Becoming a Hydrogen Offtaker: Pathways for Businesses and Organisations

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Ricardo plc

30th April 2025

Agenda

- Introduction / Workshop Objectives
- Why Become a Hydrogen Offtaker?
- Pathways to Becoming an Offtaker
- Case Study – Becoming an Offtaker
- Developing a basic hydrogen adoption plan
- Overcoming Challenges
- Open Discussion and Q&A
- Wrap-up & Summary

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Introduction / Workshop Objectives

Why Become a Hydrogen Offtaker?

Pathways to Becoming an Offtaker

Case Study – Becoming an Offtaker

Developing a basic hydrogen adoption plan

Overcoming Challenges

Open Discussion and Q&A

Wrap-up & Summary

Introductions

Dr Hamish Nichol FInstP

Head of Hydrogen
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Hamish's interest in hydrogen began a decade ago with BOC Linde leading the Aberdeen Hydrogen Bus project – the UK's first MW scale green hydrogen project. Since, he has worked on a wide range of hydrogen projects looking at everything from aeroplanes, refuse trucks, buses, crematorium(!), fish farms and hypersonic flight.

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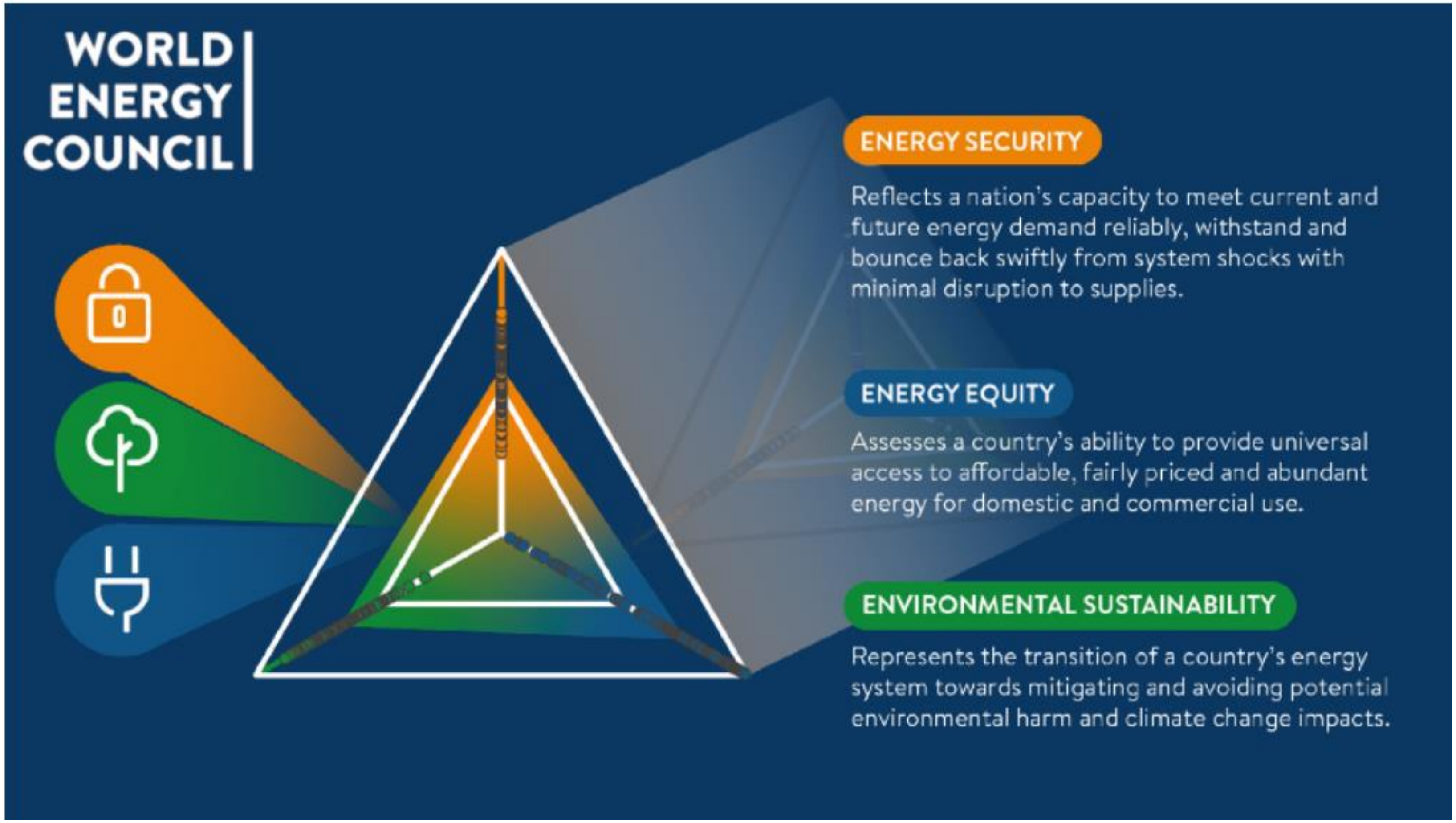
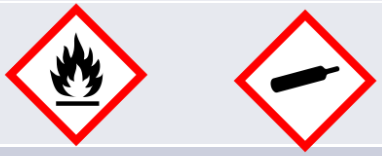
Energy Trilemma (or Quadrilemma)



Properties of Fuels

	Hydrogen	Natural Gas	Diesel
Colour	Colourless	Colourless	Colourless
Classification			
Odour	Odourless	Odourless (via stenching agent)	Yes
Vapour density (relative to air)	14 x lighter	2 x lighter	3.75 x heavier
Volumetric energy density	4 x less than diesel (compressed)	1.5 x less than diesel	~38 MJ per litre
Gravimetric energy density	3 x better than diesel	Comparable to diesel	~45 MJ/kg

Hydrogen Properties: Flammability, density and handling implications

Light and Flammable Gas

Hydrogen **burns or explodes very easily** – a mixture of as little as 4% hydrogen in air can ignite

- While this is about the **same as methane**, hydrogen needs about **1/5 of the energy to ignite**
- Fortunately, hydrogen has a **low density,** so will in many cases float away before burning, unlike petrol
- While no CO_2 is released during combustion, **NOx may be released when burned** – though not in fuel cells

Hydrogen is a **tiny molecule** and in some cases can pass straight through the wall of containers or pipes

Hydrogen is a gas unless it is cooled to -253°C (2nd coldest liquid!)

- Liquefaction is **expensive and uses lots of energy** (up to 1/3 the energy of the actual hydrogen!). Not readily available

Hydrogen's **low density** also means it is very **light**, however, its reinforced containers are heavy and **take up a lot of space**

https://energyresearch.ucf.edu/research/hydrogen/liquid-hydrogen-storage/

Hydrogen's Existing Presence

Already used today in:

Fertilisers

Adhesives

Oil refining

- The leading way of producing it is by processing natural gas (CH_4)
- Doing so produces 2.3% of global emissions, not far behind the global shipping sector, 2.5%

Hydrogen Economy – Why hydrogen!?

"We need to reduce CO_2 emissions to combat climate change"

Where electrification is not feasible, hydrogen is a critical tool because:

- Zero CO_2 emissions (only produces water and heat) when combusted (some NOx)
- Can be produced using renewable energy sources ("green hydrogen")
  and used to store otherwise curtailed energy
- Quick vehicle refuelling (minutes) and long range (300+ miles)
- Ability to be piped to consumers like natural gas
- Applicable across various transport modes (buses, trucks, RCVs, trains, etc.)
- Can replace fossil fuels in steel production, refining, and chemical processes
  but need to replace fossil fuel derived hydrogen with low carbon hydrogen
- Suitable for high-temperature industrial processes
- Can be stored for many days (or years!)
- Can be produced where it's required if there's renewables (or electricity)
- Government financial support with strike price approaching natural gas price
- Avoidance of ETS or other carbon taxation

Where could hydrogen be implemented into your business operations?

https://www.menti.com/alxksyki3twt

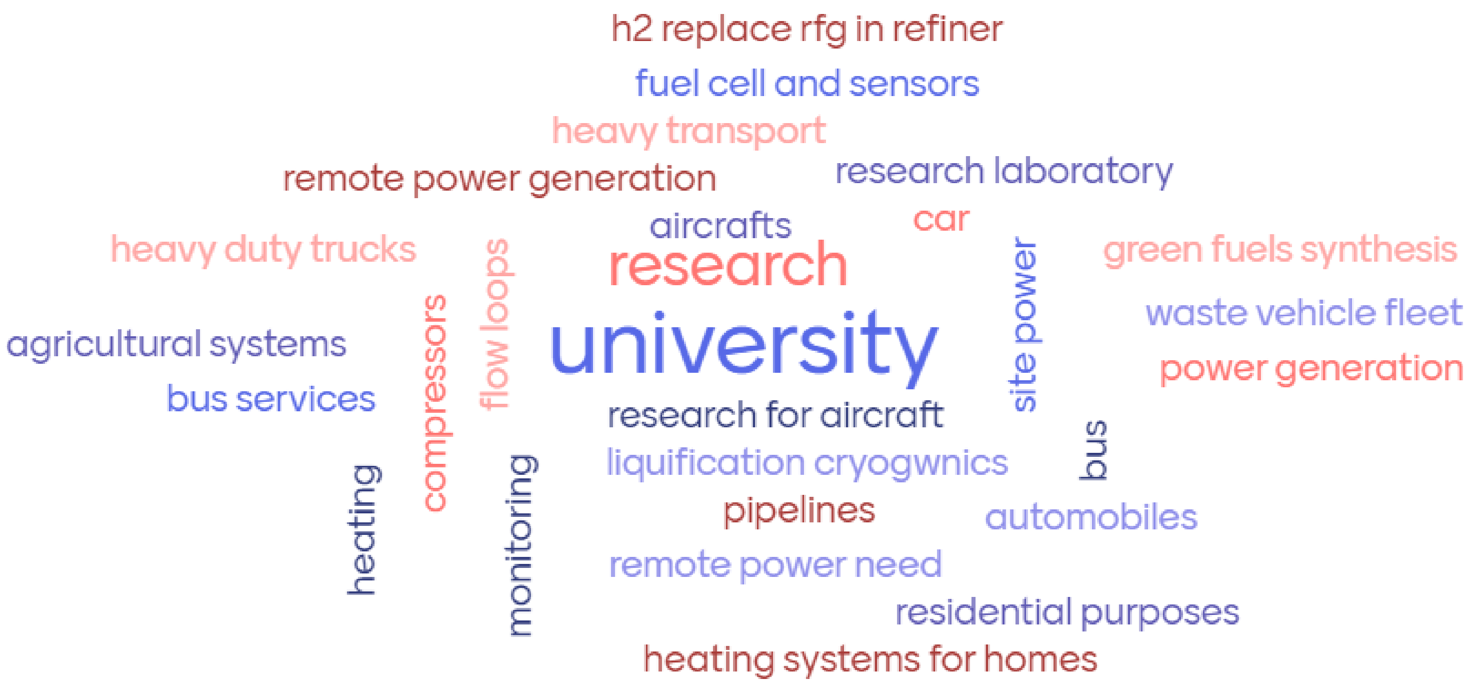
Or

www.menti.com

And enter code: **5320 4467**

Where would hydrogen fit in your business operations?

32 responses



Hydrogen Ladder

Key: No real alternative | Electricity/batteries | Biomass/biogas | Other

Unavoidable

- **A** — Fertiliser; Hydrogenation; Methanol; Hydrocracking; Desulphurisation
- **B** — Shipping*; Jet Aviation**; Chemical Feedstock; Steel; Long Duration Grid Balancing
- **C** — Coastal and river vessels; Non-Road Mobile Machinery; Vintage and Muscle Cars**; Biogas Upgrading
- **D** — Long Distance Trucks and Coaches; High-Temperature Industrial Heat; Generators
- **E** — Regional Trucks; Commercial Heating***; Island Grids; Short Duration Grid Balancing
- **F** — Light Aviation; Remote and Rural Trains; Local Ferries; Light trucks; Bulk Power Imports; UPS
- **G** — Metro Trains and Buses; Urban Delivery and Taxis; 2 and 3-Wheelers; Cars; Bulk e-Fuels; Mid/Low-Temperature Industrial Heat; Domestic Heating; Power Generation Using Non-Stored Hydrogen

Uncompetitive

**As ammonia or methanol   **As e-fuel or PBTL   ***As hybrid system*

Source: Michael Liebreich/Liebreich Associates, Clean Hydrogen Ladder, Version 5.0, 2023. Concept credit: Adrian Hiel, Energy Cities. CC-BY 4.0

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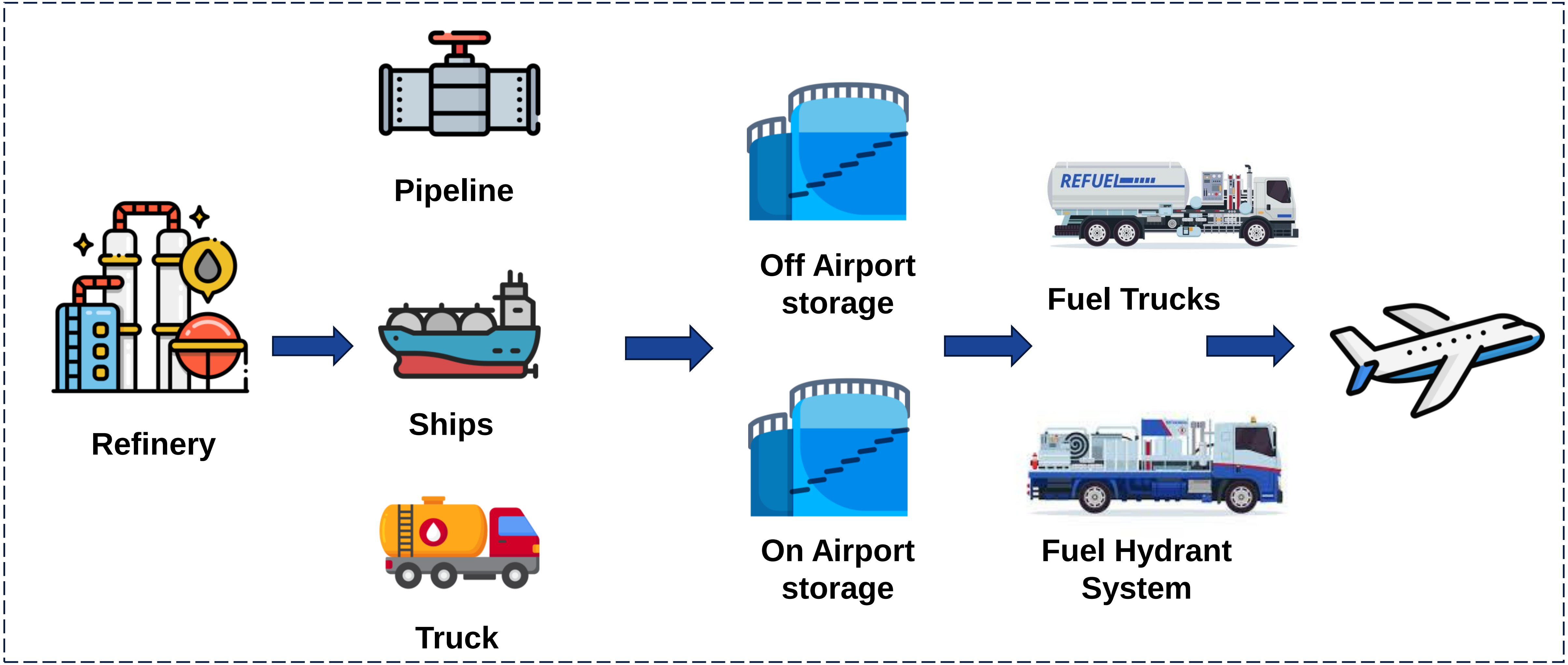
Jet fuel supply system



Hydrogen transformation & Storage

Transformation method	Hydrogen Storage Medium			
	Tank	Pipeline	Can	Cavern
Compression	✓	✓		✓
Liquefaction	✓			
Ammonia	✓	✓		
Methanol	✓	✓		
Hydrides			✓	

In order to store hydrogen, transformation process include **compression, liquefaction, conversion into another compound or adsorption**.

Once in the next state, the hydrogen can be stored in a **tank, pipeline, can or cavern** depending on its state.

When the hydrogen is required, it is then transformed to the required state at consumption.

H_2 *transformation* Storage *transformation* H_2

Gaseous Hydrogen – Transportation & storage

Supplied as pressurised gas either as:

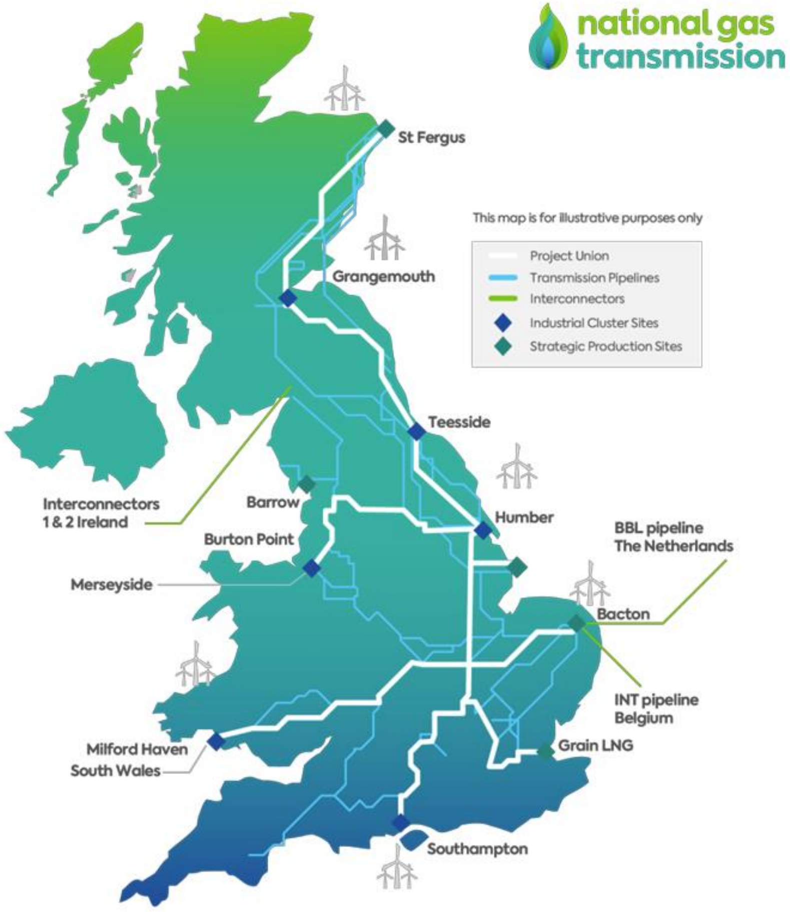
- Cylinders (typically, 150 to 200 bar for industry and laboratories)
- Trailers (large cylinders!) between 230 to 750 bar
- Pipeline (private network or potentially national transmission system?)
- Produced onsite (15 to 30 bar)

Or potentially as liquid hydrogen or via a hydrogen carrier

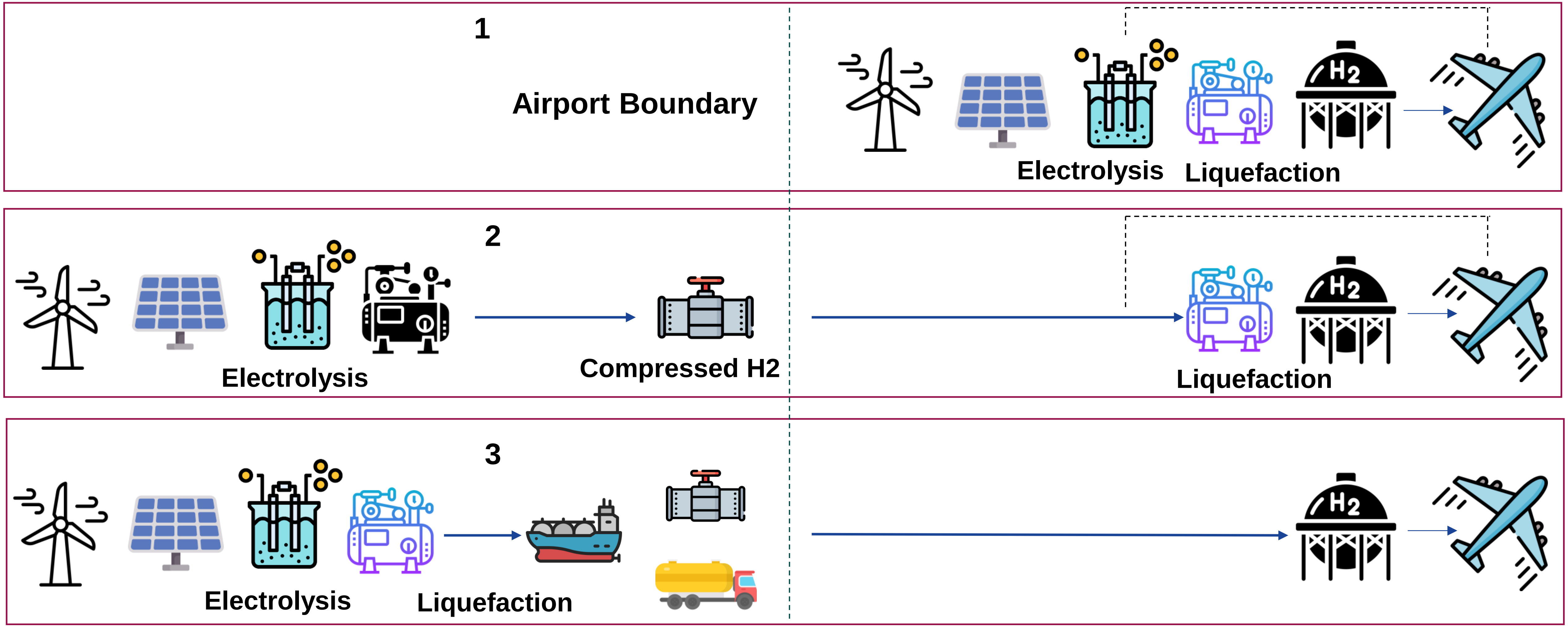
Proposed hydrogen pipelines

Example of a proposed regional industrial cluster:

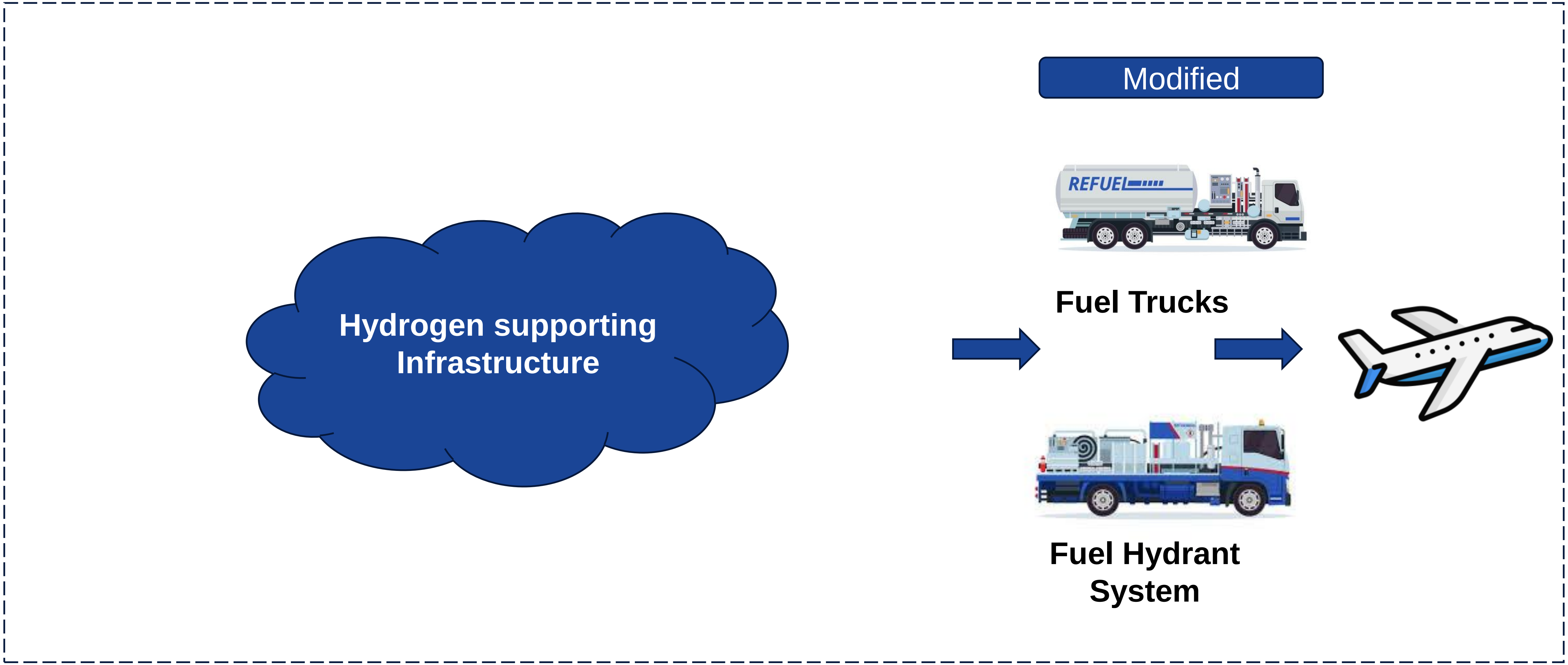
Concept for National Transmission System:



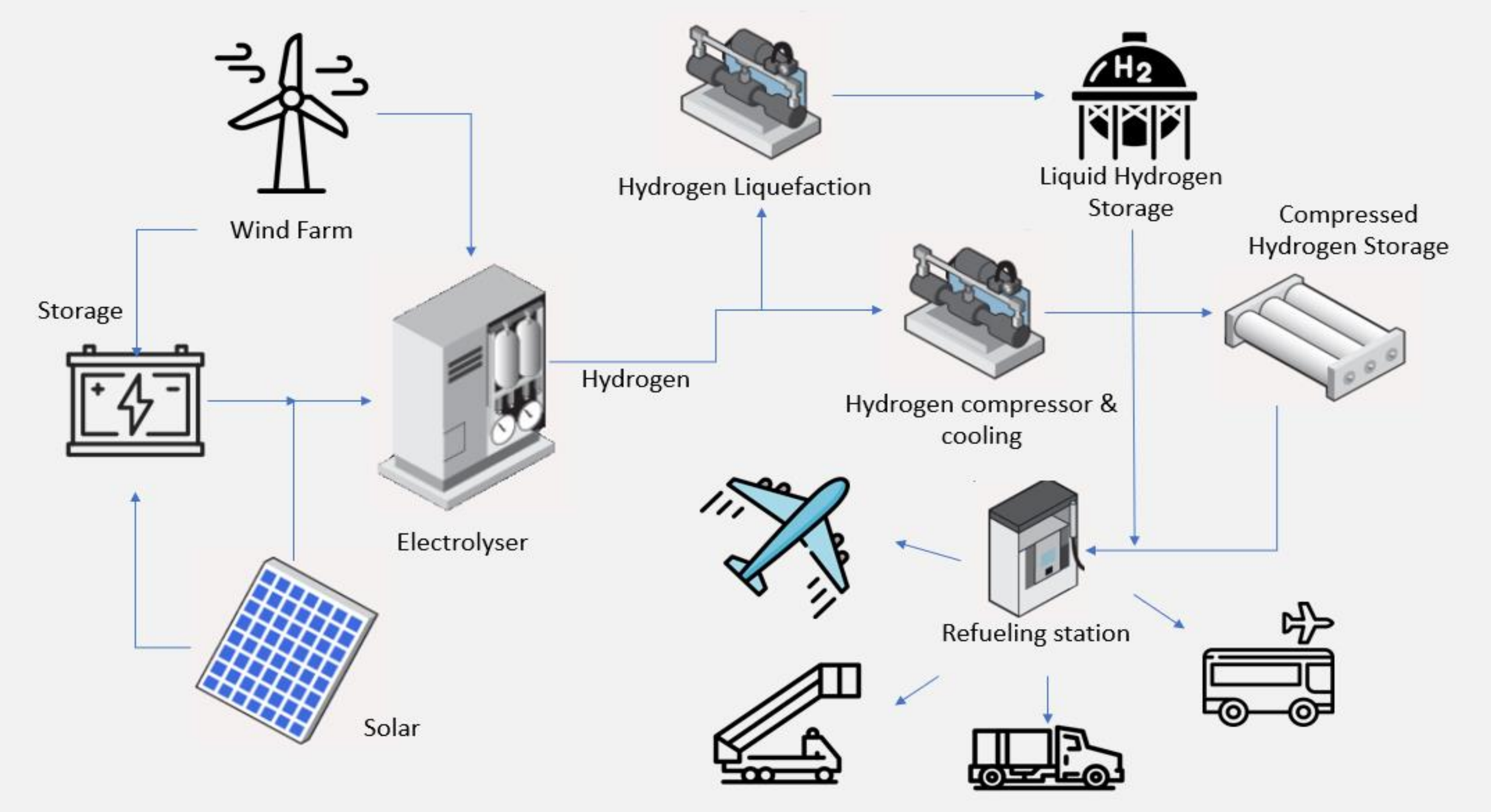
Hydrogen Supply Chain– Pathways (airport example)



Hydrogen Fuel Supply system (airport example)



New airport supporting infrastructure



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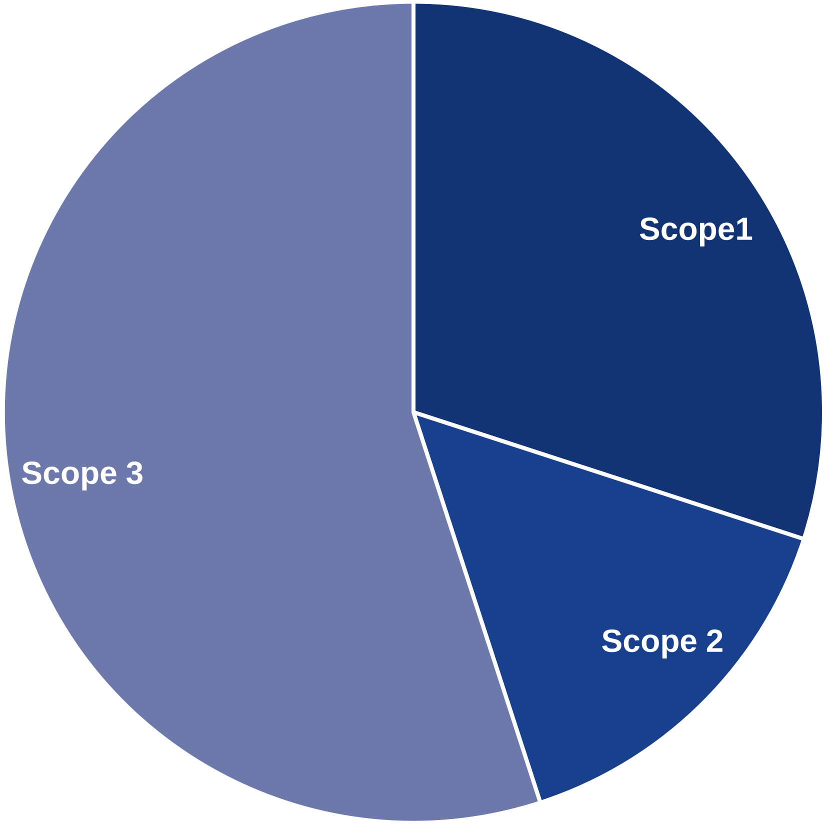
Airport Emission Sources

Scope 3
Fuel consumed by aircrafts
Logistics transportation
Customer transportation
Waste generated in operation
Purchased goods and services
Tenant electricity, natural gas
Staff commute
Water
Third party operational vehicles



Scope 1
Airport natural gas
Ground support equipment
Diesel back up power generators
Airport de-icer
Refrigerants
Fire training

Scope 2
Airport electricity

Where does hydrogen come into picture?

Scope 3
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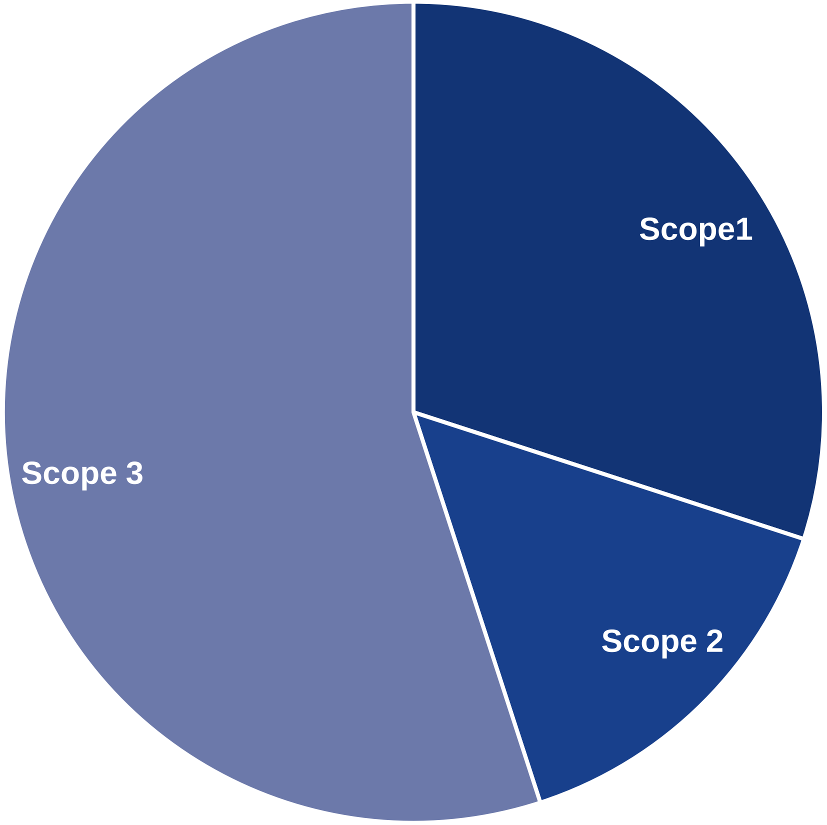

Scope 1
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Refrigerants
Fire training

Scope 2
Airport electricity

Use Case - Aircraft

Hydrogen Combustion

- Gas turbines with modified fuel injectors and fuel systems (Similar to current aircrafts)
- Example : Airbus ZEROe concepts – Turbofan - Two hybrid- hydrogen turbofan engine – <200 passenger commercial aircraft

Hydrogen Fuel Cell

- Fully electric propulsion system, hydrogen fuel cells creates electrical energy which in turn power electric motors that turn a propeller
- Examples: ZeroAvia ZA600 – 600 kW 9-19 seats hydrogen – electric power train
- Project Fresson

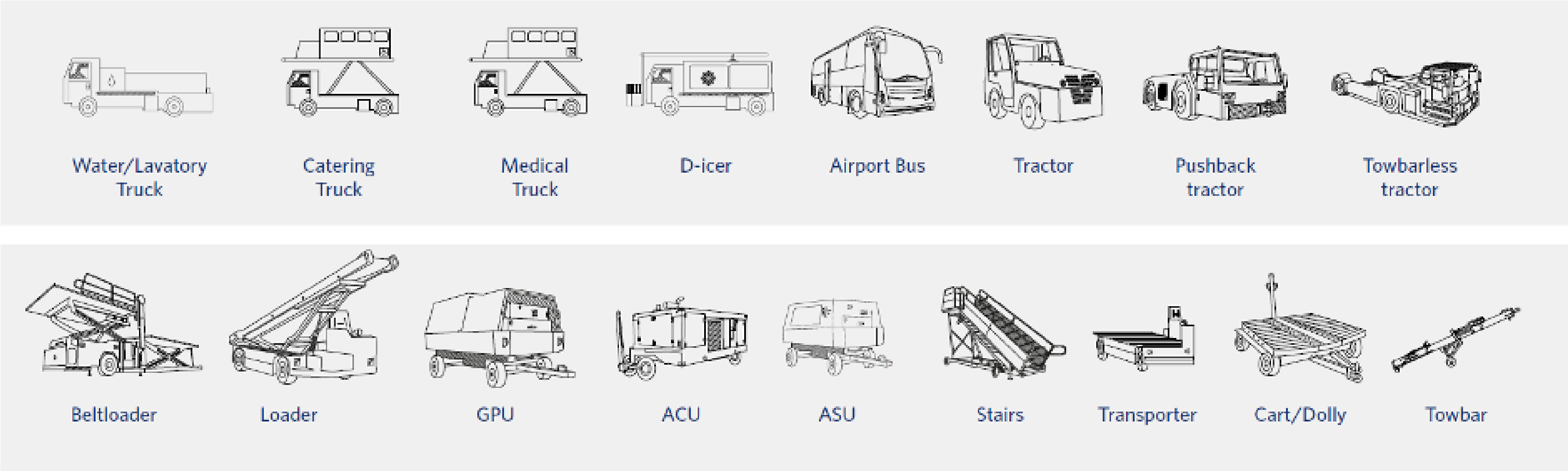
Case study – Project Fresson (hydrogen fuel cell)

Short-haul passenger aircraft

Cranfield Aerospace Solutions is leading the Project Fresson consortium project which is seeking to deliver the ‘**world’s first truly green passenger carrying airline’** services using hydrogen fuel cell technology.

Ricardo is providing the fuel cell system including its controller, which is the primary source of electricity on the aircraft. The system includes the fuel cell stack and the balance of plant.

Use Case - Hydrogen fuel cell powered mobile plant



Hydrogen-electric Ground Power Units (GPU's)

Hydrogen-electric Ground Support Equipment (GSEs)

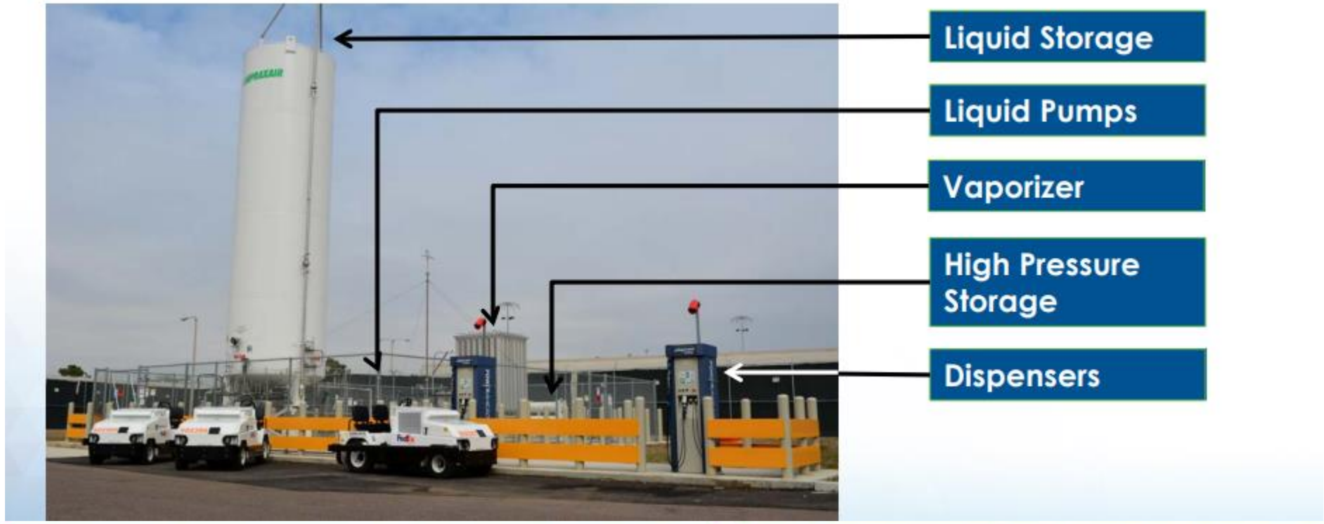
H_2 fuel cell electric HGV
Or
H_2 ICE HGV
Or
H_2 / diesel hybrid HGV

Case study – Plug Power demonstration (Non-road mobile machinery)

Cargo Tractor Demonstration (Albany Airport)

Project overview:
- Department of Energy (US) funded project in 2015 ($2.5 million)
- 15 fuel cell cargo tractors
- Infrastructure located on airport ramp
- Outdoor operations

Why the project was implemented:
- Emissions reduction
- Noise reduction
- Fuel savings



Case study: Aberdeen City Council

- UK’s first hydrogen fuel cell waste truck added to the fleet.
- Part of the EU-funded HECTOR project.
- Green hydrogen from existing infrastructure, significant CO_2 savings.

Project Milestone

- Project announcement: Sept 2019
- HECTOR truck showcased at APSE Scotland Seminar
- Project ended in 2023

Project features

Technology:
Vehicle by Geesinknorba;
Chasis by Hyzon Motors and Electric Motor: Allison 3000 Series™

Collaboration: EU Funded Interreg Project "Hector"

Hydrogen supplier: Existing infrastructure in Aberdeen

Tank Capacity: The RCV has a range of 155 miles (250 km)

Hydrogen RCVs - Benefits

Flexible full-service vehicle – both short city routes and extended suburban/rural routes

30 kg hydrogen onboard can give duty cycle of **125 km involving 3,000 bin lifts**

No performance fade and the fuel cell RCV can operate at highway speeds with a full load, even at the end of a shift

Strategic location of refueling infrastructure near industrial hub can open up use by **other potential off takers** and shared costs

Fast refueling – under 10 min for 30 kg hydrogen, no need for long down time

Similar payload load to diesel RCV and 2.5 tonne better payload (no room needed for battery pack) over battery electric RCV – 16 h or more operation

Hydrogen refueling infrastructure scales well and is cost effective as compared to electric RCV

Higher **scope for technology development**, potential reduction in Total Cost of Ownership (TCO)

Hydrogen RCVs - Challenges

- Lack of refueling infrastructure network
- High cost of green hydrogen production
- Storage and transportation challenges
- Needs policy support for infrastructure scale up
- Efficiency loss due to conversion to hydrogen as compared to direct electric RCVs
- Safety concerns – public awareness and acceptance
- Higher RCV cost (currently in the prototype phase)

Contingency plans – diesel/hydrogen RCVs example

- Hydrogen imports from local or national producers (not available at the moment at scale)
- Hydrogen storage philosophy (several days for backup)
- Dual fuel allows for diesel to be used in cases where hydrogen supply may be disrupted
- HVO can also be an option

Case study: Aberdeen City Council

- UK's first dual fuel fleet – range of vehicles including RCVs, road sweepers, vans, etc.
- Aberdeen City Hydrogen Strategy set out that all vehicles >3.5 t will be H_2 / H_2 enabled
- 16 t to 25 t vehicles now all hydrogen enabled (dual fuel = H_2 + diesel/HVO)
- Latest order of 10 vehicles will increase the fleet size to ~50 H_2 vehicles

Project Milestone

- Inception 2022
- ULEMCO announced supply of HVO/hydrogen dual fuel RCV
- February 2023, ULEMCO announced fleet conversion dual fuel vehicles

Project features

Technology: Conversions by ULEMCO to a wide range of vehicle types / manufacturers

Collaboration: Council led funding

Hydrogen supplier: Two existing HRS & two new HRS being built

Tank Capacity: Tank size increases with vehicles size 5 – 10 kg for N2/N3 rigid body

Business model – impacts and challenges with decarbonisation

Positive impacts:

- Reduction of Scope 1
- Cleaner air
- Creating a sustainable council
- Meeting net-zero targets

Challenges in building a viable business case:

- Technology readiness of equipment
- Cost of alternative fuels
- Higher CAPEX for decarbonised equipment
- Evolving regulatory landscape (funding, carbon credits/taxes)
- Which vehicles will use hydrogen vs. electrification?

Task (in small groups) – 15 minutes plus feedback time

Either selecting your own business operation or one of the businesses below, in your groups please can you identify:

- All the areas where hydrogen can be used to decarbonise the business / operations?
- How could the hydrogen be sourced?
- What infrastructure might be required?
- What needs to happen to make it a reality?
- What barriers exist?

Businesses: / The UK's largest pork-pie factory / Inshore fish farm in Scotland / / A very large Amazon warehouse / The finest whisky distillery / Milton Keynes Council /

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- **Developing a basic hydrogen adoption plan**
- Overcoming Challenges
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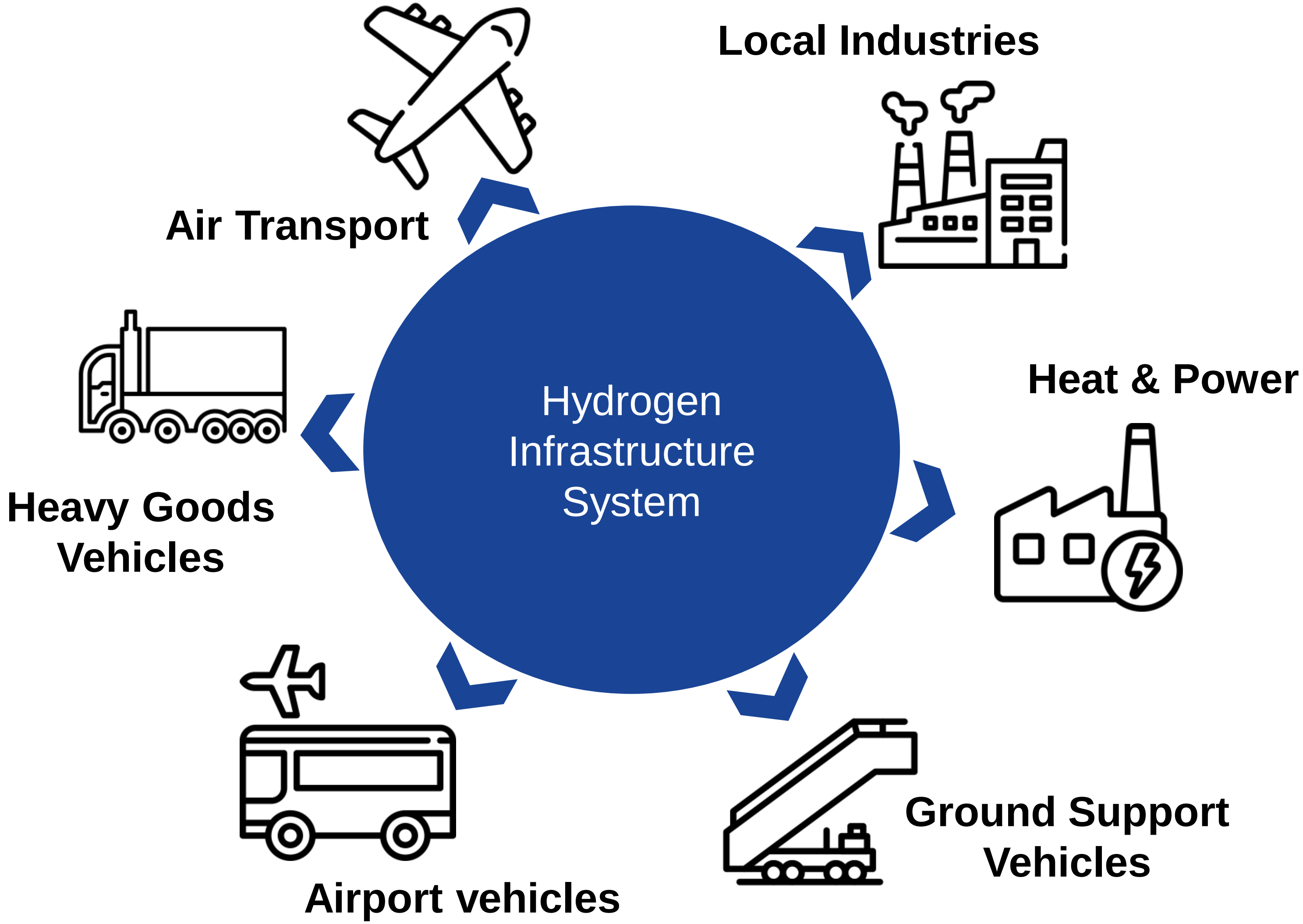
Hydrogen hub concept (airport example)



Hydrogen Risk Management

Risk management of chemicals encompasses a broad set of activities for identifying, assessing, and responding to possible chemical risks to ensure safe production and use.

Emergency response is actions taken to manage, control, or mitigate the immediate effects of an incident, which include a fire, a chemical spill, an explosion etc.

Safety Planning

Early identification

- **Risk assessment -** Hazard Identification (**HAZID**), Hazard and Operability Study (**HAZOP**), Layers of Protection Analysis (**LOPA**) and Quantitative Risk Assessment (**QRA**) techniques.
- **Safety expertise** early in project's life, reviewing design, inspecting installation, near misses and lesson learned.

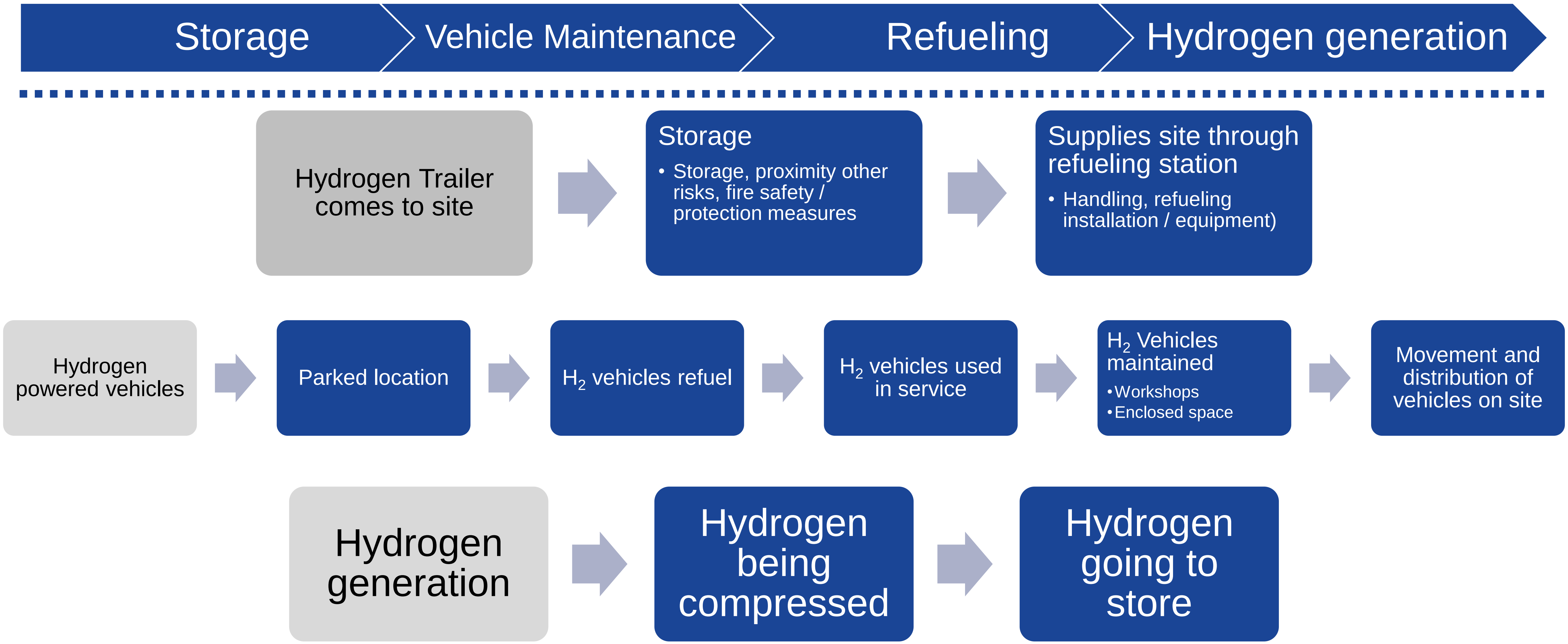
Compliance with Codes and Standards

- **Compliance** with applicable **codes and standards**, for example **BCGA guidelines** is essential for ensuring public confidence in commercial projects, particularly for deploying new technologies.

Emergency Response Team

- The project team should work with their **local first responders** to make them aware of the activities and their hazards.
- Creating a **robust emergency response procedure** and training first responders for execution

Hydrogen Application - Applications & Scenario-use process



Hydrogen Safety Codes & Regulations – Applicability

COMAH (EU = Seveso)

- The **COMAH Regulations 2015** are the enforcing regulations within the United Kingdom that aim to reduce the risk of potential major incidents resulting from hazardous substances or chemicals.
- The thresholds where COMAH applies to **H_2 are 5 tonnes for lower tier and 50 tonnes for top tier**.

Only applicable – site with H_2 > 5 tonnes

Planning (Hazardous Substances) Regulations 2015

- Consent required for any installation storing >2 tonnes

Only applicable to site with H_2 > 2 tonnes

DSEAR

- The **Dangerous Substances and Explosive Atmospheres Regulations (DSEAR)**, 2002, cover the protection against risks from fire and explosion arising from dangerous substances used or present in the workplace.
- Production, storage and use of hydrogen in the workplace is covered by DSEAR and will require a **DSEAR risk assessment** by a competent person.

Applicable to all

Pressure Equipment Regulations

- **PER 2016** cover pressure equipment and assemblies with a maximum allowable pressure above 0.5 bar.
- The purpose - **protect consumers from unsafe products** by requiring manufacturers to show how their pressure equipment or assemblies meet the essential safety requirements.
- **Suppliers of electrolyser systems** should ensure their equipment and instrumentation complies

Applicable to most

Environmental and water permitting

Environmental permitting

Only applicable to onsite production

- Environmental Permitting Regulations (EPR) require operators of “regulated facilities” to obtain an “environmental permit” from Environmental Agency.
- Abstraction and treatment of waste waters and their discharge to the environment is also regulated – Trade Effluent Consent – Water Industry Act 1991
- The application will also include risk assessments, management plans/procedure, and a demonstration of the application of Best Available Technology (BAT).

Water abstraction and discharge licensing

Only applicatble to onsite production

- A water abstraction and **discharge license** is required from Environmental Agency (EA) if there is plan to **abstract >= 20 cubic meters water a day** (project requires around **8 cubic meters per day**)
- In the < 20 cubic meters case the planning authority might want assurance that the proposed hydrogen development has a sustainable source of water without any consequence upstream and downstream.
- Consultation responses from relevant environmental regulator or water company might be important.
- If environmental permit not required – discharge consent – Water Resource Act 1991

Hydrogen safety training

Site personnel
- Hydrogen safety awareness training
- Vehicle awareness
- Project awareness
- Emergency plan

May need to be procured independently

Plant operators
- Standard operating procedures
- Maintenance guidelines
- Startup and shutdown
- Emergency response procedure

Provided by equipment suppliers

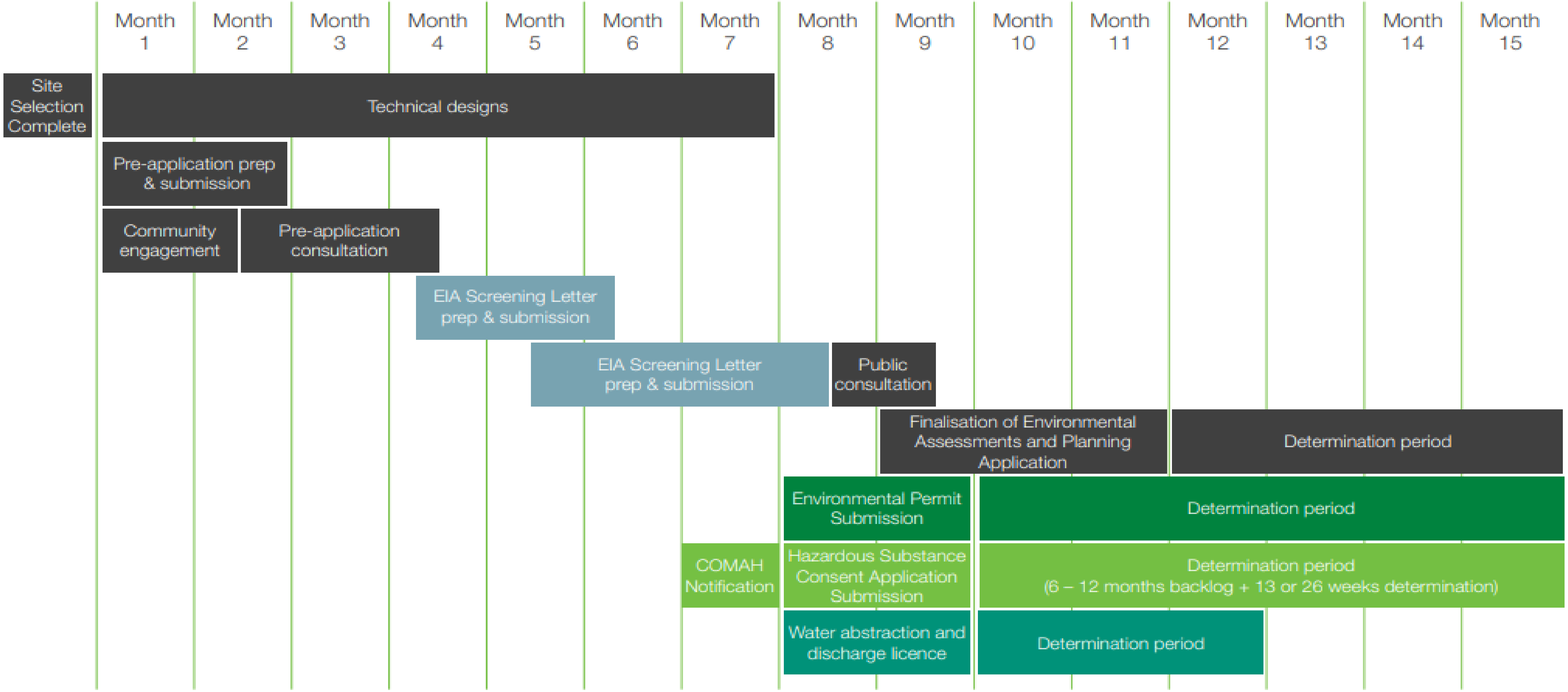
Vehicle personnel
- Vehicle operation
- Refueling process
- Vehicle safety
- Emergency procedures

Provided by vehicle suppliers

Hydrogen safety awareness training

Incorporated into standard training after initial training

Sample planning regime – Green hydrogen projects (onsite production)



Source: https://www.renewableuk.com/media/3dlb4ukx/planning-for-onshore-green-hydrogen_march-2023.pdf

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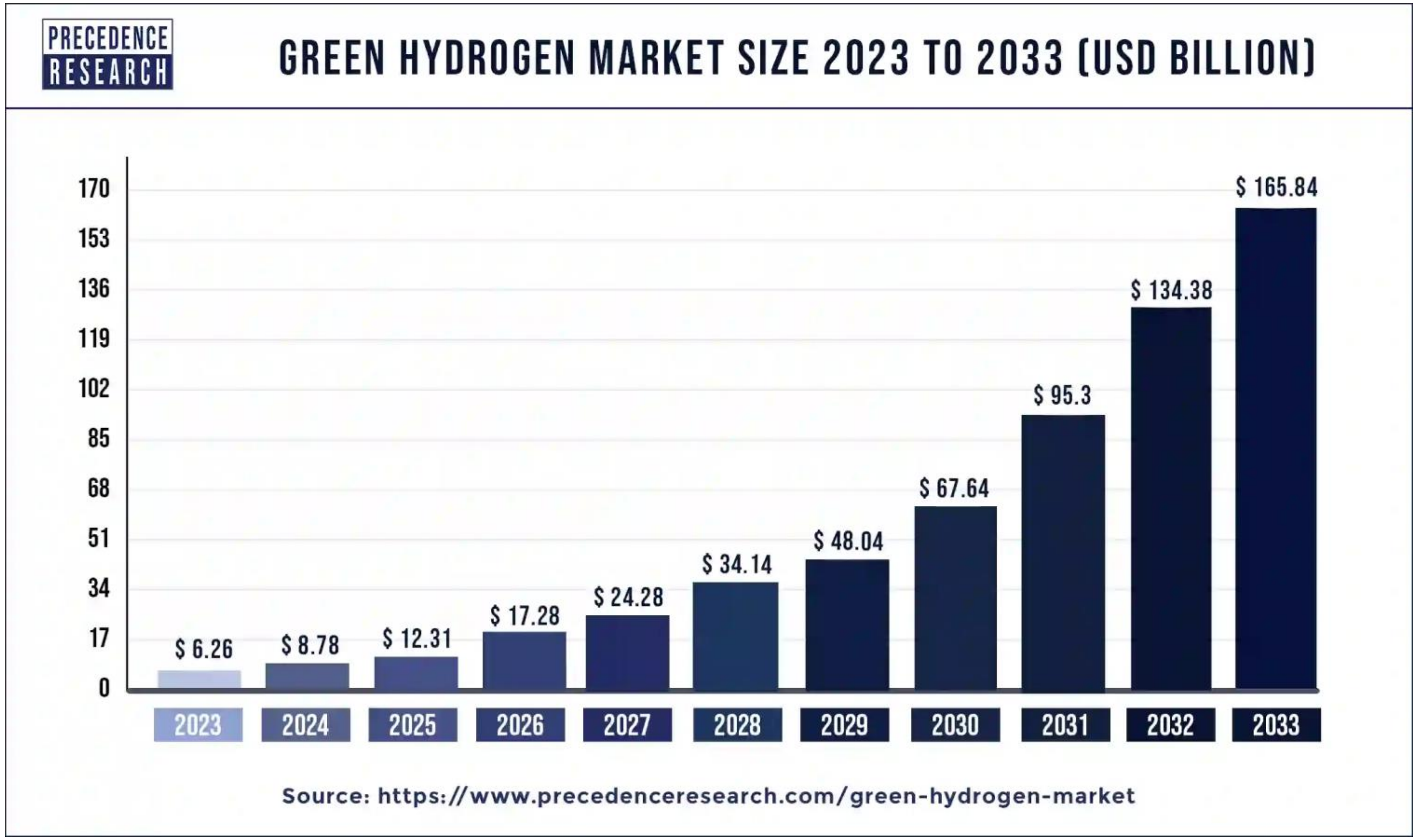
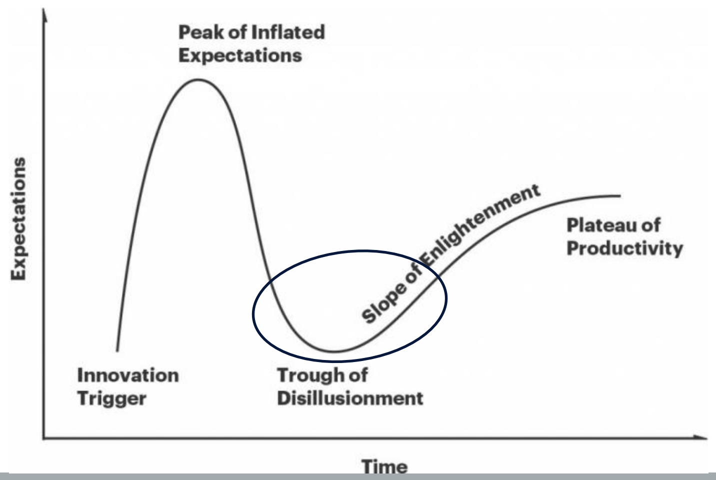
Current Market and Future outlook – a growing market with many opportunities and challenges

- Market expected to grow at a CAGR of 38.77% from 2024 to 2030
- At the moment however, only 28% of hydrogen projects in the pipeline have reach FID
- Chicken and egg situation still needs to be resolved

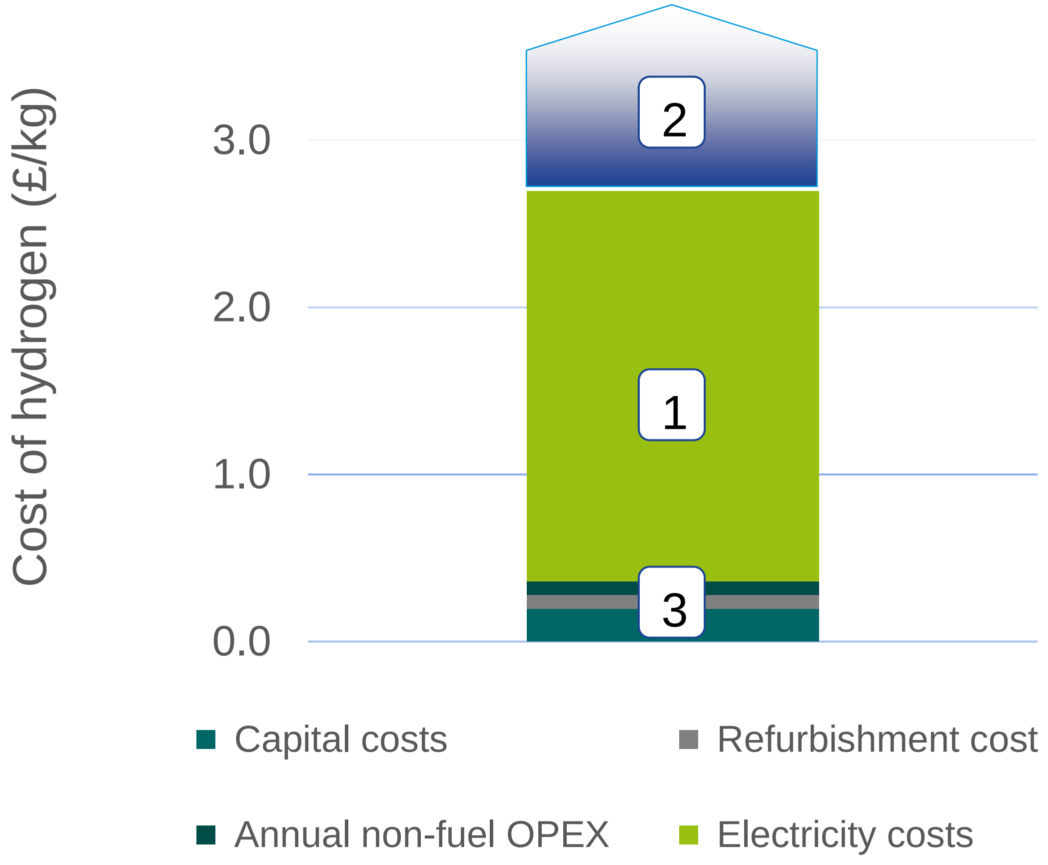




Levelised Cost of Hydrogen (LCOH) – Electricity & distribution costs make up most of the cost

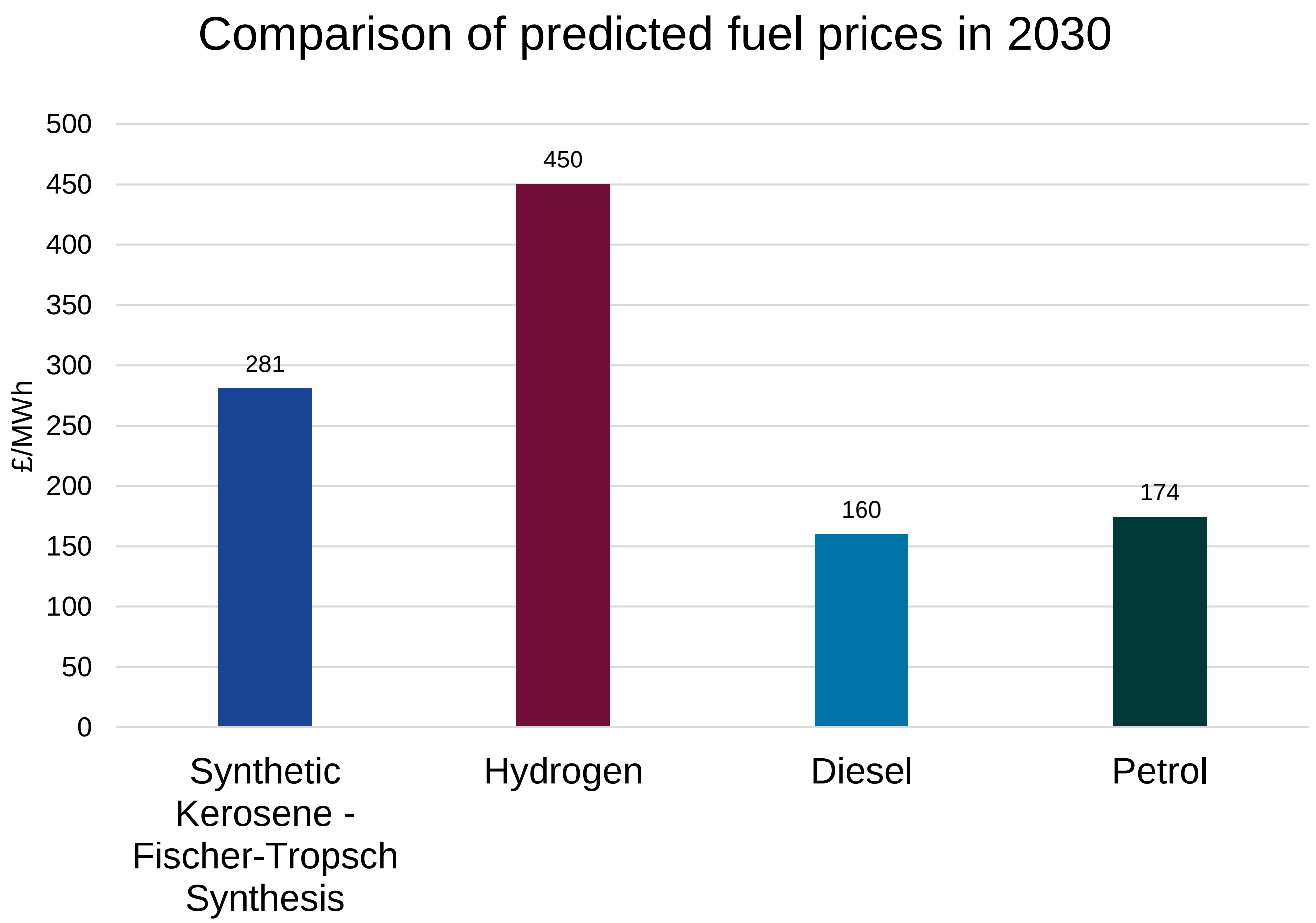
1. The **vast majority of the cost** of a unit of green hydrogen is from the **electricity,** this can be minimised by:
   - Using low-cost renewables
   - Avoiding grid-use/transmission costs
   - Utilising curtailed power
2. The **second largest** cost is to **distribute** the hydrogen including:
   - Transport
   - Storage
   - Refuelling
3. **Third largest** is the **capital cost** which can be reduced by:
   - Economies of scale
   - Maximising production

Levelised cost of green hydrogen in 2030 powered by offshore wind



RICARDO

Cost of hydrogen & SAF compared to conventional fuels – decarbonisation is costly



- Even by 2030 it is expected that alternative fuels like synthetic kerosene and hydrogen will be more costly than conventional fossil fuels on an energy basis
- Paris agreements and national commitments to net zero mean that decarbonisation through innovation will have to take place
- Policies such has carbon taxes or supply change regulations, alongside technological learnings, may make alternative fuels more competitive in the future
- Pricing and reporting of emissions reduction efforts will also stimulate innovation

Agenda

Introduction / Workshop Objectives

Why Become a Hydrogen Offtaker?

Pathways to Becoming an Offtaker

Interactive: Case Study – Becoming an Offtaker

Developing a basic hydrogen adoption plan

Overcoming Challenges

Open Discussion and Q&A

Wrap-up & Summary

Q&A

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Business model – opportunities and challenges for hydrogen end users

Opportunities for building a viable business case:

- HPBM subsidised hydrogen on its way, RTFOs available now, other funding available
- A phased approach when adopting decarbonisation measures, minimises risk
- Decarbonising heavy duty vehicles and other equipment may provide a ‘way in’
- Scale, scale, scale
- Hydrogen hubs collaborations have the potential to create many jobs and stimulate economic growth

Challenges in building a viable business case:

- Technology readiness of equipment
- Cost of hydrogen supply
- Cost of hydrogen transportation / storage
- Higher CAPEX for decarbonised equipment
- Evolving regulatory landscape (origin of fuels, carbon taxes, etc.)
- Business case dependent on realised cost of carbon
- More safety considerations than electrification
- When will the hydrogen be available?

Positive impacts:

- Reduction of Scope 1 and 3 emissions
- Cleaner air
- Creating a sustainable business
- Giving a commercial competitive edge through sustainability credentials

Some key points

Hydrogen is a key tool in decarbonising a number of sectors, particularly energy intensive applications

It is not a silver bullet, especially where electrification is available and feasible

Currently hydrogen is expensive, though in the next few years subsidised hydrogen will be available

The Hydrogen Production Business Model is due to provide hydrogen at an equivalent gate price to natural gas

Transporting hydrogen as compressed gas is tricky and adds costs, but pipelines will take many years to be implemented

The business model for hydrogen generally requires an additional carrot or stick, such as ETS / carbon taxation

The hazards of hydrogen are manageable, though undertake appropriate risk assessments and train your staff

Thank you