Overview of Cranfield University's Hydrogen and Fuels Cells Roadmap

Cranfield University

Hydrogen & Fuel Cell Showcase

Professor Upul Wijayantha

20th Sept 2022

www.cranfield.ac.uk

[About the University (cranfield.ac.uk)]

Cranfield University

88% Research

- World-leading
- International Excellent

Six-time winner of the prestigious **Queen's Anniversary Prize**

TOP 50 2022
Engineering Mechanical Aeronautical & Manufacturing
QS WORLD UNIVERSITY RANKINGS BY SUBJECT

5th in the UK for **Engineering – Mechanical, Aeronautical and Manufacturing**
QS World Rankings 2021

REF2021 Research Excellence Framework

The Queen's Anniversary Prizes
For Higher and Further Education

HR EXCELLENCE IN RESEARCH

Gaseous H_2, liq.H_2 and SFs research across Cranfield aligned to the UK Government's 10-point plan

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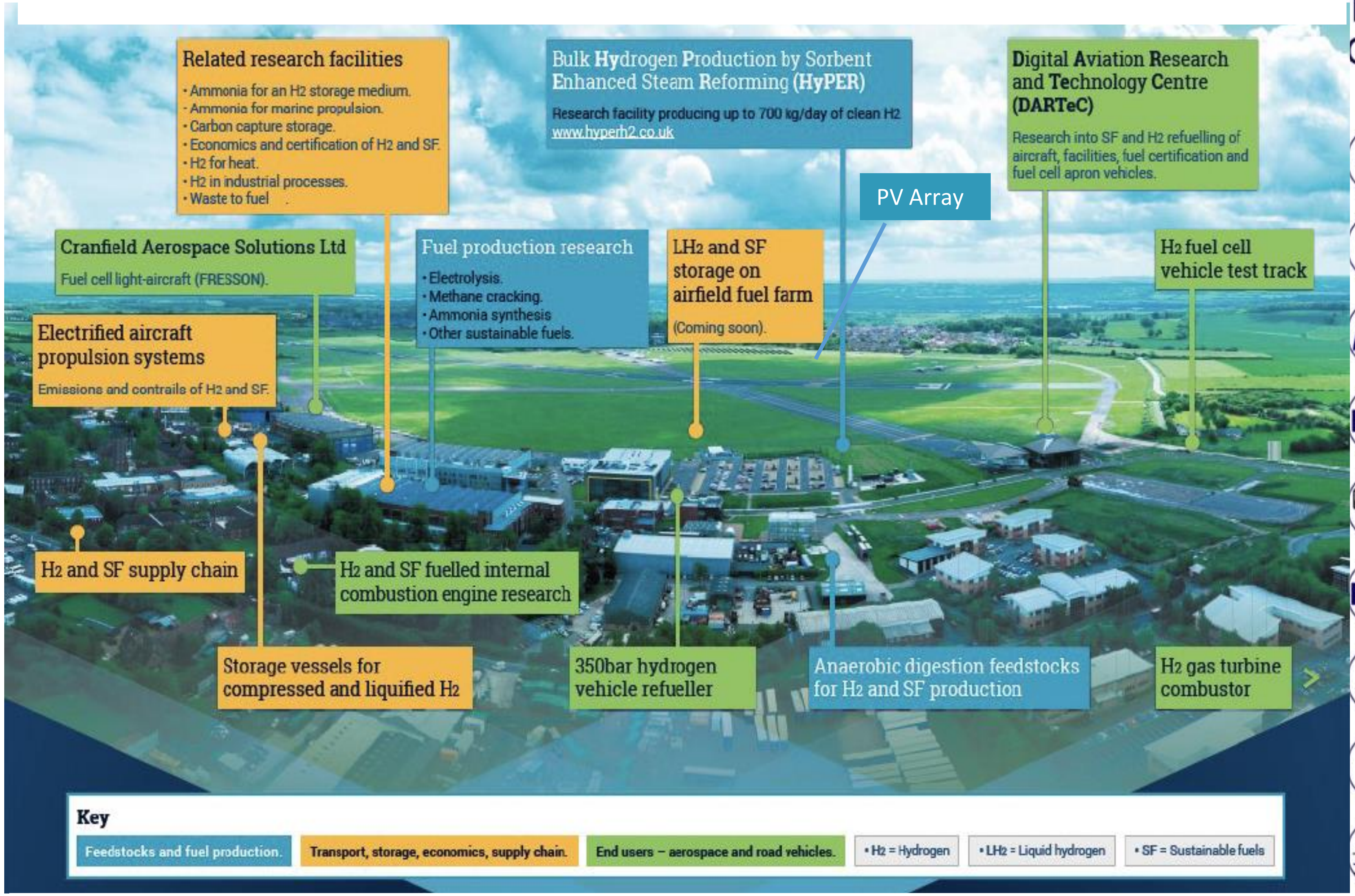


The Ten Point Plan for a Green Industrial Revolution

Point 1
Advancing Offshore Wind

Point 2
Driving the Growth of Low Carbon Hydrogen

Point 3
Delivering New and Advanced Nuclear Power

Point 4
Accelerating the Shift to Zero Emission Vehicles

Point 5
Green Public Transport, Cycling and Walking

Point 6
Jet Zero and Green Ships

Point 7
Greener Buildings

Point 8
Investing in Carbon Capture, Usage and Storage

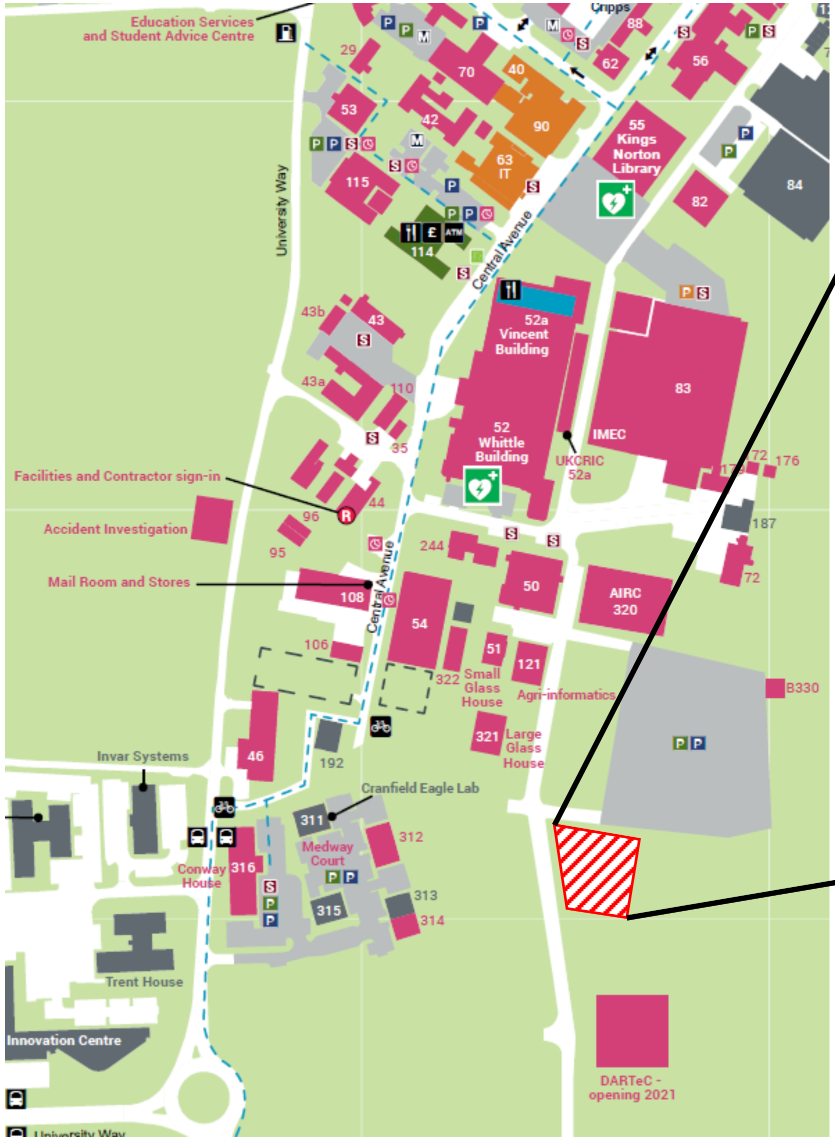
Point 9
Protecting Our Natural Environment

Point 10
Green Finance and Innovation

Blue H_2 (HyPER)

Hydrogen **P**roduction by ‘Sorbent **E**nhanced’ Steam **R**eforming

Cranfield University



Construction is ~80% completed
Operational by mid January 2023

Operating range = 4-16 bar

At 4 bar, capacity = 0.3 MWth H_2 = 200 kg/day (LHV H_2)

At 16 bar, capacity = 1 MWth H_2 = 700 kg/day (LHV H_2)

GTI ENERGY

LCRI LOW-CARBON RESOURCES INITIATIVE

DOOSAN

Blue H_2 (HyPER)

Bulk **Hy**drogen **P**roduction by ‘Sorbent **E**nhanced’ Steam **R**eforming

Phase 1 – Feasibility	**May – September 2019**
Phase 2 – Demonstration	**January 2020 – January 2023**
Phase 3 – Extended Testing	**April 2022 – January 2023**

Department for Business, Energy & Industrial Strategy

LCRI LOW-CARBON RESOURCES INITIATIVE

Current Consortium

Cranfield University	**Project Lead and Technology Development**
Doosan Babcock	**Engineering Partner**
Gas Technology Institute	**Technology Owner and Techno-economics**

GTI ENERGY solutions that transform

DOOSAN

Blue H_2 (HyPER)

Cranfield University

Compared to SMR+CCS or ATR+CCS, SE-SMR technology can achieve:

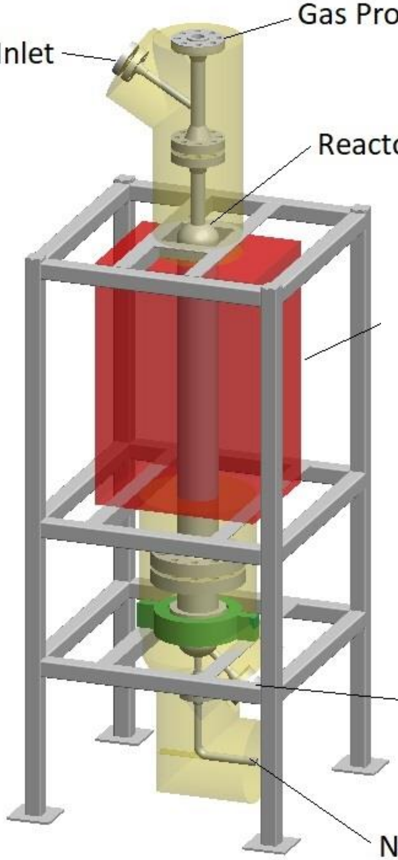
- ~25% lower Levelised Cost of Hydrogen
- >50% reduction in CAPEX with similar OPEX
- ~97% CO_2 capture rates with equivalent H_2 purity
- <40% lower carbon footprint
- Smaller physical footprint due to integrated nature of the SE-SMR process

GTI ENERGY solutions that transform

DOOSAN

Turquoise H_2 Pilot (HyDEX)

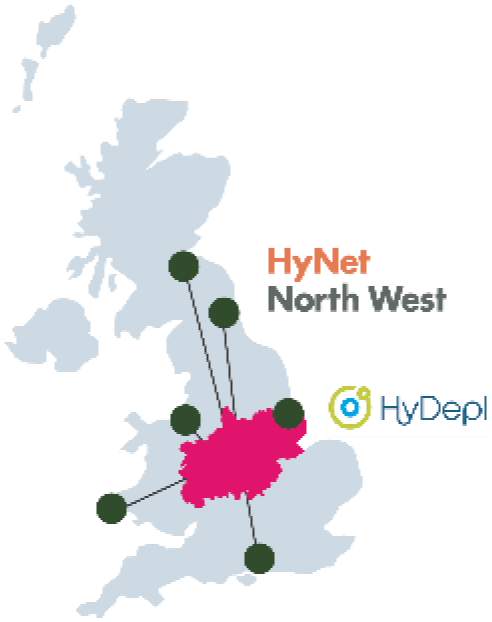
$CH_4 \rightarrow C + 2H_2$



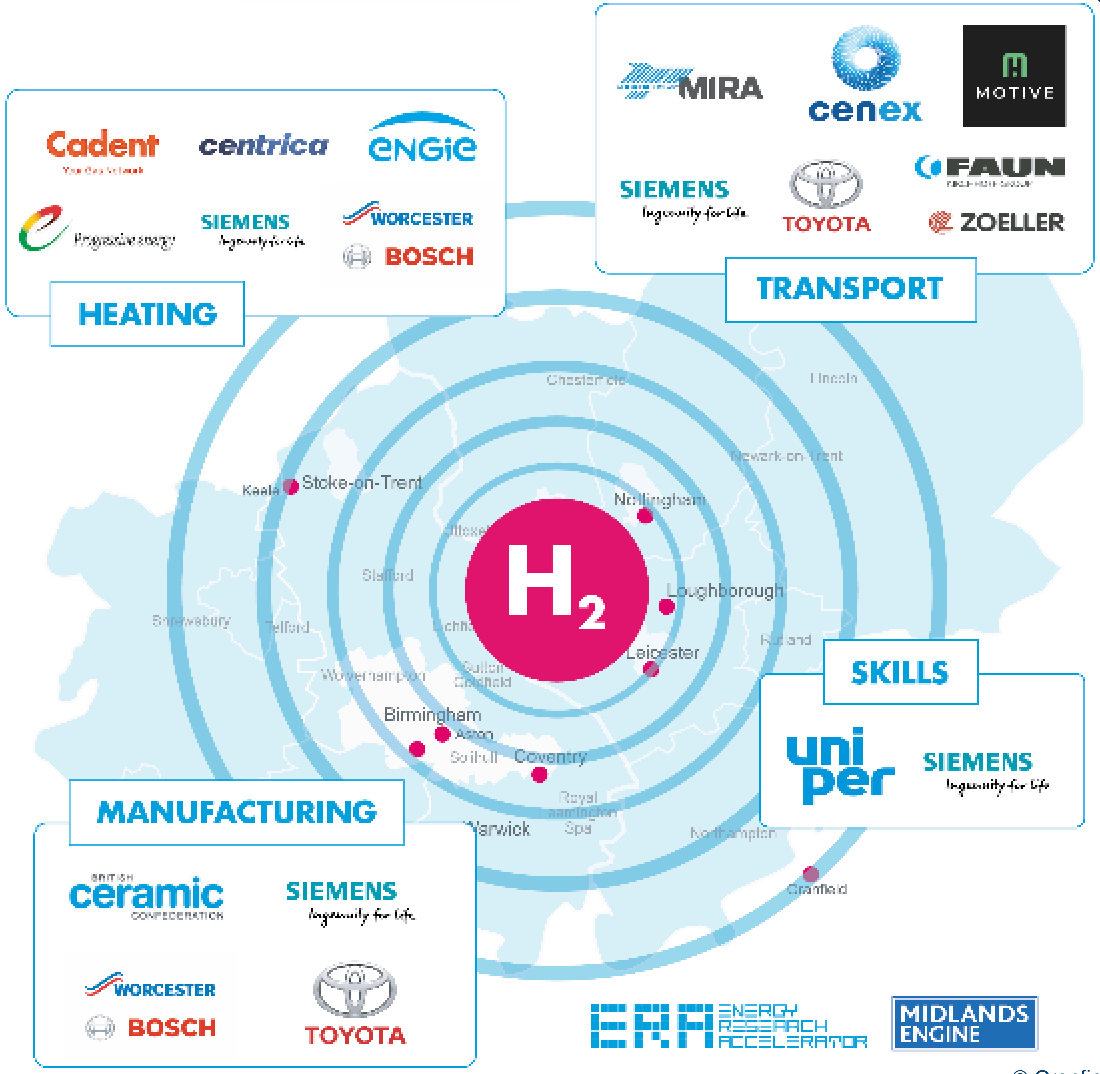
At 1 bar, = 14 kg/day (LHV H_2)

Operational in spring 2023

HyDEX



- Demonstrators
- New products development
- Skills



Regional focus, national impact, internationally networked

International academic partners

Reducing the cost of Turquoise H_2: Potential Routes

11 - 15 kWh/kg H_2

Electrolysis: ~ 55 kWh/kg H_2

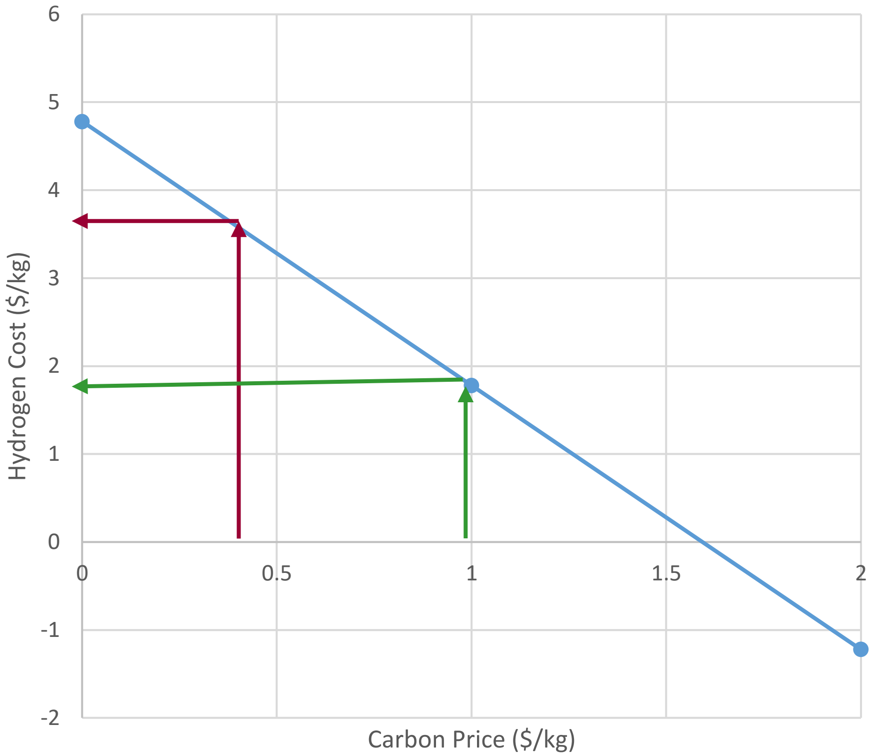
Equation:	CH_4	→	C	+	$2H_2$
Moles:	1		1		2
Molar Mass:	16		12		4

Every **kg** of hydrogen produced gives **3kg** of carbon

- **Use waste heat**
- **Add Value to Carbon by-product**

Adding value to the Carbon in Turquoise H_2 : How?

- Cost of lower grade carbon ranges from **$0.4 - 1/kg**
- Cost of special grade carbon can go up to **$2/kg**



Carbon Steel
Supercapacitors
Batteries
Tyres
Air/water purifications
Road infrastructures
Wind Turbines
Mobile Phones
Soil amendment (biochar)
Cosmetics

- **US DoE target for cost of hydrogen at $1/kg by 2030**

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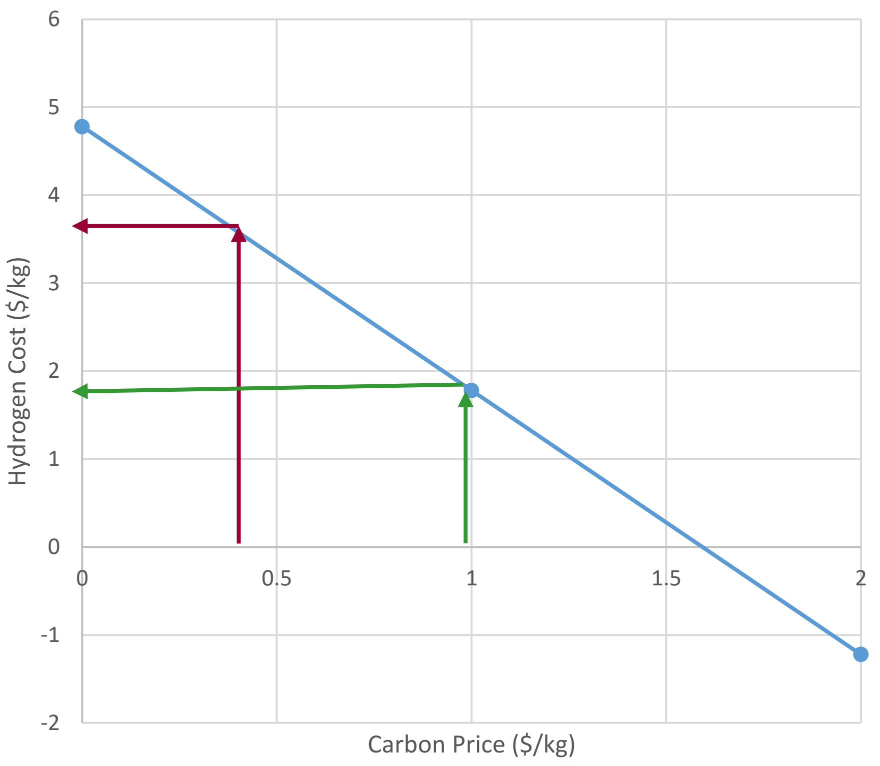

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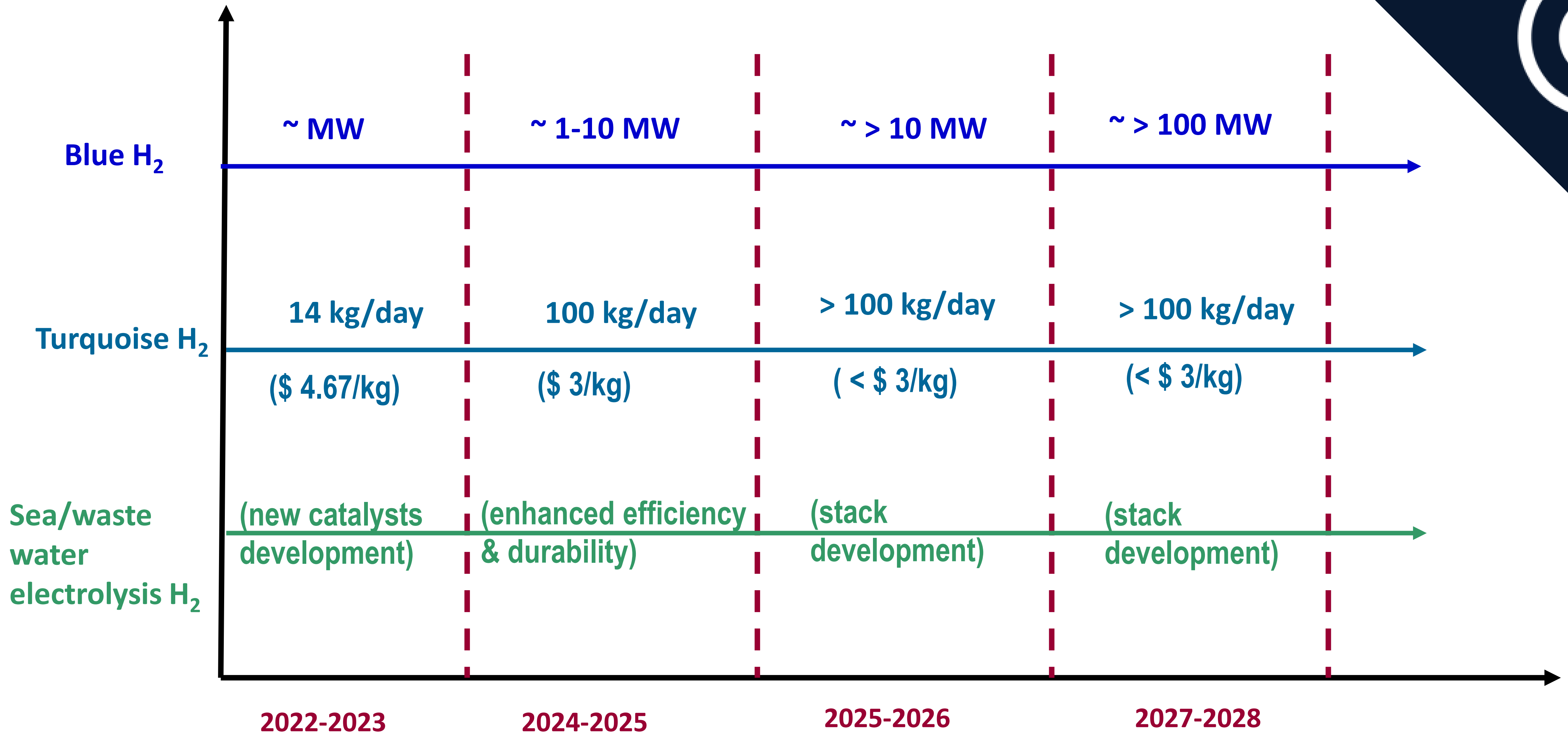

Blue H_2
~ MW
~ 1-10 MW
~ > 10 MW
~ > 100 MW
Turquoise H_2
14 kg/day
($ 4.67/kg)
100 kg/day
($ 3/kg)
> 100 kg/day
(< $ 3/kg)
> 100 kg/day
(< $ 3/kg)
Sea/waste water electrolysis H_2
(new catalysts development)
(enhanced efficiency & durability)
(stack development)
(stack development)
2022-2023
2024-2025
2025-2026
2027-2028

LH_2 – Fuelled Aircraft: CU Thought-leadership Example

Innovation Waves to Accelerate Decarbonisation

Innovation Wave 1
10-15 Years
Focus: Certification


Innovation Wave 2a
20+ Years
Focus: Efficiency



Innovation Wave 2b
20+ Years
Focus: FC Certification

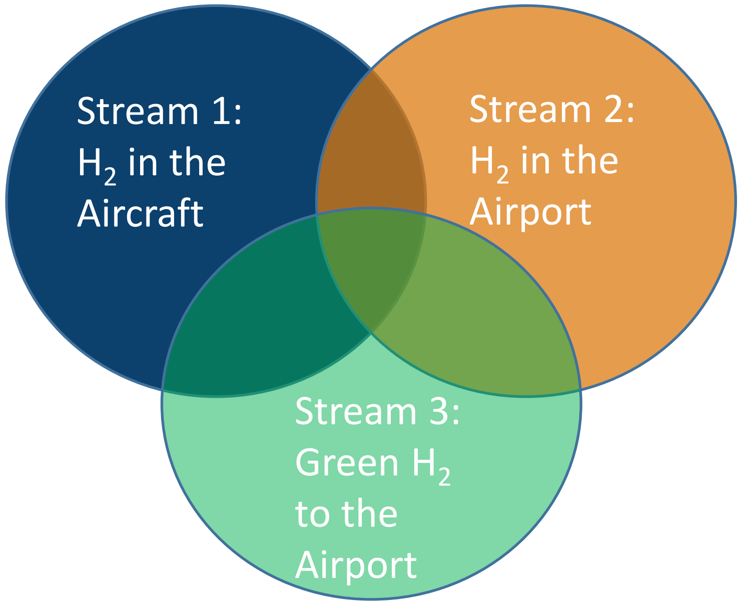

Innovation Wave 3
30+ Years
Focus: Turbo-cryo-electric



https://www.airbus.com/en/innovation/zero-emission/hydrogen/zeroe

https://www.ati.org.uk/flyzero/

UK-ARC H_2 Group Scope:
Thematic Areas and Mapping of Expertise and Ambitions



H_2 in the Aircraft
H_2 aircraft design and performance analysis
H_2 propulsion system design, integration, and performance analysis (gas turbines (including advanced cycles – intercooling, recuperation, pressure rise combustion etc.), fuel cells, hybrid and turboelectric + distributed propulsion).
LH_2 tank design, manufacturing, and aircraft integration
LH_2 tank fluid movement modelling (sloshing), sensors and gauging
LH_2 fuel system thermal management and control (fuel supply system from tanks to “consumer” (either fuel cell or gas turbine))
Solid state storage
Aircraft engine and combustion noise
Low NOx H_2 Combustion
Contrails modelling and aircraft trajectory optimisation for contrail avoidance (incl. trade-offs with mission fuel burn).
Hybrid/Dual/Blended-fuels
Technoeconomic Environmental Risk Assessments (TERA) (Mission level and over the life cycle) & Pathways towards decarbonising aviation
Materials and Manufacturing
Certification

LH_2 – Fuelled Aircraft: CU Thought-leadership Example

Strong Industry Collaboration – e.g. ENABLEH2

Project Consortium

Cranfield University
CHALMERS
EST 1892 LSBU
SAFRAN
GKN AEROSPACE
EHA EUROPEAN HYDROGEN ASSOCIATION
Heathrow
ARTTIC

ENABLE·H2

The ENABLEH2 project is receiving funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769241

Industry Advisory Board

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IAG INTERNATIONAL AIRLINES GROUP
easyJet
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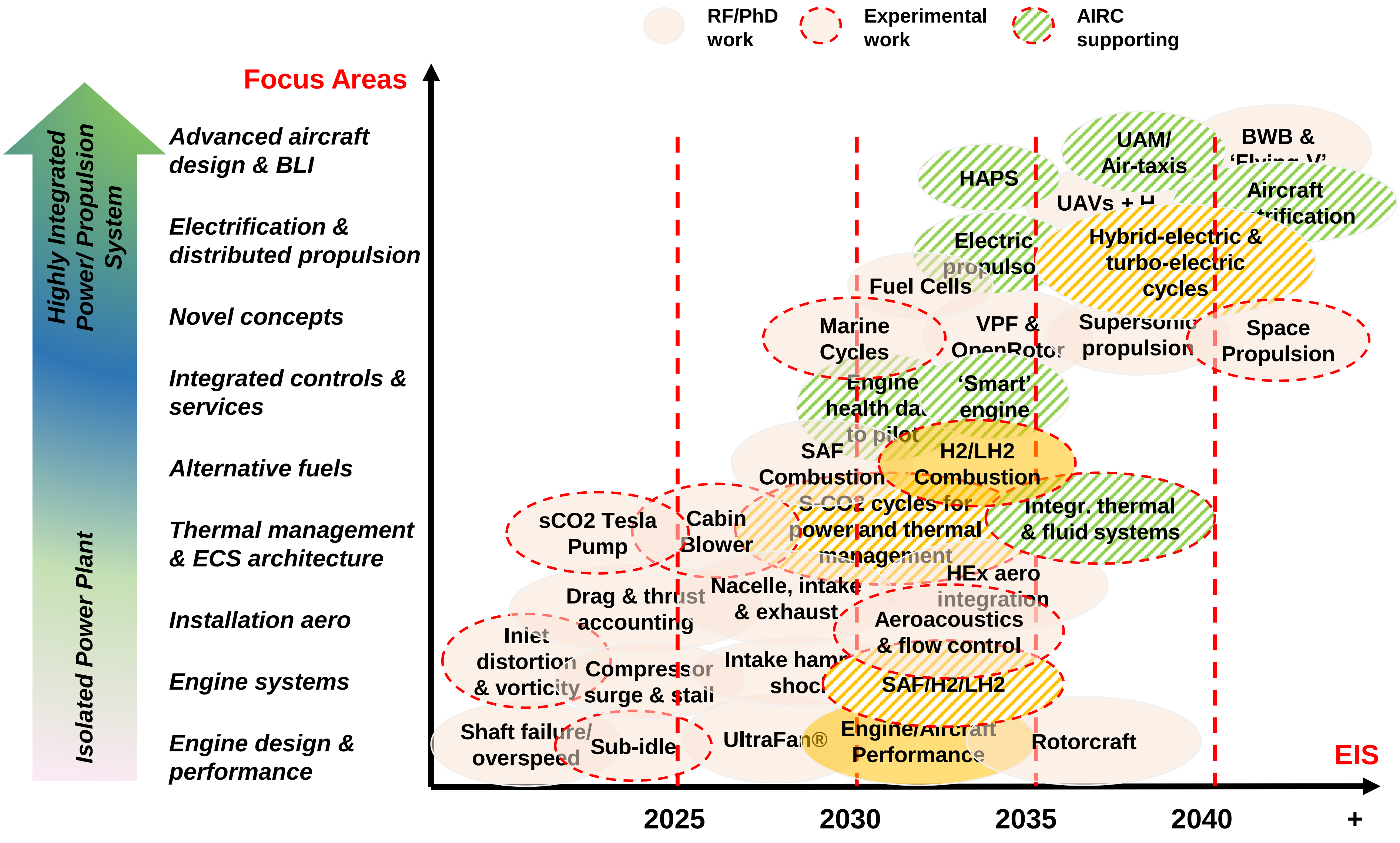
REACTION ENGINES
DASSAULT AVIATION
Infosys® Navigate your next
Air Liquide
TOTAL
GEXCON
SIEMENS energy
ABENGOA
MHPS
ACI AIRPORTS COUNCIL INTERNATIONAL
HyEnergy
Clean Sky 2 JOINT UNDERTAKING
FLY ZERO AEROSPACE TECHNOLOGY INSTITUTE
EASA European Aviation Safety Agency
MOOG
IMI

Cranfield University

Areas of Expertise (TRL1-6)

Land – Sea – Air - Space

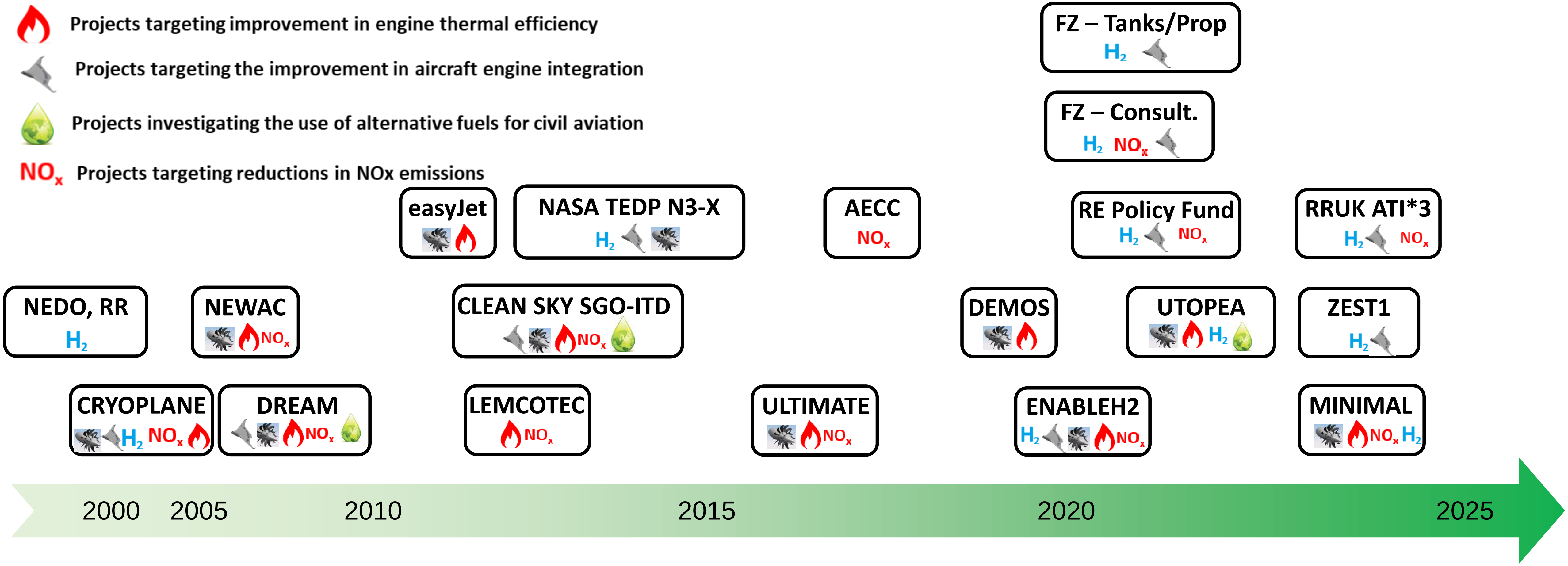


Images from an internet source

Civil Aviation Sustainability: CU "Aerospace" Sustainability Development Goals

"H_2 in the Aircraft" Research Track Record (Examples)

- H_2 Projects involving H_2 / LH_2 R&D
- Projects targeting improvement in engine propulsive efficiency
- Projects targeting improvement in engine thermal efficiency
- Projects targeting the improvement in aircraft engine integration
- Projects investigating the use of alternative fuels for civil aviation
- NO_x Projects targeting reductions in NOx emissions



Enabling H_2 research Integration at Cranfield

Cranfield's Hydrogen Integration Incubator and Research Centre (HIIRC)

CU HIIRC will integrate research & developments in hydrogen production, storage, SF, ammonia and hydrogen refuelling for mobility and zero-aviation.

Hydrogen Integration Incubator and Research Centre

Upgrade CU Global Research Airport to drive net zero mobility and 'Jet Zero' using Cranfield's UKRIC 'Living Laboratory' campus.

Upgrade CU hydrogen gas turbine combustor testbed.

We are keen to work collaborate with industry to maximise the benefit for industry through the Hydrogen Integration Incubator and Research Centre.

Please contact: upul.Wijayantha@cranfield.ac.uk

Thank you