

SUMMARY OF RESULTS OF THE CONSULTATION ON AN ALLIANCE ZERO-EMISSION AVIATION (SEPT.- OCT. 2021)

Disclaimer: This report is on stakeholder contributions to a survey conducted by the European Commission's Directorate-General Defence Industry and Space. It neither constitutes an endorsement by the European Commission of the positions expressed, nor does it prejudge the decision to establish an Alliance Zero-Emission Aviation.

ABSTRACT

The present document provides a summary of comments received during the consultation on an Alliance Zero-Emission Aviation. Its purpose is to provide feedback to the participants of the consultation as well as others interested in becoming actively involved in the Alliance.

The document explains where the different contributions came from (by geography as well as by sector) and summarises the main arguments made with respect to the utility of such an Alliance as well as its possible priorities and operational objectives.

The broad participation, not just of the aeronautical industry but also the wider aviation sector (including aircraft operators, airports, fuel providers, oversight bodies, etc) and a strong interest from the world of aviation research bears witness to the importance of facilitating the transition to zero-emission aviation and the breadth of the challenge.

THE CONTEXT

The European Commission announced in its Communication on Updating the 2020 New Industrial Strategy, adopted on 5 May 2021 [1], that it would consider preparing an Alliance Zero-Emission Aviation. The Communication "'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality" [2] noted that the Alliance will complement the Commission's efforts to introduce sustainable aviation fuels.

The proposal for an Alliance Zero-Emission Aviation reflects increasing efforts by the aeronautical industry in Europe to develop innovative technologies to support the greening of aviation. Some of the solutions under development involve technologies such as hydrogen, battery-electric or hybrid propulsion not previously used in aircraft. The commercial use of such new aircraft types will require an important adaptation of the entire aviation ecosystem.

The purpose of the Alliance would be to identify and prioritise the challenges related to the entry into service of zero emission aircraft and ultimately to help implement practical solutions to these. The Alliance will need to mobilise interested stakeholders in all parts of the aeronautical industry - from large to small enterprises - and among other relevant actors - airports, airlines, services providers, air navigation service providers, research organisations and networks, national and regional authorities, etc.

[1] COM(2021)350, 5.5.2021

[2] COM(2021)550, 14.7.2021

THE SURVEY

As part of the preparatory phase for a possible Alliance Zero-Emission Aviation, DG DEFIS asked members of the aviation community in the broadest sense to comment on the need and orientation of a policy initiative in favour of the introduction of zero emission aircraft. The consultation was launched on 1 September on EU Survey and remained open for contributions until 15 October.

More than 100 companies and organisations were directly contacted by e-mail, and DG DEFIS also used its Twitter account to point to the survey. Other services of the European Commission (Directorates-General MOVE, RTD) also forwarded the invitation to comment to their contacts, as did Eurocontrol and industry associations.

By 15 October, 73 responses from across the aviation ecosystem were received, including from major industry associations across the aviation system. Several responses were accompanied by scoping papers on the Alliance's future structure. The responses are overwhelmingly of high quality and included not just the big players but also a significant amount of smaller enterprises, research organisations and EU-funded projects.



RESULTS

QUANTITATIVE ASSESSMENT

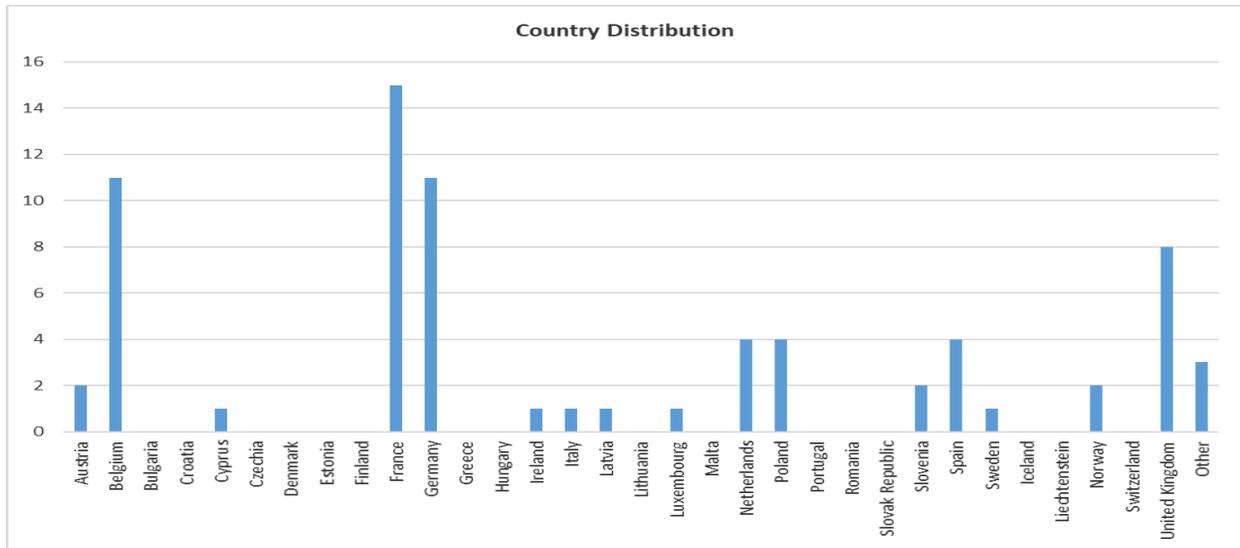
Respondents from across the ecosystem and from large to small

The survey attracted not only the big industry players but also a significant number of smaller enterprises, research organisations and EU-funded projects (see [Annex I](#)). Nearly 40% of all responses came from the aeronautical industry (including airframers and engine and component manufacturers). Research and academic institutions located upstream from the aeronautical industry accounted for around 14% of responses while the downstream segments of aircraft operators, MROs, airports and energy providers made up for 27%. Around 10% of responses came from public authorities.

By geography, the largest number of responses came from France, Germany and Belgium, followed by the United Kingdom. Several European and national aeronautical industry associations and airport and airline associations responded on behalf of their members. A number of companies with headquarters in the US answered through their European liaison offices in Belgium.

Type of organisation *)	Count
Aeronautical industry	28
Airports	6
Airlines, operators, lessors	8
MRO	1
Research and academia	10
Energy providers	5
Public authorities	7
Other	8

*) Main activities only

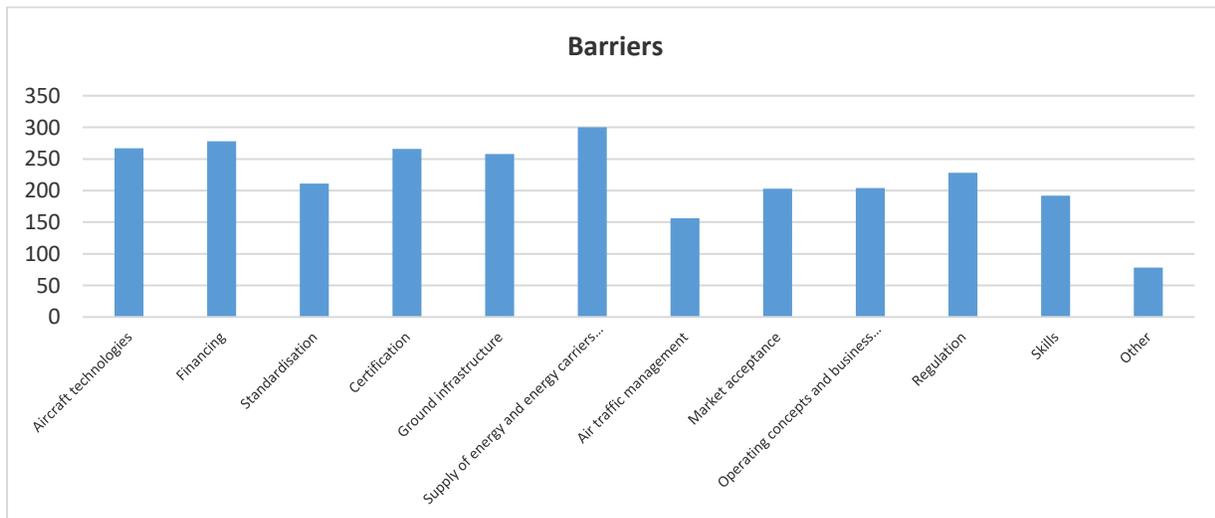


Support for a policy initiative to prepare for the introduction of zero emission aircraft

None of the respondents questioned the utility of a policy initiative in support of zero emission aviation. Formulated differently, no organisation opposed to such an initiative took part in the consultation. More information on the respective expectations with regard to a future Alliance Zero-Emission Aviation are provided [below](#).

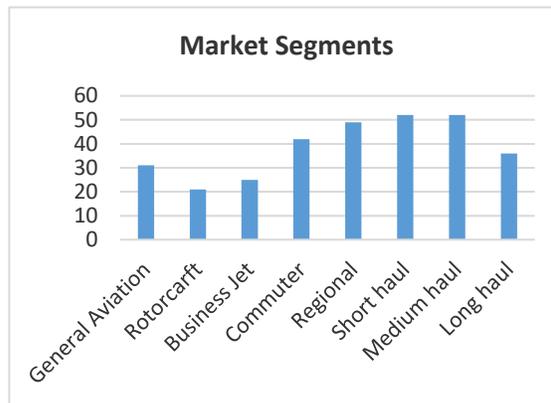
The top two barriers named are energy and financing

The barriers listed with the highest priorities are access to energy, access to finance, aircraft technologies and their certification, the readiness of ground infrastructures and regulation. The list of issues to be addressed and their are found in the chapter [Challenges](#).



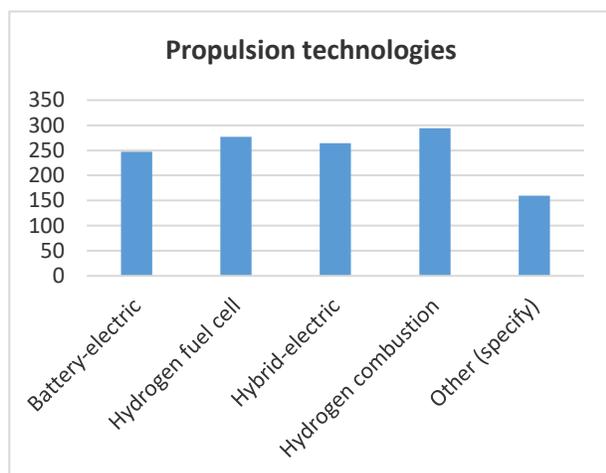
Views on priority aircraft segments evenly spread

When asked to prioritise the different market segments for aircraft, responses were relatively evenly spread across aircraft market segments, with a preponderance in favour of commercial passenger aircraft in the regional, short-and medium-haul (SMR) range and lower interest on rotorcraft and business jet. Several respondents said that the Alliance should be as inclusive as possible. The arguments in favour of a focus specific segments are outlined in the chapter on [priorities](#).



All propulsion technologies score equally highly

With respect to the prioritisation of propulsion technologies, responses were similarly evenly distributed. While hydrogen combustion received the greatest support, fully electric or fuel cell-driven electric propulsion scored nearly as high, as did hybrid technologies which typically combine combustion turbines with electric motors. Several respondents mentioned sustainable aviation fuels (SAF), i.e. drop-in fuels that can be used by today's aircraft technologies under "Other".



QUALITATIVE ASSESSMENT

CHALLENGES

Participants to the survey were asked to rank the challenges and explain their choice. The results of this exercise are summarised below.

According to the survey, the biggest challenge is to produce green **energy** in the quantities required by aviation and to do so by processes that are environmentally sustainable and socially acceptable. The challenge is exacerbated by competing needs from other sectors such as heavy industries and road transport that have greater policy backing. Secondly, energy needs to be where it is required. One view expressed was that with regard to hydrogen there should be refuelling at airports in a 500km range. The integration of airports into the broader energy supply chains will be key, whether these are centralised hydrogen distribution systems or local hydrogen networks. In the latter, airports could make the link between aviation decarbonisation and local initiatives such as regional renewable energy or hydrogen projects. A possible approach is to start small to create the momentum while setting out policies and plans to scale up production and logistics.

Finally, respondents said that it is important to regulate the price of green hydrogen to be competitive with currently available fuels either by taxation or any other methods.

Financing requirements for the development of zero-emission aircraft indicated at over 1 billion for the eVTOL market and 20 billion for commercial passenger aircraft. An example given for the timelines of development programmes is in the order of 8 to 10 years. Additional financing would allow European start-ups and OEMs speed up their efforts to introduce to market zero-emission 19-seaters. However, it is considered that the current investment ecosystem is not geared towards high risk, long timeframe investments.

One respondent pointed out that financing will decide the global race to the introduction of zero emission aircraft. Private capital has flown into these development efforts but as one respondent pointed out, “no major aerospace innovation has been made by private investment alone.” However, one respondent noted that there is no funding mechanism specifically catering for the development of zero emission technologies.

It is not only the development of zero-emission aircraft but also airlines and infrastructures that will require funding. The airlines will need € 5 trillion to roll over their fleet between 2035 and 2050 and airports and other infrastructures another 500 billion, according to one response. Airlines operating zero-emission aircraft may need commercial incentives to ensure they can compete against other less effective, but cheaper, carbon-reduction technologies.

Some respondents expressed confidence that zero-emission **technologies** will work and that as far as hydrogen is concerned, the technology roadmap does not require any fundamental scientific breakthroughs. Others stressed that the technological and commercial feasibility of the technologies needs to be assessed. Also, the supply chains required for the production of zero-emission aircraft are not yet in place. Downstream requirements on aircraft should be taken into account, and airports should contribute to defining zero-emission aircraft rather than be “mere recipients of requirements defined externally.”

According to respondents, the speed of **certification** will be crucial for the entry into service of zero-emission aircraft. However, reconciling the need to secure aircraft safety with the evolution of technologies will be complex. Whereas clear proposals exist on how to certify, no formal ways are yet established and no testing manuals written, according to one response. In particular, hydrogen fuel cells and batteries are little understood from a certification point of view. On the other hand, both technologies are well known in the automotive and power industries.

One response called on EASA and national regulators to be appropriately resourced to develop the capability and capacity so that new zero emissions aviation programmes can be fast-tracked while maintaining the outstanding safety and regulatory standards the aerospace sector depends on. They should also be prepared to think differently and to work with industry to pro-actively ensure that regulations and Acceptable Means of Compliance are fit for purpose and drive pragmatic but safe solutions.

Responses to the survey also highlighted the importance of readiness of airport **ground infrastructures** to enable the entry into service of zero emissions aircraft. However, no specific EU initiative has so far been established to identify the potential implications of new aircraft technologies on airports and their operations and business models. Since airport infrastructure is built for decades, it is important to start preparing infrastructure and operations as early as possible. Projects launched today should ideally already anticipate the needs of future aircraft and be designed with tomorrow's energy demands in mind.

According one respondent, ground infrastructure could start small, to support the first zero-emissions aircraft coming into service (e.g. on site gaseous H₂ production), with opportunities for growth to more wide-ranging solutions in gaseous and liquid H₂ supply, especially if brought together with ground transportation requirements for hydrogen.

It was also noted that there is currently no **regulation** covering certification and operations of zero-emissions aircraft, especially if they are hydrogen-powered. Therefore, it is necessary to develop the needed regulatory frameworks and to promote the European position in ICAO regulatory groups and relevant international standardization groups.

Standardisation is an important enabler for safety and efficiency. The absence of standards can deter investments, for instance with regard to charging infrastructure for electric aircraft.

Several respondents pointed out that although zero-emission aircraft respond to the general public's concerns over the climate effects of flying, this does not automatically translate into **market acceptance**. Passengers will need to be convinced that electricity and hydrogen are safe and have equivalent levels of comfort to conventional aircraft. Early demonstration and entry into service of smaller scale platforms will ensure confidence in the safety basis of larger scale platforms. An increasing number of smaller aircraft flying at lower altitude could also generate opposition from local communities. At the same time, zero-emissions aircraft will be cleaner and quieter than traditional aircraft, flown from more remote, local airfields and operating more closely to the communities they serve. Engagement with end users, local communities and local governments must start early.

Zero-emission aircraft may differ from conventional aircraft in turn-around times, maintenance requirements, operational performance, operational cost and procurement costs, affecting airlines' traditional **operating concepts**. Similarly, airport owners will need to assess new technologies and develop their infrastructure, and in particular smaller airports may find it difficult to meet requirements. On the other hand, zero-emission aircraft provide an opportunity to create a distributed regional aviation network, incorporating also door-to-tarmac services.

Qualified engineers are essential for the zero-emission aviation and for MRO organisations that assure that airworthiness standards are kept up. According to some respondents, these **skills** do not exist in the quantities required, in particular for fuel cells, and when they do exist it is often in other industries, without an understanding of aeronautical requirements. Upskilling is possible, and there is opportunity for cross-industry collaboration.

Although air traffic management (**ATM**) scored lowest in terms of priorities, several respondents nevertheless pointed to future challenges, in particular related to the advent of large numbers of manned and unmanned smaller aircraft, the diversification of aircraft performance profiles and a greater role of regional airports. Zero-emission aircraft are likely to be slower moving and flying at lower altitudes. One stakeholder predicted that this would require a shift away from a human-centred ATM framework to a digitalised (unmanned) traffic management system. Solutions could be prepared in time if ATM designers and providers and the manufacturers of the new zero-emissions aircraft cooperate.

EXPECTATIONS DIRECTED AT THE ALLIANCE

All of those who responded expressed support for initiatives to promote zero-emission aviation. The following expectations for such initiatives were cited:

- pooling of knowledge

- joint representation of interests
- visibility of zero-emission projects
- helping new aircraft developments overcome the “valley of death” between R&D and market deployment
- development of infrastructures
- proposing an appropriate regulatory framework – European and global – including incentives to produce and operate zero-emission aircraft, taxation, state aid, standardisation, certification, airworthiness and safety
- proposing regulatory constraints that will make zero-emission technologies and fuels more competitive
- identifying international, EU and national funding opportunities
- identifying the needs of the industry in terms of skills

The international dimension was also raised in a number of responses. While several called for engaging with third countries to enable deployment on the global market, one suggested the creation of global coordination platforms, open to all stakeholders across the aviation value chain.

A top concern was that there should be coordination between the Alliance and Horizon Europe and initiatives on SAF, batteries and hydrogen alliances, policies and associated regulations. As one respondent put it, “it is important to avoid overlaps between related initiatives. This requires thoroughly defining the scope of the proposed Alliance for Zero Emission Aviation so as to avoid duplication of work.” Numerous actors also referred to the EU Pact for Sustainable Aviation, which has been proposed by a coalition of industry associations.

Linked to the question of the potential benefits of the Alliance is the issue of where it should put its focus. Although covered in greater detail in other sections, several respondents expressed their priorities, for example that the Alliance should concentrate on the short-term benefits of fully electric propulsion, that it support airports and airlines or that should help SMEs and start-ups.

Finally, one stakeholder said that the Alliance’s recommendations and conclusions need to be actionable. “The work of such an initiative should be as operational as possible, setting a clear timeline for deliverables and allocation of responsibilities, including for public authorities.”

PRIORITIES – MARKET SEGMENTS

Responses to the question on priority market segments showed there are essentially two criteria to determine the Alliance’s priority, climate impact and technological feasibility. Separate from these is the criteria of economic viability that did not, however, attract much attention.

Climate impact: Several responses pointed out that the EU’s target for reducing greenhouse gas emissions will be achieved in aviation by concentrating on those aircraft most widely used. On the basis of this criteria, many respondents proposed to put the Alliance’s focus on single-aisle commercial airliners, defining these as aircraft that carry between 80 and 250 (or 165, 190) passengers on distances of around of 1500 km but up to 4000 km. Others stated that long-haul flights emit the greatest amounts of CO₂ and should therefore be targeted.

Feasibility: Several replies noted that technological solutions for carbon-neutral flight are most readily available for general aviation-class, commuter and/or regional aircraft. One also pointed out that certification requirements in these market segments are lighter. Solutions developed for the small end of the market can typically be adapted to the larger aircraft once validated and can help train tomorrow’s pilots of commercial aircraft. As was argued “a lot of the barriers to entry can be solved on a small scale first which creates momentum.” Conversely, the larger the aircraft, the larger the airport and the larger the infrastructure challenges, it was said. Furthermore, some responses pointed to the expected evolution of the air transport system, carried by the advent of smaller but environmentally friendly aircraft replacing bigger aircraft on shorter routes. However, others said that as the market was close to achieving the introduction of electric commuter aircraft, this market segment would not require support.

Economic viability: This argument was advanced only by one respondent who said that large zero-emission aircraft were not viable today and that the focus should therefore be on the small end.

A large number of replies said that the Alliance should be as inclusive as possible and address all market segments. Some suggested the Alliance could take a staged approach, taking into account technological maturity.

PRIORITIES – TECHNOLOGIES

The survey listed four technologies that could be the basis for zero-emission aviation, namely fully-(battery-) electric, hydrogen fuel cell, hydrogen combustion and hybrid technologies. Propulsion technologies not listed could be proposed under “Other”. As several respondents pointed out, “some of the technologies listed above will still create non-CO₂ emissions at exhaust eg water, NO_x that through chemical processes and at scale could still cause issues for climate change.” The Alliance would therefore need to **be clear about** what it considered to be a **zero-emission technology**.

No propulsion technology emerged as the clear favourite. All technologies scored equally high, and a large number of respondents also referred to sustainable aviation fuels, i.e. kerosene replacements (drop-ins) produced from renewable sources using renewable energy. The equal importance attached to the various propulsion technologies reflects that “each of these technologies may be better **suited for specific applications** (e.g. battery electric for small short-range modules, hydrogen or hybrid electric for mid-range capacity (regional segment) and SAF for the larger capacity platforms.” Some respondents suggested that promoting SAF would also pave the way to hydrogen – and vice versa.

With respect to **battery-electric** propulsion, several respondents underlined its advantages for smaller and novel aircraft. The advent of fully-electric flight, they said, would lead to new forms of air travel, such as eVTOLs, as well as to a more efficient alignment of aircraft performance and aircraft missions. Others considered that the unfavourable energy density of batteries makes them unsuitable for any larger aircraft, although there were differences of view on what this meant. Additionally, the effects of battery recharging cycles and rapid discharging events and battery recycling at end-of-life were cited.

Several replies said that **hydrogen combustion** would have an important role to play in market segments above commuter aircraft. Opinions differed whether it qualifies as a zero-emission technology. The same considerations for and against were also put forward with regard to hybrid propulsion systems. One noted that the incremental improvements offered by complex hybrid propulsion systems could better be achieved with conventional engines and airframes.

As concerns **fuel cells**, several saw this as the ideal solutions, pointing to the unrivalled efficiency of fuel cells coupled with electric motors. But as with batteries some respondents questioned their usefulness for larger aircraft.

One response considered that the Alliance should not just advocate zero-emission propulsion for the flight phase but also address solutions such as for taxiing.

While **SAF** is out of scope of the Alliance, many referred to the close link between SAF and the transition to hydrogen and therefore between the Alliance Zero-Emission Aviation and that for sustainable aviation fuels. Both would benefit from working jointly on specific infrastructure for hydrogen such as distribution, storage and refueling station in Airports and production/testing facilities.”

OPERATIONAL TARGETS

AIRCRAFT TECHNOLOGIES

A recurring argument made by respondents was for **targets** to be set, either at the level of dates for the entry into service of the different categories of zero emission aircraft or at the level of a research, to guide the numerous research efforts, in particular in the critical area of hydrogen.

Several respondents point to the need to **coordinate R&D efforts** or at least build on what has been achieved across Europe (with one suggesting that this could be accomplished by Clean Aviation Partnership). Many respondents warned that current R&D funding levels were woefully inadequate.

Specific areas in which further research would be required are:

- 100% SAF engines,
- pure H₂ combustion engines
- fuel-cells
- liquid hydrogen systems
- refueling and defueling systems
- cryogenic tanks
- the effects of new propulsion systems on aircraft aerodynamics and structures
- high voltage DC bus (1000V or more)

- batteries with enough kWh/kilo

Several stated that the Alliance should not engage in R&D but instead **monitor progress**. Many hoped that the Alliance would help bring R&D to market, overcoming the “valley of death”.

Horizontal to these is the requirement for tools such as a platform for the **exchange of knowledge** (“innovation gateways”) between the research communities or between these and industry. Several responses also pointed to the need for **information exchanges between aircraft manufacturers, airports and aircraft operators**, not least to identify efficiency improvements which can bring down the costs of operating zero-emission aircraft. Several called for the **certification** of new technologies to be considered early on.

The Alliance should distinguish between **technological solutions for the medium and the long term**. While one respondent suggested that these may not be identical, another said that vehicles using existing design and technology would be improved in subsequent waves of innovation. Some argued that the Alliance should **concentrate on the most mature technologies** to achieve effects quickly, including by upgrading the existing fleet. Others pointed to general aviation’s potential to provide for early validation.

Apart from aircraft technologies, respondents said that research is also required into the effects on **aircraft production processes** and facilities and specifically also into **maintenance-repair-overhaul organisations (MRO)**. The likely **operational benefits** of zero emission technology and the reduction in **climate change impact** should also be assessed.

FINANCING

Financing is one of the top concerns cited by respondents to the consultation, as the entry into service of zero-emission aircraft will incur costs in areas such

- R&D
- advancement of key technologies
- operational trials and certification testing (often not covered by R&D support)
- production facilities (including test beds)
- MRO
- pilot infrastructures and infrastructure changes and readiness
- the creation of the energy ecosystem
- and the acquisition of aircraft.

One of the replies valued these costs at € 20 bn for the development of a zero-emission aircraft, € 5 trillion between 2035 and 2050 for fleet rollover and € 500 billion for the infrastructure. Others said that the Alliance should do further work to establish an **overview of investments required and when**. The Alliance should help mitigate the risks of such investments. It could also **propose new sources** of funding, f.e. pooling proceeds from **ETS** for the transition to a climate neutral air transport system, preferably at the EU level. The Alliance should support the building of a **pipeline of potential investment projects** and **federate investment capabilities** from different actors to reach larger funds and pools dedicated to sustainable aviation. It could also inspire the creation of Important Projects of Common European Interest (**IPCEIs**) to mobilise financing from the Member States and the EU. Some of the responses suggested that in particular small-scale projects and SMEs with great innovations merited greater financial support. Others underlined the need to support start-ups.

Some pointed to the complexity of the European funding landscape and noted that the Alliance could be of particularly strong support to its members through **monitoring of financing opportunities** at a European level, **providing guidance** with relevant opportunities.

Many replies proposed that the Alliance help mobilise capital by **linking private and public investors** (especially with the European Commission and Member States), for example by building a dedicated **platform** to bring investors (private equity funds, infrastructure investment funds, EIB, national promotional banks etc...) and industrial partners together. Such a platform would allow the investors to better understand the economics and business models of the new aircrafts technologies and airports operations and identify ways to lower the risk for them. It would also help identify those areas in which the levels of risks exceeded what private investors could accept and where therefore other financing solutions were required.

Among other instruments proposed by respondents, the Alliance could call for positive **financial incentives**, e.g., through **tax measures or carbon markets** to stimulate investment in emission reduction technologies. Several stakeholders referred to the role of the **EU taxonomy** and said that the criteria of the EU taxonomy for aviation

products of the supply industry should be simplified. One suggested an **airport tax**. A further proposal was to use **public procurement** to support sustainable technologies (e.g. buying sustainable aircraft for government fleets).

STANDARDISATION

Many replies stated that standardisation should support the timely entry into service of zero-emission aircraft. It will lower the costs of new technologies. While initially European stakeholders would need to converge, many respondents commented that **standardisation needs to be international** to ensure operability worldwide. Concretely, standards should be proposed to **ICAO** and be actively promoted and defended by the EU. A respondent also said there should be **coordination between EASA, CAA and the FAA**. By being at the forefront on such a disruptive technology, Europe could lead standardisation / certification.

Among the **domains** cited where standardisation is required, are

- Refuelling standard for new alternative fuels
- Electricity charging infrastructure
- Charging protocols
- Quality and handling of hydrogen
- Norms for storage (including pressure vessels) and distribution of new fuels at airports
- Safety standards for the use of hydrogen and electricity infrastructures in Airports (supply/distribution, storage, refuelling)
- Liquid hydrogen propulsion components

According to several replies, standardisation will need the **work of experts** (including from industry and research institutes as well as infrastructures operators and energy providers) looking at the different emerging future technologies and their implications for standardisation. It was suggested that an **advisory group involving all stakeholders** should coordinate standardisation requirements. Furthermore, close **coordination** is needed **between governments, institutions and aeronautic agencies** to develop the favourable framework for standardisation, certification and regulation. This work should lead to a **standardisation roadmap**. On the other hand, one stakeholder warned that standardising too early would stifle innovation. Others said that local flexibility should be safeguarded where relevant. Several respondents recommended that standards should as much as practicable **build on existing standards**, for instance in automotive. One suggested that the Alliance should also work on **guidelines** for operating zero emission flights.

CERTIFICATION

- refer also to "[Regulation](#)" –

As zero-emission aircraft will introduce technologies to market previously not used in aviation, several stakeholders commented on repercussions for certification. Among the **needs for certification** respondents cited hydrogen-related technologies, specifically also fuel cells, electric motors, alternative fuels, including green hydrogen and guarantee of origin, airport infrastructures and their operations. Although out of scope of the Alliance Zero-Emission Aviation several also mentioned the need to certify sustainable aviation fuels and their origin.

A concern often raised is the need to **accelerate certification** to avoid that it becomes a bottleneck of a fast deployment of zero-emission aircraft. To this purpose, certification agencies and national regulators should be involved from the beginning. Some respondents specifically asked for EASA to take leadership in establishing new certification rules for future zero-emission aircraft, based also on input received from the Alliance.

As one respondent put it, the absence of certification requirements "is causing significant uncertainty in developing which acts as a barrier to entry, especially for smaller companies or those from outside the aerospace industry." Others either proposed that the Alliance presents certification agencies with a **roadmap of requirements** or that **target dates** should be set by product category. One went as far as to suggest that the Alliance could provide **rule-making proposals** as well as **conformity materials** elaborated through dedicated working groups.

Given the global nature of aviation, several cited the requirement that certifying entities and regulators **cooperate globally**. The Alliance could play a role in forming a European position.

Other comments received are that certification should be **clear and build on industry standards** (including those developed for other industries) and that it should be **objectives-based** and not rule out specific technologies. While **safety** should not be jeopardised, certification should become more "agile" and allow for **experimental implementations**. Some pointed out that while today's certification cycle is set up to certify incremental

developments, in the future it will need to facilitate certification of **combinations of radical new designs/techniques**.

GROUND INFRASTRUCTURES

As one response summarised it, "Insertion of electric and hydrogen aircraft in operational fleets will require the deployment of new infrastructures at airports including ultra-high power chargers as well as hydrogen production and storage and ground support equipment, etc. In order to overcome the "chicken or the egg" challenge faced by other industries deploying sustainable transport technologies, airport ground infrastructures deployment must be anticipated and coordinated at EU level in order to ensure their availability well in advance of the expected availability of aircraft."

Several respondent said that the Alliance should **establish the needs and requirements** for the new airport infrastructure (e.g. **prioritise airports** to be equipped, **forecast energy demand** based on realistic scenarios, **identify required interfaces**, etc.) both for battery-electric and hydrogen aircraft (possible link with the Alternative fuels infrastructures future Regulation (AFIR)), in terms of roll-out strategy and standardisation.

It should furthermore define a clear **development plan** for the adaptation and/or the development of the infrastructure required (hydrogen production and distribution ecosystem around airports, refuelling ground infrastructure, electricity supply (be aware of smart grid requirements) and charging stations, etc.), identifying priorities that enables the timely development of the required infrastructure for the different type of aircraft considered. For the development of hydrogen infrastructures, the plan should build on **synergies with other airport needs** (e.g. local ground transportation) and related industries and stakeholders that will benefit from hydrogen hubs at airports (transport and logistics firms, local municipalities operating hydrogen buses, etc.). The plan should allow to learning and adaption through the implementation of **pilot cases addressing both major and secondary airports/airfields**.

Among the topics listed by respondents that this plan should include were:

- **standardisations and harmonisation** on a global scale (including land use and ecological barriers),
- **coherent development** between all the platform,
- identification of a **common model of infrastructure readiness**.

The plan should also identify the needs in terms of new operations (in particular refuelling), including safety/security regulations, skills/training requirements.

Also, the Alliance should identify appropriate **financing paths** (possibly IPCEI-type mechanisms, CEF, etc.), incentives for early adopter investments and large scale demonstrators. Furthermore, the Alliance could

- encourage the creation of **airport working groups** that mutually support having the required infrastructure ready,
- implement a **coordination action between territories and regulatory authorities**, airports, aircraft manufacturers and energies providers,
- support to **airports around the world** to get ready for hydrogen powered aircraft.

SUPPLY OF ENERGY AND ENERGY CARRIERS

The magnitude of the challenge was described in one response as follows: "The required level of renewable energy for a global aviation system flying with 'net zero' fuels [or hydrogen] is estimated to be over 10% of global energy supply, and this energy must be renewable. So looking at global renewable energy levels today and likely fleet growth to 3-4 times today's aircraft fleet, we will likely need an increase in renewable energy of ~5x today's global energy capacity, just for aviation. When adding other sectors like electrification of heavy industry, automotive etc. the challenge is formidable."

For aviation, especially aircraft using fuel cell technology, the **supply of green hydrogen** is critical to achieve in volume in both gaseous (for smaller aircraft) and liquid (for larger aircraft) form, along with the associated **storage and liquefaction facilities**.

Respondents therefore said that the Alliance should:

1. Identify the **quantities of energy needs**. Quantify the **capacities** needed and the **investments**. Identify the required **quality** (i.e. purity) of hydrogen where and when it is required, paying special attention to remote airports and airports **in regions with low volumes**. Estimate the **impact of green electricity demand on infrastructure** and grid requirements.

2. **Reach out to the energy sector** and interface with all related European policies (such as Hydrogen Europe initiative) to ensure that aviation needs are included in a broad strategy for mobility and energy use and secure a reliable and affordable supply of clean electricity and/or clean hydrogen at airports. Airports should be considered in **hydrogen infrastructure deployment strategy** at EU level (as places of production, storage and distribution of hydrogen).
3. Promote **production of liquid hydrogen**.
4. Create a large network of **charging stations** throughout Europe to enable electric aviation to take place. Ensure production of battery and fuel cells at EU level.
5. An operational objective of the Alliance could be to provide a **deployment roadmap** (production, logistics and storage) that connects with technology, product and infrastructure readiness. In particular:
 - **Prioritise airports** in terms of building LH₂ infrastructure, support it and forecast energy demand in order to stimulate supply.
 - Identify the **appropriate interface** – or several possible interfaces - between airports and the broader energy supply chains, e.g. hydrogen distribution
 - Develop **cross-industry partnerships** to ensure supply of cost-competitive green hydrogen.
 - Propose **tax reliefs** to promote new energy carriers to mitigate the higher costs of green hydrogen.
6. Ensure smooth **coordination with related Alliances**, e.g. the Hydrogen or Battery Alliances

One response suggested that a **specific working group** could be set up to map out different ways to supply electricity and hydrogen to airports. On site energy production should be explored, as well as taking into account the challenges faced by remote locations and islands.

AIR TRAFFIC MANAGEMENT

As one respondent put it, the first zero-emission aircraft into service “will fly more slowly, have different flight profiles on take-off and landing and will fly at lower altitudes than conventional aircraft, and therefore air space design needs to allow for this, and ATM must be ready to manage such aircraft.” Others wanted more **analysis** to be done **of the expected performance** of hydrogen-propelled or battery-electric aircraft. The Alliance should **assess how these new entrants could be integrated** in the classical ATM network and determine new required services. One respondent pointed out that the impact of zero-emission aircraft on air traffic management would depend on the (initial) **deployment scenario**, for instance if this were to be limited to a number of hydrogen hubs.

ATM network adaptation also encompasses approaches to arrivals and departures from airports. One respondent said the Alliance should “start the thinking on **non-conventional approaches and landing** (higher descent angle, lateral approaches, parallel landings etc.) to allow micro-feeder aircraft to safely fly from small airports to hubs without congesting the air traffic”.

Furthermore, the Alliance should **consider** how zero-emission aircraft could give a **new role to small airports** which are currently un/underutilised assets for commercial air traffic and make them multimodal hubs. Another respondent proposed to **assess the broader changes to the aviation ecosystem**, including the advent of drones, urban airports, new destinations, seaplanes and a generally massive increase in the number of air vessels. All of these called for new structures in air traffic management. One reply suggested that the role of the Alliance could be to **extract ATM benefits and mitigation of ATM risks** from the new ground and flight operations that ZEA will enable.

Potential **environmental benefits** of an optimised ATM should also be targeted, an issue particularly of relevance during the transition to zero-emission aircraft. For this, several replies said that there should be collaboration with Eurocontrol and Single European Sky ATM partnership to build **management systems supporting aircraft missions** minimising the influence on climate. A concrete suggestion was for the Alliance to propose **incentives for aircraft operators** to use climate-optimised flight profiles, e.g. by linking them to **air traffic control charges**. The Alliance could also support **technologies for in-aircraft weather forecast** which are necessary to implement contrail-optimised flight routings. One respondent to work on a **global modernisation and standardisation** of air traffic management.

Several respondents questioned whether the challenges outlined above should be addressed by the Alliance or left to others. It was pointed out that there are already a number of work streams related to flight efficiency with **Network Managers** (deployed or ready for deployment) and in SESAR. Another said that the SESAR Joint Undertaking could be tasked with assessing the impact of zero-emission aircraft, with the Alliance monitoring progress.

MARKET ACCEPTANCE

One of the responses established three main requirements for market acceptance: An uncompromising stance on safety, meeting operators' needs (in terms of aircraft performance, ground infrastructure and energy supplies) and thirdly providing passenger comfort.

With respect to safety, a number of respondents highlighted the importance of **emphasising the safety of zero-emission aircraft**, built on testing, demonstration and industry experience.

With respect to operators, one respondent referred to the need for **finance** allowing the acquisition and operation of zero-emission aircraft. Another reply also highlighted the availability of the **capable infrastructure** at enough locations as "airlines need flexibility to change networks and routes and therefore need a lot of capable airports to have confidence to invest in green aircraft technologies."

As one response put it, **advocacy towards the general public and passengers** can be an extra incentive to nudge the airline industry towards a pro-innovation and earlier / more aggressive fleet replacement approach. Several replies thought that given the public's strong interest to the environment, market acceptance should not be an issue. Others, however, were less inclined to take market acceptance as a given. As one put it, "as with any new technology, there will be early adopters who are keen to be one of the first to fly zero emissions but the majority of people may choose to stick with what they know. If the technologies are to be taken up with the speed that is required, **public perception** of hydrogen aircraft needs to be tackled in advance – **surveys, consultation, education and demonstration**, especially around the communities that are likely to adopt the new technology first."

It was furthermore noted that the Alliance should vaunt the **passenger benefits of zero-emission flying**, which could be more comfortable and quieter than today's experience. By way of communication campaign, the public could be offered **flying experiences and/or demonstrations** of the advantages of flying electric (lower noise, less maintenance, no warm up etc). In addition, the **favourable environmental footprint** of zero-emission aircraft compared to other modes of transport should be highlighted (e.g. no roads etc. that reduce natural habitats).

The Alliance should also **demonstrate and guarantee that the hydrogen used in aviation is low-carbon** or zero-carbon.

Market acceptance may vary regionally, with one respondent pointing out that in his region there was already a long history with electric cars and now also boats/ferries and that the introduction of electric aircraft is therefore expected to proceed smoothly.

The role of public policy in forming market acceptance was cited by some. One response said the Alliance should contribute to **stimulate the demand through public policy** for the transition towards zero emission aviation. Another called for **bans to non-electric recreational flights**. It was also proposed that the Alliance should suggest **incentives** to facilitate the transition towards zero emission aircraft use, in a consistent manner all around European countries.

Although out of scope of the Alliance, a number of respondents called on the EU to work towards a global blending mandates or "book-and-claim" mechanisms.

OPERATING CONCEPTS AND BUSINESS MODELS

The impact of zero-emission aircraft on operating concepts and business models will differ across aircraft categories, and several replies said that the aim of the Alliance should be a **better understanding** of the new aircraft technologies, production and operation by airport and airlines. Business models will need to reflect the **deployment scenarios** for zero-emission aircraft, for example if this were to take the form of a limited number of hubs and spokes or direct flights between secondary airports. These could take into account the following factors highlighted by respondents:

- Future aircraft will be more closely aligned with the payload and range requirements of their actual use.
- Full-electric commuters to connect smaller airports, micro-feeders and mini-liners will create opportunities novel approaches to air transportation and provide new prospects to small and underutilised airports, not least because these aircraft will be clean and quiet.
- They will create opportunities for more distributed regional aviation network, perhaps even incorporating door to tarmac services as well as business models that are on a pay-per-use rather than ownership basis.
- Hydrogen and battery-electric aircraft will change airports' business models and operating concepts.
- As energy hubs they will be confronted with questions of load balancing and regional power supply. Battery-electric flight also raises is related to battery replacements and reuse.

As operators do not yet understand the benefits of zero-emission aircraft, some believed that the Alliance can play a major constructive role in **exploring, documenting and championing the operational benefits** to airline operators and airports' business models of a switch to hydrogen-electric propulsion, such as in terms of fast turnaround times, lower operating costs, longer lifespans of hardware. **Operating concepts and business models** could be developed together with authorities or through the (local) cooperation between airports, aircraft manufacturers and airlines.

Several respondents pointed out that fielding new technologies will be expensive. While someone said that **leasing-models** will be key, many pointed to the need for government support. Several proposals were for the creation of **IPCEIs** to accelerate investments by airports and other operators in the redevelopment of infrastructures and multi-industry assets, including hydrogen infrastructures. Other suggested **tax mechanisms**, ETS, CORSIA, subsidy for SAF/H2 fuels.

REGULATION

Several stakeholders said that the Alliance could help **prepare timely regulation** supporting the entry of new technologies into the market, based on up to date scientific knowledge. Governments, institutions and aeronautic agencies should jointly develop the **favourable framework for standardisation, certification and regulation**, and the role of the Alliance could be to **communicate the regulatory requirements** to the European as well as national legislators. Furthermore, the Alliance could undertake high quality **studies and gap analyses** to support identification and removal of regulatory barriers to market uptake of next generation of zero emission aircraft.

Several said that one of the objectives should be that zero-emission propulsion's climate advantages are priced in and incentivised correctly. Conversely, an inadequate regulatory setting may not only delay or muzzle the entry into service of zero-emission aircraft but also disrupt the level playing field in Europe and affect global supply chains. In addition, clear regulatory structures will enable private investments in clean aviation technologies, it was said. A **supportive political framework** can reduce the investment risks for new aircraft and fuelling infrastructure. Regulators should engage with industry in all stages of development of zero-emission aircraft.

Among the **specific proposals for regulation** the following were cited:

- Regulatory measures to make hydrogen and SAF use more competitive and/or finance their production, including CO₂ taxes and/or taxes that are based on actual climate change effects;
- RED II or RED III compliance for SAF and hydrogen-based fuels;
- The "green credentials" of investments;
- Regulation for storage, distribution and refuelling;
- Construction permits and environmental regulation governing infrastructure.

Certification – although a separate topic – was also referred to as a regulatory challenge, as ways had to be found to **certify new technologies** that cannot as yet point to a long history of operation. This applies not only to aircraft but also to airports, f.e. hydrogen infrastructures. Among the issues cited here are differences in failure modes of hydrogen and fuel cell technology and the need to define safety cases for leakage, venting and graceful degradation, including risk assessments and testing requirements. Another stakeholder called for a more **flexible certification framework** by which industrials can develop their innovation.

Regulations should rely as much as possible on **industry standards** as acceptable means of compliance.

One respondent pointed out that what is needed is not necessarily additional legislation but **complementarity between relevant existing legislation**. The Alliance should ensure **consistency with the broader EU regulatory and enabling framework** (clean energy strategy and mobility packages, trade policy, fiscal policy, etc.). Also, **regulations unfit for purpose** should be identified. Several respondents noted the importance of international harmonisation of regulation.

SKILLS

The advent of new technologies implies new skill requirements. More so, without new skills it may not be possible to bring zero-emission aircraft to service. As one respondent put it, "decarbonising aviation will be hugely dependent on a large and steady supply of young talent." Conversely, confronting the climate change challenge will make many current skills obsolete, and it will be vital that workers are "taken along the journey of the green transition."

For example, more interdisciplinary experts will be required, combining e.g. electrical engineering with aerospace engineering competences or skills in the area of new propulsion technologies. Similarly, it will be important to bring skills to the sector from other sectors i.e. digital skills, electric power/energy management, hydrogen, etc. Other examples cited were dealing with new fuels or **retraining maintenance engineers** for the maintenance of battery and hydrogen propulsion systems. One went as far as to call for an “**overhaul of aeronautical degrees** to ensure a focus on systems engineering, general engineering skills, whole aircraft engineering and specific technologies such as batteries, fuel cells and hydrogen as a fuel in aviation [and the] creation of the next generation of engineers”. However, as one stakeholder put it, it takes years to train aeronautical experts, and we need to act immediately with **seniors** who already have these skills and at the same time train young people for the future.

The Alliance could encourage **cross-industry cooperation** and cooperation **between academia and industry** to identify the needs, learn from other industries and implement **appropriate training in universities or centres of further education**. It could also help define, set up and perhaps even deliver **upskilling schemes** e.g. for ground operations, handling, design, transportation, development, testing, emergency response and/or **on-the-job training** for experienced aviation employees.

Furthermore, the Alliance could **promote the zero-emissions aviation sector** towards the outside world and make it appealing for young graduates as much as for experienced leaders from all over the world. The Alliance could also aim to make the **relocation of international experts** easier.

Several respondent also saw a role for the Alliance in mobilising **financial support** for additional staff training and education. Specifically, the EU should invest in supporting **cross-training programmes** to continue developing the aviation industry skills in other fields previously unused in aviation, such as the advanced materials used to store hydrogen, fuel cell technologies and electric motors

Many referred to the link to the **EU Pact for Skills**.

ANNEX I – LIST OF CONTRIBUTORS

Aeronautical Industry				Airports	Airlines, Operators, Lessors	MRO	Research organisations universities	Energy providers	Public authorities		Other		
Aircraft manufacturers	Engine powertrain suppliers /	Equipment suppliers	Associations / Clusters						CAA	Governments	Standardisation organisations	ANSP	
Airbus (D)	GE Aviation	Aernnova	ASD	AENA SME (ES)	IATA	Lufthansa Technik (D)	ACARE	Air Liquide	Norway Civil Aviation Authority	Austrian Ministry of Transport (AustriaTech)	EUROCAE	ENAIRES	3 personal contributions
Airbus	Safran	Fluid Action (F)	BDLI	Flughafen München (DE)	A4E		EREA	Hy2Gen	Cyprus Civil Aviation Authority	German Ministry of Economy (BMWl)			Open Airlines
Aura Aero (F)	MTU Aero Engines	SOBEN (F)	GIFAS	Hamburg Airport (DE)	ERA European Regions Airline Association		DLR	Jasper Corporation		French Permanent Representation			Programma-bureau Luchtvaart (NL)
Boeing	Rolls-Royce (UK)		GAMA	Swedavia (SE)	easyJet Europe		ONERA	Hydrogen Europe		Netherlands Ministry of Infrastructure and Water Management			Atmosphere
Cranfield Aerospace Solutions (UK)	Rolls-Royce (D)		Association of Polish Aviation Industry	Stavanger (NO)	Isla Air Express (ES)		Łukasiewicz Research Network - Institute of Aviation	Latvian Hydrogen Association		Airport Regions Council			
Pipistrel (SLO)	Pratt&Whitney (PL)		British Helicopter Association				Cranfield (1) (UK) Cranfield (2) (UK) Cranfield (3) (UK)						
Deutsche Aircraft	UTC Aerosystems Wroclaw		Aerospace Valley				Amazon						
Lilium	NEAE (IT) ZeroAvia (UK) AVIATHOR				ACI Europe		MAHEPA CleanSky Unifier 19						