10th December 2024

AVIATION DECARBONISATION: ISSUES, CHALLENGES AND ACTIONS FOR CHANGE

I-SEE Sustainable Energy & the Environment webinar
10th December 2024

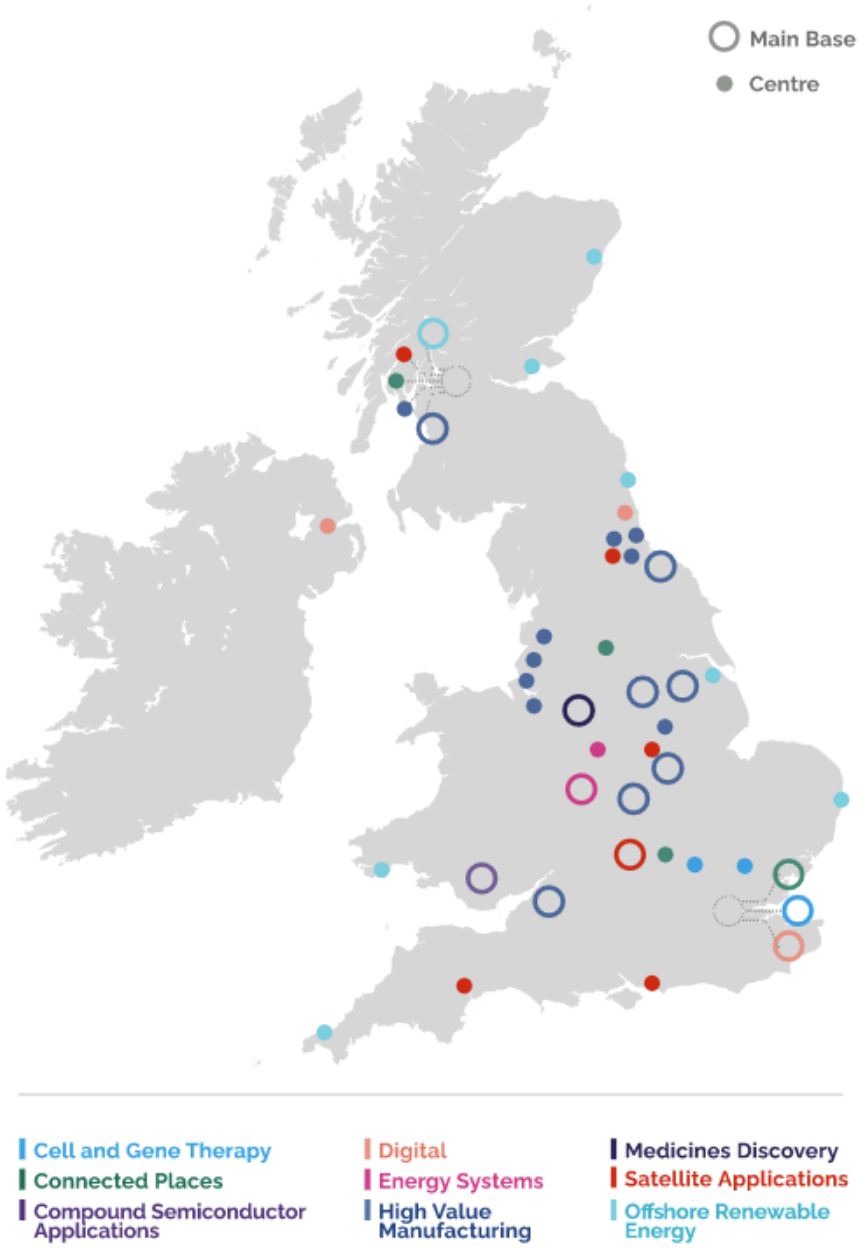
Andrew Chadwick
Ecosystem Director Air Mobility & Airports

CATAPULT
Connected Places

CONNECTED PLACES CATAPULT

Connected Places Catapult is the UK's innovation agency for transport, the built environment, and local growth.

- The Catapult Network brings together nine leading technology and innovation centres spanning over 40 locations across the UK.
- We are independent not-for-profit private organisations transforming the UK’s capability for innovation in sectors of strength.
- The Connected Places Catapult is one of the nine centres, leading in fields such as Mobility, Built Environment, Critical Infrastructure, Health & Wellbeing, Public Places and Decision Making.



CONNECTED PLACES CATAPULT IS THE UK'S INNOVATION AGENCY FOR TRANSPORT, THE BUILT ENVIRONMENT, AND LOCAL GROWTH

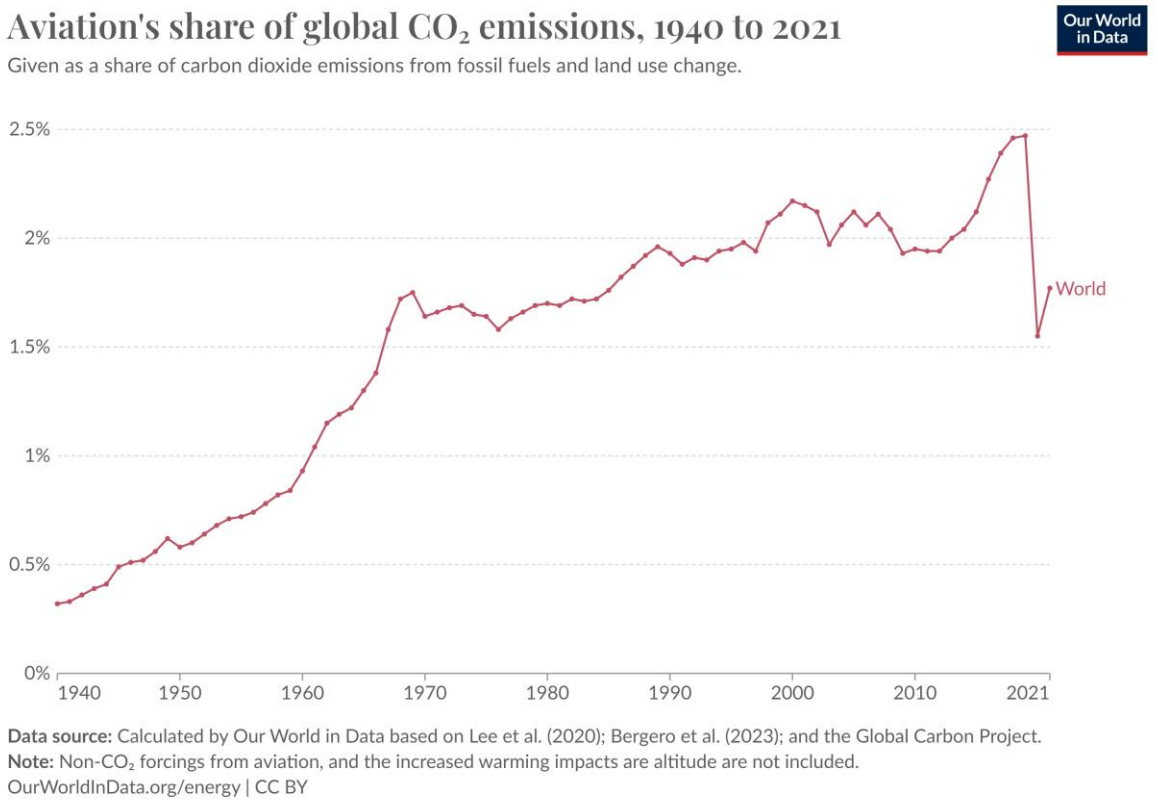
A neutral, independent, trusted, expert convenor

Our vision is better connected places across the UK; places that are more sustainable, regenerative and resilient, with prosperous economies, and thriving communities.

We work with our partners to bridge the gap between innovation and the market so that the opportunities of innovation can be adopted and scaled in communities, towns, and cities across the country.

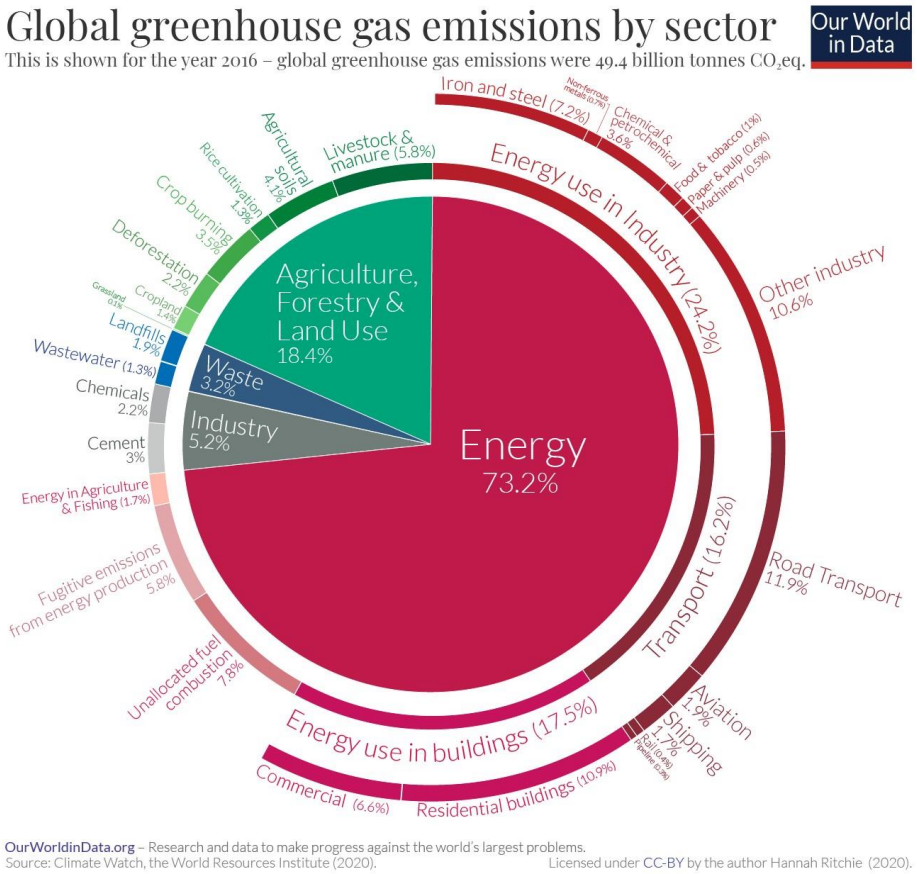
WHY DECARBONISE

- Global CO2 emissions from aviation have quadrupled since the 1960s
- Aviation accounts for 2.5% of global emissions, but 5% of total global warming
  - This figure does not take into account non-CO2 effects.



WHY DECARBONISE

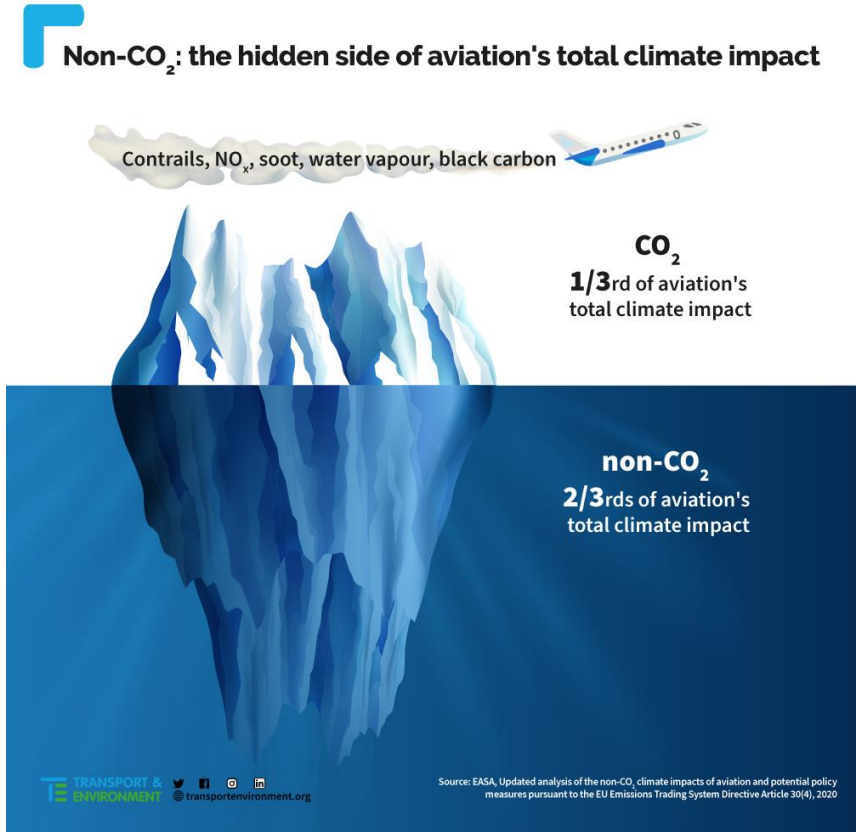
- Aviation’s share of global emissions is likely to rise as other sectors decarbonise faster. It is one of the hardest sectors to decarbonise
- CO2 emissions from aviation have reached 80% of their pre-pandemic peak
- Global demand will grow in the coming decades. Therefore, unless we can accelerate improvements in energy efficiency and switch to low-carbon fuels, our emissions will continue to grow.
- So far, the sector has made almost no progress.



WHY DECARBONISE

Non-CO2 effects

- Non-CO2 effects account for between 1/2 and 2/3 of radiative forcing, which means that the role of commercial aviation accounted for around 5% of global warming between 2000 and 2018.
- Contrails, cirrus cloud formation and the release of water vapour and NOx at high altitudes have a positive effect on radiative forcing (i.e. a warming effect), as the IPCC pointed out in its latest report

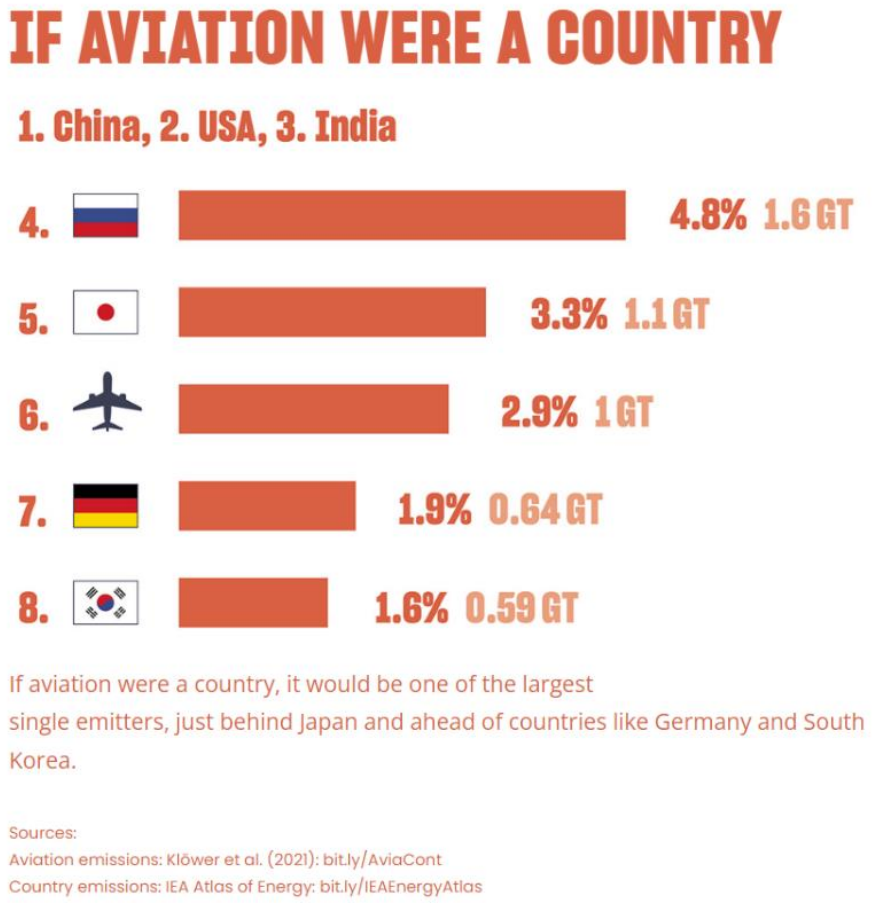


Source: Non-CO2 related climate effects from flight: Can't we just walk quietly through the doors? Stay grounded, April 2021

WHY DECARBONISE

Of note

- 1% of the world's population accounts for 50% of aviation emissions
- 80% of the world's population has never flown before
- Carbon footprint - 22 tonnes for the wealthiest 1% of EU households (air transport only)
- A flight in a private jet emits on average 10x more greenhouse gases than a commercial flight (per passenger)



Source: Common Destination, Stay Grounded / Kollektiv Periskop, 2022

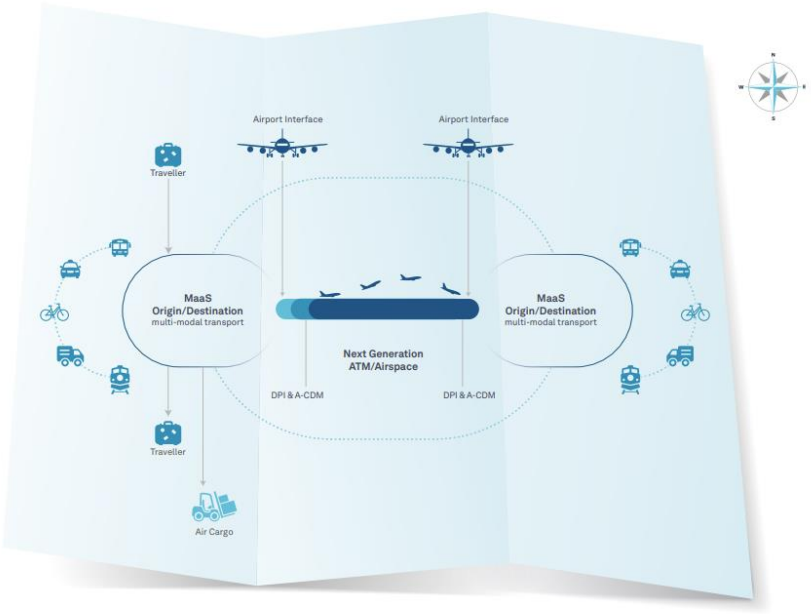
HOW CAN THIS BE ACHIEVED

Airport operations account for 5% - 6% of emissions

- Surface access
- Terminal
- Airside operations

Aircraft operations account for 94% to 95% of emissions

- Reduce aircraft fuel emissions
- Introduce new aircraft technologies & fuels
- “Smarter” airspace management
- Carbon capture & recycling
- Other non-technical solutions



WHAT DOES THIS MEAN IN PRACTICE?

- Our energy must be sourced from renewable sustainable sources
- Move from jet fuel to electrification, power-to-liquid eFuels, hydrogen, or a combination
- Novel propulsion technologies
- Initiatives to decarbonise airport operations across all the campus
- More efficient use of airspace
  - More continuous climb and descent operations
  - More direct routes across UK airspace
  - Reduced airborne holding time at destination airports
  - Working with neighbouring air traffic control providers and military airspace users to deliver more direct routes
  - Achieving or exceeding the customers preferred cruise level
  - Taking non-CO2 effects in route management

POLICY TO SUPPORT THIS

- UK Jet Zero Strategy, 2022
- UK Jet Zero Council (2022)
  - Sustainable Aviation Delivery Group
  - Zero Emission Flight Delivery Group
  - UK Jet Zero Task Force (2024)
- 2040 zero emissions airport target for English Airports
  - Consultation 2023
- Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)
- US Inflation Reduction Act
- UK SAF mandate – “10% of all jet fuel in flights taking off from the UK comes from sustainable sources by 2030”

EXAMPLE INITIATIVES

UK

- Zero Emission Flight Infrastructure programme
- Zero Emission Airports programme
- ATI Fly Zero programme
- ATI Hydrogen Capability Network
- Project NAPKIN
- Sustainable Aviation
- Hydrogen in Aviation Alliance

EU

- ACI EUROPE Airport Carbon Accreditation programme
- Alliance for Zero-Emission Aviation
- Clean Aviation
- TULIPS
- hOListic & Green Airports (OLGA) project
- Project Stargate

ZERO EMISSION FLIGHT INFRASTRUCTURE

What are the requirements for fuelling infrastructure to introduce hydrogen and electric aircraft into airports and airfields?

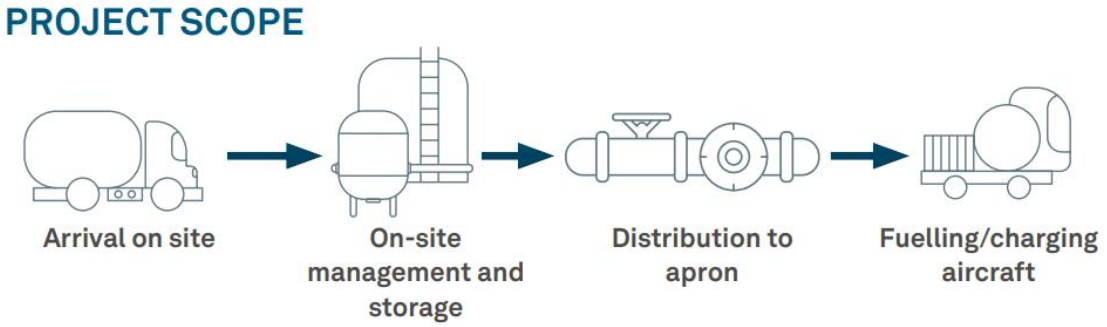
CATAPULT
Connected Places

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

ZERO EMISSION FLIGHT INFRASTRUCTURE PROGRAMME

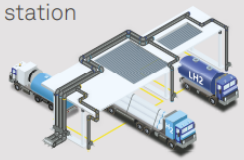
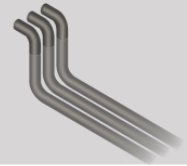
Goal : To explore the impact and requirements for fuelling infrastructure to introduce hydrogen and electric aircraft into airports and airfields



- A detailed study addressed the following areas for introducing zero emission aircraft into airports.
  - Use cases for different types of airfield and airports
  - An operational concept blueprint for all technologies that can be applied for ZEFI
  - Technology roadmaps showing the expected availability of infrastructure and operational integration
  - Standards analysis landscape and standards roadmap
  - Assessed the scale of realistic pathways for hydrogen infrastructure
  - Formed the Standards Advisory Group (SAG)
- 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.

BLUEPRINT FOR ZERO EMISSION FLIGHT INFRASTRUCTURE

- Outlines the options for fundamental infrastructure changes, presenting technologies and subsystems for airport and airfield operators to consider
- Presents a menu of options focussing on the technical features of each technology or subsystem
- Highlights the graduated transition for infrastructure to support ZEF, key challenges and interventions.

Subsystem	Description	Components
18. Liquid storage 	Liquefied hydrogen is stored in the insulated tank. Pressure and temperature are monitored, and the pressure is released through a pressure release valve.	• Loading inlet. • Cooler. • Insulated LH2 storage vessel. • Outlet for LH2 unloading. • Process management equipment. • Pressure safety valve [61]. • Vaporiser.
19. Hydrogen loading station 	Fuel filling station in bowsers/ refueller truck. Quality control is undertaken at the loading station, e.g., checking the purity of the fuel, required pressure, and temperature.	• Compressor for Gaseous H_2 loading. • Hydrogen pump for LH2 pumping [67]. • Gaseous H_2 loading hoses. • LH2 insulated loading hoses. • Metering system. • Quality control. • Deadman. • Grounding cable.
20. Hydrogen hydrant systems 	Fuel is transferred from the fuel storage (fuel farm) via the underground pipeline network to fuel dispensing hydrants on the apron.	• Gaseous H_2 underground pipeline. • LH2 underground pipeline. • Gaseous H_2 hydrant risers. • LH2 hydrant risers. • Emergency shut-off mechanism. • Pressure release valves.

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

ZERO EMISSION AIRPORTS (ZEA) PROJECT BACKGROUND

In the **Jet Zero Strategy**, the UK Government committed to several key milestones on the way to **net zero aviation emissions by 2050**.

In addition, airports and other organisations have committed to their own decarbonisation ambitions.

To achieve these aims, we need innovation in:

Infrastructure to support zero-emission flight.

Solutions to decarbonise airport operations.

ZEA 23/24

Zero emission aircraft.

Sustainable Aviation Fuels (SAFs).

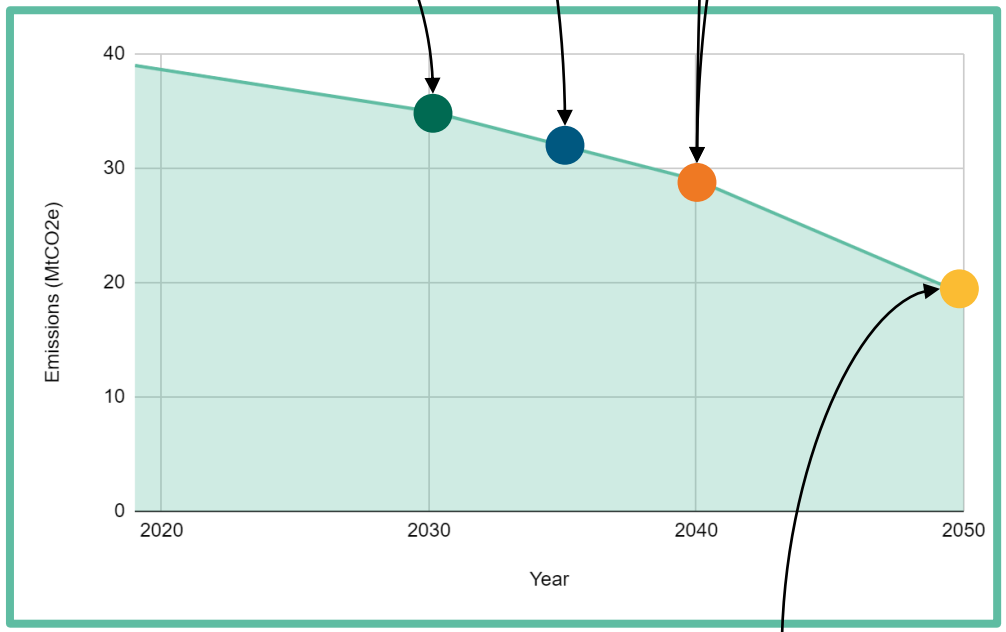
Carbon markets and removals.

First large zero emission commercial aircraft entry into service by 2035.

All UK domestic flights net zero

At least 10% SAF in UK aviation fuel mix

All airport operations in England zero emission



Source: Jet Zero Strategy, UK Government

In-sector interim target of 19.3MtCO_2e

ZEA – KEY QUESTIONS TO ANSWER

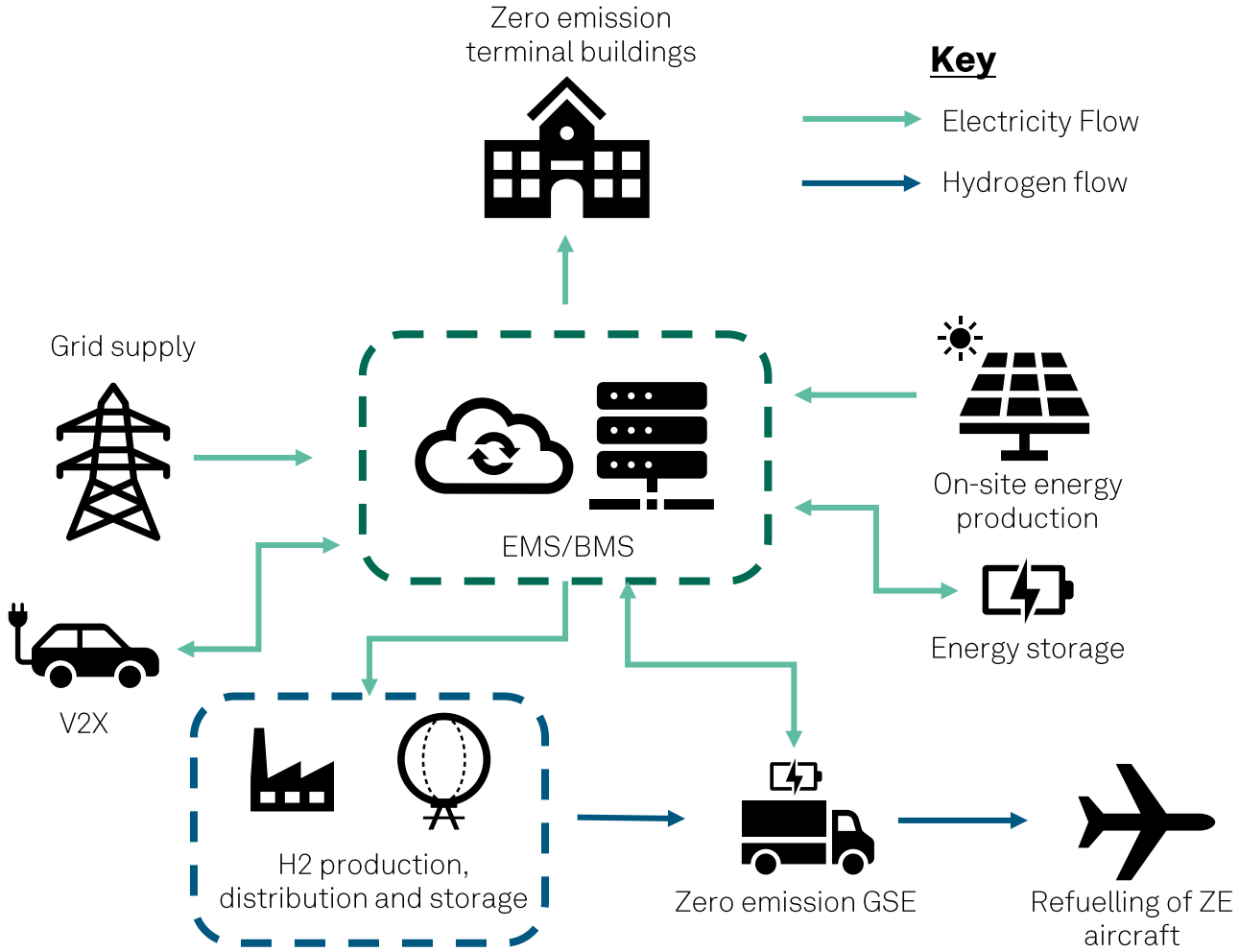
1. What are the **research challenges** preventing the decarbonisation of airports and infrastructure to support ZEF?
2. How can airports begin to **prepare for the introduction of ZEFI**?
3. What are the **standards priorities for ZEFI**? What can we address in the next 12-24 months?

RESEARCH CHALLENGES

What are the research challenges preventing the decarbonisation of airports and infrastructure to support ZEF?

CATAPULT
Connected Places

OUR ZEA VISION



Key components of our ZEA vision:

- **Energy management system** balancing multiple energy vectors.
- Onsite **energy storage and renewable generation** to reduce peak demand on the grid.
- **Zero emission Ground Support Equipment** (GSE).
- **Zero emission terminal buildings** (e.g. electrified heating).
- Use of **V2X** services to manage energy loads and provide revenue generating ancillary services to the grid.
- **Hydrogen storage and distribution** for zero emission aircraft and other use cases (e.g. GSE, HGVs, backup power and for heat).

Core challenge themes

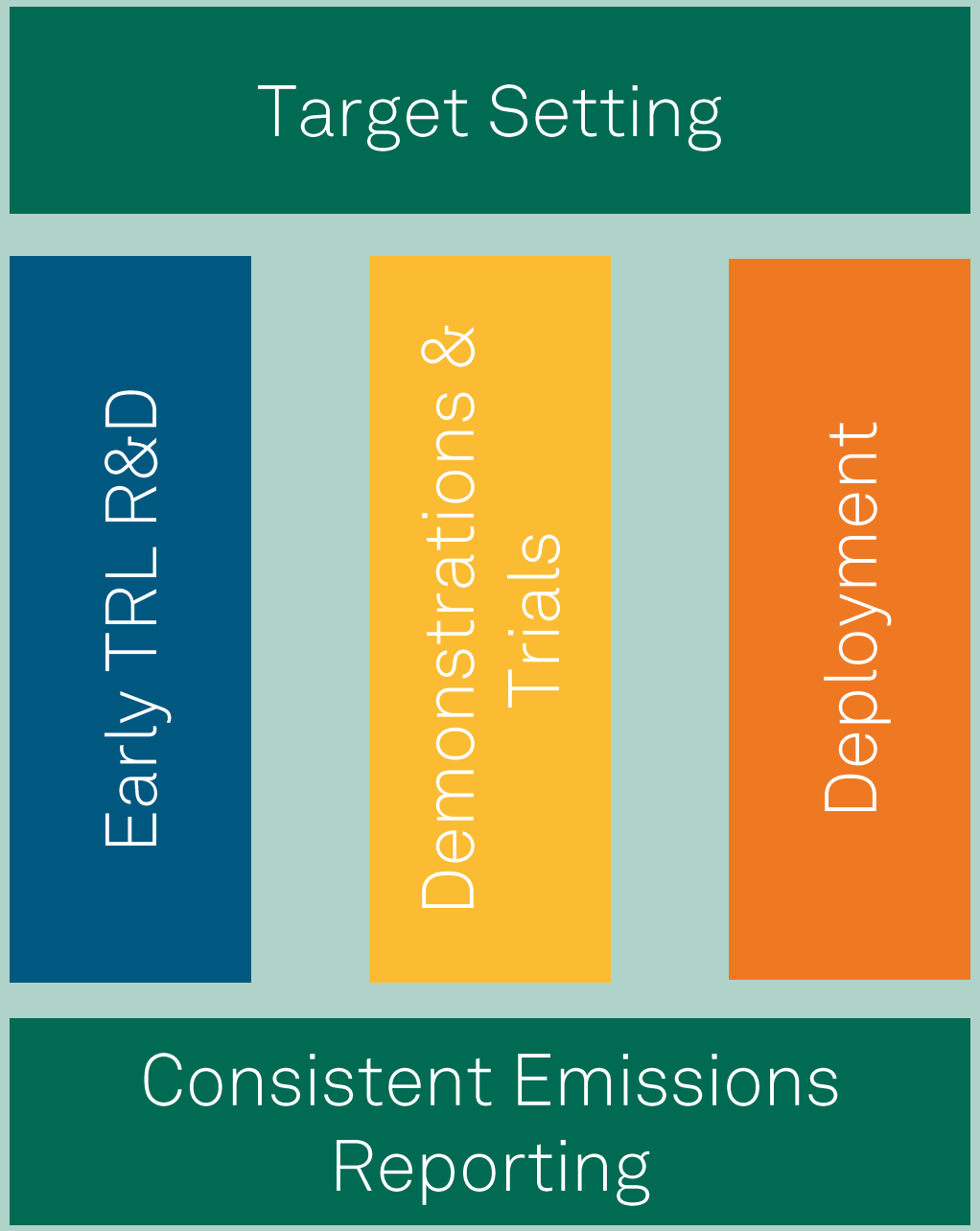
Theme 1: Improving visibility of energy use and enabling better management of energy to inform optimised system and operational design.

Theme 2: Informing fleet and infrastructure upgrades, operational changes, and staff behaviour for zero emission GSE.

Theme 3: Improving the consistency of emissions reporting to ensure fit for purpose emissions data.

Theme 4: Improving the understanding of airport requirements and building the safety case to support the adoption of hydrogen at airports to service zero emission flight.

ACTIONS TO OVERCOME BARRIERS



ZEFI TRANSITION PLAN

How can airports begin to prepare for the introduction of ZEFI?

CATAPULT
Connected Places

THE DRAFT TRANSITION PLAN IS STRUCTURED INTO SEVEN CHAPTERS TO ASSESS THE TECHNICAL, REGULATORY, AND ECONOMIC ASPECTS OF HYDROGEN AIRCRAFT AT AIRPORTS.

Net zero targets	1	Identifies the latest net zero targets established and explores how these targets may influence the decision-making of airports in relation to their approach to decarbonisation. This Chapter sets the scene for why the transition towards zero-carbon emission aircraft is critical.
Regulations and standards	2	Summary of global and national standards, also highlighting gaps in the current regulations to enable a safe transition towards zero-carbon emission flight (ZEF).
Hydrogen demand	3	The first step for airports to understand the level of infrastructure they may require and the potential timelines for implementation, is to understand the level of hydrogen demand. Chapter 3 provides a step-by-step top-down methodology to develop hydrogen forecasts for airports.
Infrastructure requirements	4	Provides a high-level overview of the key hydrogen technologies relevant for airports, along with a comparative matrix for hydrogen supply and refuelling infrastructure. The matrix supports airports establish which infrastructure and operational pathway best suits their hydrogen demands and site conditions. A step-by-step methodology on how to estimate the major infrastructure requirements is also included.
Master planning considerations	5	Guidelines for airports to identify a suitable area to develop hydrogen infrastructure. A Roadmap is also presented, showcasing the list of activities and dependencies between them, key milestones and potential timelines for implementation.
Operational considerations	6	Identifies the most significant operational challenges and safety risks for the operation of hydrogen at an airport, along with the necessary mitigation actions, enabling airports to identify the steps they need to take in the short, medium and long term to reduce the risks and to enable the transition.
Costs	7	Provides rough order of magnitude capital and operational costs for the different hydrogen infrastructure elements to enable airports to estimate, indicatively, the total costs of implementation of the different supply pathways.

CATAPULT Connected Places

STANDARDS DEVELOPMENT

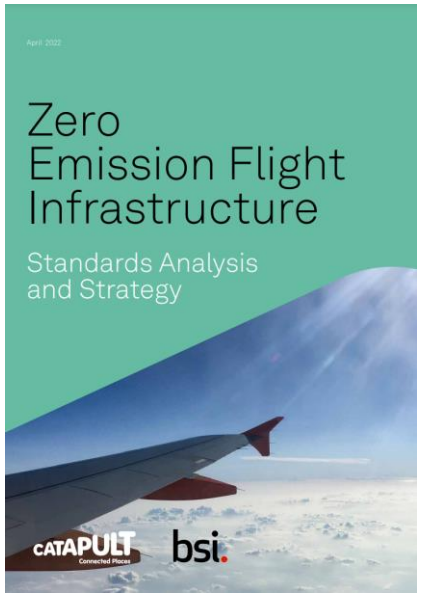
What are the standards priorities for ZEFI?

CATAPULT
Connected Places

ZEFI STANDARDS OUTPUTS

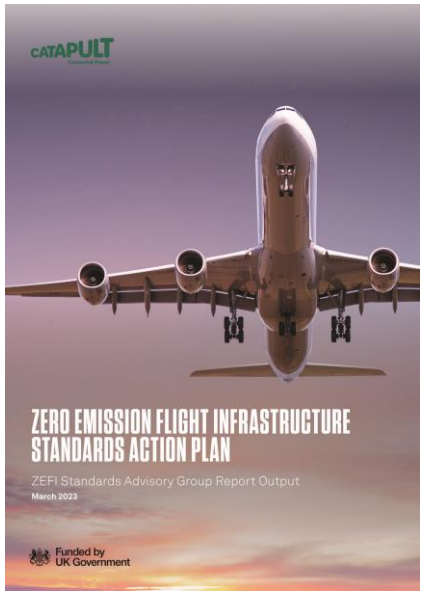
ZEFI Phase 1 – Standards Analysis and Strategy

- Standards gap analysis for Zero Emission Flight Infrastructure
- Stakeholder workshops to validate findings
- Identified around **553 relevant standards**. Just over 20% were deemed as potentially applicable for ZEFI applications, with many needing adaptation to suit the airport environment.



ZEFI Phase 2 – Standards Action Plan

- ZEFI Standards Advisory Group formed
- Standards action plan developed to agree initial standards priorities



STANDARDS HEATMAP – ZEFI

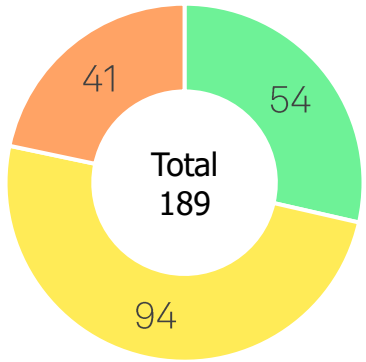
On-site production	Storage	Distribution	Supply to aircraft	Governance
Electrolysis	Liquefaction	Loading and transport	Hydrogen refuelling vehicles	Safety
Gasification	Liquid or gas storage	Distribution network	Fuel Hydrant System	Security
Purification and Quality Control	Chemical storage		Fuel cell swapping	Operations

Highly relevant to ZEFI
Mostly applicable without change

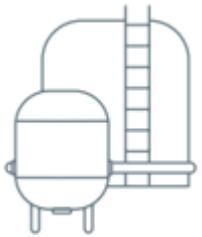
Somewhat relevant
Likely requires significant change as part of adaptation for ZEFI

Relevant, subject to review
Could be transferable to ZEFI but currently applies to parallel or similar use-cases

Little to no relevance
Likely requires significant change as part of adaptation for ZEFI



HYDROGEN



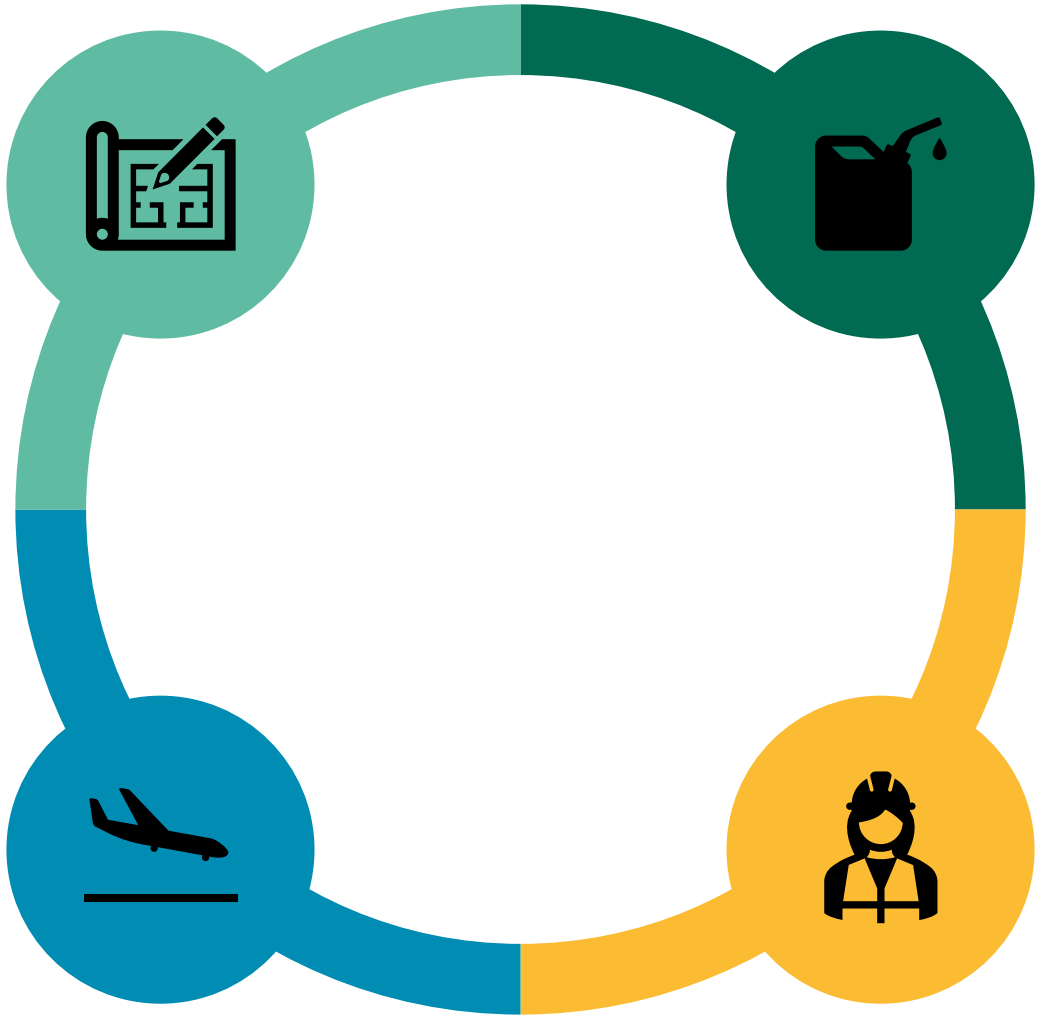
PRIORITY STANDARDS DEVELOPMENT AREAS

Airport Planning Principles

- Safety zones for fuelling, aircraft, defuelling, ground vehicles, storage etc.
- Building standards for H2 facing operations (e.g. hangars for H2 aircraft)

Minimum Airport Requirements

Defining the minimum requirements an airport would have to meet to be hydrogen ready. This must consider what might apply across all airports including diversionary sites.



Hydrogen refuelling: fuel storage and infrastructure

Airports need clear guidance on infrastructure requirements and evolution over time to be able to budget for and plan for physical space and personnel.

Fire rescue and emergency response

Likely to be major changes to the response and operations. Questions over the suitability of existing evacuation procedures and fire prevention methods such as foam blankets in an emergency.

PROGRESS TO DATE

Department for Transport

CATAPULT Connected Places

ZEFI 1

- **Defined initial ZEFI concepts** for airport operators to consider.
- Assessed the requirements and impact of infrastructure for **hydrogen and battery-electric aircraft**.
- 3 funded demonstrations and 14 TRIG:ZEF grants.

ZEFI 2

- **Assessed the scale of realistic pathways for hydrogen infrastructure**, including energy demand, space requirement and cost for 5 airport archetypes.
- **Formed the Standards Advisory Group (SAG)** to inform development of ZEF standards.
- Updated hydrogen technology roadmap.

ZEA

- **Identify future research needs for ZEAs and ZEFI** to support DfT decision making.
- **Support the move towards ZEF** through the creation of a ZEFI Draft Transition Plan.
- **Reconvening the SAG** to develop high-level scopes for the first UK ZEF standards.
- **Evaluate options for advancing R&D from 24/25.**

2021 | 2022 | 2023 | 2024

2022: ATI launch FlyZero, aiming to realise zero-carbon commercial aviation by 2030.

2022: Jet Zero Strategy launch.

2023: **DfT launch Zero Emission Airports 2040 call for evidence.**

2024: ZEA IFP Engagement & Consortia building workshops

ZEFI = Zero Emission Flight Infrastructure
ZEA = Zero Emission Airports

WHAT NEXT?

Should we be more ambitious?

CATAPULT
Connected Places

MORE PROGRESSIVE POLICY INTERVENTIONS

CATAPULT Connected Places

The Climate Crisis should be acknowledged as a national/international emergency, not subject to 5-year election cycles, with ambitious funded national programmes to tackle it

Significant funding towards clean renewable energy, with the goal of substantially lowering the UK's carbon emissions, with a specific programme focussed on aviation

Aviation acknowledged to be part of the UK's critical national infrastructure

Hydrogen for Aviation mandate

Collaborative Scope 1, 2 and 3 Framework Agreement

Or, more radically, a progressive cap on non-zero emission flights

HOW COULD WE MAKE THIS WORK?

- Funding – private and public
- Bolder cross-sector collaboration
- Systemic national aviation decarbonisation programme – not siloed
- Fully decarbonise our energy supply – renewables, less fossil fuels
- Define realistic metrics
- Open, transparent reporting with more data sharing
- Policy similar to the US Inflation Reduction Act but more ambitious
- Defined, ambitious, funded milestones
- Public engagement programme

SPEAKING OF 2025...

25

Years to Global Net Zero

CATAPULT
Connected Places

THANK YOU

Any Questions?

Andrew Chadwick
+(0) 794 465 1280
andrew.chadwick@cp.catapult.org.uk