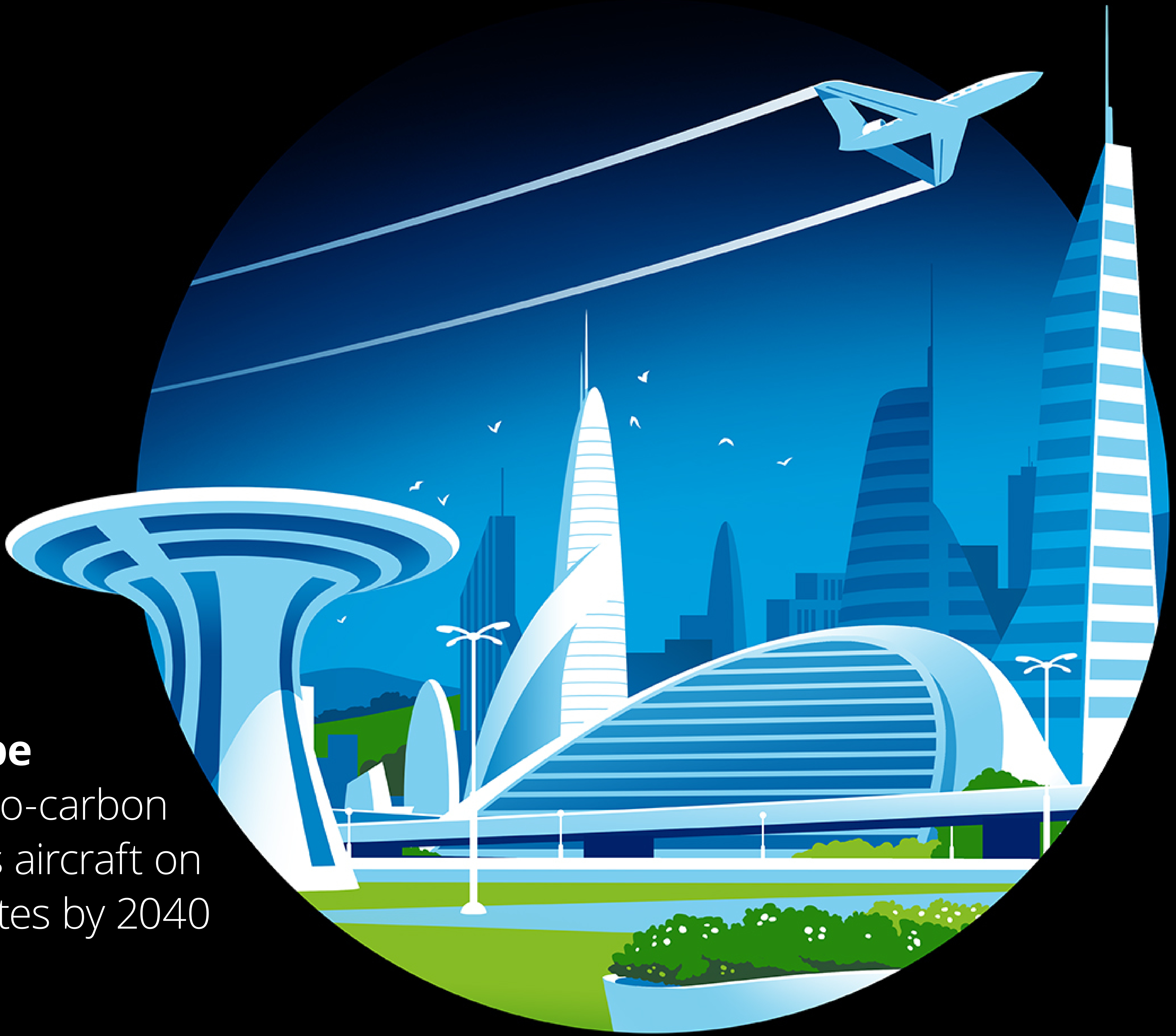
Deloitte.



Europe's future aviation landscape

The potential of zero-carbon and zero-emissions aircraft on intra-European routes by 2040

Executive Summary

April 2021


Imagine if...
You could fly across Europe without worrying about your environmental footprint.

The context for the decarbonization of the aviation sector

The aviation industry is one of many industries that has a heavy impact on global human-made emissions. If nothing were to change, the aviation industry's contribution to global carbon emissions would increase from 2-3% today to as much as 27% by 2050.[1] The past few years have seen an increase in public pressure on the sector, especially in Europe, with growing media attention for the "flight shaming" movement as well as discussions within different European governments about promoting a significant shift towards more sustainable modes of transport, such as rail.

The aviation industry is now looking towards the development of battery and hydrogen-based propulsion technologies which have the potential to play a major part in aviation's decarbonization: battery-powered airplanes produce no emissions (zero-emissions aircraft) and hydrogen-powered airplanes release no carbon while greatly reducing other greenhouse gas emissions (zero-carbon aircraft). As such aircraft are only at the pilot phase today, with smaller prototypes being developed and tested around the world, the extent to which battery- and hydrogen-powered airplanes have the potential to play an important role in the future of the aviation industry is still unclear.

Source: 1) Deloitte Article - Industry Disruption: Hybrid Electric Aviation

Focus of this report

In this context, this report aims at providing clarity regarding several questions surrounding the future of zero-carbon and zero-emissions aircraft in Europe, in order to understand the true potential of these technologies and the place they should occupy in European mobility roadmaps, policy frameworks, and investment strategies.

In order to do this, the report looks at the projected aviation technology roadmap and expected performance, as well as the distance segments that could be captured by zero-carbon and zero-emissions aircraft in the intra-European passenger travel market[i] in 2040, the date by which these new aircraft are expected to enter into service. Zero-carbon and zero-emissions aircraft are then compared to other conventional modes of transport (air and ground) to better understand the benefits and trade-offs associated with these new technologies in terms of climate impact, travel costs per passenger, and overall travel time.

Note: i) i.e., excluding: flights from or to an airport outside the EU, freight transport and VTOL aircraft

Zero-carbon and zero-emissions aircraft represent the most promising paths towards the decarbonization of the Intra-European air travel

The key features of zero-carbon and zero-emissions airplanes
As mentioned previously, electric battery-powered airplanes would completely eliminate in-flight emissions (as well as emissions related to the charging process if renewable electricity is used), whereas hydrogen propulsion would avoid any carbon emissions and greatly decrease the non-CO_2 climate impact of aircraft[i] (adding up to a climate impact reduction of up to 90% for fuel cell propulsion, and up to 75% for hydrogen combustion propulsion, when using hydrogen produced with renewable energy).[1]

However, by 2040, the technological maturity and performance gap between battery- and hydrogen-based propulsion systems and conventional kerosene engines will not yet be bridged and certain operational constraints will be linked to the use of these new systems. Until such technologies achieve a certain maturity and scale, the operating and acquisition costs of zero-carbon and zero-emissions aircraft will remain higher than those of their conventional kerosene counterparts, which will drive higher ticket prices for customers. Furthermore, the inherent lower energy and thrust power delivered by battery and hydrogen propulsion systems will impose lower cruise speeds, leading to longer flight times.

The market segments captured by zero- carbon and zero-emissions aircraft by 2040 The low energy density of battery and hydrogen propulsion systems implies that such systems will be significantly heavier than current kerosene based systems. This means that less energy capacity can be stored in aircraft, resulting in shorter distance ranges (for comparable aircraft sizes). As a result, for single-aisle aircraft similar to those used on most of intra-European routes, battery propulsion would allow flights up to 500 km, hydrogen fuel cells up to 1000 km and hydrogen combustion engines up to 2000 km, approximately.

The market potential for intra-EU commercial passenger travel in 2040
In terms of market potential and considering the total number of intra-EU commercial passengers predicted for 2040, flights up to 500 km would absorb 25% of passengers, while routes of up to 1000 km and 2000 km would cover 47% and 89% of the demand respectively. These figures highlight the fact that, despite allowing shorter flight ranges than kerosene-powered aircraft, zero-carbon and zero-emissions aircraft have the potential to absorb a significant part of the intra-European passenger market.

The climate impact reduction potential in 2040
In terms of climate impact reduction potential, up to 80% of the CO_2-equivalent emissions predicted for 2040 fall into the operating segments of future hydrogen- and battery-powered airplanes. Replacing all aircraft in those segments with zero-carbon and zero-emissions variants would represent a substantial decrease of 59% in emissions, a very promising step towards the decarbonization of the aviation sector.

Comparing zero-carbon and zero-emissions aircraft with other modes of transport
When comparing zero-carbon and zero-emissions airplanes to other modes of transport, namely kerosene airplanes, electric and gasoline cars, diesel tour bus and rail, their performance in terms of climate impact, travel costs per passenger, and overall travel time varies depending on the distance segment considered.

For routes of 500 km, the difference between all modes of transport remains reasonable. In this segment, the use of battery-powered airplanes would completely avoid emissions (if renewable electricity is used), although at a slightly higher travel cost than other zero-emissions modes (rail and electric cars). In terms of travel time, the competitiveness of air travel strongly depends on the rail network in place on selected routes. Journeys between cities connected by an efficient high-speed rail network might be faster by rail than by air, whereas less developed rail services could lead to longer travel times than air alternatives, and sometimes even longer than road travel.

Increasing the route distance to 1000 km and 2000 km, hydrogen-powered aircraft have the potential to greatly lower the emissions of air travel, although these remain slightly above those of rail and electric cars (due to non-CO_2 related emissions). Whereas road and rail transport costs grow proportionally with the distance travelled, the increase in air travel costs is not as significant (thanks to improved fuel efficiency at high altitudes), and for 1000 km and 2000 km journeys, air travel costs approach those of ground alternatives, with single-passenger cars and rail becoming the most expensive options. In general, for distances above 1000 km, the contrast between air and ground travel time becomes significant, and air travel represents a much faster option.

Note: i) Hydrogen propulsion systems emit different particles when hydrogen is reacted (nitrogen oxides and water vapor for hydrogen combustion engines, and only water for hydrogen fuel-cells). Water and NOx particles promote the formation of high altitude contrails clouds and ozone, respectively, both global warming agents. The non-CO_2 related climate impact also appears with kerosene engines, to an even larger extent, as they also produce water and NOx, as well as sulfur oxides and soot particle. Therefore, the total climate impact of kerosene aircraft' non-CO_2 emissions is estimated between 2 to more than 4 times the one of CO_2 alone.

Source: 1) Clean Sky 2 JU and FCH 2 JU (2020), Hydrogen-powered aviation - A fact-based study of hydrogen technology, economics, and climate impact by 2050

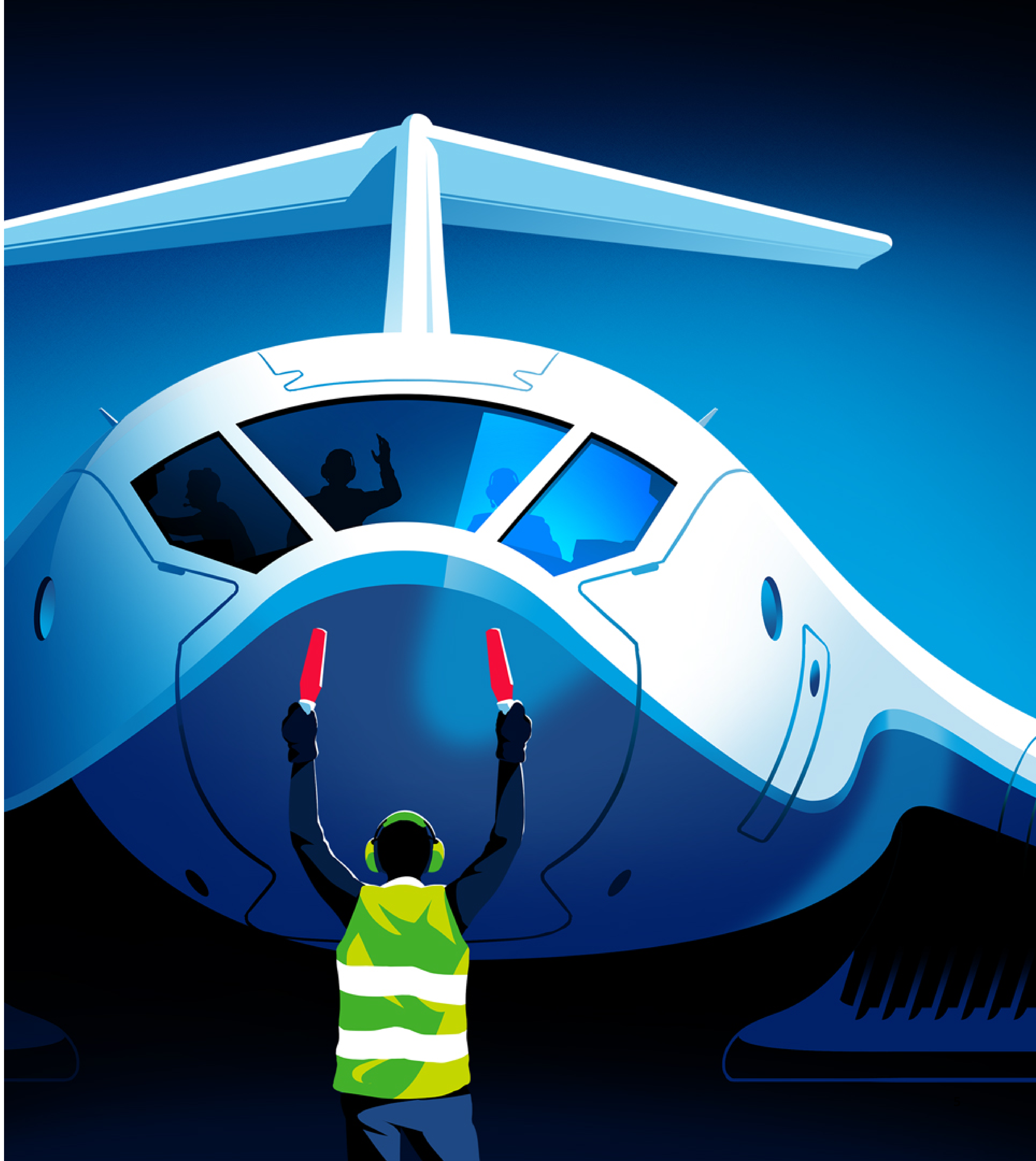
Key takeaways and drivers for success

Time is now of the essence to ensure that these technologies are ready to enter the large-scale commercial passenger market within short timelines.

With development times of 15 to 20 years and a broad deployment of large fleets usually taking up to 10 years, the aviation sector needs to invest significant resources today to develop the required innovations and technologies that will allow the sector to reach the decarbonization objectives for 2050 as set by the EU and ATAG.

Policy makers, industries and stakeholders from the broader aviation ecosystem need to cooperate to build the long-term regulatory and certification framework supporting the successful development of zero-carbon and zero-emissions technologies. Public support will therefore be fundamental in promoting both zero-carbon, zero-emissions technologies and infrastructure with targeted subsidies and economic measures to accelerate the competitiveness of these new sustainable aircraft.

Furthermore, the large-scale deployment of battery- and hydrogen-powered aircraft will substantially increase the need for renewable energy production. Relying on non-renewable energy would greatly hinder the overall climate reduction potential of these aircraft, and public entities must ensure that the future aviation sector can be supplied with sustainable energy, along with other modes of transport.



The role of policy-makers and public entities in supporting zero-carbon and zero-emissions aircraft on short routes is crucial

Whereas the benefits of hydrogen-powered aircraft over other modes of transport for routes over 500 km are undeniable, distances below 500 km represent the most competitive segment. Here, as both ground and air transport have compelling benefits, the existing infrastructure between the two travel points has a significant impact on the advantage of one mode over another (i.e., efficient rail and road network, proximity to airports). This report has highlighted the significant benefits of electric and battery-powered modes of transport (rail, EVs, battery-powered aircraft) on short-range travel in terms of low emissions and climate impact, plus attractive travel costs and times.

These three modes all represent promising solutions for the decarbonization of short-range mobility, but in each case there are obstacles to their sole domination:

- Electric autonomous cars could become the most convenient mobility option for short distances, but road capacity challenges would be even more exacerbated than they are today, with limited network expansion possibilities.
- A significant proportion of travellers could shift to rail, but the same capacity constraints as for roads would apply and the potential infrastructure investments could be significant in order to increase capacity on targeted routes.
- Battery-powered airplanes could represent a true game changer by offering a sustainable and fast travel option at an attractive price (which would further decrease in the future with new innovations and economies of scale). Furthermore, the limited infrastructure requirement needed to support battery systems would boost the development of the promising network of existing regional airports and unlock seamless air travel over large areas. Of course, the development of hydrogen aircraft for short routes also needs to be supported in parallel, as they would further the overall decarbonization of the 500 km segment by increasing the rate of kerosene aircraft replacement.

Therefore, policy makers need to strongly support the development of battery-powered (and hydrogen-powered) airplanes for the commercial passenger market on short routes and bolster the implementation of the required battery charging/swapping infrastructure, while optimizing the road infrastructure along with policies incentivizing the presence of multiple persons per vehicle and supporting an increase in capacity on existing rail routes. A first step would be to investigate the infrastructure requirements to integrate battery-powered and hydrogen-powered aircraft into the existing air network and compare them with the investments required in the rail and road network to support a potential modal shift towards ground transport.

Deloitte.