Net Zero Innovation portfolio (NZIP)

Industrial Hydrogen Accelerator (IHA) Stream 2A, Dissemination Event

Purpose: To share the findings of the Industrial Hydrogen Accelerator Stream 2A feasibility studies

27th March 2023

Antonia Mattos, IHA programme lead, Science and Innovation for Climate and Energy

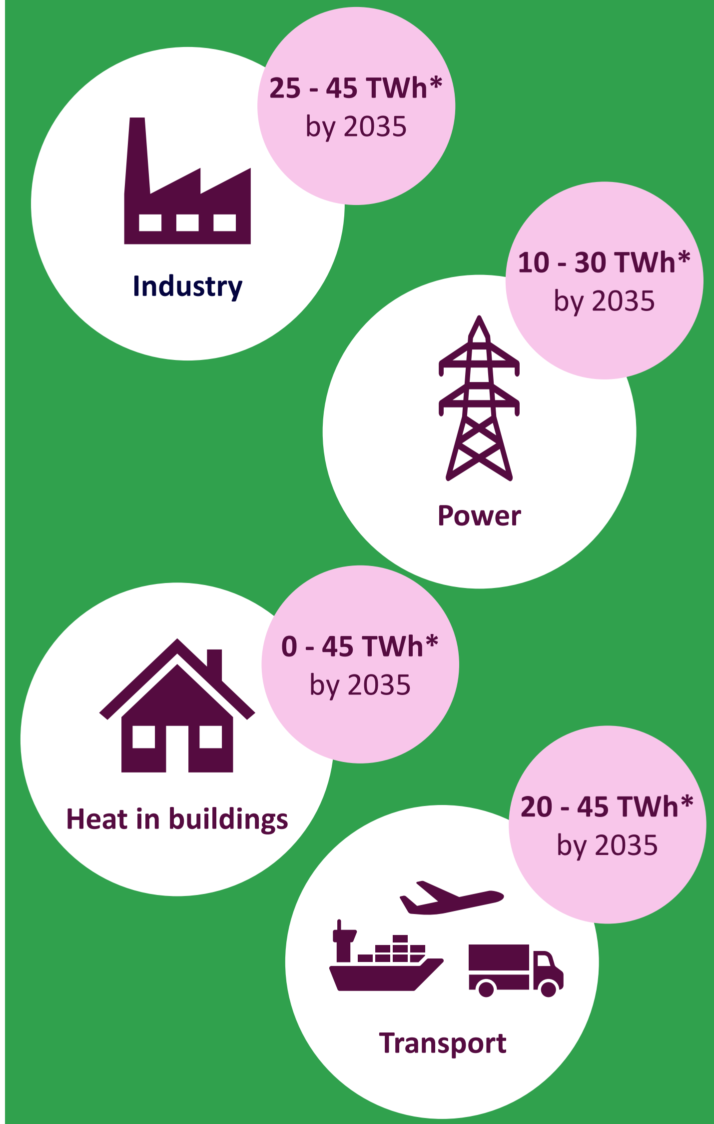
Department for Energy Security & Net Zero

Time	Minutes	Item
13:30	20	Welcome - overview of DESNZ hydrogen and the IHA Programme Guest speaker case study – Glass Futures
13:50	10	Project 1 - E.ON
14:00	10	Project 2 - Centre for Process Innovation (CPI)
14:10	10	Project 3 - EDF Energy R&D UK Centre
14:20	10	Break
14:30	10	Project 4 - ROCKWOOL
14:40	10	Project 5 - Nanomox
14:50	10	Project 6 – ASH Waste Services
15:00	10	Break
15:10	10	Project 7 - Undercover Zero R&D Centre
15:20	10	Project 8 - Costain
15:30	10	Project 9 - HiiROC
15:40	10	Final remarks from DESNZ
15:50	20	Breakout session – project Q&A
16:10	20	Breakout networking
16:30		CLOSE

Department for Energy Security & Net Zero

Hydrogen will play a significant role in the UK's energy mix

- Hydrogen has a significant role to play in the UK economy: ~20-35% of final energy consumption by 2050.
- The first UK Hydrogen Strategy focuses on driving progress to scale up hydrogen economy in 2020s. It sets out up to £1bn in UK Govt support for hydrogen and other low carbon technologies. The latest progress is summarised in the H2 strategy update Dec 22.
- We expect 2GW of H2 production to be in construction or operation by 2025 and have an ambition for up to **10GW by 2030** (of which at least half will be electrolytic). Up to half the demand for hydrogen by 2035 is expected to be from industry.
- The low carbon hydrogen standard (LCHS) ensures any production in the UK supports our net zero transition. There is currently an open consultation on the design elements of a low carbon hydrogen certification scheme.
- There is significant support for UK hydrogen projects, as outlined in the Hydrogen investor roadmap and funding landscape. The £240m Net Zero Hydrogen Fund (NZHF) supports capital costs of hydrogen production and the Hydrogen Business Model will provide revenue support (CfD style).
- In parallel, we're developing H2 T&S infrastructure and supporting fuel switching across the economy, for example in industry through the IETF and the Local Industrial Decarbonisation Plans competition opening this summer.
- We expect the UK to have a strong role in the global hydrogen economy and are developing the evidence base on all aspects through trials (e.g. the hydrogen village trial) and consultations (e.g. power sector decarbonisation readiness and industrial H2 boilers).



*Illustrative demand based on analysis for the UK Hydrogen Strategy (2021)

The hydrogen economy will grow across the 2020s

Early 2020s (2022-2024)

Hydrogen economy 'archetype'

Production
Small-scale electrolytic production

Networks
Direct pipeline, co-location, trucked (non-pipeline) or onsite use

Use
Some transport (buses, early HGV, rail & aviation trials); industry demonstrations; neighbourhood heat trial

Key actions and milestones

- Launch NZHF early 2022
- Phase 1 CCUS cluster decision 2021
- Finalise low carbon hydrogen standard 2022
- Finalise business model 2022
- Heat neighbourhood trial 2023
- Value for money case for blending Q3 2022

Mid-2020s (2025-2027)

Production
Large-scale CCUS-enabled production in at least one location; electrolytic production increasing in scale

Networks
Dedicated small-scale cluster pipeline network; expanded trucking & small-scale storage

Use
Industry applications; transport (HGV, rail & shipping trials) village heat trial; blending (tbc)

- Aiming for 1GW production capacity 2025
- At least 2 CCUS clusters by 2025
- Heat village trial 2025
- Hydrogen heating decision by 2026
- Decision on HGVs mid-2020s

Late 2020s (2028-30)

Production
Several large-scale CCUS-enabled projects & several large-scale electrolytic projects

Networks
Large cluster networks; large-scale storage; integration with gas networks

Use
Wide use in industry; power generation & flexibility; transport (HGVs, shipping); heat pilot town (tbc)

- Ambition for 5GW production capacity 2030
- 4 CCUS clusters by 2030
- Potential pilot hydrogen town by 2030
- Ambition for 40GW offshore wind by 2030

Mid-2030s onward

Production
Increasing scale & range of production – e.g. nuclear, biomass

Networks
Regional or national networks & large-scale storage integrated with CCUS, gas & electricity networks

Use
Full range of end users incl. steel; power system; greater shipping & aviation; potential gas grid conversion

- Sixth Carbon Budget

Supporting policy and activity: what needs to be in place to deliver?

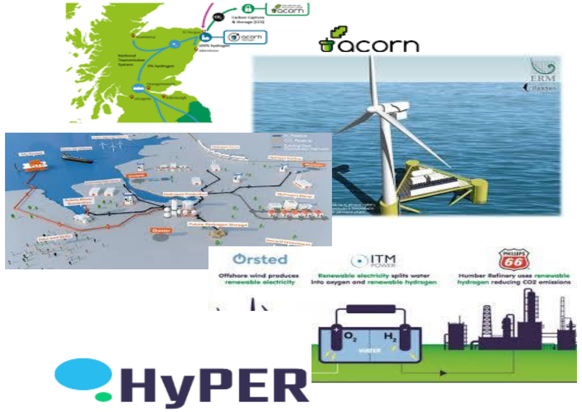
Networks & storage infrastructure · Regulatory frameworks · Market frameworks · Grant funding · Research & innovation · Sector development · International activity & markets · Public & consumer awareness · Private investment · Industry development & deployment

	Early 2020s (2021-2024)
Networks & storage infrastructure	Pipeline/ non pipeline/ co-location infrastructure in place Storage requirement and type(s) established for range of pathways (clusters, heat, power system) Decentralised storage in place
Regulatory frameworks	Networks delivered through existing regulatory and legal framework Regulatory signals (e.g. H_2 readiness) in place Wider standards (e,g. safety and purity) updated/in place Critical first-of-a-kind deployment barriers addressed Planning and permitting regimes in place
Market frameworks	Hydrogen business model (BM) finalised and in place Wider market framework structures and implications for BM understood Low carbon hydrogen standard in place Revenue support (RTFO) in place for transport sector
Grant funding	Capital grant funding mechanisms in place driving investment across production, as well as end use e.g. industry, transport
Research & innovation	Programmes in place coordinating effort, support & de-risking/ demos for production, industry, transport, storage, heating R&I ecosystems in place supporting supply chain development

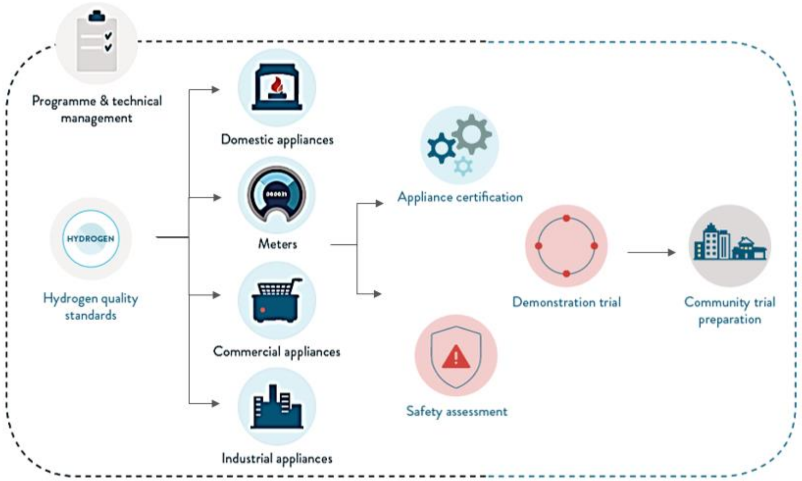
Further opportunities

- UKRI Innovate UK Hydrogen Supply Chain Directory detailing organisations across the chain to support collaboration
- The UKRI Hydrogen storage and distribution supply chain collaborative R&D fund is currently open for grant applications
- The Local Industrial Decarbonisation Plans (LIDP) competition, opening summer 2023, offers grant funding to support the development of strategic decarbonisation plans
- The hydrogen business model 2023 allocation round is under development. If you are interested, please look out for the upcoming market engagement document

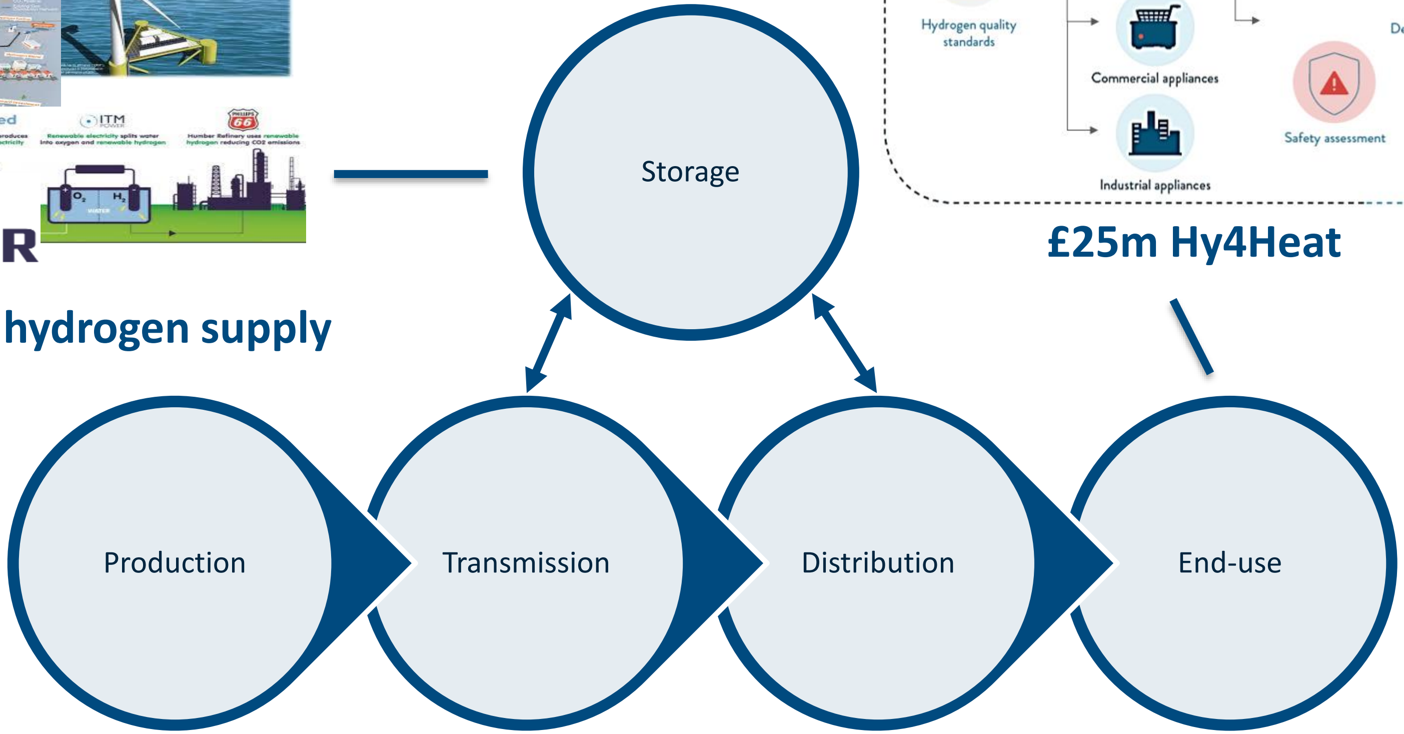
Energy Innovation Portfolio support for hydrogen & industry (2015-2021)



Low carbon hydrogen supply



£25m Hy4Heat



Industrial Fuel Switching

Case Study

Glass Futures

UK Research and Innovation

Industrial hydrogen research

BEIS IHA Dissemination Event

Rob Ireson, Glass Futures

27th March 2023

airto
driving growth and innovation

Department for Energy Security & Net Zero

EX TERRA LUCEM

UK Research and Innovation

INDUSTRIAL STRATEGY

LIVERPOOL CITY REGION
COMBINED AUTHORITY

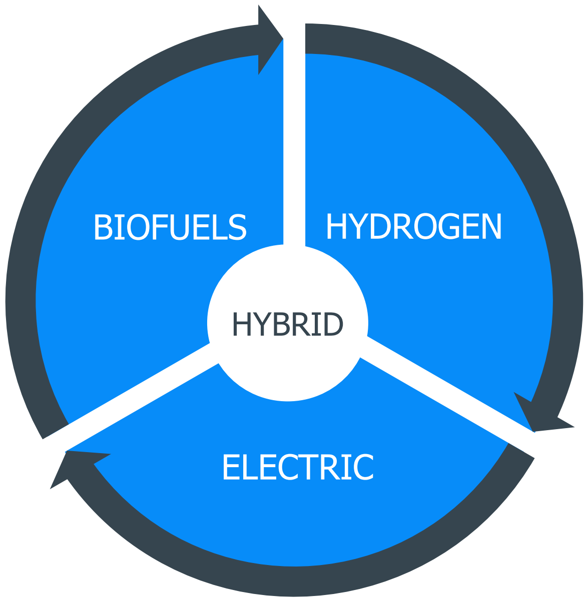
METRO MAYOR
LIVERPOOL CITY REGION

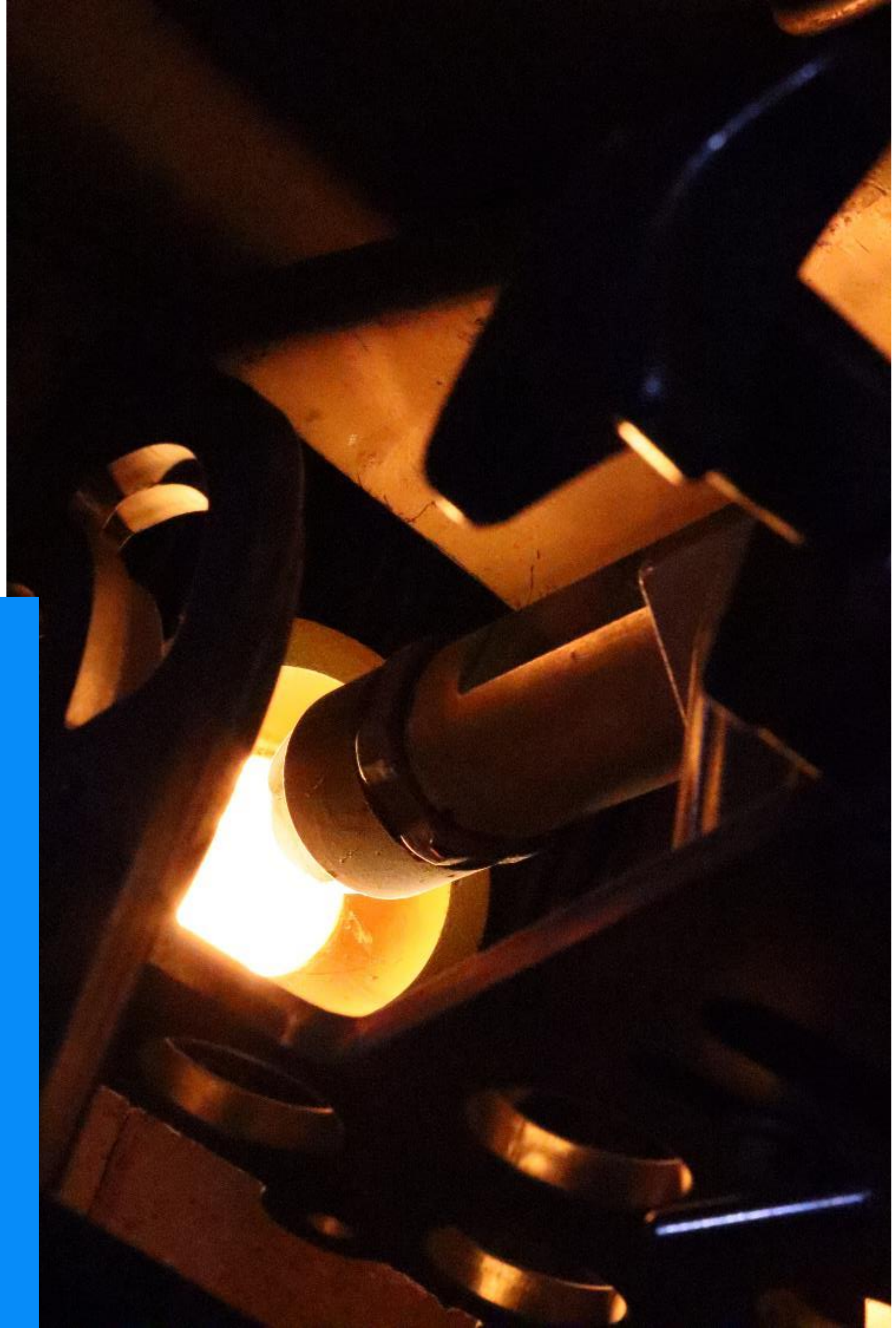
STRATEGIC INVESTMENT FUND

THE GLOBAL CENTRE OF EXCELLENCE FOR GLASS
IN R&D, INNOVATION AND TRAINING

Low carbon fuels for industrial furnaces

- More than £8 million DESNZ investment to date across five projects, with three new projects about to start imminently
- Partners from industry, supply-chain and academia, brands, across the glass, steel and ceramics sectors





Glass Futures

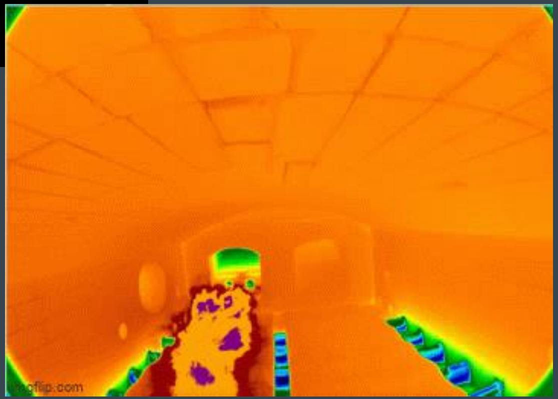
Combustion Test Bed

350kW combustion test-rig used to simulate glass furnaces, ceramics kilns and steel furnaces

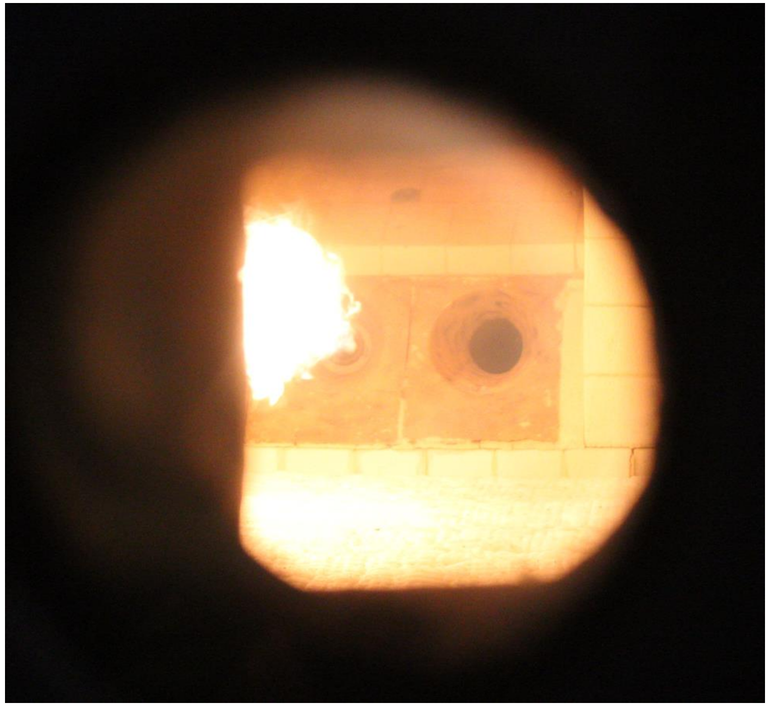
Highly instrumented

Fuels: Natural Gas, Hydrogen, Biofuels and blends

Air preheat: 0^{o}C - 1000^{o}C



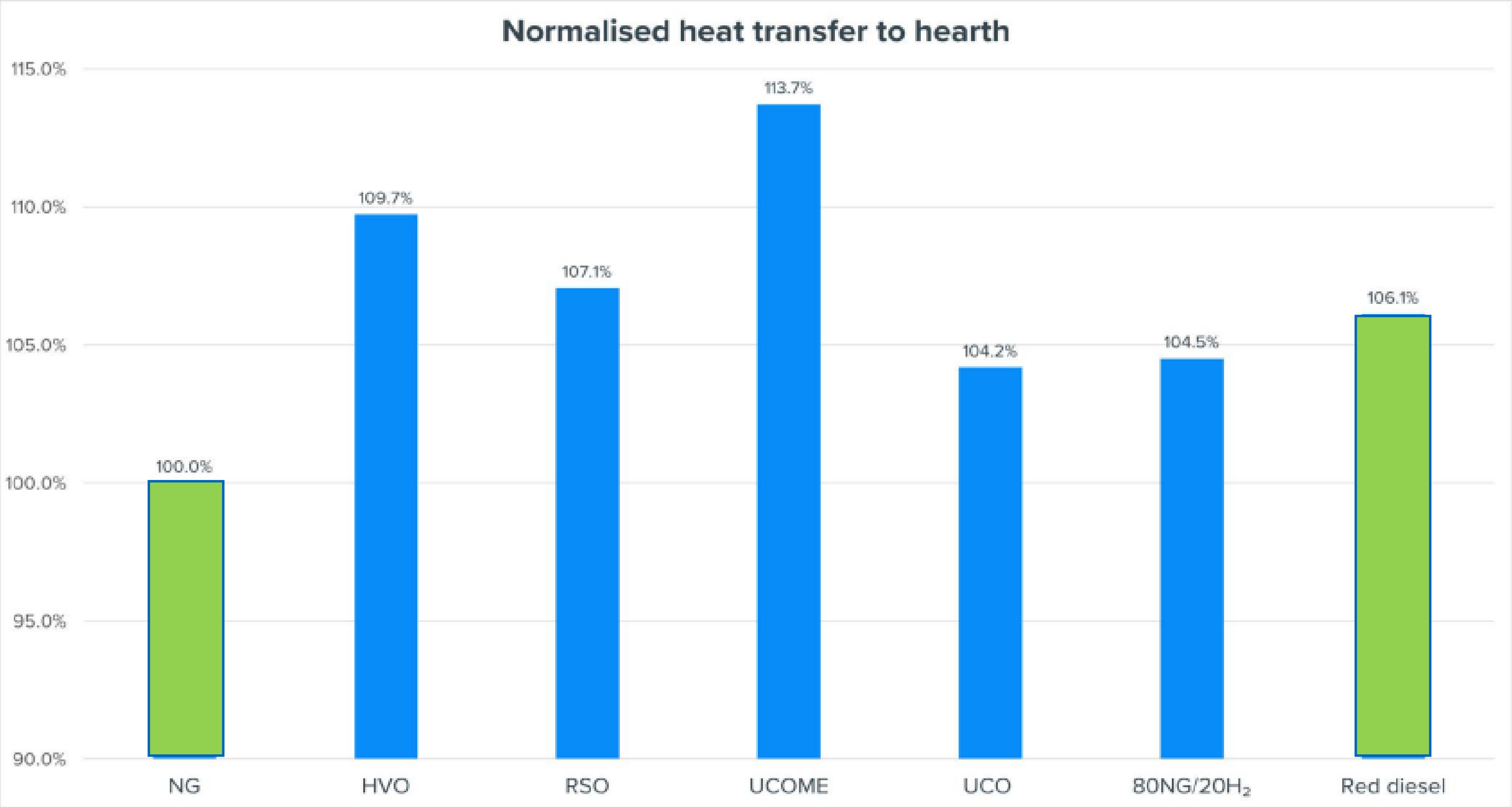
Glass Futures™



100% Natural Gas

50% Natural Gas,
50% Hydrogen

100% Hydrogen

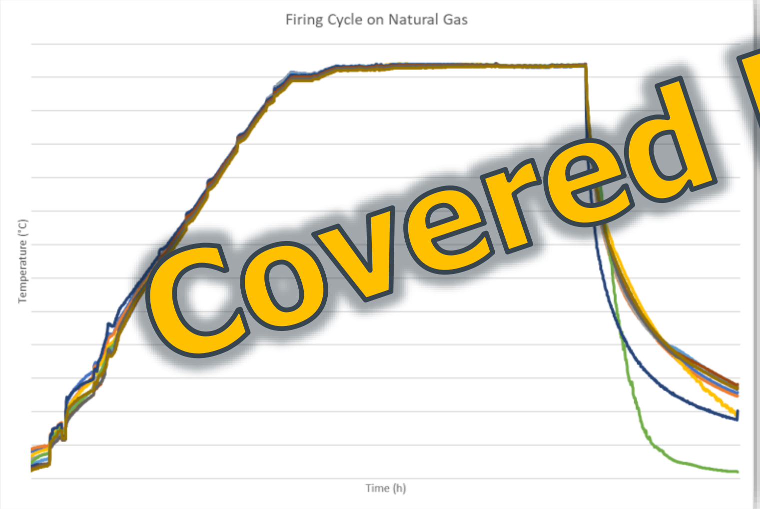


Glass Futures™

- Firing of ceramic products on 100% hydrogen
- Pilot and industrial hydrogen trials scheduled over next 2 years

HYDROGEN PROJECT

- British Ceramic Confederation
- Glass Futures
- Churchill
- Dreadnought Tiles
- dsf
- Forterra
- Ibstock Brick
- Ideal Standard
- Johnson Tiles
- Marley
- Michelmersh Britain's Brick Specialists
- Naylor
- Wavin
- Wienerberger



Hydrogen Trials: Steel

- CTB with steel backwall configuration
- Firing cycles agreed within consortium steel partners
  - Re-heat cycle
  - Degas cycle
  - Special cycle for [illegible] alloy
- Natural gas, hydrogen and blends starting from cold (ambient) temperature
- Strength analysis – No detrimental effect on material properties comparing baseline gas with hydrogen/blends

Covered later on this afternoon!

H_2 flame with cold background

H_2 flame with hot background

Glass Futures™

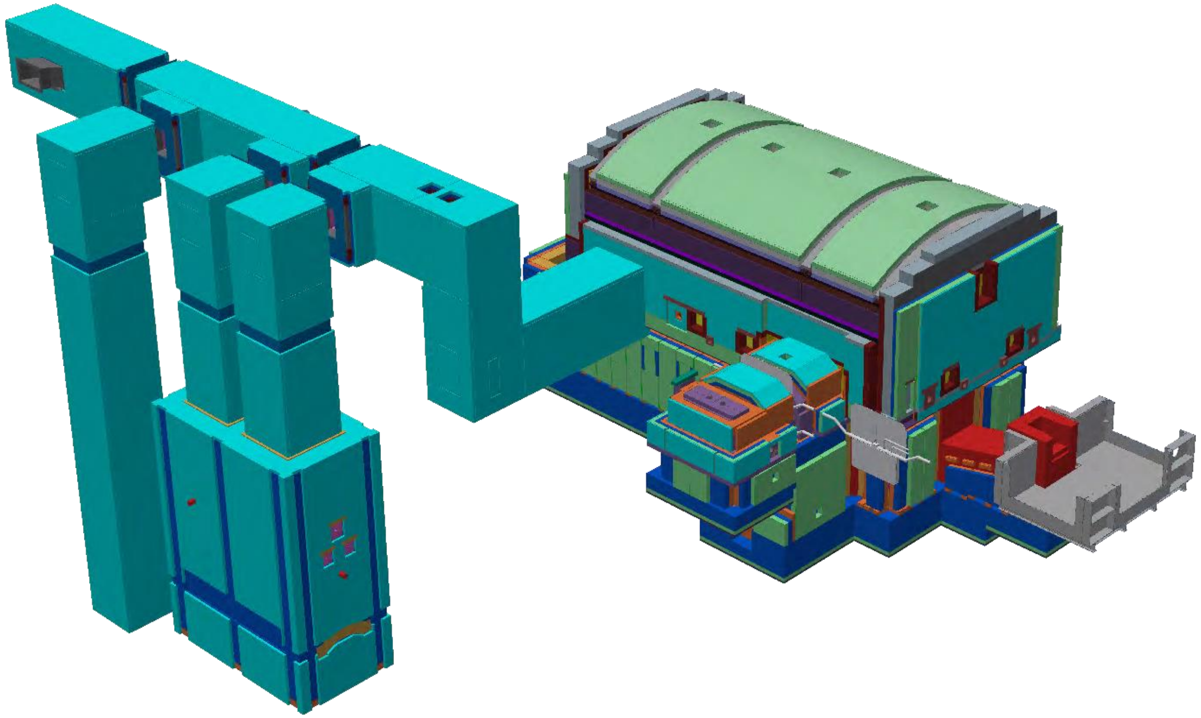
A few key learning points from trials to date

- Hydrogen fuels seem to have a comparable heat transfer efficiency to natural gas
- H&S requirements are much more stringent than for natural gas (e.g. ATEX rated equipment required)
- NOx emissions are higher for hydrogen fuels
- Hydrogen combustion doesn't appear to have a major impact on product quality
- Supply of hydrogen for trials is a big challenge
- Long-term impact of hydrogen combustion atmosphere on refractories unknown and needs to be a priority area to investigate going forwards

Glass Futures™

Pilot Facility: St Helens, UK

- 30T/day glass R&D capability
- Able to benchmark low-carbon fuels:
  - — Natural Gas
  - — Hydrogen
  - — Bio-fuels
  - — Oxy-fuel
  - — Electric-melting
  - — Hybrid fuel configurations
- Can assess complementary furnace technologies:
  - Carbon Capture
  - Waste heat recovery
  - New burner designs
  - Refractory materials
- **Due to be commissioned: 2024**



Glass Futures

Thank You for listening
Any Questions?

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Glass Futures™

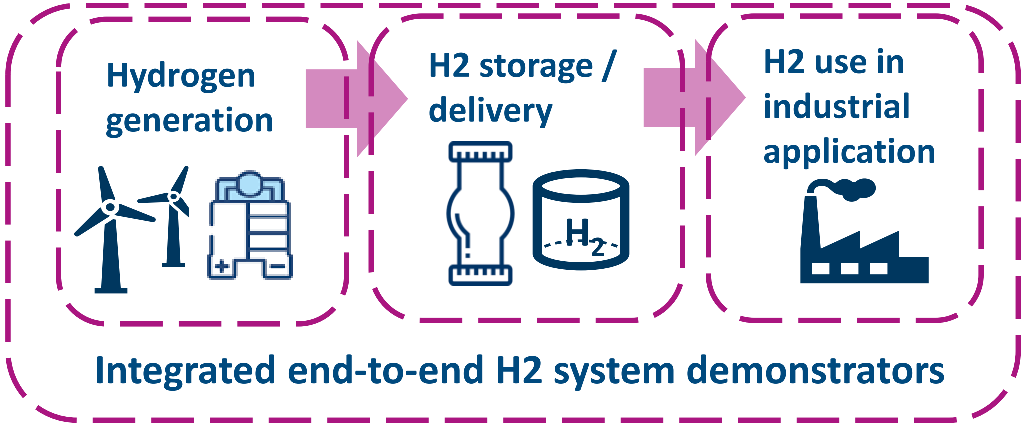
Net Zero Innovation Portfolio (NZIP)

- For more details on the previous EIP portfolio projects see: Hydrogen supply and Industrial Fuel Switching
- The current innovation funding is under the **£1bn** Net Zero Innovation Portfolio (2021 – 2025). Themes as per the Prime Minister's "Ten Point Plan for a **Green Industrial Revolution**".
- The feasibility reports for the Low Carbon Hydrogen Supply 2, NZIP Industrial Fuel Switching and Industrial Hydrogen Accelerator programmes will be published shortly on their respective websites.

Advanced Nuclear	Bioenergy	Advanced CCUS	Industry	Built Environment (Heat Pumps & Retrofit)
Offshore Wind	Greenhouse gas removal	Hydrogen	Smart Energy & Energy Storage	Disruptive technologies

Industrial Hydrogen Accelerator (IHA) - Background and objectives

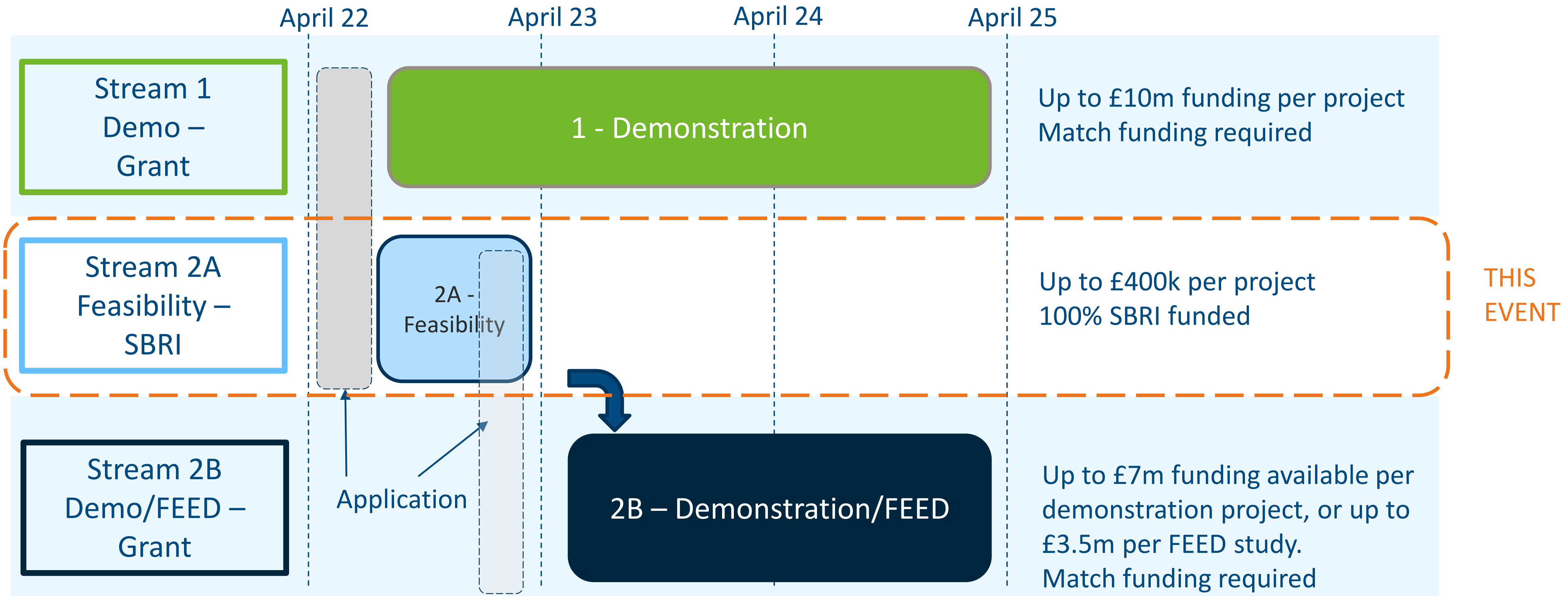
- The Industrial Hydrogen Accelerator (IHA) is an innovation funding programme to support the demonstration of end-to-end industrial fuel switching to hydrogen, through up to £26m funding provided by DESNZ as part of the £1 billion Net Zero Innovation Portfolio.
- The IHA scope includes the full technology chain, **from hydrogen generation and delivery infrastructure through to industrial end-use**, including the integration of the components in a single project.



Objectives:

1. Prove the feasibility and provide evidence towards the cost effectiveness of H2 fuel switching.
2. Improve understanding of how to design, implement and deliver a hydrogen solution on specific industrial sites.
3. Develop stakeholder knowledge, confidence and awareness of hydrogen end-to-end system solutions in industry.
4. Facilitate the development of new commercial relationships and build market awareness of industry actors

IHA – Design and structure



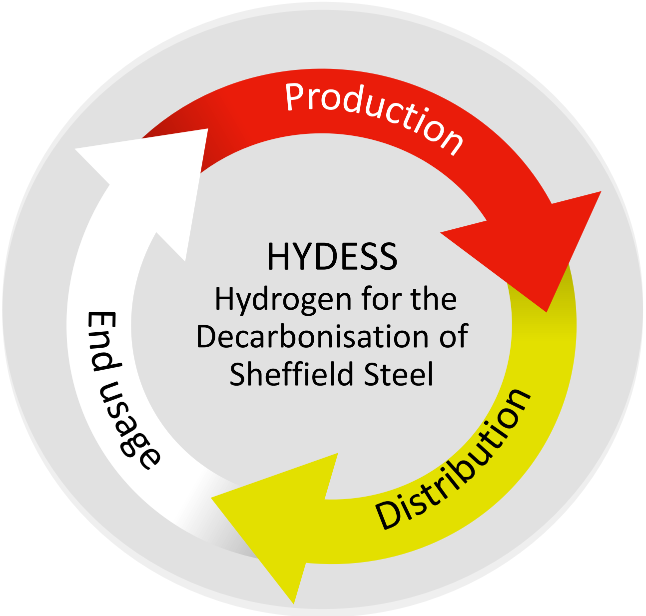
IHA Feasibility Project Findings

Industrial Hydrogen Accelerator
Project HYDESS

Stream 2A Feasibility Study & next Phase FEED Study

IHA 2A Feasibility Study: HYDESS

What is HYDESS ?



E.ON - Production
Hydrogen production and scaling from renewable energy

Hydrogen – Storage
Innovation in the storage & transport of hydrogen gas

Steel industry – End usage
Switching to or blending natural gas with hydrogen for fuelling steel reheat and heat treatment Furnaces.

Project consortium

Industry partners

SHEFFIELD FORGEMASTERS

CHESTERFIELD SPECIAL CYLINDERS

FORGED SOLUTIONS GROUP

e·on

Research, testing & modelling

Glass Futures

The University Of Sheffield.

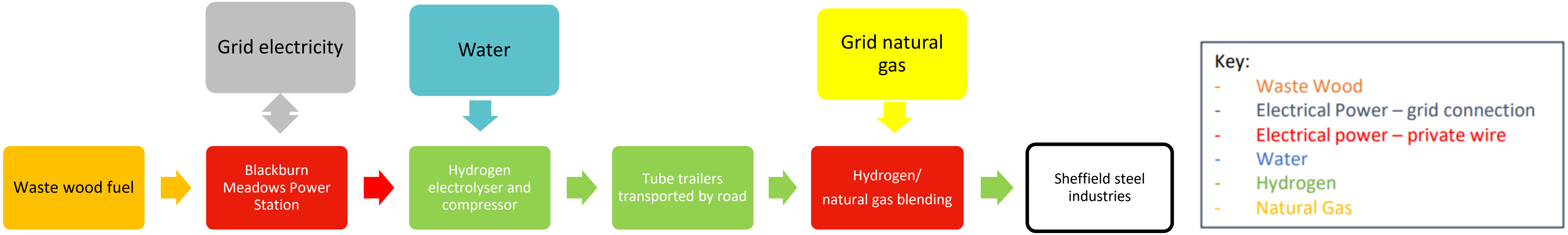
Industry supporters

LIBERTY

Project Objectives

1. Demonstrate end to end value chain of using hydrogen to decarbonise steel processes
2. Create technical design concept for the end-to-end production and use of hydrogen
3. Development of a commercial model to demonstrate the commercial viability of hydrogen production and potential delivered price for customers
4. Understand technical roadmap and barriers to be overcome for the decarbonisation of consortium furnaces

Project concept - demonstrate feasibility to decarb the steel industry



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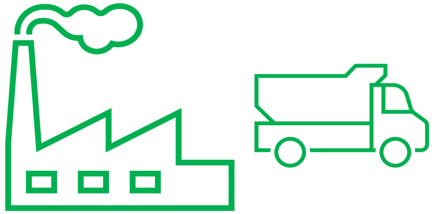
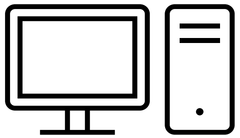


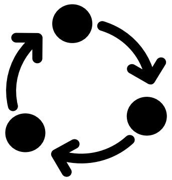
- Validate hydrogen production and transport solution through offtaker demand and commercial modelling
- Outline technical design, from electrolyser to end user

2



- Computer-based combustion modelling of furnace system - hydrogen blend feasibility assessment (0/ 20/ 50/100% hydrogen blends).
- Assess thermal performance, heat transfer rate and combustion emissions

3



- Pilot furnace trials to validate combustion model
- Trials and analysis of blends for a range of product firing cycles
- Begin assessment of impact on product quality (e.g. metallurgy, scaling, hydrogen in retention in steel), and impact on emissions (e.g. NOx).

Findings of the feasibility study

Green lights after feasibility study; areas of further investigation needed before full demonstration possible

	2025 (10MWe Electrolyser)
LCOH	£198.0/MWh_{HHV} (£7.80/kg)
LCOA	£2,977/tCO2e
Emissions reduction	23.29 gCO_2e/MJ_{LHV} H_2, or 2.82 $kgCO_2e$/kg of hydrogen. **3,468 tonnes CO_2e abated year 1**

01 – Trials – no concerns on thermal performance or product quality, however more work needed in future to gain buy-in from end steel customers

02 – Modelled price/cost of delivered hydrogen suggests commercially viable solution sustainable

03 – Electrolyser lead time from preferred suppliers is currently 18-24 months

04 – 230barg road trailer delivery is sufficient to feed most furnaces/cycles

05 – Aligning on future decision date readiness given all offtaker needs, is challenging

Lessons learned and Challenges

Time was tight; 2a very demanding

Stream 2a - Extremely short elapsed time for range and scale of feasibility (process and financial model design, test firing cycles, CFD model)

Emissions - Carbon footprint reduced; NOx increased

Further 2b test firing, modelling of other burners allied to NOx abatement on end-user furnace needed pre-FID

Trials are complex – reflecting multiple alloys/heating cycles

Challenging to deploy full range of temperature cycles and products representing product/firing cycle combinations of consortium

Supply Chain - electrolyser lead time meant 2b is FEED study not Demonstration

Current supply chain lead time misaligned to BEIS expectations, IHA Stream 2b window

Commercial model needs complete value chain knowledge

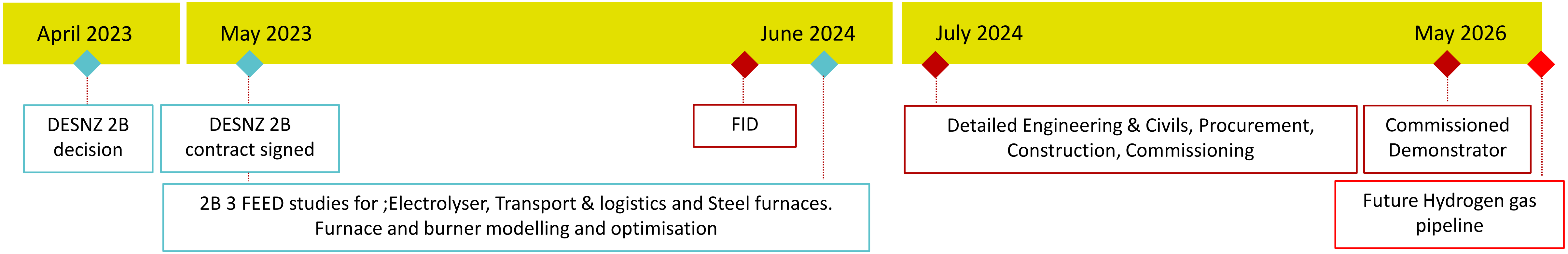
End-end value chain knowledge ideally needed earlier to commercially model new process; some steps outside consortium members' direct knowledge

Consortium challenged - Competing funding streams

Running IFS & IHA in parallel created complexity & consortium uncertainty

Future plans and contacts

Timeline



Contacts

Consortium Member	Name	Role	Contact Email Address
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Glass Futures	Dr Palma González García	Combustion Technical Lead	palma.gonzalez@glass-futures.org
Chesterfield Special Cylinders	Frank Ashton	Head of Strategy and Partnerships	frank.ashton@pressuretechnologies.co.uk
Sheffield Forgemasters	Mike Howson	Senior Development Engineer	mhowson@sfel.com
Forged Solutions	Nicholas Wood	Quality and Technical Manager	nicholas.wood3@forged-solutions.com
Liberty Steel	Edward Heath-Whyte	Head of Environment and Sustainability	ed.heath-whyte@libertysteelgroup.com

PROGREEN H2 Feasibility Study

Michael Hughes

Senior Process Engineer

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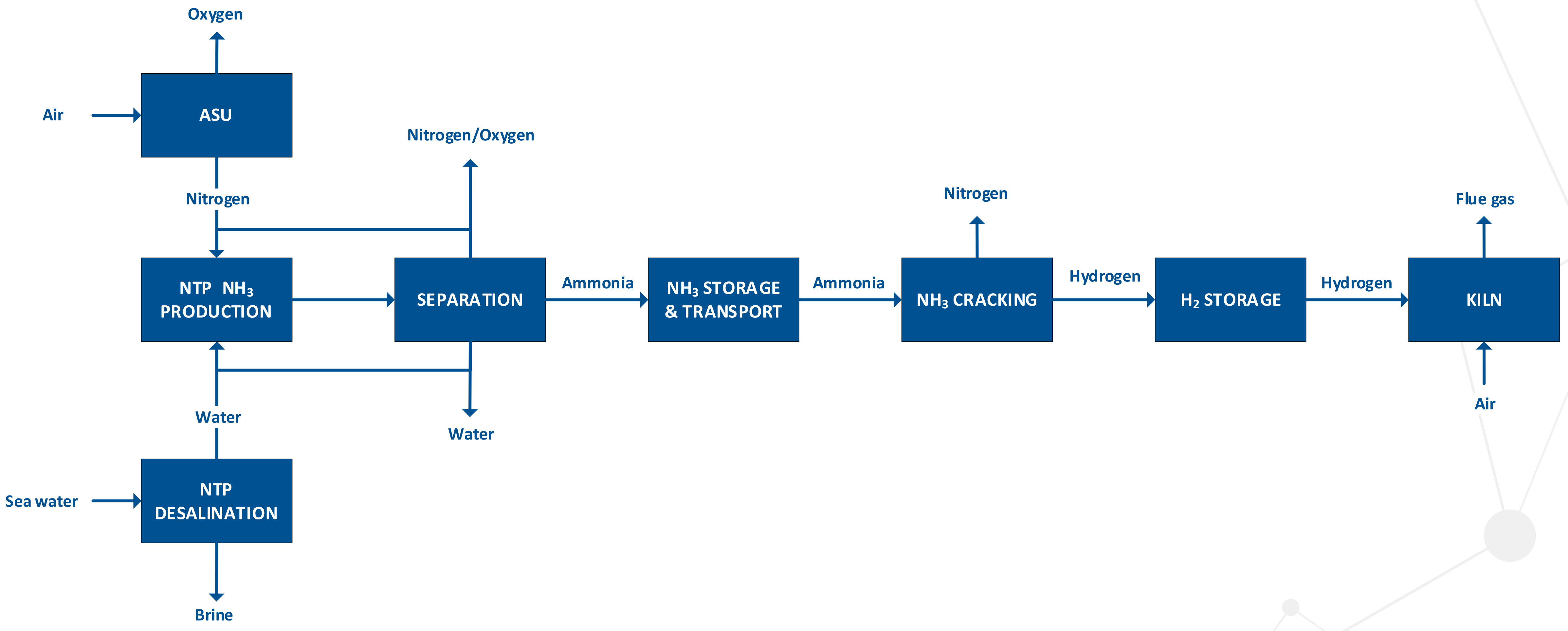
PROGREEN

Concept



Oxygen
Air
ASU
Nitrogen/Oxygen
Nitrogen
NTP NH3 PRODUCTION
SEPARATION
Ammonia
NH3 STORAGE & TRANSPORT
Ammonia
Nitrogen
NH3 CRACKING
Hydrogen
H2 STORAGE
Hydrogen
Flue gas
KILN
Air
Water
Water
Sea water
NTP DESALINATION
Brine

Study findings

Feasibility

- **NTP desalination** – has potential
- **NTP ammonia synthesis** – N_2 conversions are too low (<0.1%), with very high energy requirements
- **Separation** – Very energy and capital intensive
- **Ammonia cracking** – has potential, but needs further work to identify less expensive materials
- **Hydrogen combustion** – feasible, but further work needed to understand impact on ceramic products

Levelised Cost of Hydrogen

Between **£280,000** to **£430,000** per MWh_{HHV} H_2, depending on source of electricity (significantly impacted by poor economics of ammonia synthesis & separation steps)

Emissions intensity

	Natural Gas	PROGREEN H2 (wind/solar)	PROGREEN H2 (grid)
Fuel type used in kiln	Natural gas	Hydrogen	Hydrogen
kg CO2e / $kWh_{LHV,fuel}$	0.203	0.0011	412

Study findings

Industry feedback and concerns

- Insufficient plant size to accommodate a large ammonia cracking plant and other infrastructure
- Health, safety and planning requirements
- The need to replace pipework due to the potential for hydrogen embrittlement of certain types of metal
- Retrofitting furnaces with new burners (cost and whether it is even possible)
- Effect hydrogen firing has on furnace infrastructure such as kiln cars, burners, bearings etc
- Moisture effect on the products and kiln furniture
- Cost of hydrogen production and ammonia supply prohibitive
- Hydrogen supply pressures, storage, and transportation
- Product conformity and consistency throughout the kiln
- Modifications to the firing cycle time
- Increase in NO_x

Next steps

Significant elements of the technology are not ready to take forward into a FEED study or build a demonstration plant, however some elements within the process do show potential.

Further work is needed:

- Identify and develop the catalyst at laboratory-scale for the ammonia production step to achieve nitrogen conversion values that allow for an economically viable process.
- Lucideon to continue with kiln design and tests to determine impact on various ceramic products

Thank you

For more information visit **www.uk-cpi.com**

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Industrial Hydrogen Accelerator Programme Stream 2A Dissemination Event

27th March 23

Bay Hydrogen Hub – Hydrogen4Hanson Project

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Vision Funding and Partners

Our vision is to demonstrate solid-oxide electrolysis integrated with nuclear heat and electricity, providing low-carbon, low-cost hydrogen via novel, next generation composite storage tankers to dispersed asphalt and cement sites

Funding

Department for Energy Security & Net Zero

- Small Business Research Initiative (SBRI) £400k for Stream 2A feasibility study.
- Possible Stream 2B demonstrator in 2024.

Partners and key subcontractors

EDF R&D | EDF Generation | Hanson HEIDELBERGCEMENTGroup | NATIONAL NUCLEAR LABORATORY | hynamics EDF GROUP | ceres | NPROXX

- **EDF**: Consortium lead, bid and project management, nuclear site feasibility, H2 production and distribution engineering design, technology evaluation, economic modelling.
- **Hanson**: Industrial partner, asphalt and cement fuel switching feasibility and engineering design.
- **Ceres**: SOEC electrolyser technology, economic evaluation, site integration.
- **NNL**: Future nuclear industry impact, wider social impact, development concept.
- **NPROXX**: Hydrogen transport technology provider, site interface, business case, routes.

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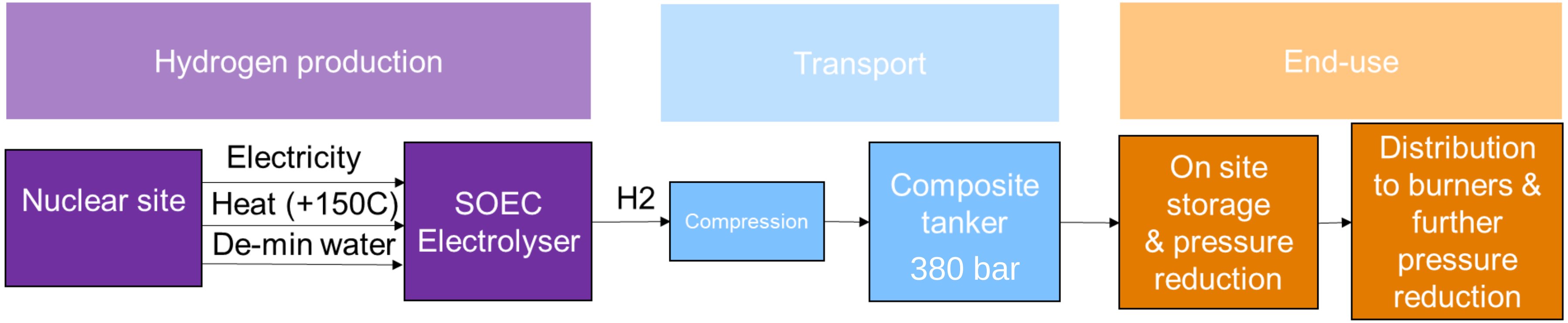
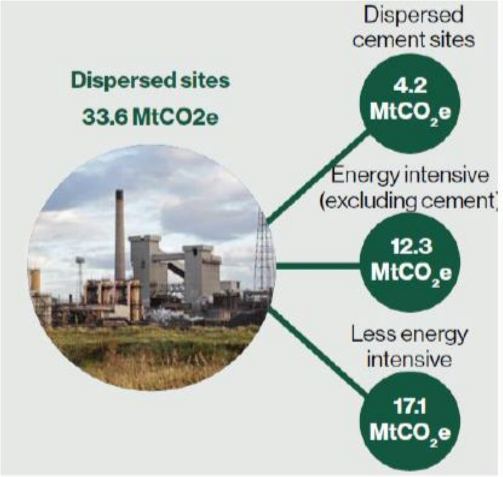
Nuclear derived SOEC hydrogen to the asphalt and cement industry

- **Innovative end to end H_2 production to end-use project** showcasing novel technologies along the supply chain



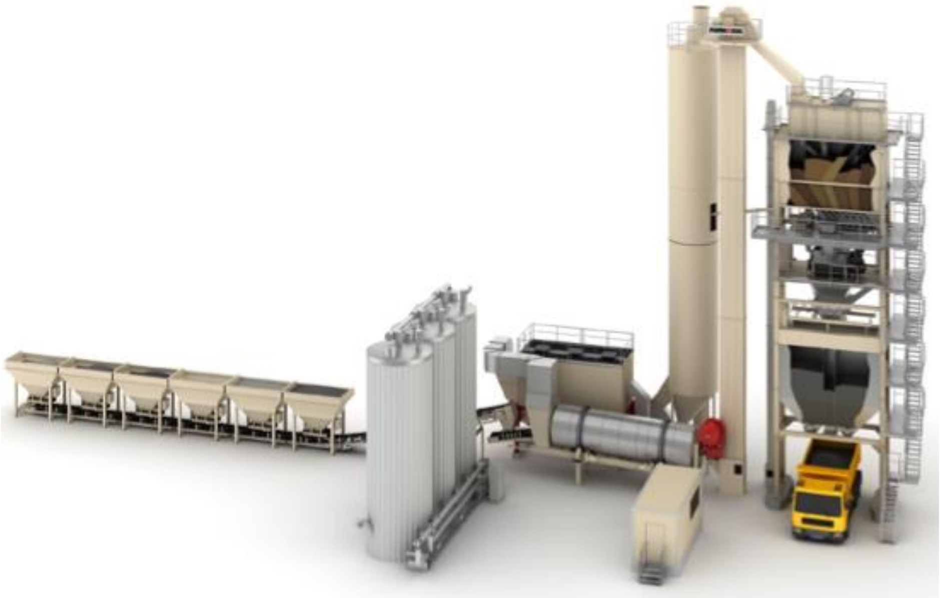
- MW scale SOEC plant to demonstrate **nuclear hydrogen production, not yet demonstrated anywhere in the world**
- Support development of H_2 fuel delivery to **dispersed end use industrial sites that generate c.50% of total industrial emissions,** utilising composite storage tankers which can transport **6-8 x more hydrogen than existing tube trailers**
- **H_2 fuel switch** demonstrating decarbonisation of critical UK industry infrastructure asphalt and cement, **Use of hydrogen as a fuel at asphalt sites has also not been demonstrated before**



Hydrogen end-use

- Focus on Asphalt plant drying process (H_2 world first)
- Building on previous learnings from trial in cement process (earlier H_2 world first)
- Assess feasibility of 100% fuel substitution ahead of demonstration phase

- UK hot mix asphalt demand c. 27 million tonnes every year
- 270+ plants nationally
- 90-100 kWh per tonne heating /drying
- Circa 2.5 TWh annual consumption



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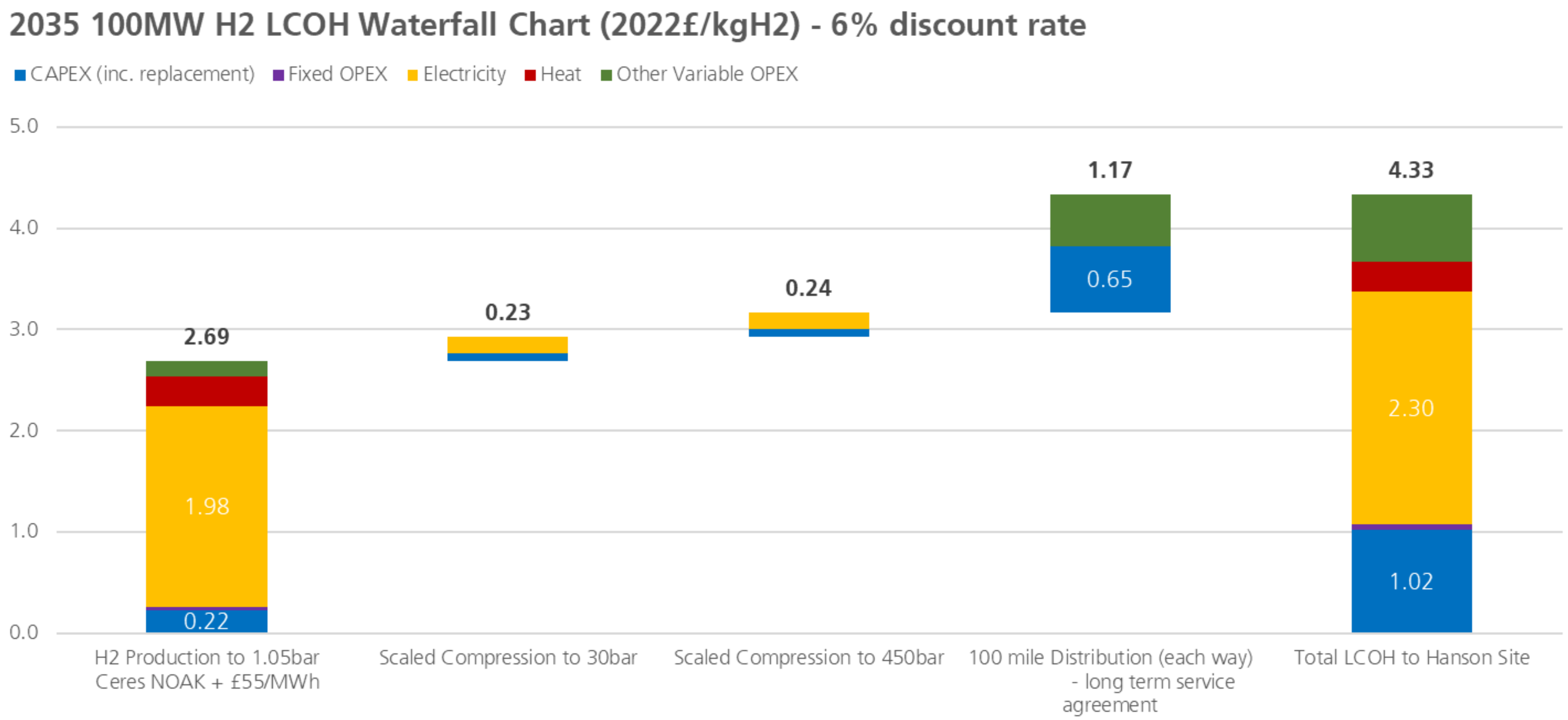
Economics of Hydrogen from Nuclear



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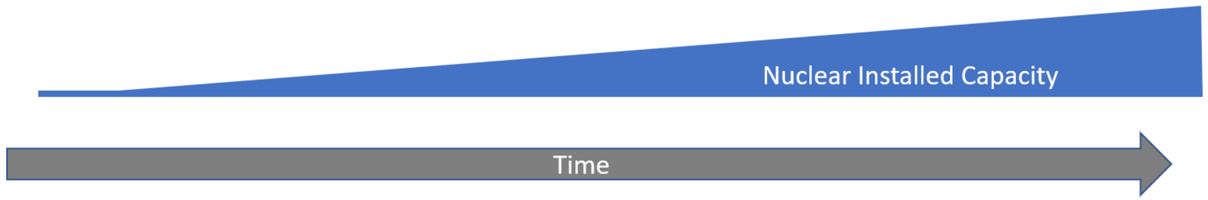
Replicability and scalability in other industries

Anticipated Hydrogen Demand	≈27 TWh	≈50 TWh	≈100-125 TWh	≈125-450 TWh
Nuclear Technology Availability	GW Scale	SMR	AMR	Fusion
	Present day	**2030**	**2035**	**2040+**



While for some processes electrification might be the most optimal solution, for others there is still requirement for heating furnaces where hydrogen can play an important role.

Chemical | Iron & steel | Aluminium | Glass | Ceramics

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Conclusions

Hydrogen produced from nuclear power plants can play a crucial role in decarbonising the UK's carbon intensive industrial sectors, including cement and asphalt sites that are often not connected to the grid.

- It is technically possible to integrate hydrogen production with nuclear
- Nuclear stations can provide low carbon heat and electricity to a solid oxide electrolyser (SOE) to produce 20-30% more hydrogen for the same overall energy input than conventional PEM and Alkaline electrolysis
- Nuclear backed hydrogen production has the potential to be competitive in a future low carbon hydrogen market
- H_2 produced can be distributed by high-capacity next generation composite type IV storage tankers to dispersed asphalt and cement sites.
- Use of H_2 as a fuel could reduce asphalt industry direct emissions by c. 560kT
- The use of hydrogen as a fuel enhancer for cement could broaden the use of lower grade, lower cost and higher biomass waste derived fuels

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Thank You

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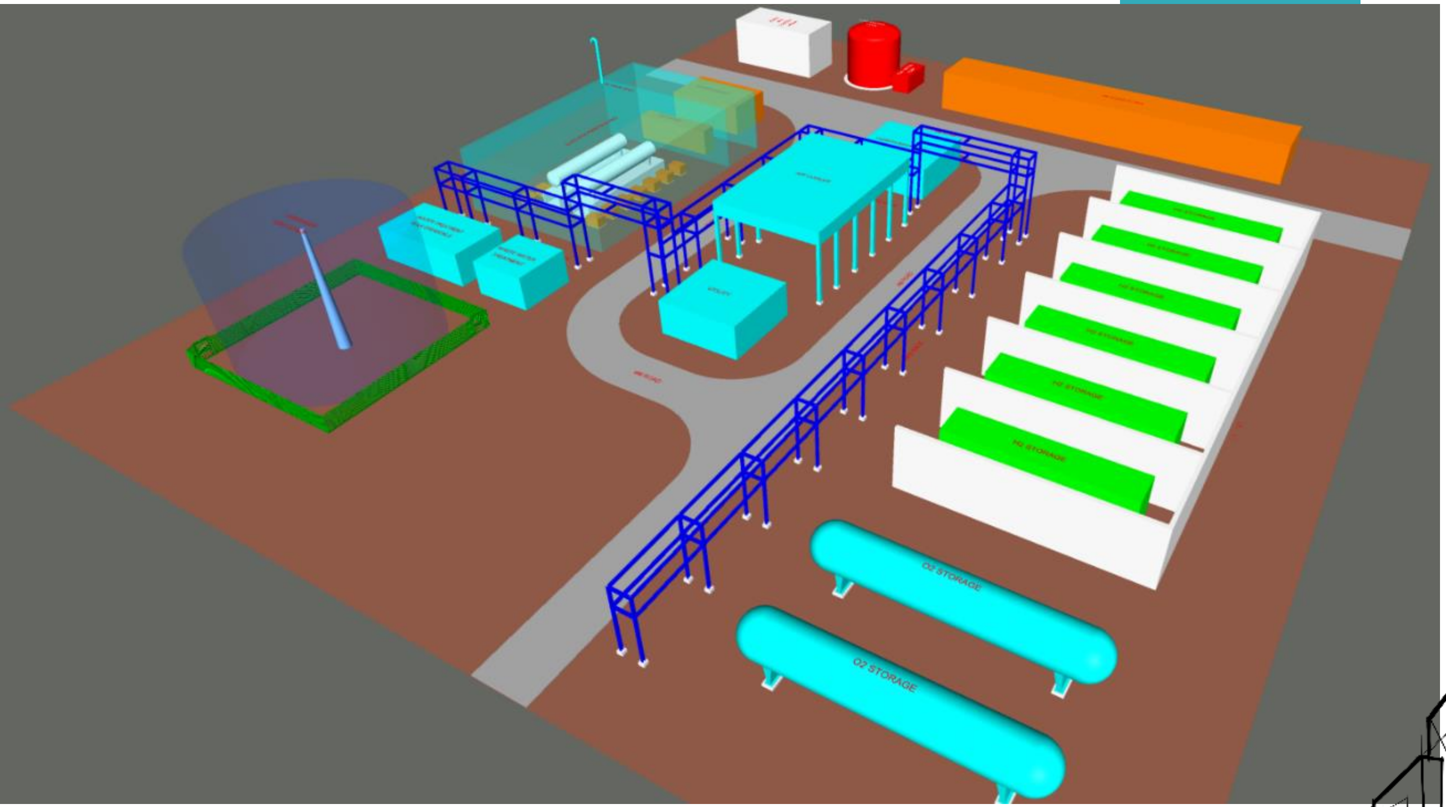
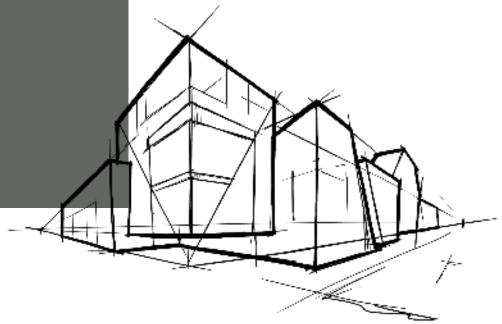
BREAK



IHA Stream 2A Findings IHA-2A-ROC

Investigating the Use of Hydrogen in Stone Wool Insulation Manufacturing

27th March 2023



ROCKWOOL Ltd | Marubeni Europower Ltd | Mott MacDonald Ltd

Agenda

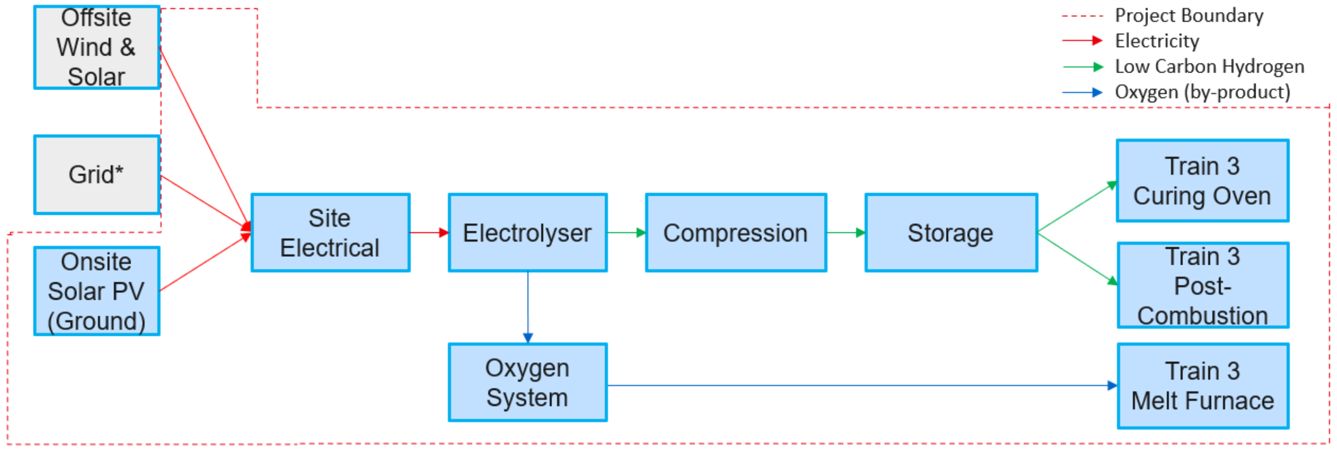
1. The Project
2. Power Supply, Planning & Environmental
3. Levelised Cost of Hydrogen & Abatement
4. Challenges / Lessons Learned & Next Steps

The Project

Design Production of H_2 = Heating requirement for Train 3 = 2,317 kg/day H_2

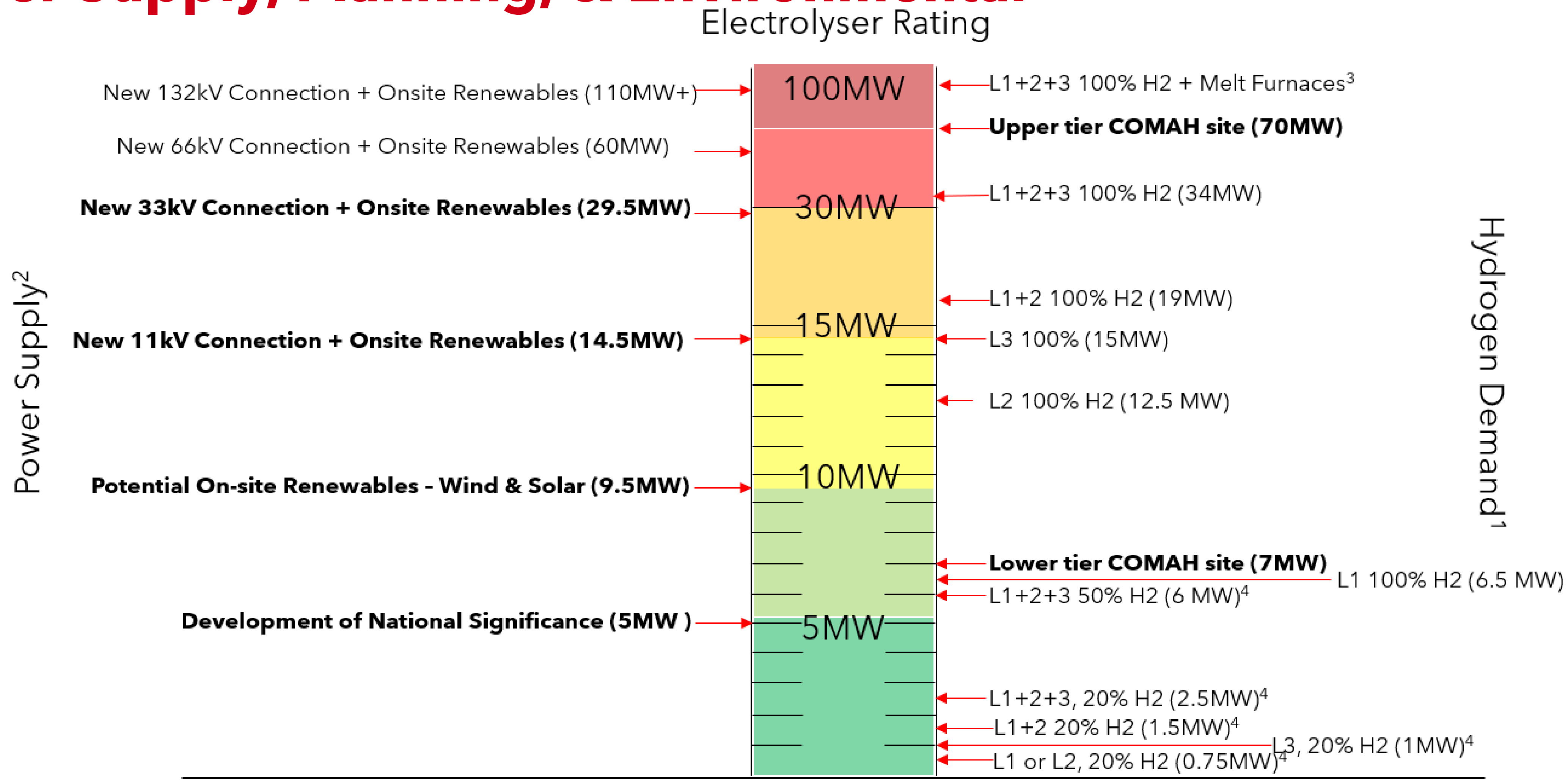
40% capacity factor for Renewable power generation → 241.4kg/hr H_2(9.5 MW H_2 HHV)

- Hydrogen Production Facility
  - ~15MW (power supply)
  - 2.16 m^3/h DMW (peak)
  - 14 x 1 MW electrolyser stacks
  - 3 days H2 storage (6951 kg net, 500 barg)
  - 1 day O2 storage (6692 kg net, 30 barg)
- Power system
  - Onsite ground-mounted solar PV (5MW)
  - Private Wire to offsite wind (13MW) and solar (10MW) Generators
- Changes to existing infrastructure
  - Changes to burner systems
  - Upgrade to building
- Future expansion: Heating requirement for entire Rockwool Facility = ~34 MW power supply



*as partial backup for periods of sustained low renewable supply

Power Supply, Planning, & Environmental



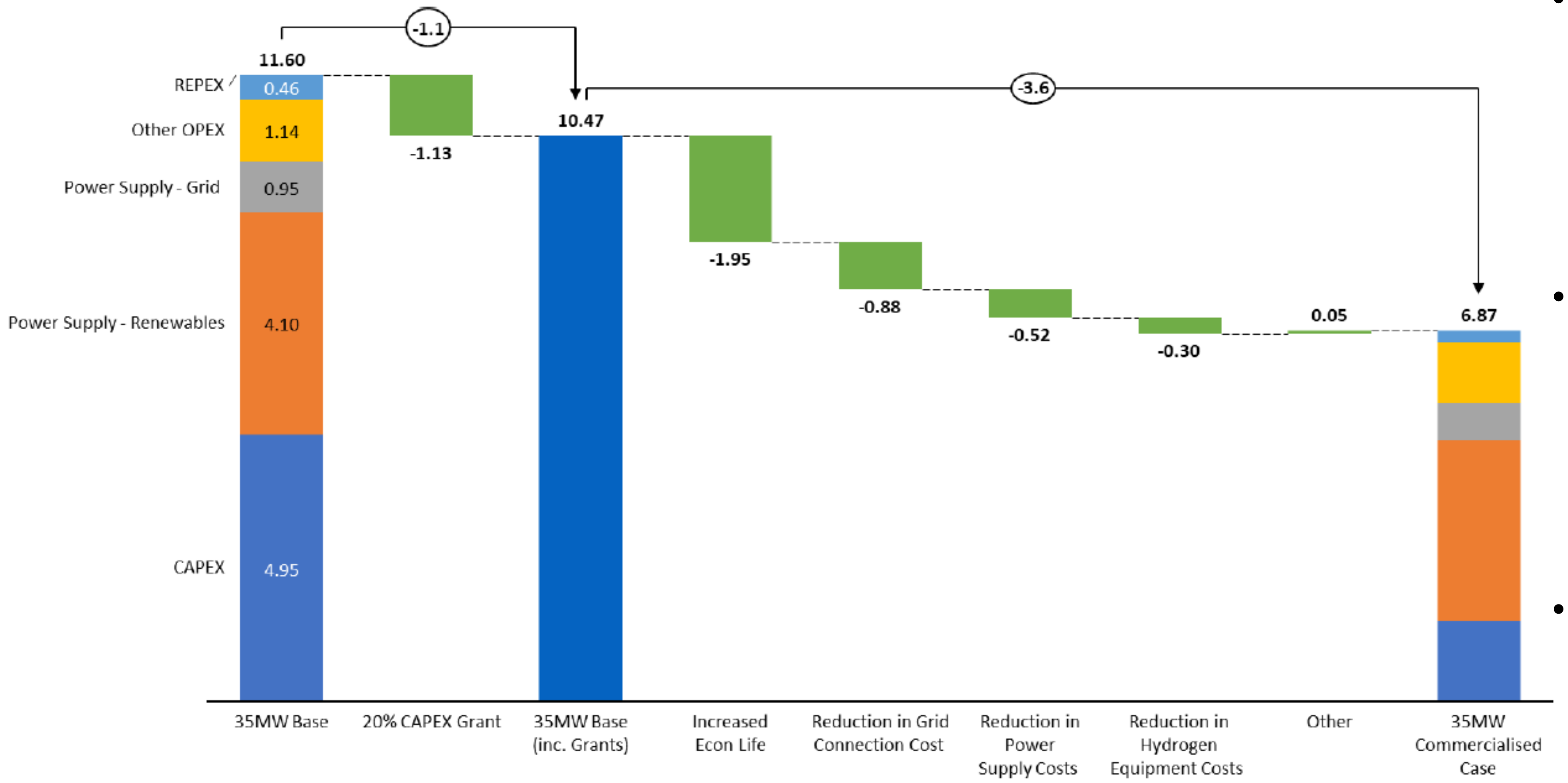
1 Based on 40% electrolyser capacity, with assumption of 3 days hydrogen storage suitable to manage power supply & hydrogen demand imbalance

2 Assumes no backup power provided via grid

3 Melt furnace electrification or conversion to hydrogen

4 Blending by volume. Energy density blending values are adjusted accordingly 50%vol = 19% by energy, 20% vol = 7.6% by energy

Levelised Cost of Hydrogen & Abatement



- LCOH £11.60/kg, falling to £6.87/kg as market reaches commercialisation
  - Majority of cost reductions (40%) based on 4 factors, remaining costs dominated by power(59%)
- Hydrogen Emissions Intensity compliant with Low Carbon Hydrogen Standard <20gCO_2/MJ_{H2}(LHV)
  - 5.4 gCO_2/MJ_{H2}(LHV) for 15 MW
  - 4.4gCO_2/MJ_{H2}(LHV) for 35 MW
- Abatement potential for hard-to-decarbonise application
  - 6,235 teCO2/year for 15 MW
  - 14,373 teCO_2/year for 35 MW

Challenges / Lessons Learned & Next Steps

- Importance of safety
- Electrolyser selection
- Feed water & cooling system
- Short feasibility study timeline
- Future expansion plans / Difficulties of a dual-fuel site
- Cost-effective renewable power & electrical Infrastructure

We are considering our options and intend to continue the relationships made in this project.

Thank you

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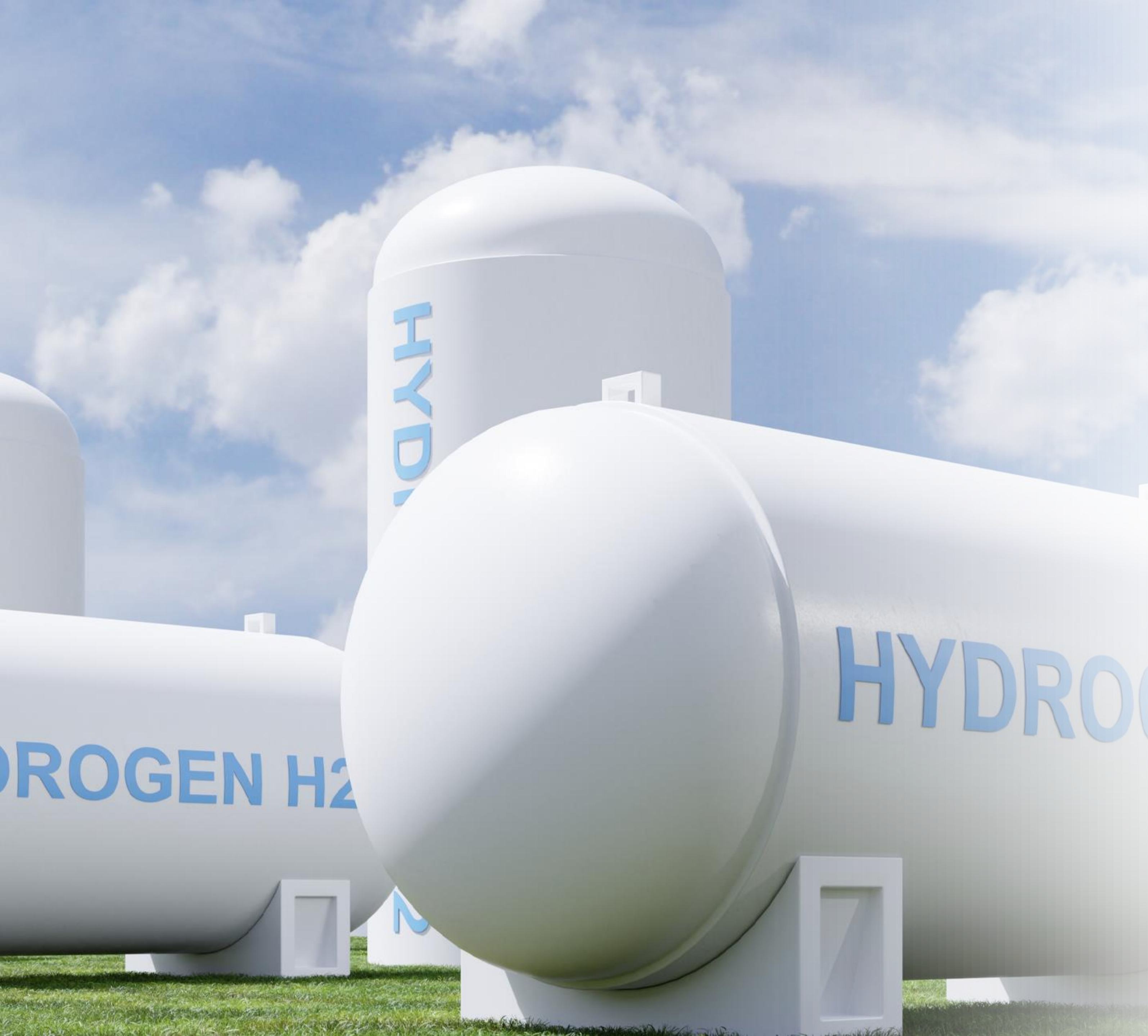


INDUSTRIAL HYDROGEN ACCELERATOR (IHA) PROGRAMME

OISH – Hydrogen from steelmaking waste as green fuel for steel production

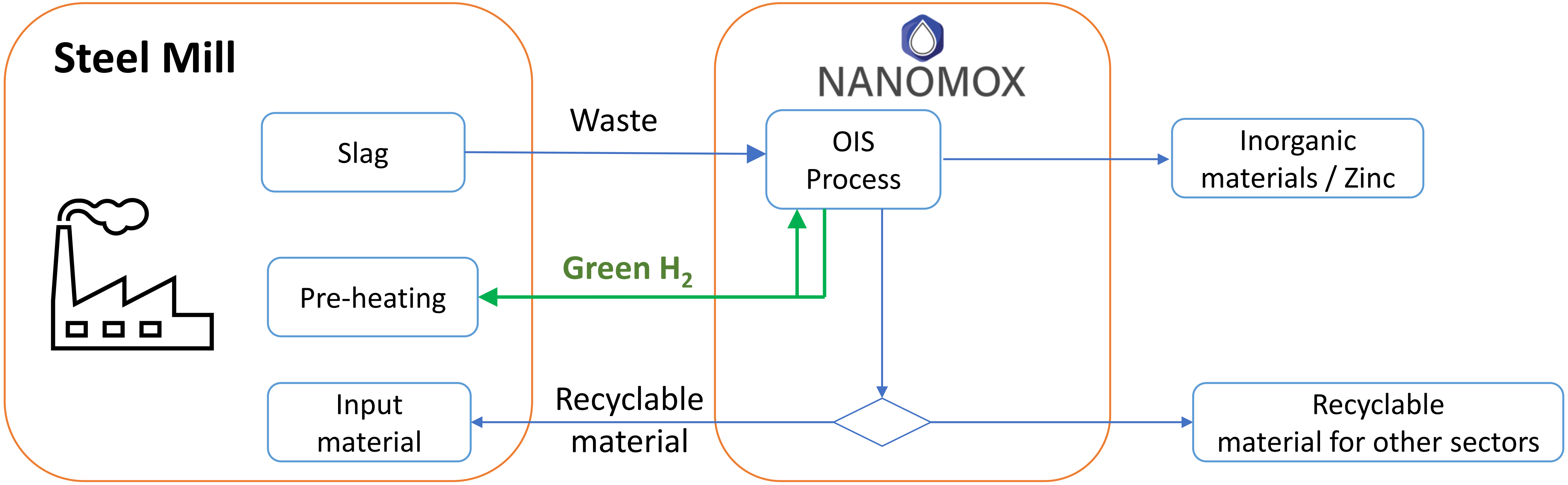
By Francisco Malaret

27th March 2023

NANOMOX

Materials Processing Institute

Department for Energy Security & Net Zero



Current state-of-the-art

Imperial College London

Materials Processing Institute

Experimental rig for H_2 measurements

- Metal: Hydrogen
- Slags: Hydrogen + CO_2

Tees Valley Hydrogen Innovation Project (TVHIP)

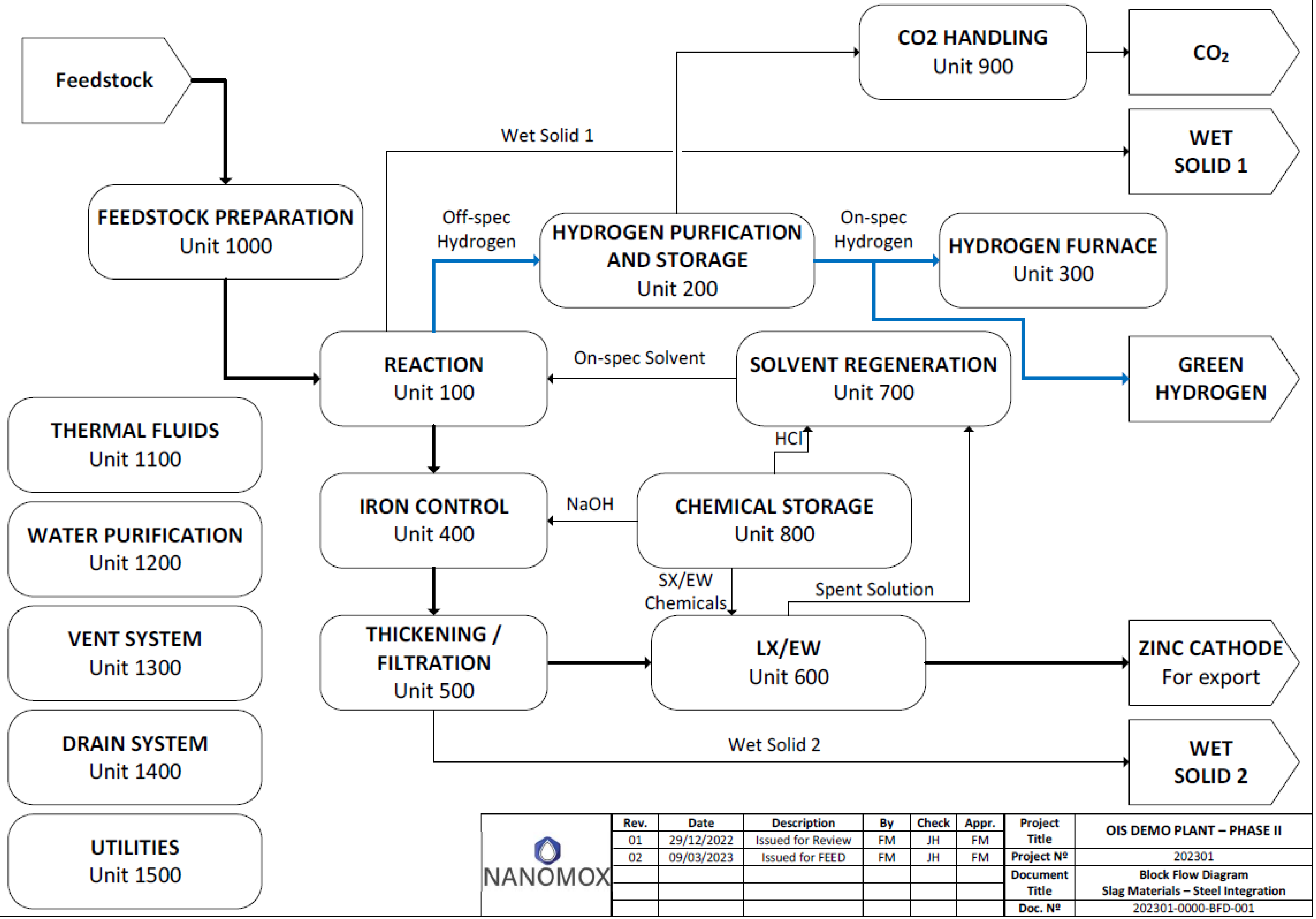
European Union
European Regional Development Fund

Teesside University

100 L Reactor

Commissioning delayed due to leak detection during pressure tests.

The pre-heat ladle at the MPI's Normanton Plant - MPI [Primary end-user stream 2B]



NANOMOX

Rev.	Date	Description	By	Check	Appr.
01	29/12/2022	Issued for Review	FM	JH	FM
02	09/03/2023	Issued for FEED	FM	JH	FM

Project Title	OIS DEMO PLANT – PHASE II
Project Nº	202301
Document Title	Block Flow Diagram Slag Materials – Steel Integration
Doc. Nº	202301-0000-BFD-001

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- **Green Hydrogen is produced [Even with electricity from the grid]**

  0.4 – 7 gCO_2-eq / MJ(LHV)

- **Technical – Environmental – Economic feasibility of the OIS process confirmed**

  LCOH: 0.03 – 0.08 £ / MJ(HHV) [20 kton/y – 2035 – 30 years]

- **Industrial synergies with significant positive impact**

Limitation: Quantities of hydrogen produced limited by the availability of suitable feedstock materials and/or demand for inorganic materials

Department for Energy Security & Net Zero

THANK YOU

Francisco Malaret
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NANOMOX

Mark Allan
Group Manager - Industrial Decarbonisation at MPI
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Materials Processing Institute

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IHA Stream 2A Virtual Dissemination Event - 27th March 2023

Small-scale Hydrogen Production Utilising a Waste Company's RDF Feedstock to Power its Industrial Plant and Equipment

Presenters:

- **Gordon Anderson (Head of Recycling & ELW at ASH Waste Services)**
- **Prof Stan Kolaczkowski (Senior Adviser Compact Syngas Solutions Ltd)**

Contact Details

Waste Segregation; RDF; H_2 application.

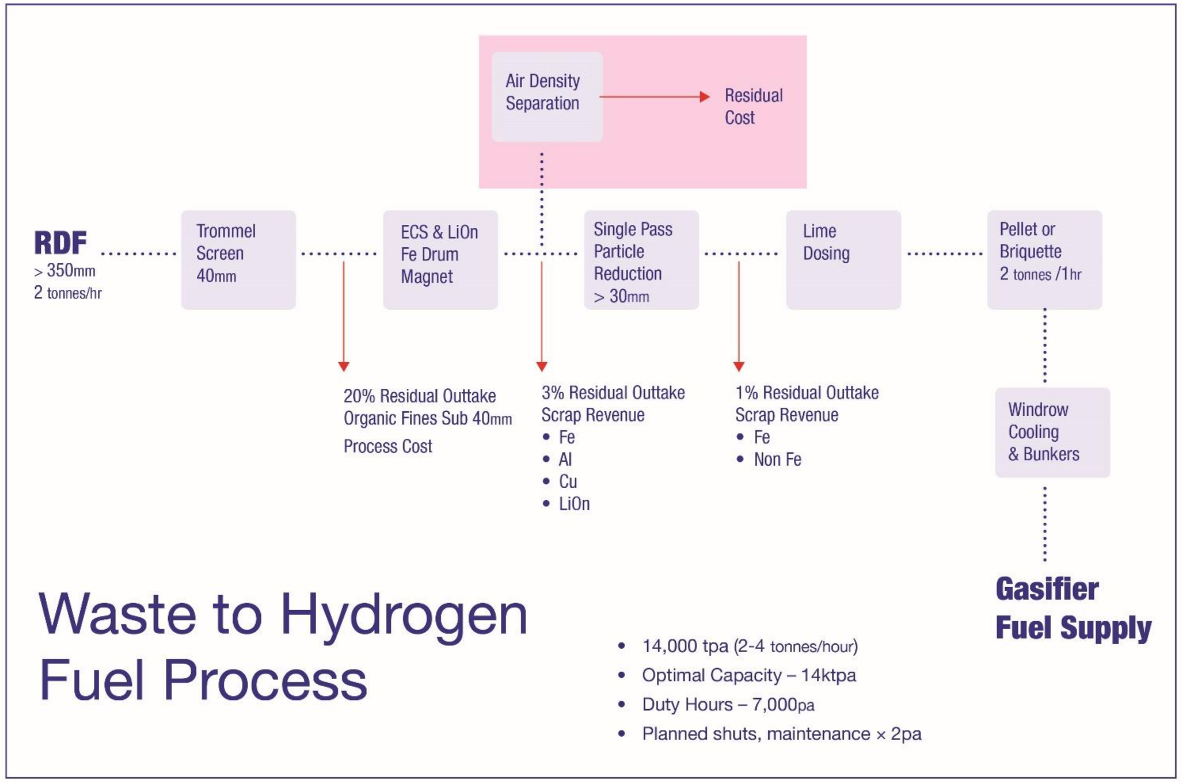
Contact: Gordon Anderson - GordonAnderson@ashgroupltd.co.uk

Gasification; Syngas Cooling & Clean-up; O_2 & H_2 PSA systems; CO_2 Capture using Water Scrubbing.

Contact: Paul Willacy - paul@syngas-solutions.co.uk

FUEL - Feedstock Equipment & Process Summary

- Fuel Feedstock Composition(s).
- Fuel Feedstock Process Flow.
- Fuel Feedstock Equipment.
- Fuel Feedstock Matrix RTFO +.
- RTFO Compliance.
- Conclusions.



Redwither RDF
sub 150mm shredded

RDF Base Feedstock
SRF Pellet 8mm

The Decentralized Concept - supporting and engaging with Industry outside of the 6 x Mega H_2 Clusters which are very focused (50% industrial emissions), but limited in their coverage (25-mile radius)

Future plans

2025-6
2 Micro-Hubs

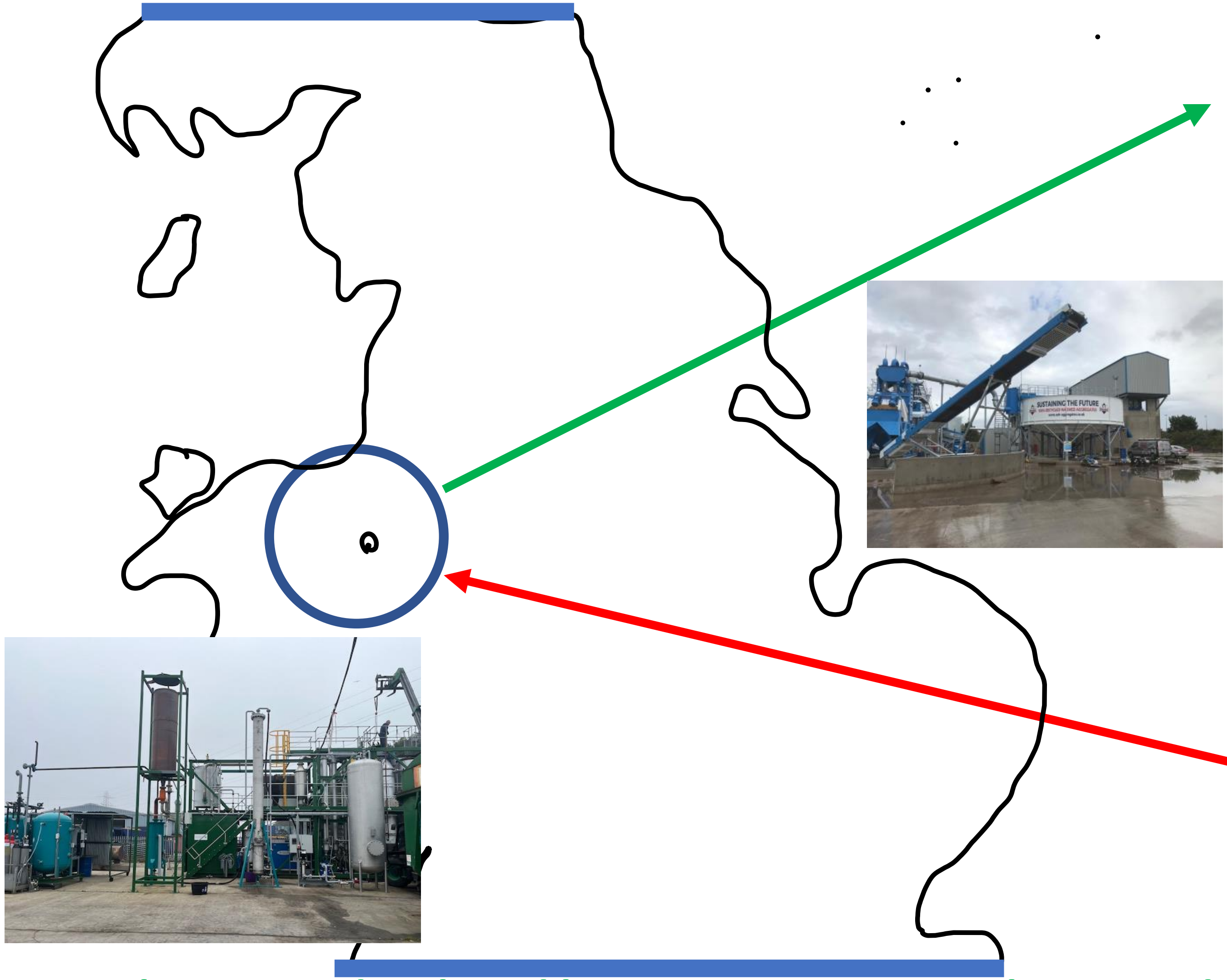
2026 - 28
8 Micro-Hubs

2028 to 2030
10 Micro-Hubs

IHA metrics

LCOH = £ 246/MWh
LCOA = £ 1,081 per t_{CO2}

Carbon intensity
= 9.2 $g_{CO2e}/MJ_{H2,LHV}$



Wrexham Micro H2-Hub & CO_2 Capture Centre

Waste Reception Centre
↓
Preparation of Refuse Derived Fuel (RDF)
↓
Gasification
↓
Syngas
↓
H_2 + Electricity
+ CO_2 capture

- *With the Micro H2-Hub concept developed by Compact Syngas Solutions Ltd with Ash Waste - utilization is at source creating a 100% utilization efficiency.*
- *No need to transport waste, H_2 or electricity across a large distance.*

Vision A: Year 2026/27 Fuel Switch: Diesel → H_2 at Ash Waste ($CO_{2,e}$ reduction 2,600 t/y)

Hydrogen Purchased (CO_2 emissions by others - in H_2 production & transport to site)

Electricity Purchased (CO_2 emissions by others – in production)

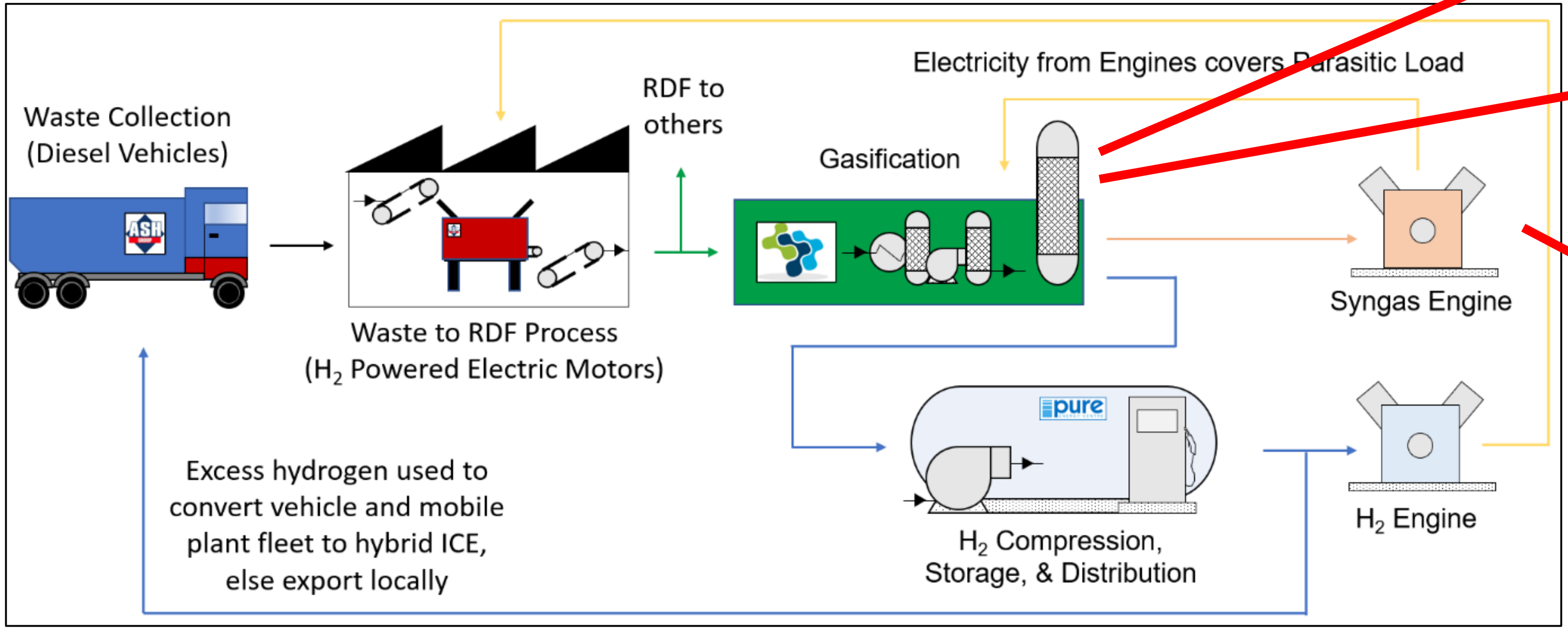
Segregated Waste sent off-site (141,000 t/y CO_2 emissions by others in an Incinerator, or CH_4 + CO_2 emissions if sent to Landfill)

Vision B: Year 2026/27 Fuel Switch: Diesel to H_2 at Ash Waste ($CO_{2,e}$ reduction 2,600 t/y)

Hydrogen production on site 8 x Gasifiers-1300 Trains

Electricity production on site

Segregated Waste in form of RDF used as a fuel



Getting Technology Ready

41 % CO_{2e} trapped in Char – now - inherent in design 58,000 t/y of CO_{2e}

18 % CO_{2e} captured via Syngas water scrubbing – now R&D 25,000 t/y of CO_{2e} (could be sold/sequestrated).

Future

35 % CO_{2e} capture from Flue Gas (could be sold/sequestrated) 49,000 t/y of CO_{2e}

Real plant trials supporting the work.

Not just a paper study!

PSA to supply O_2 enriched air
In-house IPR[1]

Waste preparation
In-house IPR [1]

Gasification
In-house IPR [1]

Syngas Cooling
In-house IPR [1]

The journey and potential areas of collaboration with 3rd Parties - even to incorporate our IPR into their schemes (hybrid designs).

Currently running an investment round and if you have funds to invest, please come and talk to us.

Gas Engine & Elec. Generation
In-house IPR [1]

PSA to remove H_2 from Syngas
In-house IPR [1]

Syngas Clean-up
In-house IPR [1]

Syngas Scrubbing with water – CO2 capture
In-house IPR [1]

[1] **In-house IPR under development**

BREAK

Undercover Zero
Research & Development Centre

NZIP
Industrial
Hydrogen
Accelerator

Zero
Emission
Laundry

STEAMOLOGY®
zero emission power solutions

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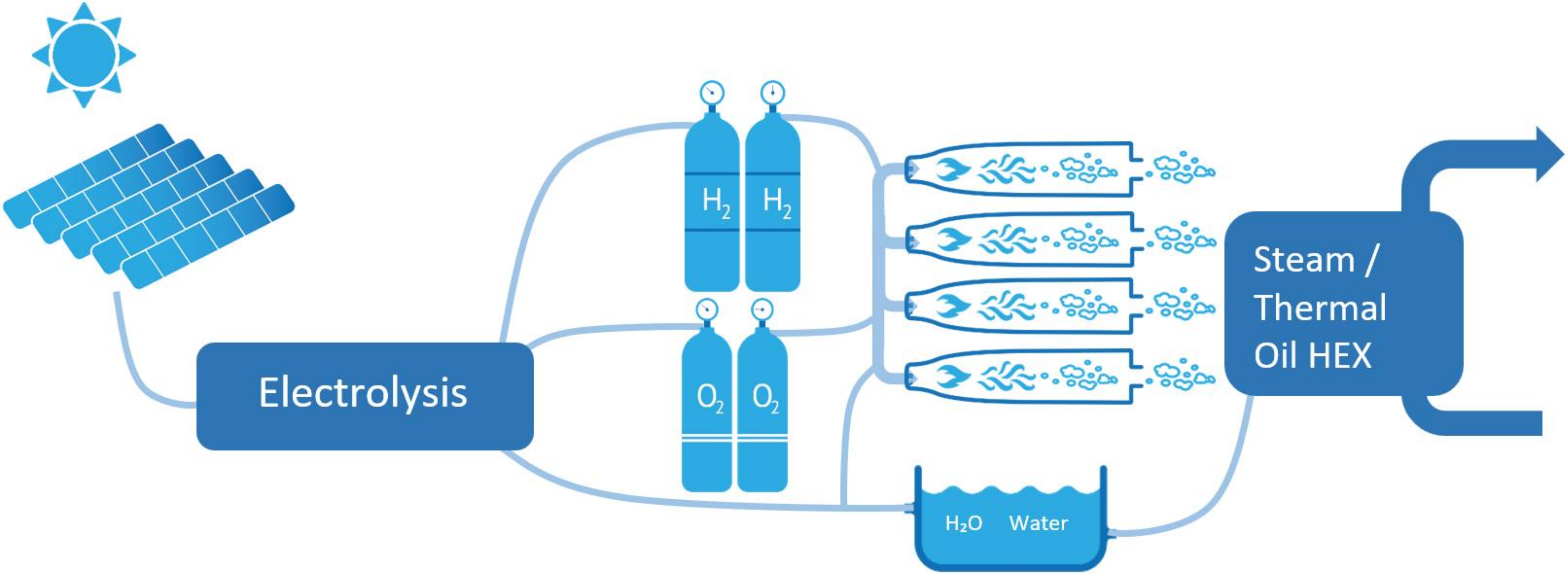
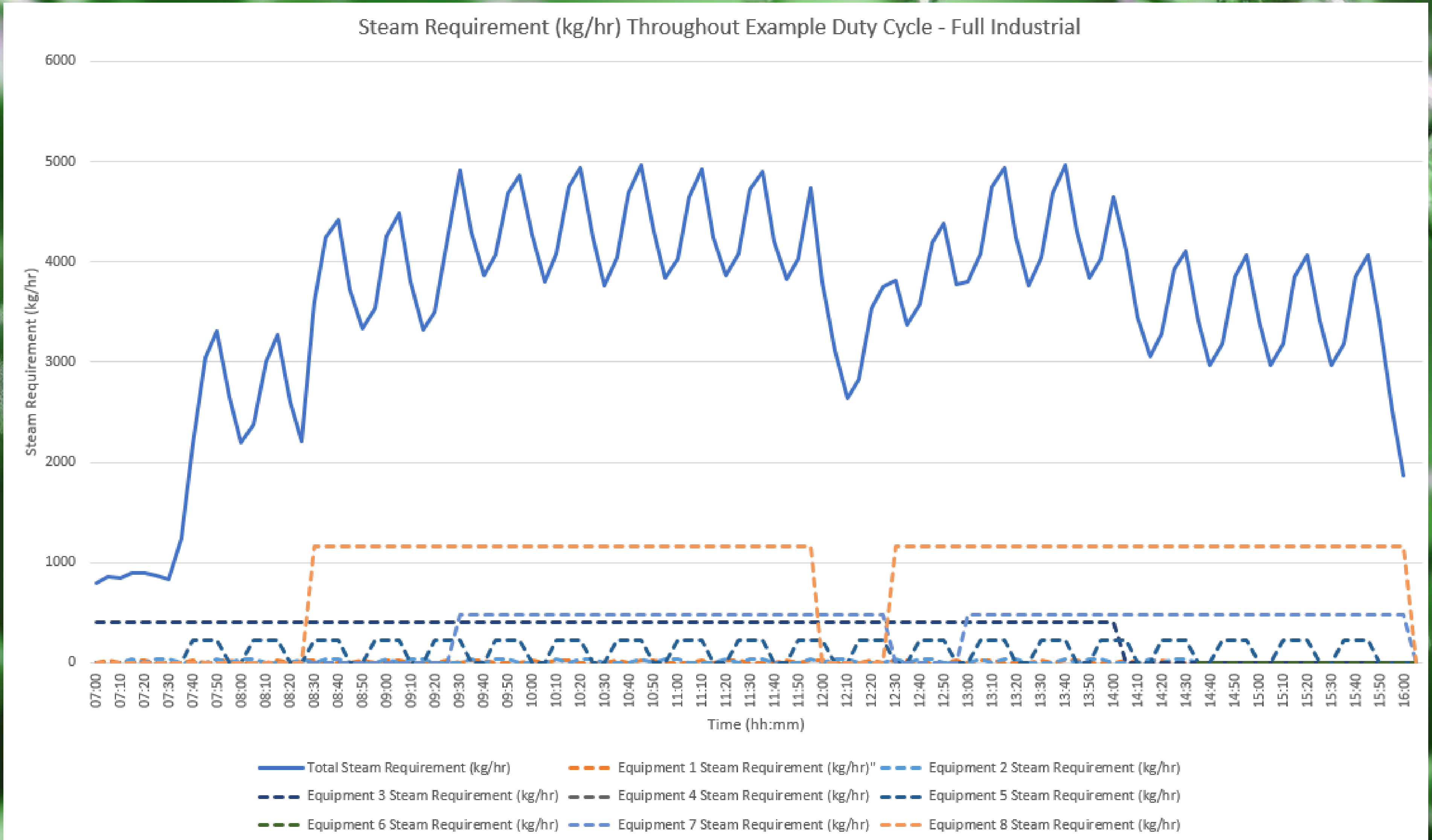
End to End Solution for the Demonstration



H2
H2
O2
O2
Electrolysis
Steam /
Thermal
Oil HEX
H2O Water

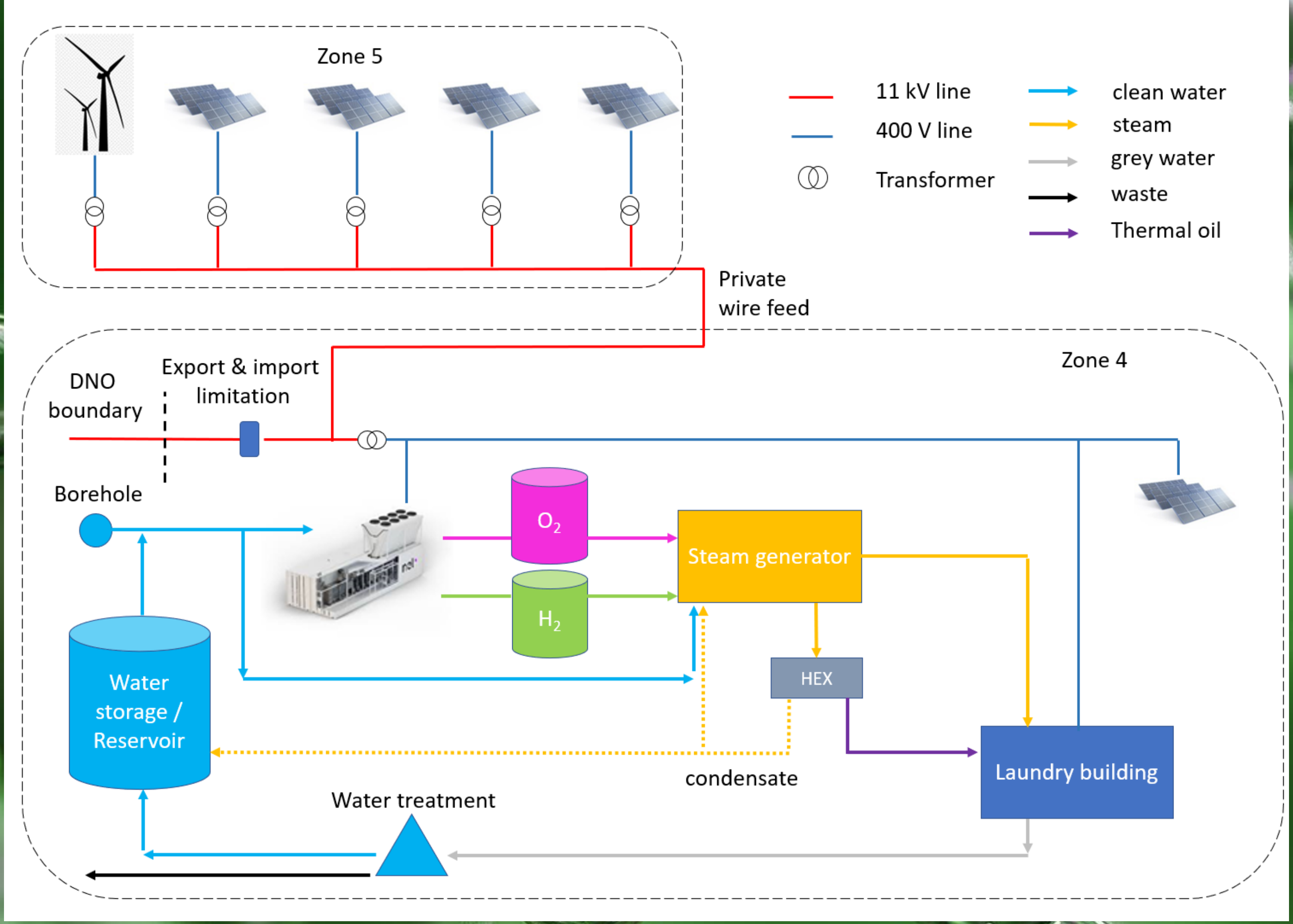
Research Findings

- 3 Energy models for laundries
- Manufacturers selected for hydrogen & oxygen production & storage equipment
- Collation of real world data
- Steam generator can follow the heat demand improving heat up time/efficiencies
- Water capture and reuse



Research Findings

- Water capture and reuse
- Regulatory
- Whole site energy model
- Steam generator design



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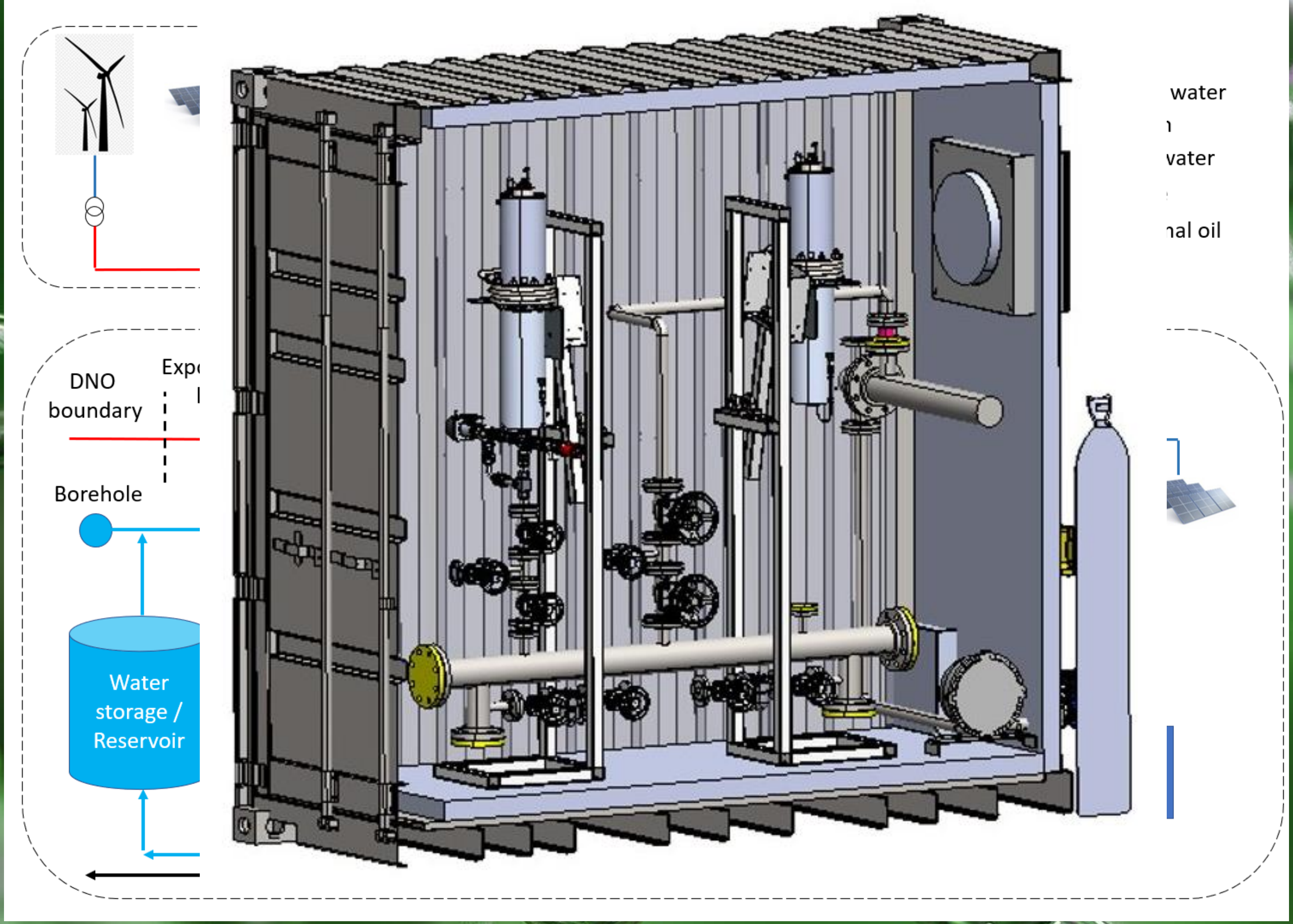

Research Findings

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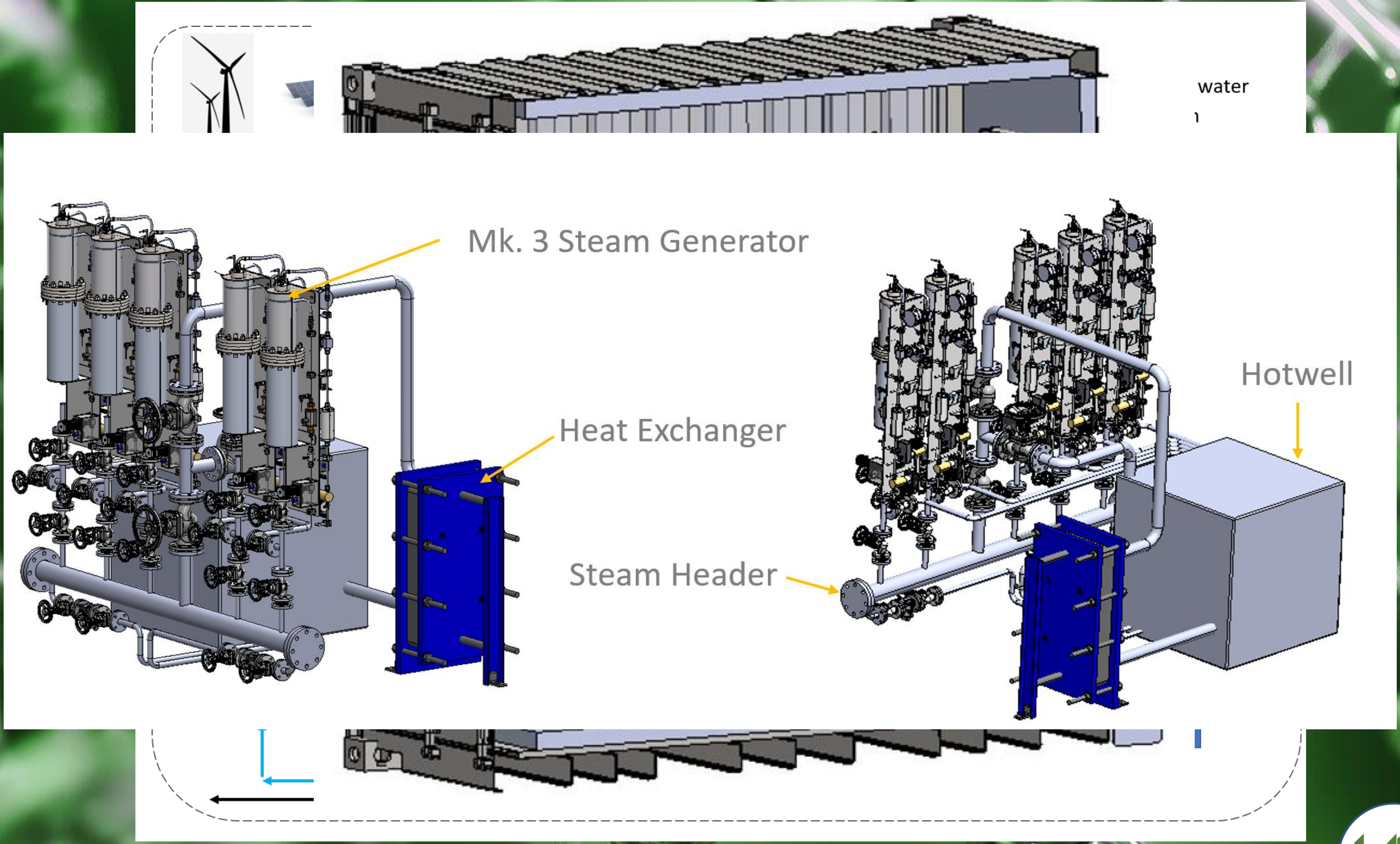


Future Plans

- Demonstration site
- Further real-world data modelling
- To carry out steam generator testing - 1544 hours across 10 months
- Develop renewables (wind & solar) for Zone 5 ready for a demonstration full industrial laundry
- Integrate Hydrogen vehicles, for a Zero EMISSION Laundry

Undercover Zero Research & Development Centre

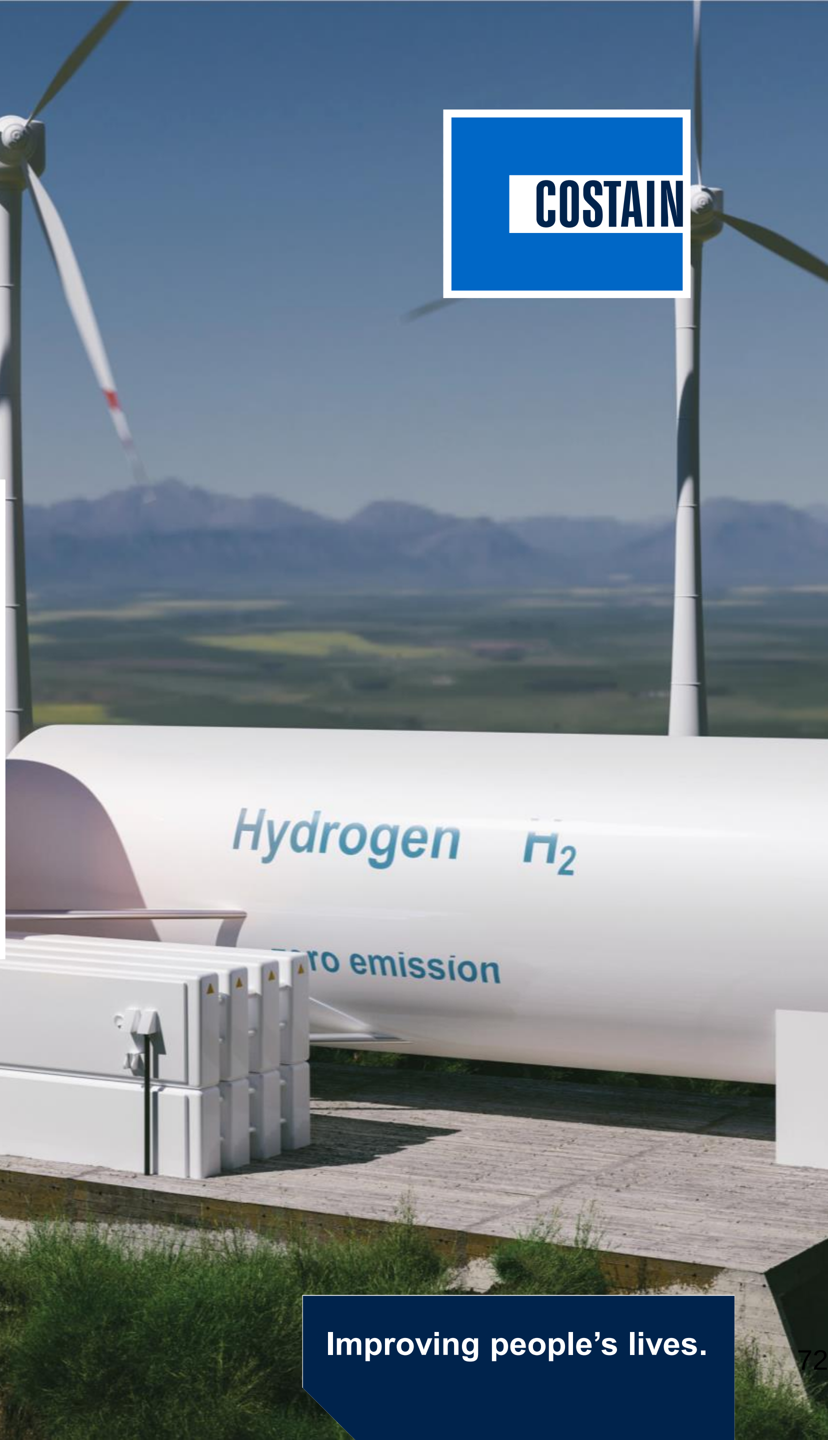
NZIP Industrial Hydrogen Accelerator

Zero Emission Laundry

- For further information
- smt@undercovergroup.co.uk

IHA Stream 2A Virtual Dissemination Event

H2Juice



IHA Stream 2A Project Overview

The H2Juice project, set in a key industrial Welsh heartland provides a replicable and scalable end-to-end fuel switching solution. The scheme entails a novel approach to hydrogen production, repurposing gas distribution pipelines, and industrial fuel switching.

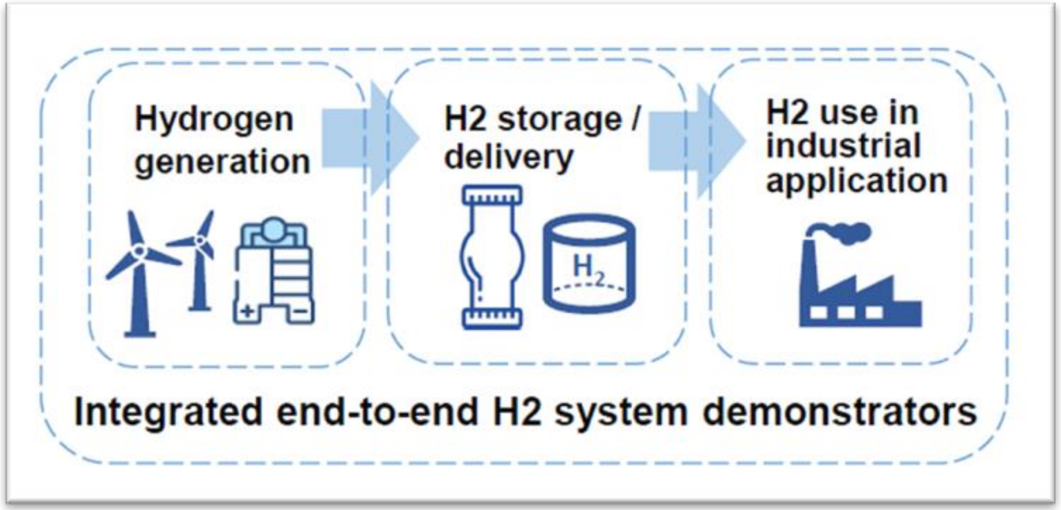
Costain led a Consortium consisting of:

COSTAIN — Stream 2A Feasibility Study Lead Partner / Engineering Consultancy

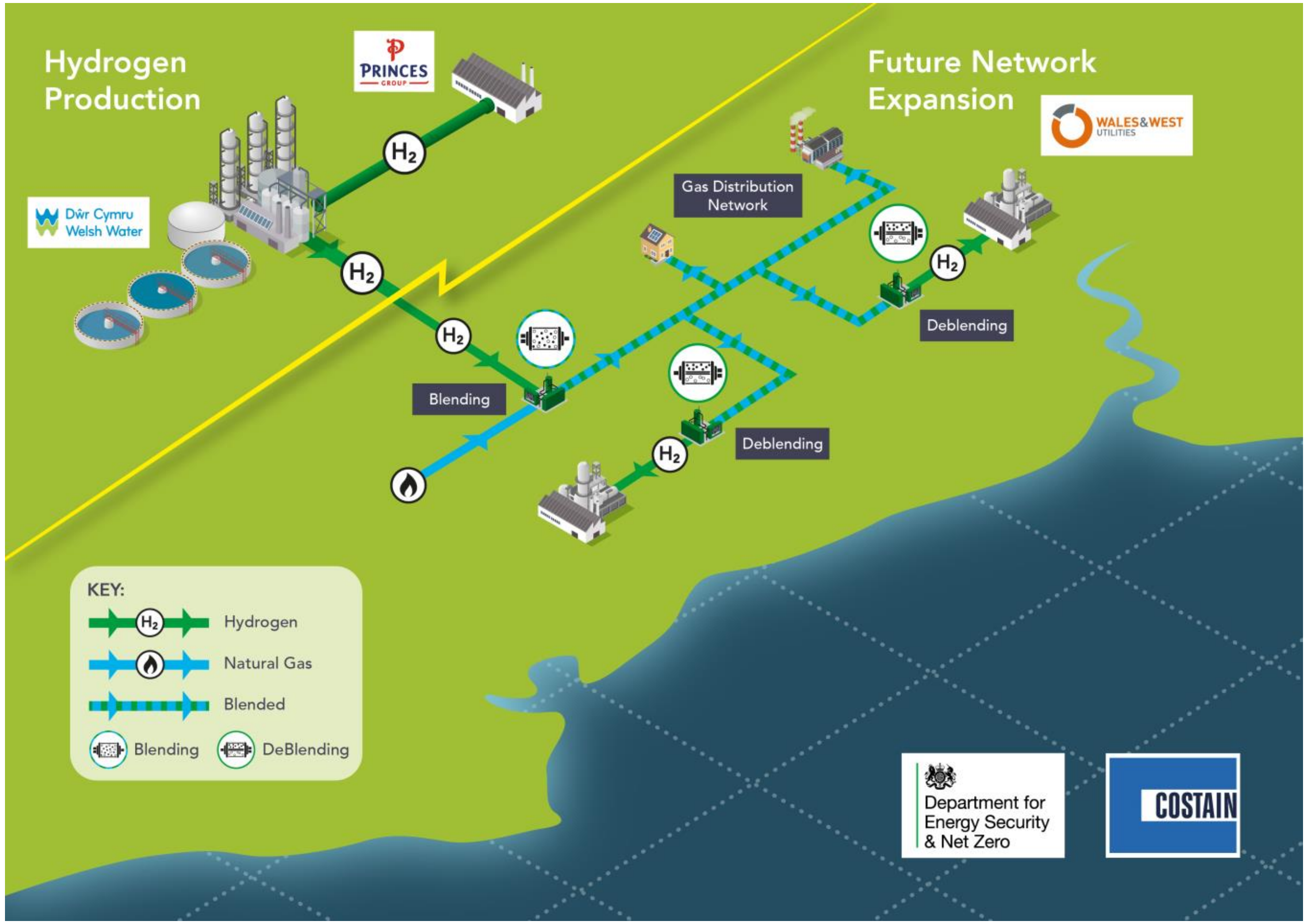
WALES&WEST UTILITIES — WP1 – Hydrogen Production

Dŵr Cymru Welsh Water — WP2 – Hydrogen Transportation

PRINCES GROUP, CR+ — WP3 – End Use (fuel switching)



H2Juice Project Overview

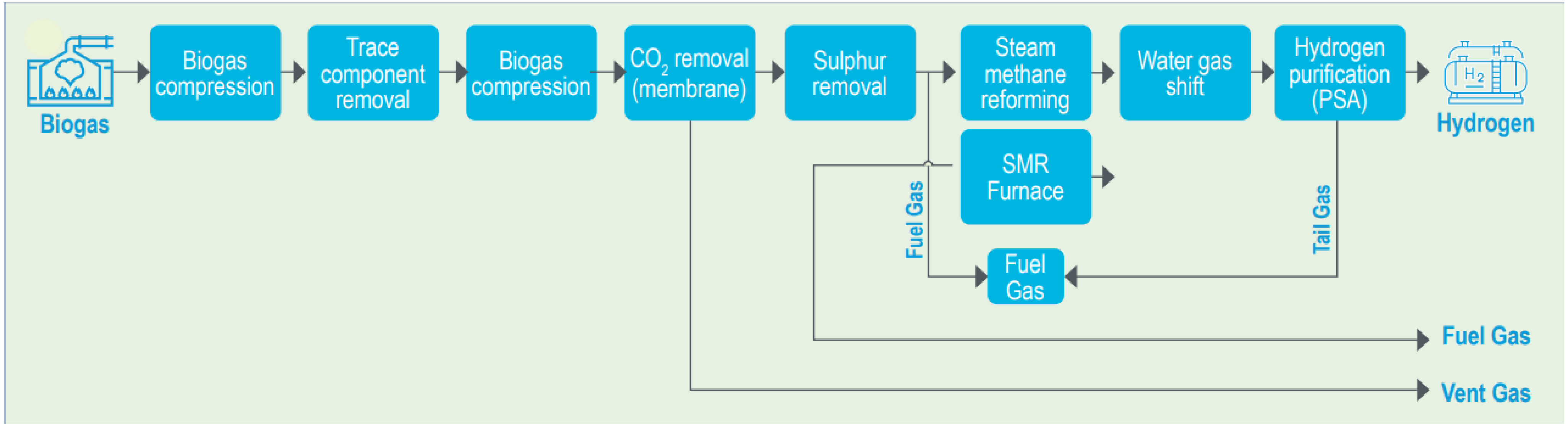


- Hydrogen Production from biogas feedstock at the Welsh Water Cardiff West Water Treatment Site – entailing biogas upgrade, 2 Nr Steam Methane Reformer trains delivering 2T per/day Hydrogen @7barg
- CCUS to be added to the hydrogen production facilities post demonstration
- Hydrogen delivered to the Princes Ltd juicing facility (approx. 2km's) via a combination of a new section of 125mm MDPE pipeline and a repurposed 8" Intermediate Pressure (IP) distribution pipeline
- Modifications and burner upgrades to the existing industrial package boilers at the Princes juicing facility (currently operating on Natural Gas) to allow dual-fuel hydrogen duty with Natural Gas back up for upset conditions
- Assessment of deblending technologies

Department for Energy Security & Net Zero

Hydrogen Production

COSTAIN



Biogas Upgrading

- Gas pre-treatment to upgrade the quality of biogas by removing carbon dioxide, water, hydrogen sulphide and trace components to meet the biomethane specification required by the BayoTech biogas SMR.

Hydrogen Production

- Hydrogen Production and Purification – converts biomethane into biohydrogen using Steam Methane Reformation (SMR) technology delivering 2T per/day >98% purity hydrogen @7barg with potential for expansion to 3.4T per/day

Levelised Cost of Hydrogen (LCOH)

H2 Production rate (t per/day)	CCUS Accounting	Case Description	LCOH 10 years (£/MWh)	LCOH 20 years (£/MWh)	LCOH 30 years (£/MWh)	LCOH 40 years (£/MWh)
2T	Gross Cost	2 t/d hydrogen production incl.CCUS	240	200	189	186
	Nett	2 t/d hydrogen production incl.CCUS	112	67	53	48
3.4T	Gross Cost	3.4 t/d hydrogen production incl.CCUS	157	133	127	125
	Nett	3.4 t/d hydrogen production incl.CCUS	29	0	-10	-13

Hydrogen Transportation

Parameter	Unit		Ref
Transported Fluid	-	Gas Phase (H2/CH4 mixture)	
Design Pressure	barg	7	
Flowrate (Princes base case)	kg/d	2,000	2
Flowrate (Princes peak demand)	kg/d	2,500	2
Flowrate (Future expansion case)	kg/d	4,000	2
Pipeline Length (Base case)	km	2.0	1

Pipeline Sizing

- The pipeline diameter and Standard Dimensional Ratio (SDR) are based on the pipeline design criteria, BS EN 12007-1 and IGEM/TD/3
- Minimum pipeline diameter of 90 mm is recommended for a new pipeline to address all Princes cases baseline and peak
- To allow for potential increased hydrogen production in future (4 te/d), the next size up, 125 mm, would be required

Pipeline Options Considered

- New 125mm Medium Density Polyethylene (MDPE) pipeline, various routing options developed
- Re-purposing existing Wales & West Utilities distribution pipeline infrastructure to hydrogen duty

Selected Option

- Combination of a section of new 125mm MDPE pipeline within the Welsh Water site boundary / repurposing existing 8” IP main from Welsh Water site boundary to Princes Ltd juicing facility

Fuel Switching

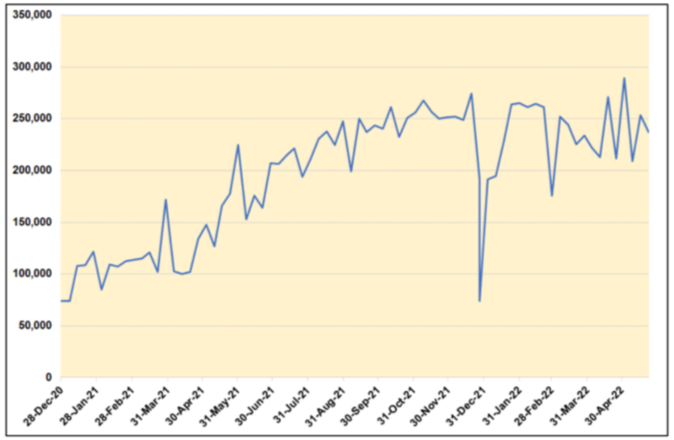


Figure 10 - Heat Demand - Princes Juice plant, Cardiff 4.2.2

Considerations:

- Heat Grade - The Princes site steam system operates at 7.5 barg, equating to a saturation temperature of 173 °C. Heat is mainly used for secondary pasteurisation processes ahead of juice transfer into containers
- Peaky Demand Profile - Base Case natural gas consumption - 1,723 kW / Peak Case natural gas consumption - 2,935 kW
- Reliability - Loss of steam results in 24 hr shut down, reserialisation and loss of production.

Fuel switching

The Princes Ltd soft drinks facility has two existing boilers, both of 6,000 kg/h steam capacity: Dennis Baldwin (2006), and Byworth (2019)

Fuel switching will be achieved through conversion of the existing boiler to dual-fuel burner configurations allowing primary operation on hydrogen.

To ensure best available uptime at Princes Ltd, the natural gas supply is retained, allowing boilers to switch back immediately upon loss of hydrogen

Technology Assessment

Case	Technical Feasibility	Plant Modification Scope	Annual Emissions ($teCO_2eq$ / year)	Emissions Reduction ($teCO_2eq$ / year)
Counterfactual: Natural Gas	N/A	N/A	2,462	N/A
H2Juice Demonstration Project	YES	LOW	349	2,113
H2Juice (with CCUS)	YES	LOW	-5,808	8,270
Alternative 1: Hydrogen from on-site Electrolyser	YES	HIGH	3,091	-613
Alternative 2: Direct Electric Heating	YES	HIGH	2,060	1,230
Alternative 3: Heat Pump	NO	N/A	N/A	N/A
Alternative 4: Biogas	YES	LOW	2.7	2,459
Alternative 5: Biomethane	YES	LOW	4.6	2,457

Questions

HiiROC & Jaguar Land Rover

IHA – Stream 2A Feasibility study

March 2023

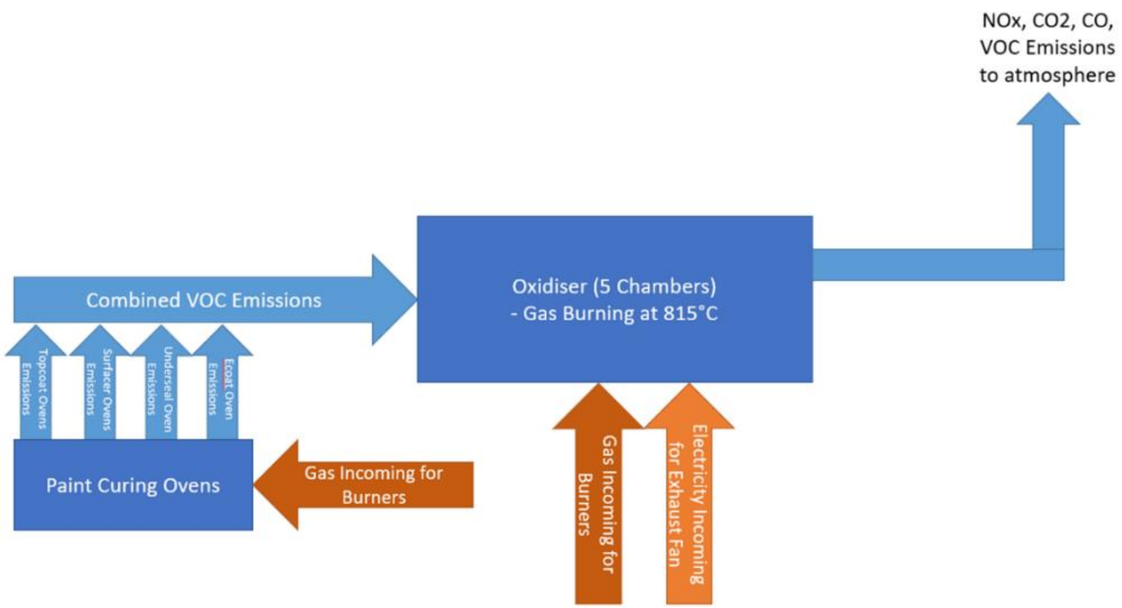
Project Overview

Using HiiROC's Thermal Plasma Electrolysis to decarbonise JLR's paint processes and create hydrogen

- IHA Stream 2A feasibility study looking into the creation of hydrogen from the Volatile Organic Compounds in the exhaust gases of JLR's paint processes
- Phases of the project:
  - Test quantities and types of VOC's present in exhaust gases
  - Test samples through HiiROC TPE system
  - Analyse outcomes of end products, both hydrogen and Carbon Black
  - Suggest and design ways to integrate hydrogen into the JLR infrastructure

Current Paint Processes at JLR

An opportunity to decarbonise an energy intensive process

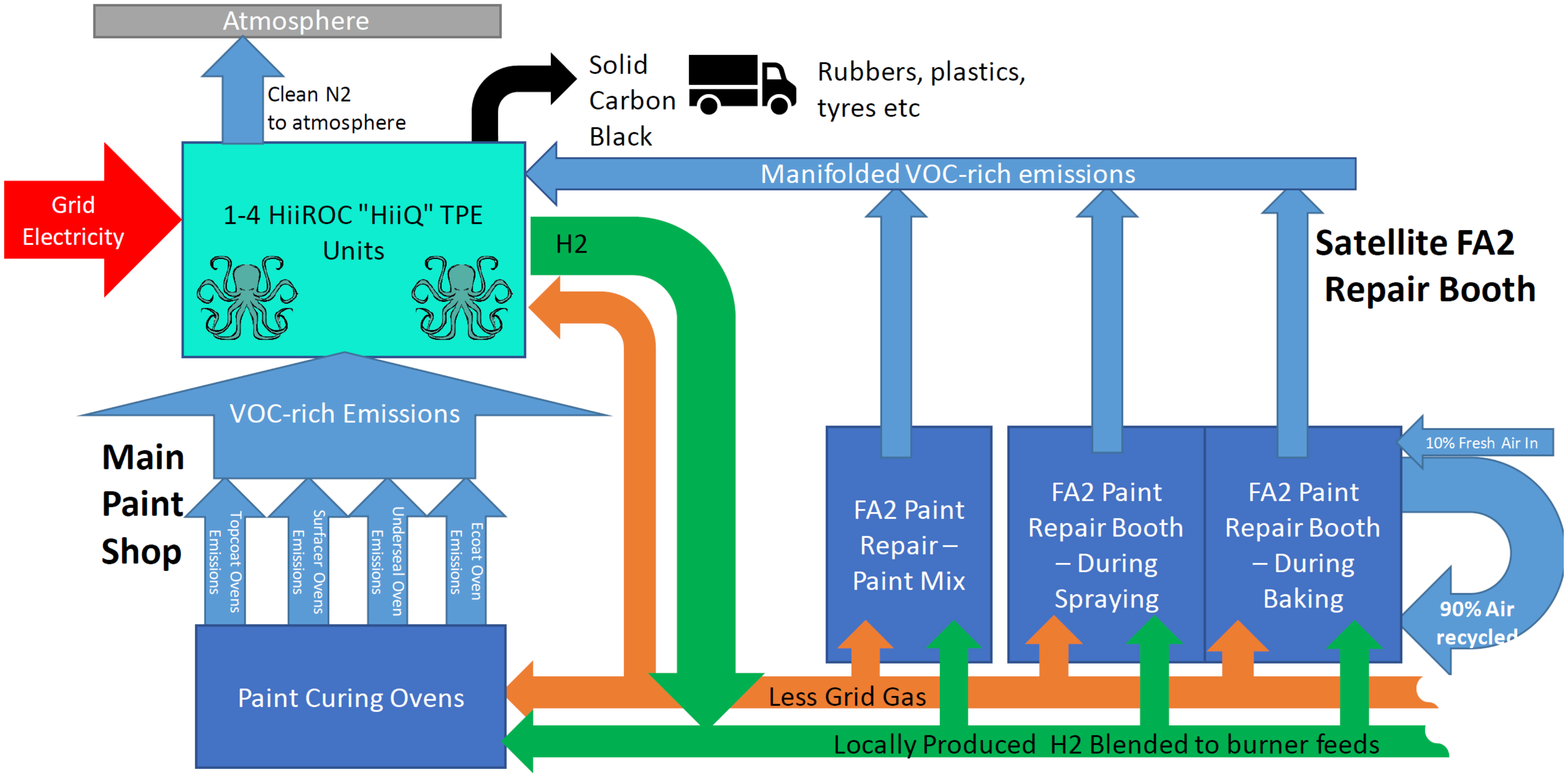


- The current paint processes at JLR Solihull are; exhaust gases from the paint curing ovens are collected and drawn through a thermal oxidizer
- The Thermal Oxidiser breaks down the VOCs in the exhaust gases
- Volatile Organic Compounds can be broken down into their base components – mainly hydrogen and carbon
- The current process uses a large volume of gas both in the paint curing ovens, and in the thermal oxidiser
- The Paint shop represents 60% of Solihull sites gas usage

Project Overview

Industrial Hydrogen Accelerator Feasibility Stream 2A

High level potential system design



Project Outcome

Industrial Hydrogen Accelerator Feasibility Stream 2A

- Our research found there was sufficient VOCs present in the exhaust gases to run the HiiROC units
- This was however majority present in the exhaust stream coming from the main paint shop, and the exhaust gas manifold idea wouldn't be a practical feasibility
- There were challenges around the extraction of the VOCs from the hot exhaust stream, the VOCs were significantly diluted with air drawn from the paint curing ovens. In fact the waste gas stream was over 90% air
- The only feasible method of extracting the VOCs would be to cool them to the extent that they would condense to a liquid and drop out of the gas stream, this could then be re-vapourised to run through the HiiROC system as a gas
- Numerous other extraction / separation technologies were investigated
- Whilst this was a technically feasible solution, this wasn't feasible in terms of OpEx or CapEx, and would require around 20MW of cooling duty
- Additionally as a space restricted site, the technology needed to cool and re-vapourise the VOCs couldn't have fitted into the space needed (by the exhaust gas outflow point)
- The TPE technology was modelled and would have worked to break down the VOCs if the extraction was feasible

Project Summary

Industrial Hydrogen Accelerator Feasibility Stream 2A

Whilst the original concept was found to be unfeasible due to the issues around extraction of the VOCs from the waste gases, several useful key findings were discovered:

- The HiiROC TPE system would be able to breakdown VOCs to hydrogen and carbon with minimal modification
- Further investigation was carried out regarding the use of hydrogen in the Thermal Oxidiser highlighting the following:
  - Introducing hydrogen from HiiROC's TPE system could increase the efficiency of the burn in the oxidiser and the efficacy of breakdown of VOCs
  - If the thermal oxidiser could have the burners upgraded to 100% hydrogen burners the end to end GHG efficiency would see a reduction of 1,070 kg / hr of CO_2, or a yearly savings figure of 6,676 tonnes of CO_2 emission p/a
  - This could be a feasible project if there can be a good commercial value ascribed to the Carbon Black
- JLR are committed to progression to Net Zero and limitations on the grid mean that electrification isn't the only solution, the potential for decarbonisation through hydrogen still remains a point of progress to be developed further with HiiROC and JLR.
- Thermal oxidiser is a key focus for decarbonisation – further R&D investigation needed into it with additional funding routes

HiiROC

Thank you for your time

Project rooms

Now is the opportunity to meet with the presenters/ project representatives.

Please join the affiliate meeting for the project that you would like to meet with, just select the corresponding link in the chat (or on this slide) and then follow to 'join the meeting'.

You can move between the rooms to meet with multiple projects, just return to this chat and select the corresponding link to join.

Please return to this meeting at the time specified to then participate in a networking event.

Project lead	Project overview
E.ON	HYDESS - Electrolysis from biomass CHP, to use H2 in secondary steel (reheat and heat treatment furnaces)
EDF Energy R&D UK Centre Ltd	Bay Hydrogen Hub – Hydrogen4Hanson - nuclear electrolytic H2 (SOEC) + next gen transport for dispersed asphalt + cement sites
ROCKWOOL Ltd	Investigating the use of Hydrogen in stone wool insulation manufacturing - onsite renewable electrolysis for hydrogen for process heat
Nanomox Ltd	OISH – Hydrogen from steel-making waste as green fuel for steel/ cement production
Ash Waste Services	Small-scale hydrogen production utilising a waste company's SRF feedstock, via gasification, to power its industrial plant and equipment
Undercover Zero R&D Centre	Zero Emissions Laundry - Z.E.L. - Green H2 from electrolysis, to generate steam for industrial laundry heat
Costain	H2Juice - Sewage derived biogas reforming, H2 blending/deblending and use in boiler for pasteurisation
HiiROC	Decarbonising JLR automotive paint operations with Thermal Plasma Electrolysis of waste gas VOCs

Thank you for coming

Opportunity for networking in breakout rooms

Hydrogen Innovation needs survey

https://forms.office.com/e/GXWzdzfxTq

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Department for Energy Security & Net Zero