DISRUPTIVE TECHNOLOGIES TO ENABLE ZERO-CARBON HYDROGEN–POWERED [HPA] SHORT RANGE AIRCRAFT

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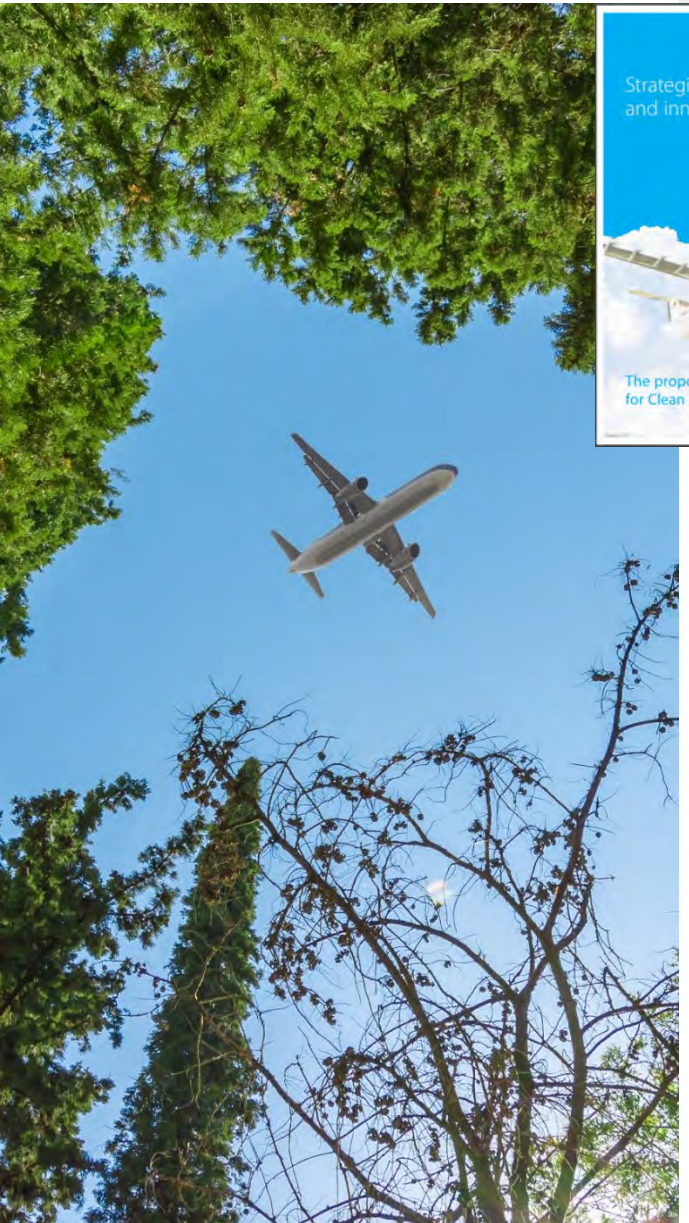
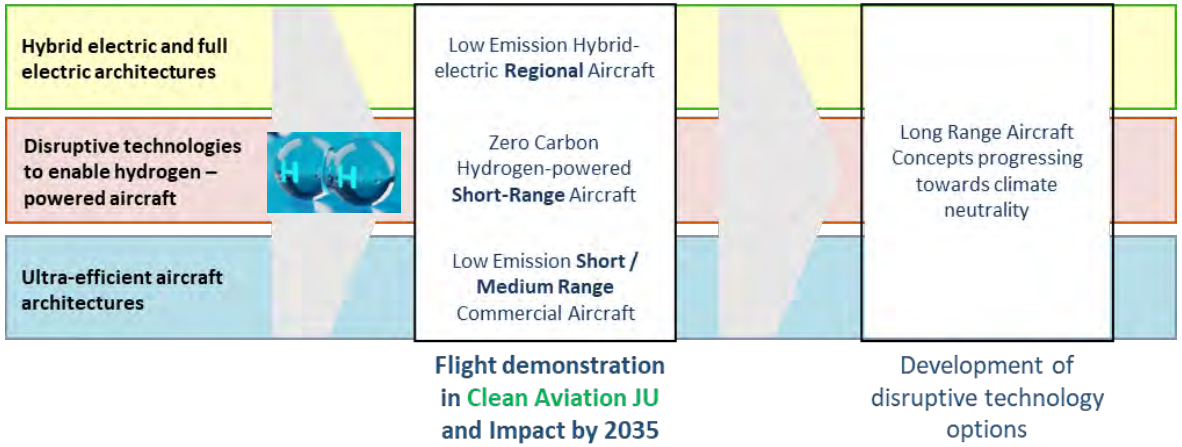
ICAS 2022 SWEDEN

“HYDROGEN-POWERED AIRCRAFT” THRUST CONTRIBUTION TO A CLIMATE NEUTRAL AVIATION





The Hydrogen-Powered Aircraft thrust represents a novel challenge targeting disruptive technologies to accelerate the transition towards a climate neutral aviation in line with the EU Green Deal ambition and SRIA objectives to:

- Mature a series of key technology developments matching requirements for carbon free short-range hydrogen fuelled aircraft platforms
- Demonstrate the potential of hydrogen as a fuel efficient, reliable and safe alternative energy source including certification aspects
- Implement a step by step phased approach in synergy with other relevant projects
- Target key ground demonstrations and permit to fly by 2026

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HYDROGEN CHALLENGE IN AVIATION

❖ Hydrogen presents several key advantages when considering aviation perspective as it allows for the elimination of CO_2 emissions in flight and along the entire life cycle if produced carbon-free

❖ Hydrogen lower volumetric energy density than conventional jet fuel requires the development of novel storage methods with a potential for higher energy density

❖ A coordinated effort is deemed necessary to overcome the current low TRL and demonstrate sufficient technology maturity for hydrogen direct burn and use in fuel cells to de-risk a future short-range application

❖ Liquid hydrogen burn in engines presents key challenges related to H_2 combustion technology, cryogenic pumping, thermal management and aircraft integration

❖ Fuel cells technology requires a scale-up effort aimed to deliver multi-MW power systems for aeronautical use

❖ Early EASA engagement in the projects will allow compliance with safety requirements to achieve permit to fly for the proposed options

❖ Opportunity to leverage other sectors technology and coordinate with other initiatives enabling hydrogen take over as a fuel option for aviation

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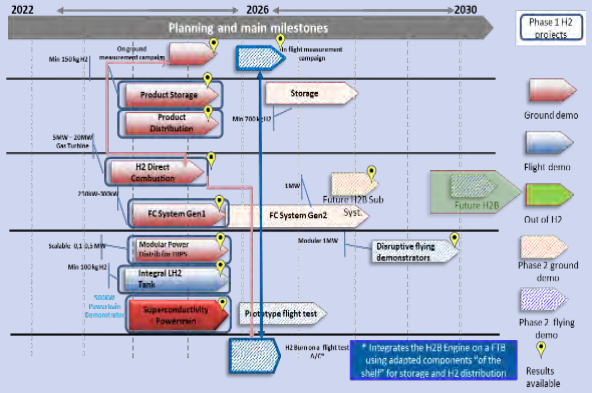
HYDROGEN POWERED AIRCRAFT ROAD MAP AND AMBITION

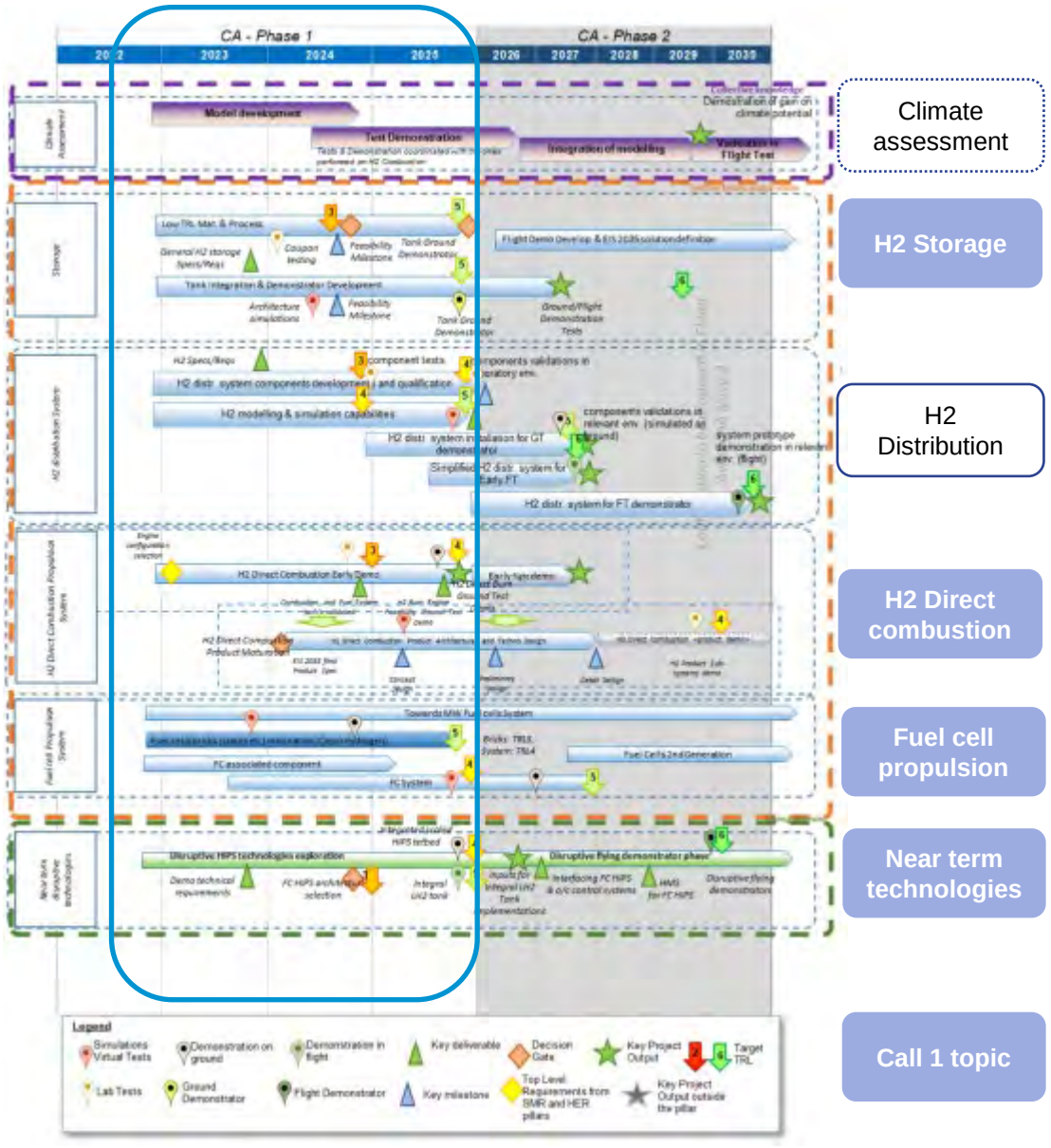
SRIA roadmap for H2 defining the key elements to be developed and matured addressing aircraft EIS 2035



4 topics / 182 M€

~ 25% Call 1 funding

Up to 7 projects



- Phase 1 intend to achieve a set of Ground demonstrations focused to prove the feasibility to develop and fly an H2 powered aircraft
- Workscope includes:
  - H2 direct combustion: donor engine envisaged to be adapted to H2 burn including engine/aircraft fuel systems to achieve TRL4 ground demonstration including emissions characterisation
  - Storage system development
  - Fuel cell propulsion system to be developed leveraging current state-of-art and aimed to multi MW solution
  - Fuel cells powertrain for small aircraft "Near term technology"
- Technology maturation targeting different aircraft platforms / aircraft concepts including climate impact, life cycle effects and certification (new means of compliance)
- Roadmap Leverage other initiatives and synergies (i.e. Clean Hydrogen JU)

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HPA RELATION TO OTHER THRUSTS “AN INTEGRATED APPROACH”

- Key focus:
  - PROPULSIVE SYSTEM DEVELOPMENT AND AIRCRAFT INTEGRATION
  - INDUSTRIAL FEASIBILITY AND GAPS
  - SAFETY ASPECTS AND FUTURE CERTIFICATION REQUIREMENTS
  - CLIMATE IMPACT ASSESSMENT
  - IMPACT MONITORING
- Challenge:
  - CURRENT LOW MATURITY OF A NUMBER OF H_2 TECHNOLOGIES
  - NON-CO_2 EMISSIONS ASSESSMEMENT
  - MANAGE TOPICS INTER-RELATIONS

HYDROGEN POWERED AIRCRAFT

Technology maturation and de risk in Phase 1 (2023 - 2025/26)

H2 Direct burn propulsion

H2 storage & distribution

H2 FC propulsion system

Clean Sky 2 Technology

ULTRA-EFFICIENT SMR AIRCRAFT

- Advanced ultra-efficient aircraft configuration and ultra-efficient engines also investigating SAF and H2
- Target to improve energy efficiency and fuel burn reduction
- Range and payload options up to 2000 NM/200 pax

HYBRID ELECTRIC REGIONAL AIRCRAFT

- Hybrid-electric propulsion also investigating H2 coupled with highly efficient aircraft configuration
- Target to improve energy efficiency and fuel burn reduction
- Range and payload options up to 1000 NM/100 pax

AIRCRAFT ARCHITECTURES & TECHNOLOGY INTEGRATION FOR A/C CONCEPTS

NEW CERTIFICATON METHODS AND MEANS OF COMPLIANCE

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CALL 1 HPA TOPIC

4 topics / 182 M€
~ 25% Call 1 funding

Call closed 23/6/22

Grants signed Dec 2022

HORIZON-JU-CLEAN-AVIATION-2022-01-HPA-01

Direct Combustion of Hydrogen in Aero-engines

Indicative funding: **115 M€**

Maximum # of projects selected: **2**

HORIZON-JU-CLEAN-AVIATION-2022-01-HPA-02

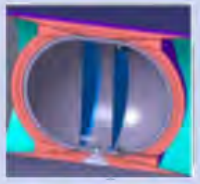
Multi-MW Fuel Cell Propulsion System for Hydrogen-Powered Aircraft

Indicative funding: **50 M€**

Maximum # of projects selected: **2**

HORIZON-JU-CLEAN-AVIATION-2022-01-HPA-03

Large Scale Lightweight Liquid Hydrogen Integral Storage Solutions



Indicative funding: **10 M€**

Maximum # of projects selected: **1**

HORIZON-JU-CLEAN-AVIATION-2022-01-HPA-04

Near Term Disruptive Technologies for Hydrogen-Powered Aircraft

Indicative funding: **7 M€**

Maximum # of projects selected: **2**

CALL 1 HPA TOPIC
“H2 DIRECT COMBUSTION”

HORIZON-JU-CLEAN-AVIATION-2022-01-HPA-01

Direct Combustion of Hydrogen in Aero-engines

- **Technology target:** TRL5 at combustion system level, **TRL4 at overall engine / propulsion system level** at project end (20 klbs / 5000 shp class)
- **Expected outcome:**
  - De-risk, mature, integrate and perform **first ground test of the propulsion system** technologies (fuel injection and delivery system, combustion chamber adaptation, controls) using a **turbofan/turboprop donor**; demonstrate technology, aircraft-engine integration, industrial feasibility and identify gaps versus new products; **achieve permit to fly by the end of phase 1**
- **Scope:**
  - Demonstrate technical feasibility mainly addressing the **combustion and fuel delivery system** ensuring at least **similar safety levels vs state of art drop in fuel technology**
  - Some complementary scope as NOx level and combustion stability, dual fuel operation, improved engine efficiency to enable tank integration, virtual flight test predictions
- **Performance targets:**
  - Specified at system, sub-system, component level to be defined vs state of art engines/systems, with analysis substantiating them together with means of progress monitoring
  - Targets complemented by maturity roadmap and development of critical components till 2030 for EIS 2035 in cooperation with other thrusts

Synergy path with SMR-01, HPA-03, TRA-01/02

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CALL 1 HPA TOPIC
“MULTI-MW FUEL CELL PROPULSION SYSTEM”

HORIZON-JU-CLEAN-AVIATION-2022-01-HPA-02

Multi-MW Fuel Cell Propulsion System for Hydrogen-Powered Aircraft

- **Technology target:** TRL 3 at subsystem/component level as minimum entry point and at least **TRL4 at subsystem level at project end**
- **Expected outcome:**
  - Demonstrate the **scalability up to multi-MW level** (2-4 MW) of fuel cell usage as power source/electricity generation in a complete **and integrated propulsion system** to be tested on ground, optimized for aircraft application and designed consistently with qualification (system availability, reliability, durability), certification and safety principles
  - Subsystems: **hydrogen distribution, H2 tank, air supply, power electronics / electrical, thermal management**. Identify gaps vs new product development, aircraft integration, certification. Investigate system availability, reliability and durability and perform ground demonstrator of a generic system.
- **Scope:**
  - Main focus on “**Electric motors on wing + LH2 Fuel Cells**” (regional application full electric, 50 pax). Other hybrid concepts are covered by other topics in HER
- **Performance targets:**
  - To be defined, vs targets vs state of art solutions, developed and specified at system, sub-system, component level, with analysis substantiating them together with means of progress monitoring
  - Targets complemented by maturity roadmap and development of critical components till 2030 in cooperation with other thrusts

Synergy path with HER-01, HPA-03, SMR-01, TRA-01/02, Clean Hydrogen JU

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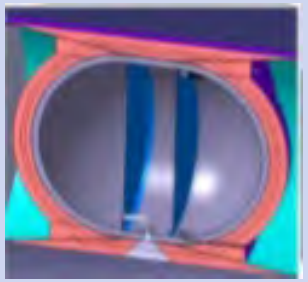
CALL 1 HPA TOPIC
“LH2 INTEGRAL STORAGE”

HORIZON-JU-CLEAN-AVIATION-2022-01-HPA-03

Large Scale Lightweight Liquid Hydrogen Integral Storage Solutions



- **Technology target:** TRL 3 at subsystem/component level as minimum entry point and at least **TRL5 at tank system level** at project end (ready to support flight test in Phase 2)
- **Expected outcome:**
  - Develop a **large scale integral LH2 storage solution** and perform **ground demonstration**
  - Develop a detailed roadmap defining the key enablers and actions needed for a large-scale concept including **compatibility with future hydrogen-powered aircraft concepts** for Phase 2 with target to deliver TRL6 at aircraft level by the end of the program
- **Scope:**
  - To adapt LH2 storage solutions for aircraft environment, including safety aspects and certification
  - Propose integral and conform solutions to optimize aircraft integration aspects
- **Performance targets:**
  - To be defined, vs targets vs state of art solutions, developed and specified at system, sub-system, component level, with analysis substantiating them together with means of progress monitoring
  - Targets complemented by maturity roadmap and development of critical components, including scalability requirements (up to 600 kg), till 2030 in cooperation with other thrusts

Synergy path with HPA-01, HPA-02, SMR-01, HER-01, TRA-01/02, Clean Hydrogen JU

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CALL 1 HPA THRUST TOPIC
“NEAR TERM DISRUPTIVE TECHNOLOGIES “

HORIZON-JU-CLEAN-AVIATION-2022-01-HPA-04

Near Term Disruptive Technologies for Hydrogen-Powered Aircraft

- **Technology target:** TRL 3 at subsystem/component level as minimum entry point and **TRL5 at project end**
- **Expected outcome:**
  - Ground test demonstration of a scaled integrated flight-ready 500 kW Fuel Cell Power Train (virtual flight test including cryo-enabled thermal management).
  - Flight test demonstration of small-scale 100 kg LH2 integral tank implemented in airborne environment. Roadmap towards adoption of H2 in gas turbine or fuel cells
  - Roadmap towards TRL6 demonstration at aircraft level by end of the program.
- **Scope:**
  - **Integrated propulsion system TRL5 at overall propulsion system level**
  - **Storage system level TRL5 through flight test**
  - De-risk future solutions addressing small aircrafts
- **Performance targets:**
  - To be defined, vs targets vs state of art solutions, developed and specified at system, sub-system, component level, with analysis substantiating them together with means of progress monitoring
  - Targets complemented by maturity roadmap and development of critical components till 2030 in synergy with HER

Synergy path with HER-01, TRA-01/02

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CONCLUSIONS

- Hydrogen is considered a very promising enabler for emissions reduction for the aviation sector but quite novel challenge in the field of propulsion technology, aircraft design and certification
- Clean Aviation will develop projects targeting disruptive technologies to enable the exploitation of hydrogen as a non-drop-in zero carbon energy source to enable short range hydrogen powered commercial flight
- Call 1 projects will support a series of ground demonstrators by 2025-26 to be further exploited targeting aircraft EIS 2035
- Close cooperation and constant alignment with SMR and HER thrusts will be implemented from projects start, in coordination with Transverse projects harmonizing aircraft concepts, certification and impact monitoring
- HPA will profit from EASA involvement from the early phases to contribute to assess the certification issues of the proposed solutions
- Call 2 will cover additional tasks required to prepare Phase 2
- Close cooperation with other EU and national programs will ensure coherent developments with required capabilities and ground infrastructure

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