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Singapore-UK Jet Zero Workshops

Workshop 3: Policy Ambitions

27 March 2024

UKRI
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Before we start...

- No fire alarms expected
- Wifi: Marina Bay Sands
- Please join the conversation about today's event on social media:

#UKGEF
#UKSingaporeJetZero
@HyDEXMidlands
@CranfieldUniversity

Time	Agenda
10:00-10:30	Arrival & Reception: coffee/tea/ snacks
10:30-11:00	Welcome & Introduction: Alex Bamford (The Deputy High Commissioner at the British High Commission in Singapore), Lauren Babuik (Head of Nature, Climate and Energy, British High Commission Singapore)
11:00-11:15	Welcome and overview, intent of the workshops: Professor Ron Corstanje (Cranfield University)
11:15-11:30	UK perspectives on the pathways aviation decarbonisation: Antony Henderson (Head of SAF Strategy and International, Low Carbon Fuels, UK Department for Transport)
11:30-12:00	Key insights from SAF and Hydrogen workshops: Dr. Diganta Das (Loughborough University), Dr. Sharon George (Keele University)
12:00-12:30	Presentation on policy ambitions: Dr. Edgar Jimenez Perez (Cranfield University), Dr. Chris Parker (Loughborough University), Dr. Nahid Yazdani (University of Nottingham) and Prof. Ghulam Sorwar (Keele University)
12:30-13:30	Lunch & Networking
13:30-14:45	Roundtable Discussion (All participants)
14:45-15:15	Afternoon refreshments
15:15-15:45	General feedback and room level discussion (All participants)
15:45-16:00	Recap and closure of workshop : Professor Ron Corstanje (Cranfield University)

Singapore UK Jet Zero Workshops

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- ***Green aviation*** is one of the priority sectors identified in the UK-Singapore Green Economy Framework and in the UK Jet Zero strategy.
- ***Creating collaboration and promotional activities for both UK and Singapore businesses and research communities***
- Establish ***a comprehensive and strategic roadmap for aviation ecosystem decarbonisation***

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Challenges in Aviation Decarbonization

Some Key facts and figures

Aviation's CO_2 emissions make up about **2.5%** of global totals, but is potentially much higher due to the **non-CO_2 effects**

Non-CO_2 impacts contribute **two-thirds** of aviation's net radiative forcing

By 2050, a projected **10 billion** air passengers will travel **22 trillion km** annually, generating nearly **2,000 Mt** of CO_2

From **2005 to 2019**, aviation fuel efficiency improved by **~ 39%**, but absolute emissions growth far more than efficiency gains

Why is Aviation a difficult sector to decarbonise ?

Long replacement time for aeroplane
(commercial aircraft can last between 20 to 30yrs)

Challenges around regulatory support

Investment required for decarbonisation
(e.g., Capital expenditure on SAF production facilities is estimated at up to $1.45 trillion over 30 years)

Requirement for global collaboration and coordination

Bold investment and breakthroughs required in R&D

Passenger reluctance on the cost of decarbonisation solutions

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Solutions for Jet Zero

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Utilisation of alternative fuels

- Sustainable Aviation Fuel (SAF)
- Hydrogen (H_2)
- Electric (propulsion)
- Ammonia (NH_3)

Improvements in aircraft fuel efficiency

- Aircraft design
- Efficient engine
- Lightweight materials
- Improved systems

Enhancements in air traffic control & operational measures

- Optimised flight planning
- Dynamic airspace management
- Artificial Intelligence (AI)

Strategies for non-CO2 emission

- Alternative fuel
- Avoidance of Contrail cirrus formation
- Aircraft design
- Advanced engine technology

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Workshop 1: Sustainable Aviation Fuel

What: Challenges around technology, capacity and capability, the availability of feedstocks and the supply chain system

- 70%-80% reduction in CO_2 emission, up to 100% (well-to-wake)
- 10%-40% Reduction in Contrail formation (high uncertainty)
- "Drop-in" fuel - handled as the conventional aviation fuel (CAF)
- Induced Land Use Change emissions
- Significantly more expensive than CAF (factor 2-8)
- Resource competition with food and animal feed

Workshop 2: Hydrogen

What: Challenges on developing the Hydrogen economy & supply chain for aviation

- Zero carbon emissions (in flight)
- Reduction in climate impact: 75%-90% reduction for H2 fuel cell; 50%-75% reduction for H2 turbine
- Improved air quality (NO2 reduction: 100% for fuel cell; 50%-80% for H2 turbine)

- Increased contrail coverage
- Aircraft, airport and air transport infrastructure redesign
- Cost: Carbon-free H2 production is 3 times CAF
- Short-range aircraft (H2 fuel cell)

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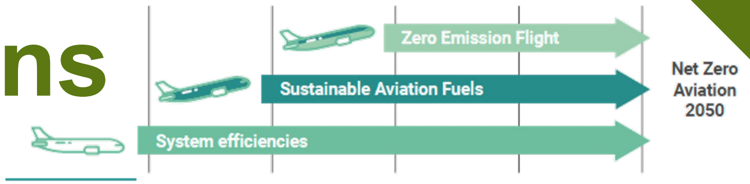
Workshop 3: Policy Ambitions



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What: Policy ambitions contrasted onto existing and future SAF and Hydrogen technological capabilities

20% in 2030, net zero by 2050

Regulatory tools	Supply & Demand-side Actions	Collaborations
SAF mandates: 2026 - Initial target of 1% SAF usage, over 1% in 2026, and 3-5% by 2030.	**Supply-side:** Regional SAF feedstock study and SAF production capacity program **Demand-side:** Corporate Buyers' Club; Offtake Mechanism for SAF; SAF procurement mechanism	**International collaboration:** "green lanes, SAF experience & knowledge sharing. **Industry collaboration:** MOU between CAAS and Airbus (SAF & Hydrogen)

Net zero domestic and airport (2040)
Net zero UK (2050)

Regulatory tools	Direct support	Enabling activities
• **SAF mandate:** 10% in UK fuel mix by 2030 (in place by 2025) • UK Emission Trading Scheme (ETS)	• **SAF infrastructure:** £180 m UK SAF industry growth; £135 m Advanced Fuels Fund • **R&D:** e.g., £12 m UK SAF clearing house; £400 m Breakthrough Energy Catalyst	• Five-year delivery plan • **Set Emissions reduction trajectory** 35.4 $MtCO_2$ in 2030, 28.4 $MtCO_2$ in 2040, and 19.3 $MtCO_2$ in 2050

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Capabilities in the HyDEX Network

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The University of Birmingham

Working with Tyseley Energy Park (TEP) and other partners in the Midlands, the University of Birmingham is pioneering infrastructure solutions in renewable heat and power, energy storage and clean transport fuels in combination with advanced waste processing. TEP features a hydrogen refuelling station and integrated ammonia cracker.

The University of Nottingham

The University of Nottingham is home to world-leading expertise in powertrain research and hydrogen storage solutions, with impressive, purpose-built hydrogen laboratories situated in the Research Acceleration and Demonstration building on the Net Zero Flagship Jubilee Campus.

Our HyDEX demonstrator is focused on the development of the "Flex Fuel" engine, which has the ability to flex between hydrogen (H_2) and ammonia (NH_3) as a retrofit solution for existing heavy duty diesel engines using advanced technology.

Loughborough University

Our hydrogen research areas encompass all areas of hydrogen from production through to end use including storage, distribution, combustion, policy, economics and safety, sustainability analysis and lifecycle management.

The University of Warwick

Warwick's focus is on exploring and demonstrating how to use renewable sources to produce hydrogen. A novel green hydrogen production system has been found to be more efficient than current methods of hydrogen production. The evaluation of the technical and economic performance of this system is a core theme in its work which will upscale this innovative green hydrogen production to full commercial scale.

Aston University

Aston University specialises in the production methods needed to provide a reliable, affordable and green supply of hydrogen. With a long history in gasification and pyrolysis research, the Energy and Bioproducts Research Institute (EBRI) at Aston carries out world-leading research into new and innovative ways of converting biomass into sources of sustainable energy such as hydrogen, using thermochemical, biological and catalytic processes.

Keele University

Keele University has a long been involved in hydrogen research and innovation. Using the campus as a living laboratory, the HyDEPLOY trial demonstrated that a blend of 20% hydrogen could be used in the heating network.

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Capabilities in Cranfield University

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Airside Hydrogen Production

Hydrogen based aviation

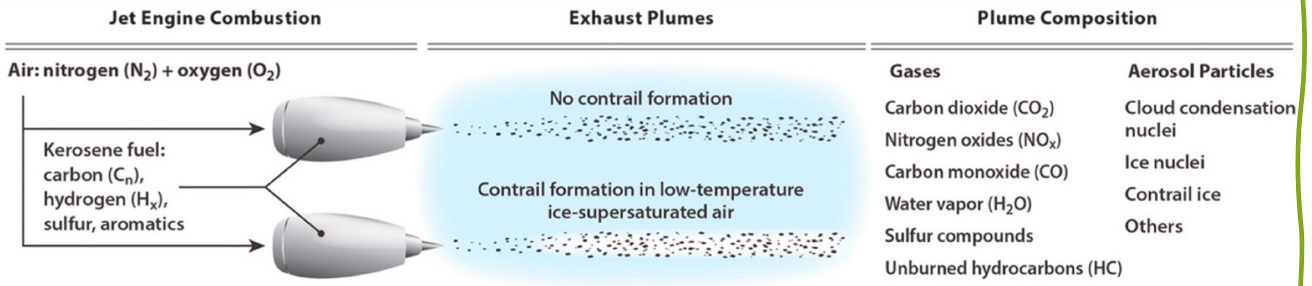
Environmentally friendly ways of making crop-based SAF

Mixed food-fuel cropping for SAF production by applying multi-cropping techniques.

Integration of hydrogen and SAF systems in the Cranfield Global Research Airport: Airport of the future

Cranfield's 'Living Laboratory' campus and airport of the future

Reducing the climate impact of aircraft (CO_2 and non-CO_2 emissions)



Aviation CO_2 and non-CO_2 emissions, adapted from Lee et al. (2021)

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Blueprint for Zero Emission Flight and Infrastructure

ENERGY INNOVATION

SYSTEMS INTEGRATION

ENABLING JET ZERO

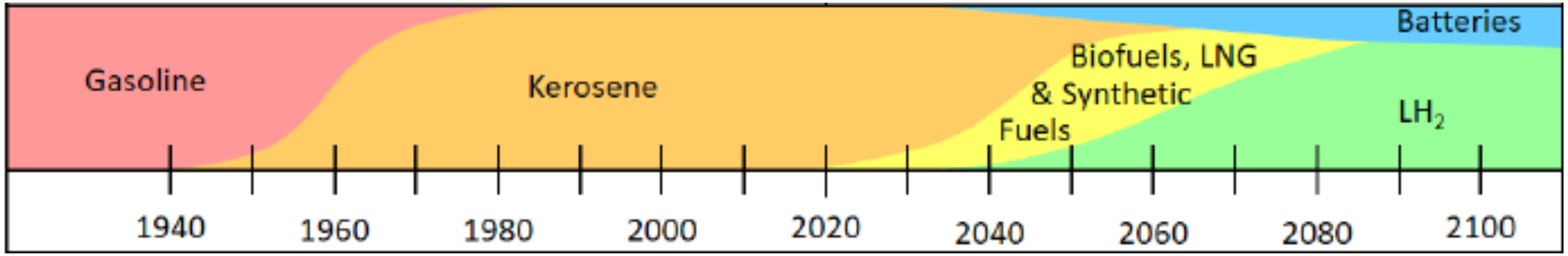
Utilization (TRL 6-9)

Innovation Wave 1
10-15 Years
Focus: Certification

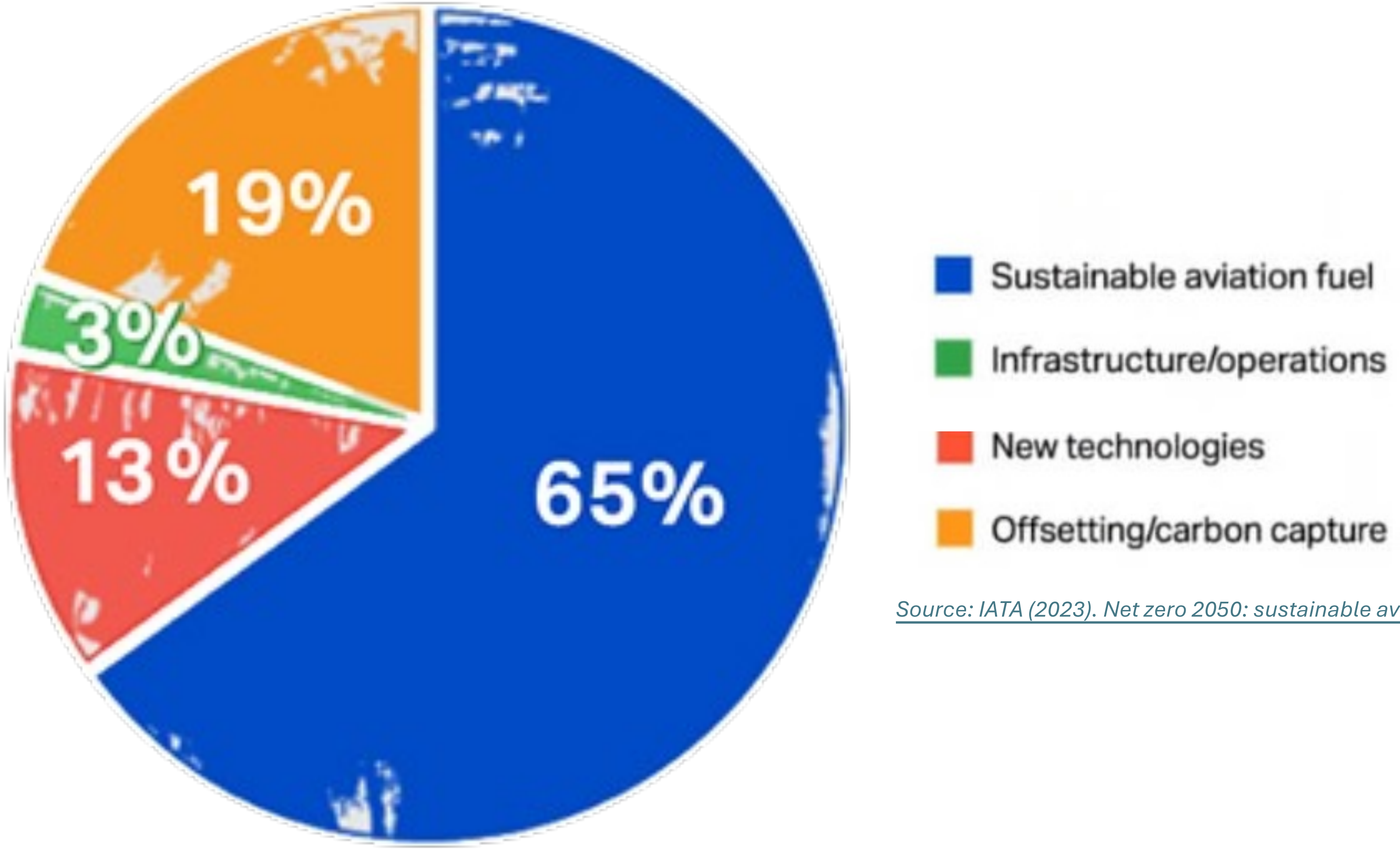
Innovation Wave 2a
20+ Years
Focus: Efficiency

Innovation Wave 2b
20+ Years
Focus: FC Certification

Innovation Wave 3
30+ Years
Focus: Turbo-cryo-electric



Contribution of mitigation strategies to achieve NET ZERO carbon in 2050 in aviation



Source: IATA (2023). Net zero 2050: sustainable aviation fuels

The State of SAF in 2023

More than 490,000 flights

2016: 500 flights

300+ million litres produced in 2022

2016: 8 million litres
2025: ~5 billion litres

7 technical pathways

2016: 4 pathways
2025: 11 pathways

57 offtake agreements since 2022

40 publicly announced SAF offtake agreements and 17 non binding agreements

130+ renewable fuel projects

have been announced publicly by more than 85 producers across 30 countries

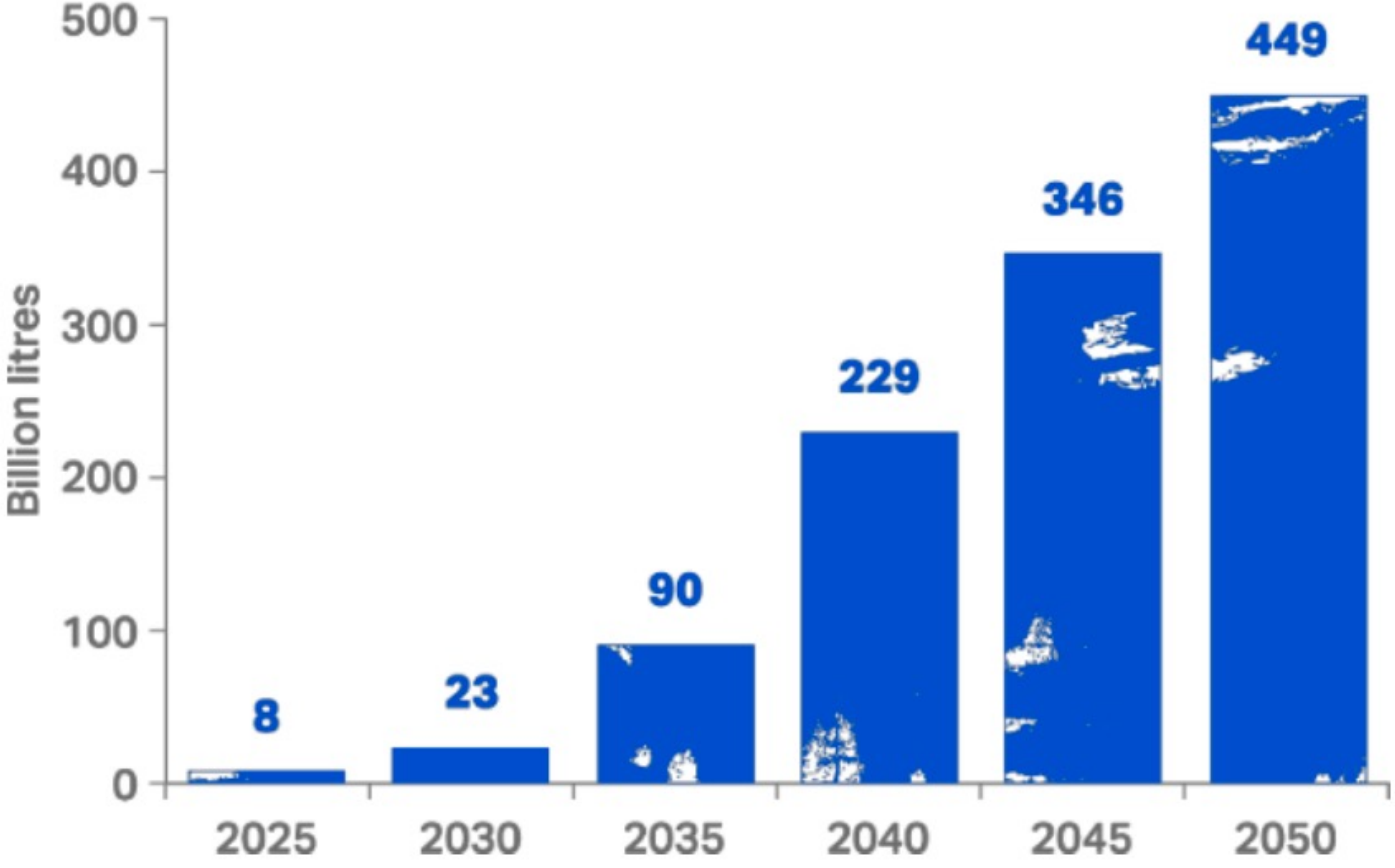
70% average CO_2 reduction

2016: ~60% reduction
2025: ~80% reduction

Source: IATA 2025 estimates

Source: IATA (2023). Net zero 2050: sustainable aviation fuels

Expected SAF required for Net Zero 2050



Source: IATA (2023). Net zero 2050: sustainable aviation fuels

How much SAF do we need?

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> 100 billion
litres/year (by 2050)

If the aviation sector's emission reduction target of 50%

~ 200 billion
litres/year

Holding the global temperature rise to no more than 1.5°C

> 450 billion
litres/year (by 2050)

If SAF to account for 65% of the mitigation to achieve net zero CO_2 emissions by 2050

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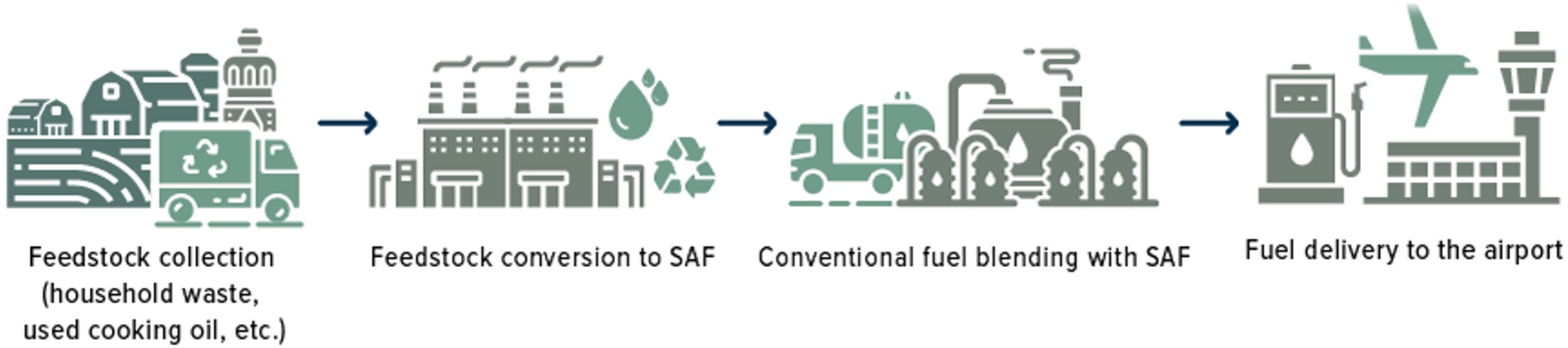
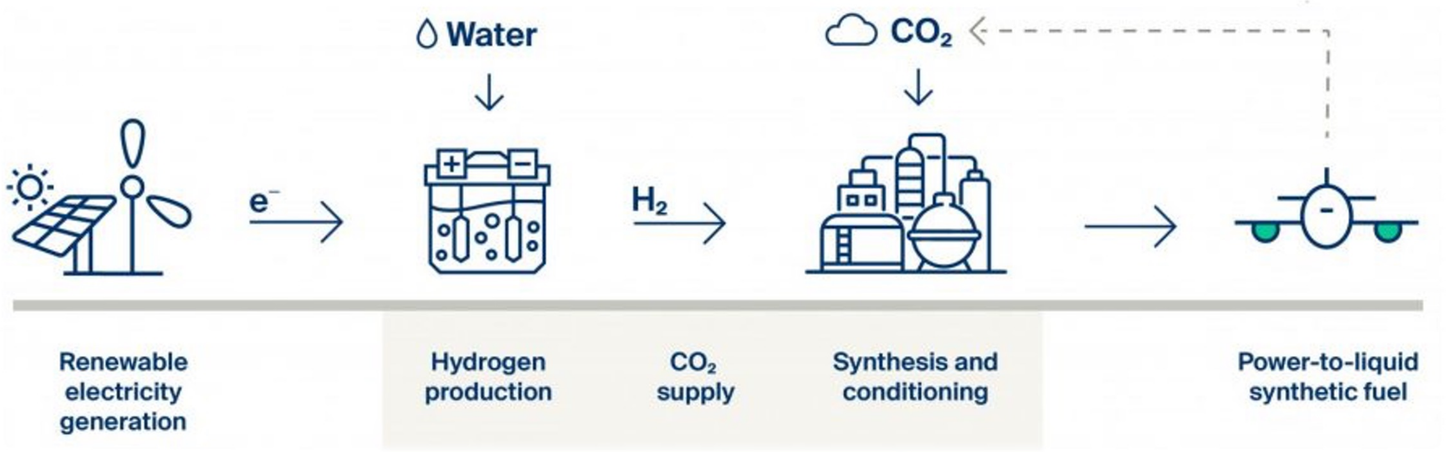
SAF : Biofuels and Synthetic Electrofuels

Biofuels made from a range of biological sources



Source: Combustion Engines, U.S. Global Investors

Electrofuels (e-fuels or Power-to-liquid (PtL)) made from CO_2 and H_2 (generated from renewable energy and water)



Source: Kuehne+Nagel (2021). Kuehne+Nagel and Lufthansa Cargo agree on exclusive partnership to promote CO2-neutral power-to-liquid fuel.

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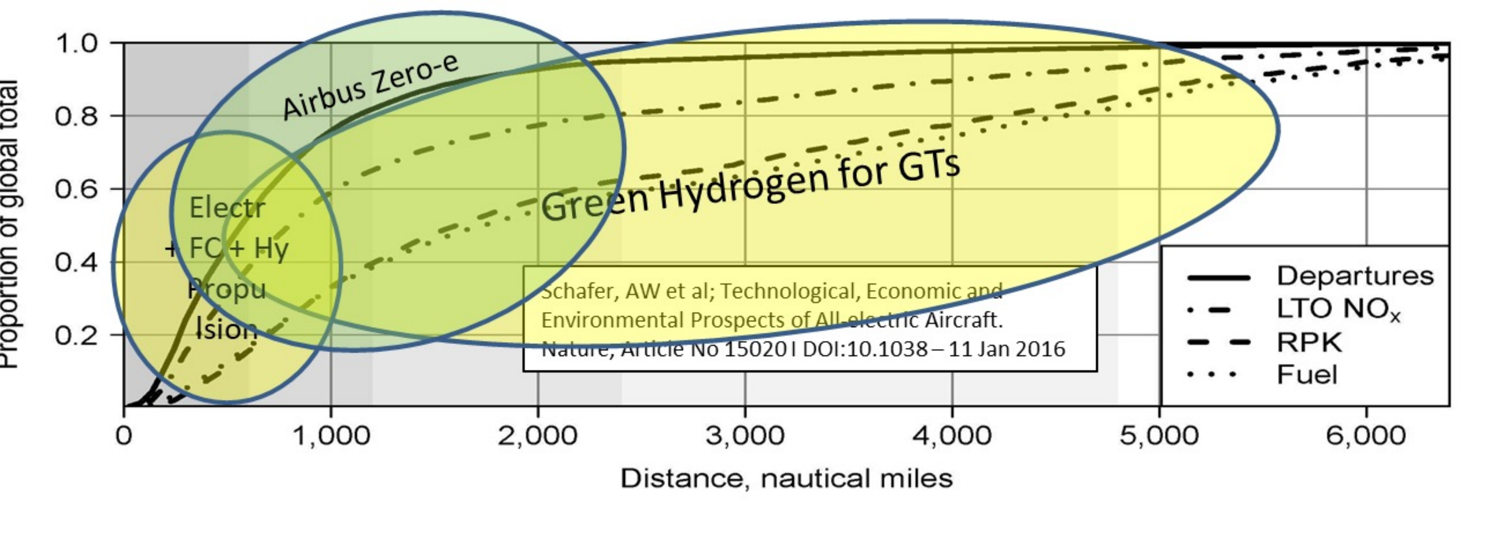
Blueprint for Zero Emission Flight



Sustainability

Decarbonise ⇒
Zero Carbon – Not "Net Zero"!

Minimise Non-CO_2 Emissions ⇒
NOx, Contrails, Noise

Improve Energy Efficiency ⇒
Advanced, Disruptive Tech.

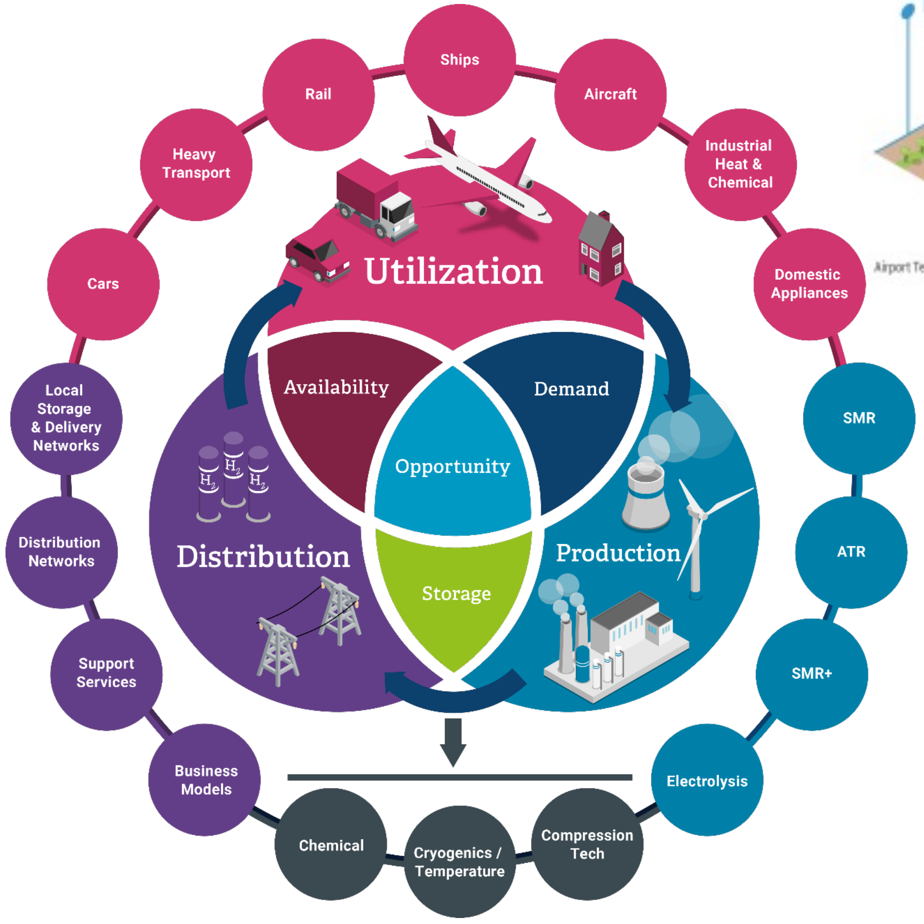
Do not Curb Aviation Growth ⇒
Protect the economy!

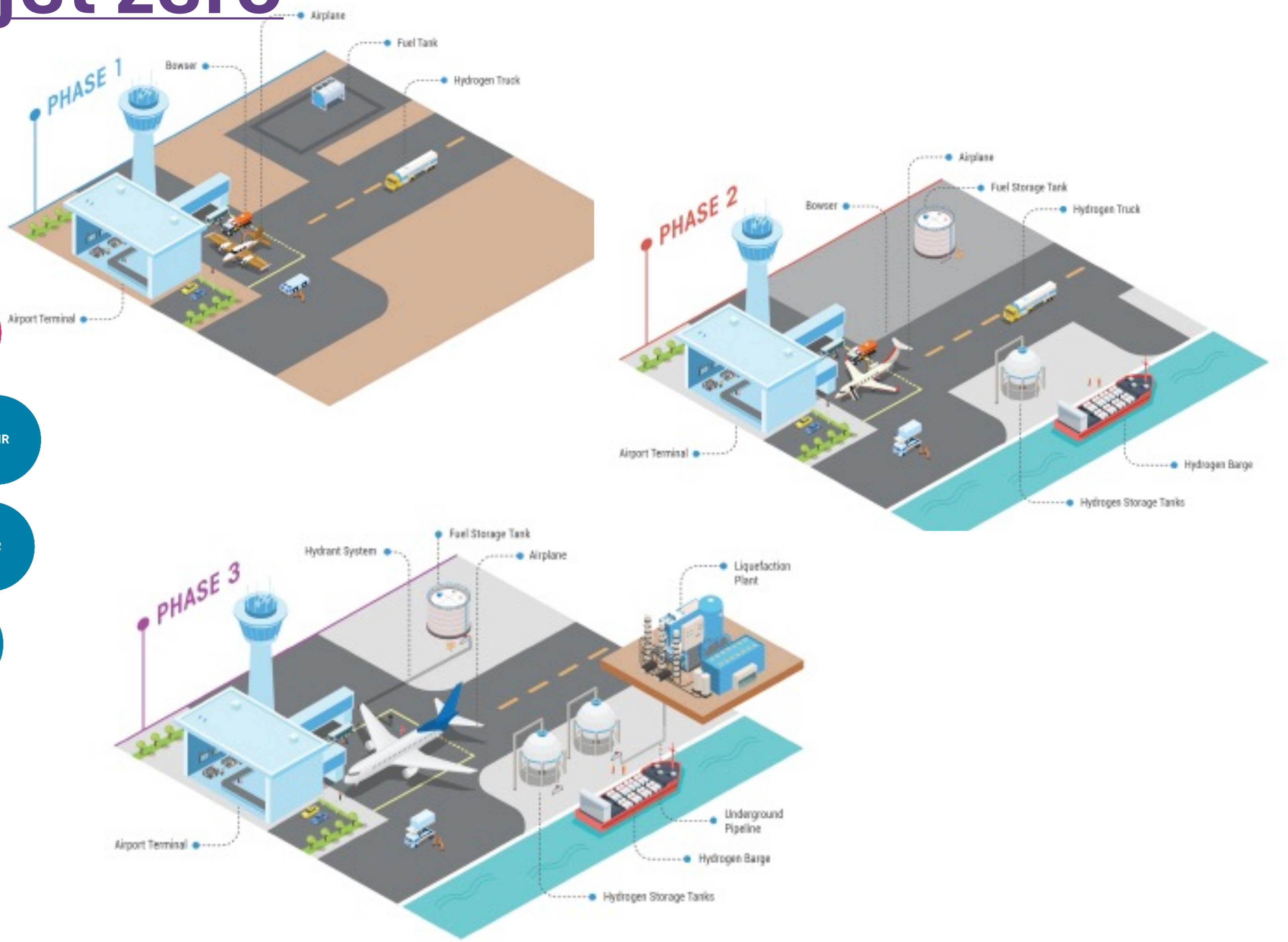
Invest and Attract Diverse Talent ⇒
Infrastructure, R&D, Education

Abbreviations
Electr: Electric
FC: Fuel Cells
GTs: Gas Turbines
Hy Propulsion: Hybrid Propulsion
LNG: Liquefied Natural Gas
LTO: Landing and Take-Off Cycle
RPK: Revenue per Passenger Kilometre

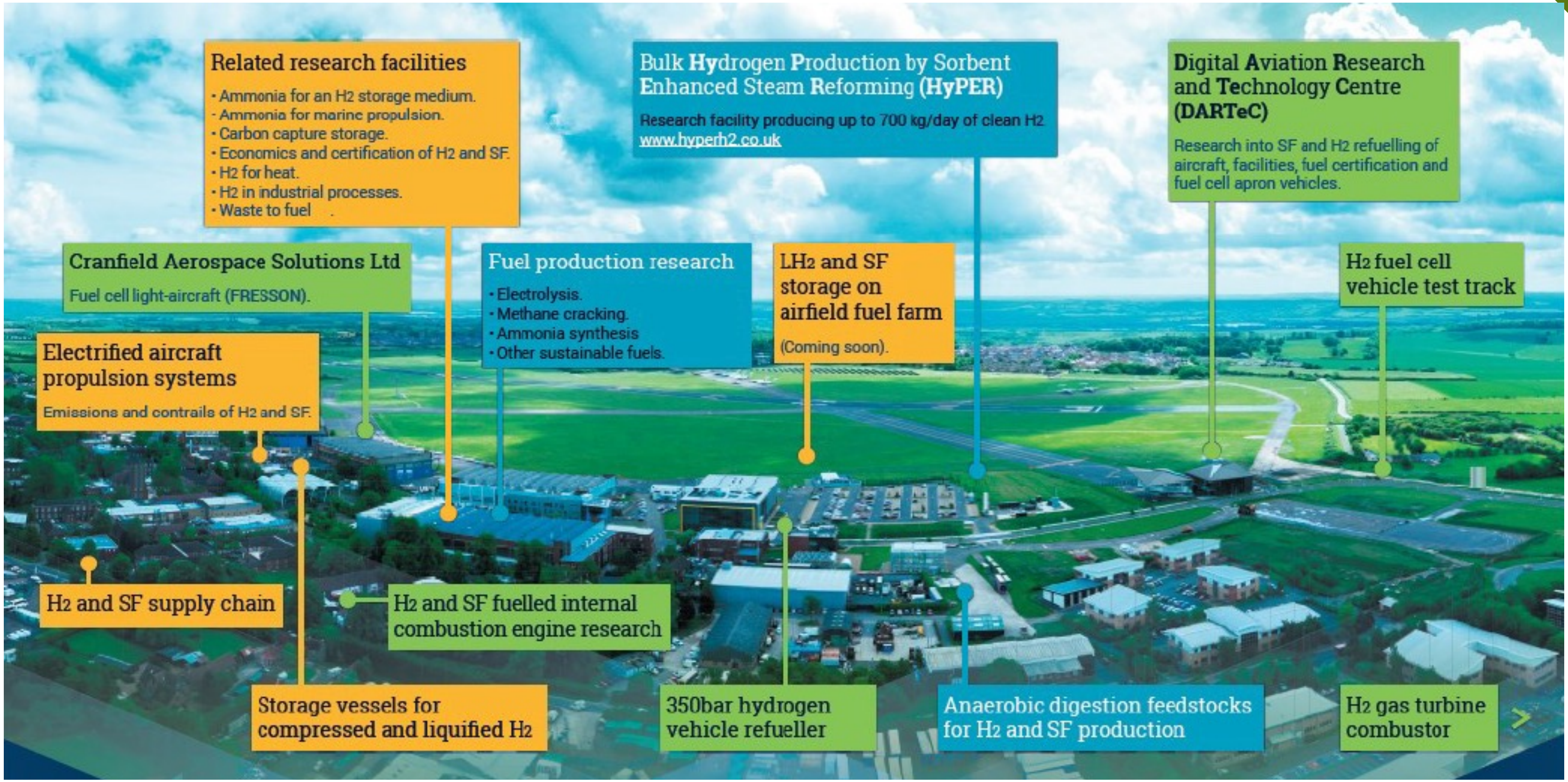
Enabling a H_2 integration ecosystem

The blue print for jet zero





Cranfield's active hydrogen research ecosystem 'A Living Laboratory' From TRL 1-9 across Production, Transport, Storage and Utilization



Key

Feedstocks and fuel production. | Transport, storage, economics, supply chain. | End users – aerospace and road vehicles. | • H_2 = Hydrogen | • LH_2 = Liquid hydrogen | • SF = Sustainable fuels

Utilization (TRL 6-9)

ENABLE H2

Net Zero Research Airport

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Cranfield Aerospace Solutions

CAeS-7

GKN-40

How can we accelerate our journey?

With over £46 million of co-investment secured from Cranfield University and our partners, we have been awarded £24 million from UK RPIF to deliver three interrelated transformative infrastructure programmes to accelerate the journey to net zero:

ENERGY INNOVATION

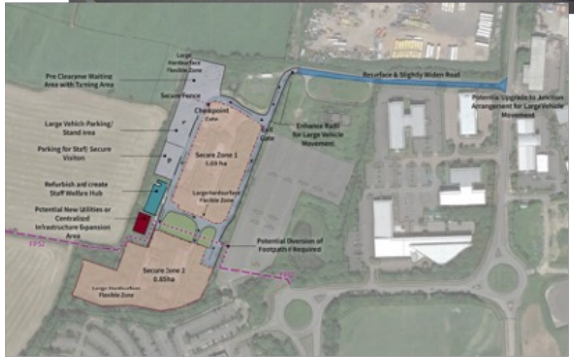
- **A new £12 million Hydrogen Integration Research Centre (HIRC)**: Enabling research linking developments in hydrogen production, storage, SAF, ammonia and hydrogen refuelling for mobility to accelerate TRLs 2-4 to Enable Jet Zero

SYSTEMS INTEGRATION

- **A £9 million investment in hydrogen gas turbine combustor testbed**. Hydrogen testbed that will enable hydrogen transition for aviation; to accelerate this expansion and modernisation is required to accelerate TRLs 4-6 to Enable Jet Zero

ENABLE JET ZERO

- **A £22 million investment in the Global Research Airport to drive net zero mobility.** Development and co-location of multiple fuels on one airport . TRLs 6-9 to Enable Jet Zero



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Pathway to aviation decarbonisation.

The UK Perspective.

Antony Henderson – Head of SAF Strategy, UK Department for Transport

27/03/24

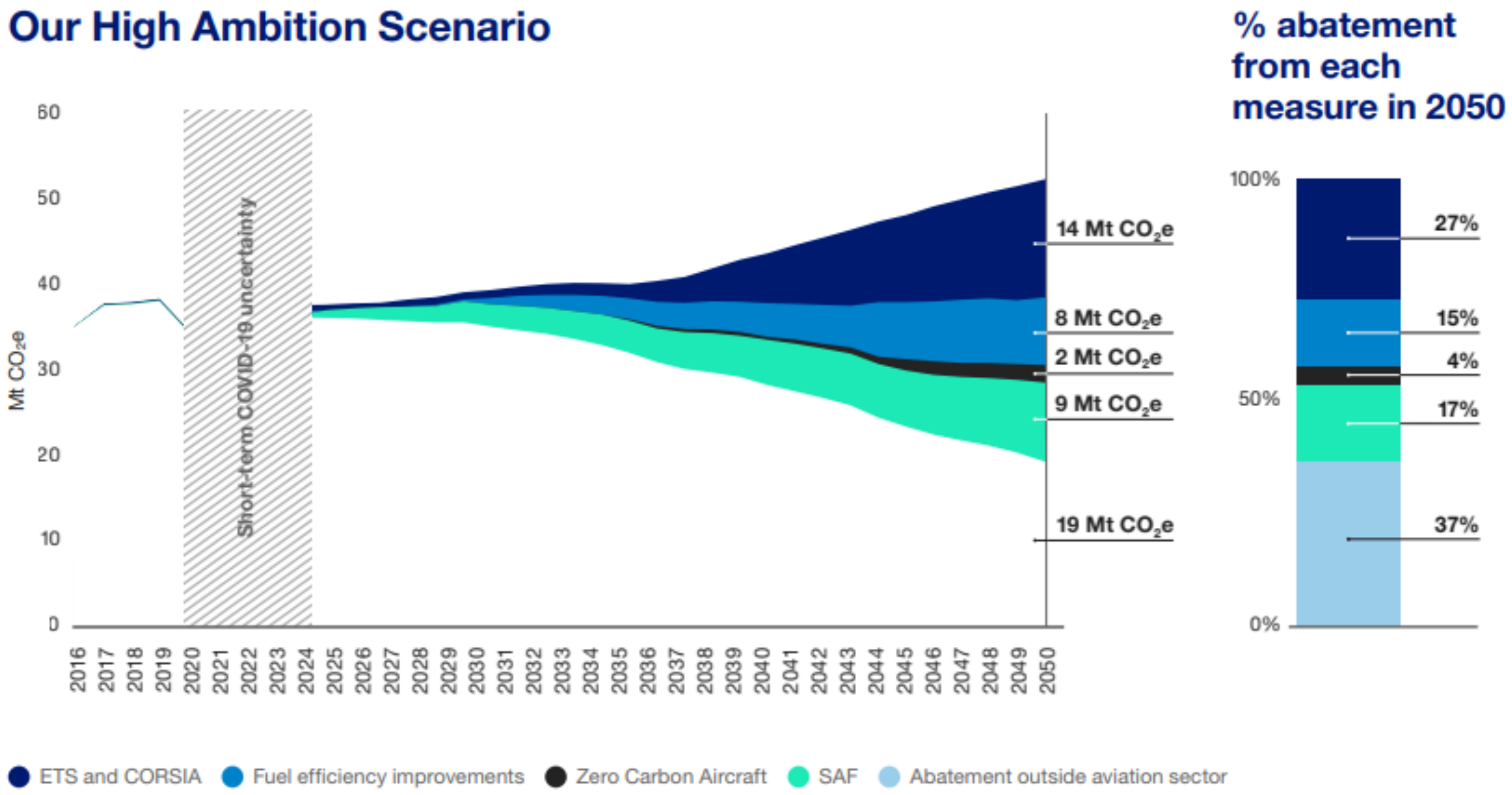
Jet Zero Strategy

Department for Transport

Jet Zero Strategy

The Strategy focuses on the rapid development of technologies in a way that maintains the benefits of air travel, whilst maximising the opportunities that decarbonisation brings for the UK.

- A **commitment to achieve net zero aviation emissions by 2050**.
- An **emissions reduction trajectory** from 2025 to 2050 that sees **aviation emissions peak in 2019.**
- **62 commitments and policies** such as 2040 targets for net zero domestic flights, a 2040 zero emission airports target, and commitments to build a UK SAF industry.
- **Three principles:**
  - — **International Leadership**
  - — **Delivered in Partnership**
  - — **Maximising Opportunities**



Six key measures...

System efficiencies

Improving the efficiency of our existing aviation system: our aircraft, airports and airspace.

Our ambition is for all airport operations in England to be **zero emission by 2040**.

Huge aerospace opportunity, **with 29,200 new aircraft** to be built over the next 20 years, worth **$2tn**.

Sustainable aviation fuels

We will be providing **£180m of funding** to support a UK SAF industry. We have committed to having at **least five UK SAF plants under construction by 2025** and a SAF mandate in place **with a target of at least 10% SAF in the UK fuel mix by 2030**.

A UK SAF industry could potentially support up to **10,300 UK jobs by 2030.**

Zero emission flight

We are supporting aerospace R&D **with £685m funding** over the next three years.

Our aspiration is to have **zero emission routes** connecting different parts of the United Kingdom by 2030.

Rapid investment in hydrogen aviation could see **60,000 jobs** working on zero-carbon aircraft by 2050.

Markets and removals

We are working with the UK ETS Authority to enhance the ambition and effectiveness of the **UK Emissions Trading Scheme (UK ETS)**.

We plan to legislate for the long-term approach to **Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)** no later than 2024, establishing the relationship between UK ETS and CORSIA.

Influencing consumers

We want to **preserve the ability for people** to fly whilst supporting consumers to make sustainable aviation travel choices.

We are working with the CAA to **provide consumers with environmental information** at the time of booking including reviewing responses from a Call for Evidence published earlier in 2023.

Addressing non-CO_2

Tackling the climate impact of aviation is not just about reducing CO_2 emissions, there are other non-CO_2 impacts that also affect the climate and local air quality.

Our focus is **to increase our understanding of non-CO_2 impacts** as the exact scale of their effect remains uncertain.

Jet Zero Council

The Jet Zero Council (JZC) brings together government and chief executive officer-level stakeholders from industry and academia with the aim to deliver at least 10% sustainable aviation fuel (SAF) in the UK fuel mix by 2030 and zero emission transatlantic flight within a generation.

The objective of the JZC is to provide ministers and government advice on how to develop the UK's capabilities for achieving net zero aviation, to identify the benefits of developing these new industries in the UK, finding solutions to overcome barriers faced by the industry and finding opportunities to drive down production costs. Furthermore, the Council aims to support grass roots innovation and challenge existing approaches by involving disruptors and innovators.

Key areas of focus for the Council are:

Sustainable Aviation Fuels

Accelerate the establishment of UK production facilities for SAF and commercialising the industry by driving down production costs.

Zero Emission Flight

Accelerate the design, manufacturing, testing, certification, infrastructure and commercial operation for zero emission flight (ZEF).

Policy & Regulatory Framework

Developing a co-ordinated approach to the policy and regulatory framework needed to deliver net zero aviation by 2050.

Jet Zero Communications and Engagement Network

Sharing and effectively communicating the work of the JZC to wider Jet Zero stakeholders and the UK public.

Chairs	The Council is co-chaired by **Rt Hon Mark Harper MP, Transport Secretary, Rt Hon Kemi Badenoch MP, Business and Trade Secretary, and Claire Coutinho, Energy Security and Net Zero Secretary (TBC)**
CEO	**Emma Gilthorpe, COO of Heathrow Airport,** is the JZC CEO responsible for driving forward the Council's agenda to ensure that it delivers its objectives.
Members	The Council's membership brings together ministers and senior leaders in aviation, aerospace and academia to drive the delivery of new technologies and innovative ways to cut aviation emissions.
Associate Members	Provides Delivery Group and Sub-group members, wider industry, academia, and NGOs with the latest updates on the work of the JZC.

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AOA THE VOICE OF UK AIRPORTS
LanzaTech
AIRLINES UK THE ASSOCIATION OF UK AIRLINES
aef Aviation Environment Federation
ROLLS ROYCE
GKN AEROSPACE
Department for Transport
Carbon Engineering
Heathrow
Department for Business, Energy & Industrial Strategy
MAG
AIRBUS
Cranfield University
Civil Aviation Authority
BOEING
bp
CATAPULT Connected Places
UKRI Innovate UK KTN
IAG INTERNATIONAL AIRLINES GROUP
ZEROAVIA
GAMA
ROYAL AIR FORCE
ADS
BRITISH AIRWAYS
Jet2
AEROSPACE TECHNOLOGY INSTITUTE
Loganair Scotland's Airline
virgin atlantic
VELOCYS
DHL
easyJet

UK SAF Policy

Our Aim

We are preparing the UK to be a global leader on the production, development, and use of SAF.

Overarching objectives

Create secure and growing demand for SAF

SAF Mandate

Kickstart a domestic SAF industry

£135m Advanced Fuels Fund

UK Clearing House

5 plants under construction by 2025

Secure investment

Revenue certainty mechanism by 2026

Working with industry to remove barriers

Why are we supporting SAF?

Reduce emissions and support the UK's legal net zero commitment. SAF to contribute 17% of the carbon abatement needed to reach net-zero aviation by 2050.

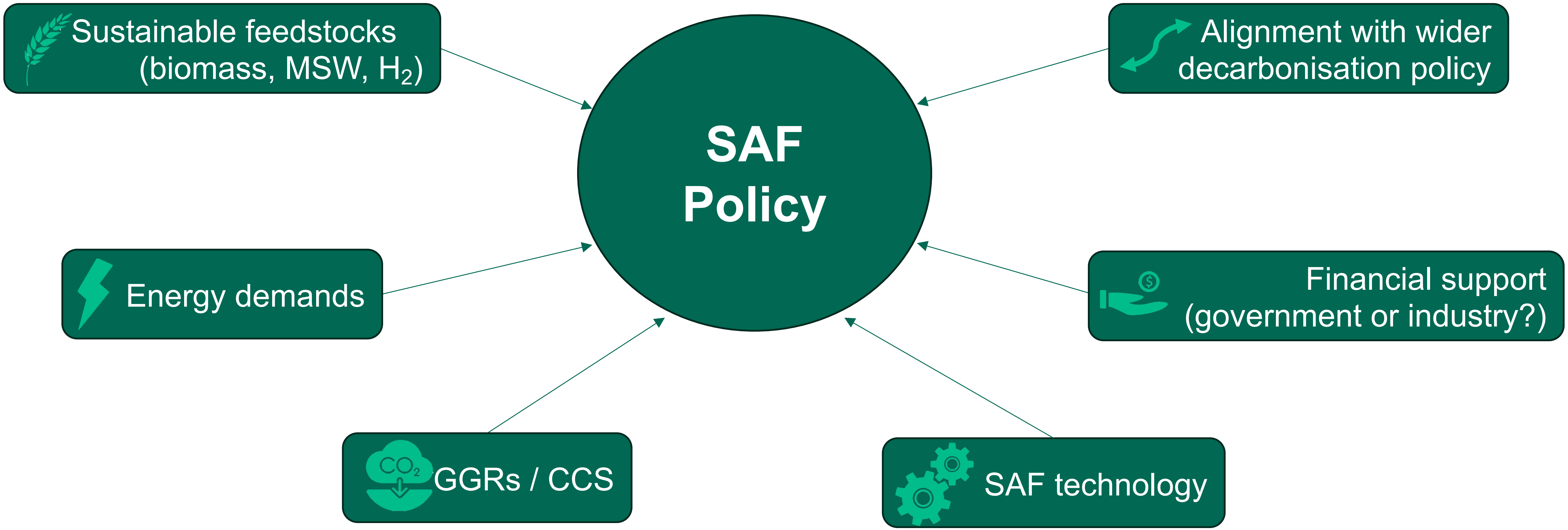
Support economic growth across regions. A SAF industry could generate up to £2.7bn GVA for the UK from UK production and global exports by 2035.

Support green jobs. 5200 jobs by 2035.

Increase domestic fuel resilience

SAF policy key considerations

In designing our SAF policy programme, we have had to consider several key areas. Many of these considerations have required collaborative working across government, to ensure alignment and that economy wider decarbonisation ambitions are achieved.



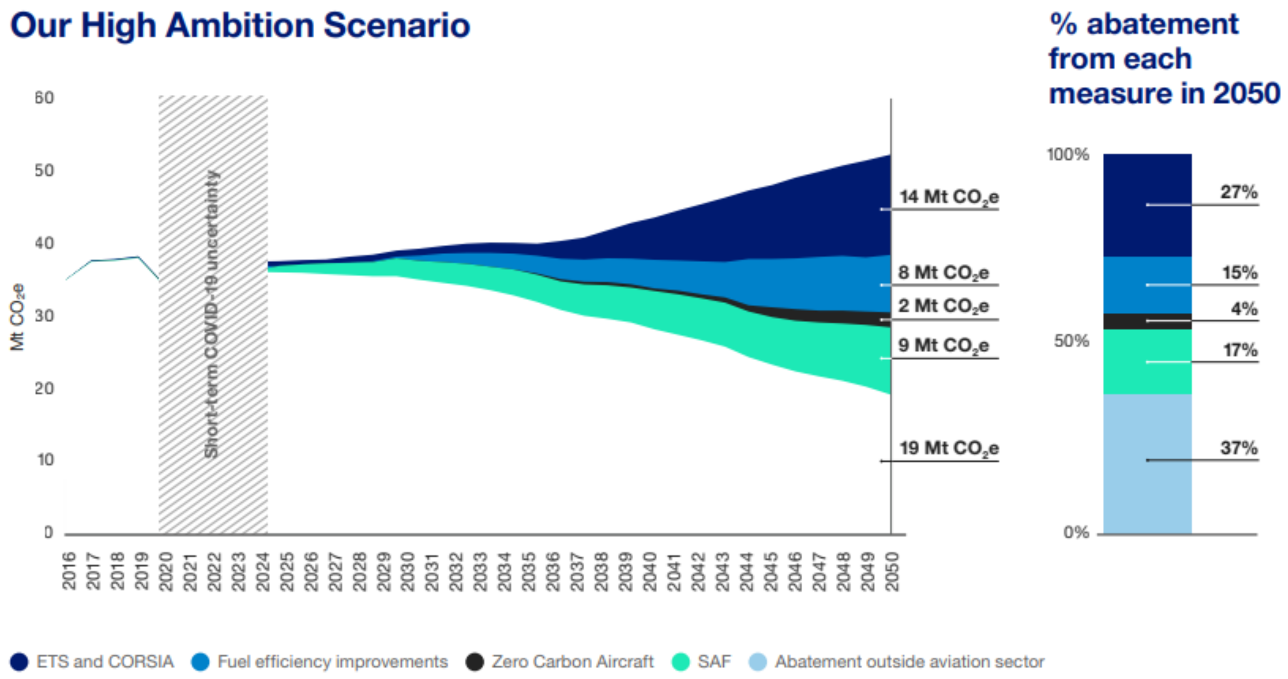
Identifying the risks to SAF growth

To direct our policy interventions, we have **worked collaboratively with industry to identify the risks to SAF uptake and growth of a domestic SAF industry.** We also commissioned an independent report to identify the conditions required to build a domestic industry. The key risks highlighted:

- **Policy certainty into the future**
- **Supply and demand uncertainty**
- **Revenue certainty**
- **Technology / construction risks**
- **Feedstock availability**

Jet Zero Strategy

The Jet Zero Strategy sets out the UK Government's ambition and approach to achieving net zero by 2050 for UK aviation. The Strategy focuses on the rapid development of technologies in a way that maintains the benefits of air travel, whilst maximising the opportunities that decarbonisation brings for the UK.



The JZS sends a clear signal to industry on the role we expect SAF to play in decarbonising aviation, encouraging investment.

The JZS sets out several public commitments on what we will do to build a thriving UK SAF sector to further provide confidence.

SAF Mandate

Core programme objective: *Create secure and growing UK SAF demand*

The UK will introduce a SAF mandate from 2025, obligating at least 10% (c. 1.5bn litres) of jet fuel to be made from sustainable sources from 2030. This policy will:

- **Deliver meaningful carbon savings** by only supporting the most sustainable SAF's. The mandate will only support waste- and residue-derived biofuels, recycled carbon fuels and power-to-liquid fuels.
- **Provide policy certainty on the future of SAF.**
- **Provide certainty on SAF supply and demand.** The mandate will secure demand for SAF by obligating suppliers to purchase from producers. It will incentivise production and supply through the provision of tradable certificates with a cash value.
- **Help address perceived feedstock risks.** Trajectories will consider cross-government agreed feedstock modelling. It will also diversify production routes through a HEFA cap and direct more support to non-biogenic feedstock pathways (which are likely to become scarcer) through a PtL obligation.

Advanced Fuels Fund (AFF)

Core programme objective: *Kickstart a domestic SAF industry*

The £135m Advanced Fuels Fund supports first-of-a-kind SAF production plants through the project pipeline to reach an investment ready stage. The AFF:

Addresses perceived technology and construction risks by taking first-of-a-kind SAF demonstration projects through the project pipeline, including through detailed feasibility studies, to the final construction phase.

Provides certainty on SAF supply by supporting our ambition to have 5 plants under construction in the UK by 2025. It will further support our mandate and carbon emission reduction targets, by securing supply in the UK.

Helps address perceived feedstock risks by supporting the advancement of a diverse range of technology routes to SAF, so we are not locked into one kind of feedstock.

UK Clearing House

Core programme objective: *Kickstart a domestic SAF industry*

A UK hub to support safety testing and certification of new aviation fuels through co-ordination, advice and funding. The UK Clearing House:

Addresses perceived technology risks by expediting and reducing the cost of testing new SAF pathways, facilitating their quick access to the market. The Clearing House will work with EU and US counterparts to ensure global efficiencies in testing.

Is a low-cost policy solution, which can still encourage investment in SAF production facilities.

Revenue Certainty Mechanism

Core programme objective: *Secure investment*

The UK has committed to delivering a revenue certainty mechanism to support the growth of a UK SAF industry and has set out how this could be achieved by 2026. The revenue certainty scheme will be industry funded. The scheme will:

- **Provide certainty on revenues from SAF products for a defined period,** with the aim of driving investment in SAF production in the UK. There are different ways to design and deliver such a mechanism. This will be the subject of a forthcoming consultation

- **Provide policy certainty on the future of SAF.**

Thank you

Antony Henderson
Head of SAF Strategy, UK Department for Transport
antony.henderson@dft.gov.uk

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Workshops 1 and 2: Roundtable Discussion Recap

Dr. Diganta Das (Loughborough University)
Dr. Sharon George (Keele University)

UKRI Research England

Discussion sessions recap: Sustainable Aviation Fuels

Barrier/need	Opportunities/solution
Production costs to be lowered	Subsidy for SAFs and tax on fossil aviation fuels Scale-up and mass-production Economic modelling supply Local production to reduce transport costs (subsidies)
Sufficient supply to meet demand and competition with food and competing markets	Broaden range of feedstocks and include waste-to-energy Increase energy security and reduce shortages Increase fuel from waste routes Increase mobility of fuel through developed transport routes and methods
Lack of momentum	Mapping of UK/Singapore infrastructure facilities – a database can be created (Cranfield has experience of facility mapping) Create UK Singapore research hub in SAF Support uptake through access to demonstration activities Access to finance
Genuine decarbonised and sustainable production and use	Enforcing international sustainability standards, e.g. ISCC, RSB Checking the certification and monitoring standard, and ensuring traceability of fuel Human ethics and environmental consideration

Workshop 1 Outcomes: Sustainable Aviation Fuel

What: Considered challenges around the availability of feedstocks, technology, capacity and capability, and the supply chain system

Outcomes:

- Regional availability
- Supply chain energy consumption
- Various feedstocks and its diversity
- Feedstock production pathways
- Regulation and cost
- Minimise land use impact

- Cost implications and regulations
- SAF entry points, location and volume requirements
- Blending, storage and logistics
- Production to point of use, traceability
- Quality control
- Mapping existing infrastructure

- E-fuel or biofuel
- Alternative SAF approaches
- Increasing efficiency
- Conversion technologies for multiple fuels types
- Lowering costs
- Life cycle of GHGs
- Trade options and hub developments
- Repurposing existing biorefineries

Technical Spec, Cost and Government Intervention

Discussion sessions recap: Hydrogen development

Barrier/need	Opportunities/solution
High cost of production	Subsidies and tax on fossil aviation fuels Investment in supply chains Scale-up of production to reduce costs
Need for decarbonisation through zero carbon production routes	Role for CCS, green hydrogen, and novel production routes that include carbon capture Need for stringent certification and regulation Testing and monitoring
Lack of awareness	More demonstrations Sharing of data/knowledge and IP
Need for rapid development	Reduction of regulatory barriers, better communication of standards, and sharing of knowledge, e.g. establishment of an international aviation hydrogen development hub
Hydrogen priority production routes	Pink/blue, carbon sequestration, ammonia, duel-fuel, exploration of local sources (Biogas from AD)

Discussion sessions recap: Research priorities

Barrier/need	Opportunities/solution
Research and development priorities in SAFs	Economic modelling Longevity of materials in service Need for retrofit to avoid need for new kit User confidence and acceptance Fuel behaviour in different climates (Singapore is more humid so microbes can degrade fuel)
Research and development priorities in hydrogen	Economic modelling Longevity of materials in service Safety (including failure analysis and testing) User confidence and acceptance New materials for storage and transport
Other decarbonisation routes	Ammonia, Hydrogen, Batteries, Compressed air, nuclear-powered aircraft, biofuels

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Singapore-UK Jet Zero Workshops

Reflections on Policy

UKRI
Research
England

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Driving Aviation Policy towards Net Zero: Overview

Dr Edgar Jimenez (Cranfield University)

Cranfield University

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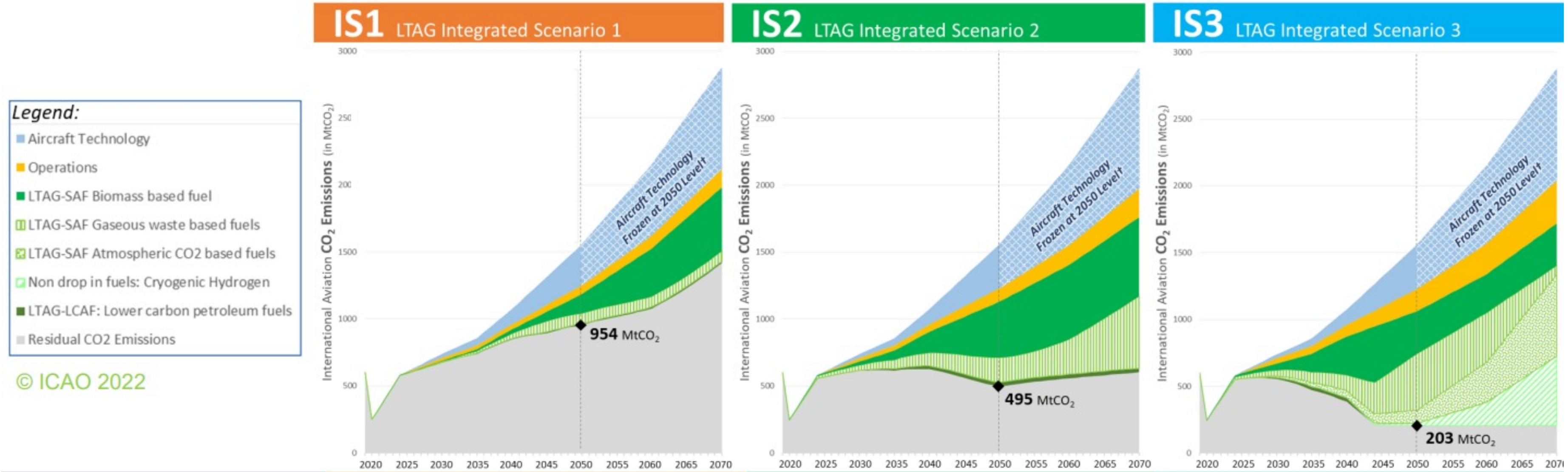
Global aspirations – ICAO LTAG



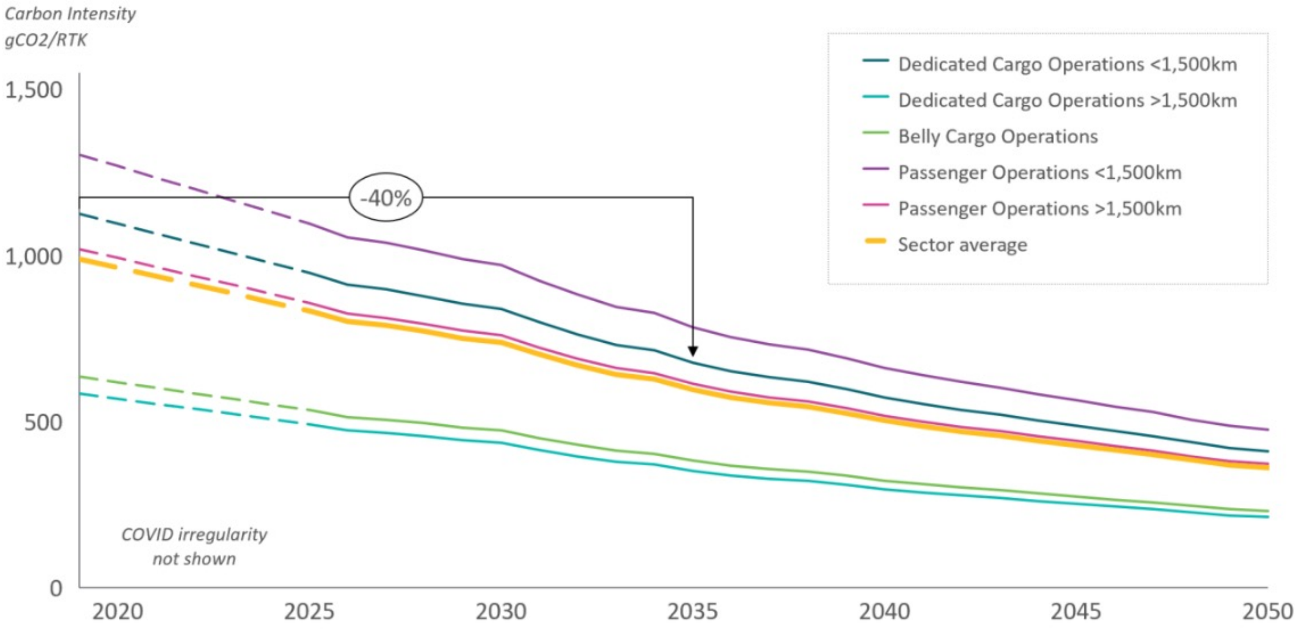
Metrics	IS1	IS2	IS3
CO_2 Emissions in 2050 after Reductions	**≈950 $MtCO_2$** in 2050 *(**160%** of 2019 CO_2 emissions)*	**≈500 $MtCO_2$** in 2050 *(**80%** of 2019 CO_2 emissions)*	**≈200 $MtCO_2$** in 2050 *(**35%** of 2019 CO_2 emissions)*
Reduction in 2050 from the Baseline	**39% total** through: Technologies - 20%, Operations - 4%, Fuels - 15%	**68% total** through: Technologies - 21%, Operations - 6%, Fuels - 41%)	**87% total** through: Technologies - 21%, Operations - 11%, Fuels - 55%
Cumulative residual Emissions from 2020 to 2070	23 $GtCO_2$ (2020 to 2050) 23 $GtCO_2$ (2051 to 2070)	17 $GtCO_2$ (2020 to 2050) 11 $GtCO_2$ (2051 to 2070)	12 $GtCO_2$ (2020 to 2050) 4 $GtCO_2$ (2051 to 2070)

ICAO Report on Feasibility of a Long-term Aspirational Goal for International Civil Aviation CO2 Emission Reductions (LTAG): Introduction to the ICAO LTAG process. Available on https://www.icao.int/Meetings/2022-ICAO-LTAG-GLADS/Documents/1_2%20LTAG-GLADs_Day-1_2%20LTAG%20report_vPOSTED.pdf

Effective action is demanded for businesses to remain competitive

Air transport accounts for a substantial proportion of scope 3 emissions for many companies, usually as part of ‘business travel’.

If other sectors pledge to be net-zero, they either reduce or eliminate flying or rely on the air transport industry effectively reducing emissions.



Note: Underlying data supporting intensity pathways is based on the IEA ETP 2020 public report
Source: Global Aviation Carbon Assessment (GACA) Model developed by ICCT; IEA SDS 2020; SBTi

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SCIENCE BASED TARGETS
DRIVING AMBITIOUS CORPORATE CLIMATE ACTION

4946 with science-based targets

7755 companies taking action

3031 net-zero commitments

Science Based Targets. (2021). *Science-based target setting for the aviation sector*. https://sciencebasedtargets.org/resources/files/SBTi_AviationGuidanceAug2021.pdf

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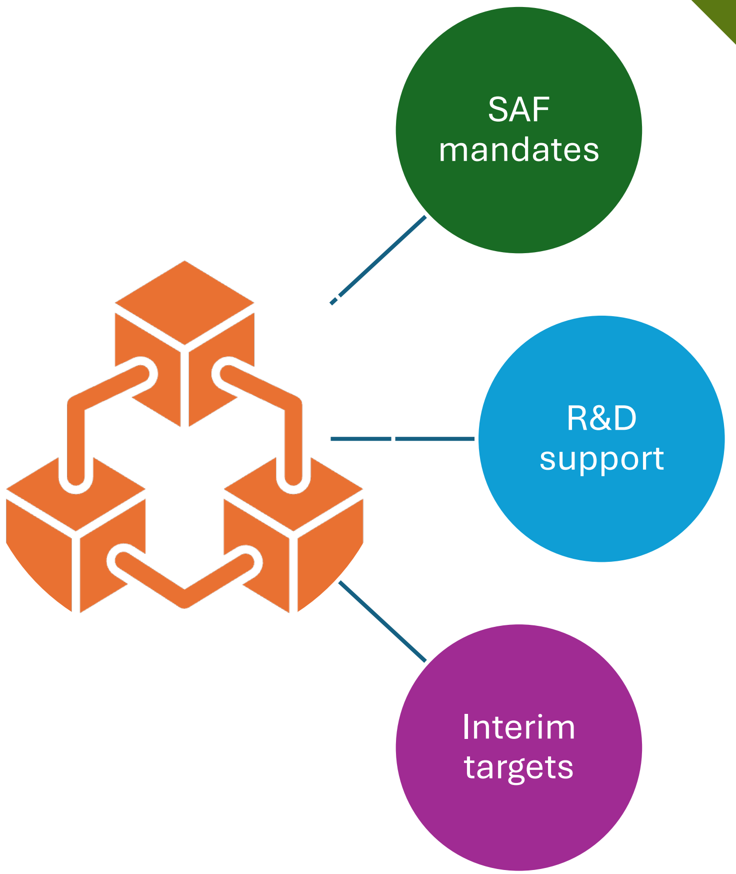
Key policy enablers

ICAO LTAG

- Reliance on broader **economy-wide decarbonisation** to release resources to be used in air transport sector
- Continued uptake and **widespread availability of renewable energy**, both for other sectors and to produce low life-cycle emissions aviation fuels
- **Incentives** to promote widespread use of low life-cycle emissions aviation fuels
- Technological development enables SAF from **carbon capture** and wide availability of **feedstock**
- **Infrastructure** investment to accommodate logistics of different drop-in and non-drop-in fuels at airports



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What has worked in other sectors?

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Policy instruments to reduce costs and stimulate adoption:

- “From 2010 to 2019 there have been sustained decreases in the unit costs of
  - solar energy (85%),
  - wind energy (55%), and
  - lithium-ion batteries (85%),
- and large increases in their deployment,
  - >10× for solar and
  - >100× for electric vehicles (EVs)
- (varying widely across regions)”

1. Public R&D
2. Funding for demonstration and pilot projects
3. Demand-pull instruments

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Calvin, K., Dasgupta, D., Krinner, G., Mukherji, A., Thorne, P. W., Trisos, C., Romero, J., Aldunce, P., Barrett, K., Blanco, G., Cheung, W. W. L., Connors, S., Denton, F., Diongue-Niang, A., Dodman, D., Garschagen, M., Geden, O., Hayward, B., Jones, C., … Péan, C. (2023). ***IPCC, 2023: Climate Change 2023: Synthesis Report***. *Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland.* (First). Intergovernmental Panel on Climate Change (IPCC). https://doi.org/10.59327/IPCC/AR6-9789291691647

Sustainable roadmaps for Future Flight

Dr Chris Parker (Loughborough University)

Sustainable roadmaps for Future Flight

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Dr Chris Parker, Loughborough University

- **CoFFEE:** Co-Creation of Future Flight Ecosystems and Enterprise
  - The motivations of aerospace industry technologists, businesses, and social entrepreneurs influence the emergent FF business models
  - How innovations can be co-developed by technologists and local communities to achieve social and environmental sustainability
  - How the emerging FF ecosystem can be nudged toward viable, safe, and sustainable business models which have low, or even positive, environmental impacts.
- **Team:** Dr Chenyi Liao (Lboro) and Prof Graham Parkhurst (UWE Bristol)

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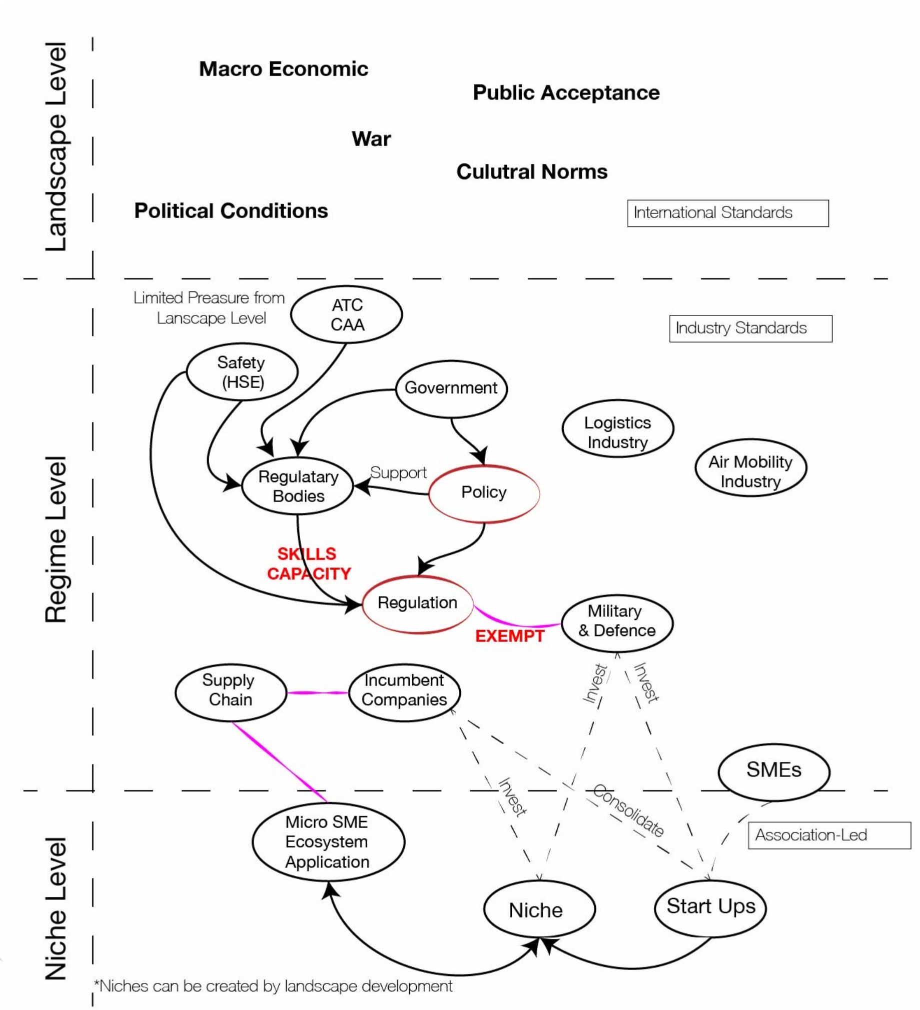
Policy's Role in Shaping Behaviours

- **The industry's growth creates demands for certifying vehicles and operational safety clearances (i.e., Future Flight)**
- **The delay and regulation gaps to support the FF industry's development.**
  - The lack of regulatory capacity, including labour and skills causes such regulatory delays.
- While the UK government has initiated policies to decarbonise flights (i.e. Jet Zero), pathways of carbon neutral timeline, laws, and regulations to accompany the policies are unclear
- **Policy could be implemented to improve the adoption of SAF in the industry.**
  - Leading companies sought for the regulators to establish "a level playing field" and address the disparity in global standards.
- **The government is critical in facilitating decarbonisation**
  - Leveraging the government's power to implement financial incentives to encourage sustainable solutions while imposing penalties on less environmentally friendly options, such as implementing taxes on traditional aviation fuels.
  - Industry representatives also expect the government to "facilitate a decarbonised energy infrastructure"

Policy's Role in Sustainable Business Models



» **Investment/big companies are motivated by their anticipation of policy implications.**

- Their interest in long-term profitability pushes them to address potential future policies on sustainability.
- By staying ahead of the technological changes, they consider the importance of longevity and sustainability in their strategic planning.

» **More regulations and policies in the next 5-10 years**

- fuel policy, passenger changes (public perception – only come with climate events)

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The World of 2050 to be Sustainable Within

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- **Baseline Trends**
  - More geopolitical wars, disrupting the supply of key materials/ components
  - An increased use of drones for weaponization/ terrorism
  - Significant changes in weather (e.g., wind patterns and extreme weather)
  - More older adults in society
  - Fewer physical shops and more online shopping
  - Water/ food scarcity due to climate change
  - Prioritise drone delivery to emergency and medical services
  - An increased awareness of sensory pollution (e.g., light and sound)

Toolkit Available at: https://coffeefutureflight.com

» **Scenario Axes**
- Public see the increased convenience of Future Flight technologies
- A shift to large corporations creating monopolies
- An increase concern on privacy near homes or public spaces
- Businesses focus more on society and the environment
- Increased public awareness and buy into Future Flight
- More people live in urban areas
- Increased congestion on the roads
- More public acceptance of low flying drones
- Retail prefers drone delivery to human delivery
- Scarce labour for freight delivery
- Widespread adoption of autonomous cars on roads
- The airspace in public areas becomes very crowded
- Decrease in wildlife (e.g., bees and birds) because of Future Flight technologies
- A reduction in availability of materials critical to FF batteries

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Example Scenario

TREND 1: More geopolitical wars, disrupting the supply of key materials/ components

TREND 2: Water/ food scarcity due to climate change

Businesses focus more on society and the environment

Future Flight technologies are limited to industrial/ military applications

Public see the increased convenience of Future Flight technologies

Businesses continue to focus on capital

Toolkit Available at: https://coffeefutureflight.com

East Midlands Airport Green Futures Study

East Midland Airport (EMA) decarbonisation: towards a hydrogen-enabled ecosystem

Dr. Nahid Yazdani (The University of Nottingham)

East Midlands Airport Green Futures Study

East Midland Airport (EMA) decarbonisation: towards a hydrogen-enabled ecosystem

The current approach to decarbonising transport is fragmented, focusing on individual technical solutions!

System approach and FCM to Net-zero transition

1. The transition to a green economy is complex and wicked
2. Needs the full cooperation of governments, enterprises, scientific research institutions and the public
3. It has no easy solution or right answer, but the decision must be made
4. It needs bringing together a knowledge of many different experts from different disciplines
5. FCM modelling tool is helpful for analysing such problem
6. It enables decisionmakers to compare the perception of stakeholders
7. simulate different policy options
8. allowing for discussion and insight into the advantage and disadvantage of possible decisions
9. The effects of different policy options can be modelled

Stakeholders’ views on Net-zero journey

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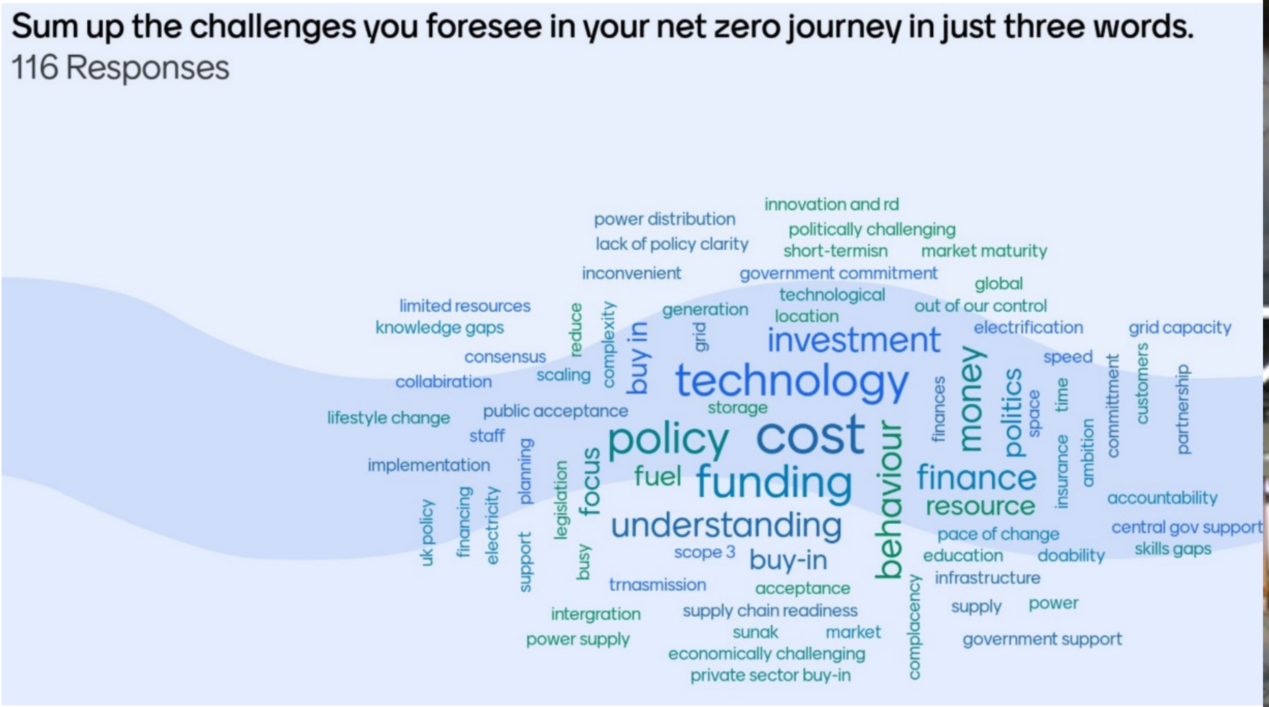
Stakeholder focus groups

50 Stakeholders attended from different groups of airports, freight, local government, energy, infrastructure, researchers, and businesses.



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FCM/ Knowledge map

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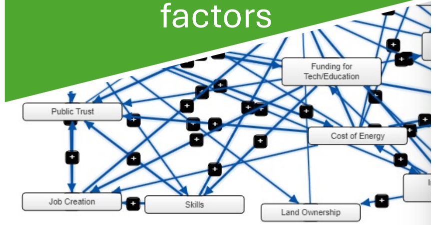
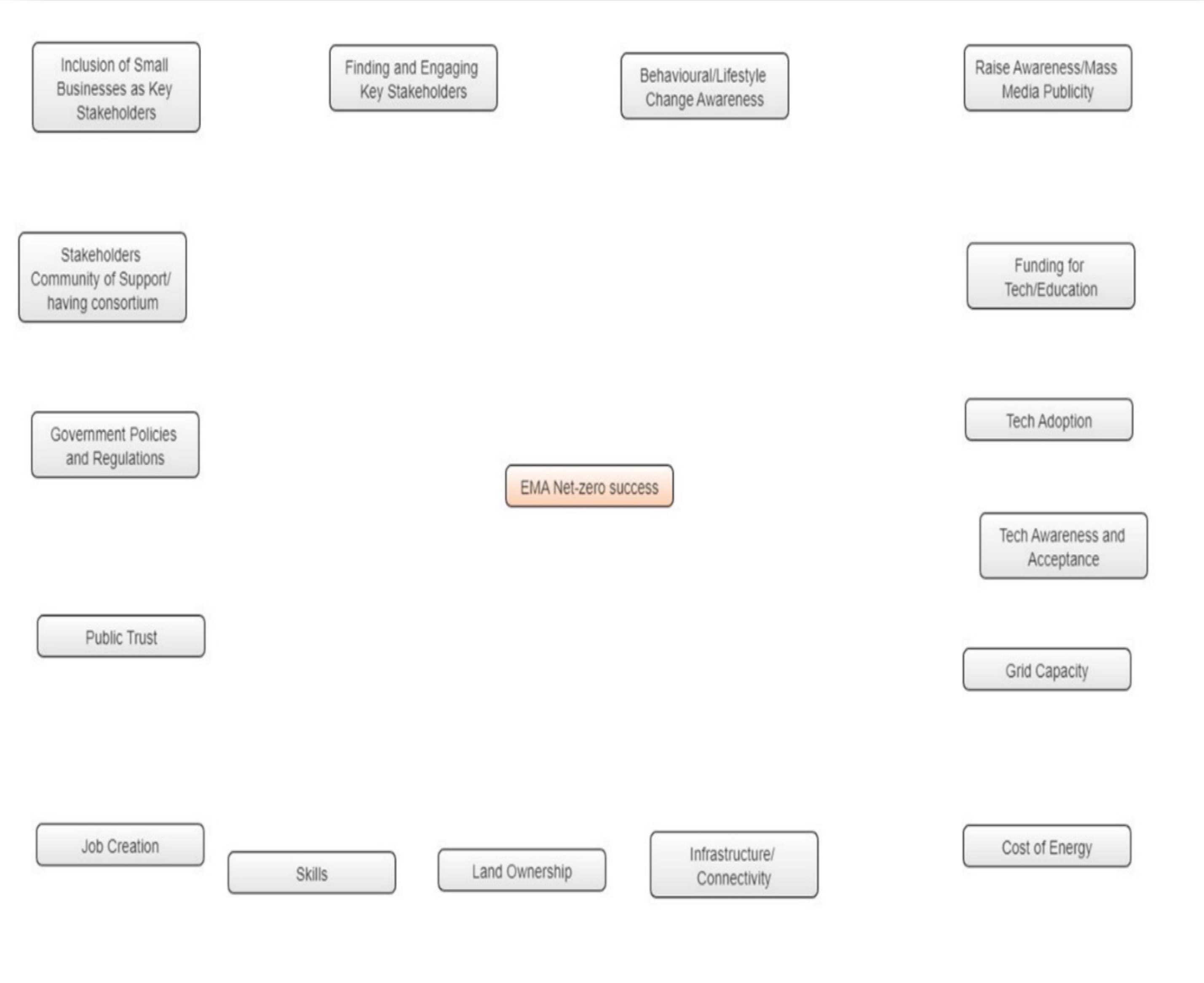
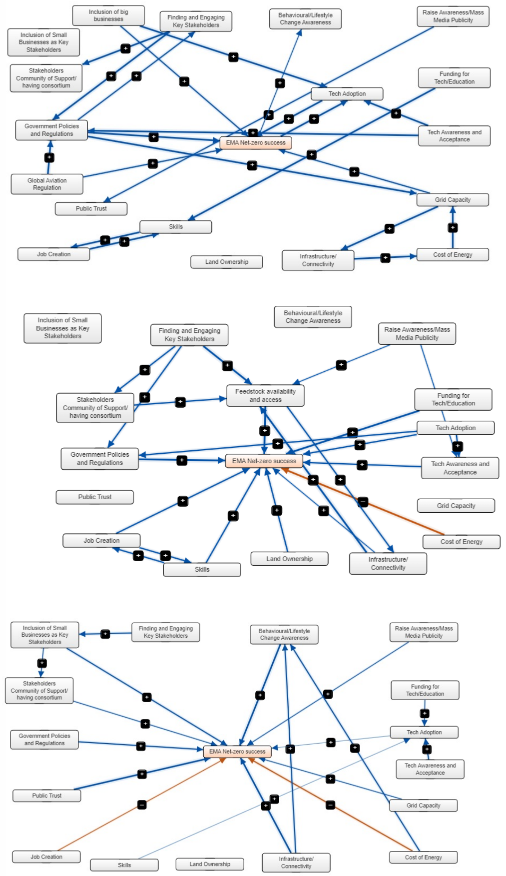
Data coding & FCM

Enablers and barriers to decarbonising airport ecosystem, coded into 16 factors and 4 categories of social, technical, legal, and economic factors







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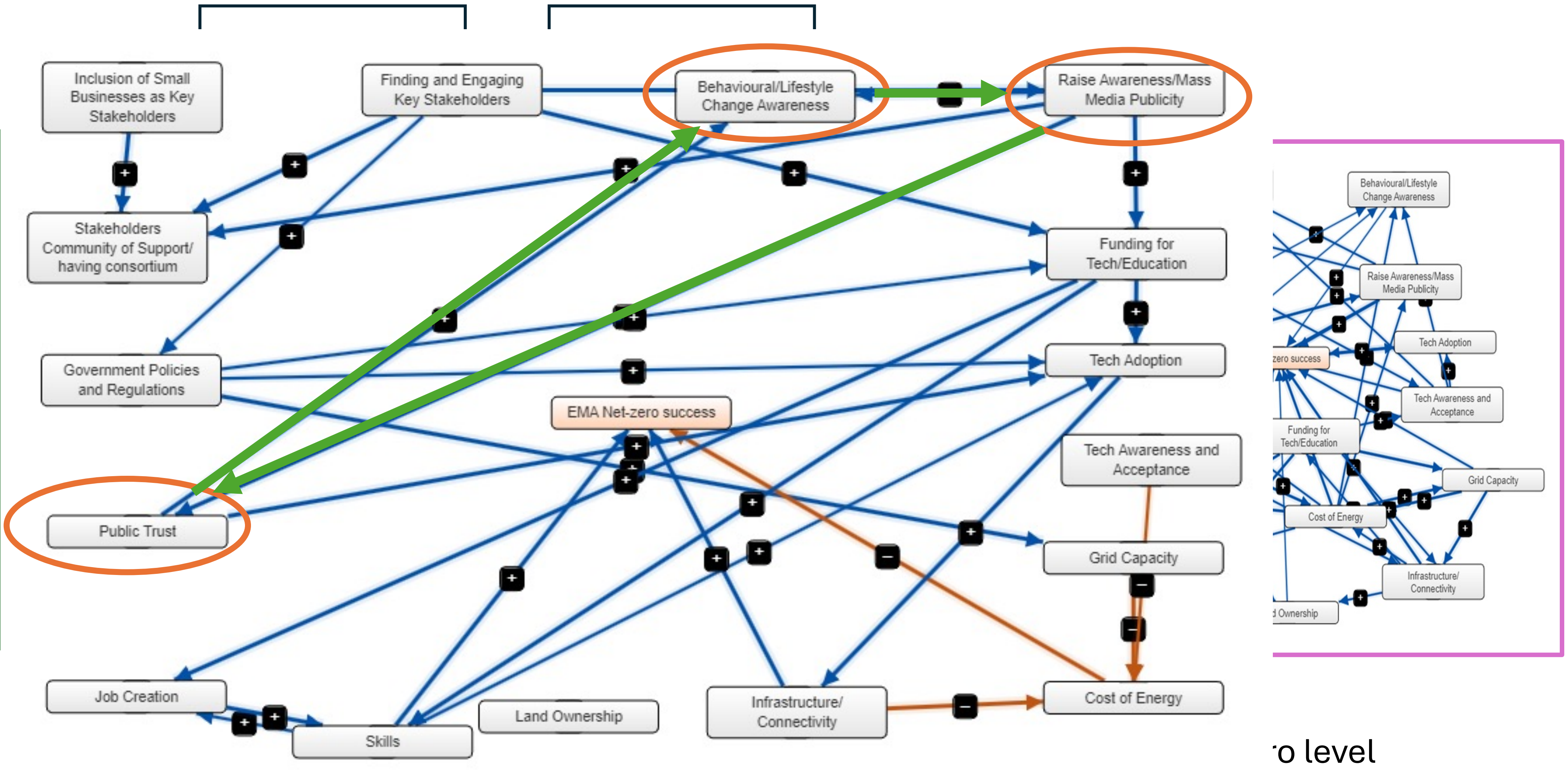
Multi-level Data analysis

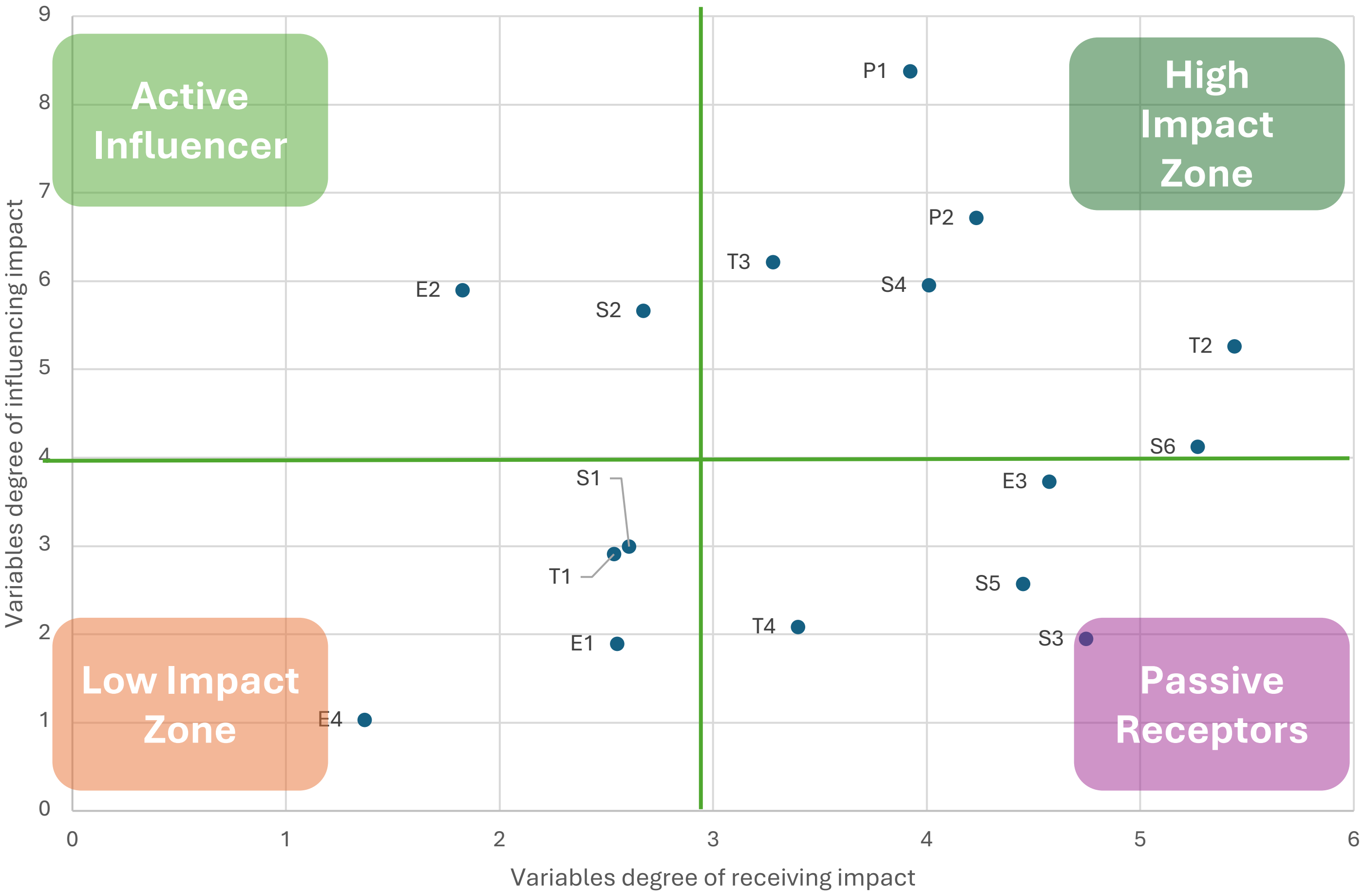
The individual maps are used to develop multi-level cognitive maps to find the patterns in different groups.



Classification of variables based on their impact degree

Scenario analysis

Assists policymakers in creating regulations that respond to stakeholder needs and maximize stakeholder buy-in for experimental policy measures.



S1	Inclusion of Small Businesses as Key Stakeholders
S2	Finding and Engaging Key Stakeholders
S3	Behavioural/Lifestyle Change Awareness
S4	Raise Awareness/Mass Media Publicity
S5	Stakeholders Community of Support/ having consortium
S6	Public Trust
P1	Government Policies and Regulations
P2	Funding for Tech/Education
E1	Grid Capacity
E2	Cost of Energy
E3	Infrastructure/Connectivity
E4	Land Ownership
T1	Skills
T2	Tech Adoption
T3	Tech Awareness and Acceptance
T4	Job Creation

Real options methodology in green hydrogen projects

- Financial implications of green policy

Prof. Ghulam Sorwar (Keele University)

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Introduction to Real Options

Examples:

Solar farm investment decision might include the option to expand capacity if government incentives increase.

Real options can guide when to invest in new electrolyzer technologies, considering future cost declines and efficiency improvements, or the option to delay investment until regulatory frameworks are clearer.

- **Definition**: Real options represent the choice to undertake certain business decisions, such as defer, abandon, expand, or contract a project, under uncertainty.
- Provide a framework for valuing the flexibility to adapt decisions
- Renewable energy projects face uncertainties including fluctuating demand, regulatory changes, and technological advancements

Green Aviation Hydrogen Supply Chain

- **Strategic Decision Making**: Determine the optimal timing for infrastructure investments and technology alternatives.
- **Strategic Flexibility**: Allows aviation fuel suppliers and airport authorities to incrementally invest in hydrogen infrastructure.
- **Risk Assessment**: Better understanding of the risks involved in the aviation hydrogen market.

Overview and Ambition

- **UK**
  - Aims for 5GW of low-carbon hydrogen production capacity by 2030.
  - Scale up low-carbon hydrogen production through investments in various production methods.
  - Create supportive market and regulatory frameworks
  - Export hydrogen technology and hydrogen itself.
- **Singapore**
  - Hydrogen as a major decarbonisation pathway towards net zero by 2050.
  - Experiment with advanced hydrogen technologies and focus on international collaborations to enhance supply chains.
  - Focus on building capabilities for import, storage, and distribution of hydrogen.

Summary:

Both countries face significant uncertainties in the implementation of their strategies – but potential for significant synergy

Areas of Cooperation & Economic Ties

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- **Green Transport**
  - Maritime and air decarbonisation, green shipping corridors, sustainable aviation fuels, zero-emission vehicles.
- **Low Carbon Energy & Technologies**
  - Hydrogen technologies, CCUS, smart grid technologies.
- **Carbon Markets & Sustainable Finance**
  - Transparency in carbon markets, UK-Singapore Financial Dialogue for sustainable finance.
- **Bilateral Economic Ties**
  - UK is Singapore's sixth largest trading partner; significant mutual investment.

SGUK GREEN ECONOMY FRAMEWORK

British High Commission Singapore

Cranfield Environment and Agrifood

HyDEX

Edgar Jimenez

- e.jimenez@cranfield.ac.uk

Chris Parker

- c.parker@lboro.ac.uk

Nahid Yazdani

- nahid.yazdani@nottingham.ac.uk

Ghulam Sorwar

- g.sorwar@keele.ac.uk

Cranfield University

Loughborough University

The University of Nottingham

Keele University

Lunch Break

Roundtable Discussions

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Policy enablers

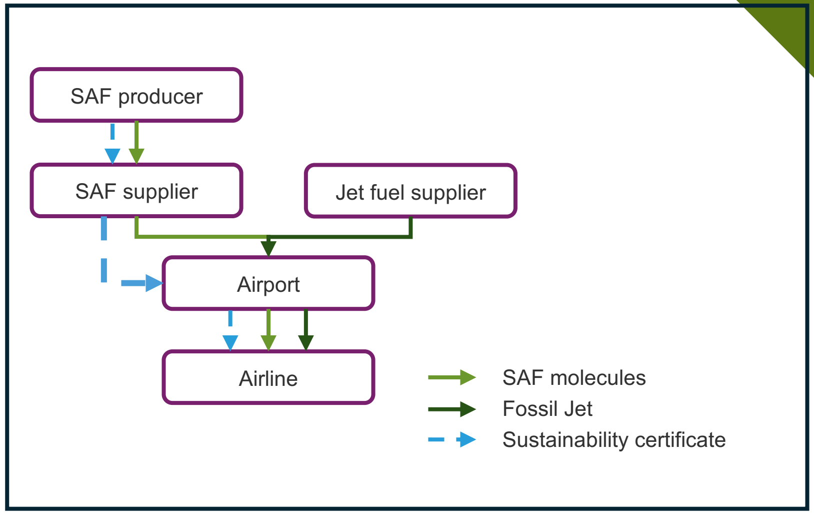
Scenario 1

- It's 2035 and both the UK and Singapore achieved their interim targets of reducing carbon emissions at domestic airport level by leveraging SAF uptake, reducing energy consumption and ensuring 100% renewable energy use for airport processes and full electrification of ground vehicles and passenger and staff surface transport.
- Thanks to joint investment, the first Hydrogen-powered commercial flight on a 100-seats aircraft is about to take off between Edinburgh and London.
- It is expected that H2 based aircraft will make up to 10% of commercial fleets by 2050.
- SAF can be blended with conventional jet fuel in a mix of up to 80% and production is expected to cover up to 40% of demand for flights in the UK and Singapore.

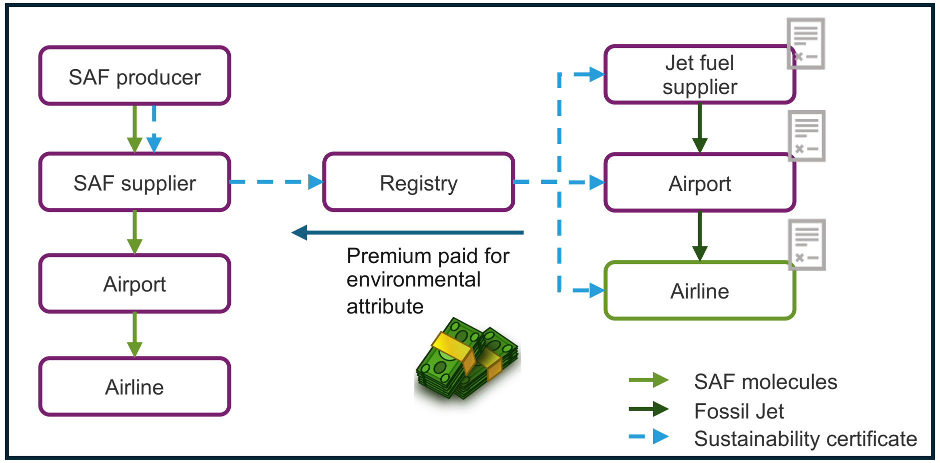
Questions to discuss

- Scenario 1
  - What good policies enabled the current environment?
    - What mix of mechanisms could support it?
  - What else can be done to accelerate the good momentum?

Mass Balance



Book and Claim



- Scenario
    - It's 2035 and both the UK and Singapore achieved their interim targets of reducing carbon emissions at domestic airport level by leveraging SAF uptake, reducing energy consumption and ensuring 100% renewable energy use for airport processes and full electrification of ground vehicles and passenger and staff surface transport.
    - Thanks to joint investment, the first Hydrogen-powered commercial flight on a 100-seats aircraft is about to take off between Edinburgh and London.
    - It is expected that H2 based aircraft will make up to 10% of commercial fleets by 2050.
    - SAF can be blended with conventional jet fuel in a mix of up to 80% and production is expected to cover up to 40% of demand for flights in the UK and Singapore.
- **Questions**
    - **What good policies enabled the current environment?**
        - **What mix of mechanisms could support it?**
    - **What else can be done to accelerate the good momentum?**

Policy enablers

Scenario 2

- It's 2035 and both the UK and Singapore are able to support up to 5% SAF uptake at local airports.
- Hydrogen and 100% SAF use for aviation have proven viable, yet feedstock has not been available at a reasonable cost to support either of them. Aircraft manufacturers could deploy H2 aircraft by 2045.
- Airlines and airports are in poor financial position following an unusually tough year of weather-related cancellations and inefficiencies produced by the lack of skilled labour, along with higher-than-anticipated costs for CORSIA carbon offsetting.

Questions to discuss

- Scenario 2
  - What policies have worked so far?
  - What could be changed to ensure net-zero by 2050 targets are not missed?