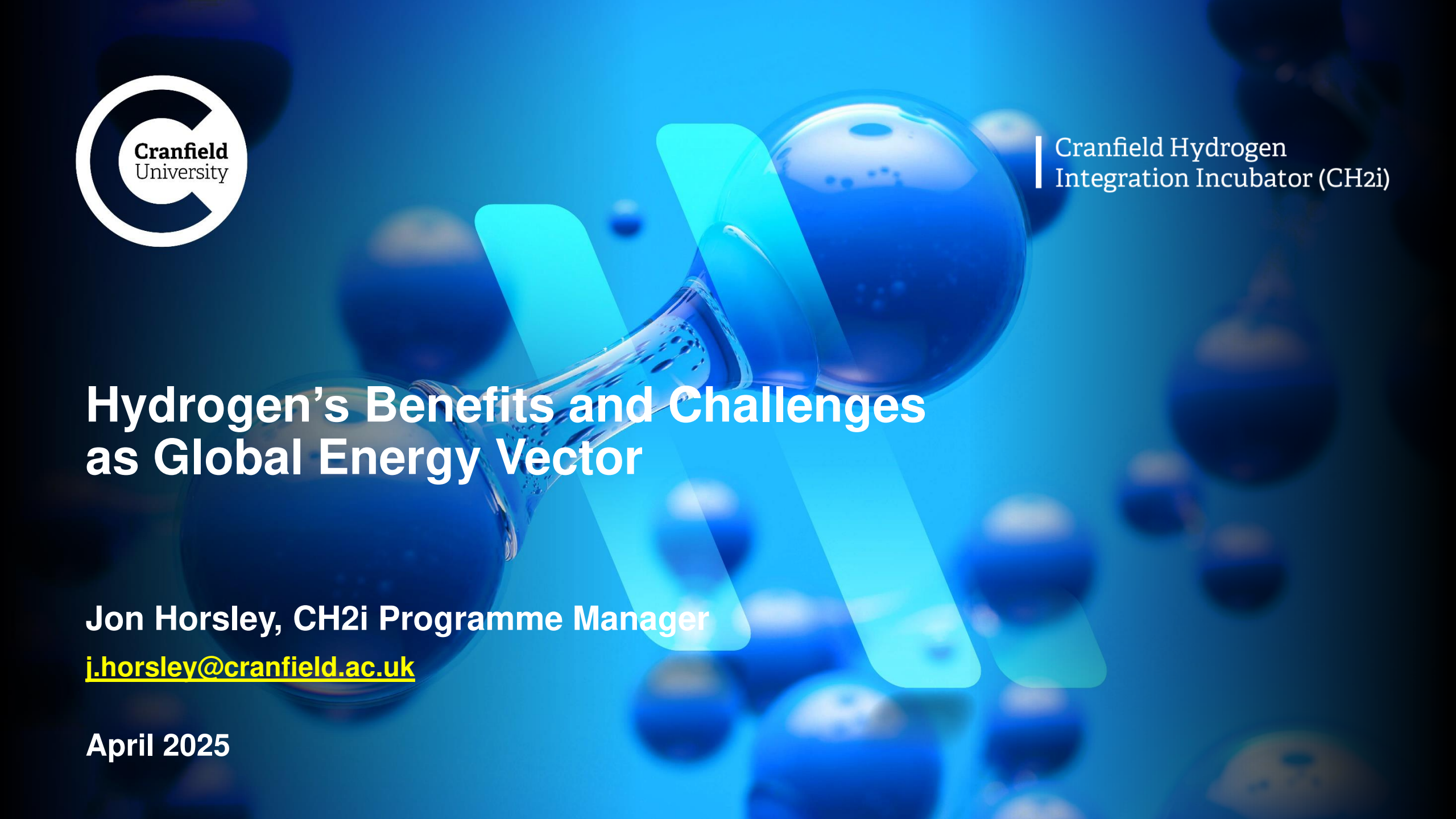

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Cranfield Hydrogen Integration Incubator (CH2i)

Hydrogen's Benefits and Challenges as Global Energy Vector

Jon Horsley, CH2i Programme Manager

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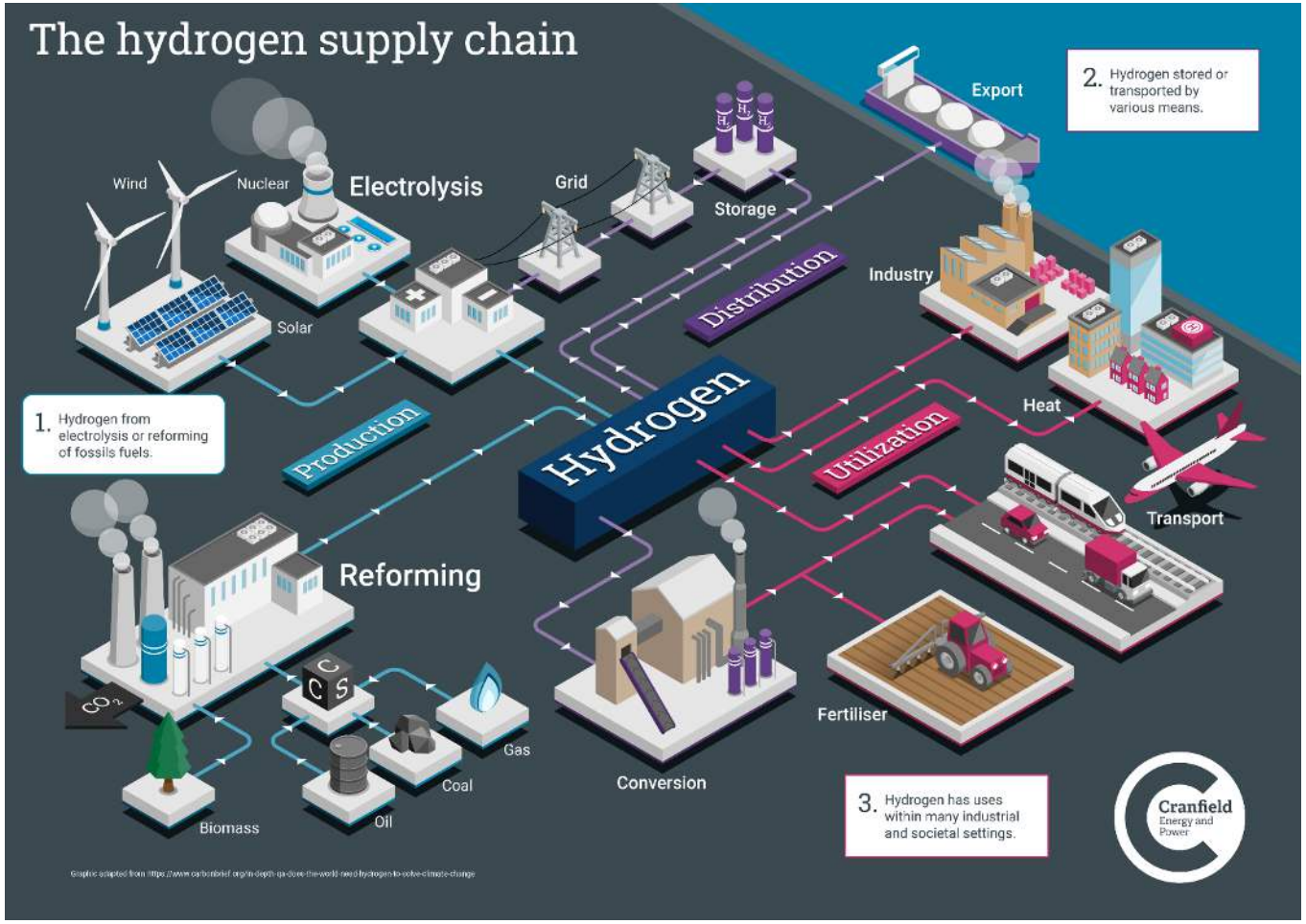
April 2025

Why all the fuss now about Hydrogen as a fuel?

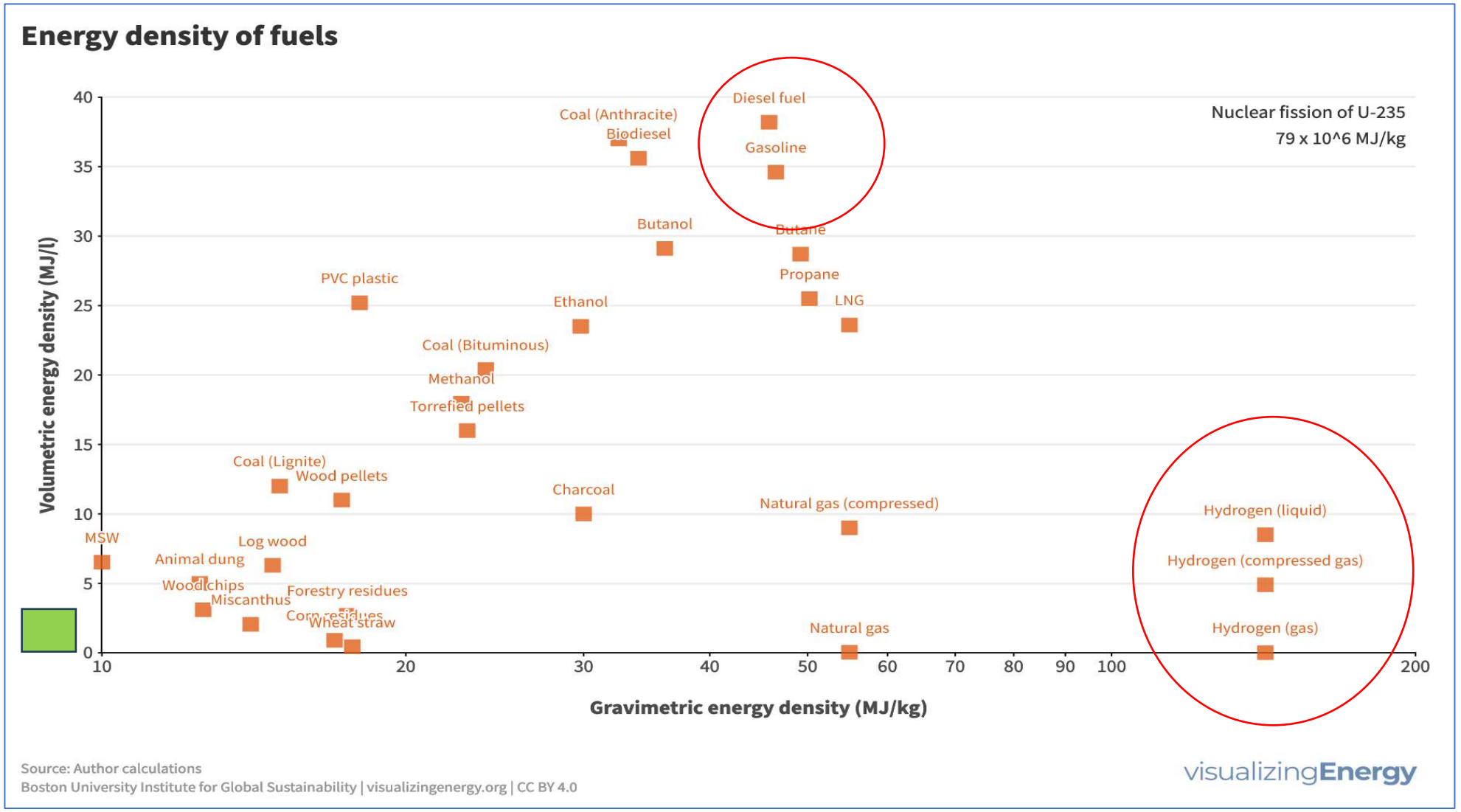
- Climate change and Sustainability: The need to stop burning Fossil Fuels for heat and transport
- There's a lot of Hydrogen about!
- Totally renewable, Globally producable, Constant and Natural
- No direct emissions (burning in air produces some NOx)
- No "fuel standards" required

So why not go all–in for Hydrogen ?

- There is no “Energy Shortage”!
- The cost & impact of accessing clean energy …
- … and the storage / conversion of captured renewable energy to perform work
- Forms of H2:
  - Gaseous – Super buoyant, highly explosive
  - Compressed – to 350, 700 or even 1000bar
  - Liquid – 20DegK
- Challenges with H2:
  - Energy cost of production: GH2 -> LH2
  - Tricky to store and transport (LH2 in particular)
  - Low energy density in gaseous form
  - LH2 boil off, GH2 leaks & embrittlement
  - And the Hazardous Challenges of H2 in quantity



Hydrogen versus other energy storage vectors



So where will Hydrogen fit into our future?

Horses for Courses

- **Batteries**
  - + Known technology, easy to use, clean in use
  - - Env' impact (manf') and EOL (recycling)
- **Sustainable fuels ("Bio" Petrol & Diesel)**
  - + Minimal infrastructure & engine changes
  - - Land use concerns, Emissions
- **Hydrogen**
  - + Can be made locally and in many ways
  - + Used in ICE, fuel-cells, turbines
  - - Energy density, handling
  - - Infrastructure

Good fits for Hydrogen

- **Automotive**
  - Large vehicles, where batteries won't work
  - Back-to-base vehicles, served by a refueller
- **Aviation**
  - Small/regional aircraft with GH2 and fuel-cells
  - Medium-range aircraft
- **Marine**
  - As Ammonia or H2 directly
  - Globally consistent fuel

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Ascending altitude, Increasing distance and payload,
Reducing cost and novelty

Completed – ZeroAvia first H2FC test flights

Completed - Acorn (BRS) and HyICE/NFLC (EGTC) GSE demos - 2024

Cranfield Aerospace (CAeS) BN Islander product

In planning – Broader and longer GSE trial on live flights (EXT) – 2025

2026/7 – Stralis (Aus) LH2 flight

2025/6 – CAeS H2FC ground running and first flight

GH2

LH2

LH2 for larger aircraft, flying longer distances using gas turbines. SAF will continue too.

GH2 then LH2 for short-range fuel-cell propellor aircraft and medium-range turbojets.

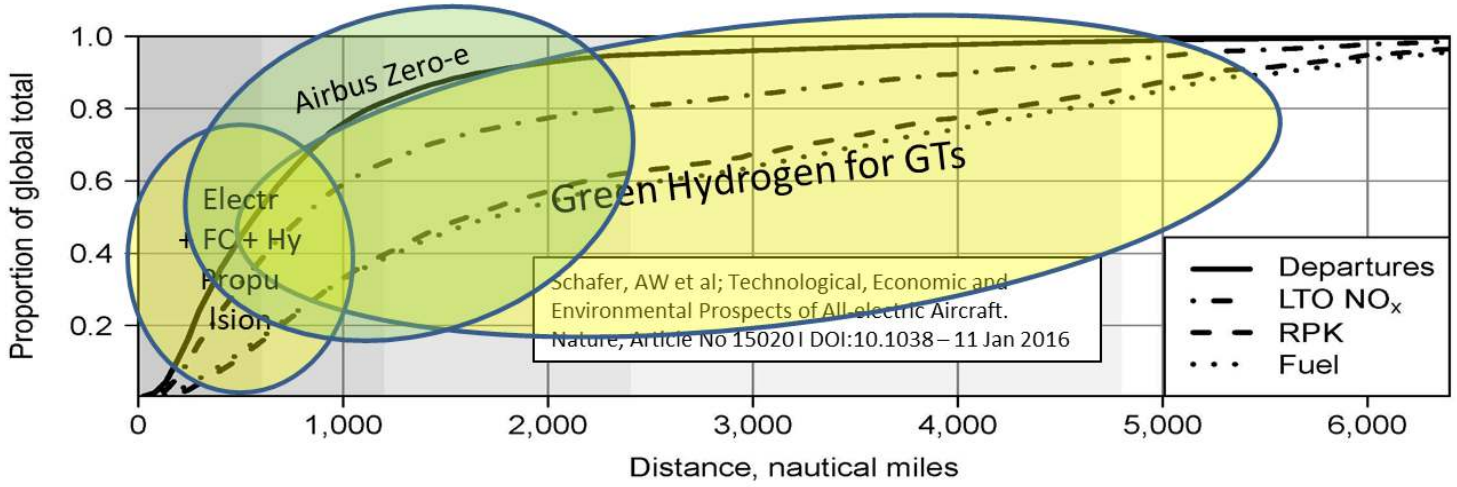
Image courtesy of Lufthansa Technik Hydro-Lab

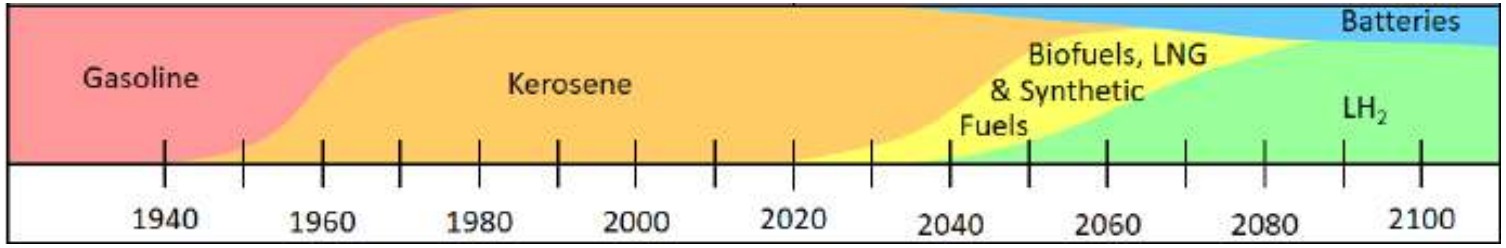
G/LH2 handling and fire & safety processes, regulation acceptance, supply infrastructure planning, …

Today 2028 2030 2035 2040 2050

Sustainable Aviation = Protecting the Environment + the Economy

Decarbonise Aviation and Minimise Non-CO_2 Emissions!





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

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

Hydrogen hazards and related R&D

Accidental releases

- Pressurised force (compressed gas)
- Explosive shock waves and heat
- Invisible flame when burning
- Gas will rise (once it's stopped travelling in the direction of the release), but
- Liquid will pool, boil (creating pressure), not rise whilst cold, then eventually rise
    - Fire and heating effects of this phase change

Other hazards

- Combined on a site with other hazardous substances (COMAH)
- Hazards of cryogenic liquids

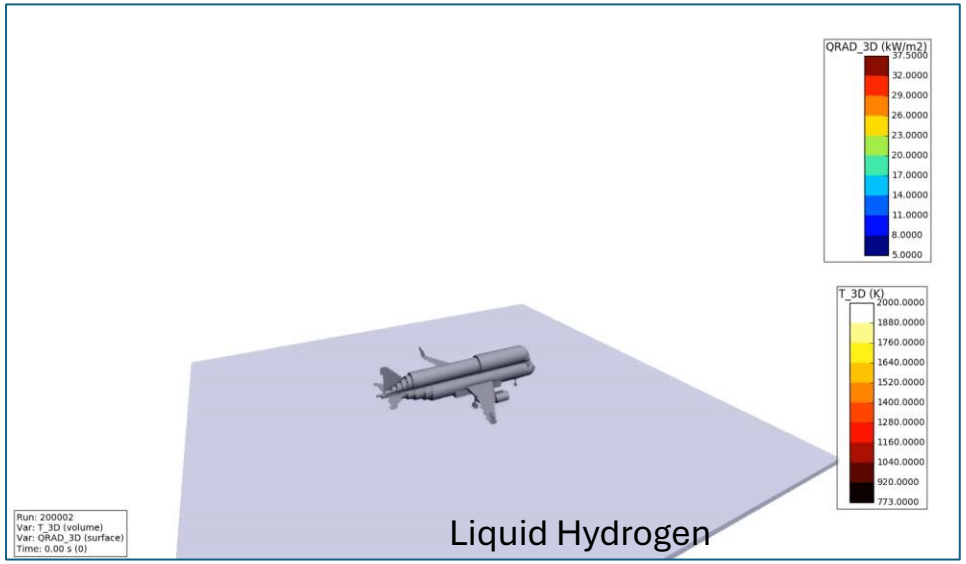
Groups working on H&S

- HSE, Buxton
- DNV, Cumbria

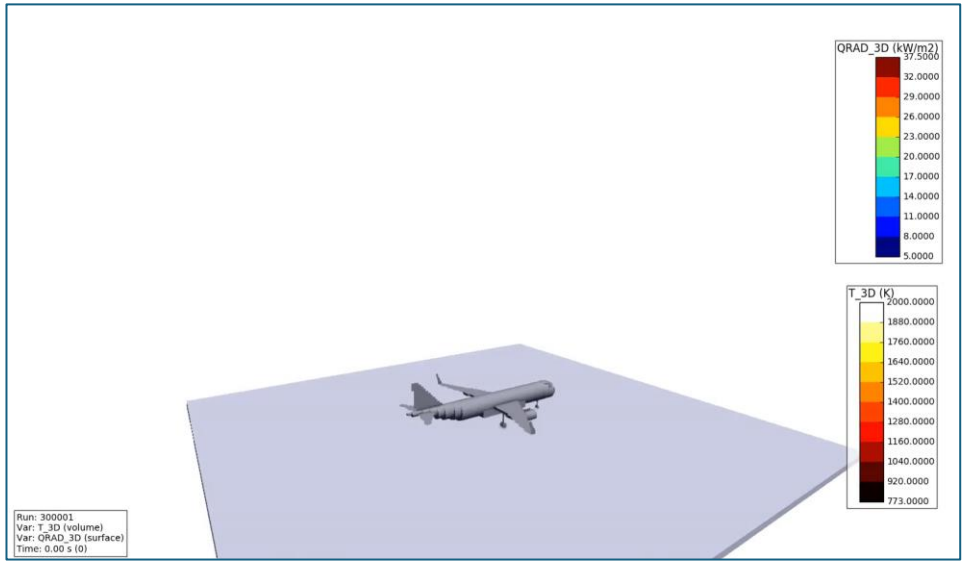
Plus universities, etc

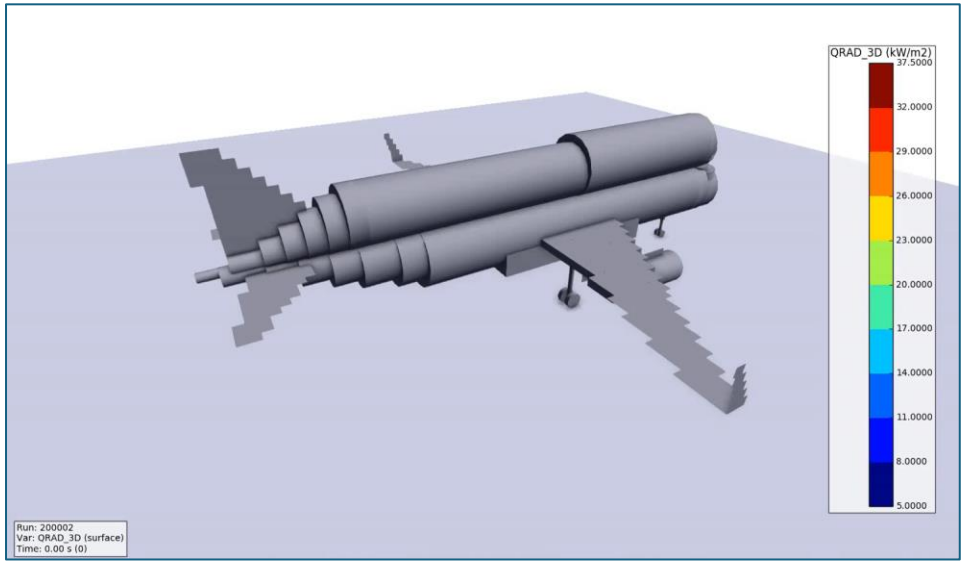
- JAXA, NASA
- DLR, Germany

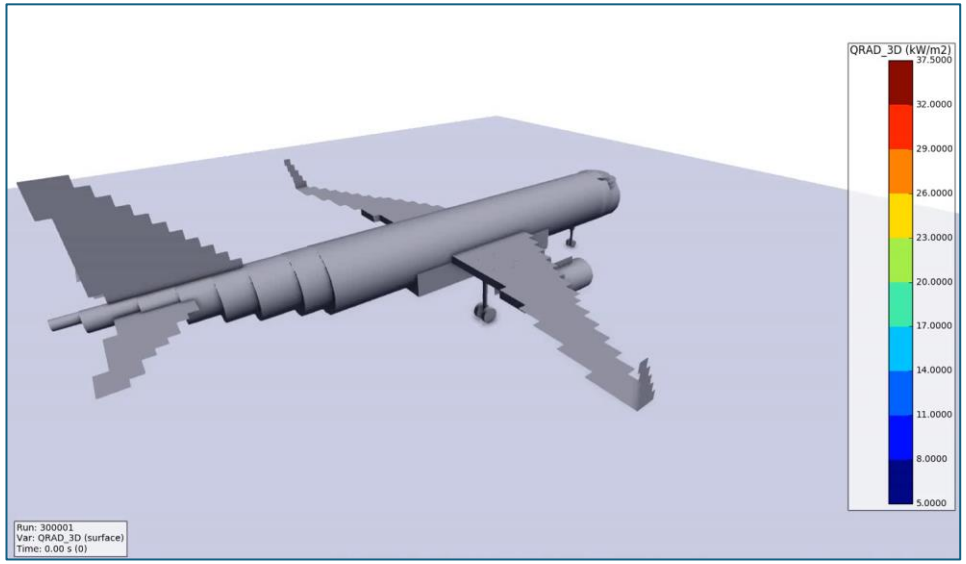
Modelling LH2 releases from an aircraft



Liquid Hydrogen







Aircraft Fuel Spill Pool Fires (top) and Radiative heat Flux on Surfaces (below) (ENABLEH2 and ZEST1)

Hydrogen and sustainable fuels research at Cranfield

From 2024: £69 million Cranfield Hydrogen Integration Incubator (CH2i), delivering:

- Hydrogen labs for research in energy production and end-uses.
- Large-scale test cells for hydrogen in civil aviation.
- Configurable test area for LH2.
- Upgrades to Cranfield Airport for larger and hydrogen-fuelled aircraft.

Research activities
- Ammonia for an H2 storage medium.
- Carbon capture storage.
- Economics and certification of H2 and SAF.
- Waste to fuel.
- Policies, economics and markets for net-zero H2 systems.
- Emissions and contrails from H2 and SAF.

Bulk Hydrogen Production by Sorbent Enhanced Steam Reforming (HyPER)
Research facility producing up to 700 kg/day of clean H2 with CO2 capture. www.hyperh2.co.uk

Digital Aviation Research and Technology Centre (DARTeC)

H2-powered whole aircraft design research

SAF provision on airport

Airport apron ground operations and MRO lab

Hydrogen vehicle test track

Cranfield Aerospace Solutions Ltd
Fuel cell light-aircraft (FRESSON).

Fuel production research
- Electrolysis.
- Methane cracking.
- Sustainable Aviation Fuel.

Advanced gas turbine thermal management rig

Electrified aircraft propulsion systems

H2 and SAF supply chain

H2 fuelled internal combustion engine research

The Global Hydrogen Production Technologies Center (HyPT)

Materials, structures, and fuel storage technologies for GH2 and LH2

40kg/day green hydrogen electrolyser

Mobile refuelling truck to refuel airside GSE and aircraft at up to 700bar

Anaerobic digestion feedstocks for H2 and SAF production

LH2 fuel system demonstrator, systems integration and ultra-low NOx H2 combustion

Key Feedstocks and fuel production. | Transport, storage, economics, supply chain. | End users – aerospace and road vehicles. | Policies, economics and markets. | • H2 = Hydrogen | • LH2 = Liquid hydrogen | • SAF = Sustainable aviation fuel

For more information, please contact: **Jon Horsley,** Hydrogen and Strategic Projects Manager E: h2@cranfield.ac.uk

June 2024

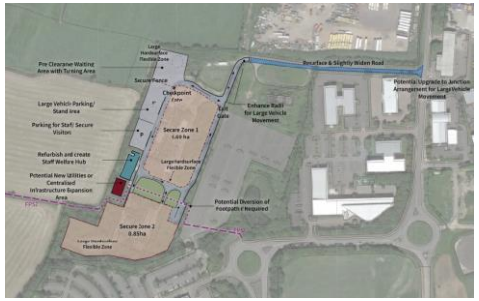
Overview of CH2i

Supported by UKRI Research England

- Largest ever research funding win for Cranfield University (£69m)
- Investment heralds a ‘step change’ in H_2 research, developing the first large scale H_2 research hub at any UK airport
- Funding will unlock technical challenges and scale-up H_2-enabled aviation to help meet net zero emissions targets

Enabling H_2 Innovation:
Hydrogen Integration Research Centre (HIRC)

Enabling H_2 Systems Integration:
Investment in CU’s H_2 gas turbine and fuel system testbed

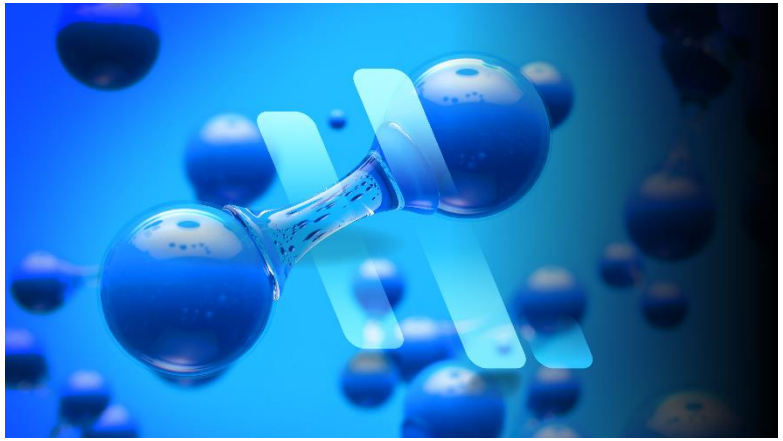


Enabling “Jet Zero”:
Investment in our Global Research Airport

Summary

- Hydrogen is coming into all aspects of our lives, particularly transport and industrial processes
- Although it's been used by industry for many decades, these new uses present new challenges and hazards, but also …
- … New business opportunities in Materials, Structures, Infrastructure, Handling, Sensing, and many more areas
- A New (Industrial) Revolution!

Image courtesy of Lufthansa Technik Hydro-Lab



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Thank you!
Any Questions?

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April 2025