SMBC AVIATION CAPITAL

People, Partnership, Prosperity.
Working towards a better future.

Fuelling the future of flight

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Exploring the technologies that will fuel the future of flight

Aviation is currently estimated to account for 2.5-3% of global carbon emissions, with an expectation that this share will increase as other industries decarbonise more rapidly.

Aviation is considered a hard to abate industry due to long development cycles and long economic lives making the fleet renewal process span decades. There are also limited alternative high density energy storage solutions.

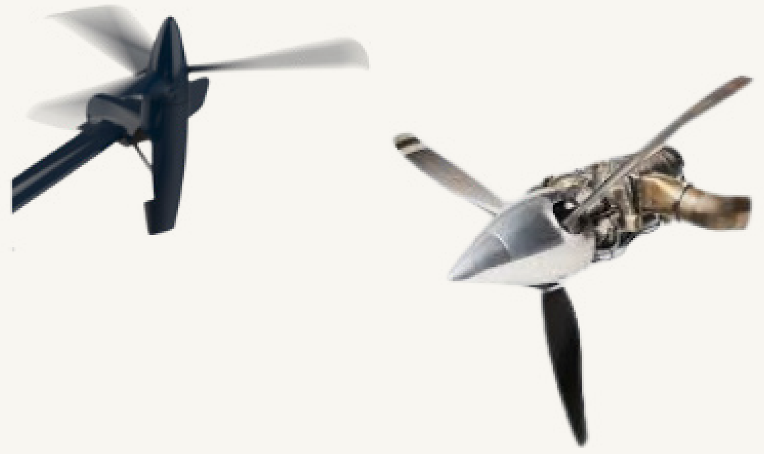
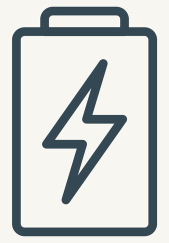
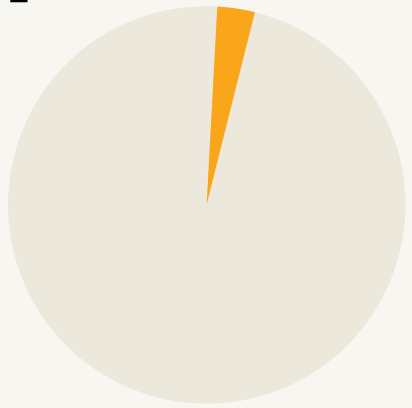
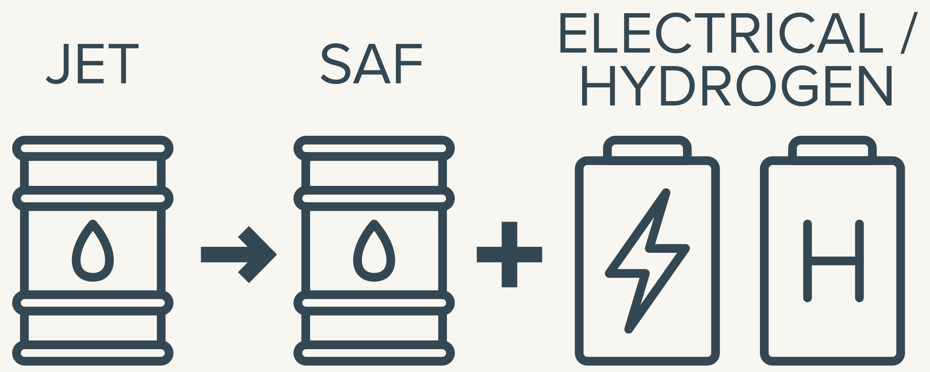
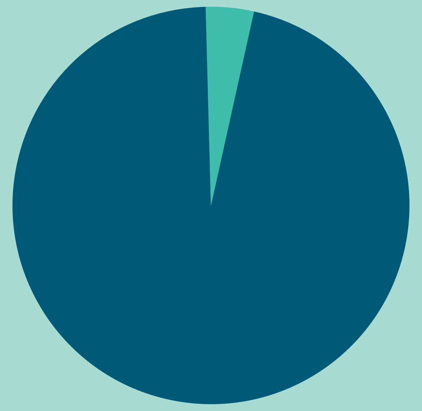
SMBC Aviation Capital as an owner of aircraft is committed to working with clients, suppliers and shareholders who are already active in the green energy space to lower aviation's carbon impact. However we also recognise that other parties need to also play a role in the transition to a greener aviation industry. These range from governments who need set up a framework that balances investor friendly incentives with specific demand/usage measures to tech companies who will potentially create flight optimisation solutions that will reduce fuel consumption.

In this paper we explore some of the various commercial technologies to help aviation on its journey to net zero. We conclude that battery and hydrogen technology will indeed be developed but will be limited to smaller aircraft with fewer passengers, a segment of the market that makes up just 16% of emissions.

We discuss what a new narrowbody replacement aircraft might look like and what type of engine might power it, how SAF which can power both future and existing aircraft will play the most important role in commercial aviation and what this means for values of the existing fleet.

We believe that the next new technology aircraft will need to be 20%+ more efficient than its predecessor to drive meaningful change.

Exploring the technologies that will fuel the future of flight

	RANGE	CO_2 EMISSIONS	AIRCRAFT	PROPULSION	FUEL
COMMUTER	Less than 500km London—Paris 	Commuter Aircraft: 1% of CO_2 emissions	≤ 20 seats EVTOL/Electric 	Rotor / Propellor 	All electric 
REGIONAL	Greater than 500km London—Madrid 	Regional Aircraft: 3% of CO_2 emissions 	≤ 100 seats 	Turbofan 	Jet — SAF/Hybrid 
COMMERCIAL	Greater than 1,000km London—Dubai 	Commercial Aircraft: 96% of CO_2 emissions 	≥ 100 seats 	Turbofan — Open rotor 	Jet — SAF 

How does aviation affect the climate?

Aviation is one of the fastest modes of transport with the ability to connect people and businesses. Air transport provides significant economic and social benefits, facilitating trade, tourism, increasing connectivity and generating economic growth.

Jet fuel is an essential component to modern aviation due to its balance of appropriate fuel properties, such as high energy per unit mass, high energy per unit volume, stability, non-volatility, materials compatibility, low freezing point and low vapor pressure.

This high-performance fuel is what has allowed for the rapid development of commercial aviation, which currently services over 4.5 billion passengers a year.

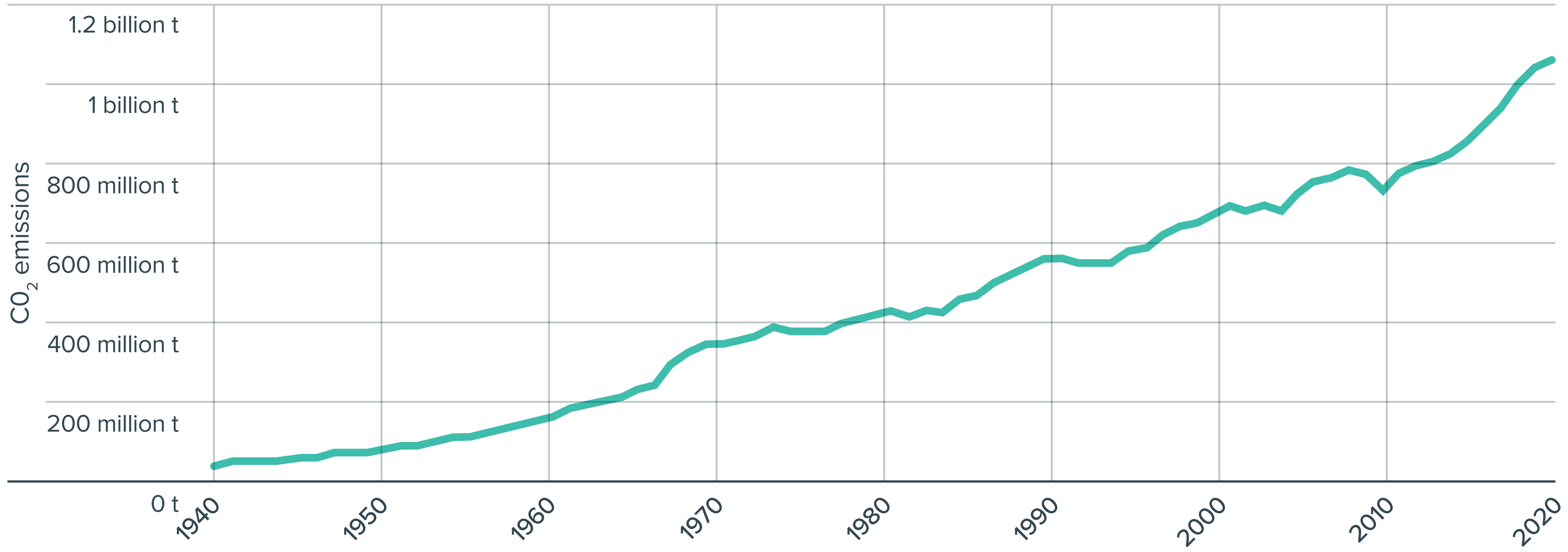
Although jet fuel has many favourable characteristics, one major cost that must be considered from its use, is its impact on the environment. CO_2 is the largest component of aircraft emissions, accounting for approximately 70% of the exhaust fumes.

According to ICIS, the growth in the fleet of conventionally powered aircraft will drive overall fuel usage by 1.5% per annum over the next 25 years.

To tackle these growing emissions, aviation has made great strides through efficiency improvements, between 1990 and 2019 the amount of energy required to produce one revenue passenger kilometre has halved. Meaning that on a passenger kilometre basis, current aircraft are twice as energy efficient as their historical counterparts. This efficiency gain has been offset by the increase in passenger numbers, which has led to an increase in aviation carbon emissions by almost 100% since 1990.

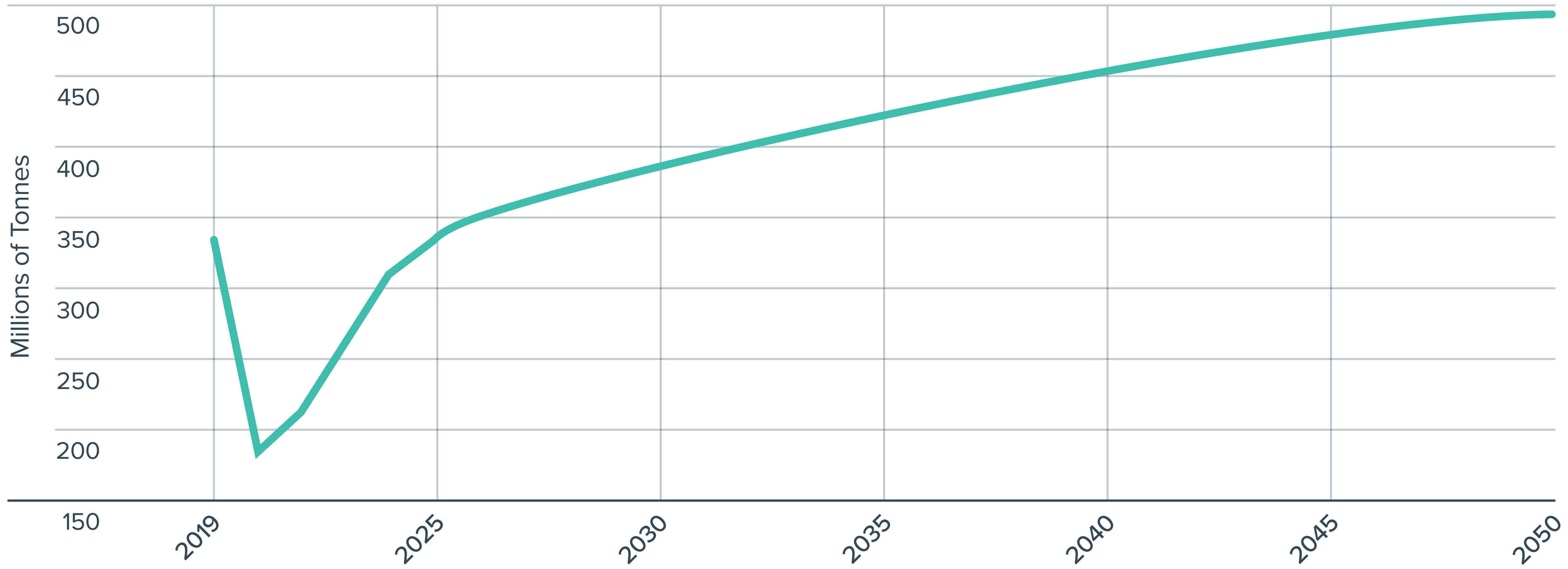
Aviation is currently estimated to account for 2.5-3% of global carbon emissions, with an expectation that this share will increase as other industries make progress on decarbonisation.

Global CO_2 emissions from aviation (1940-2019)



Source: Pre-1990 data from, Lee et al. (2021); 1990 onwards from Berger0 et al. (2023) OurWorldInData.org/transport | CC BY
Note: Does not include non-C02 forcings, and additional warming impacts at altitude.

ICIS jet fuel demand forecast



Source: ICIS

What is aviation's decarbonisation pathway?

Aviation is considered a hard to abate industry due to three key reasons:

1. **The development cycle for aircraft is long**
   As aviation has strict, uncompromising safety standards, the development and certification of a new aircraft can take up to 10 years. This limits the pace at which technological advancements can be incorporated into the global fleet.

2. **The useful life of an aircraft is long**
   Aircraft are high value assets with long economic lives of generally 20-30 years. Therefore, the fleet renewal process spans over decades.

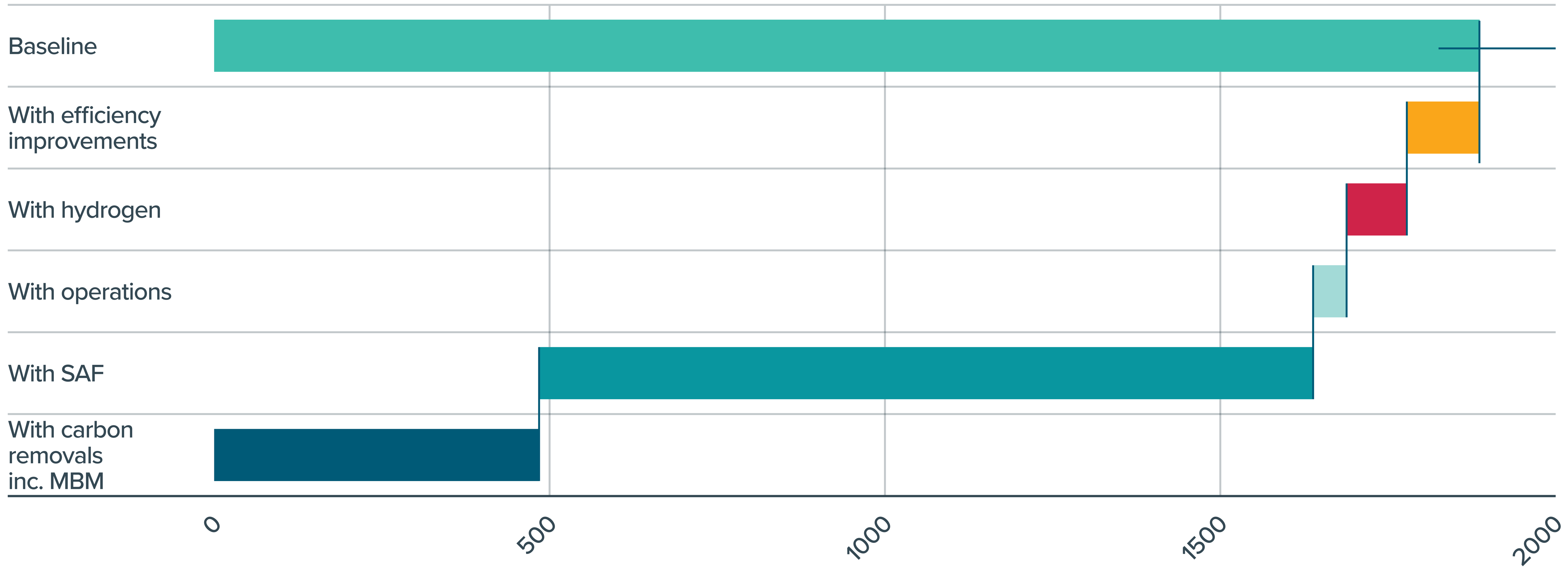
3. **Aviation is an energy intensive industry**
   Aviation is the fastest method of transport available for goods and passengers. There are currently very limited alternative high density energy storage solutions.

Due to the hard to abate nature of aviation, IATA have developed a Net Zero Roadmap to highlight a target scenario in which aviation achieves net zero carbon emissions by 2050.

The main avenues in which aviation can mitigate its emissions are through increases in the fuel efficiency of aircraft via technological advancements, increases in operational efficiency of airlines, market-based measures such as taxes and offsets and through the substitution of conventional jet fuel with sustainable aviation fuel.

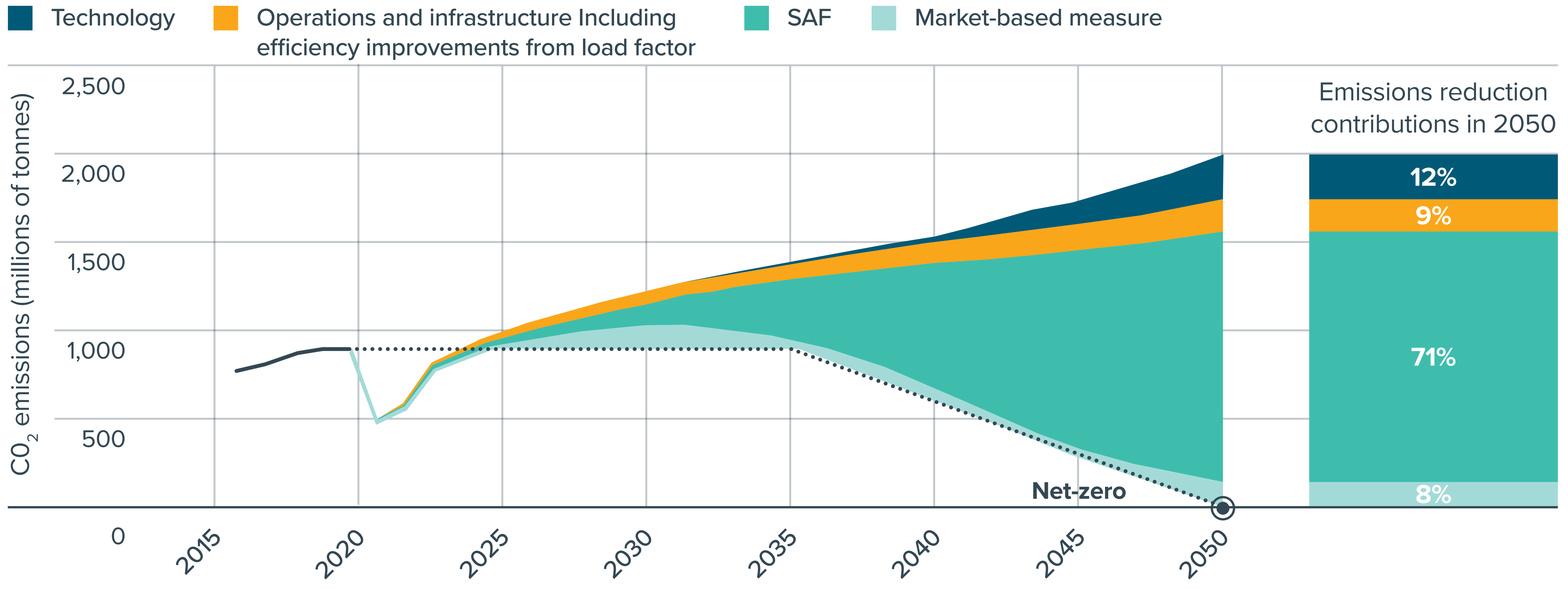
Technological advancements such as advanced wings and clean sheet engine designs are expected to contribute to over 10% of the sectors emission reduction efforts, while Sustainable Aviation Fuel (SAF) is considered as the highest impact avenue and is projected to contribute over 70% of the sector's efforts to reach net-zero emissions.

How reductions in aviation CO2 emissions can be achieved by 2050



Source: IATA

Projected Pathway to Net-Zero CO_2 Emissions in Aviation by 2050



Source: ATAG

Considering aggressive Sustainable Fuel Deployment scenario.

Which segment of the aviation market will see the next clean-sheet design?

Airbus with its A320 family is on its third iteration (including the -100), while Boeing's 737 family originated in the mid 1960's and is on its fourth iteration. We do not expect another version of either type given their limitation to accommodate bigger engines, so both replacements will be clean sheet designs.

On the lower end of the narrowbody market, Airbus retains the ability to stretch the A220 series, touted as the -500. While details on the stretch are minimal, it would have a seat capacity approximate to that of the A320neo. However, with the A220 yet to breakeven combined with Airbus's dominance of the single aisle segment, there is currently little incentive for them to invest in this model imminently.

The long-haul widebody side is more straightforward; the Airbus A350 and Boeing 787 are new-tech offerings from Airbus and Boeing and represent the heart of the widebody market segment. Meanwhile, the delayed 777X which is essentially a re-engined 777-300ER should enter service by 2026. We do not expect a clean sheet design in the medium-large widebody segment over the coming two decades, rather, there will be further Product Improvement Packages (PIP) on the engines, and eventually a re-engined offering. We forecast that deliveries of the 787 and A350 will be stronger than the A330neo with the latter winding up production in the mid-30's.

However this is sales dependant so it could remain in production longer. We do not believe that it will be a priority at Airbus to develop a direct replacement for the A330neo at that time as they would prioritise an A320neo family replacement.

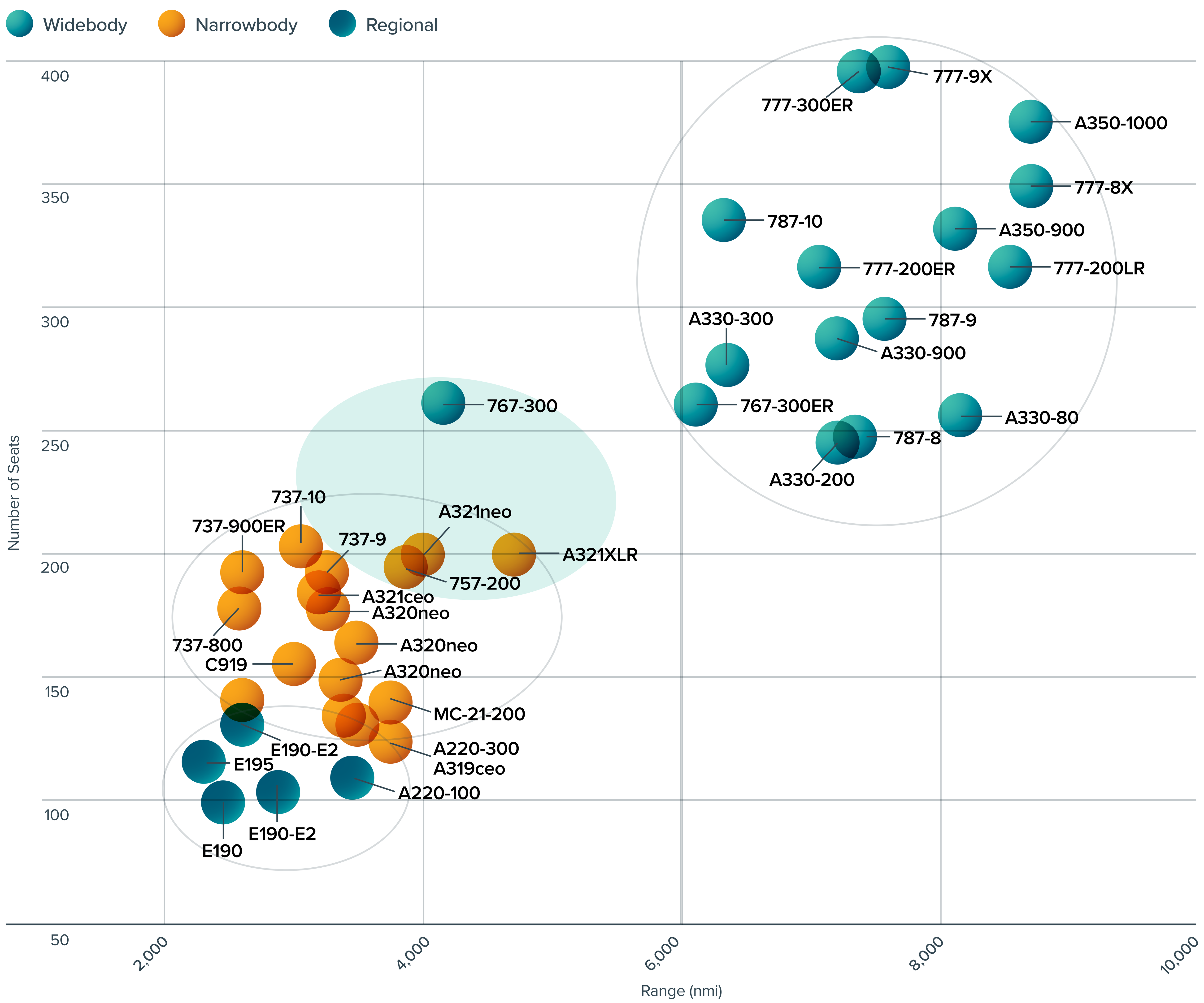
We expect both Boeing and Airbus to announce new aircraft types in the late 2020s / early 2030s to replace the neo and MAX. Due to the significant barriers to entry, including cost, engineering expertise, ability to produce at sufficient rates and global support, there will not be a competitive third-party entrant.

Developing a new aircraft is expensive with $15bn the most commonly used estimate. Single aisle aircraft have historically cost between $10-12bn but the A320 and Boeing 737 are derivatives of older designs.

Earlier in the year, Boeing's David Calhoun referenced a price tag of $50bn which presumably assumes an all-new design with significant margin for delays or cost overruns and likely includes the engine OEM development costs as well.

Either way these are not small numbers and would require a strong business case that delivers both meaningful fuel savings and a long production run.

Seat – Range Diagram



Source: Airbus, Boeing, COMAC, Embraer.

Introducing a new aircraft type takes time

Introducing a new aircraft design is a complex, expensive and time-consuming task. If we look at the history of the 737 program, now on its 4th iteration, production runs have ranged from 16 years on the 737 Classic to 23 years on the 737 NG. After entering service, a replacement was announced between 9 and 14 years into production.

Following the announcement of a new aircraft it takes a further 4-6 years before the 1st of the new aircraft delivers, with this timeline continuing to get longer. In the following 3-5 years both generations of aircraft are produced as the older type ramps down production and the new generation ramps up. This essentially means that following the announcement of a new aircraft type it is likely 10 years before production has shifted from the existing to the new technology.

Following recent news regarding Boeing repositioning engineers from their development and demonstrator program to focus on 737 and 777 deliveries, it is likely their new clean-sheet aircraft may slide to the right.

After announcement of neo / MAX replacement it will take ten years until neo / MAX are out of production.

737 Development & Production Runs

Source: Cirium Fleets Analyzer, SMBC AC Forecast

Airlines opting for more of the larger family members of narrowbody aircraft

In the single aisle space, there has been a clear shift towards the larger narrow body models. 20 years ago, the A319 and 737-700 accounted for over 40% of deliveries while the larger variants like the A321 and 737-900 accounted for only 10%.

Today the picture is very different with minimal deliveries of the smaller family members while the A321 now accounts for the majority of both Airbus deliveries and backlog.

Using the orderbook as a forecast, we see this trend continuing. Two thirds of orders in 2023 were for the stretched family members, compared to only 20% a decade ago. This has further upside as airlines and lessors with backlogs could convert some of their orders to the larger variants.

All of this indicates that the "heart of the market" is moving towards the A321neo/MAX 10 segment. The evolution of the easyJet fleet strategy is a good illustration of this. In 2002 easyJet had a backlog of 120 A319s only, a decade later their orderbook sat at 150 A320s and no A319s. By 2023, the backlog was for over 300 aircraft, split between the A320neo and A321neo, with the A321neo in the majority.

A320 and 737 Family Delivery and Backlog

Source: Cirium Fleets Analyzer

Aircraft have become more dense

Airlines are constantly looking for ways to maximise profits and one way for them to do that is fit more seats onto aircraft. This is a trend most evident with budget or low-cost airlines although even flag carriers are looking for ways to maximise revenues from slot constrained airports.

Seat manufacturers have developed thinner and lighter seats, and these newer designs often have minimal or no recline, allowing airlines to squeeze in more rows of seats and reduces the need for extra legroom when the seat in front reclines.

The average narrowbody now carries about 20 more passengers than 20 years ago, roughly adding 1 seat per year. Increased densification and utilisation of existing aircraft is a net positive in terms of reducing global emissions. Boeing estimates that without these productivity improvements, the future fleet would be 20% larger than forecast.

Should this new aircraft type be six abreast in single-aisle (3-3) or twin-aisle (2-2-2)? Structurally, a single-aisle will be slightly heavier on a per passenger basis than the twin-aisle equivalent although with reduced drag. A longer aircraft will also impact take-off rotation angles, as encountered by the 737-900ER and Max-10 which may necessitate a taller (heavier) landing gear.

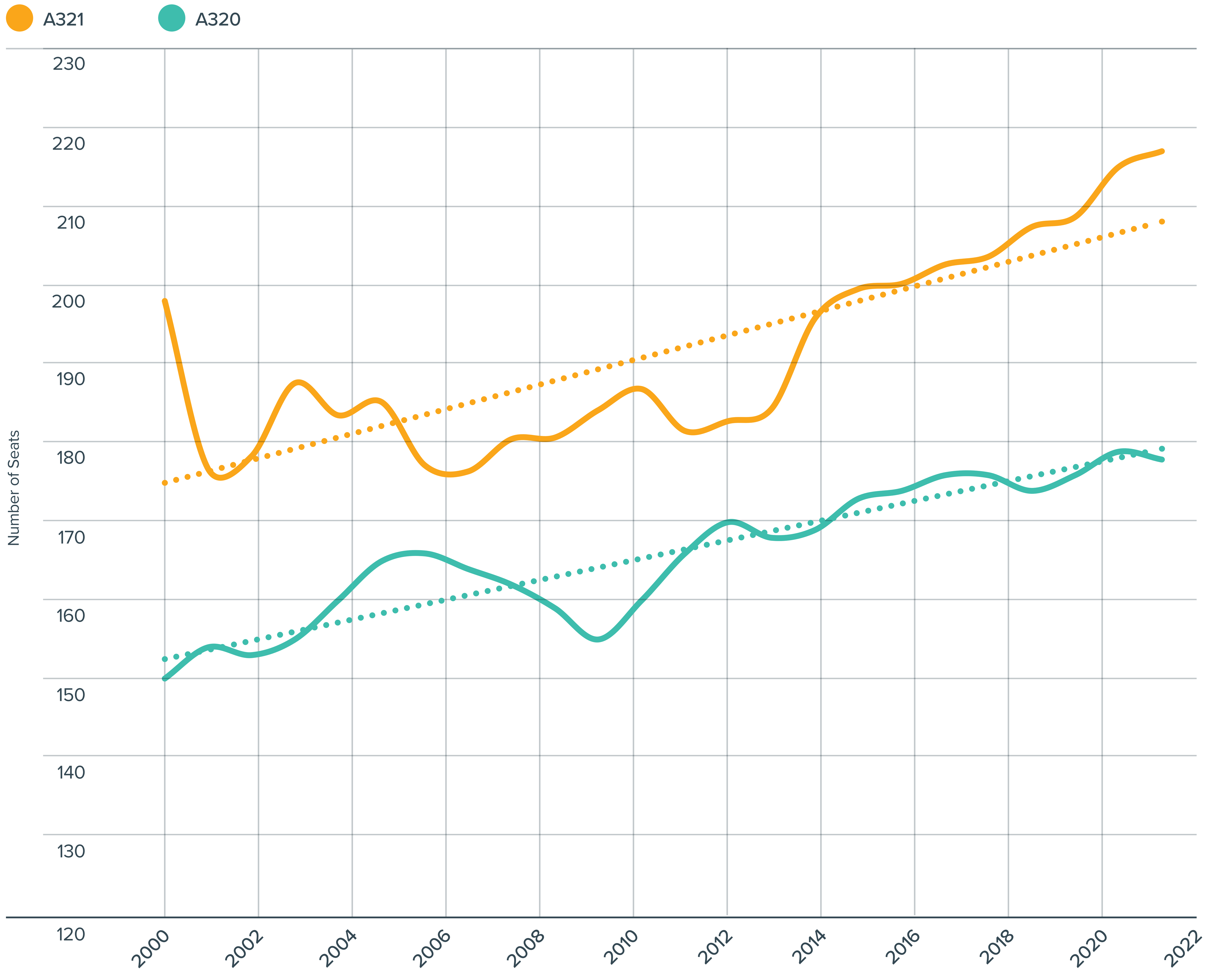
A key advantage for the twin-aisle option is the much quicker enplaning/deplaning process which reduces time on ground and improves revenue generation opportunities. This was highlighted by the poor selling single-aisle 757-300 where the aircraft was so long that deplaning and cargo loading impacted the operator's turnaround times.

Particularly on the larger family variant, there will be gate and ramp space constraints due to increasing airport ramp congestion.

Overall, we don't think there is a significant difference between the two and wouldn't be surprised to see one OEM go with a single-aisle and the other with a twin-aisle.

The average NB now carries about 20 more passenger than 20 years ago, roughly adding 1 seat per year.

Average seat capacity of A320 / A321 at delivery



Source: Airbus

Where will it fit?

Given the success of the A321 and the clear upsizing trend in the market, we believe that the next clean sheet aircraft design will occupy the highlighted area of the seat-range chart shown opposite.

We believe the aircraft will be optimised around the 180-220 pax in two-class configuration size with a shrink version available with around 30 seats less as well as a stretched design adding 30-50 seats more.

The innovative fuel tank design of the A321XLR could be deployed to maximise the range but we think the manufacturers would rather offer this technology as a premium priced option to those airlines that value the extra range in their networks.

As such we think the majority of the demand will be for the aircraft similar in size to the A321 along with the stretched version.

It is worth remembering that an aircraft typically will consume more fuel if it goes faster. Given the industry is looking to reduce fuel consumption improving the speed of the aircraft is not a critical requirement. We expect similar speeds to the current MAX / neo.

Improving the speed of the aircraft is not a critical requirement, and we expect similar speeds to the MAX / neo.

The manufacturers will naturally want to charge a premium for the new aircraft to recoup their investment so a new aircraft design will have to deliver meaningful operating cost savings to airlines, which will come from a mix of lower fuel burn via engine technology and airframe aerodynamics as well as maintenance costs. It will also have to fit or the ability to fit into existing airport gate infrastructure.

As we expect on all new aircraft, the manufacturers will have a real opportunity to not only revisit areas like cockpit design but also to use the latest technology to create better maintenance programs. There may also be scope to use technology like machine learning and artificial learning to reduce the flight crew members from two to one.

The next clean sheet design will be optimised around 180-220 pax in two-class configuration size.

Seat – Range Diagram

Source: Airbus, Boeing, COMAC, Embraer

What will power the next generation aircraft?

Two of the alternatives to jet fuel are battery / electric and hydrogen. Aviation is fundamentally different from ground transportation because of the disproportionate role that weight & volume play in aviation. Batteries are very heavy for the amount of energy they contain and have much lower energy density than jet fuel.

As an example, the batteries in a Tesla Model S weigh 544KG for a real-world range of ~420km. That would be the same weight as 640L of diesel, which would achieve ~10,000km in a modern diesel car. Another way to think about this is if your smartphone could get its energy from jet fuel (and only had a tank the same size as the battery), you would only have to fill it up every 2 months instead of charging it every 24-48 hours!

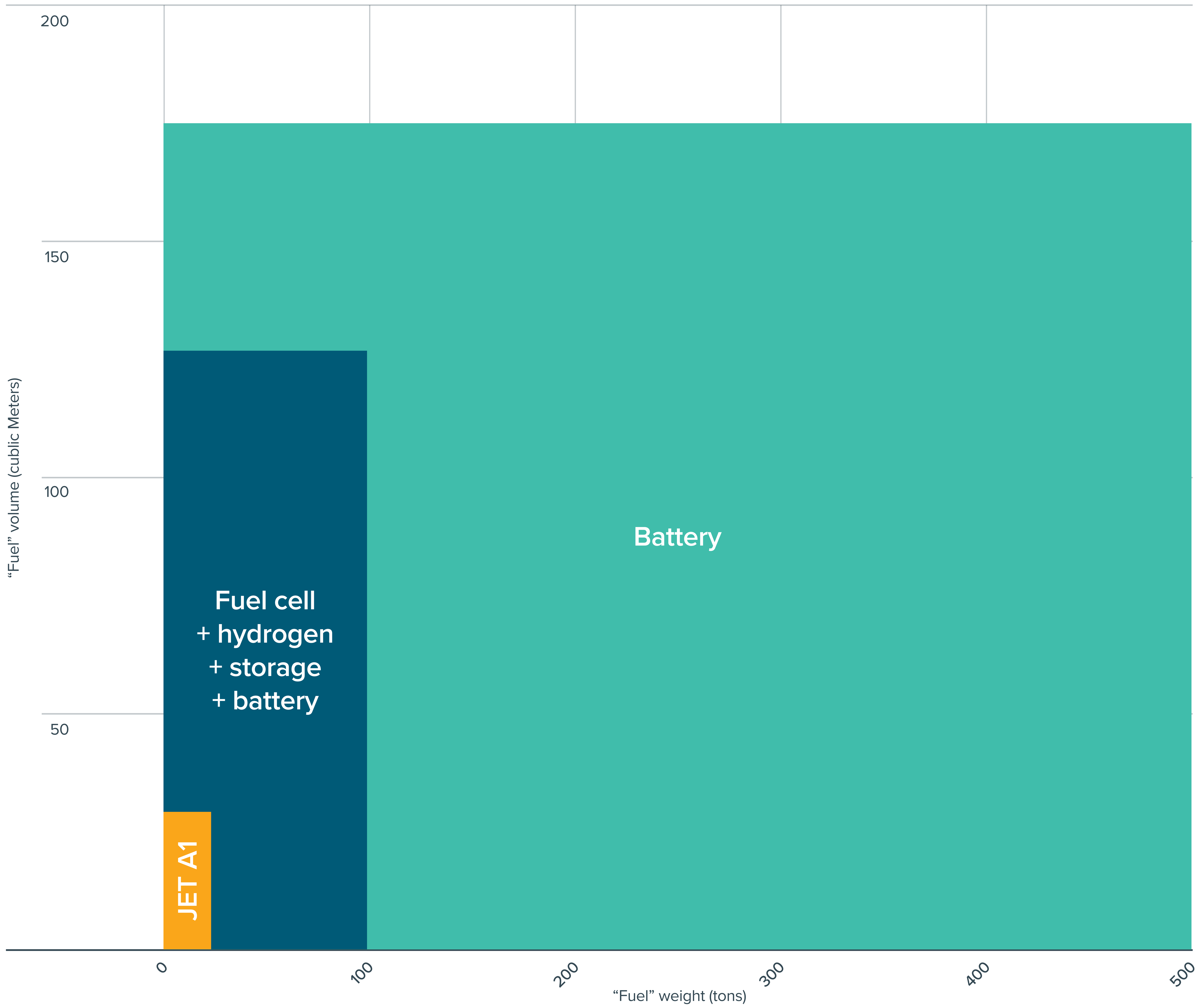
While a battery powered solution may work on some shorter-range aircraft, only 4% of emissions come from flights less than 500km. For example, the BAE Systems and Heart Aerospace ES-30 regional aircraft which is targeted for certification in 2028 would be capable of flying 200km (or 400km with a hybrid engine) with 30 passengers. To put this range in context, 200km is a trip from Birmingham to London or Los Angeles to San Diego (175km).

Hydrogen takes up to three times as much space as kerosene, needs to be stored at very low temperatures (-253°C) and is highly flammable. In addition, there are over 41 thousand airports in the world which would require substantial investment to change ground refuelling infrastructure.

Airbus' ZEROe aircraft based on hydrogen fuel is intended to carry around 100 passengers over a 1,000-2000nmi range for EIS in 2035, however the development program has not yet been launched. Boeing on the other hand is not focused on hydrogen development and questions whether using hydrogen power would make economic sense for airlines and if the required fuel volumes can be sustainably produced.

At this point, the main engine OEMs are focusing on design improvements to their kerosene / SAF powered engines.

Estimated Weight and Volume of jet fuel-equivalent capacity in a narrowbody aircraft



Source: S&P Global Commodity Insights. Spec based on 737-800

Powering the next clean sheet design

While fuselage and wing design innovations will contribute to improve efficiencies in the next aircraft, the vast majority of efficiencies will come from the engines. We believe that to make meaningful improvements, the next aircraft type will need to incorporate all three, not just a change in powerplant.

There are three engine OEMs which may power the next MAX/neo replacement aircraft; CFM International, Rolls-Royce and Pratt & Whitney. Of these three, only CFM will offer an open fan engine solution, but they can also offer a ducted engine if necessary. Pratt & Whitney will evolve their current geared-turbofan platform and are working with MTU to develop a water-enhanced turbofan. The advantage of which is a significant reduction in NOx.

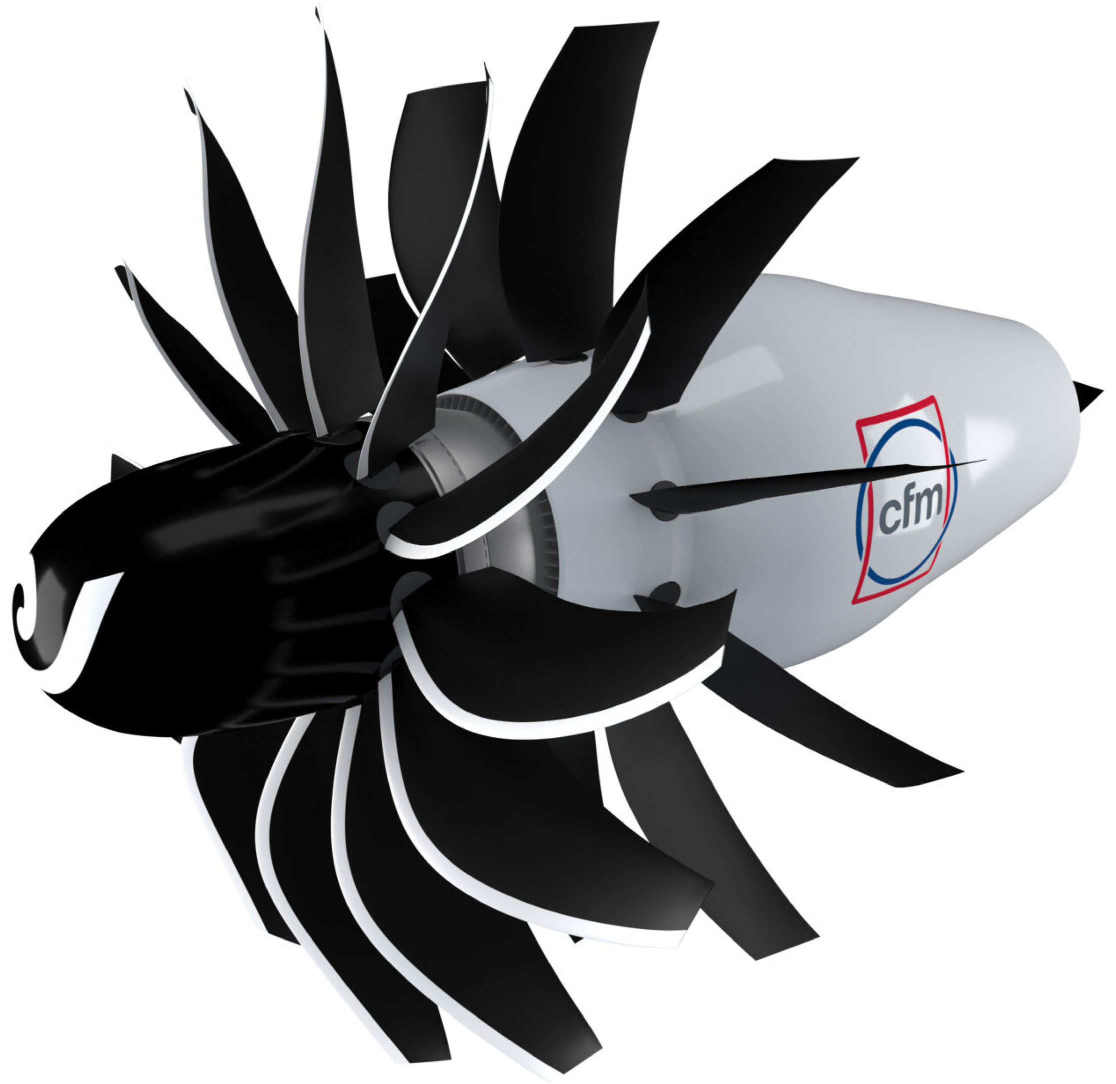
Rolls-Royce is also backing a geared, ducted fan called the UltraFan which is compatible with 100% SAF. It is a scalable engine with a thrust range of 25k lb - 110k lb for use on both narrow and widebody aircraft.

According to analysis by industry sources, future geared turbofans as offered by Rolls-Royce and Pratt & Whitney will be c.12% more efficient than today's engines, while the open-fan will be 18.5% more efficient.

While lessors tend to prefer a single engine which enhances their ability to remarket the aircraft, airlines generally prefer two engine options on their aircraft. The importance of optionality was emphasised by the well published powder metal issue on the PW1100G engines which has grounded hundreds of aircraft, while the CFM LEAP powered aircraft were not affected to the same degree.

However, due to the differences in the design of the engines and airframe integration should a new aircraft opt for an open fan engine, we would expect that it will have to be single-source.

Rolls-Royce Ultrafan: Looks similar to conventional engine with a proportionally larger fan case.



CFM RISE: Also larger than existing narrowbody engines but visually different due to the absence of a fan case.

Source: Leeham News

Image sources: Rolls Royce, CFM International

Open Fan – the next great leap?

The CFM RISE (Revolutionary Innovation for Sustainable Engines) research program is designed to develop an open fan engine delivering 20% better fuel efficiency (slightly higher than the analysis previously mentioned) and is expected to be available to enter service around 2035.

Open Fan is a more radical design where the engine has a large, exposed fan with fewer blades which could significantly improve efficiency but comes with engineering challenges. It is expected to generate thrust in the range of 20-35k lbs, so not dissimilar to the LEAP-1A. Although the concept is around since the 1970's, open-fan technology is a significant step for commercial aircraft so certifying it for use and integrating it seamlessly with the aircraft is a complex and time-consuming process.

Simply put, the physics of propulsive efficiency requires that to achieve the highest level of fuel efficiency, you need to propel the largest quantity of air, at the lowest exhaust velocity. This has led to increasing fan diameters (bypass ratios) and now to an open fan concept.

Noise was previously one of the biggest hurdles for open fan technology. The exposed blades generated significantly more noise requiring innovative solutions to meet certification standards.

CFM believe they have resolved this issue and noise levels should be comparable to the LEAP.

OPEN FAN PROS

Significantly Improved Fuel Efficiency: Open fan engines boast a substantial potential fuel burn reduction versus turbofan engines, translating to considerable cost savings for airlines and reduced emissions.

Lack of an Engine Case: Eliminates the bulky engine casing resulting in a lighter overall weight of the aircraft, hence increasing efficiency. Easier adaptation to biofuels or even hydrogen.

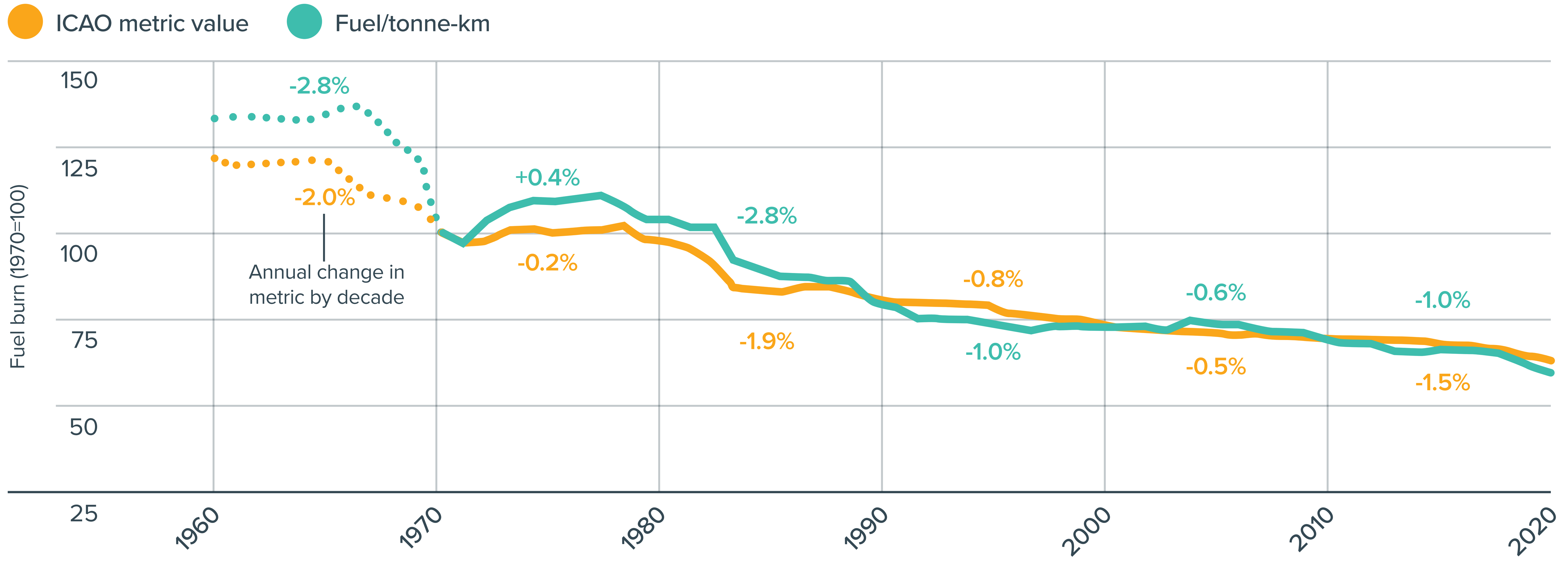
OPEN FAN CONS

Complexity of Design: While seemingly simple, open fan engines have additional challenges including developing contra-rotating gearboxes and ensuring safe and efficient blade operation at high speeds.

Size: Although smaller than prior iterations, the 12-foot diameter presents installation challenges for wing mounting.

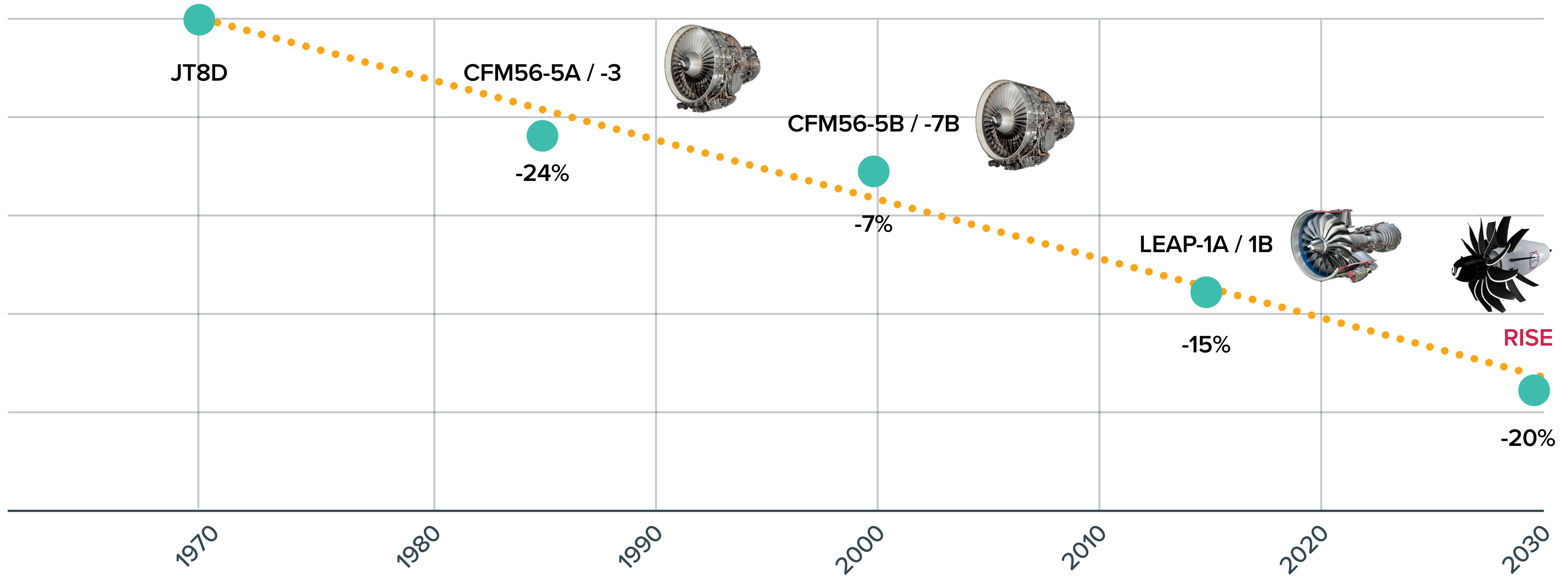
Safety: No containment in the event of a blade-off situation. Airframe strengthening to counter this will add weight.

Fleet wide fuel burn reduction



Source: ICCT: Fuel burn of new commercial jet aircraft white paper

CFM Fuel Burn and CO_2 Improvements



Source: CFM International

Airframe technologies, what to expect?

TECHNOLOGY	ADVANTAGE	CONSIDERATIONS	LIKELIHOOD
Transonic Truss-Based Wing (TTBW) This is an ultra-thin, high aspect ratio wing supported by a truss underneath. The benefit of which is an increase in efficiency and a reduction in drag. 	Expected to cut fuel burn and emissions by 10% by reducing drag. High wing means ability to accommodate open fan and higher bypass engines.	Boeing state it could be used on a 130-160 and 180-210 seat aircraft – may prove to be too small. Aircraft will need to fit into single aisle airport gates of 36m, so the long-wing TTBW will need to have folding wings to fit – increasing complexity and weight. Considerably different design to existing wings which makes design more complex. Some of the fuel will need to be stored in the fuselage due to reduced fuel tank size in the wings.	NASA/Boeing demonstrator will fly in 2028, results of which will determine its feasibility. On the Airbus side, they will most likely go with a conventional wing configuration, with folding wingtips.
Blended Wing Body (BWB) This is a fixed-wing aircraft having no clear division between the fuselage and wings and represents a revolutionary shift in design. 	The BWB design aims to significantly reduce aerodynamic drag leading to a 10-20% fuel saving. The wider body design allows for more cargo and passenger space compared to traditional tube-and-wing aircraft. Engine placement on the upper fuselage could offer better noise performance.	This comes with significant challenges including a more complex manufacturing process. The size of the aircraft may require changes to airport gates and runways and solutions to passenger evacuation. Certification for such a radical design change would be more complex and time consuming	Not likely. BWB aircraft designs have focused on 350+ seat configurations. Next clean sheet design will be conventional tube and wing.
Elliptical Fuselage While the conventional shape for commercial fuselages is circular, using an elliptical cross-section can offer greater optimization. 	Lower wetted area of the elliptical fuselage which leads to less drag. Optimized space for passenger compartment.	Increased strengthening required to resist pressurisation forces compared to circular fuselage. Composite fuselages solve the above issue, but producing enough will be a challenge. Current manufacturing methodologies support widebody rates of up to 14, but far removed from narrowbody rates of up to 70 per month. Elliptical shapes lead to less cargo space, but that is not quite as important for short-haul aircraft.	Boeing were expected to use this design on the cancelled NMA, and should the next aircraft be a twin-aisle then it will most likely have an elliptical fuselage.

Image sources: Boeing, NASA, Frigate Ecojet

How can SAF reduce aviation's climate impact?

Having explored the clean sheet engine redesign initiatives aimed at enhancing fuel efficiency and reducing emissions, we now turn our attention to sustainable aviation fuels (SAFs).

SAFs are considered by industry experts to be the key lever in aviation's decarbonisation pathway. SAF is considered a "drop in solution" that is compatible with all current aircraft and engine types.

As there is no change in the underlying aircraft engine, which requires energy dense carbon-based fuels to operate, one may wonder how SAF can reduce aviation's climate impact, as SAF will still release almost identical exhaust fumes as jet fuel. Therefore to understand SAFs benefit when compared to conventional jet fuel, it is useful to first understand the natural carbon cycle of the earth.

The carbon cycle is a complex system that regulates the amount of carbon dioxide in Earth's atmosphere, oceans, and land-based ecosystems. The system is composed of multiple reservoirs, in which carbon can be stored for various lengths of time. These reservoirs include, the atmosphere, oceans, forests, soils, peatlands, fossil fuels and sedimentary rocks.

Carbon is continuously being transferred between reservoirs, through processes such as respiration by living organisms, photosynthesis by plants, absorption by oceans, volcanic eruptions and decomposition by organic matter. Nature tends to keep carbon levels balanced, such that over the long term, the amount of carbon naturally released from reservoirs is equal to the amount that is naturally absorbed by reservoirs.

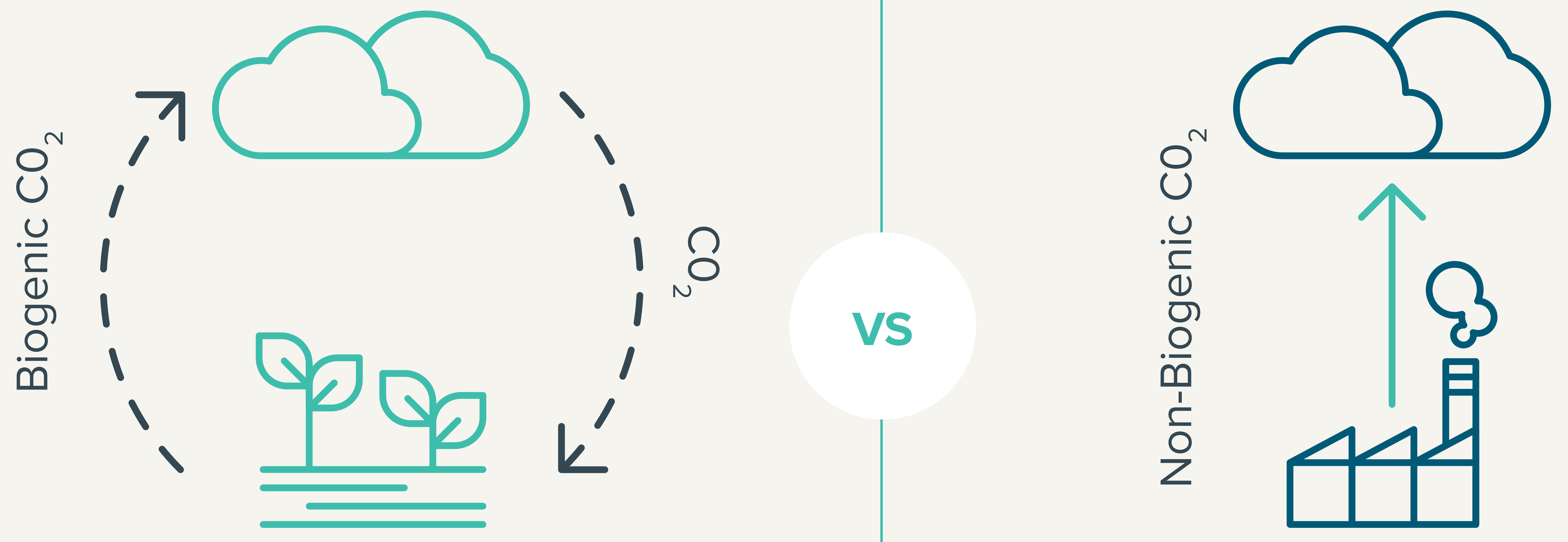
Critically, within the carbon cycle, there are two sub cycles, the short-term cycle and the long-term cycle. The short-term cycle spans from days to thousands of years, while the long- term cycle operates over millions of years.

The burning of fossil fuels, including conventional jet fuel, transfers carbon from the long-term cycle to the short-term cycle, which is a one way process that would take millions of years to reverse. In contrast, SAFs are made from feedstocks that exist within the short-term cycle, such as used cooking oil, forestry residue, crop wastes. This recycling of carbon present in the short-term cycle allows SAF to have a life cycle emissions reduction when compared to conventional jet fuel.

Although some fossil energy is still required in the production and transportation of SAFs, across the lifecycle there is generally a 70-80% reduction in carbon emissions.

The biomass carbon cycle

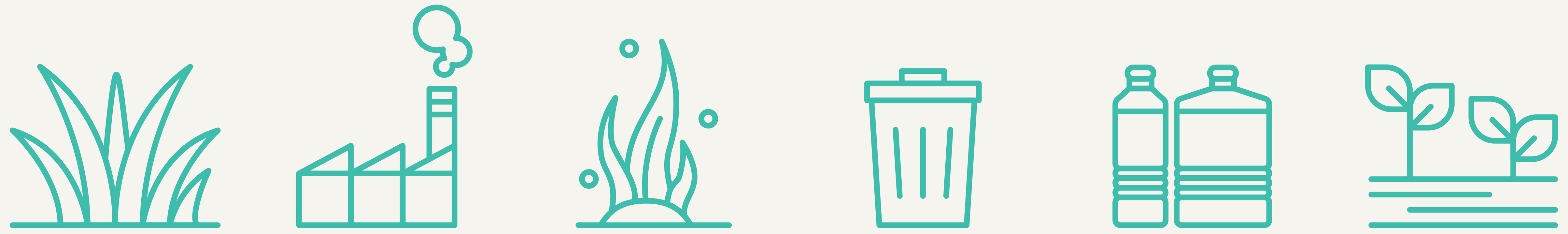
Carbon transfers from geological reserves



Biogenic carbon is part of a relatively rapid natural cycle that, while maintaining the balance between biomass carbon and atmospheric carbon, does not contribute to elevated levels of atmospheric carbon.

Fossil fuel combustion transfers geologic carbon into the atmosphere. It is a one way process.

Feedstocks suitable for SAF production



- Oil seed plants and energy grasses
- Industrial carbon monoxide waste gas
- Algae
- Municipal solid waste
- Fats, oils and greases from cooking waste and meat production
- Agricultural and forestry residue

Source: EESI & PBPC

How can SAF be scaled?

Currently, total global SAF production is less than 1% of the total jet fuel market. Favorable policy will be the most critical component in supporting the scaling of the sustainable aviation fuel market. There is currently a large price gap between SAF and conventional jet fuel, due to additional complexity in the production process, nascent technology, lack of scale and immaturity of global carbon pricing frameworks. This price difference dampens the demand for SAF relative to conventional jet fuel and hinders investment into production capacity.

One of the largest contributors to the price difference between SAF and conventional jet fuel is that there is considerable difficulty in deriving appropriate value from the primary attribute of SAF, the inherent reduction in net carbon emissions. This is due to the social cost of carbon emissions having traditionally not been included within the market price of jet fuel. Creating a policy framework to capture the value in the lifecycle carbon emissions reduction resulting from the use of SAF, will be essential in attributing fair economic value to SAF production and use.

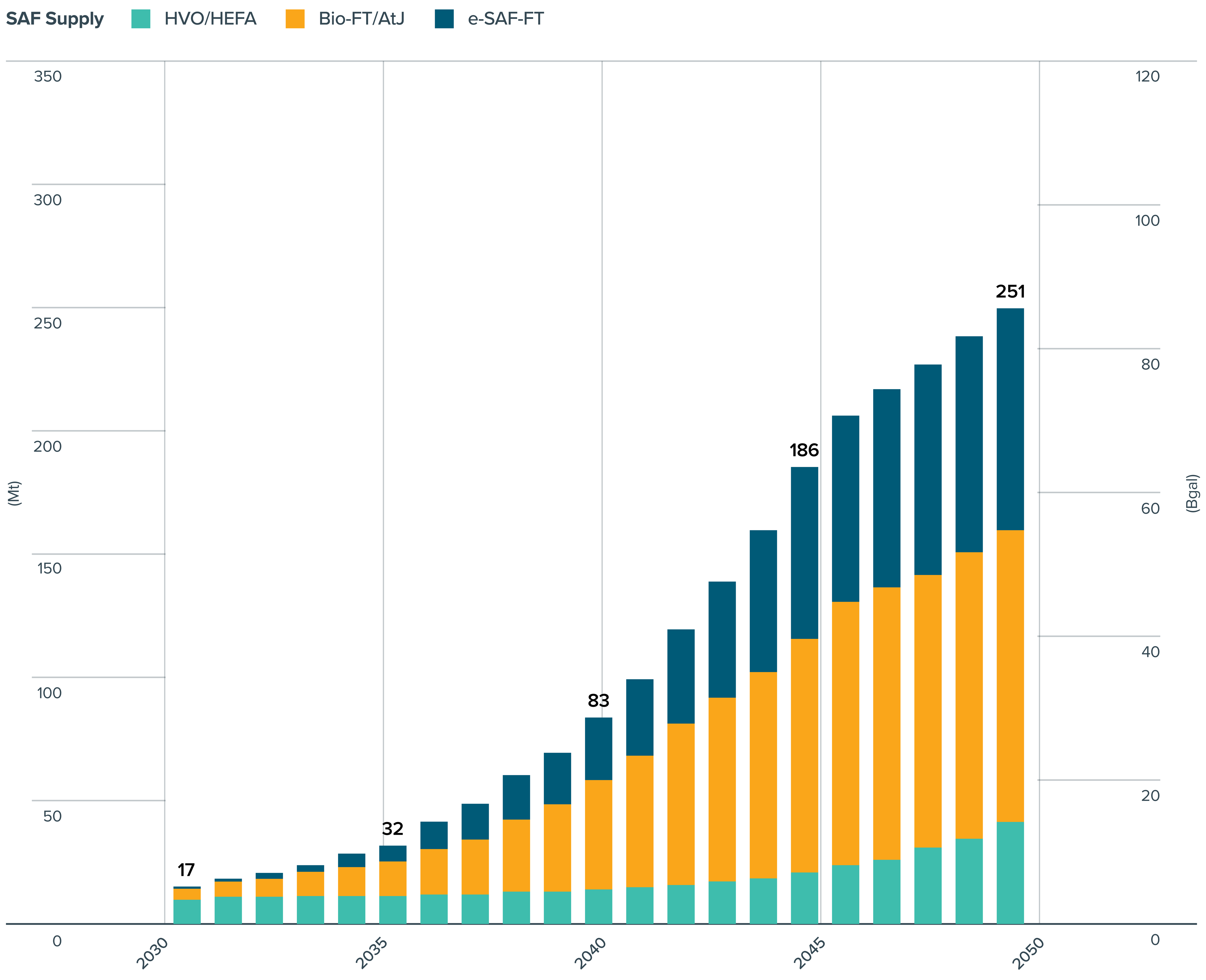
Governments can use various policy instruments to form this framework, and these include subsidies, mandates, internationally consistent standards, "buy out" or penalty mechanisms alongside emissions trading schemes.

Policy that creates long-term price and demand certainty will substantially derisk investments, which will give investors and financiers the confidence required to channel funding to these projects.

For example, the ReFuel EU Aviation Regulation obliges aviation fuel suppliers to increase their SAF supply. Commencing in 2025, it requires the minimum share of SAF to start at 2%, progressing to 70% by 2050.

The global SAF market is currently considered to be at a turning point due to the support from several major governments. Legislative support for SAF from the US, UK, EU and Japanese governments are beginning to lay the foundations for investment into this market. For example, airlines in Europe must increase their SAF usage in the coming years or else face large financial penalties.

Global SAF capacity



Source: SkyNRG

How much will SAF cost in the future?

It is very possible that the price premium for SAF when compared to conventional jet fuel will affect future airfares. Immature or non-existent feedstock supply chains, high engineering, procurement and construction costs for plants, alongside limited green hydrogen availability all apply upward pressure on SAF prices.

Currently, SAF derived from wastes, such as Used Cooking Oil (UCO) for HEFA, typically cost between 2 to 2.5 times more than traditional jet fuel. Advanced synthetic fuels, although more sustainable, can be priced even higher, between 6 to 10 times the price of jet.

According to IATA, in 2023 the industry consumed SAF at a cost of $2,500 per ton (or 2.8x jet fuel) adding c.$750 million to the industry fuel bill.

As SAF production scales up, there is an expectation that unit costs will decrease with technological advancements and economies of scale. Achieving cost parity with jet fuel and managing carbon emissions are essential long-term objectives. However, the current price premium of SAF over conventional jet fuel will likely impact airfares.

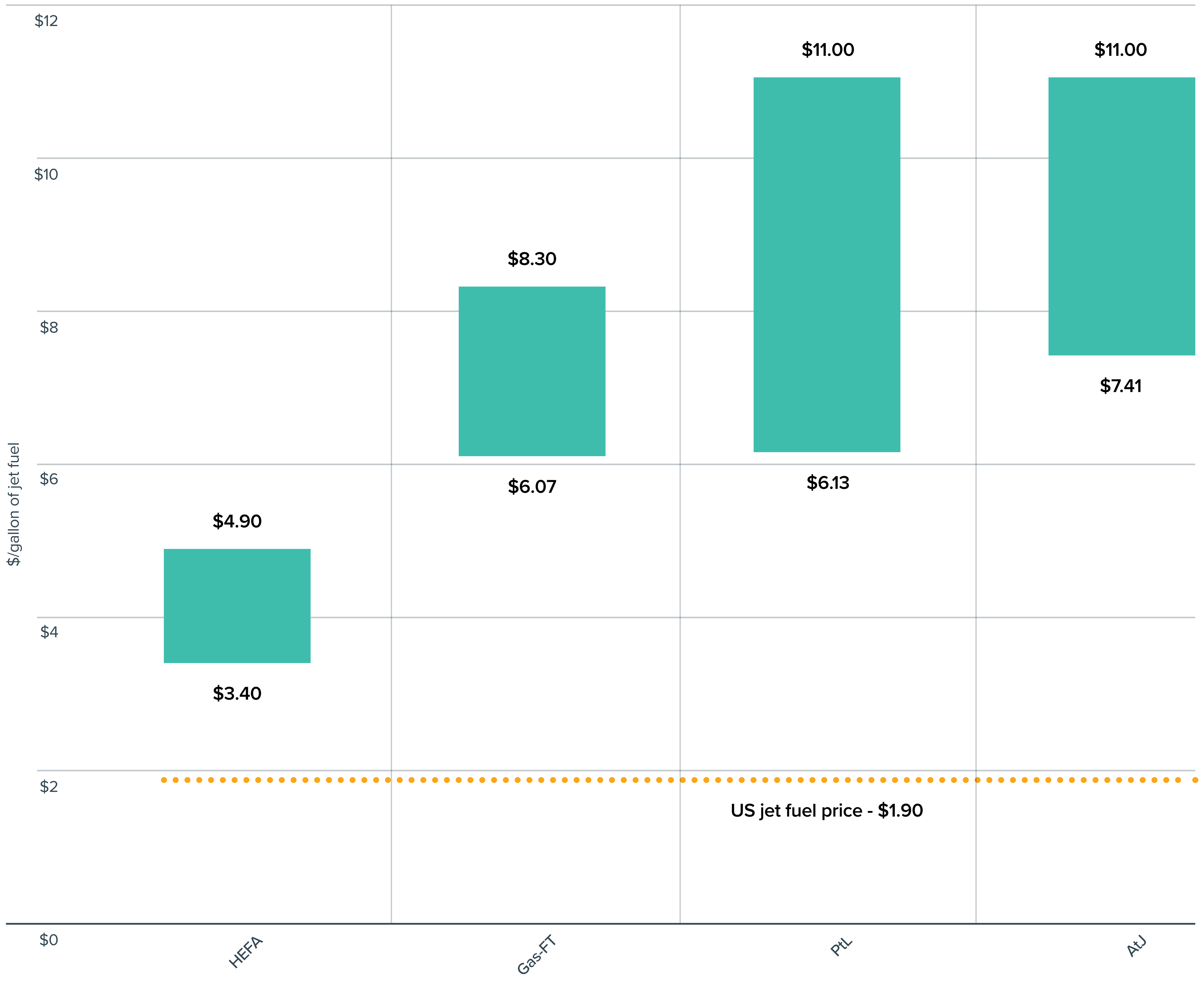
Estimates suggest that if SAF remains priced at a significant premium, airfares could increase by approximately 5% to 20%, depending on the blend ratio and market conditions. This increase reflects the pass-through of higher fuel costs to consumers.

These prices could result in some quite meaningful declines in leisure traffic where the price elasticity of demand is -1.89. This may lead to a greater seasonality in profitability for some carriers.

Ensuring SAF remains economically competitive while meeting sustainability standards is crucial. Rapid market expansion may lead to unintended consequences such as indirect land-use changes or competition with food production. Additionally, rapid expansion can attract bad actors to the space, potentially jeopardizing the credibility of certain SAFs.

To achieve aviation's decarbonisation goals by 2050, substantial investments will be required. The industry's ability to manage SAF costs and mitigate price impacts on air travel will influence the pace and extent of adoption in the coming years.

Cost of SAFs compared to jet fuel



Source: Rhodium Group. Mumbower et al., 2014, Diana Wawrzonkiewicz, 2023

Residual Values of new-tech aircraft will remain robust

As we mentioned previously, aircraft have long production runs, with few models in each generation, which leads to fleet inertia. While this represents a challenge when moving to more efficient aircraft types and declining emissions, it also means that aircraft have long economic lives.

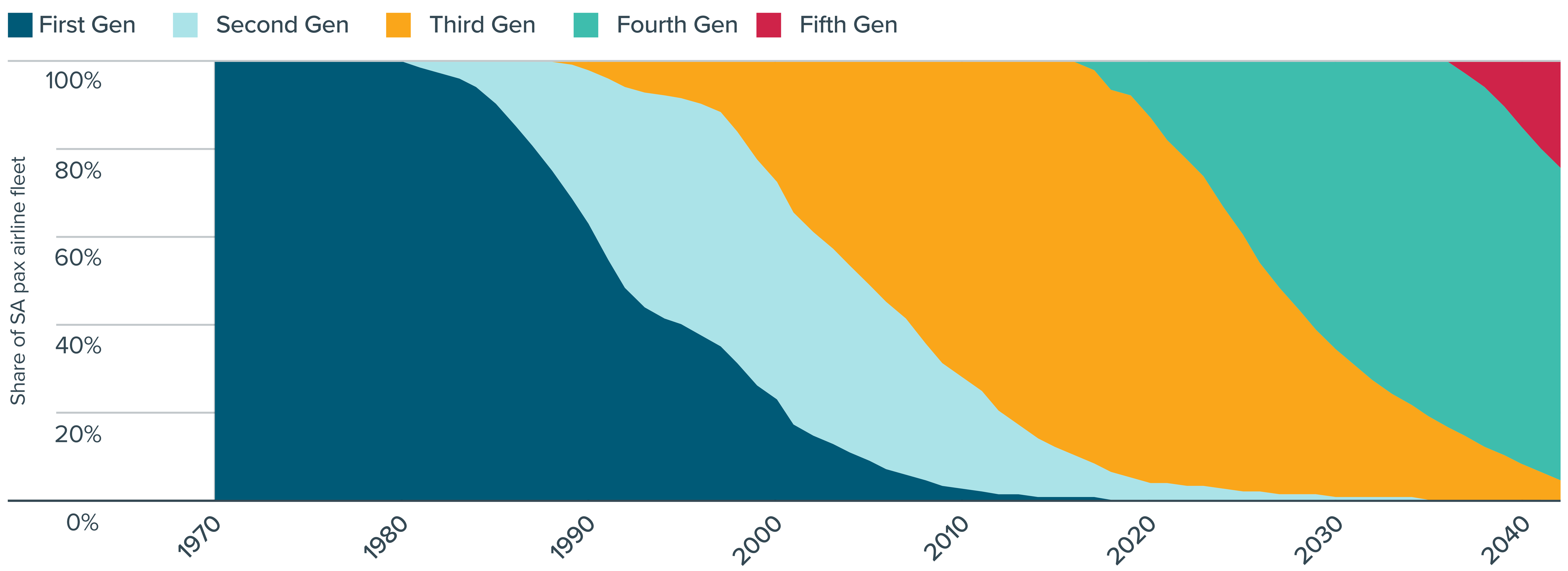
According to the Cirium Fleet Forecast, by 2027 the fourth-generation aircraft (MAX & neo) will represent half of the global narrowbody fleet, looking out to 2042 it will hold a c.70% share of the fleet, just as the OEMs ramp up production of the fifth-generation aircraft to stable levels.

Any technological advancement on a new aircraft will impact its predecessor but as we believe the next clean sheet aircraft will continue to use combustion engines, the residual value for "New-Tech" aircraft will remain robust.

This hypothesis is supported by the above chart using values from Cirium Ascend. Comparing a 2015 build ceo/ -800 forecast from 2015 to a 2024 build neo/MAX forecast from this year indicates that the value retention will slightly exceed the previous generation. In the above example, the neo/MAX will hit age 12 in 2036, in the region where we forecast the clean sheet design will soon enter service, without any noticeable impact on value retention.

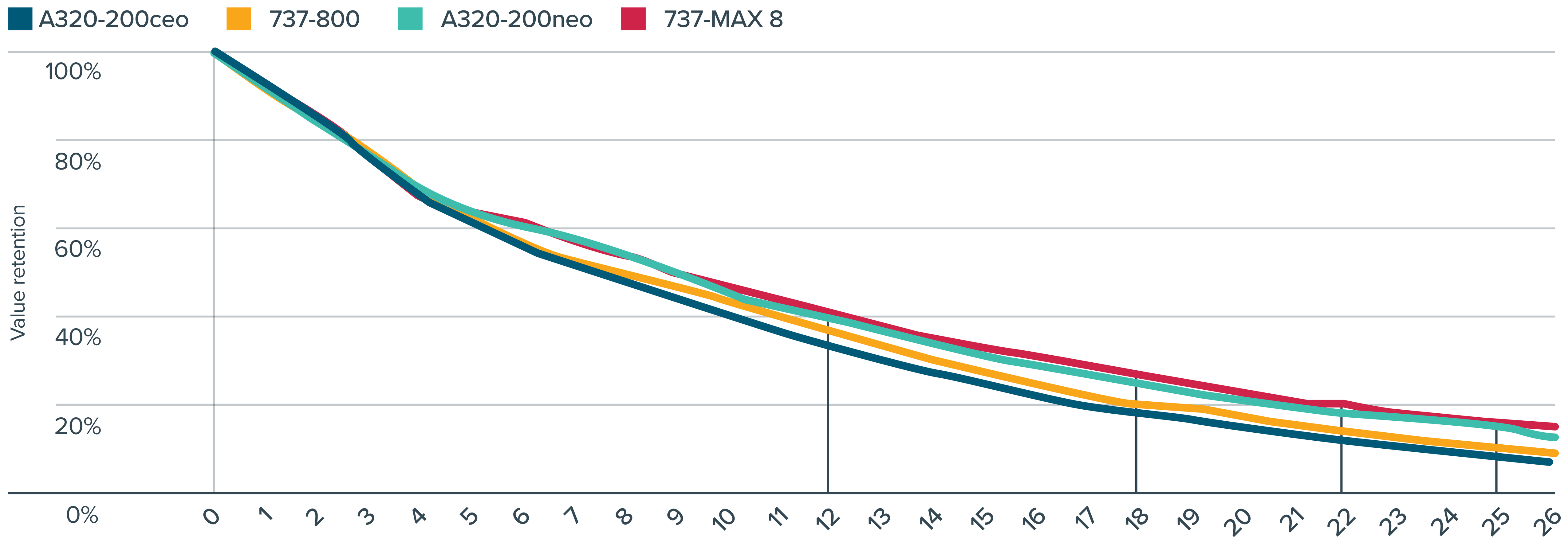
Following the launch of a new generation aircraft, it takes over 15 years to match the fleet size of the prior generations.

Single-Aisle Fleet Share by Generation



Source: Cirium Fleets Analyzer, Cirium fleet forecast

Value Retention (New Tech v Current Tech)



Source: Cirium Values Analyzer, Cirium time value series

Other measures to help reach Net Zero

There are operational improvements that can and should be implemented in the move to net zero. This does require a conscious effort from governments and regulators but some of these measures represent the lowest hanging fruit. While there are multiple solutions, the three below should be implemented:

1. The implementation of a Single European Sky (SES) air traffic management system will lead to a 10% reduction in the environmental effects of flying and offer a three-fold increase in capacity where needed.
2. Increased use of Required Navigation Performance (RNP) which optimises the operation of aircraft along a precise flight path. The use of continuous descent / climb in tandem with this offers reduced fuel burn per flight.
3. The use of electric motors fitted to the landing gear can cut the CO2 emissions by over 60% from the taxiing phase. Alternatively, single-engine taxiing can also reduce fuel burn.

The government will also play a role in its taxation policy as we do expect governments and related bodies to introduce taxes that will have some dampening effect on demand. We would caution that this effect may be temporary in that consumer taxes frequently have a once off impact as the consumer resets their price expectations within a 6-18 month period.

In May 2024, the German government increased taxes on flying by 19% representing up to 71 euro per passenger. The following month Lufthansa introduced an environmental surcharge on tickets with the funds assigned to paying for SAF and other environmental concerns.

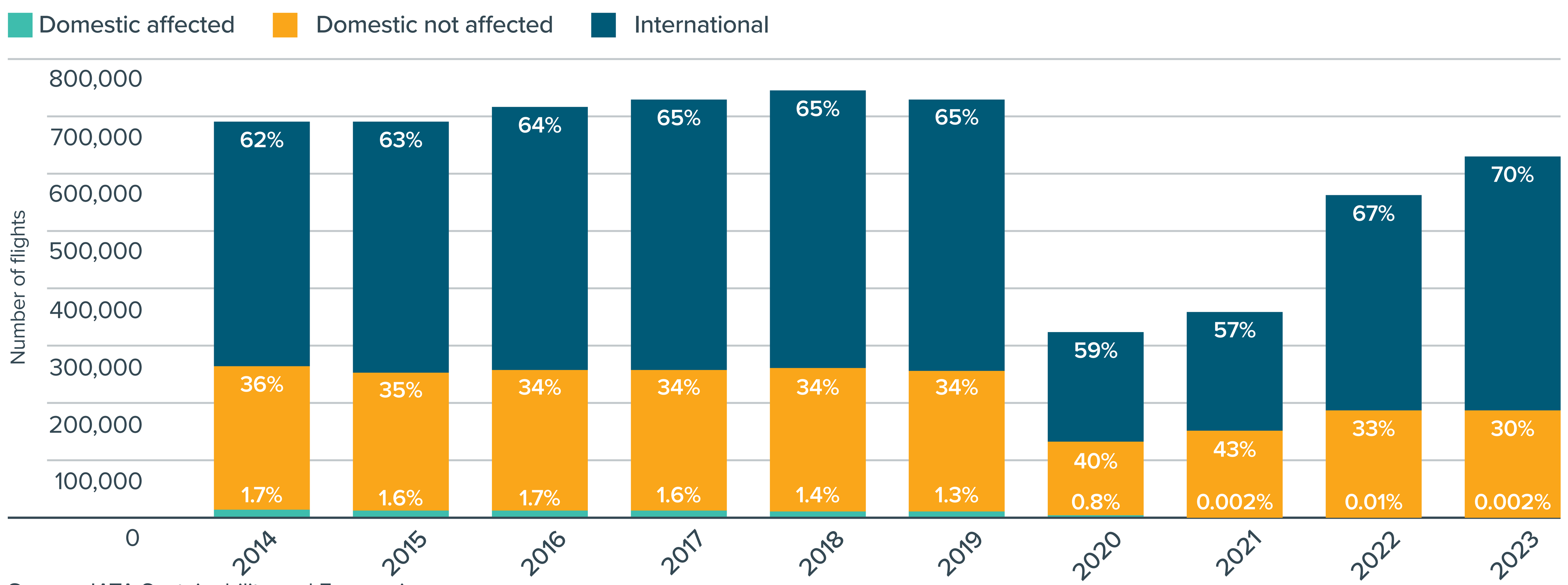
These taxes will have an impact on the more price sensitive passenger, and to date the majority of passengers have not been willing to pay voluntary offsets.

Meanwhile, in mid-2023 France introduced a ban on direct domestic flights that could be replaced by a train journey lasting under 2.5 hours. However, this only covered three routes which accounted for only 0.002% of all flights, or 4% of all domestic flights in France.

It was estimated by LeMonde that the ban reduced CO2 emissions by 0.12% if fully replaced by zero-emission transportation, much less if passengers travelled by bus or car.

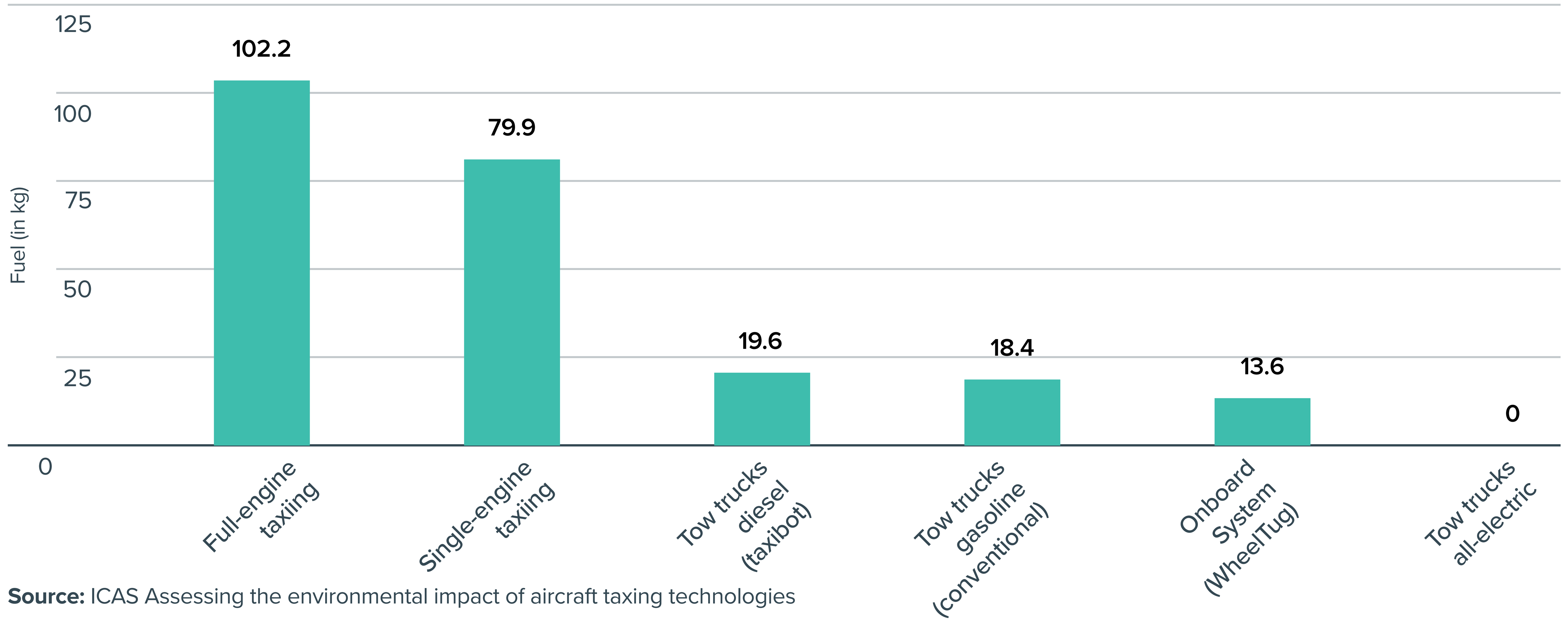
Evidently, there is a mix of approaches from improving flight and aircraft efficiencies with disincentives to flying via taxes and flight bans. We believe the former will have the greater impact on reducing emissions.

Scheduled flights in France impacted by ban



Source: IATA Sustainability and Economic

Taxiing Techniques



Source: ICAS Assessing the environmental impact of aircraft taxing technologies

Conclusions

Aviation emissions while relatively modest today, still remain firmly on a growth path as the industry remains one of the most challenging sectors to abate. However, the industry is looking to minimise its impact over the coming decades.

SMBC Aviation Capital as an owner of aircraft is committed to lower aviation's carbon footprint and looks forward to working with our suppliers, customers and shareholders who are already active in the green energy space in meeting this industry wide objective.

There are four key components on the industry move to net zero by 2050. These are technology, fuel, operational and market-based measures.

Technology
The next generation of aircraft will need to be at least 20% more efficient and environmentally friendly. This will involve a combination of new airframe designs, wing designs and advanced engine technologies. Technologies like open-fan engines and improved geared turbofans will deliver significant fuel savings.

We fully expect the next new aircraft to be a clean design aircraft where the midpoint of the family will be equivalent to the current A321neo as we expect the current trends of increased passenger capacity to continue.

This will be a measured move as OEMs will have to navigate complex challenges, including high development costs, long certification processes, and the need for global infrastructure improvements. Accordingly, we do not see a new aircraft entering service before 2035.

The transition to the new technology will also be slow given the large installed fleet and the slow ramp up in production.

Fuel
We firmly believe that SAF is critical for the aviation industry's path to net zero carbon emissions by 2050 for any aircraft greater than 150 seats as neither electric nor hydrogen are currently economical viable for this size aircraft. It offers a practical, drop-in solution for existing aircraft and can significantly reduce lifecycle carbon emissions.

The scalability of SAF production depends heavily on government policies that will create market demand and economic viability.

SAF will also support the residual value of the world's existing aircraft as they will be able to operate on SAF.

Market Based Measures
It is also important that we recognise that effective policies are crucial to support the development and adoption of new technologies and SAF. This include positive and negative financial incentives, regulatory frameworks, and international cooperation.

Operational
In the interim, operational measures such as optimised air traffic management and electric taxiing are immediate steps that can yield significant environmental benefits.

We should not lose sight of the fact that the transition to more efficient aircraft and the adoption of SAFs will require substantial investment from within and outside the aviation industry. We believe there is a role for governments, tech companies, researchers and investors to play in the transition to a greener aviation industry. We would expect to see more collaboration along the lines of SMBC Aviation Capitals partnership with Trinity College where both parties have come together to establish a SAF research facility.

The next generation of aircraft will not be cheap to develop and bring to market, therefore we believe that the next generation aircraft will come from the larger established players rather than a new entrant or smaller manufacturer.

Glossary

Air Traffic Management (ATM): Systems and processes used to manage the safe and efficient movement of aircraft through controlled airspace.

Alcohol-to-Jet (AtJ): A process that converts alcohols, such as ethanol or butanol, into jet fuel. AtJ fuels are a type of sustainable aviation fuel that can be produced from a variety of biomass sources and offer a renewable alternative to conventional jet fuel.

Carbon Cycle: The natural process by which carbon is exchanged between the atmosphere, oceans, soil, and living organisms. SAFs fit within the short-term carbon cycle, recycling existing carbon rather than adding new carbon from fossil fuels.

EIS: Entry In Service is when a new aircraft type first enters operations.

Electric Taxiing: The use of electric motors fitted to an aircraft's landing gear to move the aircraft on the ground, significantly reducing fuel consumption and emissions during taxiing.

ESG: Environmental Social and Governance is a framework that is used to determine how sustainable an organisation or company is.

Fleet Renewal: The process of replacing older aircraft with newer, more efficient models to reduce emissions and improve operational efficiency.

Geared Turbofan: A type of turbofan where a reduction gearbox is installed between the fan and the Low-Pressure Turbine (LPT). This allows the fan and the turbine to rotate at different, more efficient speeds.

Hydrotreated Esters and Fatty Acids (HEFA): HEFA refines vegetable oils, waste oils, or fats into SAF through a process that uses hydrogen.

Lifecycle Carbon Reduction: The total reduction in carbon emissions achieved over the entire lifecycle of a product, from production to disposal.

Narrowbody: Aircraft also known as a single aisle aircraft, allowing up to 6 abreast seating in a cabin less than 4m with a single aisle (passage between rows of seats)

Net Zero Carbon Emissions: Achieving a balance between emitting carbon and absorbing carbon from the atmosphere in carbon sinks, aiming for no net increase in atmospheric carbon levels.

Nitrogen Oxides (NOx): NOx are any of several oxides of nitrogen most of which are produced in combustion and are considered to be atmospheric pollutant.

Open-Fan Engines: A type of aircraft engine design with an exposed fan that offers improved fuel efficiency by propelling a larger quantity of air at lower exhaust velocities.

Original Equipment Manufacturer (OEM): Companies involved with the design, manufacture and assembly of aircraft e.g. Boeing, Airbus, CFM, P&W and Honeywell.

Price Elasticity of Demand: A measure of how sensitive the quantity demanded of a good is to changes in its price, with higher elasticity indicating greater sensitivity.

Product Improvement Packages (PIP): Updates and enhancements made to existing engines to improve performance and efficiency without developing entirely new designs.

Required Navigation Performance (RNP): A type of performance-based navigation that allows aircraft to fly precise paths with the aid of onboard systems, reducing fuel burn and emissions.

Single European Sky (SES): An initiative by the European Union to unify and optimise air traffic management across Europe to improve efficiency and reduce environmental impact.

Widebody: Aircraft also known as a twin aisle aircraft, allowing at least 7 abreast seating in a cabin more than 5m with a two aisles (passage between rows of seats)

About the authors

Shane Matthews

Shane is Head of the Strategic and Market Analysis Team leading a team of six analysts who have responsibility for SMBC Aviation Capital's proprietary models, databases and market analysis. He joined the company in 2005 as a credit risk analyst covering customers in Asia Pacific. Shane spent 10 years as an equity analyst covering airlines with NCB Stockbrokers and HSBC Securities in Singapore. He holds a Bachelor of Commerce Degree and a Masters in Business Studies in Banking and Finance from University College Dublin.

Darren Naughton

Darren joined SMBC Aviation Capital in 2004 as a Residual Value Risk Analyst before joining the credit risk team covering airlines in Europe and North Africa. In 2014 he joined the Strategic and Market Analysis team with responsibility for industry analysis, forecasting and portfolio risk management. Prior to joining SMBC Aviation Capital, Darren worked in the semiconductor industry and has an Engineering Degree and an MBA from Trinity College Dublin.

David Griffin

David is VP Strategic and Market Analysis. He initially joined SMBC Aviation Capital in 2021 as a member of the Commercial Analysis team, with responsibility for assessment and evaluation of all company transactions including asset acquisitions, placements and trading before joining the SMA team in March 2023. Prior to joining SMBC Aviation Capital, David was a Valuation Consultant with Ascend by Cirium. David holds a Bachelor's Degree in Aeronautical Engineering and a Master's in Business Management, both from the University of Limerick. He is also an ISTAT Certified Appraiser.

Shane Wilson

Shane joined The Nest, SMBC Aviation Capital's innovation hub, upon its inception in 2018. The Nest's mission is to identify and develop opportunities that add value, as well as to nurture an innovative mind-set in the business. Shane combines over 12 years' experience in the Transaction Management and Transaction Execution (now Commercial Negotiation & Execution) teams with a passion for innovation and creative problem solving. Shane holds a first class honours Degree in Industrial Design from the National College of Art & Design in Dublin.

Oisin Donnelly

Oisin joined SMBC Aviation Capital in September 2020 as part of the graduate programme. Originally on the Customer Management team, he is currently an AVP in the NEST. Oisin graduated from University College Dublin with a Bachelor of Mechanical Engineering. As part of his degree, Oisin spent 6 months studying in Australia, spending a semester in the University of Melbourne.

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