

Decarbonising Aviation: **CLEARED FOR TAKE-OFF**

Industry Perspectives

www.shell.com/DecarbonisingAviation
[#MakeTheFuture](https://twitter.com/MakeTheFuture)



IN COLLABORATION WITH

Deloitte.



CONTENTS

3	Introduction	49	Decarbonising Aviation: a New Approach
4	Report Objectives		Inflection Point – Ready for Take-off Solutions
5	Executive Summary		Market and Customer Demand
16	Where We Are Today		Regulatory Incentives
	The Drive to Decarbonise		Technology Alignment
	Decarbonising Harder-to-Abate Sectors		Clarity on Roles and Decision Making
	Carbon Dioxide Emissions in Aviation		Ease of Asset Replacement
	Ways to Reduce Aviation Emissions		Ease of Infrastructure Replacement
32	The Deadlock: Barriers to Decarbonisation	76	The Flight Plan: Accelerating Decarbonisation
	Decarbonisation Readiness Factors: Summary		Decarbonisation Pathway
	Market and Customer Demand		Flight Plan to 2030
	Regulatory Incentives		How it All Comes Together
	Technology Alignment	85	Acknowledgements and Sources
	Clarity on Roles and Decision Making		
	Ease of Asset Replacement		
	Ease of Infrastructure Replacement		



INTRODUCTION

Aviation connects people, provides global access to goods and services, and has played a vital logistical role in the fight against COVID-19. It is fundamental to the world economy and in 2019, supported \$3.5 trillion (4.1%) of the world's GDP. In the same year, before the pandemic, 4.5 billion passengers took flights. But it was also a source of around 3% of global carbon dioxide emissions. And aviation could represent up to 22% of global emissions by 2050, as other sectors decarbonise more quickly.

There is a lot at stake when it comes to the future of aviation. If the industry is to cut carbon emissions at the speed and scale needed, it must act together to make change. The International Air Transport Association, which represents most of the world's airlines, aims to halve net emissions by 2050 (from 2005 levels). But the industry must go further and faster if it is to achieve net-zero emissions.

This means not only setting out a clear route to net-zero emissions but showing greater ambition and stronger leadership. Roughly half the industry has committed to achieving net-zero emissions by 2050, including suppliers such as Shell, but we must all do more – and collaboration is critical.

We have to work together to understand the challenges, then identify and agree on solutions. This report is a starting point.

It brings together more than 100 aviation business leaders and industry experts representing 68 global organisations. I would like to thank them all for their time, energy and enthusiasm. The resulting report explores the sector's net-zero targets and what is needed to meet them. The report seeks to answer three key questions: why the sector should change, how it can change and how fast this change can happen. It is accompanied by a report on the actions Shell itself is taking. At Shell we are exploring routes to zero-carbon aviation, including hydrogen, sustainable aviation fuels (SAF) and nature-based solutions.

The report shows how a complex industry has the potential to make even greater progress, provided the right parties – government, customers, energy companies or airlines – are aligned on the right actions.

Take SAF, perhaps the most promising of today's solutions for cutting carbon emissions. There are still many challenges before it can be deployed at the scale needed. They include the need for greater availability of raw materials, better supply infrastructure and clearer policy to encourage production. These elements have to come together – and the faster, the better.

So, whether your employees would normally fly for business, or your company transports cargo by air, or you are an airline hoping to use more SAF – we invite you to collaborate with Shell. Together, we can work to identify opportunities to lower carbon emissions in your operations and help the sector achieve net-zero emissions by 2050.

This is the third report we have published with Deloitte on decarbonising sectors where low-carbon change is hardest to achieve. All three share a common message: whether you operate exclusively in aviation or have a supply chain that also spans road freight or shipping, it is time for action.

As Executive Vice President of Shell's Sectors & Decarbonisation business, I believe these reports show how much potential there is for change if we act quickly enough. The industry has a chance to reset after the global shock of the pandemic. By working together, I believe we can make the aviation sector fit for a net-zero world.



Carlos Maurer
Executive Vice President,
Sectors and Decarbonisation
Royal Dutch Shell

REPORT OBJECTIVES

This report reflects the perspectives of over 100 executives and experts, representing 68 organisations across almost all segments of the aviation sector, complemented with input from 6,000 travellers worldwide, both leisure and corporate. (see Exhibit 01). It aims to:

- Take a comprehensive view.**
 Many decarbonisation studies focus on specific challenges or stakeholder groups in isolation. Given the interdependency of factors, the sector needs a more comprehensive view, which includes economic, regulatory and organisational factors. This report builds on the existing body of knowledge in the market.
- Reflect the voice of the sector.**
 No one stakeholder group can do this alone, and everyone will have a role to play. It is essential to understand the unique motivations and challenges of different groups and locations, for the sector to be able to take collective action that will make an impact.

- Accelerate the pathway to net-zero.** Aviation experts who participated in this research are at a point where they need to make decisions around decarbonisation. We worked with them to converge on a set of solutions and a flight plan that can help the industry act now and clarify the path forward.

This report reflects the insights industry executives and experts shared with us through interviews and working sessions with the industry, not the views of Shell or Deloitte. All engagements with participants were conducted in a manner that respects competition law boundaries.

01 Research participants

102 aviation executives and experts...

35 CEOs and senior executives	33 Sustainability leads and experts	21 Technology leads and experts	8 Policy and regulation specialists	5 Strategists
--------------------------------------	--------------------------------------------	----------------------------------------	--------------------------------------------	----------------------

...representing 68 global organisations...

18 Commercial airlines and cargo airlines	6 Airports	9 Shippers and corporates	9 OEMs, technology and infrastructure providers	10 R&D and financial institutes	8 Industry groups	8 Regulators and NGOs
37 Europe			21 North America		10 Asia & Rest of the World	

...and 6,000 travellers worldwide

3,000 leisure travellers	3,000 corporate travellers	Across 6 countries: Australia, Canada, China, Germany, UK and USA
---------------------------------	-----------------------------------	--------------------------------------------------------------------------

Note: Regions indicate organisations' headquarters. Most organisations involved operate globally. Aviation executives and experts were consulted in individual one-on-one interviews. Travellers were consulted through a detailed survey. OEMs refers to original equipment manufacturers.

Executive Summary



Aviation is fundamental to the world economy, supporting \$3.5 trillion (4.1%) of the world's GDP¹. It helps foster cultural exchange and provides global access to goods and services. Throughout the COVID-19 pandemic, the industry has provided vital logistical support in the fight against the virus: empty planes have been modified to carry personal protective equipment (PPE), vaccines and other essential cargo. The sector also connects people around the world. The lockdowns of the past two years have accentuated the need for human contact, and aviation allows people to fly to see friends, relatives and business relations.

But aviation is also a source of around 3% of global carbon dioxide (CO₂) emissions, and as the global economy continues to develop in the coming years – with new parts of society joining the middle class – aviation volumes will grow. The pandemic may have caused some changes to the future of air travel, as people find new ways to meet virtually and work remotely. But the long-term forecasts suggest that overall, COVID-19 is unlikely to have a lasting impact on aviation volumes. If nothing is done, emissions are expected to more than double by 2050 (from 2019 levels).

Through our engagement with over 100 executives and experts across the global aviation industry, we have broken down what is often seen as an insurmountable problem into manageable components. We did that by focusing on three core questions: Why should the sector change? Can the sector change? How fast can the sector change? This produced nine main research highlights (see Exhibit O2).

02 Research highlights

<p>Why should the sector change?</p>	<p>1. Aviation has often been considered a sector that will decarbonise later than others, because of the complexity involved and the view that aviation accounts for “just 3% of global emissions”. But there is a need to act now.</p>	<p>3. Long-term customer demand, enabled by recognition mechanisms and differentiated propositions, will play a fundamental role in providing the funding and incentives for airlines to invest in lowering their emissions.</p>
<p>Can the sector change?</p>	<p>2. The sector is facing several barriers to decarbonisation, mainly:</p> <ul style="list-style-type: none"> ▪ targets are insufficiently ambitious, unsupported by local regulation, and constrained by the perceived need for international alignment; ▪ cost of Sustainable Aviation Fuel (SAF) is prohibitively high, with many in the sector expressing uncertainty about how to reduce it and concerns about the availability of feedstock; ▪ leisure passengers are reluctant to absorb the cost of lower emission solutions; and ▪ concerns about offsets relating to quality, transparency and communications lead to limited uptake. 	<p>4. Country- and region-based policy incentives relating to supply and demand will accelerate the adoption of SAF and regulation at regional and global level.</p>
<p>How fast can the sector change?</p>	<p>6. Choosing SAF as the primary means of decarbonisation will have a disproportionate impact on lowering emissions, because there is no need to redesign aircraft. As a result, investments and R&D efforts can focus mainly on scaling production and lowering cost.</p>	<p>5. Offsets can play an essential role in funding the early stages of decarbonisation. But for this to happen, they must be made more transparent and verifiable. They need to be more emotionally appealing to passengers, and their impact should be clearer.</p>
		<p>7. Collaboration with other sectors is essential to the successful deployment of SAF. It can drive down the cost of required technologies, such as hydrogen production, direct air capture and biomass conversion, and ensure effective use of scarce resources.</p>
		<p>8. The pathway to decarbonisation needs to be more ambitious and investments need to start sooner to address societal expectations, reach sufficient SAF volumes and bring down cost to the levels required for large-scale adoption within 15 years.</p>
		<p>9. Individual initiatives should be integrated into comprehensive plans representing all points along the value chain – from energy producers to end-customers. These plans should be systematically deployed in areas with favourable policies, market conditions, and access to SAF.</p>

1. RESEARCH HIGHLIGHT

Aviation has often been considered a sector that will **decarbonise later than others**, because of the complexity involved and the view that aviation accounts for “**just 3%** of global emissions”. But there is a **need to act now**.

Aviation has been excluded from some major efforts to tackle climate change, because decarbonising the sector is perceived as complex and it currently accounts for 3% of global emissions. For example, aviation was excluded from the Paris Agreement on climate change and partly excluded from the EU Emission Trading System (ETS), which only counts flights within the EU.

“Policymakers and those within the sector use the proportionately low emissions as an excuse to defer action,” said one NGO.

But, as other sectors decarbonise, aviation’s share of total emissions will increase. Many participants in this research said that it is now time to increase the global focus on aviation decarbonisation. We have a chance to redefine the way we fly; to break the link between aviation and emissions.

To make meaningful progress in reducing emissions in the next 20-30 years, the aviation sector must make more use of the options available now.

One of the most important of these options is sustainable aviation fuel (SAF). It comes in a variety of forms, the large majority of which have lower life-cycle greenhouse gas emissions than conventional fossil fuels. All forms of SAF have the further advantage of being drop-in fuels, meaning they can be used without the need for major changes to aircraft design or supporting airport infrastructure.

Offsets are another option that is available now. They allow passengers and other people in the aviation industry to compensate for the emissions by buying carbon credits generated by projects that either reduce the global stock of greenhouse gases – for example, by using plants to absorb CO₂ – or avoid adding to it – for example, by preventing deforestation. The result can be net-zero emissions, such as when the CO₂ emitted by a flight is cancelled out by the greenhouse gas absorbed by the offset project.

Interviewees suggested that these two options should be the priority to reduce emissions in the short term. At the same time, the sector must work to continue improvements in aircraft and operational efficiency, and develop the alternative propulsion technologies, such as batteries and hydrogen. These technologies offer the possibility of zero-emission flying, but



changing to them will be much harder than switching from kerosene to SAF. By starting to develop alternative propulsion technologies now, they could become viable for some applications by the late 2040s and 2050s.

Aviation is a highly concentrated industry, meaning that a relatively small number of manufacturers, airlines and airports have a

large share of their respective markets. This concentration of market share and influence means decisions can be made relatively quickly and have a global impact. But the sector’s long investment horizons and fleet renewal cycles mean that aviation must act now to sufficiently reduce emissions by 2050.

2. RESEARCH HIGHLIGHT

The sector is facing several barriers to decarbonisation, mainly:

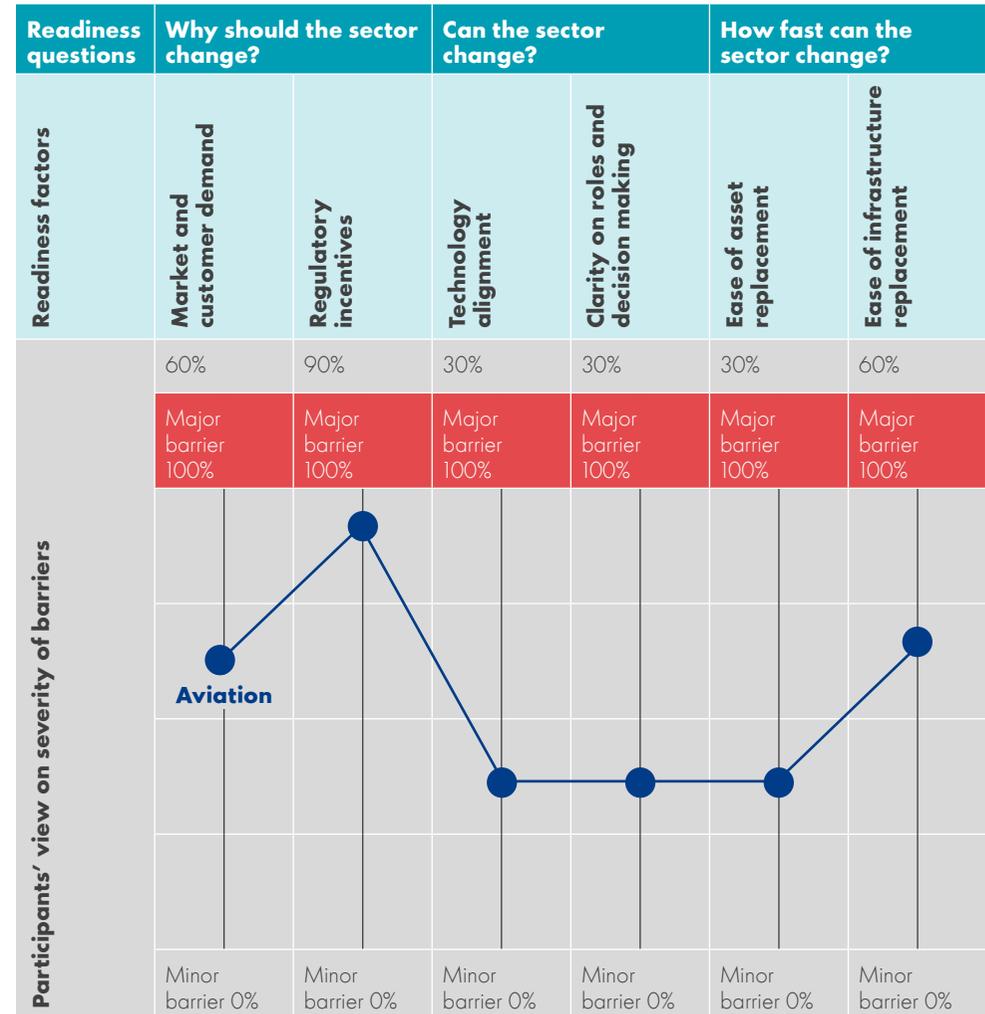
- **Targets are insufficiently ambitious, unsupported by local regulation, and constrained by the perceived need for international alignment.** This creates a widespread wait-and-see approach across the sector. “Targets without incentives – or without clarity on when those incentives will come – paralyse the industry participants,” said an airline representative.
- **Cost of SAF is prohibitively high, with many in the sector expressing uncertainty about how to reduce it and concerns about the availability of feedstock.** SAF today is two to eight times more expensive than traditional jet fuel, depending on the feedstock. If all kerosene on a typical long-haul flight were replaced with SAF tomorrow, without any policy incentives, this would equal an increase of 30–200% of airline operating costs or ticket prices. Within decades this could break even, as supply and demand grows and the cost of carbon increases. Bio-SAF, which is made from plant or animal material, such as crops, forestry or agricultural waste, is currently the cheapest form of SAF available, but its supply is structurally constrained and costs are likely to increase as readily available feedstocks are exhausted. Synthetic SAF is made using hydrogen obtained from low-emission sources and CO₂ captured from other industrial processes or captured from the air. The technology behind synthetic SAF is less developed than that for bio-SAF, so production costs are considerably higher. Synthetic SAF also competes with other sectors for hydrogen supplies, but it is thought that towards 2050 it could be cheaper and produced in bigger volumes than bio-SAF.
- **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. “It will be very difficult to pass on extra cost for sustainability to passengers who choose the cheapest seat,” said an interviewee from a research and development (R&D) organisation. Although 85% of surveyed leisure passengers say they are willing to pay to offset emissions, less than 1% do in practice. At the same time, corporate travel is likely to reduce in share after the pandemic, putting more pressure on airline margins, which might impact ticket prices for all passengers.
- **Concerns about offsets relating to quality, transparency and communications lead to limited uptake.** Some offsets are perceived to be of low quality and the market is fragmented with many standards and project types. Many relate to projects that have happened in the past, in places far removed from where emissions occurred, and with no clear link between the payment and the reduction of greenhouse gases. “People expect that when they pay for offsets, actual trees are planted somewhere in the world, and it’s still questionable whether that is happening or not,” said an aircraft operator. As a result, offset uptake is limited, which makes it difficult for the aviation sector to compensate for its emissions during the period when it is developing other ways to decarbonise.

These four barriers were mentioned most frequently by interviewees, but they also identified barriers relating to all six of the readiness factors listed in the Exhibit 03. One manufacturer said: “If you don’t have the assets, infrastructure, political support and the customers’ willingness to move, you will not proceed. All these elements have to be in place, and everyone has to be aligned – and we have to work on all those together.” As the manufacturer’s comment might suggest, “softer” barriers are also preventing the industry from making progress, such as an incremental mindset, a lack of co-operation

across the sector, and the tendency to work on many scattered and small-scale initiatives, instead of approaching the problem in an integrated way.

Overall, while aviation is a hard-to-abate sector, drop-in fuels will reduce the need for new aircraft and infrastructure. Sectors like road transport will need to change the asset fleets, produce the alternative energy carriers like batteries and hydrogen, and set up the infrastructure required to supply them. Aviation can take advantage of existing aircraft and refuelling infrastructure.

03 Barriers to decarbonising aviation¹



Notes: 1) Based on SAF drop-in solution. Ease of asset replacement and ease of infrastructure replacement will be more of a barrier for battery electric and hydrogen aircraft





3. RESEARCH HIGHLIGHT

Long-term customer demand, enabled by recognition mechanisms and **differentiated propositions**, will play a fundamental role in providing the **funding and incentives** for airlines to invest in lowering their emissions.

Large corporate flyers like big tech, financial institutes and consultancies, and cargo shippers like food and electronics manufacturers need to lead in creating demand for lower-emission aviation. Their own net-zero ambitions require them to reduce emissions from employee travel and transporting goods. Many of these customers are less price-sensitive than leisure passengers, because air travel typically accounts for a relatively small proportion of their costs. Aggregating the corporate demand for

SAF and offsets creates a market pull that incentivises airlines to act.

Leisure passengers must also be encouraged to play their part, through offers related to SAF and offsets that reward customers for supporting decarbonisation. These rewards can either be functional, such as priority boarding or meal upgrades, or more emotional, such as dedicated seats or waiting areas. One airline said: **“We started offering more loyalty points for customers who use offsets, and adoption grew well beyond the 1% industry average.”**

4. RESEARCH HIGHLIGHT

Country- and region-based policy incentives relating to supply and demand will **accelerate the adoption of SAF** and regulation at regional and global level.

Net-zero targets need to be set for 2050, with ambitious interim steps for 2030, to align aviation with the rest of the energy system, and to create the urgency to act now. Targets should be underpinned by policy measures. On the supply side, fuel producers can be triggered to invest in producing SAF through blending mandates, contracts for difference, tax credits and market-based incentives like California’s Low-Carbon Fuel Standard. On the demand side, incentives around buying choices can be created by route restrictions, pricing mechanisms and fossil-fuel taxation – for example, a carbon tax or an emissions trading scheme.

The sector does not need to wait for global regulatory alignment – country- and region-based policies that target key transportation hubs and flagship routes will go a long way to creating momentum. Examples can be found in recent announcements in the UK to include aviation in the national footprint², and Germany’s synthetic-SAF roadmap³.

5. RESEARCH HIGHLIGHT

Offsets can play an essential role in funding the early stages of decarbonisation. But for this to happen, they must be made **more transparent and verifiable**. They need to be more **emotionally appealing** to passengers, and their impact should be clearer.

Offsets 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 the sector.

Offsets will probably also play a role in the longer term, while SAF supply and demand scales, and to address the remaining 20-40% of emissions relating to bio-SAF.

With this in mind, the sector must address the concerns about offsets. Aviation must better

communicate the important role they can play in decarbonisation. It must make sure that all offsets are subject to rigorous standards and assurance mechanisms, and that customers know this. Offsets can be made more emotionally appealing to customers by including more projects that remove CO₂ rather than those that avoid emitting it, as well as more projects that are closer to passengers' homes and businesses. The way offsets are marketed and sold should also be improved - for instance, by moving towards an opt-out rather than an opt-in approach.

Interviewees flagged "insetting" - where funds raised are used directly within the sector - as an example for how the industry could keep investments within the sector to promote R&D and SAF production.

6. RESEARCH HIGHLIGHT

Choosing SAF as the primary means of decarbonisation will have a disproportionate impact on lowering emissions, because there is no need to redesign aircraft. As a result, **investments and R&D efforts can focus** mainly on scaling production and lowering cost.



Using SAF as the main way to decarbonise in the next 20 to 30 years creates focus. By converting a few production sites to bio-SAF around key hub airports, entire routes and even regions can be decarbonised relatively quickly. By investing early in synthetic SAF to move production from small quantities in labs to sustained scale production, widespread SAF use can be made possible. Towards 2050, research participants expect bio- and synthetic SAF to contribute to over 60% of the reductions in emissions from aviation.

Demand for SAF can be significantly accelerated by increasing transparency around feedstock, reducing friction in

the purchasing process, greater use of certification, simplicity in communications, and using “book and claim” mechanisms to open up access to those who are far from points of supply.

New financing mechanisms should also be developed to create clarity on returns. An indexed investment fund could help investors spread technology risk across multiple projects and help attract institutional investors in the early stages of the transition.

7. RESEARCH HIGHLIGHT

Collaboration with other sectors is essential to the successful deployment of SAF. It can **drive down the cost of required technologies**, such as hydrogen production, direct air capture and biomass conversion, **and ensure effective use of scarce resources**.

Many of the technological developments needed to produce SAF at scale and lower its costs will also be useful for other sectors. For example, bio-SAF requires exploration of new bio-feedstocks and innovation in new production pathways - both of which can help decarbonise sectors such as chemicals

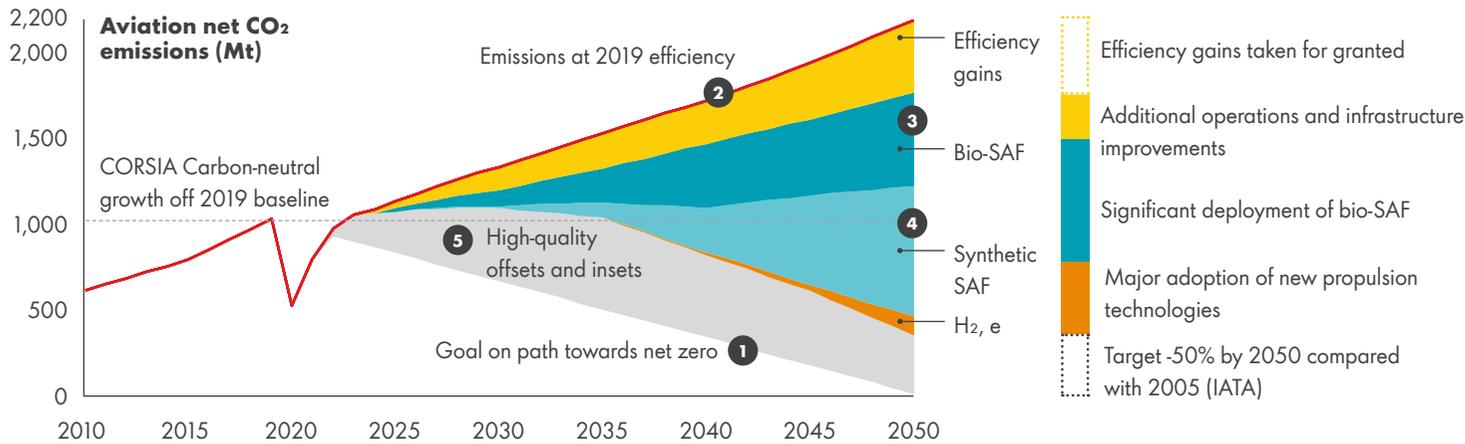
and shipping as well. Synthetic SAF requires significant improvements in large-scale electrolyzers that can produce zero-carbon “green hydrogen” by using renewable electricity to split water into oxygen and hydrogen. The steel, road freight, shipping and fertiliser sectors also need green hydrogen to help their decarbonisation efforts. More efficient technologies are also needed for capturing CO₂, which will be required to produce synthetic SAF. These technologies include carbon capture storage and utilisation (CCSU), where CO₂ comes from other industrial processes, such as steelmaking, and direct air capture (DAC), where CO₂ would be extracted directly from the air. These technologies will also have wide-ranging applications beyond aviation.

Companies across different sectors should pool their resources and direct them to the most promising R&D projects. Those companies or organisations operating across these sectors like energy providers, financiers and research institutes will need to play a critical coordination role. In this way, the required technologies are likely to develop more quickly than if each sector worked on them alone. While collaboration will be critical to accelerate progress, cross-sector coordination and policy measures will be needed to help ensure limited feedstocks are directed to where they can have the largest impact.



Shell's Energy and Chemicals Park Rheinland, Germany, home to Refhyne European consortium PEM hydrogen electrolyser.
Photo credit: © Dieter Jacobi/welcome for Shell International Ltd.

04 Decarbonisation pathway – sector sentiment



Sources: interviews; ATAG (2020); IATA (2021); ICAO (2019); Shell Energy Transformation Scenarios (2021); Deloitte analysis

Main differences compared with typical industry report

- Net zero by 2050
- Efficiencies not taken for granted
- Bio-SAF potential limited
- Synthetic SAF scale-up sooner
- High-quality carbon offsets and insets

8. RESEARCH HIGHLIGHT

The pathway to decarbonisation needs to be more ambitious and investments need to start sooner to address societal expectations, reach sufficient SAF volumes and bring down cost to the levels required for large-scale adoption within 15 years.

Most research participants take it for granted that a net-zero emissions target will soon be adopted for aviation.

One airline executive said: *“Society does not accept aviation’s special status anymore. We need to decarbonise, as do all other sectors, to remain credible.”*

A net-zero target will require a significant acceleration of efforts, now (see Exhibit 04).

Investment must be significantly accelerated – or front-loaded – compared with typical plans, and need to span all currently feasible decarbonisation options – efficiency, bio-SAF, synthetic SAF and offsets. No single option alone can reduce net emissions by the required amount and the options themselves should be approached differently than at present.

The pathways for decarbonising aviation are directionally right, but the details need changing.

Airline executive

Firstly, many interviewees said the sector should stop taking efficiency improvements resulting from better aircraft design or operations for granted. They are an important way to reduce fuel usage and emissions, but will become increasingly difficult to achieve.

Secondly, energy companies and other aviation stakeholders must accelerate developing synthetic SAF sooner and at larger scale than previously assumed, because there is uncertainty about the availability of

sustainable feedstock for bio-SAF – especially in the long term. Investing in both types of SAF will make it possible to scale-up production and bring down cost to the levels required for large-scale adoption, which can already happen within 15 years.

Thirdly, aviation must significantly increase the uptake of offsets and ensure that they all meet rigorous quality standards. This will be especially important in the short term, while SAF is still being fully developed.

Finally, continued investment in alternative propulsion technologies is needed, to prepare the sector for a truly decarbonised future – even if such technologies will make limited contributions before 2050.

9. RESEARCH HIGHLIGHT

Individual initiatives should be **integrated into comprehensive plans** representing all points along the value chain – from energy producers to end-customers. These plans should be **systematically deployed** in areas with favourable policies, market conditions, and access to SAF.

Industry stakeholders identified 15 solutions, or recommendations for action, to overcome the barriers to decarbonisation and accelerate aviation’s progress. Some of these are already being investigated. Others are new, or provide a more efficient way to overcome a specific barrier (see Exhibit O5).

In the short term (2022-25), the focus should be on solutions that **“unlock”** progress. This phase includes demand commitments from corporate and cargo customers, developing offers for leisure passengers that support sustainability, and improvements around offsets. This stage should see large-scale investments

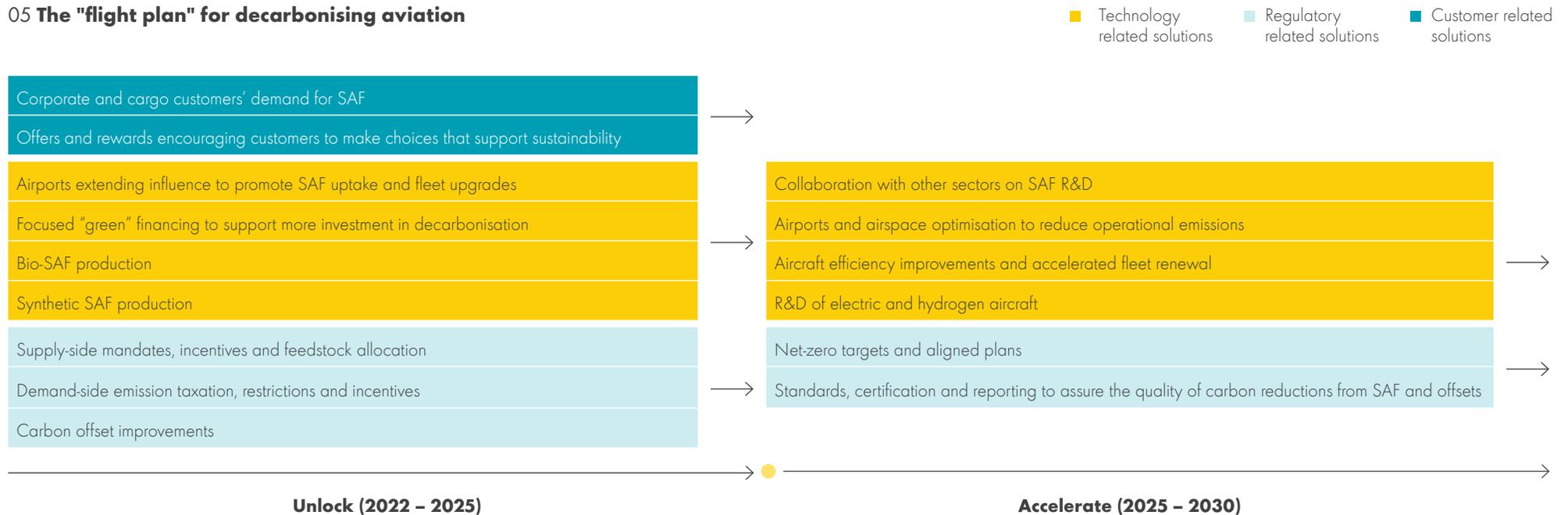
in SAF production – particularly in regions with the most favourable policy and customer environment, for example in USA and North-western Europe. Policymakers and financiers should support initial investments with targeted incentives.

The **“accelerate”** phase (2025-2030) follows. Net-zero targets for 2050 are likely to be widely adopted. R&D and supply partnerships will be formed to enable more SAF to be produced, at lower cost. Operational efficiencies from fleet renewal and optimising the use of airspace will enable further reductions in fuel consumption, making

SAF use more economically viable. Standards, certification and reporting will make it easier to track progress. Progress will also need to be made around electric and hydrogen aircraft to accelerate the development of technologies which can enable zero-emission aviation. Putting these solutions in place by 2030 will allow the sector to lay the foundation required to decarbonise by 2050.

Although each solution is important on its own, the true value lies in their combined deployment, applying the principle of “think big, start small, scale fast.”

05 The “flight plan” for decarbonising aviation



Note: Timing of solution is related to period in which most activities are expected; however, most solutions require effort across short, medium and/or long term



We cannot wait for a technical salvation, we must act now using all the options that are available today.

Travel agent

The first net-zero value chains and regularly scheduled net-zero routes can be created relatively quickly in some places. They will require favourable factors such as supportive regulation, a strong connection between airports, a significant proportion of environmentally conscious business travellers, and an ability to increase the production of SAF. Such an environment could allow airlines to use SAF and high-quality offsets to launch their first regular net-zero flights. Beyond having a marketing effect, such connections would create scale in demand, which would make it cheaper to produce SAF. They would allow airlines to test customer offers that support sustainability before putting them on other routes in the expectation that they will gradually become industry standard. These net-zero value chains should be systematically expanded as technologies mature and market conditions improve.

We just need to have one systematic sustainable flight route that operates daily, and very quickly others will follow – because they will have to.

Energy expert

Interviewees recognise that the challenge of decarbonising aviation is too large for any one organisation or even one stakeholder group to solve alone. But a joint effort will allow aviation to launch specific solutions in the short term, and hit crucial targets in the long term. First movers are likely to reap the benefits of early access to insights that set them apart. They are likely to be able to share risks and investments, and influence outcomes in their favour. Engaging with their customers and others in the aviation sector during the early phases of the transition will pay dividends for such relationships in the future. As these early initiatives expand, momentum will build, and more companies will join to create the necessary scale and impact across the sector.

In this way, decarbonising aviation will be **cleared for take-off.**

Where We Are Today



THE DRIVE TO DECARBONISE

The 2015 Paris Agreement defined a bold ambition to limit global warming to below two degrees Celsius above pre-industrial levels and pursue efforts to limit it to 1.5 degrees Celsius. This is to be achieved partly by getting the world to net-zero greenhouse gas emissions (carbon neutrality) by 2050. In response, many countries, industries and individual organisations set goals and began developing plans to limit their carbon emissions. Action is being taken at global, national, regional and sector levels. There are many positive signs, but the United Nations Environment Programme still says: **“On current unconditional pledges, the world is heading for a 3.2 degrees Celsius temperature rise.”** Clearly, more needs to be done. Decarbonisation must be accelerated using more focused approaches that produce real action. Such approaches often need to be adopted by whole sectors. Sometimes – for example, when different sectors face similar difficulties – a more unified, cross-sectoral approach may be needed.



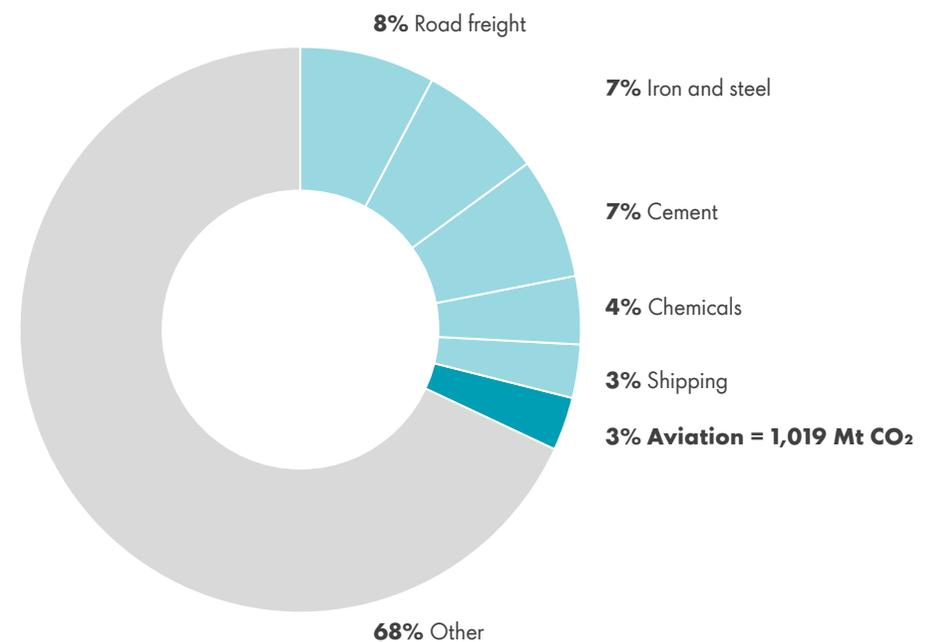
DECARBONISING HARDER-TO-ABATE SECTORS

There are six harder-to-abate sectors: road freight; iron and steel; cement; chemicals; shipping; and aviation. These sectors accounted for around 32% of global CO₂ emissions in 2019, according to the International Energy Agency (IEA) (see Exhibit 06). They share common characteristics, such as long asset lifespans, high energy dependency and being difficult to electrify. As a result, decarbonising these sectors might be more technically demanding and costly than other parts of the energy system. As decarbonisation happens more rapidly elsewhere, pressure and focus on harder-to-abate sectors will probably increase.

Although most emission-reduction targets, including the Paris Agreement, focus on carbon emissions that contribute to global warming, there are also non-CO₂ emissions that affect global climate. With aviation, these include nitrogen, sulphur, soot particles and the formation of contrails. Their impact on climate is complex, and there is uncertainty about how to quantify it⁴. As a result, while recognising that we need a deeper understanding of everything that contributes to global warming, this research focuses on how to reduce the aviation sector's CO₂ emissions – in other words, how to decarbonise it.

06 Global CO₂ emissions by sector (2019)

Six harder-to-abate sectors account for a total of 32% of global CO₂ emissions



Source: IEA (2021)

CARBON DIOXIDE EMISSIONS IN AVIATION

Where we are: Aviation is fundamental to the world economy, global prosperity and national development.

Aviation greatly assists the socio-economic growth of nations. The sector supports \$3.5 trillion (4.1%) of the world's GDP⁵. If aviation were a country, its GDP would be the 17th biggest in the world⁶. For decades, there have been year-on-year increases in aviation volume, measured in revenue passenger kilometres (RPK) – the distances travelled by paying passengers. These increases have been caused by the globalisation of business and rising economic prosperity in much of the world.

In addition to the benefits described above, aviation has enabled the emergence of a global tourism industry, which contributes around 10% of global GDP⁷. The aviation sector connects people around the world, fosters cultural exchange, and provides global access to goods and services. It supports 11 million jobs directly – for example, in airlines and airports – and another

18 million indirectly, such as in fuel provision and construction⁸.

Aviation also provided vital logistical support in the fight against COVID-19. Empty aircraft were modified to move personal protective equipment (PPE), vaccines and other essential cargo across the world to help combat the pandemic.

The disruption caused by the pandemic has dramatically expanded the possibilities of remote working. Lockdowns, though, have also made many acutely aware of the need for human contact and the way air travel can reunite them with friends and relatives.

Some groups challenging the sector, such as the flight-shaming movement, give the impression that the way to reduce aviation's contribution to global warming is to stop flying altogether. These movements tend to ignore the significant economic and social benefits that aviation brings to individuals and nations. Research participants indicated that the unintended consequence of focusing so much



attention on flight avoidance, may be less focus given to developing solutions required to reduce emissions associated with flying.

Where we are: medium- and long-haul flights drive 87% of passenger aviation volume and 81% of emissions.

Around 11% of the world population – some 800 million people – fly⁹. On average, each person takes between five and six flights a year, which means that aviation carries around 4.5 billion passengers per year. These passenger flights account for 85% of aviation volume in terms of emissions and RPK¹⁰ (see Exhibit 07). Cargo flights account for the remaining 15% of emissions.

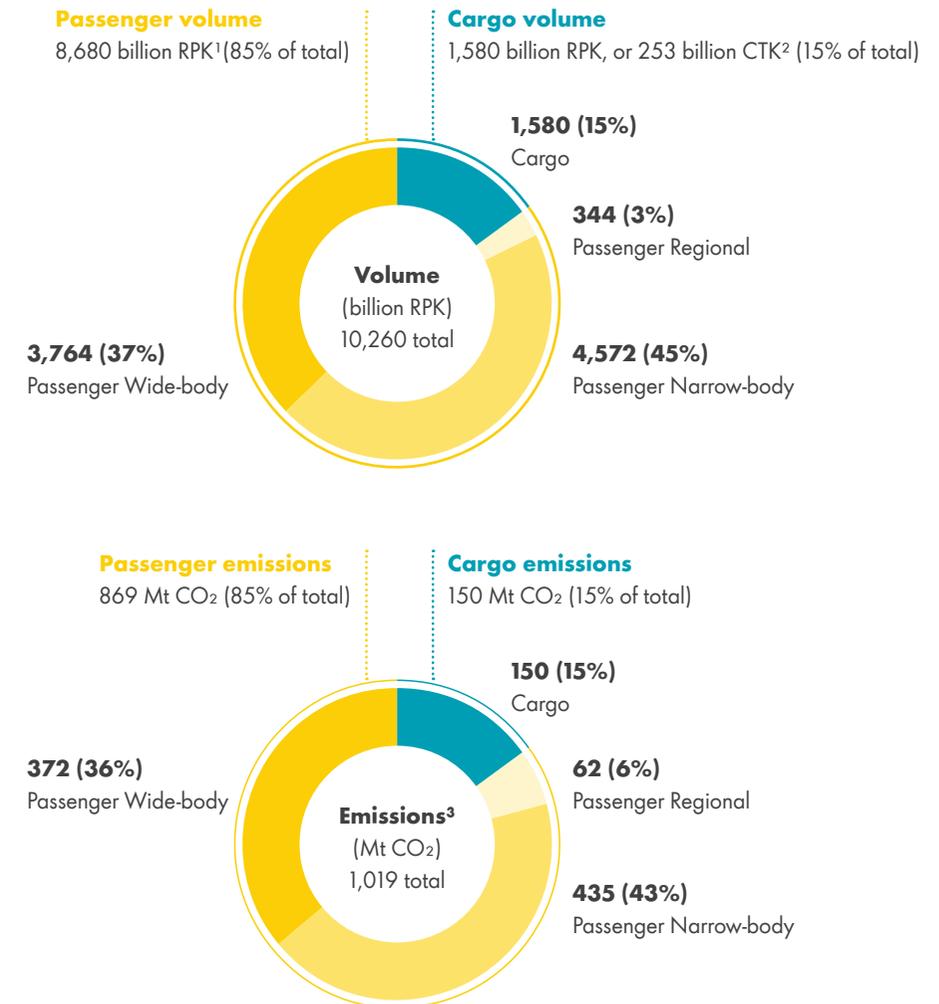
Short-haul flights – those under 1,000 km – account for 13% of passenger air travel (see Exhibit 08) and 19% of emissions. The emission intensity of short-haul flights is the highest, because with each departure, a significant amount of energy is required for the climb, accounting in many cases for more than half the total energy needed for the flight¹¹. However, the majority of emissions – 81% – originate from medium and long-haul flights.

Trains may offer a viable and more environmentally sustainable alternative to short flights in some countries. Some governments have recently introduced regulation to encourage such switches to alternative modes of transport, known in the industry as “modal shift”. For example, France introduced a ban on short-haul domestic flights where there are high-speed train alternatives. Austria and Germany have also announced plans to shift some short-haul domestic flight operations to the railways.

But in most lower-income countries – and many higher-income ones – the rail network is not developed enough to support a switch from flying to train travel. High-speed trains are only an option on a small number of routes in a handful of places, such as Japan, China and parts of Western Europe.¹²

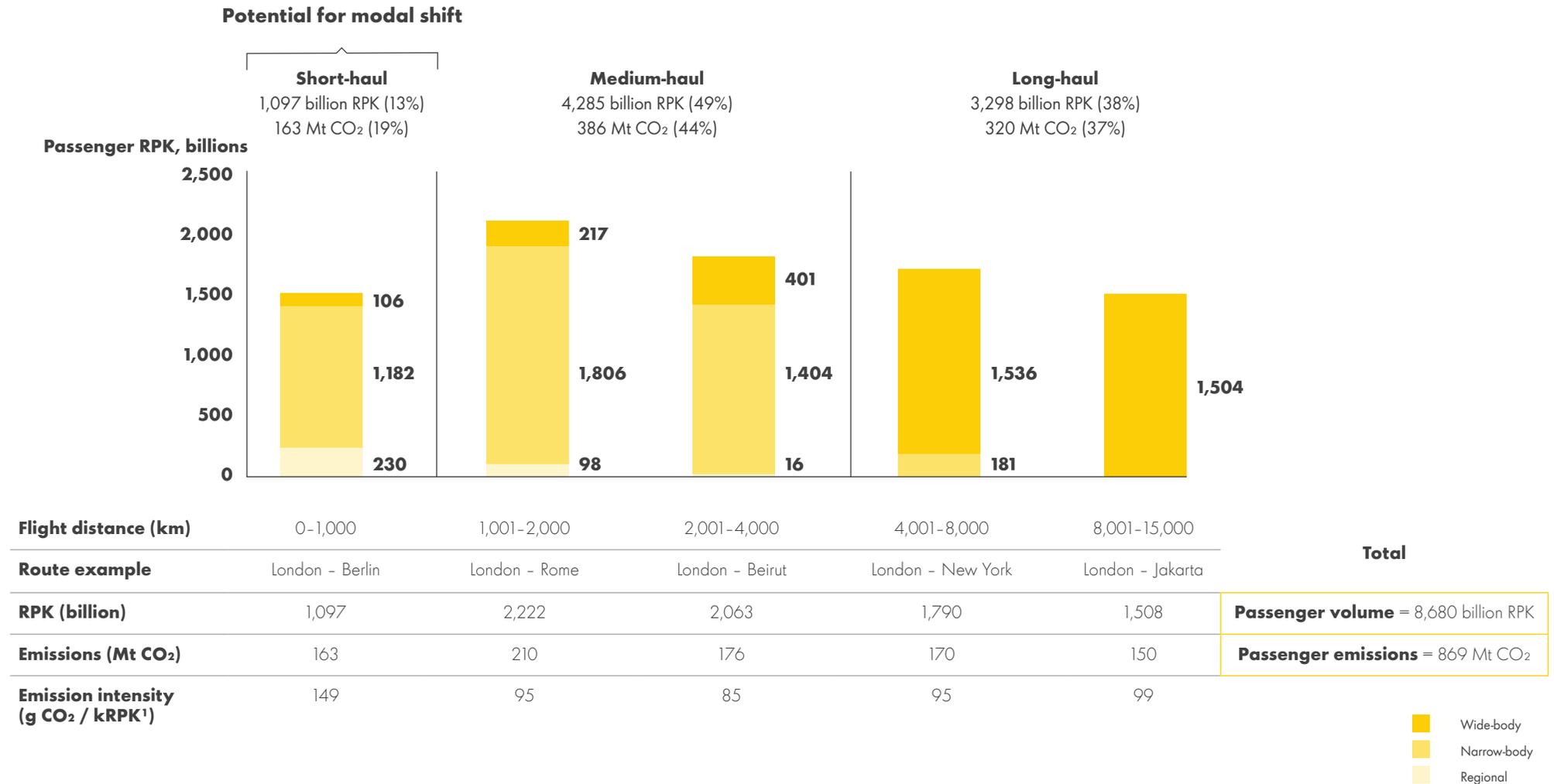
The longer the distance, the fewer the alternatives to aviation. Shifting from air to rail might, optimistically, only reduce emissions by around 45 Mt CO₂¹³, or around 5% of passenger emissions globally. One airline said: **“Modal shift receives a lot of attention in certain countries, but its global impact will be negligible.”**

07 Global aviation volume and emissions (2019)



Source: ICCT (2020); IEA (2021); Deloitte analysis
Notes: 1) RPK = Revenue Passenger Kilometres, indicates number of kilometres travelled by paying passengers; 2) CTk = Cargo Tonne Kilometres, estimated based on a passenger equivalent freight mass (PEFM) of 160 kg, one tonne divided by 160 kg is 6.25, therefore, 6.25 RPK is the equivalent of one CTk (Chandra et al., 2014), including belly freight and excluding luggage; cargo flights not allocated to specific aircraft class; 3) Metric megatonnes of CO₂

08 Passenger flights volume (RPK) by flight distance (2019)



Source: ICCT (2020); IEA (2021); Deloitte analysis

Notes: 1) g CO₂/kRPK stands for grams of CO₂ per thousand revenue passenger kilometres

Where we are heading: Aviation volume is expected to more than double by 2050, driven by population and economic growth.

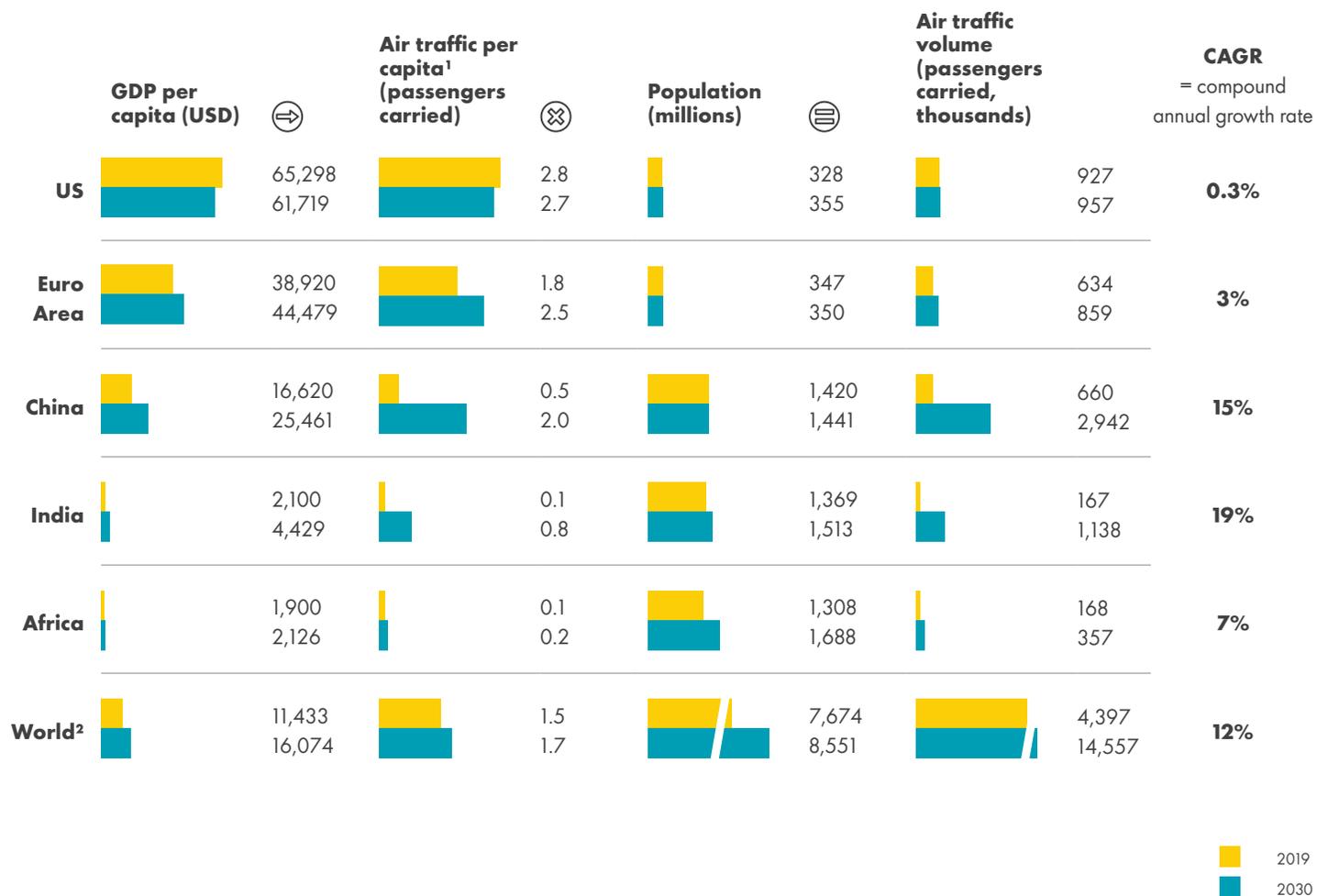
The growth in aviation volume has been the fundamental cause of the sector's increasing emissions. Aviation volume has historically developed in step with population growth and economic activity. Corporate and leisure travel have both increased in the past 30 years, when many people have risen from poverty to the middle class – especially in Asia.

Air travel reduced significantly during the COVID-19 pandemic, but this is not expected to have a lasting effect on aviation volume. Most observers expect aviation volume to grow in the coming decades, as global economic development restarts after the pandemic (see Exhibit 09). The growth in aviation volume is likely to be greatest in Asia and Africa, where population and economic growth are most pronounced.¹⁴

There will be growth in all regions for the decades to come, especially in places with a growing middle class.

Engine manufacturer

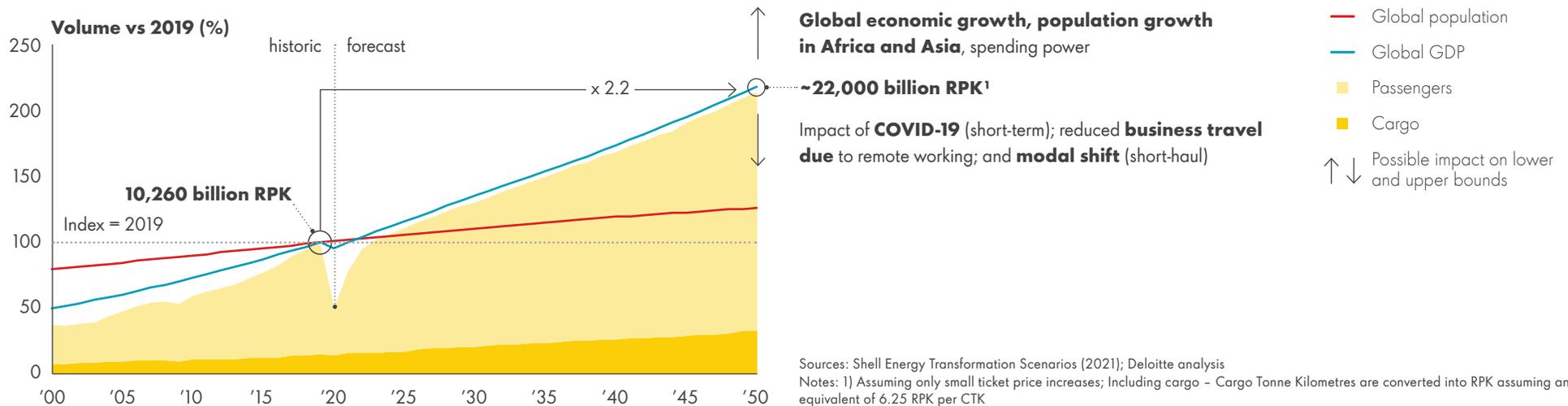
09 Drivers of air travel volume (2019, 2030 projected)



Sources: African Economic Outlook (2021); Bloomberg (2019); OECD (2021); Statista (2021); World Bank (2021); Deloitte analysis

Notes: 1) Air traffic per capita projection based on average historic trendline across all countries; 2) World average for GDP and air traffic per capita, and world total for population and air traffic volume

10 Expected aviation volume development (indexed, 2019 = 100)



A relatively conservative view is that in the next 30 years, passenger traffic will more than double from 2019 levels, to around 22 trillion RPK by 2050 (see Exhibit 10). “Developed” and “developing” countries are both expected to contribute to this growth; developed countries have yet to show signs of saturation, and in developing countries, people are starting to fly at lower income levels.

Long-term projections of aviation volume vary. For example, the IEA predicts 15.6 trillion RPK by 2050, while the Air Transport Action Group (ATAG) estimates 20 trillion RPK. The difference between these forecasts is primarily down to differing expectations of how the pandemic will affect passenger behaviour.

Corporate travellers are expected to be relatively slow to return to flying, having grown accustomed to remote working and digital meetings during the pandemic. Leisure travellers are expected to be much quicker to start flying again. **“People are keen to travel. Once the vaccines kick in and restrictions are lifted, many parts of the world could be back to normal next year,”** said one industry association executive. As COVID-19 travel restrictions are lifted, accumulated demand in the leisure segment is likely to help the sector quickly recover to pre-pandemic levels, or even exceed it on some routes.

Where we are heading: Unless the sector takes action, emissions are expected to

more than double by 2050, as aviation volume increases. Industry targets will be missed and net-zero will be way off.

The aviation industry has set two internationally applicable emissions-reduction targets.

The UN’s International Civil Aviation Organization (ICAO) has set an ambition to have carbon-neutral growth from 2020. This is to be achieved through the global Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)¹⁵.

The International Air Transport Association (IATA) has made a commitment to halve net

emissions by 2050 relative to 2005 levels. This would be equivalent to a 65% reduction in net emissions compared with 2019.

Many interviewees said these targets did not go far enough, given society’s growing expectations around energy transition. They thought the aviation sector should be pursuing full carbon-neutrality, (net-zero), by 2050, similar to many other sectors.

Historically, the main motivation for efficiency improvements in aviation has been economic. Reduced fuel consumption meant lower operating costs. Reductions in emissions tended to be seen as a welcome by-product of the efficiency gains. The main way of

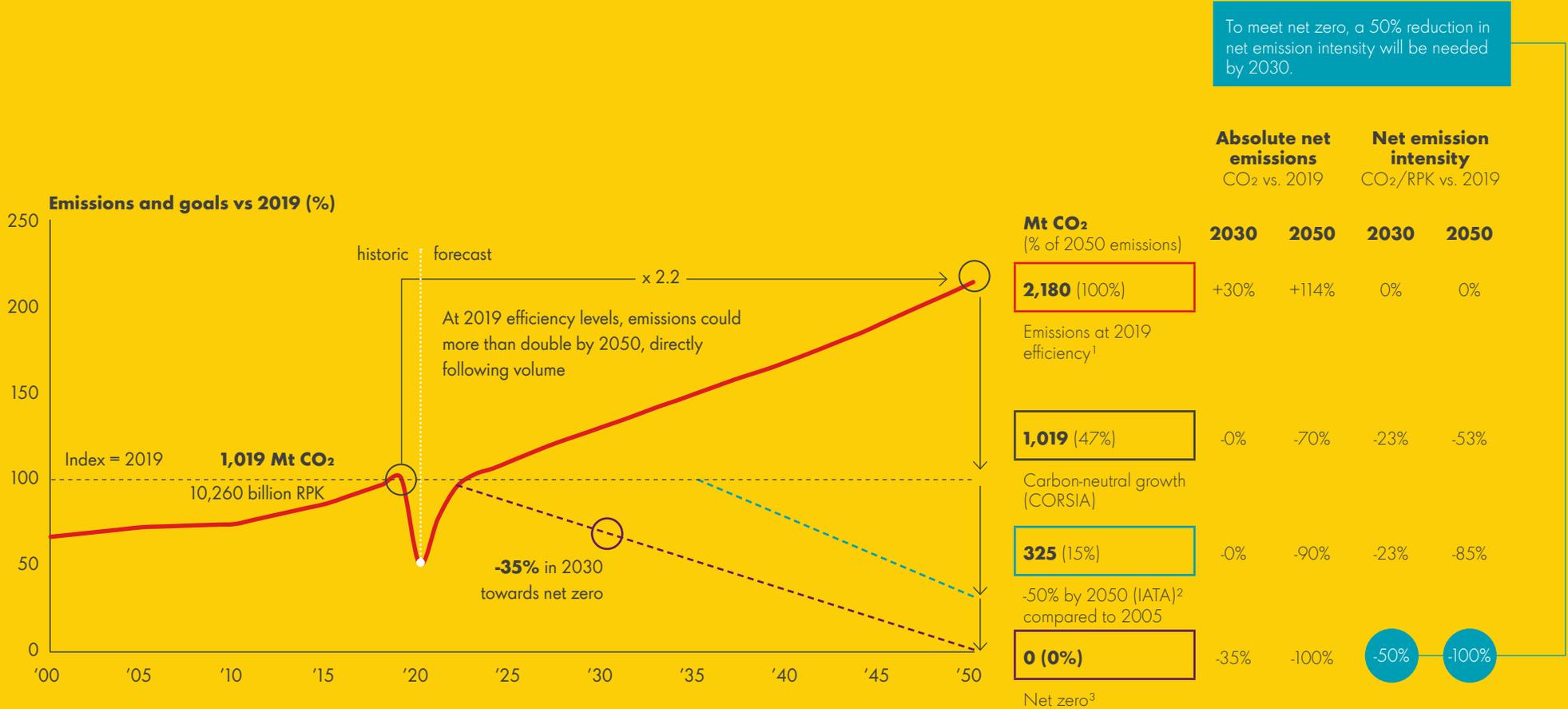


achieving efficiency improvements has traditionally been fleet renewal – changing an airline’s fleet of aircraft. For example, the Boeing 787 Dreamliner is 20-25% more fuel-efficient than predecessors such as the 767, because of improved aerodynamics, lightweight construction and more efficient engines¹⁶.

But interviewees said efficiency improvements will have less impact on total emissions in the coming decades, because their effects will be outweighed by rising aviation volume. At current efficiency levels, and in the absence of fundamental changes to the fuel mix, absolute emissions from aviation are expected to more than double in next 30 years compared with pre-COVID levels (see Exhibit 11). One airport operator said: **“Fuel efficiencies have been outpaced by growth. It is an absolute emissions game, not a relative one.”**

If we compare net-zero with business-as-usual levels of emissions, the gap in 2050 could be as large as 2,180 Mt CO₂. To put that figure in perspective, it would be similar to India’s carbon footprint in 2018 (2,650 Mt CO₂), which is the country with world’s third-largest carbon footprint after China and the USA¹⁷. It is believed that aviation needs to achieve a 35% reduction in absolute net emissions and a 50% reduction in net emission intensity by 2030 if it is to reach net-zero by 2050.

11 Aviation emission projection and goals (indexed 2019, Mt CO₂ = 1,019)



Sources: IATA (2021); ICAO (2019); Shell Energy Transformation Scenarios (2021); Deloitte analysis

Notes: 1) Emissions at 2019 efficiency directly follow volume; 2) IATA target starting from 2035 due to parallel commitment to CORSIA carbon-neutral growth until 2035; 3) Pathway towards net-zero target assumed to start from 2022 emission levels to prevent intensified burden to emission reductions at a later stage

Where we are: Aviation is a highly concentrated industry, which makes it easier to make progress around decarbonisation.

If we examine the global aviation fleet, we find that:

- the top two engine manufacturers account for around 75% of the market;
- the top two aircraft manufacturers have an over 90% market share;
- the top 25 airlines account for almost half of global volume; and
- of the 100,000 airports globally, the top 25 account for almost half of RPK and emissions.

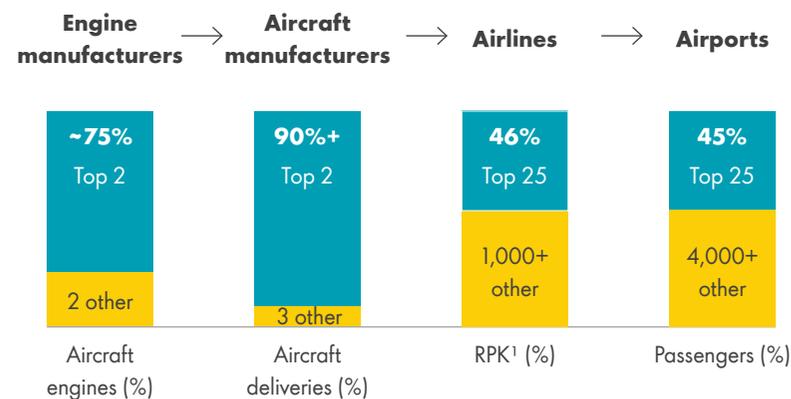
This means that aviation is a highly concentrated industry, in terms of manufacture, asset ownership and emissions (see Exhibit 12).

Many study participants said this concentration can help aviation to decarbonise. On the supply side, the high market shares of key engine and aircraft manufacturers, airports and airlines mean decisions can be made relatively quickly and have significant global impact.

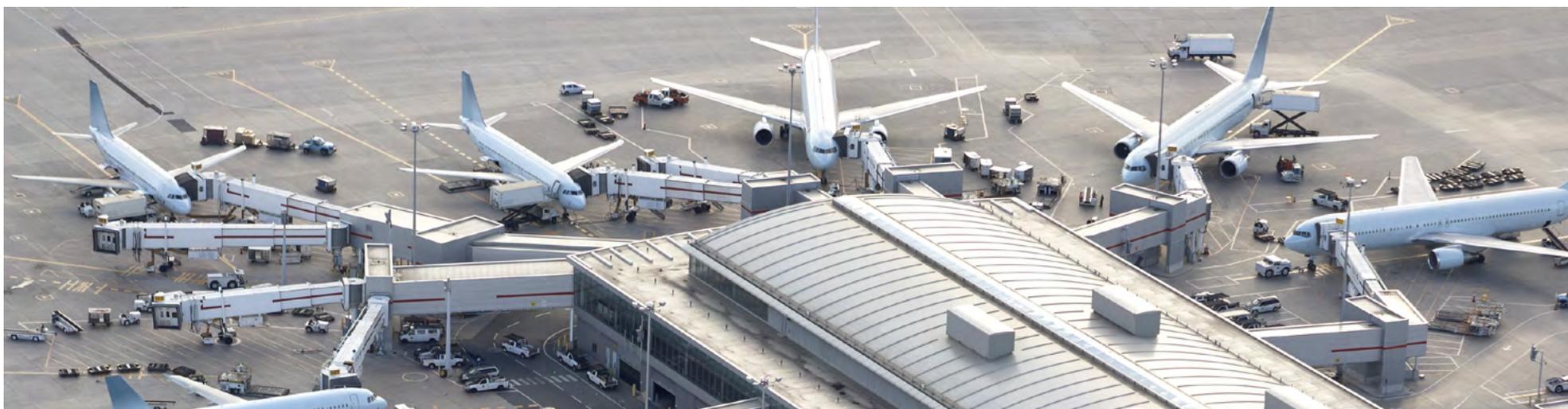
On the demand side, emissions are concentrated among frequent flyers. Out of around 800 million air passengers worldwide, 150 to 300 million individuals account for about half of all aviation emissions (see Exhibit 13).

The financial and behavioural support of this group of passengers will have a particularly significant role in helping aviation to decarbonise.

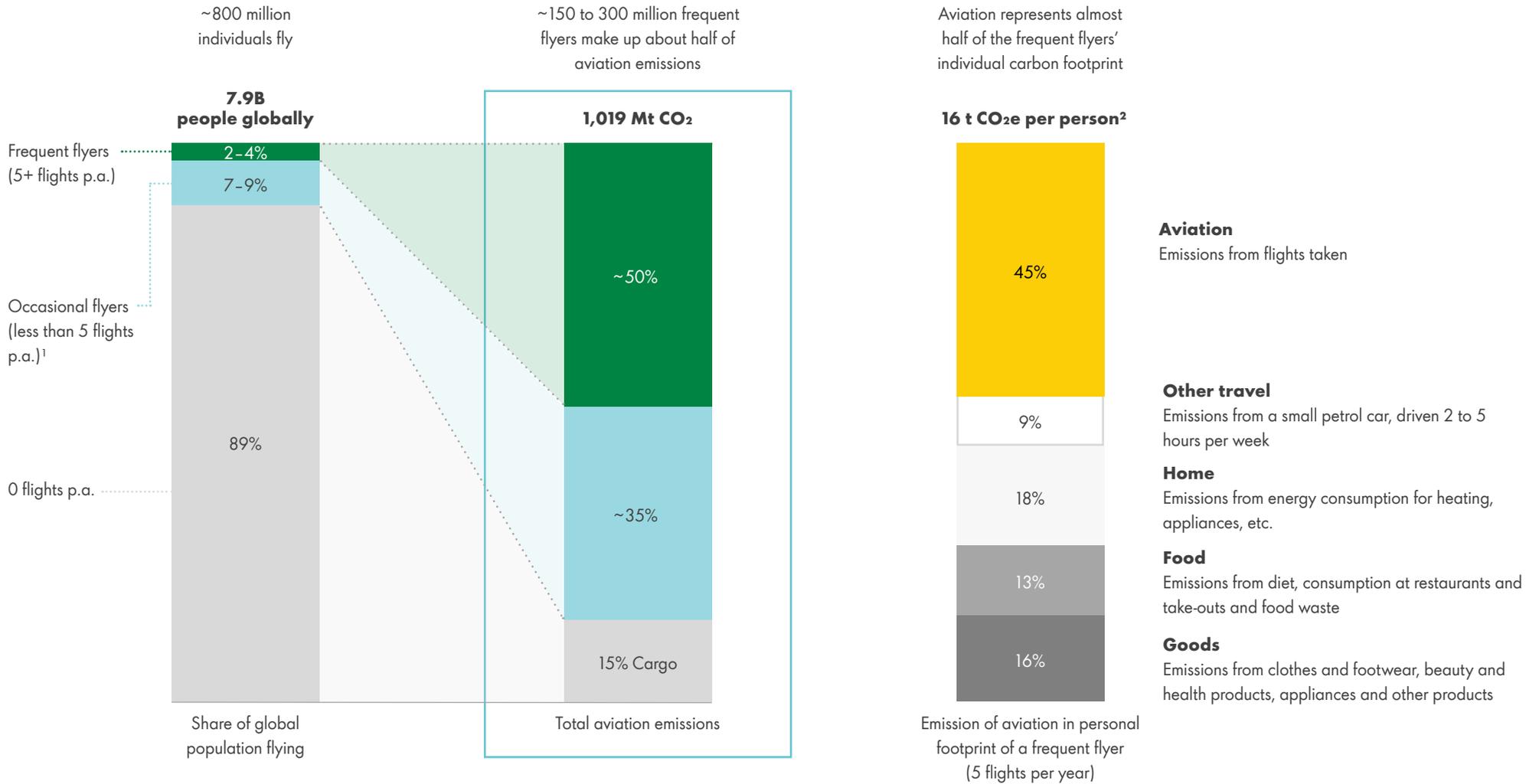
12 Market shares in aviation



Source: IATA (2020) WATS+; ICAO (2016) Air Navigation Report; ICAO (2019) Annual Report; RoutesOnline (2019) Busiest Routes in the World; Statista (2020) Engine Manufacturer Market Share; Statista (2020) Number of Jets Delivered to Global Fleet by Manufacturer; ICCT (2020); Deloitte analysis
 Notes: 1) Including cargo – Cargo Tonne Kilometres are converted into RPK assuming an equivalent of 6.25 RPK per CTK



13 Concentration of passengers and emissions – ILLUSTRATIVE



Sources: Centre for Aviation (2015); Gössling and Humpe (2020); ICCT (2019); UNFCCC (2020); WWF Footprint calculator (2021); Deloitte analysis
Notes: 1) Occasional flyers include individuals that take flights every few years; 2) Based on UK citizen, in tonnes of CO₂ equivalent

WAYS TO REDUCE AVIATION EMISSIONS

Where we are: The sector knows how to reduce emissions from aviation, and must increase the use of options available today. Otherwise, it will fail to do enough in the time left to tackle climate change.

Industry stakeholders expect SAF, efficiency improvements and significant increases in the use of high-quality offsets to play key roles in reducing emissions before 2050 (see Exhibit 14).

Changing to alternative propulsion technologies such as batteries or hydrogen will be much harder than just switching from kerosene to SAF. **“It will take decades to re-fleet aircraft and switch to new zero-emissions technologies,”** said one aircraft manufacturer.

It took more than 50 years to reach the current levels of performance and reliability in kerosene-based aircraft systems. Achieving similar performance and reliability with new systems based on batteries or hydrogen will

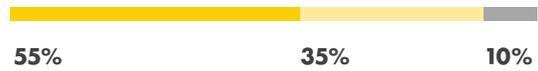
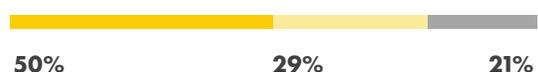
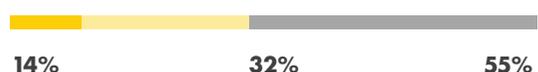
take decades, and may be impossible in some cases.

With electric power, battery weight and volume constraints would need to improve dramatically to deliver the same energy as jet fuel. This may make it impractical to transport an aircraft full of passengers on medium- and long-haul routes. Similarly, hydrogen requires four times the volume of jet fuel even when compressed to liquid form and stored at -250 degrees Celsius¹⁸. One manufacturer said: **“Hydrogen handling and storage is a serious challenge. Fuel cells simply cannot be scaled to support long-haul flights, and direct combustion will take years to develop.”**

One industry association executive said passenger and regulator concerns may also slow the adoption of the new technology: **“Even if a new technology is ready, it might not be socially accepted or approved by regulators because of safety considerations.”**



14 Aviation emission reduction options

Decarbonisation option	Description	Sector perspective on decarbonisation impact before 2050	Applicability	Sentiment (before 2050 perspective)
 Efficiency gains	Design and operations improvements to reduce fuel burn	 55% 35% 10%	All flights	Important option but impact diminishing over time
 Sustainable Aviation Fuels (SAF)	Fuels from sustainable resources to substitute fossil-based kerosene	 78% 20% 2%	All flights	Main decarbonisation option in the next 30 years; ability to use with existing aircraft
 Offsets	Investment in out-of-sector emission reductions or removal	 50% 29% 21%	All flights	Important to bridge the timing gap as other options are scaled up
H₂ Hydrogen	Combustion of (low-emission) hydrogen and/or conversion to electricity through fuel cell	 14% 32% 55%	Short- / medium-haul	Requires cryogenic storage and new airframe designs. Long time to develop, ensure safety, certify and deploy at scale
 Battery	Electric propulsion with zero emissions if charged with green electricity	 12% 14% 73%	Short-haul	Because of battery weight and size, only applicable on very short-haul routes
 Behavioural change	Reduction of demand resulting from remote working and modal shift	 15% 25% 60%	All flights	Any behavioural change likely to be outpaced by overall population and economic growth

■ Major impact ■ Moderate impact ■ Limited impact

Sources: Deloitte analysis

Another factor complicating the adoption of alternative technologies is what the industry refers to as “infrastructure lock-in”. Current infrastructure can be used with SAF, but new fuelling or charging capabilities would have to be built for hydrogen and electric-powered aircraft.

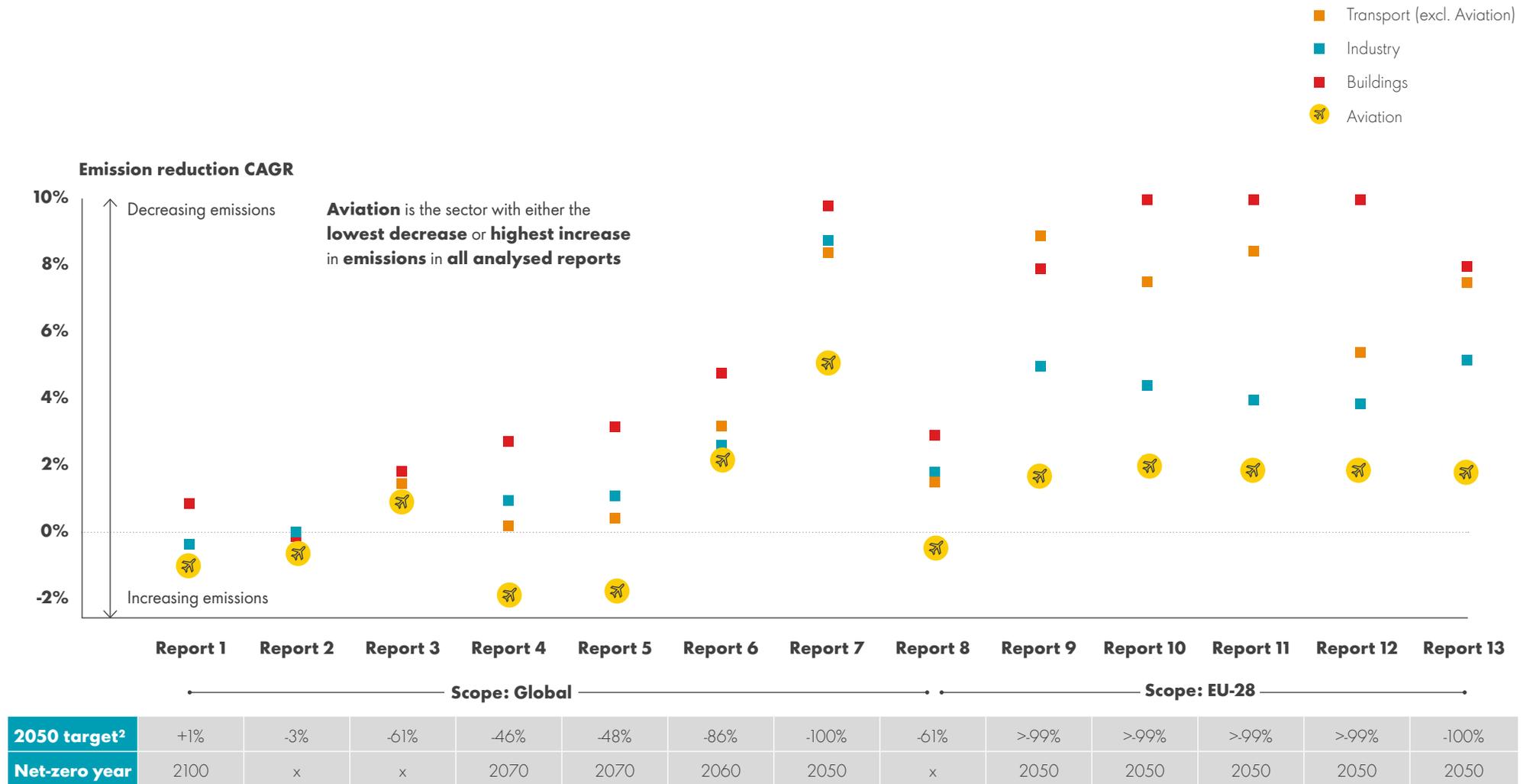
Everything is built around loading liquid fuel into an aircraft. Any other technology will be a tough nut to crack.

Airline executive

These obstacles mean the aviation sector cannot afford to wait for the new technologies if it wants to decarbonise in time. To make meaningful progress in the next 20-30 years, aviation must increase its use of the options that are available now. It should dramatically

increase its deployment of SAF, use more high-quality offsets, and seek further efficiency improvements. At the same time, aviation must also prepare for the longer-term future by working to develop the new technologies.

15 Pace of aviation decarbonisation compared with other sectors in previous industry reports¹



Sources: IEA (Energy Technology Perspectives - 2017, Net-zero by 2050 - 2021); Shell (Sky - 2018, The Energy Transformation Scenarios - 2021); European Commission (A Clean Planet for all - A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy - 2018); European Climate Foundation (Net-zero by 2050: From whether to how - 2018); Deloitte analysis

Notes: 1) CAGR is based on reduction/increase in emissions from baseline year to 2050. Baseline year differs per report; 2) Target across all sectors - not aviation-specific

1. RESEARCH HIGHLIGHT

Aviation has often been considered a sector that will **decarbonise later than others**, because of the complexity involved and the view that aviation accounts for “**just 3%** of global emissions”. But there is a **need to act now**.

In total, aviation accounts for around 3% of global CO₂ emissions¹⁹. This relatively small figure and the perceived difficulty of decarbonising aviation often leads to it receiving less focus as a means of getting the world to net zero. Main decarbonisation reports and scenarios give low priority to aviation compared to other sectors (see Exhibit 15), and policy measures often leave out aviation. For example, CO₂ emissions from aviation were only included in the EU Emission Trading System (ETS) in 2012, seven years after its launch in 2005, and the scope was limited to flights within the EU²⁰.

It will be difficult to create the conditions required for aviation to decarbonise until this focus on the sector’s relatively low contribution to global carbon emissions is changed. One NGO said: **“Policymakers and those within the sector use the proportionately low emissions as an excuse**

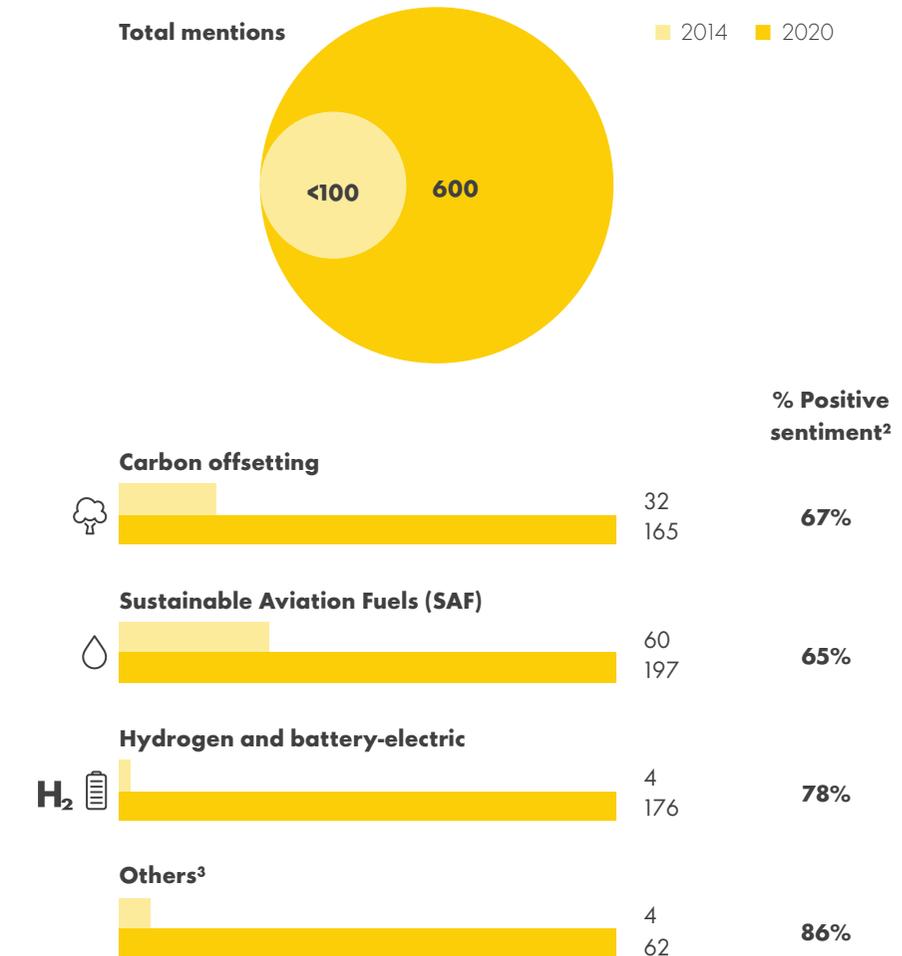
to defer action.” Several executives said there might be greater urgency if it were made clearer that aviation could represent up to 22% of global emissions by 2050²¹, as other sectors decarbonise more quickly.

If aviation accounts for a quarter of global emissions in 2050, will it retain its societal licence to operate?

Airline executive

There are signs that the focus on aviation is increasing. Mentions of decarbonising aviation in scientific journals have increased by over 600% in recent years (see Exhibit 16). Social movements have pushed aviation emissions up the agenda²². Those inside and outside the sector recognise the need for aviation to take immediate action. One airline executive said: **“The pressure to decarbonise will only increase. If we don’t take action today, we will get left behind.”**

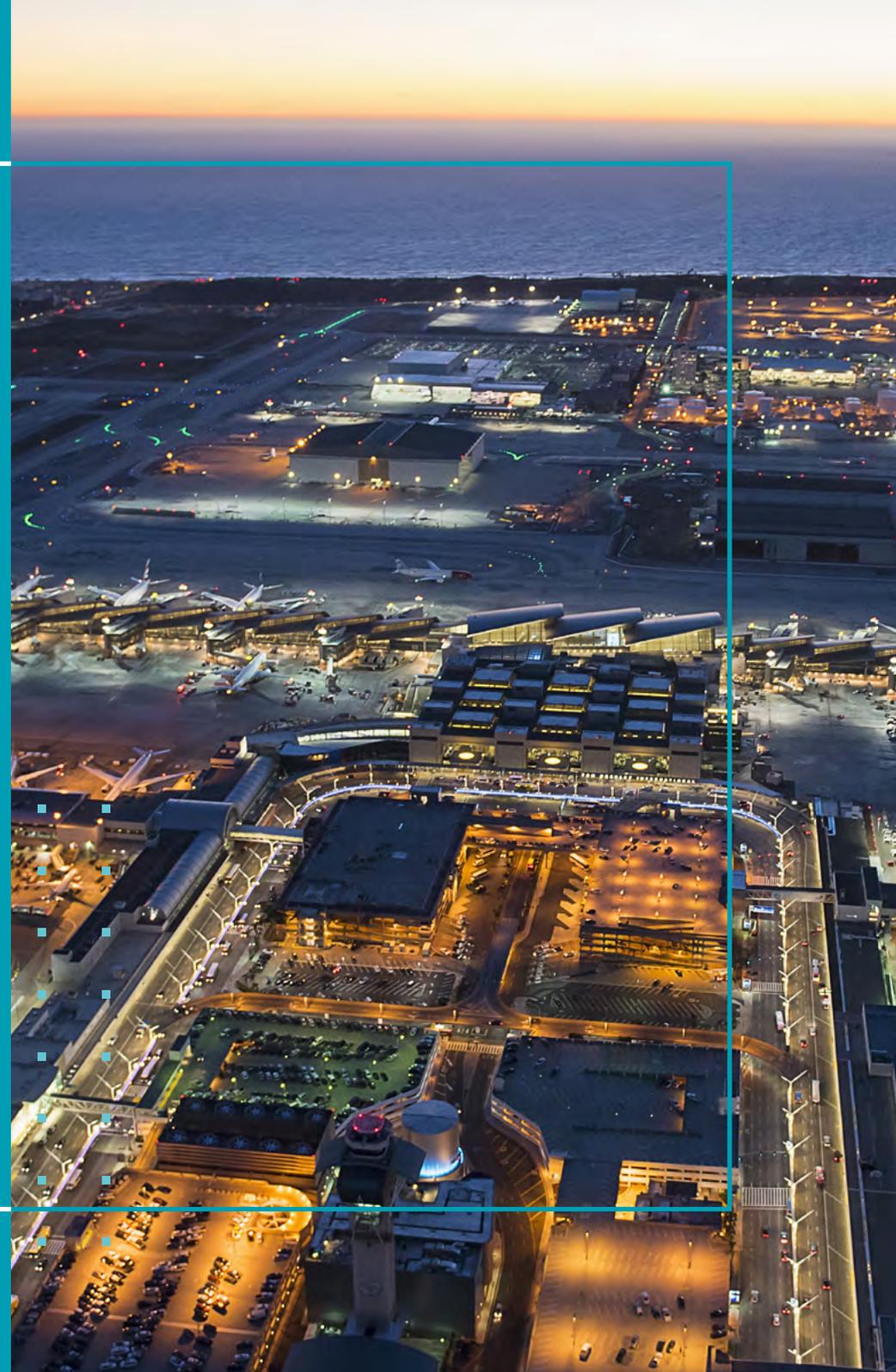
16 Mentions of ways to decarbonise aviation in main scientific journals and articles¹



Sources: News articles; Deloitte analysis

Notes: 1) <2% of unique analysed articles in 2014 and ~4% of unique analysed articles in 2020; 2) Refers to the share of articles on the specified topic that have classified the topic as desirable (based on a natural language processing technique); 3) Refers to topics that have received lower mentions (e.g., flight shaming) and articles that have combinations of the primary decarbonisation options mentioned (e.g., article that discussed Biofuel and SAF)

The Deadlock: Barriers to Decarbonisation



DECARBONISATION READINESS FACTORS: SUMMARY

We used the findings from interviews and workshops with sector executives and experts to develop a systematic approach to assessing aviation's readiness to decarbonise. Focusing on three core questions (see Exhibit 17), this research takes a comprehensive, sector-wide approach to decarbonisation.

It takes what is often seen as an insurmountable problem and breaks it down into manageable components. Based on a wide range of responses, we assessed the readiness of aviation to decarbonise against six readiness factors.

Most findings from the assessment are globally applicable. The aviation sector is highly standardised and concentrated, which means that in many respects barriers to decarbonisation are the same across the world. But geographical differences do exist. Some regions, such as Europe and California, have reached a slightly more advanced stage of decarbonisation - especially in terms of market and consumer demand and regulatory incentives. These more advanced regions feature in case studies in this report, so we can learn from the progress made so far.



17 Decarbonisation readiness framework

Readiness questions	Readiness factors	Factor descriptions
Why should the sector change? Considers the factors that may trigger stakeholders to act.	1. Market and customer demand	Pressure and incentives from society, customers, financiers and investors, which creates motivation for aircraft, engine and propulsion manufacturers, owners and operators to invest in lower-emission technologies.
	2. Regulatory incentives	Instruments applied by regional and local authorities. These can include incentives such as grants and tax cuts, and disincentives such as fines, carbon credits and carbon levies.
Can the sector change? Considers whether decarbonisation is feasible in the foreseeable future.	3. Technology alignment	Technical and commercial viability of alternative fuels and other lower-emission technologies, and clarity on development pathways.
	4. Clarity on roles and decision making	The ease in making decisions, clarity on roles and responsibilities, and alignment of priorities for key stakeholder groups in the sector.
How fast can the sector change? Considers the degree of effort required to implement change at scale.	5. Ease of asset replacement	What it takes to replace or upgrade the fleet. This depends on cost, complexity and lifespan, the rate at which alternative technologies are developed, and the impact alternative technologies have on fleet operations.
	6. Ease of infrastructure replacement	What it takes to set up production of green fuels at scale, deliver them to airports and prepare for charging or fuelling. The more production capacity needed, the more dispersed the infrastructure, the greater the challenge.



Overall, aviation scores relatively positively in terms of its readiness to decarbonise, given the ability to use drop-in fuels. But current decarbonisation efforts face barriers.

The industry must collectively recognise and align on the urgent need to act now, to accelerate the decarbonisation of aviation. There are four main barriers:

- **Targets are insufficiently ambitious**, unsupported by local regulation, and constrained by the perceived need for international alignment. This creates a widespread wait-and-see attitude across the value chain.
- **Cost of SAF is prohibitively high**, with many in the sector expressing uncertainty about how to reduce it and concerns about the availability of feedstock.
- **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.
- **Concerns about offsets** relating to quality, transparency and communications lead to limited uptake.

These are the barriers that interviewees mentioned most frequently. They also identified barriers relating to other factors listed in the decarbonisation readiness framework described above.

2. RESEARCH HIGHLIGHT

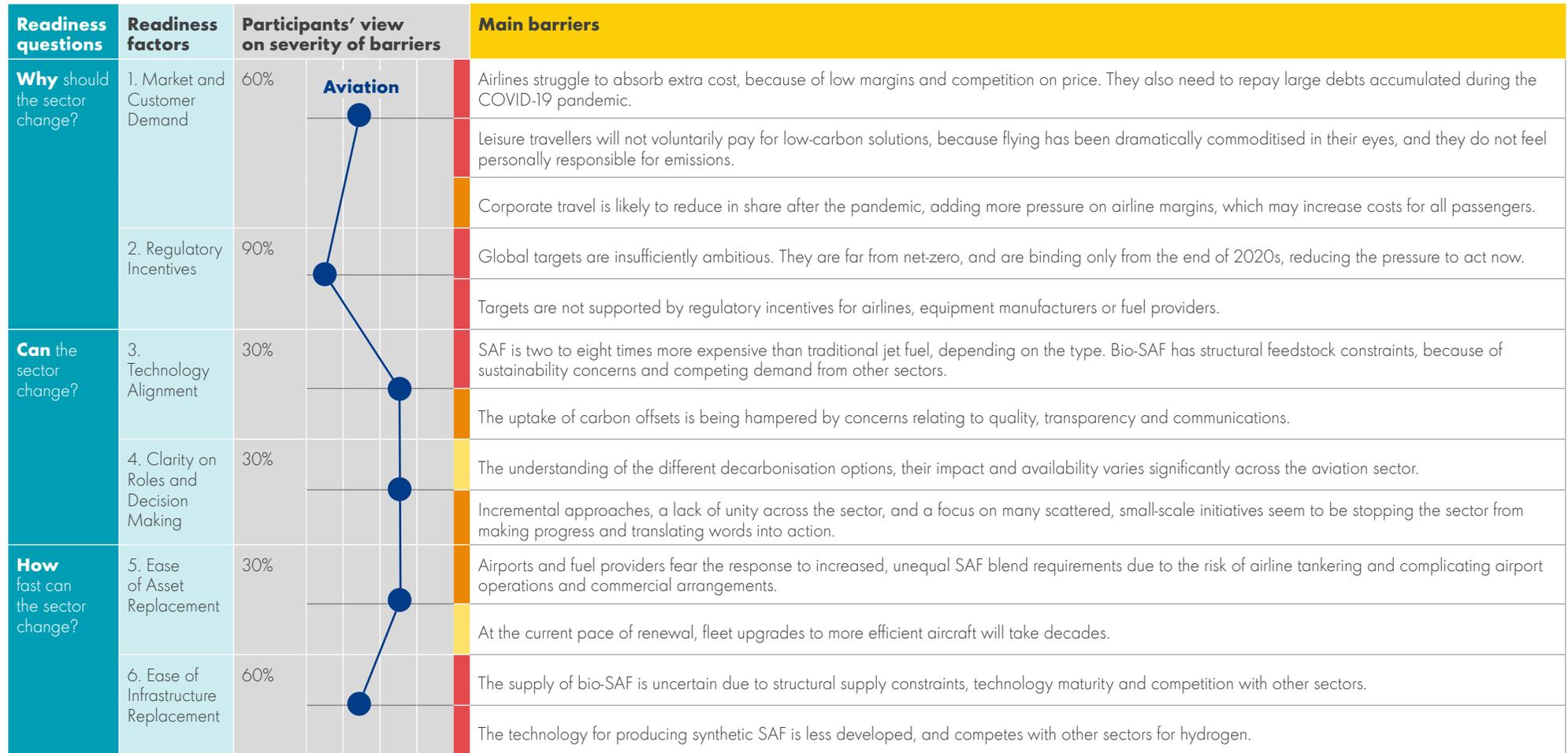
The sector is facing several barriers to decarbonisation, mainly:

- targets are insufficiently ambitious;
- cost of Sustainable Aviation Fuel (SAF) is prohibitively high;
- leisure passengers are reluctant to absorb the cost of lower emission solutions; and
- concerns about offsets.

One manufacturer said: “If you don’t have the assets, infrastructure, political support and the customer’s willingness to move, you will not proceed. All these elements have to be in place, and everyone has to be aligned – and we have to work on all those together.”

The barriers were further refined in workshops with sector executives and experts from around the world. The results are summarised in Exhibit 18. The following sections focus in greater detail on the six readiness factors and the barriers associated with them.

18 Aviation decarbonisation barriers¹



Notes: 1) Based on SAF drop-in solution. Ease of asset replacement and ease of infrastructure replacement will be more of a barrier for battery electric and hydrogen aircraft; 2) Tankering is when aircraft load up on excess fuel at a departure airport where it is cheap, so they avoid the expense of refuelling at a destination airport where fuel is expensive

MARKET AND CUSTOMER DEMAND

One of the primary considerations for any decarbonisation initiative is how it's going to be funded. Whether or not passengers and cargo customers support the notion of decarbonisation, the reality is they are going to have to participate. But 60% of interviewees cited reluctance to pay for reducing emissions as a critical barrier that

must be overcome. This is driven by several factors (see Exhibit 19).

Industry perspective: Airlines struggle to absorb extra cost, because of low margins and competition on price. They also need to repay large debts accumulated during the COVID-19 pandemic.

The aviation industry is known for its historically low margins, which make it harder to absorb the cost of decarbonisation.

As a global sector with many companies offering similar services, aviation is highly competitive. This competition is mainly about offering the lowest ticket price, not differences in service. The sector's operating model and dynamic pricing mechanisms are aimed at maximising asset utilisation; at keeping seats occupied and aircraft busy. This is often put before profitability. And the cash generated is often used to fund growth to protect market share, not profits. The result is that airlines have structurally low net profit margins of less than 5%.²³

Exhibit 19

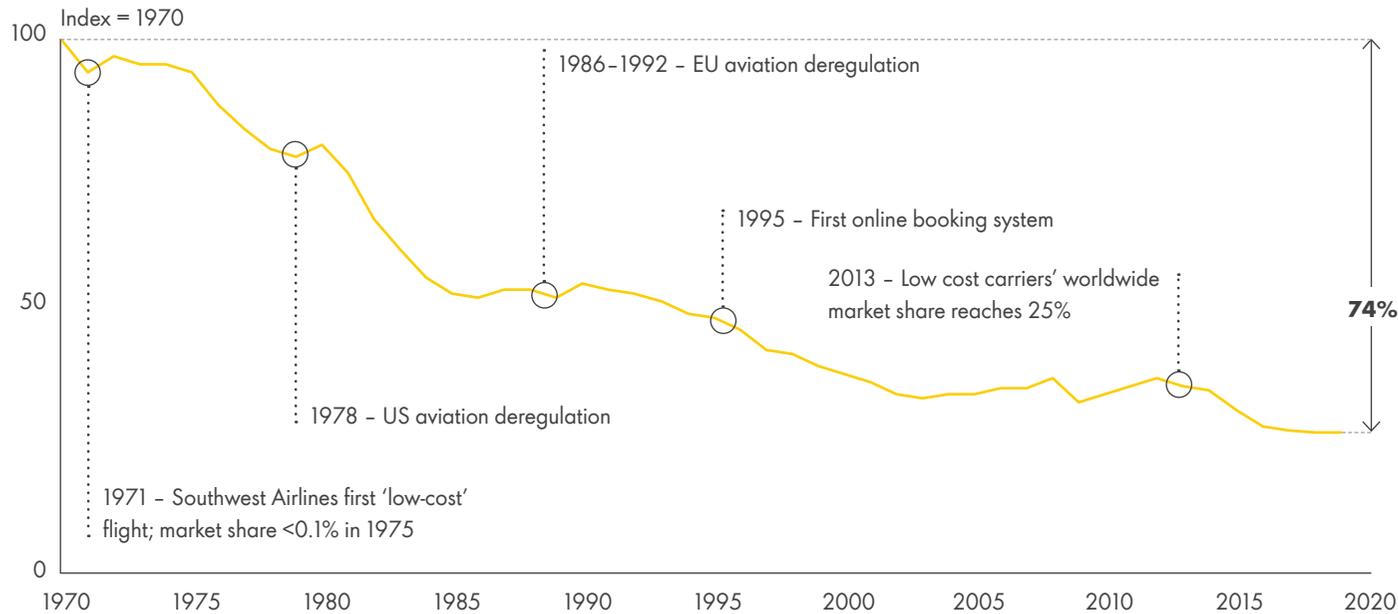
INTERVIEW INSIGHTS

60%

Research participants perceive a **lack of market and customer demand** to be a major barrier to decarbonisation



20 Average air travel ticket price development (indexed, 1970 = 100)



	1970 ¹	2017
London - NYC	\$3,375	\$940
NYC - LA	\$1,442	\$278
Milan - Paris²	\$480	\$70

Sources: Alaska Airlines (2016); ATAG (2021); EU Aviation (2017); European Parliament (2020); IATA (2018); Statista (2021); The Atlantic (2013); TransportGeography (2015); Worldbank (2021); Deloitte Analysis
Notes: 1) Historical data inflation-adjusted to 2017 USD; 2) Historical price data from 1992

The industry average profit per economy seat is \$1, which makes it very difficult to add extra costs.

Airline executive

Airlines are also emerging from the COVID-19 pandemic burdened by significant operating losses and large debts. Over the past two years, the aviation sector's total debt has grown by \$220 billion, because of government aid and increasing private debt²⁴.

One industry association said: **"After COVID, airlines will be in an even more difficult situation, due to lower corporate travel and the huge amount of debt (state aid) that airlines need to pay back."**

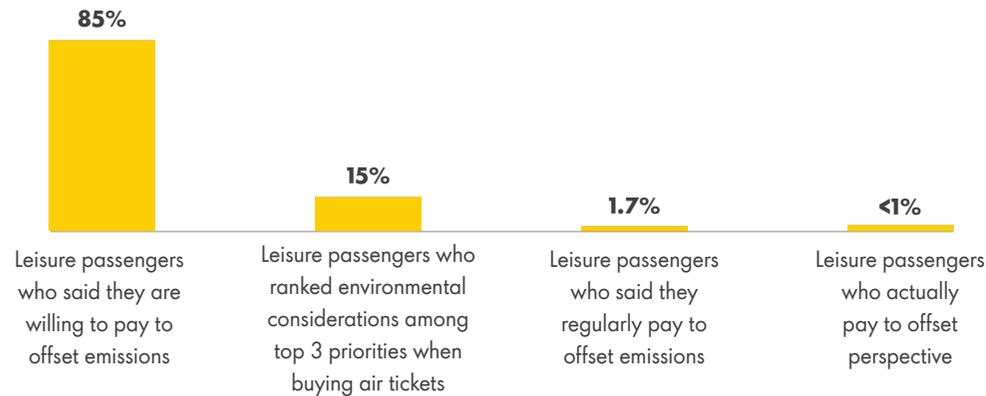
Some interviewees said airlines might need to fundamentally alter their business models, seeking new sources of revenue and differentiated sustainable propositions. Without doing this, airlines risk being unable

to absorb the cost of the transition and being left behind.

Industry perspective: Leisure travellers will not voluntarily pay for low-carbon solutions, because flying has been dramatically commoditised in their eyes, and they do not feel personally responsible for emissions.

Over the past 40 years, aviation has become more accessible as air travel changed from a status symbol to a near-commodity; ticket prices have gone down by 74% since 1970²⁵ (see Exhibit 20). This is because of regulatory liberalisation, the high frequency of flights on some routes, and the rise of low-cost carriers - airlines whose market share reached 30% in 2019²⁶.

21 Leisure passengers' stated willingness to pay for carbon offsets vs actual behaviour



Sources: traveller survey; interviews

This has made customers increasingly price sensitive. An R&D interviewee said: **“Price and availability of flights continue to be the main drivers for leisure passengers.”**

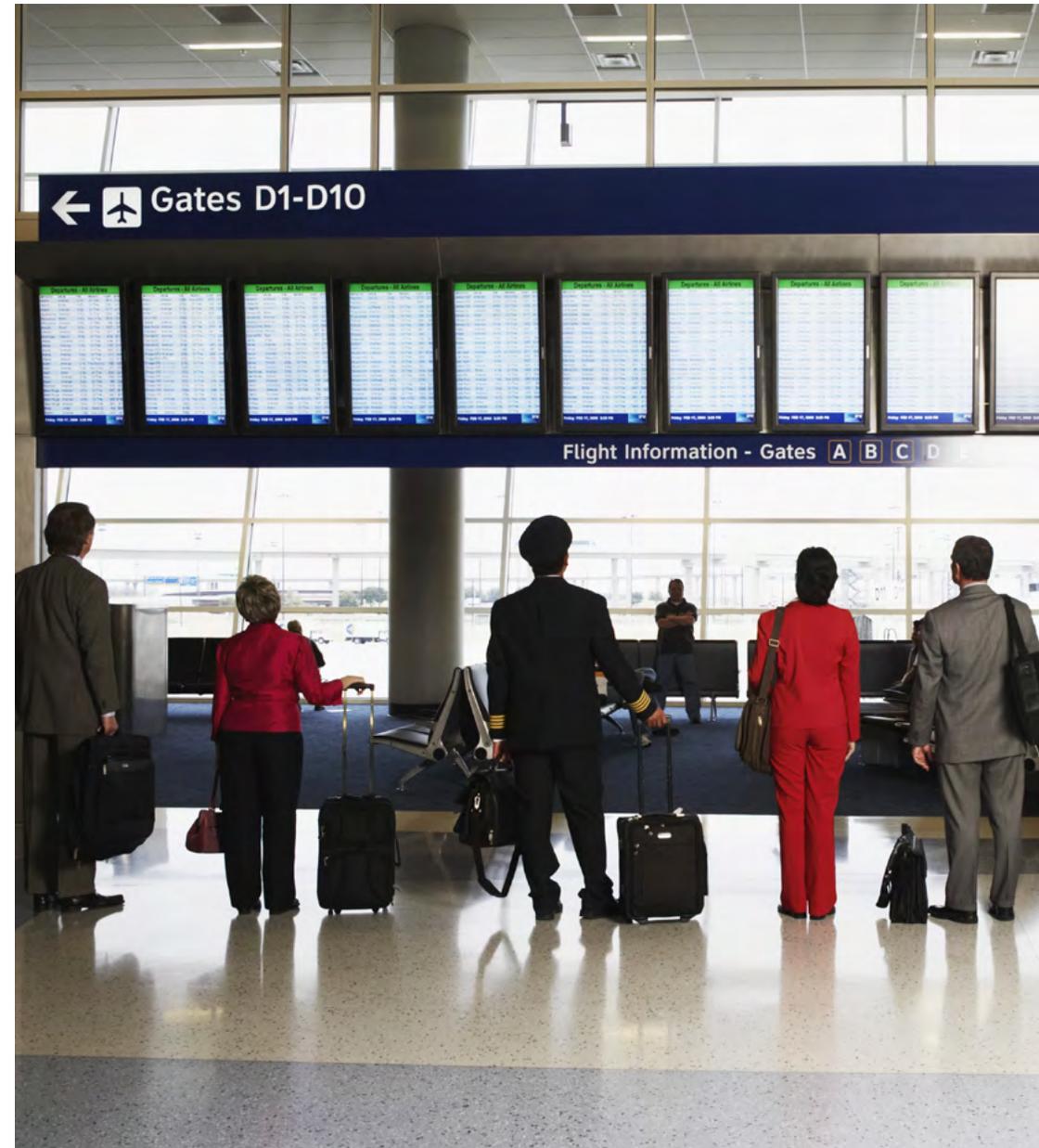
Intense competition over ticket prices makes airlines reluctant to pass the costs of decarbonisation on to passengers. Similarly, price-conscious passengers are reluctant to pay to support decarbonisation by, for example, buying offsets.

It will be very difficult to pass on extra cost for sustainability to passengers who choose the cheapest seat.

R&D interviewee

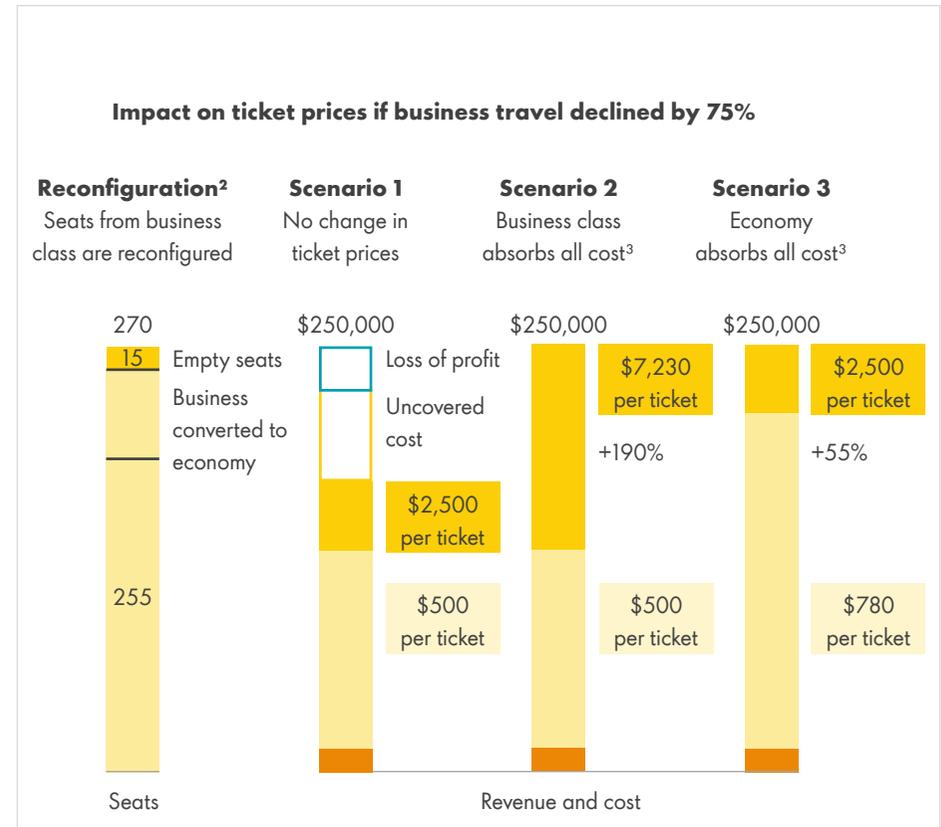
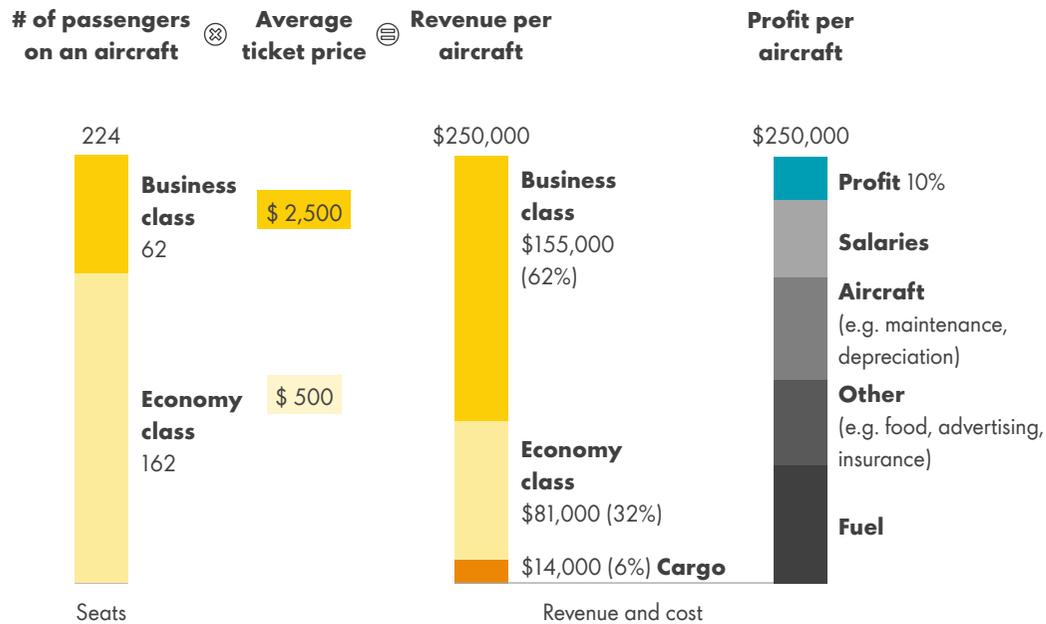
A global survey of 6,000 passengers conducted as part of this study seemed to confirm this (see Exhibit 21). Although 85% of passengers declared themselves willing to pay to offset emissions, only 1.7% said they regularly do it, and even fewer actually do, according to industry participants.

The survey also suggests that only around 30% of passengers feel personally responsible for the cost of reducing emissions. Almost two-thirds said it was solely the responsibility of airlines and aircraft manufacturers. These findings indicate that, in addition to policy support and airline contributions, more effective communication with passengers and new value propositions will probably be required to fund decarbonisation efforts.



22 Economic impact of a decline in business travel – ILLUSTRATIVE

Based on a typical journey from London Heathrow to New York JFK by Boeing 777¹



Sources: aircraftstats.com; Brons, Pels, Nijkamp & Rietveld, Tinbergen Institute, (2002); BTS (2017); Forbes (2020); IATA (2008); Investopedia (2021); McGill University (2017); Deloitte analysis
Notes: 1) Not considering ancillary revenue; all numbers are rounded; 2) 75% Of business class seats repurposed to economy seats with 1:2 ratio; 3) While maintaining current profitability

Industry perspective: Corporate travel is likely to reduce in share after the pandemic, adding more pressure on airline margins, which may increase costs for all passengers.

Interviewees expect corporate travel to take longer to recover from the pandemic than leisure travel. This is because of developments

in remote working and increasing emission reduction commitments by large companies. Corporate passengers accounted for around two-thirds of airline revenue before the pandemic, so lower levels of corporate travel will put pressure on airline margins.

To maintain profitability, airlines may have to adjust their passenger mix, and ticket

costs could rise to maintain profitability (see Exhibit 22 – scenario 3). Such widespread increases might further reduce leisure passengers’ willingness to pay extra to support decarbonisation or reduce demand.

In some instances, increased ticket prices might even result in fewer people flying. While this will have a positive effect on emissions

in the short-term, it will not help fund a long-term change in the aviation fuel mix. More positively, as noted by one airline executive, post-pandemic business model revaluations might create an opportunity for a “**structural evaluation of ticket prices, which will include the real cost of flying.**”

REGULATORY INCENTIVES

The global nature of aviation, and the different politics, policies and approaches adopted around the world, make it a complex sector to regulate.

90% of stakeholders said a lack of adequate regulatory incentives was a major barrier to decarbonisation (see Exhibit 23). They called for ambitious, mandatory global targets, and more support through regulatory guidelines and incentives.

Industry perspective: Global targets are insufficiently ambitious. They are far from net-zero, and are binding only from the end of 2020s, reducing the pressure to act now.

Many industry stakeholders said the CORSIA target to pursue “carbon-neutral growth” by stabilising net emissions at 2019 levels, and the IATA target to halve net emissions by 2050 relative to 2005²⁷, were insufficiently ambitious.

Several participants highlighted that the CORSIA target only becomes binding on member states between 2027 and 2035. One airline executive said this created a perception that **“the targets won’t have any material impact any time soon.”** In the absence of generally accepted global and sector-wide ambition, some countries have set their own targets, such as the UK with its plan for international aviation to reach net-zero by 2050. Such countries are acting on good intentions, but research participants said the result might be a patchwork of approaches in a complex, global sector. One carrier said: **“Aviation cannot work in a vacuum, it needs to be incorporated into global and regional targets.”**

Industry perspective: Targets are not supported by regulatory incentives for airlines, equipment manufacturers or fuel providers.

Interviewees said the international targets have been set without the regulatory incentives needed to support them²⁸.

Targets without incentives – or without clarity on when those incentives will come – paralyse the industry participants.

Airline executive

Stakeholders indicate that financial and non-financial support mechanisms are needed to drive the large-scale adoption of SAF and offsets. These incentives should address the challenge from several angles, including support for production capacity and infrastructure, as well as the fuel price spread faced by airlines.

Despite signs that SAF blending mandates²⁹ will be introduced, such mechanisms are missing or insufficient to make SAF as cheap as traditional kerosene.

Exhibit 23

INTERVIEW INSIGHTS

90%

Research participants perceive a **lack of regulatory incentives** to be a major barrier to decarbonisation



TECHNOLOGY ALIGNMENT

Compared with other harder-to-abate sectors like shipping, there is considerable agreement within aviation about the technology solutions needed for decarbonisation. Only around one-third of participants said lack of agreement about technology was a major barrier (see Exhibit 24). That said, while there is consensus about the central role of SAF, uncertainty remains

around the economics, pace of adoption, and the relative share of bio- and synthetic SAF in the mix. Additionally, industry stakeholders recognise that concerns about offset quality remains a challenge.

Industry perspective: SAF is two to eight times more expensive than traditional jet

fuel, depending on the type. Bio-SAF has structural feedstock constraints, because of sustainability concerns and competing demand from other sectors.

Over the next 20 to 30 years, the aviation sector will be seeking to use SAF in the existing fleet as the main way to decarbonise.

Put simply, there are two main types of sustainable aviation fuel (SAF) (see Exhibit 25). There is bio-SAF, which is made from biomass – i.e. plant or animal material such as crops, forestry or agricultural waste, including algae and inedible animal fats. Then there is synthetic SAF, which is produced by combining low-emission hydrogen with CO₂. These SAFs can be anything from two to eight times more expensive than traditional kerosene (see Exhibit 26).

Exhibit 24

INTERVIEW INSIGHTS

30%

Research participants perceive a **lack of technology alignment** to be a major barrier to decarbonisation

25 Main types of SAF and industry sentiment

Technology	Feedstock	CO ₂ emission reduction (%)	Applicability	Sentiment	
				Towards 2030	Towards 2050
Bio-SAF	Biomass	60–80% ¹	Compatible with most existing aircraft as drop-in fuel	⊕ Mature production technologies exist, e.g. HEFA	⊕ More feedstock sources to be explored and production technology to be developed
				⊖ Emerging sustainability concerns with regards to feedstock source	⊖ Supply is limited, competing for land use with forestry and food, with scattered availability
Synthetic SAF	Hydrogen, CO ₂ /CO	50–100% ²		⊕ Can first use blue hydrogen ³ and CO ₂ from carbon capture	⊕ Many large hydrogen and carbon capture projects planned
				⊖ Hydrogen supply initially limited	⊕ Getting cheaper fast

Sources: interviews; ATAG (2020); Clean Sky 2 JU and FCH 2 JU (2020); IATA (2021); IEA (2019); Scheelhaase, Maertens & Grimme (2019); WEF Clean Skies for Tomorrow (2020)

Notes: 1) 80% when used neat; 2) Net CO₂ neutral if produced with CO₂ captured from the air and green hydrogen is used; 3) Blue hydrogen is produced using hydrocarbons, but decarbonised, usually by carbon capture and storage (CCS)

26 Economic analysis for aviation fuels including carbon emission costs

	Kerosene	Bio-SAF	Synthetic SAF with carbon capture (CCU)		Synthetic SAF with Direct Air Capture (DAC)
Feedstock cost (\$/l) Values show equivalent price in meaningful unit (e.g. H ₂ in \$/kg)	Kerosene price 	Biofuel 	CO ₂ with CCU ¹ Value = 0 	Hydrogen 	CO ₂ with DAC
Production cost (\$/l)		HEFA 	CO ₂ activation and FT synthesis ² 		
Carbon cost (\$/l) ^{3, 4}					
Cost of end product (\$/l) including compound annual growth rate	Mid-range carbon price is used 				
Price premium vs. kerosene in 2020 and 2050					
Break-even vs. kerosene ⁵		2027-2037	2039-2043		2040-2049

Sources: Projections from a green hydrogen producer; De Jong et al. Cost Optimization of biofuel production

Notes: 1) Cost to capture CO₂ from operations considered to be absorbed by capturer; 2) CAPEX consisting of CO₂ activation unit (either reverse water-gas-shift or CO₂ electrolysis) and Synthesis unit (Fischer-Tropsch); 3) CO₂ cost of \$300/tCO₂ in 2050, lower bound is 50% (\$150/tCO₂), upper bound is 200% (\$600/tCO₂); 4) Carbon intensity of Kerosene: 0.0715 tCO₂/GJ, Carbon intensity of Bio-SAF: 0.0143 tCO₂/GJ (80% emission reduction compared to kerosene when used neat), Carbon intensity of Synthetic-SAF with CCU: 0.03575 tCO₂/GJ (CO₂ emission reduction assumed to be 50/50 split by CO₂ capturer and final emitter), Carbon intensity of Synthetic-SAF with DAC: 0 tCO₂/GJ; 5) Lower bound break-even based on high carbon price, upper bound on low carbon price

If all kerosene on a typical long-haul flight would be replaced with SAF tomorrow, without any policy incentives, this would equal an increase of 30-200% of airline operating costs or ticket prices. Within decades this could break even, as supply and demand grow.

The technology for bio-SAF is more developed than the technology for synthetic SAF. Depending on the production technology and feedstock used, bio-SAF is currently two to four times more expensive than fossil-based kerosene. Although some see potential for it to get cheaper, they also recognise that the supply of bio-based feedstock will likely be structurally constrained, due to land use requirements, potential contribution to increasing food commodity prices³⁰, and collection costs around other sources of biomass. This means there is a limit to how much bio-SAF can be made available to aviation.

Most research participants consider synthetic SAF to be the best long-term solution, but its production remains constrained by the availability of low-emission hydrogen from renewable electricity and the associated costs. Synthetic SAF is estimated to be five times more expensive than kerosene if it uses CO₂ captured in industrial processes such as steel making, and over eight times more expensive if using CO₂ from direct air capture (DAC).

Synthetic SAF, though, is expected to face fewer structural challenges than bio-SAF in the long term. Hydrogen production is

expected to increase significantly, and both hydrogen and CO₂ are expected to get significantly cheaper.

Synthetics will initially be very expensive, but in the long run, the cost will fall rapidly and could be cheaper than bio-SAF.

Energy expert

The difference between the cost of either type of SAF and traditional kerosene will also depend on whether a price is put on carbon emissions. Depending on the development of a carbon price, bio-SAF could reach cost parity with traditional kerosene between the late 2020s and mid-2030s, and synthetic SAF between the early 2030s and mid-2040s.

Industry perspective: The uptake of carbon offsets is being hampered by concerns relating to quality, transparency and communications.

Carbon offsets are a way to compensate for emissions, by paying money into projects that either reduce the global stock of greenhouse gases or avoid adding to it by, for example, preventing deforestation. There are over 200 types of offsetting projects³¹, and when administered well they are a useful way to mitigate emissions if other solutions are unavailable. *“We cannot run away from offsets if we are serious about net-zero,”* said one airline.

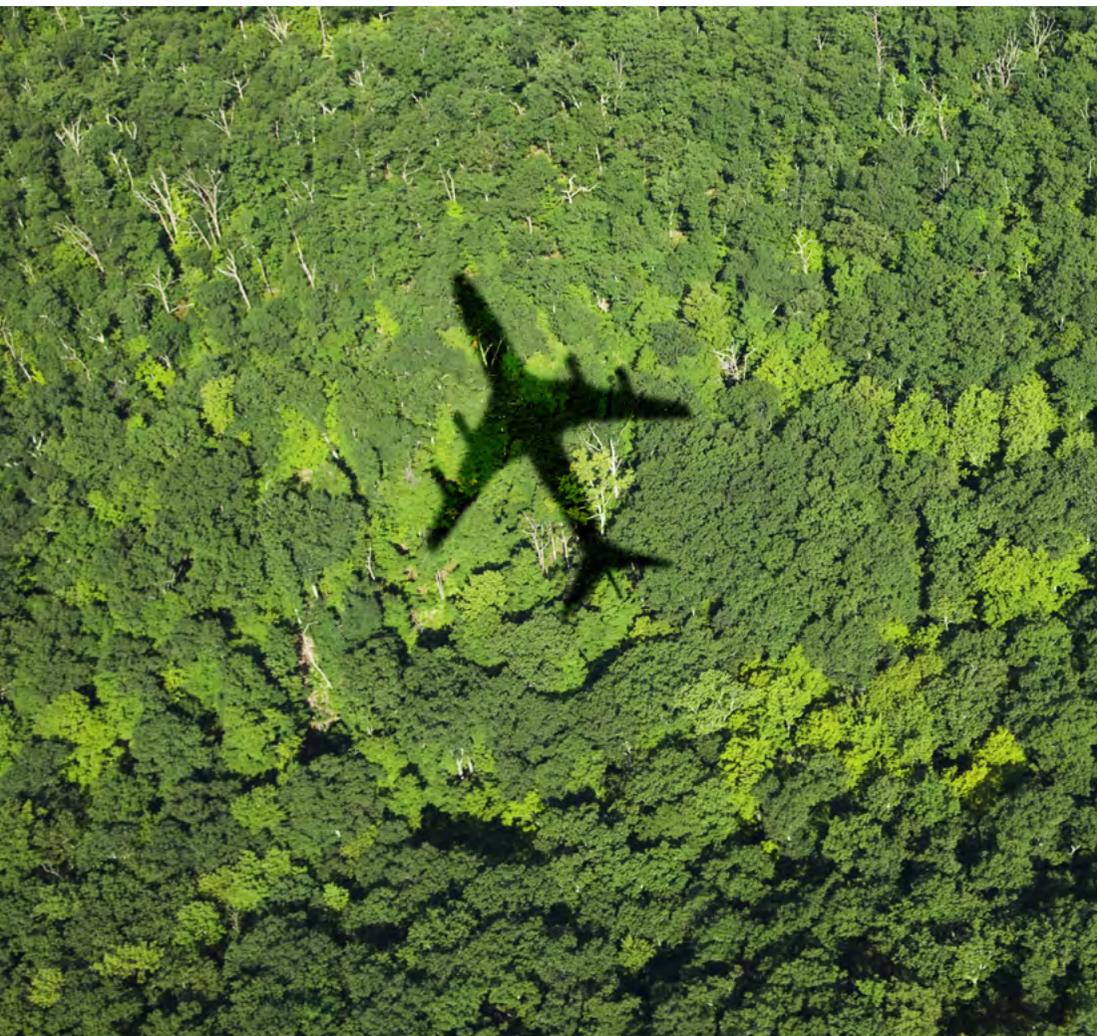


CORSIA has defined a role for offsetting in aviation. Many airlines now offer offsets, but uptake is very limited. Some participants in our research said that the main reasons for that are doubts about offset quality

and a lack of transparency. One airline said: **“There are thousands of projects out there – it is impossible to understand which are good and which are bad.”** This meant that airlines tended to resort to the cheapest

available option that satisfies the regulatory requirements on paper: **“When airlines log into the system, they just buy the cheapest offsets that are CORSIA compliant,”** said a travel agent.

to buy offsets. Over three-quarters of travellers do not understand what offsets are³². **“Passengers can’t be blamed for not understanding why offsets matter, if the sector fails to communicate,”** said a leading travel agency.



There were also concerns about what the money was actually spent on. One policymaker said: **“It’s not always clear how much of the offset cost is spent on processing fees versus actual emissions savings.”** An aircraft operator said: **“People expect that when they pay for offsets, actual trees are planted somewhere in the world, and it’s still questionable whether that is happening or not.”**

Some participants also raised the issue of double-counting. This is where the greenhouse gas reductions associated with carbon credits are counted twice. For example, a project may sell some carbon credits to an international airline that wants to offset its emissions, but the project’s host country may count the same carbon credits as having contributed to its own efforts to reduce emissions to net zero. An NGO representative summarised it **“There is a lack of trust on who is claiming what and when.”**

Participants also said a lack of effective communication meant that the aviation industry was failing to convince passengers

Some thought that there might be greater enthusiasm for offsets if they related to projects that were near passengers’ homes or air routes. One airline representative said: **“We want offsets to be close to our home, or across our routes, not in a place that has nothing to do with us.”** Perceptions about the quality of offsets might also improve if they relate to future, not past projects. One airline executive said: **“When you spend a dollar, you want to see it go somewhere useful, not to pay for something that has already happened.”**

Most participants agreed that the aviation sector must do more to offer passengers high-quality, transparently managed offsets, and to convince them to buy them. This must be done promptly because offsets have an important role to play during the time it will take to develop other ways to decarbonise. A travel agent said: **“It’s tragic that corporates aren’t using offsets today. If you wait for SAF to scale, we may lose the societal licence to operate.”**

CLARITY ON ROLES AND DECISION MAKING

Since the aviation sector is highly concentrated with relatively few large companies, only 30% of interviewees perceive clarity on roles and decision making to be a major barrier for decarbonisation (see Exhibit 27). Challenges identified relate to a limited understanding of decarbonisation options and a focus on small-scale independent initiatives.

Industry perspective: The understanding of the different decarbonisation options, their impact and availability varies significantly across the aviation sector.

There has been no significant change in aircraft propulsion technology or fuel mix since the development of the jet engine. As a result, long-term investment decisions around aircraft technology and fuel mix have traditionally been relatively simple. An understanding of operational requirements and fuel prices was sufficient.

The situation has changed in recent years, and now different types of SAF and alternative propulsion technologies need to be

considered as future options. Airline executives need to make important investment decisions about technologies that are unfamiliar to them. Many executives admit they lack the knowledge or capacity to understand the details. One said: **“I know jet engines and I know kerosene. Now I need to compare those against hydrogen and electric propulsion, different offsetting options and several types of SAF – can you tell me what cellulosic biofuels are?”** Other industry stakeholders face a similar dilemma. One financier said: **“We need to understand the technologies to make investments, but many of the new technologies being discussed are new and unproven, which creates uncertainty.”**

This need to develop technical expertise beyond what has traditionally been required delays action.

Industry perspective: Incremental approaches, a lack of unity across the sector, and a focus on many scattered, small-scale initiatives seem to be stopping the sector from making progress and translating words into action.

Many interviewees thought the sector has struggled to achieve practical results despite years of discussions about the need to increase SAF production and use.

Participants recognise that traditional supply-and-demand behaviours are unlikely to solve the problem. Part of the challenge is the chicken-and-egg situation between SAF producers and buyers (the airlines). The airlines complain that producers should supply more SAF. But the producers say the demand for SAF from the airlines is not really there because kerosene is so much cheaper.

“Demand is not the problem – we are engaging with our suppliers to get SAF, but they have not made the right investments on time, and now cannot deliver,” said one airline. But a SAF producer said: **“You need to be able to pay the extra price to say there is demand.”**

There needs to be significantly more real commitment, because it is hard to build supply chains based only on words.

SAF producer

A logistics executive said there would have to be co-operation across the sector and with policymakers to solve the problem – for example, through large-scale, long-term initiatives. The logistics executive suggested one potential solution may be

Exhibit 27

INTERVIEW INSIGHTS

30%

Research participants perceive a **lack of clarity on roles and decision making** to be a major barrier to decarbonisation

offtake agreements where airlines agree to buy a set proportion of a supplier's future SAF production: **“Fuel suppliers see an investment risk. They need large-scale, long-term offtake agreements and policy support that guarantee demand.”** The executive added that financiers also need long-term solutions: **“They need 10-year-plus commitments from the industry and all risks carefully mitigated, because stable cash flows are everything,”** and concluded: **“We need to see banks, manufacturers, airlines, airports and policymakers working together on large-scale initiatives, not high-level theoretical conversations. We need to get into action mode.”**

EASE OF ASSET REPLACEMENT

30% of interviewees think that a key barrier to decarbonisation is the time and effort needed to replace aircraft fleets (see Exhibit 28). This is a relatively low percentage because interviewees know that SAF can be used as a drop-in fuel on existing aircraft. Ease of asset replacement becomes a more significant barrier when considering alternative propulsion technologies.

Industry perspective: Airports and fuel providers fear the response to increased,

unequal SAF blend requirements due to the risk of airline tankering and complicating airport operations and commercial arrangements.

As part of the ReFuelEU Aviation and Fit for 55 legislative initiatives, the European Union recently developed a mandate that from 2025 would require fuel providers to blend an increasing share of SAF into what they supply to EU airports – up to 63% by 2050³³.



The risk is that some airlines will respond by choosing alternative routes or tankering cheaper fuel at airports outside the EU. This could result in higher net emissions, as aircraft burn more energy transporting a heavier fuel load than they need for the journey. This risk is greatest at airports with a higher concentration of short-haul routes, or those that are near other hubs for major long-haul routes.

In aviation, it is almost impossible for one country to force change – airlines will just fly around it!

Policy advisor

Some airport executives also said that in places where SAF blends are not uniformly regulated, introducing SAF for only some airlines might complicate airport operations and commercial arrangements. Such a lack of co-ordination creates complexity, which could deter potential early adopters.

Industry perspective: At the current pace of renewal, fleet upgrades to more efficient aircraft will take decades.

The aviation industry has made significant efficiency improvements in recent years. Each new generation of aircraft has brought economic benefits, by being more fuel efficient and less expensive to maintain.

Given the cost of fleet renewal and the 20-30 year technical lifespan of an

Exhibit 28

INTERVIEW INSIGHTS

30%

Research participants perceive **complexity of asset replacement** to be a major barrier to decarbonisation

aeroplane, interviewees said that at the current pace, updating the global fleet of around 21,500 aircraft will take decades. Today's fleet has an average age of 11-12 years, with almost 70% of aircraft dating from the 1990s³⁴. There is also a risk that airlines will further delay fleet-renewal programmes, because of uncertainty about the future of technology, regulation and demand. On a positive note, COVID-19 has accelerated renewal for those airlines that saw it as an opportunity to improve fleet efficiency. One financier said: **"Given low demand, the pandemic at least accelerated the phasing out of some older aircraft, like the 30-year-old Boeing 747s, to drive increased efficiency."**

EASE OF INFRASTRUCTURE REPLACEMENT

Infrastructure replacement was seen as a major barrier to decarbonisation by 60% of interviewees (see Exhibit 29). They highlighted SAF feedstock and supply constraints, and said alternative propulsion technologies would require completely new production and distribution infrastructure.

Industry perspective: The supply of bio-SAF is uncertain due to structural supply

constraints, technology maturity and competition with other sectors.

Virtually all SAF in the market today is made from first-generation biomass feedstocks, produced from sugar, starch and vegetable oil using HEFA production technology (see Exhibit 30). Concern about the sustainability of these feedstocks creates structural constraints that are expected to limit the role

they play at scale. One NGO said: “The issue with today’s feedstocks is I either need to replace food crops or cut down forests, both of which have their own sustainability concerns.” The amount of bio-SAF available to aviation will also be limited by competing demand from other sectors that want to use biofuel or biomass feedstocks. Road transport uses most existing biofuel and has well-established supply chains. Demand is also growing from other sectors, such as shipping and chemicals.

Second-generation biofuels do not have the same sustainability concerns, because they are produced from waste products. But production technologies are currently immature, and there are few established supply chains to collect and transport feedstocks. One NGO said: “It would be nice to convert all of our waste to fuel, but nobody has demonstrated they can commercially do it at scale yet.”

Once the technologies are developed, it will take time and considerable investment to create meaningful scale. One energy company said: “A trial production facility today costs \$400 million, and takes three to five years to build.” Costs are set to reduce as technologies mature, but it will probably become progressively harder to obtain quality feedstock supplies as the market scales.

To address concerns about the sustainability of biofuel feedstocks, there will have to be transparency “from crop to drop” (from planting the crop to dropping the bio-SAF

Exhibit 29

INTERVIEW INSIGHTS

60%

Research participants perceive **complexity of infrastructure replacement** to be a major barrier to decarbonisation

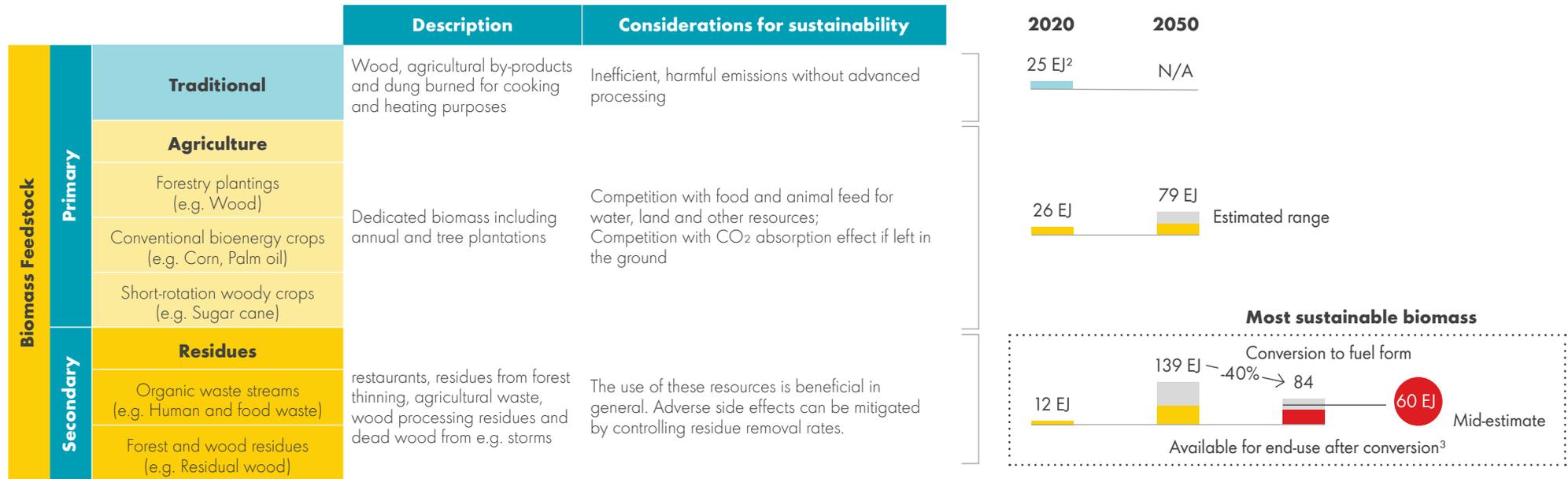
in a fuel tank). This will add complexity throughout the process, but will be critical to overcoming concerns such as those expressed by one equipment manufacturer, who said: “There is a risk that once biofuels pick up, some producers might tap into unsustainable feedstocks to meet demand. That just moves the problem, as opposed to solving it.”

Industry perspective: The technology for producing synthetic SAF is less developed, and competes with other sectors for hydrogen.

Synthetic SAF is produced using hydrogen and CO₂, with climate neutrality depending on the use of renewable electricity for hydrogen generation and the source of CO₂.



30 Biomass feedstock¹



Sources: IEA Net Zero by 2050 (2021); IEA Technology Roadmap Delivery Sustainable Bioenergy (2017); IPCC SSREN 2012
 Notes: 1) HEFA is the only current production technology, which refines vegetable oils, waste oils and fats into SAF ; 2); EJ = exajoule = 10¹⁸ Joule; 3) Due to conversion losses

The supply is theoretically unlimited, but constrained in practice by the need to develop commercial-scale technology, the availability of “green hydrogen” (produced using renewable electricity), and the cost of DAC and carbon capture storage and utilisation (CCSU).

Big electrolyzers for producing commercial quantities of green hydrogen are in short

supply, and the required renewable electricity still comes at a significant price. Compared with more established production processes, electrolysis is very expensive, so the market for electrolyzers has been small.

The attractiveness of synthetic fuels is also reduced by the conversion losses that occur when using renewable electricity to make hydrogen to make fuel. These losses are

high compared with the direct use of green hydrogen in competing sectors, such as industry. Green hydrogen and renewable electricity are both currently prioritised for direct use.

Nevertheless, a third-party logistics provider said: **“Renewable electricity and the scale development of electrolyzers will have a huge role to play in supporting synthetic SAF.”**

If we have a strong synthetic SAF solution, we might not need any hydrogen aircraft.

Aircraft manufacturer

Decarbonising Aviation: a New Approach





Increasing numbers of political and business leaders are making commitments to reduce carbon emissions. The USA has re-joined the Paris Agreement on climate change, and countries in the EU and Asia have made commitments to decarbonise. The aviation sector is also getting more public attention, with the media now talking about solutions and implementation and not just targets. Examples can be found in recent announcements in the UK to include aviation in the national footprint³⁵, and in Germany's synthetic SAF roadmap³⁶.

Corporate customers are seeking to meet their own net-zero ambitions or targets through new ways of procuring air travel and cargo shipping. Some companies are doing more than just using offsets. They are also working with the aviation sector on finding technical solutions to the challenges of decarbonisation. Investment in decarbonisation is growing. Major manufacturers are scaling up the development of SAF³⁷. Recent venture capital deals have directed investment towards start-ups in alternative propulsion technologies that could one day be used to power commercial passenger aircraft³⁸.

Exhibit 31

INTERVIEW INSIGHTS

90%

Research participants perceive **decarbonisation to be a top three priority** for their business

The fact that 90% of research participants said decarbonisation is one of their top three priorities shows how important the subject is for the aviation sector (see Exhibit 31). Positive sentiment towards decarbonisation spans all stakeholder types, and is the strongest among cargo shippers, corporate travellers, airlines and manufacturers. North American and European respondents were most motivated to decarbonise, but all regions recognise the importance of the issue, given the global nature of the sector.

INFLECTION POINT – READY FOR TAKE-OFF

We can put aviation’s progress on decarbonisation into perspective by looking at research into other sectors including the two previous reports in this series: [Decarbonising Shipping: All Hands on Deck](#) and [Decarbonising Road Freight: Getting into Gear](#).

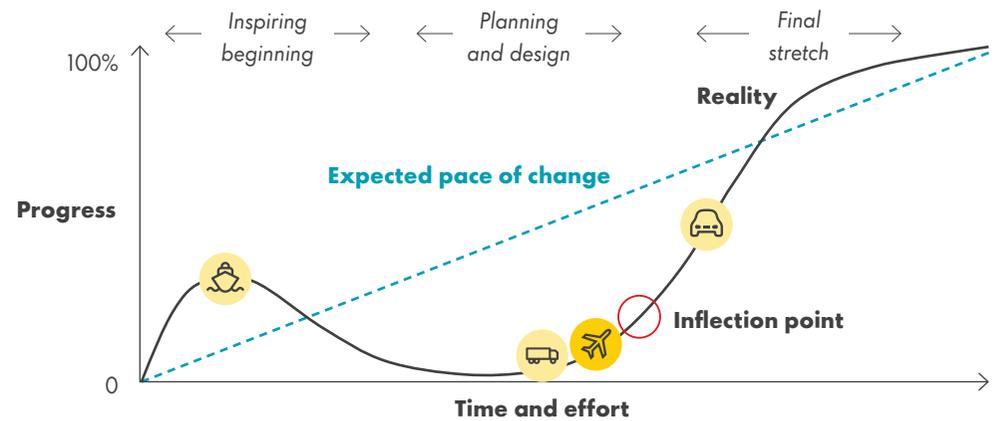
In the early stages, discussions around the “art of the possible” and the success of early trial projects can often create the optimistic expectation that a sector-wide solution is imminent. Over time, this optimism often declines, as unforeseen problems delay or complicate the widespread deployment of the required technology and infrastructure. At the same time, many interviewees believe that aviation is closer than often imagined

to entering the “final stretch” phase of decarbonisation (see Exhibit 32). The solutions are known, and a large share of emissions can be addressed through drop-in fuels which do not require fundamentally new aircraft or airport infrastructure.

This compares with road freight – where solutions are known, but will require new assets and infrastructure – and shipping – which will require new assets and infrastructure, and where there is less clarity about future fuels.

But aviation still has a lot of work to do to decarbonise successfully. While the pathway is clearer than in other sectors, there is a lot of work to execute against it. It is time for action.

32 Decarbonisation vs typical change-adoption phases – ILLUSTRATIVE



Aviation

- Solutions are known - uncertainty about economics and timelines
- Technology investment focused on the energy carrier, not on assets, so faster deployment than in other sectors (e.g. battery electric and fuel cell electric vehicles in road freight)
- Investments are needed now to develop and scale solutions

1. Inspiring beginning – e.g. shipping

- Optimism that over next 20+ years “the sector” will find a way to decarbonise
- Demand and technology alignment are key barriers – things that seem abstract
- Most investments are in the future

2. Planning and design – e.g. aviation and road freight

- Progress seems slower than expected
- Practical barriers of infrastructure and scaling fuel production are daunting
- New assets are still much more expensive, but investments need to be made now (“which truck do I buy?”, “how much SAF do I use?”)

3. Final stretch – e.g. personal vehicles

- Progress is visible
- Infrastructure is being built at scale, and assets are being replaced
- Cost of new assets is close to parity – investments are “easy”

Sources: Kanter (2006) “Confidence: How Winning Streaks and Losing Streaks Begin and End”; Raffaelli (2018) “Leading and Managing Change”; Deloitte analysis

SOLUTIONS

Aviation executives and experts identified a wide range of potential initiatives to overcome barriers to decarbonisation. These initiatives were refined into a catalogue of 15 solutions, or recommendations for action, during workshops and review sessions.

Some of the 15 solutions are already being investigated. Engaging with the stakeholders through our research helped establish what was working and what was not. Other solutions are new, or provide a new and more efficient approach to tackle a barrier.

Participants noted that particularly in the initial years of the transition, all readily available options to lower emissions should be deployed, because **“we cannot wait for a technical salvation, we need to use all the tools in our toolbox available today,”** confirmed a travel agent.

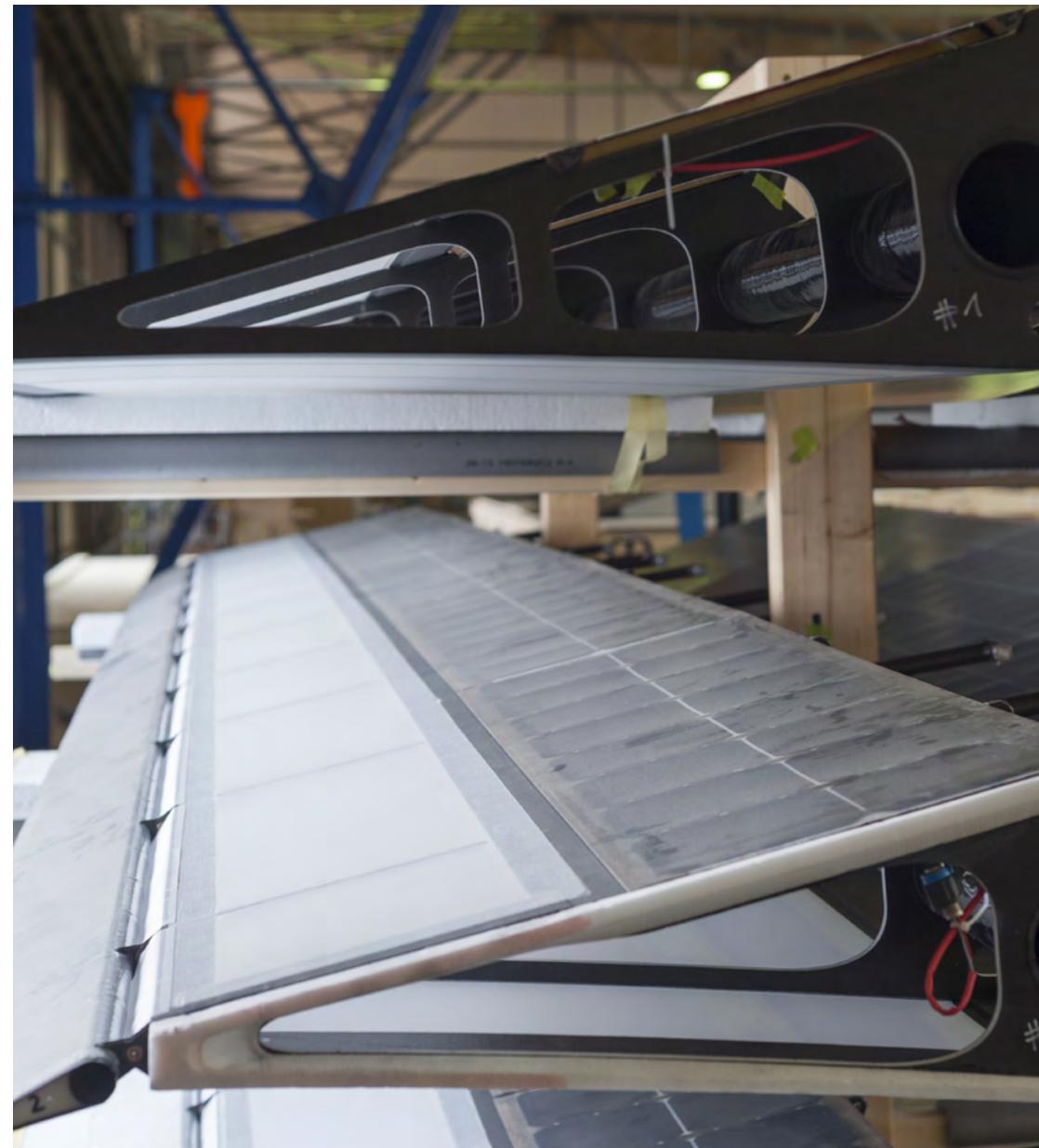
One banker illustrated the point with regards to synthetic SAF: **“It is known that we need to expand the capacity of SAF; what we**

don’t have is a detailed plan for doing it. For example, we really need to consider the role of blue hydrogen and recycled CO₂ streams when developing synthetic SAF, to boost usage while we prepare for the more sustainable green solutions.”

An airline executive had a similar response: **“We now understand the need and importance of addressing offset concerns. It’s less about small tweaks here and there, and more of a rethink through the eyes of a consumer that would increase their impact, create direct line of sight to value.”**

Participants have also concluded that while each solution is individually important, none will be enough on its own. Progress will require integration across the value chain from as far back as feedstock collection all the way to putting a low-emission aircraft in the sky.

We shall now explore the 15 solutions in terms of the six readiness factors discussed above.



MARKET AND CUSTOMER DEMAND

Solution 1: Corporate and cargo customers' demand for SAF

Large corporate flyers like big tech, financial institutes and consultancies, and cargo shippers like food and electronics manufacturers need to lead in creating demand for lower-emission aviation. Their own net-zero ambitions require them to reduce emissions from employee travel and transporting goods. Corporates with such net-zero ambitions represent a total annual

revenue of \$11.4 trillion – more than half the GDP of the USA³⁹.

More specifically, nearly 30% of the Fortune 100 companies have signed up to the Science Based Targets initiative (SBTi), which requires organisations to set targets that align with the Paris Agreement⁴⁰. The number of companies signing up to the SBTi is growing at an accelerating rate (see Exhibit 33).

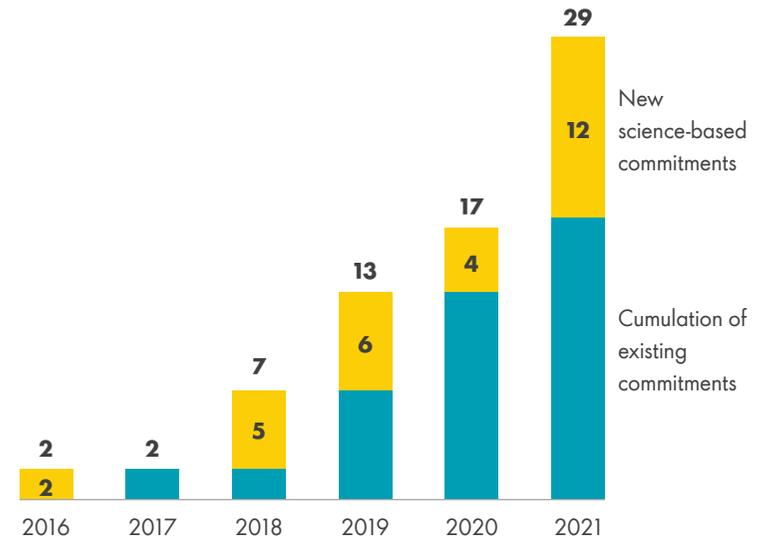
These commitments are translating into action, as companies face pressure from employees, investors, customers and other stakeholders to hit targets.

Corporate demand can play a key role in stimulating demand for flights that use SAF and for large-scale offtake agreements. They also form a more concentrated segment than leisure passengers. For example, around 200 large corporates represent a 16% share of global air travel (see Exhibit 34). Such concentration allows airlines to focus decarbonisation efforts on a relatively small number of customers who could form a critical mass in support of decarbonisation.

3. RESEARCH HIGHLIGHT

Long-term customer demand, enabled by recognition mechanisms and **differentiated propositions**, will play a fundamental role in providing the **funding and incentives** for airlines to invest in lowering their emissions.

33 Fortune 100 companies signed up to Science-Based Targets Initiative



Examples of aviation-related commitments of large corporates

Microsoft partnered with Alaska Airlines and KLM to cover CO₂ emissions of its employee commercial travel with SAF and/or SAF credits

Amazon Air purchased about 23 million litres of SAF and expects to reduce emissions by up to 20%

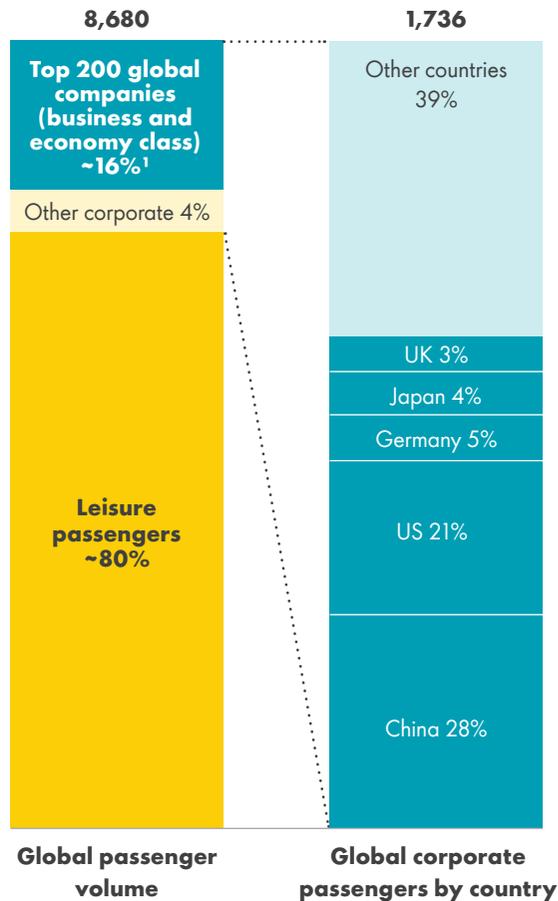
Shell and American Express GBT formed an alliance to help increase supply of SAF in order to become net zero by 2050

Deloitte entered into SAF agreements with American, Delta and United – avoiding the emissions from approximately 5,000 Mt of CO₂

FedEx has committed to purchasing 13 million litres of SAF from Red Rock Biofuel as a part of its long-term net-zero strategy

Sources: Air Cargo News; Business Traveller; Company Websites (2021); Green Air; Science-Based Targets (2021); Deloitte analysis
Notes: More than 29% of the Fortune 100 companies have climate change commitments. The analysis above includes only those signed up to SBTi

34 Share of corporates in global aviation (2019; billion RPK)



Sources: ICCT (2020); US Department of Transportation; Business Travel News (2019); Global Business Travel Association (2018); US Travel Association (2020)
 Notes: 1) Estimates based on top 100 corporates in US aviation spending.

Corporate travellers and cargo customers can often bear increased costs such as higher priced business flight tickets. One large corporate shipper said: **“Increased ticket pricing from SAF is a small percentage of our total cost of goods, but a large part of our carbon footprint, and we need to hit our 2030 emission reduction targets.”** This will be particularly important in the short term, when SAF will probably be significantly more expensive than kerosene.

Air travel represents over 80% of our carbon footprint, and we need to show our clients that we are walking the talk.

Cargo shipper

The first SAF routes are likely to be those with the highest concentration of corporate travellers, for reasons outlined by an airline executive, who said: **“If you fly from Amsterdam to London on a Monday morning, the aircraft may be 100% corporate passengers. All of these passengers are highly price insensitive, and their companies are trying to hit emissions reduction targets.”**

Organisations such as Microsoft have already signed SAF pricing agreements with airlines to offset their own emissions from air travel, and to help cover the additional cost of the fuel. Large corporates seeking to reduce their emissions from flying could also consider aggregating demand through large

buyer alliances. A recent example of this is the Sustainable Aviation Buyers Alliance, established by the Environmental Defense Fund and Rocky Mountain Institute (see Exhibit 35).

These alliances will create clear demand signals to the market, and make it easier for large corporates to reduce their emissions from flying. One regulator said: **“We need to define a mechanism that allows for aggregating demand without impacting competition laws. We are looking into this right now.”**

Air cargo customers also have a significant role to play – especially in the short term. **“Many cargo customers are looking for opportunities to differentiate by offering more sustainable products, or have set their own emissions reduction targets,”** said one logistics company. They also rarely have a choice of transport modes, because of the kind of products that are transported, such as perishables, fish and flowers.

Air cargo can often represent a large percentage of a product’s total carbon footprint, but a small percentage of its total cost. And when goods are shipped in high volumes, costs can be spread across each item, lowering the additional cost per unit. One large shipper said: **“For goods like sunglasses which are shipped in high volumes, the increased cost for net-zero transport is only pennies per unit.”** Such factors are likely

to encourage air cargo customers to be early adopters of decarbonisation measures.

Some cargo customers are already showing a willingness to pay. For example, the recently introduced DB Schenker and Lufthansa weekly flight between Frankfurt and Shanghai, which uses SAF and offsets to achieve complete carbon-neutrality is reportedly in significant demand⁴¹. Although individual passenger and cargo flights are important, large corporate offtake agreements for SAF will play a critical role in increasing production. One fuel producer said: **“New production projects need to show 10 to 15 years of signed offtake to raise the required capital.”**

For any of these solutions to work, SAF needs to be integrated into carbon-reduction

frameworks to allow large corporates to claim emission reductions, which they are not able to do today (see Solution 7).

Solution 2. Offers and rewards encouraging customers to make choices that support sustainability

Airlines need to improve the way they incentivise individual passengers to take advantage of opportunities to reduce their emissions through financial contribution to offsets and SAF.

One way to do that is by providing participating passengers with specific “functional benefits”, for example early boarding, priority security lane, preferential seats, or meal upgrades. Some airlines, such

as Qantas are already using elements of this approach. Qantas gives passengers 10 loyalty points for every Australian dollar they spend on offsets, and it also includes offsets as a default option from which passengers need to actively opt-out, rather than as an opt-in option. As a result, around 10% of Qantas passengers buy offsets⁴² - a considerably higher offset uptake than the industry average mentioned by study participants.

Although functional benefits have an important role to play, appealing to passengers’ social and emotional needs may be even more effective (see Exhibit 36). Some participants noted that in some countries sustainable flying could become a “status symbol”, similar to grocery shopping in high-end supermarkets, known for “organic” products. There could be different-coloured tickets or headrests on aircraft seats, or ranking systems of passengers who have offset the most. An ability to communicate one’s contribution on social media, for example, would probably need to be factored in. Such rewards and recognition would need to be sensitively handled to avoid coming across as unduly divisive, but could help incentivise passenger behaviour.

Airlines could also appeal to passengers’ emotional needs, by telling a compelling story of individuals who will be affected by climate change, or providing offsets generated by projects that help communities and the environment near where passengers live.



35 The Sustainable Aviation Buyers Alliance (SABA)

SABA is a corporate alliance working in collaboration with the Rocky Mountain Institute (RMI) and Environmental Defense Fund (EDF) to accelerate the path to net-zero aviation.

SABA’s mission is to support and scale SAF production and technologies and establish a robust and transparent SAF certification standard.

SABA members like Boeing, Deloitte, Microsoft, etc will drive impact by aggregating their demand for SAF certificates, incentivising SAF production and uptake, and engaging with regulatory authorities on policy planning and development.

Sources: RMI, Climate Group



36 Ways to make green propositions more attractive to passengers



Travellers can reduce the impact of their travel by offsetting the emissions generated from their flight or helping to cover the extra cost of SAF.

These solutions are available today but relatively few passengers make use of them. Airlines can change this by deploying a range of features to encourage greater passenger uptake.

At the airport, visual cues like green luggage tags or physical tickets can help these customers stand out and feel proud of the part they are playing to help tackle emissions.

During check-in and boarding, airlines can offer direct benefits like complimentary baggage, express check-in, or early boarding to help make the proposition more attractive.

Inside the plane, airlines can offer further direct benefits like designated seats, extra leg room or visual cues like green headrests. Passengers can also learn about their impact through an optional live-stream of the plane being refuelled with SAF or stories about successful offsetting projects.

In-flight communications and videos provide a chance to highlight success stories and show how everyone can help tackle climate change. They can also be used to thank travellers who have already contributed, so they feel appreciated.

Features like some of those mentioned can help build a sense of community, so travellers know their actions matter and they are part of a broader movement of people trying to make a difference.

Finally, it cannot stop at just one flight. Airlines can allow passengers to increase their impact over time, creating green points that can be collected and redeemed for flights or other services. Like airline status, these points can be given out in tiers that unlock more benefits for those who consistently choose to reduce their carbon footprint.

REGULATORY INCENTIVES

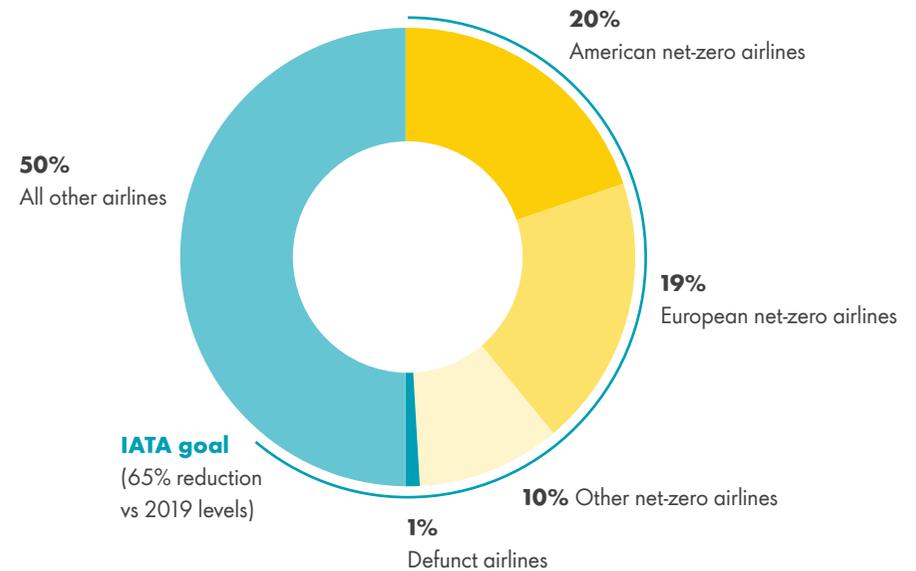
Solution 3. Net-zero targets and aligned plans

Interviewees said that the aviation sector needs more ambitious decarbonisation targets for 2030 and should commit to carbon-neutrality by 2050. These targets will help aviation to align with the rest of the energy system and encourage it to act with greater urgency.

Many airlines have already made net-zero commitments (see Exhibit 37). These include the members of Airlines for America, Airlines for Europe and the Oneworld alliance - carriers that together account for 50% of current aviation⁴³. Some countries, such as the UK⁴⁴, have included their share of emissions from international aviation in their reduction targets.



37 Share of aviation CO₂ emissions by airlines with public 2050 net-zero commitments (2019)



Sources: ICCT (2021)

Several interviewees said the ICAO 2022 General Assembly or the COP26 UN climate change conference would be great forums for bringing the required parties together and setting new targets. It would be important to set out clear regulatory milestones for the next five, 10 and 20 years. These milestones should be translated into policies aimed at fuel producers, airlines and other aviation stakeholders, to help create a clear path for investments that drive change at pace.

Solution 4. Supply-side mandates, incentives and feedstock allocation

Mandates, incentives and policy guidelines will be needed to help accelerate the production and use of SAF. Such measures are already in use in places like Germany (see Exhibit 38) and California, which has seen significant growth in new production projects⁴⁵. Here, we address each of the most-mentioned policy instruments that can increase the supply of low-carbon fuels. (see Exhibit 39)

SAF blending mandates

The principle of SAF blending mandates is that they establish minimum amounts of SAF that must be blended with fossil-fuel kerosene and be used when refueling aircraft in specific locations. This reduces emissions and encourages the development and production of SAF.

Within the EU+, which covers the EU27, the UK and the four European Free Trade Association (EFTA) countries, the ReFuelEU Aviation initiative⁴⁶ aims to boost the production and the uptake of SAF. The European Commission had considered various options, and concluded that the obligation to blend a certain percentage of SAF with kerosene is the best way to help match supply and demand, and reduce investment risks. In a recent "Fit for 55" related proposal, the Commission proposed that SAF blending mandates will see 2% blending levels by 2025, 5% in 2030, 32% in 2040 and 63% in 2050 - with minimum shares for synthetic aviation fuels included.⁴⁷

We need blending mandates to ensure investment happens in the next decade, but the system after this should be self-sustainable and driven by market forces.

Energy company

Some individual EU countries have set even more ambitious blending targets, with Finland and Norway going as far as saying bio-SAF should make up 30% of aviation fuel by 2030⁴⁸.

To be effective, mandates need to be supported by additional policies which reduce the risk of "tankering", which is buying cheaper fuel outside the regions that have SAF mandates. Tankering not only reduces the effect of mandates, but actually creates more emissions through the transportation of extra fuel when not needed. One airport said: *"Something like a 0.8% blending mandate is tiny, and won't encourage tankering. But as the size of the blending mandate increases, so does the risk of tankering."*

Low-Carbon Fuel Standard

The market-based programme in California awards Low-Carbon Fuel Standard (LCFS) credits to transportation fuels with a lower carbon intensity than the established baseline. These credits can be purchased by organisations to compensate for fuels with higher carbon intensity. Carbon intensity

benchmarks are set each year to match emission reduction goals⁴⁹.

Several interviewees from the USA were positive about the LCFS programme's benefits. One industry association said: *"It gives a clear pathway to develop SAF, which has lower life-cycle emissions."* Suggesting the scheme had helped reduce the cost of SAF, one airport said: *"LCFS has made California the market for SAF, and has driven down the cost-parity to conventional jet fuel."*

Policymakers who use LCFS-measures will also have to think about the removal of subsidies from low-carbon fuels as they become more cost-competitive, so the financial burden falls more on fuel buyers than taxpayers.

Contract for difference/green subsidies

The key constraint for greater SAF production is lack of certainty that the fuel will find buyers, considering it is more expensive than kerosene. In the regions where policy-makers consider mandates excessively interventionist, a "contract for difference" (CfD) mechanism can be used.

These mechanisms have previously been tested in the power sector, where they played an important role in stimulating production of renewable electricity. When CfDs are used, energy producers receive financial support in the amount that is equal to the difference between the cost of a low-emission solution - in this case SAF - and the fossil-

based alternative, kerosene. This allows the producers to offer a low-emission solution at market price, thus making it a viable option for the airlines. An engine manufacturer said: *"CfDs would be a great addition to blending mandates and carbon taxes on the demand side."*

Tax credits

Another way of incentivising SAF production is to provide tax credits. These should not be generic pay-outs, but rather be tailored to encourage specific types of investments.

For example, the market for biodiesel for road transport is currently more attractive than that for SAF. As a result, producers often prefer biodiesel over SAF. An airline said: *"Incentives to encourage SAF over renewable diesel will be key to scaling the production of SAF."*

One interviewee noted efforts to achieve this in the USA, saying: *"Congress is considering approving a tax credit to make up the price gap of SAF to renewable diesel."* Under the proposed Sustainable Skies Act in the USA, energy producers would receive a \$1.50-per-gallon tax credit for SAF that achieves at least a 50% reduction in life-cycle greenhouse gas emissions. Producers would receive a further credit of 1% per gallon for each extra percentage point of emissions reduction beyond 50%.⁵⁰ An 80% reduction compared with kerosene would generate a tax credit of \$1.80 per gallon.

4. RESEARCH HIGHLIGHT

Country- and region-based policy incentives relating to supply and demand will **accelerate the adoption of SAF** and regulation at regional and global level.

Scarce resource allocation

The aviation sector needs biomass and hydrogen as a feedstock for making SAF. But other sectors also need biomass and hydrogen. Policy measures will be needed to ensure feedstock is allocated to the sectors that need it the most. These will be the sectors that cannot decarbonise through other means. The allocation can be done through measures such as taxes on current production, or incentives that help to bridge price gaps between different sectors. For example, the recently proposed Sustainable Aviation Fuel Act in the USA aims to create an LCFS-like incentive solely for the aviation sector, to incentivise suppliers away from producing biodiesel only for road transport.⁵¹

Policy interventions should also support other feedstocks where the current available supply is unlikely to meet the level required to decarbonise aviation. The policy interventions should seek to increase investment in renewable electricity and in developing CCSU and DAC technology. Such interventions would encourage the production of the green hydrogen and CO₂ needed to make synthetic SAF. They could involve production or R&D incentives, or use the proceeds from carbon and other sustainability taxes to fund relevant programmes.

Supply incentives will be needed to scale SAF solutions quickly, even if the current economics are not cost-competitive. We are likely to see localised regulations that fit the dynamics of





38 Germany's synthetic SAF roadmap

In 2021 the German Federal government, together with the industry, published a roadmap for the market ramp-up of synthetic SAF.

The roadmap will pave the way for the annual production of 200 kilotonnes synthetic SAF in 2030, enough to fuel one-third of Germany's current domestic flights. Although the plan is to initially use CO₂ waste streams, the goal for the future is to use direct air capture technology.

The take-up of synthetic SAF in Germany will be supported by binding minimum blending quotas which will be introduced in 2026 at 0.5% and gradually raised to 2% in 2030.

"Electricity-based fuels need to find their pathway from laboratory to industrial production as quickly as possible", said Federal Environment Minister Schulze

Sources: German's Federal Ministry for the Environment, Nature Conversation and Nuclear safety

an area's market for fuel production, such as tax credits and LCFS-style schemes in North America, and green subsidies in the EU.

It will then be important to learn from supply incentives that have been implemented locally, so similar measures can be applied in other regions, increasing their global impact.

Solution 5. Demand-side emission taxation, restrictions and incentives

Mandates and incentives on the supply side alone will not be enough to achieve decarbonisation. Policy measures on the demand side are also needed, to help bridge the gap in cost between conventional jet fuel and SAF, and to encourage more use of SAF. The most frequently mentioned policy instruments include carbon taxes and pricing mechanisms such as ticket price floors.

Carbon tax and emissions trading schemes

Carbon taxes and emissions trading schemes create what is called a "carbon price". They effectively put a price on emissions to incentivise avoidance.

Carbon taxes are levied on greenhouse gas emissions. An emissions trading scheme (ETS), also known as "cap and trade", involves a government setting a limit - the cap - on the maximum amount of emissions allowed under the scheme. The government creates permits for each unit of emissions up to the maximum amount allowed. Companies need

to obtain a permit for each unit of emissions they produce. They must obtain permits from the government, or buy them from other companies.

Carbon taxes and ETS make it more expensive to use fossil fuels, so they are likely to help close the price gap between lower-carbon fuels such as SAF and kerosene. They are also seen as a way to price in the environmental cost of carbon emissions, reflecting a more clear picture of the true cost to society.

One manufacturer said: **"Carbon price and ETS are parts of the solution to mitigate price differences in a price-competitive sector."**

It is important that carbon taxes take an international perspective. They should not be restricted to flights within a particular group of countries, as is currently the case in the EU.

Interviewees thought the proceeds from the carbon taxes paid by aviation should be kept within the sector and directed towards technology development and emission reduction. One airline said: **"The issue with taxes is that the money does not stay in the sector, and is often not even used on anything that would have a positive environmental impact."**

Other taxation mechanisms include frequent-flyer taxes or "green taxes", as recently proposed in the UK⁵².

Although carbon taxes may be acceptable in some regions as a solution, interviewees did raise concerns. One said: **“There are already over 10 taxes on tickets in some markets. They are too complex, they often double-tax the same thing from different angles, and it is unclear how the money is used.”**

Route restrictions and pricing mechanisms

Low-cost tickets have made aviation more accessible, but ultra-low-cost tickets – some as low as \$10 for a 300+ mile route – are being questioned when viable alternative transport is available. Some countries, such as Germany and France, are exploring ways to introduce price floors or restrict routes that are also served by high-speed rail networks.

Margins are razor thin in the ultra-low-cost market, where a \$1 difference can make or break a sale. This makes individual airlines unable to bear any increased costs that may put them at a competitive disadvantage. One low-cost carrier said: **“We will struggle to be early adopters of more expensive fuel. It is all down to cost for us. Whoever has the lowest ticket price wins.”**

Government-mandated minimum ticket prices for all airlines on a certain route are likely to reduce discretionary demand – demand for non-essential travel. These measures must be sensitively managed to keep aviation accessible. They should be combined with measures such as SAF mandates, to ensure increased margins are directed towards solutions that will decarbonise aviation.

39 Possible policy instruments

Stakeholder	What gets regulated	How it could get regulated			
Engine / aircraft manufacturers	Engines and airframes produced	Minimum energy efficiency standards	Taxation for lower-performing engine / aircraft combinations	R&D incentives on alternative technologies (e.g. advanced biofuels, electric, hydrogen)	
Airlines	Fleet ownership	Incentives for accelerated fleet renewal	Incentives for flight payload and capacity optimisation		
	Fuel bought	Carbon-based fuel taxation	Cap and trade scheme (e.g. emissions trading schemes)	Carbon offsetting and reduction requirements e.g. CORSIA	R&D incentives (e.g. funds for trials)
	Route	Airspace integration and harmonisation	Differentiated airport fees or access (e.g. priority slots)	Restriction on short-haul flights with modal shift options	
Infrastructure suppliers/ energy companies	Fuel mix sold	SAF blending mandates (e.g. % of bio-SAF and / or synthetic SAF)	Contracts for difference (CfD) to compensate for difference in fuel cost	Tax credits (e.g. Low-carbon fuel standard)	Increase fuel taxation (e.g. VAT)
	Infrastructure development	Develop (safety) standards for SAF and alt. propulsion tech.	Direct funding for SAF production projects	Scarce resource allocation over sectors (e.g. biomass, hydrogen)	
Customers / cargo shippers	Ticket price	Price mechanisms (e.g. price floors)	Direct and/or tiered environmental tax (e.g. green levy or frequent flier levy)		
Financiers	Portfolio composition	Minimal sustainable finance criteria before providing a loan			

Sources: Interviews; Deloitte analysis

TECHNOLOGY ALIGNMENT

Solution 6. Carbon offset improvements

Offsets 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 solutions.

Offsets will probably also play a role in the longer term, while SAF supply and demand scales, and to address the remaining 20-40% of emissions relating to bio-SAF.

Aviation must address the concerns about offsets, and emphasise the important role they can play in decarbonisation. It must make sure that all offsets are subject to rigorous standards and assurance mechanisms, and better communicate their role to customers. Customer concerns about offsets can partly be addressed by:

- focusing as much as possible on projects that would not otherwise be delivered by market mechanisms – for example directing more funds to nature-based and carbon capture solutions and less to renewable electricity developments, which in most cases are already financially self-sustainable;
- incentivising development of projects that are physically closer to where the emissions occur, with impact now - not in

20 years – as this is believed to be more compelling to passengers;

- ensuring projects that generate offsets are additional, meaning they would not have happened without the offset scheme existing – so, for example, schemes would be disqualified if they just protected trees that were safe from being cut down anyway;
- encouraging customer uptake through clear and compelling communications, and where possible by choosing more local and tangible projects; and
- improving transparency around the use of funds, to alleviate concerns around high overhead costs – i.e. project costs not directly related to emission removal.

The above measures must always be supported by standards and assurance mechanisms, in order to ensure confidence in the quality of offsets. Offset programmes should be categorised according to quality, so it is clear when people are offering high-quality offsets (see Exhibit 40). One corporate purchaser emphasised that aggregators are needed to make it possible to compare offsets, saying: **“I don’t know if the programmes I’ve chosen are the best because it’s impossible to keep track of what’s available, and there’s no way to compare options.”**

The minimum quality thresholds of existing regulatory frameworks such as CORSIA should be updated, to ensure that the offsets used relate to projects that make a difference to the overall levels of greenhouse gas in the atmosphere. One NGO said: **“It doesn’t help if everyone just goes for the cheapest offset option, because those programmes often don’t have much of a carbon impact.”**

Airlines should also better integrate offsets into the buying experience: **“The way offsets are sold on websites is very uninspiring. By the time I’m done with my purchase, I don’t want to click through to another page and think about offsets,”** said an OEM executive.

Airlines also need to consider moving to an opt-out rather than an opt-in approach. This has proved effective where adopted. One operator said: **“We used to have almost no uptake; now we have an 80% uptake from our private customers, and 100% from charters, from this one simple change.”**

An interesting alternative to offsets is “insetting”, where funds raised are used for decarbonisation directly within the sector – for example, for producing SAF and R&D. One travel agent said: **“A sustainable aviation investment fund will let travellers directly contribute to decarbonisation, which is more appealing than bringing it to the other side of the world.”** Making sure the carbon savings from such projects can be accounted for is key, at least for corporate buyers.

5. RESEARCH HIGHLIGHT

Offsets can play an essential role in funding the early stages of decarbonisation. But for this to happen, they must be made **more transparent and verifiable.** They need to be more **emotionally appealing** to passengers, and their impact should be clearer.

Until SAF supplies scale up, offsets are the only option available to us.

Airline executive

40 Carbon offsetting instruments

Effect	Avoid			Remove	Capture
Instrument	Community projects	Industrial projects	Renewable energy	Nature based solutions	Direct Air Capture
Description	Helping communities to lower carbon emissions, through increased energy efficiency and fuel switching. Often in developing countries	Adjusting operations in e.g. factories, oilfields and farms to reduce emissions, for example methane	Building sustainable energy sources through hydropower, wind, solar power, geothermal, and waste biomass projects	Reforestation, land restoration, forest protection, sustainable land management and agriculture	New technology to capture CO ₂ from air directly
Price (\$ / ton CO ₂)	\$1-100	\$1-100	\$1-150	\$2-150	\$100-800
Availability	Medium	Medium	High	High	Low
Advantages	<ul style="list-style-type: none"> Supports low-carbon development in developing countries Funnels investments to causes in communities in need of funding 	<ul style="list-style-type: none"> Supports low-carbon development in developing countries Allows for more sustainably produced materials 	<ul style="list-style-type: none"> Lowers demand for fossil fuels Supports the development of the renewable energy markets 	<ul style="list-style-type: none"> Creates jobs Preserves biodiversity Straightforward carbon benefit calculation 	<ul style="list-style-type: none"> Is space efficient and can be built at a wide range of locations, including non-arable land
Risks	<ul style="list-style-type: none"> Not being able to validate or verify the results 	<ul style="list-style-type: none"> Not being additional - the emissions reductions might have been done with or without offsets 	<ul style="list-style-type: none"> Not being able to accurately measure the achieved impact on emissions Not being additional - the power sources might be built with or without offsets 	<ul style="list-style-type: none"> Not being able to validate permanency 	<ul style="list-style-type: none"> Not being permanent

Sources: interviews; EIC (2020); Gold Standard (2021); ICAO (2021); United Nations Carbon Offset platform (2021); UNFCCC (2021); World Bank Group (2020)

Solution 7. Standards, certification and reporting to assure the quality of carbon reductions from SAF and offsets

The demand for SAF can be accelerated by improving transparency around quality and sustainability, and using mechanisms to open up access to those who are far from points of supply.

Some corporate customers discriminate between feedstocks for bio-SAF, seeking to choose those perceived as most sustainable and avoid any that are associated with deforestation or food-crop replacement. As a result, producers must provide transparency around the source of SAF and give buyers the choice on what they buy.

There is a clear role for standards and certification to play here, in order to safeguard sustainability standards and carbon savings.

NGO

These standards should be clearly communicated to help overcome the jargon-laden language used today. One manufacturer said: **"I have no idea what**

'cellulosic' or 'gasification' mean, I just know that some feedstocks are seen as more sustainable than others, and I want to know which is which."

Widely adopted standards will also help create demand for higher-quality feedstocks.

The market for buying SAF is still relatively new. Early corporate adopters have taken a range of offtake approaches, from buying

directly from producers, to buying from individual airlines, to buying from airline alliances. One corporate customer said: **“We want to use SAF to reduce our travel emissions, but flights aren’t available and we don’t know who to buy it from, what price to pay, or what we get for that price if we want to offset.”**

To help offtake agreements, the sector must establish markets, and mechanisms for contracting and pricing. Buyers must also be

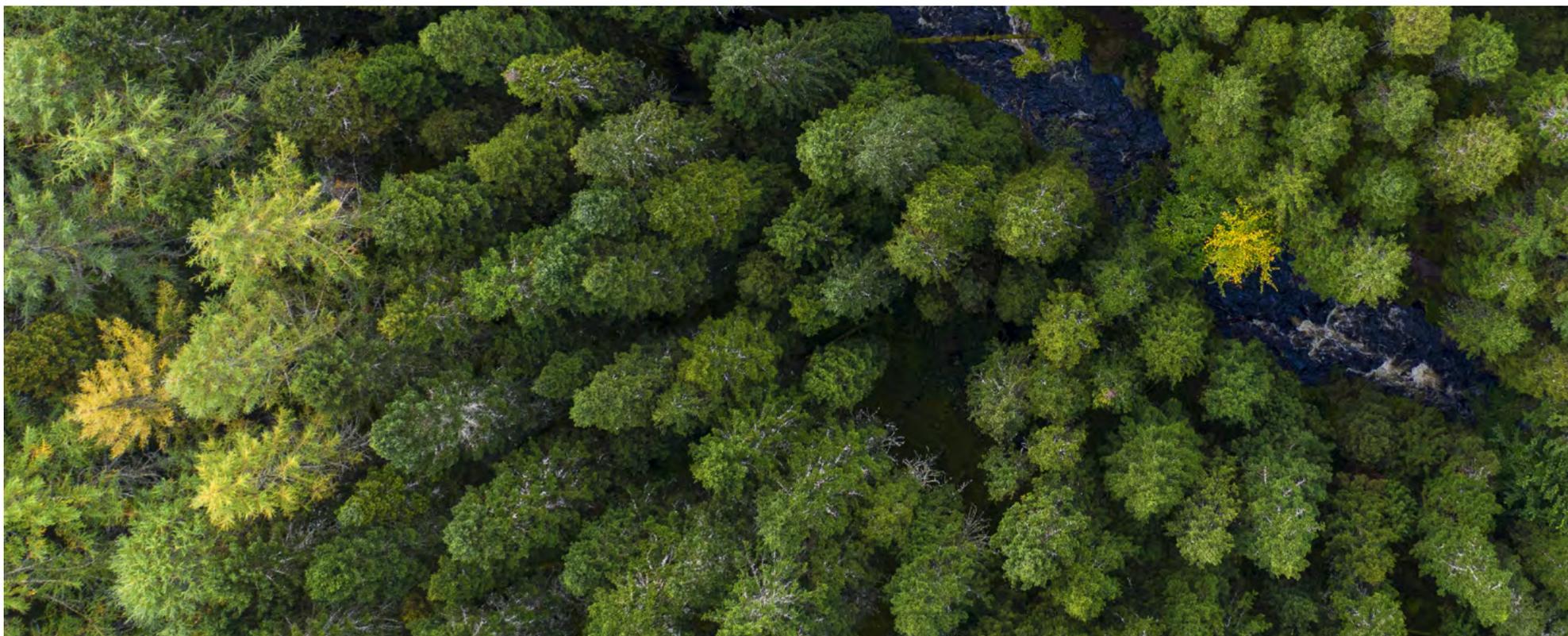
able to obtain certificates showing that SAF has helped them reduce their emissions and lower their carbon footprint. One SAF producer said: **“Corporates that set carbon reduction targets are willing to pay to hit those targets, but right now SAF doesn’t help them.”**

Certification programmes must be traceable from producer to purchaser, to avoid double-counting. A third-party logistics company said: **“SAF will be like buying a diamond ring: you want a certificate of proof of what you have**

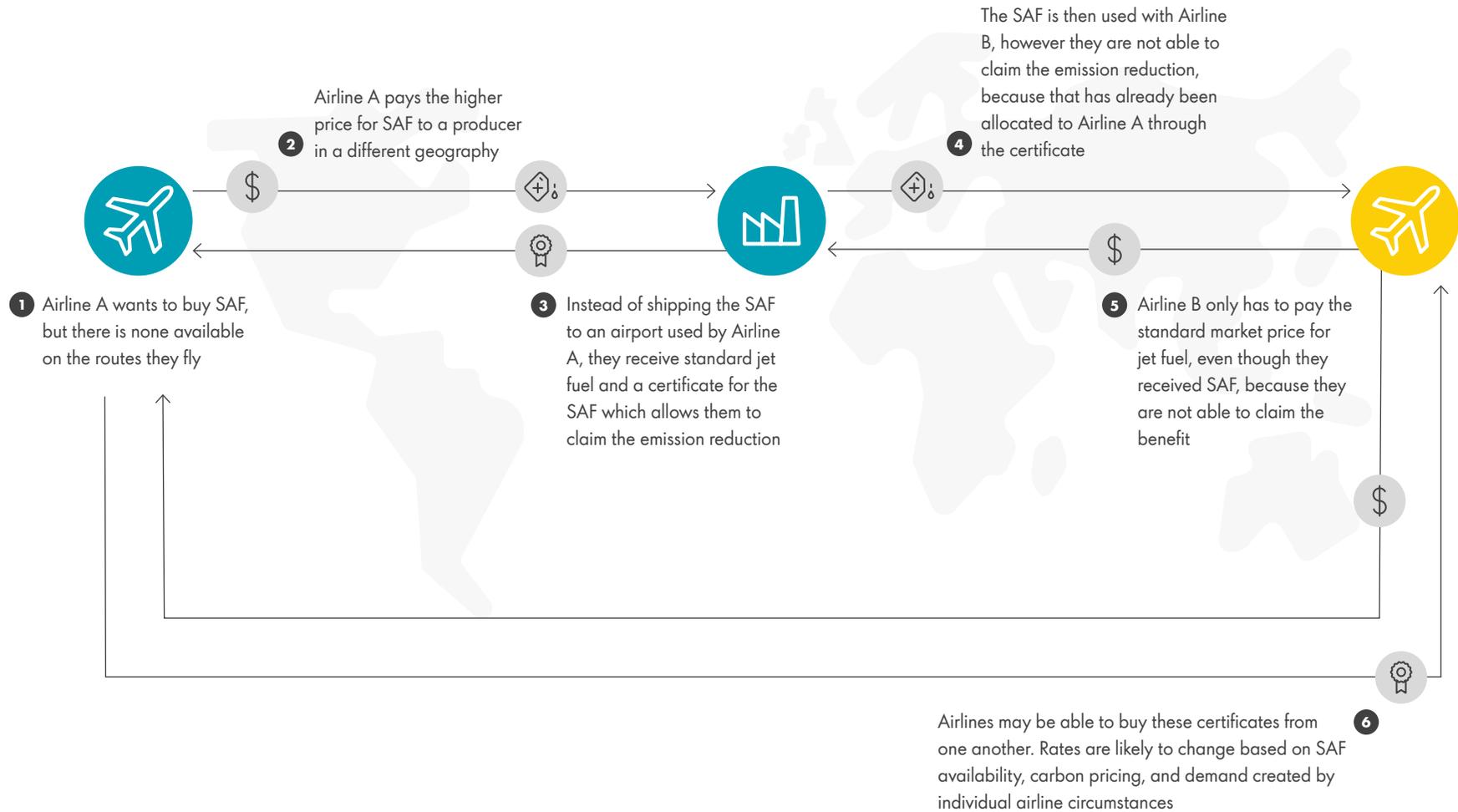
purchased. Transparency, certification and tracking needs to improve, and could help to increase usage.”

In the short term, certificates may also help buyers who are far from points of supply to gain access to SAF. Tradable certificates or book-and-claim mechanisms will help expand the market for SAF. They will also create the scale required to unlock further investment. Book-and-claim mechanisms (see Exhibit 41) will also help resolve the problem

of causing emissions by transporting SAF long distances, to take advantage of price differences. One airline said: **“It doesn’t help emissions-reduction if we produce SAF in one market and move it by diesel truck to another because a fuel producer can charge a higher price for it there.”** Such a solution might be enabled by blockchain technology to avoid double-counting and ensure a single source of truth around certificate ownership.



41 SAF “book and claim” mechanism – ILLUSTRATIVE



Sources: interviews; Deloitte analysis

Solution 8. R&D of electric and hydrogen aircraft

Although electric and hydrogen commercial aircraft appear to be a long way off, they are both likely to play a role in the future of aviation. Both are more energy-efficient solutions than synthetic SAF, as energy is lost at each stage of SAF production (electricity to hydrogen, and hydrogen to SAF). They also avoid climate concerns associated with high-altitude combustion.

While the sector should be making immediate use of all the decarbonisation options that are currently available, it should also be developing the technology for electric and hydrogen aircraft, so they can be used in the future.

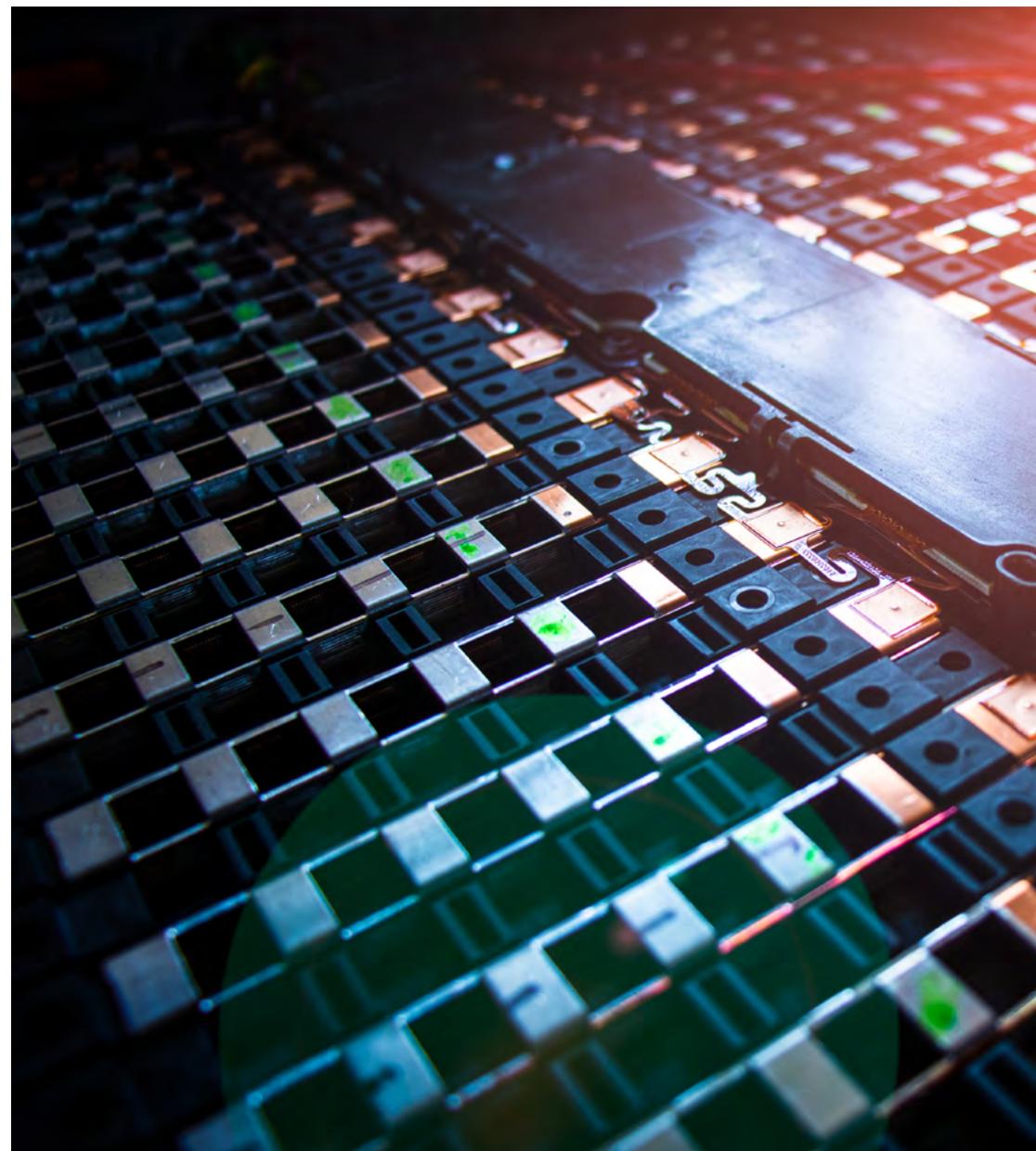
The large airframe and engine manufacturers could continue to invest in R&D to resolve aviation-specific technology challenges. But they should also expand collaboration efforts to other sectors looking to resolve similar challenges. For example, aviation could collaborate with the automotive and power sectors on battery density and hydrogen storage. Shipping and aviation could help each other to resolve shared challenges

around hydrogen applications. This will allow everyone to pool funds and ideas to help solve common problems.

Markets should continue to open up access to new start-ups exploring aviation technology. For example, there have been several large special purpose acquisition company (SPAC) deals around electric vertical take-off and landing (VTOL). Developing technology for a given commercial application first, and then expanding it to the wider market as it matures, is a recipe for success.

As technologies improve, airlines and airports should identify the first viable routes for alternative propulsion technologies, and begin trials as soon as possible. Although there are still significant doubts about the viability of these technologies for some routes, there is optimism around short-haul flights. One interviewee said: **“By 2040, we might start to see battery-electric aircraft in the commuter segment.”**

Airports are also showing optimism. Several new development projects are being built with the future in mind. One airport said: **“Our new terminals will be ready for hydrogen aircraft.”**



CLARITY ON ROLES AND DECISION MAKING

6. RESEARCH HIGHLIGHT

Choosing SAF as the primary means of decarbonisation will have a disproportionate impact on lowering emissions, because there is no need to redesign aircraft. As a result, **investments and R&D efforts can focus** mainly on scaling production and lowering cost.

Solution 9. Collaboration with other sectors on SAF R&D

Although SAF is already produced today, further technological developments are required to make it cheaper and to expand production. This technology would also be useful to other industries. Aviation and other

sectors can help each other by co-operating to develop technology that they all need.

The technology for first-generation bio-SAF is mature, but there are concerns about the sustainability of feedstocks. It may prove hard to increase supply without cutting down forests to make space for biofuel crops or cultivating biofuel crops on land that could have been used to grow food. *“While we are waiting for hydrogen, we need to be able to produce bio-SAF that doesn’t compete with food or cause land-use issues,”* said an NGO.

Innovation is required to expand feedstock supply: thermochemical and biochemical routes need further development, so new feedstocks can be used.

The largest cost components of synthetic SAF are producing hydrogen and obtaining CO₂ by DAC. Bringing these costs down will be key to enabling large-scale production.

In the coming decade, CO₂ emitted by other sectors, such as steelmaking, could be captured and reused to produce synthetic SAF. That means emissions are recycled rather than avoided altogether, but it does significantly reduce the amount of CO₂ that ends up in the atmosphere. And required technology is currently much more readily available than DAC.

The cost of hydrogen for synthetic SAF will keep falling, but we also need affordable CO₂.

Energy company

The technological developments described above should be funded using existing R&D funds, revenue from industry carbon taxes and money raised through insets (investments in emissions reduction projects within the industry’s value chain). New financing mechanisms such as ESG investment funds should also be developed, to help finance trial projects and to help manage the risk of technology failures.

Co-operation with other sectors will help bring technology to scale, and make more efficient use of money and ideas. Road freight, shipping and power are all sectors that would benefit from affordable green hydrogen and a greater availability of advanced biofuels.



7. RESEARCH HIGHLIGHT

Collaboration with other sectors is essential to the successful deployment of SAF. It can **drive down the cost of required technologies**, such as hydrogen production, direct air capture and biomass conversion, **and ensure effective use of scarce resources**.

Solution 10. Airports extending influence to promote SAF uptake and fleet upgrades

Airports can advocate for the development of lower-emission technologies, but can do

more to accelerate the uptake of SAF and operational efficiencies.

Some airports are starting to apply different airport charges for aircraft that meet low-emission and noise standards (see Exhibit 42). Interviewees noted airports could also offer other benefits, such as prime timeslots for more efficient airlines. **“We have seen airlines renew their fleet much faster, to enjoy the benefits of lower airport charges,”** explained a representative of the airport.

Publicly owned airports should also take advantage of national decarbonisation targets, to secure capital that can be used to provide incentives to airlines and fuel providers to adopt higher SAF blends. One airport said: **“Our government has established a COVID recovery fund that is heavily aimed at decarbonisation. As a major source of national emissions, we are trying to**

help bridge the cost gap between blended SAF and kerosene. At today’s blending rates, we could bridge the cost gap for thousands of flights with this fund.”

The top 25 airports handle 45% of all passengers, so a few leading airports can make a big impact. When there are no antitrust concerns, airports should create “coalitions of the willing” to apply consistent standards, commit to long-term deals and share learnings across major cities and hubs.

Solution 11. Airports and airspace optimisation to reduce operational emissions

Airports and national governments have a direct role to play in improving the efficiency of routing and airport operations. Although airport operations only contribute 2% of the sector’s total carbon emissions⁵³, technologies to reduce this impact are readily available, and many airports have reached carbon neutrality already.^{54, 55}

Measures that have been used to reach carbon neutrality include buying or producing renewable electricity, improving insulation, adopting energy-efficient equipment, and using electric ground vehicles. Some airports are also reducing their indirect emissions (scope 2 and 3) through measures such as improved public transport that helps arriving passengers complete their journeys by land.



42 Airports stimulating demand for low-emission assets

Schiphol airport in the Netherlands is using financial incentives to encourage airlines to be cleaner and quieter. The charge for the cleanest, quietest aircraft is being reduced to 45% of the basic rate, whereas those with high emissions are being charged up to 180% of the basic rate.

Heathrow airport in London has implemented the ‘Fly Quiet and Green’ programme. It tracks airlines’ performance on emissions targets and publicly ranks airlines based on the emissions in their operations. This initiative aims to recognise good performance, provide airlines with regular feedback and engage with airlines to improve their rating.

Sources: Schiphol, Heathrow



Many of these initiatives offer a positive return on investment within a few years, because they help airports to reduce their energy costs. Successful airports should create a blueprint to help others reduce their emissions, while there should be more collaboration between airports across regions, to help spread knowledge of how best to make initiatives work.

Interviewees said improved ground operations and more efficient landing and take-off (LTO) cycles could significantly reduce emissions.

You could get almost 10% energy and emission reduction by just fixing the inefficiencies of taxiing at airports and waiting for landing.

Airport executive

Aircraft routing can be significantly improved by opening up and better harmonising international airspace. One interviewee said: *“We rarely fly the most direct route because of the cost and complexity associated with international airspace. If this wasn’t an*

issue, we could easily reduce 10%–20% of our emissions immediately with no investment required.”

The primary issues with international airspace are different cost mechanisms between countries, and restrictions due to military use. The size of the potential prize is large, but it will be hard to further harmonise international airspace. There are strategic and geopolitical obstacles, and airspace costs can be a significant source of revenue for some countries.

It might be difficult to achieve the combined 10%–20% reduction mentioned by the interviewees (see Exhibit 43 – operational efficiencies), but the sector could still make progress through better collaboration between countries that do not rely on airspace revenue, in areas which are relatively free of strategic and geopolitical complications.

43 Efficiency improvement potential

	Design efficiencies			Operational efficiencies	
	Engine design	Airframe design and materials	In-flight capacity	Air traffic management	Ground operations
Description					
	Upgrades to engine design and configuration	Increased use of lightweight structures and materials that reduce drag, like carbon fibre composite materials	Maximisation of in-flight payload, in terms of passenger plus cargo	Harmonisation of airspaces and access to restricted airspaces	Optimisation of on-ground processes like single engine or electric taxiing, optimal take-off and landing routing
2050 efficiency improvement potential (vs. 2020)	20–30%		5–20%	5–10%	5–10%

Sources: interviews; Airbus; ATAG – Waypoint 2050 – “High improvement scenario”; Eurocontrol; IATA – Aircraft Technology Roadmap to 2050; IPCC; Wired

Notes: Due to interdependencies, the sum of improvements does not add up; In-flight capacity analysis estimates current capacity of low cost carriers at 97% and an average of 82% for the rest

EASE OF ASSET REPLACEMENT

Solution 12. Aircraft efficiency improvements and accelerated fleet renewal

Efficiency improvements resulting from the use of lightweight composites, changing from four-engine to two-engine configurations, and improved engine designs can help reduce aviation emissions in the coming decade. One manufacturer said: **“Each new generation of aircraft typically brings a 15% reduction in fuel-burn compared with predecessors.”** These improvements also allow airlines to reduce fuel consumption, which lowers emissions and helps to cover the greater cost of SAF.

In 2009, the sector agreed a target to deliver average annual fuel efficiency improvements of 1.5% per year from 2009 to 2020⁵⁶. There has been an efficiency improvement of 21.4% since 2009, building on an impressive 54.3% improvement since 1990⁵⁷. This equates to a compound annual reduction rate of about 1.3%⁵⁸.

We can't purely rely on current technologies becoming more efficient. We are reaching points of diminishing returns without a step change in propulsion technology or fuel type.

Aircraft manufacturer

The acceleration of fleet renewals offers an opportunity to scale the efficiency improvements across the global fleet. Some airlines and leasing companies have taken advantage of the COVID-19 disruption to accelerate their modernisation programmes. For example, Lufthansa and Singapore Airlines have continued taking orders of new aircraft while accelerating the decommissioning of older planes. One of them has publicly noted: **“The new aircraft we are putting into operation are 30% more efficient than those we are taking out.”** As demand for flights picks up after the pandemic, airlines should seek to bring the most modern aircraft back first, and where possible take older models out of circulation.

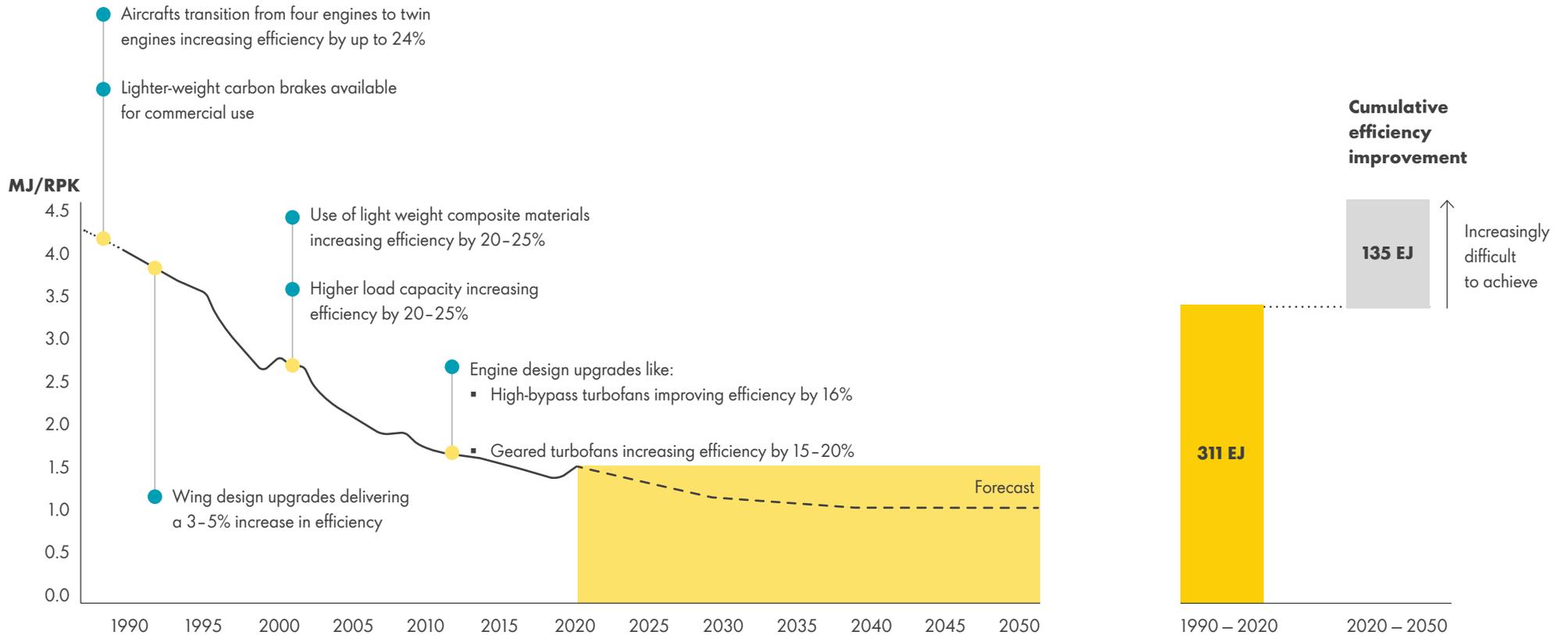
Financiers and governments will need to play an important role in helping airlines fund the fleet renewal. Governments could attach carbon-reduction conditions to COVID bail-out payments. Some governments have already done this. For example, the \$8.3 billion relief package delivered to Air France-KLM was conditional upon the airline group meeting a rigorous plan to reduce CO₂ emissions⁵⁹. Governments can also adopt

requirements similar to the Euro standard for heavy-duty road freight which applies conventional pollutant limits to fleets⁶⁰.

However, interviewees believe that as the oldest aircraft are retired in the 2020s, the efficiency improvements will be increasingly difficult to achieve, with most citing 20%-30% in emission intensity reduction as an achievable target (see Exhibit 44).



44 Historic aircraft design energy efficiency gains



Sources: ATAG - Beginners Guide to Aviation Efficiency (2016); Boeing (2009); Boeing (2019); ICCT (2018); Eurocontrol (2021); National Geographic (2013)
 Notes: Cumulative efficiency improvement based on 1990 efficiency, EJ = exajoule = 10¹⁸ Joule

Solution 13. Focused “green” financing to support more investment in decarbonisation

Global decarbonisation across all sectors is expected to cost \$4 trillion a year by 2030⁶¹, in order to meet net zero by 2050. Decarbonising aviation will require significant investments in scaling up the production of SAF, renewing the aircraft fleet, developing new technologies, and upgrading the infrastructure. For example, the 2020 amortised value of the 10 largest lessor fleets alone – which together represent less than 20% of the market – was found to be more than \$167 billion⁶².

To fund these investments, the aviation sector will need to attract new capital providers, willing to balance short-term return risks with long-term benefits of ESG financing. Interviewees thought that aviation needed an equivalent of the Poseidon Principles – an initiative developed for the shipping sector by banks and other industry stakeholders to provide a global framework for responsible ship finance. This framework measures the carbon intensity of loans, so lending decisions can involve considerations of the climate. Financiers can balance a project’s high sustainability score against its greater

economic risk. The Poseidon Principles also enable the establishment of a common baseline to assess and disclose whether a financial institution’s lending portfolio is in line with adopted climate goals⁶³. **“Aviation needs an equivalent of the Poseidon Principles, and to align lessors and lenders on climate goals when making investments,”** said one interviewee.

Addressing concerns around the long time horizons for these investments is one hurdle that needs to be overcome. **“Other energy-transition markets such as wind and solar all had long-term incentive structures in place,”** said a financier. Offtake agreements from buyer associations, and the implementation of government-mandated price floors are expected to help stabilise cash flows and encourage project financing.

Energy companies are also well positioned to help fund decarbonisation. One interviewee said: **“With their operating and asset financing expertise, energy companies can play a role in supporting customers to take more risk in scaling technology.”** Energy companies can take a long-term perspective on investment returns, have available capital to spend, and can bear more risks across projects.



EASE OF INFRASTRUCTURE REPLACEMENT

Solution 14. Bio-SAF production

The technology for creating bio-SAF from certain feedstocks is already mature, but global production is relatively low. In 2020, total production was less than 0.01 EJ (190,000 tons), or 0.1% of global aviation requirements.⁶⁴

The solutions outlined above in this report have addressed the demand, technology development and financing needed to increase the production of SAF. This solution focuses on bringing those solutions together, and expanding feedstock supply chains so more SAF can be produced.

Feedstock sources will become more sparse and expensive to develop as bio-SAF production expands. The aviation sector will have to develop new types of feedstock and

improve the efficiency with which existing feedstocks are supplied. **“A lot is made of feedstock limitations, but there are many potential sources of biomass; the challenge is accessing them and processing them efficiently,”** said a fuel producer. For example, there are currently vast untapped quantities of municipal solid waste, agricultural residue and woody biomass (see Exhibit 45).

The development of bio-SAF should be accelerated by rapidly expanding existing trial projects and quickly establishing new schemes in areas with good access to feedstocks. While we need to be mindful of the feedstock origins, we need to be careful not to **“make perfect the enemy of good, or we will always be using hydrocarbons,”** in the words of one industry source.

Although biomass supplies could theoretically meet all demand from aviation, some of that biomass will be used in other sectors. The limitations in land use and competition with other sectors might lead to a supply shortage of more than 92 EJ (see Exhibit 46). The IEA expects biomass to meet 50 to 60% of aviation demand by 2050.

Some of this demand could be unlocked earlier. As road freight begins to electrify, biomass that was being used to produce biodiesel for trucks could be diverted to making SAF for aircraft.

As feedstocks scale up, certification will be critical in safeguarding quality and sustainability, as noted in solution 7.



45 Bio-SAF production increasing

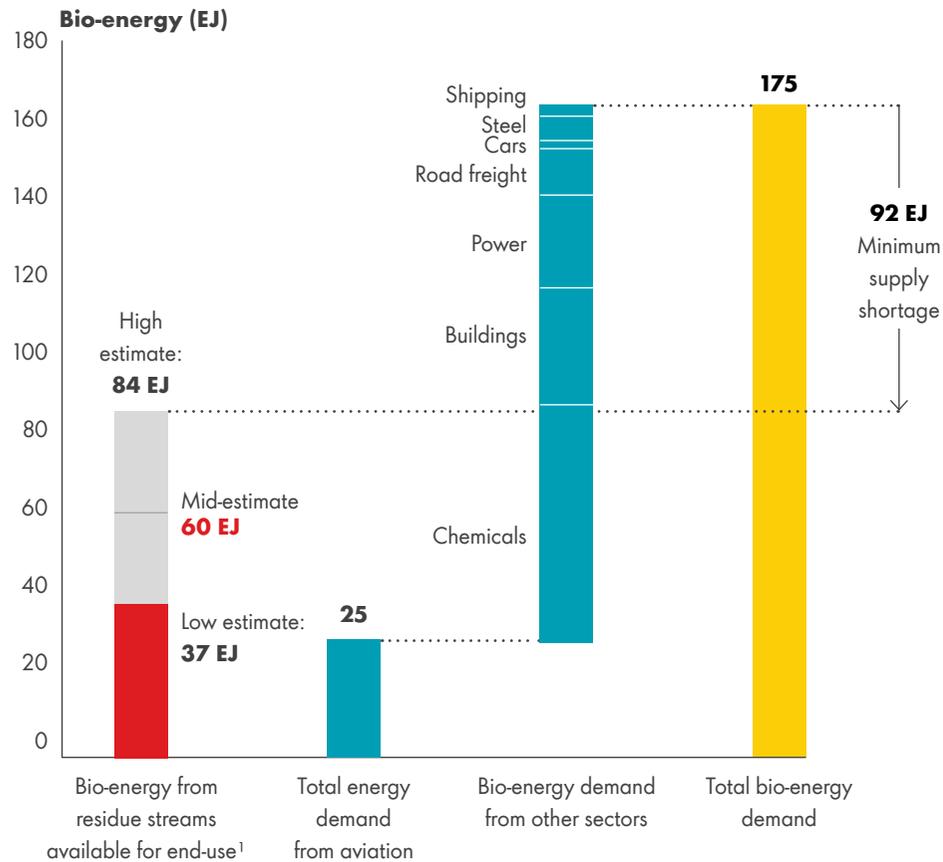
With an expected rising demand for SAF, there is an on-going quest for the best and most sustainable feedstocks. One of these potential feedstocks is municipal solid waste, which is low-grade, post-recycling mixed waste.

Various companies are looking into the production of SAF from municipal solid waste. In the process the solid waste is first gasified to create syngas, a combination of hydrogen and carbon monoxide. This syngas can then be converted to SAF via a chemical process known as Fischer-Tropsch.

In the UK, Velocys is planning to use this technology to transform 50 kilotonnes of municipal solid waste per year into SAF. In The Netherlands, Enerkem is planning to convert an additional 360 kilotonnes a year in a similar project.

Sources: Velocys, Enerkem

46 Bio-energy supply and demand (2050, EJ)



Sources: IEA Net Zero by 2050 (2021); IEA Technology Roadmap Delivery Sustainable Bioenergy (2017); IPCC SSREN (2012); Deloitte Energy System Model
 Note: EJ = exajoule = 10¹⁸ Joule

Solution 15. Synthetic SAF production

Synthetic SAF has a big role to play in decarbonising aviation, because bio-SAF on its own will be insufficient to meet 2050 net-zero targets. Synthetic SAF will probably be more expensive than bio-SAF over the next 10-20 years. It is critical to begin scaling the pathway now, to make it cheaper more quickly and ensure it can play a role in 2050.

Synthetic fuels are purer, cleaner and 4% more efficient than fossil kerosene. And they don't require much land use compared with bio. These synthetic fuels are seen as the end state.

Aircraft manufacturer

Investment is needed to increase the supplies of the renewable electricity, hydrogen and

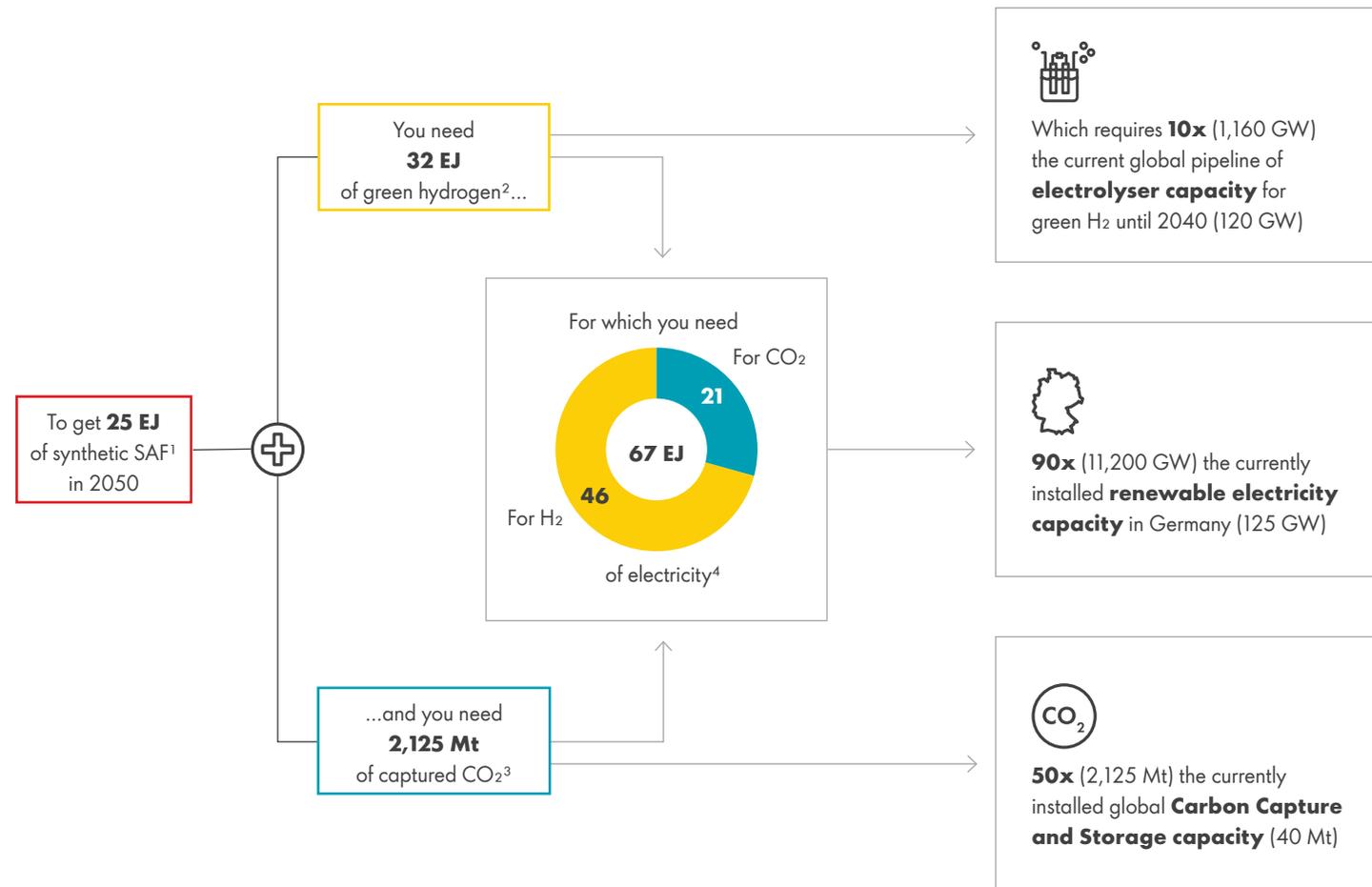


recycled CO₂ to make synthetic SAF. Policy-makers will have a critical role to play here, through continued investment in renewables projects and by assisting with further development around critical technologies such as DAC, electrolyzers and the processes for refining synthetic SAF through R&D support and grants.

Trial projects should be established at strategic points near feedstock supplies and demand hubs in order to help develop synthetic SAF technology and to begin to create supply. It will be challenging to get all the required feedstocks for aviation from renewable sources. In 2050, a total of 67 EJ of renewable electricity will be needed if we are to fuel all flights with synthetic SAF (see Exhibit 47). Likely, blue hydrogen will play a role in the short term. This will help accelerate the development of technology while renewable supplies of feedstock are being scaled up.

Governments should establish a clear roadmap for future investment in renewables projects, and producers of both bio- and synthetic SAF should make commitments around future production. This will unlock investments from others in and around the sector because it will create greater certainty around the future fuel landscape.

47 Sizing of synthetic SAF (2050, EJ)



Sources: Global CCS Institute – Global Status of CCS (2020); IEA (2020); IRENA – RE Capacity Statistics (2020); Kraan et al. An Energy Transition That Relies Only on Technology Leads to a Bet on Solar Fuels; IRENA – Green hydrogen cost reduction; Rystad RenewableCube (2021); Deloitte Energy System Model
 Notes: 1) Total energy demand for 22,000 bRPK in 2050 (forecast) equals 25EJ (exajoules); 2) Assuming 1.28 J H₂ per J synthetic SAF; 3) Assuming 85 kg of CO₂ required to create a GJ of synthetic SAF; 4) Assuming 70% efficient electrolyser and 10GJ electricity needed per ton of CO₂ captured

The Flight Plan: Accelerating Decarbonisation



DECARBONISATION PATHWAY

Most research participants take it for granted that a net-zero emissions target will soon be adopted for aviation. One airline executive said: **“Society does not accept the special status of aviation anymore – we need to decarbonise, as with all other sectors, in order to remain credible.”** A net-zero target will require a significant acceleration of efforts. This will not happen by maintaining the status quo and acceleration needs to start now.

More ambitious targets will not be enough to make a difference. The sector has already developed a number of possible pathways to decarbonisation, but aviation stakeholders said there must now be a new, more comprehensive, yet more realistic approach: **“The pathways are directionally right, but the details need changing,”** said a sector expert.

Investments must be significantly accelerated, or “front-loaded”, compared with previous plans. One industry source said that previously published plans involve **“a hockey stick effect, which is a risky approach that assumes a big part of the effort and emission reduction will magically happen after 2040.”**

The sector does recognise it will take time to build the required capacities and make change, but by doing more, sooner, the aviation sector can increase its chances of success. Most research participants believe that all the currently viable ways to achieve decarbonisation – efficiency improvements, bio-SAF, synthetic SAF and offsets – must play a role (see Exhibit 48). No single option alone can reduce net emissions by the required amount. The sector should also refine

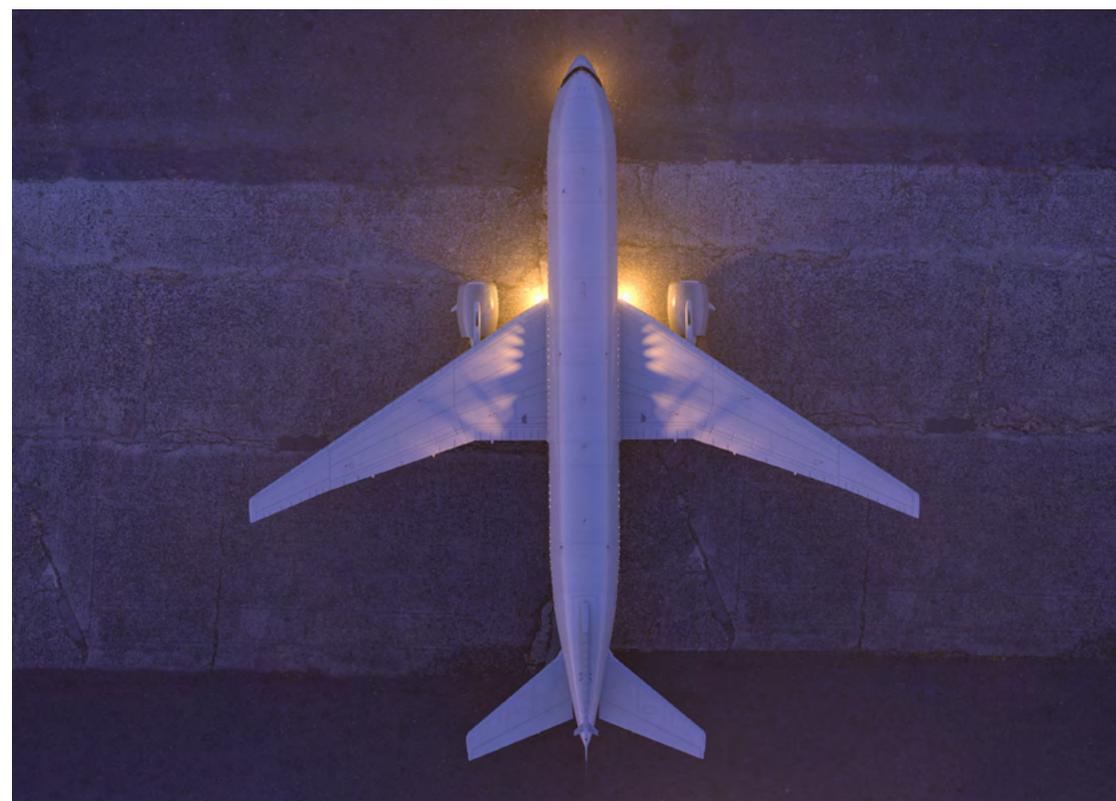
the details of how it uses these options, so it can get the best possible results from them.

Many interviewees said aviation should stop taking operational efficiencies for granted. Efficiencies of 1%-2% a year are included in most previously developed plans, as if these could happen without major effort and continue indefinitely. But one airline said: **“It is hard to believe we can continue improvements at these levels for another 30 years.”**

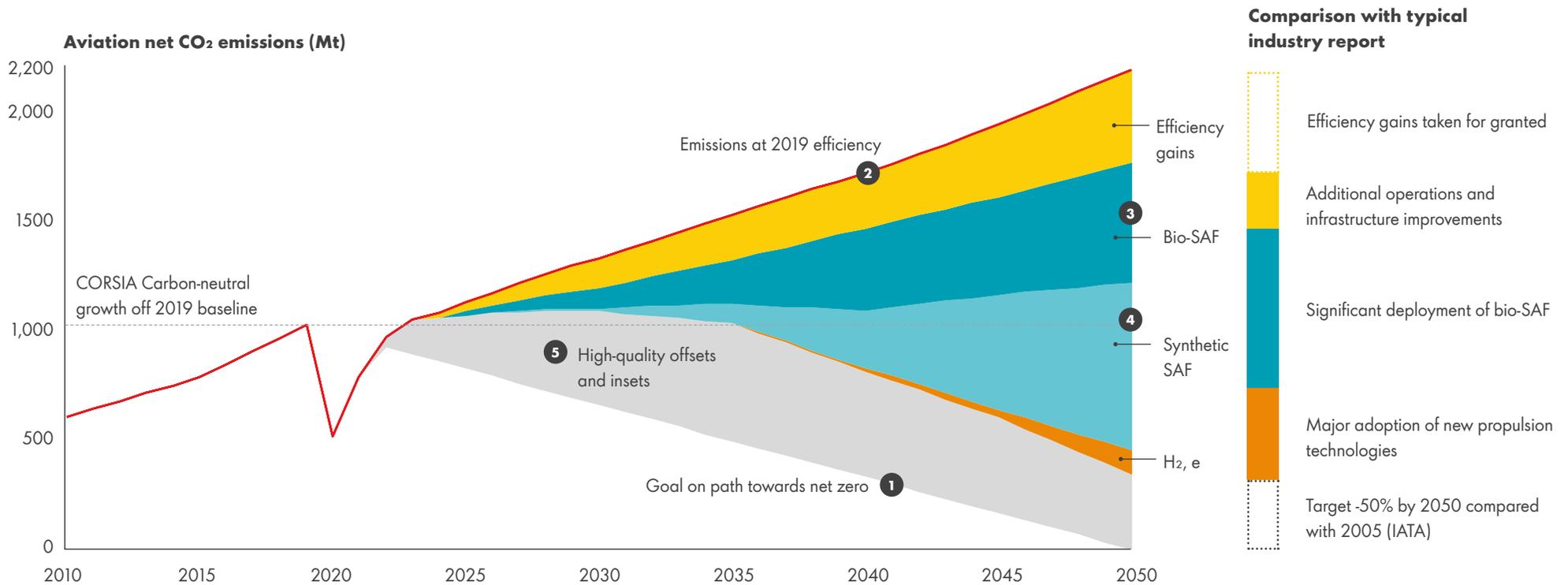
There is significant uncertainty about the availability of sustainable feedstock for bio-SAF, especially in the long term. It is hard to produce completely accurate estimates of the availability of feedstock for bio-SAF in the next 30 years, because other sectors are competing with aviation for the biomass. But it is very unlikely that there will be enough biomass feedstock and bio-SAF production capacity to meet more than 20%-30% of aviation’s requirements for SAF. As a result, research participants said synthetic SAF must

8. RESEARCH HIGHLIGHT

The pathway to decarbonisation needs to be more ambitious and investments need to start sooner to address societal expectations, reach sufficient SAF volumes and bring down cost to the levels required for large-scale adoption within 15 years.



48 Decarbonisation pathway – sector sentiment

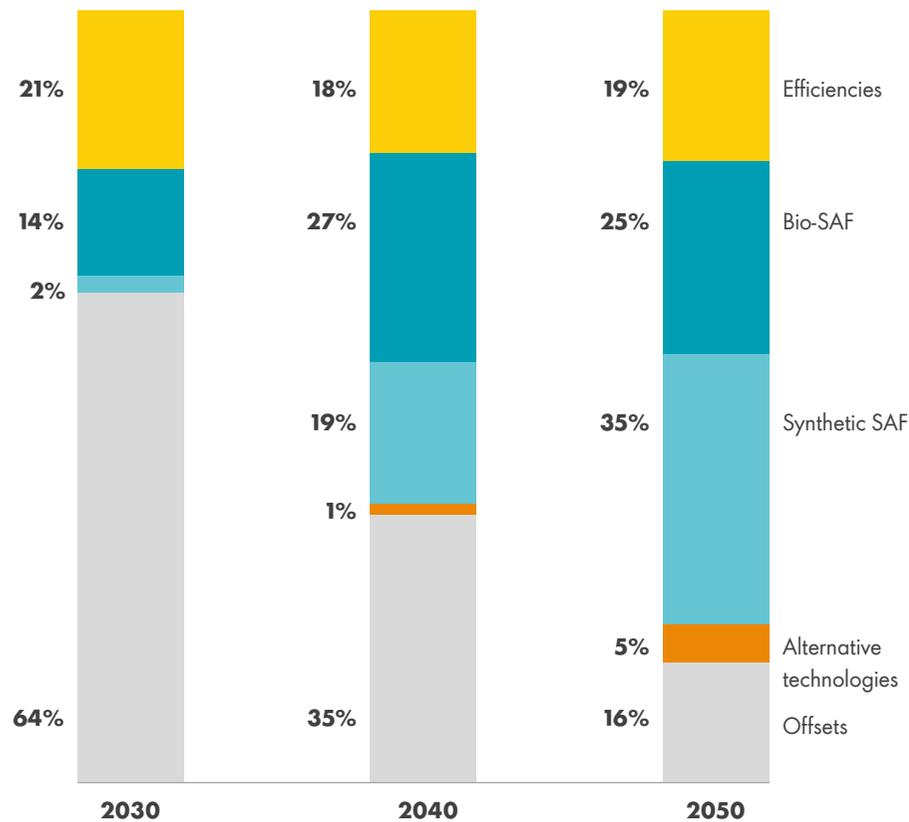


Main differences compared with typical industry report

- ❶ Net zero by 2050
- ❷ Efficiencies not taken for granted
- ❸ Bio-SAF potential limited
- ❹ Synthetic SAF scale-up sooner
- ❺ High-quality carbon offsets and insets

Sources: interviews; ATAG (2020); IATA (2021); ICAO (2019); Shell Energy Transformation Scenarios (2021); Deloitte analysis

49 Carbon reduction contribution of decarbonisation options – sector sentiment



be developed more rapidly, so it is quicker to reach commercial scale. One airline executive said: “Synthetic SAF does not come without its challenges but it is based on a relatively unconstrained resource, and its production can be ramped up if the right investments are made.” With an earlier start, synthetic SAF could by 2040 be contributing as much as bio-SAF to reducing aviation emissions. By 2050 synthetic SAF could account for 30–40% of the reductions in emissions from aviation, the sector expects (see Exhibit 49).

The sector must also ensure that all offsets are of high quality and seek to significantly increase their uptake. Offsets must play a bigger role than simply compensating the slow ramp-up of SAF, and should also drive emission reduction through CO₂ removal, as well as fund R&D in the sector. Offsets are

expected to account for as much as 50% of the reduction of aviation’s net emissions in 2030. Over time, as the average quality of offsets increases, their cost will rise as well, eventually approaching parity with other decarbonisation options. “Especially in the next 10 to 15 years, high-quality offsets will play an important role,” said an engine manufacturer. The relative importance of offsets will gradually decline as 2050 approaches, with SAF becoming increasingly available and playing a greater role in reducing emissions.

At the same time, aviation must also invest in developing alternative propulsion technologies so they can play a role in the future, even if their contribution to reducing emissions within the 2050 period is limited.



Sources: interviews; Deloitte analysis

FLIGHT PLAN TO 2030

In the short term (2022-25), the focus should be on solutions that “unlock” progress (see Exhibit 50). This phase starts by focusing on demand-side factors. Large businesses and cargo companies are more willing and able than leisure passengers to pay extra for decarbonised offerings. As a result, large businesses and cargo companies will play a fundamental role in providing the long-term demand assurance for SAF. They will need to work closely with airlines and fuel providers in this area.

The sector will have to introduce new value propositions that encourage leisure passengers to adopt green solutions. Such offers will also help cover the costs of decarbonisation and increase leisure passengers’ awareness of how they can help reduce their own and aviation’s contribution to climate change. Airlines, airports and travel agencies will have to decide how best to make these propositions work effectively.

We need a new way of engaging with the passengers, and we need to offer something fresh that attracts their attention, and desire to pay for decarbonisation.

Offset manager

More high-quality offsets should be introduced. Their benefits and impact should be clearly communicated to passengers to increase uptake that encourages sustainability. This will require a co-ordinated effort by offset providers, regulators, technology developers, energy companies and others. We see



an important role for innovation in offsets, with start-ups and scale-ups driving new business models.

The sector cannot rely purely on demand to create sustained growth in SAF and other ways of decarbonising. Regulation relating to production and fuel mandates is needed to support SAF in reaching parity with existing fuels. Although regulation will be more localised to begin with, it is important to expand the effort to regional levels. One airline said: “As a sector, we must avoid operating a global industry that is different everywhere.” Local and regional regulators

need to work closely with IATA, CORSIA and others so changes are made in a coherent and properly aligned way.

Regulation and demand will initially enable increases in bio-SAF production. These increases will first be in places where raw materials are available and conditions are favourable, such as California.

Investment in researching and developing synthetic SAF needs to increase in the coming years. More synthetic SAF should be produced more quickly and more should be blended with bio-SAF. Aviation should

9. RESEARCH HIGHLIGHT

Individual initiatives should be **integrated into comprehensive plans** representing all points along the value chain – from energy producers to end-customers. These plans should be **systematically deployed** in areas with favourable policies, market conditions, and access to SAF.

co-operate with other industries on green hydrogen, DAC and CCU. They should seek to improve the technology and increase the supply of the low-emission hydrogen and CO₂ that go into making synthetic SAF. One energy company said that they and their competitors will need to invest heavily in synthetic SAF to “**move production from small quantities in labs, to sustained scale production.**”

The ‘**accelerate**’ phase (2025-2030) will follow. It will revolve around net-zero emission targets for 2050, and agreed plans

to achieve them. The whole sector needs to work together to align on the targets and decide who must do what to deliver on them. In this phase, the production of SAF – both bio and synthetic – will scale up as demand increases. Standards, certification and reporting will be essential for expanding the benefit and use of SAF. “Book and claim” mechanisms will help those who are far from points of supply to gain access to SAF during the period when production is relatively low. Increasing the production of SAF will require co-operation between energy

companies, local and regional regulators, corporations, airlines, and financiers.

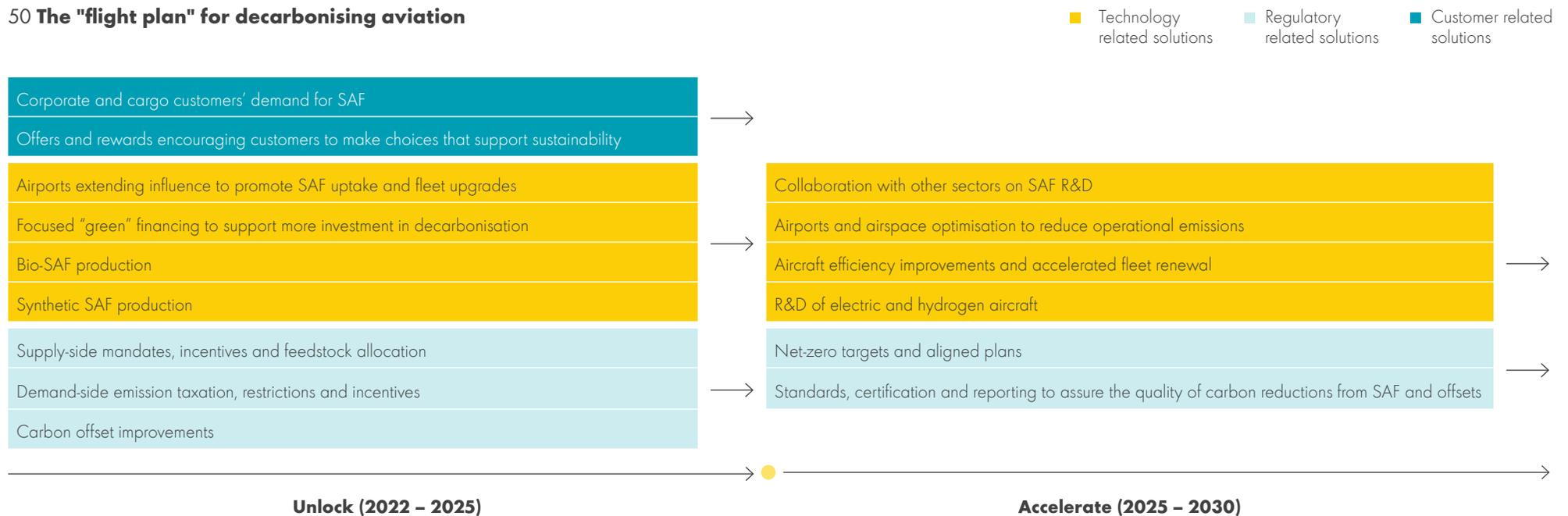
Governments and industry regulators will need to collaborate to find the best ways to deal with the scarcity of bio-SAF and the shortages of the green energy and hydrogen needed to make synthetic SAF. Regulators must ensure that aviation has sufficient access to bio-SAF and synthetic SAF.

Airports will need to co-operate with each other to advocate for commitments around

decarbonised fuels. Airports should also seek to minimise emissions through efficiency savings on the ground, and work with governments and airlines to advocate for more efficient use of available airspace.

At the same time, aviation needs to collaborate with other sectors on R&D to lower the cost of fuels and alternative technologies. Energy companies will play an essential role in this, because they operate in numerous sectors and can provide assurance on new fuels and their efficiency.

50 The “flight plan” for decarbonising aviation



Note: Timing of solution is related to period in which most activities are expected; however, most solutions require effort across short, medium and/or long term

HOW IT ALL COMES TOGETHER

Interviewees recognise that the challenge of decarbonising aviation is too large for any one organisation or even one stakeholder group to solve alone. But a joint effort (see Exhibit 51) will allow aviation to launch specific solutions in the short term, and hit crucial targets in the long term. First movers are likely to reap the benefits of early access to insights that set them apart. They are likely to be able to share risks and investments, and influence outcomes in their favour. Engaging with their customers and others in the aviation sector during the early phases of the transition will pay dividends for such relationships in the future. As these early initiatives expand, momentum will build, and more companies will join to create the necessary scale and impact across the sector.

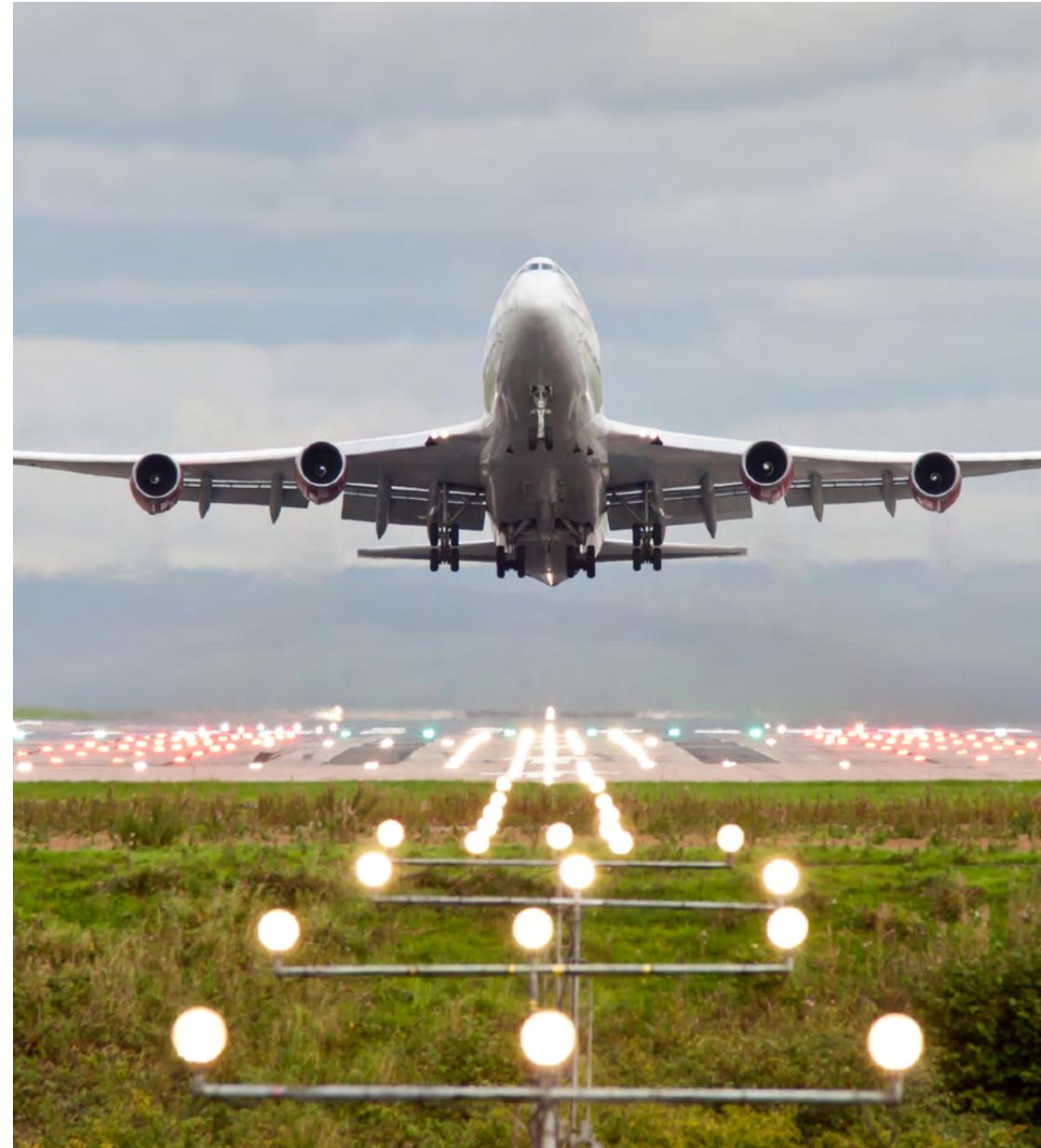
Although each measure is important on its own, their impact will be greatest if they are combined. Aviation should apply the principle of **think big, start small, scale fast**. It could use this approach to start offering low- or net-zero emissions flights in some carefully chosen areas. These areas would be chosen because they benefit from supportive

regulation, a close connection between two airports, a significant proportion of environmentally conscious corporate travellers, and an ability to increase the production of SAF (see Exhibit 52).

The benefit of a highly visible, regularly scheduled low- or net-zero emissions routes will probably outweigh any number of small-scale, one-off trial flights. The service could be based on SAF with supporting infrastructure and high-quality offsets with associated customer offers. Such a service would provide an example that could be followed by other routes and eventually become an industry standard. One energy expert said: **“We just need to have one systematic sustainable flight route that operates daily, and very quickly others will follow – because they will have to.”**

It is the collaboration and leadership of like-minded and committed companies and institutions that will enable aviation to decarbonise.

In this way, decarbonising aviation will be **cleared for take-off**.



51 Roles per solution

		Solution	OEMs	Airlines	Corporates	Cargo shippers	Travel agencies	Regulators	Airports	Financiers	Energy companies
Why should the sector change?	Market and Customer Demand	1 Corporate and cargo customers' demand for SAF									
		2 Offers and rewards encouraging customers to make choices that support sustainability									
	Regulatory Incentives	3 Net-zero targets and aligned plans									
		4 Supply-side mandates, incentives and feedstock allocation									
		5 Demand-side emission taxation, restrictions and incentives									
Can the sector change?	Technology Alignment	6 Carbon offset improvements									
		7 Standards, certification and reporting to assure the quality of carbon reductions from SAF and offsets									
		8 R&D of electric and hydrogen aircraft									
	Clarity on Roles and Decision Making	9 Collaboration with other sectors on SAF R&D									
		10 Airports extending influence to promote SAF use and fleet upgrades									
		11 Airports and airspace optimisation to reduce operational emissions									
How fast can the sector change?	Ease of Asset Replacement	12 Aircraft efficiency improvements and accelerated fleet renewal									
		13 Focused "Green" financing to support more investment in decarbonisation									
	Ease of Infrastructure Replacement	14 Bio-SAF production									
		15 Synthetic SAF production									

■ Lead role
■ Support role

52 How aviation can move towards decarbonisation in the short-term

Supporting government:

Attractive local regulation enables the growth of SAF production clusters. Mandates ensure allocation of scarce resources to aviation and close the cost gap versus existing fuel.



Airline taxation, regulation and incentives

Standards, certification and reporting to assure the quality of carbon reductions from SAF and offsets.



Supply-side mandates, incentives and feedstock allocation



Fuel producer SAF mandates and incentives

Customer demand:

Collaboration of like-minded and committed customers on key business and cargo routes with a book and claim mechanism enables net emission-free travel and transport of goods.



Corporate and cargo customers' demand for SAF



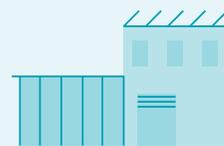
Offers and rewards encouraging customers to make choices that support sustainability

Availability of feedstock:

SAF production clusters close to feedstock sources, such as biomass and hydrogen, provide opportunity to use SAF locally and remove the need for new production and distribution infrastructure. Demand will scale supply.



Collaboration with other sectors on SAF R&D



Bio SAF production

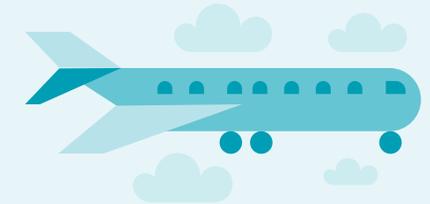
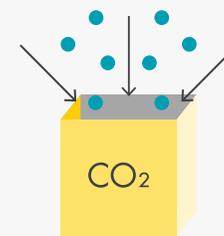


Synthetic SAF production

Mitigation through offsets:

High-quality offsets and insets that are subject to stringent certification, and directly fund the development of low-carbon fuel pathways.

Carbon offset improvements



The 2025 industry ambition
Have regularly scheduled net-zero routes.



ACKNOWLEDGEMENTS

We wish to thank all those who were involved in the development of this research. We appreciate your time, energy and enthusiasm - particularly during the period of disruption caused by the COVID-19 global pandemic.

SOURCES

- 1 Aviation benefits beyond borders "[Adding value to the economy](#)", accessed on 26 May 2021
- 2 gov.uk "[UK enshrines new target in law to slash emissions by 78% by 2035](#)", accessed on 2 August 2021
- 3 Reuters "[German govt, aviation sector agree on 'green' aviation fuel plan](#)", accessed on 2 August 2021
- 4 EASA (2019) "[European Aviation Environmental Report 2019](#)"
- 5 Aviation benefits beyond borders "[Adding value to the economy](#)", accessed on 26 May 2021
- 6 Aviation benefits beyond borders "[Adding value to the economy](#)", accessed on 26 May 2021
- 7 Aviation benefits beyond borders "[Tourism enabler](#)", accessed on 26 May 2021
- 8 Aviation benefits beyond borders "[Employment](#)", accessed on 26 May 2021
- 9 Gössling & Humpe (2020) "[The global scale, distribution and growth of aviation: Implications for climate change](#)"
- 10 Revenue Passenger Kilometres is a measure of the number of kilometres travelled by paying passengers (i.e. excluding pilot and crew)
- 11 Epstein and O'Flarity (2019) "[Considerations for reducing aviation's CO₂-with aircraft electric propulsion](#)"
- 12 Environmental and Energy Study Institute (2018) "[Fact Sheet | High Speed Rail Development Worldwide](#)"
- 13 IEA (2021) "[Net zero by 2050](#)"
- 14 ATAG (2020) "[Waypoint 2050](#)"
- 15 ICAO (2020) "[What is CORSIA and how does it work?](#)", accessed on 10 May 2021
- 16 Boeing (2019) "[First of Many: 787-Dreamliner Celebrates 10-Years Since First Flight](#)", accessed 7 July 2021
- 17 Union of concerned scientists (2020) "[Each Country's Share of CO₂-Emissions](#)"
- 18 US Department of Energy "[Hydrogen storage](#)", accessed on 30 July 2021
- 19 The CO₂ numbers do not take into account non-CO₂ emissions from aviation (e.g. nitrogen, sulphur, soot particles) and the formation of contrails. The impact of non-CO₂ effects on climate is complex, and uncertainty exists about the quantification of non-CO₂ impact on climate, as well as the trade-offs between the impacts.
- 20 EU "[Reducing emissions from aviation](#)", accessed on 04 June 2021
- 21 European Parliament (2015) "[Emission Reduction Targets for International Aviation and Shipping](#)"
- 22 Forbes (2020) "[The Spread of Flight Shame in Europe-- Is Great Thunberg the Reason Why](#)", accessed on July 06, 2021
- 23 IATA (2021) "[Airline industry financial outlook update](#)"
- 24 IATA (2021) "[Airline industry financial outlook update](#)"
- 25 ATAG (2020) "[Waypoint 2050](#)"
- 26 Statista (2021) "[Low cost carriers' worldwide market share from 2007-to-2020](#)", accessed on 04 June 2021
- 27 IATA (2009) "[Halving Emissions by 2050-- Aviation Brings its Targets to Copenhagen](#)"
- 28 ICAO (2020) "[What is CORSIA and how does it work?](#)", accessed on 10 May 2021
- 29 SAF blending mandates are described in more detail on page 58
- 30 Financial Times (2021) "[Diesel vs doughnuts: new biofuel refineries squeeze US food industry](#)", accessed 09 September 2021
- 31 CDM (2021) "[CDM Projects by Type](#)", accessed on 07 July, 2021
- 32 Based on survey of 6,000 passengers conducted as part of this study
- 33 European Commission (2021) "[Proposal for a regulation of the European Parliament and of the council on ensuring a level playing field for sustainable air transport](#)"
- 34 Oliver Wyman (2021) "[Global fleet and MRO Market forecast 2021-2031](#)"
- 35 UK Government Press Release (2021) "[UK enshrines new target in law to slash emissions by 78% by 2035](#)"

- 36 German Government Press Release (2021) "[Federal government, states and industry agree on roadmap for market ramp-up of climate friendly electricity-based aviation fuel](#)"
- 37 Rolls-Royce (2021) "[Rolls-Royce conducts first tests of 100% sustainable aviation fuel for use in business jets](#)"
- 38 Zero Avia (2021) "[ZeroAvia Secures Additional \\$24.3-Million to Kick Off Large Engine Development for 50+ Seat Zero-Emission Aircraft](#)"
- 39 United Nations (2020) "[Commitments to Net Zero Double in Less Than a Year](#)", accessed on 25 June 2021
- 40 Science Based Targets Initiative (2021) "[Driving Ambitious Corporate Climate Action](#)", accessed on July 07, 2021
- 41 International Airport Review (2021) "[DB Schenker and Lufthansa Cargo launch weekly carbon neutral cargo flight connection](#)", accessed on 30 July 2021
- 42 Qantas "[Qantas Group To Slash Carbon Emissions](#)", accessed on 2 August 2021
- 43 ICCT (2021) "[Glass half full: An invitation for IATA to update climate goals](#)"
- 44 UK Government Press Release (2021) "[UK enshrines new target in law to slash emissions by 78% by 2035](#)"
- 45 US Congress (2020) "[H.R.8769 - Sustainable Aviation Fuel Act](#)"
- 46 European Commission (2020) "[Sustainable aviation fuels-- ReFuelEU Aviation](#)"
- 47 European Commission (2021) "[European Green Deal: Commission proposes transformation of EU economy and society to meet climate ambitions](#)", accessed on July 16, 2021
- 48 Biofuels international (2019) "[Finnish government targets 30% biofuels share in aviation fuel](#)"
- 49 CARB (2021) "[Low Carbon Fuel Standard](#)"
- 50 Aviation Today (2021) "[New Legislation Could Give Tax Benefits to US Airlines for Using Sustainable Aviation Fuel](#)"
- 51 US Congress "[H.R.741-- Sustainable Aviation Fuel Act](#)", accessed on 24 June 2021
- 52 Sustainable Aviation UK "[UK aviation industry strengthens commitment to achieving net zero and launches first interim decarbonisation targets](#)", accessed on 24 June 2021
- 53 Airport Carbon Accreditation "[Airports addressing their CO₂ emissions](#)", Accessed on 25 June, 2021
- 54 FAA "[Airport Carbon Emission Reduction](#)", Accessed on 25 June, 2021
- 55 Airports Council International "[European airports commit to net zero carbon emissions under their control by 2050](#)", Accessed on 25 June, 2021
- 56 IATA "[Aviation & Climate Change Fact Sheet](#)", Accessed on 25 June, 2021
- 57 ATAG "[Fact Sheet #3: Tracking Aviation Efficiency](#)", Accessed on 25 June, 2021
- 58 ICCT "[Fuel efficiency trends for new commercial jet aircraft: 1960 to 2014](#)", Accessed on 25 June, 2021
- 59 Transport & Environment "[Air France's bailout 'climate conditions' explained](#)", Accessed on 25 June, 2021
- 60 European Commission "[Regulation \(EC\) No 595/2009 of the European Parliament and of the Council of 18 June 2009](#)", Accessed on 25 June, 2021
- 61 IEA (2021) "[Net zero by 2050](#)"
- 62 Statista 2020 & Deloitte analysis "[Leading aircraft operating lessors in 2020, by fleet value](#)"
- 63 Poseidon Principles (2019) "[A global framework for responsible ship finance](#)"
- 64 Airbus (2020) "[Sustainable aviation fuel: A recipe for cleaner flight](#)", Accessed on 2 September 2021"

LEGAL DISCLAIMER

The companies in which Royal Dutch Shell plc directly and indirectly owns investments are separate legal entities. In this Decarbonising Aviation: Cleared for Take-off report “Shell”, “Shell Group” and “Group” are sometimes used for convenience where references are made to Royal Dutch Shell plc and its subsidiaries in general. Likewise, the words “we”, “us” and “our” are also used to refer to Royal Dutch Shell plc and its subsidiaries in general or to those who work for them. These terms are also used where no useful purpose is served by identifying the particular entity or entities. “Subsidiaries”, “Shell subsidiaries” and “Shell companies” as used in this Decarbonising Aviation: Cleared for Take-off report refer to entities over which Royal Dutch Shell plc either directly or indirectly has control. Entities and unincorporated arrangements over which Shell has joint control are generally referred to as “joint ventures” and “joint operations”, respectively. Entities over which Shell has significant influence but neither control nor joint control are referred to as “associates”. The term “Shell interest” is used for convenience to indicate the direct and/or indirect ownership interest held by Shell in an entity or unincorporated joint arrangement, after exclusion of all third-party interest.

This Decarbonising Aviation: Cleared for Take-off 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: Cleared for Take-off 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 decarbonise 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 scale-up 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: Cleared for Take-off 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.

This Decarbonising Aviation: Cleared for Take-off report contains forward-looking statements (within the meaning of the U.S. Private Securities Litigation Reform Act of 1995) concerning the financial condition, results of operations and businesses of Royal Dutch Shell. All statements other than statements of historical fact are, or may be deemed to be, forward-looking statements. Forward-looking statements are statements of future expectations that are based on management’s current expectations and assumptions and involve known and unknown risks and uncertainties that could cause actual results, performance or events to differ materially from those expressed or implied in these statements. Forward-looking statements include, among other things, statements concerning the potential exposure of Royal Dutch Shell to market risks and statements expressing management’s expectations, beliefs, estimates, forecasts, projections and assumptions. These forward-looking statements are identified by their use of terms and phrases such as “aim”, “ambition”, “anticipate”, “believe”, “could”, “estimate”, “expect”, “goals”, “intend”, “may”, “objectives”, “outlook”, “plan”, “probably”, “project”, “risks”, “schedule”, “seek”, “should”, “target”, “will” and similar terms and phrases. There are a number of factors that could affect the future operations of Royal Dutch Shell and could cause those results to differ materially from those expressed in the forward-looking statements included in this Decarbonising Aviation: Cleared for Take-off report, including (without limitation): (a) price fluctuations in crude oil and natural gas; (b) changes in

demand for Shell’s products; (c) currency fluctuations; (d) drilling and production results; (e) reserves estimates; (f) loss of market share and industry competition; (g) environmental and physical risks; (h) risks associated with the identification of suitable potential acquisition properties and targets, and successful negotiation and completion of such transactions; (i) the risk of doing business in developing countries and countries subject to international sanctions; (j) legislative, fiscal and regulatory developments including regulatory measures addressing climate change; (k) economic and financial market conditions in various countries and regions; (l) political risks, including the risks of expropriation and renegotiation of the terms of contracts with governmental entities, delays or advancements in the approval of projects and delays in the reimbursement for shared costs; (m) risks associated with the impact of pandemics, such as the COVID-19 (coronavirus) outbreak; and (n) changes in trading conditions. No assurance is provided that future dividend payments will match or exceed previous dividend payments. All forward-looking statements contained in this Decarbonising Aviation: Cleared for Take-off report are expressly qualified in their entirety by the cautionary statements contained or referred to in this section. Readers should not place undue reliance on forward-looking statements. Additional risk factors that may affect future results are contained in Royal Dutch Shell’s Form 20-F for the year ended December 31, 2020 (available at www.shell.com/investor and www.sec.gov). These risk factors also expressly qualify all forward-looking statements contained in this Decarbonising Aviation: Cleared for Take-off report and should be considered by the reader. Each forward-looking statement speaks only as of the date of this Decarbonising Aviation: Cleared for Take-off report, September 20, 2021. Neither Royal Dutch Shell plc nor any of its subsidiaries undertake any obligation to publicly update or revise any forward-looking statement as a result of new information, future events or other information. In light of these risks, results could differ materially from those stated, implied or inferred from the forward-looking statements contained in this Decarbonising Aviation: Cleared for Take-off report.

We may have used certain terms, such as resources, in this Decarbonising Aviation: Cleared for Take-off report that the United States Securities and Exchange Commission (SEC) strictly prohibits us from including in our filings with the SEC. Investors are urged to consider closely the disclosure in our Form 20-F, File No 1-32575, available on the SEC website www.sec.gov.

Discover more at

www.shell.com/DecarbonisingAviation

#MakeTheFuture

Engage with us on:

[Shell LinkedIn Page](#)

[Deloitte LinkedIn Page](#)

© 2021 Shell International B.V.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, published or transmitted, in any form or by any means, without the prior written permission of Shell International B.V.

