CLEAN AVIATION

HIGHLIGHTS 2023

Towards disruptive technologies for aircraft by 2035

Co-funded by the European Union

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LIST OF ACRONYMS

A/C = Aircraft

ARE = Advanced Rear End

BATT4EU PPP = Batteries Partnership

CAAF = Clean Aviation Annual Forum

CAJU = Clean Aviation Joint Undertaking

CFD = Computational Fluid Dynamics

CFRP = Carbon Fiber-Reinforced Plastic

DEP-SFD = Distributed Electric Propulsion - Scaled Flight Demonstrator

DISCO = Large Aircraft DISruptive COckpit

EASA = European Union Aviation Safety Agency

EIS = Entry Into Service

EMA = Electromechanical Actuators

ENG = Engines

EU = European Union

FCS = Flight Control System

FRC = Fast RotorCraft

FRC IADP = Fast Rotorcraft Innovative Aircraft Demonstrator Platform

FTB = Flying Test Bed

GB = Governing Board

H2 = Hydrogen

HLFC = Hybrid Laminar Flow Control

HVDC = High Voltage Direct Current

ICAO = International Civil Aviation Organisation

ITD = Integrated Technologies Demonstrator

IWT = Innovative WingTip

LGB = Lateral Gearboxes

LH2 = Liquid Hydrogen

LPA = Large Passenger Aircraft

MCA = Major Component Assembly

MFFD = Multifunctional Fuselage Demonstrator

MGB = Main Gearbox

MoC = Memorandum of Cooperation

MoU = Memorandum of Understanding

NOx = Nitrogen Oxides

OoA = Out of Autoclave

RDF = European Regional Development Fund

RTOs = Research and Technology Organisations

SAF = Sustainable Aviation Fuel

SAT = Small Air Transport

SESAR 3 JU = Single European Sky ATM Research 3

SMEs = Small and Medium-sized Enterprises

SMR ACAP = Short and Medium Range Aircraft Architecture & Technology Integration Project

SRIA = Strategic Research and Innovation Agenda

TRL = Technology Readiness Level

*The **Clean Aviation programme** will deliver **disruptive aircraft technologies** to enable **climate-neutrality** by **2050.***

FOREWORD 2023

Axel Krein
Executive Director

Since its launch in 2022 the Clean Aviation Joint Undertaking (CAJU) has been at the forefront of pioneering technologies that are driving the sustainable aviation revolution, working towards the sector's target of achieving climate neutrality by 2050.

Cutting-edge projects to advance an aviation technology revolution

We are vigorously working on a radical revolution in aviation technology and aspire to leapfrog a generation of aircraft. Clean Aviation JU directs its efforts in particular on new **hybrid-electric ultra-efficient short and medium range** aircraft architectures, and **disruptive hydrogen-powered** technologies.

In 2023, as part of our second call for proposals, we added eight innovative projects to our portfolio, with an overall amount of activities for €380 million, including €152 million in European Union (EU) funding. The projects target novel aircraft concepts, innovative propulsion architectures, and new fuselage and wing designs, complementing those funded under Clean Aviation JU's first call for proposals and preparing all the necessary elements for ground and flight test activities starting in 2026.

Our work on the first 20 projects is advancing well to develop cutting-edge innovations including electric propulsion systems, hydrogen and hybrid gas turbine designs and the next generation of high-power fuel cells. Funded with €806 million, the total of 28 projects brings together close to 300 entities from 24 different countries. Through this crucial work, airlines will be offered new aircraft with Clean Aviation JU's technologies inside within CAJU's programme lifetime for an entry-into-service by 2035.

New Associated Members leading the way towards climate-neutral aviation

Furthermore, with our expansion to 59 Members, the Clean Aviation Joint Undertaking now possesses all the necessary capabilities required to address the programme's ambitions. The new members will engage with the Clean Aviation JU programme on a long-term basis, and **together with the European Commission** and the **other CAJU private** members, will lead the way towards climate-neutral aviation. Seeing many successful applications originating from SMEs represents a significant step towards fostering further diversity within our Membership. The increased participation of SMEs will enhance their exposure and engagement within the programme and offer vital technical contributions to drive the delivery of ground-breaking aircraft technologies before 2030.

Uniting Europe's resources to put climate-neutral aircraft into service by 2035

Achieving **climate neutral aviation by 2050** is a massive challenge and can only be achieved by joining forces at EU, national and regional levels. Therefore, **maximising synergies** with programmes and initiatives across Europe contributing to sustainable aviation remains a core priority of Clean Aviation JU. To help bridge the gap from research outcome to market, CAJU is **fostering collaborations** and aligning financing sources from regions, member states and associated countries to Horizon Europe as well as looking at mobilizing additional resources from the EU's Multiannual Financial Framework. We continued well on this front when CAJU and the Clean Hydrogen Joint Undertaking (Clean Hydrogen JU) signed a Memorandum of Understanding in March to establish a **strategic cooperation on research and innovation** related to hydrogen-powered aviation. Moreover, we also joined forces with the Occitanie region in France, as well as the Campania and Piedmont regions in Italy, renowned for their considerable initiatives in sustainable aviation. Looking ahead, more collaborations are on the horizon to bring together the key aeronautic countries and regions of Europe.

> *With our expansion to 59 Members, the Clean Aviation Joint Undertaking now possesses all the necessary capabilities required to address the programme's ambitions*

Celebrate Clean Sky 2 and its global achievements

While we keep our attention directed towards the future, it is equally crucial to pause and acknowledge the accomplishments of the past, taking a moment to reflect on and celebrate them. As the **Clean Sky 2 programme** nears its conclusion in 2024 after 10 years of activity, it will have notched up an impressive tally of **close to 1000 entities** from across Europe, delivering **more than 100 demonstrators** and **over 1,000 innovative technologies** designed to propel the sustainable aviation systems of the future. Notable accomplishments encompass ground-breaking innovations such as the Ultra Fan engine, the Multi-Functional Fuselage Demonstrator, and the RACER helicopter.

High Five Awards

Last year, we also took a moment to give a 'high-five' to some of the movers, the shakers, and the disruptors driving the clean aviation transformation through the first ever High Five Awards. Altogether, we received close to **100 applications** from **19 countries**, representing a diverse range of profiles active in the aeronautics sector. Through ground-breaking research, active innovation and game-changing disruption, our five High Five winners are enabling the future of sustainable flight in Europe. They currently serve as High Five Ambassadors to help raise awareness about Clean Aviation JU, promote its values and objectives, and highlight the critical importance of reducing aviation's impact on the environment.

Enhancing Clean Aviation JU's digital reach

Expanding our digital presence, Clean Aviation Joint Undertaking experienced a rapid evolution in its online footprint by adopting a **proactive strategy** and **diversifying content formats.** This approach yielded significant increases in social media followers, particularly on LinkedIn, and boosted website traffic. I encourage those who have not already done so, to join our social media community on LinkedIn and X (formerly Twitter), as well as **to subscribe to our newsletter** for updates.

> *Clean Aviation JU is fostering collaborations and aligning financial ressources from regions, member states and associated countries to Horizon Europe*

What to expect in 2024?

Looking ahead to 2024, the Clean Aviation Joint Undertaking is focusing on revising its Strategic Research and Innovation Agenda (SRIA) and on setting priorities for phase two of the programme, also based on the initial results of the first programme phase. Flagships events in 2024: Clean Aviation Annual Forum, Dublin, ILA Berlin, ICAS Florence and the EASN International Conference in Thessaloniki, emphasising the collaborative efforts needed to transform the aviation industry for generations to come.

For now, I invite you to dive into this report, to take stock of what we have achieved to date and what we will tackle next in our path towards climate-neutral aviation.

CLEAN AVIATION

As a European public-private partnership, Clean Aviation Joint Undertaking is driving a profound shift in aviation technology, focusing on hybrid-electric and hydrogen-powered innovations. We allocate substantial funding to advance novel aircraft concepts, propulsion systems, and sustainable fuel development. By fostering collaborations and aligning financial sources across Europe, we are paving the way for climate-neutral aviation by 2050, bridging the gap from research outcomes to market and mobilizing resources for sustainable aviation initiatives.

The Clean Aviation JU programme consists of two phases.

- **Phase 1:** aims to identify high-potential, disruptive aircraft concepts.

- **Phase 2:** will shift the focus to further develop the most promising aircraft architectures and integrate the selected best-candidate technologies.

  During this phase, the key elements will be large-scale integrated aircraft component/system tests and large-scale flying demonstrator platforms. These initiatives aim to validate and demonstrate the performance of key technologies and targeted aircraft under realistic sizes and operational conditions.

Clean Aviation:
2 Phases

EU Funding:
€1.7bn
Private Funding:
> €2.4bn

Phase 1: Develop **concepts, technology options** and **trade studies**

Phase 2: Accelerate **technology maturation through integrated demonstration**

2022 – Call 1

2023 – Call 2; Call for Expression of Interest

2024 – Configuration of Phase 2; Publication of Strategic Innovation & Research Agenda (SRIA) September

2025 – Call 3 March

2026 – Call 4

2027 – Call 5

2028 – Technology Readiness Level (TRL 6)

2035 – Entry In Service

900 mm

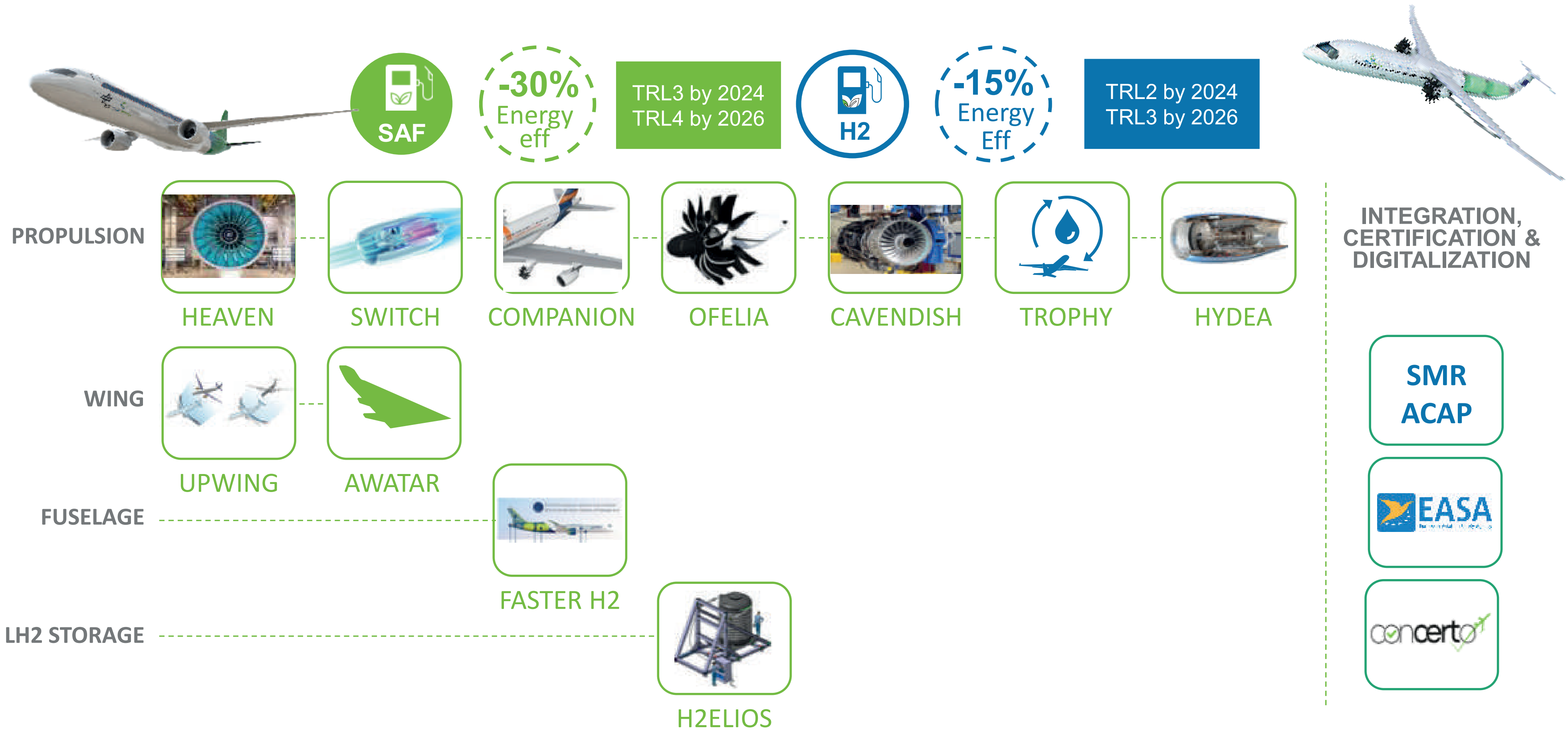
Clean Sky 2 Projects

2014 – **2024**

Clean Sky 2

28 Clean Aviation JU projects are exploring new electric and hybrid-electric aircraft concepts, ultra-efficient short-and-medium aircraft architectures, both including disruptive hydrogen-powered technologies. From 2025 onwards, efforts will be directed towards accelerating the maturation and demonstration of these technologies with ground and flight test activities starting as early as 2026.

Ultra-efficient Short and Medium Range



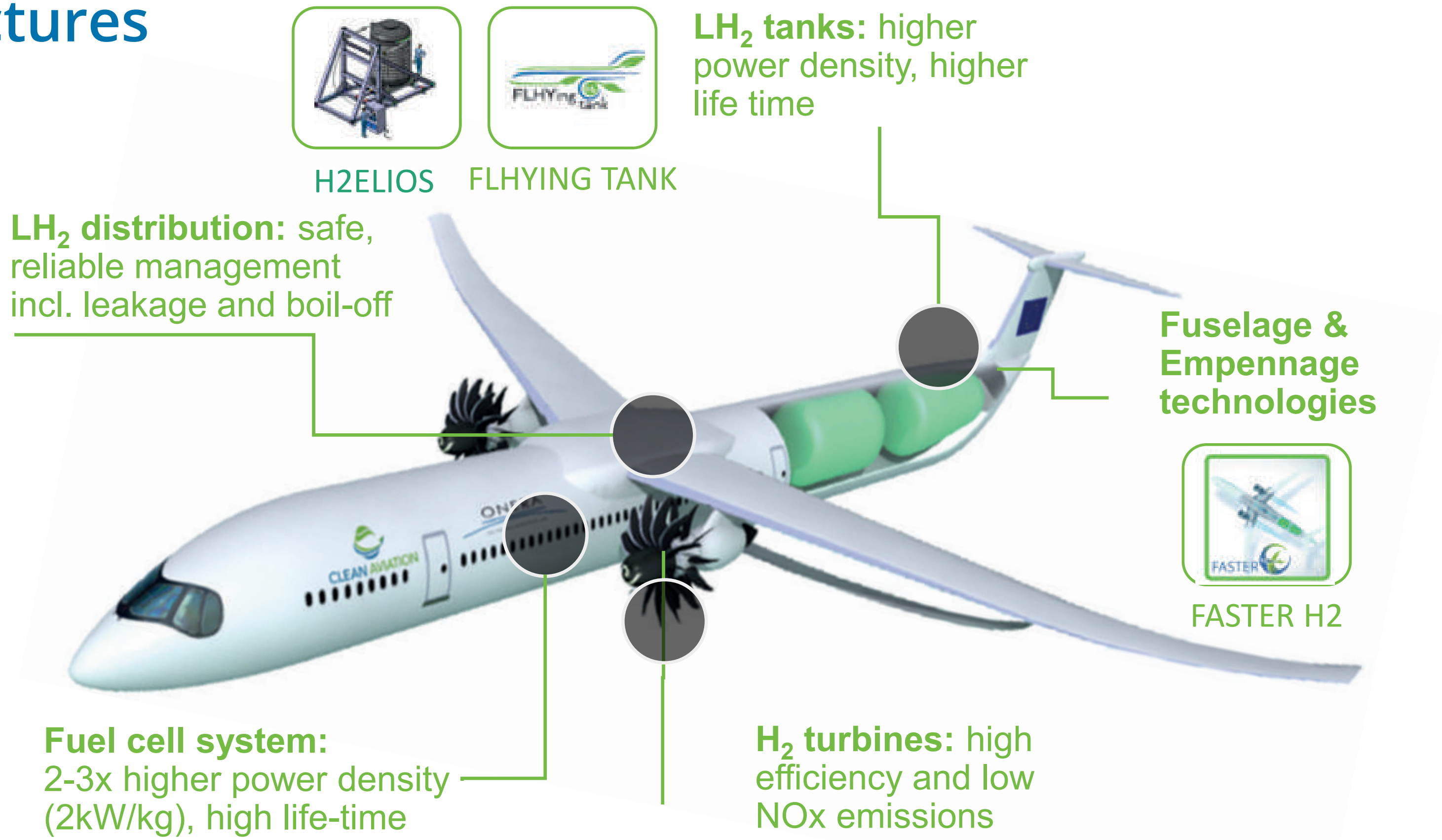
To address the short-medium range needs with innovative aircraft architectures, making use of highly integrated, ultra-efficient thermal propulsion systems and providing step-change improvements in efficiency. This will be essential for the transition to low- or zero-carbon fuels, which will be more energy-intensive to produce, more expensive, and only available in limited quantities.

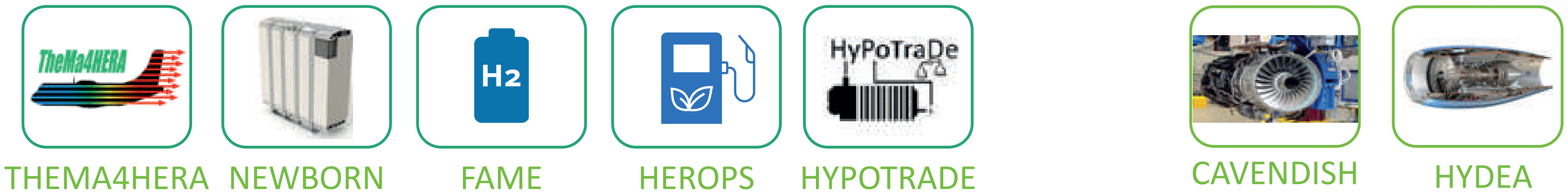
Ultra-efficient Regional Aircraft Architectures

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, and efficiency improvements for a next regional aircraft between 50 and 100 pax.

Hydrogen-powered aircraft architectures

Timeframe 2035





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 specific constraints and opportunities of hydrogen technologies might lead to new classes of aircraft, with their own specific capabilities, besides the current Regional and SMR market segmentation.

59
Members in total

12
countries represented

20
new Associated Members in 2023

SYNERGIES

The journey towards sustainable aviation is not a solo mission that a single country or an organisation can accomplish. Significant investments are required to develop critical research and innovation (R&I) and bridge the 'valley of death' between R&I results and the launch of new products. To succeed in this mission, all resources (private and public), competencies, and capabilities made available at European, member state and regional levels need to be strategically aligned within a European roadmap to secure the entry-into-service of new cleaner aircraft by 2035.

In 2023 the Clean Aviation JU has been actively fostering synergies with fellow European partnerships and relevant aeronautic regions (leveraging on EU funding instruments such as the European Regional Development Fund (ERDF)) to accelerate the demonstration of disruptive aircraft technologies reducing emissions.

Synergies and cooperation within Horizon Europe

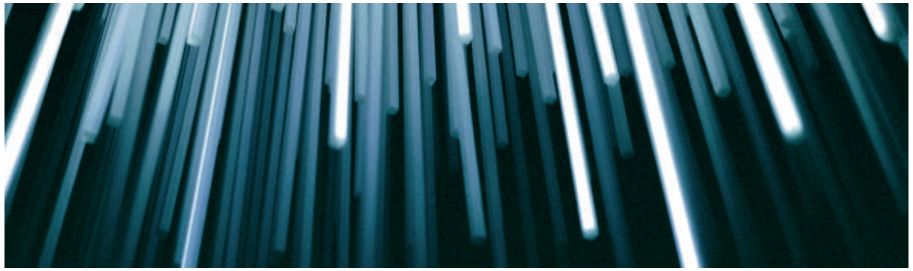
Clean Aviation JU signed a Memorandum of Understanding (MoU) with the **Clean Hydrogen JU** to strengthen cooperation on synergies for research and innovation in hydrogen-powered aviation commercial aviation compatible with an entry into service by 2035. This collaboration is based on the exchange of information concerning grants in the field of hydrogen-technologies for aviation, as well as planning and alignment of the respective Work Programmes and calls for proposals.

Bart Biebuyck, former Executive Director of the Clean Hydrogen JU, said: "*Together with Clean Aviation JU, we work towards the decarbonisation goals set by the EU Green Deal, REPowerEU and the EU's Industrial Strategy, and we're contributing to an ambitious research and innovation agenda for a cleaner and more sustainable transport sector (...)*"

In 2023, Clean Aviation JU closely collaborated with the **Batteries Partnership (BATT4EU PPP)** to ensure that the relevant batteries topics published in the Cluster 5 WP23-24 would include objectives, KPIs, and targets in line with the expected Clean Aviation requirements for batteries.

Exchanges were also initiated with the **Single European Sky ATM Research 3 (SESAR 3 JU)** aiming at ensuring a strategic alignment and identification of potential topic areas of collaboration.

Clean Aviation JU and the **European Union Aviation Safety Agency (EASA)** worked closely to support innovation and competitiveness of EU industry. In 2023, key aspects were strengthened such as: de-risking and demonstration of the feasibility of the new concepts and technologies implemented under the Clean Aviation programme, evolution of industry standards, new certification methods and means of compliance for aircraft and systems designs, and evolution of the regulatory material in coordination with other regulators and the **International Civil Aviation Organization (ICAO)**. Another key element of this cooperation was the monitoring of Clean Aviation's impact to ensure that its projects meet the environmental targets set to create the pathway towards a climate-neutral aviation system in line with the European Green Deal and EU Climate law.



3 Memoranda of Cooperation to boost competitiveness

Clean Aviation JU has joined forces with the Occitanie region in France, as well as the Campania and Piedmont regions in Italy, renowned for their considerable initiatives in sustainable aviation, resulting in **three strategic Memoranda of Cooperation (MoCs) signed in 2023.** Unified in purpose, this collaborative approach will enable not only to enhance innovation capabilities and employment opportunities in the region but also to foster skills development, crucial for **the transition to sustainable aviation,** and ultimately boosting the regions' competitiveness.

> *The benefits for the EU regions in signing a MoC with Clean Aviation are about enhancing European innovation and creating job opportunities.*


Valeria Fascione, Regional Minister for Research, Innovation and Start-ups at the Campania region:
"*(...) The joint work with Clean Aviation JU began in 2016 and has allowed our companies to participate in high value research and innovation programmes, with extraordinary results. Being here to renew our joint commitment means realigning our strategies once again and contributing together to build the Net Zero Aviation in Europe.*"

Carole Delga, President of the Occitanie / Pyrénées-Méditerranée region:
"*Occitanie is very proud to be the 1st region in France to sign a cooperation agreement with the Clean Aviation JU. After Clean Sky 2 in 2015 and 2017, this new agreement with CA JU firmly establishes Occitanie as a leader in low-carbon aeronautics in Europe (...)*"

Andrea Tronzano, Regional Minister for Economic Activities and SMEs, Piedmont Region, said: "*Piedmont Region intends to do its part by supporting investments in R&D by companies to help achieve Europe's objectives for low/zero emissions aviation, but also to transform this great challenge into a development and internationalization opportunity for the regional supply chain of the aeronautical sector.*"

Luca Bedon, Head of R&T at GE Avio Aero, said: "*There are several fruitful collaborations between regional-funded projects in Piedmont and CA JU contributing to the next generation of clean aircraft engines. The fostered collaboration between the regional authorities and CA JU under the Memorandum of Cooperation is expected to further enlarge the innovation ecosystem, in particular with increased contributions from SMEs.*"

Moreover, the Clean Aviation JU had preliminary exchanges with notable **Member States'** programmes dedicated to aeronautics, such as LUFO in Germany, CORAC in France, CDTI in Spain, Luchtvaart in Transitie (LiT) in the Netherlands and ATI in the UK, to discuss potential strategic alignments for the Clean Aviation Phase 2 (2025- 2030), which will be dedicated to technology maturation, integration, and demonstration.

CLEAN AVIATION TECHNICAL HIGHLIGHTS

1

SMR ACAP
Short Medium Range AirCraft Architecture and Technology Integration Project

SMR ACAP strives to establish SMR ultra-efficient research aircraft concepts and develop a platform to integrate key technologies in an iterative process.

Environmental objectives

- Delivery of solutions aligned with CAJU's high-level goals.
- **30%** reduction of GHG emissions compared to 2020 state-of-the-art technology.
- Support to the launch of new products by 2035.
- **75%** of the fleet replaced by 2050.

Expected technical results

- Establish a link to the Certification via CONCERTO and a dedicated EASA service contract.
- Develop and Integrate Systems architectures and Technologies.
- Develop science-based environmental targets for SMR including breakdown on suitable design targets per SMR-key design element (e.g., component or system).
- Propose and a future environmental co-design approach.
- Create and maintain a "Clean Aviation Aerospace Unit Inventory Database" (incl. integration of CS2 data-sources) to perform Life Cycle Assessments (LCA) by taking into consideration IP restrictions and future exploitation.
- Develop and implement a virtual aircraft – digital data backbone for the SMR aircraft, interfacing with contributing technology projects.
- Implement technology impact monitoring at SMR aircraft level for all technologies and deliver into Clean Aviation Impact Monitoring Framework, exploiting synergies with other national and European related programmes.

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2

HERA
Hybrid-Electric Regional Architecture

HERA's objective is to identify and trade-off concepts of hybrid-electric regional aircraft (AC) and its key architectures expected.

Environmental objectives

- -**50%** GHG emissions compared to existing regional aircraft.

Expected technical results

- Integrating cutting edge hybrid-electric techno-bricks.
- Hybrid-Electric Regional Aircraft concepts including key performance, systems enabling hybrid-electric propulsion and new power sources.
- Strategy for real-scale demonstrator in-flight and on-ground supporting the validation of hybrid-electric A/C concepts and technologies at a high Technology Readiness Level towards EIS 2035.

Progress

- An integrated Cooperation Plan between HERA and other Clean Aviation contributing projects.
- Top Level Aircraft Requirement definition.
- Two initial 2035 Regional Aircraft Concepts delivered: a Twin-Engine Turboprop Aircraft and a Distributed Engine Turboprop Aircraft.
- Digital twin simulation strategy defined.
- Sustainable industrialisation and digitalisation activities started.
- Impact Monitoring strategy was defined including reference 2020 A/C, metrics, targets and roadmaps for technology maturation.
- First performance assessment between Reference 2020 and 2035 concepts at aircraft level.

3

HE-ART
Hybrid Electric Propulsion System for Regional AiRcrafT

HE-ART, a key enabler for the regional segment involves researching and preparing a flight test for powerplant technologies considered as key enablers for the entry into service of a Hybrid-Electric Regional Aircraft.

Environmental objectives

- **30%** Greenhouse Gas (GHG) Emissions reduction vs 2020 reference engine.

Expected technical results

- To develop a Multi-Mega Watt Hybrid Electric power train.
- Technology maturation and industrialisation for EIS 2035Definition of the EIS 2035 vision for a Multi-Mega Watt Hybrid Electric power train.
- Experimental demonstration of the e-Turbo Prop (e-TP) concept and additional key technologies.
- To build on state-of-the-art technologies and tackle integration aspects for: Integrated control/command, propeller, propeller gear box, electrical machine, ultra efficient thermal core engine, electrical distribution & protection, and nacelle.

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4

NEWBORN

Power up with hydrogen – NExt generation high poWer fuel cells for airBORNe applications

Power up with hydrogen: NEWBORN aims to develop and demonstrate a TRL 4 ground demonstrator of the overall propulsion system using fuel cells technology for electricity generation and hydrogen as its energy source.

Environmental objectives

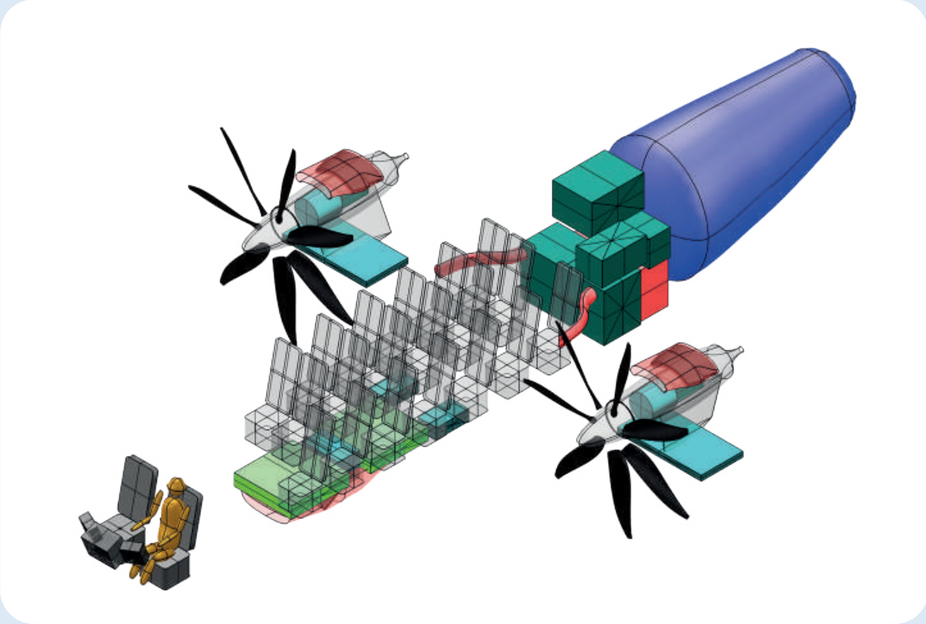
- Developed technologies are key enablers for entry into service of Hydrogen Powered Aircraft with no CO_2-emissions, low noise footprint, and lower cost of operation.

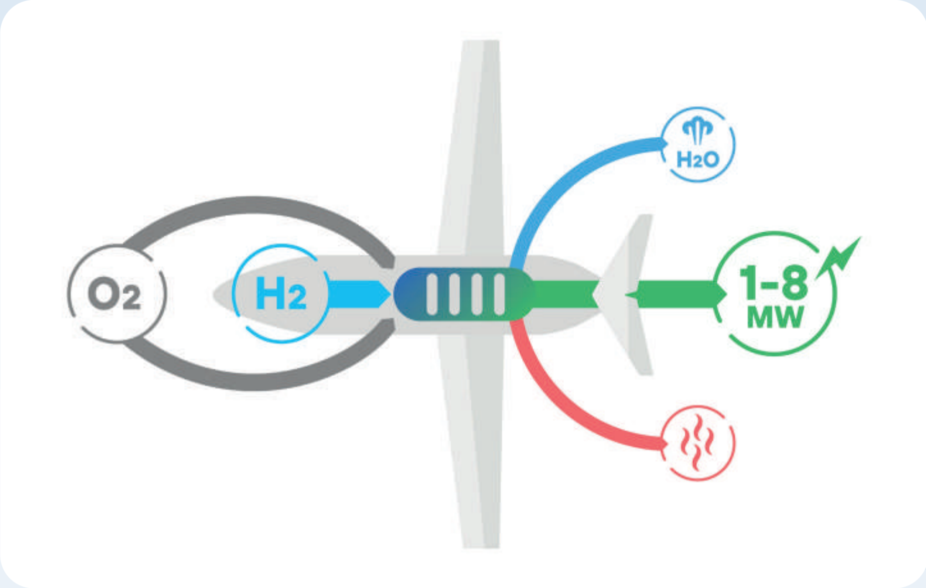
Expected technical results

- Tech demonstrator of fuel cell-based aircraft propulsion system.
- Demonstrate scalable fuel cell powered propulsion technology for civil aircraft.
- Over 1.2 kW/kg power density.
- Over 5 kW/kg stack power density.
- **1MW** modules, in parallel to exceed multi MW power levels.

Progress

- Defined system architecture and requirements.
- Defined aircraft integration concepts for CS23 (Miniliner) and CS25 (HERA).
- Established rich cooperation plan with 10 Clean Aviation projects.
- Defined approach to scale the NEWBORN technology across Aircraft platforms.
- Key subsystems architecture defined, optimized, and simulated.
- Established architecture for modular test-facility based on containers for housing: Control room, DC Load, Fuel cell, RAM Ducts, Power Sources.
- Defined demonstration scenarios.





5

CAVENDISH

Consortium for the AdVent of aero-Engine Demonstration and aircraft Integration Strategy with Hydrogen

The use of hydrogen for propulsion requires characterising combustion phenomena, but most importantly, the associated systems for a safe and reliable product use. This requires demonstrating the feasibility of, e.g., storage, system integration, or engine control. The partners in CAVENDISH are experts in each domain required to ultimately certify and clear for flight a hydrogen aeroengine.

Environmental objectives

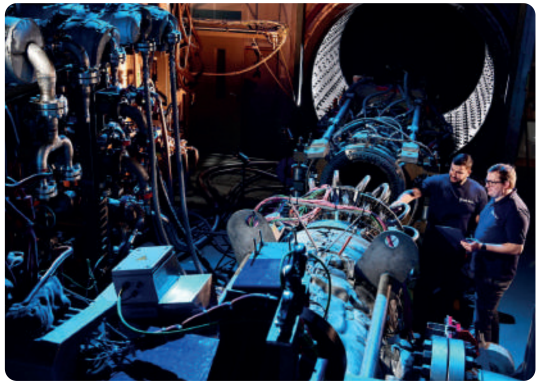
- Development of key knowledge and technologies for a climate neutral aviation.

Expected technical results

- Research, protype, and integrate direct-hydrogen combustion breakthrough technologies onto a modern donor engine for ground testing. This contributes both to exploring the feasibility of hydrogen combustion propulsion systems, and studying hydrogen combustion phenomena and its application into the combustor of a modern gas turbine aeroengine.
- Analyse system and powerplant integration to define certification pathways, and formulate a route to permit to fly.
- Explore enabling technologies that will offer flexibility and could ease the introduction of hydrogen in aviation. One is the dual-fuel combustor system (capable of operating on **100%** hydrogen and **100%** SAF). Another is the Cryo-Compressed Gaseous H2 tank.

Progress

- **Full Annular Combustion Test on Engine Representative Conditions**
  Tests on a full annular combustor of a Pearl 15 engine running on **100%** hydrogen have proven the fuel can be combusted at conditions that represent maximum take-off thrust. This is a world-first in the aviation industry.
  Key to that achievement has been the successful design of advanced fuel spray nozzles to control the combustion process. This involved overcoming significant engineering challenges as hydrogen burns far hotter and more rapidly than kerosene. The new nozzles were able to control the flame position using a new system that progressively mixes air with the hydrogen to manage the fuel's reactivity.
- **Failure Hazard Analysis (FHA) completed**
  In 2023, the Failure Hazard Analysis report was completed. This product safety engineering analysis lays the ground for the build-up of the safety case. It defines the hazards to be allocated and addressed in top-down (PSSA) and bottom-up (SSA) analyses. These analyses are part of the cooperation scope and exchange with EASA.



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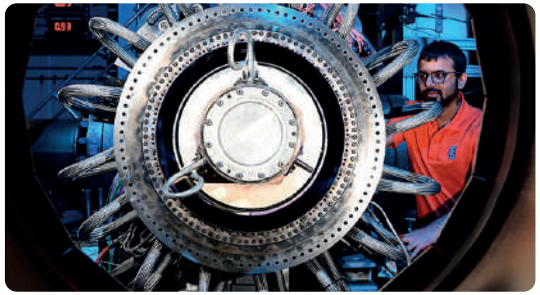

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CLEAN SKY 2 TECHNICAL HIGHLIGHTS

In Clean Sky 2, our environmental objectives are simple: we strive to decrease CO_2, NOx and noise levels by 20-30%, compared to state-of-the-art aircraft from 2014. The technologies developed up to 2022 have made significant progress, along with several important technologies of Clean Sky that have been achieved in 2023. As we are diligently working to meet the targets by 2024, you can further delve on the following pages into a selection of projects that have made substantial advancements.

1

UltraFan™ engine demonstrator successfully ground tested to maximum power

In 2023 the UltraFan™ flagship demonstrator successfully reached the ground engine test. That milestone proved a Very High Bypass ratio full scale demonstrator incorporating new component technologies, digital methods for design, manufacture, assembly, and test. This encouraging project paves the way to increase large engine performance while reducing environmental impact. In the longer term, UltraFan's scalable technology from ~25,000-110,000lb thrust offers the potential to power new narrowbody and widebody aircraft anticipated in the 2030s.

Goal

Demonstrate new technologies, such as High-speed multi-stage Low pressure turbine and easy manufacture compressor casings, integrated in the novel engine design, taking into account also aircraft integration aspects.

Method

The key technologies meant for the demonstrator were developed, modelled, manufactured, and successfully tested in dedicated test benches, prior to their integration and testing into the engine.

Progress

Following completion of engine building and commissioning, the UltraFan first ran in May 2023 using **100%** Sustainable Aviation Fuel **(SAF)**. The testing phase continued during 2023, and the demonstrator successfully reached maximum power rate in November 2023.

Environmental objectives

- **10%** fuel efficiency improvement demonstrated compared to 2020 state-of-the-art engines.
- Up to **40%** reduction of NOx.
- **30%** reduction of noise.

Expected **technical** results

- Reach demonstrator's maximum thrust of **85,000lbs**.
- Run the demonstrator on **100% SAF.**
- Complete key tests required for UltraFan Architecture **TRL 5**.
- Further develop the engine architecture through Clean Aviation's HEAVEN project (currently ongoing).

Part of Clean Sky's Engines and Large Passenger Aircraft initiatives.

2

Reducing drag thanks to Hybrid Laminar Flow Control technologies applied on wing

Hybrid Laminar Flow Control (HLFC) is one promising option to lower cruise drag and make the next generation aircraft more efficient. A significant drag reduction can be achieved by influencing the boundary layer of a wing section delaying the transition of the flow from laminar to turbulent. This can be obtained, for instance, through increasing the laminar flow wing surface region.

During the Clean Sky 2 programme the HLFC activities were focused on maturing existing HLFC principles with the goal to provide solutions which could be easily adapted for industrial needs of aircraft manufacturers.

Goal

This project's objective was to develop an innovative and simplified HLFC system and to demonstrate its system integration into a wing with a final maturity of TRL 4.

Method

The full scale outer wing ground-based demonstrator was tested after the building phase that integrated the following main technologies:

- HLFC suction system on wing, including variable micro perforation, reduced and simplified chamber system, functional integration of compressors making use of structural ribs, and novel krueger slat system.
- Inductive wing ice protection system.
- Removable outer skin system.

The ground-based demonstrator test was complemented by a high-speed wind tunnel test for aerodynamic validation of the HLFC-system.

Progress

By the end of 2023 the project was completed with a successful TRL 4 review, proving the validity of the designed HLFC system for a possible industrial application.

Environmental objectives

Up to **5%** reduction of fuel burn can be achieved by HLFC, a promising option to lower cruise drag via adaptations as, for instance, increasing the laminar flow wing surface region.

Expected **technical** results

- Up to **8%** reduction of drag friction on an aircraft.
- At least **5%** reduction of CO_2.
- At least **8%** reduction of NOx.

Part of Clean Sky 2 Large Passenger Aircraft initiative.

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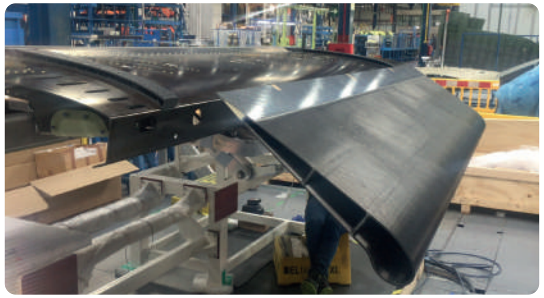

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3

De-risking the key technology distributed electric propulsion using the Scaled Flight Demonstrator DEP-SFD

The Distributed Electric Propulsion - Scaled Flight Demonstrator is a scaled typical Small/Medium Range SMR airliner for a flight condition at Mach 0.4, with a maximum take-off weight MTOW of about 150kg and a wingspan of 4m. It aimed at de-risking the distributed electric propulsion technology in terms of handling qualities and flight control during dynamic manoeuvres, which cannot be evaluated in on ground wind tunnel and iron bird tests.

The achievements were obtained in just one year from the previously developed SFD; furthermore, the project reached its **TRL 5** in January 2023 validating the scaled flight approach as a valuable mean for quickly de-risking disruptive technologies.

Goal

The demonstrator had the objective to de-risk the distributed electric propulsion technology in terms of dynamic behaviour and handling qualities. Moreover, the team envisioned to modify the Scaled Flight Demonstrator for testing distributed electric propulsion while reducing development cost.

Method

The radical configuration exceeded the Clean Sky 2 environmental objective of a **20%** reduction in block fuel. The configuration was selected from a design space exploration and featured the Distributed Electric Propulsion (DEP) produced via six electrically driven propellers mounted on the leading edge of the wing.

Despite a lower cruise speed compared to today's SMR aircraft, this propeller concept was selected due to the improvement foreseen in block fuel, and to the limited associated development risk for entry into service in 2035.

Progress

The SFD was flight-tested in 2022 and reached TRL 5 in 2023.

During the preliminary design phase for DEP-SFD, the location of the six engines and the six propeller diameters has been frozen for a representative mission flight. The propeller rotation senses have been frozen, and the nacelle design has been fine-tuned, while confirming the other design choices during the review in 2021. The manufacturing started in January 2022, and the Wing Tunnel Test in January 2023 confirmed the prediction. The high-speed taxi tests took place in March 2023, while a new structure of the DEP-SFD with customized LiPo batteries was finalised in November 2023. The first flight and the tests for TRL 5 took place in May 2024, while the mission flight test campaign lated until end of June 2024.

Environmental objectives

The DEP design builds on six propellers on the leading edge of the wing. Even if this configuration has a lower cruise speed than today's SMR aircraft, this propeller concept was selected due to:- an initially calculated **20%** improvement in block fuel.- limited associated development risk for a targeted **EIS in 2035**.

Expected **technical** results

- **20%** reduction of CO_2.
- **15%** weight reduction.

Part of Clean Sky 2 Large Passenger Aircraft initiative.

4

Multifunctional fuselage demonstrator assembly ongoing

The Next Generation Multifunctional Fuselage Demonstrator (MFFD) project examined the full potential of thermoplastic composites to help the future European airliner production to become faster, greener, and more competitive. A fuselage barrel made of thermoplastic composites weighs less not only because fasteners are no longer needed, but also because the materials are more recyclable. Thanks to this initiative, Europe's aircraft assembly lines will acquire the readiness to respond to the 5% growth rate of the global air transport market, while reaching green objectives.

Goal

The team's goal was to produce the first 8-metre-long thermoplastic fuselage barrel in the world.

Method

During the Major Component Assembly (MCA), the lower and upper shells of the MFFD were joined using innovative thermoplastic welding techniques in a highly automated plant system.

Progress

In 2023, the Upper Shell of the MFFD was completed and delivered.

The installation of the Lower and Upper Shells into the assembly plant was finally completed, and the longitudinal welding was started.

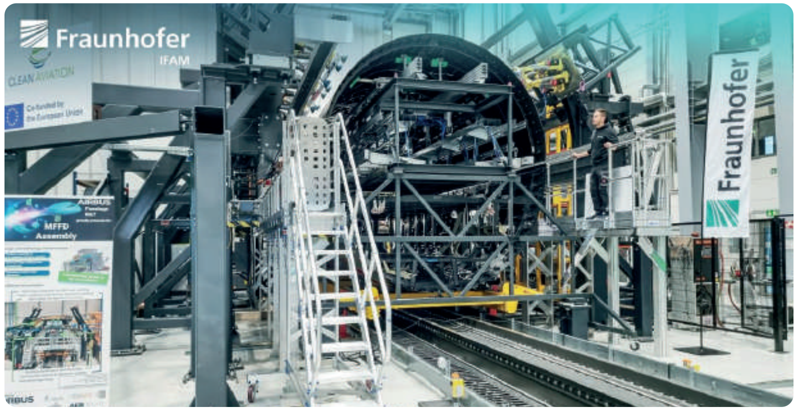
Environmental objectives

- **1 tonne** reduction of fuselage weight.
- Increase of materials' **recyclability**.

Expected **technical** results

- **70-100** increase of fuselage production per month, considering that the current rate is **60** per month.
- Flexibility in the assemblage phase, allowing increased possibilities of customisation.
- Cost reduction, ensuring European competitiveness.
- Reach of **TRL 5** by the termination of the project.

Part of Clean Sky 2 Large Passenger Aircraft initiative.



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5

Reducing weight and costs of rear end fuselages with Advanced Rear End

The consortium has developed a new aircraft rear end configuration with a reverse swept Horizontal Tail Plane. This configuration has been developed following an iterative process seeking to maximize performance and competitiveness.

In order to achieve its objectives, the project focused on the development of airframe structures using lightweight composite materials. This posed a challenge not only in relation to the disruptive configuration and geometry the consortium aimed at, but also to the industrial targets defined in terms of production rate and ramp-up for a future short and medium range aircraft.

Goal

The Advanced Rear End (ARE) demonstrator aims at integrating conceptual design, structural and systems architectures, materials, technologies, and industrial processes to provide an optimal rear fuselage and empennage for the next generation of commercial aircraft.

Method

The methodology adopted adhered with the following steps:

1. A new aircraft configuration with a forward swept tail was assessed via computational fluid dynamics (CFD) simulations and wind tunnel tests.
2. Physical and virtual mechanical tests were applied to perform a structural validation of the airframe proposed.
3. Physical demonstrators were utilized for the validation of composite airframe manufacturing and assembly technologies.

Progress

The project was concluded in December 2023 with the delivery of a full-composite Rear Fuselage **TRL 6**, supported by mechanical tests and physical prototypes.

Environmental objectives

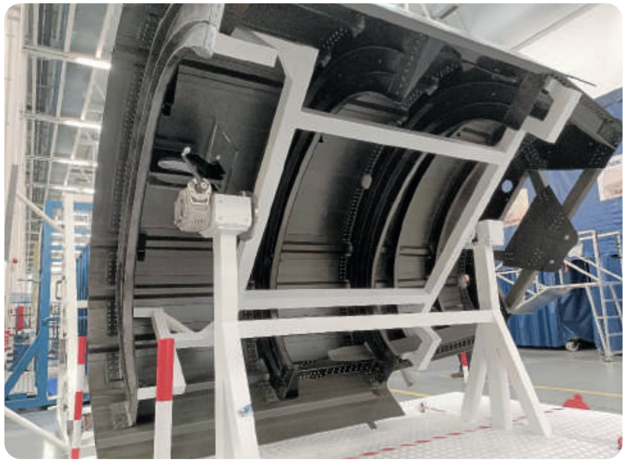
The project succeeded in achieving a **15%** weight reduction at the component level (rear end) by utilising composite lightweight structural solutions instead of metallic fuselage, with no thermal loading and a compact architecture integrating systems with the primary structure.

Expected **technical** results

The project aimed at reducing by:

- **20%** the recurring cost at component level.
- **20%** the weight at component level.
- **1,5%** the fuel burnt at aircraft level.

Part of the Large Passenger Aircraft initiative.



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6

Final demonstration of the Large Aircraft Disruptive Cockpit Demonstrator

The Large Aircraft DISruptive COckpit (DISCO) Demonstrator developed an innovative aircraft cockpit concept which could significantly enhance safety and operational efficiency thanks to new technologies related to navigation, automation, and new human-system interfaces.

Goal

The objective of the team was to redefine the pilot crew's role by supporting them in their strategic decision-making and mission management, enhancing their awareness and reducing their workload in normal and abnormal conditions.

Method

The project validates the novel cockpit technologies on ground in the DISCO integration test bench or in flight.

Progress

2023 saw the completion of the development of technological bricks contributing to DISCO. The technologies were integrated on the DISCO bench and were followed by a final demonstration assessing the overall benefits.

Environmental objectives

The reduction of both weight and drag was made possible thanks to the new cockpit architecture.

Expected **technical** results

The team dedicated to this project was able to obtain:

- Safety improvement by an increased level of automation paired with a reduced pilot workload.
- **5%** reduction of aircraft operating costs.
- The achievement of **TRL 5** by the end of 2023.

Part of Clean Sky 2 Large Passenger Aircraft initiative.

7

Flying Test Bed 1 - Innovative WingTip takes-off

The Innovative WingTip (IWT) is a wing extension with an active control surface that can perform gust and manoeuvre load alleviation for the new generation of aircraft. This reduces structural weight, improves aerodynamic performance, and decreases the amount of fuel burned, in line with Clean Sky 2 sustainability objectives. The wingtip is equipped with a moving surface. The test campaign of the IWT configuration is an important milestone towards validating the integrated technologies.

Goal

The goal of the adaptive wing integrated demonstrator was to integrate, validate, and test in-flight a meaningful set of innovative technologies for the new generation of wing and advanced flight control systems.

Method

The demonstration required two dedicated flights to confirm the aero-elastic clearance. Furthermore, the method required also two flights to measure the aircraft's handling quality and performance one dedicated flight for wing, and an IWT load survey to test maneuverable load alleviation functionality.

Progress

The preparations for the IWT integration started in September 2023 after the successful closure of the reference basic configuration flight campaign. The permit to fly was obtained in February 2024, and the activity has been completed with the five flights with the IWT configuration, during the same month. The analysis of the results has been concluded and IWT has now reached **TRL 6**.

Environmental objectives

2% reduction of CO_2 compared to the FTB#1 typical transport mission.

Expected **technical** results

- Obtainment of **TRL 6** for all the technologies included in the IWT.
- Manoeuvre **loads alleviation** by reducing the wing root bending moment of **5%**.
- Performance's improvement through:
  - **3%** reduction of the time to climb.
  - **6%** increase of the lift to drag ratio in cruise.

Part of Clean Sky Regional IADP initiative.

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8

Flying Test Bed 2 reaches TRL 5 for the Advanced Composite External Wing Box and actuation system

The Flying Test Bed 2 (FTB#2) outer external wing box was made by carbon fibers and carbon fiber-reinforced plastic (CFRP), stiffened skins, and spars with metallic ribs.

The aircraft primary surface actuation system - based on 270 High Voltage Direct Current (HVDC) Electromechanical Actuators (EMA) - was investigated to demonstrate full compatibility with the generation and distribution system.

The successfully developed 270VDC Transformer Rectifier and Power Distribution prototypes were thus integrated with the developed Flight Control System (FCS) composed of Flight Control Computer, advanced Flight Control Laws, aileron and spoiler electromechanical actuators and Actuator Control Units.

Goal

The objective of the project was to design and manufacture the Advanced Composite External Wing Box using new processes, such as the thermoplastic in situ consolidation, highly integrated dry fibre liquid resin infusion, and jigless assembly.

The team aimed also at maturing and validating an electrically driven actuation system, and assessing its impact on an electrical network.

Method

The obtain the expected result the researchers proceeded with an outer wing box made of carbon fibre reinforced plastic, cured out of autoclave (OoA) with high integration. Two different materials and manufacturing processes were thus developed.

Finally, the test bench was integrated with developed HVDC, FCS, and EMA prototypes.

Progress

For the Outer Wing Box, the Test Readiness Review was completed in October 2023. The failure test for the OoA Composite Wing Full Scale was passed in December 2023.

For the actuation system the successful ground test campaign has validated the fully integration of High Voltage aircraft electrical system and Flight Control System based on EMA.

Environmental objectives

- **5%** reduction of weight achieved for the Outer Wing Box with the use of innovative materials and processes.
- **15%** reduction of wire weight could be obtained for the actuation system, due to a lower need of wires for HVDC.

Expected **technical** results

The **TRL 5** was successfully achieved for both the Outer Wing Box and for the actuation system.

Part of Clean Sky AIRFRAME/REGIONAL initiative.

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9

Airframe for the NexGen Civil TiltRotor (NGCTR)

A pressurized fuselage section for the NGCTR was developed within the Airframe Integrated Technologies Demonstrator (ITD), including nose, central-section, and tail. All sections were completed and integrated for final assembly. Crashworthy and ejection seat provisions were included in the nose, supported by new equipment and instrumentation, as well as a cut-out for the ejection seat routing. An early understanding of the weight risks and clearance of design limit loads were fundamental to anticipate significant aircraft integration. The thorough understanding and application of key new technologies resulted in an optimum cost and weight of the tail structure and empennage.

Goal

Design, manufacture, and installation of flightworthy fuselage sections on the NGCTR, and following support towards the first flight test. The project aimed at reducing weight, noise, and costs of some structural elements.

Method

Pivotal enabling technologies - such as the Press consolidated Out-Of-Autoclave C/PEKK C-Spar used on the tail fin structure - were investigated to contribute to low weight and low drag solution for the V-tail configuration.

Progress

The nose, the central fuselage section, and the tail were designed, produced, and successfully assembled into the NGCTR. These elements were all essential in contributing to the first flight, and to the overall emissions reduction at the vehicle level.

Environmental objectives

- **50%** reduction of CO_2.
- **14%** reduction of NOx.
- **30%** reduction of noise at the vehicle level.

Expected **technical** results

- All the technologies which were assembled into the vehicle target **TRL 6.**
- Out of Autoclave technologies have achieved **TRL 5**.
- **10%** weight reduction contributed by the tail.
- Up to **40%** cost reduction contributed by the tail.

Part of Clean Sky's Airframe Integrated Technologies Demonstrator initiative with deliveries to FRC IADP for the Fast Rotorcraft Innovative Aircraft Demonstrator Platform (FRC IADP) demonstrator.

10

Airframe for the RACER

The wings, doors, - and their integration into the airframe - and the rotorless tail for the RACER flying demonstrator were developed within the Airframe ITD. All components were completed and assembled into the RACER demonstrator; co-pilot, pilot, cabin sliding, luggage, and avionic door were developed and manufactured along with the highly integrated door frame. Furthermore, the electrically actuated footstep and the emergency exit were completed in collaboration with Fast Rotorcraft (FRC) projects. A disruptive, lightweight, and efficient rear fuselage for high-speed compound, the rotorless tail was developed, manufactured, and delivered, after testing under flyable conditions - including permit to flight documentation.

Goal

Design, manufacture, and installation of flightworthy airframe components for the RACER, and support towards the first flight test, with the goal to obtain emissions and noise reduction at the demonstrator level.

Method

A highly optimised aerodynamic performance-driven wing design was applied, which considered also the interference between wing, main and lateral rotors. Furthermore, composites were used with innovative technologies, including Out of Autoclave and additive manufacturing for the tail's surfaces and structures.

Progress

The wing, the doors integrated into the airframe, and the rear end of the fuselage with rotorless tail were designed, produced, and assembled into the RACER successfully. These elements were all indispensable in contributing to the first flight, and to the overall emission and noise reduction at the vehicle level.

Environmental objectives

- **15%** reduction in CO_2.
- NOx and noise emissions reduction at demonstrator level.

Expected **technical** results

- All the technologies which were assembled into the vehicle target **TRL 6**.
- **9%** reduction in CO_2, **8%** reduction in NOx, and **3dB** reduction in noise contributed by the wing.
- **14%** weight reduction contributed by the doors compared to conventional helicopters.
- **14%** aerodynamic drag reduction for the assembled airframe with all its components.
- **10%** drag reduction in hover as aerodynamic benefits resulting from the rotorless tail design.

Part of Clean Sky's Airframe Integrated Technologies Demonstrator initiative with deliveries to Fast Rotorcraft Innovative Aircraft Demonstrator Platform for the RACER demonstrator.

11

RACER Main Gearbox (MGB) and Lateral Gearboxes (LGB) cleared for flight

The successful completion of the test Main Gear Box endurance program and Lateral Gearboxes represented a substantial step forward for the RACER. Following the testing phase, all the subcomponents of the MGB and LGB were checked before implementing fatigue and loss of oil tests.

Meanwhile, the flight MGB and LGB was integrated into the RACER demonstrator.

Goal

To develop and deliver flight-worthy:

- RACER Main Gearbox (MGB) – connecting engines to the helicopter blades.
- RACER Lateral Gearboxes (LGBs) – pushing gearboxes assembled on the helicopter wings.

Method

Different teams have contributed providing multiple levels of technological expertise, facing unprecedented complexities. In fact, such developments and testing operations on a unique aircraft were reached without any prior practice or reference points.

Progress

Safety Of Flight process included completion of MGB for ground tests in April 2023, endurance tests in September 2023, fatigue and oil-off tests (after inspection) started in November 2023. LGBs (Left and Right configuration) as well tests following the same methodology, were completed by December 2023.

Environmental objectives

By integrating innovative materials for gears, ceramic bearings, and additive heat/exchanger, the MGB and LGB represent one of the major enabling techno-bricks contributing to RACER performances, corresponding to a **reduction of 20% of CO_2/NOx emissions.**

Expected **technical** results

The ambition of the researchers who worked to this project was to deliver a flight-worthy critical system for the RACER flight testing.

Part of the Clean Sky 2 Fast RotorCraft (FRC) initiative.

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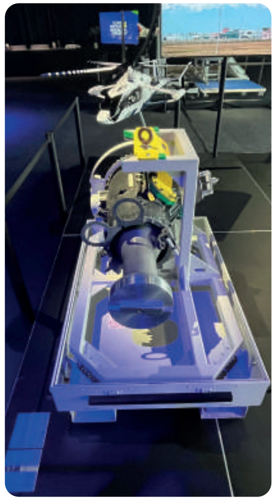

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12

Electrical Environmental Control System: towards a more energy-efficient aircraft

The electrical Environmental Control System (eECS) plays a crucial role in the advancement of the 'More Electric Aircraft' (MEA) initiative. Instead of bleeding air from the engines, the eECS will use only ambient air from outside the aircraft. Without using bleed air, the engines will have more thrust available – especially during the take-off and climbing phases. The efficiency of the engines is increased, which leads to fuel savings and lower emissions.

The innovative eECS was designed to achieve high performance and reduce power consumption by combining a turbomachinery-based air cycle system with an innovative vapor cycle system.

Goal

The integration and optimization of key components aims at delivering a high performance eECS for future single aisle aircraft by combining an air cycle system with an improved vapor cycle system.

Method

The key technologies of the eECS were manufactured and have been successfully tested in dedicated test benches: high-power motorized turbomachinery, centrifugal compressor, compact heat exchanger, and vapor cycle pack.

The behaviour of the system was captured and integrated into an overall aircraft air model that virtually demonstrates its performance.

Progress

Thanks to a risk-driven development approach that spans from technology bricks to representative virtual demonstrations, the eECS reached **TRL 5** at the end of 2023.

Environmental objectives

CO_2 and NOx reduction:

- Enablement of an optimized aircraft configuration without engine air bleed, with up to **1% less block fuel** (the total fuel required for the flight).

Competitiveness:

- Reduction in maintenance costs due to higher reliability at system level;
- Improvement of aircraft availability by increasing the reconfiguration of the systems' capabilities.

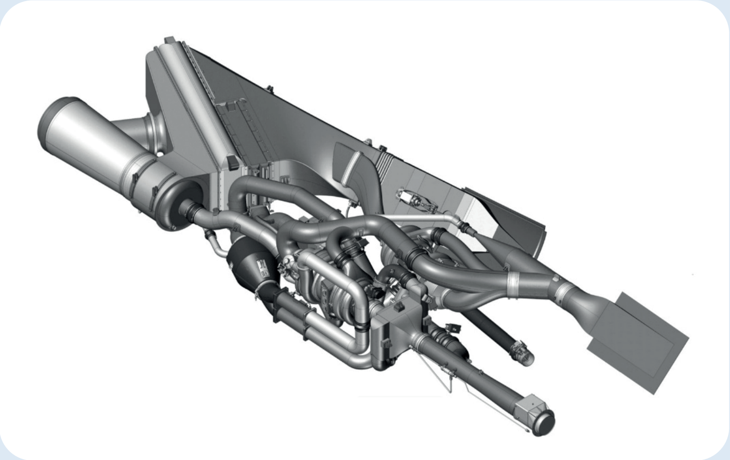
Mobility:

- Improvement of air quality in the cabin for comfort of cabin crew and passengers.

Expected **technical** results

- Based on the eECS demonstration, the Clean Aviation projects SMR ACAP and TheMa4HERA will target a fully integrated thermal management concept for hybrid-propelled aircraft.

Part of Clean Sky's SYSTEMS initiative.



13

Aircraft-0 Lab for Small Air Transport (SAT)

The current demand for a more sustainable and safer air mobility makes System Electrification and Digitalisation essential drivers for the competitiveness of future Small Aircraft.

The traditional civil aircraft are characterized by a combinations of mechanical, hydraulic, pneumatic, and electrical systems, developed over decades by a network of suppliers integrating a system architecture. Such aircraft design entails inherent drawbacks including, for instance, limitations towards further improvement in safety and efficiency, and operating costs.

The project gave the opportunity to break these barriers with the development and integration of breakthrough and affordable Fly-by-Wire Flight Control System (FCS) and Electrical Technologies.

Goal

The consortium envisioned to design, develop, and produce an Iron Bird integrating several technologies that could enable digital and more-electric aircraft design validation in a fully representative environment, operating in closed loop with an immersive cockpit and a flight simulator.

Method

The process involved to define the system and subsystem requirements from the aircraft manufacturer's perspective, team up for the development of technology demonstrator bricks, verify them in isolated conditions, and integrate and verify them at the aircraft level using an incremental approach.

Progress

During 2023 more electric and digital systems (Electrical Power Generation and Distribution, Fly-by-Wire, Electrical Landing Gear and Brake) have been integrated and tested on dedicated demonstrators.

Rigs and airborne equipment have been integrated and verified at Aircraft-0 level.

Environmental objectives

- **Reduction of direct operating costs** and safety increase for SAT using more electric systems.
- **Reduction of fuel consumption** through on-board system optimization and replacement of pneumatic/mechanical/hydraulic systems.

Expected **technical** results

- Validation of digital and more electric technologies.
- On-ground demonstration of maturity in a representative and integrated environment, reproducing **TRL 5**.

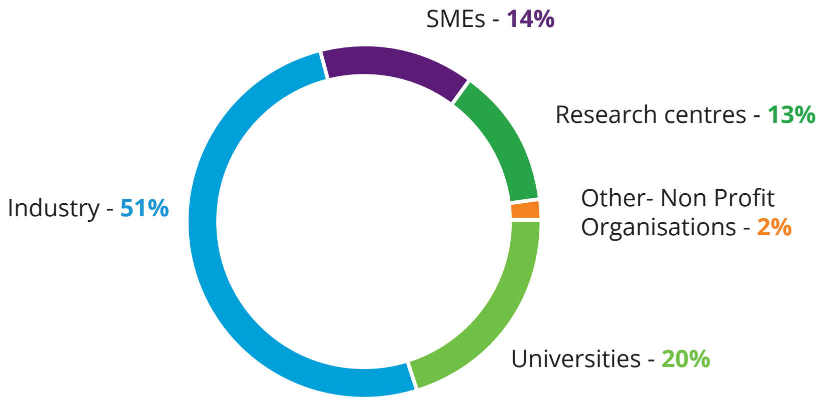
Part of Clean Sky 2 Small Air Transport initiative.

PARTICIPATION IN CLEAN AVIATION (CALL 1 AND CALL 2)

Further to the launch of Call 1 & 2, our funded projects now include 281 participants, with EU funding totalling 806 million euros, thus underscoring our commitment to driving innovation and sustainability in the aviation industry.

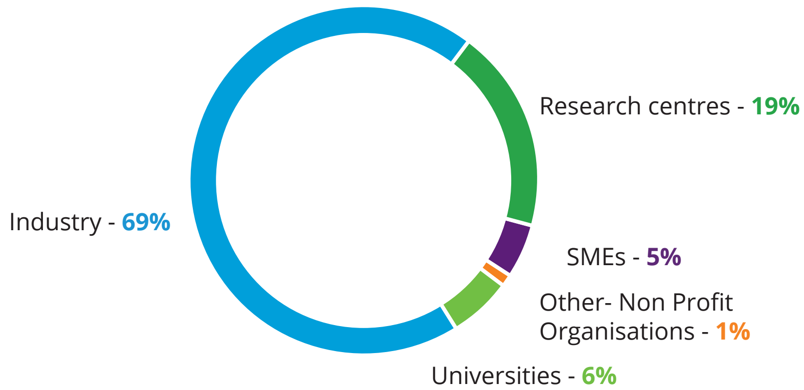
PARTICIPANTS IN FUNDED PROJECTS

281 participants (Call 1 + Call 2)

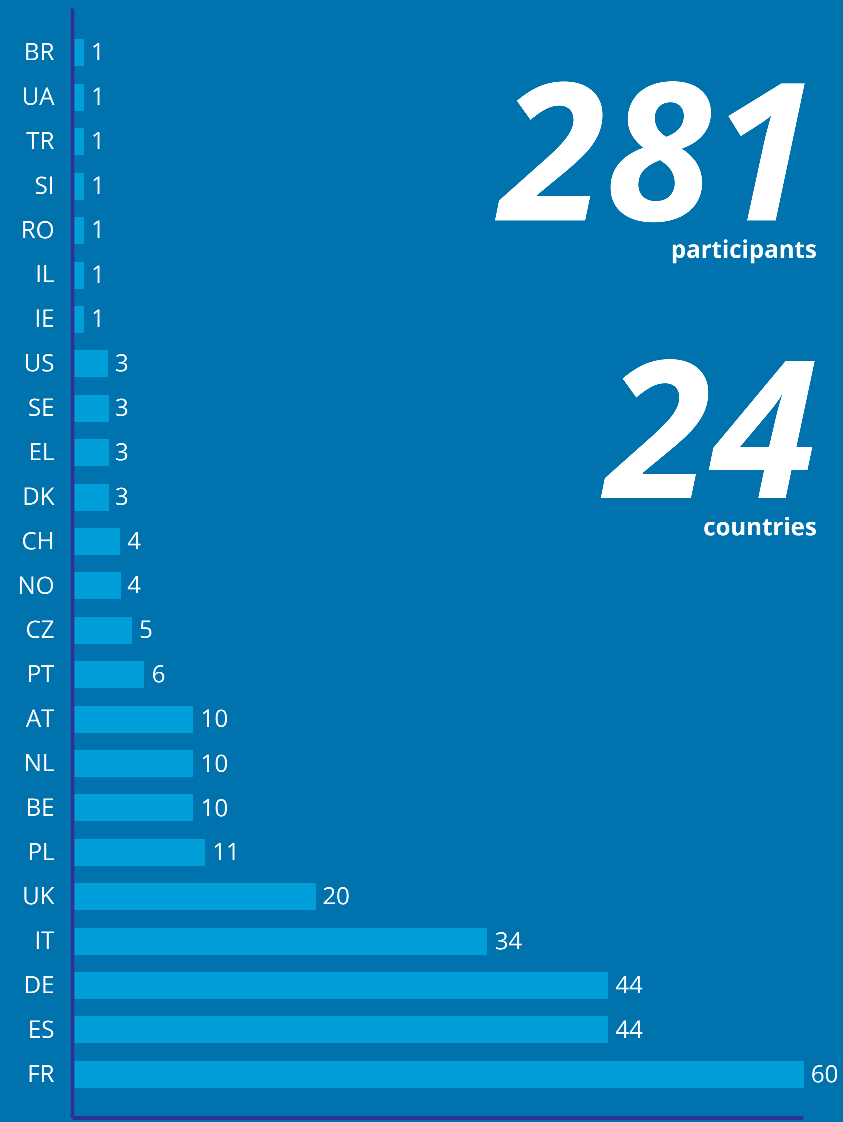


SHARE OF BUDGET FOR ALL PARTICIPATIONS

EU Funding: 806 million euros (Call 1 + Call 2)



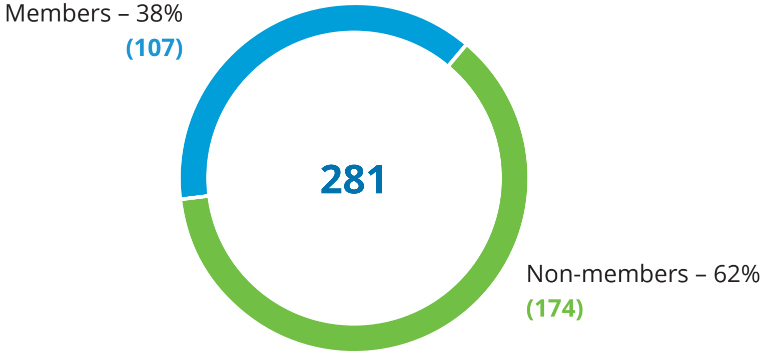
PARTICIPANTS BREAKDOWN PER COUNTRIES



281 participants

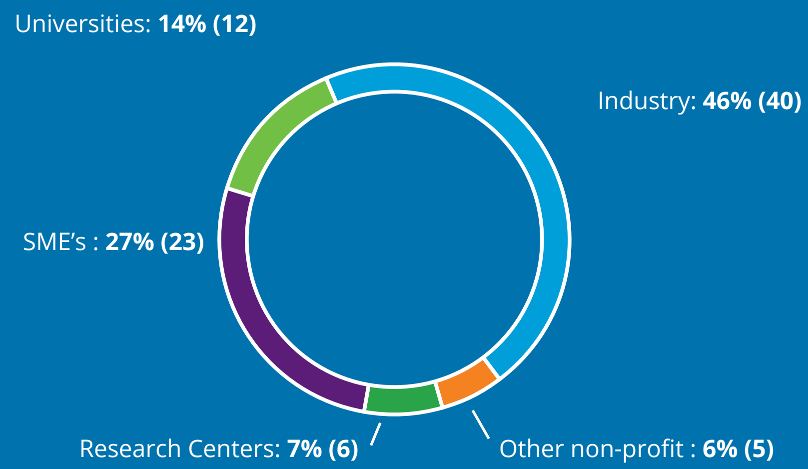
24 countries

NUMBER OF PARTICIPANTS

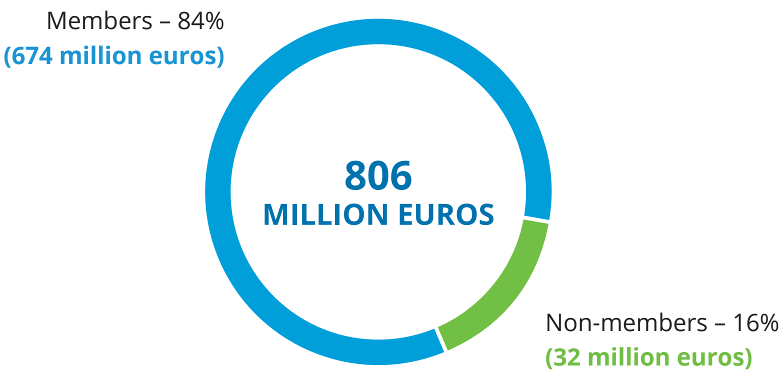


NUMBER OF NEWCOMERS

Call 1 + Call 2 (Single entities) : 86

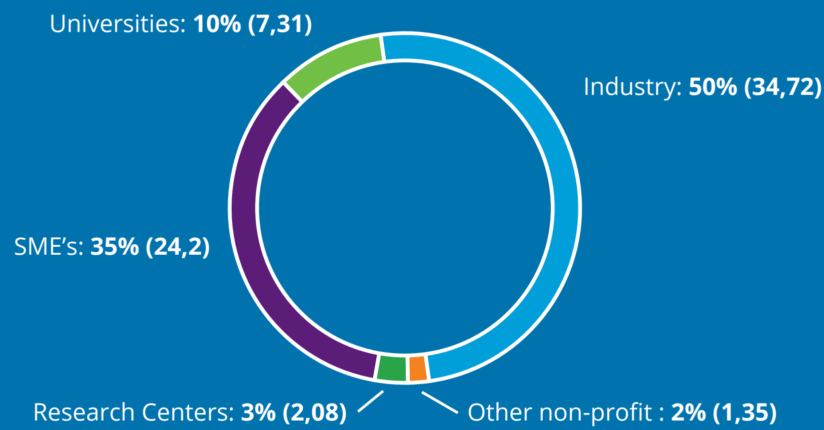


EU FUNDING FOR PARTICIPANTS



EU FUNDING FOR NEWCOMERS

Call 1 + Call 2 : 69 million euros



HIGH FIVE AWARDS

Clean Aviation Joint Undertaking launched the first edition of the High Five Awards in March 2023 to celebrate five individuals working to make sustainable flight a reality. Applications were open to a wide range of profiles active in the aeronautics sector, including researchers, academics, students, engineers, entrepreneurs, journalists, economists and public servants. Applicants could either apply as an individual or on behalf of their team.

Axel Krein, Co-chair High Five Awards Jury, and Executive Director of the Clean Aviation Joint Undertaking: "*These prestigious awards recognise outstanding individuals leading the clean aviation transformation and their commitment to promoting sustainability. Our five winners are inspiring others to join our journey towards a greener future. I very much look forward to working closely together with them as High Five ambassadors.*"

Clean Aviation JU announced the five winners of the inaugural High Five Awards at the Paris Air Show:

Amelia Gilchrist
Mechanical Engineering student at Durham University, United Kingdom, and currently on a placement year at Rolls Royce Derby, *United Kingdom.*

Jean-Christophe Lambert
Co-founder & CEO at Ascendance Flight Technologies, *France*.

Tine Tomažič
Director of Engineering & Programs at Pipistrel Aircraft, *Slovenia*.

Christiane Voigt
Head of Department Cloud Physics, Institute of Atmospheric Physics at German Aerospace Center (DLR), *Germany.*

Henri Werij
Dean, Faculty of Aerospace Engineering, Delft University of Technology, *the Netherlands.*

In total, close to **100** applications were received, from **19** countries, from a wide range of profiles active in the aeronautics sector.

The winners serve as High Five Ambassadors for one year to help raise awareness about Clean Aviation JU, promote its values and objectives, and highlight the critical importance of reducing aviation's impact on the environment.

Communications

Newsletter

+11.9%

subscribers during 2023

Social Media

+19%

of followers during 2023

Events

33

Key events organised:

- Clean Aviation Annual Forum (CAAF)
- Paris Air Show
- High Five Awards







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