Alliance for Zero-Emission Aviation

Progress Report

June 2023

0. Purpose of this document

This document summarises the work undertaken by the Alliance for Zero-Emission Aviation (AZEA) since its launch on 24 June 2022.

Chapter 1 briefly explains the focus of the Alliance, namely the decarbonisation of aviation through the introduction of hydrogen and electric propulsion technologies. Chapter 2 describes the principal steps taken by the Alliance since its creation. A particular emphasis of this report is on the activities and discussions that have taken place in the six working groups of the Alliance (Chapter 3). Chapter 4 provides an outlook on the challenges ahead.

This progress report is issued by the AZEA Steering Committee at the occasion of the Alliance's second General Assembly of 19 June 2023.

1. Why focus on H2 and electric propulsion?

In 2015 the EU signed the Paris climate agreement to contain "the increase in the global average temperature to well below 2°C above pre-industrial levels" and pursue efforts "to limit the temperature increase to 1.5°C above pre-industrial levels".[1] The European Green Deal adopted by the European Commission in December 2019 strives to make Europe the first climate neutral continent by reducing to zero the net greenhouse gas emissions by 2050, while maintaining economic growth. Setting the regulatory path, the Fit for 55 package adopted by the European Commission in July 2021 tightens and broadens the EU legislation to meet the ambitious 2050 objective and supports its interim goal of reducing emissions by 55% by 2030 compared to 1990 levels. Ahead of the 41st ICAO General Assembly[2], representatives of European aviation alongside European governments signed the "Toulouse Declaration" in February 2022 aligning all EU stakeholders on the principles and actions needed to decarbonise and transform Europe's aviation sector.

Breaking the link between air travel and rising global emissions requires multiple solutions at different stages of technological and commercial readiness, ranging from new technologies, operational and policy measures, and new propulsion sources. Sustainable Aviation Fuels (SAF) as drop-in-fuels to be used in existing aircraft configurations and airport infrastructure are a key technology available to the industry to deliver net CO_2 emission savings as well as reduced non-CO_2 emissions through cleaner jet fuel. However, battery and hydrogen propulsion are the only true zero-carbon technologies.

Aviation has already stepped up to the challenge of reducing CO_2 emissions. Worldwide, traditional OEMs, new entrants and start-ups are working on hydrogen and electric aircraft[3] to enter into service in the coming fifteen years, either as conversions of existing aircraft or clean sheet developments. All market segments between the two-seater trainer and the single-aisle, medium-range commercial aircraft are represented.

While the reliable, safe and economic integration of electric and hydrogen propulsion in aircraft systems still poses a number of challenges, confidence in the feasibility of hydrogen and electric aircraft is high, and the focus is turning to what is needed to prepare the air transport system for these new entrants.

The technological step-change in aviation technology needs to be matched by a transformation of the entire aviation ecosystem. Hydrogen-powered and electric aircraft will require entirely new energy and fuel infrastructures at airports, new skills in their production, operation and maintenance. They will likely have different performance characteristics compared to aircraft in use today.

[1] UNFCCC, https://unfccc.int/process-and-meetings/the-paris-agreement
[2] In November 2022, the 41st ICAO Assembly adopted a long-term global aspirational goal (LTAG) for international aviation of net-zero carbon emissions by 2050.
[3] The term hydrogen and electric aircraft includes also the combined usage of these technologies in an aircraft system.

Only a combined effort of manufacturers, operators, airports, fuel and energy providers, governments, financers and the many other actors in the aviation value chain can address the challenges associated with the introduction of hydrogen and electric propulsion. This is the purpose of the Alliance for Zero-Emission Aviation (AZEA). AZEA is a platform for aviation stakeholders to combine forces and align strategies in preparing for zero-emission aviation. AZEA's objective is to make the transition to hydrogen and electric flight possible.

2. Description of the Alliance and steps taken to date

On 24 June 2022, the Commission launched the Alliance for Zero Emission Aviation (AZEA), which aims to prepare the aviation ecosystem for the entry into service of hydrogen and electric aircraft. The Alliance gathers representatives of aircraft manufacturers, airlines, airports, energy companies and fuel providers, standardisation and certification agencies, research bodies, the EU partnerships Clean Aviation and SESAR, environmental interest groups and regulators. 141 members have joined the Alliance to date (see Appendix 1).

AZEA members jointly work to identify all barriers to the entry into commercial service of these aircraft, establish recommendations and a roadmap to address them, promote investment projects and create synergies and momentum amongst members. In particular, the members look at issues such as the required financial support and investment to put such aircraft on the market, the fuel and infrastructure requirements of hydrogen and electric aircraft at airports, industry standards and regulations, and the implications for operators (airlines) and air traffic management.

> **What is an Industrial Alliance?**
> Industrial alliances are a tool to facilitate stronger cooperation and joint action between all interested partners and can play a role in achieving key EU policy objectives through joint action by all the interested partners. The European Commission has launched several industrial alliances to support the digital and green transition. As with other alliances, AZEA's members have to publicly commit to supporting its objectives. The mode of functioning, including the Alliance's governance structure is described in its Terms of Reference.

In September 2022, the Commission designated representatives of the main stakeholder communities to the Alliance's Steering Committee composed of a balanced group of representatives of Member Organisations not subject to control by a third country. A support group to the Steering Committee has been established to provide operational support to the functioning of the Steering Committee. At the Alliance's first General Assembly on 14 November 2022, six working groups were formed to address priority topics, and by the close of the year, all but one of the working groups had been constituted and began working under the mandate allocated to them. This work is detailed in the next chapter.

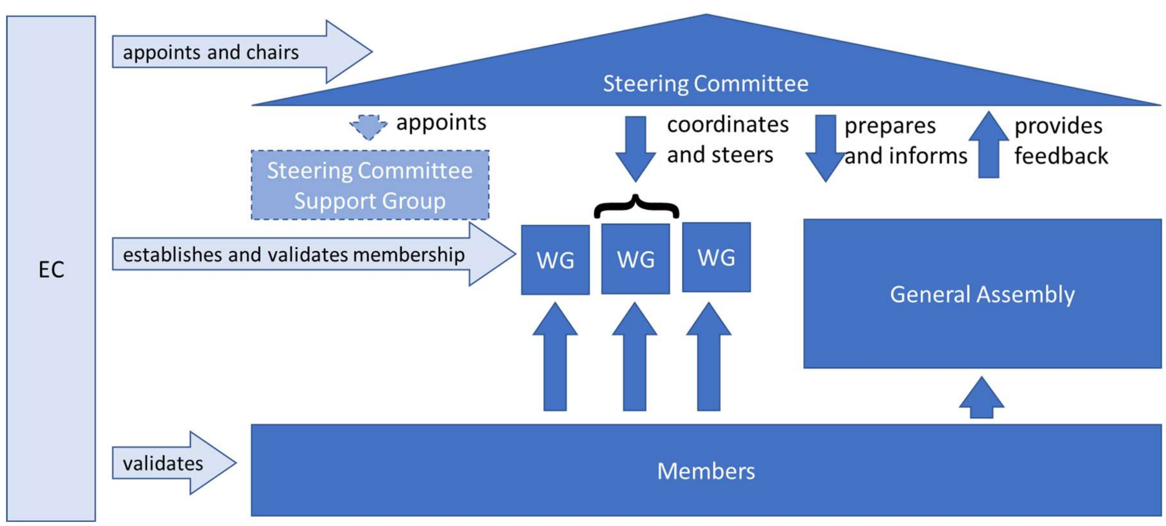

Figure 1: Governance structure of the Alliance

The governance structure of the Alliance is presented in Figure 1.

With the first anniversary of the AZEA approaching, the below timeline shows the main milestones that have been achieved to date.

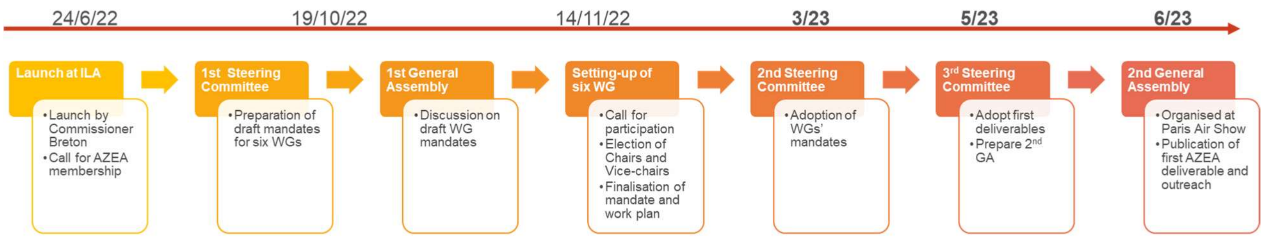

Figure 2: Main milestones of the Alliance

The Alliance has established the structures, set itself the priorities and organised its work to address its objectives.

3. Priority issues addressed by the Alliance

The Alliance has launched six working groups to address the problem statements highlighted in the following sub-sections. Each of the working groups addresses issues that are fundamental when preparing for the roll-out of hydrogen and electric aircraft, beginning with a common vision of where such aircraft can and should operate in the initial phase and how to ensure their certification. Next, the working groups are looking at how to prepare aerodromes for the new requirements of hydrogen and electric aircraft and how to ensure they are supplied with the necessary renewable energy and fuel and how to integrate them in the European network. Finally, a separate analysis is underway to identify challenges and incentives along the value chain.

In line with their respective mandates, working groups have established work breakdown structures and a planning of deliverables.

Target scenarios: In which market segments and where will hydrogen and electric aircraft first enter into service? (**Working Group 1**)

The goal of AZEA Working Group 1 is to establish quantified objectives (roll-out scenario) supporting the market uptake of hydrogen and electric aircraft by 2050, for the European air traffic. WG 1's figures of reference will allow the Alliance to develop and promote an inclusive view (all hydrogen and electric aircraft are addressed), and notably to define the corresponding requirements for carbon free electricity and hydrogen to be supplied at airports as propulsive energy of zero-emission aircraft. The work on the roll-out scenario has been based on:

- Literature review: selection of aviation evolution scenarios, deep dive into aviation traffic forecasts and zero-emission platforms market penetration hypotheses, when they exist;
- Assumptions related to the entry into service of the various zero-emission platforms and their related propulsion technologies in each market segment of interest. The inputs from WG1 members, from all areas of the European aviation landscape, are key to build a first-of-a-kind view of such new markets;
- Aggregation and adaptation of data in order to build 1) a base-case scenario of European fleet evolution 2) a view of zero-emission platforms market insertion, including the creation of new markets 3) a quantification of required volumes of propulsive energy.

In terms of inputs WP1.1 selected the following reference scenarios:

- Green Aviation Technologies Market Uptake, DLR/Steer, 2023, and
- Aviation Outlook 2050, EUROCONTROL, 2022.

A dedicated questionnaire has been answered by 10 OEMs companies on technological insertion. Dedicated support has been obtained from EUROCONTROL, DLR, Roland Berger, and McKinsey.

The first step was to define and agree the market segmentation, from eVTOL to long-haul twin-aisles, as each of those segments will integrate zero-emission platforms with their own requirements and technology choices (all electric, hybrid or hydrogen).

Figure 3: Market segmentation (Source: AZEA members)

The second step aimed at forecasting the evolution of the mobility demand (new aircraft deliveries and associated number of flights) from now to 2050, in a baseline scenario, i.e: i.e without considering a significant ramp-up of zero-emission aircraft. The perimeter of AZEA is from/to/within Europe.

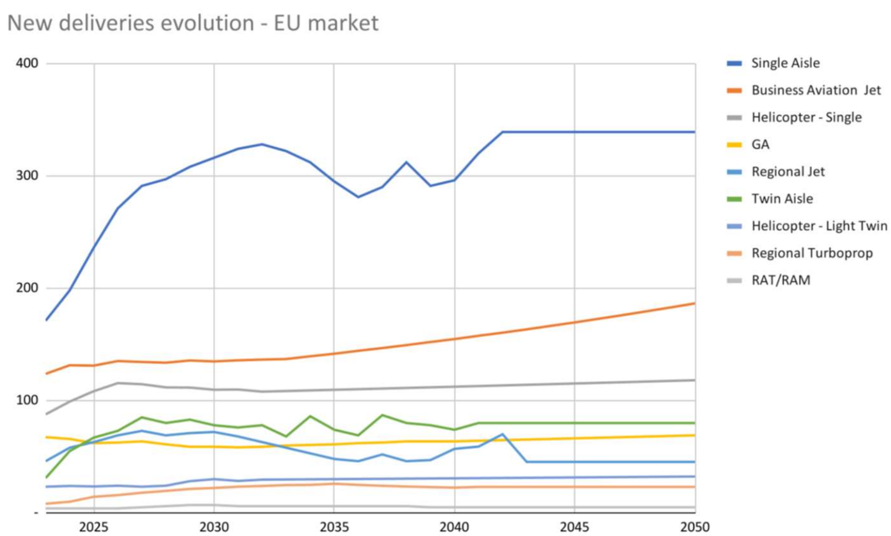

Figure 4: Evolution of the mobility demand – baseline scenario (Source: AZEA members)

The third step of the work consisted in defining the market penetration of zero-emission platforms, including the creation of new routes, notably by smaller aircraft, including eVTOLs but also small regional aircraft of 19 seats. This is a first-of-a-kind exercise, for which no historical data nor robust forecast exists. Consequently, WG1 is building two visions: a scenario based on the development/certification/industrial experience of legacy OEMs, with conservative growth assumptions for the zero-emission market, and a more dynamic version supported by OEM innovators.

The following graph describes the zero-emission technology insertion predictions for regional turboprop in Europe under a conservative scenario.

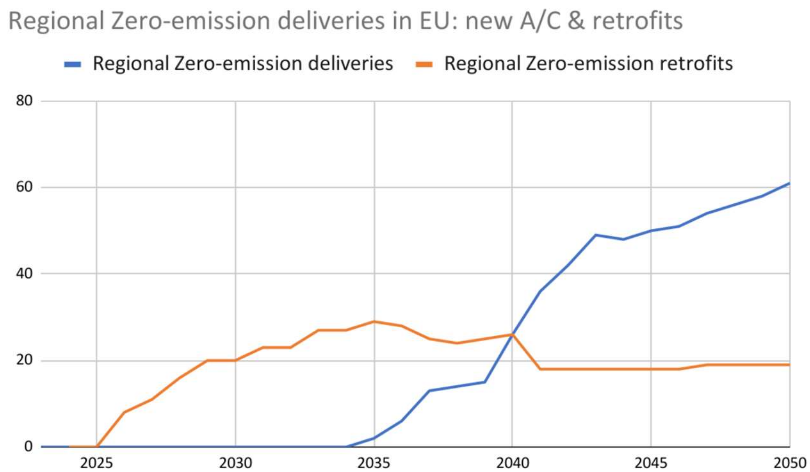

Figure 5: Forecast regional turboprop technology insertion (Source: AZEA members)

Key findings of WG1:

- Robust and validated entry-into-service timelines and market penetration targets for hydrogen and electric aircraft are essential for the Alliance's planning.
- Predictions regarding the entry-into-service of these aircraft vary, but all concur that market entry will be well before 2030.
- Market penetration of new propulsion technologies is easier to forecast for existing market segments than it is for new business cases, including in regional aviation.

As regards the next steps,

- WP1.1 will finalise technology insertion in the missing segments and will document the hypotheses
- Members of WG1 working on WP1.2, notably innovating OEMs, wish to take some time to converge on an ambitious vision of zero-emission platforms penetration.
- WG1 WP1.3 will compute the requirements in terms of propulsive energy (electricity and hydrogen) for the realistic and the ambitious visions, globally for Europe in a first step.
- WG1 WP1.4 will refine the set of hypotheses taken during this first iteration and the energy requirements per airport type. Further objectives need to be re-assessed, notably:
    - Investments should be addressed by AZEA WG2
    - Detailed vision of where the zero-emission platforms will fly may be built by AZEA WG5.

Aviation regulation, certification **specifications and industry** standards: What regulatory, certification and standardisation challenges need to be overcome to allow hydrogen and electric aircraft to enter service while maintaining the highest levels of safety and environmental protection? (Working Group 4)

To support an effective market uptake of electric and hydrogen aircraft and the roll-out of zero emission aviation, the aviation regulatory framework for safety and environmental protection needs to be adapted. AZEA WG4 is working on this by focusing work on the following areas.

EASA regulatory framework

The first electric aircraft has already been certified. WG4 has screened the entire aviation regulatory framework to describe what requirements exist today. These include EU regulations as well as certification specifications (CSs), acceptable means of compliance (AMC) and guidance material (GM)) in all relevant areas (initial airworthiness, environmental protection (e.g. emission limits, noise), operations, flight crew licensing, maintenance, air traffic management, aerodromes, etc.).

Following the completion of this analysis, the group will identify areas requiring adaptation, further analysis or work at ICAO level (e.g. Annex XVI).

Finally, the group will issue recommendations for rulemaking work which will feed the European Plan for Aviation Safety (EPAS) published by EASA. The group will also identify opportunities for cooperation with international actors (ICAO or other aviation authorities).

This subsequent workstream will benefit from the certification-related work done under the Clean Aviation programme with which synergies have already been established.

Industry standards

Looking forward, AZEA WG4 will also identify industry standards required to support the rulemaking and certification needs. Industry standards are often used as means to demonstrate compliance with aviation rules.

The group has already screened the existing industry bodies that are developing industry standards for zero-emission aviation. In the coming months it will perform a gap analysis of worldwide existing industry bodies and working groups that are performing relevant work (e.g. EUROCAE, SAE, ASTM) to identify missing standards in all relevant areas (e.g. aircraft coupling to power source, refuelling/defueling, hydrogen purity requirements, safety distancing, operating procedures, leakage prevention, fire inerting, etc.).

Finally, the group will develop an industry standards roadmap containing recommendations to support their development (including the need for deeper analysis and coordination mechanisms).

Climate impact of non-CO_2 emissions

The significance of non-CO_2 climate impacts from aviation activities, is at least as important in total as those of CO_2 alone. Additionally, elements to the GHGs set in the Fit for 55 package, such as NOx, deserve to be addressed. Based on scientific assessments, uncertainties from the overall non-CO_2 effects are eight times larger than those from CO_2, and the overall confidence levels of the largest non-CO_2 effects (e.g. contrails) are considered 'low'. The European Commission has given a role to EASA in monitoring non-CO_2 emissions.

WG4 will provide a qualitative assessment of the research regarding non-CO_2 climate impacts of aviation with a view to facilitate robust impact assessments (e.g., costs, benefits, trade-offs, implementation challenges) to ensure 'no regret' options are addressed when introducing electric/hydrogen aircraft into the aviation system and as a foundation for future regulatory work on non-CO_2 emissions,

In the first half of 2023, AZEA WG4 has already finalised the following documents:

– A description of the current EASA aviation regulatory landscape for zero-emission aircraft across all aviation domains.
– A description of the current industry standards landscape for zero-emission aircraft.

Key findings of WG4:

– The adaptation of the regulatory framework across domains for zero emission aircraft has already started.
– Work is more advanced when it comes to electric aircraft than hydrogen propulsion.
– The certification rules provide flexibility to certify new technology.
– Organisations can now de-risk their zero emission projects by using EASA's pre-application services.

In the following months, AZEA WG4 will deliver the following:

– Qualitative assessment of research on aviation non-CO_2 climate impact to facilitate robust impact assessments (e.g., costs, benefits, trade-offs, implementation challenges) to ensure 'no regret' options are addressed when introducing electric/hydrogen aircraft into the aviation system (Target Q3/2023).
– Gap analysis of the certification requirements needed for the entry into service of zero emission aircraft (Target Q1/2024).
– Gap analysis of the industry standards needed for the entry into service of zero emission aircraft (Target Q1/2024).
– Certification roadmap containing recommendation for the certification of zero emission aircraft (Target Q4/2024).
– Industry standards roadmap containing recommendation to develop standards for the entry into service of zero emission aircraft (Target Q4/2024).

As progress is made, additional deliverables will be identified.

Aerodromes: What do aerodromes need to do to prepare for hydrogen and electric aircraft and what new opportunities may arise for them? (**Working Group 3**)

AZEA Working Group 3 has worked on two main topics within its mandate:

– The preliminary design of an Airport Scenario setting tool
– A strategic, financial, and operational risk analysis to assess the entry into commercial service of hydrogen-powered and electrical aircraft.

The Airport Scenario setting tool

Considering the variety of aircraft, decarbonised electricity/hydrogen requirements, supply variants and business models, it is not always easy for airports to identify requirements and prepare for the future. Therefore, WP1 aims at providing airports with guidance to prepare an actionable plan and identify opportunities. This guidance document is planned as a catalogue where multiple factsheets will be available for airports regarding infrastructure, operation, and safety.

To identify the relevant factsheets for an airport, WG3 initially drafted a scenario flow by analysing four items:

– number of annual passengers at an airport
– traffic mix by range (mix by share of connected destination distances)
– macro environment factors (local infrastructure / H_2 power demand)
– micro environment factors (space availability for new infrastructures, local communities' attitudes).

Following this flow, a specific airport operator will have access to several factsheets relevant to specific airport categories. The scenario produced will facilitate the airport's long-term development strategies. AZEA WG1 will feed the airport scenario by categorising zero-emission aircraft and estimating the aircraft's entry into service.

The main objective is to provide airports with a scenario or a set of procedures in order to plan and manage the impacts of the new aircraft on the airport's operations and infrastructure requirements over different time horizons. In the picture below a high level diagram of how the tool is expected to be applied.

The Scenario-Flow visualises the various steps, including 4 items – Pax, Range, Macro and Micro factors - that airports can follow in order to end up at the relevant factsheet.

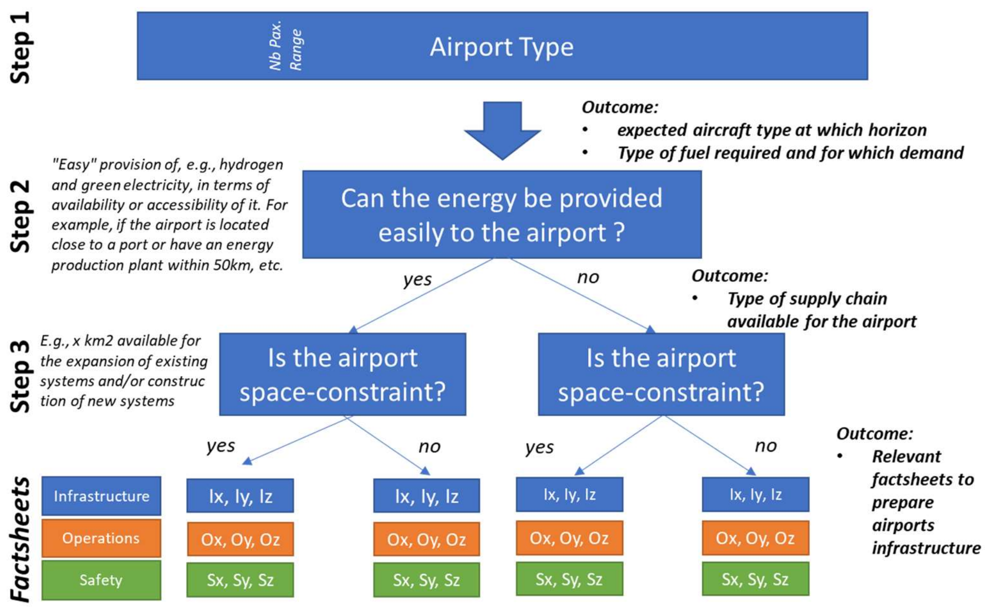

Figure 6: Scenario flow

<u>The barrier / open issues risk assessment and mitigation evaluation model</u>

A risk catalogue has been prepared to identify the type, family and category of potential risks along the lifetime of airports from conceptual phase to operation. A risk matrix has been developed to rank the level of criticality of the top 10 main risks (likelihood x impact) related to strategy, finance and operations. This helps to assess the preventive or mitigation actions proposed to reduce the criticality level of gross risks.

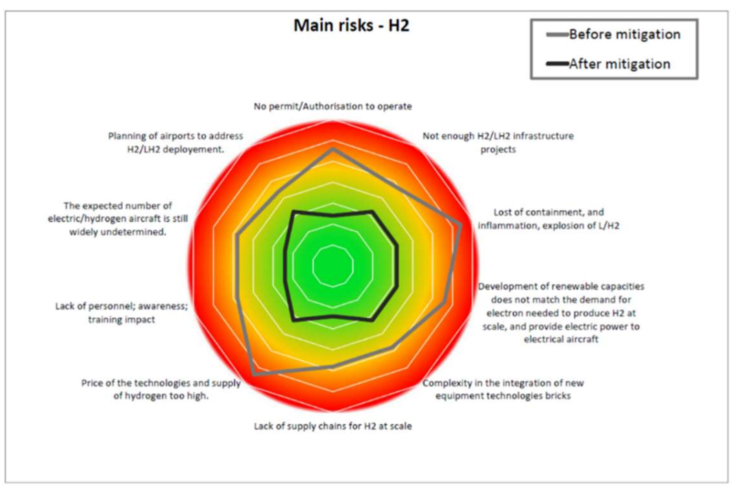

Figure 7: High level view of the results related to H2 aircraft handling at airports

Key findings of WG3:

- Technology is not identified as a critical risk for airports. However, under the risk analysis classification, regulations, standardisation, permitting, skills, and energy/fuel availability were identified as critical.
- Regarding a design of a sustainable hydrogen supply chain network for airports, there is no one-size-fits-all solution, not even for the quantitative aspects.
- Traffic figures and mix are the key driver. The energy ecosystem, the community and the available space at and around the airport may be the main aspects to evaluate.

Electricity/hydrogen supply: How to secure the zero-carbon energy needs of hydrogen and electric aircraft? (**Working Group 2**)

From the supply side perspective, initiating a transition towards zero-emission aviation requires concepts for hydrogen and electricity infrastructures to the airports on the one hand, and at airports on the other hand. Relevant infrastructure will include pipelines, liquefaction, filtration, hydrogen storage, trucks and additional grid development. Depending on the size, location and traffic structure of an airport, the design of the infrastructure may vary, e.g. the location of liquefaction or refuelling mode. The necessary hydrogen infrastructure does not exist yet and must be built and integrated in time for the market-entry of zero-emission aircraft. Airports need infrastructure scenarios to anticipate their investments.

While some regulatory proposals in the context of the Fit for 55 package such as the Alternative Fuels Infrastructure Regulation (AFIR) address the use of renewable energy in the transport sector, there is currently no policy framework for the direct use of hydrogen and electric propulsion in aircraft. Regulatory whitespaces may imply a lack of planning security and have the potential to impede timely investments. Sectors that cannot easily be electrified to reduce emissions will compete for hydrogen. There are several European cross-sectoral initiatives on hydrogen and/or sustainable aviation promoting the setup of a European hydrogen market, e.g. the Hydrogen Alliance, RLCF, Hydrogen Valley Partnerships. While each initiative has a specific agenda on its own, there are possible synergies with AZEA. Coordination is needed to benefit from synergies and avoid doubled structures.

Building upon the aerodrome categorisation from Working Group 3, Working Group 2 will develop hydrogen supply scenarios for different airports, extrapolating the anticipated hydrogen demand from zero-emission aircraft from the projected deployment identified by Working Group 1. These scenarios will allow airports to situate their infrastructure and investment requirements as they prepare for hydrogen and electric aircraft.

WG2 is dependent on results produced by WG 1 and WG 3, some of which are currently expected for October 2023, but preparatory work has already commenced:

- Sub-group A is in charge of defining the infrastructure sizing, related costs and material requirements as well as the required associated electricity generation assets focusing on renewable energy. Concepts for consumption, storage and distribution will consider space constraints by airports.
- Sub-group B is focusing on identifying regulation support and possible alignment with other decarbonisation initiatives at national and international level to consolidate the different initiatives and leverage work done by other decarbonisation initiatives.
- Finally, Subgroup C is developing tools to determine the investment needs and in alignment with the outcome of Subgroup B identify for the corresponding investments the relevant funding and financing strategy.

The initial results obtained in sub-group A provide a high-level framework and model to apply to the scenarios produced by WG1 and calculated need of hydrogen and electricity for the years 2030, 2040 and 2050. Within this sub-group technical boundaries (electrical energy consumption and space needed) for the hydrogen generation based on electrolyser technology were aligned, furthermore additional infrastructure requirements to build up the hydrogen infrastructure and additional electricity supply infrastructure to the airports were identified. This includes the liquefaction infrastructure as well as the transport (trucks and pipelines) and storage capabilities at the delivery points at the airports. This first basis will allow to estimate the required capex for the hydrogen and energy infrastructure and will allow to extrapolate the required investments needed in the different scenarios for the years 2030, 2040 and 2050 which will be the main task of sub-group C.

Sub-group B is analysing regulatory drafts, national hydrogen strategies, EU policies and funding opportunities concerning the direct use of hydrogen in aircraft and electric propulsion. During the first two quarters of 2023, sub-group B completed a broad mapping and thereafter a prioritisation of all relevant documents and information in this context. Preliminary results of the analysis and synthesis of national hydrogen strategies have been presented.

Key findings of WG2:
– There is currently no regulatory framework for the direct use of hydrogen and electric propulsion in aircraft.
– Aviation needs are not addressed in most on the national hydrogen strategies.

Integration into the European network: How will hydrogen and electric aircraft impact airspace, aerodrome services and ATM provision and what needs to be done to ensure the efficient and sustainable use of European airspace and aerodromes? (**Working Group 5**)

The most operationally efficient introduction of hydrogen and electric aircraft into an increasingly congested airspace system, or at airports with limited runway capacity, is of utmost importance, so that neither a drop of liquid green hydrogen, nor a kilowatt-hour of green electrical energy is wasted. Equally important is to ensure the performance of the conventionally powered aviation traffic will not be negatively impacted by the integration. These two considerations form the core mission of AZEA WG5, more specifically optimising the network in the context of the future demand (likely to grow), diversity (different a/c with heterogeneous performance) and complexity (including non-CO_2) coupled with capacity bottlenecks. AZEA members are also conscious that the correct policy, operational and financial incentives need to be properly designed, assessed and put in place to add momentum into the market and provide confidence. Ensuring that operational, financial, and policy-driven incentives sustain a rapid performance improvement is also one of the tasks of WG5.

The focus of WG5 is on:

- Describing how future aircraft are intended to be used, together with the operational processes for both airside and landside operations;
- Optimising the network bringing into play a performance-based approach as promoted by ICAO;
- Assessing the environmental performance as early as possible so that any potential impacts can be mitigated for at an early stage of development;
- Evaluating the efficiency of the introduction of incentives on emissions savings.

The AZEA aircraft classification scheme developed by WG1 does not consider the different scope of aircraft performance expected to be addressed by the concept of operations therefore it was decided that WG5 would propose a classification scheme solely based on aircraft performance. To support this proposal, WG5 asked both legacy and start-up Original Equipment Manufacturers (OEM) in AZEA to detail the performance of aircraft types they are currently developing. In particular, electric, electric-hybrid and hydrogen aircraft to replace the current 9-19 seaters and turboprop/regional jets have different performance characteristics compared to conventional commercial aircraft, notably in terms of: (1) cruising levels, (2) cruising speed, (3) final approach speed and (4) rates of climb and descent. This has led to the development of an initial[4] proposal for aircraft performance classification as shown in Figure 1 below. This classification complements the categorisation presented above by WG1 that relates to market segmentation based primarily on mission range, expected passenger numbers and power plant type.

[4] Whilst it may be expected that some of the performance characteristics may be fully understood through appropriate testing and mature aircraft performance assessments, it is also possible that for some newer aircraft concepts, they may be based upon estimates of potential flight performance characteristics or conceptual thinking.

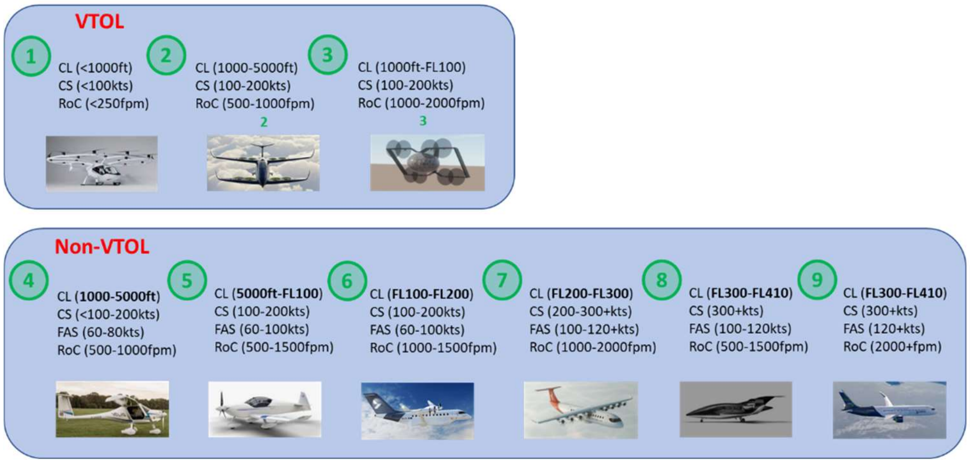

Figure 8: Initial proposal for an aircraft performance classification

In order to fully understand the impact of performance differences of AZEA aircraft, it is also relevant to understand the expected market penetration of each proposed group. For example, if 80% of expected AZEA aircraft are expected to be in Group X whose performance is not expected to be too different from current aircraft, the impact of integration will not be so high. Therefore, it is essential that inputs from WG1 will be taken into account when assessing performance impacts.

Closely related to the questionnaire was the development of a first draft of a Concept of Operations for zero carbon-emission aircraft. This document aims at describing the impacts on sequencing and separations (in particular on standard instrument departure routes (SID) and Standard Instrument Arrival Routes (STAR)), speed management in the en-route phase, impacts on Coordination, Clearances and Communication, and addressing in a systemic approach the knock-on effects of ground operations (e.g. pre-flight "fuelling"), taxiing and engine start up requirements etc. The expected impacts upon airport management, airspace configuration, SID / STAR design, Air Traffic Flow and Capacity Management (ATFCM), and Air Traffic Services (ATS) will be described and analysed through the lens of a performance-based approach considering not only environmental performance but also safety (e.g. ATCO situational awareness, safety nets), capacity, predictability as well as access and equity. The Concept of Operations also feeds the regulatory gap analysis conducted by WG4.

The work so far has established the foundational elements on which WG5 will capitalise to eventually deliver jointly a roadmap to enable the successful roll-out of these new types of aircraft.

Key findings of WG5:

- Hydrogen and electric aircraft represent one of the most profound changes to the aviation ecosystem for years. Once in operation, the number of operations by such aircraft is set to steadily increase. Therefore, it is imperative that such operations can take place safely, efficiently and without a disproportional impact on conventional air traffic operations. Change is needed to evolve from how we work today to fully support these new aircraft types and propulsion methods so that these operations are able to fully achieve their objectives.
- Depending on the market penetration, ATM, ground and air operations may be impacted by the performance characteristics of hydrogen and electric aircraft including any impacts on legacy aircraft by the safe and efficient integration of new aircraft. The AZEA Concept of Operations will serve as the vehicle for identifying those areas which will require further activities when maturity allows, and can be synchronised with the arrival on the market of new aircraft.
- Adaptation of existing operational and environmental performance indicators should be promoted in order to measure the different capabilities of aircraft using electric and hydrogen power sources for propulsion.
- It is vital to assess and communicate information on the potential non-CO_2 emissions that may be expected from AZEA aircraft, with appropriate analyses or assessments.

As regards the next steps, WG5 will:

- Steadily augment the Concept of Operations adopting as a driving factor the entry into service of the aircraft from 2024 to 2050; and,
- Progress on the modelling and assessment activities while duly considering in the modelling sophistication the current limits of our understanding (in particular with respect to non-CO_2).

Incentives: Looking at the entire value chain, what incentives may be required to support the entry into service of hydrogen and electric aircraft? (**Working Group 6**)

Incentives to accelerate the shift towards zero-emission aviation are very important for all actors through the whole aviation ecosystem and the financial system around it, as they give more certainty in business models. Working Group 6 has been mandated to formulate concrete proposals in order to shape the future EU common market for Zero-Emission Aviation. It is important to acknowledge that the market itself and the financial capabilities of some actors will not be enough to support all roll-out scenarios, therefore some enablers need to be activated in a short and medium time. Some incentives may already be in discussion but most of them need to be addressed as a new topic in EU legislation.

WG6 has opted to cover the whole range of aviation industry segments and identify the need for each segment. This is very important, especially in aviation, as each segment highly depends on each other, thus being the definition of one ecosystem. It has identified the following actors:

- OEMs, lessors, finance actors,
- Energy providers
- Support services
- Airports
- Airlines
- Global distribution (ground agent), including booking platforms and travel information systems
- Passengers

WG6 is also exploring the decarbonisation initiatives launched by other industries (ports, renewable energy production, cars, etc.) in order to learn lessons about the incentive mechanisms that worked, their effect and the pitfalls to avoid.

In terms of deliverables, WG6 plans to deliver a preliminary report mid-2023 recording the main topics, barriers and levers that will be addressed in a final report to be delivered at the end of 2023. The purpose of the initial release is to trigger feedback from other members of the Alliance.

The EU has a great power of shaping its own market and providing clear policies when it comes to economic rules and operating regulations. Across the whole aviation value chain, WG6 has identified several regulations that could greatly support the entry into service of zero-emission aircraft, by either adding new dispositions or modifying existing ones. In particular, instruments such as public service obligations or the air service regulations could be a great enabler for early adoption of zero-emission aircraft, and various regulatory initiatives could be improved to allow energy providers to bridge the gap of energy prices for end users in aviation. On a safety perspective, while a lot has already been done, it should be ensured that every corner of safety regulations has reference to zero-emission aircraft, in order to ensure safe maintenance and safe skills for pilots flying these planes. Passengers are also a key element in the value chain; safety communication will be key to reassure them, while information on environmental performance of different air travel options could make them opt for zero-emission aircraft as a greener alternative to traditional aircraft.

An option is also to advocate for the creation of funds, or reserving a portion of existing funds, or incentivising the industrialisation and development of zero-emission aircraft in Europe or the infrastructures required for zero-emission aircraft in aerodromes. This could also be formulated in a potential EU answer to the US Inflation Reduction Act (Green

Industrial Plan) to promote public investments in the different segments of the zero-emission value chain (from critical raw materials to the airlines as end-user that need to be supported in its purchase).

Another lever could be for the Alliance to support the classification of zero-emission aircraft as assets meeting environmental, social and governance sustainability criteria for financing by the financial community. Globally, new approaches are needed to de-risk investments in ZEA for airlines, lessors and financiers.

Key findings of WG6:

– Numerous barriers for the deployment of ZE aircraft have been identified across the aviation value chain. Some of these barriers are of technical nature, but many are linked to economic or regulatory aspects.
– Policies, regulations and incentives can have a positive contribution to the development and deployment of ZE aircraft, by improving their competitiveness and providing market certainty.
– A number of such policies, regulations and incentives have been identified. In the next phase of work, WG6 will assess how those instruments can be adapted to support ZE aviation.

Summary of results/deliverables to date

Numerous AZEA members have participated in the working groups according to their possibilities and interests. More than 290 experts have signed up to a demanding pace of work that added to the obligations of their jobs. The largest workload has fallen on WG chair teams and leaders of the sub-groups. Their drive and dedication and the commitment of member organisations have built the foundations for the Alliance's next steps.

At the occasion of its second General Assembly, the Alliance will publicly release two deliverables produced by Working Group 4, namely

– a review of the current regulatory landscape for zero-emission aircraft, and
– an assessment of the current standardisation landscape.

The topics addressed by the above documents are crucial for the entry-into-service of hydrogen and electric aircraft, and both follow lengthy implementation processes and therefore need to be addressed early on. Further deliverables from WG4 will follow with the aim to advance the necessary work.

In addition to the above, the working groups have prepared documents supporting the internal alignment of classification systems (aircraft and aerodrome typologies) and to stimulate cross-WG discussions (concept of operations, initial report on obstacles and incentives). This and other output may give rise to self-standing deliverables for public release.

Beyond their tangible output, discussions in the working groups have helped develop an understanding among the members of the Alliance of each other's interests and constraints. The Alliance brings together airframers large and small, promoters of hydrogen and those of electric propulsion, those who will acquire and operate such aircraft and those who will invest in the infrastructures that make hydrogen and electric flight possible – and many more. A value chain can only work if all find their requirements addressed.

4. Outlook

Expected outcome of the working groups

Upon completion of most of the work of the six working groups in the course of 2024, the Alliance will establish targets for the entry-into-service of hydrogen and electric aircraft, defined on the basis of

– expected aircraft capabilities (WG1),
– plausible entry-into-service dates (WG1),

– a profiling of airports and flight operations to identify opportunities for early deployment of hydrogen and electric aircraft (WG3 and WG1).

These entry-into-service targets will be flanked by

– recommendations for the evolution of the aviation regulatory framework, certification and standards for hydrogen and electric aircraft (WG4),
– recommendations for action to ensure availability and access to renewable electricity and hydrogen (WG2),
– a concept of operations outlining how hydrogen and electric aircraft can best be integrated in airspace (WG5, WG3 and WG4),
– assessment of performance impacts and optimisation (WG5) and
– a comprehensive assessment of the obstacles that need to be overcome along the aviation value chain to ensure that zero-emission flight becomes viable, including the necessary incentives and other actions (e.g. policy frameworks) which promote the uptake of zero-emission aircraft (WG6).

This analytical phase and its recommendations will help the Alliance take the next steps to practically prepare for the roll-out of hydrogen and electric aircraft.

As aviation is a global activity, it may be necessary for AZEA to check and discuss its work with international partners working on similar activities in other regions of the world fostering a harmonised approach where needed.

Setting priorities

When determining the actions to prepare the aviation ecosystem for zero-emission aviation AZEA will need to set the right level of prioritisation in order to achieve the Alliance's objectives, which are

– tackle aviation's effect on the climate by supporting the entry into service of zero (carbon) emission aircraft
– support the aeronautical industry by creating the conditions for innovative, climate-neutral technologies to enter the market.

In doing so, AZEA will give due consideration to the following priorities:

Safety: Zero-emission technologies and infrastructure will need to be developed providing, as a minimum, the same levels of safety the aviation industry is delivering today. There shall be no compromise to safety.

Climate change mitigation: Europe has a clear objective to decarbonise the continent by 2050. On a global level ICAO has agreed in 2022 a long-term aspirational goal to decarbonise aviation by 2050. To contribute to achieving those goals, the Alliance will work to identify priority routes where the early introduction of H_2 and electric aircraft will have maximum climate benefit.

Strengthening the industrial fabric: AZEA will also identify and promote market opportunities for zero-emission aircraft that have a more limited impact on climate change mitigation. Novel technologies usually enter the market in the lower aircraft market segments, allowing for gradual adoption and scaling into the wider aviation system, taking benefit from the experience and lessons learned.

The actions derived from these priorities will be timed against a baseline of entry-into-service dates established on the basis of manufacturers announcements and standardisation and certification timelines.

Raising awareness in the aviation ecosystem

Hydrogen and electric aircraft are an opportunity for the entire aviation system, but not all actors are aware of or confident that they will become a reality, and this not in the distant future but in the next ten years. An information campaign addressing the different parts of the value chain beyond the Alliance would help raise awareness. This effort could initially concentrate on Europe, targeting first and foremost airports and air operators. It could be supported by upcoming Alliance deliverables and be launched before the end of 2023.

The Alliance is lucky to have several organisations among its members that are themselves large membership organisation, reaching a substantial number in particular of European airports and air operators.

Raising awareness of and interest in the transition to hydrogen and electric aviation can become easier when supported by a clear message of what is expected from the aviation community: their expression of interest by a set date to become early adopters of these technologies and to be listed in a pipeline of projects (see below) for which financing will be mobilised.

Further ahead, the Alliance will consider launching a broader communication campaign reaching beyond the aviation industry to generate public awareness of and interest in the possibility of climate-neutral flying.

Promoting the Alliance and its goals towards national and regional authorities

Under the Alliance's terms of reference, EU Member States can participate in the work of the Alliance in relevant working groups. For this, they do not need to become a member of AZEA. The Commission may also consider establishing a State Representative Group.

Member States and regional authorities have regulatory competence over a range of fields that touch aviation. They are instrumental in agenda setting for transport and environmental policies, for the provision of essential public services, for the deployment of H_2 infrastructures, to name but a few. National and regional authorities are also important potential sources of financing to support the transition to climate-neutral aviation, and the Alliance will look at ways to strengthen cooperation with national and regional authorities.

International dimension

The objectives of the Alliance imply that the effects of its action should not be limited to Europe. Fortunately, AZEA is already international by its membership and can use this to reach out beyond Europe. The Alliance could also reach out to likeminded initiatives (such as for example the World Economic Forum's Target True Zero initiative).

Establishing a roadmap

Based on the roll-out scenario and the identification of barriers and needs performed by the different working groups, the Alliance will establish a roadmap presenting the Alliance's members' common ambition towards the entry into service of hydrogen and electric aircraft. It will provide a clear description of the actions and their appropriate timing that the different stakeholders involved in the aviation ecosystem should undertake to enable the earliest possible entry into service of those aircraft and contribute Europe's aviation target of climate neutrality by 2050.

The roadmap will constitute a unique instrument to reach out to all actors who must contribute to prepare for the arrival of hydrogen and electric aircraft, including operators and airports, national and regional authorities, investment projects, financial institutions, passengers and citizens, etc. It will help federating the actions undertaken by the different actors in a coherent effort.

A first issue will be established towards the end of 2023 or the beginning of 2024, dependent upon the working groups' advances in their analyses and recommendations. It should be published at the occasion of the June 2024 General Assembly. The roadmap and its recommendations will be updated as appropriate to take into account the progress towards the objectives of the Alliance. The roadmap may also inform the European Union's process of establishing an objective account of the state of environmental protection relating to civil aviation, as documented in the European Aviation Environmental Report, which is published at least every three years.

Opening a pipeline of projects for early adopters

The AZEA roadmap and its roll-out scenario will give early adopters and infrastructure providers for hydrogen and electric aircraft a point of reference and lend credibility to their projects. To help mobilise the necessary investments, the Alliance will establish a list of projects (a project pipeline) that contribute to its roll-out strategy and require financing.

Before implementing a pipeline of projects, the Alliance will need to decide who to open the call to as well as the principles governing inclusion.

Financial

The transformation of aviation towards zero emissions will require investments all along the value chain – investments in R&D, in production capacities, in new aircraft and their operations, in energy and infrastructures, in people. Much of this will be private capital, but public funds will have a role to play in de-risking investments and supporting initial demand.

A guide to potential source of EU financing for aviation has been drawn up and will be extended with analysis of national support programmes of relevance. In parallel, the Steering Committee Support Group has begun exchanging with financial institutions on how they can support aviation's green transition and what the sector needs to do to attract capital. These considerations will also have a bearing on how the pipeline of projects referred to previously is drawn up.

Raising public awareness (citizens, passengers)

For too long public perception has been the aviation sector has been perceived as nonchalant towards climate change. The commitment and work of the members of the Alliance, on top of their normal duties, demonstrates the sector's dedication to tackle CO_2 emissions and its confidence in hydrogen and electric aircraft propulsion. As the Alliance advances in its analysis and the roll-out of hydrogen and electric aircraft becomes more tangible, the Alliance will devise a communication strategy to inform the broader public on the Alliance and raise awareness of the potential for climate-neutral travel.

Mobilising policy support

While there is large policy support for zero-emission technologies in the EU and beyond, this rarely translates into explicit support for zero-emission aviation. For example, no dedicated funds are available today for the deployment of hydrogen or electric aircraft and the investments required at airports, by MRO (i.e. maintenance, repair and overhaul) organisations, for training and other purposes. This means that as the Alliance establishes a list of projects to support the implementation of its roadmap, it will need to apply to existing transversal funding instruments for the transition to climate neutrality. These are easier to mobilise with reference to official policy documents, but no such documents focussing on hydrogen and electric aviation exist today.

Furthermore, aviation – not specifically zero-emission aviation – is impacted by a large breadth of policies which are defined at national, European (or in other regions) and international level through ICAO. As part of the ongoing work in the working groups, AZEA will identify and notify to the appropriate authorities such policies and regulation that will need to be adapted to better suit zero-emission aviation.

5. Conclusions

ZE aircraft can play a key role in reducing the climate impact of aviation, but their deployment requires a coordinated effort from the aviation industry to create a new ecosystem comprising energy supply, airport infrastructure, staff training and more. AZEA was created to bring together the aviation stakeholders that can help shape that ecosystem to make hydrogen and electric powered flights possible.

The Alliance has mobilised experts from all over the aviation sector, including OEMs, airlines, airports, energy companies, research institutions and civil society organisations. This shows the great interest across the board in developing a set of technologies that will help meet the EU's climate targets and secure a strong future for the European aviation industry.

Through their active participation and work, the Alliance members are preparing the aviation ecosystem for the arrival of hydrogen and electric powered aircraft. Going forward, setting the right priorities will be essential to make sure the Alliance fulfils its mandate in the most effective way.

Appendix – List of members of the Alliance for Zero-Emission Aviation (as of 19 June 2023)

Abelo Capital Aviation Management Limited

ACI-Europe

Aciturri Aeronáutica

Aegean Experts

AELIS Group

AerCap Holdings

Aernnova

Aeromechs

Aéroports de Paris (Groupe ADP)

Aeroporto Guglielmo Marconi di Bologna

Aeroports Públics de Catalunya

Aerospace and Defence Industries (ASD)

Aerospace Valley

Air France-KLM

Air Liquide

Airbus S.A.S.

Aircraft Design & Certification

Aircraft Leasing Ireland

Airlines for Europe (A4E)

Airport Regions Council

Airsight

Amedeo Ltd.

Amelia

Ascendance Flight Technologies

ASL Group

Asociación Cluster de Aeronáutica y Espacio del País Vasco – HEGAN

Aura Aero

Avions Mauboussin

Beyond Aero

Blue Spirit Aero

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

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

Consorcio del Aeropuerto de Teruel

Cranfield Aerospace Solutions

Dublin Airport Authority (daa)

DAHER Aerospace

Destinus

Deutsches Zentrum für Luft- und Raumfahrt (DLR)

EasyJet

EH Group Engineering

Electric Flying Connection (EFC)

Electron Aerospace

Elixir Aircraft

ELSA Industry

EENUEE

Estonian Aviation Academy

Euroairport (Basel-Mulhouse-Freiburg)

EUROCAE

Eurocontrol

European Cockpit Association

European Federation for Transport and Environment

European Regional Aerodromes Community (ERAC)

European Regions Airline Association Ltd. (ERA)

Association of European Research Establishments in Aeronautics (EREA)

European Union Aviation Safety Agency (EASA)

Federation of European Tank Storage Associations (FETSA)

Fleasy

Flughafen Friedrichshafen

Flying Whales

Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung

FSR TU Darmstadt

Fundación CTA - Centro de Tecnologías Aeronáuticas

General Aviation Manufacturers Association

GE Avio

Groningen Airport Eelde

Groupe Absolut

H2Fly

H3 Dynamics SARL

Hamburg Aviation

Hamburg University of Applied Sciences (HAW Hamburg)

Heart Aerospace

Hevel Eilot Hub

IATA

IBEROJET (Evelop Airlines SA)

IMIEU

impact on sustainable aviation e.V.

IndustriAll European Trade Union

Instituto Nacional de Tecnica Aeroespacial (INTA)

ITP Aero

Jeppesen

Lazarski University

Leonardo

Lilium

Linde

Łukasiewicz Research Network - Institute of Aviation

Maeve Aerospace

Magpie Aviation

Netherlands Airport Consultants (NACO)

Nordic Aviation Group

Nordic Initiative for Sustainable Aviation (NISA)

Normandie AeroEspace

Napier Park Global Capital

New Electric Aircraft Engines-GSI

nrg2fly

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

Panta Holdings

Pipistrel

Pratt&Whitney Rzeszow

Poznan Airport

Région Nouvelle-Aquitaine

Région Occitanie / Pyrénées – Méditérannée

Rhein-Neckar Flugplatz (Mannheim)

Roland Berger

Rolls-Royce

Royal Netherlands Aerospace Centre (NLR)

SAE International

Safran

SATA Air Açores

Scandinavian Seaplanes

Service technique de l'Aviation civile (STAC)

SESAR 3 Joint Undertaking

SiriNoR

SKYCORP

SONACA

Stichting AeroDelft

Supernal

Swedavia

Swedish Aviation Industry Group (SAIG)

Thales

To70

Torino Airport - SAGAT

TU Delft

Universal Hydrogen Europe SAS

VÆRIDION

VELICA

VGA

Vinci Concessions

Volocopter

VoltAero

Výzkumný a zkušební letecký ústav (VZLÚ)

Widerøe Zero

Wizz Air Innovation

Wright Electric

Zadar Airport

ZE-Aviation Alliance

Zentrum für angewandte Luftfahrtforschung ZAL

ZeroAvia