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Towards efficient disruptive technologies for new aircraft in service by 2035

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Clean Aviation

Swedish Aerospace Technology Congress
14 October 2025

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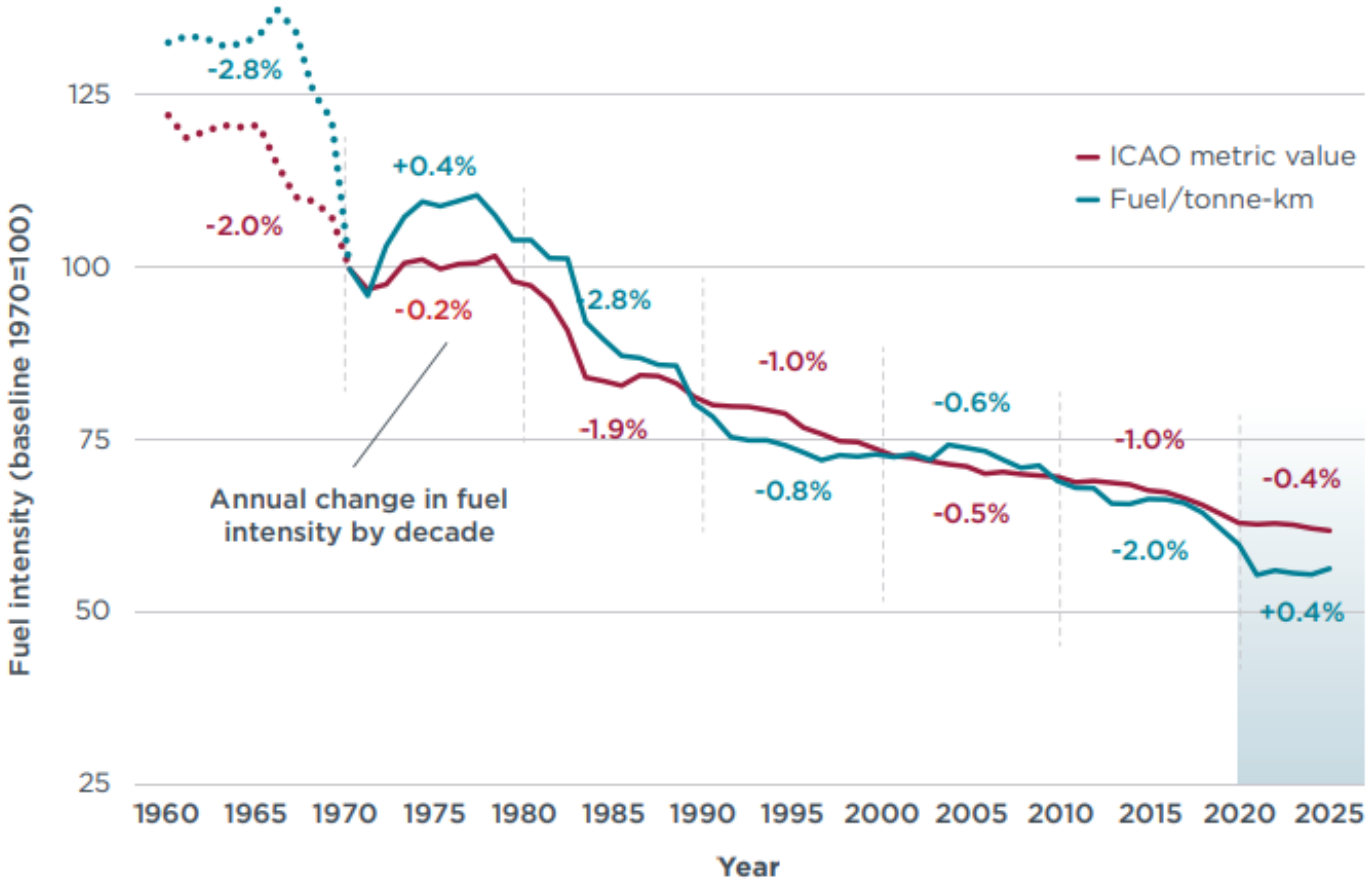
SECTION 1

The **Performance** Challenge

Fuel burn trends for new commercial aircraft

Performance improvements are dependant on the introduction of newer aircraft models



ICCT January 2025

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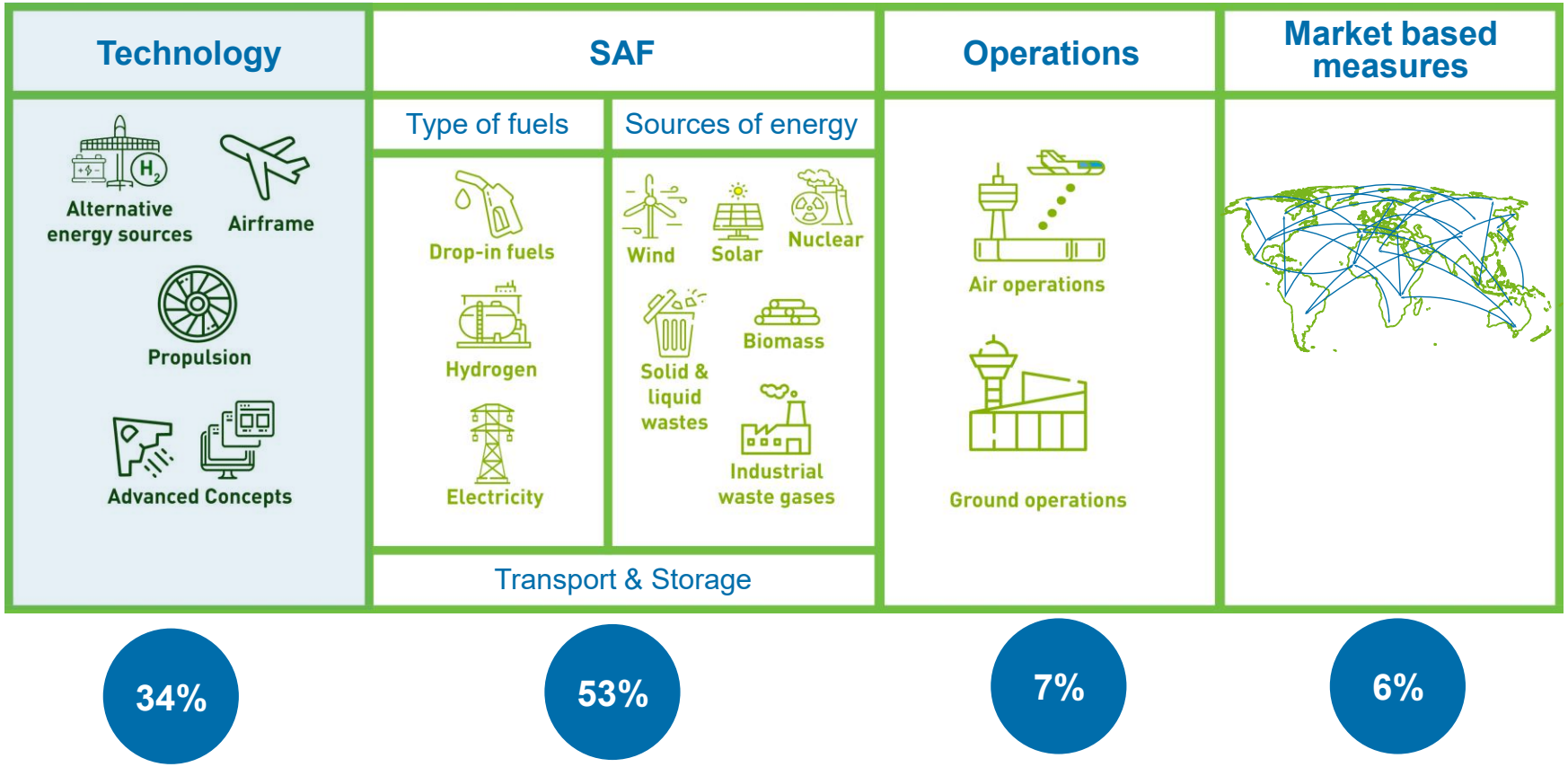
SECTION 2

The **Sustainability** and **Competitiveness** Challenge

The CO_2 contribution reduction panorama by 2050

Breakthrough in CO_2 reduction will be triggered by disruptive **technologies** & SAF

ICAO WORK ON LONG-TERM ASPIRATIONAL GOAL



ATAG Waypoint 2050 (2021), Scenario 3: aspirational and aggressive technology perspective

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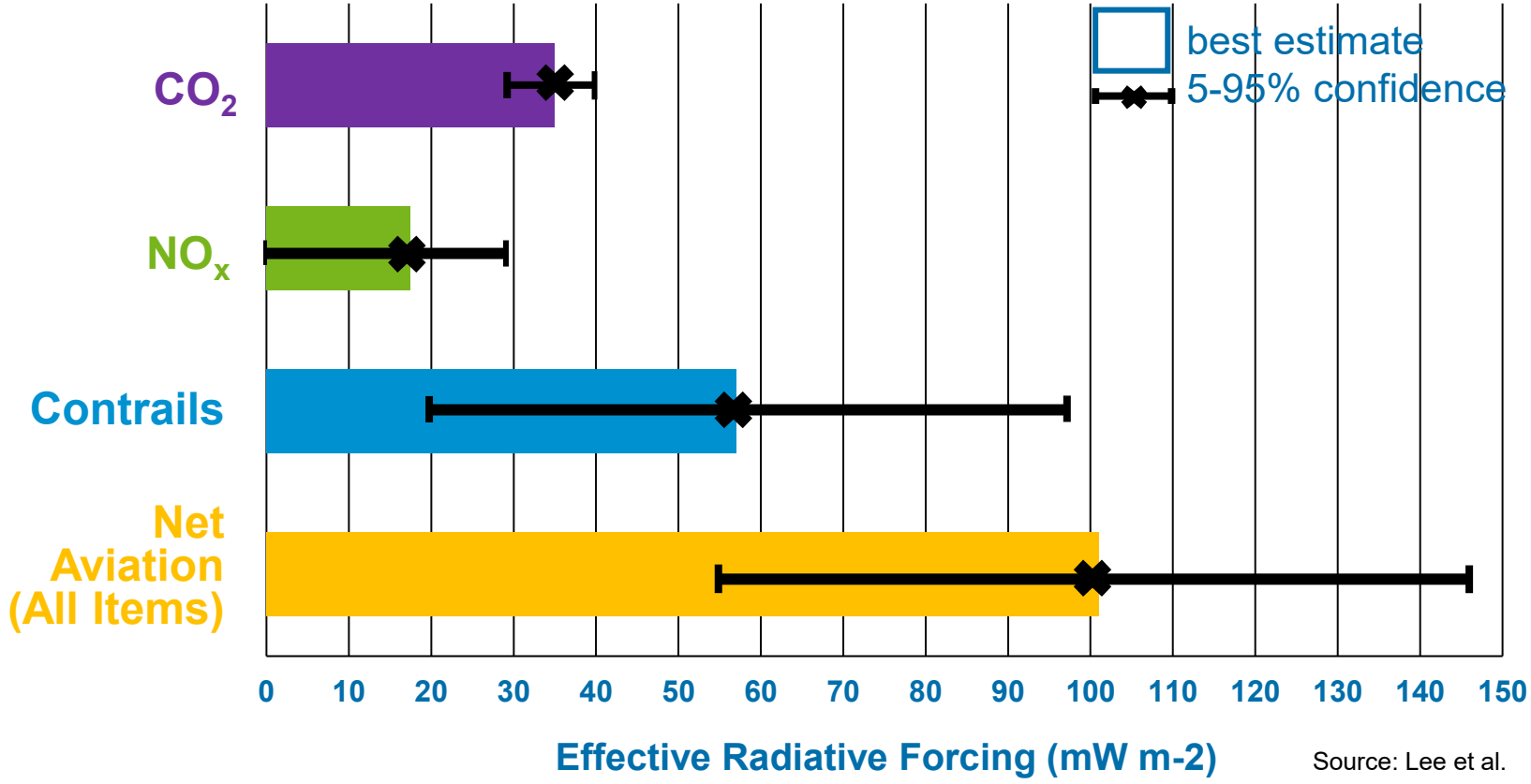
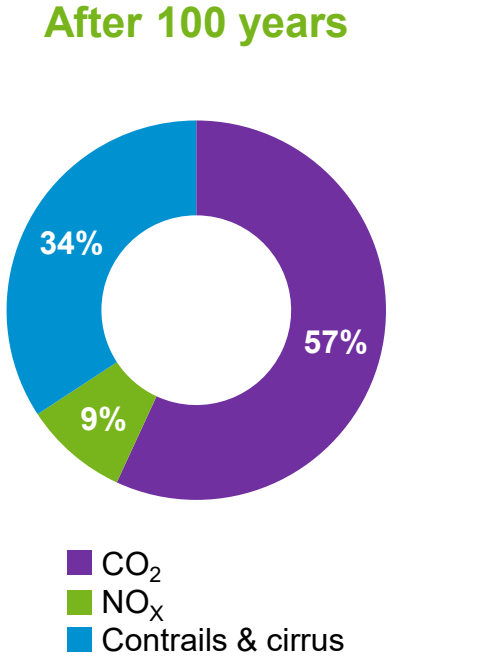
Climate Impact is NOT only about CO_2

GLOBAL AVIATION EFFECTIVE RADIATIVE FORCING (ERF) TERMS (1940 TO 2018)



Source: Lee et al.

GLOBAL WARMING POTENTIAL



Source: DLR

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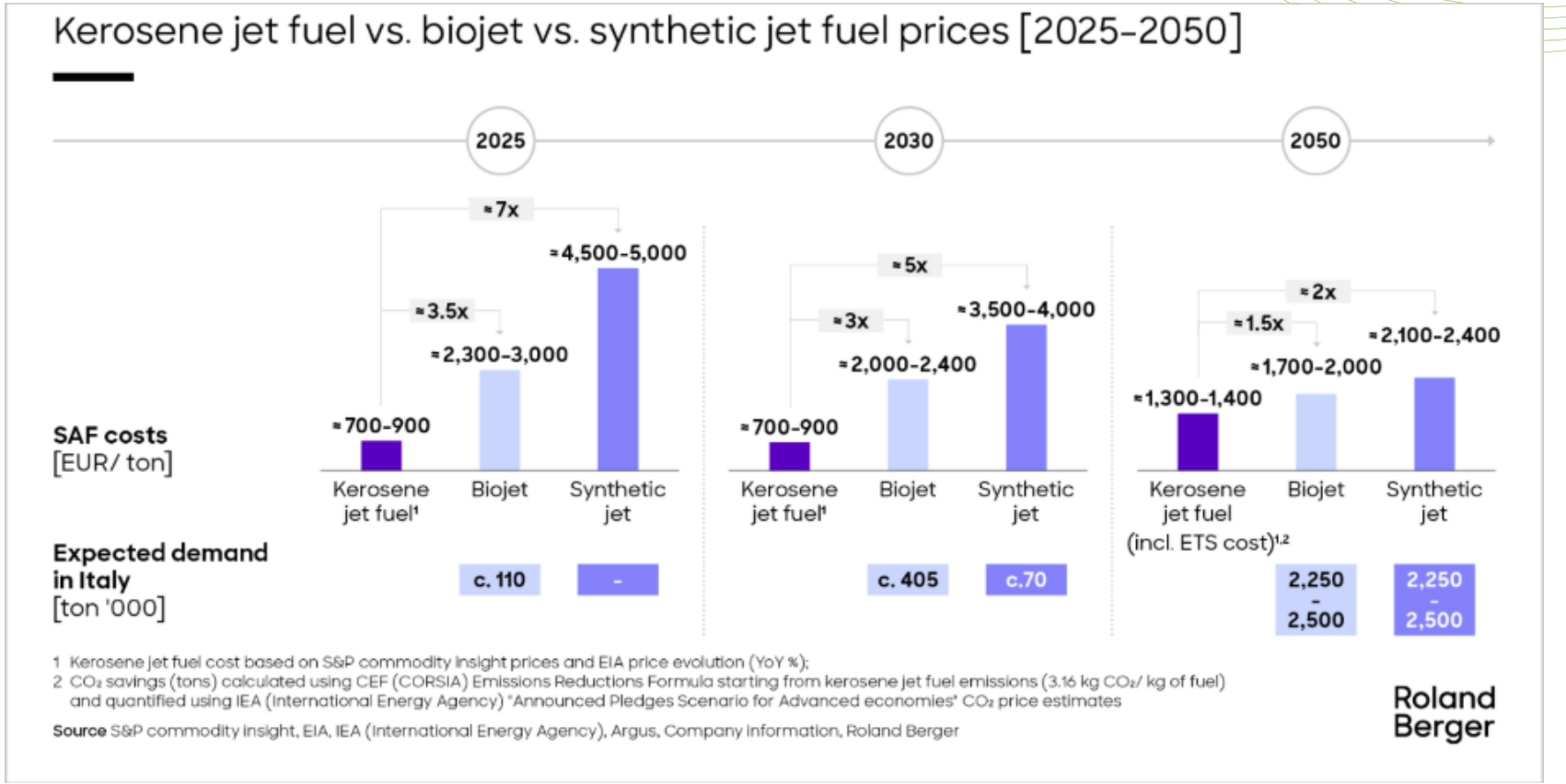
Fuel price evolution – estimates

Biojet & eSAF prices will remain **35% to 70% more expensive** than kerosene in 2050



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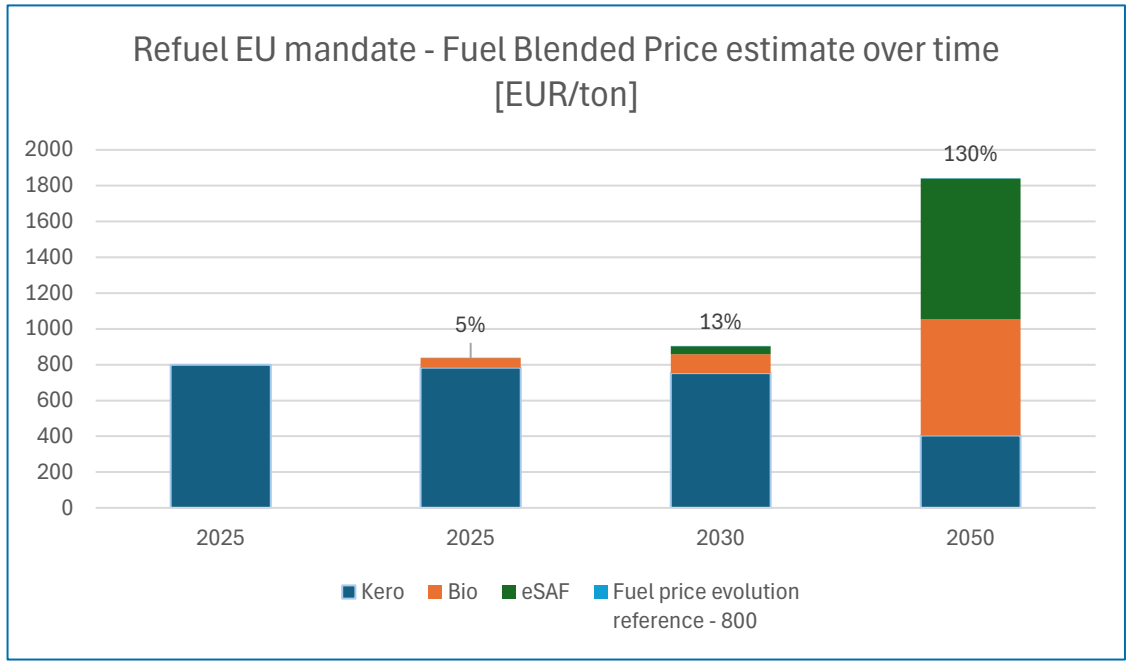
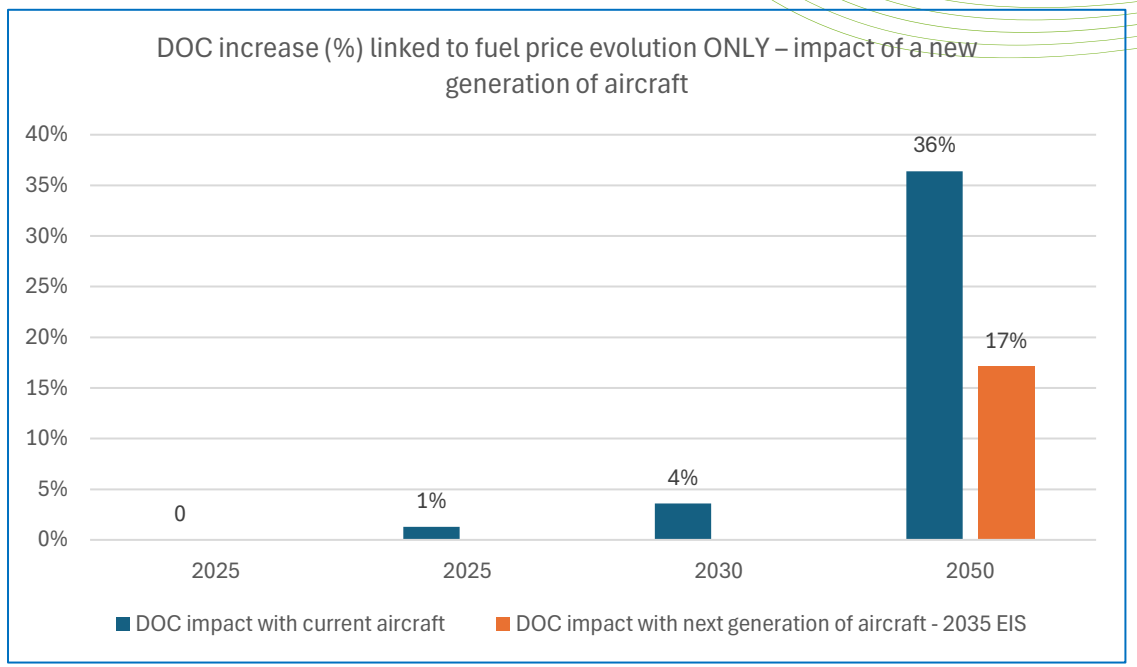
The need for a new generation of aircraft





>>> Transitioning **to carbon neutrality** while preserving the **competitiveness of airlines** required a **new a generation of aircraft** (30% improved performance) and **the availability of SAF at a competitive price**

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The **Technology** Challenge

Clean Aviation programme outlook and overview

Clean Aviation: an impact driven programme

Achieve

-30%

GhG reduction

Support

Entry-into-Service of new aircraft by

2035

Enable

75%

fleet replacement by 2050

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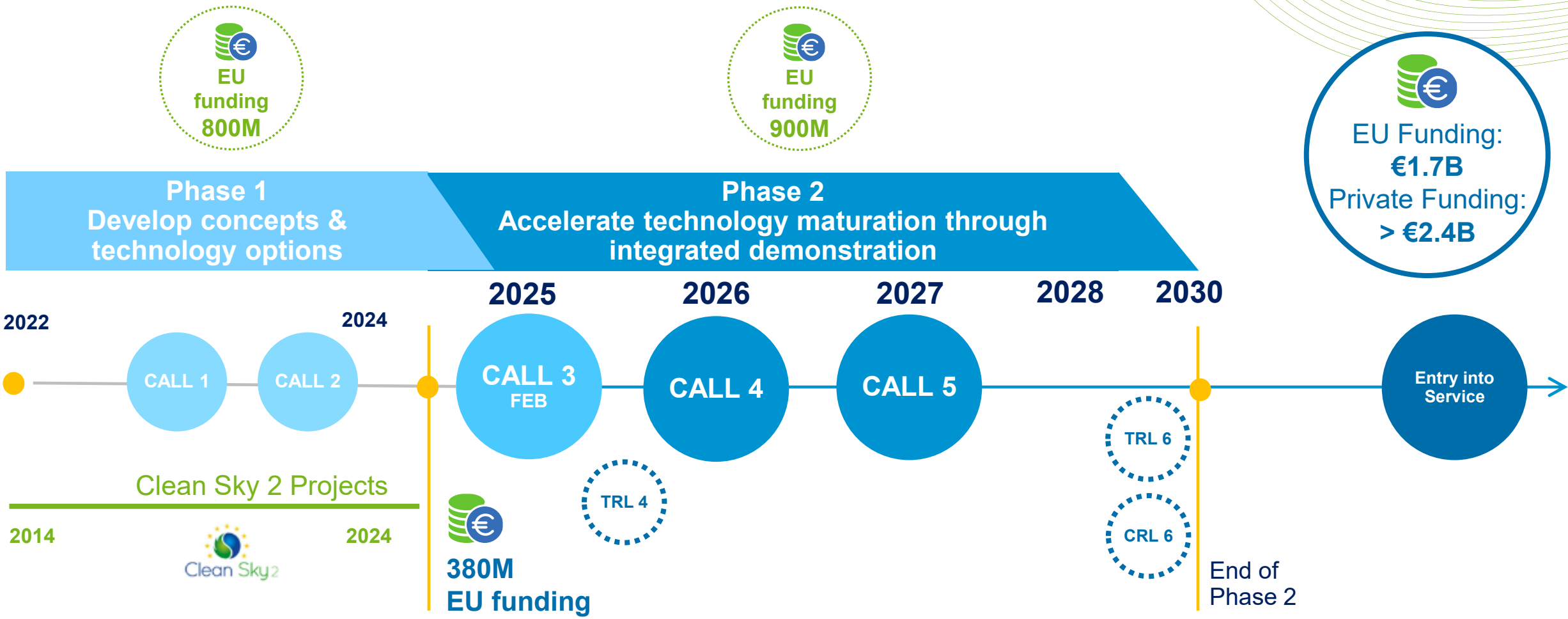
Accelerating maturation & demonstration



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Call 3: 12 projects with New Fast Track Areas

EU € 380M | Private € 570M

ULTRA-EFFICIENT SHORT-MEDIUM RANGE AIRCRAFT	ULTRA-EFFICIENT REGIONAL AIRCRAFT	FAST-TRACK AREAS	AIRCRAFT CONCEPT INTEGRATION & IMPACT ASSESSMENT
TAKE OFF Technology And Knowledge for European Open Fan Flight *SAFRAN AIRCRAFT ENGINES*	**PHARES** Powerplant Hybrid Application for REgional Segment *PRATT & WHITNEY CANADA CORP.*	**CRYOSTAR** Certification Roadmap to Yield an Optimal and Safety methodology of crashworthiness for an integrated cryogenic Tank for liquid hydrogen storAge on board of future aircraft *UNIVERSITA DEGLI STUDI DELLA CAMPANIA LUIGI VANVITELLI*	**HERACLES** Hybrid Electric Regional Aircraft Concept for Low EmissionS *AVIONS DE TRANSPORT REGIONAL*
LEIA Large scalE Integration demonstrator of hybrid electrical Architecture *AIRBUS OPERATIONS GMBH*	**DEMETRA** Demonstrator of an Electrified Modern Efficient Transport Regional Aircraft *AVIONS DE TRANSPORT REGIONAL*	**MODABAT** Modular, scalable and technology-Open Design for future Aviation BATteries *FRAUNHOFER GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG EV*	**ACI&I** Short Medium Range - Aircraft Configuration Integration and Impact *AIRBUS OPERATIONS GMBH*
UNIFIED Ultra Novel and Innovative Fully Integrated Engine Demonstrations *ROLLS-ROYCE PLC*	**OSYRYS** On-board SYstems Relevant for hYbridization of Regional aircraftS *SAFRAN ELECTRICAL & POWER*	**POWER4AIR** Arc Fault Detection, low EMI and Reliability for Power Electronics in Electric Aircrafts *SKYLIFE ENGINEERING SL*	
		LIME Lithium based Innovation for Modular Energy *ASCENDANCE FLIGHT TECHNOLOGIES*	

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Clean Aviation's aircraft concepts

Ultra-efficient **Regional** aircraft

-30% CO_2*

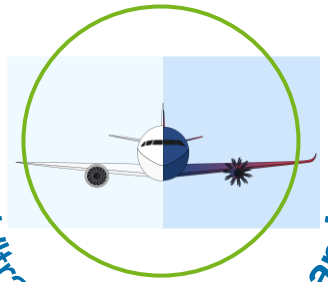
-90% CO_2* incl. **SAF**

SAF

Hydrogen powered aircraft

-100% CO_2*

H2



Ultra-efficient **Short and Medium Range** aircraft

-30% CO_2*

-90% CO_2* incl. **SAF**

SAF

* non-CO_2 effects not yet quantified

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SMR Aircraft: Main tech challenges

Integrated fuselage and rear end fuselage, cabin & cargo (up to -3% CO_2 emissions @ aircraft level)

Ultra Efficient Propulsion & Propulsion Integration (approx. -20% CO_2 emissions @ component level)

Ultra performing wing with high aspect ratio (up to -15% CO_2 emissions @ aircraft level)

Small Medium Range Technology Roadmap

Reference:
State of the Art
2020

2023 2024 2025 2026 2027 2028 2029 2030 **EIS 2035**

Unducted Engine Concept

TRL 4 — TRL 5 Ground Test Demonstration — Flight Test Demonstration — TRL 6

Ducted Engine Concepts

TRL 4 — TRL 5 Ground Test Demonstration SMR UltraFan — Flight Test Demonstration — TRL 6

TRL 4 Ground Test Demonstration Hybridised Propulsion — Flight Test Demonstration — TRL 6

-20% CO_2

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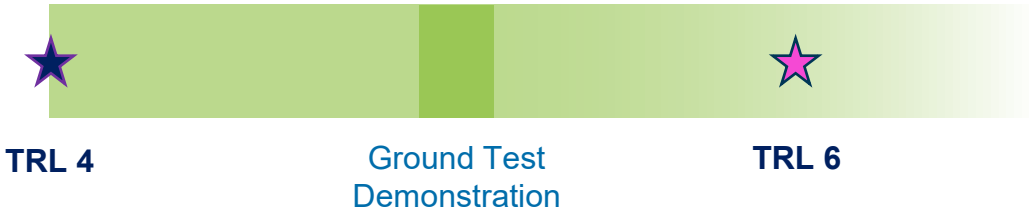
Small Medium Range Technology Roadmap

Reference:
State of the Art 2020

2023 2024 2025 2026 2027 2028 2029 2030 **EIS 2035**

On Ground Demonstration of a Non-Propulsive Energy Systems Platform



On Ground Demonstration of a Optimized System Platform

Ultra-efficient RFE & Industrial Systems

Enabler for MEA

2% CO2 reduction at AC level

High rate Industrial system @100p/m

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Phase 1 - Technical progresses

OFELIA

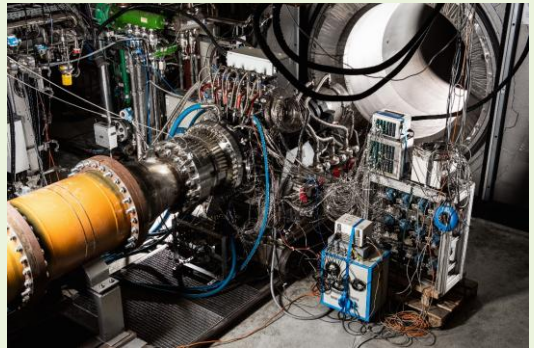
First full-scale demonstrator
parts manufactured for testing

HEAVEN

Architecture studies confirm the project
can meet fuel burn reduction targets

OFELIA
Efficient integrated propulsion

2023 DLR high-pressure combustion chamber test rig



- Advanced compact core engine combustion technologies using both JET-A1 and SAF at critical operating conditions assessed
- Optimum open fan installation to maximise fuel burn and acoustic emissions reductions

2024 SESTA LAB full annular combustion test rig

- HP Core Technology assessed successfully at TRL4

2025

- TRL4 on key technologies for the Open Fan Low Pressure
- First full-scale demonstrator parts manufactured for testing
- Maturation of advanced systems technologies

2026

Flight Test 2028

TRL 4/5

- TRL5 on Reduction Gear Box and Open fan architecture
- Ground test & Flight test preparation

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HEAVEN
Hydrogen Engine Architecture Virtually Engineered Novelly

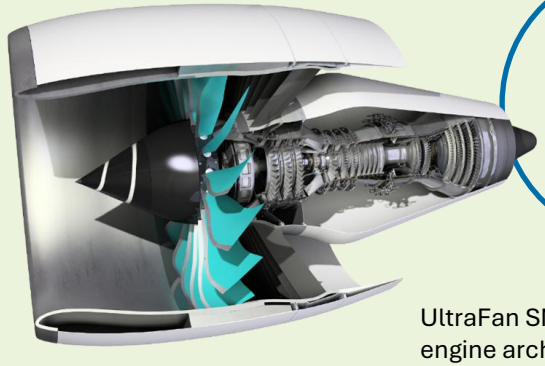
2023-24

TRL 3

Low-emission combustion test unit in the HBK5 rig with DLR and RR teams

- Development of the propulsion system MBSE supporting the SMR architecture definition
- Design of the key elements of the SMR engine: Power Gearbox, Combustion system FSN
- Subsystem maturation: Fan, IPT, hybridisation

2025-26



TRL 4/5

UltraFan SMR engine architecture

Engine PDR end of 2025

- Testing the key components for the SMR engine architecture, demonstrating TRL5 at subsystem level
- Completion of SMR engine integration studies
- Virtual PDR of the engine architecture at SMR scale, demonstrating TRL4 at system level

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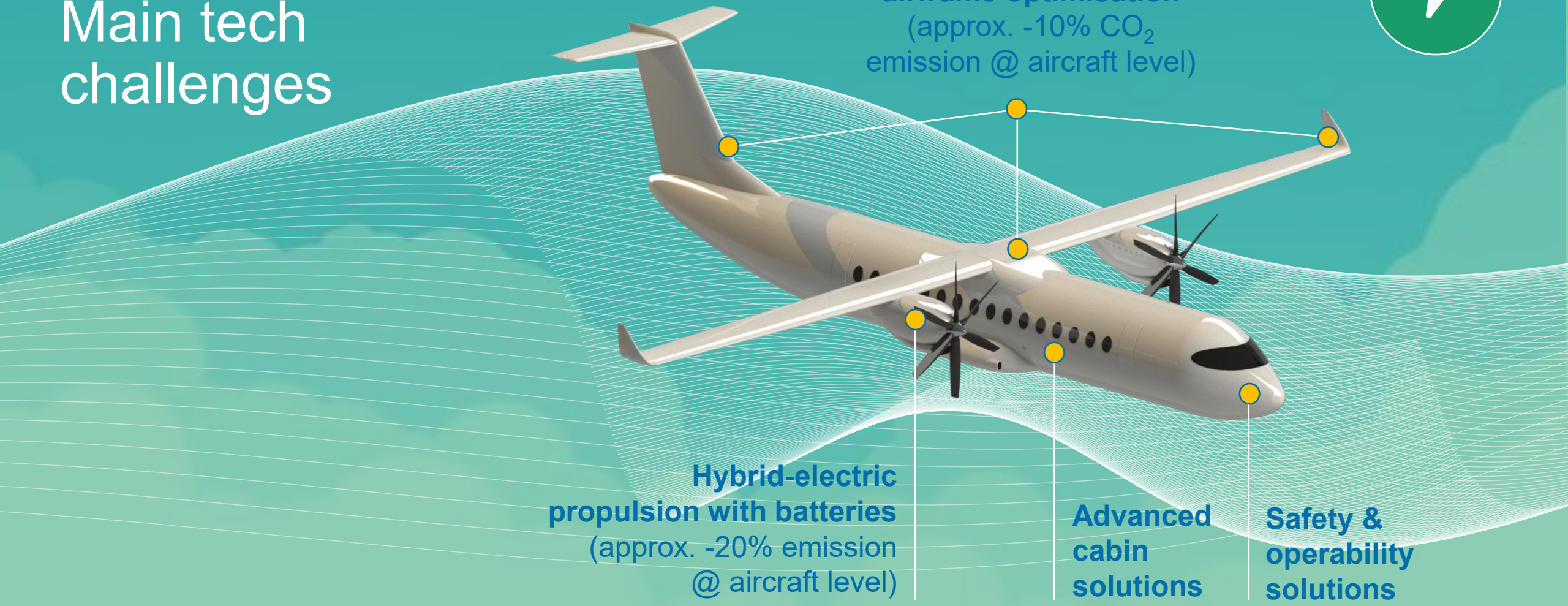
Regional Aircraft: Main tech challenges



Aerodynamic and airframe optimisation (approx. -10% CO_2 emission @ aircraft level)

Hybrid-electric propulsion with batteries (approx. -20% emission @ aircraft level)

Advanced cabin solutions

Safety & operability solutions

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Ultra-Efficient Regional Technology Roadmap

Reference:
State of the Art 2020

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Phase 1 - Technical progresses

AMBER

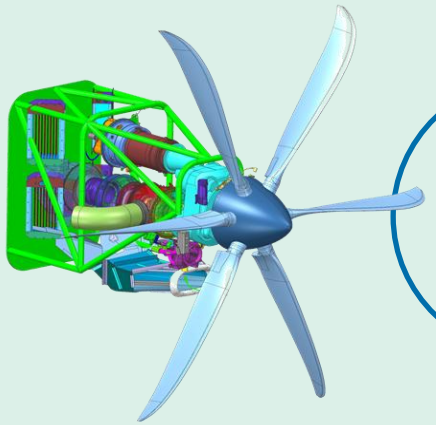
Finalisation of the conceptual design reviews of the power train and related techno-bricks

HE-ART

Technology bricks matured towards the critical design review

AMBER
innovAtive deMonstrator for hyBrid-Electric Regional application

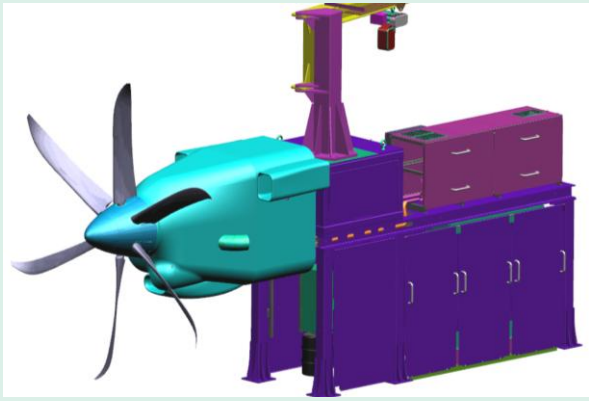
2023-24



TRL 3

- ~2MW Hybrid electric propulsive architecture conceptual design
- Preliminary design of all key techno-bricks
- A/C integration studies and engagement with EASA
- Launch of long lead time procurements

2025-26



TRL 4-5

- HE Power train final design
- All key technos developed, assembled and tested
- MW-class FC and E-motor system validation
- Integration HE power train testing

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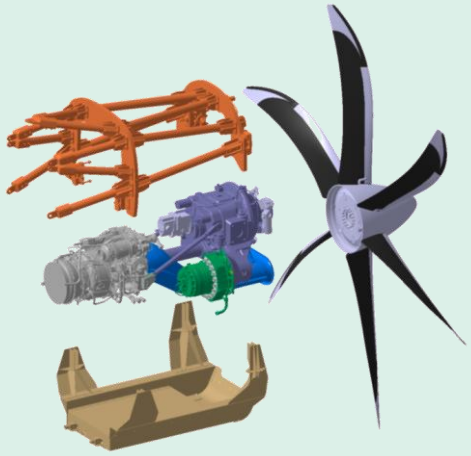
HE-ART
Hybrid Electric propulsion system for regional AiRcrafT

2023-24



TRL 4

2025-26

TRL 5

- System and sub-system Preliminary Design and Critical Desing gate Review
- Components (heat exchanger, electric machine) and materials (Engine mounting systems) testing to support system design and performance validation
- Testing facility modifications started

- Complete Critical design and release drawing
- Purchase, manufacturing and testing techno-bricks
- Progress Ground Test Facility modifications and assemble the hybrid-electric propulsion system
- Testing in representative operative conditions incl. extensive hybridization rates and flight

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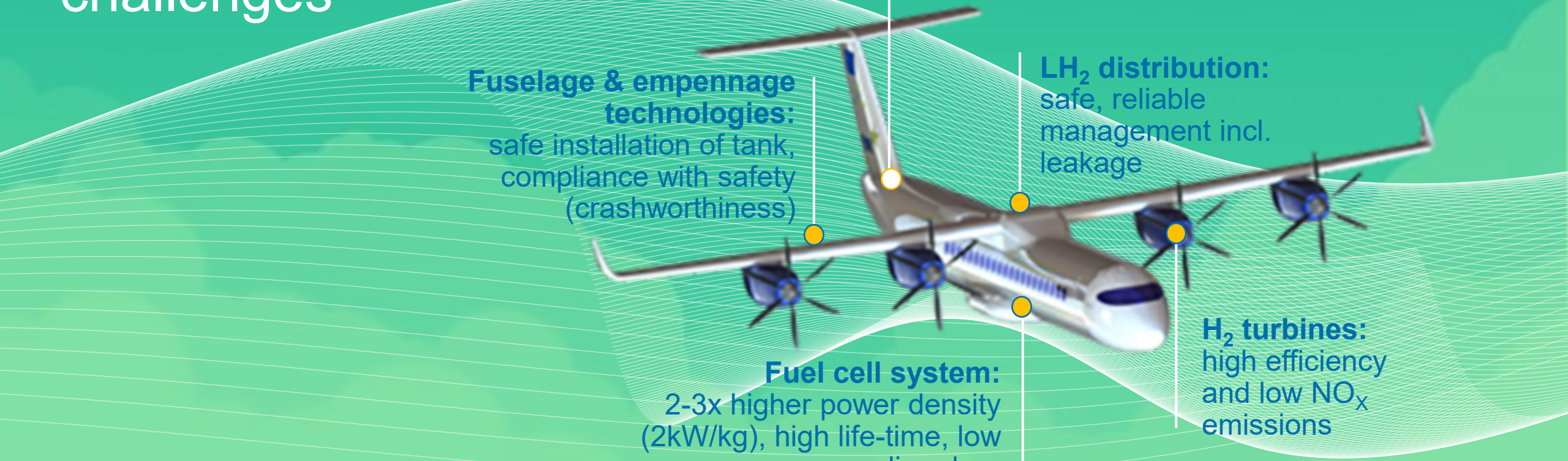
Hydrogen aircraft: Main tech challenges



LH_2 storage:
2x higher energy density (12 kWh/kg or gravimetric index of 35%)

LH_2 distribution:
safe, reliable management incl. leakage

Fuselage & empennage technologies:
safe installation of tank, compliance with safety (crashworthiness)

H_2 turbines:
high efficiency and low NO_x emissions

Fuel cell system:
2-3x higher power density (2kW/kg), high life-time, low cooling drag

H2

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Hydrogen Powered Aircraft Technology Roadmap

H2

-100% CO_2

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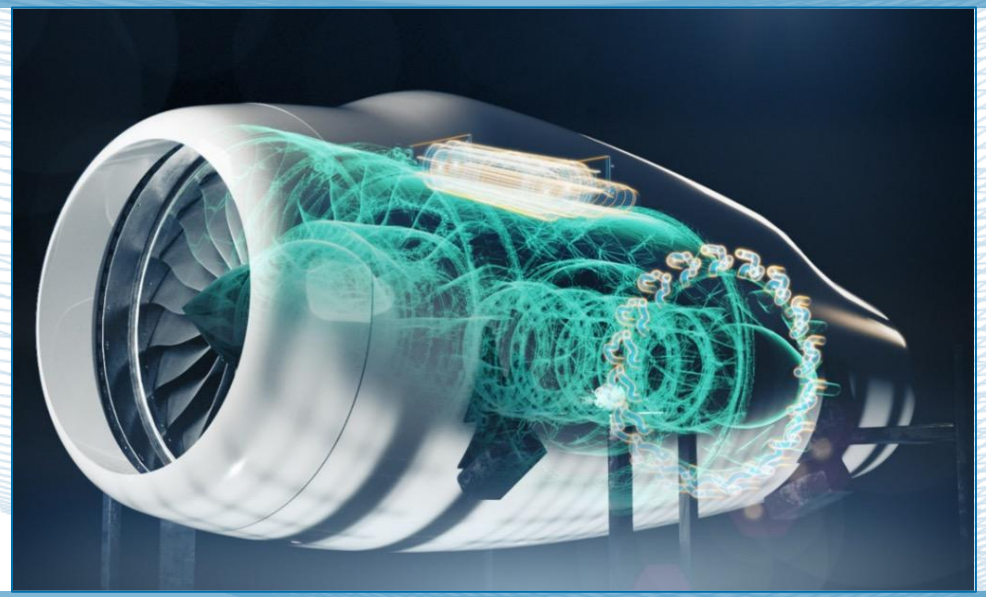
Phase 1 - Technical progresses

CAVENDISH



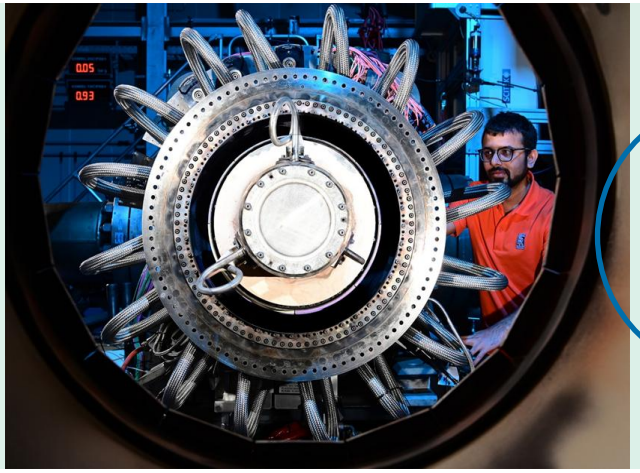
Completion of annual combustion rig tests up to maximum take-off conditions

FAME

Manufacturing of the first subsystems

CAVENDISH
Hydrogen combustion engine demonstrator

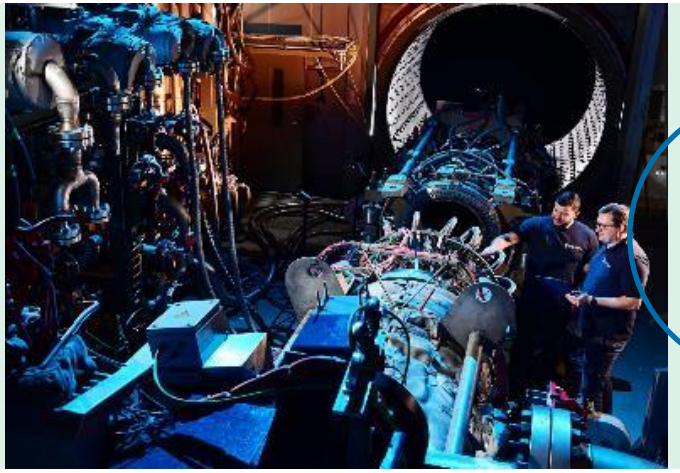
2023-24



TRL 3

- Full annular combustor with novel spray nozzles 100% hydrogen tested in representative engine conditions
- Initial tests performed on modern donor engine to calibrate and prepare for subsequent hydrogen tests
- Components development for full scale engine test

2025-26



TRL 4-5

- Engine upgrade with novel actuation and thermal management for hydrogen
- Engine test preparation including test facility readiness, hydrogen components availability for a first test with gaseous hydrogen
- Hydrogen propulsion system aircraft installation studies and safety analysis performed

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FAME
Fuel cell propulsion system for Aircraft Megawatt Engines

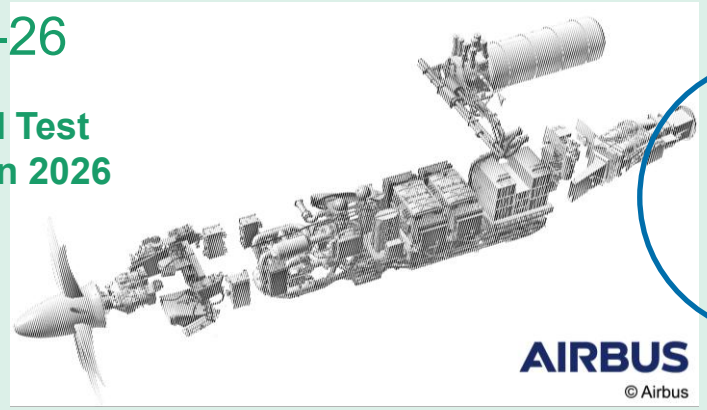
2024

TRL 3

- Top Level Aircraft Requirements defined, subsystem specifications determined
- Architecture of the ground test demonstrator finalised
- Development of key components and subsystems, with manufacturing and functional testing of the first ones

2025-26

Ground Test Demo in 2026



TRL 4-5

- Development of the subsystems finalised, integration into the Ground Test Demonstrator (GTD)
- 1MW Fuel Cell GTD commissioning, testing to validate TRL5 @ subsystem and TRL4 @ system level
- Design scaling and optimisation of the 2-4MW POD propulsion system, considering aircraft integration

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Aviation Research & Innovation Strategy (ARIS)

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AVIATION RESEARCH & INNOVATION STRATEGY

A pathway to competitive and sustainable aviation supporting Europe's sovereignty.

ARIS: handover to the European Commission

- ARIS handover to Commissioner Apostolos Tzitzikostas
- Paris Airshow, 16 June 2025
- +100 contributors

Clean aviation official recognition: Moonshot project

European Commission

Moonshots

Clean Aviation

What: Lead the world in developing the next generation of CO_2-free aircraft.

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ARIS: A Strategic Roadmap for Competitive and Sustainable Aviation

Europe's aviation leadership in some areas is strong but not guaranteed

Aviation is vital to Europe's economy and sovereignty

Urgent investment in R&I is needed to stay competitive and meet climate goals

Three key areas for R&I investment:
> Aircraft Technologies
> Air Traffic Management
> Transforming Enablers

Collaboration is key: a Europe-wide R&I strategy

2028-2034 EU multiannual financial framework:

EUR 66 bn investment (of which **EUR 22.5 bn** at EU level) in EU aviation R&I and support to market uptake to meet competitiveness, sustainability, and sovereignty objectives

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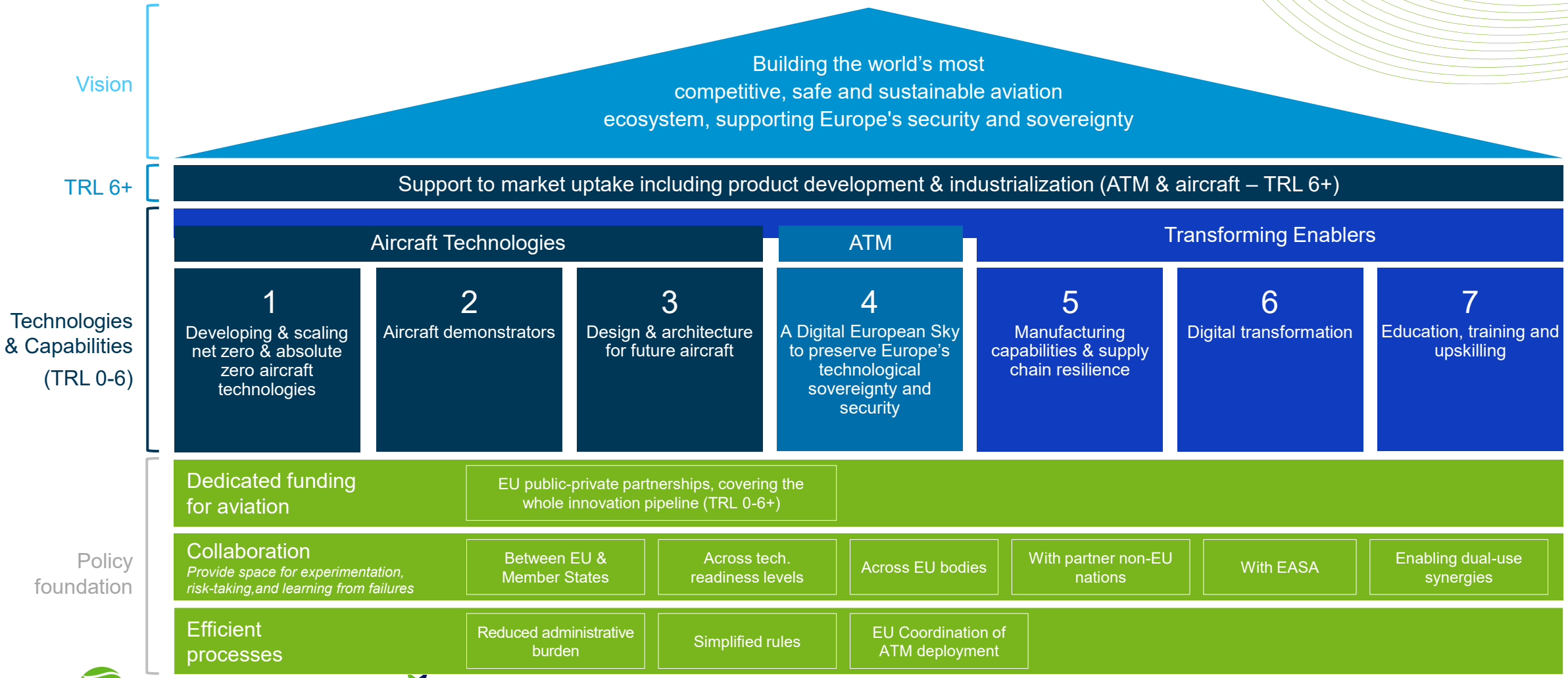
A new framework for action on European aviation



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Call for action

Accelerating investments across **the full innovation pipeline, from research to market uptake (TRL0 to TRL6+)** for a **competitive** and **sustainable** EU aviation economy

Strengthening investments to build **a strong and resilient EU supply chain** and creating conditions for **successul deployments**

Shaping conditions for a future Clean Aviation Moonshot partnership

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