SGUK GREEN ECONOMY FRAMEWORK

British High Commission Singapore

Cranfield Environment and Agrifood

HyDEX

Singapore-UK Jet Zero Workshops

Workshop 1: Sustainable Aviation Fuel

25 March 2024

UKRI Research England

Before we start...

- No fire alarms expected
- Toilets
- Wifi:

Please join the conversation about today's event on social media:

#UKSingaporeJetZero
#UKSGEF
X @HyDEXMidlands, @UKinSingapore
LinkedIn HyDEX, UK in Singapore

British
High Commission
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Programme for today

Time	Agenda
10:00-10:30	Arrival & Reception (coffee/tea/ snacks)
10:30-11:00	Welcome & Introduction: Adrienne Scott Cox (Nature, Climate and Energy Attaché, British High Commission Singapore)
11:00-11:30	Welcome and overview, intent of the workshops: Prof. Ron Corstanje (Cranfield University)
11:30 -12:30	UK presentation on SAF: Prof. Kumar Patchigolla (Teesside University), Dr. Ali Nabavi (Cranfield University), Dr. Diganta Das (Loughborough University), Dr. Vinod Kumar (Cranfield University); Singapore presentation on SAF: Dr Roong Jien Wong (A*Star)
12:30-13:30	Lunch & Networking
13:30-14:45	Roundtable Discussion (All participants)
14:45-15:15	Afternoon refreshments
15:15-15:30	General feedback and room level discussion (All participants)
15:30-16:00	Recap and closure of workshop: Prof. Ron Corstanje (Cranfield University)

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Singapore UK Jet Zero Workshops

- ***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

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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 cloud formation
- Aircraft design
- Advanced engine technology

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Blueprint for Zero Emission Flight and Infrastructure

ENERGY
NNOVATION

SYSTEMS
INTEGRATION

ENABLING
JET ZERO

CATAPULT Connected Places

Funded by Department for Transport

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Workshop 1: Sustainable Aviation Fuel

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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

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Workshop 2: Hydrogen

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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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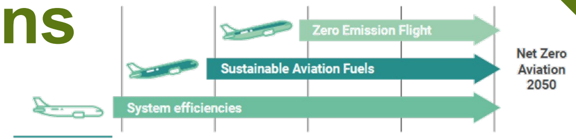
Workshop 3: Policy Ambitions



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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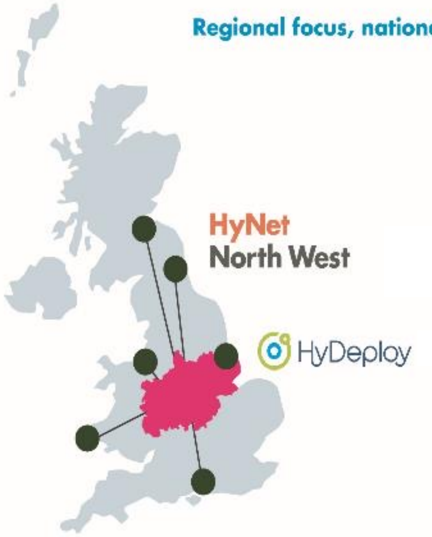
Delivered by ERA Energy Research Accelerator

Supported by Midlands Engine

Regional focus, national impact, internationally networked



Enable large-scale

- Access to large scale demonstrator and test facilities
- Support for technology development and R&D
- Support for IP development and commercialisation
- Development of hydrogen skills and expertise in businesses
- Civic engagement and policy activities to build understanding
- Development of access to international markets and inward investment

Industrial processes

HEATING

Cadent, centrica, EQUANS, Progressive energy, SIEMENS, WORCESTER BOSCH

TRANSPORT

MIRA, cenex, Intelligent Energy, JCB, MOTIVE, SIEMENS, TOYOTA, FAUN, ZOELLER

PRODUCTION

EDF Energy, Progressive Energy, uniper

INTERNATIONAL ACADEMIC PARTNERS

ERA, RWTH Aachen University, UNSW Sydney

ERA UNIVERSITY PARTNERS

Aston University, University of Birmingham, Cranfield University, Keele University, University of Leicester, Loughborough University, University of Nottingham, Warwick

MANUFACTURING

British Ceramic Confederation, SIEMENS, WORCESTER BOSCH, TOYOTA

REGIONAL POLICY & SKILLS

Black Country LEP, Coventry & Warwickshire, D2N2, Greater Lincolnshire, llep, Marches, Stoke-on-Trent & Staffordshire

Capabilities in Cranfield University

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Airside Hydrogen Production

Hydrogen based aviation

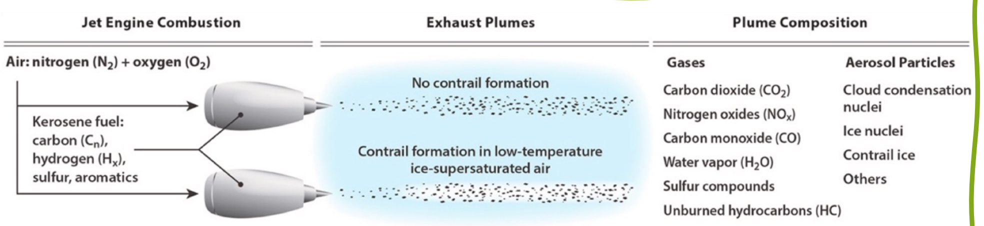
Environmentally friendly ways of making crop-based SAF

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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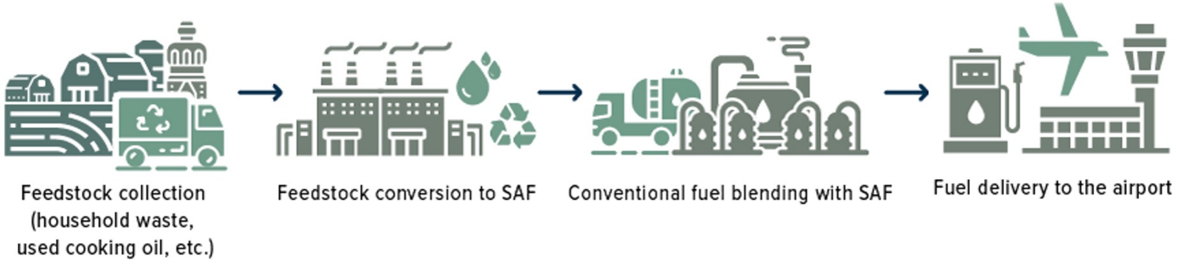
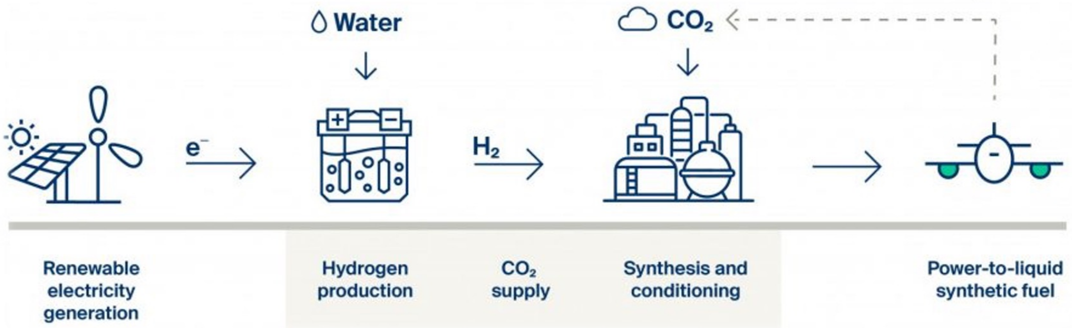
SAF : Biofuels and Synthetic Electrofuels

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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	TRL	Deliverables	
Research	1	Idea... basic principles investigation	Energy Innovation
	2	Concept development, core questions investigated through simulation/bench top component models	
	3	Concept validation experiments/experimental core systems bench top tests	
Development	4	Experimental bench top pre-prototype system in lab	Systems Integration
	5	Small-scale prototype in relevant environment	
	6	Integrated pilot scale demonstrator	
Deployment/ commercialisation	7	Pre-commercial demonstrator	Enabling Jet Zero
	8	MVP/commercial launch	
	9	Commercialisation and product enhancement	

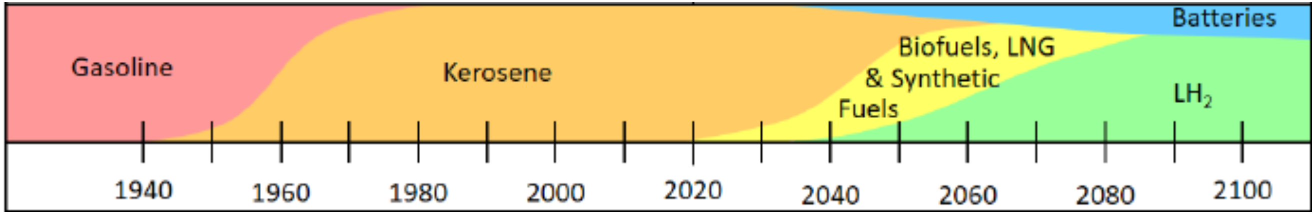
Utilization (TRL 6-9)

Innovation Wave 1
10-15 Years
Focus: Certification

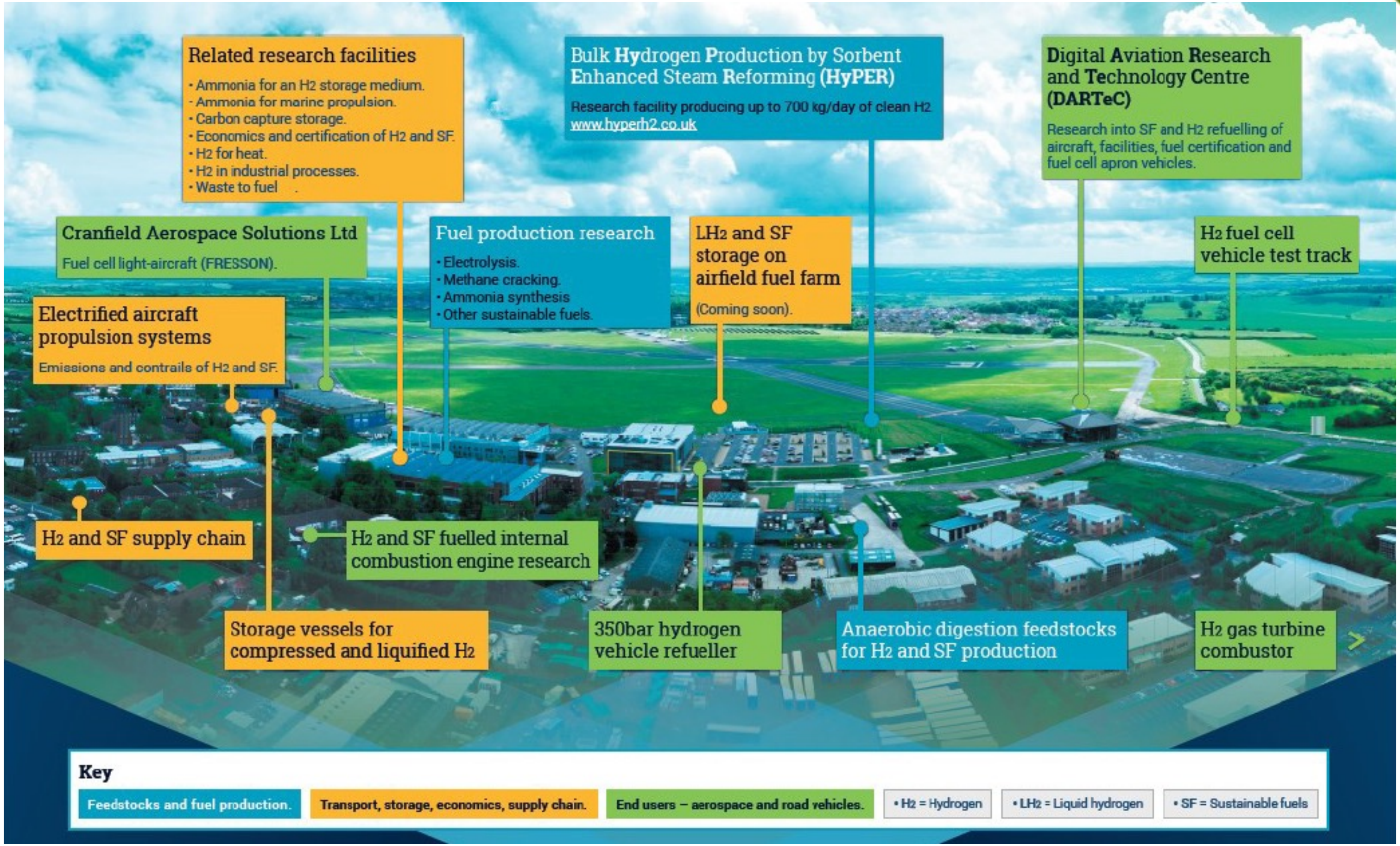
Innovation Wave 2a
20+ Years
Focus: Efficiency

Innovation Wave 2b
20+ Years
Focus: FC Certification

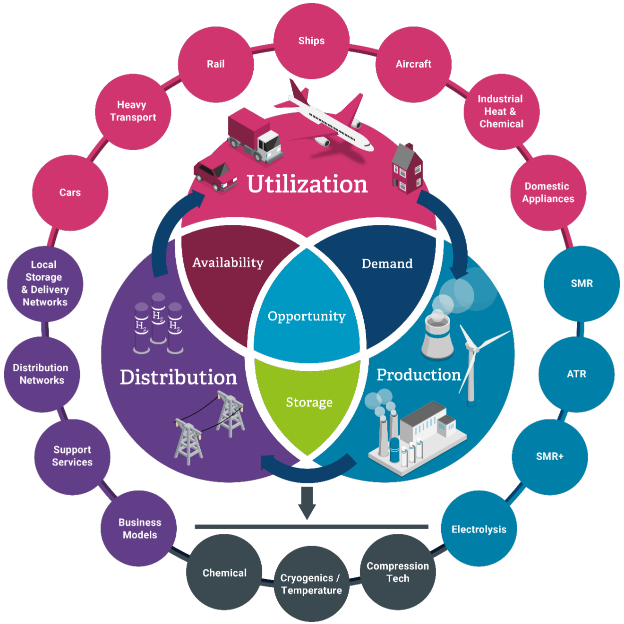
Innovation Wave
30+ Years
Focus: Turbo-cryo-electric



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



Utilization (TRL 6-9)



ENABLE H2

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Net Zero Research Airport

Cranfield
Aerospace Solutions

CAeS-7

GKN-40

1. Enabling H_2 Innovation:

A new £12 million Hydrogen Integration Research Centre (HIRC)

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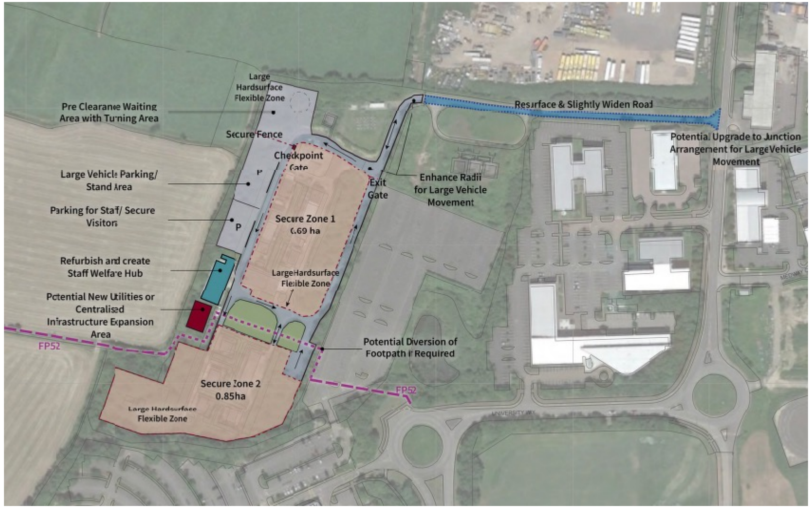
To bridge our related RPIF-funded centres, **AIRC, DARTeC**, **Net Zero Research Airport** programmes and our £7.5 million BEIS-Funded 1.5 MW blue-hydrogen demonstrator- **HyPER**. Dedicated laboratories will enable research linking developments in materials for hydrogen production, storage, SAF, ammonia and hydrogen refuelling for mobility (Figure 1), addressing Points 2, 4, 6, 8 and 10 of the TPP.

GKN | ENERGY RESEARCH ACCELERATOR | HyDEX | NPL National Physical Laboratory | National Centre for Atmospheric Science NATURAL ENVIRONMENT RESEARCH COUNCIL | ROLLS ROYCE | AIRBUS

2. Enabling H_2 Systems Integration:

A £9 million investment in our hydrogen gas turbine and fuel testbed.

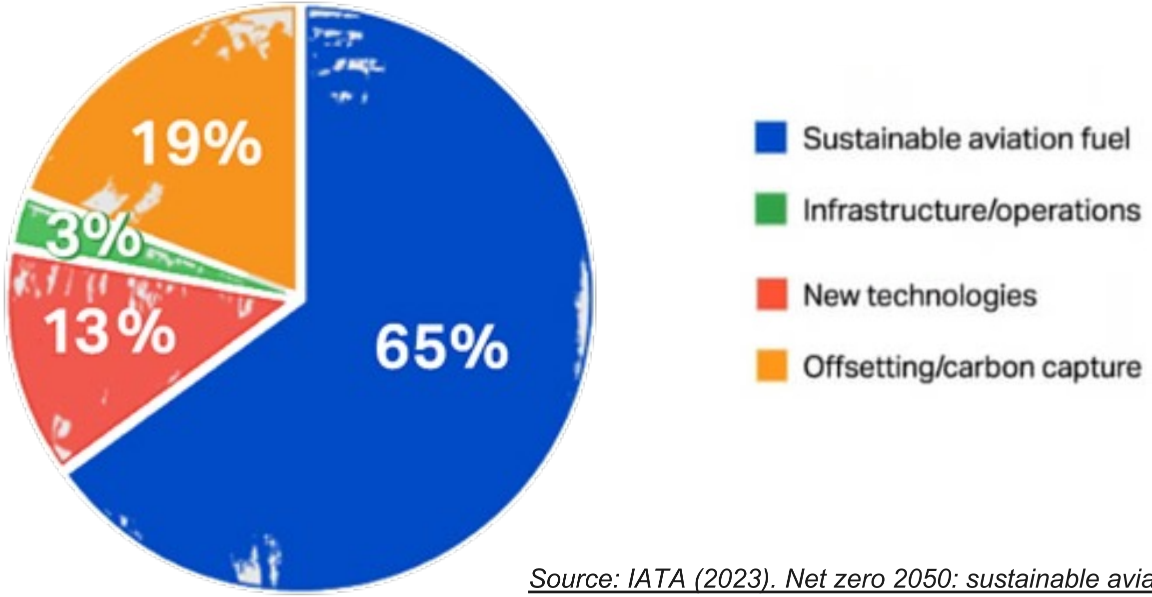
2024: 6 New test cells



2025: A major secure remote test bed

Our 1950s testbed and test cells have been pivotal to gas turbine developments for decades, and central to the rollout of hydrogen in turbines for 'Jet Zero'. Through transformative programmes including **ENABLEH2** and **EU-Cryoplane** our testbed has provided R&D that will enable hydrogen transition for aviation; to accelerate this expansion and modernisation is required, addressing Points 4 and 6 of the TPP. *This will be delivered as staged development avoiding any impact on our existing programmes.

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



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

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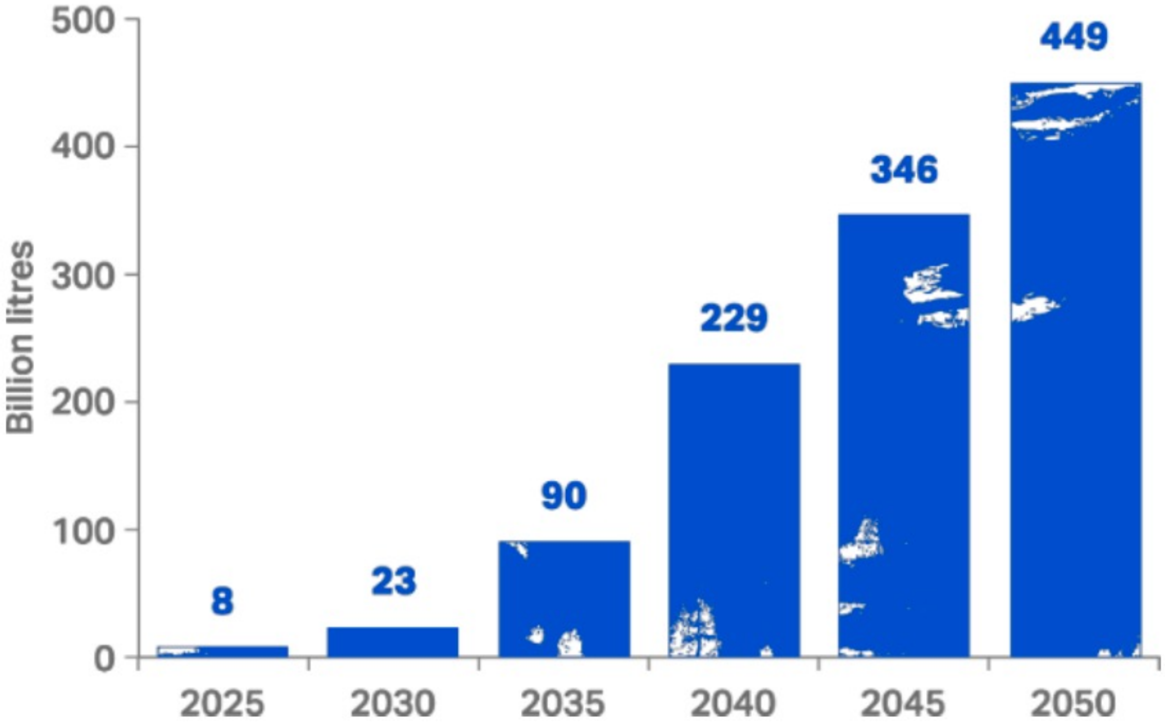
Expected SAF required for Net Zero 2050



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

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How much SAF do we need?

> 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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UK Presentation on SAF

Prof. Kumar Patchigolla (Teesside University)
Dr. Ali Nabavi (Cranfield University)
Dr. Diganta Das (Loughborough University)

UKRI Research England

UK presentation on SAF

This session will cover:

- UK SAF strategy
- Analysis of Jet-Zero Model & Scenarios
- Low TRL academic activities
- High TRL industrial demonstrations, specific to UK
- UK-Singapore developments

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Spot the location, where is it?

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UK SAF Strategy

£165 million government investment

Jet Zero Council

In the UK, at least 10% of aviation fuel to be made from sustainable feedstocks by 2030

5 commercial SAF plants under construction

300,000 tonnes of SAF each year

Slash CO2 by average of 200,000 tonnes each year

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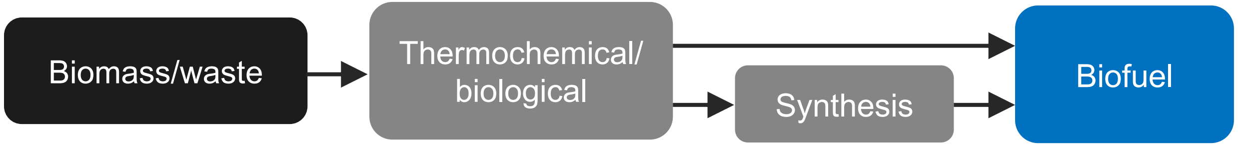
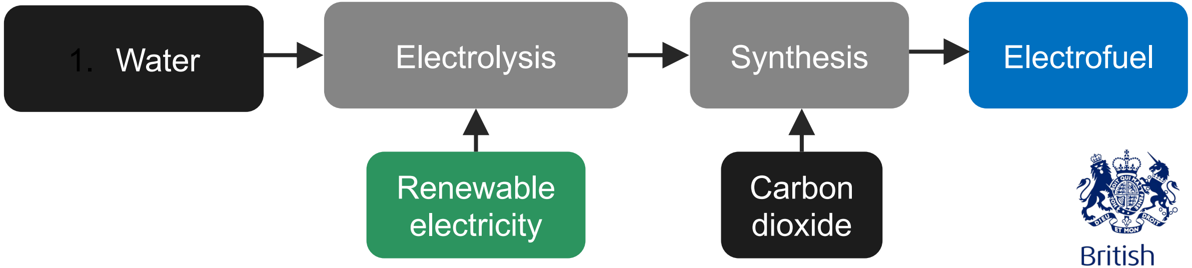
Carbon-based sustainable synthetic fuels:

- Synthetic biofuels

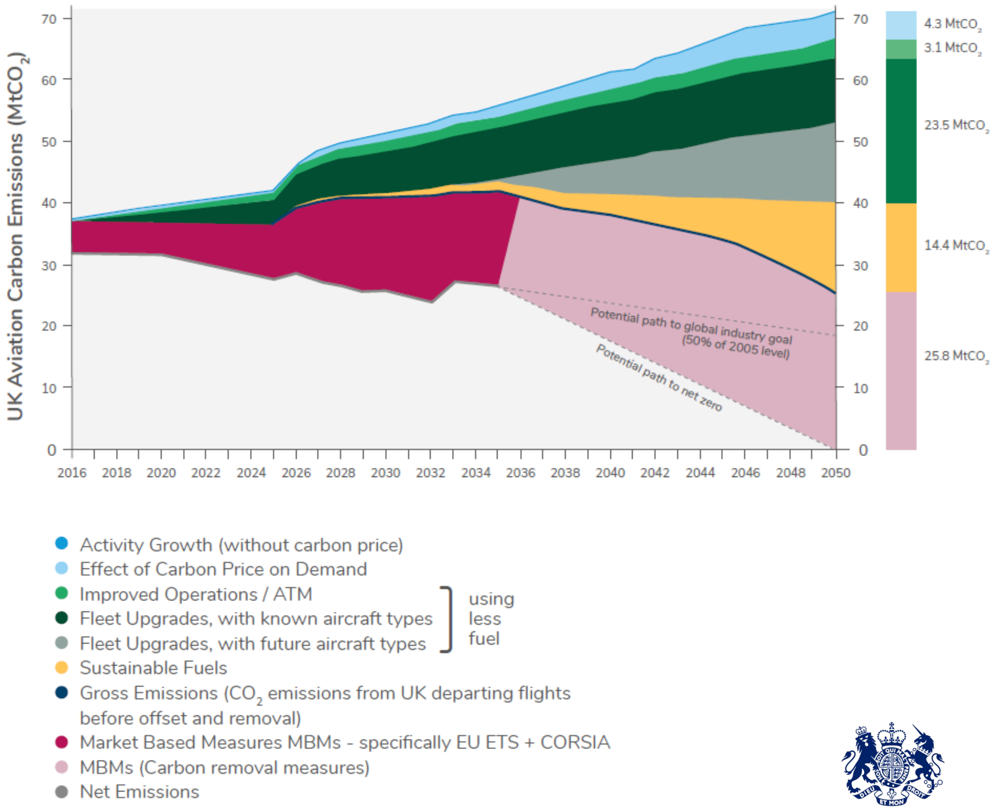


- Electrofuels (power-to-liquid, PtL)



Aviation carbon emission reduction approaches

- Understanding assumptions will be important as this will dictate the residual emissions.
- Each assumption category is linked to one of the other workstreams
  - (1) Operational Efficiencies
  - (2) Clean Propulsion Technology
  - (3) Sustainable Aviation Fuels
  - (4) Model Update



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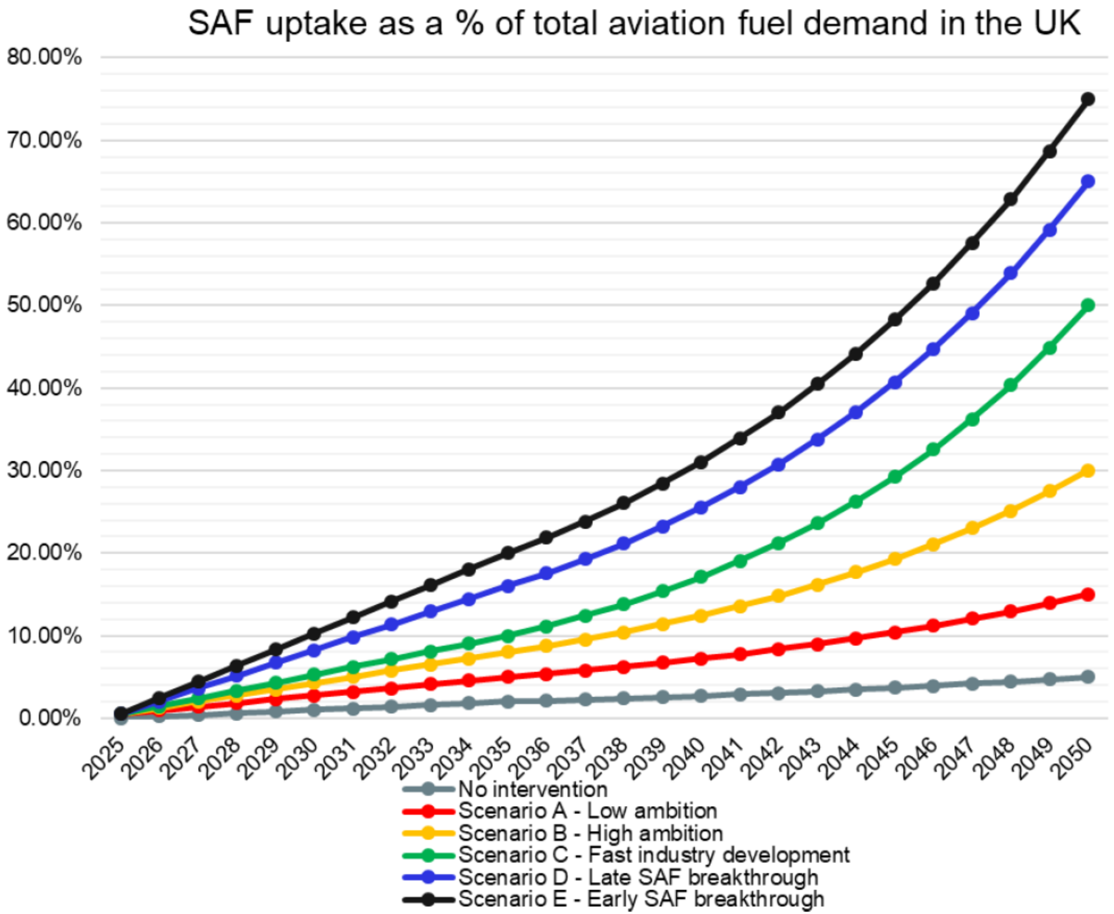
SAF uptake – proposed UK mandate



SAF uptake 10% by 2030 and 100% 2050;

hydrogen powered aircraft by 2035; 50% SAF uptake by 2050

Early industry engagement to deploy SAF intake

step-up in ambition on fuel efficiency improvements, SAF uptake and the introduction of zero emission aircraft

minor fuel efficiency improvements, but no introduction of zero-emission aircraft

DfT, 2022. Sustainable aviation fuels mandate, Summary of consultation responses. London, UK. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1060601/sustainable-aviation-fuels-mandate-consultation-summary-of-responses.pdf

Assumption	Scenario A: Current trends	Scenario B: High ambition	Scenario E: High ambition with breakthrough on sustainable aviation fuels (SAF)	Scenario D: High ambition with breakthrough on zero emission aircraft (ZEA)
Demand	74% increase in UK terminal passengers by 2050 (from 2018) Passenger numbers 493 million in 2050	70% increase in UK terminal passengers by 2050 (from 2018) Passenger numbers 482 million in 2050	70% increase in UK terminal passengers by 2050 (from 2018) Passenger numbers 482 million in 2050	70% increase in UK terminal passengers by 2050 (from 2018) Passenger numbers 482 million in 2050
Carbon price (£$_{2020}$)	DfT mid ETS prices £150/t in 2030, £378 in 2050 Low CORSIA Prices £6/t in 2030, £37/t in 2050	DfT mid ETS prices £150/t in 2030, £378 in 2050 Mid CORSIA Prices £6/t in 2030, £378/t in 2050	DfT mid ETS prices £150/t in 2030, £378 in 2050 Mid CORSIA Prices £6/t in 2030, £378/t in 2050	DfT mid ETS prices £150/t in 2030, £378 in 2050 Mid CORSIA Prices £6/t in 2030, £378/t in 2050
Capacity	Based on airport capacity constraints (Jet Zero Consultation assumptions)	Based on airport capacity constraints (Jet Zero Consultation assumptions)	Based on airport capacity constraints (Jet Zero Consultation assumptions)	Based on airport capacity constraints (Jet Zero Consultation assumptions)
Fuel efficiency improvements	ATA Central Efficiency 1.5% pa (2017-2050)	ATA Central Efficiency 2.0% pa (2017-2050)	ATA Central Efficiency 2.0% pa (2017-2050)	ATA Central Efficiency 2.0% pa (2017-2050)
SAF uptake	10% by 2050 Assumed 70% reduction in carbon intensity vs kerosene	50% by 2050	100% by 2050 10% by 2030	50% by 2050
Zero emission aircraft uptake	None by 2050	27% ATMs zero emission by 2050 Zero emission aircraft introduced after 2035	27% ATMs zero emission by 2050 Zero emission aircraft introduced after 2035	38% ATMs zero emission by 2050 Zero emission aircraft introduced after 2035
Residual emissions ($MtCO_2e$)	35.9	15.4	0.0	9.2

Rank scenarios that you think offer the best trade-offs between ambition and deliverability?

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SAF uptake – proposed EU targets

Detailed goals and milestones are laid out in European Climate Law. The **‘Fit f**
package sets out an initial target of reduction in emissions by 55% in 2030 (co
1990 levels). As part of the ‘Fit for 55’ package, the Commission proposed to b
the uptake of SAF in air transport.

The proposed rules therefore set a sub-target to ensure that a certain amount of SAF used are synthetic fuels (see table).

	2025	**2030**	**2035**	**2040**	**2045**	**2050**
Percentage of SAF used in air transport:	2%	5%	20%	32%	38%	63%
Of which: sub-mandate synthetic fuels (or e-fuels):	-	0.7%	5%	8%	11%	28%

https://www.easa.europa.eu/en/light/topics/fit-55-and-refueleu-aviation

What are the key research gaps for SAF?

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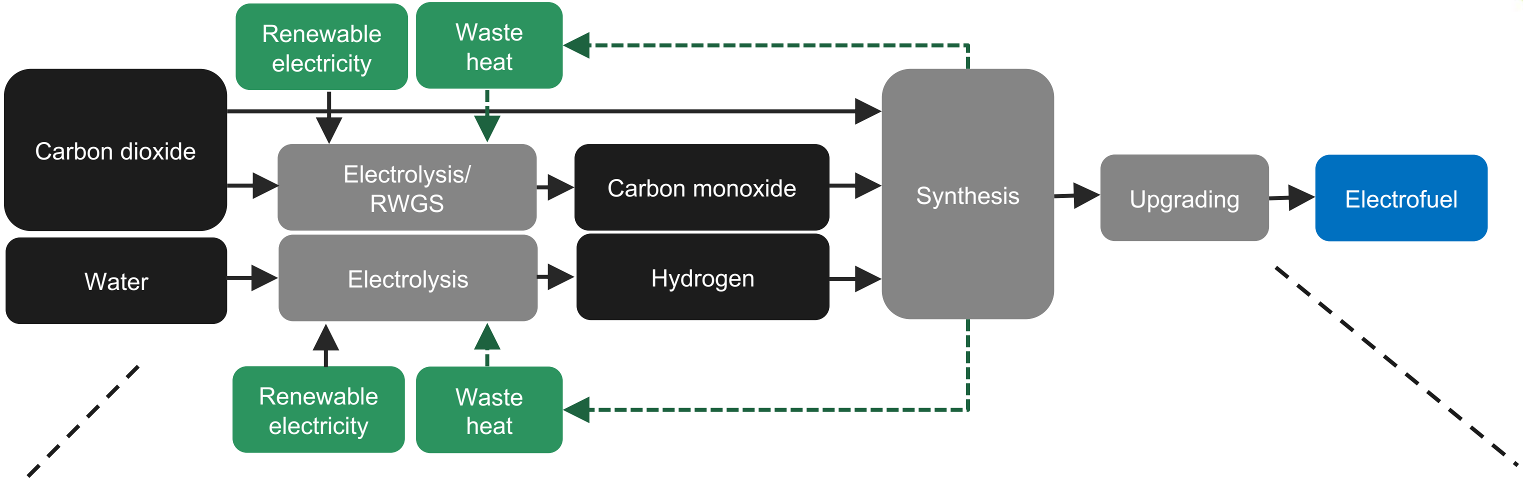
Cranfield activities (1/4) – power to liquids



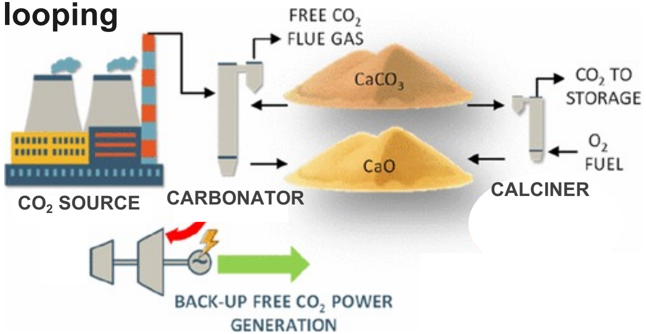
Routes	Synthesis	Electrolyser	CO_2 source	Efficiency (%)	TRL	Limitation
High –Temp.	Fischer-Tropsch	SOEC	DAC*	45-46* 62-63** (2050: 47-64)	5	SOEC / RWGS
	Methanol				5	SOEC
Low – Temp.	Fischer-Tropsch	PEM/AEL	Point sources**	38-41* 48-53** (2050: 42-54)	6	RWGS
	Methanol				8	-

Schmidt et. al., Power-to-Liquids. Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel, 2016.

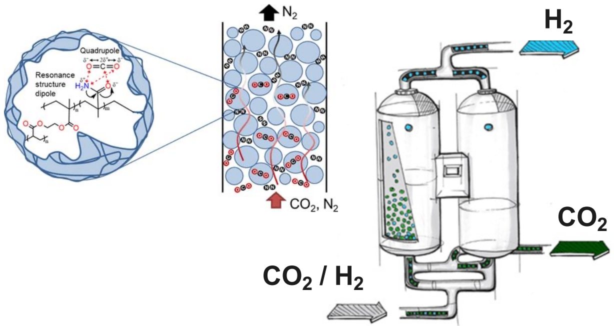
Innovate UK | Engineering and Physical Sciences Research Council | Department for Business, Energy & Industrial Strategy

Cranfield activities (2/4) – CO2 capture and removal

High temperature - Carbonate looping



Low temperature – Functional sorbents



Testing & prototyping

Pilot-scale demonstration

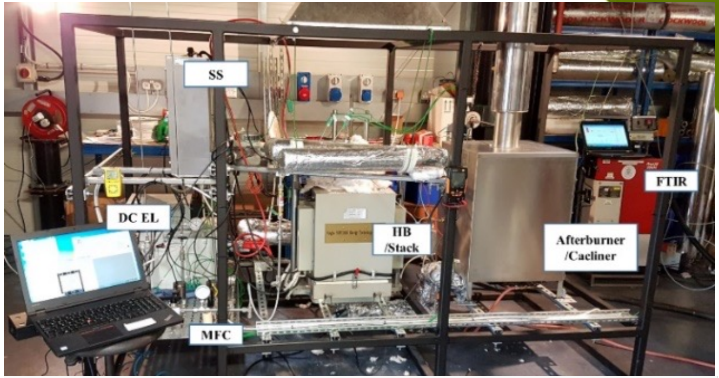
Material formulation, synthesis, & multi-scale characterisation

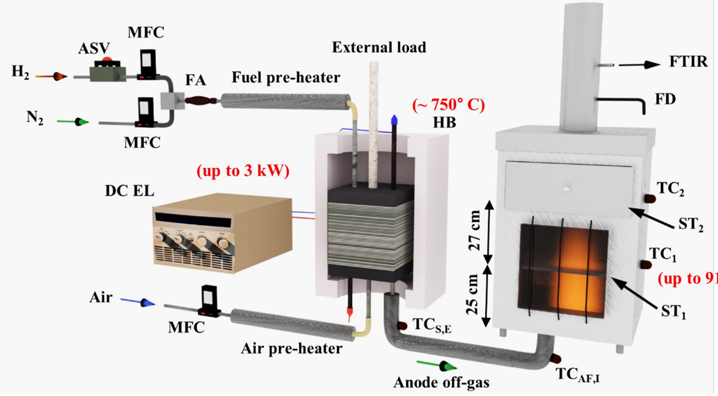
LCA, TEA, supply chain, market analysis

Commercialisation

Cranfield activities (3/4) – Solid oxide facility

- The facility runs:
  - Electrolyser mode to generate green H_2 and H_2/CO which can be further upgraded to SAF
  - Fuel cell mode to generate electricity and high-grade heat (CHP)

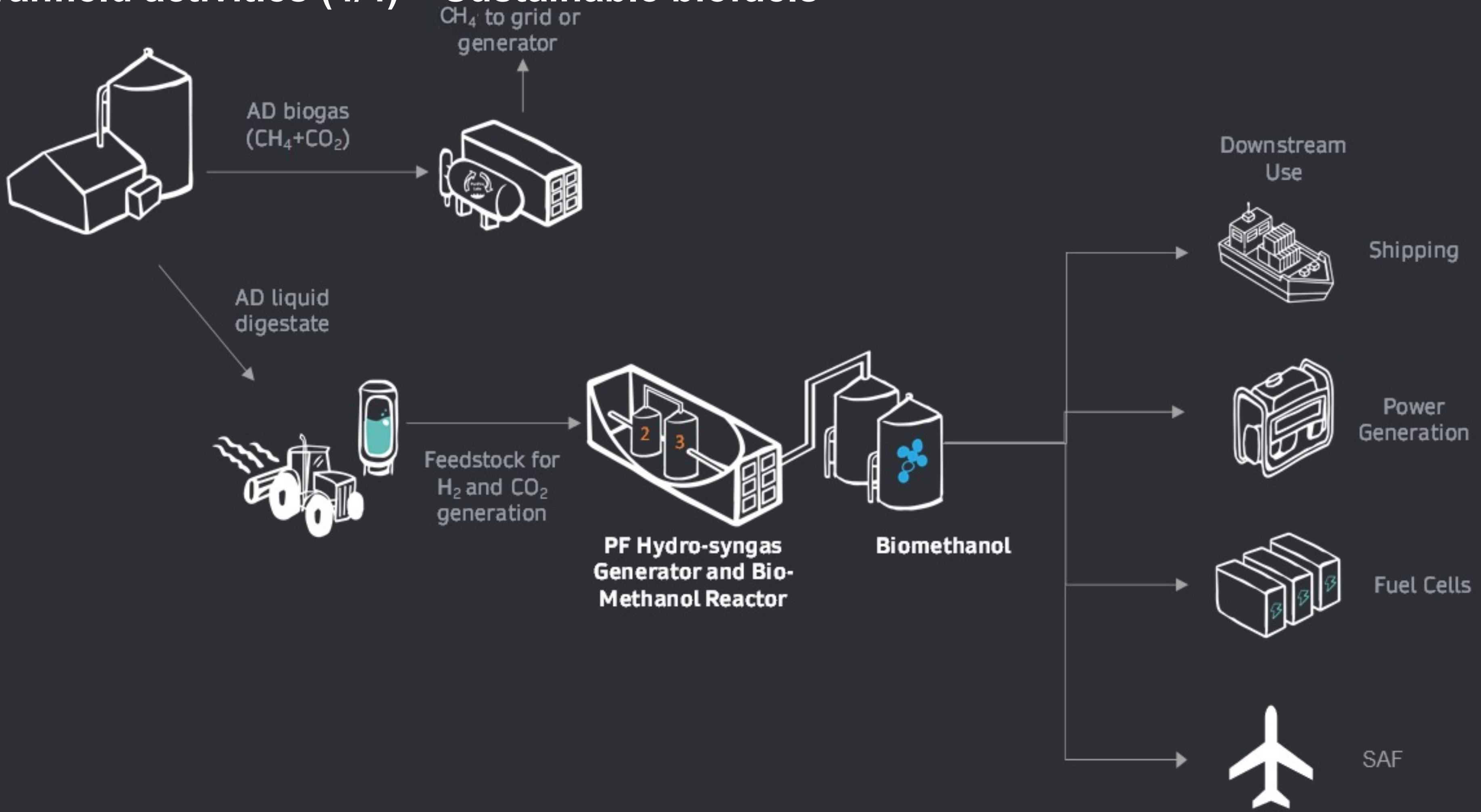




- Test fuel flexibility (low-grade H_2; biogas, biomethane, ammonia, H_2/CO)
- Evaluate performance and durability
- Test next-generation electrodes

TRL: 4

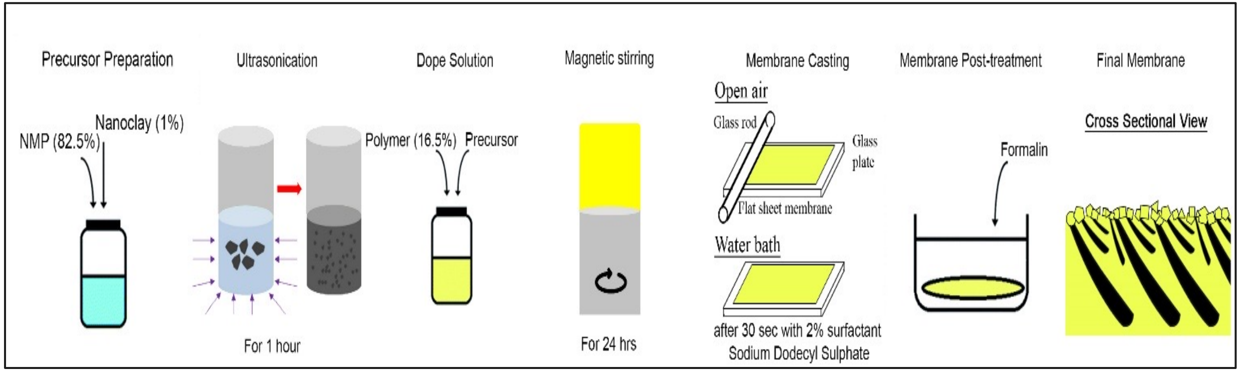
Cranfield activities (4/4) – Sustainable biofuels

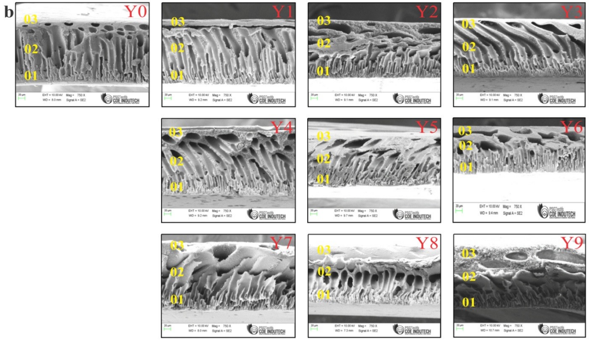


Loughborough University activities (1/3) - membrane bioreactor systems for treatment and conversion of agrowaste

The details on this slide have been omitted as they pertain to unpublished research.

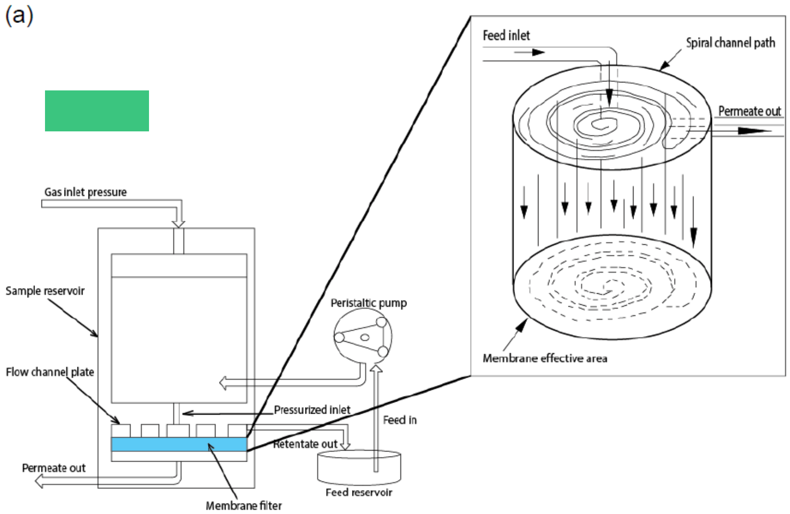
Loughborough activities (2/3) - Porous Membrane Preparation and Separation for Downstream Processing



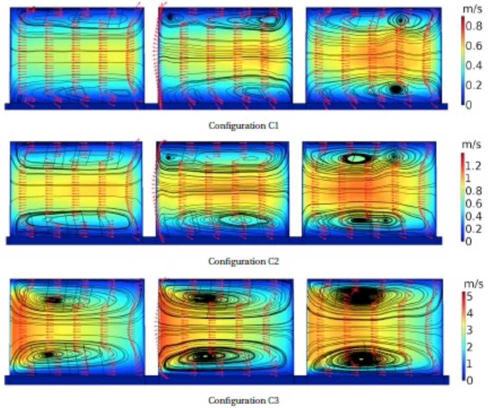


Journal of Water Process Engineering, Volume 37, October 2020, 101408, doi: 10.1016/j.jwpe.2020.101408

Loughborough activities (3/3) – Smart Hybrid Membrane System that combines dead-end and tangential flow for improved separation



Vortices to remove fouling



Journal of Water Process Engineering, Volume 37, October 2020, 101408, doi: 10.1016/j.jwpe.2020.101408
Applied Mathematical Modelling, Volume 80, April 2020, Pages 84-98, doi: 10.1016/j.apm.2019.11.016

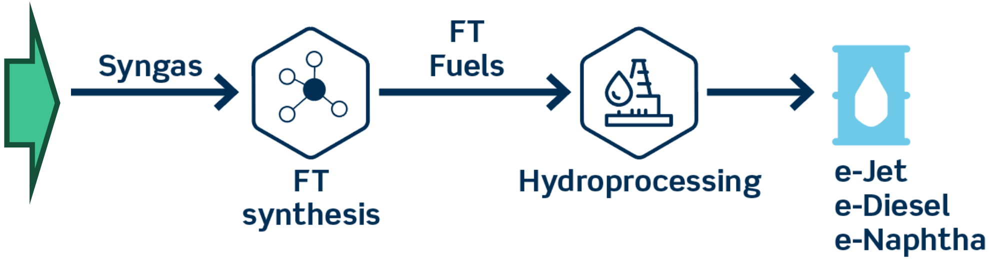
Recent Projects:
EPSRC - Membrane-Cyber-Physical System (m-CPS) for Smart Water Treatment (10/20-03/24)

Cranfield University

British High Commission Singapore

Teesside activities (1/3)- SAF

Gasification/Pyrolysis/microwave system



Teesside activities (2/3)- DAC

- Investigating DAC properties of different inorganic, organic and bio-catalytic agents
- Part of the CO2RE, the national GGR Hub and offering training to external students
- Supporting DAC based SMEs with analytical facilities and consultancy through the Open-Air Coalition
- Several projects completed/underway - BIOCO2MIN, TENET, Carboscopic and Airhive

- Potential to extract up to 80 Tons CO_2 from atmosphere each year from the atmosphere each year

- Direct air capture, liquefication and transport – B9 Energy

Teesside activities (3/3) – Methanol

The details on this slide have been omitted due to pending patent application.

UK SAF Demonstrators based at Teesside

Arcadia e-Fuels (NABOO) –£12m
- power-to-liquid technology to convert biogenic CO2 and green hydrogen into SAF.
- expected to be operational in 2028
- produce 67.7kt/y of SAF.

Nova Pangaea Technologies (Project Speedbird) – £9m
•pyrolysis and ethanol-to-jet technology to convert agricultural waste into SAF.
•expected to be operational in 2025
•produce 2.7kt/y of SAF.

Alfanar Energy (Lighthouse Green Fuels) – ~£9m
•uses gasification and Fischer-Tropsch technology to convert biogenic and non-biogenic wastes and residues into SAF.
•under construction in 2025, operational in 2028, and produce 124.2kt/y of SAF.

Willis Sustainable Fuels (Carbonshift PtL) – ~£5m
•power-to-liquid technology to convert carbon dioxide and green hydrogen SAF.
•expected to be operational in 2026
•produce 14kt/y of SAF.

Abundia Biomass-to-Liquids (A-Jet UK) – £4m plus
•uses pyrolysis and hydrotreatment technology to convert sawmill and forestry residues into SAF.
•expected to be operational in 2026
•produce 2.6kt/y of SAF

SAF Conversion Pathway: feedstock, blending limit, TRL

Production pathway	Feedstocks[30]	Certification name (blending limit)	TRL
Biomass Gasification + Fischer-Tropsch (Gas+FT)	Energy crops, lignocellulosic biomass, solid waste	FT-SPK[31] (up to 50%)	7-8
Hydroprocessed Esters and Fatty Acids (HEFA)	Vegetable and animal fat	HEFA-SPK (up to 50%)	8-9
Direct Sugars to Hydrocarbons (DSHC)	Conventional sugars, lignocellulosic sugars	HFS-SIP[32] (up to 10%)	7-8 or 5[33]
Biomass Gasification + FT with Aromatics	Energy crops, lignocellulosic biomass, solid waste	FT-SPK/A[34] (up to 50%)	6-7
Alcohols to Jet (AtJ)	Sugar, starch crops, lignocellulosic biomass	ATJ-SPK (up to 50%)	7-8
Catalytic Hydrothermolysis Jet (CHJ)	Vegetable and animal fat	CHJ or CH-SK[35] (up to 50%)	6
HEFA from algae	Microalgae oils	HC-HEFA-SPK[36] (up to 10%)	5
FOG Co-processing	Fats, oils, and greases	FOG (up to 5 %)	-
FT Co-processing	Fischer-Tropsch (FT) biocrude	FT (up to 5 %)	-

Source: European Union Aviation Safety Agency (EASA). (2024). Sustainable Aviation Fuels (Figures and Tables).

SG UK
GREEN ECONOMY FRAMEWORK

British
High Commission
Singapore

Cranfield
Environment
and Agrifood

HyDEX

Singapore Presentation on SAF

Dr Roong Jien Wong (A*Star)

UKRI
Research
England

ISCE²

Initiatives on Sustainable Aviation Fuel (SAF) and Low-Carbon Hydrogen

Institute of Sustainability for Chemicals, Energy and Environment

ISCE²

A*STAR and ISCE²

A*STAR:

The Agency for Science, Technology and Research (A*STAR) is a statutory board under the Ministry of Trade and Industry of Singapore

ISCE²:

ISCE² is one of 17 Research Institutes (RI) under A*STAR. We develop innovative sustainable technologies and partner with the ecosystem to catalyse the transformation and growth in green energy and chemicals

Our Approach

1. **Balanced Portfolio** of technologies
2. Platforms and infrastructure as **critical enablers** to accelerate innovation
3. Bridge the valley-of-death with partners towards **industrial scale-up**

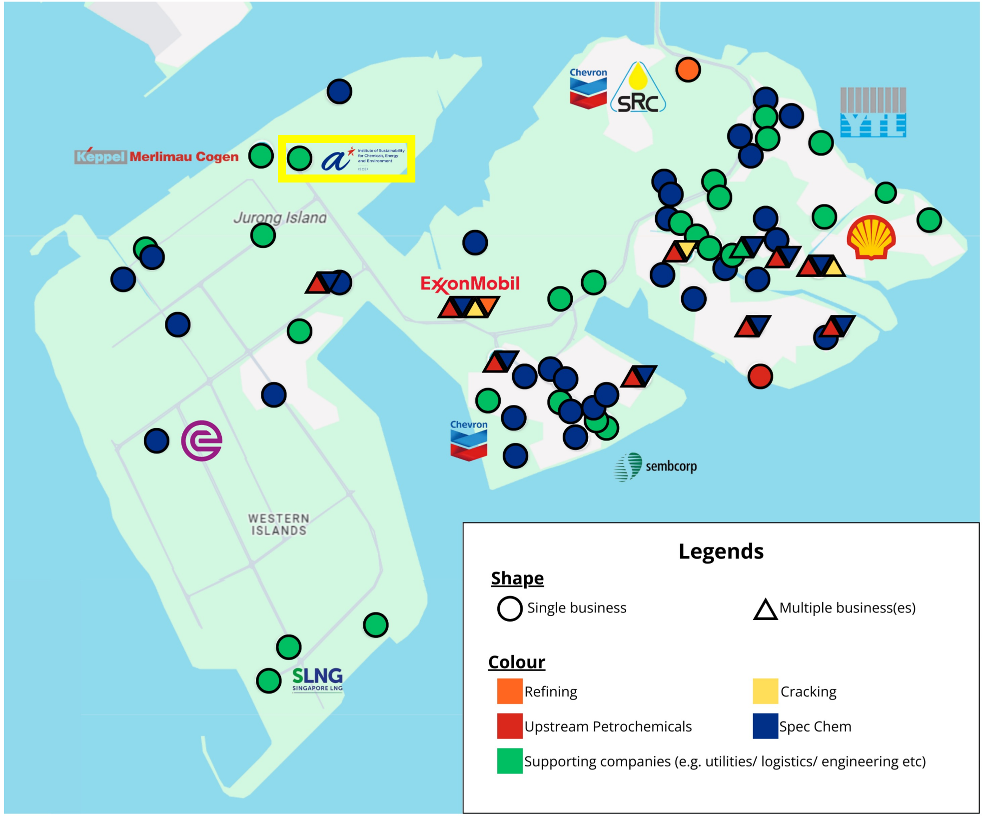
CREATING GROWTH, ENHANCING LIVES

Jurong Island contributes to 54%[1] of Singapore's total carbon emissions

Non-renewable raw materials (petroleum)

Carbon-intensive fossil fuels (natural gas, petroleum) as energy source

High capex > 100 MNCs; 3rd party utilities, waste treatment, storage & terminalling



The government invested S$7 billion to reclaim Jurong Island to develop an integrated refining, petrochemical and specialty chemical hub

Naphtha, aviation, automotive fuels, etc.

Petrochemical and specialty chemical products

[1]Hon, C.L., et al. Energies, **2021**, 14(20):6455

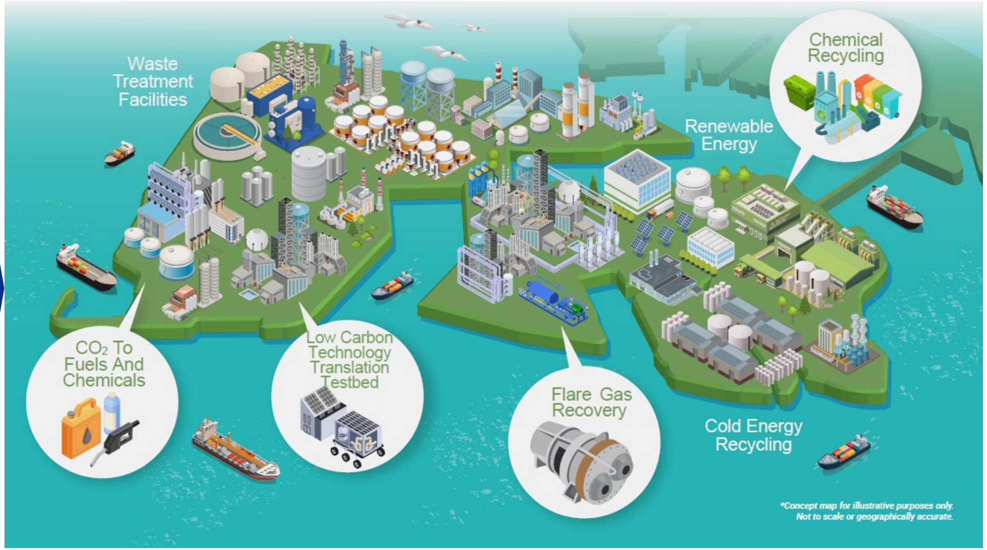
Greening Jurong Island - the future direction of E&C is to reduce dependency on fossil fuels

CREATING GROWTH, ENHANCING LIVES

Alternative raw materials (e.g. CO_2, biomass, waste)

New energy mix to support the clean energy transition (e.g. H_2/NH_3, green electricity)

Emergence of climate-tech companies with sustainable technologies



Jurong Island is envisioned to transform into a sustainable energy and chemicals park

Methanol, Biofuels, Sustainable Aviation Fuel (SAF), Hydrogen

New circular materials

Image source: Sustainable Jurong Island Report, 2021

ISCE² Technology Development

CO_2 to X (X = fuels, chemicals, materials)

Develop carbon-neutral/carbon-negative processes (at lab scale up to TRL ~4; with further scale-up (up to TRL ~8) to demonstrate the technology)

- **CO_2 methanation** technology developed and commercialised with **IHI**

- **CO_2 to SAF**: *Active collaboration with industry to establish larger scale demonstration unit*

- **CO_2 to methanol**: *Preparing proposal for government funding*

Accelerated Catalyst Development Platform (ACDP)

Accelerated discovery and develop heterogeneous catalytic processes by 5x, to TRL ~4

- 16 parallel catalyst syntheses; Flexible 16 reactor system
- Mimics industrial temperatures, pressures & reaction feeds; leverages automation, ML and high-performance computing

ASEAN Outstanding Engineering Achievement Award 2023

IES Sustainability Awards 2023 - *Innovative Solutions for Sustainability*

Low Carbon Technology Translation Testbed (LCT3)

Bridging the translational gap by rapidly piloting and scaling-up new CCU tech to TRL 4 - 8

- Reduce test-bedding time by 2x (from 2 years to <12 months)

- Future state Modularisation + Digital Twin for CCU

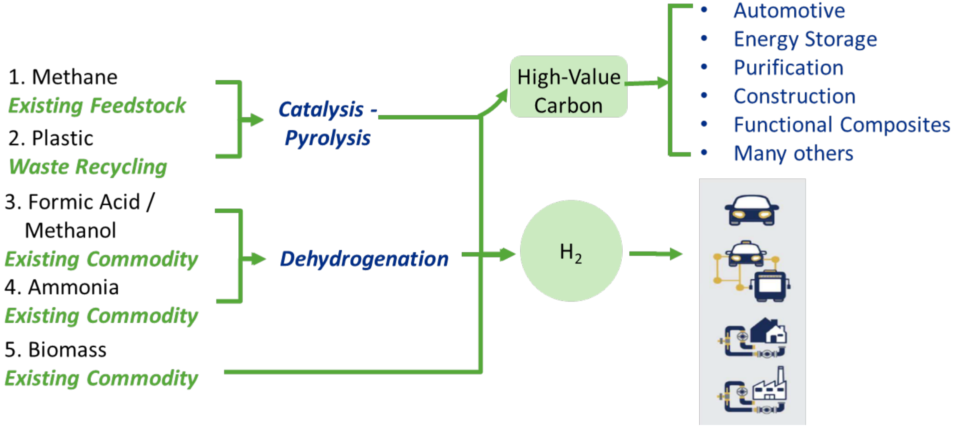
- Expected to be ready by 2026

In partnership with >20 ecosystem partners including E&C companies, technology adopters, solution providers, IHLs and A*STAR RIs

ISCE² Technology Portfolio

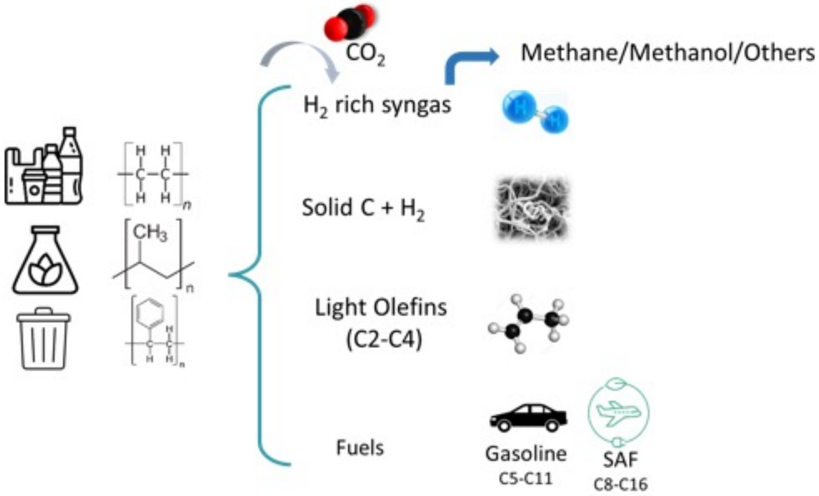
Low Carbon Future

Low-Carbon H_2



Circular Economy

Waste to Chemicals/Fuels/Materials

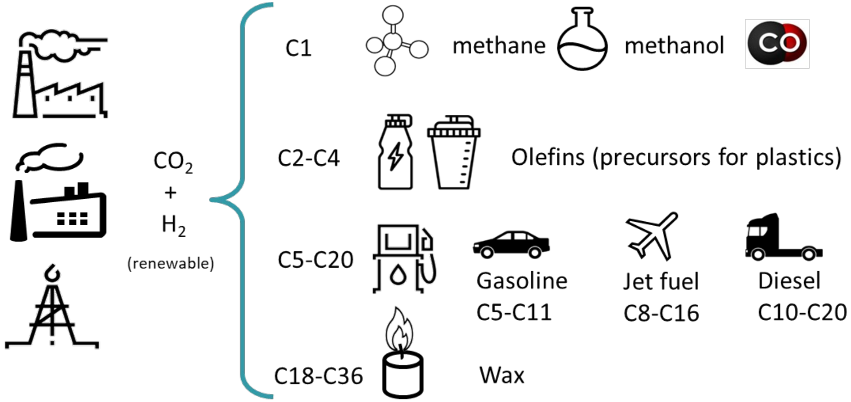


SG GREEN PLAN

ISCE² Technology Portfolio

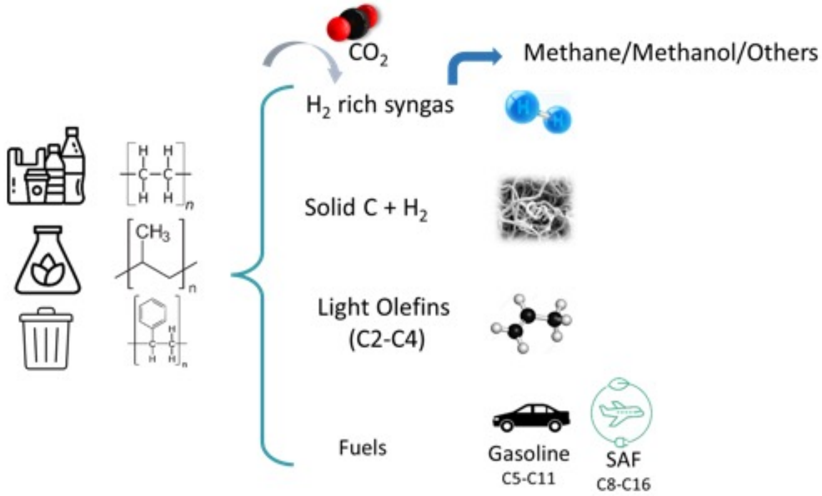
Low Carbon Future

CO_2 to X



Circular Economy

Waste to Chemicals/Fuels/Materials



TOWARDS ZERO WASTE

SG GREEN PLAN

Agency for
Science, Technology
and Research

SINGAPORE

CREATING GROWTH, ENHANCING LIVES

SGUK GREEN ECONOMY FRAMEWORK

British High Commission Singapore

Cranfield Environment and Agrifood

HyDEX

Lunch Break

#UKSingaporeJetZero
#UKSGEF
@HyDEXMidlands
@UKinSingapore

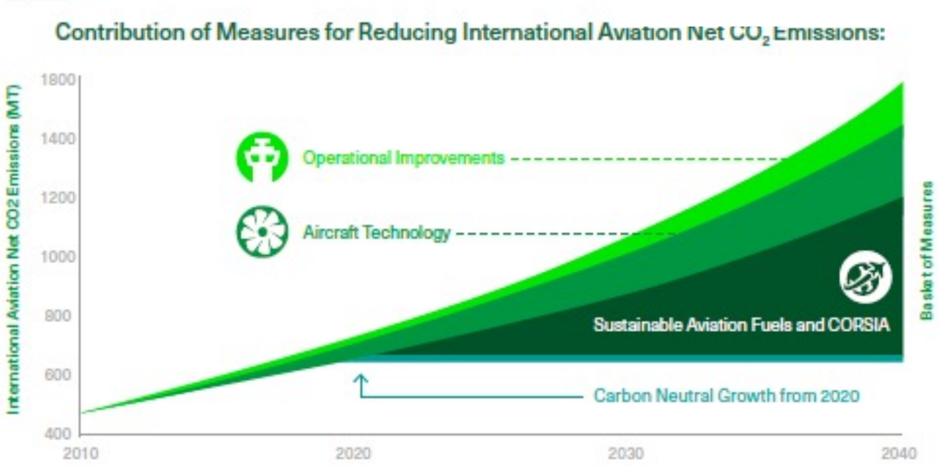
UKRI Research England

Afternoon Discussion Session

Working group themes – ranking exercise

1 Feedstock and sustainability
2 Process and economics
3 Infrastructure
4 Technical specification and certification

- Any other themes?



Cranfield University

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British High Commission Singapore

Roundtable discussion points

- Identifying significant gaps in research across each thematic area
- What areas we need to focus on increasing efficiency and lower costs
- How to maintain fuel integrity
- What strengths and expertise we have in the UK and Singapore

- Any alternative fuels instead of SAF?

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Any comments or questions from this SAF workshop?

Cranfield University

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Refreshment Break

#UKSingaporeJetZero
#UKSGEF
@HyDEXMidlands
@UKinSingapore

UKRI Research England

Summary and final thoughts…

Prof Ron Corstanje

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Cranfield University

HyDEX

British High Commission Singapore

Thank you for coming to our workshop

Please join the conversation about today's event:

#UKSingaporeJetZero

#UKSGEF

X @HyDEXMidlands, @UKinSingapore

LinkedIn HyDEX, UK in Singapore

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