Draft proposal for a

European Partnership under Horizon Europe

Clean Aviation

Version 25 June 2020

Summary

Clean aviation aims to put aviation on route to climate neutrality, by accelerating the development, integration, and validation of mainly disruptive R&I solutions, for deployment as soon as possible. Also developing the next generation of ultra-efficient low-carbon aircraft, with novel power sources, engines, and systems, which will emerge from the research and demonstration phase at a high TRL.

About this draft

In autumn 2019, the Commission services asked potential partners to further elaborate proposals for the candidate European Partnerships identified during the strategic planning of Horizon Europe. These proposals have been developed by potential partners based on common guidance and template, taking into account the initial concepts developed by the Commission and feedback received from Member States during early consultation[1]. The Commission Services have guided revisions during drafting to facilitate alignment with the overall EU political ambition and compliance with the criteria for Partnerships.

This document is a stable draft of the partnership proposal, released for the purpose of ensuring transparency of information on the current status of preparation (including on the process for developing the Strategic Research and Innovation Agenda). As such, it aims to contribute to further collaboration, synergies and alignment between partnership candidates, as well as more broadly with related R&I stakeholders in the EU, and beyond where relevant.

This informal document does not reflect the final views of the Commission, nor pre-empt the formal decision-making (comitology or legislative procedure) on the establishment of European Partnerships.

In the next steps of preparations, the Commission Services will further assess these proposals against the selection criteria for European Partnerships. The final decision on launching a Partnership will depend on progress in their preparation (incl. compliance with selection criteria) and the formal decisions on European Partnerships (linked with the adoption of Strategic Plan, work programmes, and legislative procedures, depending on the form). Key precondition is the existence of an agreed Strategic Research and Innovation Agenda / Roadmap. The launch of a Partnership is also conditional to partners signing up to final, commonly agreed objectives and committing the resources and investments needed from their side to achieve them.

The remaining issues will be addressed in the context of the development of the Strategic Research and Innovation Agendas/ Roadmaps, and as part of the overall policy (notably in the respective legal frameworks). In particular, it is important that all Partnerships further develop their framework of objectives. All Partnerships need to have a well-developed logical framework with concrete objectives and targets and with a set of Key Performance Indicators to monitor achievement of objectives and the resources that are invested.

Aspects related to implementation, programme design, monitoring and evaluation system will be streamlined and harmonised at a later stage across initiatives to ensure compliance with the implementation criteria, comparability across initiatives and to simplify the overall landscape.

In case you would like to receive further information about this initiative, please contact:

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The Strategic Research and Innovation Agenda will be made available publicly at the following links: www.clean-aviation.eu

[1] https://www.era-learn.eu/documents/final_report_ms_partnerships.pdf

EUROPEAN PARTNERSHIP ON CLEAN AVIATION

Step	Title Document	Version Ref.*	Date	Reason for change
CS2JU	**20200212 Clean Aviation_EC template_v.4.41.0**	V1.0	20/11/2019	**1.1.1.1 Released to CS3PG**
	20191203 Clean Aviation_ EC Template_v2.0	V2.0	03/12/2019	**Comments by RR, Thales, EASN, FhG, EREA, DLR, Dassault**
	20191209 Clean Aviation_ EC Template_v2.1	V2.1	09/12/2019	**Comments by Leonardo, EREA, Dassault, EASN**
	20191219 Clean Aviation_EC template_v.3.0	V3.0	19/12/2019	**2nd iteration**
	20200206 Clean Aviation_EC template_v.4.4	V4.0	06/02/2020	**3rd iteration: Modifications as agreed at the CS3PG meeting on 23/01/2020; Updates based on the comments received from the EC**
	20200610 Clean Aviation_EC template_v.5	V5.0	10/06/2020	**4th iteration: Updates based on the comments received from the EC and the revised SRIA**
	20200624 Clean Aviation_EC template_v.6	V6.0	24/06/2020	**Updates based on the comments received from the EC; Modifications as agreed at the CS3PG meeting on 24/06/2020**

This proposal is a living document and subject to further revision and updates in the course of the strategic programming and legislative stages. It will be versioned and dated accordingly.

Foreword

Substantial amounts of information contained within this document originate from before the coronavirus crisis

Information and figures, data and forecasts included in this document originate from before the coronavirus-related crisis. It is much too early to understand the full impact of the coronavirus-related crisis on short and mid-term traffic. However, it is clear that this crisis calls for even more action from the European Union institutions on green innovation and in support of the aviation sector's transformation than there has been to date.

- The need and challenge of tackling climate change is an unrelenting priority.
- Connectivity and mobility are essential to humanity. While we believe the long-term need for connectivity and mobility will remain strong, and demand for aviation will recover, in the short- to medium-term, the aviation sector will be significantly impacted.
- The capability of the sector to self-finance is rapidly eroding due to the severity of the economic and financial emergency that is propelling the aviation and aeronautics industries into an unprecedented crisis.
- For Europe to maintain a leading role in aviation its industry needs a level playing field, where on the worldwide stage other economic powers such as the US and China are heavily supporting their sectors with R&I. The US has recently announced a significant stimulus package for the aeronautics industry going well beyond previous levels of R&I support and tax breaks. China's capacity to invest is comparable. There is a significant risk of losing jobs, intellectual property and activity if Europe does not invest proportionately and protect its sovereign capability.
- For the EU political agenda, the success of the Green Deal in aviation depends on the European aeronautics industry's ability to keep its rank on the worldwide stage through its capacity to export its aircraft and European technologies.

By making smart use of the recovery programmes being prepared in terms of accelerating the technology transition to a new, sustainable aviation system encompassing green aircraft, engines and systems we can position the European aviation and aeronautics sectors to take a commanding leadership role in a globally strategic value chain, ensure critical capabilities and set new global standards in sustainability.

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Executive Summary

Europe needs to accelerate and enhance its efforts to achieve the ambitious goals set out in the Paris Agreement. A cornerstone policy of the European Union will be to achieve climate neutrality by 2050.

The **European Green Deal** will include the first European Climate law to enshrine the 2050 climate neutrality objective in legislation. The task facing the aviation sector in this and the next decades is to develop and introduce safe, reliable, and affordable low- to zero- emission air transport for citizens and to concurrently ensure Europe's industrial leadership is maintained and strengthened throughout the transition to climate neutrality.

The ambition of the Clean Aviation Partnership is to ensure that advancements in breakthrough technologies allow **new 'clean sheet' aircraft developments by 2030**, with maximum progress towards climate-neutral aviation. It will go well beyond the previous R&I Framework Programme, and will accelerate the transition towards a climate-neutral system by enabling all-new aircraft platforms and configurations, and taking a system-wide approach. The partnership will aim to take decisive steps in new aircraft performance demonstrated and **on offer to airlines and operators by 2030 and available by 2035**. The focus will be on pursuing two pivotal aircraft demonstration efforts for the validation of selected technologies. **Ultra-efficient short-medium range aircraft** coupled with the use of sustainable aviation fuels, and **hybrid electric regional aircraft** together with optimised green trajectories and operations will deliver major steps and will accelerate the transition to low or zero carbon fuels. Clean Aviation will develop the technologies needed to deliver full climate-neutrality by 2050 in parallel by bringing key technologies to a maturity that will allow for appropriate scaling across the full spectrum of aircraft segments and flight operations, including long-haul travel.

Clean Aviation low and zero emissions disruptive technologies will allow fuel efficiency gains of one-third to one-half in 2050, compared to today's fleet. The partnership will enable aircraft, engines and systems to utilise the full potential of low or zero carbon fuels, and investigate potential pathways towards the use of breakthrough options such as hydrogen.

Ambitious resourcing is essential to reach sufficient technology readiness within the Horizon Europe timeframe. The support of the EU institutions and European Member States will be essential to create the conditions needed for impact and to ensure the trajectory is successful. The research needed to meet this challenge within the Horizon Europe timeframe is likely to exceed ~€12 billion in effort. This effort can stimulate a product development in this sector worth over €50 billion. This stimulus can finally lead to an overall private investment in product deployment of more than €5 000 billion by 2050.

The approach proposed in the SRIA will require a research effort of roughly €4.5 billion as a key component of the overall €12 billion effort. This will require significant and balanced contributions from the public and private sides, based on funding rates and mechanisms that are appropriate for the high levels of risk, long timescales and uncertain financial returns; and on the participation of industry as well as research organisations and academia.

1 Context, objectives, expected impacts

1.1 Context and problem definition

1.1.1 Global context

The Intergovernmental Panel on Climate Change (IPCC) issued a Special Report[2] in October 2018 on the impact of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways. In response, the European Commission issued the report: "*A Clean Planet for all (A European strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy)*" [3]. While the report recognises the different challenges facing the various sectors (e.g. energy vs. transport), it shows the scale of the challenge for transport sectors to meet an appropriate level of contributions towards the decarbonisation goals set by the EU for 2050 (see **Figure 1**).

Poignantly, the report singles out the severity of the challenge for aviation, and the need to tackle emissions using advanced technologies and fuels.

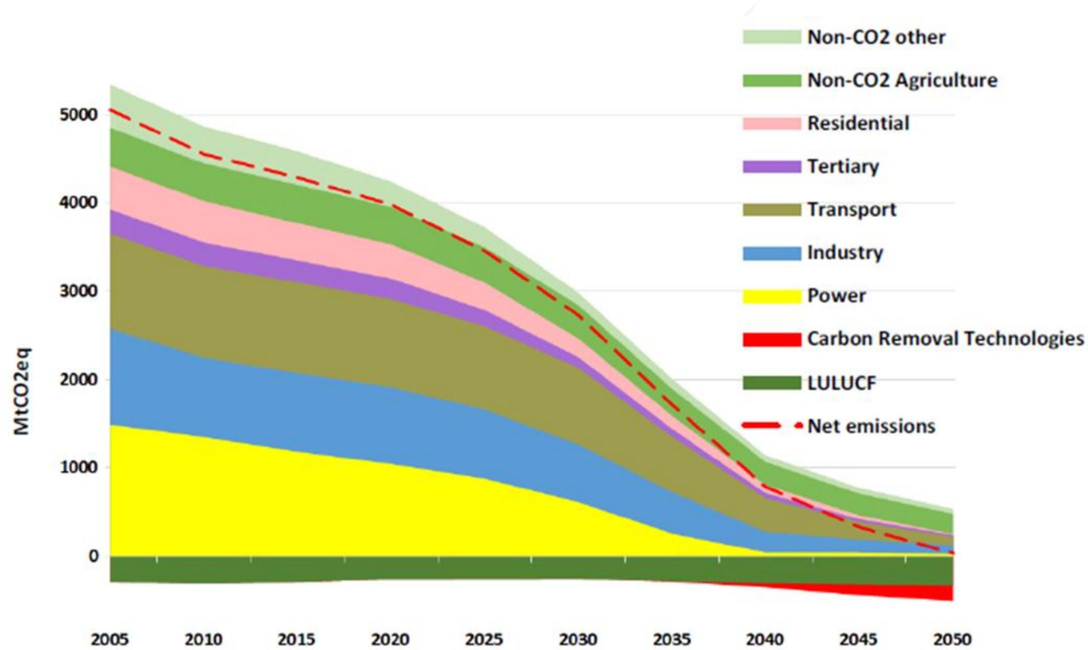

Figure 1: Europe's GHG emissions trajectory in a 1.5°C scenario.

The aviation industry's contribution to economic growth, societal development and cohesion is well recognised. While already subject to intense and increasing global competition, there is now an urgent

[2] Intergovernmental Panel on Climate Change (IPCC) Special Report Summary for Policymakers (SPM) ISBN 978-92-9169-151-7

[3] [Ref COM 2018 773 dated 28 November 2018].

need to address the developing climate emergency[4]. To avoid jeopardising its role and foregoing the benefits to citizens, the aviation sector has a duty to act. With the European Union's support, European aviation has the power to lead the way toward a climate-neutral system and set new global standards in aviation.

The European Green Deal[5] will include the first European Climate Law to enshrine the 2050 climate neutrality objective in legislation. It aims to 'transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use. At the same time, the newly launched Industrial Strategy for Europe[6] lays out the importance of industrial leadership in making the transformation to a green and digital Europe fit for the future. It states *inter alia* that 'there should be a special focus on sustainable and smart mobility industries. These have both the responsibility and the potential to drive the twin transitions towards climate neutrality and digital leadership, to support Europe's industrial competitiveness and improve connectivity. This is notably the case for the automotive, aerospace, rail and ship building industries, as well as for alternative fuels and smart and connected mobility'.

The economic benefits European aviation and aeronautic industries bring to the continent are estimated to be worth over €700 billion per annum, on top of important social benefits – shrinking and unifying Europe in its diversity and connecting it to global markets and societies. Aeronautics, including the design, development, manufacturing and 'through life' product support of aircraft and related systems and components, is a high-tech and highly competitive industrial sector, providing over 550 000 direct jobs, and contributing significantly to the EU economy. 75% of its €200 billion annual turnover is export related[7]. However, there is fierce competition in the world market for aircraft and related systems and services. On the one hand, there are the established US rivals, and on the other hand, new competitors such as China and Russia are entering the market with new products; both with significant national government support.

1.1.2 State and scale of the problem

Aviation, apart from being the safest and fastest mode of transport, is currently the only option suitable for rapidly covering mid- and long-range distances. Recent data shows significant and sustained growth of the aviation sector, and by consequence, the ecological footprint of aviation is also growing. Today global aviation CO_2 emissions represent more than 2% of the global anthropogenic CO_2 emissions and this figure is rising fast. The growth for the next decades is estimated to lie between 3.5 to 5% annually worldwide. This long term and stable growth[8] is highlighted in **Figure 2**.

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[4] European Parliament Declaration 25 November 2019
[5] The European Green Deal, COM(2019) 640
[6] A New Industrial Strategy for Europe COM(2020) 102 final
[7] ASD 2018 Facts and Figures (https://www.asd-europe.org)

[8] Airbus Global Market Forecast [GMF] 2019 – 2038

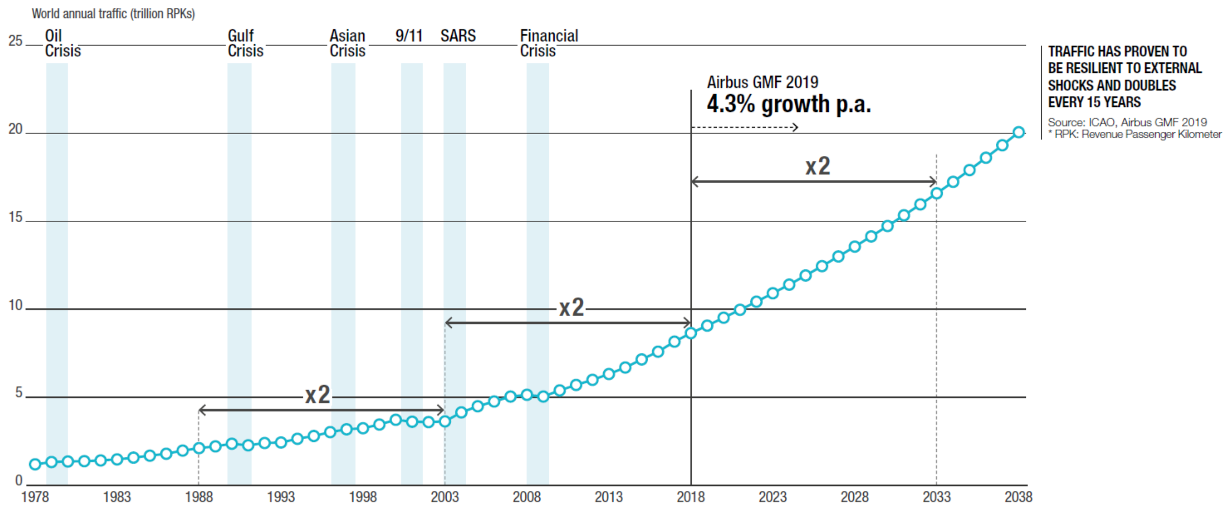


Figure 2: World Annual Traffic Forecast 2019 – 2038. Source: Airbus.

Global aviation demand is expected to quadruple between 2020 and 2050. This constitutes a promising outlook for the aviation sector and its users, with regards to new aircraft production, aviation volumes and related economic and social benefits, but at the same time, it also presents increasing challenges related to airport and airspace capacity, overall emissions and their impact on the environment and climate.

The energy efficiency of aircraft has improved in leaps and bounds over the past decades: today's aircraft are over 75% more fuel (and CO_2) efficient than aircraft from the early jet age. However, the growth of air transport has consistently outstripped these improvements. EU aviation CO_2 emissions increased from 88 to 171 million tonnes (+95%) between 1990 and 2016[9]. Worldwide, aviation CO_2 emissions more than doubled in this period. The growth rates currently forecast and the historical rate of technological improvements would lead to aviation's global CO_2 emissions tripling by 2050. If all other sectors achieve the emission reduction targets envisaged, aviation would constitute the overriding majority of humankind's carbon budget by mid-century.

Research in the past years indicates that of aviation's emissions, CO_2 and NO_x form the sector's largest contributor to global warming, even if other emissions species contribute as well (e.g. sulphur oxides and water vapour). Due to the extremely long latency of CO_2 emitted at common flight levels, addressing CO_2 as the primary driver of global warming impact and steering policies and measures based on CO_2-equivalent emissions is justified, as this can ensure other emissions are appropriately factored in. As such, the primary challenges facing the aviation and aeronautics sectors in the coming decades is achieving *net zero emissions* within the aeronautical life-cycle. In any case, reduction of other emissions (e.g. NO_x, SO_x) is needed as well, and they are not necessarily achieved with the same solutions. The development of game-changing technologies and their rapid implementation in successful products needs to be a key priority in order to have maximum positive impact on the environment.

Alongside CO_2 reductions, reducing non-CO_2 emissions will require additional and different technical and/or operational solutions. Likewise, the overall life cycle impact of aircraft, their engines and systems

[9] European Aviation Environmental Report 2019

including design, manufacturing, operations and disposal will need continued focus; in particular when implementing new technologies, materials and energy carriers.

While maintaining a strong focus on the urgent need to address aviation's CO_2 emissions, other environmental and local nuisance impacts also need to be tackled. The noise footprint and local emissions that occur at low levels due to on-ground operations, take-off, landing, and flight will need continued research efforts and innovative solutions. These emissions are extremely critical with regards to their impact, real or perceived, on people. They must be improved in view of the expected increase in air traffic due to the anticipated growth in air transport and the development of future air mobility concepts. Public acceptability of these is critical to their market adoption.

Developing and maturing game-changing technologies and ensuring their rapid implementation in successful products is the only way to achieve the required impact in terms of a climate-neutral, economically prosperous Europe and a sustainable European aviation industry.

1.1.3 Links and lessons learned from Clean Sky and Clean Sky 2

Addressing and improving aviation's environmental performance has been one of the key challenges and aims of EU research and innovation programmes in the past decades, where major progress has been made by the aeronautics industry. Industry, research organisations, academia and the public sector have laid the foundations for research priorities in the Advisory Council for Aviation Research and Innovation in Europe (ACARE) based on the strategic "Vision 2020" document produced in 2001, which outlined the key challenges for European aviation and aeronautics.

While there were important collaborations between the aviation industry, research centres and academia during first six Framework Programmes for Research and Innovation, the seventh Framework Programme for Research and Innovation (FP7) brought the European aeronautics sector and the EU together for the first time in a binding long-term partnership. The aim of this partnership was to accelerate and drive technology development that would enable game-changing steps in reducing aviation's emissions and climate impact. The first Clean Sky programme (CS1), which was executed as part of the first generation of Public Private Partnerships (PPP) in the EU under FP7, built on earlier collaborative research efforts in EU and national programmes. CS1 drove technology in selected 'green aviation system' areas from the conceptual stage to a small number of integrated demonstrator areas that were aimed at demonstrating the potential of green technology in aviation on the air transport system's emissions in the 2020 to 2050 timeframe. Key technology options were down-selected and matured in six different integrated technology demonstration areas to provide insight into the reduction in emissions (CO_2, NO_x) and noise that would be feasible under viable market conditions, and compared to year-2000 reference aircraft. Among them were natural laminar flow, contra-rotating open rotor, electrification of on-board systems, green taxiing, and flight management systems enabling optimised 'green' trajectories. However, both budget and time were too short to bring some of the most far reaching and complex of these technologies to a flight demonstration. Market conditions in the aftermath of the financial crisis of 2008-2011 prevented an early adoption of fuel-saving and low-emissions options that were disruptive and more risky than incremental and lower risk product enhancements. Nonetheless, the final evaluation of CS1 under the FP7 programme clearly recognised the value and the power of the public-private partnership and the significance of the potential of the demonstrated aircraft, engine and systems technologies.

Clean Sky 2 (CS2), under Horizon 2020 (H2020), is currently building upon the achievements of CS1 and continues to utilise complex and integrated technology demonstrations of major systems of new architectures, such as advanced hybrid laminar flow, ultra-high bypass engines, hybrid-electric propulsion and new vehicle configurations. CS2 was predicated on a ‘dual agenda’ of continuing the ambitious programme of environmentally sustainable air transport, while concurrently ensuring that industrial competitiveness in the aeronautics industry was maintained and extended. While aiming at the same or better level of potential gains in environmental performance, CS2 added a crucial dimension of industrial viability and market acceptance during the decade following H2020. The CS2 programme underwent its H2020 Interim Evaluation in 2017, and achieved strongly positive results. This encourages the further use of the PPP instrument to continue Europe’s ambitious aviation research mission into the future but also highlights the need for stronger engagement by all stakeholders in addressing all Technology Readiness Levels.

An important dimension of success in CS1 and CS2 can be seen in the development of a strong innovation pipeline, starting from low TRL technological research, progressing to technology maturation, systems integration and finally platform demonstration. Concerning the innovations achieved so far, the Clean Sky 2 programme is delivering cutting-edge results for greener aviation in fields like propulsion, systems, aerostructures, aerodynamics and overall aircraft configurations. These technologies are targeted for integration into global airline and operator fleets in the next two decades. However, there is a further urgent need to close the innovation gap in the aviation technologies existing today in Europe but also globally, in order to be able to meet the challenges related to climate neutrality.

Within the context of its mission, CS2 has brought together the competences and capabilities of over 800 participants. The figures on participation per type of organisation show that CS2 has been highly successful in attracting and involving industry, RTOs, academia and a large number of SMEs, with a good geographical distribution (see **Figure 3**).

Figure 3: Clean Sky 2 Facts and Figures to date[10]

A new Institutionalised European Partnership under Horizon Europe can nonetheless benefit from lessons learned during the previous two PPP programmes (including from earlier mid-term assessments) and can be designed to be even more efficient, transparent and impact-oriented. This can enable a new Partnership to execute transformative research and innovation (R&I) at all Technology Readiness Levels (TRLs) and bring tangible commitment to their implementation in the future aviation system.

[10] includes data from CPW01-04 and CfP01-09

1.1.4 Research, Innovation and Deployment

Achieving a climate neutral aviation system is a formidable task. The sector is globally competitive and characterised by complex system integration, significant technological risk, exacting safety standards and certification requirements. The long design and operational cycles of aviation and the highly regulated international framework mean that technological and operational advances will only be noticeable at the global operating fleet level 10-15 years after their introduction. Without transformative solutions being rapidly introduced into the next generation of aircraft, it is clear that aviation's CO_2 emissions and contribution to climate change will rapidly reach levels where it would be the dominant sector in terms of greenhouse gas (GHG) emissions. Notwithstanding international aviation's exclusion from signatories' commitments towards the Paris Agreement, this trend would be societally unacceptable. It would also go against the EU's targets for environmentally friendly transport, the EU vision for 'A Clean Planet for All', the Energy Union package, and the EU mobility package. The European Commission's stated ambition of a Green Deal will also undoubtedly make intervention in the aviation sector necessary if the sector's emissions and global warming impact cannot be reversed.

This makes the proposed European Partnership under Horizon Europe particularly meaningful, since it will reduce the industrial risk for transformative R&I. This will secure the long-term industrial commitments needed for long innovation cycles triggering direct leverage and a high level of engagement from all stakeholders. It will also ensure that the research activities of industry are aligned with the Union's policy priorities. Additionally, this new Aviation Partnership will aim at embedding elements from other European Partnerships (e.g. key digital technologies, batteries, clean hydrogen and air traffic management) in a synergetic approach (the Innovation Architecture).

1.2 Common vision, objectives and expected impacts

1.2.1 General, specific and operational objectives

Becoming the world's first climate-neutral continent is a great challenge and an opportunity for Europe. To achieve that, Europe needs to heavily invest in innovation and research, redesign our economy and transform our industrial policy.

The grand challenge facing the aviation sector in this and the next decades is to develop and introduce safe, reliable, and affordable low- to zero emissions air transport for citizens as well as ensure Europe's industrial leadership is maintained and strengthened throughout the transition to a climate-neutral Europe by 2050.

Technologies stemming from the Clean Sky and Clean Sky 2 programmes, complemented where possible with early results from the Clean Aviation programme, may allow retrofit or systems upgrade opportunities in the operating fleet in some limited cases.

To unfold their full potential, the major Clean Sky/Clean Sky 2 technologies and innovations such as laminar flow wings and empennages, and new engine architectures such as 'Open Rotor' need a new 'clean sheet' aircraft design. Radical new solutions stemming from the Clean Aviation Partnership will reach the maturity needed for adoption in new aircraft development programmes around 2027 – 2030.

The first wave of these new, radically re-designed aircraft will be on offer to customers before 2030, with an entry into commercial service from approximately 2035.

The primary justification for EU public intervention in aviation is to set out a viable path towards climate neutrality within aviation by 2050, therefore contributing to the EU's climate and energy goals.

Clean Aviation's ultimate objective is to reach net-zero greenhouse gas emissions, and to enable a climate-neutral aviation system in Europe by 2050.

The Clean Aviation Partnership's approach will target impact against the two horizons linked to the European Union's Green Deal legislative package and geared towards climate neutrality by 2050 (Table 2.1). The overall European aviation system forecast progress, and the Clean Aviation contribution is shown here below:

Year	European Aviation's forecast progress towards the Green Deal objectives
2030	• Efficiency and emissions in the European aviation fleet in operation will have improved, as the benefit of fleet replacement (roughly 2% improvement per annum) will exceed growth in intra-EU travel volumes (currently around 1% per annum). • Technologies from the Clean Sky and Clean Sky 2 programmes suitable for retrofitting in the existing fleet or 'forward fitting' in product enhancements will allow for additional efficiency gains and related impact. • Optimised flight trajectories and 'smart' redesign of flight operations (speed, cruise altitude, routing, and potentially utilising operational concepts such as flying in formation) developed in close collaboration with SESAR JU will allow further improvements of at least 5%. • The ramp up of low carbon sustainable aviation fuels (in first instance sustainable bio-fuels) up to around 15% usage by 2030 will bring further gains of up to 10%. • The next generation of disruptive aircraft offering 30 to 50% lower fuel burn and emissions compared to 2020 will emerge from the Clean Aviation research and demonstration phase at a high R&I technology readiness level (TRL). • Regional and SMR aircraft **will be defined by 2030 so they can be available for airlines by 2035**.
2050	• Aircraft exploiting the research demonstrated in Clean Aviation will continue to replace the legacy airline fleets from 2035 onwards and they will progressively infiltrate the (global) operating fleet, with ~75% of the fleet being replaced by 2050. • Technologies matured through Clean Aviation will become available across the majority of aircraft classes and the 2050 operating fleet will be one-third to one-half more fuel-efficient than today's fleet. • The continued acceleration in the use of sustainable fuels and optimised 'green' operations will deliver progressively lower net emissions compared to 2030. • European airport, ATC and energy production improvements will be synchronised in support of the introduction of the new aircraft and fuels/energy systems. • Further breakthrough technologies developed and matured beyond Clean Aviation, coupled with full deployment of sustainable aviation fuels and alternative energy carriers will lead to fully climate-neutral aviation in Europe.

Table 2.1: Forecast progress towards the Green Deal objectives in 2030 and 2050

The main objective of the proposed partnership will be to accelerate the development and demonstration of integrated aircraft technologies towards net zero carbon emissions within the aeronautical life-cycle, and a significant reduction of all other emissions concurrently (e.g. NO_x, PM, noise), while ensuring safety, security and European leadership. To reach the goal of climate-neutral aviation, a new breed of aircraft with entirely new configurations allowing significantly lower environmental impact will be required. These aircraft will need to start entering the air transport system in the 2030s in order to have an impactful contribution by 2050. In addition, in line with the Green Deal, innovations contributing to emissions reduction by 2030 will be introduced.

Clean Aviation will go well beyond the technological progress achieved under previous R&I Framework Programmes, and will accelerate the transition towards a climate-neutral system by enabling all-new aircraft platforms and configurations, and taking a system-wide approach.

This trajectory matches the two horizons towards climate neutrality in the Green Deal legislative proposal (**Figure 4**):

Figure 4: Two horizons in the trajectory towards climate-neutral aviation

Given the scale of the challenge and limited R&I resources, the Clean Aviation partnership will focus on the most promising technologies. It will pursue a demonstration strategy to mature these to the highest possible TRL for their integration on aircraft in the market segments most likely to absorb new clean sheet designs by 2035 and those that represent a significant share of aviation's climate impact. Technology potential compared to programme and budget constraints and market readiness have been considered as well as the need to deliver actual results to the public and private stakeholders of the partnership.

The Clean Aviation Partnership will aim for decisive steps in new aircraft performance to be demonstrated by 2030 and available by 2035. In parallel, it will develop key technologies that will support the transition to full climate neutrality by 2050 and mature these to a level that can allow for appropriate scaling across the full spectrum of aircraft segments and flight operations, including long-haul travel.

The demonstration efforts in the proposed programme will focus on progressing decisively in technology maturity and performance with regards to two pivotal aircraft concepts (see for detailed descriptions Chapter 2): ultra-efficient short/medium range aircraft and hybrid electrical regional and short-range aircraft. They will deliver major steps in the operating fleet, together with optimised green trajectories and operations, and accelerate the transition to low- or zero-carbon fuels. The technology development strategy within these efforts will create significant positive spillover effects towards other aircraft categories and in the exploitation of R&I results. This will bring additional benefits across a wide selection of aircraft sizes and missions, as shown schematically in Figure 4.

Reaching maximum impact will depend on new architectures, effective technology maturation and integration, product development and certification, deployment in the market, and on the new aircraft concept's operational suitability and affordability in the aviation system. Public policies, including certification, will need to evolve to enable the fast adoption of disruptive technologies. Economic policies will need to spark the rapid transition to new sources of sustainable energy and aviation fuels, which will have to be available within far more aggressive timescales than anticipated to date.

1.2.2 Common vision, ambition and impacts

The proposed Clean Aviation Partnership will allow for a strong and shared vision and its related roadmap for the aviation industry and its supply chain need to be agreed, providing direction and enabling private sector investment to be aligned and focused on these societal needs. This can be achieved more effectively with a European Partnership that provides a long-term framework for research and innovation driven by EU policy priorities and under EU oversight. A partnership approach is best to ensure high impact-oriented research and commitment from all stakeholders on the required investment and market adoption.

Clean Aviation will contribute to the delivery of Europe's climate neutrality by 2050 by pioneering new solutions in the aeronautics disciplines, addressing the relevant EU policy priorities (e.g. the Green Deal) and supporting the sector-wide European Sustainable Aviation Roadmap[11]. It will trigger a technology revolution that will target climate-neutral aviation in Europe by 2050. Ambitious zero- and low-emission technologies will drive the transformation. They include hybrid-electric solutions for regional and short-range flights and ultra-efficient aircraft designs utilising thermal engines suited for the adoption of sustainable aviation fuels (SAF) covering the larger and more energy intense medium and long-range sectors.

The ambition of the Clean Aviation Partnership is to ensure that advances in breakthrough technologies will allow new aircraft developments by 2030, enabling maximum progress towards climate-neutral aviation, meeting socio-economic expectations, and providing benefits for European society and businesses.

Clean Aviation low and zero emissions technologies will allow fuel efficiency gains of one-third to one-half in 2050, compared to today's fleet. In addition, the partnership will enable aircraft, engines and systems to utilise the full potential of low or zero carbon fuels, including potentially disruptive innovations such as hydrogen. Together these outcomes will accelerate the transition towards climate-neutrality.

Initial analysis has identified several low and zero emissions technologies with promising potential for deployment in the aviation system. By 2050, these should result in an emissions reduction of one third to one-half compared to today's aircraft. Together with the large scale deployment and the use of new, net-

[11] Publication under preparation, publication foreseen in June 2020

zero or fully decarbonised sustainable aviation fuels such as power-to-liquid synthetic fuels, methane and/or hydrogen, the operating fleet in 2050 could achieve a >90% improvement in carbon efficiency compared to today's fleet. Even allowing for the forecast growth in air transport, these measures would allow the sector to meet the Air Transport Action Group's (ATAG) goal to halve total CO_2 emissions in 2050 compared to 2005 levels, while maintaining its forecast growth. The ATAG commitments are schematically depicted in **Figure 5** below, where the European aeronautics sector's approach in terms of contributing change drivers is shown.

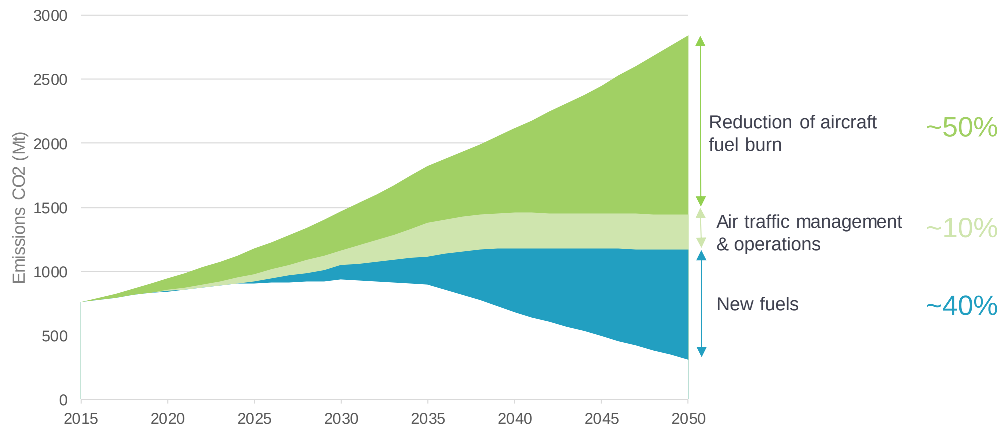


Figure 5: Schematic of the ATAG goals and change drivers

The ambition of Clean Aviation is also to minimise the environmental impact of air transport by introducing new green air transport solutions from which further societal and economic benefits will be derived. Implementing the ambitious research agenda will make more substantial changes in the aviation system performance possible at significantly reduced timescales. To achieve this, Clean Aviation will simultaneously address the following actions, which are critical for an early and decisive impact within the timescales needed:

- link an ambitious research agenda with EU public policy in order to drive changes in the aviation system performance within vastly reduced timescales;
- reduce the time needed for demonstration, technology maturation and product certification as well as for bringing products to market and into service;
- increase affordability and ensure a compelling economic case for market adoption, improving customer acceptance and fleet integration.

The Clean Aviation Partnership will cultivate an ecosystem approach that allows the aviation sector to introduce disruptive technologies in a timely and economically prudent manner, in close coordination with airlines, operators, service providers and authorities. Regular assessments including life-cycle aspects will support the selection of technology routes and ensure a close monitoring of progress and tracking of potential benefits. The Partnership will focus on tackling energy and climate neutrality challenges, while ensuring the EU's global competitiveness and sustainable mobility for European citizens. An ecosystem-based approach should be followed to meet the environmental goals, introducing disruptive technologies that enable a climate-neutral aviation system. This will help the EU Member States to meet the Paris Agreement, reach or surpass the International Civil Aviation Organisation (ICAO) environmental goals (on global emissions, local air quality and noise) and meet EU mobility targets.

Clean Aviation will contribute to the scientific dimension of Horizon Europe, by creating and disseminating high-quality new knowledge, skills, technologies and solutions and thus providing the following scientific impact:

- Increase scientific knowledge of climate impact and atmospheric effects and so enable optimised interventions in the aviation system;
- Accelerate development of know-how and knowledge transfer for key new technologies and ‘differentiators’;
- Create new high-value skills and new engineering capacities for future generations of the European workforce;
- Create models and metrics for new and different lifecycle assessments of disruptive solutions.

The scale of technological challenges required to meet the societal expectations for climate-neutral transportation requires a paradigm shift. Added to this, the size of the task means exploring and exploiting the capabilities of the entire sector, as well as tapping into technologies emerging from other sectors with the potential for adoption into the aviation environment. The Clean Aviation Strategic Research and Innovation Agenda (SRIA) will strengthen the impact of R&I in developing, supporting and implementing EU policies, and to support the uptake of innovative solutions in industry and society to address global challenges such as climate change and environmental protection. Therefore, the Clean Aviation partnership is expected to have the following societal impact:

- Deliver solutions to reduce the environmental impact of aviation by cutting emissions and ensuring better air quality and lower noise, in particular around airports;
- Contribute to increased safety and security levels, in cooperation with the European Union Aviation Safety Agency (EASA), by deeply transforming present operations with the help of innovation;
- Fulfil customer and general public expectations of a globally competitive European industry;
- Offer innovative solutions that improve the mobility and connectivity of European citizens with safe, reliable, affordable and resilient air travel options;
- Utilise lifecycle ‘eco-design’ approaches that will develop a strong circular economy dimension for aviation.
- Support the European Commission where appropriate in input for policies including international coordination and in extracting benefits for Europe.

Additionally, the Clean Aviation Partnership is expected to have an essential economic impact by fostering breakthrough innovations and strengthening Europe’s intellectual property, sovereign capability, design and manufacturing base, and the market deployment of innovative solutions towards a dynamic and prosperous EU economy.

- Permit new sustainable business models for innovative aircraft technology for future aircraft and fleet retrofits, exploiting next generation digitalisation/automation technologies;
- Enable valuable spin-off opportunities that will benefit European citizens through exploitation in critical areas such as disaster response, emergency interventions, space and security;
- Facilitate new safe and efficient airborne transport modes that have the potential to reduce traffic congestion in highly populated areas, and connect remote regions;

- Encourage strategic partnerships with non-aviation sectors to make use of emerging technologies (e.g. drop-in and non-drop-in fuels, fuel cells, batteries, artificial intelligence, electronics, materials);

The partnership will set up an Impact Monitor to serve private and public stakeholder needs to monitor the progress of their joint efforts in the Clean Aviation Programme. Its outputs can help to accelerate the trajectory towards climate-neutral aviation. The benefit of having an integrated Impact Monitor as part of the programme stems from the close collaboration of all stakeholders on the implementation and the accessibility to key data and results needed. The Impact Monitor will build on the project efforts and their achievements, their progress against objectives and their contributions to overall impact, and support strategic decisions. It will establish effective mechanisms across all relevant R&I efforts to collect and assimilate research results and their potential benefits, from integration studies up to large-scale demonstrations, to weigh and deliver valuable impact information. The goal of this new instrument will be the provision of data collection, modelling and simulation based assessments to summarise and visualise the cumulated programme impacts versus the aviation sector's trajectory towards climate neutrality, including interdependencies between technical, operational, and environmental dimensions.

A number of promising technology options for low or zero emissions flights have emerged over the last few years, such as electric or hybrid-electric propulsion architectures. However, they are currently limited to very small and/or very short-range applications. Their application within mainstream commercial aviation sectors should be a major thrust of future research. Developing and integrating alternative on-board energy sources and carriers, such as high energy density fuel cells and batteries, will be critical to support this transition. Aircraft that can make full use of sustainable aviation fuels are another critical element to achieve deep decarbonisation. Deploying hydrogen as a fuel is a further key avenue to fully decarbonise aviation. The application of these technologies across all aviation sectors will have a very high potential impact. Technical challenges in the field of fuel systems and storage and in thermal management will require specific aircraft configurations, propulsion systems and energy integration in the airframe.

Beyond the 'technology-based' improvements that the programme will develop, the rapid development and large-scale adoption of new sustainable aviation fuels is essential. For the aviation sector to achieve the commitment that it made in 2005 to halve its CO_2 emissions in 2050 compared to 2005 levels – including overall system growth – and transform aviation towards climate neutrality, an overall improvement of at least 90% in net carbon emissions per passenger-kilometre is considered necessary. This reduction versus the current trend is only possible with new low- or zero-carbon fuels in various forms, ranging from "drop-in" to more promising "non-drop-in" options such as liquid hydrogen (LH_2) based energy systems. Investigating these non-drop-in fuel concepts necessitates significant research into the technical system requirements. Progress beyond the ATAG goals towards climate-neutral aviation by 2050 would be feasible via hyper-efficient aircraft using fully decarbonised energy sources on the path. Progressive demonstration through Clean Aviation will lay the foundation for a long-term zero-emissions outcome.

As an ultimate goal, aviation is committed to achieving climate neutrality by 2050. Not all technologies that have been developed to realise this goal relate to aircraft level improvements; also system level changes such as operational improvements and availability of other energy carriers such as hydrogen or sustainable fuels are necessary to reach this highly ambitious goal. More direct routes, flying at different altitudes and speeds, avoiding climate sensitive areas, stop-overs for refuelling on long- haul flights etc. can reduce the climate impact alongside aircraft level improvements. Moreover, new aircraft configurations in terms of payload/range combinations can have a large impact. Replacing one larger conventional aircraft by several smaller zero or very low emission aircraft can create a large impact on system level. To accommodate this, changes are also needed in the infrastructure. Synergies will have to be sought with other research programmes and more understanding of the climate impact of novel technologies such as hydrogen combustion or fuel cell emissions is necessary.

To meet all the above objectives and aim for the maximum impact achievable within the next decades, the European Clean Aviation Partnership will be the best vehicle to build an effective European 'innovation architecture' for aviation. This will ensure shared roadmaps and will enable synergies with other European Partnerships and EU Research Programmes; national research and innovation programmes; the European Regional Development Fund (ERDF) and financial instruments. Combining resources and funding will produce a substantial leverage effect, and help reach the challenging objective of climate-neutral aviation.

1.2.3 Links and synergies with other Partnerships and EU Programmes and initiatives

Within Pillar II of Horizon Europe, Clean Aviation would reside within the cluster of Climate, Energy and Mobility. The partnership will need to have effective and efficient means to draw key results from relevant projects funded from Horizon Europe work programmes, as well as from other Partnerships. It will need to develop and exploit synergies with the European Partnership for Integrated Air Traffic Management [aka SESAR]. Synergies with other proposed Partnerships in that cluster are most notably (but not exclusively) with Clean Hydrogen (regarding fuel cells, as well as hydrogen, as potential fuel sources) and European Partnership for an Industrial Battery Value Chain.

Outside the cluster of Climate, Energy and Mobility, the Digital, Industry and Space cluster is particularly relevant as the digital agenda, industrial leadership and competitiveness are key integral components of a successful transition to a net-zero emissions aviation system. For instance, more opportunities exist within Key Digital Technologies [aka ECSEL] for many subsystems and electronics solutions that can be applied to the aeronautical case. The Made in Europe Initiative, which deals with advanced manufacturing, can bring key enabling technologies to take new disruptive products successfully into production and into service. The space sector will be highly relevant, where decades of experience in highly safety critical applications of hydrogen technologies can serve as an important stepping-stone for the challenges related to this research agenda.

The Clean Aviation Partnership will work towards establishing strategic collaboration with other European Partnerships and Horizon Europe cross-cutting initiatives:

Integrated Air Traffic Management

As autonomous operations are expected to be key drivers for the next generation of aircraft, the research programme activities dealing with flight management need to be well aligned with research aspects and activities regarding air traffic management as tackled in the SESAR 2020 Programme and the Integrated Air Traffic Management Partnership proposed under Horizon Europe.

Clean Hydrogen

Fuel cells represent a unique opportunity to reduce CO_2 emissions thanks to their high system efficiency of about 50% and their higher power density compared to batteries, as well as not releasing NO_x or particulates. They also have a very low noise footprint. It is necessary to prepare the next generation of innovations, products and services in close alignment with the Hydrogen and Fuel Cell Initiative, to ensure a European technology breakthrough of this value chain in air transportation.

European battery research

Batteries are a valuable solution for full or partial electrification through hybridisation, mixing electric engines with on-board electricity production. As fundamental battery research cannot be addressed in the Clean Aviation programme, European battery research should include a dedicated area devoted to the high standards required for climate-neutral aviation.

Sustainable Aviation Fuels

Sustainable aviation fuels (SAF) will make a crucial contribution to mitigating the current and expected future environmental impacts of aviation. Thus, it is important that EU initiatives related to sustainable [bio]-fuels include a dedicated area to address the development, production and deployment of bio- or synthetic aviation fuels as well as the logistics and required adaptations of the airport infrastructure.

Electronics / Semi-conductors

The proposed Clean Aviation Partnership agenda relies on several complementary research activities proposed under the Electronic Components and Systems for European Leadership Joint Undertaking (ECSEL JU) regarding electronic components and systems and semiconductor manufacturing.

Advanced Materials and Structures

New materials, their future production processes and assembly techniques are key complementary contributors to improved performance and reduced environmental footprint. An effective systemic approach between Clean Aviation and several Horizon Europe initiatives, such as Made by Europe, Climate Neutral and Circular Industry and the European Institute of Innovation and Technology (EIT) Manufacturing and EIT Raw Material is key to maximise the results.

Artificial Intelligence

Artificial intelligence will be required to contribute to achieving the ambitious goals of Clean Aviation, incorporating design, manufacturing, testing and certification, operation and maintenance of aircraft as well as efficient and secure passenger management.

Security

As in many other sectors, increased automation and autonomy in systems of aircraft are expected to significantly increase the competitiveness. Security and increasingly cybersecurity are prerequisites for making use of the fast-increasing potential of new automated functions in aviation. Large-scale use of digital data/data transfer (e.g. wideband data link between aircraft and ground) will require an increased focus on cybersecurity. Here the inherent safety and security of the on-board systems is at stake. Therefore, the fundamental issues of cyber resilience will be tackled in the Global Challenges Digital Europe and dedicated Horizon Europe initiatives, but their respective work programmes must assign appropriate topics and their resources must cover the challenging aviation specific requirements.

All the above synergies with European Partnerships and initiatives, together with other EU research programmes, national research and innovation programmes in aeronautics fields, European regional development fund and financial instruments, should be aligned in a shared, integrated and comprehensive roadmap. Combining resources and funding will produce a substantial leverage effect and help reach the challenging objective of carbon neutral aviation. Further elaboration of the links with the other EU partnerships and initiatives will be included in the SRIA.

1.2.4 Research & Innovation investments

The programme's technical objectives and the key demonstration areas that are described in the Annex need to reach sufficient technology readiness within the Horizon Europe timeframe in order to ensure the required impact is achieved by 2050. This points to a need for ambitious investments.

The overall resource requirement to meet this challenge inside the Horizon Europe timeframe is likely to exceed ~€12 billion in research effort alone, with several times this amount in private sector investment thereafter during the phase of product development and certification.

The approach proposed in the SRIA will require a research effort of roughly €4.5 billion as a key component of the overall €12 billion effort. This will require significant and balanced contributions from the public and private sides, based on funding rates and mechanisms that are appropriate for the high levels of risk, long timescales and uncertain financial returns; and on the participation of industry as well as research organisations and academia.

1.2.5 Transformational changes in Research & Innovation ecosystem

The task facing the aviation sector in this and the next decades is to develop and introduce safe, reliable, and affordable low- to zero-emission air transport for citizens and to concurrently ensure Europe's industrial leadership is maintained and strengthened throughout the transition to a climate-neutral Europe. Transforming aviation towards climate neutrality will require an integrated approach spanning the Research & Innovation ecosystem, technology providers and innovators, manufacturers and operators, public sector authorities and travellers. It will involve re-inventing the innovation, product development and fleet replacement cycles needed to introduce a new breed of aircraft with decisive gains in performance and efficiency much more swiftly than 'business as usual'. It will also require significant investment in new infrastructure to make new fuels and energy sources available. Innovative public policies and regulations will need to encourage and enforce renovation in operating networks and operations.

Transforming from the current, entirely fossil-based kerosene fuel-powered system to such a future aviation system with multiple energy carriers and architectures constitutes a massive and systemic challenge.

Aircraft are highly complex and safety critical capital equipment. Introducing new technologies requires disciplined systems integration, so that the improvement of one system does not adversely affect the performance of other systems or of the aircraft as a whole. As such, the overall research and innovation (R&I) agenda must be organised in a manner that addresses the complexities, risks and vigour of an aircraft development programme. European aviation R&I therefore needs an integrative approach that enables stable and long-term collaboration across the full innovation chain. The strong interdependencies between technologies, the integration challenges at an overall aircraft design level, and the timescales and risks involved call for a coordinated programmatic approach.

The European aeronautics community is convinced the trajectory towards climate-neutral aviation is achievable despite the level of complexity and interdependency. However, this will be contingent on:

- an exceptional research and technology effort to reduce energy needs and fuel consumption, while ensuring safety and competitiveness in a spirit of a public private partnership and with shared investments and commitments;
- fast-tracked research, development and deployment of sustainable aviation fuels by the relevant actors and proactive policies for wide-scale and economically viable use within the next decade;
- optimised green air operations and networks to fully exploit new aircraft and systems capability;
- a suitable global aviation regulatory framework creating the conditions for a transition.

This new Partnership will execute transformative Research and Innovation (R&I) and bring tangible commitment to its implementation in the future aviation system. Other forms of cooperation would not allow the same level of ambition in facing aviation's grand challenge, and would not allow the required high level of integration of stakeholders' contributions and activities, to work together and deliver the desired integration of technologies such as in flying demonstrators. They would be even less able to bind the public and private parties to implementation in the aviation system through fully matured, developed, and certified new aircraft, engines and systems.

To implement those transformational changes in aviation ecosystem, research and demonstration efforts are needed over the next two decades. The partnership will develop at early stages of the programme a realistic plan for continuation outside the scope of an institutionalised partnership after Horizon Europe, and discuss it with the Governing Board. The proposed European Partnership under Horizon Europe strives to be more ambitious, efficient and impact-oriented, notably by taking into account the lessons learned during the previous two PPP programmes (including from earlier mid-term assessments).

The partnership will also align and build on significant efforts and results stemming from national and regional programmes in the EU Member States and can definitely stimulate a smart use of ERDF directed via Regional Research and Innovation Strategies for Smart Specialisation (RIS3). It should operate as a signpost for the sector in joining forces to make effective use of synergies between funding schemes, and research programmes, and use of financial instruments from which the EU, Member States and the aviation sector can jointly benefit. The Clean Aviation partnership cannot only leverage efforts and create synergies and multiplier effects across technology domains, but also across European, national and regional boundaries.

1.2.6 Strategic Research and Innovation Agenda

The Strategic Research and Innovation Agenda (SRIA) has been prepared by the CS3PG Stakeholder Group, following a comprehensive approach that ensures a strong and broad stakeholder involvement, while it makes connections to ongoing policies and strategy debates. The SRIA has just undergone a public consultation that lasted from 14 May until 11 June 2020. The CS3PG will subsequently update this version with further inputs and results from the open online consultation.

The timeline for the preparation and finalisation of the draft SRIA of the European Partnership for Clean Aviation is depicted below:

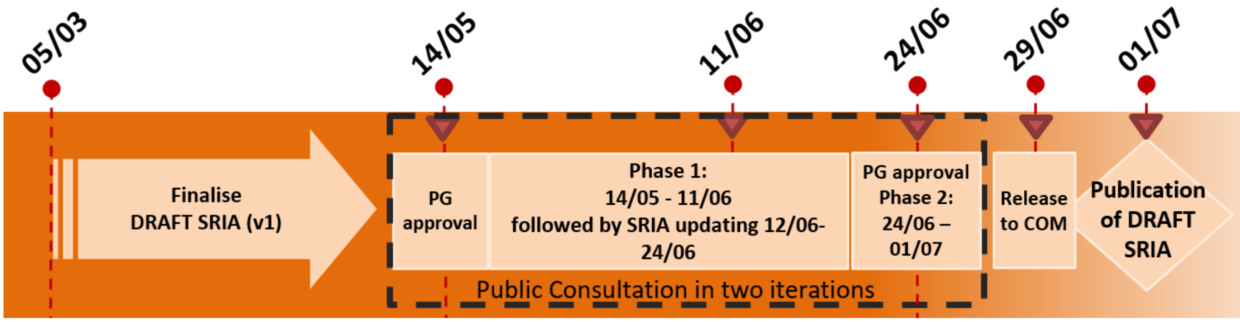


Figure 6: Current timeline to prepare the draft Clean Aviation SRIA

1.3 Necessity for a European Partnership

1.3.1 Alignment to EU objectives

The journey to a climate-neutral aviation system is well beyond the private sector's capability and capacity to invest alone. Equally, no single country in Europe has the financial, technological and industrial capability to affect the transformation, nor the capability to promote and support the required changes to global rules and operative frameworks necessary to implement those solutions. As such, the European additionality is well justified and recognised.

In addressing the challenge set for Partnership Area n°4 'Accelerate competitiveness, safety and environmental performance of EU air, traffic, aviation and rail' in the common understanding for Horizon Europe[12], a Clean Aviation Partnership will need to build upon the research performed under the previous Framework Programmes. Notably but not solely, the previous Art. 187 initiatives (the Clean Sky programmes) are important building blocks for addressing the aviation sector's environmental performance. Additionally, a broad and stable ecosystem of collaborating research actors across Europe has been formed. Significant private investment has been catalysed through the public-private partnership (PPP) approach under FP7 and H2020, and some synergistic links to national research programmes exist that can augment and complement the actions needed under Horizon Europe. The Clean Sky (FP7) final evaluation report and the Clean Sky 2 (H2020) interim evaluation reports unequivocally acknowledged the additionality and effectiveness of the PPP approach and its implementation in the form of a Joint Undertaking (JU).

Aircraft are composed of many distinct and complex systems that are carefully integrated and regulated to maximise performance and safety. Disciplined system integration is required to introduce new technologies so that the improvement of one system does not adversely impact the performance of other systems or of the aircraft as a whole. As such, the research agenda should be organised in a manner that is reflective of the risk and complexity management, and dynamism of an aircraft development programme. European aviation research therefore needs an integrative approach to enable stable and long-term collaboration from the full spectrum of innovation chain actors. The inhibitors to increased investment in disruptive research and innovation, and the inherent 'market failure' risks can only be

[12] Annex Va. Available at https://data.consilium.europa.eu/doc/document/ST-7942-2019-INIT/en/pdf

overcome in this manner. The timescales and risks involved, and the strong linkages and interdependencies between technologies as well as the integration challenges at an overall aircraft design level, call for a strongly coordinated programmatic approach. This allows a single integrated and joint roadmap to be agreed upon and executed with a shared commitment, where dynamic and flexible planning and active re-orientation of efforts can be efficiently implemented without project boundaries inhibiting the optimal course of action.

Notably the institutionalised partnership is seen as best approach compared to other partnership forms. There the Commission plays an active role as representative of the public interest, aligning and directing R&I efforts together with the aviation sector. This creates a powerful platform for integrating elements from other EU level R&I, Member States' national research programmes and regional specialisation strategies and can ensure close alignment with the Commission's policy leadership. This partnership approach is the most effective way to assure a strong alignment of the research roadmap with public policy to secure critical enablers for which the public partner's participation and co-governance are essential, thus ensuring that structural and societal impacts contributing to the overarching policy objectives can be achieved. These include close coordination towards future safety standards and certification requirements, thus involving the European Aviation Safety Agency (EASA) early in the research phase, in order to reduce the development time and cost, and ensuring that disruptive new technologies meet high levels of safety and reliability.
Equally, the active role of the public partner in the policy setting will be instrumental in creating the regulatory/legislative and economic conditions for a successful deployment of globally competitive new aircraft with disruptive performance gains into the aviation system in time to achieve the necessary impact by 2050.

A new European Partnership for Clean Aviation focusing on the most impactful solutions constitutes the most effective approach that can adequately reduce the industrial risk for transformative research and innovation (R&I). This approach will secure the long-term industrial commitments needed for long innovation cycles. It is the best assurance for keeping an effective and vibrant, competitive ecosystem with academia, research organisations, SMEs and industry closely collaborating to achieve the common objectives in line with the societal challenge.

An Institutionalised European Partnership with a dedicated programme office will allow strong programme management and monitoring, and the ability to execute a single integrated technology acquisition plan. The size and the urgency for transforming aviation towards climate neutrality make multiple parallel tracks of investigation necessary, but crucially these need to have strong interconnections and to make use of shared technology inputs and results. The management of such a multi-pronged effort on the challenge will involve robust use of decision gates, reviews, re-orientations and the re-allocations of resources and funding across different technology platforms. The ability to make these decisions in a format that maintains the investment and commitment of a large community of research actors, and the need to dynamically optimise over the course of the Horizon Europe funding period, make the highest form of co-committed, co-designed and co-governed partnering indispensable. A smooth transition of results including sensitive intellectual property between demonstration efforts and projects is essential. A co-governed and co-managed partnership can ensure that adequate assessments of progress and of expected impacts are performed independently, to monitor the partnership's execution of the research agenda, progress towards achieving strategic objectives, and assess the potential impact of its results/outputs when these are implemented into the aircraft fleet within a relevant timeframe. The partnership approach also entails extended impact assessment and monitoring of socio-economic and societal aspects and as such will inform public policy.

1.3.2 Synergies with Members States, regions and associated countries

An important lever for synergies is the link to national/regional innovation through cooperation agreements and steering mechanisms, which can enable coordinated and/or joint programming. The national innovation schemes across Europe are complementary to aviation R&I and can deliver solutions in support of the Clean Aviation ambitions. In this regard, a comprehensive mapping will be carried out to identify those national programmes, which may be linked to the European Partnership for Clean Aviation (EPCA) and its objectives as soon as the Commission adopts the proposal for regulation. Furthermore, mechanisms for fostering alignment of those programmes on common priorities/objectives and synergies of funding will be developed.

The partnership model has to date proven to be a catalyst of public and private investments and has the potential to promote and exploit synergies at all levels (national, regional, and private) and to create economies of scale by pooling dispersed resources and aligning efforts and resources. Synergies with other research and industrial ecosystems can be established through a systematic and programmatic approach under effective public and private co-governance. In this regard, Clean Aviation Partnership will be the best vehicle to enable strategic collaborations with Member States/Associated Countries and relevant national/regional authorities. The Partnership in close collaboration with the Commission Services and Member States will identify and connect with relevant national and/or regional activities and programmes that allow common challenges to be addressed more effectively and efficiently. These synergies shall be based on shared roadmaps and joint activities, as well as on the significant efforts and results stemming from national/regional research and innovation programmes. The Partnership shall also stimulate a smart use of ERDF and the related Smart Specialisation Strategies. Strategic collaborations will help identify potential solutions based on emerging technologies (including those from other sectors) and consider their implementation on the new aircraft concepts. This will include the assessment, adoption and development of technologies, skills and methods unreachable within the term of the Clean Aviation demonstrations and potentially beyond the traditional boundaries of the pure Aviation sector, and contribute to a long-term convergence towards full decarbonisation and climate neutrality.

Additionally, the concept aircraft demonstrations within the European Clean Aviation Partnership will complement and complete EU and nationally-driven research efforts by enabling trans-European research consortia, gathering even wider resources and expertise and enabling the Partnership to allow to reach beyond the otherwise achievable targets.

1.4 Partner composition and target group

1.4.1 Partner composition

The CS3PG stakeholder group is composed of 36 members[13] coming from the European aviation industry, academia and research centres, which are committed to prepare the draft SRIA. Among those members, the three associations EASN (European Aeronautics Science Network), EREA (Association of European Research Establishments in Aeronautics) and Pegasus (Partnership of the European aerospace

[13] See http://clean-aviation.eu/

universities) are representing over 90 different universities and research & technology organisations from across Europe and highly active in aviation research.

In terms of future Membership, a process would be defined in the preparatory stage of the programme to identify the Founding Members of the Partnership – ready to develop the principles of establishing the private members' commitment and to take an upfront long-term commitment as required for the successful implementation of the programme. This will ensure a wide representation of the entire aviation innovation chain willing to commit to the Partnership as well as enable the accession of new innovators in the course of the programme's initiation. Additional members (Associated members) will be selected by open calls after the launch of the programme. It is envisaged that the private membership of the EPCA will include a wide representation of industry, SMEs and entrepreneurial initiatives as well as public research organisations and higher education establishments / universities; and represent a wide geographical and competence base across the Member States and Associated Countries.

1.4.2 Collaboration networks and initiatives

The magnitude of transformation will be profoundly disruptive to innovation and investment cycles. The journey to a climate-neutral aviation system is well beyond the private sector's capability and capacity to invest alone. It is also beyond the reach of any individual European Member State to act alone. Achieving this transformation therefore requires joint action between the public and private sectors at the European level, including tightly coordinated policy measures to overcome market failure. This will raise the bar in Europe and trigger the global adoption of a sustainable aviation system.

A strong and stable partnership is a condition for success. It needs to embrace all relevant research and innovation actors: from within the aeronautics sector as well as newcomers bringing key technologies from other sectors. This partnership must include the EU as a public authority to enable a policy orientation that strengthens and aligns the research efforts' outputs towards market adoption. Institutionalised links with key EU bodies and agencies such as the European Aviation Safety Agency (EASA) should be an integral feature of the set-up and approach.

The leading European aircraft manufacturers and aerospace supply chain, together with European research stakeholders, share the ambition to accelerate progress towards a climate-neutral aviation system by 2050. Building on their own investments and national research programmes, the aeronautical manufacturing sector and research ecosystem jointly aspire to create an efficient collaboration in a Clean Aviation Initiative. This cooperation is crucial to create the critical mass needed to push beyond market-driven innovation, to respond to the societal challenge of decarbonisation and to meet the high expectations of Europe's citizens.

1.4.3 Innovation Architecture

The European Clean Aviation Partnership can create a critical force and bring together all required actors for a decisive change to the aviation system: OEMs, suppliers, EASA, airports, airlines, leasing companies, maintenance providers, universities, research organisations and more. Moreover, Clean Aviation will implement a strategic programming mechanism for the necessary research and innovation activities across Europe and across disciplines. This new and radical innovation chain must make maximum use of collective resources spanning national and regional efforts as well as transversal synergies leveraging non-aerospace capabilities. By defining and executing a common roadmap, the European Clean Aviation

Partnership can pull together and pool the resources needed to launch the innovations required. Linking research and technology demonstration with effective public policies will redefine market conditions and accelerate market adoption. This integrated and shared research roadmap needs to include substantial upstream 'exploratory' research – essential to finding tomorrow's pathways to mature technologies – for incorporation into further new and disruptive innovations. Demonstrating and validating these disruptive technologies is a prerequisite to building the necessary confidence for the momentous long-term investments needed for product development and rollout into a competitive global market.

The Clean Aviation initiative will be designed to efficiently engage the capabilities of the private sector and all other research stakeholders, drawing upon existing European excellence to deliver impact through joint research efforts under competitive research conditions, while ensuring the necessary thematic and geographical coverage. In this endeavour, non-aviation leaders in innovation areas such as alternative fuels, electrification or digitalisation will also be involved. The goal of this Innovation Architecture is nothing less than uniting Europe's research and industrial resources and capabilities for setting the new standard of sustainable and clean aviation.

The strategic programming of this architecture will allow the Partnership to build effective bridges to create essential synergies with other EU level research programmes and initiatives with potential technological contributions towards decarbonising aviation. Obvious examples are batteries, hydrogen, and sustainable fuels. In addition, the synergies both in research and technology development as well as in demonstrating and potentially piloting solutions with the proposed Air Traffic Management Partnership are beyond question. As the transformation towards a climate-neutral air transport system will only prove feasible under conditions of continued strengthening of Europe's industrial competitiveness, other disciplines such as digitalisation, electronics, artificial intelligence, advanced 'factories of the future' etc. will provide important contributions.

Working together with national research programmes and regional smart specialisation efforts can leverage the scope and impact of Clean Aviation, potentially doubling the financial resources available.

Where appropriate, international collaboration outside the framework of Horizon Europe's Associations will be considered on a case-by-case basis. EU policy in terms of shared values and goals will be applied when extending research efforts towards international consortia or collaborations, with the EU as an informed and involved public partner.

Schematically, this is depicted in **Figure 7**. The areas of synergistic programmes are indicative and non-exhaustive, but they give a representative picture of the overall research agenda that the aviation sector can contribute to and visualise the areas and enabling technologies from which the sector can draw benefit.

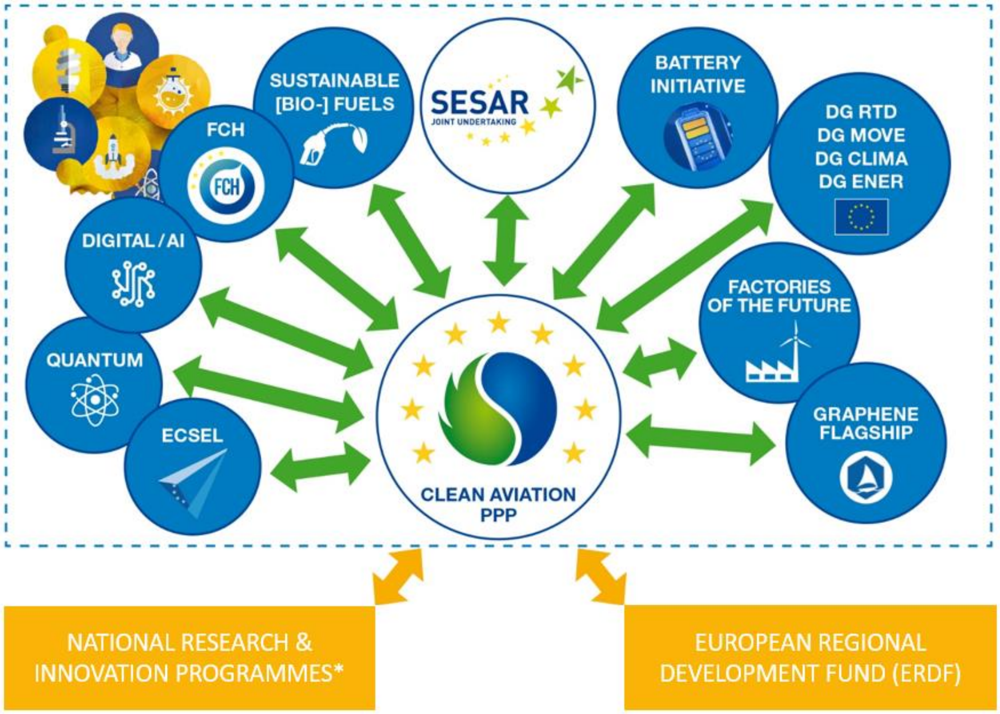


Figure 7: Clean Aviation Partnership Innovation Architecture

2 Planned Implementation

2.1 Activities

Realising the ambition of Clean Aviation requires a transformation, a disruptive step towards overall efficiency improvement, based on new propulsion solutions and leading to new aircraft configurations, which might be quite far from classic architectures. Achieving these new configurations will challenge current conventions and approaches related to the design, integration, production, and flight performance of all aircraft known to date, and lead to new approaches to the safety assurance, certification and regulation of on-ground and in-flight operations.

2.1.1 Principle set-up of the Clean Aviation European Partnership

In order to achieve the expected impact (as described in 1.2), aeronautics research in Horizon Europe must be structured on the basis of *a single integrated high-level roadmap,* developed by the sector's stakeholders and agreed upon by the public and private actors within the Institutionalised Partnership's governance structure. This will enable synergistic pathways towards innovation with maximum exchanges and transferability of results and outcomes, and allow dynamic resource allocation and flexibility to re-orient and re-prioritise research and demonstration efforts with the aim of maximum impact.
The Partnership will identify the key building blocks of R&I (sourced from key upstream enabling technologies) needed to effectively and efficiently develop ambitious large-scale high technology

readiness level (TRL) demonstration projects. Technologies and solutions that are cross-sectoral, or that are developing in other sectors, but can contribute to achieving the Partnership objectives will be identified for potential synergies. Developing these to suit aviation will require collaboration with other sectors and with other mechanisms in Horizon Europe, whether they are partnerships or other instruments.
Continuous and close research collaborations between the stakeholder community of academia, research centres, small-medium enterprises (SMEs), tier-one suppliers and aircraft manufacturers are essential. Non-aviation sector innovators will play an increasingly important role. These collaborations will help energise the upstream 'exploratory' research required for finding tomorrow's pathways to mature technologies, ready for incorporation into further disruptive innovations.

2.1.2 Integrating and Demonstrating Disruptive Technologies: the three thrusts

Three key thrusts for the R&I efforts have been identified that will drive energy efficiency and emissions reductions of future aircraft.

- **Hybrid electric and full electric architectures** – driving research into novel (hybrid) electrical power architectures and their integration; and maturing technologies towards the demonstration of novel configurations, on-board energy concepts and flight control.
- **Ultra-efficient aircraft architectures** – to address the short, medium and long-range needs with innovative aircraft architectures making use of highly integrated, ultra-efficient thermal propulsion systems and providing disruptive improvements in fuel efficiency. This will be essential for the transition to low/zero emission energy sources (synthetic fuels, non-drop in fuels such as hydrogen), which will be more energy intensive to produce, more expensive, and only available in limited quantities.
- **Disruptive technologies to enable hydrogen-powered aircraft** – to enable aircraft and engines to exploit the potential of hydrogen as a non-drop-in alternative zero carbon fuel, in particular liquid hydrogen.

The application of results from these areas to new aircraft will depend on performance requirements for various aircraft categories, technological capabilities, maturity level and feasibility of performance gains.

The thrusts will develop technologies and enablers, leverage essential knowledge and capabilities and de-risk the identified research topics where further maturation, validation and demonstration is required to maximise impact. The thrusts will chiefly target two pivotal aircraft demonstration programmes: the **hybrid electric regional** and the **ultra-efficient short-medium range aircraft** concepts. These aircraft demonstrations will enable the integration of technologies that have been matured and demonstrated into new aircraft concepts, and provide a clear understanding of the full aircraft performance achievable at a high maturity and fidelity, as of 2030. The two aircraft demonstration programmes will also anticipate the operational and certification issues (CS 25) of future aircraft models, and are relevant for an actual in-service introduction of the disruptive innovations.

The proposed research agenda for Clean Aviation is shown below, with a mapping of the potential applicability of the aforementioned thrusts to the most relevant aircraft categories (**Figure 8**).

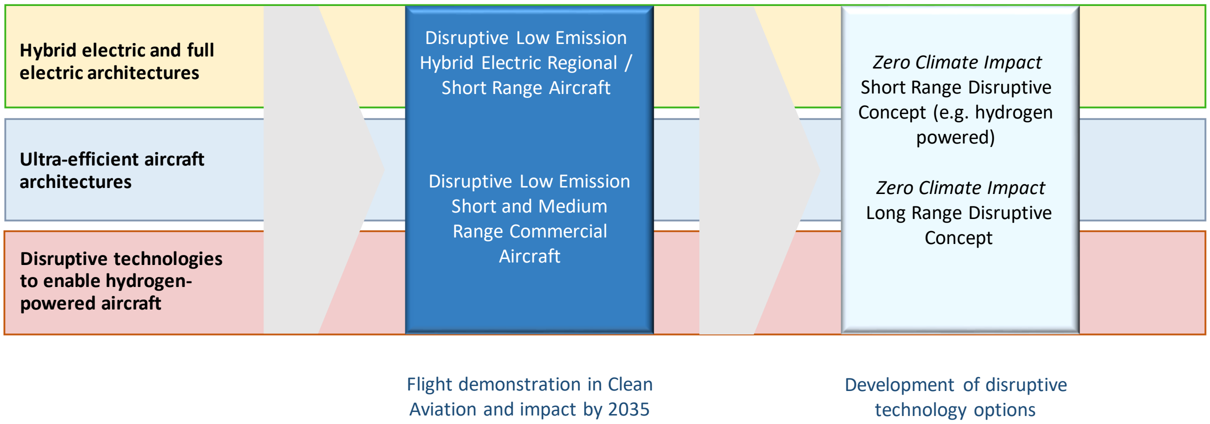


Figure 8: Mapping of the research thrusts against aircraft categories and concepts

While the primary focus of the demonstration efforts will be on the hybrid electric regional and the ultra-efficient short-medium range aircraft concepts, the approach will involve a stepwise development and demonstration strategy. This will allow several opportunities for technology spin-off to other aircraft categories: on one hand towards commuter and vertical lift applications that can benefit from the hybrid-electric technology development; and on the other hand from the ultra-efficient architectures towards long-range applications. This is particularly important, as it will allow both a broad-based participation in the programme, and a much broader and deeper penetration of the overall air transport system with **important additional environmental and climate-related benefits.**

The figure highlights the priority areas for research, which can lead to early adoption, i.e. where high technology readiness level (TRL) outcomes will result. The target performance levels across the aircraft categories selected for demonstration in Clean Aviation are below in **Table 3.1.**

Aircraft Class	Key technologies and architectures to be validated at aircraft level in roadmaps	Earliest EIS Feasibility	Fuel burn reduction (technology based) [1]	Emissions reduction (net – i.e. including fuel effect) [2]	Current share of air transport system emissions
Regional Aircraft	Hybrid-electric, distributed propulsion coupled with highly efficient aircraft configuration	~2035	-50%	-90%	~5%
Short-Medium Range Commercial Aircraft	Advanced ultra-efficient aircraft configuration and ultra-efficient gas turbine engines, ultra-high bypass (possibly open rotor)	~2035	-30%	-86%	~50%

Table 3.1: Clean Aviation aircraft category targets

The Clean Aviation Programme aims to demonstrate the cleanest technology that will present a viable solution for the respective next product generation, considering the technologies that could be mature and available by 2030. Each demonstration ambition builds on a distinct set of specified key technologies that will be integrated on board the final concept aircraft.

Additionally, through a concurrent research and engineering approach, the expected following generation of technologies will be explored and pushed towards maturation in order to deliver the remaining impact and achieve the 2050 goals.

Thrust No. 1: Hybrid electric and full electric architectures

The thrust linked to full electric and hybrid propulsion and carbon-free flight will drive the technology maturity and payload/range capability markedly beyond the state-of-the-art and the current development initiatives underway.

This thrust will require and develop programmed and executed research and innovation in the field of energy carriers and storage, in particular advanced fuel cells and batteries. In these areas, the core 'energy provider' technology should be acquired from (EU) initiatives outside the partnership in accordance with the aviation-specific and integration-related specifications and efforts provided through the proposed Clean Aviation European Partnership. Collaborative and synergistic arrangements via the Innovation Architecture will also be explored and implemented.

The target of the hybrid-electric regional aircraft is to flight test a regional aircraft in the 50-passenger range (up to 70 depending on the technology maturity) as close as possible to real industrial integration solutions and complying with certification rules spirit and scope. The aim is that the flight test bed – despite flight test instrumentation, features and specific solutions – demonstrates the potential for payload, range, speed and operative features comparable to a realistic revenue service regional air mobility at much lower emissions. The ambition is to achieve 50% less gaseous emission compared to similar aircraft while being fully compliant with ICAO noise rules in 2030.

Full electric and hybrid propulsion can be considered as a continuum at different stages of hybridisation with related technologies, complexity, safety and integration evolving at a different pace depending on air vehicle application and potential for scalability. Electric propulsion offers additional degrees of freedom for optimising the aircraft performance and reducing fuel consumption, also opening up a new design space for aircraft configuration, performance, operation and eventually business case. Considering size, range and performance, regional aircraft are the most suitable candidates for demonstration under Clean Aviation, as this market segment is able to return a sensible impact on global greenhouse gas emissions.

The hybrid-electric regional aircraft activities will contribute to the overall Clean Aviation objective that will result in a regional aircraft with technologies ready for entry into service by 2035, incorporating product-viable solutions for technologies, integration, infrastructure, and certification. The aircraft will include hybrid-electric propulsion supported by 100% drop-in fuels for the thermal power source, to reach up to 90% lower emissions while being fully compliant with ICAO noise rules.

Thrust No. 2: Ultra-efficient aircraft architectures

The mid-2030s will see the entry of a new generation of large aircraft platforms aiming towards sustainable climate-neutral flight. While hybrid/electric energy architectures and ultra-efficient aircraft designs will have paved the way towards climate-neutral aviation on <1 000km routes, aircraft for classical short and medium-range distances rely on ultra-efficient thermal energy-based propulsion technologies using sustainable drop-in and non-drop-in fuels to enable climate-neutral flight. The novel aircraft and propulsion concepts will enable low source noise and low noise flight procedures.

The research and innovation activities within this thrust aim to improve the energy efficiency of a new generation of short/medium-range aircraft by 30%. This will be available by 2035 by combining disruptive technologies related to the airframe with ultra-efficient propulsion systems and integrating them. The roadmap activities also include an option for the demonstration and validation of an even more disruptive concept using hydrogen as a non-drop-in fuel, subject to sufficient maturity being achieved through the Clean Aviation H_2 technology development programme.

The roadmap of this development and demonstration programme goes well beyond the integration of an improved propulsion concept into 'any' short- and medium-range aircraft. It results in a holistic aircraft suite solution for a future green, eco-efficient, economically viable and competitive large number serial product that will create momentum and targeted impact at European and global scales. Within this context, four pillars are key constituents of the 'Green Short/Mid-Range Aircraft' development and demonstration roadmap.

They include the overall efficient and optimised aircraft design with ultra-efficient wing and fuselage that integrates all key innovative aircraft systems (such as cabin platforms, landing gear and features) enabling maximum impact on climate neutrality via a competitive, affordable green product. Another important pillar is the development and integration of the ultra-efficient propulsion system onto a tailor-made airframe and system architecture. An additional aspect when designing climate-neutral aircraft capable of sustained highly efficient green operations and services is to be thoughtful with respect to maintainability. An eco-sustainable end-to-end, no-waste manufacturing and digital design process enabling an efficient green industrial architecture will be included in order to ensure the emergence of impactful climate-neutral aircraft from the programme.

The SMR programme in the Clean Aviation Partnership will also stimulate the extension of applicability of technologies towards neighbouring aircraft segments, here in particular from the short to medium segment towards medium to longer ranges. Green large and heavy long-range aircraft are considered to have an entry into service timeframe of beyond 2035. The outcomes of the Clean Aviation Programme will open up opportunities for a strategy of scaling and applying results to a new generation of climate neutral heavy long-range aircraft in a next major step of innovation immediately following this programme.

Scalability and spin-offs for other aircraft types like large business jets will promote and spread the operability of this technology to other airports outside of Europe.

Thrust No. 3: Disruptive technologies to enable hydrogen-powered aircraft

Hydrogen presents several key advantages when considering aviation application: it allows for the elimination of CO_2 emissions in flight and along the entire life cycle if produced carbon-free. Its usage in fuel cells allows for zero-emission propulsion (including NO_x and particles). When burnt in a turbine engine, very low particle emissions can be expected, as well as reduced NO_x emissions, if the combustion system is optimised. Considering also non-CO_2 emissions (high altitude phenomena), the use of hydrogen in a thermal (combustion) engine can lead to different emissions and consequently a change in the global environmental impact, still to be assessed.

Incremental improvements – i.e. higher fuel efficiency of conventional fuels – are not sufficient to achieve the ultimate objective of a climate-neutral aviation system. The emission of greenhouse gas and especially non-CO_2 emissions and secondary effects (NO_x, SO_x, soot) can only be avoided by disruptive propulsion technologies, i.e. ultra-efficient engines using alternative fuels. The hydrogen-powered aircraft seems to be a promising solution to limit this climate impact. However, considering the challenging fluid properties and impact on the overall aircraft system optimised for conventional fuel, high research effort is required to introduce this technology onto the market.

The development of hydrogen (especially liquid hydrogen) aviation will require substantial efforts, as most of the needed technologies are currently at low TRL and have never been demonstrated. Maintaining an optimal level of safety is key for aviation and thus the shift to hydrogen will imply radically new challenges in terms of safety, procedures, but also certification and qualification of aircraft components.

Clean Aviation aims to mature and demonstrate all relevant systems ready to be integrated into future aircraft. This comprises the selection and validation of the most suitable concepts, materials and designs to provide the required performance, lifetime, costs, and safety. Beyond that, the integration of these systems into the aircraft platform requires a deep understanding of operational, maintenance, and certification aspects.

To ensure the impact of clean hydrogen propulsion, the high-level requirements of potential aircraft platforms will be considered from the beginning. Systems will be scalable for different propulsion architectures (fuel cell or H_2 burn) as well as aircraft sizes (commuter, rotorcraft, regional, short/medium/long range). In this light, early impact can be expected through application of the hydrogen fuel cell for hybrid electric regional aircraft in 2035. Building on this, radical short and medium range aircraft will benefit from storage and feed system architectures to exploit hydrogen burn propulsion systems, paving the way for even longer range applications. Clean Aviation will lay the foundations for the future clean hydrogen aircraft propulsion architecture.

2.1.3 Supporting research for breakthrough innovations

Clean Aviation concept aircraft taken to the demonstration phase will only achieve their expected performance gains by the end of the programme and at the required maturity level needed if a number of key enabling technologies are identified, explored and matured in parallel, and are available for take-up.

Strategic synergies with several other areas of R&I within Horizon Europe, including other partnerships, as well as national/ regional R&I programmes will be crucial to address specific requirements and rapidly progress low maturity solutions in order to enable convergence to a full decarbonisation of aviation.

This will require the assessment, adoption and development of technologies, skills and methods that are potentially beyond the traditional boundaries of the aviation sector.

Clean Aviation will aim at down-selecting and integrating the most promising technologies into low-emission aircraft concepts. It will steer these synergies in order to support both the short-term and the medium-long-term impacts by maturing technologies to be integrated in the next innovative aircraft systems to reduce the environmental impact of aviation. The solutions will be the outcome of synchronised exchanges of top-down concept requirements and bottom-up solutions between Clean Aviation and the other R&I efforts such as Horizon Europe Partnerships, the Commission’s Work Programmes (often referred to as the Collaborative Research Programme); and national/regional initiatives.

Synergies with other EU R&I programmes and initiatives will generally focus on low(er) TRL research related to technologies and methods that can help accelerate progress towards the targeted aircraft performance. Synergies will be pursued to address all phases of developing components, systems, the preparation of integrated Clean Aviation demonstrator projects, and assessing integrated aircraft concepts, including design tools and methods.

R&I projects related to aeronautics and planned for the European Commission's Cluster 5 Work Programme ('Collaborative Research') should support all these steps. This applies to the early identification of promising emerging technologies as well as to exploiting innovative and valuable methods required for the discovery of unconventional configurations and the manufacturing concepts for new aircraft. Two main research streams complement one another:

- Breakthrough zero emissions technologies: The aim is to explore, prepare and mature all the potential innovations that can be integrated into novel aircraft and propulsion system configurations (next aircraft generation), and discover disruptive technologies that can be integrated into long-term products (EIS beyond 2035);
- Transverse technology enablers: These will develop the means to accelerate affordable decarbonisation by leveraging all the steps of the product life cycle – from the early trade-offs, technology down-selection, and integrated demonstrations on ground, up to the certified operational aircraft that will join the fleet.

Each stream consists of research areas that contribute directly or indirectly to the Clean Aviation objectives, while exploratory research will be more specifically conducted to set-up the scientific knowledge base to support the long-term sustainable aviation vision, which is mandatory for the introduction of radical solutions beyond 2035 and the Clean Aviation timeframe.

2.1.4 Programme monitoring and optimisation

The objective of Clean Aviation demonstrations is to diminish the risk and validate disruptive technologies in areas where there is not sufficient knowledge or experience to simulate or predict results. This will allow all research stakeholders to jointly make informed risk-sharing research investments to accelerate the arrival of a new era of clean and sustainable aviation.

The Clean Aviation demonstration strategy is multi-dimensional by definition. While it must ensure control of risks and cost, it is at the same time the means to understand the potential of new technology and fully assess its performance in interaction and correlation with other systems (legacy or new).

Clean Aviation will define the most effective demonstration strategy in an environment, which includes three critical correlated dimensions:

a) from the single component in laboratory tests to its integration in a real scale system as part of the final product;
b) from assessment of a single performance parameter to the assessment of whole system multi-parameter functioning;
c) from small to large final product applications.

The programme allows for a first wave of critical ground and flight demonstrations delivering important early verification and orientation before a mid-term review and a second wave of more advanced complex and more highly integrated demonstrators that can validate and demonstrate performances at aircraft level thereafter. This will enable the subsequent development of new generations of vehicles.

The initial aircraft demonstrations will make use of cutting-edge key enabling technologies of which at best initial prototypes may exist. In order for these technologies to be integrated in future aircraft, a potential route for certification needs to be established before the end of the programme and before final demonstrations. Dedicated research focusing on the validation and maturation of these respective underlying key technologies should start in parallel.

Derived from the well-specified needs of the respective classes of air transport missions and ambitions, a series of dedicated and associated research projects on those key enabling technologies will need to start with the aim of achieving critical maturity milestones mid-way through the programme.

Technology investment analysis

When proposing demonstration activities applicants will be required to describe in detail the technological challenges, expected benefits, risks, timelines, and expected market availability in relation to the level of funding requested. Thus, an informed and independent investment analysis can provide a basis for selection.

The Partnership will establish impartial, efficient, and transparent means to conduct ex-ante technology investment analysis up to the level of vehicles.

Technology impact assessment and monitoring mechanism

Technology impact assessments will provide Clean Aviation with an efficient and impartial means of shaping, monitoring, evaluating and promoting the programme's research and innovation activities. By examining and evaluating future impacts of emerging technologies, the benefits of research and demonstration activities will be verified comprehensively and transparently.

Providing independent forecasting and scenarios as well as state-of-the-art modelling and assessment capabilities is vital for success. The Partnership will establish tailored indicators and metrics for climate impact (global warming) as well as for local air quality, noise emissions, and competitiveness.

Its implementation will allow for appropriate capacity building, regular global assessments, and constant monitoring of the progress of the programme, as well as predicting and reporting on exploitation and impact. It will support the steering of the partnership, and feed the work of the Governing Board.

2.2 Resources

To reach sufficient technology readiness in the Horizon Europe timeframe ambitious resourcing is essential. The support of the EU institutions and Member States will be essential in creating the conditions for impact, and ensuring the trajectory is successful. The research needed to meet this challenge within the Horizon Europe timeframe is likely to exceed ~€12 billion in effort.

In close collaboration with its public partner (the Commission) the partnership can play a central role within a European 'innovation architecture', ensuring shared roadmaps and synergies with EU collaborative research, other relevant European Partnerships and EU research programmes; national research and innovation programmes, and European Regional Development Fund and financial instruments (see 1.2.3 and 1.3.2). Within this architecture, the Clean Aviation Partnership should mobilise impact-orientated research representing a relevant and significant share of the total estimated R&I effort needed. Further EU collaborative research dedicated to aeronautics would need to address the wider agenda, e.g. upstream exploratory research towards future breakthrough technologies.

Within this architecture, in order to deliver on the goals set for the Clean Aviation European Partnership an investment of around €4.5 billion is needed (as a key component of the overall €12 billion effort). This will require significant and balanced contributions from the public and private sides, based on funding rates and mechanisms that are appropriate for the high levels of risk, long timescales and uncertain financial returns; and on the participation of industry as well as research organisations and academia.

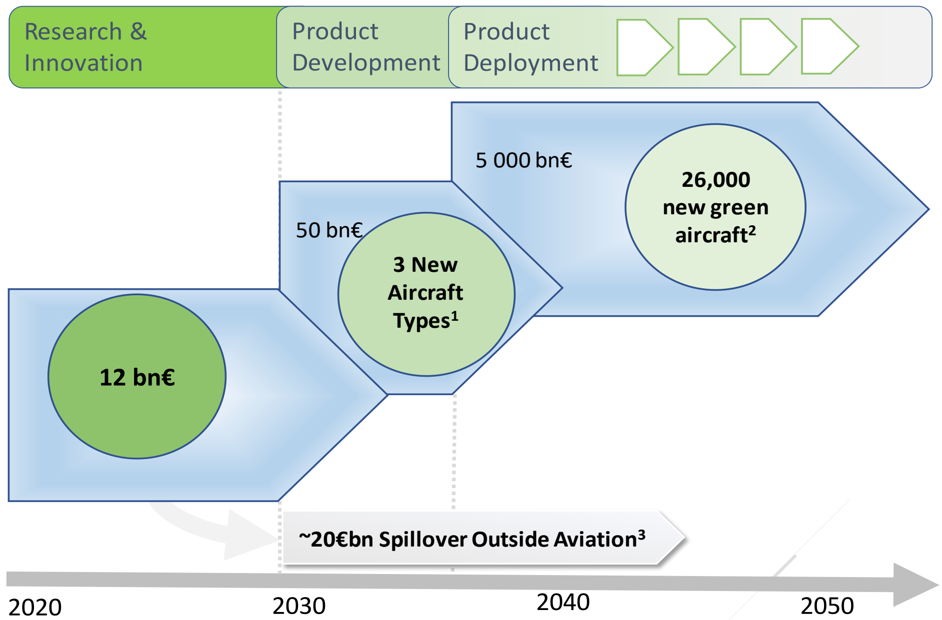
Resources contributed by the private side may be:

- In-kind contributions to the projects funded by the Union contributions (on the basis of non-reimbursed eligible costs);
- In-kind contribution for additional activities foreseen in the SRIA not covered by Union funding;
- Investments in operational activities that is spend beyond the work that is foreseen in the SRIA;
- In cash contribution used to finance the administrative costs, in case of an Institutionalised European Partnership (Joint Undertaking).

The envisaged programme set-up and management will ensure both a gate review process linked to monitoring progress, and an impact assessment process. These will enable dynamic allocation between projects inside the demonstration thrusts as well as between thrusts, based on maximum potential impact and the technological and industrial strategies involved.

A rough estimate indicates that this EU public and private investment of €12 billion in aviation research and innovation in the timeframe of Horizon Europe can stimulate product development in this sector worth over €50 billion. This stimulus can finally lead to an overall private investment in product deployment of more than €5 000 billion by 2050, see **Figure 9** below. The support of both the EU institutions and EU Member States will be crucial in ensuring the success of Clean Aviation.

The overall leverage effect in the partnership of EU funding to private investment in the research phase alone (so not including any development beyond the research phase) is expected to be ~200%. Additional public investment (e.g. from Member States) will further increase the EU's leverage significantly beyond this. This estimate is based on the current estimates of project costs and funding rates that would be representative of the nature of the research in terms of risk, long development cycles and highly uncertain payback periods. The funding level includes an estimate of non-profit entities' participation and requisite funding rates and conditions.



1 – Based on Aircraft Development 15bn€ per type
2 – Estimated on basis of Airbus GMF 2028-2037:
37,400 new a/c scaled to 2035-2050 in order to reflect larger baseline in 2035. 50% market share assumed.
3 – Estimate based on 12€bn investment in aviation R&T over 10 yrs. Value at 2020 NPV.

Figure 9: Towards climate-neutral aviation: total effort required

2.3 Governance (under preparation[14])

The Clean Aviation is a candidate Institutionalised Partnership in the meaning of Horizon Europe Regulation. This European Partnership will be based on an open and transparent governance and management structure, which will be regulated by a lean and effective regulatory framework and designed in such a way as to allow Clean Aviation to operate smoothly and be able to meet its objectives.

Based on the experience and lessons learnt in CS1 and CS2 and in light of the rules and criteria for European Partnerships laid down in Horizon Europe, the governance should be structured as follows:

Governing Board

The Governing Board (GB) would be the highest decision-making body of the JU and would have the overall responsibility for the strategic orientation of the SRIA and technical roadmap towards reaching the objectives set under the JU Regulation and the expected results and impact to be brought by the European Clean Aviation Partnership.

Based on the experience and lessons learnt in the implementation of the CS1 and CS2 currently operating under H2020, the Governing Board's tasks and responsibilities shall be shifted towards a stronger focus on strategic tasks, monitoring and assessing the results and impact of the programme, including policy

[14] Subject to definition under the expected legislative proposal for a Council Regulation establishing the Clean Aviation JU

and regulatory aspects. In order to achieve this evolution not only in terms of statutory tasks but also in terms of *modus operandi* and GB agenda setting, the composition and representation of its members shall reflect these strategic responsibilities. In case of an institutionalised partnership, the programme management tasks, administrative responsibilities and processes as well as compliance obligations are assigned to the Executive Director and the Programme Office under his/her control as stated in the Regulation.

A revised and upgraded impact assessment and monitoring mechanism, going beyond the earlier Technology Evaluator role and responsibilities as laid out in the FP7 and H2020 related Regulations of Clean Sky and Clean Sky 2 should be established. Its implementation shall allow for the regular assessment and measuring of the progress of the programme, as well as predicting and reporting on exploitation and impact; and in this role, it will support the role of the partnership and of the Governing Board.

When Clean Aviation Partnership operations commence in 2021, the Governing Board will play a key role in the strategic orientation of the Partnership, priority setting and steering of the programme.

The role of the Commission in the Governing Board, both in the preparatory phase of the Clean Aviation and its implementation phase, is crucial in terms of allowing an effective framework for the implementation of the programme. It is equally important to ensure that this European Partnership supports and contributes to key EU policies and priorities as described in section 1.3 and the political priorities and initiatives of the new Commission such as the 2050 climate neutrality goals, the Green Deal communication and other key political and legislative initiatives relevant to aviation. By holding 50% voting rights in the Governing Board, the Commission can defend the public interest.

Composition: The Governing Board shall be composed of the following members with voting rights:

1. representative/s of the Commission on behalf of the European Union;
2. an inclusive and balanced representation of the *private sector* consisting of:
   - representatives of the Founding Members that will make a long-term commitment upfront towards the establishment of the JU, towards ensuring the necessary allocation of resources and private contribution to the JU and achieving the research objectives and their ultimate impact;
   - representatives of the Associated Members that will be appointed following the launch of the open calls for the selection of additional private Members. A rotational mechanism will be applied to ensure structured and inclusive participation in the setting of programming priorities and a broad representation.

Wider participation, additional contributions and inputs from other stakeholders will be assured through the presence of representatives with permanent observer status and other observers that may be invited by the GB depending on the topics in the agenda.

Executive Director

The Executive Director should be the chief executive responsible for the management of the JU, the programme and operations in line with the strategic orientations and decisions of the Governing Board. The Executive Director should monitor the progress of the programme and its key deliverables vs programme objectives and KPIs and consider any appropriate measure in the interest of meeting the JU objectives.

The Executive Director is expected to develop synergies with other programmes and partnerships within Horizon Europe and other Union programmes as well as seeking alignment and complementarity with National and Regional Programmes where relevant. The Executive Director should also be the chief executive of the staff of the JU and be the legal representative of the JU.

States Representative Group (advisory function)

Member States would be involved via a States Representative Group (SRG) - an advisory body that would allow Member States to provide inputs to the SRIA and programme priorities at an upstream strategic level and to be consulted regarding the Work Plans, programme implementation/execution, progress towards objectives and any update of its strategic orientation. The SRG should also play a role in terms of supporting alignment and synergies and promoting the programme at national level and in providing access to information on National Programmes and Smart Specialisation Strategies where relevant. As part of the SRG mandate and composition, the SRG should ensure adequate liaison with the Mobility Programme Committee to reinforce the overall visibility and consultation of Member States on the Clean Aviation Partnership and also to identify and develop synergies with other relevant programmes and partnerships of Horizon Europe.

Composition: the SRG should consist of representatives of Member States and countries associated with Horizon Europe that have the necessary institutional mandate and representative level to be able to perform its role on behalf of the Member States.

Scientific Committee (advisory function)

The Scientific Committee - an advisory body of the partnership - would advise on the scientific priorities to be addressed in the programme and Work Plan, and on the scientific achievements of the programme in relation to its objectives.

Composition: The scientific committee should be composed of representatives that will be selected via an open call, which will be launched by the JU based on specific criteria and a selection process to be agreed upon by the Governing Board. The composition of the Scientific Committee members should reflect a balanced representation of worldwide-recognised independent experts from academia, RTOs, industry and end-users, who have the necessary scientific competencies and expertise covering the core technical domain of this Partnership and the thematic areas covered in the technical programme needed to make science-based recommendations to the partnership.

2.4 Openness and transparency[15] (under preparation)

The partnership will have an open and transparent governance and management structure. A lean and effective regulatory framework will allow the partnership to operate smoothly and be able to meet its objectives. The Clean Aviation Partnership will function via open and competitive calls. These will be open to all interested stakeholders willing to commit, contribute and collaborate in the partnership, including the demonstration of new ambitious technology solutions and climate-neutral aircraft concepts.

[15] Subject to definition under the expected legislative proposal for a Council Regulation establishing the Clean Aviation JU

The programme will identify those solutions with the highest impact in terms of climate combined with the best chance of evolving into sustainable product and service innovations. This will enable a realistic and fast uptake by of the markets, thereby introducing green aviation operations and delivering the expected benefits for Europeans.

Participation in the Partnership

The partnership will ensure an open and transparent process for all open calls and will ensure a broad and wide participation from the stakeholders. Open calls should be the principle for any allocation of Union funding to project activities.

The membership and overall stakeholders' base will continue to grow over the lifetime of the programme. Active recruitment of additional private Members (Associated Members) will take place via open calls in order to further expand the stakeholders base and to enable large-scale deployment of clean aviation technologies in line with EU goals and targets.

Type of open calls mechanisms

The calls for additional private members (Associated Members) will be launched over the lifetime of the Partnership in order to ensure the consortia have the appropriate configurations, key capabilities and skill sets needed to implement the programme, maximise results and impact. The Partnership will ensure an open and inclusive approach along the lifetime of the Partnership allowing any required new key capability/competence to enter the Membership and to accede to the relevant consortia and perform the activities, as appropriate in line with the programme implementation.

Complementary calls for proposals are foreseen in order to allow for tailored and time-limited contributions from partners (in particular from SMEs), towards the integration and build-up of demonstrator hardware as well as for analysis, simulation, testing and validation activities.

Participation in the calls and activities launched by the partnership

Participation in the calls issued within the scope of the partnership will remain open, on a fair and non-discriminatory way to all stakeholders eligible for funding under Horizon Europe rules. The partnership will design a dedicated type of open calls for the large demonstration projects in cooperation with the Commission. The calls will invite the submission of proposals by industry-led consortia and will set out the requirements needed in the demonstration area including the required key capabilities in the field of aeronautics as well as from other sectors as appropriate. The call topics will require long-term commitment from the stakeholders to deliver the necessary resources to the Partnership and execute research activity as defined by the technical roadmap.

Conditions may be included to such calls to ensure the commitment to implement the results in terms of European exploitation, thus warranting a targeted effect in terms of climate impact and European competitiveness.

A mechanism will be established by the partnership in order to allow access to results and connect the lower TRL projects that have potential for possible uptake into the demonstrators' part of the programme.

The calls should include flexible mechanisms to allow additional private Members and partners/other contributors to enter the partnership and contribute to the core activities based on capabilities needed as well as programme priorities and possible evolution. In addition, the grant agreement framework should be flexible in terms of duration, budget allocation and composition of its core partnerships.

In terms of dissemination of results and access to projects results, the partnership will apply an open access policy and open access to research data policy to any possible extent depending on the nature of the topics and the TRL of the activities being performed in the JU in line with the principles and provisions of Horizon Europe.

The Strategic Research and Innovation Agenda and associated technology roadmaps will be developed through broad engagement of stakeholders and Member States with an element of public consultation.

KPIs will be set up to monitor the openness and outreach of the partnership and its activities.

3 Annex: Strategic Research and Innovation Agenda

Executive Summary

Figures, data and forecasts included in the document originate largely from before the COVID-19 pandemic. It is much too early to understand the full impact of the *corona crisis* on short and mid-term traffic demand. However, it is clear that this crisis calls for even more action from the European Union institutions on green innovation and in support of the aviation sector's transformation than to date.

The **European Green Deal** will include the first European Climate law to enshrine the 2050 climate-neutrality objective in legislation. The task facing the aviation sector in this and the next decades is to develop and introduce safe, reliable, and affordable low- to zero emission air transport for citizens and to concurrently ensure Europe's industrial leadership is maintained and strengthened throughout the transition to a climate-neutral Europe. The trajectory towards climate-neutral aviation is achievable but will be contingent on:

- an **exceptional research and technology effort** to reduce energy needs and fuel consumption, while ensuring safety and competitiveness in a spirit of public private partnership and with shared investments and commitments;
- fast-tracked research, development and deployment of **sustainable aviation fuels** by the relevant actors and proactive policies for wide-scale and economically viable use within the next decade;
- **optimised green air operations and networks** to fully exploit new aircraft and systems capability;
- a suitable **global aviation regulatory framework** creating the conditions for a transition.

An institutionalised (Art. 187) European Partnership for Clean Aviation under Horizon Europe is the most effective and impactful means through which the aeronautics and air transport sectors can bring a decisive contribution towards a climate-neutral Europe. Only such a partnership can pull together the resources, develop, and enable the introduction of safe, reliable, efficient and affordable climate-neutral air transport. This Partnership aims to play a central role within a European 'Innovation Architecture', ensuring shared roadmaps and synergies with EU collaborative research and other European, national and regional programmes and initiatives. It will build Europe's leadership in innovation and technology, and deliver jobs and economic growth throughout the transition to a climate-neutral Europe by 2050. It can offer future generations the promise of continued, affordable and equal access to air travel, and its social and economic benefits, and contribute to the UN's Sustainable Development Goals.

Clean Aviation low and zero emissions disruptive technologies will allow fuel efficiency gains of one-third to one-half in 2050, compared to today's fleet. The partnership will enable aircraft, engines and systems to utilise the full potential of low or zero carbon fuels, and investigate potential pathways towards the use of breakthrough options such as hydrogen.

The ambition of the Clean Aviation Partnership is to ensure that advancements in breakthrough technologies allow **new 'clean sheet' aircraft developments by 2030**, with maximum progress towards climate neutral aviation. It will go well beyond previous Framework Programme R&I, and will accelerate the transition towards a climate neutral system by enabling all-new aircraft platforms and configurations, and taking a system-wide approach. The partnership will aim for decisive steps in new aircraft performance demonstrated and **on offer to airlines and operators by 2030 and available by 2035**. The focus will be on pursuing two pivotal aircraft demonstration efforts for the validation of selected technologies. **Ultra-efficient short-medium range aircraft** coupled with the use of sustainable aviation fuels, and **hybrid electric regional aircraft** will deliver major steps, together with optimised green trajectories and operations and with accelerated transition to low or zero carbon fuels. Clean Aviation will develop the technologies to deliver full climate-neutrality by 2050 in parallel to these by bringing key technologies to a maturity that can allow appropriate scaling across the full spectrum of aircraft segments and flight operations, including long-haul travel.

Three key R&I *thrusts* will drive the energy efficiency and the emissions reductions of future aircraft.

- **Hybrid electric and full electric architectures**– driving research into novel (hybrid) electrical power architectures and their integration; and maturing technologies towards the demonstration of novel configurations, on-board energy concepts and flight control.
- **Ultra-efficient gas turbines powered architectures** – to address the short, medium and long-range needs with innovative aircraft architectures making use of highly integrated, ultra-efficient gas turbines.
- **Disruptive technologies to enable hydrogen-powered aircraft** – to enable aircraft and engines to exploit the potential of hydrogen as a *non-drop-in* alternative *zero carbon fuel*, in particular liquid hydrogen.

An **Impact Monitor** mechanism and work programme will be included in the Partnership's work breakdown structure to ensure regular strategic monitoring and steering, and ensure objectives are met.
The performance levels in targeted the aircraft types to be demonstrated in Clean Aviation are below.

Aircraft Class	Key technologies and architectures to be validated at aircraft level in roadmaps	Earliest EIS Feasibility	Fuel burn reduction (technology based) [1]	Emissions reduction (net – i.e. including fuel effect) [2]	Share of air transport system emissions
Regional Aircraft	Hybrid-electric, distributed propulsion coupled with highly efficient aircraft configuration	~2035	-50%	-90%	~5%
Short-Medium Range Commercial Aircraft	Advanced ultra-efficient aircraft configuration and ultra-efficient gas turbine engines, ultra-high bypass (possibly open rotor)	~2035	-30%	-86%	~50%

[1] Improvement targets are defined as fuel burn reduction compared to 2020 State-of-the-Art aircraft available for order/delivery
[2] Assumes full use of SAF at a State-of-the-Art level of net 80% carbon footprint, (or where applicable zero-carbon electric energy)

Technologies developed and validated through the Clean Aviation Partnership's R&I efforts will allow a broader cross section of the air transport system to benefit as well, through scaling and adaptation to segment-specific needs. Ultimately, the full spectrum of aviation, including long-haul travel (which has a sizeable climate impact) will benefit from the results of the programme.

To reach sufficient technology readiness in the Horizon Europe timeframe ambitious resourcing is essential. The EU institutions' and European Member States' support will be essential in creating the conditions for impact, and ensuring the trajectory is successful. The research needed to meet this challenge within the Horizon Europe timeframe is likely to exceed ~ €12 billion in effort. This effort can stimulate a product development in this sector worth over €50 billion. This stimulus can finally lead to an overall private investment in product deployment of more than €5 000 billion by 2050.

The approach proposed in the SRIA will require a research effort of roughly €4.5 billion as a key component of the overall €12 billion effort. This will require significant and balanced contributions from the public and private sides, based on funding rates and mechanisms that are appropriate for the high levels of risk, long timescales and uncertain financial returns; and on the participation of industry as well as research organisations and academia.

The partnership will have an open and transparent governance and management structure. A lean and effective regulatory framework will allow the partnership to operate smoothly and be able to meet its objectives. **Open and transparent calls will be the principle for the selection and allocation of all Union funding.** These will be open to all interested stakeholders willing to commit, contribute and collaborate in the partnership, including the demonstration of new ambitious technology solutions and climate-neutral aircraft concepts.

The final draft of the Strategic Research and Innovation Agenda will be made available publicly at the following link: www.clean-aviation.eu

4 List of Abbreviations

ASD	Aerospace and Defence Industries Association of Europe
ACARE	Advisory Council for Aviation Research and Innovation in Europe
ATAG	Air Transport Action Group
BLI	Boundary Layer Ingestion
CH_4	Methane
CO_2	Carbon dioxide
CS1	Clean Sky programme under FP7
CS2	Clean Sky 2 programme under Horizon 2020
DG RTD	European Commission's Directorate-General for Research and Innovation
EASA	European Union Aviation Safety Agency
EASN	European Aeronautics Science Network
ECSEL JU	Electronic Components and Systems for European Leadership Joint Undertaking
EIT	European Institute of Innovation and Technology
EREA	Association of European Research Establishments in Aeronautics
ERDF	European Regional Development Fund
EPCA	European Partnership for Clean Aviation
FP7	Seventh Framework Programme for Research and Innovation (2007-2013)
GB	Governing Board
GHG	Greenhouse Gas
H2020	Horizon 2020, EU Research and Innovation programme (2014-2020)
H_2	Hydrogen
ICAO	International Civil Aviation Organization
JU	Joint Undertaking
LNG	Liquefied Natural Gas
NO_x	Nitrogen Oxides
OEM	Original Equipment Manufacturer
Pegasus	Partnership of a European Group of Aeronautics and Space Universities
PM	Particular Matter
PPP	Public Private Partnership
R&I	Research and Innovation
RIS3	Regional Research and Innovation Strategies for Smart Specialisation
RoM	Rough Order of Magnitude
RTO	Research and Technology Organisation
SAF	Sustainable Aviation Fuel
SESAR	Single European Sky Air Traffic Management Research
SME	Small and Medium-sized Enterprises
SMR	Short-Medium Range
SO_2	Sulfur Dioxide
SRG	States Representative Group
SRIA	Strategic Research and Innovation Agenda
TRL	Technology Readiness Levels
TFEU	Treaty on the Functioning of the European Union
WG	Working Group