Decarbonising Aviation: **SHELL'S FLIGHT PATH**

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INTRODUCTION

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The aviation sector enables immense social and economic progress. In a typical year, it supports $3.5 trillion of economic activity (around 4.1% of global GDP)[1]. But aviation is also one of the fastest growing sources of greenhouse gas emissions, currently accounting for around 3% of the world's annual carbon emissions.

If the world is to continue enjoying the benefits of flight, the aviation sector must reduce its emissions. Shell believes that aviation can and should get to net zero by 2050, meaning that by mid-century the sector will no longer be adding to the total amount of greenhouse gases in the atmosphere.

This presents significant challenges. It requires immediate, ambitious action, but I believe that if all parties in the sector work together, aviation can accelerate its pace to net zero.

As one of the world's largest providers of fuel and lubricants, and as a global company investing in low carbon fuel technologies and production, as well as nature-based solutions that can offset emissions, Shell will play its part.

To that end, we have now adopted an ambition to produce around 2 million tonnes of sustainable aviation fuel (SAF) a year by 2025. This would make us a leading producer of SAF and help accelerate the aviation sector's progress towards net zero.

It will add to Shell's other efforts – some of them mentioned in this report – such as our work with World Energy to develop SAF supplies, our investment in SAF technology company LanzaJet, and our support for ZeroAvia as it seeks to develop hydrogen-powered flight.

Aviation may be reeling from the impact of the COVID-19 pandemic, but decarbonisation must remain one of its highest priorities.

Shell believes there is no single solution for decarbonising aviation. The sector must use every measure that is currently available to tackle emissions.

In the short to medium term, technology must be used to create the operational efficiencies that **avoid** emissions in aircraft and fuel operations, focusing on supply chain and improvements in aircraft design and ways of operating. Also, the supply of SAF must grow to levels where aviation can **reduce** emissions at scale. This will require the support of ambitious government policies that encourage the large-scale adoption of alternative fuels.

High-quality **offsets** provide a way to compensate for emissions through buying carbon credits generated by projects that either reduce greenhouse gases – for example, by using plants to absorb carbon dioxide – or avoid adding to them.

At the same time as this is happening, considerable research and development must go into the technologies behind battery-electric and hydrogen-fuelled propulsion. Such technologies are unlikely to have significant impact before the 2040s at the earliest, but they may provide the basis for zero-carbon flight in the future.

In part, my confidence in that future comes from aviation's history.

This multi-billion-dollar industry started with two brothers working out how to get into

the sky and then return to the ground safely. Soon after the Wright brothers' epoch-making flight, Shell became a passionate supporter of aviation. In 1921, it decided to establish Shell Aviation to help develop flight's obvious potential to become a strong business that could move people and goods further and faster than anything else.

So, what lessons might we take from those pioneering days? In every instance where significant progress was made, people collaborated to solve a challenge.

In many instances, Shell Aviation played an enabling role in identifying the barrier and working with others to tackle it. In this way, airports got their first dedicated refuelling system, countless first flight milestones were achieved and the jet engine and infrastructure that supported it were developed. As a result, aviation, economies and society made progress.

Today, as we face the greatest challenge for aviation since the Wright brothers' first flight, we all need to rediscover that collaborative, problem-solving behaviour.

Now, as before, the starting point is to truly understand the challenge. That is why, in early 2021, Shell engaged the aviation industry's experts to explore how best to accelerate progress towards decarbonisation.

I extend my sincere thanks to more than 100 leaders who participated in interviews and workshops and generously shared their insights with us. We have compiled and presented their views in the Decarbonising Aviation: Cleared for Take-off report prepared by Shell and Deloitte. The report highlights the reasons why progress has been slowed by some barriers to decarbonisation, and suggests solutions to overcome them.

In this companion report, Shell builds on these industry perspectives and outlines our views on what can be achieved.

There is a long way to go, but in Shell Aviation's centenary year, my hope is that as a sector we can learn from our past, work co-operatively and accelerate progress to net-zero emissions.

Shell's Perspectives

THE AVIATION INDUSTRY CAN AND MUST GET TO NET ZERO BY 2050

Shell believes that the aviation industry can and needs to achieve net-zero emissions by 2050.

We supported the International Air Transport Association's (IATA)[2] goals to halve 2005's emissions by 2050 and the UN's International Civil Aviation Organization's (ICAO) ambition to have carbon-neutral growth from 2020[3]. But we now believe these goals are not sufficiently ambitious and must be revised. The aviation industry must go further faster. There is no time to lose if society is to meet the Paris Agreement's most ambitious target to limit global warming to 1.5 degrees Celsius.

We would like to see the industry, and those who rely on aviation, develop a clear long-term strategy to reach net zero by 2050. This will require:

- all stakeholders to collaborate on accelerating the production and use of SAF;
- continuing to explore new fuel and aviation technologies;
- continuing to explore new fuel and aviation technologies;
- involving consumers and corporations in the decarbonisation journey in order to create the right demand signals for the industry to thrive and transform.

Together with the Decarbonising Aviation: Cleared for Take-off report, this companion report aims to outline Shell's view of how the industry can decarbonise and the steps that it is taking to accelerate progress.

In Shell's view, a comprehensive regulatory regime, industry-wide collaboration on developing SAF, investments in technology and new fuels and repositioning nature-based carbon credits could enable decarbonisation by 2050. We believe that to achieve net zero, a sectoral approach is needed to increase the demand and supply for low-carbon energies, such as SAF. Shell is already playing a key role when it comes to advocating for policy development and, providing low-carbon fuels and nature-based solutions. We are willing to play an even bigger role with a new ambition to produce SAF at scale. But we can only do this in partnership with other industry participants, including customers and governments.

Three-step approach to decarbonisation

Shell advocates a three-step approach to decarbonising the aviation industry, enabled by policy revisions and sector collaboration.

Avoid CO_2 emissions

- by improving energy efficiency in the air, for example through aircraft design, and adopting renewable or carbon-neutral energy on the ground; and
- by developing new net-zero emissions fuel technologies.

Reduce CO_2 emissions

- by accelerating the development and deployment of SAF.

Offset CO_2 emissions

- by compensating for remaining emissions using high-quality nature-based carbon credits.

The timeframe within which these three strategies will have their greatest impact differ. Some, such as nature-based carbon credits are available now. Some sustainable aviation fuels are being used already but are not yet available to be deployed at scale. But net-zero emission technologies, such as hydrogen-fuelled planes or electric aircraft, are in their infancy and will probably only materially affect sector emissions after 2040, at the earliest.

SAF IS THE CLEAREST ROUTE TO NET-ZERO FLYING

What is sustainable aviation fuel?

Sustainable aviation fuel (SAF) enables a significant reduction in carbon emissions.

It is a drop-in fuel, which means it can be blended with current kerosene jet fuel and used in the world's existing aeroplanes, without the need for them to be significantly redesigned or upgraded.

SAF can be produced by using biomass, such as used vegetable oils or agricultural waste, to create biofuels. But Shell has demonstrated that it is also possible to produce SAF synthetically, for example via power-to-liquids technology. Synthetic SAF can be produced with fewer or no carbon emissions.

When burned by an aircraft engine, SAF still produces emissions but compared with conventional jet fuel, it can reduce net carbon emissions by up to 80% when used in neat form.[4] It is the only proven and commercially approved measure which can reduce aviation emissions at scale over the next two to three decades.

SAF is today, however, two to eight times more expensive than kerosene. It is therefore essential to close this cost gap so that demand for SAF can drive increases in production volumes.

A leading pathway to net zero

Shell believes that the clearest pathway to achieve carbon-neutral flying is investing in SAF and scaling it up. The faster the aviation sector can deploy more SAF, the likelier it is to achieve net-zero emissions by 2050.

In 2019, fewer than 200,000 metric tonnes of SAF were produced globally, which is less than 0.1% of the current total of around 300 million metric tonnes of jet fuel used by commercial airlines.[5] Even if all SAF production projects announced reach completion, capacity would only increase to just over 1% of expected global jet fuel demand in 2030.

Shell supports the industry view described in the Decarbonising Aviation: Cleared for Take-off report that new policy incentives for fuel producers and airlines could accelerate the wider adoption of SAF.

To achieve greater supply and demand of SAF, Shell will collaborate with businesses, industry organisations and governments to advance a sectoral policy framework that incentivises customer demand and provides fiscal support for infrastructure development, new technologies and SAF production plants. Shell believes it is essential to have mandates that set minimum amounts of SAF to be blended with traditional jet fuel. The policies should be globally applied and regulated and should be coordinated across the aviation sector to include those who benefit

SPOTLIGHT

USING 100% SAF IN ROLLS-ROYCE AIRCRAFT ENGINES

SAF is used as a drop-in fuel, blended with traditional jet fuel. The percentage of SAF used in the blend varies. The larger the proportion of SAF, the greater the reduction in net carbon emissions. In November 2020, Shell and Rolls-Royce co-operated on using 100% SAF in ground tests of aircraft engines.

Previously, aircraft engine seals were believed to need the aromatics associated with hydrocarbons to ensure they functioned properly. The Rolls-Royce tests showed that new aircraft engines can operate effectively on 100% SAF, paving the way for certification that will increase the proportions of SAF in blends with traditional jet fuel.

In June 2021, Shell and Rolls-Royce announced they were going to expand and accelerate several existing areas of cooperation between them, such as working together on demonstrating the viability of 100% SAF as a full drop-in solution. This will see the companies explore opportunities to help progress the use of 100% SAF towards certification, building on Rolls-Royce's ongoing 100% SAF testing programme.

"Supporting the decarbonisation of aviation while continuing to enable progress in flight are goals that Rolls-Royce and Shell both share," said Paul Stein, Chief Technology Officer at Rolls-Royce. "We believe that working together on these aims can deliver benefits for both the development of new innovations as well as collaborating to find ways to unlock the net carbon emissions reduction potential of technology that is already in use today."

from flight, such as cargo handlers, corporate flyers and consumers.

We are also a founding member of The Clean Skies for Tomorrow Coalition (CST), which is working together to help make SAF widely available. The coalition aims to support the ambition to achieve net-zero emissions in the aviation industry by 2050, and Shell supports its view that SAF production can feasibly ramp up to 10% of total European jet fuel consumption by 2030[6].

SHELL'S AMBITION FOR THE AVIATION SECTOR

Shell aims to produce around 2 million tonnes of SAF a year by 2025, making us a leading global producer of SAF. This production, together with our supply deals, positions us strongly to support the decarbonisation of aviation. This forms part of Shell's previously announced plan in February 2021,[7] to invest $5-6 billion annually in Shell's Growth pillar which includes marketing, hydrogen, power and low-carbon fuels. Investments in low-carbon fuels include putting money into SAF. By 2030, we aim to have at least 10% of our global aviation fuel sales as SAF.

Our Environmental Products business is one of the largest carbon market participants in the world and we are engaging with our customers to help them purchase nature-based carbon credits to offset emissions that they cannot yet avoid or reduce.

Decarbonisation tools exist and the aviation sector must make use of all available options if it is to stay in step with society's expectations and achieve net zero by 2050. Shell's preferred approach to decarbonisation is based on three steps: to avoid emissions, reduce emissions and then offset any emissions that remain. Each of these will achieve its greatest impact at different times but all of them will be critical between now and 2050.

We help customers avoid emissions:

- We research and develop new aviation fuel technology, e.g. hydrogen.
- We help airports develop strategies for minimising emissions on the ground.

We help customers reduce emissions by supplying, investing and collaborating:

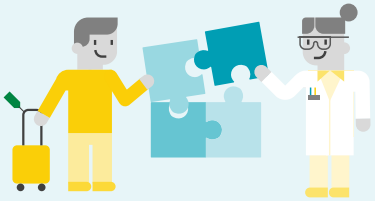
- We supply SAF through partnerships and investing in our own production.
- We collaborate with others to improve the pace of change and drive developments in new technologies.
- We aim to produce around 2 million tonnes of SAF per year by 2025.

We help customers offset emissions:

- We provide high-quality, nature-based carbon credits.

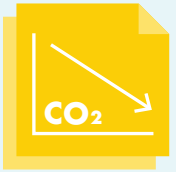
To decarbonise aviation, the sector will need:

All parties: In aviation decarbonisation, there are no passengers – everyone must play their part: governments, businesses, civil society and individuals.



All measures: The challenge is too great to favour any one pathway. All viable solutions must be deployed between now and 2050. Different measures will have different timelines for greatest impact.

All together: All stakeholders must collaborate to combat rising carbon emissions. Together, we can identify challenges, work to overcome them and power progress.



Views from The Industry

FLIGHT IS CRITICAL BUT MUST GROW RESPONSIBLY

Aviation powers progress. Flight plays a vital role in expanding horizons and broadening opportunities to live, learn and work for people all around the world. Future growth will enable even more people, communities and businesses to enjoy such opportunities. But the sector must grow responsibly and play its part in a net-zero future.

Governments and civil society are placing increasing pressure on aviation to decarbonise. Aviation is one of the six harder-to-abate sectors[8] that together accounted for 31% of global carbon emissions in 2019, according to the International Energy Agency (IEA). Historically, aviation has been excluded or partially excluded from some major efforts to tackle climate change.

This is largely because aviation is perceived as difficult to decarbonise and its global 3% contribution to overall emissions is relatively small in comparison with road freight or the iron and steel sectors. But on its current trajectory, aviation could represent up to 22% of global carbon emissions by 2050 as other sectors decarbonise more rapidly.[9]

Aviation emissions are hard to abate for multiple reasons. Like other harder-to-abate sectors, aviation has long asset lifespans, high energy dependency and is difficult to electrify. As a result, decarbonisation of these industries might be more technically demanding and capital-intensive than other sectors. Currently the only proven and viable way to power jets is with fuel that is high in energy density, such as kerosene.

Before the COVID-19 pandemic significantly reduced travel, aviation produced around 1 billion tonnes of carbon emissions in 2019[10]. While this may be less than other transport sectors, policy makers and regulators have paid insufficient attention to aviation.

The vast majority – some 85% – of aviation CO_2 emissions are driven by passenger travel, and only 11% of the world's population fly annually. Many of those who do use air travel are frequent flyers. Around 4.5 billion passengers flew in 2019 and passenger traffic is forecast to more than double in the next 30 years[11]. If carbon emissions associated with aviation are not urgently reduced, emissions could more than double by 2050.

DECARBONISATION FACES KEY BARRIERS

The Decarbonising Aviation: Cleared for Take-off report shows that 90% of respondents perceive decarbonisation to be a top three priority for their business, but also identified key barriers that must be overcome.

SAF is expensive

SAF is currently two to eight times more expensive than traditional jet fuel, depending on the mix of feedstock, technology and manufacturing processes used to produce SAF. This cost is more than most airlines can absorb. Airlines are already operating on tight margins in a highly competitive industry. However, producing SAF at scale could lead to costs falling but improvements in cost and technology efficiencies for SAF production could take time to deliver as many production pathways are still developing to their full potential.

Regulatory frameworks are absent or in early development

There is a lack of clarity and alignment across government and regulatory bodies when it comes to emission reduction targets. Local regulations do not always support or encourage decarbonisation and there is a shortage of mandates and incentives to motivate stakeholders to use sustainable fuels or offsets.

Price sensitive consumers

Leisure passengers are reluctant to absorb the cost of lower emission solutions, because they have come to expect cheap air fares and do not feel personally responsible for emissions. Although 85% of surveyed leisure passengers say they are willing to pay to offset emissions, less than 1% do in practice.[12] At the same time, corporate travel is likely to reduce in share after the pandemic as businesses continue to use online platforms for engagement. This will put more pressure on airline margins.

Scepticism about offsets

Many within the aviation industry are sceptical about the value of carbon offsets, but they have an immediate role to play in helping aviation to reduce its net emissions. They will be particularly important during the time it takes to fully develop other ways to decarbonise aviation. But they must be made more transparent and verifiable. They need to be more appealing to passengers, and their impact should be clearer.

DECARBONISATION STRATEGIES EXIST

While barriers to decarbonisation exist, the industry believes there are clear strategies for overcoming these barriers.[13]

Increased production, supply and use of SAF is crucial. For this to occur, airlines will need clarity from end users, corporate flyers and cargo shippers on whether they are willing to pay more for flights using SAF. If airlines have a clear demand outlook, they may be more willing to purchase SAF, which in turn would provide clarity for SAF producers to invest in more production infrastructure. A very encouraging finding of the Decarbonising Aviation: Cleared for Take-off report is the increasing number of companies setting net-zero targets and signing up to the Science Based Target Initiative (SBTi). Equally encouraging is the number of Fortune 500 companies entering into large offtake agreements with SAF producers. However, more must be done to incentivise further SAF demand.

Governments and regulators should offer incentives, such as tax credits, and introduce mandates for fuel producers to supply SAF and for airlines to use it. Banks and other financial institutions should be encouraged to provide funding for producing and purchasing SAF, as part of their environmental, social and governance (ESG) commitments.

When it comes to regulations and decarbonisation goals, the industry believes that more ambitious targets must be set in order to achieve net-zero emissions. Industry respondents view the UN's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) plan as the only formal regulatory measure in place at the moment. CORSIA aims to keep emissions at or below 2019 levels and reduce emissions by 50% relative to 2005 levels. Yet many of the respondents have made their own commitments to get to net zero by 2050.

The industry also believes that a key measure for accelerating decarbonisation would be aligning and clearly communicating more ambitious emission reduction goals across airlines and international organisations such as the International Air Transport Association (IATA) and the International Civil Aviation Organization (ICAO).

The industry believes that scepticism about the impact of carbon offsets could be addressed by ensuring that all offsets are of high quality and subject to rigorous, credible standards and assurance. The industry also believes that airlines should raise awareness among consumers about the role of offsets, make it easier to buy offsets and reward those who do so through loyalty programmes.

THE ROLE OF ENERGY PROVIDERS

The Decarbonising Aviation: Cleared for Take-off report shows how all stakeholders can play their part in decarbonisation, and respondents were clear about the role they see for energy providers, like Shell:

- produce and supply SAF at scale and help smaller producers to do so through partnerships;
- participate in industry groups to encourage regulators to introduce incentives for SAF production and use, and for the purchase of carbon offsets;
- play a leading role in research and development (R&D) partnerships on new fuels and technologies, such as biomass conversion, synthetic SAF and hydrogen; and
- inform society about the benefits of using nature-based carbon offsets.

This report will show the role that Shell is already playing and how we plan to expand our efforts to achieve decarbonisation in aviation.

Shell's Role in Decarbonising Aviation

POWERING PROGRESS IN FLIGHT

Shell's target is to become a net-zero emissions energy business by 2050, in step with society[14]. For our aviation business, that means we will invest in new SAF production plants and continue to partner with SAF producers, new technology developers, aircraft manufacturers and airlines to provide the best products and services for our customers. We will also offer customers nature-based carbon credits.

While Shell will continue to meet demand for traditional jet fuel, Shell will pivot towards serving the businesses and sectors that, by 2050, aim to achieve net-zero emissions themselves. That means we will work with our customers to help them reduce their emissions.

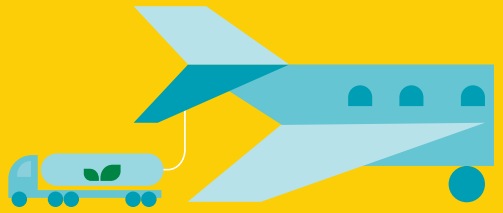
SPOTLIGHT

SUPPORTING AVIATION PIONEERS FOR OVER A CENTURY

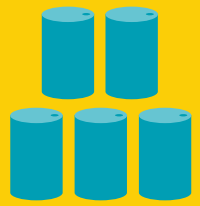
Shell has helped support aviation's progress for over 100 years, working with others to identify and overcome challenges, from powering the flights of early aviators like Louis Blériot and Amy Johnson, through to designing the combustion chamber that enabled Frank Whittle's jet engine to get airborne.

Presence in approximately **60** countries.

Each year more than
2 MILLION AIRCRAFT
are fuelled by Shell.



In 2017, we sold Shell Aviation Lubricants
IN MORE THAN 40 COUNTRIES.



Shell Aviation is one of the few energy companies with a dedicated aviation research facility, and
THE ONLY ONE
with an avgas piston engine research rig.

Over
100 YEARS
of innovation.

On average Shell fuels an aircraft every **14** seconds.

WORLD'S BEST SELLING
Piston engine oil.

AVOIDING CO_2 EMISSIONS

Battery electric and hydrogen

Avoiding emissions altogether is the ultimate goal, so we fully agree with the findings of the Decarbonising Aviation: Cleared for Take-off report that significant research and development is needed to advance battery electric and hydrogen technologies. Co-operation will be crucial for this, and Shell has a key role to play in producing clean hydrogen[15] and making it available to the sector as demand increases.

We are monitoring the industry's progress in developing hydrogen planes and will continue to work closely with our partners, such as the start-up ZeroAvia, to enable progress. But we emphasise that while these new technologies are being worked on, aviation must immediately accelerate the development of SAF and make full use of high-quality carbon offsets, such as those based on projects involving nature-based solutions.

We believe that battery electric and hydrogen-fuelled propulsion technologies will play an important role in future aviation.

But even if viable technologies were available today, they would have little material impact before 2040. Certification may take years and these technologies will require new aircraft design and airport infrastructure. As a result, the clearest path to avoiding emissions over the next decades is through energy efficiency in the air and on the ground.

Energy efficiency is critical

In most assessments of how aviation can reduce its emissions between now and 2050, engine and operational efficiency improvements play a critical role. Aircraft manufacturers have helped and must continue to help deliver these improvements.

Efficiency improvements in aircraft and engine technologies have made the greatest impact in reducing aviation emissions until now. Efficiency improvements will continue to have the greatest impact until sustainable aviation fuels are used at scale.

SPOTLIGHT

FLYING HYDROGEN-FUELLED PLANES

Shell believes hydrogen can play an important role in decarbonising aviation. The first hydrogen planes are already being developed and tested for flight operations. Companies like ZeroAvia and Airbus are leading industry development. We could see small regional planes in flight in the middle of this decade with larger-capacity aircraft in service during the 2030s

In 2020, Shell announced an investment in the California-based hydrogen plane start-up ZeroAvia to develop zero-emission commercial aircraft. ZeroAvia has completed more than 35 test flights with a six-seater propeller plane powered by its hydrogen fuel cell powertrain.

In March 2021, Shell announced an additional investment in ZeroAvia as it aims to develop hydrogen technology to the point where it can power larger regional aircraft at commercial scale. ZeroAvia has been conducting test flights in Britain. It aims to enable hydrogen-electric commercial flights of up to 500 miles using 10- to 20-seat aircraft by 2024, and commercial jet flights that can carry up to 200 passengers 3,000 miles in the 2030s.

Credit: ZeroAvia

REDUCING CO_2 EMISSIONS

Aviation will continue to need a high-density, liquid fuel until at least 2050. Shell believes that the most successful path to decarbonising the aviation industry is through expanding the use of SAF. We aim to become one of the world's leading producers and suppliers of SAF as demand increases.

The Decarbonising Aviation: Cleared for Take-off report found that respondents consider SAF to be prohibitively expensive. There is uncertainty over how to reduce these costs and sustainably source feedstock for SAF. Shell believes that the industry needs to accelerate the development of SAF and ensure it is deployed at scale. To enable this, we believe the sector needs significantly more production facilities and new policy incentives to encourage the production and use of SAF.

We aim to supply a significant share of SAF through our own production and by working with others, including World Energy, one of the largest suppliers of biodiesel and SAF in the USA, and the Finnish biofuel producer Neste. By 2025, Shell aims to produce around 2 million tonnes of SAF per year. We also have a range of SAF technologies in development.

Shell's production of SAF

Shell aims to produce SAF in two ways: from biomass, such as used vegetable oils or agricultural waste, and, at a later date, by using synthetic technologies to convert non-recyclable waste and alcohol to jet fuel. We hope it will be possible to use these synthetic technologies by 2030. Some of our production projects are at the stage where we can proceed if sufficient demand can be demonstrated. Others require further investment in developing new technologies.

Biofuels (including hydrotreated esters and fatty acids - HEFA)

Most biofuels are produced from agricultural crops, such as corn, sugar cane or used vegetable oil. Our main focus for biofuels development and investment is in using waste, inedible crops or forestry products.

In September 2021, Shell announced that it will be building one of Europe's largest biofuels facilities[16]. The Shell Energy and Chemicals Park Rotterdam, in the Netherlands, formerly known as the Pernis refinery, is expected to begin production in 2024 and will be able to produce 820,000 tonnes of low-carbon fuels per year. It will use feedstocks such as used cooking oil, waste animal fat and other industrial and agricultural residual products. Sustainable aviation fuel could make up half of the low-carbon fuels produced by the facility, with the remainder being renewable diesel intended to decarbonise road transport. The facility will have the flexibility to adjust this mix to meet customer demand.

In 2019, Shell also announced that it will support SkyNRG to develop Europe's first dedicated sustainable aviation fuel production plant.[17] We will bring our technical and commercial expertise to the project. Once operational, the plant will produce 100,000 tonnes of fuel made from waste cooking oil. It will run on sustainable hydrogen.

Sustainable SAF production

There are concerns around biomass as a feedstock for SAF because of potential competition with crop growers for land. One worry is that if land is used to produce feedstock for biofuels, it could result in deforestation because farmers might fell trees to provide space for agriculture.

With this in mind, Shell believes that if there are limits on how much land can be used for biofuels, priority should go to producing feedstocks for SAF. This is because aviation currently has few viable options for decarbonisation.

We have robust sustainability criteria for our biofuel feedstocks, and we fully support the adoption of international sustainability standards for agricultural practices. All of our purchased feedstocks that are considered to be high risk from a human rights, biodiversity, or release of carbon stock perspective are certified as sustainable by credible sustainability initiatives. 99% of our purchased volumes of biofuels are covered by contracted sustainability clauses.

Shell is also a leader in the development of synthetic sustainable fuels technology. These fuels are needed because there is a limit to how much biofuel can be produced, given the competition for land in some places between feedstock producers and food growers. If synthetic fuel can be produced competitively and at scale, then we believe it should be preferred over biofuel – given its low emissions and its environmental and land-use benefits. There are several technology pathways being considered:

Alcohol-to-jet (ATJ)

Shell has invested in sustainable fuels technology company LanzaJet, which uses catalytic conversion technology to convert alcohol into SAF.[18] We will sublicense its ATJ technology and explore the potential to scale production facilities over the coming years.

Fischer-Tropsch

This technology has the potential to be used to create SAF in future projects. The Fischer-Tropsch process converts carbon monoxide and hydrogen produced from coal, natural gas or biomass into a synthetic lubrication oil and synthetic fuel.

Shell and Canadian biofuels and renewable chemicals company Enerkem recently announced they would use the Fischer-Tropsch technology at a waste-to-jet fuel project in Rotterdam.[19] The project would use Enerkem's technology to create synthetic gas from waste. This gas would then be upgraded to SAF through the Fisher-Tropsch process.

The project would process up to 360,000 tonnes per annum of recycling rejects and produce up to 80,000 tonnes of renewable products, of which around 75% could be SAF and the remainder used for road fuels or to feed circular chemicals production.

Enerkem, Shell and the Port of Rotterdam – are looking to submit a permit application for the project by the end of 2021. If the final investment decision has been taken, construction of the project could take about three years, with production starting in 2025 or 2026.

Power-to-liquids

A long-term solution for aviation may be power-to-liquids (PTL), using direct air capture and point source emissions capture coupled with renewable power and hydrogen sources to produce synthetic fuels. However, to deploy PTL commercially, major breakthroughs are needed on costs and scale on all main feedstock components, i.e. renewable electricity and hydrogen production as well as CO_2 capture.

Shell believes that the level of cost improvement needed to make PTL competitive before the 2040s will be difficult to achieve and any scalable production will take time to deliver. However, we are encouraged by the findings of the Decarbonising Aviation: Cleared for Take-off report and the level of support PTL has among many in the aviation industry. Shell is taking steps to develop this technology and demonstrate its potential applications.

In February 2020, Shell, KLM and the Dutch Ministry for Transport enabled the world's first passenger flight from Schiphol to Madrid partly flown on sustainably produced, certified synthetic kerosene.[20] This was made using Shell's PTL technology.

In Germany, we are looking into building a commercial bio-PTL plant at our Energy and Chemicals Park Rheinland.[21] Construction could start in 2023 with commissioning at the end of 2025. The capacity would initially be

around 100,000 tonnes per year. The project awaits a final investment decision.

Shell as a supplier of SAF through partnerships

While we are investing in the development of our own SAF technologies and production facilities, we are also partnering with existing producers to operate supply deals. We were the first fuel supplier to deliver SAF via mainstream fuels infrastructure in Europe and North America.

In October 2020, we signed an agreement with Red Rock Biofuels to market and distribute SAF from Red Rock's new biorefinery in Lakeview, Oregon, USA.[22] Shell will distribute the SAF to Red Rock's existing airline customers and market Red Rock's cellulosic renewable diesel fuel.

In January 2021, ECB Group and Shell signed a five-year contract that will provide more than 500 million litres of renewable diesel and renewable jet fuel per year to Shell.[23] ECB is building a plant in Paraguay and the contract is expected to run from 2024.

SPOTLIGHT

WORKING WITH WORLD ENERGY ON SAF SUPPLY

In January 2020, Shell and World Energy, a low-carbon solutions provider for transport and the world's first, and America's only, commercial-scale SAF producer, announced a collaboration to develop a scaleable supply of SAF. The deal represents one of the most significant SAF supply contracts globally, with up to one million gallons of SAF to be supplied to Lufthansa Group at San Francisco International Airport (SFO).

The supply will reduce Lufthansa's carbon emissions on intercontinental flights on three routes operated by Deutsche Lufthansa and Swiss International Air Lines from SFO to Frankfurt, Munich and Zurich. The SAF is produced by World Energy at its refinery in Paramount, California, from a feedstock of agricultural waste fats and oils.

"The shift to low-carbon fuels will not happen in a day and won't be done alone... We are committed to making low-carbon fuels readily available to those who choose to act now and to lead the transition to a cleaner energy future," said Gene Gebolys, Chief Executive Officer of World Energy.

In July 2020, Shell Aviation announced that it and World Energy would supply Amazon Air's cargo operations with up to six million gallons of blended SAF over 12 months.

OFFSETTING CO_2 EMISSIONS

Nature-based carbon credits must be used now

Shell believes that it is necessary to offset emissions now with high-quality carbon credits linked to nature-based solutions (NBS). The development of SAF is a priority but it will take time before there is enough of it to have a significant impact. NBS are available now, and Shell strongly believes that at this stage the aviation industry should use them to offset emissions. NBS provide the best available means for aviation to mitigate its contribution to climate change while developing SAF and other technologies that will, in time, enable the sector to further reduce and avoid emissions.

Climate scientists are clear that nature, which can absorb and store carbon, can play an important role as the energy system transitions. But Shell acknowledges the industry view, described in the Decarbonising Aviation: Cleared for Take-off report, that scepticism exists within the aviation industry, civil society and the public when it comes to the value of offsets. There are doubts, in particular, as to whether offsets and carbon credits legitimately compensate for CO_2 emissions. Many people don't understand what defines a high-quality offset.

Reposition offsets clearly

We support the findings of the Decarbonising Aviation: Cleared for Take-off report that offsets need greater transparency and more agreement about the standards required for a credible, high-quality offset. We also agree with the industry that the benefit of using offsets now as a vital tool in decarbonising aviation must be more clearly communicated to all stakeholders, including consumers.

A global survey of 6,000 passengers conducted for the report found that less than 1% of passengers offset their emissions from flying.[24] This is despite the same survey finding that 85% of passengers said they would be willing to pay to offset emissions. We, as an industry, need to make it easier for consumers to buy offsets.

It is also important that airlines and airports provide clear and accurate information that encourages passengers to think about how they can reduce their own carbon footprints and help decarbonise aviation. Passengers should be encouraged to buy offsets. Shell sees an opportunity to co-operate with airlines and airports in helping to provide customers with clear and accurate information about offsets.

SPOTLIGHT

INVESTING IN NATURE FOR A NET-ZERO FUTURE

Shell has an ambition to invest up to $200 million between 2020 and 2021 in nature-based projects that reduce or avoid CO_2 emissions. These projects involve restoring and protecting forests, grasslands and wetlands. In addition to the other steps we are taking to avoid and reduce emissions, nature-based projects will help us achieve net-zero emissions by 2050.

The following are examples of Shell's investments in nature-based projects:

- We are working with WeForest to restore 4,775 hectares of mangrove forest between 2020 and 2022 in the Sine-Saloum area of Senegal.
- In 2020, Shell and the Tŝilhqot'in National Government announced they are jointly undertaking a reforestation project in Tŝilhqot'in territory in British Columbia, Canada, where wildfires in recent years have significantly impacted the region and Tŝilhqot'in communities. The planting of approximately 840,000 trees, all native species, will be managed by Central Chilcotin Rehabilitation, a Tŝilhqot'in-owned forestry company. Reforestation will take place in fire-impacted areas that have not regenerated on their own or have been slow to regenerate.
- We acquired Select Carbon in 2020, a company that partners with farmers and other landowners to develop carbon farming projects throughout Australia. Carbon farming involves managing land so plants remove as much CO_2 as possible, by absorbing it in their leaves, storing it in their wood or drawing it into the soil through their roots. Select Carbon has developed and manages a portfolio of more than 70 projects covering around 9 million hectares across Australia.
- In 2019, we formed a partnership with Staatsbosbeheer, the Netherlands' state forestry service, to plant more than five million trees in Dutch forests over a 12-year period.

Shell's NBS products

We offer our customers, both individuals and companies, the opportunity to voluntarily deal with the emissions they generate. Shell offers globally diverse, high-quality nature-based carbon credits. Our Environmental Products business is one of the largest carbon market participants in the world. Our team works with a carefully selected group of environmental project developers across the world whose projects generate voluntary carbon credits.

Shell is supporting customers by providing certified, high-quality carbon credits from its portfolio of nature-based solutions. In January 2021, we started providing Etihad Airways with carbon credits, supporting the airline as it seeks to get to net zero.[25] In February 2021, Shell Aviation also signed an agreement that will enable Jetex customers to offset the emissions from their flights[26].

SPOTLIGHT

HOW SHELL OFFSETS ITS OWN EMISSIONS

Our net-zero target covers the emissions from our operations and the emissions from the use of all the energy products we sell. Crucially, it also includes emissions from the oil and gas that others produce and Shell then sells as products to customers, making the target comprehensive.

In line with this target and our Powering Progress strategy, we aim to use NBS to offset emissions of around 120 million tonnes a year by 2030. The NBS we use will be of the highest independently verified quality. We will work with the Science Based Targets Initiative, Transition Pathway Initiative and others to develop standards for the industry and align with those standards.

More than 80% of our corporate travel emissions are related to long-haul flight and we are putting in place a range of measures to ensure that we reduce and offset the emissions from these journeys. Since 2019, Shell has also used NBS carbon credits to offset emissions for all commercial flights, hotel accommodation and car-rentals of Shell staff that are booked through Shell's corporate reservation service.

New sector policies to enable change

NEW SECTOR POLICIES TO ENABLE CHANGE

The critical role of governments

Shell believes that government support is a key driver for the growth of sustainable aviation fuels, new energy technologies and the use of carbon offsets to mitigate emissions. We therefore advocate for a new aviation policy framework that is consistent and long-term.

New policies should include all sector participants, including aircraft manufacturers, airlines, fuel suppliers, fuel producers, airports and, most importantly, consumers to enable collaboration and the development of a sectoral approach to decarbonisation. Such an approach can deliver the significant investments and changes that are required throughout the sector. All participants have a role to play.

However, collaboration and a sector-wide approach can only succeed if underpinned by enabling policies. Shell believes that policies should include incentives to encourage investment in production of SAF and mandates that ensure this supply is taken up. In other words, we believe that policies need to drive increased supply and demand where the two move in step, providing investors with confidence and potentially leading to the deployment of SAF at scale.

We believe that policies should be globally applied and regulated because aviation is a worldwide business. For example, if SAF mandates are higher in one country than another then this could result in airlines choosing to refuel in a location where lower SAF mandates result in lower fuel prices. Policies that are globally, or at least regionally, aligned could help avoid this distortion in the market.

Shell collaborates with businesses, industry organisations and governments to advance our proposed sectoral policy framework. Shell is active in several policy forums, including WEF Clean Skies Initiative, the UK Jet Zero Council and the Dutch Sustainable Aviation

Roundtable and works with many industry partners, stakeholders and governments to develop a coordinated approach to policy that supports long-term deployment of SAF and a supportive policy environment that drives aviation decarbonisation.

This framework has the goal of developing aligned policy, across the world, to drive aviation decarbonisation, with a focus on one of the key enablers of this - the deployment of SAF globally at scale.

Increasing the use of SAF

To create demand for SAF, it is essential to have SAF mandates. These set minimum amounts of SAF to be blended with traditional jet fuel. They should be set at levels that are ambitious but consistent with the pace of building out supply capabilities and infrastructure. Shell supports the goal to have this at 10% of jet fuel production by 2030 and at least 50% by 2050 globally.

We believe that the mandates should be reviewed regularly, so they can be systematically ramped up, as SAF production grows and commercialises. There should be clear financial penalties for non-compliance.

Any mandate should initially allow the continued use of SAF made from first generation feedstocks (e.g. cereals, maize, sugar beet and cane, and rapeseed) and fuels made from waste that are compliant with clear and globally agreed sustainability and CO_2 emission criteria. The mandate should provide clear pathways to produce SAF from advanced feedstocks (e.g. agricultural and forestry residues) and synthetic fuels.

Mandates should initially allow for the use of a book-and-claim approach ahead of wider deployment of SAF through the fuels supply chain to individual airports. This would ensure that there is no need to develop small uneconomic supply chains as the SAF industry goes through early stage development. Instead, the production of SAF could be maximised where there is sufficient feedstock, production capacity and demand.

SAF blending mandates are a necessary policy measure, but they will not on their own provide enough incentive to invest in SAF at the scale required to get aviation to net zero by 2050. Governments should provide or encourage long-term financing and offer fiscal incentives that encourage new SAF technologies to be scaled up quickly.

Policies should include fiscal and financial policy instruments to allow for grants, loan guarantees and tax incentives, such as accelerated depreciation whereby the book value of an asset can be reduced earlier in its life.

Fiscal and financial measures should also include other bankable policies for SAF products, such as a durable purchase agreement or a performance-oriented production tax credit of sufficient duration to

cover the project's lifetime. This would help to mitigate price volatility and provide market stability, protecting both suppliers and buyers.

The policy framework for SAF should be accompanied by a robust and rising carbon price. This would partially bridge the long-term cost difference between SAF and conventional aviation fuel. It would also incentivise greater energy efficiency in aircraft and aviation operations.

Governments should also consider the impact of early-stage mandates on the airline industry and acknowledge the financial challenges the sector is facing. Support for sustained demand will be critical to encourage SAF producers to invest in increasing capacity.

Airports, airspace service providers and regulators should be encouraged to provide operational incentives that encourage airlines to use new technologies or alternative fuels such as SAF. These incentives could, for example, come in the form of lower landing fees for aircraft that use SAF or zero-carbon technologies.

Governments should consider options such as feed-in tariffs, SAF blending credits or a credit multiplier for SAF. These options would provide the necessary initial support for SAF over the short- to medium-term and should come with a clear time limit.

If a country or region is considering taxing aviation fuel, it should base the tax on carbon emissions, and make SAF fully exempt. Linking the rate of excise duty to a fuel's emissions intensity would provide an additional incentive for low- or zero-carbon aviation fuels.

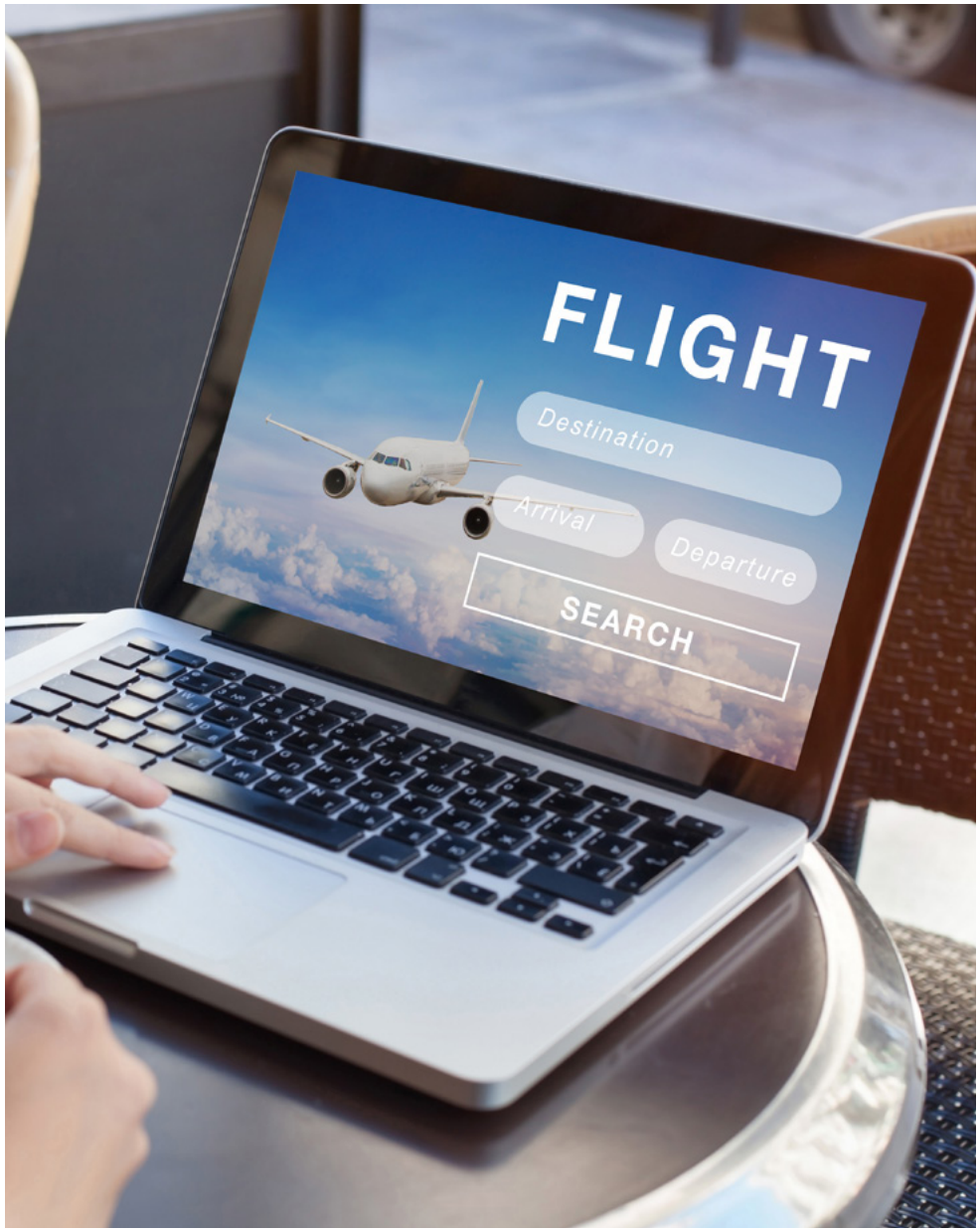
Clarifying and encouraging offsets

Governments and international organisations should include the use of NBS in requirements for regulatory compliance. They should also support a functional, high-integrity market for NBS credits and encourage the continued use of voluntary offsets.

We believe that CORSIA should ensure that any offset programme encourages the development and increased use of low-carbon fuels. This can be done by:

- placing a limit on what percentage of compliance can be met by using offsets;
- ensuring there is a high compliance value for using SAF, for example by applying a multiplier; and
- allowing national regulators to buy carbon credits at market price for a planned emissions reduction fund, before selling them at a ceiling price to those who cannot otherwise comply with regulation.

CORSIA should also ensure there is a transparent process where offsets represent real, verifiable and permanent emission reductions and removals.



Conclusion

SHELL IS READY TO PARTNER TO DECARBONISE AVIATION

Aviation is vital for social and economic progress but if people are to continue to benefit from flight, the sector must reduce its emissions faster and reach net zero sooner. Shell believes that the aviation sector can and must achieve net-zero emissions by 2050. This report gives our view on how best to achieve this.

We believe that SAF is of crucial importance in decarbonising aviation. We would like to see the sector accelerate the production and use of SAF. Aviation should also continue to explore alternative propulsion technologies, such as battery electric and hydrogen, which may eventually enable zero-emission flight.

But it will take time for SAF to be deployed at scale, and even longer for the alternative technologies to become viable for commercial aviation.

By contrast, high quality offsets using well managed NBS to offset carbon emissions are available now, and should be encouraged as a way of signalling to the industry that consumers value decarbonisation solutions.

We are already taking action to expand our role in the production and supply of SAF – in both biofuels and synthetic fuels. We aim to produce around 2 million tonnes of SAF a year by 2025, and by 2030, we aim to have at least 10% of our global aviation fuel sales as SAF. We already have many SAF supply partnerships. As a global leader in fuel supply, we will keep seeking new alliances.

The decarbonisation of aviation will require sector-wide collaboration and alignment, underpinned by government policy support that brings incentives and mandates. Getting to net zero in aviation can only be achieved if all parties – from airlines and consumers to energy producers and governments – act together and act fast.

Shell is looking for partners on this path to decarbonisation. We can't do it alone. Nobody can. Whether you are a business wanting to lower your aviation-related emissions, an airline or a SAF producer, we are ready to work with you to help make flight net zero by 2050.

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This Decarbonising Aviation: Shell's Flight Path report contains data and analysis from Shell's Sky 1.5 scenario. Shell Scenarios are not intended to be projections or forecasts of the future. Shell scenarios including the scenarios contained in the Decarbonising Aviation: Shell's Flight Path report are not Shell's strategy or business plan. When developing Shell's strategy, our scenarios are one of many variables that we consider. Ultimately, whether society meets its goals to decarbonize is not within Shell's control. While we intend to travel this journey in step with society, only governments can create the framework for success. The Sky 1.5 scenario starts with data from Shell's Sky scenario, but there are important updates. First, the outlook uses the most recent modelling for the impact and recovery from COVID-19 consistent with a Sky 1.5 scenario narrative. Second, it blends this projection into existing Sky (2018) energy system data by around 2030. Third, the extensive scaleup of nature-based solutions is brought into the core scenario, which benefits from extensive new modelling of that scale-up. (In 2018, nature-based solutions required to achieve 1.5°C above pre-industrial levels by the end of this century were analysed as a sensitivity to Sky. This analysis was also reviewed and included in the IPCC Special Report on Global Warming of 1.5°C (SR15).) Fourth, our new oil and natural gas supply modelling, with an outlook consistent with the Sky 1.5 narrative and demand, is presented for the first time. Fifth, the Sky 1.5 scenario draws on the latest historical data and estimates to 2020 from various sources, particularly the extensive International Energy Agency energy statistics. As with Sky, this scenario assumes that society achieves the 1.5°C stretch goal of the Paris Agreement. It is rooted in stretching but realistic development dynamics today but explores a goal-oriented way to achieve that ambition. We worked back in designing how this could occur, considering the realities of the situation today and taking into account realistic timescales for change. Of course, there is a range of possible paths in detail that society could take to achieve this goal. Although achieving the goal of the Paris Agreement and the future depicted in Sky 1.5 while maintaining a growing global economy will be extremely challenging, today it is still a technically possible path.

Shell's operating plan, outlook and budgets are forecasted for a ten-year period and are updated every year. They reflect the current economic environment and what we can reasonably expect to see over the next ten years. Accordingly, Shell's operating plans, outlooks, budgets and pricing assumptions do not reflect our net-zero emissions target. In the future, as society moves towards net-zero emissions, we expect Shell's operating plans, outlooks, budgets and pricing assumptions to reflect this movement.

Also, in this Decarbonising Aviation: Shell's Flight Path report we may refer to Shell's "Net Carbon Footprint", which includes Shell's carbon emissions from the production of our energy products, our suppliers' carbon emissions in supplying energy for that production and our customers' carbon emissions associated with their use of the energy products we sell. Shell only controls its own emissions. The use of the term Shell's "Net Carbon Footprint" is for convenience only and not intended to suggest these emissions are those of Shell or its subsidiaries.

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