DESTINATION ZERO

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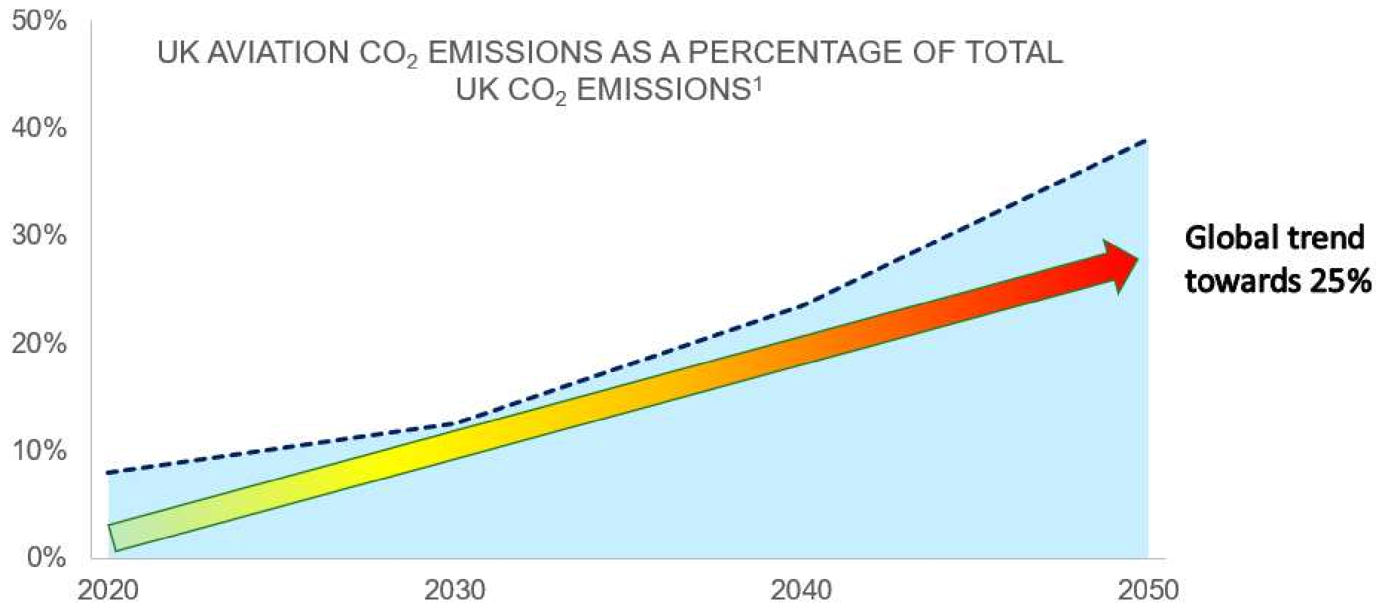
Why Do We Need to Decarbonize Aviation

For the forecast increase in air traffic and with no action, UK aviation emissions could reach 40% of total UK emissions (25% globally) by 2050.

- Aviation produces around 2.5% of global CO_2 emissions and 3.5% of effective radiative forcing, when non-CO2 impacts are taken into account[1].

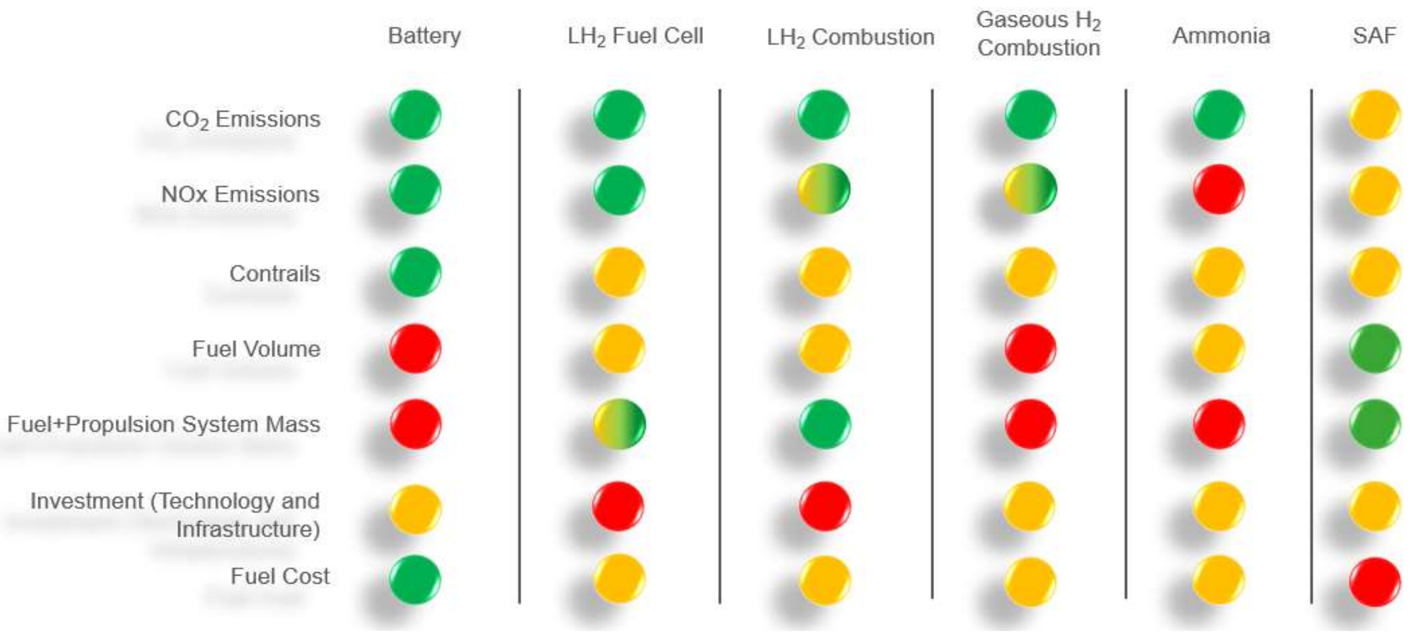


1. Lee et al. (2021), Atmospheric Environment, The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018
2. UK Climate Change Committee (2020), Aviation

Zero Carbon Aviation Fuel Comparison

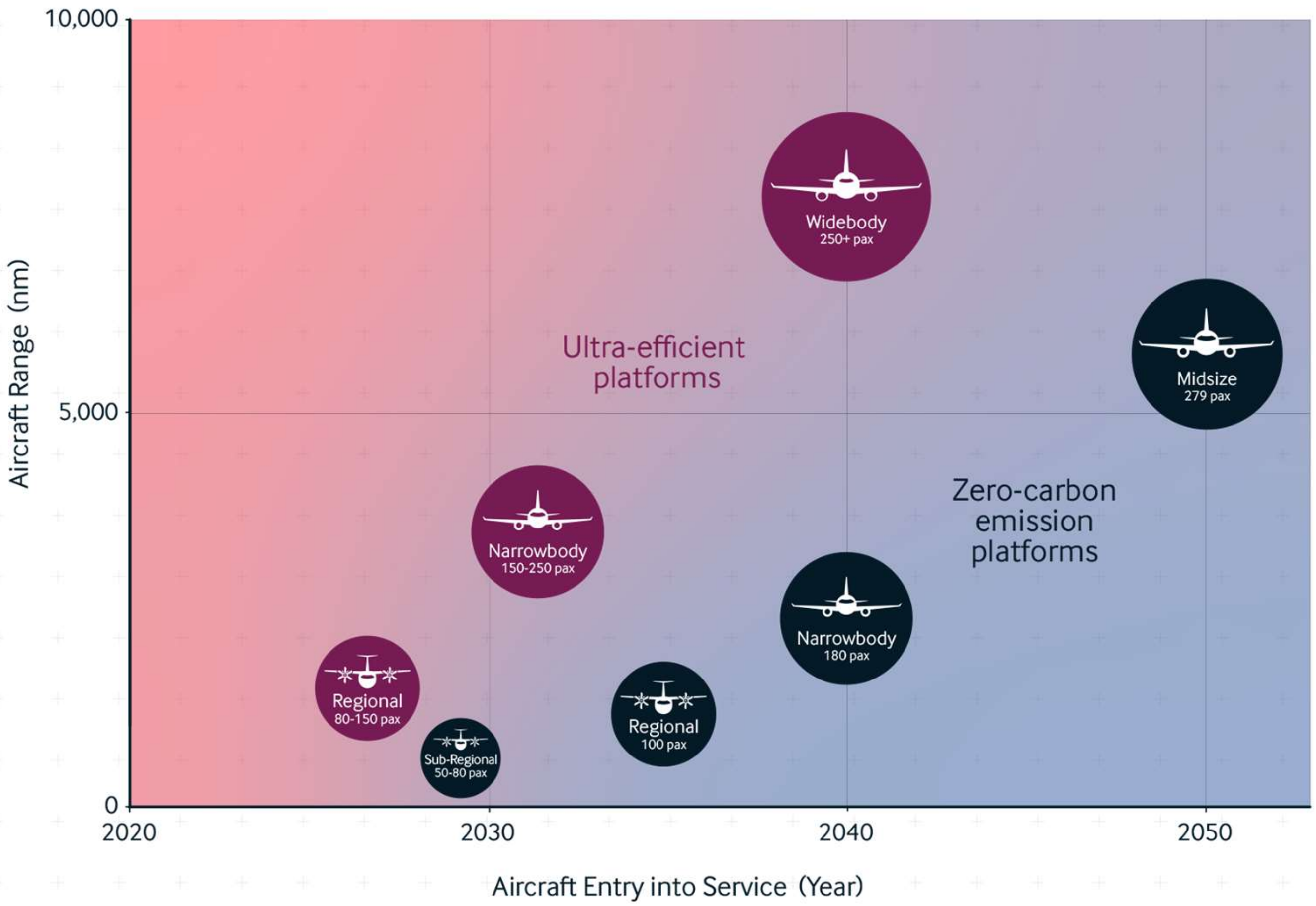
Liquid hydrogen is a lightweight, relatively affordable fuel.

PRELIMINARY ASSESSMENTS OF ZERO CARBON AVIATION FUEL CAPABILITY FOR FZ SCOPE FOCUS MARKET & RANGE



Aerospace Market Potential

- £4.3 trillion market from 2022 to 2050
- UK industry could grow its market share from 13% to nearly 18% by 2050

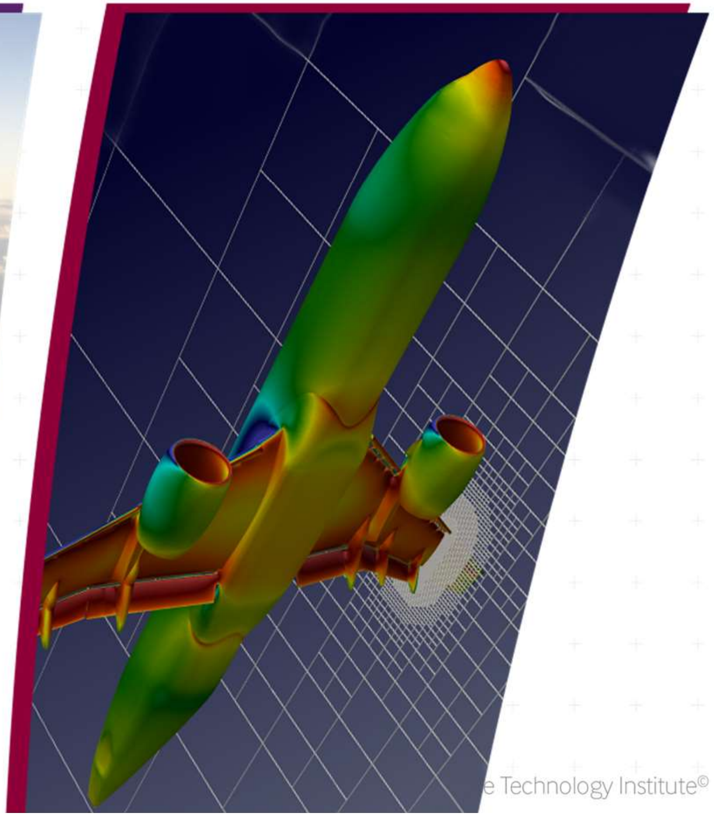


ATI Priorities

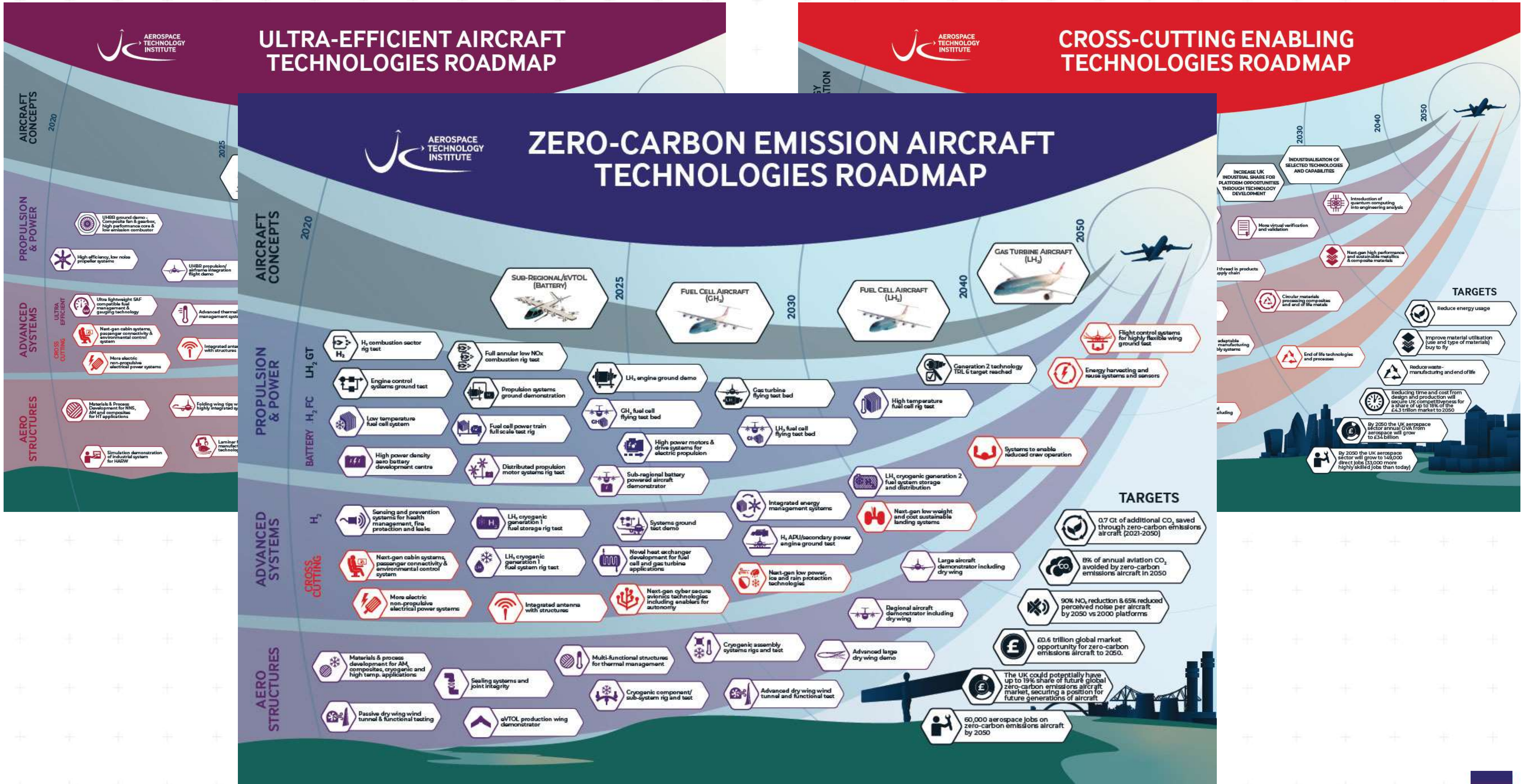
Zero-carbon aircraft technologies

Ultra-efficient aircraft technologies

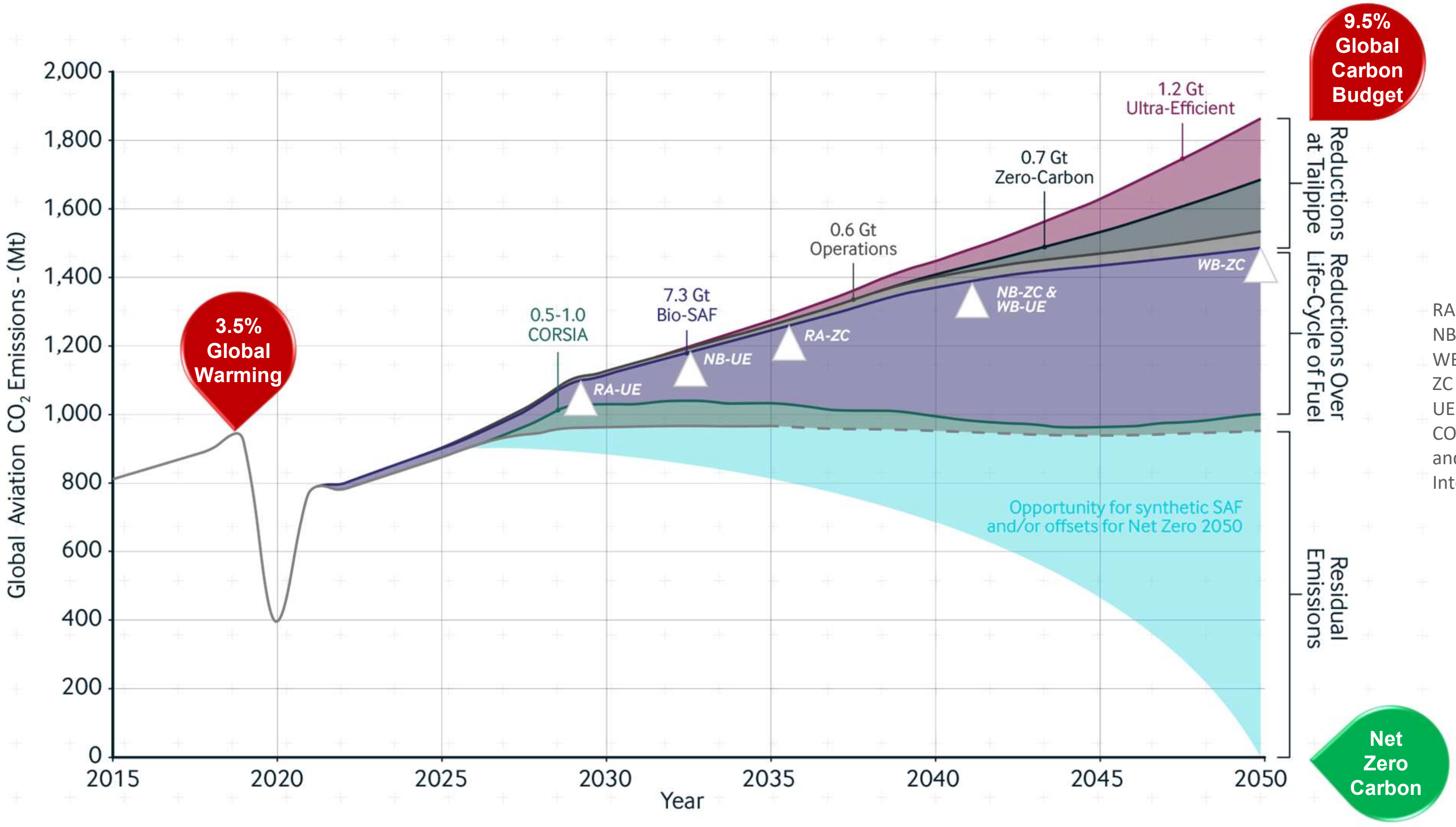
Cross-cutting technologies & infrastructure



Technology Roadmaps

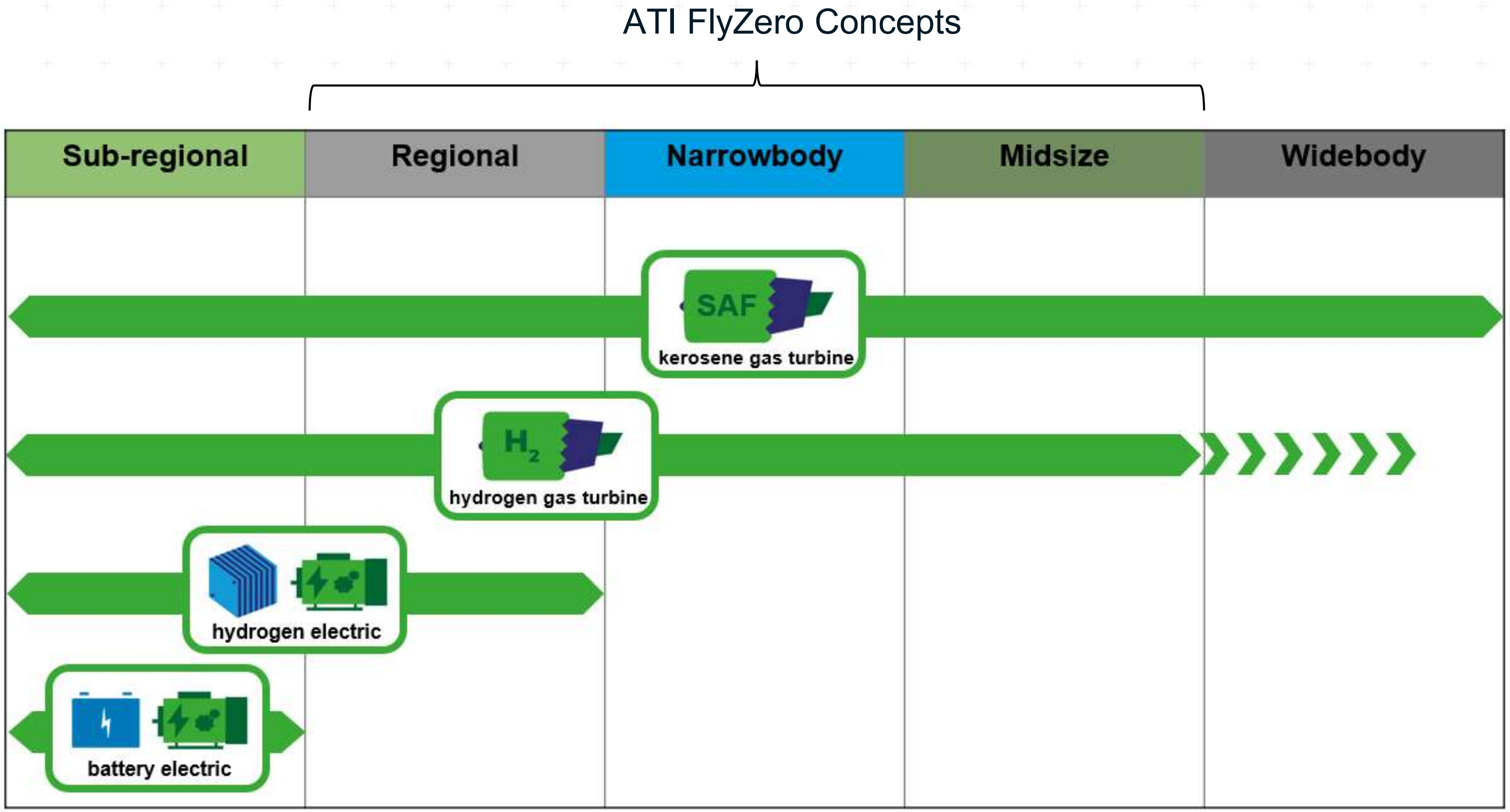


Achieving Net Zero 2050



RA = Regional Aircraft
NB = Narrowbody
WB = Widebody
ZC = Zero-Carbon
UE = Ultra-Efficient
CORSIA = Carbon Offsetting and Reduction Scheme for International Aviation

Hydrogen Technology Applicability



The FlyZero Concepts

FlyZero concepts were created to understand the technology potential and developments required.

- **Regional FZR:** hydrogen fuel cell electric, 75 passengers, 800 nmi design range (Edinburgh to Prague)
- **Narrowbody FZ-N:** hydrogen gas turbine, 179 passengers, 2,400 nmi design range (Manchester to Tel Aviv)
- **Midsize FZ-M:** hydrogen gas turbine, 279 passengers, 5,750 nmi design range (London to San Francisco)

Regional Concept

Concept created to understand the commercial and technical feasibility of a fuel cell aircraft

Typical route: Edinburgh to Prague

Key Learning Points:
- More efficient to oversize the fuel cells
- Thermal management is a key weight driver

Propulsion: Fuel cell electric

CO_2 reduction: 100% less than reference aircraft [4]

Climate impact reduction[1]: ~ 65% less than reference aircraft[4]

Energy per ASK: 7% more than baseline aircraft[5]

DOC per RPK: 15% less than baseline aircraft[5]

MTOW[2]: 28.8 tonnes

OEW[3]: 19.8 tonnes

Mission fuel mass: 1.2 tonnes

Aircraft length: 28m

Wingspan: 31m

1.Global warming potential over 100 years
2.Maximum take off weight
3.Operational empty weight
4.FlyZero reference aircraft for the regional concept is an ATR72-600. Assumes fuelled by fossil fuel kerosene.
5.FlyZero baseline aircraft for the regional concept updates the reference with 2030 tech factors and the same mission as the concept

Narrowbody Concept

Concept created to demonstrate a hydrogen mass-market aircraft

Typical route: Manchester to Tel Aviv

Key Learning Points:
- The 3 lifting surface (3LS) configuration with tailplane, wing and canard, could improve the centre of gravity envelope. Issues and opportunities of 3LS configuration need to be understood.
- Smaller fan diameter increases specific fuel consumption (SFC) but reduced engine weight reduces overall fuel consumption
- Low weight LH_2 fuel makes 'tankering' fuel for outbound and return trip more feasible, which could be crucial early in transition when fewer airports have LH_2 supply

Propulsion: Fuel cell electric

CO_2 reduction: 100% less than baseline (fossil fuel kerosene)

Climate impact reduction[1]: 60-85%

Energy per ASK: 7% more than baseline aircraft

DOC per RPK: 15% less than baseline aircraft

MTOW[2]: 28.8 tonnes (10% less than baseline aircraft[3])

OEW[3]: 19.8 tonnes (24% less than baseline aircraft[3])

Mission fuel mass: 1.2 tonnes

Aircraft length: 28m

Wingspan: 31m

1. Global warming potential over 100 years
2. Maximum take off weight
3. Operational empty weight
4. FlyZero baseline for the regional aircraft is an ATR72-600

Midsize Concept

Concept created to demonstrate a hydrogen global capability with one stop

Typical route: London to San Francisco

Key Learning Points:
- Fuel burn. Engine weight is a powerful lever for reducing fuel burn. Higher cruise altitude did not improve fuel burn
- This conventional tube and wing will fit airport gates. Studies on radical configurations (e.g., blended wing body) may show added value
- Potential for future study into variants – larger aircraft with the same range or same size aircraft with higher payload and / or shorter range

Propulsion: Hydrogen gas turbine

CO_2 reduction: 100% less than baseline (fossil fuel kerosene) aircraft

Climate impact reduction[1]: 60-80%

Energy per ASK: 37% less than baseline aircraft

DOC per RPK: 32% less than baseline aircraft

MTOW[2]: 150.8 tonnes (13% higher than baseline aircraft[3])

OEW[3]: 104.8 tonnes (8% less than baseline aircraft[3])

Mission fuel mass: 16.7 tonnes

Aircraft Length: 59.5m

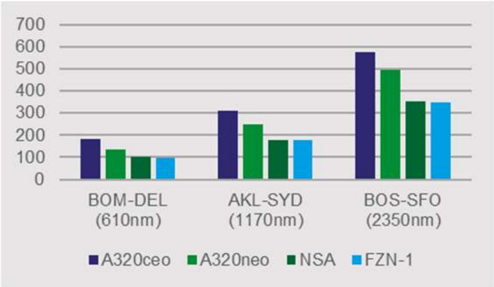
Wingspan: 52m

1. Global warming potential over 100 years
2. Maximum take off weight
3. Operational empty weight
4. FlyZero baseline for the regional aircraft is a 767-200ER

Competitiveness of Hydrogen Aircraft

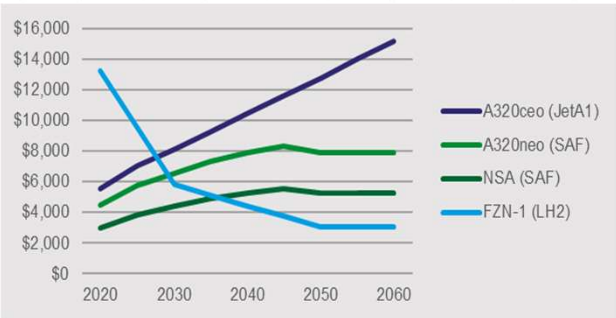
FlyZero analysis on competitiveness of hydrogen gas turbine powered narrowbody aircraft compared to kerosene burning alternatives, A320neo and a new single aisle (NSA) aircraft.

Sector Energy (GJ energy over sector nautical miles) for three routes

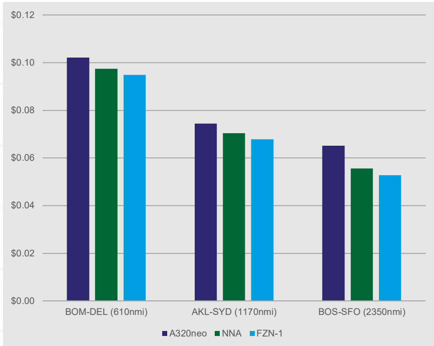


- FlyZero hydrogen gas turbine powered narrowbody concept FZN has uses **30% less energy than an A320neo**, and is on par with a clean-sheet design kerosene-burning new single-aisle (NSA) aircraft
- The FZN **Direct Operating Costs per Revenue Passenger Kilometre are about 20% less than a A320neo**, and 5% less than and new single aisle aircraft burning SAF

Trip Fuel Cost AKL-SYD, 1170nm sector USD (2020 prices)



Direct Operating Costs per Revenue Passenger Kilometre USD (2050 fuel price) for three routes



Global Connectivity

Liquid hydrogen's low weight and high energy density makes global connectivity possible with just one stop

A family of hydrogen powered aircraft with ranges from up to ***5,250nm*** could address 92% of tailpipe carbon emissions. If a single-stop was introduced for all segments above 5,250 nautical miles, then tailpipe carbon emissions could be fully eliminated.

TOP LEVEL FINDINGS

- Green liquid hydrogen can enable zero-carbon emission flights to anywhere in the world with just one stop.
- SAF and Liquid hydrogen and should both be at pace to decarbonise the current and future fleets respectively.
- The UK needs to invest and act now, to avoid being ‘locked out’ of the zero-carbon aerospace sector by :
  - **Directing targeted research on CO2 and non CO2 emissions effects on climate change**
  - **Accelerating the maturity of key onboard technologies to enable safe certifiable hydrogen powered flight**
  - Influencing the development of liquid hydrogen fuel supply and airport infrastructure (globally)
- We need international collaboration and partners to address this global challenge.