

ZERO EMISSION FLIGHT INFRASTRUCTURE

The Zero Emission Flight Infrastructure Programme

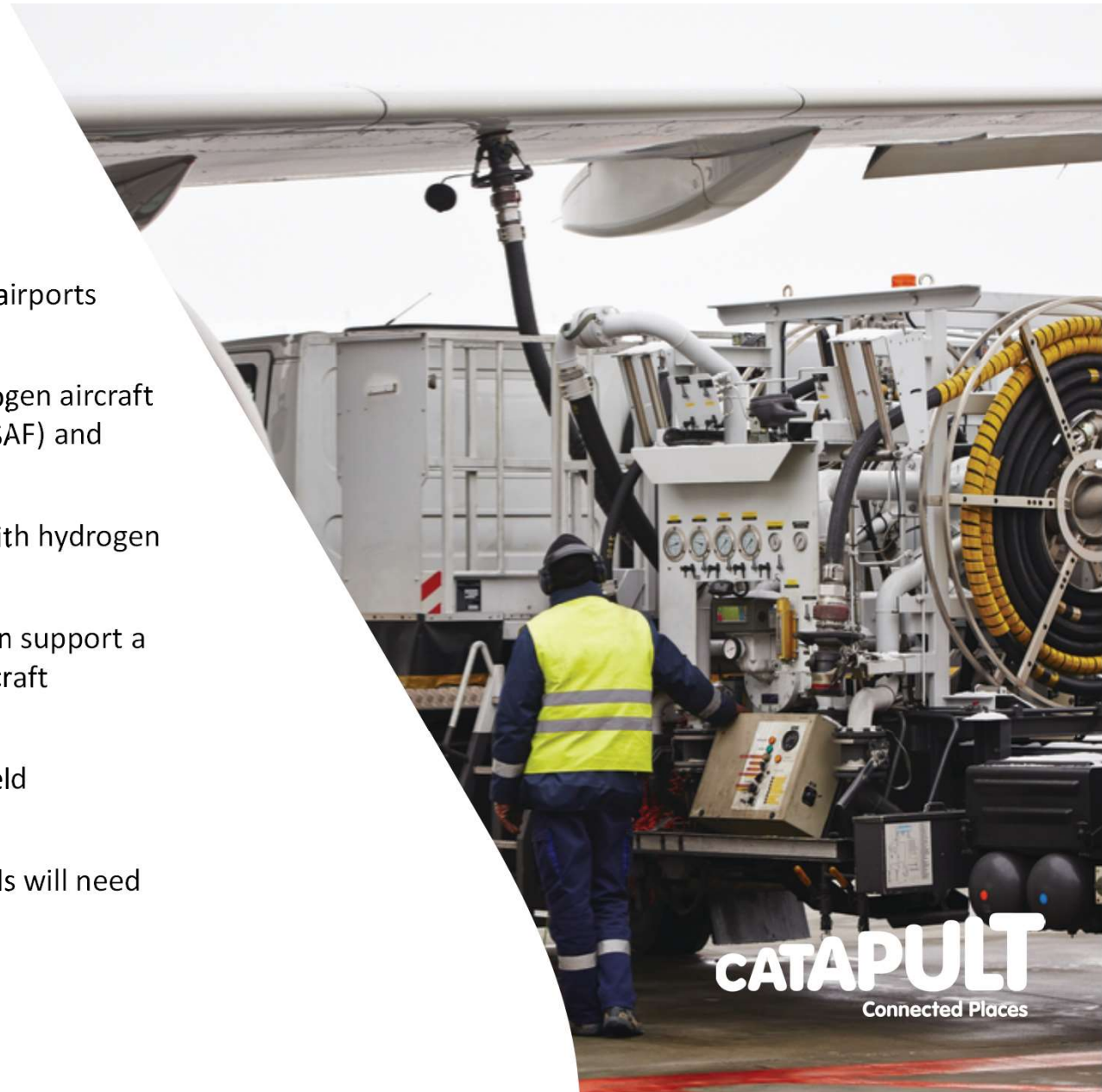
4th International Hydrogen Aviation Conference, 7th September 2023

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The challenge

- Introducing new and sustainable aviation fuels into airports brings with it new challenges
- We expect a mixed economy with electric and hydrogen aircraft operating alongside existing gas turbine (kerosene/SAF) and internal combustion (Avgas)
- Current fuel infrastructure will not be compatible with hydrogen and electric propulsion aircraft
- UK airports and airfields will need to ensure they can support a range of different aircraft fuel types to suit their aircraft operators
- This will add complexity to existing airport and airfield operations
- New infrastructure, operational procedures and skills will need to be developed to service new aircraft types



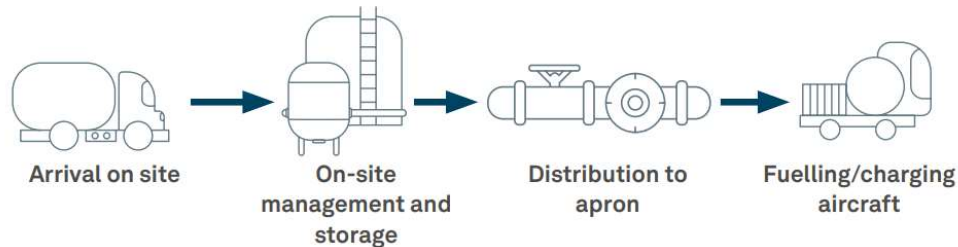
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ZERO EMISSION FLIGHT INFRASTRUCTURE PROGRAMME

Goal : To explore the impact and requirements for fuelling infrastructure to introduce hydrogen and electric aircraft into airports and airfields



PROJECT SCOPE



Year One of the programme was split in to three projects; Research, Demonstrations & Innovation Grants

- A **detailed study** addressed the following areas for introducing zero emission aircraft into airports.
 - Use cases for different types of airfield and airports
 - A operational concept blueprint for all technologies that can be applied for ZEFI
 - A technology roadmap showing the expected availability of infrastructure and operational integration
 - Standards analysis landscape and standards roadmap
- We funded 3 **demonstrations** to showcase more mature technologies in airside operational environments at airports and airfields.
- A **Transport Research and Innovation Grant: Zero Emission Flight (TRIG:ZEF)** competition for 14 projects each receiving up to £50k funding each.

ZEFI YEAR 1 OUTPUTS

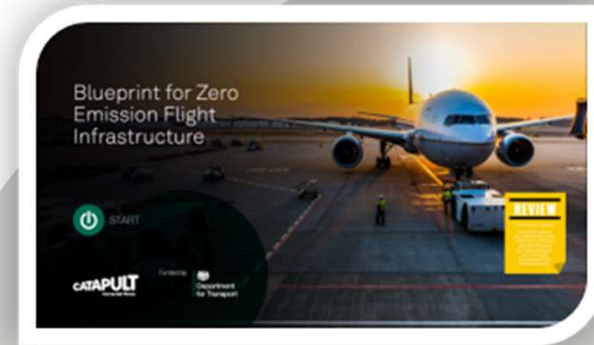


ZEFI White Paper
September 2021

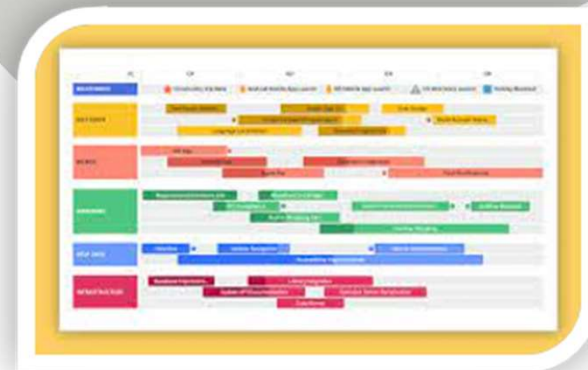


Airports & Airfields Case Studies
March 2022

Project website: <https://cp.catapult.org.uk/project/zero-emission-flight-infrastructure-preparing-uk-airports-for-zero-emission-aircraft/>



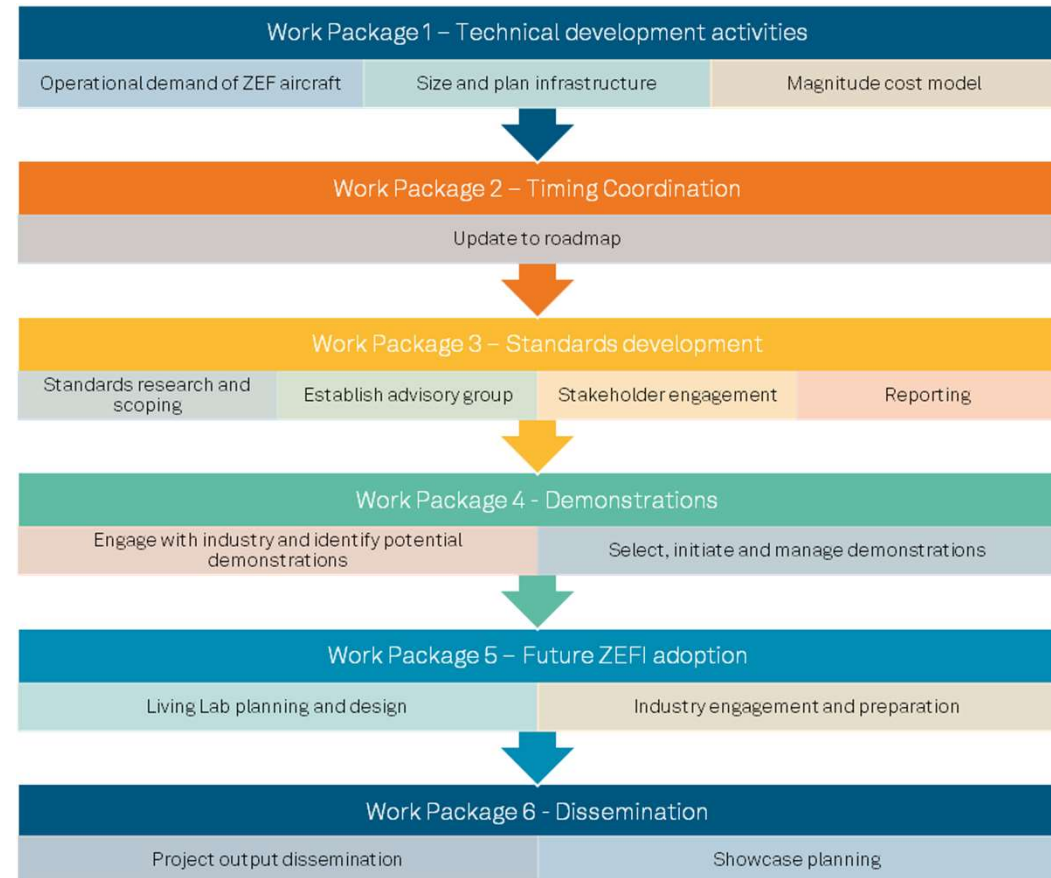
Blueprint for Zero Emission Flight Infrastructure
March 2022



ZEFI Roadmaps – Hydrogen & Electric
March 2022






ZEFI 2 OBJECTIVES

- Provide **an understanding of scale and cost for realistic pathways** for airfield and airport infrastructure to support the transition to zero emission flight (ZEF) aircraft operations. This includes capturing energy demand, fuelling technology capabilities, and order of magnitude costs.
- Provide outputs to an **updated hydrogen roadmap** of the expected availability of the capabilities with reduced uncertainty as development of technology matures.
- Create and ensure the **self-sustaining status of standards governance** and development for the design, operation, and certification of ZEFI
- Enable industry to showcase near to market technology through **demonstration(s), disseminating outputs to increase knowledge base in industry of technologies.**

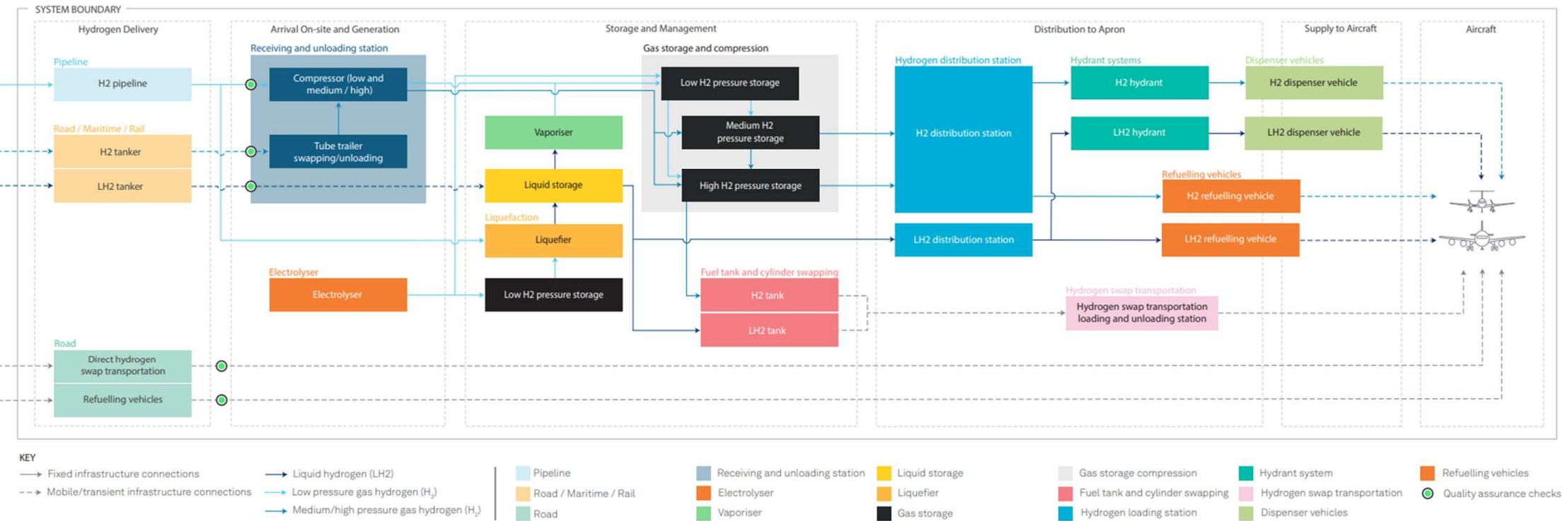


HYDROGEN INFRASTRUCTURE OPTIONS FOR AIRPORTS

- Liquid hydrogen the most viable future fuel source for ZEF
- Identified suitable infrastructure for different sizes of airports and airfields - 'archetypes'
- Considered from arrival of hydrogen fuel at the airport or airfield, through to the connection to the aircraft
- Airports with scheduled commercial flights, including Public Service Obligation (PSO) flights
- Hydrogen-fuelled conventional take-off and landing (CTOL) fixed-wing aircraft

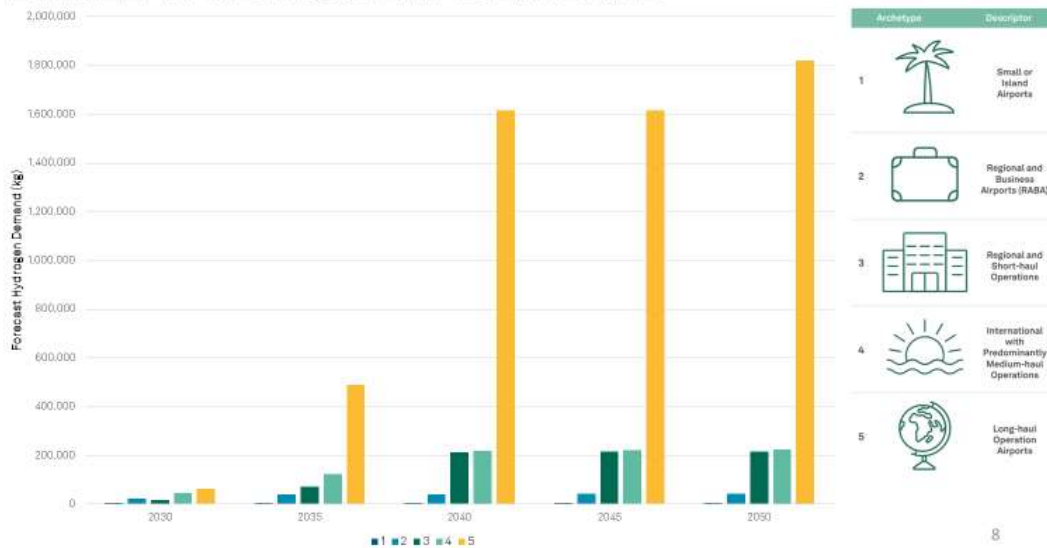
| Archetype | Descriptor | Pax (approx.) | Other Defining Factors |
|-----------|---|------------------|---|
| 1 |  Small or Island Airports | < 150,000 | <ul style="list-style-type: none"> • Small or island airport and airfields, including those from Regional and Business Airports Group (RABA) Trade Body • The only airport for an entire island or community • The primary or only way of accessing the location it serves, potentially receiving Public Service Obligation Flights (PSOs) |
| 2 |  Regional and Business Airports (RABA) | < 2 million | <ul style="list-style-type: none"> • All RABA airports, except those that fit into Archetype 1 (island airports) and Archetype 3 (regional and short-haul operations) |
| 3 |  Regional and Short-haul Operations | 2-5 million | <ul style="list-style-type: none"> • Larger-scale operation RABA airports, i.e. those that do not fit into Archetype 1 or 2 |
| 4 |  International with Predominantly Medium-haul Operations | 5-20 million pax | <ul style="list-style-type: none"> • Up to approximately 200,000 aircraft movements a year |
| 5 |  Long-haul Operation Airports | > 30 million pax | <ul style="list-style-type: none"> • International focus with intercontinental flights • Approximately > 200,000 aircraft movements a year |

SYSTEM ARCHITECTURE



IMPLEMENTATION REQUIREMENTS

DAILY HYDROGEN DEMAND



- As UK aviation transitions to a hydrogen future, airports and airfields face a number of challenges and constraints
- Changes will not be limited solely to the refuelling infrastructure
- Consideration must be given to the implications on some of the wider enabling systems, such as:
 - billing and metering
 - safety management
 - emergency response
- More information can be found in the CPC Hydrogen Infrastructure Options for Airports: Supplementary Report

KEY FINDINGS



Arrival on site

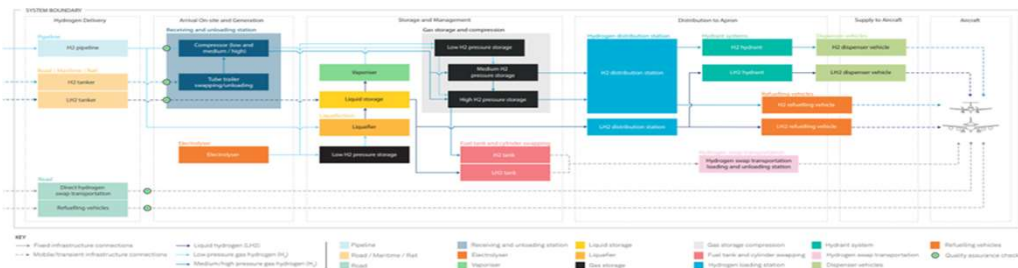
- Where demand is low, and delivery is viable, direct gaseous or liquid refuelling is optimal
- Where it is not possible to produce liquid hydrogen, then liquid tanker and liquid hydrant delivery become optimal
- If space is at a premium, then liquid tanker and liquid refueller pathways are optimal
- The UK's largest airports will not be possible to use tankers – instead they will require a pipeline

Reducing Space Requirements

- Hydrogen storage often takes up the most space for a particular system
- Whilst more energy-dense forms of storage can help to reduce the footprint, a trade-off is required
- Liquid hydrogen pipelines may be required for the bigger airports to move the liquefaction offsite

Other considerations

- Onsite electrolysis is only feasible for the smallest airport archetypes
- For Archetypes 1-4 the annual OPEX is nearly as high as the total CAPEX for many pathways

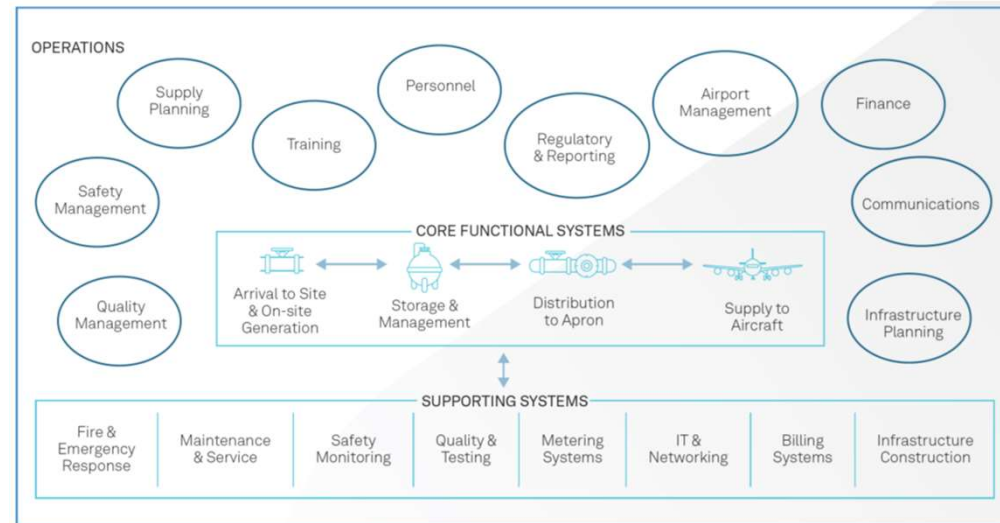


KEY CHALLENGES

| Archetypes | Key challenges |
|------------|---|
| All | Safety distances Human Factors Operating Hydrogen and Kerosene/SAF in Parallel Regulatory Approval |
| 1 - 2 | Logistics |
| 3 - 4 | Space |
| 5 | Hydrogen Demand |

Roadmap and timing

Standards



ZEF AIRPORT OF THE FUTURE

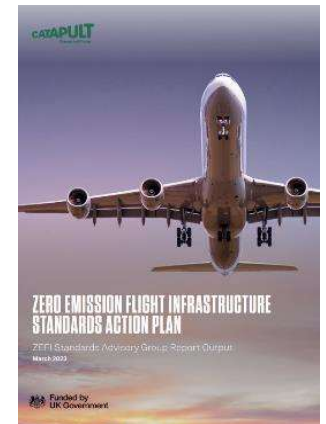
Future energy and fuel systems will operate in parallel within the airport environment, providing a selection of technologies suited for different aircraft and routes



WEB LINKS TO REPORTS

<https://cp.catapult.org.uk/programme/preparing-uk-airports-for-zero-emission-aircraft/>

- Zero Emission Flight Infrastructure – Hydrogen Infrastructure Options For Airports
- Zero Emission Flight Infrastructure – Hydrogen Infrastructure Options For Airports: Supplementary Report
- Zero Emission Flight Infrastructure – Roadmap Update
- Zero Emission Flight Infrastructure: Standards Action Plan
- Zero Emission Flight Infrastructure: Demonstration Summary Report



THANK YOU

Any Questions?

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