to 20% by 2050, reaching up to 100 HRS in the country by 2030 |
| Italy | €2-3bn funding allocated to develop hydrogen distribution and consumption facilities, including hydrogen-powered trains, HGVs, refueling stations. |
| Sweden | Swedish Energy Agency awards funding for hydrogen projects that can lead to fossil-free aviation. |
| Denmark | PtX strategy to support the direct use of hydrogen as fuel in sectors where direct electrification is challenging (i.e. aviation, shipping and heavy road transport). |
| Norway | Aim to develop a network of geographically and demand-based hydrogen hubs in line with access to vessels and vehicles. |

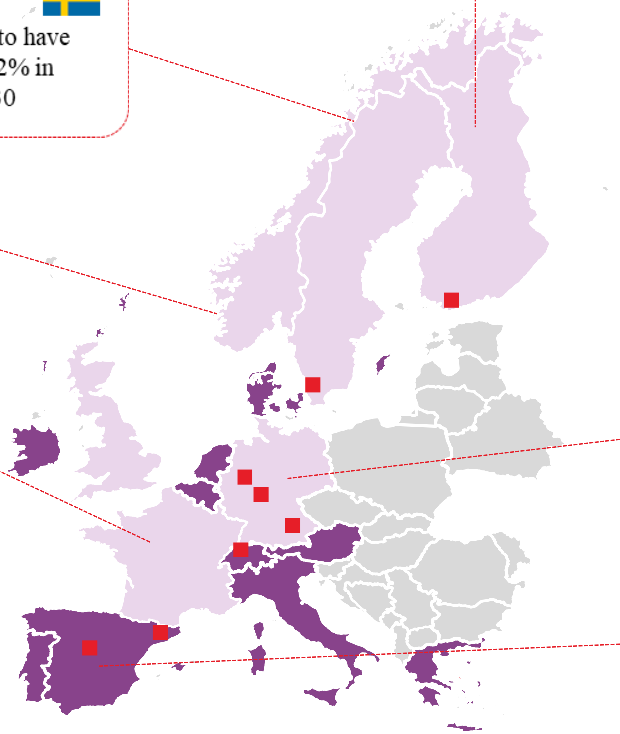
**Source: Country Hydrogen Strategies**

Section 5: Policy Landscape

# The regulatory environment for the aviation industry in the EU is amongst the most stringent globally and will support bridging the kerosene and SAF production gap in the region.

## EU SAF Mandates

- EU (SAF Blending Mandate)
- Country SAF blending mandates
- Airports that regularly offer SAF



**Sweden**

- SAF mandate (2021) to have 1% SAF in fuel mix, 2% in 2022 and 27% by 2030

**Norway**

- 0.5% SAF in fuel mix from 2022 – first country to implement SAF mandate

**France**

- 1% SAF mandate introduced in 2022 – will rise to 2% in 2025, 5% in 2030 and 50% in 2030

**Finland**

- SAF obligation of 30% by 2030.

**European Union**

- EU Fit for 55 package includes a proposed SAF blend (up to 63% by 2050) mandate, with a sub-target for e-fuels.

**EU Regulatory Parliament Proposals**
*(under review)*

- Increase EU SAF blend to 85% by 2050
- Reduce cost gap in SAF production (fuel tax for intra-EU flights)
- Increase $CO_2$ emissions cost (through EU ETS)

**Germany**

- Synthetic fuel roadmap – 200,000 Mt sustainable kerosene produced annually by 2030

**Spain**

- Climate Change Law established 2% SAF supply objective for 2025.

| Other Global SAF Mandates | |
|---|---|
| UK | SAF Mandate to be published in 2023 – 10% SAF in fuel mix by 2030. |
| USA | 3 billion gallons of SAF supply by 2030. The Inflation Reduction Act also includes SAF-specific tax credit. |
| Canada | Opt-in policy for SAFs in Canadian Governments Clean Fuel Regulation will be implemented in July 2023. |
| Brazil | The National Blokerosene Program promotes SAF – Brazilian Government mandate expected in 2027. |
| China | China's 14th Five-Year Special Plan for Civil Aviation includes SAF targets of a minimum of 20,000 t by 2025. |
| Japan | Target for SAF to account for 10% of jet fuel demand from Japanese airlines by 2030 (not mandated). |
| New Zealand | SAF mandate under development. |

Source: EU, BNEF

Section 5: Policy Landscape

# The EU Fit for 55 includes a range of packages that impose mandates to support SAF production and uptake in the aviation sector (ReFuelEU) and introduce jet fuel taxes through the EU ETS and the Taxation Directive.

## EU policies that specifically impact SAF

| Directive | Overview | Key Implications for SAFs uptake |
|---|---|---|
| Fit for 55 Package July 2021 | Program seeks to adapt EC directives and regulations to reduce GHG emissions by at least 55% by 2030 and promote fair and reasonable market organisation, technical neutrality and counteract negative externalities. The program will impact a range of sectors and the following packages directly impact the aviation sector: | Obligations on fuel suppliers to distribute an increasing share of SAF over time – ~2.3 Mt of SAF required by 2030, 14.8 Mt by 2040 and 28.6 Mt by 2050. |
| (1) RefuelEU Aviation Initiative | • Proposal included in the Fit for 55 package to impose a mandate on fuel suppliers to include SAF in aviation fuel supply to EU airports. The package aims to prevent carbon leakage and fuel tankering and define sustainable fuels and required infrastructure.<br>• SAFs are defined as liquid, drop-in fuels, fully fungible with conventional aviation fuel and compatible with existing aircraft engines and qualifying SAFs must meet criteria set in the Renewable Energy Directive (RED).<br>– Food, crop-based SAFs are explicitly excluded from the eligibility criteria, while other feedstock (i.e. animal fats) will be excluded beyond 2030.<br>• Blending mandates have been introduced for SAFs to account for at least 2% of aviation fuels by 2025, gradually increasing to 6% of aviation fuels by 2030 and 70% by 2050. This includes a sub-mandate for synthetic fuels to account for 35% of share by 2050. | Package targets use of cleanest, advanced biofuels and e-fuels (mostly consisting of synthesised hydrogen and captured carbons).<br><br>Potential obligation on airlines to limit uptake of jet fuel before departing EU airports to avoid fuel tankering – the practice of carrying more fuel than necessary for the journey to avoid refuelling costs. |
| (2) EU ETS mechanism for aviation | • Aviation sector is allocated with free credit allowances to assist with transition towards lower-carbon economy. Progressive phase-out of free allowances distributed to aircraft operators between 2024-26 (by 25%, 50% and 75% in each year) and 100% by 2027.<br>• Reduction in emissions cap by 4.2% annually (from 2.2%) from the aviation sector.<br>• EU ETS applies to intra-EEA flights and EEA to/from UK and Switzerland.<br>• More detail on the EU ETS and proposed amendments discussed on subsequent pages. | Faster than anticipated reduction in free allocation phase-out will increase kerosene prices - airlines likely to partially pass through costs to passengers (higher impact for intra-EU flights) in near-term.<br>In the long-term, airlines will be incentivised to increase SAF use. |
| (3) Energy Taxation Directive | • Removal of current tax exemptions for jet fuel in intra-EU flights from 2023.<br>• Impose a gradual aviation fuel tax over 10 years, reaching €10.75/Gigajoule by 2033. | Improve SAF cost competitiveness – SAFs exempt from aviation fuel tax for intra-EU flights. |
| (4) Alternative Fuels Infrastructure Regulation (AFIR) | • Targets to deploy sufficient alternative fuel infrastructure for all transport modes with a network coverage across the EU.<br>• Airports with less than 10,000 flights per year may be exempt. | Deployment plans for electric re-charging of aircraft to encourage uptake of new technologies and sustainable fuels. |

Positive impact  No impact  Negative impact

## Section 5: Policy Landscape

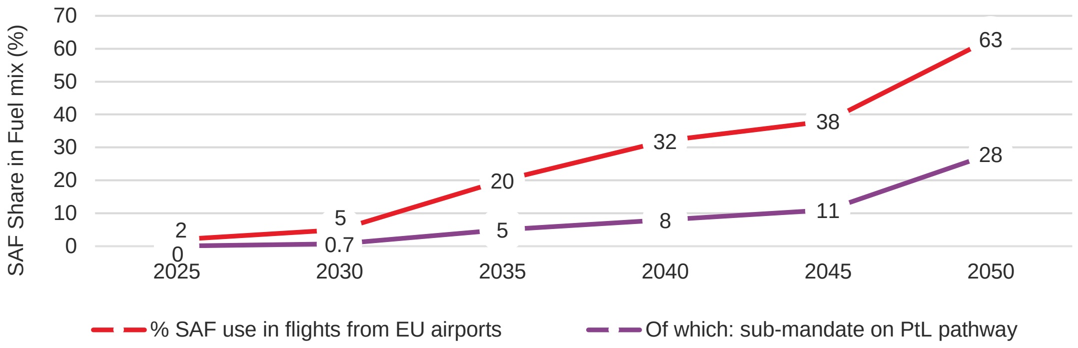
# EU SAF use can reach approximately 2.3 Mt by 2030 and 14.8 Mt by 2040 to achieve Fit for 55 targets. Synthetic fuels are expected to play a role in meeting these quantities.

### Fit for 55 Mandate

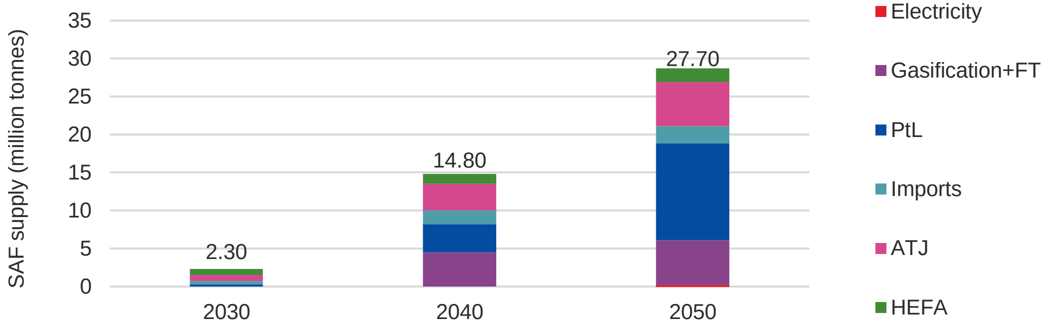
- Current SAF supply accounts for ~0.05% of total EU aviation fuel use. Under the Fit for 55 package, the European Commission aims to gradually increase SAF to 70% in 2050.
- There is a sub-mandate for synthetic fuels (PtL) to account for 35% by 2050.
- SAFs are currently subject to 50% maximum blending ratio with fossil-based jet fuel, however this is expected to increase to 100% SAF by 2030 (dependent on the production pathway).

### SAF Pathways

- Following exhaustive approval and certification processes, drop-in SAFs can be used within existing global fleets and fuel supply infrastructure without any adaptation to the aircraft or infrastructure. These are expected to play a key role in aviation decarbonisation.
- The EU SAF blending mandates focus on advanced biofuels and synthetic fuels (including synthetic fuel production method). The synthetic fuel sub-mandate recognises the high decarbonisation potential of synthetic fuel.
- The current SAF production capacity in the EU is approximately 0.24 Mt, which accounts for only 10% of SAF required to meet 2030 mandate.
- Significant capacity increases will be required to meet targets. While the majority of the European SAF supply is expected to come from HEFA and Alcohol-to-Jetty (ATJ) pathway, the synthetic fuel production pathway is expected to account for 25% of total production by 2040 and 44.3% by 2050.




**Proposed Fit for 55 SAF Mandate (Source: EASA)**




**ReFuelEU modelled SAF supply per production pathway in the EU27 (Source: EASA)**

# $CO_2$ emissions from intra-EEA flights are included in the EU ETS with free allocation on ~80% of aviation allowances to not hinder sector competitiveness or enable carbon leakage.

## Aviation in EU Emissions Trading System

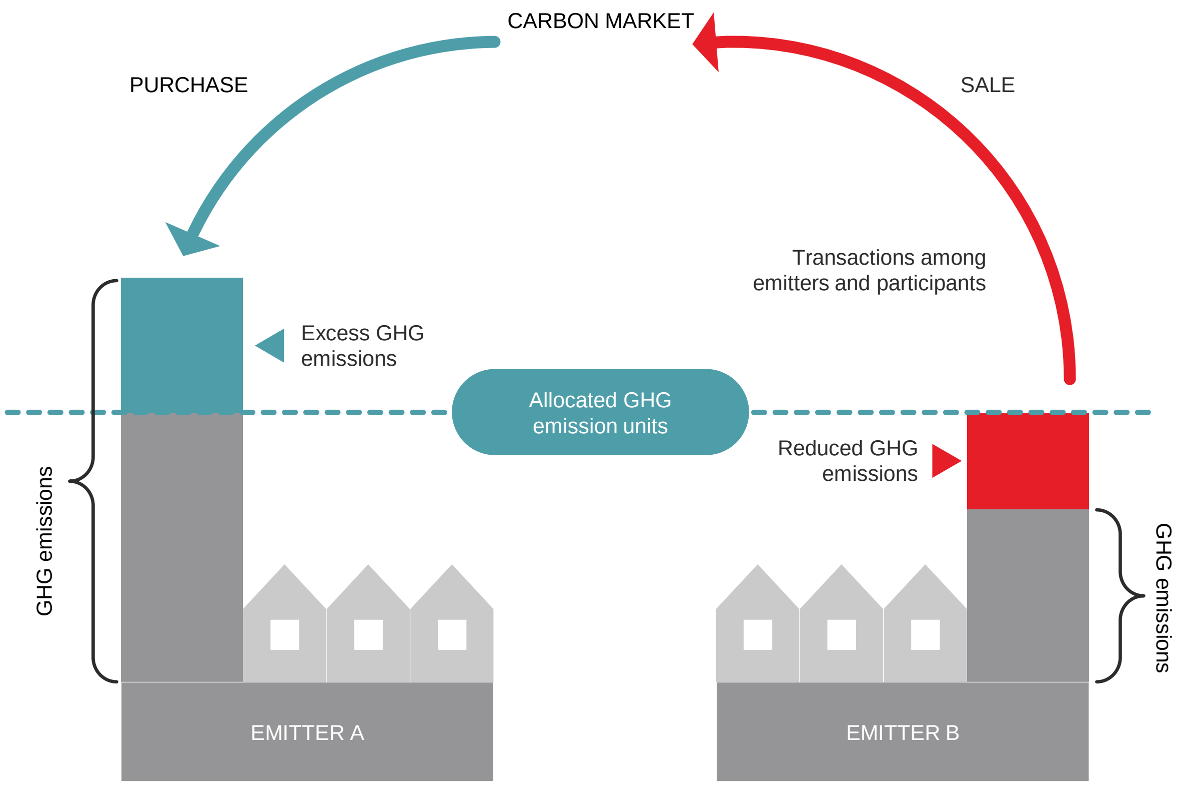
- $CO_2$ emissions from aviation are included in the EU emissions trading system (EU ETS).
- The EU ETS is the world's largest carbon market designed to account and reduce emissions on a 'cap and trade' principle.
- The annual emissions allowance limit (cap) which sets total amount of GHG emissions emitted by participants decreases each year.
- Operators buy or receive emissions allowances, which they can trade with one another. If operators do not cover all emissions, they are subject to fines.

### Free Allocation

- The ETS allocates some allowances for free to enable the EU to meet reduction targets without impacting sector competitiveness and resulting in carbon leakage.
- Over 2013-2020, approximately 40% of allowances are available for free allocation.

### Aviation Industry in EU ETS

- Until 31 December 2023, free allocations in the EU ETS apply to flights between airports located in the European Economic Area.
- Allowances are distributed to:
  - 82% free allocation to aircraft operators.
  - 15% auctioned.
  - 3% special reserve for distribution to fast-growing aircraft operators.
- Free allowances are allocated to ~500 aircraft operators based on airline efficiency benchmarks. The allocation of free allowances in the aviation sector will decrease gradually by -25% in 2024, -50% in 2025 and ~75%n in 2026 with phase-out by 2027.
- To date, it is estimated the carbon footprint in the aviation sector has been reduced by 17 Mt due to the ETS.




**EU ETS Cap and Trade System (Source: EC)**

# EU initiatives are supportive of the deployment of infrastructure required for sustainable aviation fuels and the synthetic fuel pathway is generally compliant with other EU policies and is reasonably well-aligned with the current EU taxonomy. (1/2)

## General EU Energy policy that could impact SAF market

| Directive | Overview | Key Implications for SAFs uptake | |
|---|---|---|---|
| Renewable Energy Directive II (RED II) Final RFNBO regulations published Feb 2023 | • The recast Renewable Energy Directive II (RED II) introduces new provisions for promoting the use of renewable liquid and gaseous transport fuels of non-biological origin and recycled carbon fuels. | | Provides an eligibility framework for type of fuels that count toward the 14% target and a cap for food-based biofuels' contribution. |
| | • Renewable Fuels of Non- Biological Origins (RFNBO) regulations under RED II seek to develop methodologies that ensure (1) hydrogen producers are adding to renewable capacity deployment and (2) can demonstrate renewable electricity has been used to produce hydrogen.<br>• Minimum threshold for greenhouse gas (GHG) emissions savings of recycled carbon fuels and by specifying a methodology for assessing GHG emissions savings from renewable liquid and gaseous transport fuels of non-biological origin and from recycled carbon fuels.<br>– If hydrogen producers cannot exclusively generate hydrogen using 100% fully renewable electricity, there is a minimum threshold of GHG savings for recycled carbon fuels to be RED II compliant.<br>– For the synthetic fuel pathway, it specifies the origin of carbon used for production is not relevant for determining emission savings in the short-medium term. This opens up use of industrial carbon in SAF production, potentially reducing drive for demand for DAC in the near-term. | | Sets guidance around GHG emissions threshold to produce compliant RFNBOs at 28.2g$CO_2$eq/MJ, resulting in a 70% GHG emissions saving. |
| Single European Sky | • 37 air navigation service providers (ANSPs) collaborating to organise the interoperability of European Air Traffic Management. Reform for Air Traffic Management to cope with traffic variations due to COVID-19 and European Green Deal Measures.<br>• Aim to drive sustainable development in the aviation sector and deploy efficient and optimal travel trajectories in European airspace, which can reduce $CO_2$ emissions.<br>– Estimated 6% - 10% GHG emissions savings are possible by de-fragmenting airspace and deploying initiatives such as direct routing, continuous descent approaches, high altitude flying (burns less fuel). | | Organisational efficiencies to better utilise travel trajectories in EU airspace decrease fuel demand. |
| CCS Directive 2009/31/EC | • The Directive on the geological storage of $CO_2$ (commonly referred to as the CCS Directive) establishes the legal framework for the environmentally safe geological storage of $CO_2$. It covers all $CO_2$ storage in geological formations in the EU and the lifetime of storage sites. The Directive also sets out regulations on the capture and transportation element of the process. | | The Directive focusses on geological storage of captured $CO_2$ and therefore is of less relevance for SAFs that use the captured $CO_2$ directly. |

Positive impact | No impact | Negative impact

# EU initiatives are supportive of the deployment of infrastructure required for sustainable aviation fuels and the synthetic fuel pathway is generally compliant with other EU policies and is reasonably well-aligned with the current EU taxonomy. (2/2)

## General EU Energy policy that could impact SAF market

| Directive | Overview | Key Implications for SAFs uptake |
|---|---|---|
| Taxonomy Regulation (EU) 2020/852 | • Taxonomy establishes a list of environmentally sustainable economic activities by defining how these are deemed to substantially contribute to climate adaptation and do no significant harm, including minimum safeguards. An Article 9 Fund is required to assess its portfolio against the principle of "do no significant harm" and incorporating considerations of the minimum social safeguards.<br>• Transport & Environment, a clean transport campaign group, has criticised the Taxonomy criteria as potentially allowing continued investment in fossil fuelled aircraft, without driving investments towards decarbonisation options. | Provides an eligibility framework for type of fuels that count toward the 14% target and a cap for food-based biofuels' contribution. |
| Effort Sharing Regulation (EU ESR) | • Mechanism designed to share emissions reduction efforts across Member States on the basis of members' wealth (GDP per capita). Countries are assigned national reduction targets to reduce sectoral emissions, however are awarded flexibility in annual quotas and can bank allocations to future years and trade between themselves. | Potential for collaboration across Member States to accelerate cross-sectoral emission reduction efforts. |
| Important Project of Common European Interest (IPCEI) | • Support research and innovation and upscaling in the hydrogen technology value chain. Member States will provide up to €10.6 billion in public funding. | Sustainable aviation fuel producers will benefit from this funding, as SAF is part of the broader hydrogen value chain that is covered by the IPCEI. |
| EU Innovation Fund | • The Innovation Fund is one of the world's largest funding programmes for the demonstration of innovative low-carbon technologies, including SAF technologies.<br>• ~ €40bn for the development of low emission alternatives mostly focussing on hydrogen and sustainable fuels. For example, it recently provided an €80 million grant to the HySkies SAF project in Sweden. | Funding provisions for the deployment of hydrogen infrastructure and SAF technology. |
| EU Hydrogen Bank (under development) | • The EU is developing a Hydrogen Bank of ~€3bn to help accelerate upscaling of initiatives. | |
| Clean Hydrogen Joint Undertaking (CHJU) | • Public-private partnership supporting research and innovation activities in hydrogen technologies in Europe (part of the Horizon Europe programme) | |

Positive impact | No impact | Negative impact

# The UK government has set out a target of 10 GW hydrogen production capacity by 2030, with at least half of this from electrolytic hydrogen. The transport sector is to become one of the largest components in the hydrogen economy with demand estimated to reach up to 140 TWh by 2050.

## UK Hydrogen Economy Roadmap

| Hydrogen economy 'archetype' | Early 2020s | Mid-2020s | Late 2020s | Mid-2030s onward |
|---|---|---|---|---|
| 1 | **Production** Small-scale electrolytic production | **Production** Large-scale CCUS-enabled production in at least one location; electrolytic production increasing in scale | **Production** Several large-scale CCUS-enabled projects & several large-scale electrolytic projects | **Production** Increasing scale & range of production – e.g. nuclear, biomass |
| 2 | **Networks** Direct pipeline, co-locations, trucked (nom-pipeline) or onsite use | **Networks** Dedicated small-scale cluster pipeline network; expanded trucking & small-scale storage | **Networks** Large cluster networks; large scale storage; integration with gas networks | **Networks** Regional or national networks & large-scale storage integrated with CCUS, gas & electricity network |
| 3 | **Use** Some transport (buses, early HGV, rail & aviation trials); industry demonstrations; neighbourhood heat trial | **Use** Industry applications; transport (HGV, rail & shipping trials) village heat trial; blending (tbc) | **Use** Wide use in industry; power generation & flexibility; transport (HGVs, shipping); heat pilot town (tbc) | **Use** Full range of end users inc. steel; power system; greater shipping & aviation; potential gas grid conversion |

UK Government initiatives for hydrogen in transport include:

- £23M Hydrogen for Transport Program: 10+ hydrogen RFS, 100+ hydrogen fuel cell vehicles
- ZEBRA1: 120+ hydrogen fuel cell buses and accompanying refuelling infrastructure
- £20M funding to trial electric road system and hydrogen fuel cell HGVs to establish feasibility
- ZERFT2: £200M to demonstrate HGV technologies at scale
- UK Shipping Office for Reducing Emissions: £206M for maritime decarbonization
- £12M in the Clean Maritime Demonstration Competition
- Jet Zero Strategy 2022 to reduce in-sector emissions from aviation by ~50% by 2050

**Source: UK Government. 1 – Zero-Emission Bus Regional Areas (ZEBRA), 2 – Zero-Emission Road Freight Trials Program (ZERFT)**

Section 5: Policy Landscape

# The UK Jet Zero Strategy sets out a SAF mandate for a minimum of 10% SAF in UK aviation fuel mix by 2030 and 75% by 2050 and establishes a number of initiatives that will accelerate the development of a domestic SAF industry.

## UK policies that specifically impact SAF

| Directive | Overview | Key Implications for SAFs uptake |
|---|---|---|
| Jet Zero Strategy<br>July 2022 | • Key policy measures include (1) improving system efficiencies for all England airport operations to be zero-emission by 2040, (2) deploy domestic zero-emission flight routes, (3) implement carbon markets and GHG removal technologies (i.e. CORSIA, ETS) and (4) support the development of SAF industry.<br>• Established the SAF Delivery Group (2020) to accelerate project development and SAF uptake in the UK and collaborate in standard setting with ICAO, industry and government. Key policy measures include:<br>– SAF mandate to be published by 2025 to drive at least 10% SAF in UK aviation fuel mix by 2030 and 75% by 2050.<br>▪ SAFs include waste-derived biofuels, recycled carbon fuels (waste industrial gases) and synthetic fuels.<br>▪ The blend mandate will apply to jet fuel suppliers and begin in 2025 (outside of the Renewable Transport Fuel Obligation).<br>▪ HEFA SAFs are expected to be capped and a synthetic sub-target will be introduced to encourage the development of strategically important SAFs.<br>– 5 commercial scale UK SAF plants under construction by 2025.<br>– Interim targets of 35.4 $MtCO_2$ reduction in 2030, 28.4 $MtCO_2e$ in 2040, and 19.3 $MtCO_2e$ in 2050.<br>– Advanced fuel funding competitions ($165M) to support commercial and demonstration plants £12M funding for a domestic SAF clearing house to deliver early-stage aviation fuel testing in 2022.<br>– £1M funding in support of first 100% SAF transatlantic flight. | SAF mandate (2025) will introduce obligations for fuel suppliers to reduce emissions through a tradable emissions credits scheme. |
| | | Capital grant funding to kickstart UK SAF industry and drive development of at least 5 commercial scale UK SAF plants by 2025. |
| Effort Sharing Regulation<br>(EU ESR) | • The fund competitively allocates up to £165 million in grant funding to support UK advanced fuels projects and the construction of five commercial scale SAF plants in the UK by 2025.<br>• The fund was launched by the Department for Transport and will support first-of-a-kind (FOAK) commercial and demonstration-scale projects at all development stages.<br>• The recipients of the first funding round were announced in December 2022. The selected projects all demonstrated their potential to produce SAFs capable of reducing emissions by more than 70% on a lifecycle basis relative to conventional fuel.<br>• Additional rounds are expected to be announced over the coming year. The Advanced Fuel Fund has allocated a sub-pot for UK projects that source the majority of their fuel carbon from $CO_2$ (point source or direct air capture). | Supporting investment environment for SAF producers.<br><br>The commercialisation of SAF technologies could decrease production costs and drive demand up. |

Positive impact    No impact    Negative impact

# CORSIA is the first global initiative to address emissions from international aviation through cooperative measures designed to drive uptake of Corsia-eligible fuels and international offsets.

## Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

International Civil Aviation Organization (ICAO) to devise CORSIA, the first global scheme to address emissions from international aviation. From January 2021, aviation carriers voluntarily offset any emissions growth above 2019 levels. ICAO has set a long-term global aspirational goal (LTAG) of net zero carbon emissions by 2050, which relies on States' adoption of sustainable aviation fuels, improved aircraft efficiencies and new technologies. The scheme is split into 3 phases and will be reviewed and adjusted at the end of each phase:

| Pilot phase | Phase 1 | Phase 2 |
|---|---|---|
| 2021 – 2023 | 2024 – 2026 | 2027 – 2035 |
| Voluntary participation | Voluntary participation | Mandatory participation |
| 88 volunteer countries have signed up to the voluntary phase (incl. EU + UK). Non-signatories include major emitters, such as China, India and Russia. | | Uncertainty on scale of participation in future |
| 100% sectoral emissions | 100% sectoral emissions | 100% individual emissions |
| Offsetting requirements = annual emissions * sectoral growth factor: % increase in sector-wide emissions from baseline in given year (equal for all operators). | | Offsetting requirements = annual emissions * individual operator rates. |

### Routes to Compliance

| | | |
|---|---|---|
| 1 | Eligible fuels<br>Proactive compliance | • CORSIA-eligible fuels include SAFs (renewable or waste-derived) which meet sustainability criteria (i.e. carbon emissions of fuel / carbon stock biomass) approved by the Corsia Approved Sustainability Certification Schemes.<br>• More sustainability criteria to be announced at the end of the Pilot phase.<br>• Lower-carbon aviation fuels (i.e. 10% lower emissions profile than standard aviation fuel) are eligible. |
| 2 | Offsets<br>Reactive compliance | • Corsia-eligible emission units are purchased to account for emissions above baseline.<br>• Offsetting activities that occurred between 2016-2020 are permitted in the pilot phase. |

| Key Implications for SAFs | |
|---|---|
| Positive impact | First global initiative to tackle aviation emissions and incentivise reduction efforts at a global-scale. |
| No impact | Objectives reviewed and adjusted after each phase to ensure it aligns with UN, EU and other aviation initiatives. However, it is not currently in line with Paris Agreement temperature goals. |
| Positive impact | Long-term scope of some Fit for 55 packages (i.e. ETS mechanisms) dependent on CORSIA assessments and policy stringency. |
| No impact | Challenging to endorse participation across countries and industry. Lack of participation from key emitters likely to dilute efforts and contribution. |
| Negative impact | May discourage countries from developing own national / regional targets. |
| Positive impact | Applies to all flights between participating states – shared efforts across operators on the sectoral approach. Individual rates likely to impact developing nations which are likely to have higher emission rates growth. |
| Positive impact | Supporting investment environment for synthetic fuel SAF producers to qualify. |
| Negative impact | If lower-carbon eligible jet fuels remain eligible – reduces overall demand for offsets and offsets prices remain low. |
| No impact | If offsets remain inexpensive, there is less incentive for airlines to invest in sustainable fuels. |

Positive impact — No impact — Negative impact

# The US has introduced the Inflation Reduction Act (2022) to reduce the costs of hydrogen and SAF production through a $250 billion investment funding package. Global investment may be diverted to the US as a result, although the EU is expected to respond with similar funding and regulation.

## US Inflation Reduction Act 2022

### IRA 2022

- The US Inflation Reduction Act (IRA) 2022 introduces new federal spending that aims to reduce carbon emissions and accelerate the transition to a green economy, amongst others.
- It directs over $250 billion into clean energy through a mix of tax incentives, grants and loan guarantees to reduce renewable energy production costs. The IRA offers investment tax credits and production tax credits for renewable electricity generation, such as solar and wind. The IRA also provides incentives for environmental programmes such as forest and coastal habitat protection.

### Hydrogen IRA

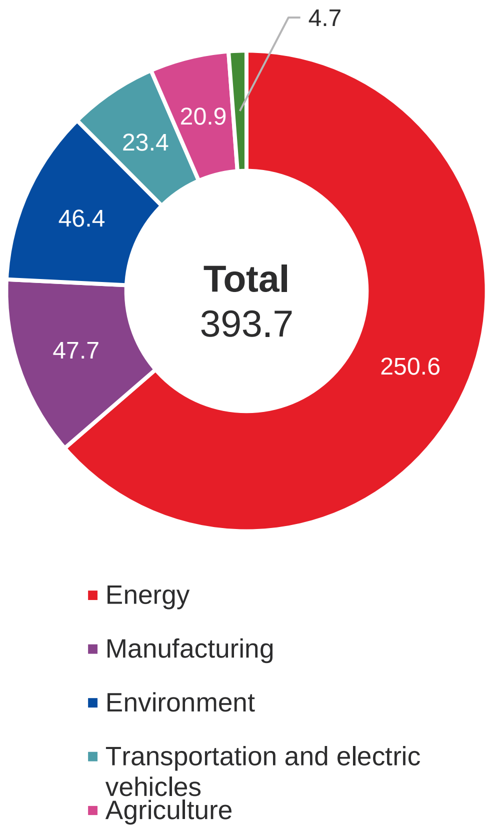
- The Act provides tax credits for the production of 'clean hydrogen' (blue or green hydrogen) in the US. The IRA offers substantial increases in tax credits depending on the hydrogen's lifecycle greenhouse gas emissions up to $3.00 per kg. Estimates claim it could reduce green hydrogen production costs, making them as low as $0.73 per kg.
- Alongside production credits, the IRA offers a 30% credit for energy storage technology built before 2025. Given hydrogen's high production cost is one of its main barriers, the US IRA offers a valuable opportunity to affordable clean energy.

### Aviation and Shipping

- The Blenders Tax Credit for producers offers a $1.25 per gallon credit for SAF as part of a fuel mixture, provided the SAF has reduced the lifecycle GHGs by at least 50%. For every percentage of lifecycle GHG emissions reduction over 50% in comparison to conventional jet fuel, the credit increases by $0.01 up to a value of $1.75 per gallon. This credit applies to all transportation fuels, beginning in 2025.
- The IRA also provides grants and rebates to reduce air pollution at ports through zero-emission port equipment or technologies. Although it does not explicitly offer grants or credits for sustainable shipping fuels, the hydrogen provisions should reduce the cost of producing sustainable fuels using hydrogen.

### EU & UK Market Response

- Following the introduction of the IRA, green economy and hydrogen investment may be diverted towards US markets. Investors may find it more attractive to shift their production locations to benefit from the credits – there has already been interest in project relocations, such as Tesla, Northvolt and Drax.
- The EU is looking to respond with its own funding and regulation that will keep the EU as an attractive location for hydrogen and SAF production. The EU recently announced the Net Zero Industry Act that aims to create a simpler legal framework for net zero industries in the EU, enabling Europe to improve its net zero technology manufacturing capacity.
- The UK government has responded that it will not seek to replicate or try to match the IRA and will strategically target public funding in sectors where the UK has a clear competitive advantage.



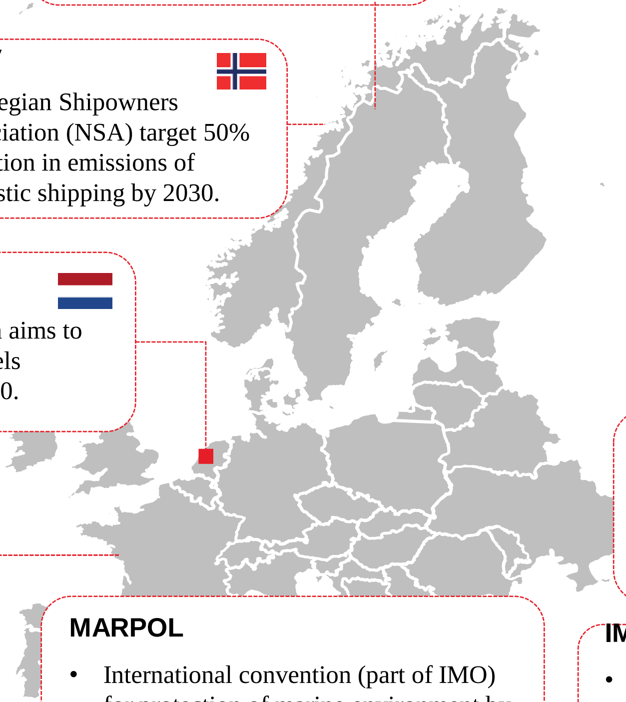

**Inflation Reduction Act investments by sector, $ billion (Source: McKinsey)**

Section 5: Policy Landscape

# The regulatory environment for the decarbonisation of the shipping industry in the EU has been slow to develop, however there is an increasing number of national-level and association-level targets aiming to reduce GHG emissions.

## EU Shipping Targets

Ports with Hydrogen bunkering infrastructure



### Sweden

- Swedish Shipowners Association (SSA) targeting zero-carbon shipping by 2050.

### Norway

- Norwegian Shipowners Association (NSA) target 50% reduction in emissions of domestic shipping by 2030.

### Netherlands

- Maritime Masterplan aims to make 30 Dutch vessels emission free by 2030.

### France

- France-Mer 2030 provides €300 million over 5 years to accelerate decarbonisation of the maritime sector.

### European Union

- EU Fit for 55 package includes the FuelEU Maritime initiative, which imposes constraints on the GHG intensity of on-board energy used by ships and promotes the adoption of sustainable fuels.

### FuelEU Maritime targets

Relative to 2020 GHG intensity:

- 2% reduction in 2025
- 6% reduction in 2030
- 75% reduction in 2050

### Global Maritime Forum

- Full decarbonization by 2050 – commercially viable deep sea zero emission vessels powered by zero emission fuels by 2030

### MARPOL

- International convention (part of IMO) for protection of marine environment by ships – sets limitations on air pollution (i.e. sulphur oxides).

### IMO

- Reduction of 20%, striving for 30% by 2030; 70%, striving for 80% by 2040 and net zero by 2050.

| Other Global Shipping Targets | |
|---|---|
| UK | • UK Shipping Office for Reducing Emissions (SHORE) are targeting decarbonisation of the domestic maritime industry by 2050. |
| USA | • Clean Shipping Act sets carbon intensity standards for marine vessel fuels, current proposal is 100% zero-emission fuels from 2040. |
| Canada | • Canada's Shipping Act limits on ozone depleting substances from ships and outlines fuel-quality specifications. |
| China | • The Chinese Government has imposed restriction on Sulphur emissions within domestic emission control areas (DECAs) to help reduce emissions from ships. . |
| Japan | • Roadmap to decarbonisation by 2050 includes a transition towards carbon-recycled methane and hydrogen/ammonia fuels from 2025. |
| South Korea | • Implemented domestic emission control area with restrictions on Sulphur emissions for specific Korean ports. |

Source: BNEF, EMSA

National regulations are more difficult to implement in the sector as ship operators can be registered under a different country than the country of ownership, often to avoid restrictions in the owners' country.

# The European Commission has begun to implement EU-specific policies to promote the uptake of sustainable shipping fuels. These are primarily driven by the FuelEU Maritime GHG reduction targets, as well as the inclusion of shipping in the EU ETS and the revision of the RED II (1/2).

## EU policies that specifically impact the sustainable shipping fuels market

| Directive | Overview | Key Implications for Sustainable Shipping Fuels[1] uptake |
|---|---|---|
| Renewable Energy Directive II | • The recast Renewable Energy Directive II (RED II) introduces new provisions for promoting the use of renewable liquid and gaseous transport fuels of non-biological origin and recycled carbon fuels.<br>• RED II's impact assessment identified a specific challenge to the maritime sector: the divided incentives for shipowners and operators do not stimulate the deployment of renewable fuels. Therefore, shipping fuels are measured at 1.2 times their energy content when demonstrating compliance with the renewable energy target. This aims to boost uptake of renewable fuels.<br>• Renewable Fuels of Non- Biological Origins (RFNBO) regulations under RED II seek to develop methodologies that ensure (1) hydrogen producers are adding to renewable capacity deployment and (2) can demonstrate renewable electricity has been used to produce hydrogen.<br>• Minimum threshold for greenhouse gas (GHG) emissions savings of recycled carbon fuels and by specifying a methodology for assessing GHG emissions savings from renewable liquid and gaseous transport fuels of non-biological origin and from recycled carbon fuels. | Defines what renewable fuels are and the targets to be implemented by Member States. This includes a sub-target of 14% of renewable energy for road and rail transport. This target can be supplemented with shipping fuels, but is not obligatory.<br>Offers maritime–specific incentives aimed at increasing uptake of renewable fuels. |
| FuelEU Maritime | • As part of the Fit for 55 package, the EC launched the FuelEU Maritime Initiative to increase demand for renewable and sustainable fuels from ships using EU ports. It also aims to reduce emissions from navigation and at berth. The current proposal focuses on demand policy which sets requirements for the fuel consumption of ships.<br>• Ships are required to use fuels that enable:<br>– 2% reduction in GHG intensity (relative to 2020 level) by 2025.<br>– 6% reduction by 2030.<br>– 80% reduction by 2050.<br>• The policy sets a cohesive regulatory framework in the EU and aims to increase the share of RLF used in the fuel mix of maritime transport. This includes liquid biofuels, decarbonised gas, decarbonised hydrogen and derived fuels (methanol and ammonia), and electricity.<br>• The initiative will also contribute to wider goals: enhance predictability by setting a clear regulatory environment for the use of RLF in maritime transport; stimulate technology development and large-scale production of RLF, reduce to price gap to current fuels; create demand from ship operators to bunker RLF or connect to electric grid while at berth; and avoid carbon leakage. | Obligations on ships to reduce the GHG intensity of their fuels will increase demand for sustainable fuels.<br>Concerns that the proposal risks supporting the adoption of LNG over zero-emission fuels. |

Positive impact   No impact   Negative impact

# The European Commission has begun to implement EU-specific policies to promote the uptake of sustainable shipping fuels. These are primarily driven by the FuelEU Maritime GHG reduction targets, as well as the inclusion of shipping in the EU ETS and the revision of the RED II (2/2).

## EU policies that specifically impact the sustainable shipping fuels market

| Directive | Overview | Key Implications for Sustainable Shipping Fuels[1] uptake | |
|---|---|---|---|
| EU ETS | • The Fit for 55 package proposed the gradual addition of the shipping sector into the EU Emissions Trading system (ETS) from 2023 onwards. Under this, shipowners must buy allowances for each unit of $CO_2$ they emit during their voyage. For 'intra EU' voyages all emissions must be accounted for, and for 'extra-EU' voyages (begin or end outside the EU) only 50% of voyage emissions are included and 100% of emissions while ships are at berth in EU ports. This contrasts to the FuelEU Maritime and the RED where emissions are accounted for on a tank-to-wake basis. Tank-to-wake refers to the emissions produced during the downstream processes (i.e. during the vessels journey, onboard storage), however does not account for emissions from upstream process (i.e. fuel production, transport and storage, bunkering).<br>• Emissions of cargo and passenger ships of 5,000 Gt and above will be included in the ETS with the following geographical scope: all emissions between EU ports count for 100%; and all emissions from non-EU ports to EU ports (and vice versa) count for 50%.<br>• The current proposal will begin in 2023 and the sectors requirements will be phased in over a period of three years.<br>• The aim of the inclusion of the maritime sector in the EU ETS is to address GHG emissions of the sector and to ensure that shipping contributes to meeting economy-wide reduction targets. | Positive impact | Under the proposed package, no allowances need to be surrendered for the use of biofuels, therefore could help boost the uptake of sustainable shipping fuels in Europe. |
| | | Negative impact | Could undermine attempts for IMO to adopt global absolute emissions reduction targets. This could slow the implementation of supportive legislation and demand for sustainable fuels. |



Positive impact | No impact | Negative impact

# The European Commission has issued several regulations that impact the wider shipping industry and have the potential to positively impact the sustainable fuel uptake.

## General EU energy policy that directly impact the sustainable shipping fuels market

| Directive | Overview | Key Implications for Sustainable Shipping Fuels[1] uptake |
|---|---|---|
| CCS Directive 2009/31/EC | • The Directive on the geological storage of $CO_2$ (commonly referred to as the CCS Directive) establishes the legal framework for the environmentally safe geological storage of $CO_2$. It covers all $CO_2$ storage in geological formations in the EU and the lifetime of storage sites. The Directive also sets out regulations on the capture and transportation element of the process. | The Directive focusses on geological storage of captured $CO_2$ and therefore is of less relevance for sustainable shipping fuels that use the captured $CO_2$ directly. |
| Taxonomy Regulation (EU) 2020/852 | • Taxonomy establishes a list of environmentally sustainable economic activities by defining how these are deemed to substantially contribute to climate adaptation and do no significant harm, including minimum safeguards. An Article 9 Fund is required to assess its portfolio against the principle of "do no significant harm" and incorporating considerations of the minimum social safeguards. | The current EU Taxonomy only prescribes partial activities for sustainable shipping fuels like hydrogen production (must be 70% GHG reduction) and transportation of captured carbon (max 0.5% leakage and leakage detection). |
| Energy Tax Directive (ETD) | • The ETD determines minimum taxation rates for fuels, including those used in transport. Under the Fit for 55, the EC announced a number of reforms to the directive with the intension to rank fuels and electricity according to energy content and environmental performance and for member states to tax them accordingly, helping to ensure that the most polluting energy products bear the greatest amount of tax. | A larger tax burden on the most polluting fuels could help boost demand for sustainable shipping fuels. |
| Fuel Quality Directive | • The EU's Fuel Quality Directive (FQD) sets a reduction target for the average GHG intensity of road transport fuels.<br>• The directive aims to create policies that support sustainable sourcing and production of biofuel feedstock. It also offers fuel specifications that determine the amount of biofuel that can be blended with regular road transport fuels.<br>• There is currently no decision on whether FQD will be extended to 2030, however it is likely to be incorporated into the RED III. | The directive focuses on road transport fuels. Does not provide incentive for the uptake or development of sustainable shipping fuels.<br>Advances in sourcing and producing biofuel feedstock could be transferable to the maritime industry. |

Positive impact No impact Negative impact

ARUP

Section 5: Policy Landscape

# The European Commission has issued several regulations that impact the wider shipping industry and have the potential to positively impact the sustainable fuel uptake.

## General EU energy policy that directly impact the sustainable shipping fuels market

| Directive | Overview | Key Implications for Sustainable Shipping Fuels[1] uptake | |
|---|---|---|---|
| EU MRV Regulation | • The regulation requires shipping containers to monitor the fuel consumption and other parameters (including $CO_2$ emissions) of ships above 5,000 Gt carrying passengers or cargo for commercial purposes to or from European ports.<br>• Implemented in 2015, companies must submit an emissions report to the Commissions annually, reporting the ships $CO_2$ emissions. | | Focus on emissions monitoring. No incentive to reduce $CO_2$ emissions or to switch to sustainable fuels. |
| EU Innovation Fund | • The Innovation Fund is one of the world's largest funding programmes for the demonstration of innovative low-carbon technologies, incl. marine fuel technologies. ~ €40bn for the development of low emission alternatives mostly focussing on hydrogen and sustainable fuels. | | Funding provisions for the deployment of infrastructure and marine fuel technology. |
| International Convention for the Prevention of Pollution from Ships (MARPOL) | • The EU is compliant with the MARPOL convention. It is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. This included accidental pollution and that from routine operations.<br>• Annex VI sets limits on the air pollution from ships, specifically sulphur oxide and nitrogen oxide. It was adopted in 2011 to cover mandatory technical and operational energy efficiency measures aimed at reducing GHGs. | | Introduced efficiency measures aimed at reducing GHG emissions but no specific regulations supporting sustainable fuels use. |

Positive impact   No impact   Negative impact

Section 5: Policy Landscape

# The UK is beginning to establish initiatives to accelerate the development of a domestic clean shipping industry. This includes investing in R&D for clean maritime technologies (UK SHORE) and bilateral green corridor agreements (Clydebank Declaration) (1/2).

## UK policies that specifically impact the sustainable shipping fuels market

| Directive | Overview | Key Implications for Sustainable Shipping Fuels[1] uptake |
|---|---|---|
| UK Shipping Office for Reducing Emissions (UK SHORE)<br>May 2022 | • UK Government department dedicated to decarbonising the maritime industry and transitioning to zero emissions shipping. The department aims to transform the UK into a global leader in the design and manufacturing of clean maritime technologies.<br>• The Department received £206m in funding and is the largest government investment even in the UK commercial maritime sector.<br>• The UK SHORE incentive program includes:<br>– Clean Maritime Demonstration Competition (CMDC).<br>– Feasibility studies exploring green shipping corridors.<br>– Exploring initiatives on green shipbuilding skills in partnership with the Department of Education.<br>– Set out plans for a Centre for Smart Shipping (CSmart) as a commitment in the Maritime 2050 strategy.<br>– Grant schemes for early research projects for future technology solutions to decarbonise the maritime sector. | Dedicated department within the UK Government provides more political support and representation for the decarbonisation of the maritime industry – may decrease the timeframe for supportive legislation to be passed and increase available funding. |
| Clean Maritime Demonstration Competition (CMDC) | • Grant funding competition run by UK SHORE in partnership with Innovate UK. The competition aims assist in meeting net zero targets through funding projects that develop clean maritime technologies.<br>• To date, approximately £98 million of total funding has been invested through the competition.<br>• The CMDC has had three funding rounds so far:<br>– First round (March 2021) – 55 projects received £23.3m in funding for feasibility studies and technology trials in clean maritime solutions.<br>– Second round (May 2022) – 31 projects received a total of £15m funding for feasibility studies and pre-deployment projects – including hydrogen-powered hovercraft and feasibility studies of Green Shipping Corridors.<br>– Third round (September 2022) – allocate £60 million in funding to 19 projects to deliver technology and system demonstrations. Applications closed in November 2022. | Sustainable fuel producers could benefit from this funding, as sustainable fuels are included under the umbrella of clean maritime technologies. |

Positive impact  No impact  Negative impact

# The UK is beginning to establish initiatives to accelerate the development of a domestic clean shipping industry. This includes investing in R&D for clean maritime technologies (UK SHORE) and bilateral green corridor agreements (Clydebank Declaration) (2/2).

## UK policies that specifically impact the sustainable shipping fuels market

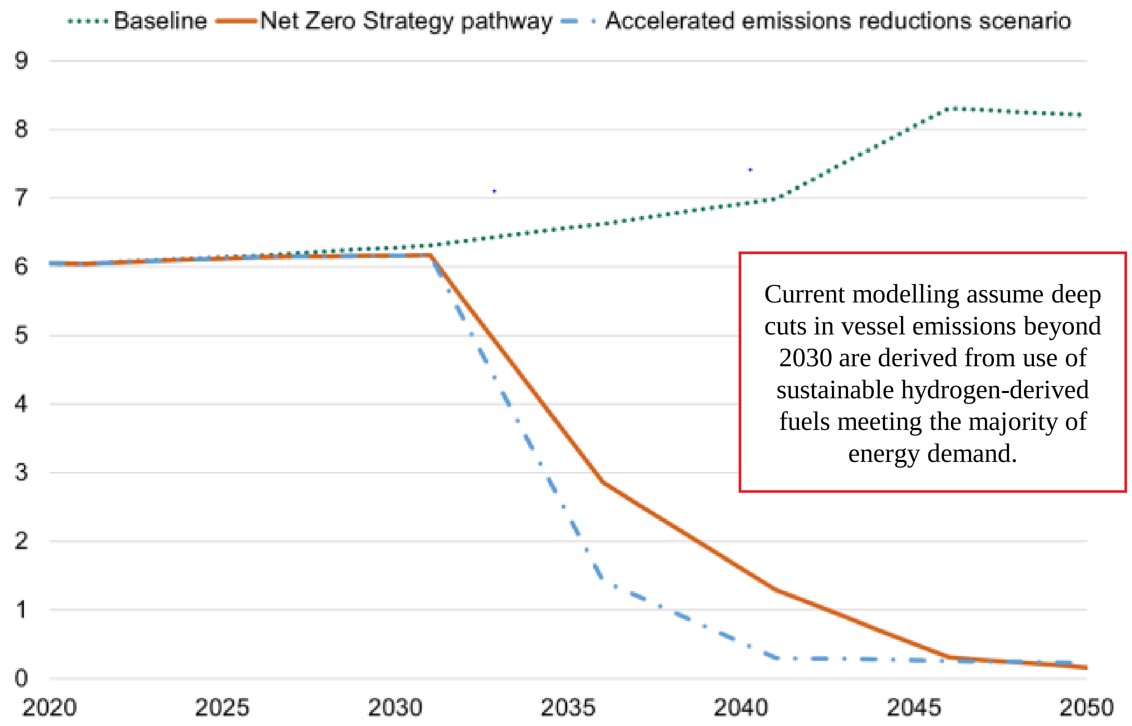
| Directive | Overview | Key Implications for Sustainable Shipping Fuels[1] uptake | |
|---|---|---|---|
| Clydebank Declaration for Green Shipping Corridors November 2021 | • The declaration was launched at COP26 with the aim to establish green international shipping corridors – fully decarbonised maritime routes between two or more ports. (discussed in more detail in subsequent pages)<br>• The over-arching aim of the declaration is to contribute to the maritime sector's target of achieving net-zero by 2050.<br>• Currently 24 signatories including: UK, US, France, Germany, Belgium, Canada, Netherlands, and Italy.<br>• Participation in the Declaration is voluntary however, signatories must collaborate on:<br>– Establishing partnerships with all stakeholders along the value chain.<br>– Address the technical and operational challenges of green corridors – including regulatory frameworks, incentives, and infrastructure.<br>– Include green corridor provisions in the development or review of national action plans.<br>– Ensure sustainability is at the forefront of plans when implementing green corridors. | Positive impact | Declaration promotes incentives for the development of sustainable fuels. Those who decarbonise operations gain first-mover advantage from the use of the green corridors. This could drive up demand for sustainable fuels. |

Positive impact | No impact | Negative impact

# The UK SHORE reflects the government's commitment to advance the decarbonisation of the shipping sector and its related supportive policy. The domestic maritime decarbonisation consultation requested opinions from stakeholders on the most optimal policy options to address barriers.

## UK Domestic Maritime Decarbonisation Pathway

- Following its creation, UK SHORE released the domestic maritime decarbonisation: the course to net zero emissions consultation in July 2022.
- The consultation aims to gather stakeholder views and evidence to:
  - Identify the optimal pathway to net zero.
  - Highlight the remaining barriers to maritime decarbonisation.
  - Collect views on the various additional policy options that could be used to address these problems.
  - The possibilities for future interventions to help accelerate the decarbonisation of the maritime sector are set out in the consultation. These are split into four over-arching categories: economic measures, regulatory interventions, information programmes, and voluntary action.
- Economic measures options include the recently published consultation on expanding the UK's ETS to include the domestic maritime sector and funding commitment into R&D through UK SHORE.
- Regulatory interventions possibilities include adopting efficiency and energy saving measures for domestic vessels or regulating carbon intensity to help stimulate the uptake of sustainable fuel alternatives. There is also the option to regulate the design capabilities for new ships. For instance, the Clean Maritime Plan expressed an ambition that by 2025, "all new vessels being ordered for use in UK waters are being designed with zero-emission propulsion capability".
- The findings will produce the 'Course to Zero' intermediary targets which will be published in the refreshed Clean Maritime Plan in 2023. These targets are expected to be indicative, rather than legally binding and will only apply domestically.




UK maritime decarbonisation pathway: estimated GHG emissions from UK domestic vessel (Source: UK Gov)

# The UK Government has also issued industry-wide initiatives, such as Operation Zero, that will impact the decarbonisation of operations in the sector as part of wider targets (1/2).

## General UK energy policy that directly impact the sustainable shipping fuels market

| Directive | Overview | Key Implications for Sustainable Shipping Fuels uptake | |
|---|---|---|---|
| Expansion of the UK ETS | • In March 2022, the UK government published a consultation exploring the expansion of the UK ETS to include UK domestic maritime emissions. The expansion does not consider international shipping, hence overlooking a larger source of emissions (see next slide). | Positive impact | Imposing a price on the GHG emissions would strengthen the incentive of the domestic maritime sector to adopt fuels with lower GHG emissions. |
| Renewable Transport Fuel Obligation (RTFO) | • In 2021, the UK government amended the existing RTFO regulations to increase carbon savings by raising renewable fuel targets and expanding support to certain renewable fuels in maritime and rail. If produced using eligible processes, sustainable synthetic fuels can now be classified as renewable fuels of non-biological origin (RFNBOs). | Positive impact | Given the new financial support and incentive, the RTFO will help encourage the uptake of RFNBOs within the maritime sector. |
| Shore power consultation | • The UK government committed to consult on how to support the uptake of shore power in the UK 2021 Transport Decarbonisation Plan. Shore power is the provision of renewable electricity for ships at berth. The consultation resulted in a call for evidence on shore power, held in 2022. It was designed to address the gaps in the knowledge of the benefits and costs of short power. A further consultation on specific policy proposals to support uptake it expected.<br>• The Department of Transport is expected to provide further details on the approach to shore power as part of the refresh of the Clean Maritime Plan in 2023. | Positive impact | An expansion of shore power provision would encourage the supply and demand of renewable electricity for ships at berth, supporting the shift away from carbon intensive fuels. |
| Phase-out of non-zero emission vessel sales | • The Department of Transport committed to consult upon the potential for a planned phase-out date for the sale of new non-zero emission domestic vessels in the Transport Decarbonisation Plan. This is intended to build on the experiences of other mods and transport and will focus on vessel types where near-term technical solutions are becoming available (i.e. electrification) and considering the longer-term deployment of sustainable fuels (i.e. ammonia and hydrogen). | Positive impact | The policy could help accelerate long-term decarbonisation. |
| Operation Zero | • Operation zero is an industry coalition launched by the Department of Transport at COP26. The UK is part of the initiative which convenes industry stakeholders across the North Sea's offshore wind value chain to accelerate the decarbonisation of operation and maintenance vessels in the sector. | Positive impact | The target of zero-emission ships could act as a source for zero carbon fuels. |

Positive impact / No impact / Negative impact

Section 5: Policy Landscape

# The UK Government has also issued industry-wide initiatives, such as Operation Zero, that will impact the decarbonisation of operations in the sector as part of wider targets (2/2).

## General UK energy policy that directly impact the sustainable shipping fuels market

| Directive | Overview | Key Implications for Sustainable Shipping Fuels uptake | |
|---|---|---|---|
| Zero-Emission Shipping Mission | • The UK is a core member of the mission, launched in 2021 under the second phase of Mission Innovation. It brings together countries, companies and research institutes to develop, demonstrate, and deploy zero-emission fuels, ships, and fuel infrastructure. | Positive impact | By contributing to the development of fuel, ships, and infrastructure deployment the initiative will help develop an economy for zero-emission shipping. |
| International Convention for the Prevention of Pollution from Ships (MARPOL) | • The UK is compliant with the MARPOL convention. It is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. This included accidental pollution and that from routine operations.<br>• Annex VI sets limits on the air pollution from ships, specifically sulphur oxide and nitrogen oxide. It was adopted in 2011 to cover mandatory technical and operational energy efficiency measures aimed at reducing GHGs. | No impact | Introduced efficiency measures aimed at reducing GHG emissions but no specific regulations supporting sustainable fuels use. |

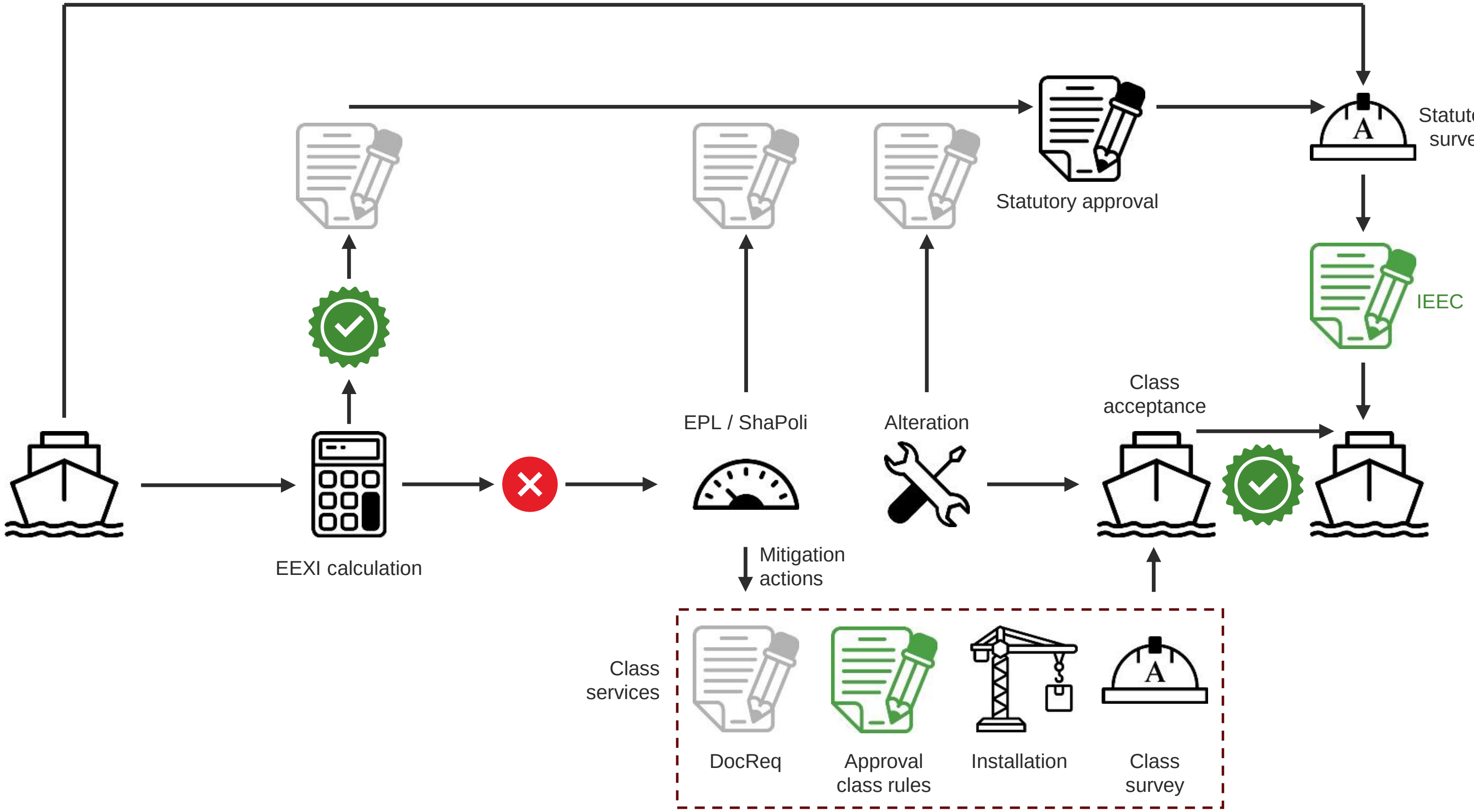
Positive impact | No impact | Negative impact

# The IMO is targeting net zero GHG emissions from international shipping by 2050, with two emission reduction programs being implemented in 2023. However, despite policy initiatives, the sector is unlikely the meet IMO targets by 2050.

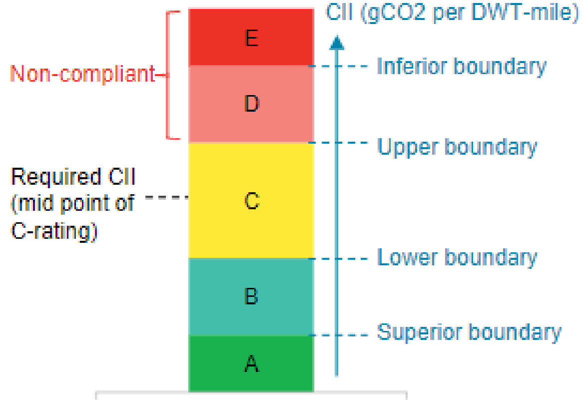
## International Maritime Organisation (IMO) Policy

- The IMO is an intergovernmental organisation which regulates global shipping through cooperation of member countries.
- The IMO has set a 2050 net zero reduction target in GHG emissions from international shipping, under its Revised Greenhouse Gas Strategy (adopted July 2023). The Revised Strategy also includes GHG reduction targets for 2030 (at least 20%, striving for 30%) and 2040 (at least 70%, striving for 80%).
- To achieve the targets the IMO has implemented two key short-term initiatives to reduce GHGs in 2023: Energy Efficiency Existing Ship Index (EEXI) and Carbon Intensity Indicator (CII). These initiatives will be mandatory for all member countries.
- The EEXI is a technical standard that indicates the energy efficiency of a vessel relative to a design baseline. For 2023, it will be mandatory for ships is calculate their EEXI and it must be lower than the required level. The CII will rate a ships emissions performance based on actual annual $CO_2$ emissions per deadweight tonnage and miles travelled per year. For 2024, ships must demonstrate a continuous fall in $CO_2$ intensity.
- The use of lower-carbon fuels and hull cleaning (to reduce drag) have been highlighted as ways vessels can reduce their CII.
- In the near-term, emission reductions in the shipping sector will mainly depend on these energy efficiency mechanisms and operational measure across the global fleet.
- Despite these initiatives, without more stringent policies the IMO is unlikely to reach its 2050 target. One of the main barriers continues to be a lack of comprehensive international policy framework to push decarbonisation further.
- A further driver of this is the IMOs decision-making process. Rules require the agreement of all 175 IMO members and can result in long negotiations. The IMO is currently developing a range of mid-term measures to help incentivise the global availability and uptake of low and zero carbon fuels. These could include technical and economic components.
- Measures the IMO has imposed have also received criticism. While they contribute to the IMO $CO_2$ reductions targets, they provide limited practical incentive for the large-scale adoption of low-and zero carbon technologies and fuels. However, the Revised GHG Strategy (adopted July 2023) includes a 2030 target for the uptake of zero and near-zero GHG emission technologies , fuels and energy sources of at least 5%, striving for 10%, of the energy used by international shipping.

The IMO is targeting net zero GHG emissions from international shipping by 2050, with two emission reduction programs being implemented in 2023. However, despite policy initiatives, the sector is unlikely the meet IMO targets by 2050.




IMO EEXI Process (Source: DNV)




| Reporting year | Reduction factor required relative to 2019 reference CII |
|---|---|
| 2023 | 5% |
| 2024 | 7% |
| 2025 | 9% |
| 2026 | 11% |
| 2027-2030 | TBC after review |

IMO CCI ratings and reduction requirements (Source: BNEF)

# With the lengthy negotiations process and ambiguities around current IMO emissions policies, countries have started negotiating bilateral agreements, such as green corridors, to align interest and stimulate demand for sustainable shipping fuels.

## Green Shipping Corridors

- Green corridors are specific trade routed between two or more countries or ports along which stakeholders have agreed to decarbonise. They aim to establish a supply of sustainable fuels and promote investment in suitable bunkering infrastructure.
- The uptake of international shipping emissions regulation has been slow and is significantly less developed that its counter parts in aviation and road transport. Green corridors are increasingly being used as a way to overcome this.
- Countries are beginning to sign such bilateral agreements to help decarbonise the shipping industry, working outside the confines of the IMOs processes.
- The expectation is that this early action will kickstart the use of clean fuels in shipping, helping to establish commercial scale demand for sustainable fuels. The corridors also aim to encourage more countries to create these green trade routes. Nonetheless, there is no clarity on the fuels that are eligible as low / zero carbon on the majority of these corridors, hence the implications for green hydrogen as a source are not clearly defined.
- Over recent years, there has been an increase in the number of green corridor initiatives emerging. Most notably, at COP26 multiple countries signed the Clydebank Declaration. Similar agreements have been established in Europe and along key trade routes.
- The COP26 Clydebank Declaration aims to support the establishment of 6+ green corridors by 2025 and the scale up of more corridors by 2030.
- Green shipping corridors can effectively act as indicators of sustainable fuels demand across major routes and ports and may even dictate locations of production hubs.

| Activity | | Countries/ Ports | Description |
|---|---|---|---|
| | COP26 Clydebank Declaration | 24 countries including UK, US, Japan, Australia | Pledging to act collectively to demonstrate the viability of multiple green corridors. |
| | World's longest green corridor | Maritime and Port Authority of Singapore and Port of Rotterdam Authority | Green Corridor between two of the largest bunkering ports in the world and along key Asian-European shipping lanes. |
| | Maersk Mc-Kinney Moller's European Green Corridors Network | Port authorities of Gdynia, Hamburg, Roenne, Rotterdam, and Tallinn | A partnership that will focus on establishing green corridors in Northern Europe and the Baltic Sea. |
| | Trans-Pacific Corridor | Ports of Los Angeles and Shanghai | Zero emissions route along the world's busiest cargo route. |
| | North Atlantic Corridor | Ports of Antwerp and Montreal | Cooperation agreement for the first green corridor in the North Atlantic. |
| | Chilean Green Corridors Network | Chile (in partnership with Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping) | First country in South America to announce a green corridor incentive, with plans to establish a network of corridors for transportation of goods in and out of Chile. |
| | Australia-East Asia iron ore Green Corridor | Australia and East Asia | Global Maritime Forum, BHP, Rio Tinto, Oldendorff Carriers, and Star Bulk Carrier Corp letter of intent to assess the development of an iron ore Green Corridor between Australia and East Asia |

Source: BNEF

ARUP

Section 6

# The Jobs and Skills Required for the Fuel Transition

This report will provide an overview of the skills and jobs required to enable the decarbonisation of the aviation and shipping industries, considering the impact on developing countries and the benefits of the Just Transition.

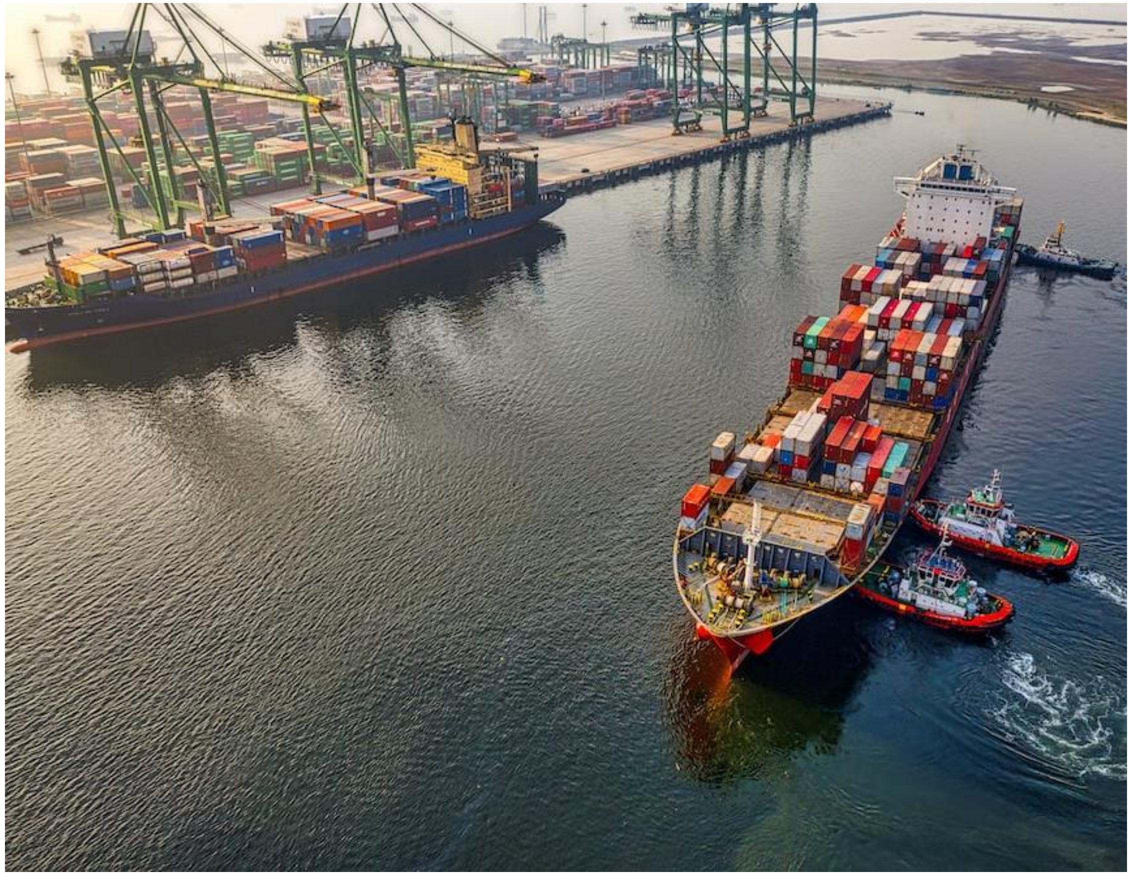
## The purpose

### Overview of the challenge and opportunity

- Governments are developing policy and regulations surrounding the energy transition. Policies can prioritise the use of hydrogen and carbon-dioxide from DAC in applications where there is a lack of alternative decarbonisation interventions – such as the aviation and shipping sectors. Hydrogen, ammonia and methanol are the most promising options for shipping, and synthetic kerosene for aviation.
- The SASHA Coalition aims to highlight the potential demand in the aviation and shipping sectors for decarbonising technologies in order to influence policy in favour of these sectors. The Coalition will encourage urgent policy coherence and support mechanisms to promote the supply of green hydrogen and carbon-dioxide from DAC for application in these sectors. With ambitious targets and government support, this will improve the business case and enable investment into decarbonising infrastructure.
- Through prioritising green hydrogen and carbon-dioxide from DAC for sectors where decarbonisation is less easy, the climate transition will be accelerated.
- There is an opportunity to create an equitable low-carbon economy across the globe, although this outcome is dependent on strong policy support.

### Research purpose and objectives

- Opportunity Green has commissioned Arup for this two-part research project. The findings from this will inform the narrative of prioritising green hydrogen and carbon-dioxide from DAC for aviation and shipping, feeding into the development of the SASHA Coalition.
- This first part provides an overview of the most likely fuel production pathways to reach net zero carbon emissions in the aviation and shipping sectors.
- The part of the report provides an overview of the skills and jobs that will be needed to enable the decarbonisation pathways to be realised, considering future and current skills gaps through the lens of the Just and Equitable Transition. The potential benefits for developing countries is also included.



Source: Unsplash

# The supply chains for sustainable fuels will create significant new jobs and allow for upskilling and skills transfer. Immediate opportunities exist in the distribution of fuels for these sectors.

## Aviation & Shipping

### Current Energy Usage

- The UK's aviation and shipping fuel use has been reasonably consistent over the last few years, with the UK using 13.6 and 0.9 million tonnes of aviation and shipping fuel in 2019, respectively.
- However, this was significantly impacted in 2020/21, caused by a dip on demand due to covid-19.

### Current Skills Gap in Aviation & Shipping

- Recently there have been aviation fuel shortages across Europe and the US. This has been partially as a result of skills shortages in the supply chain. This is particularly evident in the transportation of jet fuel to airports, as a shortfall in truck drivers is causing a bottleneck in the delivery of jet fuel to airports. In the US, it has recently been estimated that 20% of tankers are parked due to a lack of qualified truck drivers, with low pay cited as exacerbating the skills shortage. Although there have been fuel shortages in the shipping industry, these are mostly attributed to the reduction in availability of oil – particularly due to the war in Ukraine.
- Across the energy industry, key causes of skills shortages have been identified as: insufficient education, training and knowledge transfer for new/prospective entrants, as well as a lack of motivational factors. Poor skills retention of experienced workers is also an issue.
- Hence, an ageing workforce and lack of incoming workers across the value chain, particularly due to a lack of interest from the younger workforce, are cited as contributing to the shrinking workforce.

### Effect on Industry Transition

- The current skills and labour shortages in these sectors already pose challenges to these industries – particularly in more technical roles. This provides an opportunity to catalyse the training and skills required for the energy transition by encouraging and scaling up the required training.
- Some sustainable fuels, such as hydrogen and ammonia, have a lower energy density than the fuels they replace. Therefore, a larger volume of these fuels will be required to provide the same amount of energy to vessels, meaning that more infrastructure will be required across the supply chain. Hence it is likely that more workers will be required per unit of energy delivered than for traditional fuels.
- Companies and governments will need to recognise and address the need for a balance of centralised and decentralised production in order to minimise the cost of production and transport.

### Opportunity

- The current fuel production industry is well established with wide-ranging production, transportation and distribution networks. These industries are typically dominated by a few global companies. The energy transition presents an opportunity for smaller companies, developers and cooperatives to be part of establishing the new sustainable fuel industry.
- The transition also creates an opportunity for secure jobs across the skills range from relatively low skilled to highly skilled professionals. Jobs could be created in geographically diverse areas with better gender and minority equality across the supply chain. The transition could also reduce public health disparities around airports and ports, with a reduction in those affected who are part of low income or indigenous groups.

**Source: Unsplash**

## Section 6: Current Skills Gap

# Filling in the skills gap will create opportunities to mend communities which are the most affected by the results of climate change, contributing to an equitable and just transition.

### The Green Hydrogen Gap

- Maritime decarbonisation is set to be a trillion-dollar opportunity globally, and the UK's SAF industry could be worth £16.7 billion per year in exports by 2050, supporting approximately 130,000 highly paid jobs. During the development of the industry, 6500 well paid jobs could be created across Scotland, Wales, North West England, Teesside and the Humber by 2035, adding £1 billion annually to the UK economy. Globally, investment in SAF can create or sustain an estimated 13.7 million jobs.
- The Africa Green Hydrogen Alliance estimates that green hydrogen production could create 2 to 4 million green jobs by 2050 in its member countries. This will be relevant to the UK and EU – in enjoying high solar and wind power potential, African countries are well positioned to produce low-cost green hydrogen. Production of green hydrogen in Africa could sustainability industrialise and boost GDP by 6-12% in Egypt, Kenya, Mauritania, Morocco, Namibia and South Africa – also creating secure job opportunities for people who have historically lived in politically unstable areas. The perspectives and involvement of those who identify as women, and ethnically diverse groups will be key in shaping the industry. In the renewable energy workforce, female-identifying people represent 32% of the workforce. This figure is only 22% in the oil and gas industry, and represents how women have opportunities to excel in the renewables industry.
- In areas where airports and ports are located, their decarbonisation will improve localised air quality by reducing the particulates and gas emissions associated with burning those fossil fuels. This will have a knock-on effect on public care workforces by decreasing some strain on health services.
- Low income and indigenous groups are the most effected by climate change caused by shipping and aviation emissions. In Canada, indigenous groups have been trailblazers in tackling the climate crisis, demonstrating that a just transition can be achieved, not only by including these communities, but also by leading by their example.

**Oil Spill (Source: Unsplash)**

# Technical training and education are key to develop the skills needed for the future fuel transition in aviation, with over 20,000 jobs expected in UK SAF production alone. Job creation is expected to be substantial, creating production and distribution hubs across the UK and Europe.

## Aviation

### Future Skills & Job Opportunities

- Production of sustainable fuels, such as hydrogen and synthetic fuels, require technical training and STEM knowledge. The graphic to the right shows the processes and each stage of the value chain. The future jobs and skills opportunities at each phase are detailed in the following paragraphs.
- Although it is possible to use hydrogen and batteries in aviation, these applications will be relatively limited in the medium-term. Hence, almost all decarbonisation of aviation will be through hydrocarbon SAF pathways. These fuels are chemically very similar to the fuels currently used in the industry and require the same infrastructure.
- The majority of fuel routes require green hydrogen to varying extents. The UK's National Energy Skills Accelerator's research indicates that over 90% of the knowledge and qualifications in hydrogen-related job descriptions are already covered by many educational institutions.

### Fuel Production

- A recent report commissioned by the Sustainable Aviation industry body suggest that the UK SAF industry could create up to 20,000 jobs in production alone. Furthermore, transportation and distribution jobs would also be important.
- By 2035, Sustainable Aviation estimate the UK SAF supply chain could support up to 13,600 jobs, although the fuel mix underpinning this scenario is unclear. This short timespan indicates a real need to begin training and upskilling of the future workforce to keep up with demand.
- Our research indicates that job creation in the EU has not been quantified to the same extent as the UK, although many companies have announced production hubs that are likely to support significant numbers of jobs.
- Transport skills would depend on the transportation type – via road, pipelines or other methods. Transportation skills requirements are likely to include specialist technical knowledge and drivers with specialist safety and technical understanding of their freight.

### In Airport

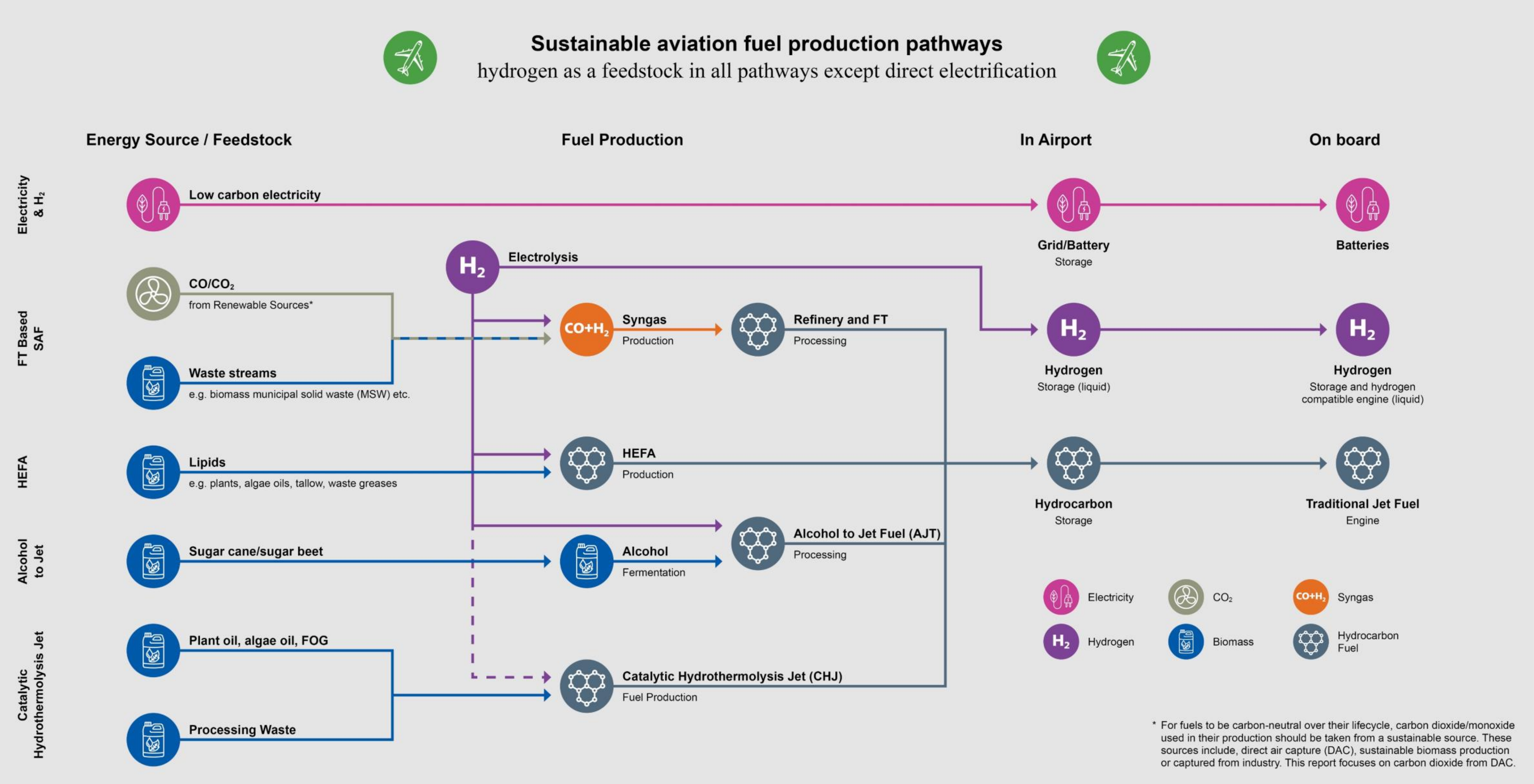
- Many of the skills required at the airports already exist in technical and mechanical staff at airports. However, retraining for handling of sustainable fuels (such as hydrogen) would be important, particularly in terms of safety considerations. Training will need to cover aircraft refuelling and emergency services.

### Onboard

- As many sustainable aviation fuels require similar handling to current aviation fuels, few changes to skills and job opportunities onboard are likely to occur.

### Induced/Indirect Jobs

- According to Sustainable Aviation, up to 14 plants could be built across the UK in the next decade to be able to supply the anticipated demand created through SAF blending mandates, creating industrial production clusters across England, Scotland and Wales. Current estimates from Sustainable Aviation show that the UK SAF industry could add £2.9 billion to the UK economy per year. Much of this would be through indirect jobs alongside increased demand and spending in local production and distribution hubs.



Sustainable aviation fuel production pathways
hydrogen as a feedstock in all pathways except direct electrification
Energy Source / Feedstock
Fuel Production
In Airport
On board
Electricity & H₂
Low carbon electricity
Grid/Battery
Storage
Batteries
FT Based SAF
Electrolysis
CO/CO₂
from Renewable Sources*
Waste streams
e.g. biomass municipal solid waste (MSW) etc.
CO+H₂
Syngas
Production
Refinery and FT
Processing
Hydrogen
Storage (liquid)
Hydrogen
Storage and hydrogen compatible engine (liquid)
HEFA
Lipids
e.g. plants, algae oils, tallow, waste greases
HEFA
Production
Hydrocarbon
Storage
Traditional Jet Fuel
Engine
Alcohol to Jet
Sugar cane/sugar beet
Alcohol
Fermentation
Alcohol to Jet Fuel (AJT)
Processing
Catalytic Hydrothermolysis Jet
Plant oil, algae oil, FOG
Processing Waste
Catalytic Hydrothermolysis Jet (CHJ)
Fuel Production
Electricity
CO₂
Syngas
Hydrogen
Biomass
Hydrocarbon Fuel
* For fuels to be carbon-neutral over their lifecycle, carbon dioxide/monoxide used in their production should be taken from a sustainable source. These sources include, direct air capture (DAC), sustainable biomass production or captured from industry. This report focuses on carbon dioxide from DAC.

# The shipping industry is likely to require similar skills to aviation in the production stage, with variations at distribution level. However, the literature is lacking estimates of job creation and skills requirements for the shipping industry.

## Shipping

### Future Skills & Job Opportunities

- Although the production routes for aviation and shipping fuels differ, the supply chains have similar characteristics. Technical training and STEM education are likely to be highly important in both industries as hydrogen is a component in all future fuels, as demonstrated in part one and summarised in the adjacent figure.

### Energy Source/Feedstock

- A Organisations, such as the World Resources Institute, suggest that renewable energy investments, such as solar photovoltaic energy production, create about 50% more jobs than fossil fuels. More diverse feedstocks (e.g. renewable electricity, $CO_2$) are required to produce sustainable shipping fuels compared with fossil fuel derived fuels, creating increased scope for job creation across the skills spectrum.

### Fuel Production

- Research suggests most job creation would emerge from the production and transportation of sustainable fuels as the majority of jobs at distribution (at ports and onboard) already exist, although using different fuels. Particularly in a decentralised production model, there would be significant direct job opportunities created. Estimates of the job creation vary significantly depending on the fuel type, location, projected shipping demand and uptake time – and there is little data currently available.

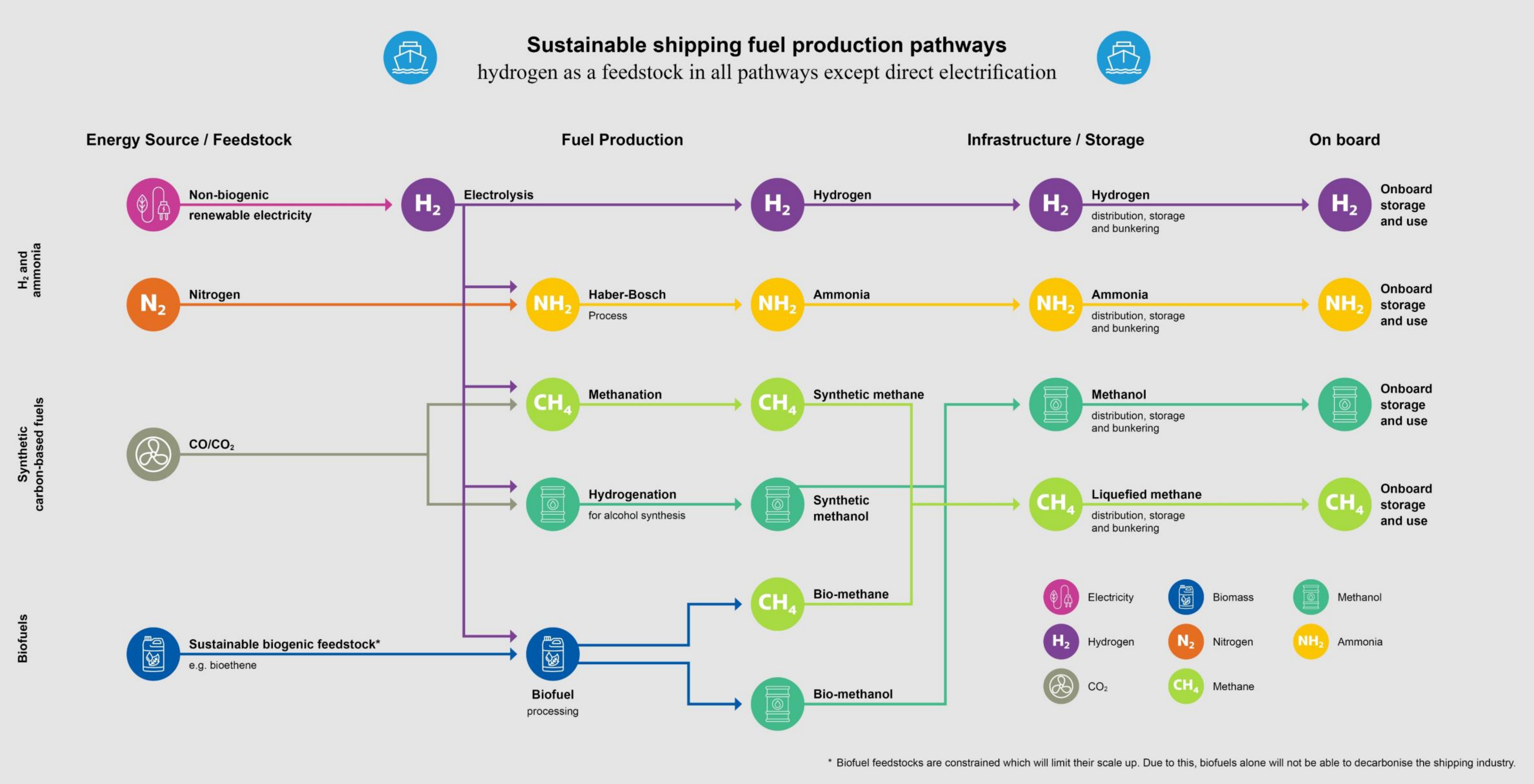
### At ports

- Many sustainable fuels present different safety and environmental challenges from current fuels that will require specialised training, particularly for transport and at ports. Training will need to cover inspection processes as well as emergency service responses.
- These future skills requirements will necessitate significant investment into training and upskilling in the next few years. This will enable the supply of workers to match the expected demand as sustainable fuels increase in the share of shipping fuels.

### Induced/Indirect Jobs

- If production decentralises, it can be located near ports, benefiting local communities and economies. As more direct jobs are created, there will be surges in demand for housing, education, transport, utilities, and more. This will create induced jobs in the surrounding areas, resulting in economic benefits. Indirect jobs may also be created in those industries that produce goods and services used in the industry, such as steel production for wind turbine manufacturing.


**Plane Refuelling (Source: Unsplash)**



Sustainable shipping fuel production pathways
hydrogen as a feedstock in all pathways except direct electrification
Energy Source / Feedstock
Fuel Production
Infrastructure / Storage
On board
H2 and ammonia
Synthetic carbon-based fuels
Biofuels
Non-biogenic renewable electricity
Electrolysis
Hydrogen
Hydrogen distribution, storage and bunkering
Onboard storage and use
Nitrogen
Haber-Bosch Process
Ammonia
Ammonia distribution, storage and bunkering
Onboard storage and use
CO/CO2
Methanation
Synthetic methane
Methanol distribution, storage and bunkering
Onboard storage and use
Hydrogenation for alcohol synthesis
Synthetic methanol
Liquefied methane distribution, storage and bunkering
Onboard storage and use
Bio-methane
Sustainable biogenic feedstock* e.g. bioethene
Biofuel processing
Bio-methanol
Electricity
Biomass
Methanol
Hydrogen
Nitrogen
Ammonia
CO2
Methane
* Biofuel feedstocks are constrained which will limit their scale up. Due to this, biofuels alone will not be able to decarbonise the shipping industry.

# The energy transition provides an opportunity to create inclusive, fair growth across industries – particularly if the gender imbalance is addressed and upskilling occurs across all ages and stages of education (1/2).

## Aviation & Shipping

### Transition Opportunity

- There is evidently a clear opportunity to transition both industries creating skills and job opportunities. It is estimated that there are over 20,000 active seafarers in the UK alone and over 11 million people directly working in the aviation industry worldwide (Department for Transport; Aviation Benefits Beyond Borders). The Maritime Just Transition Task Force has estimated that over 800,00 seafarers could require training by 2035 in order to support the fuel transition.
- The EU and the UK have already begun to move forward on upskilling their workforces – particularly in hydrogen fuels. Institutions in the UK and EU are investing in green skills education, including:
  - UK Government's Local Skills Improvement Plans.
  - Department for Education in England.
  - Institute of Technology in England.
  - Redcar Further Education College in England.
  - InvestEU programme funding sustainable education.
  - European Training Foundation.

### Transition Considerations

- In order to upskill the working population to impact the fuel transition, substantial changes need to occur. Stakeholders have the opportunity to build education infrastructure to train and develop a whole new market. Currently, the skills gap occurs from those in education through to people working in the fossil fuel industry – changes to education and upskilling need to take place across all age ranges. Beginning at education level, STEM subjects and vocational courses should be widely introduced and encouraged to enable more skilled workers to come into the workforce.
- Recent research has indicated that people under the age of 30 believe climate impact of an employer is an important factor in their job hunting – more than people over the age of 30. 19% of young people indicated that the climate impact of a prospective employer is their top priority. This indicates that the transition offers an attractive proposition for the younger and incoming workforce.
- There is also an opportunity to redress the gender imbalance in both the aviation and shipping industries. It is estimated that fewer than 2% of the global seafarer population are women (Maritime UK). Globally, less than 10% of pilots and aviation engineers are women (IATA). Particularly through STEM education, women could be encouraged into the fuel production industry to address the gender imbalance.
- Dealing with the gender imbalance addresses only a small part of the problem. The industries need more inclusive workplaces that allow for retention and promotion of underrepresented genders and ethnicities and sees their progression to senior position.

# The energy transition provides an opportunity to create inclusive, fair growth across industries – particularly if the gender imbalance is addressed and upskilling occurs across all ages and stages of education (2/2).

## Aviation & Shipping

### Transition Plans

- Transition plans for fossil fuel or carbon intensive industries towards sustainable fuels should utilise a number of frameworks to reduce job losses, such as: reskilling, redeployment, retention and early retirement, where desired. As indicated, many jobs will be directly transferable with additional training required. Planning for the transition should begin immediately and support dialogue with employers, governments and employees.
- In line with strategic focuses such as the UK government’s levelling up agenda, geographical distribution of jobs across the UK and EU should also be considered. This potential has already been recognised, with the UK’s second consultation on reducing the GHG emissions from aviation fuel highlighting that many SAF production plans are already being planned in areas undergoing regeneration.

### Job Type

- It is important that the vast majority of jobs created in the fuel transition are not temporary but are permanent or secure jobs. When temporary jobs are unavoidable, measures should be taken to integrate the local community and upskill local workers.
- Particularly in the construction phase, it is possible that multiple jobs will be created in construction hubs, resulting in induced job creation as communities adapt to the new demand for their services. If those are temporary contracts then there could be a significant reduction in local spending when the construction ends, resulting in stagnation of towns and cities. To avoid this outcome, funding should be used to support economic development and diversification to stimulate new permanent employment opportunities.

Section 6: Future Skills Gap & Job Opportunities

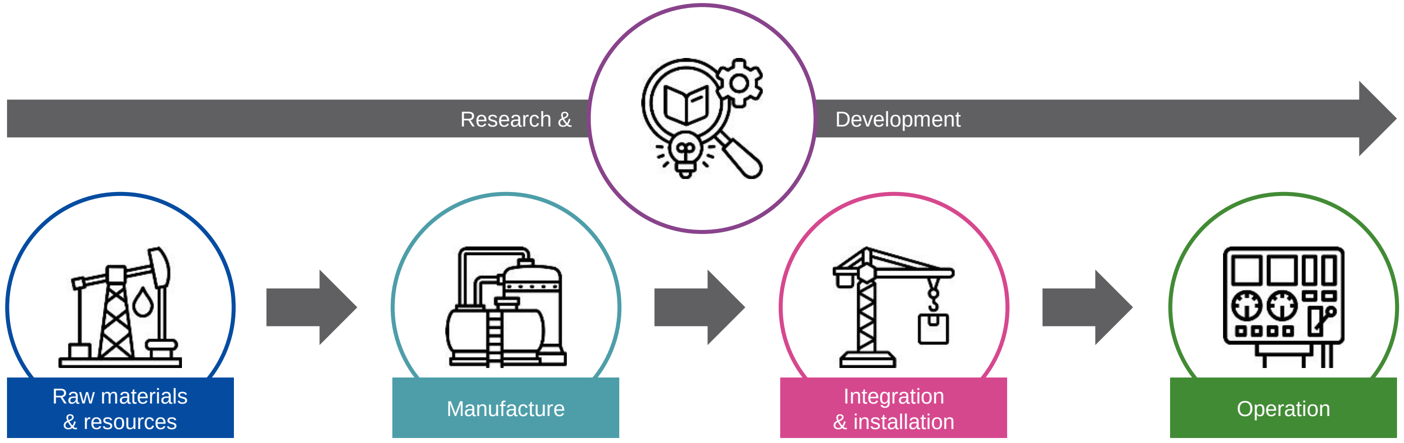
# Future jobs in sustainable fuels are likely to utilise similar skills as those used in the existing fuel supply chain. The transition will provide an ecosystem of direct and indirect jobs at different skill levels at all stages of the fuel supply chain and production lifecycle.

## Aviation & Shipping

- The transition to sustainable fuels provides opportunities for new jobs and skills across the fuel supply chain, from feedstock to onboard. Although some of the emerging jobs do not exist in the current market, they utilise similar skills as those used in the existing fuel supply chain. It is important to recognise both the similarities and the differences between current and future roles to enable education providers to account for these gaps through 'cross-skilling' across industries.
- The transition requires an ecosystem of direct and indirect jobs at different skills levels within the sustainable fuel industry. Jobs will be available at low skilled and entry level, mid-level and advanced or highly skilled. This wide range of jobs will be available at all stages of the fuel supply chain and fuel production lifecycle, as discussed below.

### Stages of the Fuel Production Lifecycle

- Research & development – research and development is required at each stage of the lifecycle and production chain to create and improve new technologies and processes to increase efficiency, lessen environmental impact, and reduce costs.
- Raw Materials & resources – extraction and production of the raw materials required at each stage the fuel production chain will require jobs and skills in themselves. Raw materials are required as inputs for fuel production, but also as the basis for equipment construction, for each stage of the supply chain.
- Manufacture – the manufacturing of components required at each stage of the fuel production chain will combine the raw materials and resources, research and development and result in demand for new jobs.
- Installation & integration – installing and integrating all the components in the construction of facilities required at each stage of the fuel production.
- Operation – the facilities and assets at each stage of the supply chain will need to be operated and maintained.




**Stages of the Fuel Production Lifecycle**

# The fuel transition enables production hubs in developing countries that provide opportunities for inclusive economic growth through formal, skilled work and education, provided that international companies focus on local skills development and creation of good quality jobs.

## Aviation & Shipping

### Fuel Production

- Currently, developing countries contribute ~40% of the world's exports, which are mainly transported through aviation and shipping. Developing countries will require production of fuel for national use so they will require production hubs around airports and ports for sustainable fuels. Renewable energy and fuel production will increase in those areas, with a resulting increase in job opportunities and skill requirements. Developing countries can also be a source of low cost renewable electricity so international companies may choose to produce sustainable fuels for export around the world.

### Local Communities

- Local communities around airports and ports are likely to benefit significantly from development of sustainable fuel supply chains, as the transition brings demand for new skilled workers and more disposable income into the area.
- Research suggests that the benefits of the transition are likely to be higher in countries and communities that are currently highly reliant on fossil fuels provided that Just Transition plans are implemented to benefit local communities.

### Benefits

- The benefits to developing countries of the transition to sustainable fuels could be immense. An increase in direct jobs in fuel production would increase the indirect and induced formal, skilled work and could enable significant spending in local areas.
- The transition would require increased education so skilled workers can be trained to the required standard for fuel production.
- If principles of a Just Transition are followed, and the human impact is considered in the planning and execution of the move away from carbon intensive industries, developing countries can take advantage of the opportunity to develop their economies further.

### Risks

- There are significant risks to developing countries, many of which centre around the possibility of large corporations bringing skilled workers into the country to produce sustainable fuels, with local communities and workers not benefiting from the transition. Developing countries' governments would benefit from upskilling to create a highly skilled local labour force.
- There is also a risk of local people and indigenous communities losing their land to make way for production hubs. International cooperation is likely to be required to prevent risks being realised.
- It is important that governments have the ability to focus on decarbonising their own domestic energy supply alongside possible international use for sustainable fuel production – particularly if that fuel is for export.

# The fuel transition enables production hubs in developing countries that provide opportunities for inclusive economic growth through formal, skilled work and education, provided that international companies focus on local skills development and creation of good quality jobs.

## Aviation & Shipping

### Policies and Regulations

- Governments in developing countries need to ensure local communities are benefitting from the transition to sustainable fuels through policies and regulations which require the financial benefits to be transferred to local communities through ownership or financial instruments such as taxes or investments. Research from IRENA suggests that local communities are more likely to embrace local development if they are benefiting from renewable energy investments. Governments have different options for funding the transition, such as using the proceeds from taxes to help decarbonise the industry.
- For example, regulations such as the Broad-Based Black Economic Empowerment (B-BBEE) programme in South Africa set requirements for ‘local content’ where access to jobs are prioritised for minority groups and companies are required to evidence skills development and socio-economic development of the local community. Similar models could be applied in other countries to suit their unique context.

| Area of Focus |
| --- |
| Sector Policies |
| Employment and Labour Practices |
| Process Management and Sensitisation (including social dialogue) |
| Social Policies and Impacts on Workers, Communities, and Consumers |
| Impacts on Investors and Companies (including stranded assets) |
| Funding and Resources for a Just Transition |

Areas of focus for developing countries in the energy transition (Source: GIZ)

# The transition provides an opportunity to provide high quality jobs and reduce public health disparities at airports and ports through Just Transition plans. Collaboration will be required between all stakeholders to avoid the negative effects of displacement and redundancy.

## Aviation & Shipping

### Just Transition

- A Just and Equitable Transition is a 1.5°C-aligned transition which implements the “polluter pays” principle and which leaves no country behind by particularly supporting climate vulnerable States with adaptation and mitigation, ensuring all States are supported to access the benefits of the transition. A Just Transition looks different for each worker, company and country, requiring individual solutions with supporting government policies.

### Displacement

- As the share of sustainable aviation and shipping fuels increases, fossil fuel production will plateau and ultimately decrease. With many fossil fuel workers retraining and relocating to work in sustainable fuel production, displacement of local workers could occur. Furthermore, towns centred around the production of fossil fuels could reduce in economic vibrancy and in extreme cases could even become abandoned, resulting in decreased spending and increased poverty in these areas.
- Decarbonisation in line with the Just Transition needs to account for displacement of workers and stagnation of towns to ensure balanced development across the country.

### Job Quality

- In addition to the quantity of jobs created, the quality of those jobs is also important. These jobs should be well paid with other non-financial benefits, commensurate with the role.
- Gender equality and minorities should also be considered in job creation to allow for inclusive and diverse work that benefits the whole community.
- Safety is a key concern in the aviation and shipping industries, particularly regarding production and handling of fuels.

### Environmental Justice

- Often communities around airports and ports are disproportionately affected by high airborne emissions and reduced water quality. The infrastructure for low-carbon fuels should be engineered to reduce public health disparities and protect communities, particularly low income and indigenous groups.
- Not only does the transition to a low-carbon economy benefit communities around airports but low income and socially vulnerable populations tend to be disproportionately affected by the impacts of climate change. The transition will contribute to the reduction in climate change impacts.

### Transition Opportunity

- As the transition to low-carbon economies occurs, there is an opportunity to develop the new economy to benefit a wider range of people and create balanced development. By considering and including these aspects of the Just Transition, an equitable and fair low-carbon economy can be created.

### Primary Goals


### Secondary Goals


**Alignment of the just fuel transition against Sustainable Development Goals**

# Notice/Disclaimer

## Confidential

This report has been prepared specifically for and under the instructions and requirements of Opportunity Green (our "Client") under an Appointment dated 10 February 2023. The report has been edited by Opportunity Green and we have no responsibility for any such edits.

This report is not for reliance and no party is entitled to rely on this report. We do not in any circumstances accept any duty, responsibility or liability to any third party whatsoever. Accordingly, we disclaim all liability of whatever nature (including in negligence) to any party.

In developing this report, we have relied on information provided. We do not accept responsibility for the information provided any third party. We did not, however, seek to establish the reliability of the sources by reference to other evidence.

You should note that the findings of our Report will not constitute recommendations.

Appendix A

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