



CLEAN AVIATION

HIGHLIGHTS

2022

Clean Aviation takes off



Co-funded by
the European Union



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PDF: ISBN:978-92-95222-06-9 doi: 10.2886/306825

Catalogue number: HR-05-23-137-EN-N



*The launch of Clean Aviation's
daring projects marks the start of a*

COLLABORATIVE SPRINT

towards **HIGHER EFFICIENCY**

AND LOWER EMISSIONS

*for European aviation in line
with the ambitions of*

EUROPEAN GREEN DEAL



FOREWORD 2022



Clean Aviation has started to work on disruptive technologies that will underpin tomorrow's sustainable aircraft "

Axel Krein
Executive Director

The Clean Aviation Joint Undertaking (CAJU) lifted off in 2022. Following our successful first call for proposals in 2022, work began on 20 projects to steer aviation towards a sustainable future.

With an announced value of €654 million in EU grant funding, the call has successfully brought together a wide array of public and private partners, research centres and academia to find impactful solutions that can deliver sustainable aircraft and, ultimately, climate-neutral aviation by 2050. From all across Europe, **244 entities** will be involved in executing the projects resulting from this call, amongst them: **34 SMEs** and a total of **51 universities**, as such showcasing an enthusiastic interest in joining and demonstrating a compelling agenda for European aviation.

The 20 'daring new projects' that have been selected ensure a broad coverage of the programme's three 'thrusters' and constitute a flying start to the programme:

- **Hydrogen-powered aircraft**
- **Hybrid-electric regional aircraft**
- **Ultra-efficient short and medium-range aircraft**

Alliances and Collaboration

Clean Aviation has forged several new agreements over the last year.

In September 2022, Clean Aviation became a founding member of the **Alliance for Zero-Emission Aviation (AZE)**. This new EU group, formed by the **European Commission's Directorate-General for Defence Industry and Space (DG DEFIS)** brings together public and private stakeholders from across the aeronautical sector to support the roll-out of hydrogen-powered and electric aircraft.

Clean Aviation also signed a Memorandum of Cooperation with the **European Union Aviation Safety Agency (EASA)** in October 2022. This collaboration will help to set new global standards for safe, reliable, affordable and clean air transport, while ensuring a regulatory framework that can support accelerated transformation.



Enhanced cooperation between Clean Aviation and EASA will help to set new global standards for safe, reliable, affordable and clean air transport "

Socio-economic impact of European Aviation and Clean Sky 2

A new independent study on the socio-economic impact of the Clean Sky 2 Programme underlined the total estimated economic benefit for Europe to be worth **€8.6 billion**. The study also noted that the Clean Aviation programme's **Strategic Research and Innovation Agenda (SRIA)** – which sets out how to achieve the objectives related to sustainable aircraft by 2030 and climate neutrality by 2050 – is both “resilient” and “fit for purpose”. This would apply even in a wide range of possible economic scenarios, potential developments and structural changes to the aviation system. The study also called for more coordinated action in the sector, making six recommendations in the areas of aircraft technology, infrastructure and operations, and sustainable fuels (see also page 9).



Clean Sky 2 delivers a total estimated benefit of €8.6 billion for the European economy "

Synergy is a word that resonates throughout Clean Aviation. For instance, our recent Regions report highlights how Clean Sky 2 fostered **strategic collaborations with EU Member States and Regions** and their own research and innovation programmes in aviation. These collaborations were largely formed thanks to the leveraging of synergies with the European Structural and Investment Funds. We are especially proud of the 18 Memoranda of Understandings signed, sparking the launch of 52 pilot projects and the award of 12 Clean Sky Synergy Labels.

What to expect in 2023?

Well, a busy year to come! Clean Aviation launched its second **call for proposals**, in February.

This call is an important milestone in accelerating the development of disruptive research and innovation solutions, for a greener future in the regional and short-medium range commercial aircraft sector. We will focus on eight topics in total covering all three Clean Aviation thrusts, with a total EU funding of around €137 million. This includes €65 million for hydrogen-powered aircraft; €32 million for hybrid-electric regional aircraft; and €40 million for short and medium-range aircraft. In addition, €0.75 million will be dedicated to impact monitoring of EU aviation research and innovation.



Clean Aviation's second call for proposals is an important milestone in driving a greener future in the regional and short-medium range commercial aircraft sector "



In 2023, we also plan to build more regional synergies, by setting up Memoranda of Understanding with other Horizon Europe partnerships such as Clean Hydrogen, with national administrations, and with European regions.

Clean Aviation is also launching an open **Call for Expression of Interest** in the course of 2023. Our aim is to encourage interested entities to apply for associate membership of the Joint Undertaking. Associate Member status enables an institution or company to tap into the programme's governance, capabilities, competences and commitments as well as to support the programme's objectives.

Clean Aviation's High Five Awards will celebrate trailblazers of sustainable aviation.

Last but not least, we can look forward to the roll-out of numerous Clean Sky 2 demonstrators. I hope you will join us at our Annual Forum in March and also at the Paris Air Show in June. For now though, I invite you to dive into these highlights, to take stock of what we have achieved to date and what we will tackle next in our journey towards climate-neutral aviation.

CLEAN AVIATION 2022



THREE THRUSTS GUIDING R&I AND DEMONSTRATORS

The Clean Aviation programme is built on three key 'thrusters', each featuring targeted research and innovation (R&I) and demonstration efforts aimed at driving the 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

Novel concepts with hydrogen direct burn & fuel cell based propulsion to enable aircraft and engines to exploit the potential of hydrogen as a non-drop-in alternative zero-carbon fuel, in particular liquid hydrogen.

In addition, **transversal projects** have been launched as an essential part of our programme to cross-fertilise innovation across the 3 thrusts. An example of transversal project is aircraft architecture and technology integration. Novel certification methods and means of compliance are another illustration of the transversal collaboration required.

DARING PROJECTS

In September 2022, Clean Aviation selected 20 'daring new projects' from its first call for proposals, with the support of the Governing Board. The projects aim at researching innovative solutions to power the next generation of sustainable aircraft and to support EU Green Deal ambitions for a climate-neutral future.

With grant negotiations successfully signed and sealed, work started quickly on these daring projects. Kick-off meetings across Europe, took place in January and February 2023, were the first critical step in a **collaborative process** that will power Europe towards sustainable and ultimately, climate-neutral aviation by 2050.

Clean Aviation is taking the first critical step in a collaborative process to power Europe towards sustainable and ultimately, climate-neutral aviation by 2050 "

Our innovative projects, selected by independent groups of experts, focus on 13 topics built around the three core thrusts:

One further topic is aimed at developing a European Clean Aviation Ecosystem.

These impact-driven projects aim to drastically **optimise efficiency by 30-50%** and cut total net emissions, when combined with the use of sustainable aviation fuels (SAF), by approximately **90% compared to 2020** state-of-the-art aircraft. This approach will culminate in a new breed of regional, short-haul and short/medium-haul airliners for entry into service by 2035.

€4.1 billion will be spent for the development of disruptive technologies for sustainable aviation in line with EU Green Deal and Paris Agreement ambitions. This budget is divided into €1.7 billion in EU funding and no less than €2.4 billion in private funding until 2031.

Clean Aviation Joint Undertaking is a 10-year programme, launched in 2021 and ending on 31 December 2031. The JU's first call for proposals opened in spring 2022 and a second Call was launched in February 2023. Phase 2, accelerating work under the partnership, will start in 2025. Projects under the earlier programme, Clean Sky 2, will end in 2023.

PROGRAMME OFF TO A FLYING START IN 2022

Clean Aviation made good progress in 2022. In March, it launched its first call for proposals in search of impactful solutions to deliver sustainable aircraft by 2050. Six months later, 20 'daring new projects' were selected – covering hybrid electric-powered aircraft, hydrogen-powered aircraft, ultra-efficient short & medium range aircraft, transversal areas, and support action. Work has already begun on these projects, ahead of the selection of further ones in 2023, following a second call.

Other notable achievements over the year include Clean Aviation becoming a full member of the **Alliance for Zero-Emission Aviation (AZE)**. Created by the European Commission's Directorate-General for Defence Industry and Space, this new EU group is a broad alliance of some 160 public and private stakeholders across the aeronautical sector. Their goal is to drive the development of zero-emission aircraft, particularly hydrogen-powered and electric.

Clean Aviation also signed a Memorandum of Cooperation with the **European Union Aviation Safety Agency (EASA)** in October 2022, to boost cooperation on research and innovation in aviation. EASA will play an active role in the main Clean Aviation bodies. Their joint work will cover de-risking and demonstration of the feasibility of the new concepts; industry standards; new certification methods and compliance; evolution of regulatory material; and monitoring the impact of the Clean Aviation programme.

In 2022, the programme's predecessor Clean Sky 2 (CS2) was notably awarded the prestigious **Von Kármán Award for International Cooperation in Aeronautics**.

CLEAN SKY 2 R&T BRING SUBSTANTIAL ECONOMIC BENEFITS

Aviation brings society numerous benefits, linked directly to connectivity and economic growth, but it also produces greenhouse gas emissions. A new independent study on the socio-economic impact of Clean Sky 2 underlined how the programme's innovative technologies could ultimately help to reduce global aviation CO₂ emissions by around 15% and Nox emissions by around 31% per seat kilometre compared to 2014 levels, in addition to having a positive and growing socioeconomic impact.

Clean Sky 2 technologies could ultimately reduce global aviation CO₂ emissions by around 15% per seat kilometre vs. 2014 levels

Overview of 6 key recommendations to ensure climate-neutral aviation by 2050

- 1 **Accelerate adoption** of 2030+ EIS aircraft
- 2 **Shorten aircraft design**, development, and certification
- 3 **Reconfigure aviation** and Air Traffic Control infrastructure
- 4 Boost availability of **sustainable fuels** and feedstocks
- 5 Enable the adoption of **new network strategies**
- 6 Develop effective mitigation strategies for **non-CO2 effects**

Recommendations already supported by Clean Aviation Joint Undertaking

Additional recommendations

Download *Socioeconomic Impact of the Clean Sky 2 Programme*:

www.clean-aviation.eu/media/publications/socioeconomic-impact-of-the-clean-sky-2-programme

CRUISING SPEED IN 2023

Clean Aviation's **second call for proposals** will close on 11 May 2023. It has an overall budget of over **€350 million** including private contributions, alongside €137 million in EU funding. This call aims to pave the way towards entry into service of new highly efficient aircraft by 2035, to significantly contribute to climate-neutral aviation by 2050. Under the programme's three 'thrusters' and a total of eight topics, the EU funding budget amounts to:

- **€65 million for hydrogen-powered aircraft**
- **€32 million for hybrid-electric regional aircraft**
- **€40 million for short and medium-range aircraft**

A further €0.75 million is available for impact monitoring of EU aviation research and innovation.

In the first half of 2023, Clean Aviation will also launch an open **call for expression of interest (CEI)**. This will encourage interested parties to apply for associate membership of the Joint Undertaking, so they can take more advantage of its capabilities, competences and commitments, whilst supporting the programme's objectives. The CEI will also encourage national and regional authorities to develop synergies with the Joint Undertaking.

Clean Aviation will have a stand at this year's Paris Air Show, the first to be held since the COVID-19 pandemic, from 19 to 25 June.



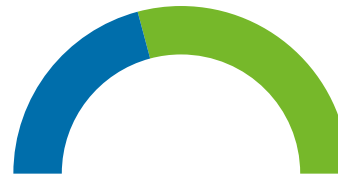
Clean Aviation's second call paves the way for entry-into-service of new highly efficient aircraft by 2035, and thus to climate-neutral aviation by 2050 "

In 2023, Clean Aviation will be busier than ever developing **key synergies**, building on the achievements of earlier programmes. The goal is to forge synergies with other partnerships, with other similar-minded partnerships such as the Clean Hydrogen Joint Undertaking; with other EU funding instruments like the Recovery and Resilience Facility (RRF); with national innovation programmes; and with the EU's Regions via a structured cooperation and Memoranda of Understanding / Memoranda of Cooperation.

Clean Aviation: 2 Phases

Total budget

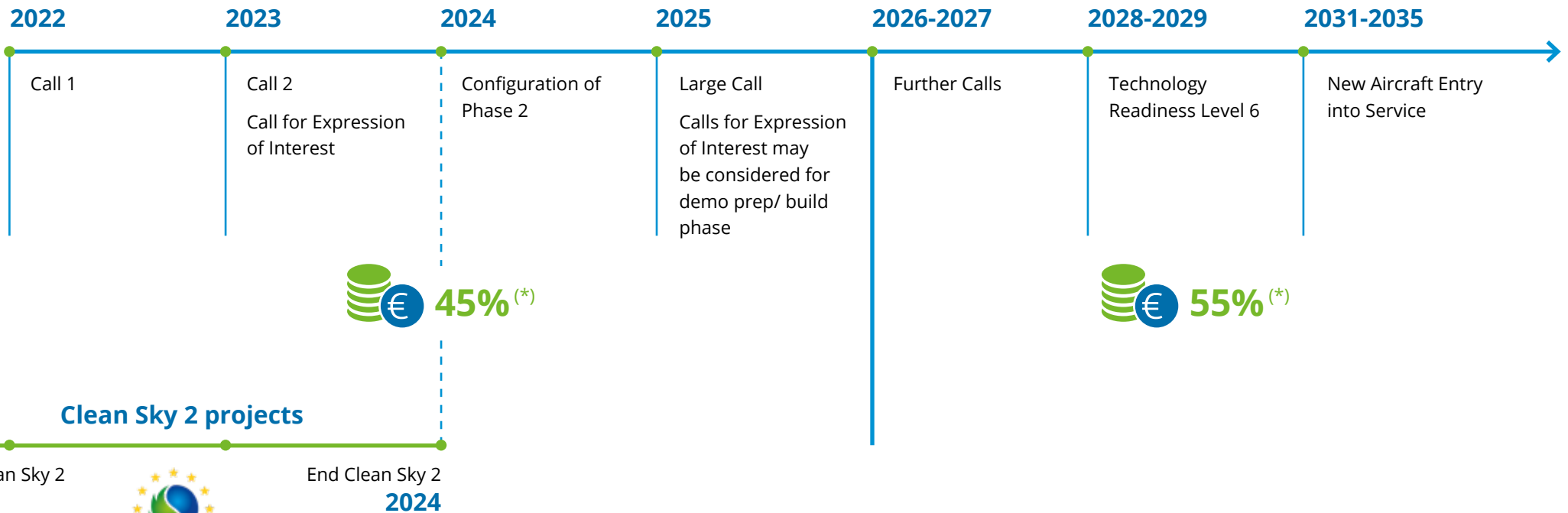
EU Funding:
€1.7bn



Private Funding:
> €2.4bn

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

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



(*) Out of total budget



Hybrid Electric

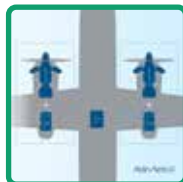
Combining Innovative Airframe,
Novel Systems & HE power train



HE-ART

**2.150-2.850 MW Multi Hybrid
Electric propulsion system
for regional AiRcraft**

ROLLS-ROYCE (*)



AMBER

**2250 MW Multi Power train
InnovAtive for hyBrid-Electric
Regional Application**

GE AVIO (*)



TheMa4HERA

**Thermal Management
Solutions for Hybrid
Electric Regional Aircraft**

HONEYWELL (*)



HECATE

**Electrical Distribution
Solutions for Hybrid-Electric
Regional Aircraft**

COLLINS (*)



HERWINGT

**Hybrid Electric Regional Wing
Integration Novel Green
Technologies**

AIRBUS (*)

(*) Consortium Leader



Ultra Efficient / Short Medium Range

Combined powerplant & Airframe efficiency



HEAVEN

**Ultrafan – Hydrogen & hybrid
gas turbine design**

ROLLS-ROYCE (*)



SWITCH

**Sustainable Water-
Enhanced-Turbofan (WET)
Comprising Hybrid-electrics**

MTU AERO (*)



OFELIA

**Open fan engine demonstrator
incl. gas turbine design
hybridisation for Environmental
Low Impact of Aviation**

SAFRAN (*)



UP WING

Ultra performance wing

AIRBUS (*)



FASTER-H2

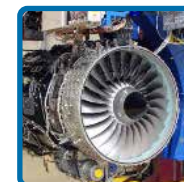
**Fuselage H2 integration &
Ultra efficient empennage**

AIRBUS (*)



Hydrogen Powered Aircraft

Novel concepts with H2 direct burn &
fuel cell based propulsion



CAVENDISH

**Consortium for the AdVent of aero-
Engine Demonstration and aircraft
Integration**

ROLLS-ROYCE (*)



HYDEA

**HYdrogen DEMonstrator for
Aviation**

GE AVIO (*)



NEWBORN

**NEx generation high poWer fuel
cells for airBORNe applications**

HONEYWELL (*)



H2ELIOS

**HydrogEn Lightweight &
Innovative tank for zero-emisSion
aircraft**

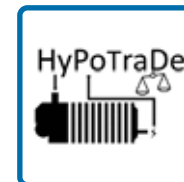
ACITURRI (*)



FLHYing Tank

**HydrogEn Lightweight &
Innovative tank for zero-emisSion
aircraft**

PIPISTREL (*)



HyPoTraDe

**Hydrogen Fuel Cell Electric Power
Train Demonstration**

PIPISTREL (*)

Transversal projects



CONCERTO

Construction Of Novel CERTification methOds and means of compliance for disruptive technologies

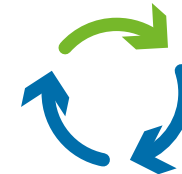
DASSAULT (*)



HERA

Hybrid-Electric Regional Aircraft Architecture and technology integration

LEONARDO (*)



SMR ACAP

SMR Aircraft architecture and technology integration Project

AIRBUS (*)



ECARE

European Clean Aviation Regional Ecosystem/synergies with regions

(*) Consortium Leader



Technical Highlights 2022

Clean Sky 2 environmental goals are simple: we aim to **reduce CO₂, NO_x and noise by 20-30%** compared to state-of-the-art aircraft from 2014. The technologies in 2022 progressed well with several important Clean Sky's main final technological achievements being delivered in 2023. In the next pages, you'll find a sample of some of the projects that made important strides forward or already completed.

Validation of Scaled Flight Testing

Although many airframe and engine optimizations enabled a reduction of about 80% in aircraft fuel burn since the beginning of air transportation, the aeronautical eco-system is actively exploring innovative and disruptive solutions that would provide further step changes in terms of energy consumption. Among a set of promising technologies, some will affect the aircraft flight behavior. However, in this domain, the classical approach based on numerical simulations and wind tunnel test is characterized by uncertainties. One promising solution is the Scaled Flight Testing approach that consists in flying in real atmosphere a scaled version of the future concept aircraft.



Goal

In the Clean Aviation Large Passenger Aircraft Platform, Industry and Research Centers launched a validation task to demonstrate that overall full scale aircraft behavior can be obtained with a dynamically scaled model.



Method

To perform the validation, partners compared the dynamic behavior of the Scaled Flight Demonstrator, a scaled version of an existing transport aircraft, with the one of the corresponding full-scale version.



Progress

In April 2022, the SFD system has been validated through 6 Qualification Flights in Deelen (NL). Later in October, the operational team located in Grottaglie (IT) completed 70 flight manoeuvres distributed over 19 Mission Flight Tests enabling a thorough flight dynamic analysis of the SFD and the comparison with the full-scale aircraft behavior.

Expected technical results

- Validation of the approach: Scaled Flight Testing technology passed Technology Readiness Level 5 gate
- Development and flight tests of a European Scaled Flight Demonstrator

Environmental objectives

- Enabler for new generation aircraft design with lower environmental impact through drag and weight reduction

Part of Clean Sky 2's Large Passenger Aircraft initiative



Multi-Megawatt hybrid-electric aerospace propulsion system successfully integrated

Power Generation System (PGS1) is designed as a 2.5MW, 3000VDC state-of-the-art electrical generation system - integrating a direct-drive high-speed aerospace generator and power electronics with a Rolls-Royce AE2100 gas turbine and the control, protection and thermal management systems required to operate safely.

To deliver effectively, technology development was sub-divided into phases beginning with single generator and power electronics testing at a purpose-built facility in Trondheim, Norway – through back-to-back full speed, voltage and current testing with the support of CleanSky 2– culminating in integrated full-system demonstration at an upgraded Rolls-Royce engine test bed in Bristol, UK with the support of Innovate UK.



Goal

To develop and demonstrate the underpinning technology bricks required for a multi-megawatt aerospace propulsion system and mature them to TRL4.



Method

Design, build and test an integrated hybrid-electric propulsion system including test facilities and infrastructure.



Progress

Demonstrated successful integration of a gas turbine and generator, including:

- High speed operation.
- High voltage operation.
- High current operation.
- Steady state and transient performance.
- Thermal and rotor-dynamic characterisation.
- Demonstrated safe systems of work
- Multi-megawatt continuous electrical power generation
- TRL4 awarded Q1 2022

Expected technical results

- Develop technology bricks for hybrid electric propulsion
- System design, architecture, and integration
- Product safety and flight clearance
- MW, high voltage electrical system (HVES)
- Novel thermal management
- Hybrid-electric control and protection systems
- Demonstrate a hybrid electric propulsion system in the MW range

Environmental objectives

- Contribution to CO₂/NO_x reduction through hybrid-electric propulsion

► Part of Clean Sky 2's Large Passenger Aircraft initiative



Completion of the lower shell of the Multi-Functional Fuselage Demonstrator

The **Next Generation MultiFunctional Fuselage Demonstrator (MFFD)** project is examining the full potential of thermoplastic composites to help future European airliner production to become faster, greener, and more competitive. A fuselage barrel made of thermoplastic composites weighs less because fasteners are no longer needed, and the materials are more recyclable. Thanks to this initiative, Europe's aircraft assembly lines will be better placed to respond to the 5% growth rate of the global air transport market, while reaching green objectives.



Goal

To produce an 8 metre long thermoplastic fuselage barrel - a world's first!



Method

The Lower Shell has a modular build philosophy with pre-installed systems. Part manufacturing and (sub-) assembly processes make extensive use of robotic-automation.



Progress

This ground-breaking lower half fuselage structure made by GKN Fokker, NLR, TU-Delft and SAM|XL consists of more than 400 thermoplastic fibre-reinforced parts, as well as thousands of spot welds and hundreds of meters of continuous welds. The lower half fuselage structure was completed in the end of 2022 and it will be joined with the upper half in 2023.

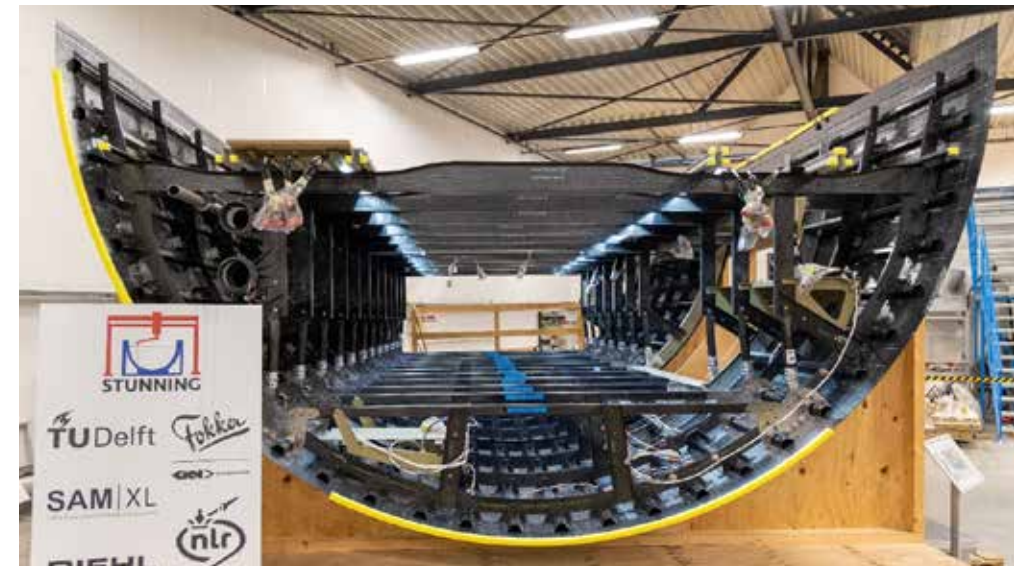
Expected technical results

- Increase fuselage build rate to 70-100 per month: current rate is 60 per month
- Flexibility in assembly & increased possibilities for customisation
- Cost reduction ensuring European competitiveness
- Technology Readiness Level 5 by 2023

Environmental objectives

- Reduce fuselage weight by 1 tonne
- Increase recyclability of materials

► Part of Clean Sky 2's Large Passenger Aircraft initiative



NGCTR wing development, manufacturing and assembly

Next Generation Civil Tiltrotor (NGCTR) is a passenger aircraft that can take off and land vertically without airports, making it ideal for a range of specialised missions such as medical evacuation and search-and-rescue while performing an unrivalled Door-to-Door time advantage with respect to other air carrier expandable up to about 600 nm range.

Cruising up to 280 kts which is twice that of typical helicopters and close to turboprop aircraft speeds while offering same riding comfort, one of the primary aims of the NGCTR project is to support the ACARE Flightpath 2050 goals for meeting societal & market needs to ensure European citizens are able to make affordable informed mobility choices, taking into account of economy, speed and a tailored level of service.



Goal

To utilise cutting-edge technologies to develop an environmentally friendly composite wing.



Method

Design based on high fidelity models to meet technical requirements, modular tools to allow for highly integrated upper skin manufacturing without defects.



Progress

T-WING project has the aim to develop and qualify an innovative composite wing for the Next Generation Civil Tiltrotor based on a highly integrated composite structure able to maximise fuel capacity. The highly integrated structure consists in having a one-shot component (upper integrated skin) which includes multi-cell spars, stringers and an aft curved spar, able to maximize fuel capacity and to guarantee the proper torsional stiffness of the wing box with respect to the aeroelastic requirements. Sizing loads for the tiltrotor are significantly different from a fixed wing aircraft.

Expected technical results

- Technology Readiness Level 6 by 2023
- Strengthening European competitiveness within the aeronautical arena
- Improving innovation capacity and integration of new knowledge
- Contribute to strengthening EU mobility

Environmental objectives

- 20%: CO₂ reduction
- 20%: NOx reduction
- 20%: noise reduction

Part of Clean Sky 2's Fast RotorCraft initiative



RACER – On the path to build a Compound Flight Demonstrator

RACER – Rapid and Cost-Effective Rotorcraft is a full-scale fast helicopter demonstrator, embodying the new European compound rotorcraft architecture which will be flight tested in 2023.

The RACER project supports the ACARE Flightpath 2050 goals regarding mainly new mobility of EU citizens, still with high environmental objectives.



Goal

To integrate cutting-edge technologies to develop and validate the compound helicopter high-speed architecture that can take off and land vertically for use in a high-speed mission such as research and rescue, and for passenger transport.



Method

The RACER compound concept involves the use of forward propulsion through shaft driven propellers on short wings, complementing the main rotor providing vertical lift and hover capability. Cruising up to 400 km/h (216 kn), it aims for a 25% cost reduction per distance over a conventional helicopter.



Progress

In 2022, RACER assembly continued with integration of other major systems such as the wing, the two ANETO engines, lateral rotors, the shafts and GearBox Mock-ups and the different networks (hydraulic, Flight Control Systems, Electrical Harnesses). This has allowed the ground tests to start.

On December 2022, RACER successfully **completed the «POWER ON» test** at the Airbus Helicopter facility in Marignane (FR), firing up all systems to conduct initial functional checks to finally validate the readiness of the aircraft's core avionic systems, software integration compatibility, and electrical harnesses.

Expected technical results

- Technology Readiness Level 6 (Flight Test) by 2023
- Contribute to strengthening EU mobility

Environmental objectives

- 20%: CO₂ reduction
- 20%: NOx reduction
- 20%: noise reduction

► Part of Clean Sky 2's Fast RotorCraft initiative



Conceptual design review of a 19 seat E-STOL aircraft

The European Flightpath 2050 connectivity goal increases interest in Small Air Transportation (SAT), to enhance European connectivity. Goal should come alongside with environmental target aiming to reduce by 75% CO₂ and 90% NO_x emissions. Within the EU CS2 SAT framework, a future affordable and small green 19 seats commuter has been designed, collecting all the novel technologies developed in CS2. The technology readiness and assessment to **electrify the short take-off and landing (STOL)** aircraft has been performed during 2022, rationalizing the design choices considered as most suitable to obtain a hybrid electric E-STOL and the consequent gains in emissions reduction.

Goal
To assess emissions reduction for hybrid electric small commuter aircraft forecasting the technologies maturation at EIS 2032.

Method
Preliminary design model for estimating performance of hybrid electric small commuter aircraft using modules for assessing efficiency of electrical power train (from "tank to wheel").

Progress
On board systems electrification has been further developed during CS2 framework aiming to improve the efficiency and safety of small commuter aircraft. Electrical propulsion system has been considered as further step for the whole enhanced electrification toward hybrid electric aircraft.

Expected technical results

- Technology Readiness Level 3 in 2022 for energy storage technologies and electric propulsion
- Technology Readiness Level 5 in 2022 for electric systems developed during CS2 framework

Environmental objectives

- 37%: CO₂ reductions (expected in 2032)
- 35%: NO_x reductions (expected in 2032)

Part of Clean Sky 2's Small Air Transport initiative



© Piaggio Aerospace

Open Fan demonstrator concept design achieved

Ultra-High-Performance Engine (UHPE) Technology maturation plan progressed during 2022 on Low pressure modules & rigs ground demonstrations to validate enablers for new engine architectures.

Different Engine layouts have been evaluated along the UHPE project to identify the most impactful configuration to prepare a full-scale engine ground test demonstrator

The Open fan architecture was finally selected mid 2022 as best candidate for a full-scale ground demonstrator to be later tested in the frame of Clean Aviation. Technology maturation and engine ground demo design is progressing towards the freeze of the design in the frame of the programme. Good example of progress is the completion of the High Speed Low Pressure Turbine Module demonstration rig test.



Goal

To develop advanced technologies to be integrated into a novel engine architecture for Short Medium Range aircraft targeting enhanced performance and fuel burn with additionally a significant reduction in noise.



Method

System level technologies are being developed as a step change from current state-of-the-art engine architectures and capable of delivering substantial reductions in emissions. An incremental approach to TRL progression is being taken, with multiple maturation studies implemented to select the best candidate.



Progress

The technology maturation plan has progressed well through the completion of several rig test campaigns on the key enabling technologies preparing the engine ground test demonstrator. The Open Fan engine architecture has been selected for further evaluation and for preparing the engine ground test demonstrator.

Expected technical results

- Disruptive architecture validated at Technology Readiness Level 4 for high energy efficiency and noise reduction

Environmental objectives

- 11%: CO₂ reduction for variable pitch fan configuration (ducted) vs 2014 SMR reference aircraft;
- 20%: CO₂ reduction for the Open Fan vs current in-service engines

Part of Clean Sky 2's Engines initiative



UltraFan® technology demonstrator build complete and ready to test

The trend towards **Very High Bypass Ratio engines (VHBR)** requires technology development across a broad range of complex gas turbine systems, encompassing fan inlets, complete compression systems, combustion processes, turbines and exhausts. Key technologies developed and demonstrated will include a low-speed, low pressure-ratio fan, the aerodynamic and structural design of a high efficiency multi-stage intermediate pressure turbine, the integration of novel accessories and a power gearbox. These technology developments will contribute to the goals of significantly reducing emissions and noise levels towards ACARE targets.

Goal

To develop advanced technologies to be integrated into a novel engine architecture targeting enhanced performance and fuel burn alongside reduced CO₂ and NO_x emission reduction with additionally a significant reduction in noise.



Method

The programme design, build and test a novel Very High Bypass Ratio (VHBR) engine at a large engine scale with technology suitable for the wide and narrow body aircraft markets.



Progress

During 2022 the Module & Engine first build continued, and by the end of 2022, had transitioned to Test Bed 80 in readiness to start the significant testing of the engine, supporting validation of the cycle & technology components through 2023. A significant step being the assembly of the fully instrumented Fan System, the largest of any engine, to the Core.

Expected technical results

- Ground testing campaign in 2023 to demonstrate Technology Readiness Level 5

Environmental objectives

- 10% more fuel efficient vs CS2 baseline 2014 (25% vs first Trent engines)
- 100% Sustainable Aviation Fuel use

Part of Clean Sky 2's Engines and Large Passenger Aircraft initiatives



Tech TP ACHIEVE hybrid electric turboprop demonstrator completes test campaign

Tech TP ACHIEVE engine demonstrator completed in 2022 all final tests required to validate the full set of Clean Sky2 technologies including an innovative electrical motor-generator developed in the project ACHIEVE.

ACHIEVE (Advanced mechatronics devices for a novel turboprop electric starter-generator and health monitoring system) is a Clean Sky project coordinated by the UK University of Nottingham. Within this project, an innovative and more powerful electrical motor-generator has been developed and integrated in the Tech TP propeller and accessory gearbox (PAGB). This device comprises an electrical machine, an electronic power converter and associate controllers.

Goal

The Tech TP is an Ardiden 3-based technological demonstrator intended to provide an innovative, compact, sustainable, light and easy to maintain turboprop for business aviation and commuter aircraft applications.



Method

Tech TP required to develop a series of technologies to be incorporated in a full scale engine demonstration. A series of complementary grants delivered essential components for the demonstration.



Progress

The final Tech TP ACHIEVE demonstration including a parallel hybridisation feature through the power gearbox integrated machine ran successfully. It completed a series of previous campaigns that delivered at first test engine run in 2019 rated 1150shp with hydro-mechanical Pitch Control Unit and 4-blades conventional propeller, followed by a demo with full digital engine and propeller control system with 7-blades composite silent propeller developed in the project.

Expected technical results

- Technology Readiness Level 5 achieved
- Improved and easy maintenance

Environmental objectives

- 18%: CO₂ reduction
- 52%: NOx reduction
- 5dB: noise reduction

Part of Clean Sky 2's Engines initiative



Electrification reaching Small Air Transport (19 seats)

A very significant share of aviation's emissions come from flights of less than 1500 km, making Small Air Transport (SAT) between 4 and 19 seats an interesting niche. Utilizing electric power to feed non-propulsive aircraft systems, has numerous advantages such as reduction of operating and maintenance costs and improvement of aircraft performance. However, the difficulties are challenging in this aircraft's segment where reduced space, weight and competitiveness is sine qua non. A new **Electrical Power Generation and Distribution System (EPGDS)** has been developed with the aim of increasing power generation and implementing a light weight, small size, software controlled, fault tolerant, power distribution and processing system.

Goal

To enable the electrification of small aircraft (4 to 19 seats), through the implementation of High Voltage and Low Voltage electrical systems and keeping the system design affordable in cost, weight and space.

Method

High Voltage (HV) and Enhanced Low Voltage Electrical Systems have been implemented and tested in a relevant laboratory environment: HV generation, HV protection electronics and High-Density Electronic boxes have been developed.

Progress

Electric Power Generation and Distribution System (EPGDS) for Small Air Transport High Voltage and Low Voltage tests completed, achieving Technology Readiness Level 5.

Expected technical results

- Enhanced mission efficiency
- Increased aircraft safety
- Technology Readiness Level 5 achieved end 2022
- Direct Operation Costs reduction

Environmental objectives

- 2%: CO₂ reduction weight/fuel savings

Part of Clean Sky 2's Systems initiative



Connected Cabin & Innovative Water & Waste System ready to fly

Current cabin layouts and operations rely heavily on systematic and thorough manual checks before, during and after the flight for reasons of passenger safety and comfort checks and health and operability of the cabin equipment. A connected seat with sensors has been developed to automatize the safety procedures before take-off and landing and to allow predictive maintenance. For galleys and trolleys, the current mechanical monuments have been transformed into intelligent connected elements, including inventory systems, which share data automatically in real time. The data are analysed and continuously processed within the Galley System.

In addition, the introduction of recycling concepts for Water & Waste in the cabin is essential. The Grey Water Reuse System (GWRS), has also been designed and successfully tested, reusing grey water from wash basins for toilet flushing.



Goal

The goal of the Connected Cabin Demonstrator is to provide timely and precise information to the crew about cabin elements which shall enhance key operations and maintenance activities.

The goal of the new Water and Waste System is the reuse of grey water from wash basins (i.e. handwash water) for toilet flushing.



Method

A real-size Cabin Demonstrator has been furnished with connected cabin equipment (seats, galley & trolley) to show the connected functionalities in the final environment.

The innovative Water & Waste System has been designed, manufactured and integrated in an aircraft with the goal of utilizing onboard potable water.



Progress

The Connected Cabin and the Grey Water Reuse demonstrators have been successfully completed and validated. The Grey Water Reuse demonstrator is currently being evaluated in a flight test campaign. In addition, clear paths have been presented for exploiting these technologies in the near term.

Expected technical results

- The connected cabin will enable the optimisation of turnaround times as well as enhanced maintenance of the seats with positive impacts on mobility and competitiveness.
- The grey water reuse will have a direct impact on weight reduction.
- 20%: saving of onboard drinkable water on every flight corresponds to approximately 210kg net weight saving for a large passenger aircraft in long range operation.

Environmental objectives

- CO₂/NO_x reduction as consequence of less fuel consumption due to optimisation of turnaround times and weight decrease.

Part of Clean Sky 2's Systems initiative



Large fuselage business jet configuration concluded tests

A new business jet concept with several large fuselage configurations is designed using a bi-objective optimisation for maximised cabin space and minimised mass at the end of which 17 configurations were selected for testing in the ONERA L1 Wind tunnel. The test campaign included different fuselage widths and several HTP/VTPs rear-ends: reference-Tail, V-Tail, Π-tail, U-Tail and T-Tail, which were sized by running an optimization study w.r.t handling quality criteria. The gains of each configuration were also evaluated numerically against the reference low speed configuration.

Goal

Evaluate the environmental footprint reduction of innovative aircraft architecture with various large fuselage configuration applied to a new business jet concept as compared to the reference low speed business jet with a goal to find the shape of the fuselage maximizing the cabin space while minimising the fuselage mass, with various constraints w.r.t. the height and the width of the fuselage.



Method

Numerical simulations integrated in the Overall Aircraft Design ONERA process down selection of configurations based upon High-Fidelity simulations applied within the process to finalize the design of the different aircraft configurations considering several disciplinary modules such as Handling Qualities (based upon Vortex Lattice method), structure (Finite Element methods) and aerodynamic (CFD codes) ones.



Progress

The LSBJ (Low Speed business Jet) Large Fuselage configurations were designed, manufactured, and assembled by the ONERA Model Shop at ONERA Lille, equipped with 6 component balance and 80 pressure taps. Local 2d PIV measurements were performed near wake downstream of various HTP/VTP combinations. The test campaign was concluded in September 2022 and the numerical results have been validated against the Wind Tunnel Test results.

Expected technical results

- Technology Readiness Level 3 in 2023

Environmental objectives

- 10% CO₂ reduction target
- 10EPN dB noise reduction target

Part of Clean Sky 2's Airframe initiative



BLADE Flight Test Data results, analysis and Exploitation Conclusive workshop

The **Natural Laminar Flow (NLF)** Laminar Wing Demonstrator aims to increase the Wing efficiency by means of application of natural laminar flow technologies. This demonstration will achieve full integration of laminarity on the complete wing leading to significant improvements on drag and aerodynamic efficiency at the aircraft level. It is taking also advantage of a proper exploitation of the Flight Test data as outcome of the BLADE project.

Goal
To achieve significant drag reduction at aircraft level by inclusion of natural laminar flow on lifting surfaces.



Method

- Interchangeable laminar leading edge
- Innovative Composite multi-material structures
- Advanced aerodynamic simulations



Progress

Flight Tests were carried out to completion in 2019 to capitalise on the BLADE project initiated in CleanSky SFWA. Concretely, analyses of the flight without and with surface imperfections, RANS simulations and transition analyses for some BLADE flight test cases, validation of BLADE Geometries CFD vs. Flight Test, Hot-film measurements behind imperfections and associated stability analysis, and then completed with NLF Concept Feedback have been carried out by the BLADE project participants. Final results and outcomes were shared at the BLADE workshop held in July 2022.

Expected technical results

- Natural Laminar Flow Wing Flight Test Data Exploitation completed

Environmental objectives

- 12-18% CO₂ reduction

Part of Clean Sky 2's Airframe initiative



Verification of Flutter onset on leading edges by wind tunnel tests

The smart use of flight control system can avoid the use of structural reinforcements on the Vertical Tail Plane (VTP), Horizontal Tail Plane (HTP) and Wings to counteract flutter initiation in flight to allow full accessibility to the full flight domain, while reducing the structural weight of an aircraft. The assessment of flutter behaviour of an innovative aircraft aft body like the U-tail configuration exhibits complex aerodynamic behaviour due to interactions between the tail surfaces. To validate the aerodynamic models and aeroelastic coupling strategy involved in flutter, a U-tail flutter mock-up for Wind Tunnel tests on a business jet configuration was designed, manufactured and tested within the CleanSky program support (SFWA – Smart Fixed Wing) and tested in 2016. An improved mock-up with no leakage and modified HTP/VTP corner is tested to validate the efficient flutter margin control laws that could ensure the same speed margin with less aircraft mass.

Goal

Reduction of structural weight by lowering sizing cases with optimised use of control systems for vibration, gust load alleviation and flutter control.

Method

To achieve through Numerical simulation validated against Wind Tunnel Test results, Use of innovative control laws, Use of LIDAR sensors to predict the impact of gusts, and Load and flutter modelling enhancements.

Progress

The Wild Tunnel model was modified, keeping the mass and inertia very close to the preliminary model. No changes in modal and flutter behaviour were reported.

The Wild Tunnel Test was successfully completed in December 2022. The analysis of the results will continue and flutter methods will be jointly evaluated by ONERA and Dassault Aviation.

Expected technical results

- Technology Readiness Level 4 in 2023

Environmental objectives

- 50-200kg reduction with related impact on fuel consumption

Part of Clean Sky 2's Airframe initiative



Flight Test Bed wingtip installed on aircraft for ground vibration test

The Innovative Wingtip, 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's sustainability objectives. The wingtip is equipped with a moving surface. The ground vibration test is an important milestone towards obtaining the permission to fly for the Flight Test Bed 1 demonstrator.

Goal

Ground vibration test aims to collect aircraft structural data for verification and updating of the FTB#1 aero elastic mathematical model used for A/C flutter justification and flight test clearances.



Method

Structure vibration modes and relevant mass and damping coefficients, characterizing the aero elastic behaviour of the wing, are measured by accelerometers installed on the wing while the structure is excited by shakers.



Progress

Ground vibration test results of the Flight Test Bed 1 fitted with innovative wing tip have confirmed the reliability of the A/C theoretical dynamic model. Therefore, the model is valid, fully representative and can be used for first flight clearance, moving to the next step in the technology development: the flight test by 2023. Similar exercise for morphing winglet will be performed early 2023.

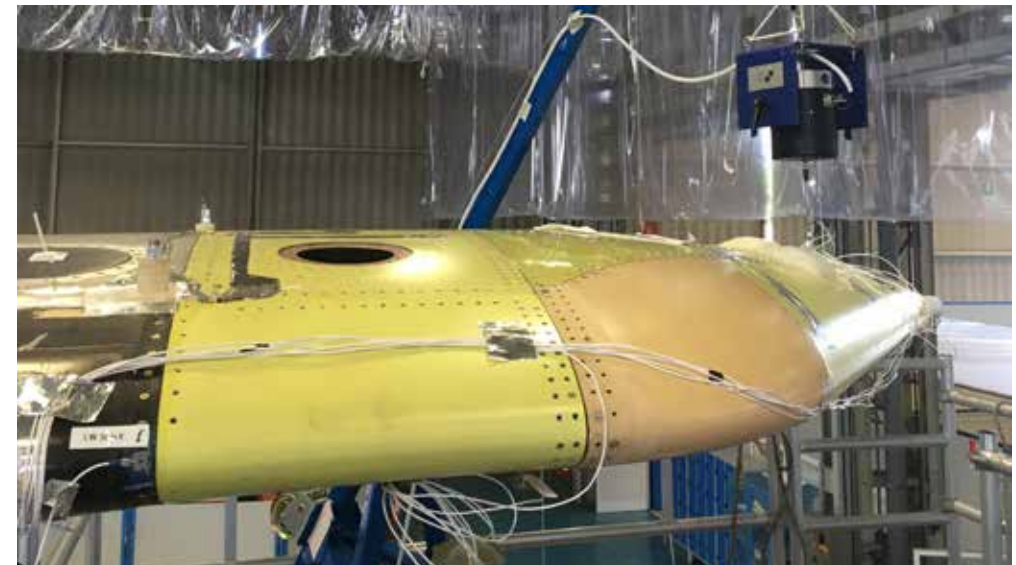
Expected technical results

- Technology Readiness Level 6 in 2023
- Manoeuvre Loads Alleviation
- Wing Root Bending Moment: - 3 %
- Performance
- Time to climb: - 3 %
- L/D Cruise: +2 %

Environmental objectives

- 2%: CO₂ reduction

Part of Clean Sky 2's Regional Aircraft initiative



Regional aircraft cabin demonstrator assembly ongoing

The cabin regional aircraft fuselage full-scale on-ground integrated demonstrator is on track for demonstrations in 2023.

The technologies implemented in the cabin demonstrator structure include: low weight and cost thermoset, thermoplastic composites components manufactured through innovative thermoforming, compression moulding, resin transfer moulding, additive manufacturing, automated fibre placement, liquid resin infusion.

With the installation of the interiors, the assembly activities will be completed in 2023 to then carry out the comfort test through which the aspects of improved comfort for passengers will be verified.

Goal
Validation at full scale level of innovative structural technologies and improvement of the physical cabin environment in terms of comfort and well-being on board for Regional Aircraft interior items.

Method
Full scale vibro-acoustic, comfort, thermal tests and systems integration to assess and validate innovation based on a human-centered-design approach.

Progress
The two sections of the demonstrator have been successfully joined together in 2022. Each section assembled is composed by 3 stiffened panels, the frames, shear ties, and the pax and cargo floor grids. The compliance with the design requirements has been verified and assured. The integration of the electrical cabling is also ongoing.

Expected technical results

- Improvement of cabin comfort and wellbeing
- Cabin Interiors Weight ~ -8 /-12% (wrt ATR scaled)
- Cabin Interiors Manuf. Rec. Cost ~ -5% (wrt ATR scaled)
- Technology Readiness Level 6 by 2023

Environmental objectives

- CO₂ reduction as consequence of less fuel consumption due to weight decrease
- Increase recyclability of materials

Part of Clean Sky 2's Regional Aircraft initiative

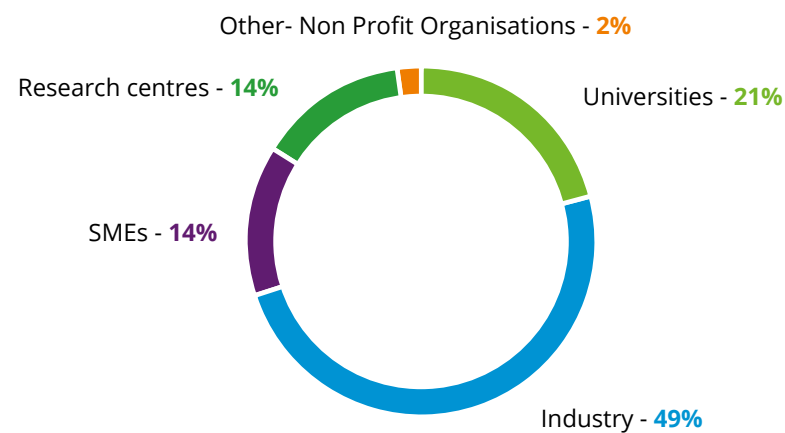


PARTICIPATION IN CLEAN AVIATION

Following the first call for proposals in 2022, a wide array of public and private partners, research centres and academia was brought together.

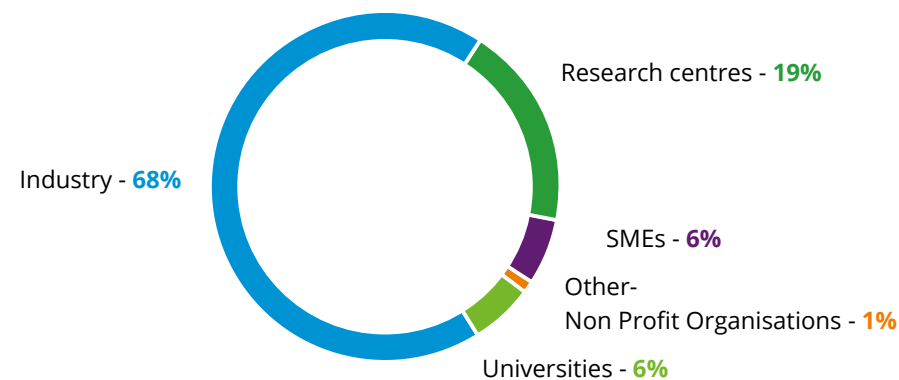
PARTICIPATION IN FUNDED PROJECTS

244 participants



SHARE OF BUDGET FOR ALL PARTICIPATIONS

EU Funding **653.91 million euros**



KEY FIGURES

EU funding

654

million euros

New participating entities
(Newcomers)

52

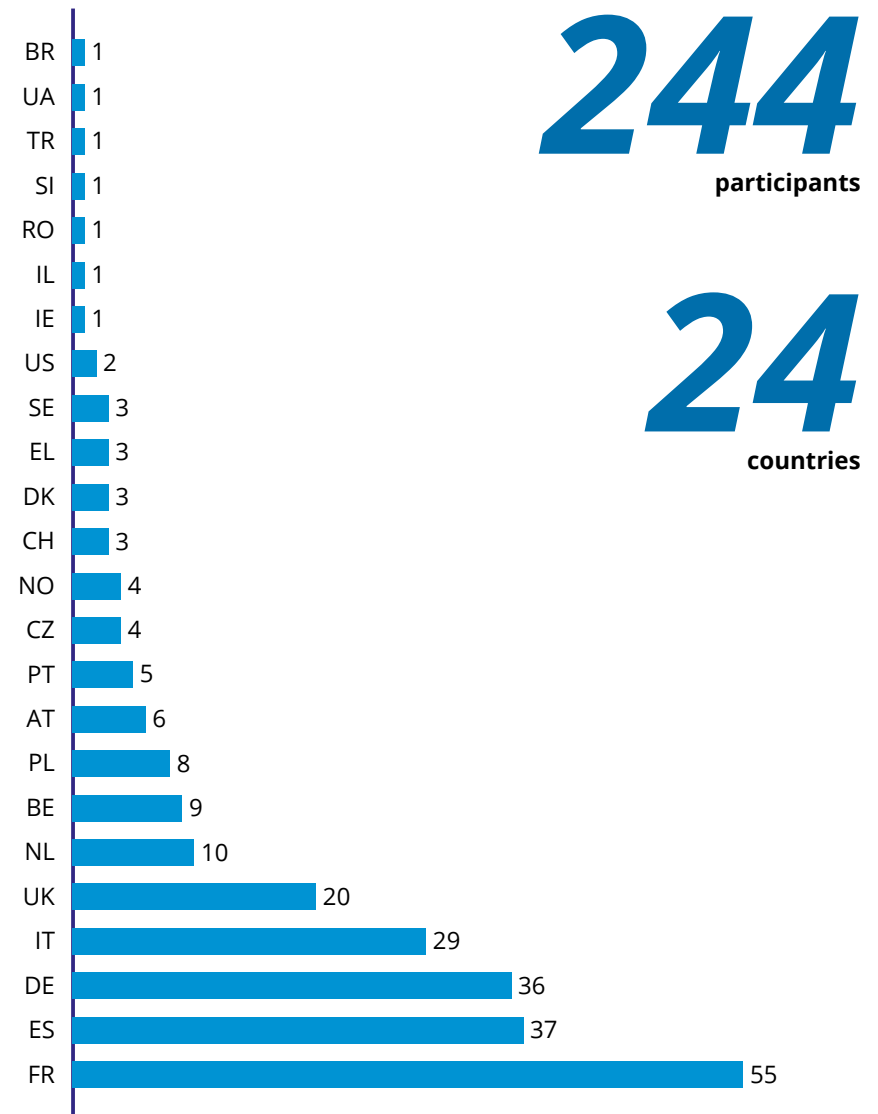
34

Small and medium
sized enterprises

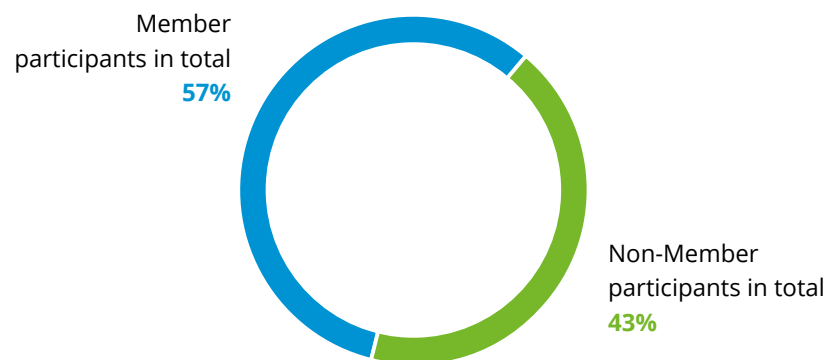
51

Universities

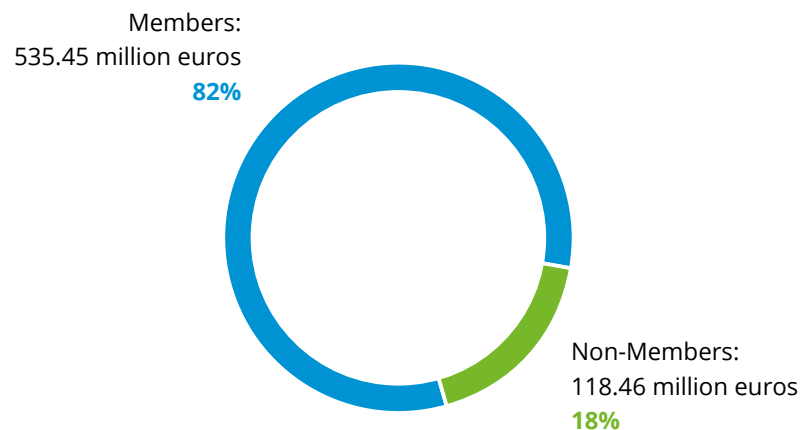
Participation breakdown per countries



NUMBER OF PARTICIPANTS

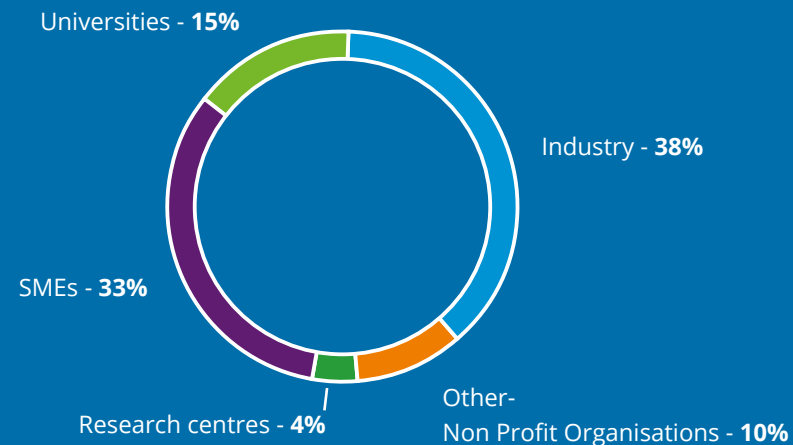


FUNDING FOR PARTICIPANTS

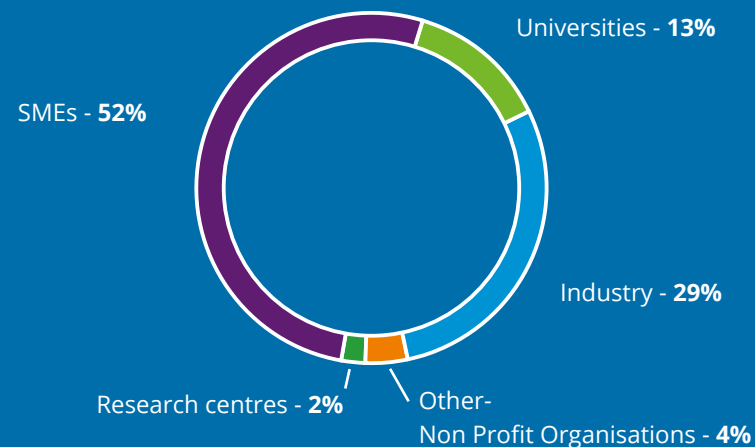


NUMBER OF NEWCOMERS VS CLEAN SKY 2 & CLEAN SKY

(single participation) Total 52



FUNDING FOR NEWCOMERS: 37.43 MILLION EUROS



Newcomer: a legal entity awarded for the first time as a beneficiary of a grant in the 1st call of Clean Aviation since the start of Clean Sky (Clean Sky and Clean Sky 2) and who is not an affiliated entity to a Clean Aviation Member or a Clean Sky/Clean Sky 2 Leader.

SYNERGIES

By working together we can achieve more. Clean Aviation has stepped up efforts to capitalise on synergies with national and regional Research & Innovation programmes and is extending its network of collaborating Member States and Regions at both strategic and operational levels. This builds on extensive experience gained from the Clean Sky 2 (CS2) programme whereby 18 Memoranda of Understanding (MoUs) have been signed at national or regional level. At the end of 2020, the MoUs had also fostered 52 pilot projects, covering a broad range of cutting-edge technologies. The projects have a total budget of more than €50 million from the **European Structural Investment Funds (ESIF)** and are supported by different funding schemes. CS2 projects will run until 2024, alongside early work on the 20 'daring new projects' already selected in Clean Aviation.

18

Memoranda of
Understanding

€50 million

from the European
Structural Investment Funds

52

pilot projects

COMMUNICATIONS



Newsletter:

+24,8%

subscribers during 2022



Website:

Website visits:

284.366

Number of pageviews:

1.131.545

Social Media:

Total social media following:

16.506

+37,5%

of followers during 2022



Total impressions Twitter:

504.900



Total Impressions LinkedIn:

681.900



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Co-funded by
the European Union

ISBN:978-92-95222-06-9