Alliance for
Zero-Emission Aviation

PREPARING EUROPE
FOR HYDROGEN
& ELECTRIC FLIGHT


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A Roadmap for the deployment of hybrid, electric and hydrogen flights in Europe

April 2026

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FOREWORD

Timo Pesonen

Director-General, European Commission DG Defence Industry and Space

The European aeronautics industry and the aviation sector are essential to Europe's sovereignty and prosperity. Civil aeronautics industry is a pillar of the EU's industrial strength, and recent wars and conflicts have demonstrated the strategic importance of air capabilities. Aviation, for its part, is a key driver of the European economy. It also plays a crucial role in the movement of military assets both in peace time and crises situations. Europe needs therefore a competitive aeronautics industry and a sustainable air transport.

Electric and hydrogen propulsion will help achieving both objectives. In Europe more than anywhere else, aircraft and powertrain manufacturers—both large and small—have turned the climate challenge into an opportunity to innovate, developing electric and hydrogen propulsion. Staying at the forefront of technological development has always been the key to the European industry's success. By reducing or eliminating in-flight CO_2 emissions, the entry-into-service of hybrid, battery-electric and hydrogen-powered aircraft will reduce the climate impact of existing intra-European routes, reduce the sector's dependence on fossil fuels, and enable the development of new green regional air mobility offers.

The deployment of electric and hydrogen propulsion in aviation is expected to begin in the coming years. It requires, however, coordinated actions by various public and private stakeholders to prepare the aviation sector for these new technologies. To support this effort, DG DEFIS is offering with the Alliance for Zero-Emission Aviation a platform designed to foster the necessary cooperation. The Alliance's objective is to identify all obstacles and requirements arising from the use of electricity and hydrogen as new fuels for aircraft propulsion, to define the necessary measures to address them, and to promote their implementation.

With the publication of this Roadmap for the deployment of hybrid, electric and hydrogen flights in Europe based on the contributions of its 200 members, the Alliance for Zero-Emission Aviation achieves an important milestone. It provides to the entire European aviation ecosystem a common ambition for the deployment of hybrid, battery-electric and hydrogen-powered aircraft in Europe. It identifies the actions required by all private and public stakeholders, including the Commission, to adapt the aviation ecosystem and achieve this deployment. It showcases the determination and the capacity of the European aviation ecosystem to achieve the deployment of electric and hydrogen-powered flights in Europe.

I invite all stakeholders to consider the Roadmap when defining their own strategies with respect to these new types of aircraft. The Roadmap will help them identifying the challenges and opportunities that these new aircraft may bring. It will support a consistent implementation of the various actions required from the many public and private stakeholders involved.

The successful implementation of the Roadmap will strongly contribute to the competitiveness of the European aeronautics industry and to the development of green air transport in Europe, including new air mobility offers.

STATEMENTS BY AZEA MEMBERS

Bruno Fichefeux

Head of Future Programmes at Airbus

"We are on a shared journey to decarbonise the aerospace industry, an ambition achievable only through joint action, transnational collaboration and global mobilisation. That is why AZEA's Roadmap is so crucial. It is a powerful driver, providing Europe with a clear path to bring hydrogen to commercial aviation, alongside hybridisation and electric propulsion technologies. At Airbus, we are honoured to take part in this collective action plan. Our dedication to hydrogen-powered flight is unwavering, as we firmly believe that a fully electric aircraft powered by hydrogen fuel cells is set to be amongst the lowest climate impact solutions for aviation."

Jérémy Caussade

President and cofounder of Aura Aero

"We have everything to succeed in the European Union to lead the global race for innovation in aerospace, providing industrialised and competitive aircraft programmes that are needed worldwide to connect the communities in a sustainable way. We need strong support and clear actions from the EU, just like this Roadmap is providing. This is the right flight plan to scale new technologies such as high hybridisation with electric propulsion. We thank the European Commission and all AZEA partners for having set up such a high-quality document."

Ivor van Dartel

Co-founder and CEO of VÆRIDION

"The AZEA Roadmap clearly lays out what is needed to advance zero-emission technologies and decarbonize the aviation sector. Among the policy recommendations and upcoming technologies milestones, what stands out is the need to act immediately to ensure Europe maintains its industrial leadership. By following this Roadmap, the EU can turn ambition into action and lead the race against global players. Let's play to win!''

Nathalie Tarnaud Laude

CEO of ATR

''The AZEA Roadmap represents a crucial milestone in accelerating the transition toward truly sustainable aviation. It strongly underscores that Europe must act now to preserve its industrial leadership while advancing breakthrough technologies. At ATR, we are convinced that regional aviation has a key role to play in this transformation, thanks to innovative, pragmatic and economically accessible solutions for operators. We are proud to contribute to this collective momentum and fully committed to supporting the European ecosystem on the path toward zero emission operations.''

Kyle Martin

Vice President, European Affairs of GAMA

''General Aviation manufacturers in Europe are already leading the way with the world's first certifications of a fully electric aircraft and an electric propulsion engine. General Aviation is uniquely positioned as an incubator of new safety and sustainability enhancing technologies, which will further help bring electric, hybrid and hydrogen aircraft to market faster, enabling these new means of propulsion to be de-risked before being scaled up to larger commercial aircraft operations. This important AZEA Roadmap presents an ambitious vision for what can be achieved through the combined efforts of industry, investors, regulators and policymakers to help make this a reality.''

Olivier Jankovec

Director General of Airports Council International-Europe

“For airports, this Roadmap provides a clear basis for planning the transition to electric and hydrogen aircraft. And while it helps preparing for the massive infrastructure and operational changes needed to support their entry into service, the Roadmap also highlights the opportunities ahead: new energy aircraft can open new markets, strengthen regional connectivity, better serve underserved communities and reinforce the long-term competitiveness of European aviation. Turning that promise into reality will depend on a fully functioning and closely integrated aviation and energy ecosystem. For that timely policy action and the right level of funding are an absolute prerequisite.”

Manish Patel

Director Liquid hydrogen and RFNBO Merchant H2 for Europe & Africa of Air Products

”Air Products is the world’s largest hydrogen supplier, with more than 65 years of experience and a long track record supplying liquid hydrogen to NASA and aerospace R&D. Today, the company works with several AZEA members to prepare airports and their operations for hydrogen adoption. Through the JV project of the Neom Green Hydrogen Company, and the largest liquid hydrogen plant in built in Europe, Air Products is bringing renewable hydrogen to market to decarbonize hard to abate sectors. These activities directly support the objectives of the AZEA Roadmap, in particular the energy pillar, by enabling the large-scale supply of renewable hydrogen and the associated infrastructure required for zero-emission aviation.''

Marion Labatut

Director of EDF European Affairs

‘’The next major journey for the aviation sector is the path toward carbon neutrality. We are convinced that low-carbon electricity will become the driving force behind the sector’s energy transition. Low-carbon electricity, whether used directly or to produce synthetic fuels, will play a structuring role in transforming the aviation industry. Electrification is not only a lever for climate action, energy independence, and sovereignty: it is also a driver of reindustrialization and local employment, capable of anchoring long-term value in Europe. ''

Montserrat Barriga

Director General of the European Regions Airline Association (ERA)

‘’Regional aviation supports the development of hybrid, electric and hydrogen aircraft in Europe. Aviation decarbonisation will require a combination of solutions, including advances in aircraft technology, sustainable aviation fuels and operational improvements. In this context, the roadmap of the Alliance for Zero-Emission Aviation recognises the role of zero-emission aircraft in supporting regional connectivity. Their deployment will require a supportive policy framework, targeted investment, and timely infrastructure to ensure viable operations.’’

Axel Krein

Executive Director of the Clean Aviation Joint Undertaking (CAJU)

”The AZEA Roadmap demonstrates the European aviation ecosystem’s commitment to creating a new era of flight – powered by hybrid, electric and hydrogen solutions. But time is of the essence: Europe must speed up the development of these disruptive technologies, the deployment of the necessary infrastructure and the related certification frameworks. This transformative era of flight promises to make Europe more competitive and sustainable, but this can only be achieved if Europe invests significantly in the aviation ecosystem.”

Florian Guillermet

Executive Director of the European Aviation Safety Agency (EASA)

"The European Union Aviation Safety Agency has a key role to play in AZEA, supporting the aviation ecosystem in developing global standards and policies for the deployment of electric, hybrid and hydrogen-powered flights. The Agency is working to ensure that we are fully equipped to do this in terms of skillset and resources. Through the AZEA Roadmap, we join others in committing to making aviation truly sustainable by deploying zero emissions technologies by 2050."

Raúl Medina

Director General of EUROCONTROL

"At EUROCONTROL, we recognise that transforming aviation is essential to achieving Europe's sustainability goals. Alongside operational improvements and sustainable fuels, innovations in propulsion and the emergence of zero-emission aircraft will shape the long-term evolution of aviation. The AZEA Roadmap is a key milestone guiding this transition. Through the EUROCONTROL Trajectory 2030 strategy, we remain committed to supporting European operational concepts, enabling technologies and stronger collaboration to ensure the safe, efficient and sustainable integration of next-generation aircraft into the European ATM network."

Markus Fischer

Divisional Board Member for Aeronautics of the German Aerospace Center (DLR)

"Developing zero-emission aviation requires major advances in airframe design, propulsion technologies, energy systems and infrastructure and certification processes. The AZEA Roadmap provides an important framework to guide the technological development required to achieve this transition. Advancing hybrid-electric and hydrogen propulsion will require related research and technology infrastructures, large-scale technology demonstrations and particularly close collaboration across the European aviation ecosystem to bring these concepts to operational reality."

Isabelle Barthès

Deputy General Secretary at IndustriAll

"IndustriAll Europe welcomes AZEA's Roadmap as an ambitious and inspiring vision for the future of clean aviation. By clearly outlining the challenges and next steps across the aviation ecosystem, it provides a strong foundation for accelerating zero-emission technologies in Europe. This shared direction of travel can help build confidence, encourage investment - including in quality jobs - and support the smooth rollout of innovative aircraft solutions, ensuring that the sector and its workforce move together into this new phase of innovation."

EXECUTIVE SUMMARY

This Roadmap provides the European aviation ecosystem – industry, policy makers and financial institutions – with a plan for a gradual introduction of electric and hydrogen-powered flights in Europe.

This Roadmap has been established by the Alliance for Zero-Emission Aviation (AZEA), an industrial alliance created by the European Commission in 2022 to facilitate stronger cooperation within the sector. It consists of a voluntary gathering of private and public organisations from the entire aviation ecosystem and beyond committed to achieving the earliest possible entry into operational service of hybrid, battery-electric and hydrogen-powered aircraft.

The Alliance is currently formed by more than 200 organisations, including: aircraft, powertrain and equipment manufacturers, aerodromes, airlines and lessors, air navigation service providers, energy providers, industry associations, standards development organisations, research and technology organisations, clusters and networks, aviation authorities, regions, public and private investors, non-governmental organisations and trade unions, as well as the European Union Aviation Safety Agency (EASA), Eurocontrol and the Clean Aviation Joint Undertaking (CAJU).

While encouraging international cooperation to support worldwide deployment of electric and hydrogen propulsion, the Roadmap demonstrates the willingness and the ability of a sovereign European aviation ecosystem, from manufacturers to operators, to create EU technological champions and achieve a new step towards greening Europe's air transport by enabling the integration of innovative hybrid, battery-electric and hydrogen-powered aircraft in all segments of the intra-European aviation market. The Roadmap demonstrates also the potential of those technologies to introduce and develop new green air mobility offers. This Roadmap calls upon public authorities and financial institutions to support this transformation and ensure Europe's strategic autonomy in this technology, which is set to shape the future of aviation.

Hybrid, electric and hydrogen propulsion are key technologies to develop a climate-friendly air transport. While Sustainable Aviation Fuel (SAF) is anticipated to be the main contributor to reduce life-cycle CO_2 emissions in the short-to-medium term, battery-electric and hydrogen propulsion (fuel cells and direct combustion) offer a transformative opportunity to eliminate CO_2 emission and significantly reduce non- CO_2 emissions. The deployment of these technologies will reduce the emissions of air transport on existing intra-EU routes, while also enabling the development of new offers for green air mobility, especially on short routes, complementing the existing mix of green mobility offers. This will also help to prioritise the use of SAFs on those segments with longer flight ranges where they are the only available solution and reduce the sector's dependencies on fossil-fuels.

The Roadmap provides to the entire ecosystem (industry, public authorities and financial institutions) a detailed pathway on how flights powered by electricity and hydrogen could be deployed in Europe up to 2050 and beyond, identifying enablers and defining the actions required to achieve it as well as the responsibilities for each actor[1].

The Roadmap sets ambitious objectives and issues a call for action to all categories of stakeholders. While the technologies covered by the Roadmap are still maturing, the long lead times that characterise the aviation sector require that actions start to be planned and taken now to ensure their timely deployment, as demonstrated by initiatives and policies developed in other parts of the world (e.g. UK[2],Japan[3], Australia[4], Canada[5], etc). The Roadmap will help monitor the progress towards the objectives and should be regularly updated.

The Roadmap assumes that hybrid, battery-electric and hydrogen-powered aircraft will be gradually developed, certified and brought to the market. It

[1] The Roadmap is based on the "AZEA Vision: Flying on electricity and hydrogen in Europe" published in June 2024

[2] E.g. the Jet Zero Strategy. presented in 2022 by the UK Department of Transport and the Hydrogen Challenge regulatory sandbox launched in 2023 by the UK Civil Aviation Authority (CAA)

[3] E.g. In 2024, the Japanese Ministry of Economy, Trade and Industry (METI) unveiled a strategic plan to commercialise a next-generation passenger aircraft from 2035, which could be based on hybrid-electric or hydrogen propulsion.

[4] E.g. Hydrogen Flight Alliance (HFA) is an industrial-led initiative launched in 2023 in Australia aimed at developing the hydrogen flight ecosystem that is needed to enable the operation of hydrogen-powered aircraft.

[5] E.g. H2CanFly is a Canadian national consortium and not-for-profit organisation launched in 2024. Led by National Research Council of Canada (NRC) and aerospace sector leaders, this initiative aims to accelerate the commercialisation of hydrogen and electric propulsion technologies in aviation.

focusses therefore on the preparation of the aviation ecosystem to ensure that a market is in place when those aircraft will enter into commercial service. The Roadmap does not cover research and development needs, as they are addressed by other initiatives such as the *Aviation Research & Innovation strategy* (ARIS) or the upcoming one by the *Advisory Council for Aviation Research and Innovation in Europe* (ACARE). Nevertheless, the Roadmap builds on the results of such research. It addresses all aspects of Europe's aviation sector that will need to be adapted to enable the introduction of these types of aircraft, as well as other aspects related to these new propulsion technologies, such as the need to ensure the availability at aerodromes of the required volumes of electricity and hydrogen, and the corresponding airport infrastructure.

The Roadmap identifies actions required on the short-term as well as actions to be implemented on the longer term until 2050. As electric and hydrogen propulsion will continue to spread beyond this date, both in terms of market segments and fleet penetration, the Roadmap includes the necessary actions to prepare the path for further deployment after 2050. As an example, the Roadmap addresses the sharp increase in liquid hydrogen (LH2) demand caused by the large-scale deployment of hydrogen-powered aircraft in the Regional Aviation and Medium Range markets expected after 2050.

This document is based on the work carried out by AZEA members since the creation of the Alliance in 2022 including the various reports published, as well as on direct inputs from the members obtained from various consultation processes.

1.1 The deployment of hybrid, electric and hydrogen flights

The Roadmap foresees the entry-into-service (EIS) of 20,000 hybrid, battery-electric and hydrogen-powered aircraft by 2050, meaning that more than one in every two aircraft entering the European market over the next 25 years could be hybrid, battery-electric or hydrogen-powered, starting with smaller aircraft categories. The first entry-into-service are already expected within the next five years.

The Roadmap also demonstrates the potential of those aircraft to support existing routes and develop new mobility offers (e.g. in Regional Air Mobility). The Roadmap also presents possible networks of hybrid, electric and hydrogen flights, suggesting how these aircraft may be deployed across Europe and how aerodromes may progressively become involved in servicing these new aircraft, including deployment of the necessary infrastructure.

The Roadmap addresses with greater details five market segments (General Aviation, Regional Air Mobility, Regional Aviation, Business Aviation, Short and Medium range) while three others are addressed more succinctly (Rotorcrafts, Urban Air Mobility and Airships).

1.2 The path towards the deployment

The deployment of hybrid, electric and hydrogen flights in Europe requires specific efforts along six main Pillars covering the main dimensions of the aviation value chain.

Aircraft

The design, testing, certification, production and maintenance of new hybrid, battery-electric and hydrogen-powered aircraft will require the aviation industry, including many start-ups and Small and Medium-sized Enterprises (SMEs), to develop new knowledge and capabilities. Significant investments will be necessary from manufacturers, not only in terms of Capital Expenditure (CAPEX), but also in terms of new skills, knowledge development and specialised human resources. This may also include, in the shorter term, the development of the industry capacity to retrofit existing in-service aircraft.

Although the European aerospace industry has the potential to be a leader in these innovative technologies, it will face strong global competition in this innovative sector, as in all other sectors of the aeronautics industry. This will require appropriate measures to ensure a level playing field and the retention of these innovative players in Europe. Particular attention must be paid to the many SMEs and startups supporting innovative projects. Their certification costs should, for instance, be adequately supported.

Finally, to support the commercialisation of hybrid, battery-electric and hydrogen-powered aircraft a demonstration strategy should be developed, including the establishment of regional cross-border centres of excellence[6] supported by regulatory sandboxes[7], on the model of those

6 See the Communication from the Commission COM(2025) 664, Sustainable Transport Investment Plan , p16

7 The Proposal for a Regulation on establishing a framework of measures to facilitate the transport of military equipment, goods and personnel across the Union, COM(2025)/ 847 includes an amendment of EASA Basic Regulation 2018/1139 to allow Member States or EASA to establish regulatory sandboxes.

already deployed in the UK[8] and Norway[9] By allowing demonstrations at an early stage in a real-world controlled environment, such test arenas will be essential for assessing the operational impact of those new technologies and supporting the necessary learning by regulators and operators (aerodromes, airlines, etc.).

Manufacturers will need to contribute with their resources in the development of certification policies and standards to put into place a future-proof regulatory framework. EU or national funds should support the setup of network of centres of excellence and regulatory sandboxes to support industry in the commercialisation of innovative products.

Energy

Operation of hybrid, battery-electric and hydrogen-powered aircraft will require significant quantities of renewable and low-carbon energy. The quantity of renewable or low-carbon hydrogen[10] required in 2050 to support the intra-EU operations of hydrogen-powered aircraft foreseen by the Roadmap (excluding the production of e-SAF) is estimated at 1.5 Mt/a[11], which corresponds to over 2% of the total estimated hydrogen demand in the EU in 2050[12]. The quantity of green electricity required in 2050 to support the intra-EU operations of hybrid and battery-electric aircraft foreseen by the Roadmap (excluding the electricity supplied to stationary aircraft) is estimated at around 26 TWh/a[13]. Another 84 TWh/a will be required to produce the required hydrogen. The total amount of electricity necessary for the foreseen operations of hybrid, battery-electric and hydrogen-powered aircraft in 2050 (110 TWh/a) represents 4% of the total electricity production of the EU in 2023[14].

The transition towards hybrid, electric and hydrogen propulsion in aviation, depends primarily on the capacity of the European Union to ensure the availability of renewable and low-carbon electricity and hydrogen at the appropriate pace. While the quantities of renewable and low-carbon electricity and hydrogen needed represent a limited percentage of the total renewable and low-carbon electricity and hydrogen required by the European industry, ensuring that these quantities are available for the aviation sector represents however a challenge that will necessitate a better recognition of those needs across all EU and national policies and plans (both for e-SAF and hybrid, electric and hydrogen flights). Aerodromes wishing to evolve into an energy hub will also need to receive adequate support. The potential concentration of energy requirements in the long-term (i.e. top 10 European airports may require a large portion of the total energy uptake) will also require an adequate understanding of those needs by energy producers.

To ensure the distribution of electricity and to satisfy the needs of electric and hybrid aircraft, it will be essential to ensure that aerodromes are well integrated into the electricity grid. The electricity grid should be also adequately upgraded to accommodate the growing electricity demand at airport. The transport of hydrogen to aerodromes will also depend on a reliable and efficient distribution network as is the case for aviation fuels currently. In the first stages of development, the transport of hydrogen to the aerodromes is likely to take place mainly by truck. Over the long-term, to meet the increasing hydrogen-powered aircraft demand, hydrogen transport by pipeline in gaseous form may become the preferred option. In this case, it will be necessary to ensure that relevant aerodromes are well-integrated in the hydrogen network, including through connections to the Hydrogen Backbone or regional hydrogen pipelines.

Finally, it will be important that the price of electricity and hydrogen for aviation remains affordable for airline operators, especially as compared to Jet-A fuel and SAF. As the energy market for zero-emission aviation develops, predictability in energy price projections will become increasingly important. Effective communication channels between energy suppliers, airline operators and aerodromes will be crucial, while public authorities and market makers will also have a decisive role to play in ensuring

8 Regulating hydrogen use in aviation | UK Civil Aviation Authority

9 International Test Arena for Zero and Low-Emission Aviation, managed by Avinor and the Norwegian Civil Aviation Authority (CAA).

10 Regulation (EU) 2023/ 2405 of 18 October 2023 on ensuring a level playing field for sustainable air transport (ReFuelEU Aviation) defines ''hydrogen for aviation'' as ''renewable hydrogen for aviation'' or ''low-carbon hydrogen for aviation'' in Article 3.17.

11 The AZEA Vision estimated between 1.2 and 2.9 Mt/a (baseline vs ambitious scenario). The reduction results mainly from the postponement of some projects in the medium range market segments. Quantities are expected to increase quickly after 2050.

12 JRC Publications Repository - The role of hydrogen in energy decarbonisation scenarios

13 The AZEA Vision estimated between 9 and 30 TWh/a (baseline vs. ambitious scenarios).

14 Electricity and heat statistics - Statistics Explained - Eurostat, Total gross electricity production in the EU in 2023 is used as a reference (2749 TWh).

stable and transparent, high liquidity electricity and hydrogen markets for aviation.

Aerodromes

The entry-into-service of hybrid, battery-electric and hydrogen-powered aircraft foreseen by the Roadmap requires the progressive adaptation of many aerodromes of all sizes across Europe. This adaptation concerns not only infrastructures (hydrogen liquefaction, hydrogen and electricity storage, hydrogen refuelling facilities, electricity grids and recharging stations, aprons modification, external infrastructures to aerodromes, etc). Operations will also be impacted

and workforce will need to be prepared. It will require important investments from many aerodromes and/or infrastructure providers.

With the expected entry-into-services of first small hybrid or battery-electric aircraft within the next five years and hydrogen-powered ones following soon after, the first commercial deployment of recharging and refuelling infrastructures must soon become a reality.

Aerodromes should as a priority start considering the impact of new propulsion technologies on their activities. Depending on local policies and opportunities (e.g. integration into a Hydrogen Valley, etc), the possibility for aerodromes to become energy hubs and produce renewable and low-carbon energy on-site to meet the demand for electricity and hydrogen-powered aircraft must be encouraged, when it is considered appropriate and economically feasible. This will require a detailed analysis of existing national and regional supply chains and consideration as to how airport infrastructure development can be suitably phased with demand growth to derisk investment and optimally utilise existing resources.

Small regional aerodromes will be essential to support the development of new air mobility offers in the lower segments of the aviation market (e.g. Regional Air Mobility) and will require appropriate supports.

Aerodromes must identify and plan their transformation through long-term Aerodrome Master Plans and be able to attract sufficient investments. National and regional policies must be developed to support these adaptations.

Regulatory constraints, such as obtaining permits to build and operate specific infrastructures, must also be addressed. Appropriate standards for airport infrastructures and operations must be identified from similar use cases and where they do not exist must be developed. Operational procedures and protocols must be adapted to ensure the safe and efficient handling of hydrogen and of the aircraft operations. The adaptation of existing EU and national legislations may also be needed. The Roadmap will also monitor and forecast the required financial resources at EU level, as well as contribute to the required regulatory adjustments at EU and international level.

Certification, regulation and related standards

Certification and operation of aircraft incorporating innovative electric and hydrogen propulsion technologies represent a challenge for both regulators and manufacturers alike.

The European Union Aviation Safety Agency (EASA) must develop the necessary technical expertise, adapt the EU aviation regulatory framework in collaboration with International Civil Aviation Organisation (ICAO), the National Aviation Authorities in the Member States and global aviation authorities (such as the US Federal Aviation Administration/ FAA, Transport Canada Civil Aviation/ TCCA, the Brazilian Civil Aviation Authority/ ANAC, UK Civil Aviation Authority/ CAA), support the development of the necessary standards and certify innovative aircraft.

While EASA's work is more advanced in the area of battery-electric and hybrid propulsion technologies and small aircraft (CS-23), it will need to be extended to other aircraft categories (e.g. CS-25) and propulsion technologies. EASA will need the necessary resources to develop its expertise and support innovative projects, while continuing to serve traditional aviation and to ensure a high level of safety.

Airspace readiness

Hybrid, battery-electric and hydrogen-powered aircraft may have performance envelopes (cruise speed, flight levels, etc.) different from those of legacy aircraft currently operating in the European airspace. This type of aircraft may operate on specific flight and flow management rules taking specific aircraft characteristics and environmental performance into consideration. Their deployment may also lead to an increased number of operations in some market segments. Their integration into the European Air Traffic Management (ATM) network will therefore present challenges that need to be identified and addressed with regards to both safety and capacity. As required, Air Navigation Service Providers (ANSPs) will have to prepare the ATM design and procedural adaptations.

Operators

Airlines, operators and leasing companies are at the core of the transition of aviation to electric and hydrogen propulsion as they are the ones that will acquire and operate the new aircraft, starting with smaller regional actors. They may have to adapt their operations and business models to integrate these aircraft into their fleet.

They will only do that if acquisitions and operations of hybrid, battery-electric and hydrogen-powered aircraft are supported by appropriate business cases, viable business models, market development potential, risk sharing and specific incentives.

At the same time, clean electric and hydrogen propulsion technologies will offer opportunities to develop new markets and green offers in regional and intra-regional segments that operators will need to fully seize so that these new technologies can bring all their benefits to society.

The introduction of hybrid, battery-electric and hydrogen-powered aircraft will require public support and regulatory incentives to compensate for increased operational costs in early years and to ensure the existence of acceptable business cases, accelerate the deployment of these new aircraft and thus incentivise private investments.

The AZEA Roadmap

1 Introduction

The Roadmap is designed to provide the entire aviation ecosystem with a shared vision on the necessary actions to be implemented in Europe to enable the deployment of hybrid, electric and hydrogen flights (or 'zero- and low- emission' flights) in Europe by 2050 and beyond. It aims to provide stakeholders within the aviation ecosystem with ambitious, yet realistic, objectives on the path towards hybrid, battery-electric and hydrogen-powered aviation.

This Roadmap aims to guide various aviation stakeholders – manufacturers; aerodromes; airlines operators; energy suppliers; policy makers; the EU, Member States and regions; air navigation service providers; certification agencies; standards development organisations; public and private investors; non-governmental organisations and trade unions; etc. – through this transition to hybrid, battery-electric and hydrogen-powered aviation by offering recommendations on the actions that should be implemented to support the deployment of hybrid, battery-electric and hydrogen-powered aircraft.

While the scope of the document is limited to civil aviation, the Roadmap lessons and recommendations could guide the defence sector in assessing the potential use of hybrid, battery-electric and hydrogen-powered aircraft for military applications.

1.1 Context of the Roadmap

Since its creation in 2022, the Alliance for Zero-Emission Aviation (AZEA) has gathered a wide range of members representing all the main categories of stakeholders involved. Through thematic Working Groups (WGs), AZEA has identified key elements needed to deploy hybrid, electric and hydrogen flights in Europe.

In June 2024, AZEA published "*Flying on electricity and hydrogen in Europe*"[15], a report providing a vision for the sector's ambition towards hybrid, battery-electric and hydrogen-powered aviation, identifying high-level objectives and related enablers.

The Roadmap now provides a path identifying actionable recommendations over the short and long-term to make hybrid, electric and hydrogen flights a reality in Europe and implement the AZEA Vision. While the Vision report refers to two extreme scenarios, a 'baseline' and an 'ambitious', the Roadmap considers only a single scenario, situated between the 'baseline' and the 'ambitious' scenarios depending on each market segment, that is described in section 3.2.

The Roadmap also considers recent sector reports such as the European Aviation Research and Innovation Strategy (ARIS)[16] developed by a broad range of European aviation stakeholders and supported by the Clean Aviation and SESAR Joint Undertakings (June 2025), the 2025 update of the European ATM Master Plan[17], Destination 2050[18], the EASA European Aviation Environmental Report 2025[19] and the ReFuelEU Aviation Annual Technical Report 2025 by EASA.[20]

Finally, the Roadmap builds on the resolution of the European Parliament "*Electric aviation – a solution for short- and mid-range flights*" of 16 January 2024 which highlights the benefits of aircraft electrification[21].

1.2 Importance of the transition to hybrid, electric and hydrogen flights by 2050

The European aviation sector is committed to achieving net-zero CO_2 emissions for all flights departing European aerodromes by 2050, in alignment with the EU Green Deal objectives. While Sustainable Aviation Fuel (SAF) will be the main contributor to reduce life-cycle CO_2 emissions in the short-to-medium term, battery-electric and hydrogen propulsion (fuel cells and direct combustion) technologies offer a transformative opportunity to eliminate CO_2 emission and significantly reduce non- CO_2 emissions. Hybrid configurations will also play an important role in the progressive introduction of these technologies. Hybrid propulsion systems, with range extenders powered by hydrocarbons, may for instance already significantly reduce in-flight CO_2 emissions of short-haul and regional aircraft. A hybrid aircraft is an aircraft whose propulsion system relies on both electric and thermal energy sources for flight operations other than solely

15 Report Flying on electricity and hydrogen in Europe published by AZEA in June 2024

16 AVIATION RESEARCH & INNOVATION STRATEGY

17 European ATM Master Plan

18 Destination 2050 Roadmap

19 European Aviation Environmental Report 2025

20 ReFuelEU Aviation Annual Technical Report 2025

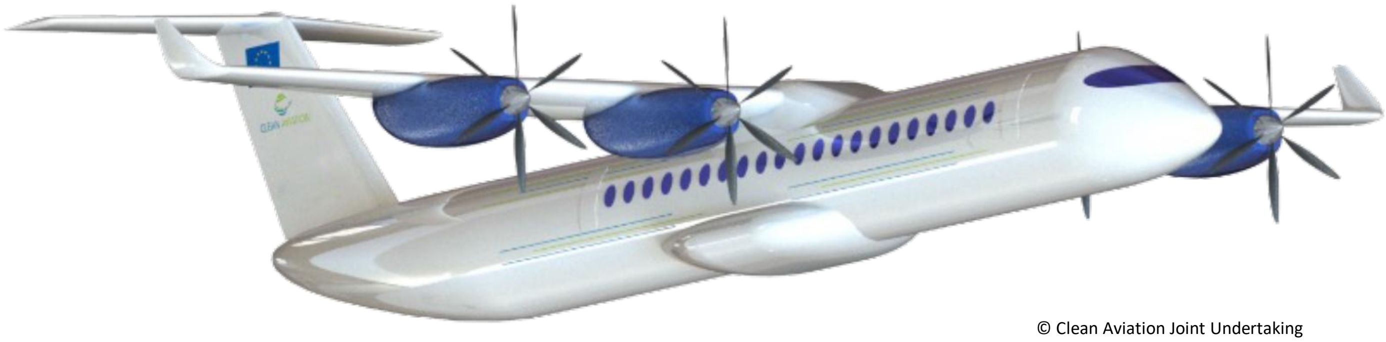
21 European Parliament resolution of 16 January 2024 on electric aviation – a solution for short and mid-range flights (2023/2060(INI))

for taxiing, as certified in accordance with Article 11 of Regulation (EU) 2018/1139 or equivalent.[22]

The deployment of these technologies will not only enable to reduce or eliminate in-flight CO_2 emissions and significantly reduce the negative climate impact of existing short and medium haul routes. It will enable the development of new green regional air mobility offers and allow to refocus the use of SAF on long-haul flights, where SAF is the only solution. It will also bring other benefits like better air quality at aerodromes and noise reduction. Finally, it represents an opportunity for the European aviation industry to lead on that innovative technology.

Electric and hydrogen propulsion will initially be introduced in smaller aircraft (typically under or at 19 seats) and for short-range segments, such as General Aviation and Regional Air Mobility. These aircraft presenting drastically reduced climate impact will provide the opportunity to develop new green air mobility solutions complementing the existing mobility offers on short distances. Innovative markets powered by electricity and hydrogen can revitalise regional connectivity and accessibility across Europe, making new routes more affordable and stimulating economic development at the local level, especially in remote areas. This transition will not only benefit well-established manufacturers but will also revitalise the European aeronautics industry by offering development opportunities to many innovative Small and Medium-sized Enterprises (SMEs) and start-ups.

Other countries have also engaged in this transition as UK[23], Japan[24], Australia[25] or Canada[26].



[22] This definition of hybrid aircraft is included in the subsection ''Substantial contribution to climate change mitigation'' of the Technical Screening Criteria for activity 3.21 ''Manufacture, repair, maintenance, overhaul, retrofitting, design, repurposing and upgrade of products (i.e. an aircraft, an engine or a propeller) or parts'' under the Draft Commission Delegated Regulation amending Delegated Regulation 2021/2139 as regards enhancing the usability of the technical screening criteria. This Draft Delegated Regulation was published on 17 March 2026 and it is open for feedback until 14 April.

[23] e.g. the Jet Zero Strategy presented in 2022 by the UK Department of Transport and the Hydrogen Challenge regulatory sandbox launched in 2023 by the UK Civil Aviation Authority (CAA)

[24] e.g. In 2024, the Japanese Ministry of Economy, Trade and Industry (METI) unveiled a strategic plan to commercialise a next-generation passenger aircraft from 2035, which could be based on hybrid-electric or hydrogen propulsion.

[25] e.g. Hydrogen Flight Alliance (HFA) is an industrial-led initiative launched in 2023 in Australia aimed at developing the hydrogen flight ecosystem that is needed to enable the operation of hydrogen-powered aircraft.

[26] e.g. H2CanFly is a Canadian national consortium and not-for-profit organisation launched in 2024. Led by National Research Council of Canada (NRC) and aerospace sector leaders, this initiative aims to accelerate the commercialisation of hydrogen and electric propulsion technologies in aviation.

2 SETTING THE SCENE

This section introduces the Roadmap by presenting the context and scenario selected by the Alliance for its development. The assumptions and milestones presented in this section highlight an ambitious, yet realistic scenario to guide the aviation ecosystem, encouraging the relevant stakeholders to support the transition to hybrid, battery-electric and hydrogen-powered aviation.

The Roadmap builds on all the work performed by AZEA members since its launch in 2022 and the various reports issued.

2.1 Scope of the Roadmap

Considering the complexity of the aviation ecosystem, the scope of the Roadmap covers all actions from aircraft certification and production through to their Entry-Into-Service (EIS) and subsequent operations. The Roadmap does not address Research and Development (R&D) needs, which are already described by other initiatives such as the Aviation Research & Innovation Strategy (ARIS) and the Advisory Council for Aviation Research and Innovation in Europe (ACARE), as its scope is to describe the transition path to hybrid, battery-electric and hydrogen-powered aviation.

The primary focus of the Roadmap is to prepare the aviation ecosystem for the deployment of hybrid, battery-electric and hydrogen-powered aircraft and to ensure that there is a market in place for this type of aircraft in the decades to come. Consequently, broader sustainability impacts and actions aimed at enhancing the overall sustainability of the aviation industry are also considered out of scope.

In addition, the Roadmap makes no distinction between the types of hydrogen supplied to the aircraft (renewable or low carbon). Instead, the Roadmap uses the term ''hydrogen for aviation'', as defined in Article of 3.4 of ReFuelEU, which encompasses both renewable and low-carbon hydrogen for direct use in aviation[27].

The present Roadmap encompasses various components that include:

- Aircraft manufacturing and maintenance aspects including the capacity to retrofit existing aircraft, supply chain management, safety validation, demonstration and testing, and financing and investment needs.
- Low-carbon and renewable energy required to supply the aircraft at aerodromes, including an estimation of the infrastructure capacity that will be required to satisfy the growing fuel demand, an identification of the deployment needs for energy transmission infrastructure over the long-term and an overview of the investments, regulatory developments and adaptations needed.

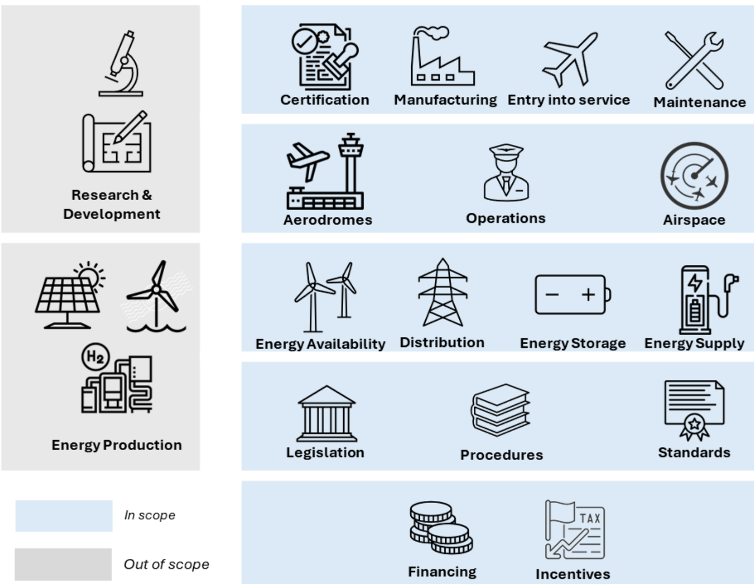


Figure 1 Scope of the Roadmap

[27] Under Article 4.1 the ReFuelEU Regulation, both renewable hydrogen for aviation and low-carbon aviation fuels can be used by aviation fuel suppliers to meet the minimum shares of SAF that are mandated. Article 3.18 defines ''low-carbon aviation fuels'' as synthetic low-carbon aviation fuels and low-carbon hydrogen for aviation.

- Changes in existing infrastructure, protocols and operations at aerodromes to install the required recharging, refuelling and storage capacities to accommodate future hybrid, battery-electric and hydrogen-powered aircraft, including investment needs, testing infrastructures and regulatory and standardisation challenges.
- Aircraft and aerodromes certification, standardisation and other regulatory processes supporting the deployment and Entry-Into-Service of electric, hybrid and hydrogen-powered aircraft, which will require a close collaboration among European Union Aviation Safety Agency (EASA), National Aviation Authorities (NAA) in the Member States, standards development organisations, global aviation authorities and industry.
- Adaptations required in the European airspace procedures and operations to accommodate the performance particularities of these new aircraft as compared to legacy aircraft.
- Enablers to promote the deployment and uptake of electric and hydrogen aircraft by airline operators, lessors and other stakeholders.

Regarding aircraft types, the Roadmap covers all aircraft, referred to as hybrid, battery-electric and hydrogen aircraft, using electricity or hydrogen as an external energy source, either alone or in combination with conventional jet fuel or SAF. A wide variety of configurations exists.

Hybrid aircraft incorporate a propulsion system relying on both electric (battery or fuel-cells) and thermal energy sources (jet-A fuel or SAF) for flight operations other than solely for taxiing. On-going developments cover multiple configurations.

Most ambitious designs have an electric engine with battery or hydrogen fuel cells supplying the necessary power. On the longer-term, hydrogen combustion may offer solutions for larger aircraft and the development of engines able to work with multiple fuels.

While battery-electric configurations may be used more often on smaller aircraft and hydrogen fuel cells for longer-range aircraft there are no absolute conception rules. The success of a configuration depends not only on the capacity to develop the most efficient design, mature the technology or demonstrate it in real-life test, but also on the capacity to adapt it to the market conditions and align it with airline economics (Designated Operational Coverage (DOC) constraints, Cost per Available Seat Kilometre (CASK), maintenance costs, etc. are factors that dominate decision-making for airlines) to ensure its widespread penetration.

2.2 Stakeholders

All the stakeholders addressed by the Roadmap are grouped in three high-level types of stakeholders: public authorities, industry and finance sector. Where relevant, specific stakeholders are mentioned for a particular activity, such as regulators and international organisations; aerodrome and airline industry associations; passengers, trade unions, environmental interest groups; and private and public investors.

Public authorities represent all levels of the decision-making process, encompassing the EU, national and regional dimensions. They include the relevant government bodies at the level of Member States and regions, as well as the European Commission and other European Institutions. This type of stakeholders also covers regulators and international organisations with a specific mandate, such as EASA and EUROCONTROL (ECTL), as well as the EU institutionalised partnerships Clean Aviation (CAJU) and SESAR 3 Joint Undertakings (JUs) and their respective successors.

Industry includes all actors developing hybrid, electric and hydrogen flights, covering both the aviation and energy sectors. This includes aircraft manufacturers, aircraft operators and lessors, aerodromes, and Air Navigation Service Providers (ANSPs), EUROCONTROL as the Network Manager and as a service provider for the Maastricht Upper Area Control Centre (MUAC), as well as electricity and hydrogen producers and energy distribution actors, like electricity transmission system operators and hydrogen network operators.

Financial stakeholders comprise public and private organisations funding the transition. Public investors operate at EU, national and regional levels, providing subsidies and financing through specific instruments. Examples of these instruments at the EU level include Horizon Europe's European Innovation Council (EIC), the Connecting Europe Facility (CEF) Transport Alternative Fuels Infrastructure Facility (AFIF) and the Innovation Fund. Other forms of financial support under the European Investment Bank (EIB) are also considered. Private investors range from specialised funds, like Innovacom or Hy24, to traditional bank.

2.3 General assumptions

In defining the Roadmap, the Alliance starts from the assumption that hybrid, battery-electric and hydrogen-powered aircraft will be developed over time and will gradually enter commercial service as defined by the rollout scenario. The policy and regulatory environment support the development of hybrid, battery-electric and hydrogen-powered aircraft, while also incentivising the necessary market conditions for its effective deployment.

A VISION FOR THE DEPLOYMENT OF ELECTRIC AND HYDROGEN POWERED FLIGHTS IN EUROPE

The deployment of hybrid, electric and hydrogen flights in Europe will only be possible if all public and private actors take the required actions in a consistent way. This requires sharing amongst all concerned parties a common vision on how this deployment can happen. The Alliance proposed high-level objectives in the Vision report published in June 2024. This chapter provides a more detailed scenario. This scenario is ambitious and requires implementing all actions and recommendations identified in the Roadmap.

3.1 The aviation market

Innovative electric, hydrogen and hybrid propulsion technologies will deploy at different times and paces in the different segments of the aviation market, according to the maturity levels of the different types of aircraft and the needs of the market.

To enable a detailed analysis of these deployments, the Roadmap has adopted precise definitions of these segments. Those definitions may sometimes diverge from common ones to better correspond to the specific situation covered by the Roadmap. For instance, aircraft belonging to one segment may also support the development of new operations within the adjacent segment. Market segments are not mutually exclusive domains, but rather form a continuum. This is illustrated by the overlapping boundaries between segments. However, the Roadmap does not intend to propose these definitions to establish standards or influence policy.

The section below identifies the segments of the aviation market for which a detailed roll-out scenario is proposed. It provides their main characteristics, and the impact electric and hydrogen propulsion may have on their evolution.

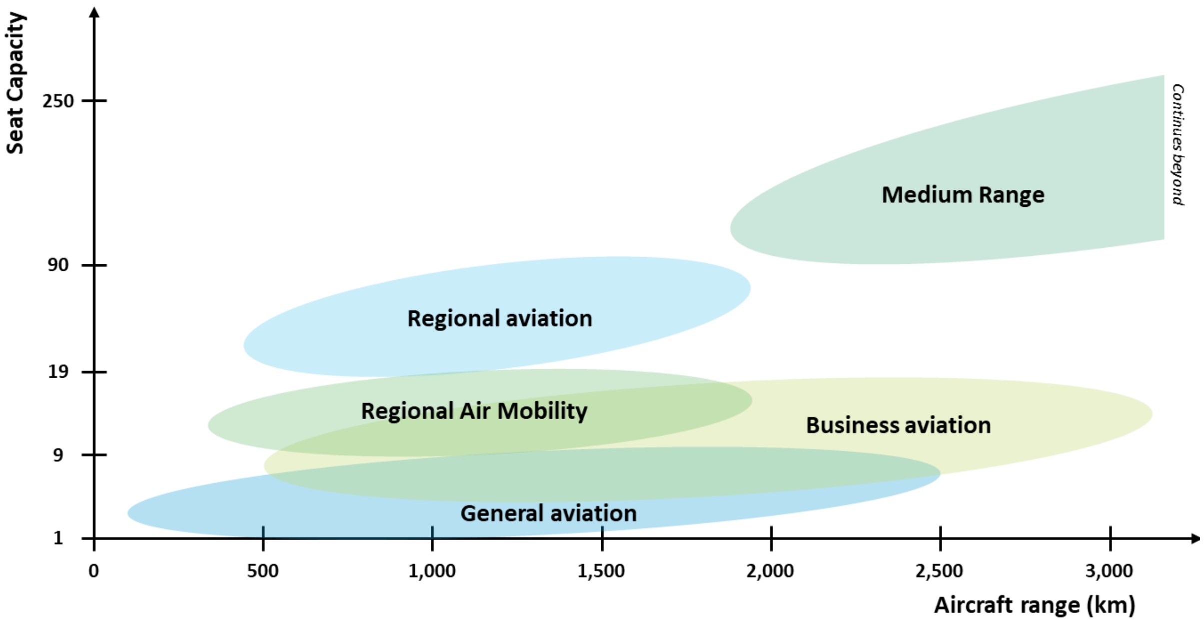


Figure 2 Market segments characteristics with conventional aircraft

General Aviation	
General aviation covers all civil aviation operations other than scheduled air services and non-scheduled air transport operations for remuneration or hire. It covers private transport, recreational flights, flight school and training, emergency medical services and other aerial activities, including commercial ones (fire, surveillance, etc). In this Roadmap, business aviation is covered separately. Innovative (hybrid) electric aircraft will, however, not only replace the current fleet in this segment. Their introduction will also support new developments such as new training opportunities in flight schools or the emergence of new air mobility solutions similar to those in the Regional Air Mobility segment, allowing for specific point to point routes with very low passengers supported by new business models. The Roadmap includes these new commercial applications with aircraft up to 9 PAX within this market segment.	
Involved aerodromes Aerodromes receiving a majority of Visual Flight Rules (VFR) flights	Aircraft operating in this segment Range (km): 180 – 2,500 Capacity (PAX): 1 – 9 Examples: Cessna 172, Piper PA-28, Beechcraft Bonanza, Daher TBM, Elixir, Pilatus PC-12
Flight characteristics Average flight length: 300 km	

Regional Air Mobility	
The regional air mobility (RAM) segment covering short distance flights with commuter aircraft up to 19 PAX (CS-23 aircraft) has steadily decreased over the last 30 years with airlines shifting to bigger aircraft and larger aerodromes. The segment is limited today and mainly concentrated in areas where geography justifies maintaining vital short flights (Nordics/Scandinavia, islands, and remote locations), in some cases under Public Service Obligation (PSO). Deliveries of new aircraft supporting operations in this category are very limited today (less than 10 aircraft annually delivered in the EU over the past years). However, studies[28] show a strong potential for growth enabled by green propulsion technologies. New aircraft are expected to gain significant market share not only justified by the geography but also by gain in connectivity due to travel time reduction, compared to other modes of transport. This could lead to the opening of new or previously discontinued routes to connect point to point cities, exploiting existing capacity of underutilised aerodromes.	
Involved aerodromes Aerodromes receiving aircraft with small number of passengers or serving short range routes	Aircraft operating in this segment Range (km): 350 – 1,900 Capacity (PAX): 9 – 19 Examples: Cessna 208 Caravan, DHC Twin Otter, Dornier 228
Flight characteristics Average flight length: 400 km	

Regional Aviation
The Regional Aviation segment today plays a socio-economic role across Europe by ensuring access to public services, employment and business opportunities. Around half of the routes in this segment provide connectivity for remote, insular and outermost regions. There are currently 190 PSO routes in Europe, representing about 7% of flights in 2025, and around 80% of these services are operated by regional aircraft, which in this segment are predominantly fuel-efficient turboprops. Regional routes have decreased in the last 20 years, and recent operators' bankruptcies have highlighted the sector's fragility and the need to preserve the economic viability and operational feasibility of regional airlines. The ageing of the fleet calls for investment in the next generation of regional aircraft as soon as possible. As with the Regional Air Mobility segment, green propulsion technologies could facilitate the development of new regional routes. This could be particularly true in the lower end of the segment, which involves shorter routes and lower demand, where smaller aircraft—including those operating in the Urban Air Mobility segment (aircraft with 19 passengers or fewer)—could contribute to the emergence of new routes.

28 See for instance, The prospect of hybrid-electric air transport, Wolfgang Grimme, DLR.

Involved aerodromes Aerodrome serving mainly domestic, regional and intra-EU routes	Aircraft operating in this segment Range (km): 450 – 1,900 Capacity (PAX): 19 – 90 Examples: ATR-42 or 72, Embraer E145 or E175, DHC Dash 8-Q400
Flight characteristics Average flight length: 500 km	

Business Aviation	
The Business Aviation segment is characterised by a small passenger load and longer distances. The introduction of battery-electric, hybrid and/or hydrogen-powered aircraft in this market segment aims to replace the current fleet.	
Involved aerodromes All aerodromes with a focus on business aviation	Aircraft operating in this segment Range (km): 500 – 3,700 Capacity (PAX): 6 – 19 Examples: Dassault Falcon 6X, Bombardier Global 8000, Gulfstream G700, Pilatus PC-24
Flight characteristics Average flight length: 1,000 km	

Medium Range	
The medium range segment covers a large proportion of commercial intra-EU flights. It involves larger aircraft with more than 90 PAX, essentially regional jets (e.g. A220, Embraer) and single-aisle aircrafts (e.g. A320), operating short and medium haul flights. It is forecasted to grow continuously at the condition to decarbonise, as it has the highest impact on intra-EU emissions. While an increasing use of SAF will constitute the shorter-term[29], hydrogen-powered aircraft will start playing a substantial role after 2050, contributing to address the SAF volumes challenge and the need to prioritise SAF to the long-haul segment where electric and hydrogen propulsion will not play a role in the predictable future.	
Involved aerodromes Aerodromes serving intra-EU routes	Aircraft operating in this segment Range (km): 1,800 – 5,500 Capacity (PAX): 90 – 250 Examples: Embraer E190 or E195, Airbus A220 or A320
Flight characteristics Average flight length: 1,200 km	

Beyond these segments of the aviation market, electric and hydrogen propulsion may also play a role in three other segments: helicopters, airships, and Urban Air Mobility (UAM).

Rotorcraft can accommodate from few passengers (3-4) up to 16-18, with flight range spanning from a few tenths of km to hundreds. Some future solutions will be capable of carrying 10 passengers and more for as much as 1,500 km. Rotorcraft play a unique role in various strategic services and applications, like offshore aviation that forms an integral part of Europe's energy infrastructure, particularly in the North Sea basin. Hybrid and hydrogen-powered rotorcraft could become early deployment cases due to fixed-route operations and hub-based logistics. The rotorcraft industry is committed to advancing sustainability by progressively electrifying rotary-wing platforms to reduce emissions, maintenance needs, and improve safety and performance. Building on mature thermal engine technology and electrical systems, the sector is focused on developing hybrid and fully electric solutions. These efforts aim to support the transition to hybrid, battery-electric and hydrogen-powered aviation, while maintaining operational efficiency and reliability.

Urban Air Mobility (UAM) is emerging as a transformative segment within the aviation market, focused on providing efficient, on-demand air transport solutions in urban areas using electric vertical take-off and

[29] According to Destination 2050 Roadmap, the use of SAF should achieve 35% of the total decarbonisation objective for flights within and departing from the EU+ region, by 2050.

landing (eVTOL) aircraft. The main need of this segment, in the context of this Roadmap, is the development of vertiports equipped with fast-charging infrastructure and their integration with existing transport networks.

Electric and hydrogen propulsion also supports the rapid development of **airships** that have the potential to support the emergence of new aerial services. Small unmanned airships are already operating or close to commercial deployment, supporting surveillance and inspection activities. Larger unmanned and optionally piloted airships are expected to scale operations for logistics, regional connectivity, and offshore support in the 2030-2040 period. Over the longer term, large, manned cargo airships will provide heavy-lift zero-emission transport for remote and infrastructure-poor regions.

3.2 Aircraft rollout scenario

To provide the ecosystem with a concrete roadmap and to identify quantified needs, the Alliance has developed a scenario for the market deployment of hybrid, battery-electric and hydrogen-powered aircraft (rollout scenario), which it intends to propose as a reference for the entire ecosystem. This scenario is based on concrete development projects, in particular those of members of the Alliance, and the estimated entry-into-service (EIS) dates for these aircraft in the different segments of the market.

While the Vision report published by AZEA in June 2024 presents to two extreme scenarios, a 'baseline' one and an 'ambitious' one, the Roadmap considers, for each market segments, only one intermediate scenario, closer to the baseline or the ambitious scenario, depending on the maturity of the technology in the segments.

Table 1 presents the cumulative number of aircraft that AZEA estimates possible to place on the market per technology, market segment and timeframe.

These numbers are based on assumptions on several factors related to EIS (such as technology development, certification processes, industrialisation, profitability, etc.) and future markets evolution (market forecast, creation of new markets and business models, etc).

Table 1 Cumulative hybrid, battery-electric and hydrogen aircraft deliveries in Europe until 2050

Cumulative deliveries of hybrid, battery-electric and hydrogen aircraft until 2050 in Europe							
	Type of Aircraft	General Aviation	Regional Air Mobility	Regional Aviation	Business Aviation	Medium Range	Total
2030+	Battery-electric aircraft	130	20	-	-	-	150
	Hybrid aircraft	-	20	-	-	-	20
	Hydrogen aircraft	-	10	-	10	-	20
	Total	130	50	-	10	-	190
2040	Battery-electric aircraft	400	1200	100	200	-	1900
	Hybrid aircraft	1600	1300	250	-	-	3150
	Hydrogen aircraft	400	200	250	550	-	1400
	Total	2400	2700	600	750	-	6450
2050	Battery-electric aircraft	1600	8000	500	300	-	10400
	Hybrid aircraft	3000	1900	550	-	-	5450
	Hydrogen aircraft	900	800	650	1150	600	4100
	Total	5500	10700	1700	1450	600	19950

Figure 3 - Aircraft rollout per market segments and propulsion technologies

The Roadmap foresees the deployment of 20,000 hybrid, battery-electric and hydrogen-powered aircraft by 2050, meaning that more than one in every two aircraft entering the European market over the next 25 years will be battery-electric, hybrid and hydrogen-powered, starting with smaller aircraft categories.

Hybrid, battery-electric and hydrogen-powered aircraft will first appear in the general aviation, regional air mobility, and business aviation sectors. Initially, they will replace existing aircraft, then begin to meet demand arising from the development of new green air mobility offers, accelerating their entry into the market. This will be particularly true in the regional air mobility segment, where these aircraft will account for more than 90% of deliveries starting in 2040. Hybrid, electric and hydrogen-powered aircraft will begin to appear in the regional aviation segment after 2030, and in the medium-haul segment only after 2040 (see Figure 4).

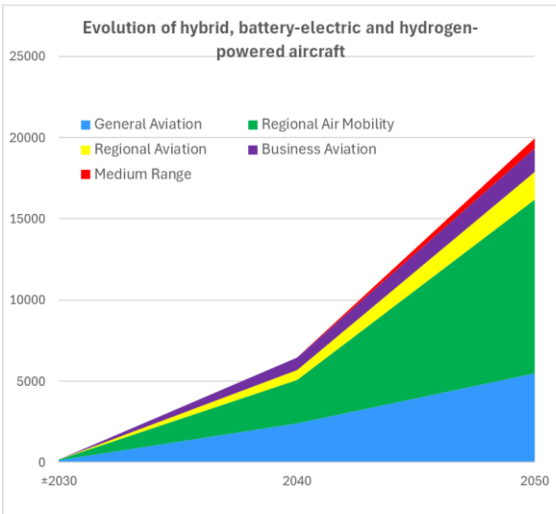


Figure 4 - Cumulative aircraft deliveries per market segments

Electric propulsion, which focuses on smaller aircraft, accounts for the majority of deliveries. Deliveries of hybrid aircraft will grow in the early years and then level off (see Figure 5).

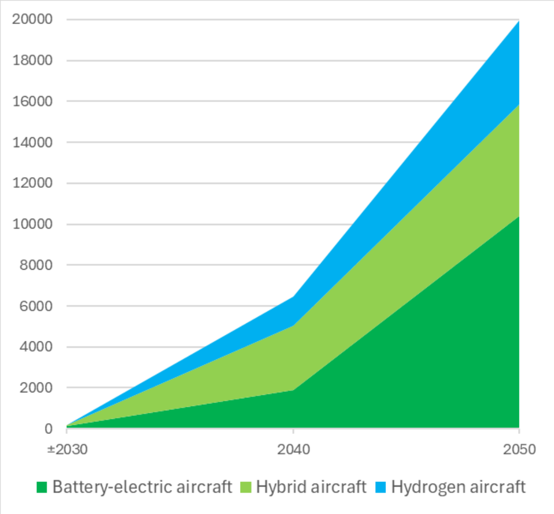


Figure 5 - Evolution of the entries into service per propulsion technology

By 2050 the penetration of hybrid, electric and hydrogen propulsion is expected to be substantial (> 60% of deliveries) in all lower market segments. These technologies will, however, only largely develop on larger aircraft in the medium range segment after 2050 (see Figure 6).

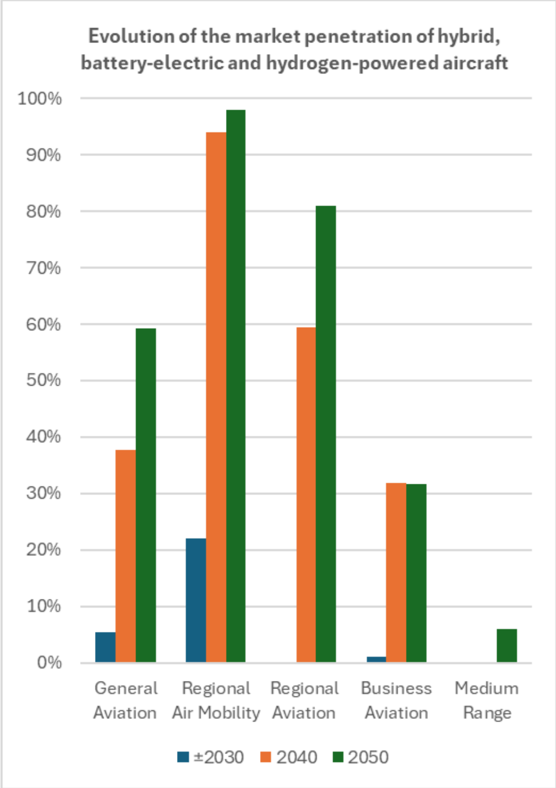


Figure 6 - % Hybrid, battery-electric and hydrogen-powered aircraft on total aircraft deliveries

General Aviation

This segment, together with the Regional Air Mobility segment, will be the first to see the introduction of electric-powered aircraft. Based on the historical trend, the growth in the market would be relatively flat. However, the current high demand in pilot training could fuel the development of electric (battery and fuel cell) aircraft constituting a competitive solution, with very low cost per hour and with close to zero environmental footprint, whether it is on CO_2 emission or noise. It may also offer new green air transport solutions that could lead to a development of the market. This development may include new point to point routes and additional training aircraft or even cargo (last mile mobility). Around three-quarters of new aircraft in this category are anticipated to be hybrid, battery-electric or hydrogen-powered by 2050.

AZEA Members' Projects:

- ✓ Dragonfly from Blue Spirit Aero
- ✓ E5 from Electron,
- ✓ Alerion M1h from Avions Mauboussin,
- ✓ ATEA from Ascendance
- ✓ INTEGRAL E from AURA AERO
- ✓ Phoenix from AeroDelft
- ✓ Dovetail electric aviation
- ✓ ALIA from BETA

First EIS: 2028-2032

Regional Air Mobility

The rapid progress in the development of CS-23 electric (battery and fuel cell) and hybrid aircraft, together with the emergence of new business models (e.g. on-demand flight services), and the availability of new analytical tools able to identify regional needs of air connectivity may allow to develop the existing potential of regional air transport. Due to congestion at large aerodromes and their greater proximity to passengers' end destinations, underutilised regional aerodromes could be best positioned to serve these extra flights. The development of green Regional Air Mobility may complement the existing short-distance mobility mix in many regions. It could provide communities living close to small regional aerodromes new opportunities for transport. National or regional policies could support such regional point-to-point travel from secondary smaller aerodromes. Some geographies (Nordics/Scandinavia, islands, and remote locations) would be potential first use cases, as for Regional Aviation.

The development of battery-electric (amphibian) seaplanes may provide additional opportunities to develop regional air mobility offers in coastal regions, without the need to create new full airport infrastructures.

The aircraft development in this segment focuses on both clean sheet aircraft (mainly for battery-electric and hybrid) and retrofit (mainly for hydrogen). The certification of the first aircraft is expected around 2030, with development and certification of electric engines (e.g. ENGINeUS 100 from Safran as the first electric motor certified by EASA) supporting the rollout. Most of the forecasted deliveries are expected to represent fleet extension.

AZEA Members' Projects:

- ✓ ZA600 powertrain from ZeroAvia supporting retrofit (e.g. Cessna 208B, Dornier 228, DHC-6 Twin Otter),
- ✓ ERA from Aura Aero,
- ✓ Microliner from Vaeridion,
- ✓ EENUE,
- ✓ CASSIO 330 from Voltaero,
- ✓ EcoPulse from Daher,
- ✓ Alta from Odys,
- ✓ Retrofit of 10-20 seat hydrogen-electric fuel cell propulsion system from Stralis

First EIS: 2030-2032

Regional Aviation

Fleet replacement of ageing aircraft will be the main trend underpinning regional aviation development on the higher end of the segment (>50 PAX), with new routes representing a part of the aircraft demand. While clean-sheet hybrid and battery-electric aircraft as well as incremental improvement of current regional aircraft will play a significant role from mid-30s, renewal of the current fleet may start by the retrofit with fuel cell electric powerplants.

The development of new "intra-regional" routes or specific use cases at the lower end of the segment (shorter routes, lower demand) may represent a significant part of the demand of the smaller aircraft in the segment. Those new routes may also involve aircraft under 20 PAX operating the Regional Air Mobility segment.

Regional aviation can make use of similar smaller regional aerodromes as the Regional Air mobility segment, increasing the value of these aerodromes developing electric

AZEA Members' Projects:

- ✓ EVO from ATR,
- ✓ MAEVE Jet from MAEVE,
- ✓ E9X from Elysian,
- ✓ ES30 from Heart Aerospace,
- ✓ ZA2000 powertrain from ZeroAvia supporting retrofit (e.g. ATR72, Dash 8, etc)
- ✓ Powertrain from Conscious Aerospace

and hydrogen infrastructure. In this context, hybrid-electric technologies will not only support operations on shorter or lower-demand routes, but also strengthen regional aviation's core role in providing feeder services to major hubs and enabling point-to-point connectivity across Europe. The business case for the execution of these flights will depend on the local context, with zero emission opportunities potentially increasing the support available from local and regional governments.	supporting retrofit (e.g. ATR72, Dash 8, etc) **First EIS**: 2035-2040

Business Aviation	
For now, the aircraft development in this segment focuses on clean sheet designs and smaller configurations, with less projects than in other segments (size constraints and large differentiation in range, PAX and other specifications make business jets difficult candidates for electrification or using hydrogen in all propulsion options). Due to the relatively low amount of PAX in business aviation, ranges could be extended as technology develops. Hybrid, battery-electric and hydrogen-powered aircraft in this segment will mainly support current operations, with the potential to open some new routes where feasible. With increasing scrutiny on private jet use, there may be a higher willingness to pay for aircraft in this segment than in other segments, increasing the potential to enter the market.	AZEA Members' Projects: ✓ One from Beyond-Aero **First EIS**: 2030-2035

Medium Range	
While all technology routes are investigated to address aircraft in this category, it seems likely that hydrogen propulsion (fuel cell or combustion) will be most suited to decarbonise this segment first, aside to hybrid propulsions, due to power density of batteries. Considering the remaining challenges to mature the technology, the deployment of hybrid, battery-electric and hydrogen-powered aircraft will not start in the Medium Range market before 2040 and will first focus on point-to-point intra-European flights and feeder flights to large hubs. As a second step, technologies are considered to also be accessible to single aisle aircraft (e.g. A320). The aircraft in this market segment are being developed with a focus on clean sheet designs. The business case for this segment will depend heavily on the support from major airlines. This can be ensured by aligning the development of the aircraft with the needs of the airlines, and with their business cases. The introduction of electric and hydrogen-powered aircraft in this segment will also strongly depend on the appetite of the global market for such aircraft.	AZEA Members' Projects: ✓ ZEROe from Airbus, ✓ Fokker Next Gen ✓ Wright BAe 146 First EIS: 2040+

3.3 Flight network

Based on the rollout scenario presented in the previous section, the Roadmap provides a simulation of how hybrid, electric and hydrogen-powered flights might be deployed in Europe (Flight Network), enabling to estimate the total needs of green and low-carbon electricity and hydrogen, as well as their geographic distribution.

Hybrid, battery-electric and hydrogen-powered aircraft may either replace aircraft on existing routes or support the development of new operations triggered by the benefits of hybrid, electric and hydrogen propulsion (cfr. The DESAT study[30])

The introduction of hybrid, battery-electric and hydrogen-powered aircraft within the existing network IFR flights has been modelled based on EUROCONTROL's forecasts for IFR flights in Europe and on the identification of routes eligible for the introduction of these aircraft, considering factors such as the aircraft's range, passenger capacity, and tankering capability. It assumes an even distribution of flights across these routes.

[30] The DESAT Model for Estimating Demand for Small Air Transport in Europe - ScienceDirect

These operations have been modelled in detail by EUROCONTROL allowing the production of maps (see Annex 3) that provide a detailed description of the potential development of the network (per market segments, energy type, etc) of hybrid, battery-electric and hydrogen flights corresponding to the replacement of forecasted IFR flights (excluding new operations). More detailed information may also be obtained by stakeholders.

As the actual deployment of electric, hydrogen, and hybrid flight will depend on the decisions taken by various political, industrial, and financial actors, the network will not expand evenly across Europe, and the Flight Network represents an achievable potential helping to quantify needs and challenges rather than a predefined objective.

The figures below present the evolution of hybrid, electric and hydrogen flights per market segments (Green bars) together with the forecast of IFR flights eligible for replacement by hybrid, electric and hydrogen-powered aircraft (Blue bars).

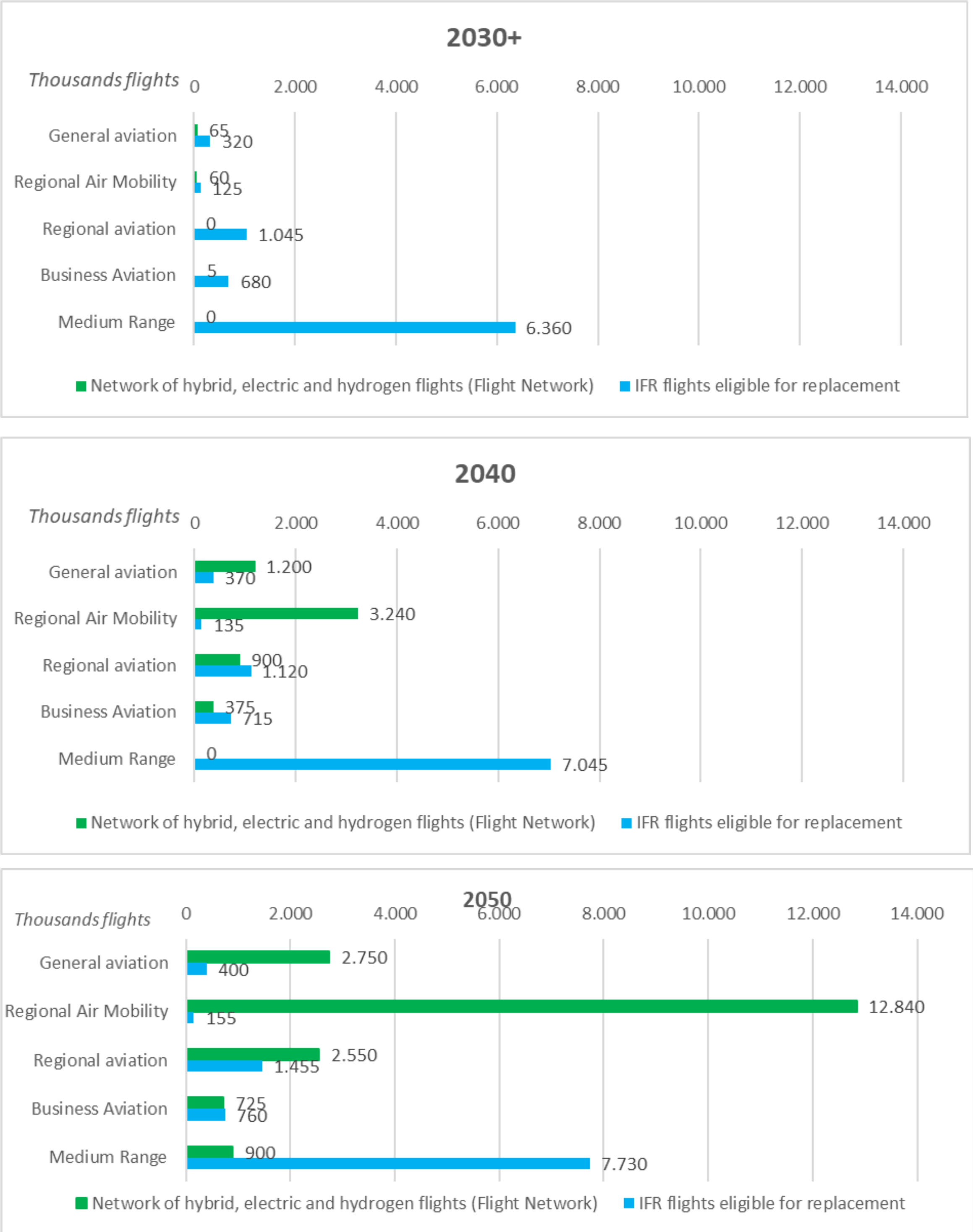


Figure 7 - Flight Network and IFR flights eligible for replacement

3.3.1 General Aviation (GA) and Regional Air Mobility (RAM)

The results of the simulation show that smaller aircraft categories (in particular in the RAM market segments) could already account for a significant share of the predicted IFR flight during the 2030s. In 2050, the number of zero- and low-emission flights could massively exceed the number of predicted IFR flights (8-80 times more), suggesting that many hybrid, battery-electric or hydrogen-powered aircraft could create new business opportunities and operate new routes. This suggestion is supported by research done in the DESAT study of DLR, showing the potential for zero and low emission flights to connect non-connected or badly connected sub-regions or replace some regional ground connections. Figure 8 presents a possible network of hybrid, electric and hydrogen flights in the GA market segment (limited to the replacement of forecasted IFR flights – no new operations).

Figure 8 - Possible network of hybrid, electric and hydrogen flights in the GA market segment by 2050

3.3.2 Regional Aviation (RA) and Business Aviation (BA)

In the BA and RA markets segments hybrid, battery-electric and hydrogen-powered aircraft could operate respectively about 50% and 75% of predicted flights in 2040s.

If market uptake in regional aviation accelerates, this type of aircraft could potentially replace the majority of IFR flights eligible for replacement in the RA segment from 2050 onwards and create some limited new market opportunities.

Although market penetration in the BA segment is expected to be slower, significant part of the flights eligible for replacement could be also replaced in this segment by 2050. Nonetheless, it is important to note that legacy aircraft are expected to continue to operate in regional and business aviation throughout the 2050s and beyond. In both market segments, there is also potential to develop new business opportunities (up to 2 times more). Figure 9 presents a possible network of hybrid, electric and hydrogen flights in the RA market segment (limited to the replacement of forecasted IFR flights – no new operations)

Figure 9 - Possible network of hybrid, electric and hydrogen flights in the RA market segment by 2050

3.3.3 Medium range (MR)

The MR market segment will see zero emission aircraft deliveries not before 2040. In 2050, it is expected that about 12% of the medium range IFR flight network can be replaced by zero-emission (hydrogen) aircraft. Figure 10 presents a possible network of hybrid, electric and hydrogen flights in the MR market segment

Figure 10 - Possible network of hybrid, electric and hydrogen flights in the MR market segment by 2050

More information on the simulation of the geographical repartition of hybrid, electric and hydrogen flights in Europe is provided in Annex 3.

The path towards the Vision

The present chapter identifies the key challenges, and the actions required to enable the introduction of hybrid, electric and hydrogen flights presented in the previous chapter.

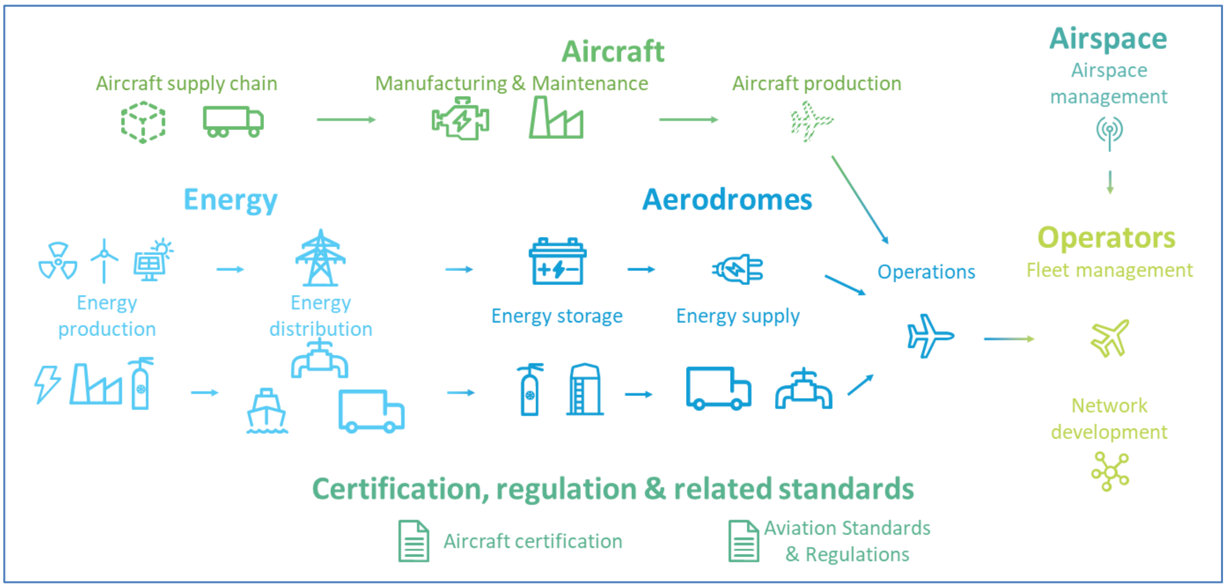


Figure 11 - Battery-electric, hybrid and hydrogen aviation value chain

4.1 Main challenges addressed

Based on AZEA's analysis, the Roadmap identifies four key challenges for introducing hybrid, electric and hydrogen flights, once aircraft are produced and certified:

- Market readiness: The electric and hydrogen aviation market is new and immature. Segments, such as Regional Air Mobility, require further development, while others, such as General Aviation, need business model adaptations. Operators must be convinced of the opportunities offered by hybrid, electric and hydrogen aviation and must be supported by public authorities and investors to adopt these technologies.
- Regulatory challenges: Introducing hybrid, battery-electric and hydrogen-powered aircraft requires adapting EU and international aviation regulations, including certification regulation of aircraft or safety protocols. National rules, such as those governing hydrogen supply at aerodromes or infrastructure authorisations, also impact deployment.
- Investments: Deploying electric and hydrogen flights demands significant investments from private actors (aviation infrastructure and energy funds, as well as private investors, and corporate fundings) and public sectors (EU funding mechanisms, and national/regional support). Regulatory incentives will help drive funding.
- Interdependencies: Deployment depends on coordinated decisions and actions among many actors—manufacturers, aerodromes, operators, energy and infrastructure providers, certification bodies, governments, and financiers—who rely on each other. The Roadmap aims to unify the sector's ambition, foster collaboration, and derisk the transition by guiding these interdependencies.

4.2 Roadmap presentation

The Roadmap is built around six pillars covering the aviation ecosystem dimensions involved in the development of electric and hydrogen aviation by 2050.

In the document, "Short-term" includes the next decades until 2035. "Long-term" represents the period beyond, until 2050

The first pillar, "Aircraft", addresses the capacity to produce the hybrid, battery-electric and hydrogen-powered aircraft required to achieve the foreseen aircraft rollout scenario.

The second pillar, "Energy", aims to ensure that the deployment of hybrid, electric and hydrogen flights is supported by the availability of the required renewable and low-carbon energy at the aerodromes supplying the aircraft and the affordability of such energy. It addresses both the production and distribution up to the aerodrome.

The third pillar, “Aerodrome”, addresses the required adaptation of aerodromes legislations, procedures and infrastructures and the readiness of a sufficient number of aerodromes in suitable size and location, including the required investments.

The fourth pillar, “Certifications, regulation and related standards” is focusing on ensuring the timely certification of hybrid, battery-electric and hydrogen-powered aircraft. It also involves adapting the aviation legal framework to support the establishment of a network of hybrid, electric and hydrogen flights and the development of the required standards.

The fifth pillar is looking at “Airspace readiness”, making sure the European airspace can accommodate the expected deployment of electric and hydrogen-powered aircraft.

The last pillar on “Operators & Incentives” is related to ensuring that operators and lessors have viable business cases for investing in aircraft and that adequate incentives exist to promote the required investment by manufacturers, aerodromes and operators/lessors.

For all these pillars, the Roadmap defines several enablers and activities

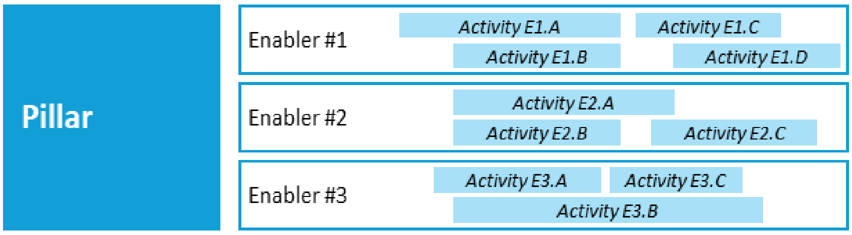
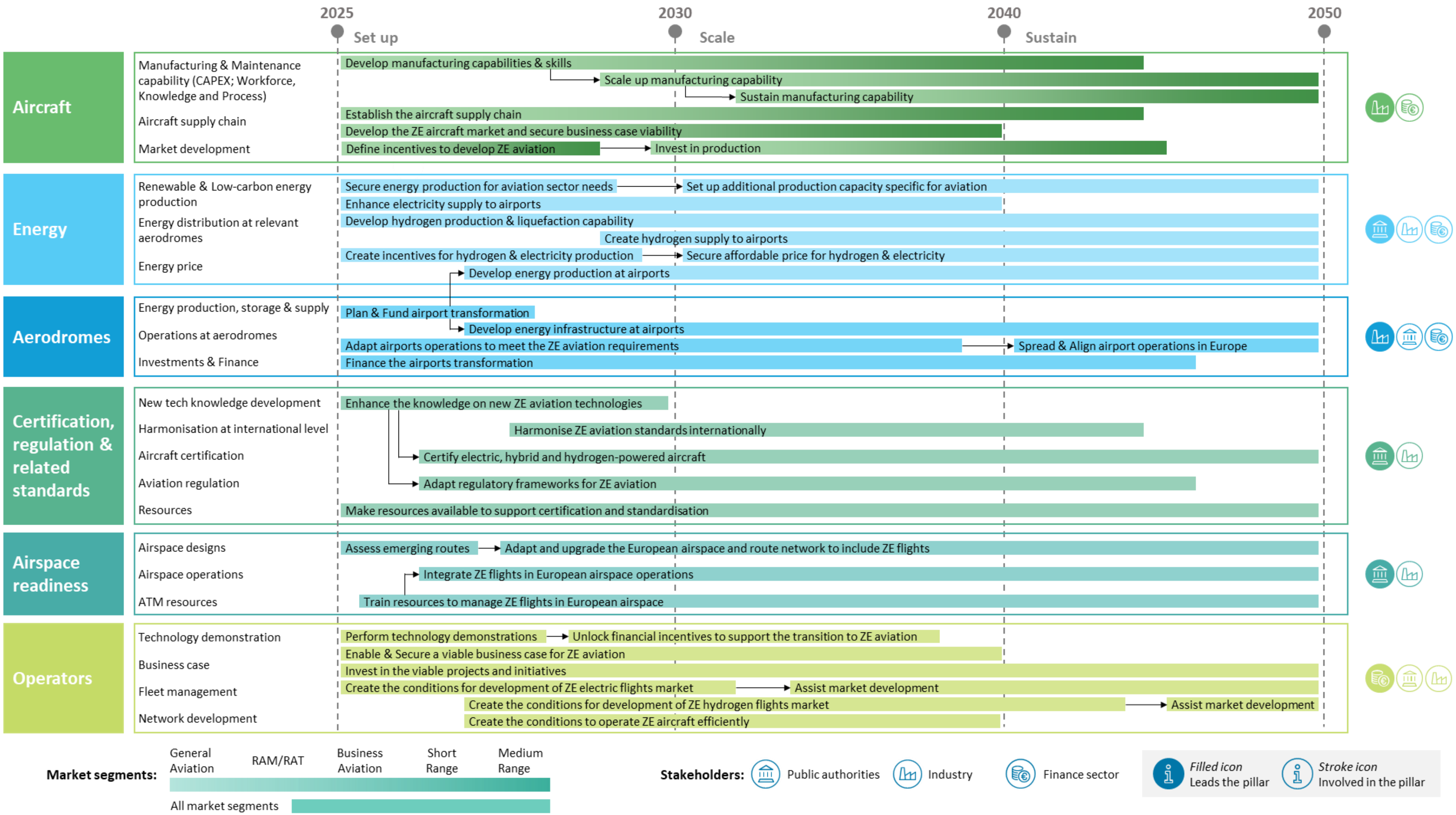


Figure 12 - Structure of the Roadmap

Figure 13 Roadmap for the deployment of electric and hydrogen-powered flights in Europe



4.3 Enablers and key activities per pillar

4.3.1 Aircraft

The deployment of a network of hybrid, electric and hydrogen flights in Europe depends primarily on the aeronautics industry's ability to deliver hybrid, battery-electric and hydrogen-powered aircraft in all market segments. This will be achieved both through the design and production of clean-sheet aircraft as well as the design and production of powertrains and other systems that can initially support aircraft retrofits or be integrated in new aircraft.

The challenges faced by industry are indeed not limited to the development of these aircraft and powertrains. Their industrialisation, mass production, marketing, maintenance and operation will also be challenges that will vary depending on the production method (clean-sheet design or retrofit), the propulsion technology and the market segment and will require appropriate solutions.

With dozens of projects covering all market segments, led by start-ups, SMEs and global leaders, the European aeronautics industry is actively supporting the introduction of electric and hydrogen propulsion in aviation and has the necessary capabilities to develop its sovereignty in this field. However, initiatives to develop such aircraft are being supported in many parts of the world and European manufacturers will face a fierce competition. It is therefore important that they are adequately supported to ensure a level playing field.

The challenges posed by the industrialisation phase do not only concern the certification of the new powertrain and aircraft (discussed in section 4) but also the development of the production tools. Building powertrain and aircraft manufacturing and assembly lines represents an important **Capital Expenditure (CAPEX)** investment. Raising the necessary financing is particularly challenging in this case, since many of these aircraft and/or powertrains will be built by start-ups and SMEs.

The adaptation of Maintenance, Repair and Overhaul (MRO) facilities to these new technologies may also present difficulties as they are already under significant pressure due to a combination of aging fleets requiring more maintenance, severe skilled labour shortages and supply chains difficulties. They will also need to support the development of aircraft retrofit capacities.

The shift towards electric and hydrogen propulsion will also require new **competencies**, both for production and maintenance, in the areas of electric and hydrogen propulsion. This challenge comes on the top of a severe gap in skilled labour forces across the entire aeronautics industry.

Series production will face, on the top of existing general **supply chain** issues, specific challenges to secure the supply of critical components, like appropriate batteries and fuel cells, and raw materials.

The successful **commercialisation** of these innovative aircraft will require in the early stages the capacity to demonstrate their operational performances and impact to attract the interest of customers (airlines and lessors) and secure investors. Networks of centres of excellence supported by regulatory sandboxes will play a key role in this regard. Another important success factor will be the acceptance of these aircraft by the public as they rely on new technologies. Finally, appropriate policy support will be required to ensure the development of new markets (e.g. Regional Air Mobility) in segments where aviation currently plays only a limited role.

Four high-level enablers have been identified to address these challenges and ensure the required delivery of hybrid, battery-electric and hydrogen-powered aircraft. They relate to the financing of the CAPEX required to develop the production capacities, the development of the required skills, the establishment of the supply chain and the development of the aircraft market. They are described in the table below with the main activities to be undertaken by different categories of stakeholders to ensure their implementation.

Manufacturing & Maintenance Capability (CAPEX)	
Aeronautics companies, particularly start-ups and scale-ups, have adequate access to finance to develop, adapt and expand production, retrofit and MRO capabilities.	
Short-term	
Public authorities	EU Institutions, Member States and Regions to support the industry financially and politically to create battery-electric, hybrid and/or hydrogen aviation European champions.
Public authorities	Member States and Regions to develop industrial strategies and measures to support the development of the production capacities of hybrid, battery-electric and hydrogen-powered aircraft and powertrain of manufacturers located in their respective country or region. Support in particular advanced manufacturing technologies (including automation, AI, and IoT)
Public authorities	EU institutions to ensure the existence of an appropriate funding and financing mechanism (e.g. EU Clean and Smart Aviation Manufacturing Initiative) under the Smart and Clean Aviation Moonshot foreseen in the next EU Multiannual Financial Framework to support the development of the required production capacity of CS-23 and CS-25 hybrid, battery-electric and hydrogen-powered aircraft, including by start-ups and SMEs. This can come in the form of, for example a separate initiative under the Clean Industrial Deal (CID), with the objectives of incentivising participation in the transition toward hybrid, battery-electric and hydrogen-powered aviation.
Public authorities	EU Institutions to increase the support to startups and scale-ups using European Innovation Council (EIC) investments.
Public authorities	Member States to enable new public funding tools for hybrid, battery-electric and hydrogen-powered aircraft projects beyond TRL 6, aimed to support the scale-up of production and the commercial entry-into-service
Public authorities	When designing their national programmes, EU Member States to make use of the Clean Industrial Deal (CID) State aid Framework regarding ensuring sufficient manufacturing capacity in clean technologies (which covers electric propulsion systems for air transport).
Public authorities	Member States to establish and expand existing green investment funds specifically aimed at supporting hybrid, battery-electric and hydrogen aircraft projects, providing targeted financing and attracting private sector co-investments.
Public authorities	Member States to create specific tax schemes to incentivise financing organisations to invest in industrialisation projects of hybrid, battery-electric and hydrogen-powered aircraft, including building or transforming production and strengthening maintenance capabilities.
Public authorities	Member States to provide incentives and financial support (e.g. green bonds) to accelerate the transition towards hybrid, electric and hydrogen-powered aviation by de-risking private investments with loan guarantees tailored to the specific needs of aircraft and powertrain manufacturers.
Public authorities	EU Institutions, Member States and regions to facilitate and promote public-private partnerships to co-finance and de-risk large-scale hybrid, battery-electric and hydrogen aircraft projects, leveraging public funding to attract larger private sector investments and aligning on existing framework such as the Clean Aviation Joint Undertaking and its successor instruments. This funding mechanisms must be transparent, technology-neutral, and accessible ensuring equitable access for SMEs and start-ups, alongside established Original Equipment Manufacturers (OEMs). EU institutions, Member States and regions should organise matchmaking event to attract private investment to hybrid, battery-electric and hydrogen-powered aircraft projects.
Finance sector	Private industrial investors to create private investment funds dedicated to battery-electric, hybrid and hydrogen aviation
Finance sector	Private industrial financiers to develop and promote green bonds specific to battery-electric, hybrid and hydrogen aviation infrastructure.
Industry	Manufacturers to capitalise on the non-financial support from public institutions to become investment-ready (business planning, pitching, compliance), as the actions (e.g. workshop) organised by EIB to help startups and SMEs.
Public authorities	EU Member States to facilitate the permitting process for building manufacturing plants, especially for those projects with the status of Net-Zero Industry Act (NZIA) strategic projects (permit granting process should be limited to 9-12 months)

Long-term	
Public authorities	EU Institutions and Member States to facilitate cross-border investment forums to attract global capital for aircraft manufacturing.
Public authorities	EU Institutions, Member States and regions to Increase funding opportunities for organisations, in particular startups and SMEs, engaged in innovative manufacturing and maintenance solutions, encouraging growth and competitiveness.
Manufacturing & Maintenance Capability (workforce, knowledge and process)	
Ensure that aircraft and powertrain manufacturers and MRO organisations have the required trained workforce and appropriate knowledge to produce hybrid, battery-electric and hydrogen-powered aircraft.	
Short-term	
Industry	Manufacturers to develop the attractiveness of the sector towards students by developing promotion campaigns with education and training organisations and include aviation in university programs.
Industry	Manufacturers to strengthen industrial collaboration with other sectors (e.g. automotive) to facilitate exchanges of expertise.
Industry	Manufacturers to develop upskilling and reskilling strategies and tools with appropriate training organisations focussing on the new competencies required.
Industry	Manufacturers to set up pilot production lines for electric/hydrogen aircraft to validate scalable manufacturing processes.
Industry	Aircraft manufacturers to cooperate with Maintenance, Repair, and Overhaul (MRO) organisations to build adequate competencies and provide appropriate support to facilitate the retrofit of their existing aircraft.
Industry	MRO providers to update their capabilities through targeted research and development to prepare for the maintenance of hybrid, battery-electric and hydrogen-powered aircraft, including workforce training and digital maintenance tools, predictive maintenance and digital twins (including through the use of AI models when relevant), infrastructure, and certification needs.
Long-term	
Industry	Manufacturers and MRO providers to expand collaborative platforms to share best practices and technology advancements in hybrid, battery-electric and hydrogen aircraft production and maintenance.
Industry	Manufacturers and MRO providers to establish feedback loops from operational data to manufacturing and maintenance for ongoing optimisation.
Aircraft Supply Chain	
Ensure that manufacturers develop resilient and agile supply chains capable to deliver the required parts, components and material to support the production rates and their fluctuations and to ensure European strategic autonomy on critical components.	
Short-term	
Industry	Industry bodies or joint initiative like AZEA to conduct a comprehensive mapping of the supply chain for hybrid, battery-electric and hydrogen aircraft, identifying critical components, raw materials, single-source dependencies and geopolitical risks and issue recommendations.
Industry	Manufacturers to identify critical suppliers for key components, as batteries as they may represent a challenge from a technology, CRL and deployment perspective.
Industry	Manufacturers to develop and implement qualification standards for new suppliers, especially for batteries, fuel cells, and hydrogen systems.
Industry	Manufacturers to establish agreements with suppliers of critical raw materials (e.g., lithium, rare earths, hydrogen) to secure long-term supply.
Industry	Manufacturers to leverage on the learnings and knowledge from other transport modes (such as the car industry) to increase the production capacity of critical components (e.g. batteries).
Industry	Manufacturers to support the investment in the upstream value chain to strengthen key aircraft components manufacturers and secure the whole transition.
Industry	Manufacturers to support their suppliers by providing financial guarantees or long-term visibility on their future orders.

Long-term	
Industry	Manufacturers to consider international partnerships to extend the supply chain to decrease the level of the supply chain criticality.
Industry	Manufacturers to monitor closely their supply chain to anticipate disruptions (e.g. by implementing digital platforms for real-time supply chain monitoring, conducting audit and stress-test, performing predictive analytics, etc.).
Public authorities	Member States to support circular supply chain models and programmes that focus on the recycling and reusing components and materials used in hybrid, battery-electric and hydrogen aircraft.
Industry	Manufacturers to develop closed-loop systems for recycling and reusing aircraft components and materials.
Aircraft Market Development	
The market potential for hybrid, electric and hydrogen-powered aircraft is sufficient and well demonstrated to convince manufacturers to launch aircraft industrialisation and production. The benefits of these aircraft are presented to operators, passengers and the general public.	
Short-term	
Public authorities	European Union, Member States and Regions to promote the establishment across Europe of several centres of excellences supported by regulatory sandboxes to create a set of diversified test arenas where demonstrations of electric and hydrogen-powered flights can be performed, preparing their commercial exploitation in the different segments of the market, showcasing their viability to investors and highlighting benefits to the public to build trust in a new propulsion technology.
Public authorities	Member States and Regions to develop networks of regional aerodromes to promote their transformation into mobility and energy hubs and support the deployment of hybrid, battery-electric and hydrogen-powered aircraft, in particular in the General Aviation and Regional Air Mobility market segments.
Public authorities	Member States and Regions assess the potential of hybrid, battery-electric and hydrogen-powered aircraft to support the development of new green air mobility offers based on under-used aerodromes, in particular in the Regional Air Mobility and Regional Aviation segments.
Industry	Operators to identify potential for new business models and new market developments in segments like regional air mobility and launch pilot projects to show viability and societal benefits.
Public authorities	European Union, Member States, and Regions to launch pilot routes using hybrid, battery-electric and hydrogen aircraft to create initial demand.
Industry	Manufacturers and operators demonstrate viable business cases on smaller market segments to show the economic viability of hybrid, battery-electric and hydrogen-powered aircraft.
Industry	Manufacturers and operators develop communication tools to present the benefits of the electric, hybrid and hydrogen aviation and the potential for the development of new air mobility offers. They develop targeted information campaigns toward investors, policy makers and the general public.
Industry	Operators develop targeted customer awareness campaigns to inform passengers and logistics customers about the benefits of hydrogen and electric flights.
Industry	Manufacturers and Operators conduct surveys to assess and monitor the acceptance/confidence of passengers to fly hybrid, battery-electric and hydrogen-powered aircraft.
Industry	Manufacturers to develop cooperation with initiatives supporting the deployment of electric and hydrogen-powered flights outside Europe (including through joint initiatives like AZEA).
Public authorities	EASA to continue to actively support progress in understanding non- CO_2 climate impacts of hydrogen propulsion as well the impact of the use of SAF and jet fuel.
Public authorities	Member States to promote the provision of sustainability information (e.g. EASA Flight Emissions Label) on booking platforms to empower passengers to make informed choice.
Finance sector	Member States and private investors to finance demonstrations and pilot projects
Long-term	
Industry	EU institutions and Member States to facilitate cross-border investment forums to attract global capital for European battery-electric, hybrid and hydrogen aviation.
Industry	EU institutions and Member States to expand funding based on performance and milestones, tied to technology demonstration and certification achievements.

Aircraft pillar: Enablers & Key activities

4.3.2 Energy

The deployment of electric and hydrogen propulsion in aviation will depend for a large part on the **availability of renewable and low-carbon electricity and hydrogen**. Obtaining on the market the necessary quantities of energy may represent a challenge, even though they may represent a small share of the EU's total projected energy needs.

The deployment of hybrid, electric and hydrogen flights in Europe defined in section 3 will require to secure 1.5 million tonnes (Mt) of hydrogen (H2) per annum by 2050 (excluding the production of e-SAF), which corresponds to over 14.7% of the total hydrogen production capacity in the EU in 2024[31]. and about 2.2% of the EU projected total hydrogen demand by 2050[32].

Similarly, the quantity of low-carbon and renewable electricity required by 2050 to support intra-EU operations of hybrid and battery-electric aircraft (excluding the electricity supplied to stationary aircraft) amounts to approximately 26 terawatt-hours (TWh) of electricity per annum by 2050. This represents 1% of the total electricity production capacity of the EU in 2023[33].

It is also estimated that another 84 TWh per annum will be required to produce the required volume of hydrogen to be used in aircraft. As a result, the total amount of electricity required to support the operations of hybrid, battery-electric and hydrogen-powered aircraft in 2050 (110 TWh/a) represents approximately 4% of the total EU electricity production in 2023.

The simulation of the Flight Network performed by EUROCONTROL allowed to identify the energy requirements at aerodromes level for hybrid, battery-electric and hydrogen-powered aircraft operating forecasted IFR flights (see Figure 15 and Annex 3).

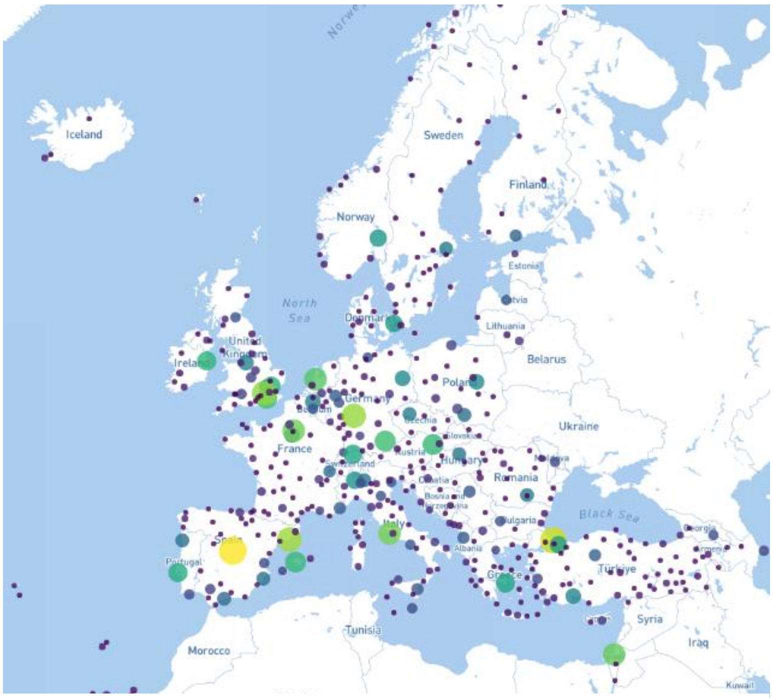


Figure 14 Energy (H2) required at different Aerodromes to support the network of hydrogen flights in the Medium Range market segment

31 Hydrogen Production | European Hydrogen Observatory. The total EU27 hydrogen production capacity in 2024 is used as a reference value (10.2 Mt). It is important to note that approximately 99% of the total hydrogen production capacity in the EU27 in 2024 corresponded to grey hydrogen production via Steam Methane Reforming (SMR).

32 JRC Publications Repository - The role of hydrogen in energy decarbonisation scenarios. An estimated hydrogen demand of 68 Mt at the EU level by 2030 is used as a reference value (scenario based on a faster transition to net-zero)

33 Electricity and heat statistics - Statistics Explained – Eurostat. Total gross electricity production in the EU in 2023 is used as a reference (2749 TWh).

Table 2 – Total energy required by electric and hydrogen-powered aviation

	2030	2040	2050
Hydrogen			
Hydrogen demand – GH2 & LH2 (direct use in aircraft, excluding eSAF production)	2 kt	0.3 Mt	1.5 Mt
% vs H2 production in EU27in 2024 (10.2 Mt, ≈99% grey H2)[34]	*<1%*	*3.0%*	*14.7%*
% vs projected H2 demand in the EU in 2050[35] (68 Mt)			*2.2%*
Electricity			
Electricity demand for direct use in aircraft	87 GWh	6.3 TWh	26 TWh
Electricity demand for production of H2 used in aircraft *(excluding eSAF production)[36]*	115 GWh	12 TWh	84 TWh
Total electricity demand	202 GWh	18.3 TWh	110 TWh
% vs electricity production in the EU in 2023 (2.749 TWh, 44.3% of renewable electricity)[37]	*<1%*	*<1%*	*4.0%*
% vs projected electricity demand for transport in the EU in 2050 (640 TWh[38])			*17%*
% vs projected total electricity demand in the EU in 2050 (3.760 TWh[37])			*3%*

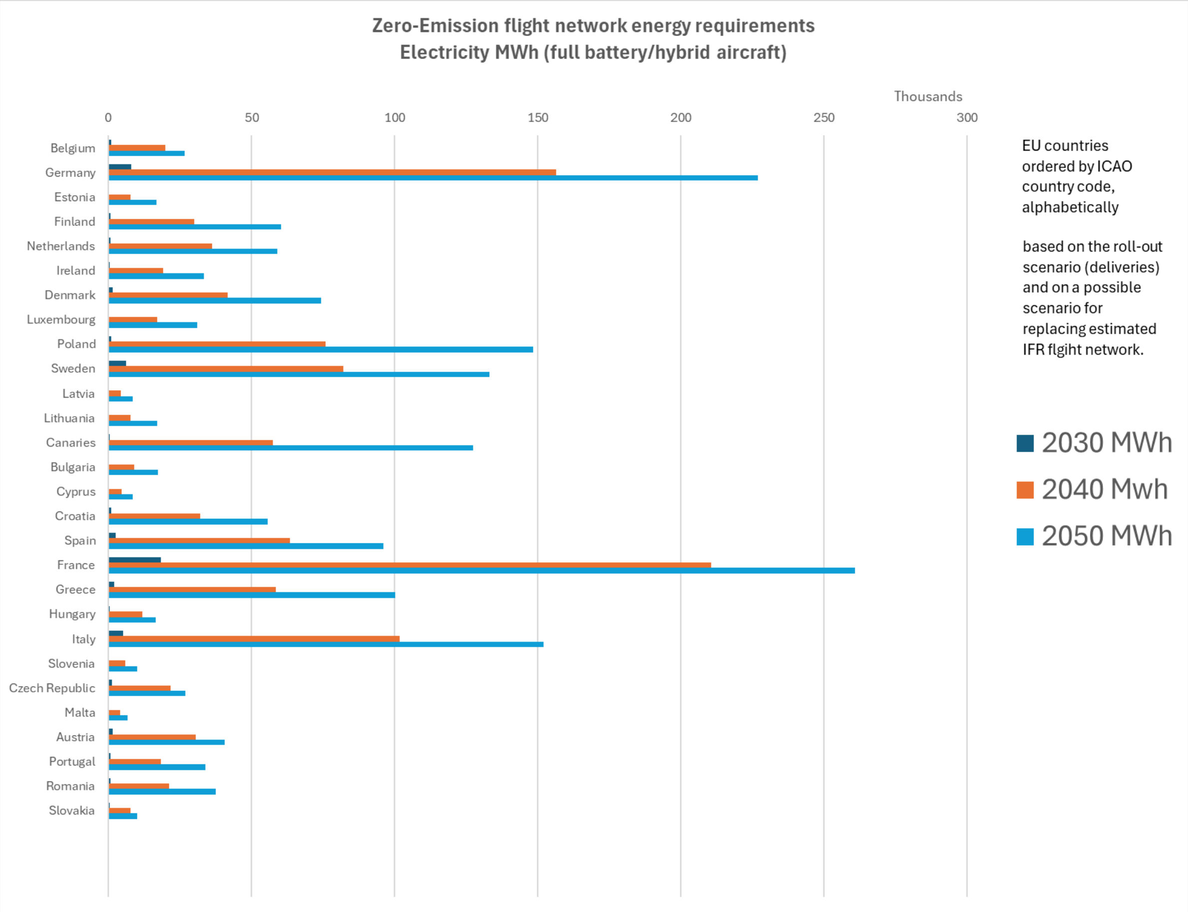


Figure 15 - Electricity required at aerodromes to support operations of hybrid and battery-electric aircraft (limited to the replacement of forecasted IFR flights – no new operations)

34 Hydrogen Production | European Hydrogen Observatory

35 JRC Publications Repository - The role of hydrogen in energy decarbonisation scenarios.

36 Taking 50kWh/kg as the electricity consumption to produce 1 kg of hydrogen.

37 Electricity and heat statistics - Statistics Explained – Eurostat.

38 Impact Assessment Report accompanying the Communication from the European Commission COM(2024)63 "Securing our future Europe's 2040 climate target and path to climate neutrality by 2050 building a sustainable, just and prosperous society", see Part 3 Fig. 18.

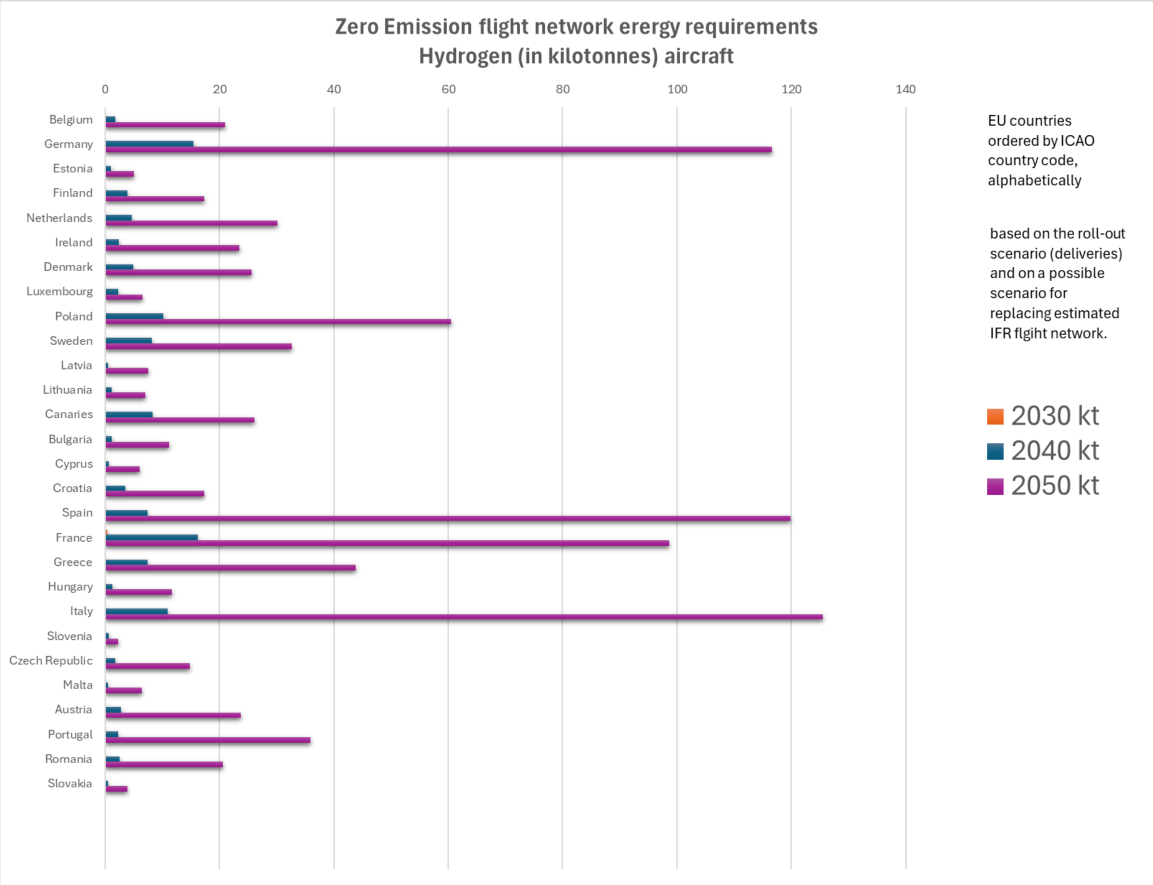


Figure 16 - Hydrogen required at aerodromes to support operations of hydrogen aircraft

Securing the necessary quantities of affordable "hydrogen for aviation"[39] as defined by ReFuelEU Aviation legislation (i.e. renewable and low-carbon hydrogen) to satisfy the growing demand of hydrogen-powered aircraft may present important challenges, especially in the first stages of deployment. These challenges include the fact that renewable hydrogen production is a capital-intensive process, due to the high costs of renewable electricity production and electrolysers.[40] Another important challenge is the existing competition with SAF and synthetic low-carbon aviation fuels due to the high volumes of renewable and low-carbon hydrogen that are required to produce this type of fuels[41]. The hydrogen demand for hydrogen-powered aviation needs also to be better recognised in EU and national policies to ensure availability at the required aerodromes across Europe.

The RePowerEU Plan[42] and the EU Hydrogen and Gas Decarbonisation Package[43] establish a new regulatory framework for the deployment of hydrogen infrastructure and for the development of the hydrogen market, which is an essential prerequisite to ensure the timely entry-into-service

39 Article 3.17 defines of the ReFuelEU Regulation defines ''hydrogen for aviation'' as ''renewable hydrogen for aviation or low-carbon hydrogen for aviation''.

40 According to the European Hydrogen Observatory, in 2024 the total CAPEX of an alkaline water electrolyser amounted to 2310 euro/ kW, while the OPEX amounted to 46 euro/ kW/year, excluding electricity costs. The CAPEX of a Proton Exchange Membrane (PEM) electrolyser amounted to 2503 euro/Kw, while the OPEX was 50 euro/kW/year (also excluding electricity costs).

41 Article 3.7 of the ReFuelEU Regulation defines ''sustainable aviation fuels (SAF)'' as ''syn*thetic aviation fuels, aviation biofuels and recycled carbon aviation fuels*''. Article 3.13 of the same regulation defines ''synthetic low-carbon aviation fuels'' as ''*aviation fuels that are of non-biological origin, the energy content of which is derived from non-fossil low-carbon hydrogen, which meet lifecycle emissions savings threshold of 70 % and the methodologies for assessing such lifecycle emissions savings pursuant to relevant Union law*''

42 Communication on the RePowerEU Plan, 2022

43 The Hydrogen and Gas Decarbonisation Package is formed by Directive 2024/1788 on common rules for the internal markets for renewable gas, natural gas and hydrogen the and Regulation 2024/1789 on the internal markets rules for renewable gas, natural gas and hydrogen.

of hydrogen-powered aircraft. [44] The Renewable Energy Directive (RED III) also mandates a sub-target of 1% for the use of Renewable Fuels of Non-Biological Origin (RFNBOs) in the transport sector by 2030, a term that covers renewable hydrogen.[45] However, these policy instruments do not directly address the sectorial needs of hydrogen for aviation.

The latest Innovation Fund Auction launched in December 2025 under Hydrogen Bank provides an illustrative example of how the hydrogen aviation needs could be better acknowledged across EU policy instruments. This auction includes a dedicated window offering a fixed premium for RFNBOs and/or electrolytic low-carbon hydrogen for both the aviation and maritime sectors[46]. However, it is important to point out that the term RFNBOs also covers e-SAF.

Securing the necessary quantity of low-carbon and renewable electricity for electric and hybrid electric aviation is less critical than hydrogen, and aviation can benefit from the increased electrification and associated electricity demand from other sectors to push production. However, distribution of this electricity (e.g. grid connections) remains a critical challenge.

EU and national authorities will be key to secure the required energy volumes for hybrid, battery-electric and hydrogen-powered aviation, supported by energy producers, energy Transmission System Operators (TSOs) and aerodromes. Investors will also play a role in developing energy infrastructure and enabling energy production at aerodromes where there are significant opportunities.

National governments and aerodromes should coordinate closely with electricity suppliers and energy TSOs to ensure that **aerodromes are well integrated into the electricity grids** and that electricity grids are adequately upgraded to accommodate the growing electricity demand. To support these objectives, the European Commission will present in 2026 an EU Electrification Action Plan. This Plan will be aimed at increasing the investments in electricity grids, addressing the insufficient storage and grid capacity for distributing electricity to meet the demands of end-users[47].

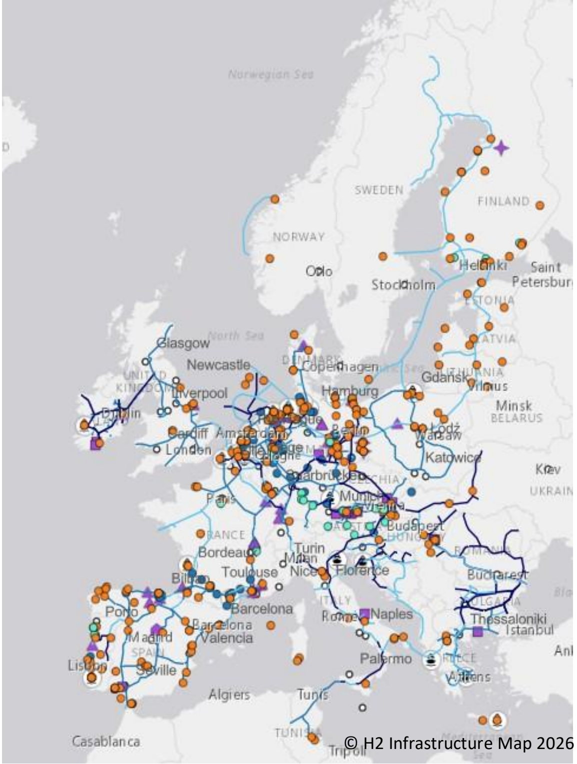


Figure 17 - H2 infrastructure Map, February 2026

The **transport of hydrogen to aerodromes** will also depend on a reliable and efficient **distribution network**. Unlike other hard-to-abate sectors that rely mostly on gaseous hydrogen (GH2), the future demand of liquid hydrogen (LH2) to be used directly in aircraft is expected to be significantly higher. In the first stages of deployment, the transport of hydrogen to the aerodrome is likely to take place mainly by truck, either in gaseous or liquid form. Over time, LH2 is expected to become the preferred option for delivery by truck as hydrogen supply needs increase, given the larger volumes of LH2 that can be transported compared to GH2. In this case, the liquefaction process will need to take place outside of the boundaries of the aerodrome and its vicinity, being carried out in most of the cases by the energy supplier.

The need to use trucks to transport the hydrogen to the aerodrome in the initial stages is explained by the long lead times required to ensure that aerodromes are adequately connected to the local pipeline network. Over the long-term, to meet increasing hydrogen-

[44] This framework is complemented by the Delegated Regulation 2025/2359 defining and certifying low-carbon hydrogen, alongside Delegated Regulation 2023/1185 establishing the certification framework for renewable hydrogen (as part of RFNBOs) under the Renewable Energy Directive.

[45] Directive 2023/2413 from 2023 as regards the promotion of energy from renewable sources. Article 25.1.b mandates a 1% sub-target for RFNBOs by 2030, derived from the combined advanced biofuels, biogas and RFNBOs corresponding to 5.5% of the energy supplied to the transport sector. Article 1.36 defines Renewable Fuels of Non-Biological Origin (RFNBOs) as ''liquid and gaseous fuels the energy content of which is derived from renewable sources other than biomass''. This term covers renewable hydrogen, but also e-SAF.

[46] Auction call for proposals Innovation Fund fixed premium auction call 2025 for Hydrogen, December 2025

[47] Call for evidence for the EU Electrification Plan, August 2025

powered aircraft demand, national governments and aerodromes will also need to closely cooperate with hydrogen producers and hydrogen transmission network operators (HTNOs) to **ensure that relevant aerodromes are well-integrated in the hydrogen network**, including through connections to the European Hydrogen Backbone[48]. Under this scenario, hydrogen will be transported by pipeline in gaseous form and liquefied and stored at the aerodrome or in its vicinity.

The building of specific hydrogen liquefaction and storage plants, located on-site or near-site the aerodrome, also poses challenges due to the high costs of this infrastructure. As a result, these plants will primarily be established at larger aerodromes where there is a match with the local context (i.e. close to ports, or access to large amounts of renewable electricity) to benefit from economies of scale.

To facilitate the transport of electricity and hydrogen to end-users, the European Commission presented in December 2025 an upgrade of the EU energy infrastructure regulatory framework, as part of the newly presented Grids Package and the Energy Highways Initiative[49], which identified priority electricity interconnections and hydrogen corridors. This package also includes a proposal to revise the Trans-European Networks for Energy (TEN-E) Regulation.[50]

In the first stages of development, the green premium associated with purchasing energy for aviation should remain acceptable for airline operators, especially as compared to Jet-A fuel and SAF. As the energy market for zero-emission aviation develops, **predictability in energy price projections** will become increasingly important for airline operators. Alongside electricity and hydrogen production costs, energy distribution and transport to the aerodrome will also need to be considered when calculating the total energy price.

Effective communication channels between energy suppliers, propulsion technology developers, airline operators and aerodromes will be crucial, enabled by regular exchanges on expected electricity and hydrogen production and distribution costs and on airline operators' willingness to pay. This will be key for the successful conclusion of long-term offtake agreements.

The European Commission's Hydrogen Mechanism[51] provides an illustrative example of how an EU-wide platform can support hydrogen suppliers to establish direct contact with operators and aerodromes. This initiative allows hydrogen suppliers to introduce their offers on a dedicated platform and to indicate aerodromes as potential delivery locations.

At the same time, operators have access to this information and can introduce their demand requests, indicating the estimated volume of hydrogen that they need for their operations.

The platform also allows the sharing of indicative price information and invites hydrogen suppliers and offtakers to communicate their support needs to financial institutions, in terms of private equity, standard loans and offtake guarantees. This platform can contribute to mitigating market uncertainty by providing transparent information on estimated hydrogen for aviation demand and pricing. Building on the Hydrogen Mechanism, new platforms could be also initiated at the national and regional levels to better connect the hydrogen supply and demand for aviation locally.

Public authorities will also have a decisive role to play in ensuring stable and transparent **electricity and hydrogen prices** for aviation through different market mechanisms and incentives.

Availability of low-carbon and renewable electricity and hydrogen for aviation depends on three enablers: renewable and low-carbon energy production, energy distribution at relevant aerodromes, and energy pricing.

48 The H2 Infrastructure Map Europe is a joint initiative by ENTSOG, GIE, CEDEC, Eurogas, GEODE, GD4S in cooperation with European Hydrogen Backbone

49 Communication on the European Grids Package, December 2025

50 Proposal for a Regulation on Guidelines for trans-European energy infrastructure amending Regulations 2019/942, 2019/943 and 2024/1789 and repealing Regulation 2022/869, December 2025. The TEN-E Regulation establishes a framework for the selection of Projects of Common Interest (PCIs) and Projects of Mutual Interest (PMIs). PMIs and PCIs are cross-border energy infrastructure projects in priority geographical corridors and thematic areas, including electricity and hydrogen and electrolysers. The selected projects are eligible to apply for CEF funding, while also having access to faster planning and permit approvals. This revision is aimed to further accelerate the permit granting procedures for these projects and to support their faster deployment through different measures.

51 The EU Hydrogen Mechanism covers renewable and low-carbon hydrogen supply and offtake, but also the supply and offtake of derivatives (e.g. e-SAF, ammonia and methanol). Hydrogen suppliers were invited to provide their preliminary supply offers until 2nd January 2026. 265 supply projects have been submitted in this first phase, with 194 of them located in the EU . The supply projects submitted so far aim to deliver hydrogen and derivatives (including e-SAF) to 25 aerodromes in Europe. In a second phase, offtakers are invited to submit demand requests by 20 March 2026.

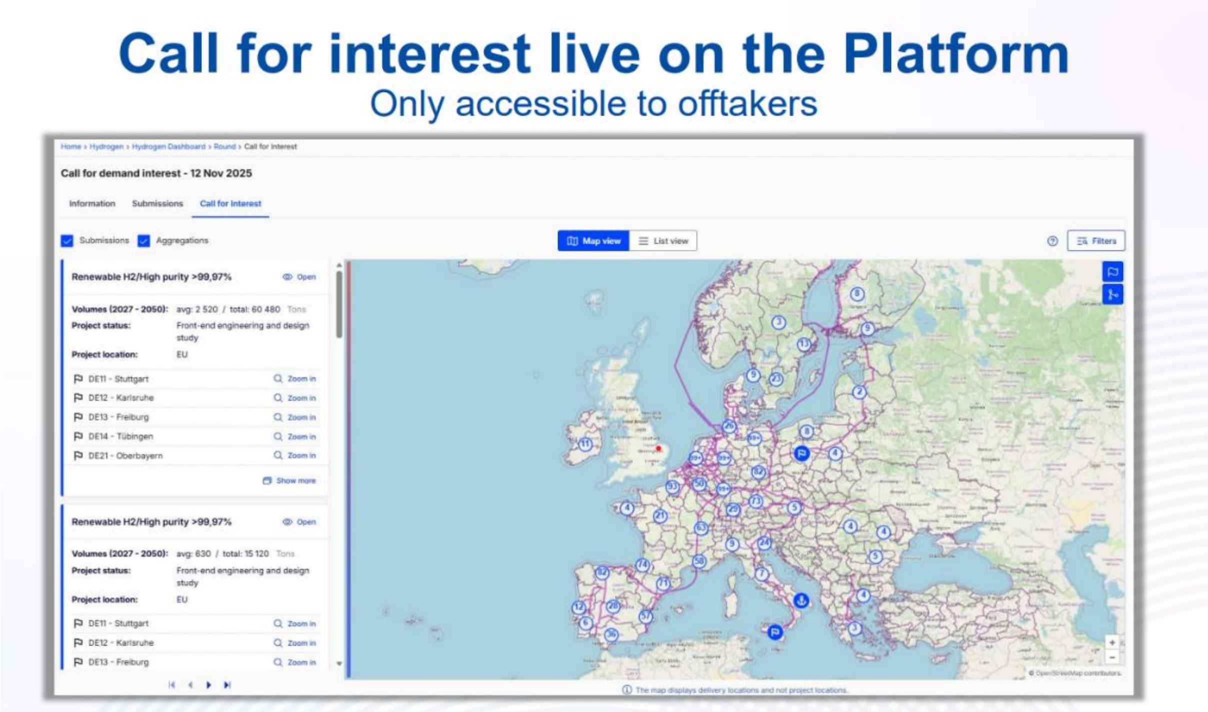


Figure 18 - EU Hydrogen Mechanism: Preliminary supply information available for offtakers
(**Source:** **Webinar on EU Hydrogen Mechanism's offtake collection, January 2026**)

Renewable and Low-Carbon Energy Availability for Aviation	
The required volumes of electricity and hydrogen (especially in liquid form) are available for zero-emission aviation applications	
Short-term	
Public authorities	EU institutions and Member States ensure that battery-electric, hybrid and hydrogen aviation is identified as a priority in European and national electricity and hydrogen production policies and that the required quantities of electricity and hydrogen identified by AZEA are well covered.
Industry	Energy suppliers, operators and aerodromes provide (including through joint initiatives like AZEA) an overview of the required electricity and hydrogen demand and develop targeted recommendations to EU Member States regarding renewable and low-carbon electricity and hydrogen needs and supply infrastructure.
Public authorities	Member States develop plans and adapt existing policies in respect of the development of renewable and law-carbon electricity and hydrogen production and distribution addressing the needs of hybrid, battery-electric and hydrogen-powered aviation.
Public authorities	Following the example of the EU Hydrogen Mechanism, EU, Member States and Regions explore the establishment of matchmaking platforms aimed to connect the requests of hydrogen suppliers and operators as off takers.
Public authorities	EU institutions provide the equivalent regulatory and funding treatment to ensure a level playing field for hydrogen and electricity, SAF and jet fuel aircraft.
Public authorities	EU institutions and Member States develop strong policies in collaboration with the sector and ensure these policies build upon other mobility sector policies that also require scale up of energy use.
Industry	Energy suppliers, TSOs and aerodromes support the adequate development of the energy ecosystem by providing clear specifications on the hydrogen infrastructure needs for aviation. Detailed and clear specifications will assist in the development of fit-for-purpose liquefaction plants.
Industry	Energy suppliers, TSOs and aerodromes collaborate with other energy-intensive industries for hydrogen production and for development of the required joint infrastructure.
Industry	Individual aerodromes and operators provide energy suppliers with information on their actual and future demand to drive hydrogen production and distribution infrastructure

	investments and electricity grid upgrades, as well as to facilitate the production of the right volumes of energy to avoid shortages.
Finance sector	Finance large-scale low-carbon and renewable energy production projects dedicated to aviation, which should also incorporate other types of key infrastructure such as electricity and hydrogen storage and hydrogen liquefaction plants.
Industry	Large aerodromes engage with public authorities to assess the possibility and plan their connection to the European Hydrogen Backbone.
Long-term	
Public authorities	EU institutions and Member States ensure that the evolving needs of battery-electric, hybrid and hydrogen aviation are well reflected in relevant energy policies to support the continuous development of electric and hydrogen-powered flights in Europe.
Public authorities	EU institutions and Member States incentivise the partnering between energy suppliers and operators as off takers with the close involvement of aerodromes.
Industry	Based on EU-wide overview of the required low-carbon and renewable electricity and hydrogen demand at aerodromes and other energy-intensive industry users, energy providers define the scale and timing of energy supply to aerodromes to plan for the required long-term investments in energy production infrastructure.
Energy Distribution to Aerodromes	
Electricity and hydrogen distribution networks are in place and efficient, the necessary energy is made available at the required aerodromes to support the deployment of the expected networks of electric and hydrogen flights. The electricity grid is adequately upgraded and expanded over time to meet the growing demand. In the first stage of hybrid and hydrogen-powered aircraft hydrogen delivery is ensured by truck, in the long-term aerodromes are connected to the Hydrogen Backbone when required and possible.	
Short-term	
Public authorities	EU institutions, Member States and regions ensure that the requirements from the aviation sector for energy transmission infrastructure are integrated into energy roadmaps and industry projects, including the European Hydrogen Backbone. Where possible, develop policy to prioritize aviation as a hard to abate sector.
Public authorities	EU institutions adjust EU tax rates and subsidies to encourage investment in aviation energy distribution.
Industry	Each aerodrome collaborates with energy suppliers and distributors to identify the most efficient energy distribution modality (especially in the case of hydrogen, which can be transported by truck or pipeline).
Industry	Hydrogen suppliers develop resilient hydrogen supply chains dedicated to the aviation sector using diverse delivery methods (initially by trucks and progressively by pipelines when the demand increases, and the infrastructure starts to be ready).
Industry	Electricity Transmission System Operators (TSOs) and Hydrogen Transmission Network Operators (HTNOs) start planning the required electricity grid upgrades and extensions of the hydrogen network to ensure the future supply of energy to meet the demands of battery-electric, hybrid and hydrogen aviation.
Long-term	
Industry	Aerodromes and operators establish relationships and contracts with nearby low-carbon and renewable energy providers to secure reliable supply during peak demand.
Industry	Member States and regions ensure that aerodromes are integrated when necessary, in the European Hydrogen Backbone.
Energy Price	
The prices of renewable and low-carbon hydrogen (especially in the case of liquid hydrogen) and electricity compared to Jet-A fuel/SAF are adequate to support commercial operations of hybrid, battery-electric and hydrogen-powered aircraft.	
Short-term	
Public authorities	EU institutions and Member States ensure that the price of renewable and low-carbon hydrogen and electricity are competitively against conventional fuels and Sustainable Aviation Fuels (SAF), securing the economic viability of battery-electric, hybrid and hydrogen aviation (e.g. through hydrogen free allowances under the EU Emissions Trading System (ETS), zero-rate energy taxes for electricity and hydrogen, subsidy schemes for hydrogen purchase).

Public authorities	Following the example of the Hydrogen Mechanism, Member States establish matchmaking platforms to enable the exchange of information between Energy Suppliers, Operators and Aerodromes to address market uncertainty and provide transparent estimations on energy supply, demand and prices.
Public authorities	EU institutions develop EU market mechanisms stabilise energy prices and ensure price transparency.
Industry	Energy suppliers clarify the expected price ranges of hydrogen and electricity for 2030 and 2040. In the case of hydrogen, this should account for the price of production and distribution (different distributions methods may account for different costs).
Industry	Operators clarify to energy suppliers and to propulsion technology developers the price they are ready to pay for hydrogen and electricity for use in aircraft.
Industry	Energy suppliers and operators favour the conclusion of long-term offtake contracts with a fixed price to ensure certainty and reduce the existing risks for operators.
Long-term	
Industry	Energy suppliers develop long-term estimates on the evolution of low-carbon and renewable electricity and hydrogen prices up to 2050, considering the needs of the aviation sector

Energy pillar: Enablers & Key activities

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4.3.3 Aerodromes

The deployment of hybrid, electric and hydrogen flights across Europe requires the establishment of appropriate networks of aerodromes in the different market segments ready to support the handling of hybrid, battery-electric and/or hydrogen-powered aircraft.

Aerodromes need to engage without delay in a strategic reflection about the challenges and opportunities that the introduction of electric and hydrogen propulsion will bring to them. They should plan their transformation through their long-term Aerodrome Master Plans to attract sufficient investments.

The smallest regional aerodromes will play a key role in supporting the development of Regional Air Mobility. It is, therefore, vital to maintain such aerodromes infrastructure until hybrid, battery-electric or hydrogen-powered aircraft become available in the early 2030s. Financial support needs to be maintained for these aerodromes. To compensate for the lack of operated commercial routes and sustain their business model, these aerodromes may for instance consider developing into energy hubs.

Aerodromes will have to develop the infrastructure necessary for the supply, storage and aircraft recharging/refuelling of the required quantities of electricity and/or hydrogen.

The required adaptations will differ depending on operators' needs, aerodrome typologies and the regional context. Small aerodromes may be the first to adapt their infrastructure but could limit it to electric recharging capacities, while international hubs may start later and require at a certain stage to have hydrogen refuelling infrastructure connected to the hydrogen backbone. The aerodromes will rely on the regional energy and infrastructure systems, particularly in coastal and offshore contexts. Early-adopter aerodromes will be the "living labs" for the others. The Airports Infrastructure Factsheets Tool developed by AZEA may help aerodromes identifying the related challenges[52]

Table 3 – Total quantity of energy to be supplied at all aerodromes in a specific market segment

	Electricity (GWh)					Hydrogen (kt)					
	GA	RAM	RA	BA	TOTAL	GA	RAM	RA	BA	MR	TOTAL
2030	26	61			87	0	1	0	1		2
2040	308	3.829	1.773	382	6.292	5	23	269	57		354
2050	818	18.740	5.937	617	26.112	12	92	269	122	966	1.462

The initial development of electric charging and hydrogen refuelling infrastructure is already underway. With the pace of certifications expected to accelerate in the coming years and new aircraft entering in service, the development of this infrastructure must be stepped up, starting with electric charging infrastructure at aerodromes supporting the GA and RAM operations.

According to EUROCOTROL's simulation of the Flight Network, by 2030 60 aerodromes supporting GA operations (5% of total aerodromes active in that segment) and 140 aerodromes supporting RAM operations (13%) should be able to supply more than 100 MWh of electricity per year. By 2040, 375 (60%) aerodromes supporting GA operations and 350 (40%) aerodromes supporting BA operations will also need to be ready to supply these quantities of electricity[53]. Deployment should continue at the same pace after that date in all market segments. Although most regional aerodromes and larger hubs have already begun working on the electrification of ground equipment fleets, ground handling activities and the supply of electricity to stationary aircraft, electricity supply for aircraft operations will require planning for additional infrastructure.

[52] Helping Airports understand the challenge of zero-emission aviation: AZEA Airports Infrastructure Factsheets Tool

[53] One aerodrome may support operations in different market segments. These numbers are therefore not cumulative.

The necessary infrastructure adaptations depend not only on the number of aircraft to be serviced, but also on their charging characteristics. Upgrading the power grid may be often required to meet the high-power charging needs of hybrid and battery-electric aircraft.

With electric and hybrid aircraft expected to enter service in the coming years, aerodromes face a major challenge in planning and implementing charging infrastructure, as technical specifications have not yet been finalised and no equipment has yet been fully certified. This urgency is compounded by a broader uncertainty in market perspectives.

The large-scale development of the infrastructures needed to supply hydrogen is expected to begin in the next decade, with the goal that by 2040 30% of all aerodromes in the Network (580 aerodromes) will be able to supply at least 10 tonnes H2 per year, and 15% (280 aerodromes) more than 100 tonnes H2. By 2050, 190 aerodromes are expected to supply more than 1000 tones H2 per year.

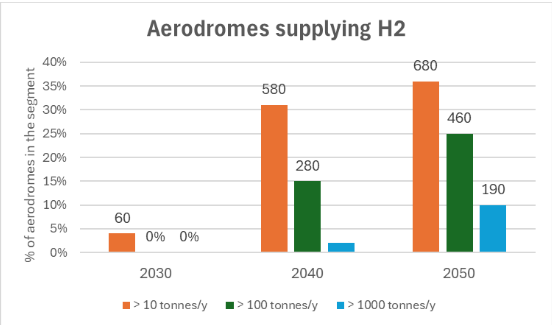

Figure 15 - Evolution of the number of aerodromes supplying H2

Figure 16 and Figure 17 present the energy supply repartition by aerodrome in different market segments (an aerodrome may serve different market segments). Aerodromes supplying H2 are essentially supporting operations in the regional aviation, business aviation and medium range market segments.

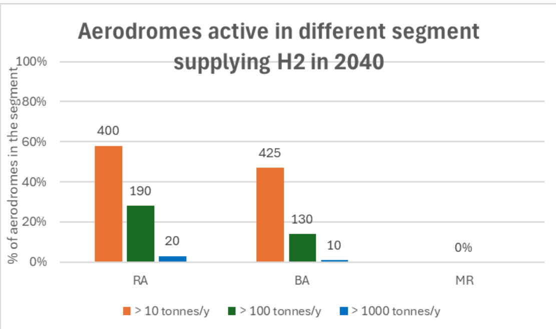

Figure 16 - Requirements of H2 supply at aerodromes in 2040 for different market segments

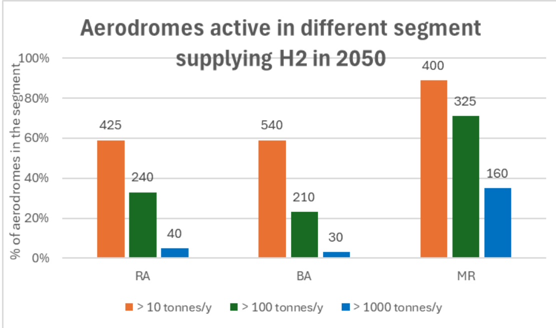

Figure 17- Requirements of H2 supply at aerodromes in 2050 for different market segments

The supply of hydrogen at airport will first take place by truck [54]. It will often start with the supply of gaseous hydrogen for other purposes like refuelling of GSE. For larger quantities, hydrogen supply may require a connection to the Hydrogen Backbone. This would be typically the case of aerodromes supporting MR operations after 2040.

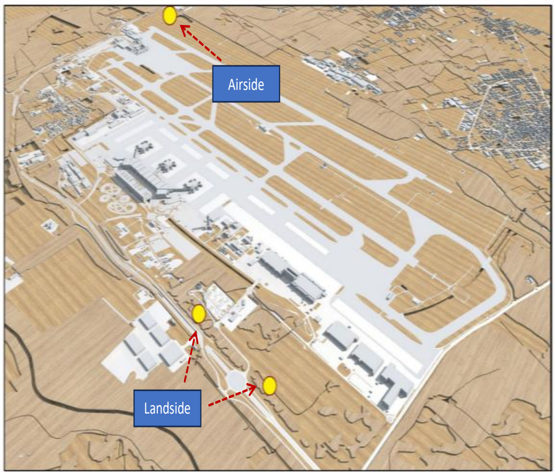

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Figure 22- Example of a study for the location of hydrogen pipeline entry points at Milan Malpensa Airport (MXP)

Depending on the nature (gaseous or liquid) and quantities of hydrogen to be supplied, aerodromes may also need to develop liquefaction, storage and distribution facilities. In a first step, supply of LH2 by truck may, however, avoid the need for liquefaction and storage infrastructures. Among these challenges, the shift to Liquid Hydrogen (LH2) represents the most significant disruption, requiring a systemic overhaul of technology maturity, supply ecosystems, and refuelling protocols.

In the short to medium term, it is expected that H2 refuelling into an aircraft will be carried out by refueller trucks. On the long-term, distribution of H2 at the aerodrome by pipelines and refuelling by hydrant dispenser vehicles may be considered for

54 Supply of H2 to aerodromes may be done by truck either in gaseous and liquid states (average capacity of H2 trailer is 500 kg for GH2 and 3500 for LH2).

higher quantities. Hydrogen refuelling at aprons may require modification of the terminal areas and aircraft parking zones.

Appropriate regulations, permits for hydrogen infrastructure and new safety requirements specific to hydrogen-powered aircraft will have to be developed and harmonised.

To support the development of the appropriate infrastructures, regulatory constraints, as obtaining the permits to build and operate specific infrastructures, must also be addressed and appropriate standards developed.

As mentioned under the previous section, aerodromes may also develop their own electricity and/or hydrogen production or liquefaction facilities with renewable energy sources. O Regional small (RS) and regional medium (RM) aerodromes will consider meeting their current and future energy needs e.g. with solar or wind energy production, while larger aerodromes might need to consider more efficient solutions (especially in terms of available space).

The adaptation required at aerodromes to handle hybrid, battery-electric or hydrogen-powered aircraft does not only concern infrastructures but also **operations and skills**. It requires the **adaptation of existing EU and national legislations, operational procedures and protocols.**

To move beyond the current state of uncertainty, aerodromes require a definitive market scenario for the next three decades. Such a scenario, outlining when and where "first movers" will emerge and the types of connectivity they will provide, is mandatory for strategic planning. With this clarity, aerodromes can transition from passive observers to active stakeholders, forging partnerships to lead the management of next-generation aircraft.

The timely involvement of operators in presenting credible adoption plans and providing sufficient certainty regarding demand at each airport will therefore be a determining factor in initiating the necessary **investments.** This is even more important for smaller aerodromes, since they are not automatically covered by the ReFuelEU Aviation mandate and therefore cannot rely on regulatory-driven demand to justify investments.

The development of public strategies and appropriate financing mechanisms will also be necessary to support the investments required at aerodromes. AZEA has the capacity to inform Member States and regions about potential local needs for airport adaptation.

The transformation of aerodromes is driven by three high-level enablers: developing energy storage and supply systems, including necessary adaptation of apron infrastructure, adapting operations at aerodromes, and securing adequate investment.

Infrastructure	
A sufficient number of aerodromes develop the capacity to store and supply electric and/or hydrogen to aircraft (e.g. hydrogen liquefaction facilities, hydrogen and electricity storage infrastructure, hydrogen refuelling infrastructure, electricity recharging infrastructure etc.) to support the deployment of the expected networks of electric and hydrogen flights in the different segments of the market Several aerodromes also develop their own internal energy production facilities for their own airside and landside needs and eventually beyond.	
Short-term	
Industry	Industry bodies (associations, clusters, etc.) undertake awareness raising campaigns to make aerodromes of all sizes, including smaller ones, aware of technological developments in aircraft propulsion and inform them about the challenges and opportunities the expected deployment of electric and hydrogen-powered flights in their segment(s) of the market represent.
Industry	Aerodromes engage in a reflection on challenges and opportunities, using for instance of the Aerodromes Factsheets developed by AZEA. They evaluate the nature and quantities of energy required and analyse the airport context (opportunities to become an energy hub, energy supply infrastructure and necessary expansions, space for new infrastructure, potential for on-site renewable energy production, etc.). Aerodromes engage with appropriate stakeholders (energy suppliers, transmission systems Operators (TSOs), airlines, local communities, etc.). On the basis of the hybrid, electric or hydrogen adoption plans identified with airlines, aerodromes validate with energy suppliers and other stakeholders the feasibility and viability of aerodromes transition plan.
Industry	Individual aerodromes communicate clear demand signals to Member States and regions regarding infrastructure locations requirement and capacity needs.
Public authorities	Member States develop plans in respect of the deployment of electric recharging and hydrogen refuelling for aircraft and report the progress in their national policy framework as

	mandated by the Regulation (EU) 2023/1804 on the deployment of Alternative Fuels Infrastructure (AFIR). This includes a focus on charging infrastructure including rollout, locations, feasibility and timeline.
Public authorities	Member States and regions assist aerodromes willing to transform into energy hubs by providing an adequate regulatory framework and support measures, including by strengthening their participation in regional initiatives (e.g. local Hydrogen Valleys).
Industry	Industry organisations (including joint initiatives like AZEA) develop and provide harmonised guidelines and procedures to aerodromes and ground handlers, to support the development and deployment of hydrogen and electric infrastructure.
Industry	Aerodromes identify (with the support of join initiatives like AZEA) and industry develops missing standards related to energy infrastructures supporting the operation of electric and hydrogen aircraft including recharging/refuelling facilities.
Industry	Aerodromes identify (with the support of joint initiatives like AZEA) regulatory gaps and barriers (e.g. permitting, etc.) related to the installation and operation of electricity and hydrogen production, storage and supply infrastructures and the servicing (including ground handling) of electric and hydrogen powered aircraft at aerodrome.
Public authorities	Member States address regulatory gaps and barriers (e.g. permitting, etc.) related to the installation and operation of electricity and hydrogen production, storage and supply infrastructures and the servicing (including ground handling) of electric and hydrogen powered aircraft at aerodrome.
Industry	Aerodromes capitalise on the already existing activities to supply hydrogen and electricity for airside (e.g. ground handling, electricity delivery to stationary aircraft) and landside usages under the airport carbon accreditation scheme
Industry	A sufficient number of aerodromes timely integrate the required infrastructure developments and transformation into their aerodrome master and urban plans (including possible on-site energy production infrastructure), ensuring alignment with permitting and local regulatory requirements in order to ensure the expected deployment of electric and hydrogen-powered flights in the different segments of the market.
Long-term	
Industry	Larger airports start planning for additional energy infrastructures to be able to deliver the high-power charging in order to address the raising demand in the Regional aviation and Medium Range market segments.
Industry	Aerodromes optimise infrastructure efficiency and plan for expansion, including diversification of fuel supply, to enable the operation of additional aircraft with higher passenger capacity.
Industry	Aerodromes progressively integrate digital twin models into their operations to connect airside energy consumption with weather and energy grid forecasts, incorporating AI models where relevant.
Industry	Individual aerodromes develop electricity and hydrogen demand ramp-up scenarios to establish a roadmap for the evolution of the consumption levels and the infrastructure requirements including possible on-site energy generation.
Operations at Aerodromes and Skills	
The necessary procedures and protocols are available, and the workforce is adequately trained at the required aerodromes to operate and maintain the energy infrastructure and supply the required electricity and/or hydrogen to aircraft.	
Short-term	
Public authorities	EASA and Member States develop EU-wide Standard Operating Procedures for hydrogen and electric ground handling and aircraft ground operation, including firefighting protocols, safety distance requirements, aerodrome capacity, and crew certification standards.
Industry	Aerodromes, ground handlers and energy suppliers to adapt operational processes (e.g. firefighting procedures, safety procedures, refuel protocols) and train their workforce to manage both regular and emergency procedures.
Industry	Aerodromes and operators initiate small-scale hydrogen refuelling and electric recharging demonstrations to support early aerodrome operations.

Long-term	
Public authorities	Member States establish mutual-recognition frameworks for ground crew certification across Member States.
Public authorities	Resilience audits for energy and safety systems are included into standard aerodrome certification processes.
Public authorities	Public-private partnerships are established to provide advanced training for hydrogen, electricity, and high-voltage ground operations.
Industry	Aerodromes and operators implement improvements to operating procedures based on experience gained in the short-term (e.g., refuelling with passengers on board, reduction of safety zones and stand sizes, etc.).
Investments & Finance	
Aerodromes identify and undertake necessary investments, incorporating them into master planning to support the development of market segments. Aerodromes have adequate access to finance.	
Short-term	
Public authorities	Member States and Regions develop plans to revitalise local and regional aerodromes.
Industry	Industry bodies or initiative like AZEA support aerodromes investment decision by developing appropriate guidance and decisions support tools.
Public authorities	Initial funding mechanisms are established by Member States and/or EU institutions support both the deployment of hybrid, battery-electric and hydrogen aircraft and the adaptation of aerodrome infrastructure simultaneously. The fund should prioritise small and regional aerodromes hosting early operations, and cover aircraft demonstration projects along with the installation of hydrogen and electric refuelling systems.
Public authorities	EU and national programmes support the development of hydrogen production, storage and supply at aerodrome on a phased approach that can start with non-aircraft services such as landside/airside mobility. Matchmaking events for stakeholders are organised to facilitate discussions and secure funding for aerodromes.
Finance sector	Private banking institutions facilitate access to low-interest loans and attract private funding through "green finance" certification.
Finance sector	EU institutions and Member States incentivise the channelling of private investments towards aerodromes via appropriate policies and incentives, as increasing the focus on sustainability criteria for investments from private banks and sovereign wealth funds (e.g. EU Sustainable Taxonomy).
Finance sector	Private financing institutions establish dedicated long-term funds for large-scale aerodromes infrastructure upgrades.
Finance sector	Member States and Regions mobilise public and private investments (e.g. European Regional Development Fund, infrastructure and energy provider funds) to finance aerodrome transformation and the deployment of the required energy infrastructure.
Finance sector	Launch dedicated EU and EIB funding windows under existing programmes (e.g. Innovation Fund) for hydrogen and electricity infrastructure at small and medium-sized aerodromes.
Long-term	
Finance sector	Member States and private funding institutions fund additional Infrastructure investment according to future aerodrome needs.

Aerodrome pillar: Enablers & Key activities

4.3.4 Certifications, Regulations and standards

The certification of the new concepts of hybrid, battery-electric and hydrogen-powered aircraft and engines is one of the main factors (with the existence of a market) conditioning the EIS of these new types of aircraft or engine. In the case of innovative hybrid, electric or hydrogen propulsion, the certification process represents a challenge, both for the authority and for the manufacturers.

Collaboration schemes between the authority and industry, like the EASA Innovation Partnership Contracts (IPC) or Pre-Application Contracts (PAC) or the set-up of regulatory sandboxes, will be important to accelerate the learning on both sides.

Before applying for a type certificate at the EASA, manufacturers will have to demonstrate 1) the necessary technical knowledge, 2) the maturity of their product and design organisation, 3) the availability of the first draft rulemaking material developed through one of the contracts mentioned above (IPC, PAC) and 4) to confirm the path towards certification using the CRL scale[55]. Based on that scale from 3 to 5 years may be necessary for a manufacturer with a solid experience to evolve from availability of draft rulemaking material (CRL 6) to mature draft generic elements of a certification basis (CRL 7), in the form of published Generic Special Conditions (SCs), Interpretative Material, or Means of Compliance (MoC), and at least another 5 years are needed to complete the certification process.

Obtaining a type certificate in 2035 would therefore require industry to reach CRL 6 by 2028/2029 and to have a solid design capability proven by a Design Organisation Approval (DOA) certificate.

The successful completion of the certification will require that appropriate funding is secured by industry, especially by SMEs and start-ups.

The first type certificates may be issued by EASA based on the development of policies such as SCs (e.g. SC E-19) and MoC. Policies will be developed benefitting from this cooperation with other Certification Authorities (FAA, TCCA, ANAC, UK CAA).

However, over time, to facilitate the certification process, adequate safety standards must be developed to cover these new propulsion technologies to support the amendment of Certification Specifications for the related aircraft (CS-23 and CE-25) and engines (CS-E; SC E-19). A progressive approach will be taken starting with smaller aircraft under CS-23, before the larger aircraft under CS-25. Close cooperation will be required between EASA, EUROCAE, ASTM and other Standards Development Organisations (SDOs) to support this step. An open-minded approach is needed as standards developed by non-aviation SDOs are also used for some aspects, thus benefitting from lessons learnt in other sectors.

The use of industry standards will be key to put in place a future-proof performance based regulatory system.

In addition to ensuring the certification of innovative aircraft and engines and amending the certification legal framework, EASA will have to ensure the adequacy of the overall aviation legal framework to support the deployment of hybrid, electric and hydrogen flights in Europe. This will require cooperation at global level, with International Civil Aviation Organisation (ICAO) and other international organisation as well as with the National Aviation Authorities in EASA Member States.

To develop the necessary technical expertise, conduct the required certification programmes, adapt the EU aviation regulatory framework, and ensure international coordination, EASA will need appropriate resources.

Achieving the required certification programmes, developing the necessary standards and ensuring the adaptation of the aviation regulatory framework will require to act along the following lines: developing knowledge on new technologies; harmonising policies and rules at international level; certifying aircraft; launching sandboxes to allow operations at small scale; enhancing aviation regulation; and increasing resources' availability.

55 The Certification Readiness Level (CRL) scale has been defined by the CONCERTO Project in Clean Aviation and introduced by EASA to assess the future certifiability of an innovative concept of operation, business model, and product/system (see definition of CRL levels here).

New Technologies Knowledge Development	
EASA, National Aviation Authorities (NAAs) and industry acquire necessary knowledge of the new technologies and related safety issues.	
Short-term	
Industry	Manufacturers to strengthen collaboration and spread their knowledge about new aviation technologies with EASA, NAAs and Standardisation Organisations (SDOs) to accelerate the establishment of standards.
Public authorities	EASA to develop knowledge on new technologies through involvement in R&I projects and initiatives to source the projects and support the certification process and the development of industry standards to be referred to in policies and regulatory material.
Industry	Manufacturers lead and share with EASA and other regulators the risks associated with hybrid, electric and hydrogen propulsion technologies (evaluation of dysfunctional aspects).
Public authorities	NAAs and EASA develop regulatory "sandbox" to support the demonstration of specific technologies in real-life environment, as the Norwegian International Test Arena for Zero and Low Emission Aviation and the full operational concept on a small scale.
Public authorities	Member States identify the specific authorities to be involved in a regulatory "sandbox", specifically for cross-border use cases.
Public authorities	EASA secures the knowledge sharing and dissemination of the results after closing the regulatory "sandbox".
Finance sector	Funding programmes supporting innovation and technology development together with certification, testing and regulatory sandboxes are available at the EU and national levels. These programmes should address different market segments, energy types and technologies in the short as well as long-term.
Long-term	
Public authorities	EASA and NAAs increase their knowledge on new technologies by collaborating with industry.
Harmonisation at International Level	
EASA, NAAs, Standardisation Organisations (SDOs) and International Organisations work together towards defining a common approach and common principles for certifying and operating hybrid, battery-electric and hydrogen-powered aircraft at the global level.	
Short and long-term	
Public authorities	EASA, in cooperation with global aviation authorities, to finalise global approach for certifying and operating hybrid, battery-electric and hydrogen powertrain and aircraft worldwide.
Public authorities	EASA to amend CS-23/27 to increase MTOW threshold for Hybrid and electric aircraft and rotorcraft in order to enable innovative products to be competitive.
Industry	SDOs promote the creation of standardisation Working Groups dedicated to new technologies and collaborate at the global level to monitor progress.
Industry	Manufacturers identify missing standards (including through join initiatives like AZEA) and engage in standardisation Working Groups to voice their priorities and work on their development as soon as technologies are mature.
Public authorities	Harmonise the national plans, regulations and standards between EU and Member States, as EU initiatives will have an impact at local level and several will be cross-border.
Aircraft Certification	
Adequate certification means are developed to support the expected EIS of hybrid, battery-electric and hydrogen aircraft.	
Short-term	
Public authorities	EU institutions facilitate access to certification for smaller companies by implementing measures to alleviate or compensate certification costs, including those of early engagement with ESA through IPC and PAC.
Finance sector	Public and private funds are available to cover all or part of EASA fees for start-ups and scale-ups.
Public authorities	EASA provides Special Conditions and Means of Compliance to enable the certification of powertrain via CS-E, CS-23 aircraft (2026-2027) and CS-25 aircraft (2028-2030). Certification requirements will be driven by aircraft concepts.

Industry	Manufacturers engage EASA early when planning the certification of new technologies to address critical gaps and ensure an equivalent level of safety, recognising the challenges posed by limited experience with new technologies.
Industry	Manufacturers support development of policies such as Special Conditions and Means of Compliance through use of EASA Innovation Services, ahead of applying for a type certificate.
Long-term	
Public authorities	EASA to finetune the certification policies and amend certification specifications based on experience gathered within projects and cooperation with global aviation authorities.
Aviation Regulation	
The regulatory framework is timely adapted to reflect the maturity of the technologies, to benefit of industry standards and to enable the operations of electric and hydrogen flights.	
Short-term	
Public authorities	EASA identifies the needs and adapts the regulations to include the battery-electric, hybrid and hydrogen-powered aircraft needs.
Public authorities	EASA ensures, at least, a level playing field for battery-electric, hybrid and hydrogen aviation compared to conventional and SAF aviation in term of resources and prioritisation.
Industry	In the light of the latest technological and market developments, Manufacturers (supported by AZEA and other initiatives) identify and communicate to EASA the needs of battery-electric, hybrid and hydrogen-powered aircraft that should be better addressed by adaptations to be introduced in the regulatory framework.
Long-term	
Public authorities	EASA continues to adapt the regulatory framework (initial airworthiness, operations, continuing airworthiness, licensing, aerodromes, ATM/ANS) based on the learnings from regulatory sandboxes and projects as well as based on exchanges and collaboration activities with NAAs and global aviation authorities.
Resources	
Availability of human and financial resources at the authority and industry side to develop the required standards and regulations.	
Short-term	
Public authorities	Under the next EU Multiannual Financial Framework (MFF) 2028-2034, the EU institutions adequately support EASA by providing the required resources for developing scientific expertise and technological capabilities, as well as by ensuring access to testing facilities.
Finance sector	Public and private financing institutions provide adequate resources to industry to support certification projects and the development of the regulatory framework.
Public authorities	EU institutions introduce a flexible staff cap in EASA to facilitate the management of workforce and then of innovation for certification and rulemaking tasks.
Long-term	
Finance sector	Private and public financial institutions ensure financial sustainability for further developing the regulatory framework and mature technologies by financing access to testing facilities and the establishment of regulatory sandboxes.

Certification, Regulations and standards pillar: Enablers & Key activities

4.3.5 Airspace Readiness[56]

Hybrid, battery-electric and hydrogen-powered aircraft may have performance envelopes (cruise speed, flight levels, etc.) that differ from those of legacy aircraft currently operating in the European airspace or may operate on specific flight and flow management rules taking aircraft characteristics and environmental performance into consideration. Their deployment may also lead to an increased number of operations in some market segments. Their integration into the European Air Traffic Management (ATM) network will therefore present challenges that need to be identified and addressed.

Aviation authorities and ANSPs in collaboration with aircraft operators will have to **prepare ATM design and procedural adaptations** as required to facilitate the **operational readiness of the European airspace** and the seamless entry-into-service of hydrogen and electric-powered aircraft in Europe.

According to the AZEA rollout scenario and the suggested Flight Network, detailed in appendix, the objective is to operate more than 250,000 flights by around 2030. This number is projected to increase to 6.4 million around 2040, and further to 20 million flights near 2050. These figures exclude UAM solutions, Helicopters and Airships, but do include new opportunity flights in the Small Air Transport sector and traffic that operates under VFR rules.

The EU wide flight network is expected to be fully operational by 2040. Consequently, airspace stakeholders will ensure **procedures for hydrogen and electric aircraft are established by 2030 and continuously optimised afterwards as normal ATM management practices.**

The main stakeholders involved in this pillar are the **ANSPs**, responsible for delivering Air Traffic Management services to flights within the EU, and **national civil aviation authorities**, tasked with regulating the airspace and harmonising the operations.


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To successfully incorporate hybrid, electric and hydrogen flights in the EU airspace, ensure airspace security and avoid bottlenecks, AZEA identified three enablers: developing airspace/route network design, enhancing operations, and ATM resources.

Table 4 Expected number of hydrogen and electric flights at the EU level

	2030+	2040	2050
Hydrogen (H2)			
# of flights in the EU	150,000	2,200,000	5,400,000
Electricity			
# of flights in the EU	100,000	4,200,000	15,500,000

56 Airspace/route readiness actions refer to the transformation of the existing VFR/IFR flight network and the growth thereof to include zero emission aircraft. These actions do not specifically refer to required operational adaptations foreseen in urban areas as described in the U-Space Concept of Operations (ref. CORUS-XUAM project under SESAR). It should be noted however that ongoing projects address Uncrewed Aerial Systems and Urban Air Mobility operations (UAS/UAM) and their alignment with ATM and U-Space EU strategies, including demonstration projects aiming for early harmonized implementation approach of UAM in low level airspace. Stakeholders are advised to consult progress in these programmes. In addition, stakeholders should refer to ongoing exploratory research in the context of SESAR regarding introduction of Zero emission aircraft.

Airspace Designs	
Airspace/routes and flight levels are established to support the entry-into-service of electric and hydrogen-powered aircraft.	
Short-term	
Public authorities	NAAs and ANSPs, possibly in coordination with EUROCONTROL as the Network Manager, revise airspaces routes and operational processes to ensure sufficient airspace capacity and continue providing the highest levels of air safety to operate battery-electric, hybrid and hydrogen-powered aircraft, considering initiatives such as the Single European Sky. This will include a possible redesigning of the low-level airspace, interaction with U-Space, and the identification or establishment of corridors to operate battery-electric, hybrid and hydrogen-powered aircraft over specific areas and routes.
Public authorities	EASA, in cooperation with EUROCONTROL, defines rules to harmonise airspace classification across Europe, including consistent application of Instrument Flight Rules (IFR) in controlled and uncontrolled airspace classes, with full consideration of regulatory requirements and specific operational requirements of battery-electric, hybrid and hydrogen-powered aircraft.
Public authorities	EU institutions, in coordination with Member States, develop regulatory and economic measures to incentivise the operation of battery-electric, hybrid and hydrogen-powered aircraft, while avoiding adverse effects on conventional aviation.
Industry	Operators assess and indicate to NAAs and ANSPs new business opportunities for battery-electric, hybrid and hydrogen-powered aircraft, to initiate airspace design processes as required. NAAs and ANSPs facilitate the uptake of these new business opportunities.
Industry	Operators assess diversion aerodromes and address fuel supply logistics for battery-electric, hybrid and hydrogen-powered aircraft into (strategic) flight planning.
Long-term	
Public authorities	EUROCONTROL continues the dialog with ATM stakeholders, including ATM Research centres, to plan and deploy Airspace Management, Air Traffic Flow Management and Air Traffic Services solutions related to battery-electric, hybrid and hydrogen-powered aircraft, including an extensive low-level IFR route network to accommodate routine low-level IFR battery-electric, hybrid and hydrogen-powered aircraft operations across Europe.
Industry	ANSPs deploy Air Traffic Control (ATC) tools to allow controllers to handle an increased diversity of aircraft performance to seamlessly integrate the initial demand of hybrid, battery-electric and hydrogen aircraft with fossil fuel or SAF powered aircraft, without a negative impact on the capacity of the European network.
Industry	ANSPs deploy future en-route Terminal Manoeuvring Area (TMA) ground platforms and aerodrome platforms, as foreseen in the European ATM Master Plan, with full consideration of battery-electric, hybrid and hydrogen-powered aircraft operations.
Airspace Operations	
Procedures for airspace operations in Area Control Centre (ACC), Terminal Manoeuvring Area (TMA), Control Region (CTR) and Upper Airspaces are developed to accommodate new aircraft types and technologies.	
Short-term	
Public authorities	EUROCONTROL defines processes for harmonised and continuous exchange of information between hybrid, battery-electric and hydrogen aircraft developers and the SESAR programme to ensure that aircraft requirements in the area of ATM are collected as early as possible and are adequately considered in the ATM R&D programme.
Public authorities	EUROCONTROL, in coordination with network stakeholders, models hybrid, electric and hydrogen flight network scenarios to support stakeholders' hybrid, electric and hydrogen operations strategy definitions.
Public authorities	EU institutions, and Member States, in coordination with EUROCONTROL, reduce en-route charges towards electric and hydrogen-powered aircraft to provide a financial incentive.
Public authorities	EUROCONTROL and Member States drive ANSPs towards a green transition by raising awareness of the current system's limitations and the necessity to integrate sustainability aspects for future operations.
Public authorities and Industry	NAAs, ANSPs, Aerodromes and Operators develop local CONOPS to accommodate initial low-level flights of hybrid, battery-electric and hydrogen aircraft in areas with existing Communication, Navigation, and Surveillance (CNS) infrastructure.

Public authorities and Industry	EASA, NAAs, ANSPs, Aerodromes, Operators and EUROCONTROL define and validate harmonized IFR procedures for arrival, approach, and landing tailored to fixed-wing hybrid, battery-electric and hydrogen aircraft, as well as for eVTOLs.
Public authorities and Industry	EASA, NAAs, ANSPs and EUROCONTROL define and validate harmonized Airspace Management (ASM) and Air Traffic Flow and Capacity Management (ATFCM) procedures to incorporate specific operational needs of battery-electric, hybrid and hydrogen-powered aircraft.
Industry	Manufacturers define and communicate aircraft performance characteristics to the SESAR 3 JU or its successor and to EUROCONTROL, while also identifying critical safety and interoperability elements considering variations in aircraft performances by means of agreed network Concept of Operations (CONOPS)
Industry	ANSPs, Aerodromes, EUROCONTROL and Operators implement validated air traffic management procedures and discuss with SESAR JU or its successor how to initiate the development of new technologies.
Long-term	
Public authorities	EASA, EUROCONTROL and ANSPs and ATM Research Centres define, validate and harmonise ATM procedures, particularly for arrival, approach, and landing tailored to electric and hydrogen-powered aircraft. They deploy initial routes linking aerodromes with and without (in the case of tankering operations) and incorporate (where possible) environmental performance in preferred ATM operations. They also continuously improve operations for extensive battery-electric, hybrid and hydrogen-powered aircraft operations across the European network.
Public authorities and Industry	NAAs, ANSPs, Aerodromes and Operators rollout and/ or expand arrival and departure procedures for electric and hydrogen-powered aircraft to all aerodromes with or without (in case of tankering operations) energy supply.
Industry	ANSPs, Aerodromes, Operators and EUROCONTROL define and validate the Concept of Operations (CONOPS) for hybrid, battery-electric and hydrogen aircraft, ensuring harmonisation of procedures at European and global levels.
Industry	ANSPs, EUROCONTROL and operators engage with SESAR 3 JU or its successor to develop new technologies related to the widespread operation of battery-electric, hybrid and hydrogen-powered aircraft.
ATM Resources	
Availability of appropriate people and resources to implement and operate established ATM design and procedures.	
Short-term	
Public authorities	EU institutions and Member States revise the economic regulatory framework to allow ANSPs' and regulatory authorities to invest on resources (personnel, procedures, and tools) to adequately integrate and manage the introduction of battery-electric, hybrid and hydrogen-powered flights and provide the necessary support to National Supervisory Authorities (NSA) in the management of the European airspace.
Public authorities	EU institutions and Member States set up an economic regulatory framework allowing ANSPs to deploy initial CNS infrastructure to support low-level IFR flights of battery-electric, hybrid and hydrogen-powered aircraft in early operational areas.
Public authorities	EU institutions ensure appropriate funding opportunities (e.g. SESAR or initiatives under the future R&I Framework Programme) to support the integration of battery-electric, hybrid and hydrogen-powered flights into the airspace.
Public authorities	ANSPs and Aerodromes ensure that their staff have access to training programmes focused on battery-electric, hybrid and hydrogen-powered aircraft to build the required skills and sustain sufficient resource availability.
Long-term	
Public authorities	NAA and ANSPs assess and progressively deploy CNS to support the extensive low-level IFR route network enabling flights of battery-electric, hybrid and hydrogen-powered aircraft.

Airspace pillar: Enablers & Key activities

4.3.6 Operators

The deployment of hybrid, electric and hydrogen flights in Europe ultimately depends on operators' and lessor's decisions.

Operators and lessors need to **understand the opportunities** provided by these new technologies and their impact on their business models which depend on the incremental or sometimes disruptive technology development (e.g. battery density) by manufacturers. This transition implies a new paradigm for the operators, compared to their current operations. On the other hand, clear and credible market demand signals from operators and lessors are also essential to support manufacturers' investment decisions and help them to secure the required financing as highlighted in Pillar 1. Operational demonstrations of the evolving potential of these technologies should be facilitated and communication towards policy makers and the public developed.

Operators and lessors will adopt battery-electric, hybrid or hydrogen-powered aircraft only when their operation, instead of legacy aircraft, generates **viable business cases**. Appropriate incentives will have to be made apparent in tangible business terms to allow operators and lessors to adopt new aircraft, to share the costs of this transition, and to justify and de-risk the large investments required.


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In parallel, operators will need support to **develop the network** of hybrid, electric and hydrogen flights. To support early deployment, the most appropriate framework(s) should be explored to provide financial support to airlines for the acquisition and deployment of these technologies, including through targeted EU funding instruments, calls for tenders, or national support schemes such as specific projects or State aid.

Any such framework should be designed in a way that does not jeopardise the continuity and reliability of regional air services. Effectively, initial zero- and low-emission products will be ideally suited to short-haul routes (both passenger and cargo) that align with the footprint of the continent's underutilised network of regional aerodromes.

When replacing existing fleets, operators may have to adapt their business model to the performances of these new aircraft while new business models (e.g. on-demand flight) may also provide new opportunities. In addition, these technologies may provide new transport solutions, allowing to develop new markets in some segments (e.g. regional air mobility).

The development of the market will depend on the capacity of policy makers to pass clear, consistent and reliable messages to all stakeholders when creating policies and measures to facilitate the decisions and actions of the electric and hydrogen-powered aviation industry stakeholders.

The development of the network will also require investments from all the stakeholders as identified under the different pillars. Public and private sectors will need to cooperate to redirect fundings towards the transformation of the sector thanks to the creation of specific incentives. Measures to boost market adoption should be ambitious, coordinated, and feasible, as we have to get them right from the get-go. Consortia of multiple parties can be created to spread the financial burden and risk with governments involved. This could involve the introduction of government guarantees established for preliminary payments, which could contribute to reduce the investments costs for operators.

Finally, measures to accelerate the entry-into service and the **replacement of existing fleets** should be developed.

AZEA has identified four enablers to meet this objective: technology demonstration, business case, development of the market, and fleet renewal.

Business Case	
Aircraft operators have a viable business case to operate hybrid, battery-electric and hydrogen aircraft.	
Short-term	
Public authorities	EU institutions and Member States develop the policies and measures to ensure viable business cases for the operation of hybrid, battery-electric and hydrogen-powered aircraft. This could include, amongst others, offering tax incentives, such as tax breaks for private investments and low-interest financing for airlines and operators.
Public authorities	EU institutions, Eurocontrol and NAAs ensure that hybrid, battery-electric and hydrogen-powered aircraft are not penalised when entering the market by basing en-route and aerodrome charges on aircraft type and environmental performance rather than solely on weight, incentivising the adoption of these new aircraft rather than penalise conventional aircraft.
Public authorities	EASA and NAAs support operators in assesing battery-electric, hybrid, and hydrogen aircraft business models through the development of demonstration programmes, such as the establishment of a regulatory "sandbox" on commercial routes, to test commercial operations.
Public authorities	Member States and regions develop incentives to support the development of new green air mobility offers based on under-used aerodromes, in particular int the Regional Air Mobility and Regional Aviation segments.
Industry	Operators identify potential for new business models and markets in segments like regional air mobility. They collaborate with aircraft manufacturers, aerodromes and energy suppliers to adapt their business models when necessary.
Industry	Operators ensure that sustainability information is made available and displayed on online booking platforms for customers.
Long-term	
Public authorities	EU institutions and Member States facilitate and support the creation of new airlines operating hybrid, battery-electric and hydrogen-powered aircraft.
Fleet Management	
Operators have the financial capacity and the appropriate incentives to invest in renewal of their fleets.	
Short-term	
Public authorities	EU institutions and Member States develop appropriate frameworks, with potentially policy targets, to support the renewal of existing fleets with hybrid, battery-electric and hydrogen-powered aircraft.
Finance sector	Private financial institutions to develop and promote green bonds specific to renewal of the fleet with hybrid, battery-electric and hydrogen-powered aircraft.
Industry	Operators incentivise the use of hybrid, battery-electric and hydrogen-powered aircraft by prioritising them in their overall operation.
Long-term	
Public authorities	EU institutions and Member States ensure that EU green operators using hybrid, battery-electric and hydrogen-powered aircraft as part of their fleet are not penalised vis-à-vis non-green Third Country Operators (TCO) who are not using these types of aircraft for their operators.
Network Development	
The network of electric and hydrogen-powered flights including new markets and routes develops at the expected pace.	
Short-term	
Industry and Public authorities	Operators and manufacturers, together with public authorities and EUROCONTROL (including through initiatives like AZEA), will identify opportunities for electric and hydrogen-powered flights with the aim of informing policy making and supporting industry investment decision.
Public authorities	EU institutions and Member States explore the most appropriate framework(s) to support the early deployment of electric- and hydrogen-powered flights, including through adaptation of legislations, EU funding instruments, calls for tenders, or nationally designed support schemes such as specific projects or State aid. This should take into account the date for the entry-into-service of the different technologies in the different market segments

Public authorities	EU institutions and Member States provide clear guidance in the form of political and financial support available, such as grants, tax credits, and public-private partnerships.
Public authorities	EU institutions and Member States establish regular dialogue with industry, including aircraft and engine manufacturers, as well as airline operators, to align incentives with technological advancements.
Public authorities	Member States and regions incentivise aerodromes to plan hydrogen and electric flights by, for example, prioritising aerodrome slots for hybrid, battery-electric and hydrogen-powered aircraft.
Public authorities	Member States and Regions promote the creation of networks of pioneer aerodromes developing the required capabilities to service battery-electric and/or hydrogen-powered aircraft in different market segments. Consideration could be given to investigate reopening old case routes and/or aerodromes for regulatory “sandbox” as well as for initial flight planning.
Industry	Operators work jointly with powertrain and aircraft manufacturers, and aerodromes to support the definition and preparation of potential regulatory sandboxes (e.g., defining most viable (pilot) routes and assess market access strategies (e.g. initial commercial routes).
Industry	Operators (including cargo operators) promote the environmental benefits of battery-electric, hybrid, and hydrogen-powered aircraft by issuing certificates or other proof, enabling companies to demonstrate their commitment to reducing their environmental footprint in line with Corporate Sustainability Reporting Directive (CSRD) reporting requirements and the Sustainable Taxonomy Framework.
Public authorities	Member State and regions lead by example, where and when possible, in the adoption of hybrid, battery-electric and hydrogen-powered aircraft. Examples include the usage of hybrid, battery-electric and hydrogen-powered aircraft by government officials, medical services, or the military to demonstrate the trustworthiness of the technology and aircraft.
Public authorities	Member States define annual milestones and Key Performance Indicators (KPIs) to guide technology deployment and market readiness.
Long-term	
Public authorities & Industry	Regions and operators create and participate in cross-sector clusters and shared test regions to strengthen ecosystem collaboration, with the participation of operators.
Financial Incentives	
Development of financial incentives for operators and lessors to adopt electric and hydrogen aircraft.	
Short-term	
Public authorities	EU institutions, Member States and regions implement comprehensive regulatory measures and financial incentives across the aviation market to create supportive conditions, including targeted incentives that promote battery-electric, hybrid and hydrogen aviation relative to conventional operations.
Public authorities	EU institutions ensure that the uptake of hydrogen and electricity by operators is supported with the allocation of free allowances under the EU ETS the same way SAF is supported.
Public authorities	EU institutions assess the possibility to revise the existing state aid framework to allow Member States to provide financial support to the purchase of hybrid, battery-electric and hydrogen-powered aircraft.
Finance sector	Public and private financial institutions (e.g. EIB, private funds) create purchase guarantees or adjusted loan conditions for hybrid, battery-electric and hydrogen-powered aircraft to incentivise and support operators and lessors in their acquisition.
Long-term	
Finance sector	Private financial institutions develop tailored financial structures that mitigate risks and improve the attractiveness of investments in operators of hybrid, battery-electric and hydrogen-powered aircraft.

Operators pillar: Enablers & Key activities

Recommendations

Policy Makers and public authorities

EU aviation strategy

The **European Commission** should develop an aviation strategy that adequately supports this Roadmap, including actions to support the manufacturing of hybrid, battery-electric and hydrogen-powered aircraft and their gradual deployment in Europe. It should also adopt strong political statements supporting these technologies.

National battery-electric, hybrid and hydrogen aviation strategies

Member States should develop national strategies for the deployment of hybrid, battery-electric and hydrogen-powered aircraft operations. These strategies should address both aviation and energy dimensions, covering the entire value chain (renewable and low-carbon energy supply, aircraft manufacturing, infrastructure deployment for the aerodrome ecosystem). They should be developed on the basis of a close cooperation between Member States in order to ensure a coherent deployment of hybrid, electric and hydrogen flights in the EU, as well as cross-border cooperation whenever possible.

Member States should not only consider the replacement of existing fleets but also evaluate together with Regions the potential of those technologies to develop new air mobility offers on regional and intra-regional routes.

Involvement of public authorities

Considering the important investments required, **policy makers and public authorities** must provide strong support to the deployment of the hybrid, electric and hydrogen flights in Europe to guarantee its success and share the risk between public and private sectors.

Creation of incentives

EU, Member States and Regions should create incentives to attract private investments in electric and hydrogen aviation and accelerate the development of projects.

Creation of a seamless financing scheme

The **European Commission** should ensure that, in the context of a 'Clean and Smart Aviation moonshot' proposed under the next EU Multiannual Financial Framework, a coherent sequence of funding programmes is developed to support the transition of aviation to hybrid, electric and hydrogen propulsion from research and innovation to development, demonstration, industrialisation and full-scale deployment and integration into the European airspace.

Aviation and energy policy alignment

The **European Commission and Member States** should better coordinate their policies within the EU, while the policies addressing the energy and aviation sectors should be aligned to guarantee the success of the transition towards hydrogen and electric aviation. The energy required by hybrid, electric and hydrogen flights must be adequately addressed in the different energy strategies and planning.

Development of cross-border centres of excellence and regulatory sandboxes ('test arena')

To help regulators and industry (aerodromes, airlines, etc.) understand the impact of electric and hydrogen propulsion on commercial operations, **Member States,** in cooperation with their **National Aviation Authorities, EASA and Industry,** should establish regional cross-border centres of excellence to test, through regulatory sandboxes, specific technologies in real-life (operational) environment in the different segments of the market. Teose centres will contribute to the development of an appropriate regulatory framework and supporting the coordinated deployment of related infrastructure and services.

Industry

Demonstration of the aviation market viability

Manufacturers should demonstrate the economic viability of battery-electric, hybrid and hydrogen aviation business models and business cases, and present them to every stakeholder, from investors and financial institutions to customers, including national and regional public authorities and aerodromes. The specific value proposition of zero-emission aviation should be promoted in these demonstrations. This approach will enhance credibility and help securing orders, while also attracting funding.

Aircraft deployments

Operators should start considering how hybrid, battery-electric or hydrogen-powered aircraft could progressively integrate into their current fleet or offer them new business opportunities, starting from the regional and intra-regional market segments. They should closely cooperate with individual aerodromes to provide them with the necessary visibility on the required infrastructure adaptations and support their investment decisions.

Energy production and distribution to aerodromes

Energy suppliers expecting to supply into this market should start assessing the renewable and low-carbon electricity and hydrogen needs for aviation at Member State level and by type of aerodrome, with the aim of phasing their future production capabilities to address future demand. To this end, **individual Aerodromes and Operators** should regularly provide **Energy suppliers** with updated information on their current and projected electricity and hydrogen demand.

Energy suppliers and individual Aerodromes should work together to identify the most efficient mode of energy transport for each aerodrome use case. This is particularly important for hydrogen distribution, since hydrogen will be primarily distributed by truck in gaseous form for smaller aircraft and for larger aircraft use cases in liquid form in the early stages of deployment. For large airports it is expected that as demand grows liquid hydrogen supply chains will transition to gaseous pipeline transport to the airport or adjacent with liquefaction at or adjacent to the airport.

Electricity Transmission System Operators (TSOs), in close coordination with Member States, should start planning the required grid upgrades to ensure that aerodromes are adequately integrated into the network and that the grid can accommodate the growing demand for electricity in aviation. Similarly, **Hydrogen Transmission Network Operators (HTNOs)** should also start planning the deployment of the required infrastructure to ensure that relevant aerodromes have future plans to connect them to the network by pipeline, including through links to the cross-border Hydrogen Backbone.

Energy price transparency and predictability

Operators should regularly communicate to Energy suppliers and propulsion technology developers

the price they are willing to pay for electricity and hydrogen for use in aircraft.

Energy suppliers should provide **Operators and Aerodromes** with clear and transparent energy price projections or market pricing instruments to facilitate the conclusion of long-term offtake agreements with ideally more predictable pricing and transparent pricing mechanisms, supporting increased affordability over time.

Infrastructure development

Aerodromes should start without delay assessing with their customers, energy providers and other local actors the challenges and opportunities brought by the upcoming introduction of electric and hydrogen propulsion in aviation. They should start planning and initiating their transformation and including demand driven and phased infrastructure development options. In particular, aerodromes should collaborate with energy providers and distributors to anticipate energy shortage or surplus and work with energy suppliers, infrastructure providers and operators to ensure efficient investment in the energy infrastructure. They should also identify permitting and regulatory gaps, overlaps or sticking points for hydrogen **infrastructure**.

Small regional aerodromes that will play a decisive role in the development of new air mobility offers should consider how new opportunities (like transforming into energy hubs) may compensate the lack of operated commercial routes and sustain their business model.

Skills and resources development

Aviation industry, from manufacturers and maintenance organisations to aerodromes and operators, should start preparing the required adaptation of their resources (such as skilled workforce, procedures and tools) to adapt them to the new propulsion technologies and their use in operations.

Educate end-users

The **Aviation industry**, with the support of public authorities, such as EASA, should communicate and educate end-users (passengers, freight) and the wider public about the benefits of the deployment of hybrid, electric and hydrogen flights supported by the AZEA Roadmap.

Collaboration, sharing of information and strategic partnerships

Aviation and energy industry should continue to collaborate at EU level through the Alliance for Zero-Emission Aviation (AZEA) to share knowledge, foster coordination and speak with one voice to advocate sector's needs.

Promote and implement the AZEA Roadmap

Aviation industry should build on the broad sector's commitment demonstrated by the Roadmap to promote it to policymakers in Europe and beyond, with a view to transforming it into a political vision.

AZEA members should also promote the AZEA Roadmap within the aviation industry, encouraging the different stakeholders to consider the actions included in the Roadmap and contribute to them for their own part.

Financing organisations

Funding from public and private investors

Public financial institutions (EIB, Regional Funds, Innovative Funds, etc.) and **private financial institutions** (Infrastructure funds, Energy funds, etc.) should be prepared to support the **significant** CAPEX and operational costs needs expected to be required throughout the entire aviation value chain (manufacturers, energy providers and distributors, aerodromes, operators) to enable the deployment of hybrid, electric and hydrogen flights in Europe.

Support to public organisations

EU and Member States should provide the appropriate resources and funding to public organisations that are key actors in the transition of aviation to electric and hydrogen propulsion, including EASA, NAAs and ANSPs, to address the challenges outlined in the Roadmap.

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MONITORING AND EVOLUTION

The actual deployment of hybrid, electric and hydrogen flights in Europe will depend on the actual decisions taken and the measures implemented by the public and private stakeholders concerned. By defining objectives and the measures to be taken, the Roadmap provides a tool to measure the effectiveness of the actions taken and the progress made.

To remain an effective and accurate tool, the Roadmap must be regularly adapted to the evolution of the aviation sector.

Monitoring high-level indicators can help identifying the main adjustments needed.

The table below presents the list of KPIs and the monitoring approach to assess the evolution of the Roadmap. The selected KPIs are simple and straightforward to facilitate the monitoring of the Roadmap. These KPIs might be updated over time, while other new KPIs might be introduced in the light of relevant market and ecosystem developments. They can also be broken down into other more detailed KPIs to support a more detailed progress monitoring.

ID	Key Performance Indicator	Monitoring	Frequency
01	Maturity/Reality index number Maturity of the technology bricks per product categories	AZEA	Yearly
02	Aircraft fleet deployment • # of entry-into-service of aircraft ✓ Per market segment ✓ Per energy type	EASA certification or Eurocontrol new aircraft	Yearly
03	Energy capacity and delivered • Amount of gaseous and liquid hydrogen (tonne) and electricity (MWh) aerodromes are capable to supply • Amount of gaseous and liquid hydrogen (tonne) and electricity (MWh) delivered by aerodromes to supply aircraft	Union Database (UDB)	Yearly
04	Aerodrome transformation • # of aerodromes planning adaptation of their infrastructure • # of aerodromes equipped with recharging/refuelling infrastructures	ACI EUROPE data	Yearly
05	Certification • # of type certificate issued by EASA for hybrid, battery-electric and hydrogen-powered aircraft or engine	EASA certification	Yearly
06	Network and flights development • # of flights • Amount of passenger.km	EUROCONTROL data	Yearly
07	Public incentives • Amount of public fundings from EU and national funds	Publicly available data	Yearly

Table 5 - Indicators to monitor the AZEA Roadmap

Following the KPIs enables to understand how much the Roadmap objectives are deviating from the reality. After a major change or approximately

every three years, the Roadmap would need an update to comply with the actual aviation sector situation.

Two main elements of the Roadmap can be updated over time to ensure the consistency of the Roadmap, the AZEA ambition with quantitative objectives, and detailed activities.

First, the ambition of AZEA to develop hydrogen and electric flights in Europe should be updated to fit with the reality. The objectives should be revised every three years based on an updated scan of the environment and priorities of the members, as well as performance indicator. AZEA can set new objectives matching the actual situation and their updated ambition.

Second, the underlying activities should be adjusted to modify the potential start date and duration of the activity. Additional activities could be added, and previous activities can be removed in this new version.

WAY FORWARD

With this roadmap, the Alliance for Zero-Emission Aviation and its 200 members are proposing to the entire aviation ecosystem an ambitious goal for the deployment of battery-electric, hybrid and hydrogen flights in Europe, along with a set of actions to achieve it.

The deployment of zero-emission aviation technologies involves complex challenges for all actors in the ecosystem.

Manufacturers face the dual challenge of developing, certifying, and industrialising new aircraft and powertrains, while securing and adapting their resources, as capital expenditure and their workforce, to novel technologies such as batteries and hydrogen fuel cells as well as ensuring the infrastructure is present to deliver the fuel required to operators.

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Operators and airlines must adapt their business models and operations to new aircraft capabilities and performance profiles. They require viable business cases supported by risk-sharing mechanisms, incentives, and clear market demand signals to justify fleet renewal investments and clarity on supporting airport infrastructure development.

Aerodromes must secure the supply of electricity and hydrogen, adapting infrastructure, operations, and regulatory compliance to safely handle hydrogen and electric aircraft. This requires significant investment, planning, and coordination with energy providers and regulator, infrastructure companies, operators and regulators.

Energy suppliers and infrastructure providers need to develop plans to be able to scale up the production of renewable and low-carbon electricity and hydrogen to satisfy the growing zero-emission aviation needs over time as demand becomes visible and ensure efficient and timely distribution to aerodromes and maintain competitive pricing to support the economic viability of zero-emission flights.

Energy suppliers, Operators and Aerodromes must establish regular exchanges on expected electricity and hydrogen production and distribution costs and on the Operators' willingness to pay. This should pave the way for the conclusion of appropriate offtake agreements.

EASA, regulators and standardisation organisations face the challenge of accelerating certification processes for innovative propulsion technologies, adapting regulations and developing new standards while maintaining safety and harmonising internationally.

Air Navigation Service Providers (ANSPs) must prepare the European airspace for the integration of aircraft with different performance characteristics and increased traffic volumes, ensuring seamless and efficient operations, while continuing ensuring the safety of operations.

To ensure a successful implementation of this Roadmap, the following key milestones and actions are critical in the near term (up to 2035):

- Effective demonstration of electric, hybrid and hydrogen technologies,
- Preparation of the ecosystem for market entry,
- Identification and support of key regions and aerodromes,
- Development of low-cost energy production for aviation,
- Creation of cross-industry standards for low-carbon hydrogen usage,
- Engagement with operators to remove entry barriers and enable fleet renewal.

AZEA members are committed to promoting the roadmap and contributing to its implementation by undertaking the actions incumbent upon them.

They call on all relevant stakeholders to join them in this journey towards a revolution in aviation and to contribute for their part to its success.

AZEA members call on public authorities at EU, national and regional levels to integrate zero-emission aviation in their respective policies, provide the necessary regulatory framework and develop the required supports and incentives.

Finally, AZEA members invite private and public financial institutions to work closely with industry to support the massive investments needed and to contribute to the transformation of aviation into a climate-neutral mode of transport.

Annexes

1. AZEA

Objectives

In June 2022, the European Commission established the Alliance for zero-emission (AZEA) as a platform to foster collaboration between all aviation stakeholders to support the transition of European aviation towards low/no in-flight climate harmful emissions ('zero-emission') and promote the competitiveness of the European aeronautics industry.

The specific objective of AZEA as defined by its Declaration is to "to prepare the aviation ecosystem for the earliest possible entry-into-service of hydrogen- and electric-powered aircraft", in other words to address all barriers and requirements stemming from the use of electricity and hydrogen as novel fuels to power aircraft. It covers all technologies leveraging hydrogen and electricity as power source (battery-electric, hybrid, fuel cell, hydrogen combustion, etc) and all market segments in which these aircraft are expected to operate within the 2050 timeframe.

AZEA brings together more than 200 members representing all the different categories of stakeholders involved, including representatives from aircraft and powertrain manufacturers as well as their supply chain, airlines and lessors, aerodromes, air navigation service providers, energy producers and distributors, research and standardisation organisations, regulators, aviation authorities, industry associations, regions, public and private investors, trade unions, environmental interest groups, as well as the European Union Aviation Safety Agency (EASA), Eurocontrol and the Clean Aviation Joint Undertaking (CAJU).

AZEA members jointly work to identify all barriers and requirements to the entry into commercial service of these aircraft, proposes objectives to the entire ecosystem, identify the tasks to be performed by the different stakeholders and establish recommendations towards industry, public entities and financing organisations.

In June 2024, AZEA published a Vision setting objectives and identifying hi-level requirements for the deployment of hybrid, electric and hydrogen flights in Europe.

With the present Roadmap, AZEA details the path toward the Vision to create synergies and momentum amongst all stakeholders involved.

Membership (April 2026)

Abelo Capital Aviation Management Limited
ACI-Europe
Aciturri Aeronáutica
Advanced Drivetrain Technologies
Aegean Experts
AELIS Group
Aer Arann Islands
AerCap Holdings
Aernnova
Aeromechs
Aeroport de Bordeaux
Aeroporto Guglielmo Marconi di Bologna
Aéroports de Paris (Groupe ADP)
Aeroports Públics de Catalunya
Aerospace and Defence Industries (ASD)
Aerospace Valley
Air France-KLM
Air Liquide
Air Products
Airbus S.A.S.
Aircraft Design & Certification
Aircraft Electronics Association
Aircraft Leasing Ireland
Airlines for Europe (A4E)
Airport Regions Council
Airport Wroclaw
Airsight
ALBATROSS Holding GmbH
Amedeo Ltd.
Amelia
Ascendance Flight Technologies
ASL Group

Asociación Cluster de Aeronáutica y Espacio del País Vasco – HEGAN

Association of European Research Establishments in Aeronautics (EREA)

ASTM International

Atlas LTA Advanced Technologies

ATR

Aura Aero

Aviagility

Avinor

Avions Mauboussin

Aytana Aerospace & Defence

BETA Technologies

Beyond Aero

Blue Spirit Aero

Bosch General Aviation Technology GmbH

Bundesverband der Deutschen Luft- und Raumfahrtindustrie e.V. (BDLI)

Bureau de Normalisation de l'Aéronautique et de l'Espace (BNAE)

CANSO

CEN and CENELEC

Centre of Competence for Climate, Environment and Noise Protection in Aviation (CENA)

Centro Italiano Ricerche Aerospaziali (CIRA)

CHESCO - Center for Hybrid Electric Systems Cottbus

Clean Aviation Joint Undertaking

Collins Aerospace Ireland

Compañia Española de Sistemas Aeronáuticos

Conscious Aerospace

Consorcio del Aeropuerto de Teruel

Cranfield Aerospace Solutions

Cranfield University

DAHER Aerospace

Den Helder Airport

Destinus

Deutsches Zentrum für Luft- und Raumfahrt (DLR)

Dovetail

DronePort/Brustem Airport

Dublin Airport Authority (daa)

EasyJet

EDEIS

EDF

EENUEE

EH Group Engineering

Electric Flying Connection (EFC)

Electron Aerospace

Elixir Aircraft

ELSA Industry

Elysian Aircraft

Enagás Infraestructuras de Hidrógeno

Engie

Estonian Aviation Academy

Euroairport (Basel-Mulhouse-Freiburg)

EUROCAE

Eurocontrol

European Business Aviation Association (EBAA)

European Cockpit Association

European Federation for Transport and Environment

European Flyers

European Regional Aerodromes Community (ERAC)

European Regions Airline Association Ltd. (ERA)

European Union Aviation Safety Agency (EASA)

EVIA AERO

Federation of European Tank Storage Associations (FETSA)

Fleasy

Flughafen Friedrichshafen

Flying Whales

flyvbird GmbH

FMO Airport Münster/Osnabrück GmbH

FokkerNextGen

Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung

FSR TU Darmstadt

Fundación CTA - Centro de Tecnologías Aeronáuticas

GE Avio

General Aviation Manufacturers Association

GKN Aerospace Sweden AB

Grasshopper Air Mobiity

Green Aerolease

Green Aviation Hub

Groningen Airport Eelde

Groupe Absolut

H2Fly

H3 Dynamics SARL

Hamburg Aviation

Hamburg University of Applied Sciences (HAW Hamburg)

Heart Aerospace

Hevel Eilot Hub

Hydrogen Europe

IATA

IBEROJET (Evelop Airlines SA)

IMIEU

impact on sustainable aviation e.V.

IndustriAll European Trade Union

Ingeteam

Instituto Nacional de Tecnica Aeroespacial (INTA)

Intelligent Energy

International Council on Clean Transportation (ICCT)

Irelandia Aviation Ltd

ITP Aero

Jeppesen

Lazarski University

Leibniz University Hannover, Institute for Electric Power

Leonardo

LICRIT s.r.o

Lilium

Linde

Lufthansa Innovation Hub

Łukasiewicz Research Network - Institute of Aviation

LYNEports

Maeve Aerospace

Magpie Aviation

Ministerium für Umwelt, Naturschutz und Verkehr des Landes Nordrhein-Westfalen

MTU

Napier Park Global Capital

Netherlands Airport Consultants (NACO)

New Electric Aircraft Engines-GSI

Nordic Aviation Group

Nordic Initiative for Sustainable Aviation (NISA)

Normandie AeroEspace

Norwegian University of Science and Technology (NTNU)

NOW GmbH

nrg2fly

Odys Aviation

Office national d'études et de recherches aérospatiales (ONERA)

Panta Holdings

Pipistrel

Poznan Airport

Pratt&Whitney Rzeszow

Région Nouvelle-Aquitaine

Région Occitanie / Pyrénées – Méditérannée

Rhein-Neckar Flugplatz (Mannheim)

Roland Berger

Rolls-Royce

Royal Netherlands Aerospace Centre (NLR)

Ruhr University Bochum, Chair of Thermal Turbomachines and Aeroengines

SAE International

Safran

SATA Air Açores

Scandinavian Seaplanes

Service technique de l'Aviation civile (STAC)

SESAR 3 Joint Undertaking

SINTEF Energi AS

SiriNoR

SKYCORP

SkyCrest Aviation SPC

SONACA

Stichting AeroDelft

Stichting Luchtvaart in Transitie

Stralis Aircraft

Supernal

Swedavia

Swedish Aviation Industry Group (SAIG)

Swiss Federal Office of Civil Aviation (FOCA)

Terega

Thales

To70

TOFF MOBILITY

Torino Airport - SAGAT

TU Delft

TUI AG

ULPower Aero Engines

Universal Hydrogen Europe SAS

University of Southampton

VÆRIDION

VELICA

VGA

Vinci Concessions

Volocopter

VoltAero

VZLU Aerospace, a.s.

Wankel Aviation GmbH

WheelTug

Widerøe Zero

Wizz Air Innovation

Wright Electric

Zadar Airport

ZAL Zentrum für Angewandte Luftfahrtforschung

ZE-Aviation Alliance

ZeroAvia

Ziegler Aerospace SA

2. AZEA aircraft rollout detailed scenario

The scenario for the rollout of hybrid, battery-electric and hydrogen-powered aircraft in the different aviation market segments used as basis for this Roadmap is based on two extreme scenarios, the 'baseline' scenario and the 'ambitious' scenario.

Those two scenarios have been developed using input from AZEA members and considering historical Internal Combustion Engines (ICE) statistics to include the risk of unforeseen events prior to the entry-into service of new aircraft.

They consider several factors related to the EIS of the different aircraft type and sizes, the propulsion technologies and their associated energy requirements based on current and future travel patterns. Additional aspects, as the project's necessary investment and the complexities of disruptive aviation systems and their development, were also included, and enable to describe the evolution of the European fleet between 2023 and 2050. The specific assumptions underlying the two rollout scenarios differ and are described below.

The 'baseline' scenario uses a conventional market modelling approach. It provides a basis for the replacement of conventional aircraft but does not capture entirely the impact of the new propulsion technologies on the possible development of new market. This scenario incorporates restrictive assumptions on possible growth, reflecting limitations in technological and infrastructure investment. These assumptions consider factors such as technology development, certification processes, industrialisation and profitability.

In contrast, the 'ambitious' scenario is based on the creation of new markets and business models for airlines. This scenario is more optimistic as it is depending on future regulations, the ramp-up of production capacities and the opening of new markets. It relies on two complementary approaches; the first approach integrating existing aircraft segmentation projections sourced from existing industry data, and the second approach validating the results through modelling of revenue passenger mile growth. No constraints have been inserted on the adoption of electric hydrogen aircraft with respect to aerodrome infrastructure and energy requirements. This ambitious scenario provides a vision of accelerated technological development, contingent on the availability of supportive infrastructure and enabling policies. It raises question on what resources, investments and policies will be needed to facilitate a quicker transition.

3. Flight Network

To further specify aerodromes energy requirements and network operational requirements, AZEA members, transformed the rollout scenario of hybrid, battery-electric and hydrogen-powered aircraft into a possible network of hybrid, electric and hydrogen flights.

Using EUROCONTROL's IFR flight data of 2024 and EUROCONTROL long-term forecast and modelling capabilities, projections were created of the future flight network in the years 2030, 2040 and 2050. The flight data represented only known IFR traffic. Based on the characteristics of hybrid, battery-electric and hydrogen-powered aircraft in each market segments (passenger seat capacity, range) the resulting initial networks showed the forecasted **IFR flights eligible for replacement by battery-electric, hybrid or hydrogen powered aircraft** (Blue bar in Figure 6 in section 3.3).

By applying aircraft deliveries and energy limitation as determined by the rollout scenarios, the flight network model reduced the eligible flight network to optimally utilise available energy (it was assumed that electricity would be available at all aerodromes (to a certain maximum amount) and that initially only a limited number of aerodromes would offer hydrogen (10 aerodromes in 2030, 20 aerodromes in 2040 and all aerodromes in 2050)).

Other assumption applied in the flight network scenarios:

- Zero-emission aircraft could also replace slightly larger aircraft in order not to be too restrictive to passenger seat capacity definition per market segment.
- Tankering opportunities are included which impacts especially the early flight network of hydrogen powered aircraft where there are limited aerodrome offering hydrogen.
- Network logics need to be respected. This basically reflects the network calculation engine inside the model, ensuring arrivals and departures flights to certain aerodromes are balanced (i.e. no dead-ends) and taking energy availabilities into consideration.

VFR traffic wasn't included in the forecasted flight network described above. An additional analysis using DLR's DESAT model was performed to obtain an impression of the resulting Small Air Transport (seat capacity <19 PAX) network. The DESAT model aims to present emerging opportunities for small air transport network. It was considered to include new opportunities and VFR traffic in addition to the flight network scenarios from the EUROCONTROL modelling (using IFR flight data and related forecasts) and provide the final Flight Network forecast (Green in Figure Y in section 3.3).

Based on the roll-out scenario, the forecasted zero-emission flight network per market segment has been modelled. Below the different market segments are presented with on the left the modelled flights and on the right the energy requirement per airport to fuel departing flights. It should be noted that new business opportunities are not presented in these figures.

Especially in the smaller market segment, there is significant number of deliveries of aircraft foreseen. In 2050, for all market segments except the Medium Range market segments, the estimated aircraft deliveries can fully replace the forecasted eligible IFR flight network.

The modelling allows to specifically indicate where energy would be available, per country, aerodrome, region, etc. However, the Flight Network presented in the Roadmap does not assume specific locations for energy quantities.

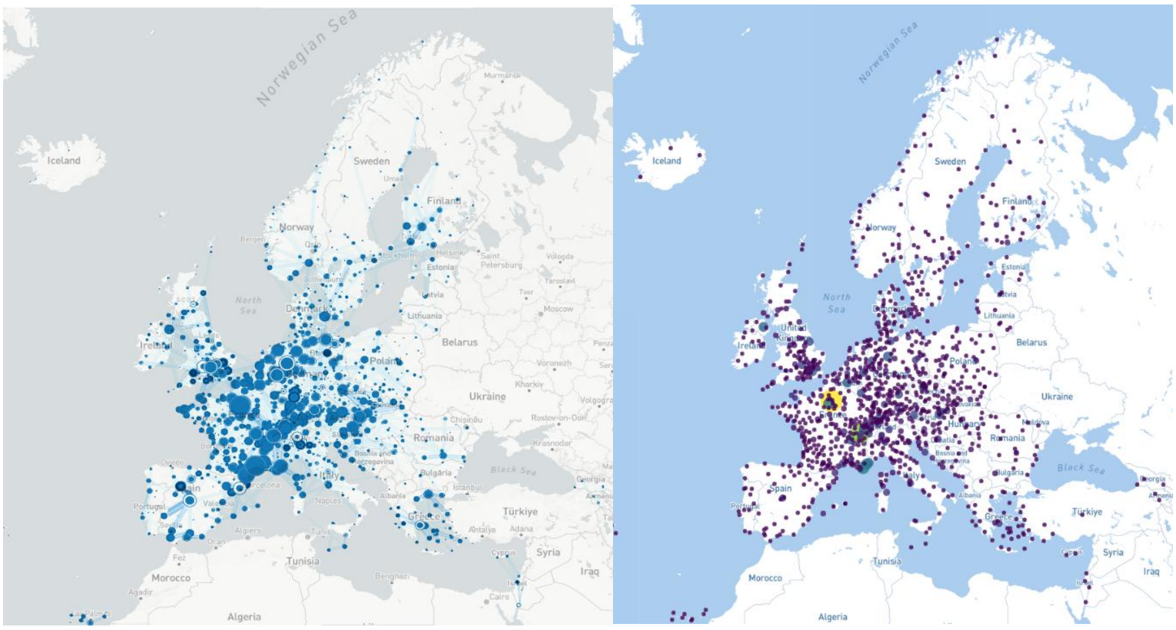


Figure A: The General Aviation (1-9 pax) 2030 network of IFR flights eligible for replacement (~65k flights) (left) and energy requirement at airports (right)

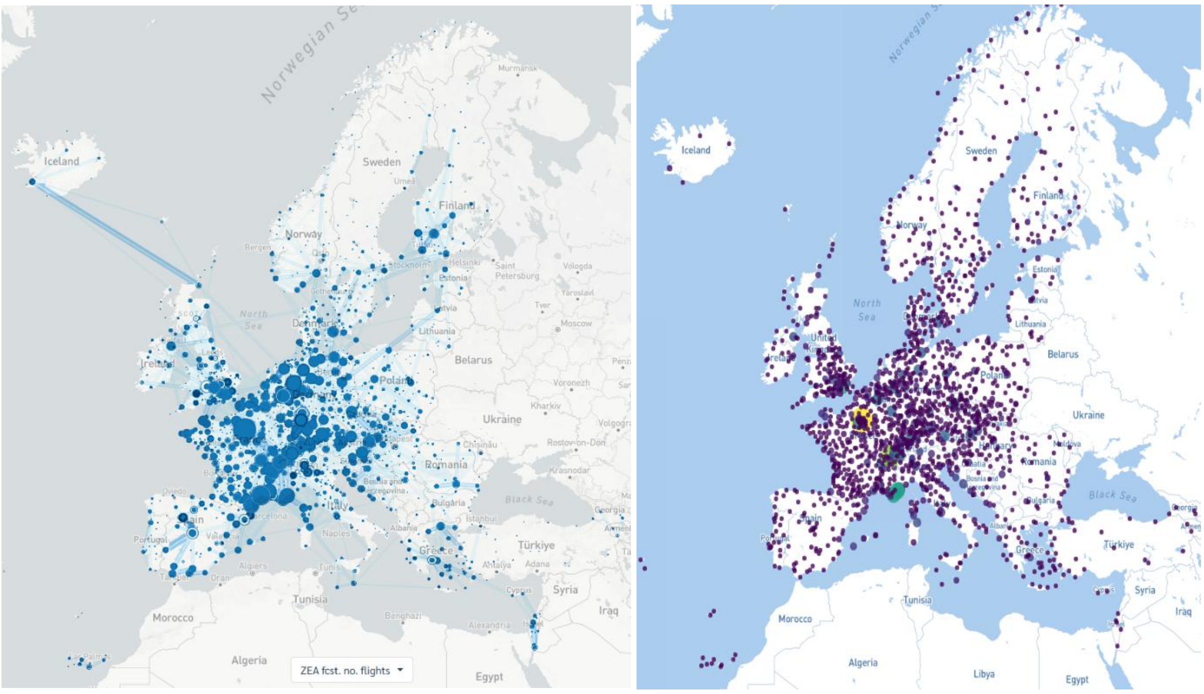


Figure B: The General Aviation (1-9 pax) 2040 network of IFR flights eligible for replacement (~370k flights) (left) and energy requirement at airports (right)

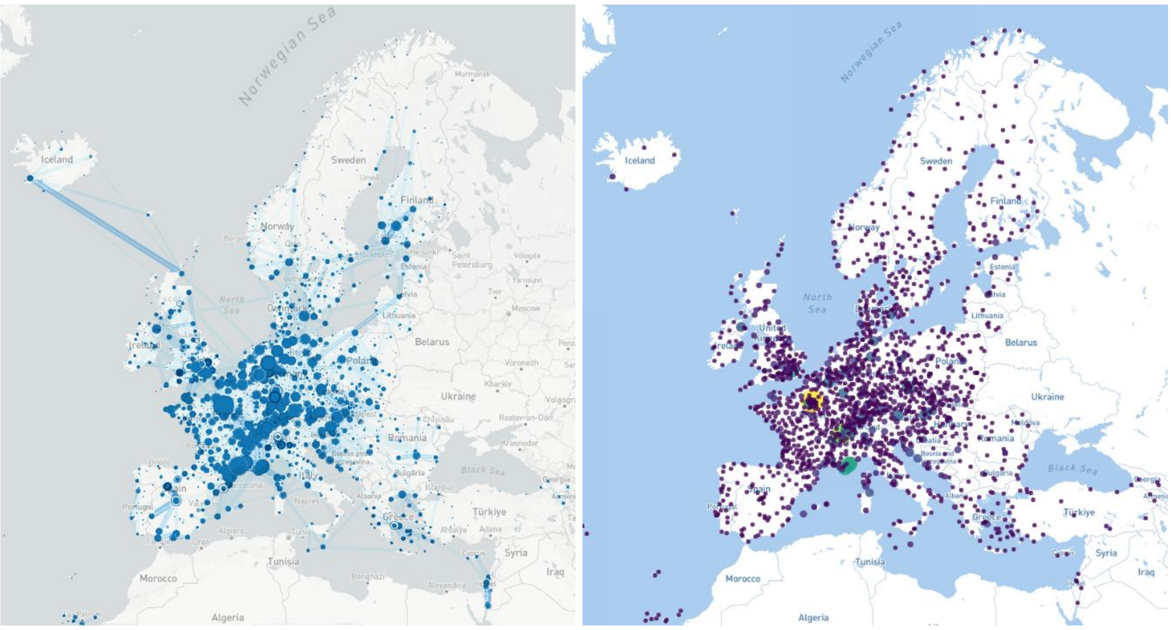


Figure C: The General Aviation (1-9 pax) 2050 network of IFR flights eligible for replacement (~400k flights) (left) and energy requirement at airports (right)

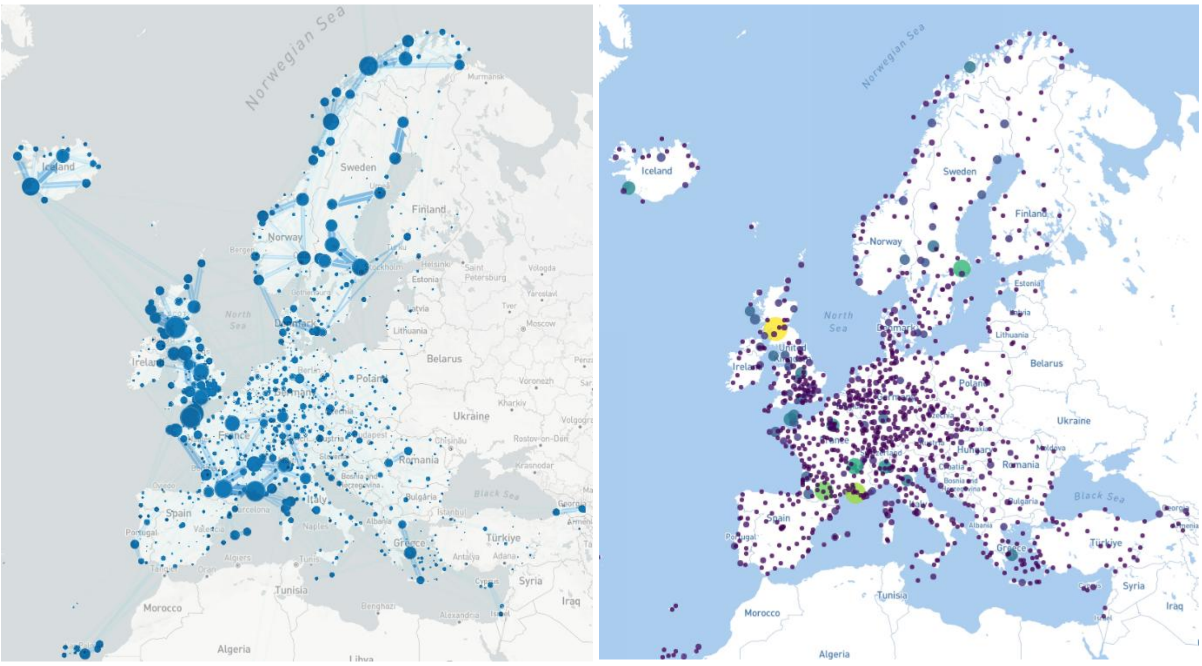


Figure D: The Regional Air Mobility (9-19 pax) 2030 network of IFR flights eligible for replacement (~60k flights) (left) and energy requirement at airports (right)

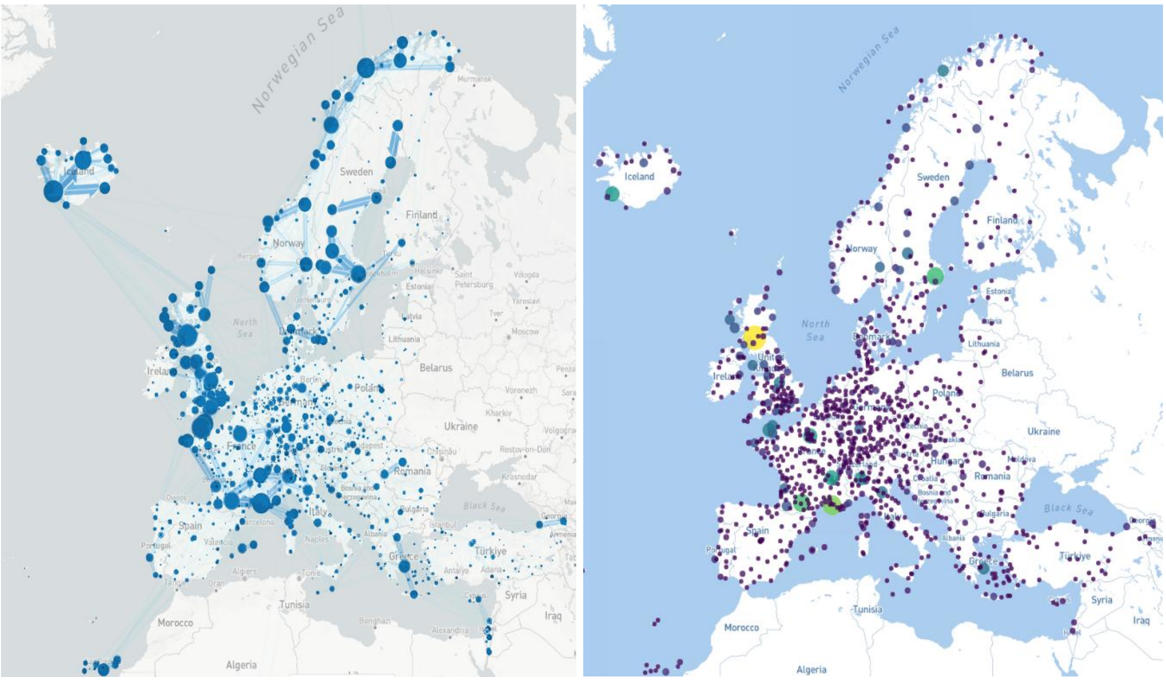


Figure E: The Regional Air Mobility (9-19 pax) 2040 network of IFR flights eligible for replacement (~135k flights) (left) and energy requirement at airports (right)

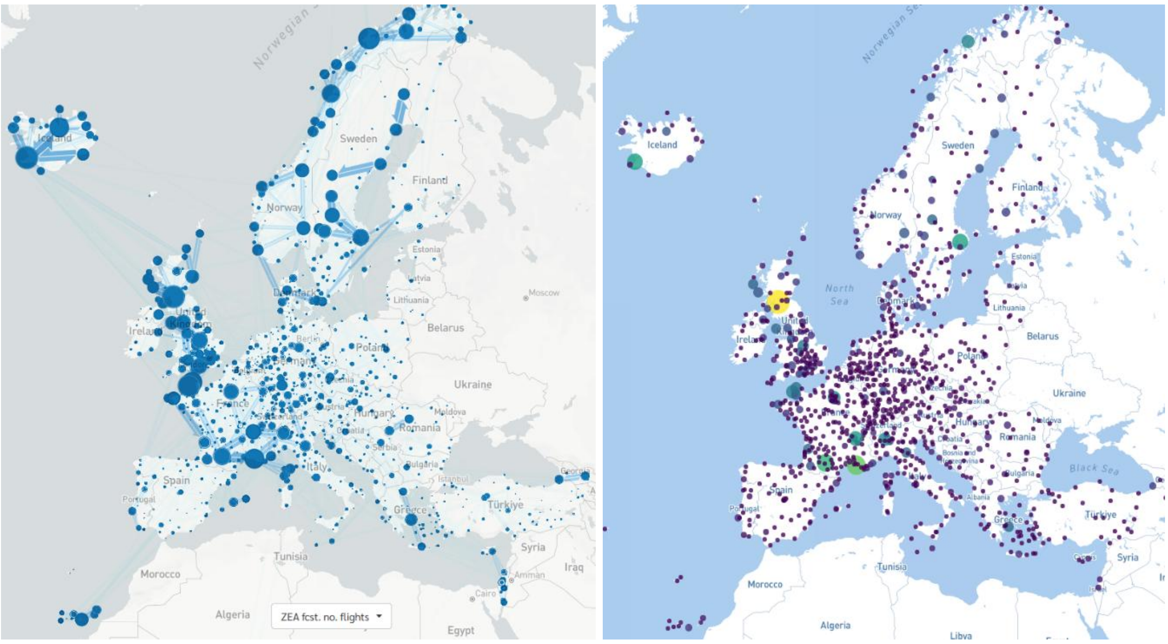


Figure F: the Regional Air Mobility (9-19 pax) 2050 network of IFR flights eligible for replacement (~150 k flights) (left) and energy requirement at airports (right)

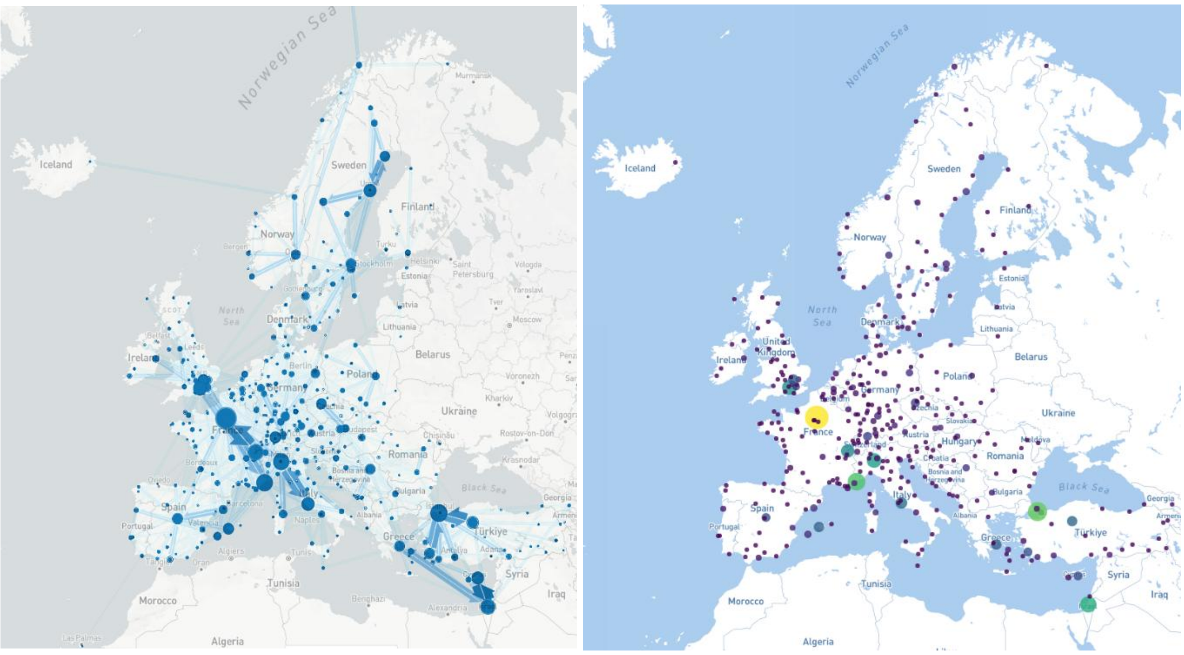


Figure G: the Business Aviation (6-19 pax) 2030 network of IFR flights eligible for replacement (~5k flights) (left) and energy requirement at airports (right)

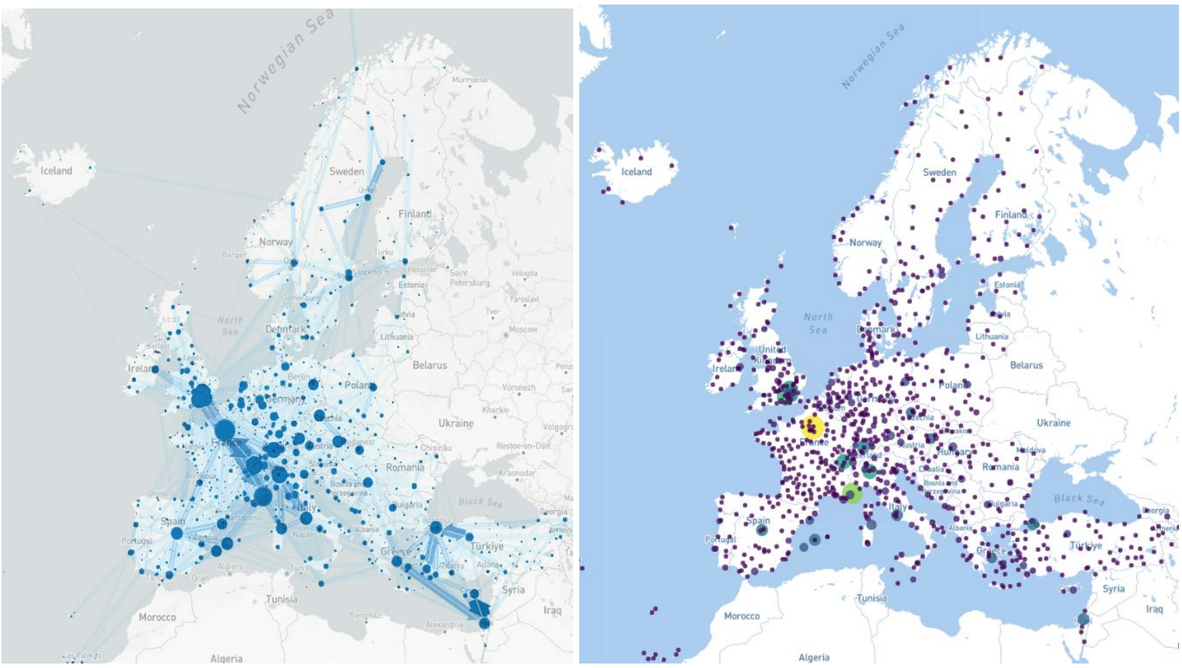


Figure H: the Business Aviation (6-19 pax) 2040 network of IFR flights eligible for replacement (~375k flights) (left) and energy requirement at airports (right)

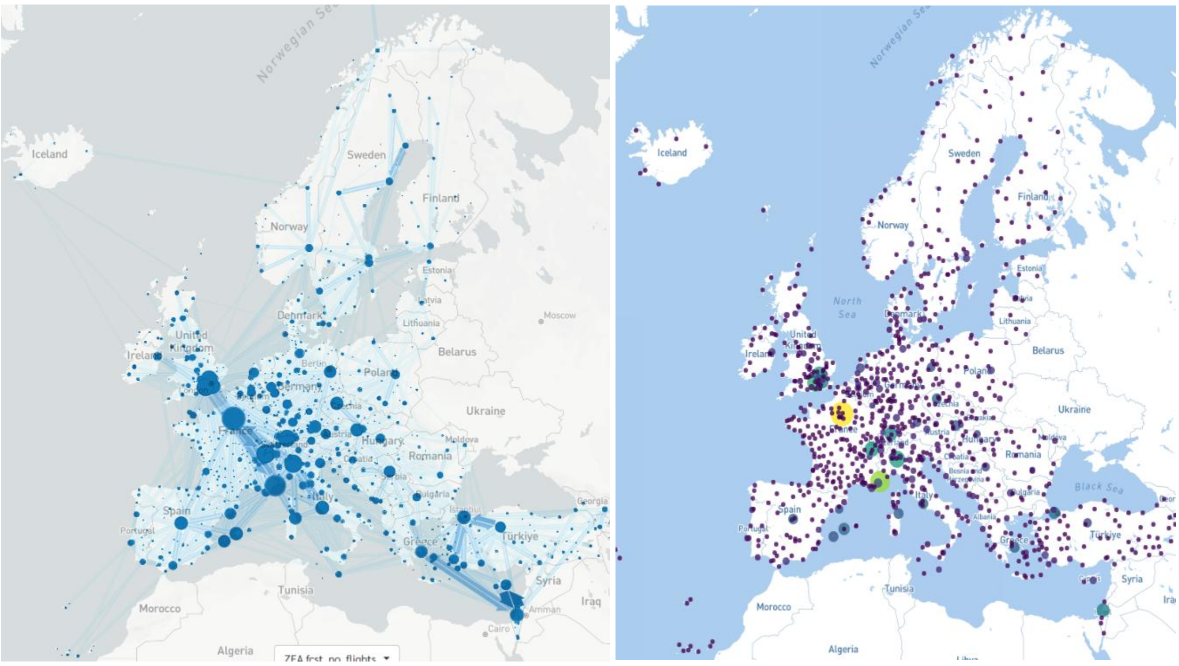


Figure I: the Business Aviation (6-19 pax) 2050 network of IFR flights eligible for replacement (~725k flights) (left) and energy requirement at airports (right)

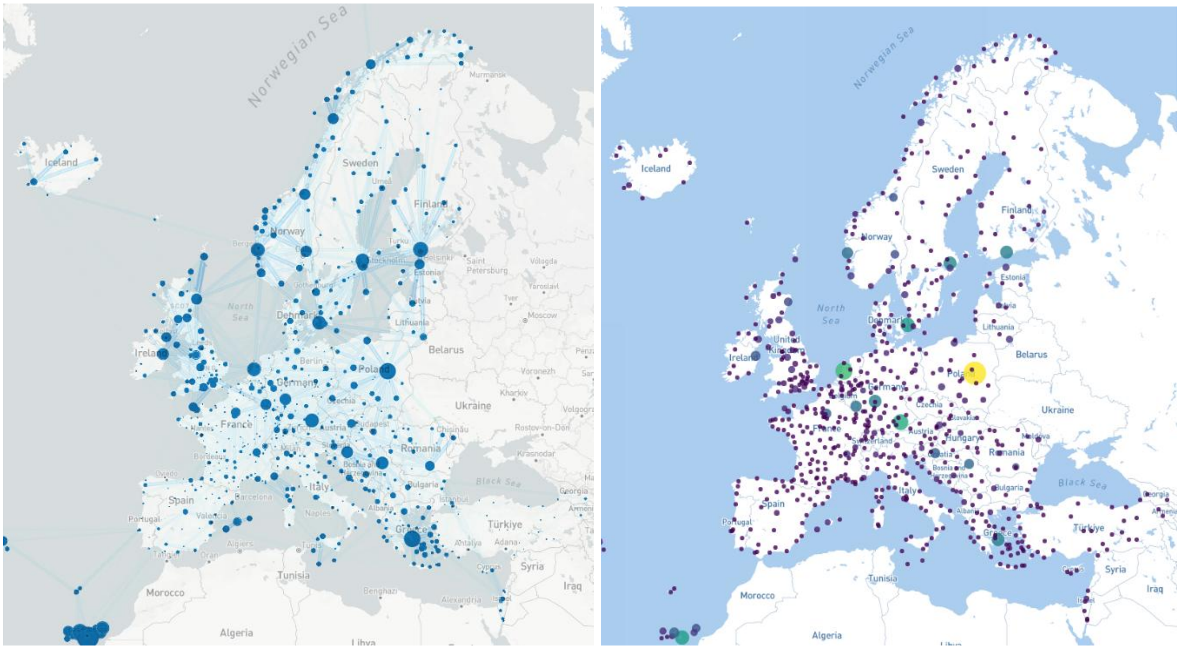


Figure J: the Regional Aviation (19-90 pax) 2040 network of IFR flights eligible for replacement (~900 k flights) (left) and energy requirement at airports (right)

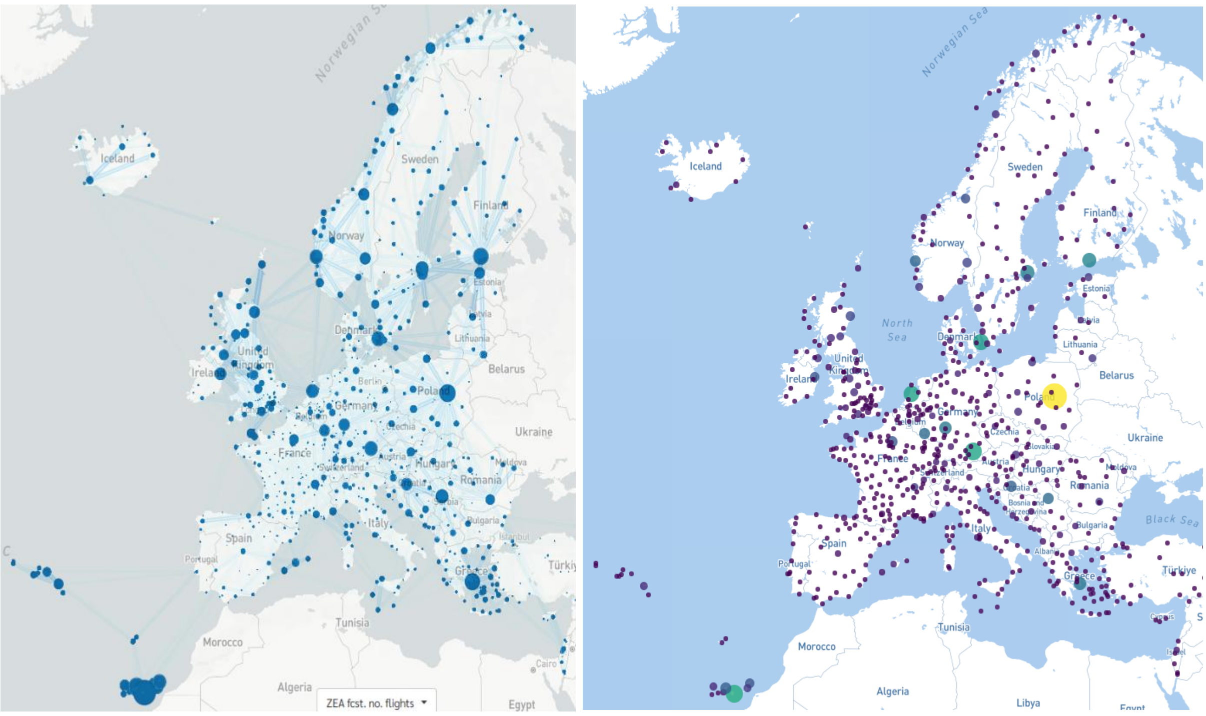


Figure K: the Regional Aviation (19-90 pax) 2050 network of IFR flights eligible for replacement (~1.5 M flights) (left) and energy requirement at airports (right)

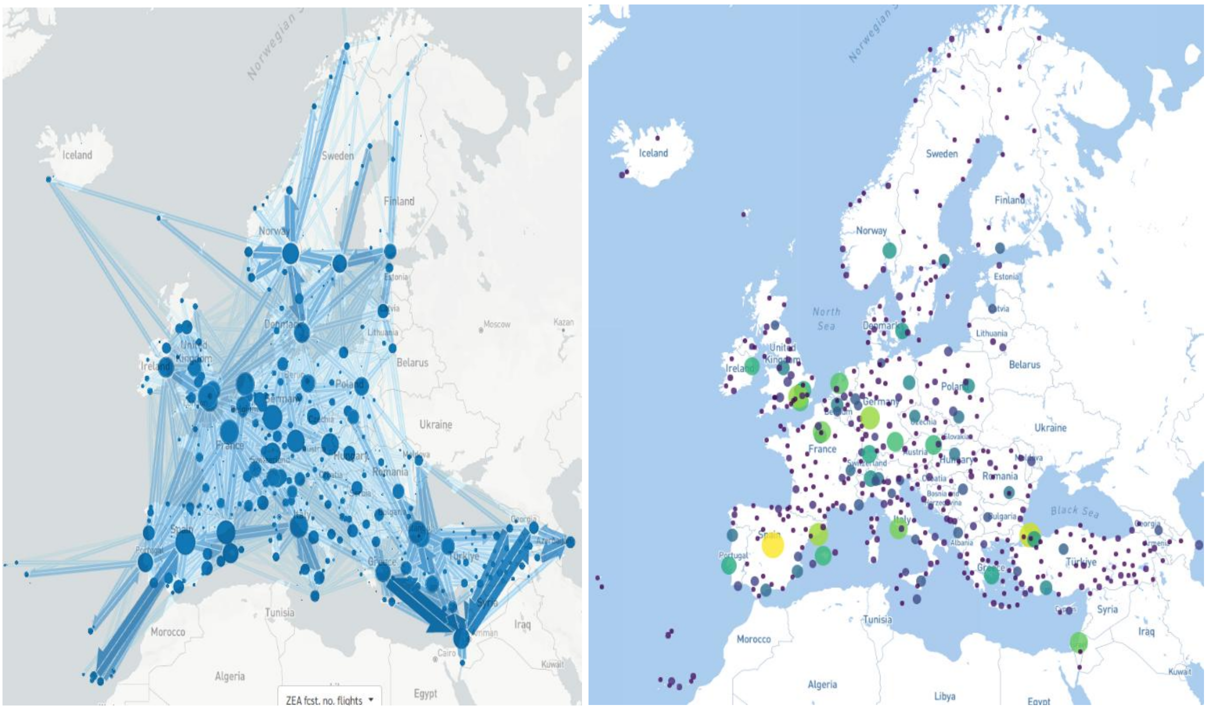


Figure L: the Medium Range (90-250 pax) 2050 network of IFR flights eligible for replacement (~900k flights) (left) and energy requirement at airports (right)

4. Aircraft and powertrain projects from AZEA members

Integral-E, Aura Aero	
Technology: 100% electric aircraft **Market segment:** General Aviation	
Aircraft Manufacturer **Country:** Headquartered in France, with an assembly site in Florida (United States).	**Number of employees:** Less than 750
Description of the project: AURA AERO is an industrial actor acting for decarbonation and competitiveness of air transport by bringing new aircraft technologies at industrial scale. The company has currently three aircraft programmes, Integral (2 seater training aircraft, including a 100% electric version), ERA (19 seats regional aircraft hybrid electric) and the Enbata MALE (Medium Altitude Long Endurance) drone, for defence and civil application. AURA AERO is starting in 2026 the construction of a factory in Toulouse Francazal of 50.000m2 to produce all its aircraft programmes. The Integral E is a two-seater training aircraft, 100% battery-electric, propelled by the ENGINeU engine of Safran. All versions of the Integral (Integral S and Integral R) are currently flying, the full electric version (Integral E) will be certified before mid-2027.	
Expected entry into commercial service: Mid-2027	**Maximum range of the aircraft (in km)**: 200 **Maximum capacity (PAX):** 2

ALIA VTOL and CTOL, BETA Technologies	
Technology: Beta has selected battery-electric propulsion for its aircraft platforms, leveraging advanced battery systems integrated with high-efficiency electric motors and sophisticated power management electronics. This architecture enables zero-emission operations with scalable performance across CTOL and VTOL configurations. **Market segment:** General Aviation (BETA components for use by other OEMs fall under the General Aviation and Regional Air Mobility Market segments)	*CTOL* © Beta Technologies 2026 
Aircraft Manufacturer **Country:** United States (Headquarters). Aircraft and charge infrastructure demonstration throughout Europe, with primary focus in Scandinavia, Germany, the Netherlands, France, the UK, and Ireland.	**Number of employees:** 750 or more
Description of the project: Beta is designing both fully electric CTOL (conventional take-off and landing) and fully electric VTOL (vertical take-off and landing) configurations to address diverse mission requirements across Europe's emerging electric aviation ecosystem. Beta's aircraft have accumulated over 200,000 kilometres of real-world flight, demonstrating operational maturity and reliability. This extensive flight data supports the company's certification pathway and validates its integrated systems approach. Beta has completed a comprehensive six-month development program with the Norway Test Arena, advancing aircraft and infrastructure capabilities in demanding operational environments. Beyond aircraft development, Beta supplies integrated multimodal charging infrastructure serving its platforms and other OEM partners. This infrastructure - combining fast-charging, battery storage, and grid integration technologies - addresses a critical barrier to electric aviation adoption across Europe. Beta also provides advanced propulsion, power management, thermal systems, Flight Computers, battery integration, and more components to partner manufacturers, positioning the company as a comprehensive systems provider.	
Expected entry into commercial service: CTOL in 2027 and VTOL in 2028	**Maximum range of the aircraft (in km)**: VTOL 178; CTOL 435 **Maximum capacity (PAX):** 1 pilot + 5 Pax or (2 pilots + 4 pax)

E5 Albatross, ELECTRON aerospace B.V.

Technology: The E5 is powered by two high-power-density geared electric motors paired with a 265 Wh/kg battery pack, delivering around 750 km real-world range today and targeting up to 1,000 km by service entry. For extended-range or endurance-focused military missions, a modular hybrid generator system can be swapped in to achieve 3,500+ km range or up to 24 hours endurance, while using the same CS-23 Level 2 airframe.

Market segment: Business Aviation, Regional Air Mobility

Aircraft Manufacturer

Country: Netherlands

Number of employees: Less than 50

Description of the project: The E5 is a pure battery-electric aircraft as a clean-sheet design for the next generation of sustainable air transport. The E5 is designed for business aviation, making private flying zero-emission, while its larger market potential lies in unlocking on-demand regional air mobility. It's pure battery-electric architecture targets the lowest possible operating cost, while its clean-sheet cabin is optimised for passenger comfort, with up to six seats, easy access, and premium economy-style seat pitch. The E5 is therefore sized not like a traditional commuter aircraft, but like the travel behaviour it is meant to replace small-party, high-frequency, time-sensitive journeys that can be shifted from road to sky. The aircraft is designed first and foremost for passenger transport, with cargo, medical evacuation and pilot training as additional use cases. A full-size cargo door enables easy access and unlocks both cargo operations, including EU pallet-based freight, and medical evacuation missions where rapid access is essential. A hybrid propulsion configuration also unlocks defence use cases, including surveillance, troop logistics, and pilot training. The E5 is targeted to fly up to 1,000 km on a single charge. The programme has passed an external Design Concept Review, secured pre-orders from four operators for more than 60 aircraft, and has its Design Organisation Approval application ready for submission. ELECTRON is now progressing towards a full-size flying prototype, with first flight planned for 2027.

Expected entry into commercial service: 2032 (Defence 2031)

Maximum range of the aircraft (in km): 1000 (at service entry)

Maximum capacity (PAX): 6

One, Beyond Aero

Hydrogen-powered propulsion technology: The company is redesigning the architecture of an aircraft around hydrogen electric propulsion, integrating fuel cells, gaseous hydrogen storage at 700 bar, two electric engines, and advanced cooling systems.

Market segment: Business Aviation

Aircraft Manufacturer

Country: France

Number of employees: Less than 250

Description of the project: Beyond Aero is building One, the first electric business aircraft powered by hydrogen propulsion, enabling six passengers to fly up to 800 NM (1,500 km), a range unattainable with battery-electric aircraft. Founded in December 2020, the company is redesigning the architecture of an aircraft around hydrogen-electric propulsion, focusing on fuel cell technology, gaseous hydrogen tank integration, and advanced cooling systems. Beyond Aero has secured over $50 million in funding, backed by investors such as Giant Ventures, Bpifrance, and prior supporters like Initialized Capital, Female Founders Fund, and 7 Percent Ventures. Beyond Aero also completed Y Combinator in 2022. The company has secured $1.1bn in Letters of Intent (LOIs), completed France's first manned, fully hydrogen-electric flight, and acquired Universal Hydrogen Co.'s assets, IP, and flight data. Beyond Aero is a member of the World Economic Forum's First Movers Coalition and the Alliance for Zero Emission Aviation, underscoring its commitment to electrifying aviation with hydrogen propulsion.

Expected entry into commercial service: 2030-2035

Maximum range of the aircraft (in km): 1500

Maximum capacity (PAX): 8

Microliner, VÆRIDION

Technology: The Microliner relies on two key technological innovations: a dual-engine configuration driving a single propeller, and modular high-energy battery packs integrated into the wings, enabling a fully electric propulsion system. Combined with a high-aspect-ratio wing and structurally integrated batteries, this architecture reduces material intensity while enabling a fully electric commercial aircraft designed to comply with EASA CS-23 certification requirements.

Market segment: Regional Air Mobility

Aircraft Manufacturer

Country: Germany (Headquarters), with offices in Belgium and the Netherlands

Number of employees: Less than 250

Description of the project: VÆRIDION is a German start-up founded in 2021, developing the first certified all-electric commercial aircraft aimed at enabling zero-emission regional aviation by 2030. The company is developing the Microliner, a nine-seat battery-electric aircraft capable of flying up to 500 km. The aircraft is designed to cover approximately 80% of current European turboprop routes. With a focus on short-haul connectivity, the Microliner provides a sustainable, quieter, and more accessible solution. According to internal life-cycle assessments, large-scale deployment of the Microliner could avoid up to 10 million tonnes of CO_2 emissions by 2040. To support certification and market entry, VÆRIDION is working closely with the European Union Aviation Safety Agency (EASA). In 2024, the company became the first company to complete a Pre-Application Contract (PAC) with EASA, confirming the certifiability of the Microliner under the CS-23 regulatory framework. This included a detailed review of the aircraft's propulsion architecture, validating safety in engine-failure scenarios. In 2025, VÆRIDION initiated a second PAC focused on battery technology and high-voltage safety, with final signature expected in March 2026. Within five years, the programme has successfully completed most R&D activities and is progressing on its industrialization plans of battery and aircraft manufacturing. The first flight of the Microliner is planned for 2027, with certification targeted for 2029 and entry- into-service in 2030.

Expected entry into commercial service:

2030

Maximum range of the aircraft (in km): 400 under IFR (reserves on top)

Maximum capacity (PAX): 9 + 2 pilots

Electric Regional Aircraft (ERA), Aura Aero

Technology: Hybrid-electric aircraft.

Market segment: Regional Air Mobility & Regional Aviation

Aircraft Manufacturer

Country: Headquartered in France, with an assembly site in Florida (United States).

Number of employees: Less than 750

Description of the project: AURA AERO is an industrial actor acting for decarbonation and competitiveness of air transport by bringing new aircraft technologies at industrial scale. The company has currently three aircraft programmes, Integral (2 seater training aircraft, including a 100% electric version), ERA (19 seats regional aircraft hybrid electric) and the Enbata MALE (Medium Altitude Long Endurance) drone, for defense and civil application. The Electric Regional Aircraft (ERA) is a hybrid electric, with electric propulsion (8 ENGINeUS engine from Safran), where the electricity is provided both by battery packs and 2 gas turbine generators at the back of the plane (Arrano by Safran). The first flight of the ERA is planned for end of 2027, starting certification in 2028 and with a planned entry-into-service end of 2029. The Enbata MALE drone will perform its first flight in 2026 and is planned to enter into operational service by 2028.

Expected entry into commercial service: 2029

Maximum range of the aircraft (in km): 1500

Maximum capacity (PAX): 19

EVO, ATR

Technology: Based on mild hybridisation, the ATR 'EVO' concept aims to incorporate innovative technologies to enable significant improvements in operating costs and sustainability, while remaining affordable and versatile.

Market segment: Regional Aviation

Aircraft Manufacturer

Country: France

Number of employees: 750 or more

Description of the project: The ambition of the ATR 'EVO' is to combine an ultra-efficient thermal engine with a battery-powered electrical motor, to optimise the engine core size through the use of electrical power, therefore maximising the overall efficiency of the propulsive system. Designed to significantly reduce CO_2 emissions and direct maintenance costs while enhancing aircraft performance, the ATR EVO will remain a two-engine turboprop, with 100% SAF capability. In addition to an innovative propulsion system, the ATR EVO also foresees significant upgrades, including an eco-designed cabin, leveraging lighter, new bio-sourced materials, along with recycled and reusable materials, with a focus on reducing waste throughout the entire lifecycle of our products. The key technologies that will support the ATR EVO are developed through the Ultra-Efficient Regional Aircraft (UERA) thrust of the Clean Aviation Joint Undertaking, in particular within the HERACLES (aircraft concept and key technologies integration, and impact assessment) and DEMETRA (flight test demonstration of hybrid-electric propulsion on an ATR 72-600 test bed by 2030) projects led by ATR. These initiatives support Clean Aviation's strategic goal of achieving up to 30% improved fuel efficiency and significantly reduced carbon emissions for next-generation regional aircraft, targeting an entry-into-service by 2035.

Expected entry into commercial service: 2035

Maximum range of the aircraft (in km): 1900

Maximum capacity (PAX): 78

E9X, Elysian Aircraft

Technology: Battery-electric propulsion with 6 engines on a low-wing configuration.

Market segment: Regional Aviation

Aircraft Manufacturer

Country: Netherlands

Number of employees: Less than 50

Description of the project: Battery-electric, large aeroplane development. Several technology bricks are being developed, to enable safe battery-electric flight. This includes battery-wing integration, high-voltage architecture and integrated propulsion units.

Expected entry into commercial service: 2035

Maximum range of the aircraft (in km): 800

Maximum capacity (PAX): 90

ZEROe, Airbus	
Technology: Hydrogen-powered propulsion using Fuel Cell technology (electric) **Market segment:** Medium Range	 © Airbus SAS 2026
Aircraft Manufacturer **Country:** France, Germany, Spain, UK	**Number of employees:** 750 or more
Description of the project: ZEROe is set to be amongst the lowest climate impact solutions for commercial aviation through fully electric operations. It will provide an innovative integrated airframe and propulsion offering and unique differentiation, upholding long-term societal expectations.	
Expected entry into commercial service: TBD	**Maximum range of the aircraft (in km):** 1852 **Maximum capacity (PAX):** 100

LCA60T, Flying Whales	
Technology: The hybrid electrical power generation system of the LCA60T is based on a turbogenerator technology coupled to an HVDC network with a parallel battery design for power cycling rather than energy. The objective of the system is to decouple the dynamics of the turbine relative to the fast transient power demands requested by the airship flight control system, ensuring hovering flight and protecting turbine lifespan. The system delivers a total power of 4 MW. It will reach its initial certification in 2029 with this first-generation propulsion system (which accepts jet fuel or SAF) and allows a swift transition towards the LCA60T's second generation propulsion system, hydrogen-based. FW will achieve this fully-electric propulsion by 2031, either through turbine injection or fuel cell technology. **Market segment:** Lighter-than-Air/ Airship (cargo transport)	 © Flying Whales 2026
Aircraft Manufacturer **Country:** France	**Number of employees:** Less than 250
Description of the project: With more than 300 active prospects and over 90 pre-commercial agreements signed with major companies, FLYING WHALES addresses a clear market need for point-to-point transport across various markets such as energy infrastructure, construction, Defence, disaster relief and access to remote regions where roads, railways or ports are constrained or too costly to build or upgrade. The LCA60T offers 12 times the payload of heavy-lift helicopters at a cost per ton-kilometre 8 times lower. FW has conducted over 100 customer use cases, demonstrating the strong value add of its solution: logistics costs reduced by 3 to 7 times, project timelines accelerated by 2 to 7 times and GHG emissions reduced by 60% to 87%.The aircraft is developed according to established aerospace industry practices, by a consortium of more than 50 European and Canadian companies representing around 500 engineers. Following its Critical Design Review in 2024, the program has entered its final testing and integration phase, before its first flight planned in 2028.	
Expected entry into commercial service: 2029 for the first propulsion generation (i.e. hybrid electrical power generation with turbogenerator)	**Maximum range of the aircraft (in km):** 1000 nominal; 5000 for ferry flight **Maximum capacity (Cargo transport):** 60 tonnes of cargo

Battery-electric Aircraft Propulsion System, Safran

Technology: Battery-Electric Propulsion System 150 kW

Market segment: General Aviation

Powertrain manufacturer

Country: France

Number of employees: 750 or more

Description of the project: 150kW Electric motor certified in January 2025 equivalent of 180shp thermal engine. This engine development has required more than 3,000 hours of testing dedicated to certifying the new technologies introduced on the ENGINeUS™ range and more than 1,500 hours of motor certification tests. Industrialisation (TRL8) is expected by the end of 2026, while production (TRL9) initially scheduled for the end of 2027.

Expected entry into commercial service:

End of 2027

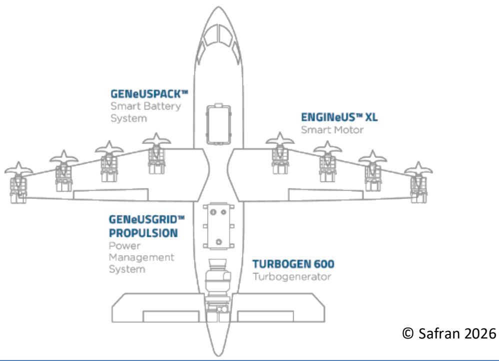
Maximum range of the aircraft (in km): 1h30 autonomy leading to over 300 km range

Maximum capacity (PAX): 2

Hybrid-Electric Commuter Aircraft Propulsion System, Safran

Technology: Hybrid-Electric Distributed Propulsion System with 600 kW Turbogenerator feeding several propulsion e-motors

Market segment: CS-23 Level 3 and 4 Commuter and Regional Air Mobility



Powertrain manufacturer

Country: France

Number of employees: 750 or more

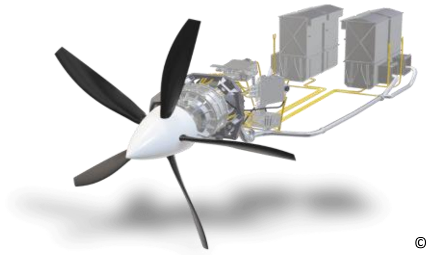
Description of the project: Providing Commuter Aviation Aircraft customers and Regional Aviation Aircraft customers with a comprehensive solution for distributed hybrid-electric propulsion system encompassing a turbogenerator built on the legacy of helicopter engines, power electronics and electrical distribution/protection system, e-motors, controls and HVDC Battery Pack. Ground tests are expected to take place in 2026, while flight tests are scheduled for 2027. Industrialisation is expected to start in 2029.

Expected entry into commercial service:

2030

Maximum range of the aircraft (in km): 1500

Maximum capacity (PAX): 19

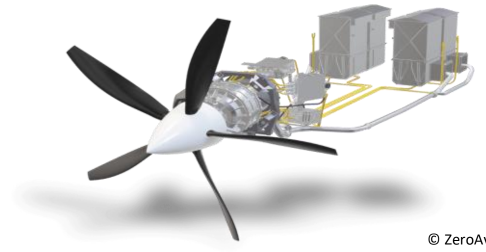
ZA600- Hydrogen-Electric Engine, ZeroAvia	
Technology: ZeroAvia is developing a 600kW hydrogen-electric propulsion system for 9-19 seat commercial, Part 23 aircraft (such as the Cessna Caravan, Twin Otter & Dornier 228). **Market segment:** Regional Air Mobility	
Powertrain manufacturer **Country:** Kemble, Gloucestershire, United Kingdom / Everett, Seattle, United States	**Number of employees:** Less than 250
Description of the project: ZeroAvia is developing ZA600 to provide electrification to commercial operations, where battery energy-density and cycling costs render this option unpractical. The system is made up of 3-4 200kW Low Temperature PEM fuel cell power generation systems, and ZeroAvia's inverter and electric motor designs. The company has secured a launch operator for the system (RVL Aviation in the UK), and close to 1,000 powertrain pre-orders subject to certification. The company has also secured EU Innovation Fund support to demonstrate the technology in commercial operations by retrofitting 15 Cessna Caravan with the technology and establishing supporting infrastructure at 15 Norwegian airports to support these aircraft (Project ODIN). ZeroAvia has flight tested a prototype 600kW hydrogen-electric system and has progressed its design through various certification gates. The FAA has awarded G1 and P1 issue papers for the electric propulsion system and published special conditions. With the UK CAA, ZeroAvia has been working towards the certification of the full hydrogen-electric powertrain and as a participant in two rounds of the regulator's Hydrogen Sandbox Challenge. The company has also received Design Organisation Approval, confirming that confirms that the CAA is satisfied that ZeroAvia has the technical expertise, facilities and capabilities to design safe and reliable products, and is prepared to comply with stringent requirements for certification. These requirements are intended to ensure safe global market entry and have been adopted by other regulatory authorities, including EASA and the FAA.	
Expected entry into commercial service: ~2030	**Maximum range of the aircraft (in km)***:* 463 (including reserves) **Maximum capacity (PAX):** 19

Hydrogen Aircraft Propulsion and Storage (HAPSS), Conscious Aerospace	
Technology: The propulsion technology selected is hydrogen-electric, including Electric Propulsion Motor with reduction gearbox, Electric Power Distribution System, Fuel Cell System, Thermal Management System and an on-board cryogenic Liquid Hydrogen storage and Distribution System. **Market segment:** Regional Aviation, Business Aviation	
Powertrain manufacturer **Country:** Netherlands	**Number of employees:** Less than 50
Description of the project: Conscious Aerospace is developing hydrogen propulsion systems in the up to 5MW class for aircraft in the Regional Aviation market category. The initial target market is retrofit of existing regional turboprop aircraft, with evolution to providing propulsion systems for clean sheet aircraft designs in the future. The first project is a powerplant development for the retrofit of a DHC dash-8-300 for an initial target market of selected regional routes. The first phase of the project is partially funded by the Dutch Government Innovation Growth Fund and includes the initial development of the propulsion system and demonstrating its functionality on a dash-8-300 flying testbed. The focus of the project is to develop a certifiable powerplant from the start. In this regard, Conscious Aerospace has engaged with EASA in an Innovation Partnership Contract (IPC) as part of the pre-certification activities for this development. The IPC was kicked off in February 2026 and is underway. Following the IPC phase, there will be a pre-application phase, followed by the actual certification phase. The status of the project is the Concept Phase in 2026, leading up to PDR in the first half of 2027.	
Expected entry into commercial service: The expected date of entry-into-service for the initial project (Retrofitted DHC dash-8-300) is between 2032 and 2034	**Maximum range of the aircraft (in km)***:* Specified range with 32 passengers in economy class layout, 750 km including standard safety margins. **Maximum capacity (PAX):** 36

ZA2000- Hydrogen-Electric Engine for 40-80 seat aircraft, ZeroAvia

Technology: ZeroAvia is developing a 2-5 MW modular hydrogen-electric powertrain designed for 40-80 seat commercial, Part 25 aircraft (such as the ATR and Dash 8 families).

Market segment: Regional Aviation



Powertrain manufacturer

Country: Kemble, Gloucestershire, United Kingdom/ Everett, Seattle, United States

Number of employees: Less than 250

Description of the project: ZeroAvia is developing ZA2000 to provide electrification to commercial operations, where battery energy-density and cycling costs render this option unpractical. The system is made up of ZeroAvia's liquid hydrogen management system, high temperature PEM (HTPEM) fuel cell system and a modular 900 kW motor which is stackable to support multi-MW applications. As well as critical to the regional segment, these technologies will be the building block for progressing hydrogen-electric technologies into future larger aircraft such as narrowbodies. The hydrogen-electric propulsion system relies on an electro-chemical reaction to generate electricity, meaning there is no combustion of fuel. Ultimately, the only exhaust is low temperature water vapour, meaning a climate impact reduction of around 90% (Clean Skies/McKinsey). ZeroAvia has already demonstrated its HyperCore 900kW modular electric motor technology with a 1.8 MW ground demonstration using a propeller and gearbox from an ATR72 aircraft. The system will also rely on the same inverter technology advanced as part of the ZA600 programme, meaning a high degree of maturity for this component. The company's HTPEM fuel cell technology is under development as part of the UK ATI funded AFCAD programme, alongside Universities of Kent, Bristol, Coventry and Sheffield (AMRC). These technologies are progressing through TRL stages. Building on the company's traction with its smaller ZA600 powertrain and its successful award of Design Organisation Approval, the company is working towards certification around 2032. The company in excess of 1,000 orders for its ZA2000 powertrain for turboprops and also regional jet variant planned for later EIS.

Expected entry into commercial service: ~2032

Maximum range of the aircraft (in km): 463 (including reserves)

Maximum capacity (PAX): 70

Powertrain, SiriNor

Technology: Electric jet engines. The engine architecture is scalable from fixed-drones to large passenger aircraft. The engines are power source agnostic - they can be powered by batteries, hydrogen fuel cells, generators etc.

Market segment: General aviation, Business aviation, Regional aviation, Medium Range

Powertrain manufacturer

Country: Norway

Number of employees: Less than 50

Description of the project: SiriNor develops a patented electric jet propulsion architecture enabling zero-emission high-thrust flight — a capability currently unavailable in aviation. Existing electric aviation solutions primarily rely on propeller-based systems, mainly suitable for smaller, short haul aircraft. Conventional jet engines deliver high thrust but depend on combustion, producing CO_2, NOx and particulate emissions. SiriNor introduces a clean-sheet electric jet architecture designed specifically for electric and hydrogen-electric operation. SiriNor architecture is designed from first principles for zero-emission propulsion in jet-class applications. The initial commercial focus is fixed-wing drones, followed by ground-effect maritime vehicles (GEVs), and subsequently aviation. SiriNOr is currently performing TRL-7 testing and will fly for the first time on a fixed-wing drone this year.

Expected entry into commercial service: 2027 for fixed-wing drones; 2028 for ground-effect vehicles; 2035 (TBD) for aircraft

Maximum range of the aircraft (in km): Depends on choice of energy source and the aircraft's capacity to carry the energy source(s).

Maximum capacity (PAX): 160-180 PAX for a medium range aircraft with 2m diameter engines, potentially much more if 3m diameter engines are used on a future blended-wing body design.

Projects at aerodromes

International Test Arena for Zero and Low Emission Aviation, Avinor

Country: Norway (Avinor operates a network of 43 airports and acts as ANSP in Norway, in close collaboration with the Norwegian CAA)

Number of annual flights: The project spans multiple airports with varying traffic levels across the Avinor airport network.

Type of project: The project establishes operational test and demonstration infrastructure for zero- and low-emission aviation at airports. It includes facilitation for electric and hydrogen aircraft, charging and refuelling infrastructure, energy supply interfaces, adapted airport operations, airspace integration, and regulatory sandboxing. The initiative enables testing in real operational environments across multiple aerodromes, supporting scalability and future commercial deployment.

Description of the project: Avinor, in close cooperation with the Civil Aviation Authority of Norway (CAA Norway), has established the International Test Arena for Zero and Low Emission Aviation to accelerate the transition towards sustainable aviation. The test arena is designed to reduce barriers for testing and demonstration of new aircraft technologies by enabling operations in a real airport and airspace environment. The initiative provides a coordinated framework covering infrastructure, energy supply, airport operations, airspace, safety, and regulatory facilitation. Avinor contributes access to airports, ground infrastructure, energy interfaces and operational support, while CAA Norway provides regulatory facilitation through a regulatory sandbox. Together, the parties offer a single point of contact and a structured process from concept development to flight demonstrations. The test arena spans, in principle, the entire Norwegian airport network, allowing test projects to be located at different aerodromes based on technological maturity, energy availability, and market needs. Initial demonstration programmes have focused on battery-electric aircraft operations in regional aviation, including cargo-oriented test flights between multiple Norwegian airports. These activities have generated valuable knowledge on airport adaptations, energy management, airspace integration, operational procedures, and safety in Nordic operating conditions. In parallel, the test arena is expanding to include hydrogen as a future energy carrier for aviation. This includes preparatory work, feasibility studies, and dialogue with industry on the establishment of hydrogen infrastructure at airports, covering distribution, storage, and refuelling concepts. Overall, the International Test Arena prepares the full aviation ecosystem for zero- and low-emission aircraft by generating and sharing operational knowledge, supporting regulatory development, and laying the foundation for future scaling and commercialization.

Expected timeline for the project: The International Test Arena is an ongoing, long-term initiative. Initial operational demonstration programmes were conducted during 2025–2026, with further test projects planned in subsequent years. Activities are expected to continue in phases, supporting progressive introduction, scaling, and commercial deployment of zero- and low-emission aviation technologies.

Solar park, Groningen Airport Eelde (GRQ)

Country: Groningen Airport Eelde, Netherlands

Number of annual flights: 65 408

Type of project: Energy generation and storage

Description of the project: The Solar Park at Groningen Airport Eelde is a large-scale renewable energy project that supports the airport's long-term role in zero-emission aviation. The solar park has an installed capacity of 21.9 MWp and includes more than 63,000 solar panels. While most of the electricity generated by the solar park is supplied to the public grid, a smaller share is owned by the airport itself. At the time of commissioning in 2020, this share was sufficient to cover the yearly electricity demand of the airport company with renewable energy. Part of the solar park has a shorter lease arrangement. This preserves flexibility for the airport to reuse parts of the site in the future for its own energy production, should this become necessary in support of zero-emission aviation. Groningen Airport Eelde is developing a Battery Energy Storage System (BESS) to support its on-site energy generation. The BESS will be connected to the airport's solar park and is intended to improve the flexibility, reliability and strategic use of locally generated renewable electricity.

Expected timeline for the project: Solar Park Commissioned in February 2020. Battery Energy Storage System (BESS) expected commissioning in 2027.

Renewable energy rooftop self-production, Torino Airport (TRN)

Country: Torino Airport, Italy

Number of annual flights:

~45 000 (commercial and General Aviation)

Type of project: Own 2 MWp energy generation project through installation of PV panels on the main terminal roof and other near buildings

Description of the project: First big size implementation of a PV installation inside the airport. It consists of more than 4.400 modules covering a total area of around 8,000 square meters. The system is able to meet 17% of the airport's annual needs. Photovoltaic panels have been installed on the roof of the passenger terminal, on the roof of the Baggage Handling System (BHS) building and on the roof of a technical building. The electricity produced by the solar plant allows Torino Airport to avoid the emission of more than 500 tonnes of CO_2 per year. With a lifespan of up to 40 years and a very high-performance index, the photovoltaic modules installed are among the most efficient on the market. The modules are designed to produce 60% more energy in the same space over 25 years, offering high mechanical resistance to degradation and not causing glare.

Expected timeline for the project: First installation starting operations: Q4 2023. Last section completed: Q1 2025.

Photovoltaic Energy Park, Airport Münster/Osnabrück (FMO)

Country: Airport Münster/Osnabrück, Germany

Number of annual flights: 35 000 (in 2025, 50% landings, 50% departures)

Type of project: Photovoltaic Energy Park of 70ha space (in planning phase, no photo available yet). Generated green power can be used for loading electric aircraft and to produce green hydrogen.

Description of the project: Once the Photovoltaic Energy Park is serviceable earliest 2028, the Airport Münster/Osnabrück will be able to produce its own green energy to operate the airport, the terminal and ground equipment in the first phase. In addition to this the installation of hydrogen liquefaction, storage refuelling, electrical storage and a recharging infrastructure and electric grids are planned. All of this will be in full force in 2029/2030 latest. Currently it is under evaluation who will be the shareholder of the energy park and who will plan and build it. As civil airports in Germany belong to the sensitive infrastructure also for military use, details of the construction are not yet known in detail.

Expected timeline for the project:

- Further details: 2026/2027
- Start of construction: 2027/2028
- Serviceable (first phase): 2028/2029
- Operation in full force (last phase) 2029/2030

Green Flyway 2.0, Åre Östersund Airport (OSD) - Swedavia airports

Country: Åre Östersund Airport, Sweden

Number of annual flights: ~3000

Type of project: At OSD airport the project has mainly consisted of understanding the scope of infrastructure needed to recharge electric aircrafts, however a smaller charging station for GA-aircraft has been built.

Charging station for battery-electric aircraft at OSD

Description of the project: Green Flyway is a project to create an international testbed for electric flight and autonomous aircraft in Östersund and Röros. The project is connected to an airspace corridor between Trondheim, Röros and Östersund.

Expected timeline for the project: Start: December 2023. End: November 2026.

Electric aviation as an engine for strengthened regional growth, accessibility and sustainability, Visby Airport (VBY) – Swedavia Airports

Country: Visby Airport, Sweden

Number of annual flights: ~5400

Type of project: Feasibility study for battery-electric aviation, preparation for a possible sand-box project as a continuation of the project. At VBY there are already several charging stations for smaller GA-aircrafts, that can be used for future test-beds.

Charging station for electric aircraft at VBY

Description of the project: The project "Electric aviation as a driver for stronger regional growth, accessibility and sustainability" sees electric aviation as a new mode of transport that combines commercial and public values for both the development of electric aviation and the Swedish regions. The primary objective of the project is to analyse and establish a public-private partnership (PPP) to support the electrification of air traffic. This includes developing different business models that can increase accessibility and reduce carbon emissions, especially for smaller towns that currently have limited transport infrastructure. By identifying and mapping costs, revenues and risk distribution within these models, the project aims to create a robust foundation for the implementation of electric aviation. The project will be implemented in four phases: a start-up phase, a feasibility study to collect and analyse the necessary data, implementation of market dialogues and finally dissemination of the results.

Expected timeline for the project: Start: December 2024. End: April 2026.

DIOL – Digital Offshore Logistics (Airside Electrification & Energy Infrastructure)
Den Helder Airport (DHR), Netherlands Offshore Aviation Mainport

Country: Den Helder Airport, Netherlands

Number of annual flights: 12 000–15 000 movements per year (primarily offshore helicopter operations); Range 500+ Km / 22 PAX average

Type of project: Development of electrical energy infrastructure at a regional airport to enable charging of large drones and future electric regional aviation.

Description of the project: Den Helder Airport is implementing a set of infrastructure upgrades under the Interreg North Sea Region project DIOL (Design Innovative Offshore Logistics), aimed at preparing the airport for zero-emission offshore aviation and large drone-based offshore logistics. The project focuses on the electrification of the airside energy system to enable the operation of large, unmanned aircraft systems (UAS) and soon, electric and hybrid aircraft. A key component is the upgrade and adaptation of the airport's power infrastructure, including transformer station modifications, installation of new distribution cabinets, and reinforcement of the local grid connection. The system has been designed to support high-power demand scenarios while ensuring operational continuity through redundancy measures such as emergency power supply and synchronized network integration. These upgrades enable DHA to function as a testbed for integrating energy, aviation, and digital logistics systems. The project supports real-life demonstrations of large drone operations for offshore inspection and logistics, contributing to the development of scalable concepts of operations for zero-emission offshore and regional aviation in coastal and offshore environments. In addition, the project aligns with broader ambitions to position Den Helder Airport as an energy-integrated aerodrome, capable of supporting future charging infrastructure for electric regional aircraft and connecting to offshore energy ecosystems, including offshore wind developments in the North Sea.

Expected timeline for the project: Start: 2024; End: March 2027

- Main infrastructure implementation: 2025 - 2027
- Demonstration phase: 2025–2026 with the launching of the first large offshore drone into international airspace on 10 March- and the demonstration flight of a BETA ALIA aircraft on 29 May 2026.
- Further scaling and integration: 2026 onwards

Development of alternative fuels infrastructure at airports in Poland

Airport Wroclaw (WRO), Airport Wroclaw Port Lotniczy Wrocław S.A.

Country: Airport Wroclaw, Poland

Number of annual flights: 4 907 527 in 2025

Type of project: The project consists of deploying a comprehensive alternative-fuel energy hub at Wrocław Airport, including electric ground handling infrastructure, 4 new 400 Hz Ground Power Units (GPUs), a set of EV charging stations for airside vehicles, and a 2 MW photovoltaic power plant integrated into the airport's energy management system. The investment supports the decarbonisation of airport operations through clean energy generation, storage, and electrified ground services.

Description of the project: The project has received funding from the 2024 CEF Alternative Fuels Infrastructure (AFIF) Call, as part of a broader initiative encompassing different airports in Poland. The Wrocław component of the AFIF_PL_AIRPORTS project aims to create a fully integrated, airport-level clean-energy hub enabling the gradual decarbonisation of ground operations. The investment includes the installation of 4 modern 400 Hz Ground Power Units (GPUs) to supply stationary aircraft with clean electrical power, eliminating the need for onboard Auxiliary Power Units (APUs) and significantly reducing local emissions. In parallel, the project will deploy a fleet-supporting system of airside electric vehicle (EV) charging points that will electrify ground handling operations such as pushbacks, baggage transport and logistics. An element of the project is the construction of a 2 MW photovoltaic (PV) installation, fully integrated with the airport's energy management system. This renewable energy source will directly support airside electrification, stabilise operational energy demand and increase the airport's resilience by providing cost-efficient, locally produced clean energy. The Wrocław project is financially mature and ready for implementation, backed by strong institutional capacity and long-term sustainability commitments from Port Lotniczy Wrocław S.A. Its design prioritises safety, operational efficiency and the gradual transition towards low- and zero-emission airport services.

Expected timeline for the project: Total duration: 39 months (full implementation cycle of the CEF AFIF call). Start date: 2025. End date: 2028.

Baltic Sea Region Hydrogen Airports (BSR HyAirports)

Swedavia Airports (ARN, GOT, MMX, RNB, KRN, LLA, UME, VBY, OSD, BMA)

Country: Swedavia Airports (Stockholm-Arlanda, Göteborg Landvetter, Malmö, Ronneby, Kiruna, Luleå, Umeå, Visby, Åre Östersund, Bromma Stockholm), Sweden

Number of annual flights: Network of aerodromes

Type of project: At Swedavia the BSR HyAirport has given Swedavia mostly input for future master plans and development plans and has provided valuable insight on the ecosystem of Hydrogen. No actual physical infrastructure has been built so far.

Hydrogen powered snow removal truck

Description of the project: The BSR HyAirport is a comprehensive project analysing the possibilities of commercial regional hydrogen powered aviation, looking at the whole value chain of the hydrogen ecosystem from production to usage on the airport. Swedavia is leading the business model and business toolbox work-package, to understand the total possible routes and flights with hydrogen aircrafts. In the business toolkit we are able to better understand the cost of hydrogen per kg depending on chosen scenarios and thus understand the investments needed and infrastructure needed depending on the volume of flights.

Expected timeline for the project: Start: November 2023. End: October 2026

AeroH2ub, Lleida-Alguaire Airport (ILD) –Aeroports de Catalunya

Country: Lleida-Alguaire Airport, Spain

Number of annual flights: 42 207 operations in 2025

Type of project:

Deployment and demonstration of a hydrogen-based energy ecosystem at Lleida-Alguaire Airport, including on-site renewable energy generation, hydrogen production, storage and refuelling infrastructure. The project supports the decarbonisation of airport operations through the integration of hydrogen applications and energy systems, while providing a platform for testing and validating zero-emission solutions in a real operational environment.

© Lleiida Alguaire Airport 2026

Description of the project: AeroH2ub Lleida-Alguaire is an innovation and demonstration project focused on the deployment and validation of hydrogen-based energy solutions in an operational airport environment. The project aims to support the decarbonisation of airport activities and contribute to the transition towards climate-neutral aviation. The project includes the installation of renewable energy generation capacity, based on photovoltaic systems, to produce green hydrogen via electrolysis. The hydrogen is stored and distributed on-site through dedicated infrastructure, including a refuelling station, enabling its use across different airport applications. Hydrogen production and dispensing infrastructure has been operational since late 2025. A key component of the project is the integration and testing of hydrogen technologies in real operational conditions. This includes the adaptation of ground handling equipment to hydrogen, as well as the development and validation of hydrogen-powered unmanned aerial systems. At the current stage, these activities are being carried out at partner facilities, pending the completion of on-site testing infrastructure. Construction works for the hydrogen testing platforms at the airport are expected to start in April 2026, with commissioning foreseen between June and July 2026. These facilities will enable on-site demonstration activities, including hydrogen refuelling operations, validation of ground operations and testing of aerial platforms. The airport provides a controlled and flexible environment for the demonstration of integrated energy systems combining renewable electricity, hydrogen production, storage and end-use applications. The project is designed to generate transferable knowledge and provide a replicable model for other airports, supporting the deployment of hydrogen solutions across the European aviation sector.

Expected timeline for the project: Start date: January 2023. End date: December 2026

WAviatER, Groningen Airport Elde (GRQ)

Country: Groningen Airport Elde, Netherlands

Number of annual flights: 65 408

Type of project: Demonstration of local hydrogen production

© Groningen Airport Eelde

Description of the project: WAviatER supports the transition to zero-emission aviation by demonstrating how hydrogen can be produced locally and used directly within the airport environment. The project focuses on the development of a small-scale, scalable electrolyser that converts renewable electricity into hydrogen.

Expected timeline for the project: Start: March 2022. End: June 2024

Poznań Airport Smart Energy Hub & Hydrogen PoC, Poznań Airport (POZ)

Country: Poznań Airport, Poland

Number of annual flights: 44 823 in 2025

Type of project: Project optimizes a 4 MWp solar PV farm via 8 MWh battery storage (BESS) and an operational hydrogen proof-of-concept (AEM electrolyzers, forklift retrofitting). Crucially, this pilot acts as a foundational step toward a future large-scale Hydrogen Hub.

Description of the project: The "Poznań Airport Smart Energy Hub & Hydrogen PoC" focuses on building a highly resilient, zero-emission ecosystem. Currently, the airport operates a 4 MWp solar PV farm with uncompensated grid export in peak times of production. To establish a robust foundation for new energy sources, the project implements a dual-vector storage strategy. Firstly, to meet future infrastructure requirements, the project deploys two Battery Energy Storage Systems (BESS), each with a 1 MW / 4 MWh capacity. This critical grid reinforcement maximizes green energy self-consumption, stabilizes the local network, and provides recharging infrastructure capacity for zero-emission ground operations. Secondly, the initiative deploys hydrogen technologies in small scale through an operational Proof-of-Concept (PoC). Utilizing surplus solar power, the airport is installing modular AEM electrolysers (2-3 kg H2/day) and retrofitting electric forklifts to hydrogen fuel cells. This micro-scale refuelling facility serves as a vital testbed to decarbonize initial Ground Support Equipment (GSE) and develop critical operational expertise. Most importantly, this PoC acts as a strategic catalyst. It is designed to validate technologies and operational safety before scaling up to the aerodrome's ultimate vision: a large-scale Hydrogen Hub. This future hub will be fuelled by a planned expansion of on-site solar PV up to 50 MWp, enabling high-capacity green hydrogen production. It will secure the airport's long-term energy autonomy, fuel local transport, and supply wholesale off-takers, ensuring full infrastructure readiness for zero-emission aviation in the coming decades.

Expected timeline for the project: Expected start date: 2026 (Implementation of the BESS and the micro-electrolyser pilot). Duration: 2 years for PoC integration, paving the way for the 50 MWp expansion phase.

First green hydrogen production on an Italian airside, Torino Airport (TRN)

Country: Torino Airport, Italy

Number of annual flights:

~45 000 (commercial and General Aviation)

Type of project: Installation of a Hydrogen Pilot plant producing green hydrogen from renewable energy operating inside a smart grid.

Description of the project: The pilot plant allows to study the interaction between different components characterizing a smart grid: a photovoltaic system, different storage systems (car batteries and an electrolyser with its hydrogen storage), fuel cells powered by methane and hydrogen, the network and the load represented by the fire station building. The objective is to maximize the self-consumption of renewable energy produced by the photovoltaic system by storing the surplus of energy produced through batteries or through the transformation of electricity into hydrogen that can feed the fuel cell (able to operate also at 100% hydrogen) and thus decoupling the production and consumption of renewable energy.

Expected timeline for the project: The project is one demonstration that have been carried out as part of the H2020 TULIPS project. Start of the design phase : 2022. Start of operations: Q4 2023. End of the project: 2026

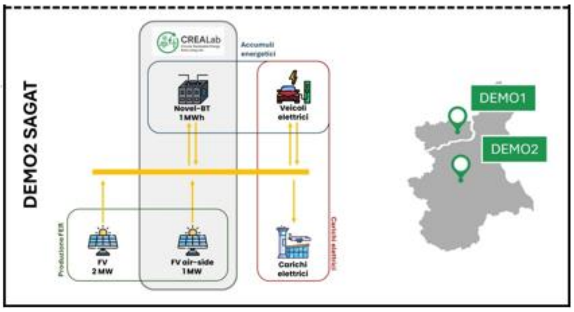
Installation of an innovative storage solution, Torino Airport (TRN)

Country: Torino Airport, Italy

Number of annual flights:

~45 000 (commercial and General Aviation)

Type of project: Installation of an innovative storage solution to maximise the consumption of self-produced energy.



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Description of the project: The airport in 2025 has participated to a national fund with a project named CREAlab (Circular Renewable Energy Area Living Lab), in partnership with the Val d'Aoste Water Consortium (CVA), the Polytechnic University of Turin, and the Italian Institute of Technology. The activities involve the installation of an innovative storage system with a capacity of approximately 1 MWh and reduced content of critical raw materials at the airport, coupled with a photovoltaic system featuring cells with low electromagnetic impact located near the flight support infrastructure. The aim of the project is to demonstrate the feasibility in the installation of flow batteries supporting the decarbonization of the airport energy needs and to install the first large size ground installation on the airside. This will pave the way for larger installations, with a focus on the maximization of the self-consumption of the renewable energy produced.

Expected timeline for the project: Project awarded in 2025 (3-years life span). Studies, design phase and first installations in 2026.

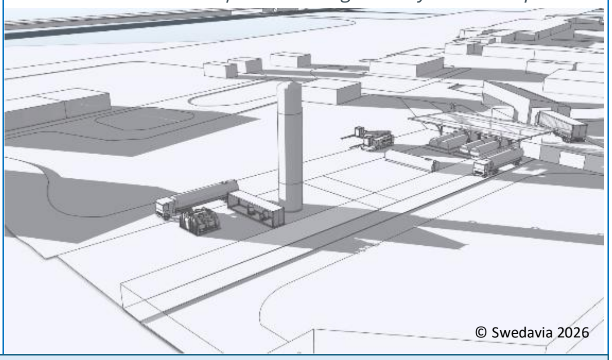
FlyH2UME, Umeå Airport (UME) - Swedavia Airports

Country: Umeå Airport (UME) , Sweden

Number of annual flights: ~8000

Type of project: Blueprint for a scalable storage facility of Liquid H2 at Umeå Airport, to accommodate future needs of LH2 at the airport from the early stages of adoption up until when LH2 is fully adopted by the aviation industry.

Vision of a future Liquid H2 storage facility at UME airport



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Description of the project: The FlyH2UME project develops knowledge and prepares for a scalable facility at Umeå Airport for flights powered by hydrogen and later liquid hydrogen. The project contributes to accelerating the transition to fossil-free aviation where the development of aircraft, the airport's supply and the capacity of the electricity grid go hand in hand. The aim is to prepare for the establishment of hydrogen at airports and enable hydrogen flights in 2035. The project digs deeper into the conditions at Umeå Airport and will propose concrete measures to meet the future need for hydrogen, based on the regional market for hydrogen. An important part concerns safety requirements that must be followed when handling hydrogen, as well as highlighting risks and possible shortcomings in laws and regulations that are discovered during the project. The design of the hydrogen facility and its scaling up are expected to serve as a model for other airports to establish hydrogen flights.

Expected timeline for the project: Start: January 2024. End: December 2026.

HYmpulsion & GOLIAT, Lyon Saint-Exupéry Airport (LYS), VINCI Concessions

Country: Lyon Saint-Exupéry Airport, France

Number of annual flights: 90 000 movements per year

Type of project: HYmpulsion project, supported by VINCI Airports at Lyon-Saint Exupéry, provides hydrogen produced from renewable electricity, positioning Lyon-Saint Exupéry as a pilot airport for hydrogen integration within the VINCI Airports network. The GOLIAT project, led by Airbus, aims to advance liquid-hydrogen adoption in aviation. Lyon–Saint Exupéry plays a key role as a demonstration site, hosting by 2027 a pilot test of small-scale LH2 aircraft ground operations. This real-world trial will deliver essential operational and safety insights.

Description of the project: The HYmpulsion hydrogen station at Lyon–Saint Exupéry Airport, inaugurated on June 30, 2025, is a key milestone in the Zero Emission Valley (ZEV) program. Located at a major multimodal hub, it strengthens the regional hydrogen network by supporting light vehicles, utility fleets, and heavy-duty transport. The facility features a unit capable of delivering up to 1 ton of hydrogen per day at 350 and 700 bar, meeting EU standards. Integrated into a dense regional network that includes nearby stations in Saint-Priest and Vénissieux, it can supply up to 150 vehicles daily. This infrastructure supports regional ambitions to deploy hydrogen mobility at scale and contributes to decarbonizing airport operations and transportation. The GOLIAT project (Ground Operations of LIquid hydrogen AircrafT), coordinated by Airbus and funded by the EU's Horizon Europe program, aims to develop and demonstrate safe, high-performance liquid hydrogen (LH2) ground operations for future hydrogen-powered aircraft. The project brings together ten partners across eight countries to advance LH2 refuelling technologies, define future certification frameworks, and assess airport-scale hydrogen value chains. Lyon–Saint Exupéry Airport is one of the three European airports selected to host small-scale demonstrations. The site will receive its first hydrogen aircraft in 2027 for taxiing and refuelling trials, marking a major step toward integrating LH2 into airport operations and supporting aviation decarbonization. These demonstrations will help validate operational procedures and infrastructure needed to enable large-scale hydrogen aviation in the future

Expected timeline for the project:

- 2025 for HYmpulsion: the hydrogen refuelling station at Lyon–Saint Exupéry has already been inaugurated.
- 2027 for the GOLIAT demonstration: Lyon–Saint Exupéry Airport is scheduled to host its first hydrogen aircraft demonstration as part of GOLIAT.

VHyTTA, Groningen Airport Eelde (GRQ)

Country: Groningen Airport Eelde, Netherlands

Number of annual flights: 65 408

Type of project: Demonstration of liquid hydrogen mobile refueller

Description of the project: VHyTTA is a development and demonstration project focused on practical hydrogen refuelling solutions for airports and other transport applications. The project aims to design and test both a fixed compressed hydrogen station and an innovative mobile refuelling solution capable of supplying liquid hydrogen. In addition to the physical infrastructure, VHyTTA also includes the development of digital models and validation methods to support safe, efficient and scalable operation of hydrogen refuelling systems. The liquid hydrogen mobile refueller is being demonstrated at Groningen Airport Eelde.

Expected timeline for the project: Start: December 2025. End: December 2027.

Hydrogen Refuelling Station, Groningen Airport Eelde (GRQ)

Country: Groningen Airport Eelde, Netherlands

Number of annual flights: 65 408

Type of project: Landside gaseous hydrogen refuelling station with airside dispenser

Description of the project: Groningen Airport Eelde and its partners are developing a landside gaseous hydrogen refuelling station with an airside dispenser as part of its wider preparation for zero-emission aviation. The station is primarily intended to serve road-based applications, in particular buses and heavy-duty freight transport. In addition, the inclusion of an airside dispenser on the business aviation platform makes it possible to support practical airside operations and future hydrogen use in aviation-related applications, including aircraft and ground support equipment.

Expected timeline for the project: The project is scheduled to start in March 2027 and to end by December of the same year.

5. Glossary

Term / acronym	Meaning
ACARE	Advisory Council for Aviation Research and Innovation in Europe
ACI Europe	Airports Council International Europe
AFIF	Alternative Fuels Infrastructure Facility
AFIR	Alternative Fuels Infrastructure Regulation
AI	Artificial Intelligence
ANSPs	Air Navigation Service Providers
ARIS	Aviation Research & Innovation strategy
ATFCM	Air Traffic Flow and Capacity Management
ATM	Air Traffic Management
AZEA	Alliance for Zero-Emission Aviation
BA	Business Aviation
CAPEX	Capital Expenditure
CEF	Connecting Europe Facility
CID	Clean Industrial Deal
CNS	Communication, Navigation, and Surveillance
CONOPS	Concept Of Operations
CO_2	Carbon Dioxide
CRL	Certification Readiness Levels
CS	Certification Specification
CSRD	Corporate Sustainability Reporting Directive
CTR	Control Region
DOA	Design Organisation Approval
GA	General Aviation
GH2	Gaseous Hydrogen
ICAO	International Civil Aviation Organisation
IPC	Innovation Partnership Contracts
EASA	European Union Aviation Safety Agency

Term / acronym	Meaning
ECAC	European Civil Aviation Conference
ECTL	Eurocontrol
EIB	European Investment Bank
EIC	European Innovation Council
ENNOH	European Network of Network Operators for Hydrogen
ENTSO-E	European Network of Transmission System Operators for Electricity
EIS	Entry-into-service
EU	European Union
eSAF	electro-Sustainable Aviation Fuel
ETS	Emissions Trading System
eVTOL	Electric Vertical Take-Off and Landing aircraft
FAA	Federal Aviation Administration
GH2	Gaseous Hydrogen
H2	Hydrogen
HTNOs	Hydrogen Network Operators
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
IPC	Innovation Partnership Contracts
IoT	Internet of Things
Kg	Kilogram
Kt	Kilotonne
KPI	Key Performance Indicator
LH2	Liquid Hydrogen
LTA	Lighter Than Air
MRO	Maintenance, Repair and Overhaul
Mt	Megatonne
MWh	Megawatt hour
NAAs	National Aviation Authorities

Term / acronym	Meaning
NOx	Nitrogen Oxides
OEM	Original Equipment Manufacturers
PAC	Pre-Application Contracts
PAX	Passenger
PSO	Public Service Obligations
RAM	Regional Air Mobility
R&D	Research & Development
SAF	Sustainable Aviation Fuel
SDOs	Standards Development Organisations
SMEs	Small and Medium-Sized Enterprises
TCCA	Transport Canada Civil Aviation
TCO	Third Country Operators
TEN-E	Trans-European Networks for Energy
TMA	Terminal Control Area
TRL	Technology Readiness Level
TSOs	Transmission System Operators
TWh	Terawatt-hour
UAM	Urban Air Mobility
UK	United Kingdom
UK CAA	UK Civil Aviation Authority
VFR	Visual Flight Rules
WG	Working Group
ZE	Zero-Emission

6. Bibliography

This section presents the literature from AZEA on which the Roadmap is based:

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