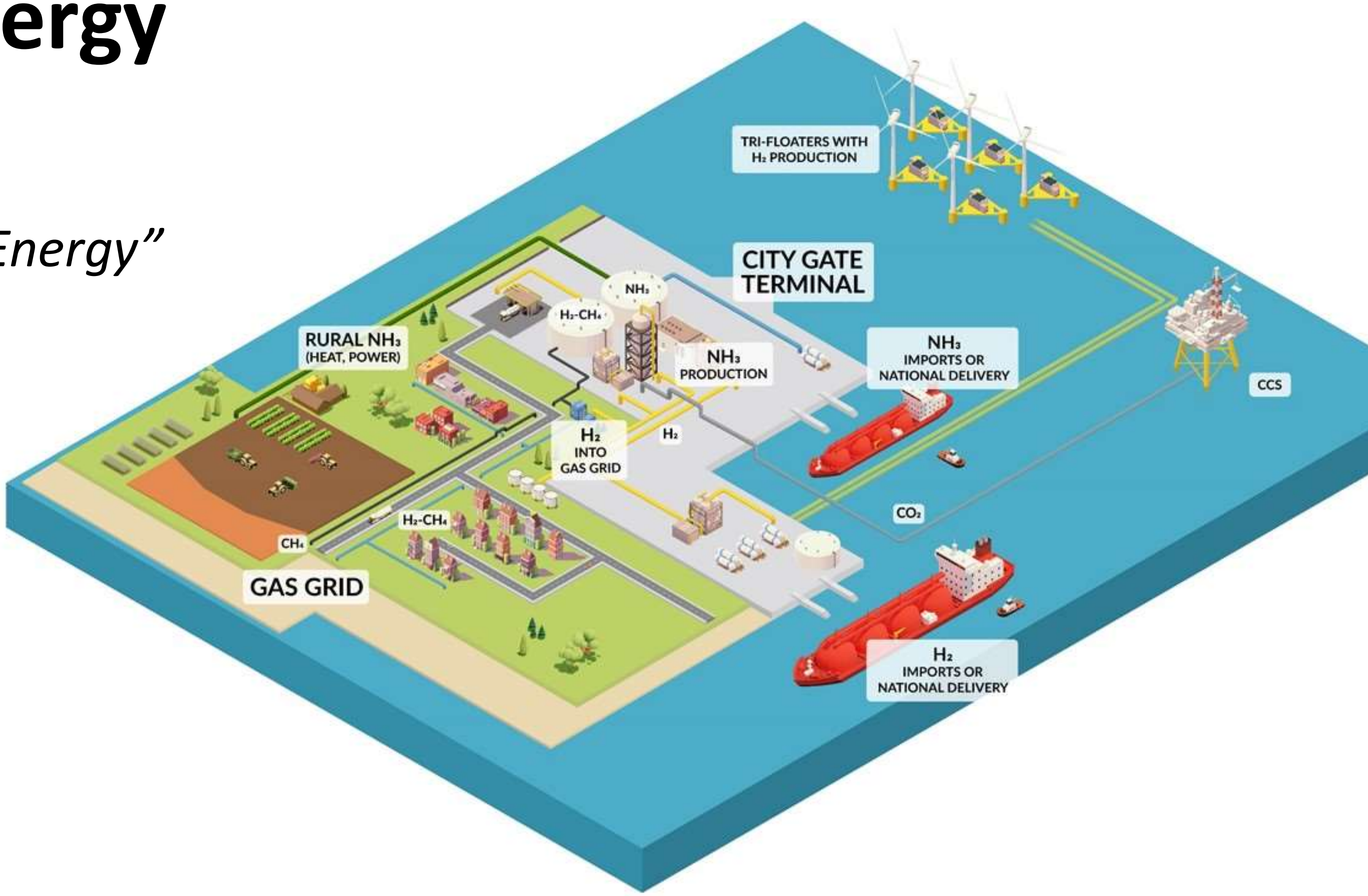
UKRI Engineering and Physical Sciences Research Council | Cardiff University Prifysgol Caerdydd | Imperial College London | Newcastle University | University of Nottingham UK | CHINA | MALAYSIA | University of Strathclyde Glasgow

Ocean-REFuel
(Ocean Renewable Energy Fuel)

“Next generation Renewable Ocean Energy”

9th Sept 2025

Stakeholder Update



Ocean REFuel Stakeholder Meeting - Agenda

- **09:30 – 10:00** Registration, refreshments
- **10:00 – 10:10** Ocean REFuel intro/welcome
- **10:10 – 10:30** Work Stream 1 Update (Offshore structures, logistics and power generation)
- **10:30 – 10:50** Work Stream 2 Update (Power to Carbon Free Fuel)
- **10:50 – 11:05** *Q&A/Discussion/Feedback*
- **11:05 – 11:25** Work Stream 3 Update (Carbon Free Fuel Transportation & Storage)
- **11:25 – 11:45** *Comfort/Coffee break*
- **11:45 – 12:05** Work Stream 4 Update (Ammonia, Carboniferous H2, System Optimisation)
- **12:05 – 12:25** Cross cutting themes (Economics, public perception & LCA)
- **12:25 – 13:00** *Q&A/Discussion/Feedback*
- **13:00** Close
- **13:00 – 14:00** Lunch

Ocean REFuel

Workstream 1
Offshore structures, logistics, and power generation

Nottingham, 09 September 2025 – Stakeholder event

www.strath.ac.uk/engineering

University of Strathclyde Engineering

Workstream 1: the team

Prof Feargal Brennan, PI

Prof Maurizio Collu, WS1 Lead

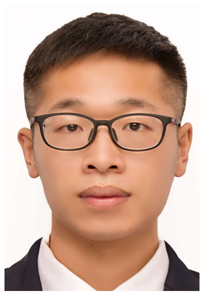
Dr Shen Li, Lecturer

Dr Claudio Rodriguez-Castillo, PDRA

Dr Abel Arredondo-Galeana, PDRA

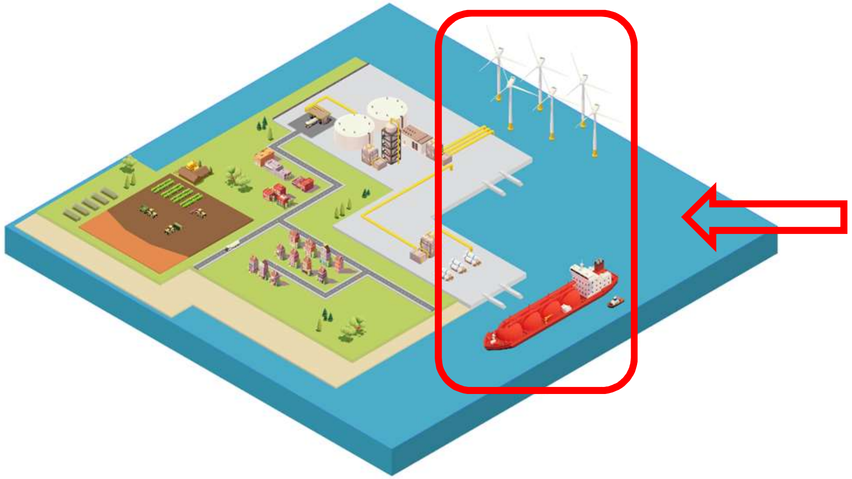
John Harris, PhD res.

Miracle Mbaekwe, PhD res.



Xiaoming Ran PDRA

Dr Xintong Wang PDRA



Ocean-REFuel

Research Workstreams \ Cross cutting Themes	Materials	Safety	Socio Economics	Process Engineering	Environmental Impact
Offshore structures, logistics and power generation	●	●	●		●
Power to Carbon Free Fuel	●	●		●	●
Carbon Free Fuel transportation and storage	●	●	●	●	●
Networks, Compatibility and Demand		●			

Workstream 1 – WPs and tasks

Workstream	Tasks
WS1.1 Scenarios definition	T1.1.1 Locations? Metocean conditions?
	T1.1.2 Which ORE technologies?
WS1.2 Production of H_2 in offshore conditions	T1.2.1 Support platform: objectives, constraints
	T1.2.2 Support platform: MDAO analysis
	T1.2.3 Impact of offshore conditions on H_2 production
	T1.2.4 Offshore platform for H_2 **production**: optimum configuration
WS1.3 Storage of H_2 in offshore conditions	T1.3.1 Optimum materials for H_2 storage
	T1.3.2 Impact of offshore conditions on H_2 storage system equipment
	T1.3.3 Offshore platform for H_2 **storage**: optimum configuration
WS1.4 H_2 transportation to shore	T1.4.1 Materials and technologies for H_2 transportation
	T1.4.2 Damage modelling and mitigation solutions

1 journal paper

- Rodríguez et al, 2023. A critical review of challenges and opportunities for the design and operation of offshore structures supporting renewable hydrogen production, storage, and transport. Wind Energy Science, 9-3, pp.1-34.

3 conference papers/seminars

- OMAE 2024, Singapore
- WESC 2023, Glasgow- UK;
- Seminar SINDIC2023, Lima-Peru;

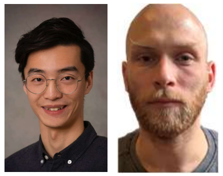
6 journal papers:

- **Arredondo-Galeana, A.**, Scarlett, G. T., Collu, M., & Brennan, F. (2025). A hybrid wind-wave floating platform to ensure a minimum power base load. Preprint: https://doi.org/10.31224/4553 (Ocean Engineering – Under review).
- **Rodríguez** et al, 2025. "Feasibility of a Centralised 200 MW Floating Hydrogen Production System on a Tri-Column Semisubmersible: Design and Dynamics". Renewable Energy (under review).
- Rodríguez et al, 2025. "Comparative Design Space Exploration of Centred and Off-centred Semisubmersible Configurations for Floating Offshore Wind Turbines". Ocean Engineering, 324,p.120740.
- Rodríguez et al, 2024. "Design considerations and preliminary hydrodynamic analysis of a decentralised floating wind-hydrogen production system". International Journal of Hydrogen Energy, 89, p. 496-506.
- Yeter et al, 2023. Macroeconomic impact on the risk management of offshore wind farms. Ocean Engineering, 284, p.115224.
- Li, S. and Brennan, F., 2024. Implementation of digital twin-enabled virtually monitored data in inspection planning. Applied Ocean Research, 144, p.103903.
- Li, S. and Brennan, F., 2024. Digital twin enabled structural integrity management: Critical review and framework development. Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment, p.14750902241227254.

Workstream 1 – Tasks & Interactions

Platform design and dynamics
Floating substructure design and overall dynamics

Overall offshore system

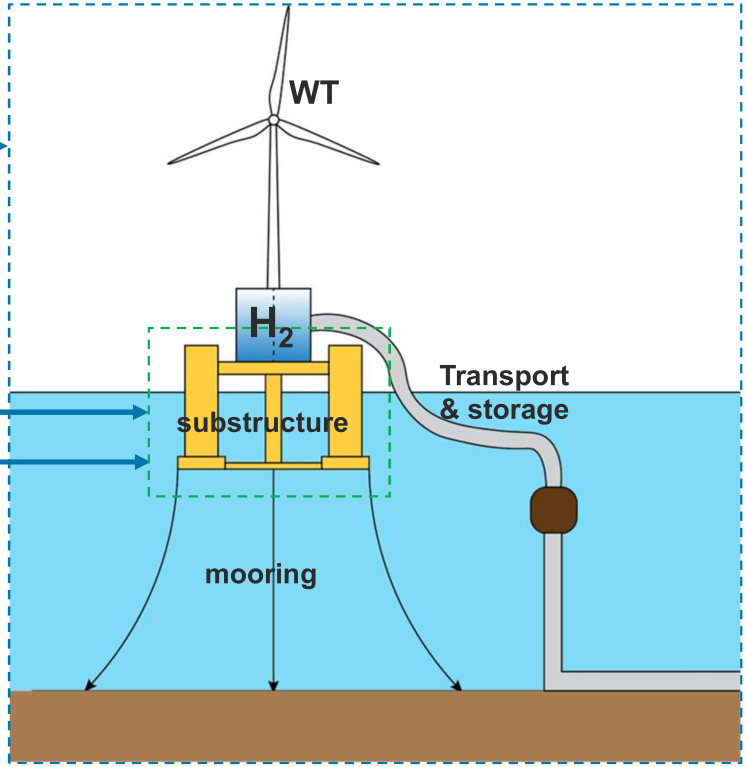


Risk-based structural design
Ensuring safety with high degree of freedom for innovative design

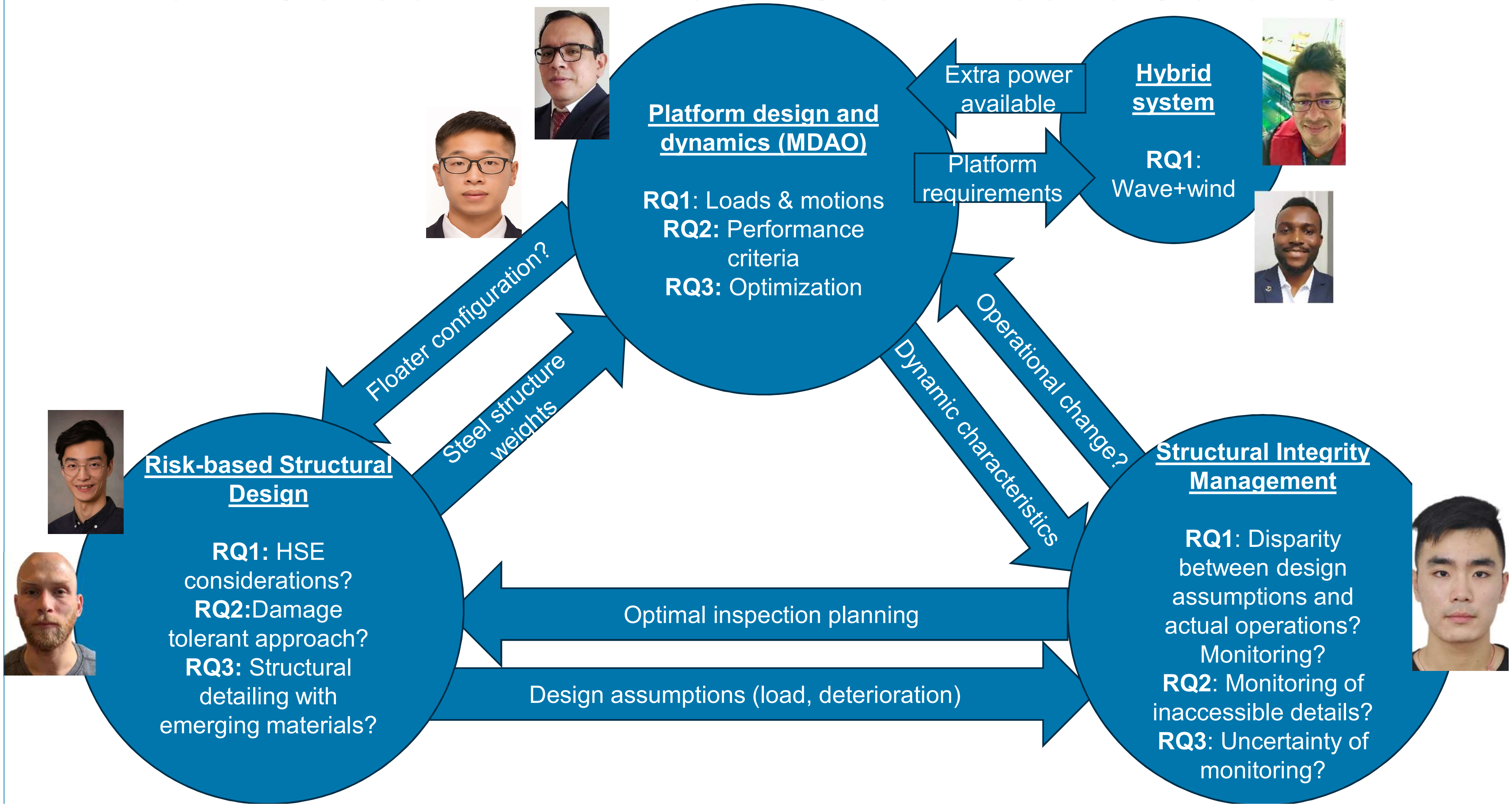
Floating substructures

Structural integrity management
A rational in-service scheme to support through-life fitness-for-service

Floating substructures



Workstream 1 – Tasks & Interactions



Workstream 1 – Focused Areas

Engineering and Physical Sciences Research Council

Ocean-REFuel

Ocean-REFuel
Mid-Term Review Report

November 2024

Version: Final

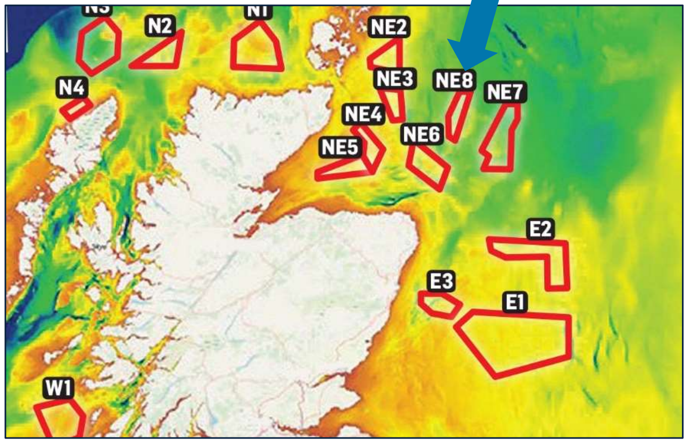
Date: 18 November 2024

1

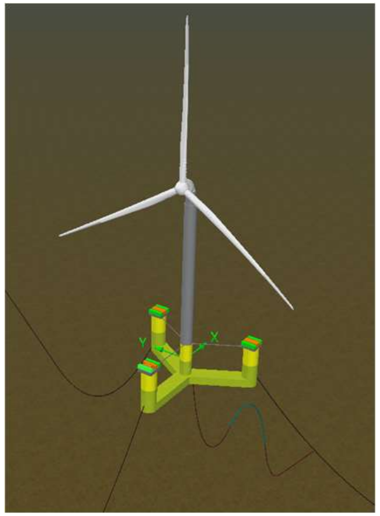
- **Centralised Offshore production system** floater design methodologies;
- **Hydro-structural model integration** potentially considering a novel energy flux approach allowing an unconstrained shape and optimising this through a seamless hydromechanics structural analysis;
- **Hybrid materials & structures** e.g. concrete, composites.
- Re-examine/revise the **design/control strategy** for optimised H2 production (turbines are currently designed for production of cheapest electricity not to optimise feed to H2 production).

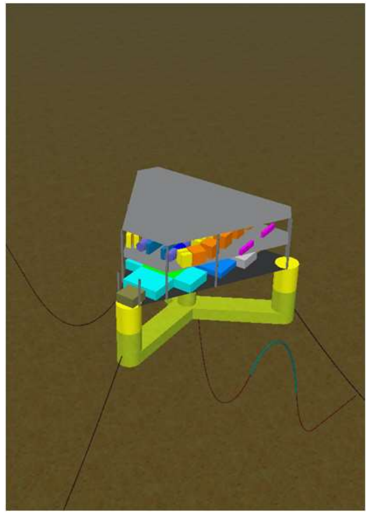
Recap of previous results

- **WS 1.1**:
  - T1.1.1: NE8 Scotwind site:
    - 960 MW (FOW), 330 km², depth: 75 – 110 m, ~75 km from coast
    - 20 years of hourly data (wind, wave, surface temp)
  - T1.1.2: FOWT most promising for local H2 production (wind-wave system also investigated)

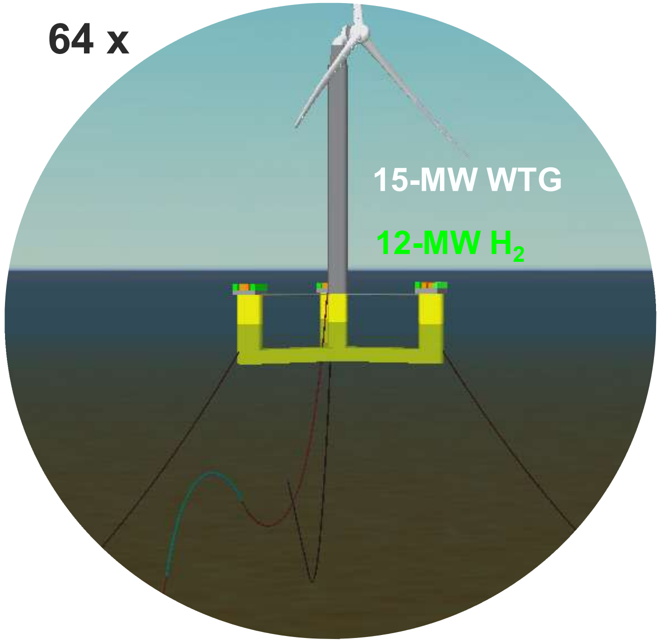


- **WS 1.2 & 1.3:**
  - "Strawman" case scenario (explore design reqs. & premises):
    - Decentralised: 64 x 15-MW WTG (12-MW Electrolysis)
    - Centralised: 4 x 200-MW Electrolysis
  - Substructure:
    - Open access WT data
    - EoS → Tri-column semisubmersible (UMaine VolturnUS);

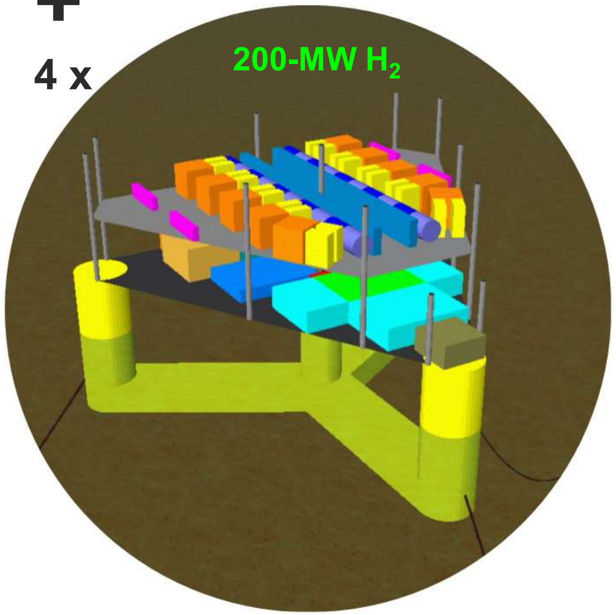




Offshore Hydrogen Production

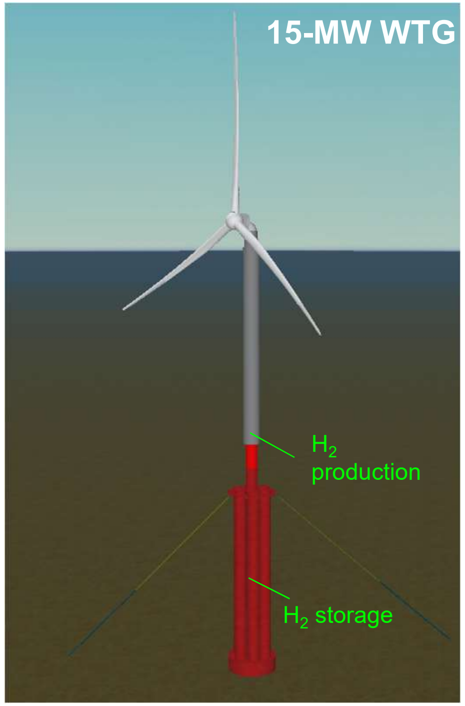


Rodríguez, C.A. et al., 2024. ***"Design considerations and preliminary hydrodynamic analysis of a decentralised floating wind-hydrogen production system".*** *Int'l Journal of Hydrogen Energy, 89.*



Rodríguez, C.A. et al., 2025. ***"Feasibility of a Centralised 200 MW Floating Hydrogen Production System on a Tri-Column Semisubmersible: Design and Dynamics".*** *Int'l Journal of Hydrogen Energy (under review).*

Offshore Hydrogen Production & Storage



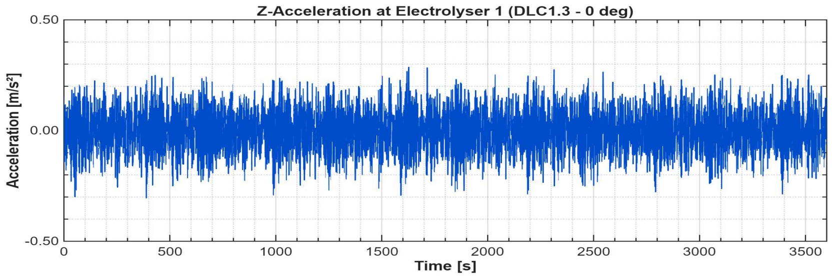
- Concept by 12toZero®
- Decentralised system
- Compressed H_2 storage
- Tackles resource variability
- Good motion behaviour
- Further research: design, sizing, layout, etc.

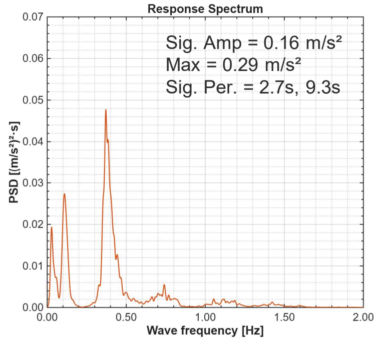
- *Storage on multilevel-topside semisubmersibles?*

Rodríguez, C.A. et al., 2025. ***"Synergising Floating Wind and Hydrogen Production and Storage: Insights from the Hyfloat Concept"****. OMAE2025, Jun. 2025, Vancouver.*

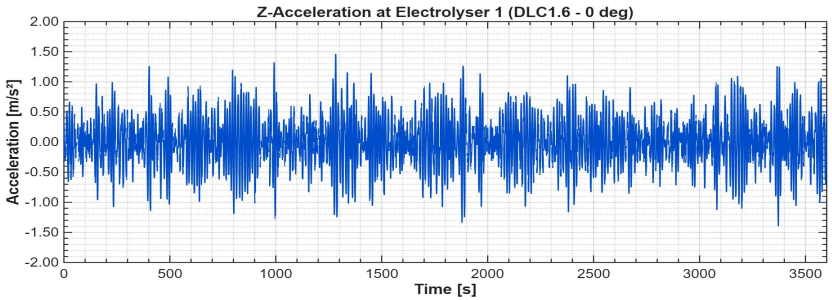
"Short-term" dynamics @ Offshore H_2 Facilities

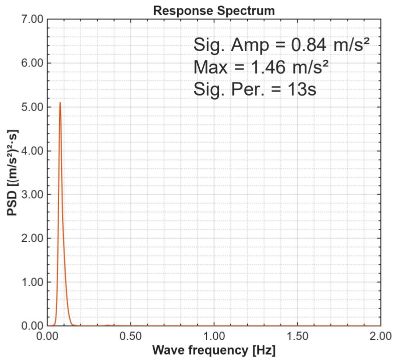
Operational – DLC1.3 (typical)



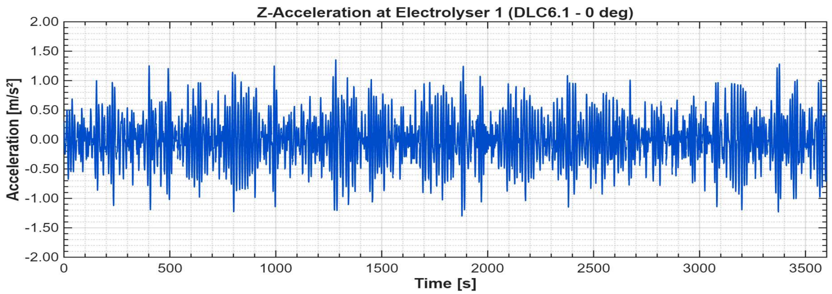


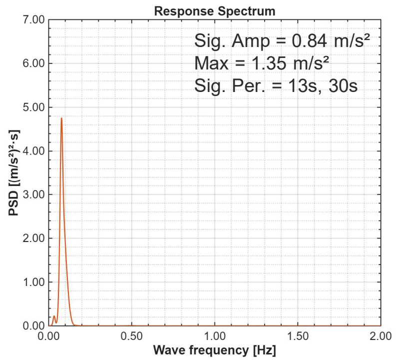
Operational – DLC1.6 (severe)





Survival – DLC6.1 (extreme)





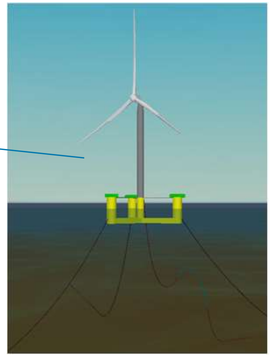
Scale 1:38

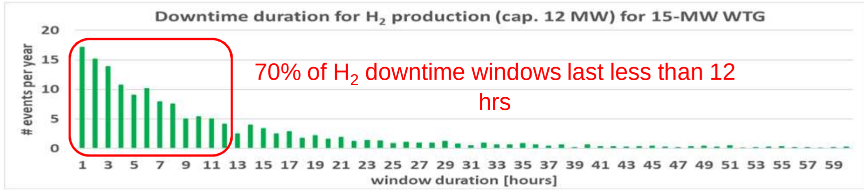
PS-6TL-350 Motion Platform (x 1)

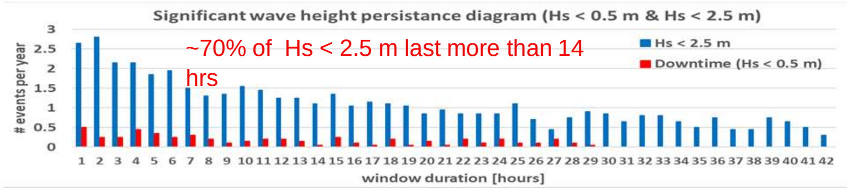
Newcastle University

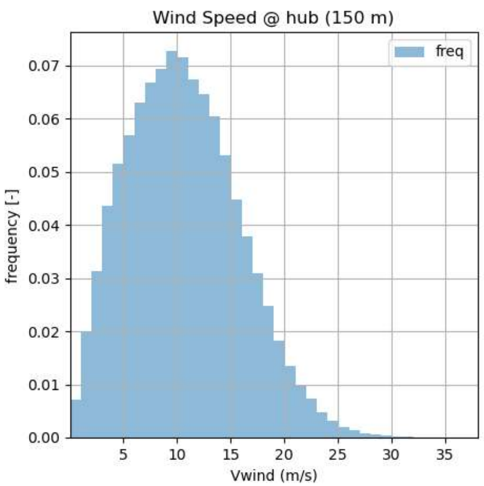
X THE FACULTY OF ENGINEERING

“Long-term” WTG variability vs. H_2 cap.

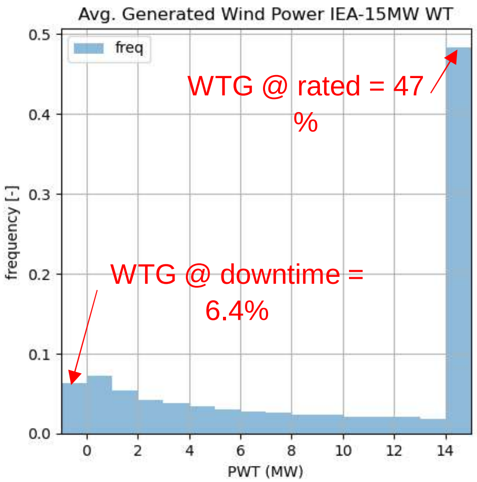




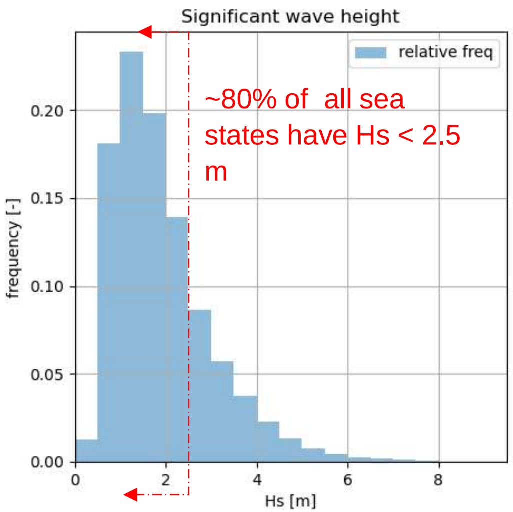




15-MW WTG capacity factor = 64.5%



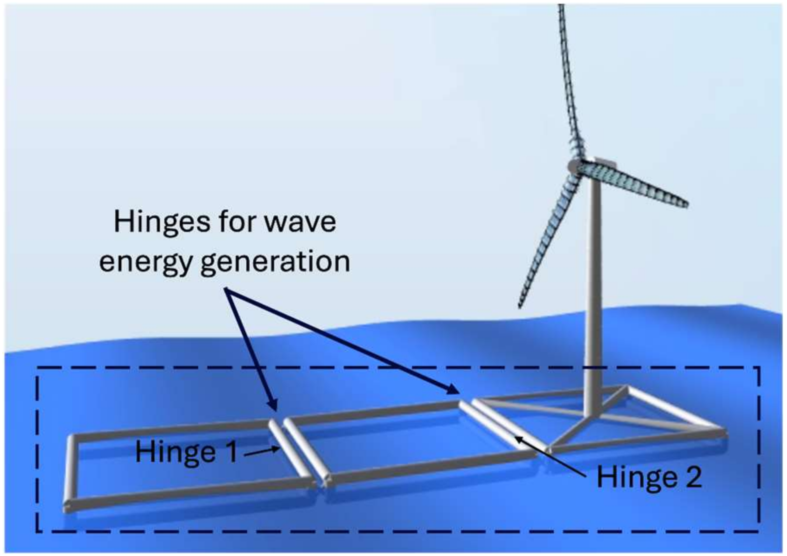
12-MW AEK oper. factor = 83.1% (wrt WT gen. power)

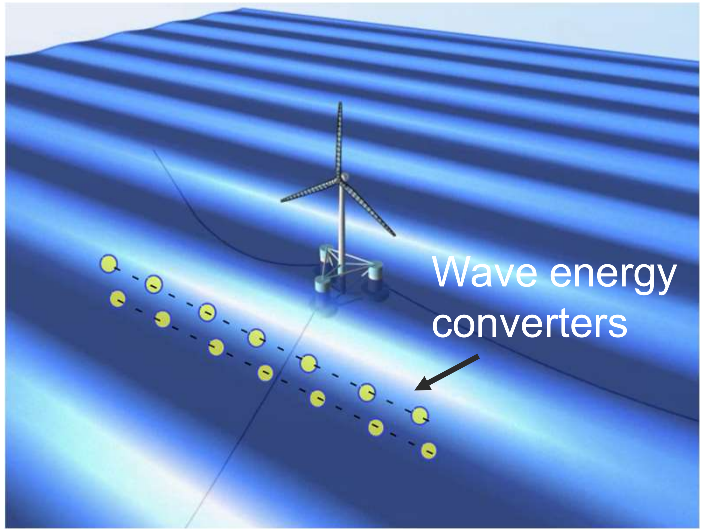


Potential complementarity (20% H_2 capacity):

- 10 WECs (~250 kW), or
- 02 tidal devices (~1.2 MW)
- Other ORE devices?

From hybrid platform to co-located farm





Hybrid platform

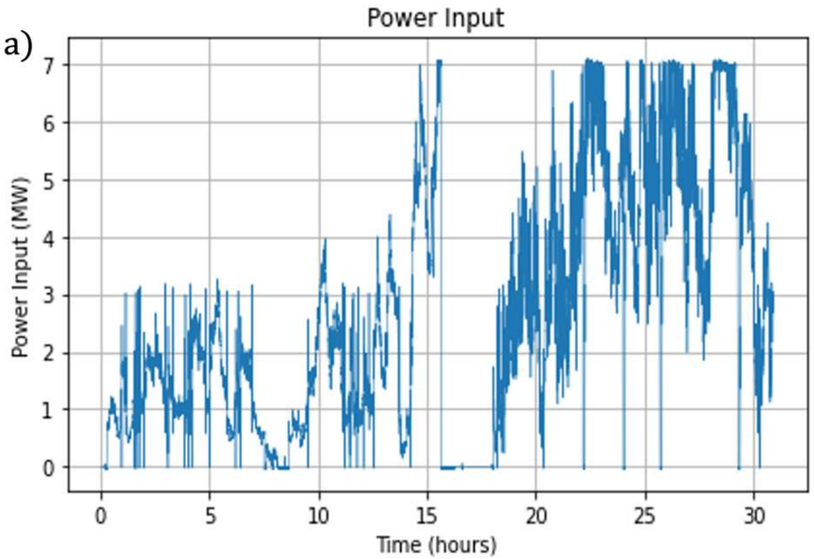
Arredondo-Galeana, A., Scarlett, G. T., Collu, M., & Brennan, F. (2025). A hybrid wind-wave floating platform to ensure a minimum power base load. Preprint: https://doi.org/10.31224/4553

Co-located wind-wave farm

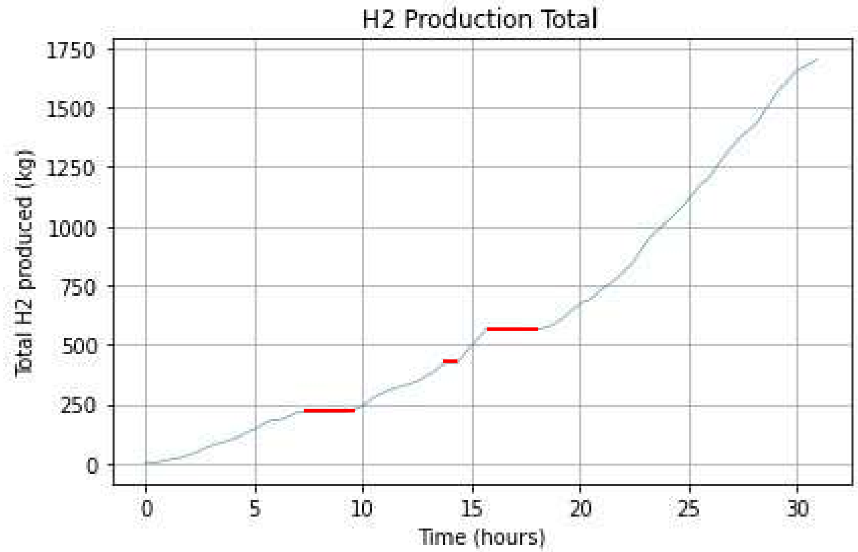
Arredondo-Galeana, A., et al. (2026). Exploiting wind and wave synergies for cost efficient offshore hydrogen production. (*In preparation*)

H2 production from wind only

a)



b)



Niblett, Daniel; Yeter, Baran; Mamlouk, Mohamed (2023). Wind Speed & Power Generated Dataset For Floating Offshore 7 MW and 15 MW Turbine. Newcastle University. Dataset. https://doi.org/10.25405/data.ncl.24516718.v1

Niblett, D. (2025). *powerToElectrolysis* [GitHub repository]. Retrieved August 28, 2025, from https://github.com/DNiblett/powerToElectrolysis

With co-located wind wave farm

1) How can wave power prevent no production intervals of hydrogen production?
2) What are the cost implications of bringing wave power into the mix?
3) How are higher frequency fluctuations detrimental to hydrogen electrolysers?

Arredondo-Galeana, A., et al. (2026). Exploiting wind and wave synergies for cost efficient offshore hydrogen production. *(In preparation)*

Integrating Novel Design, Strategic Lifespan, and Operational Frameworks to Minimise LCOH

•Mixed-Height Farm Design

•Smoothed power feed for electrolyser

Phased Retrofit Strategy

Designing new assets for future tech recapitalisation

Beyond 'Bolt-On' Integration

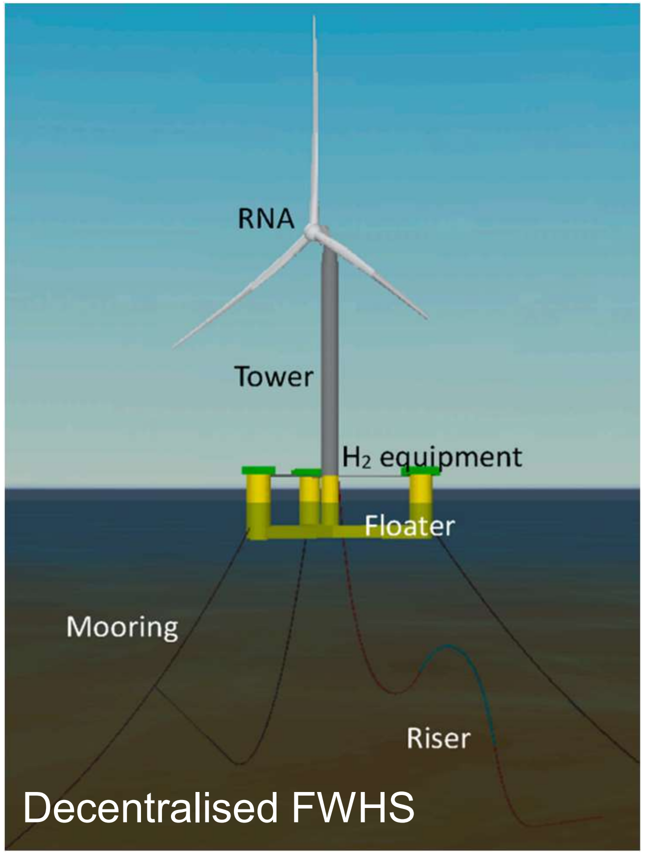
Low-Capex Turbine Specification

Shorter design life optimised for H_2

Unified Techno-Economic Framework

Co-optimising CAPEX, OPEX & real options value

Integrated analysis for H2 production system

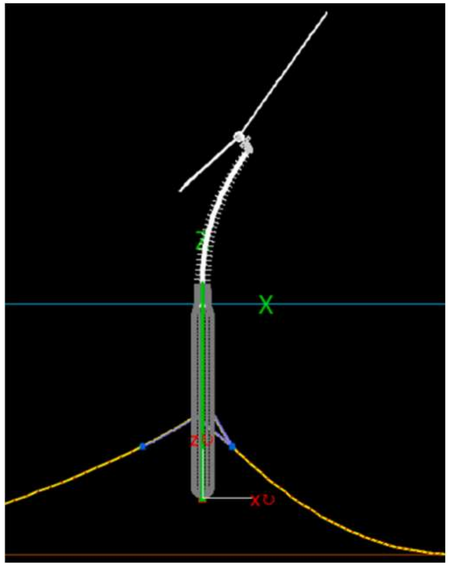


- Coupled dynamics
- Integrated analysis
- Basic design: aero-hydro-servo-elastic models
- Floating platform:

Rigid VS Multibody/ flexible

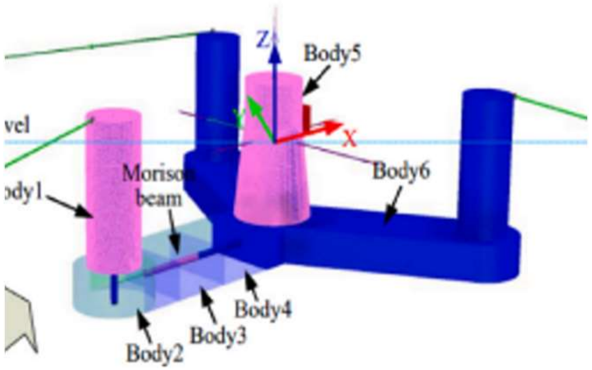
Rodríguez, C.A. et al., 2024. ***"Design considerations and preliminary hydrodynamic analysis of a decentralised floating wind-hydrogen production system"****. Int'l Journal of Hydrogen Energy, 89.*

Hydro-structural modelling for integrated analysis



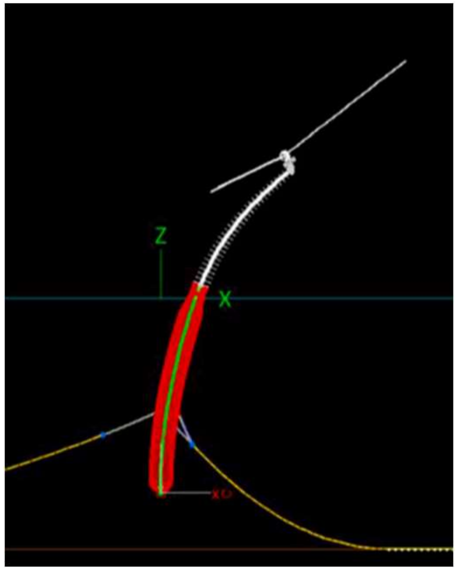
Lee, I., Kim, M., & Jin, C. (2025). Impact of hull flexibility on the global performance of a 15 MW concrete-spar floating offshore wind turbine. *Renewable Energy*, 197, 1081–1098.

Rigid
- Implementation is easy
- Computational efficient
- No platform structural analysis



Wang, S., & Moan, T. (2024). Analysis of extreme internal load effects in columns in a semi-submersible support structure for large floating wind turbines. *Ocean Engineering*, *291*, 116372.

Multibody
- Implementation is medium
- Acceptable computation effort
- Platform structural analysis



Lee, I., Kim, M., & Jin, C. (2025). Impact of hull flexibility on the global performance of a 15 MW concrete-spar floating offshore wind turbine. *Renewable Energy*, 197, 1081–1098.

Flexible
- Implementation is hard
- Elastic analysis
- Platform structural analysis

Conclusions

- Accelerations and motion frequencies at electrolyser locations vary greatly between operational, severe, and extreme sea/wind conditions.
- Most hydrogen production downtimes are short and coincide with mild seas, suggesting that small-scale complementary generation or storage can effectively maintain system reliability.
- Wind and wave offshore renewable generation in swell dominated regions decreases wind power downtime.
- Co-location of wind and wave technologies is a feasible alternative. The monetary impact of co-location for hydrogen generation is one objective of our new study.
- Multi-fidelity structural modelling of the floating platform allows its application at various design and optimization stages.

Next steps


Ocean-REFuel
Mid-Term Review Report
November 2024

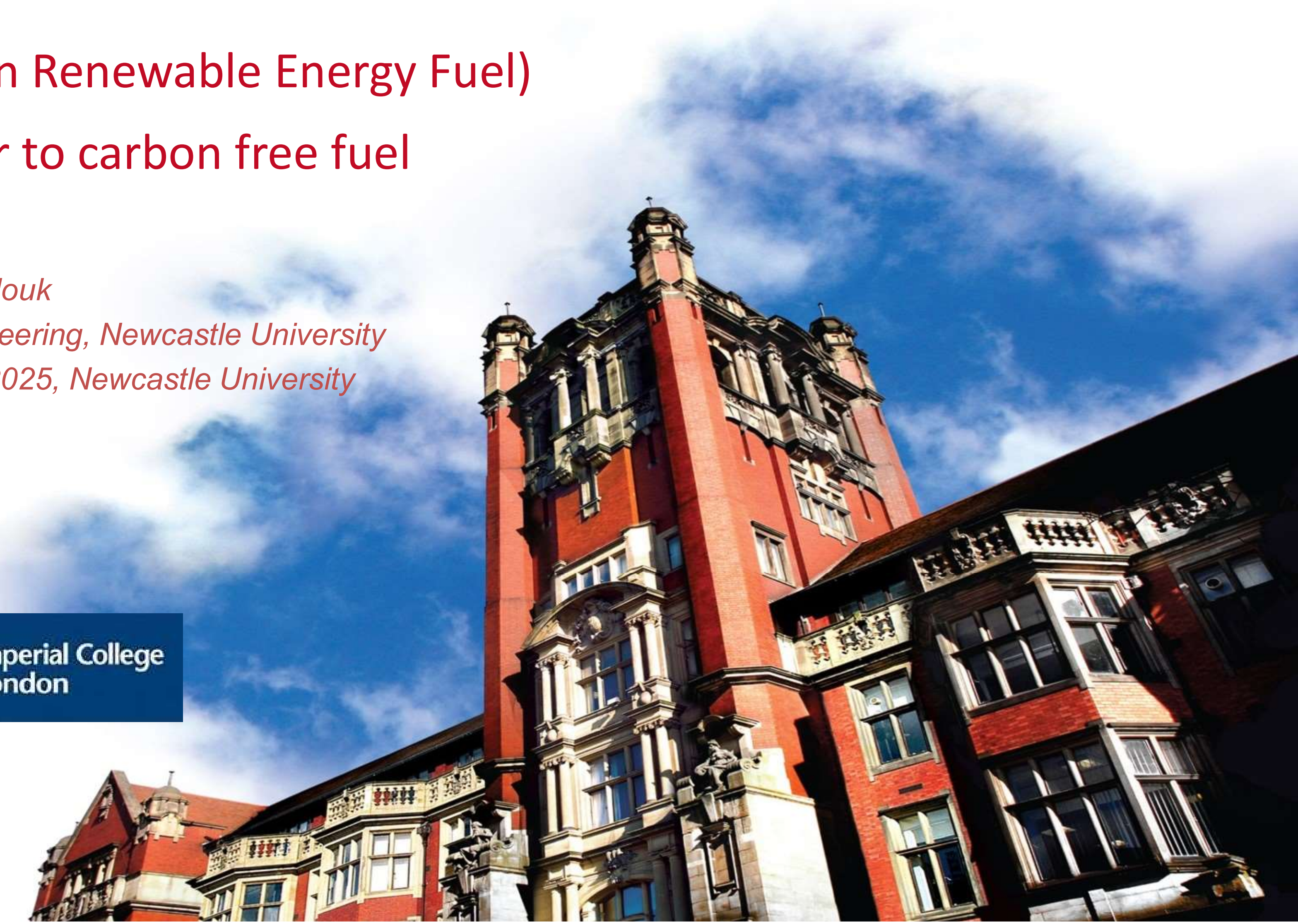
- Continue interacting: NU → validate design limits and hydrogen system integration
  UoN → LCA comparison: centralised vs. decentralised);
- Continue with CorPower and NU the study on co-location of wind and wave energy.
- Assess complementary offshore devices or storage to support hydrogen production during partial-load wind conditions, not just during turbine downtime;
- Establish an integrated engineering model for time-domain structural analysis for the FWHS under various loading conditions → review paper
- Continue collaborating with Imperial College to develop an optimised LCOH model, providing clearer insights into how offshore wind farm design and operational strategies influence the cost of green hydrogen.

University of Strathclyde Engineering

Ocean-REFuel (Ocean Renewable Energy Fuel)

Workstream2: Power to carbon free fuel

Mohamed Mamlouk
School of Engineering, Newcastle University
9th September 2025, Newcastle University



Overview

1. Membrane-less electrolyser
2. AEM based Electrolysers
3. Rotating cells and MFIE
4. Electrolyzer in floating Offshore simulation
5. Questions and open discussion

Overview

1. Membraneless electrolyser & modelling
2. AEM based Electrolysers
3. Rotating cells and MFIE
4. Electrolyzer in floating Offshore simulation
5. Questions and open discussion

Daniel Niblett

Publication

May 2025 - Niblett, Daniel, Hosni Ahmed Elwan, and Mohamed Mamlouk. "**Membraneless water electrolysis enabled by flow and porous electrode design for bubble separation.**" *Chemical Engineering Journal* 519 (2025): 163444. https://doi.org/10.1016/j.cej.2025.163444

Covering the insights established during numerical simulations and small electrolyser cell prototyping

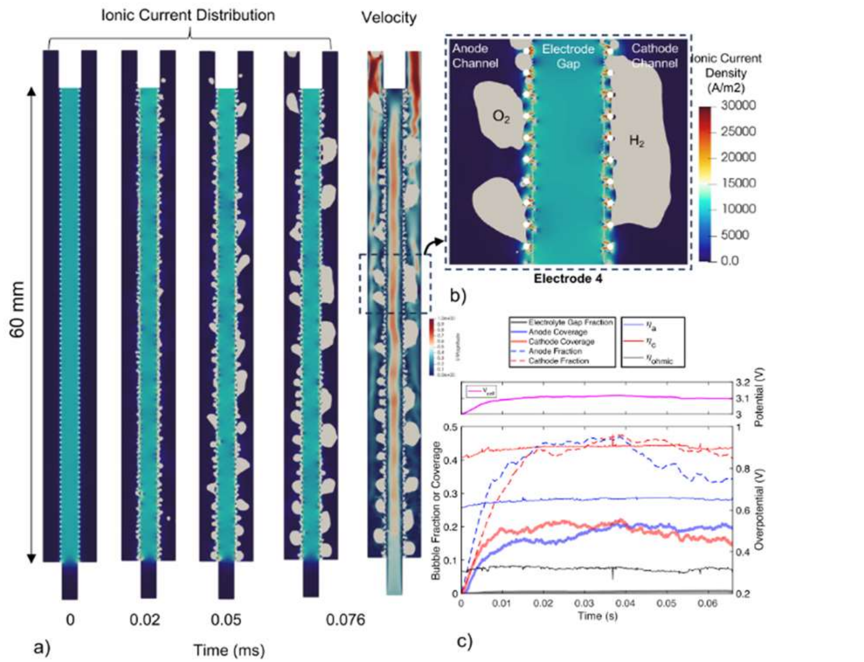


Fig. 8. Simulation of the experimental cell with electrode 4 (2.1 mm electrode gap), scaled to 6 cm operating at a fixed current density of 1 A cm^{-2}. (a) timeframes of the ionic current distribution, bubble fraction and velocity field. (b) close-up view of the electrode gap and current distribution affected by bubbles in outlet channels. (c) breakdown of the cell potential into electrode and ohmic overpotentials along with bubble surface coverage (thick lines) and bubble volume fraction (dashed lines).

Re = 595, j = 3 A/cm2

Re = 595, j = 5 A/cm2

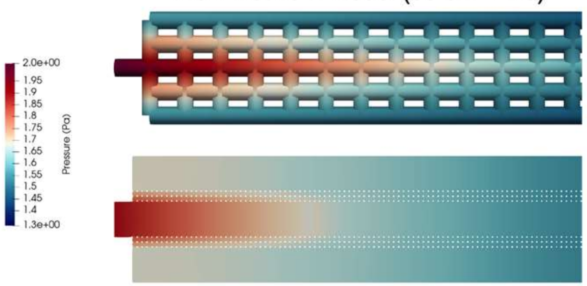
Membraneless Scaling

April 2025 - Small fund awarded to team: EPSRC North East Net Zero Accelerator Fund: Dr Niblett (PI), Prof Mamlouk (Co-I) Scaling of Membranless Electrolyser (£30k) - working on scale up of membraneless electrolyser technology.

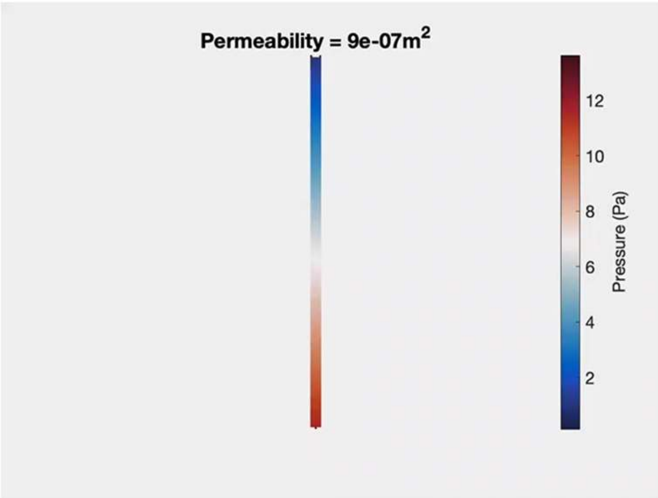
July 2025 - Patent Update: **UK Patent Application No 2410504.1 Membrane free electrolysis PCT and top-up application**

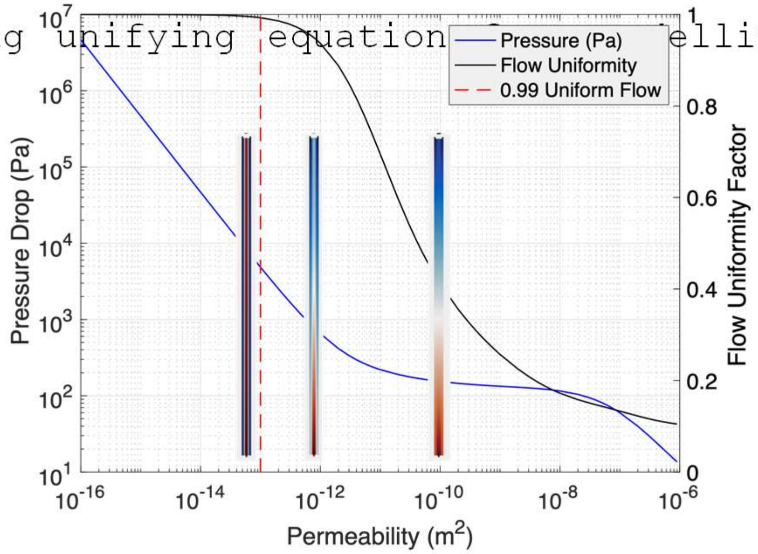
New limitations on electrode properties found by deriving unifying equation [illegible] elling results of flow distribution

Flow Network Model (50 cm = 1 s)



CFD Pressure Distribution (50 cm = 1 hour)





Electrolyser Height = **20 cm length**,
Electrode Thickness = 1.5 mm
Electrode Gap = 1 mm
Inlet Re = 50
Viscosity = 0.002 Pa s
Density = 1288 kg/m3

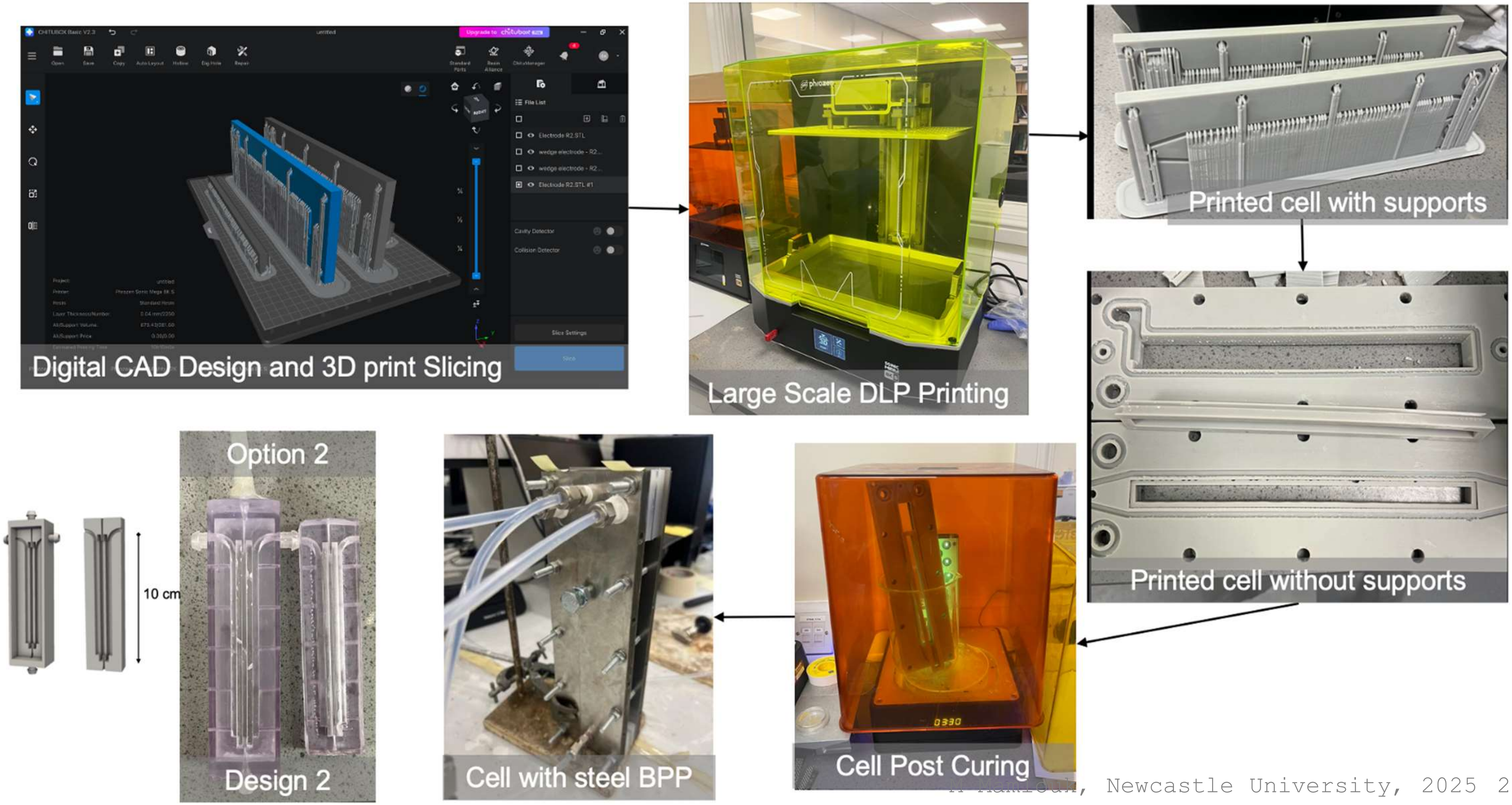
Target Permeability: 10^{-13} – 10^{-12} m^2

Cutom code for flow network established in MATLAB (x3600 faster than CFD)

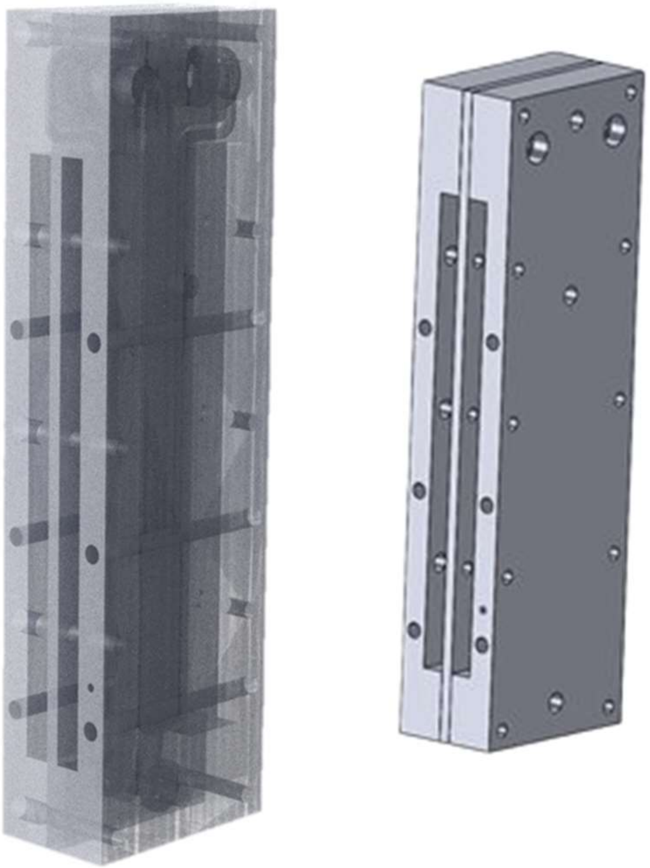
Membraneless Scaling Manufacturing Cell

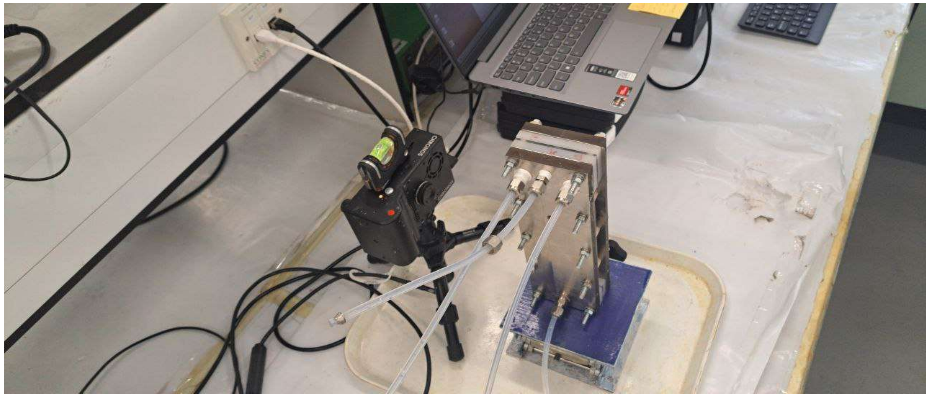
Ocean REFuel

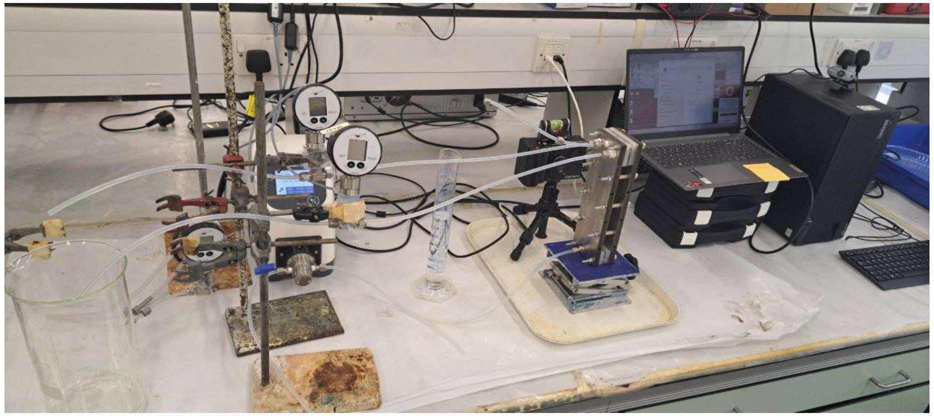
Newcastle University

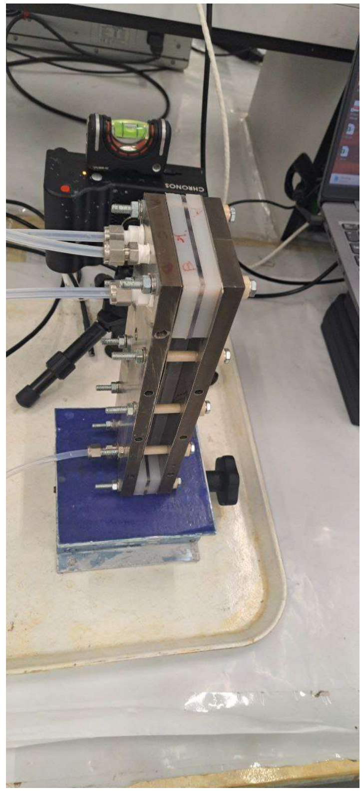


Membrane-less flow through electrolyzer

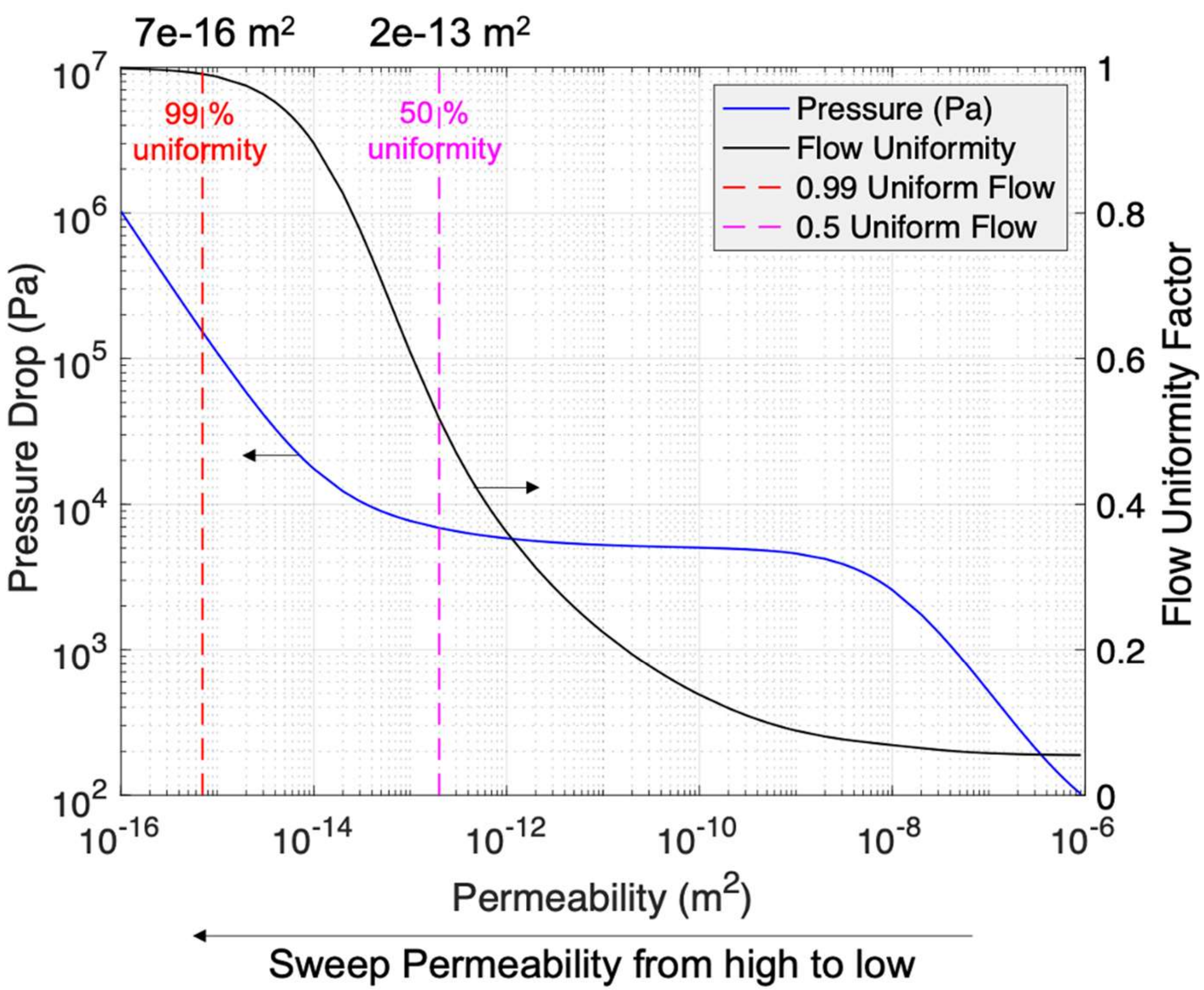


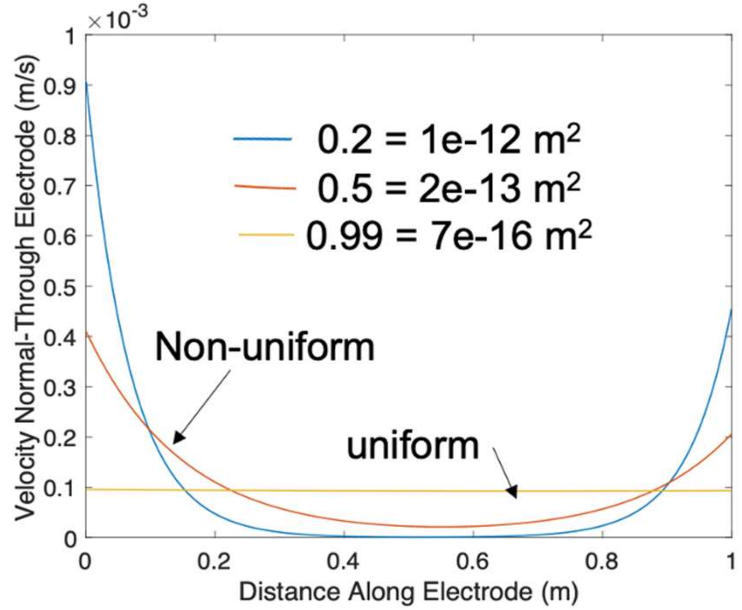






Simulation of flow distribution **100 cm**

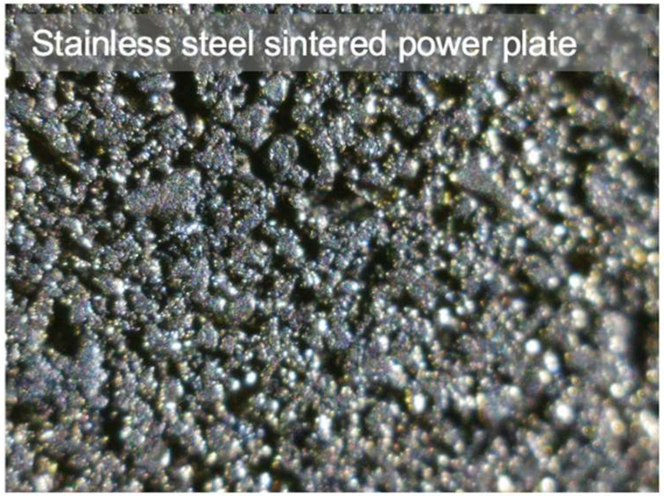


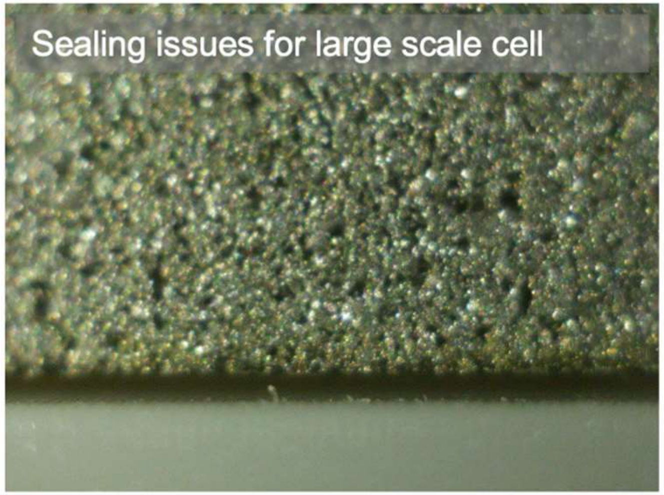


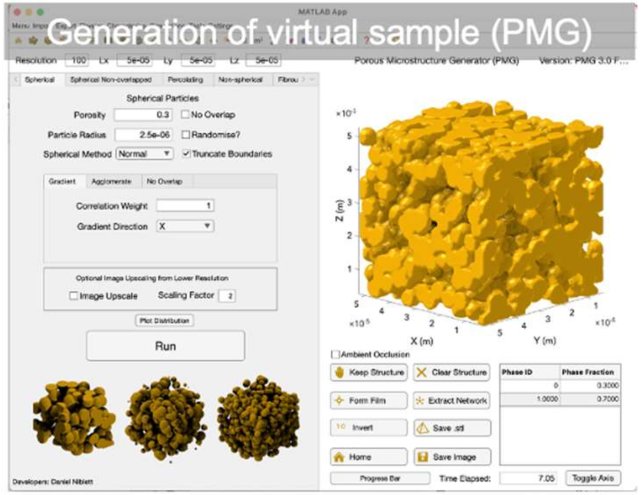
Flow distribution through electrode at different permeability values

Lower permeability electrode required for scale: Function of gap size, electrode thickness, Electrolyser height

Electrode Material Characterisation

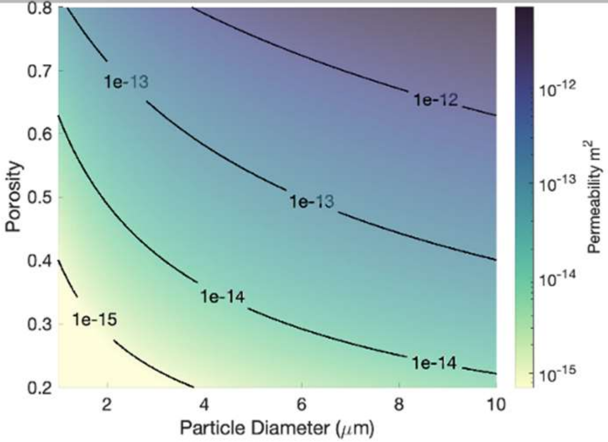






Specific surface area estimation from PMG 3.372x10^5 m^2/m^3

Estimating permeability for packed spheres



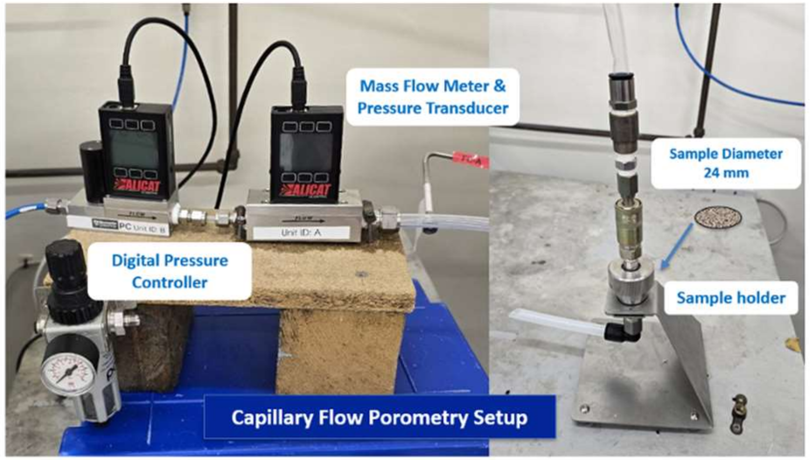
$$k = \frac{d_p^2 \epsilon^3}{180(1-\epsilon)^2}$$

$$d_{pore} = \frac{d_p \epsilon}{1-\epsilon}$$

Kozeny Eqn

Permeability and pore size method from manufacturer not specified so cannot be trusted

Permeability Measurements - CFP

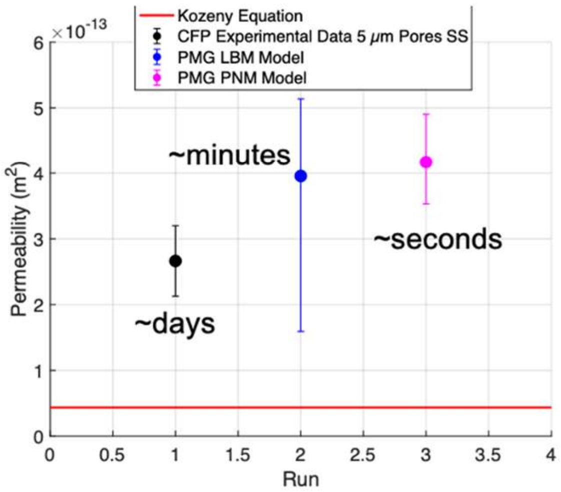


3 mm stainless steel plate (30% porosity)

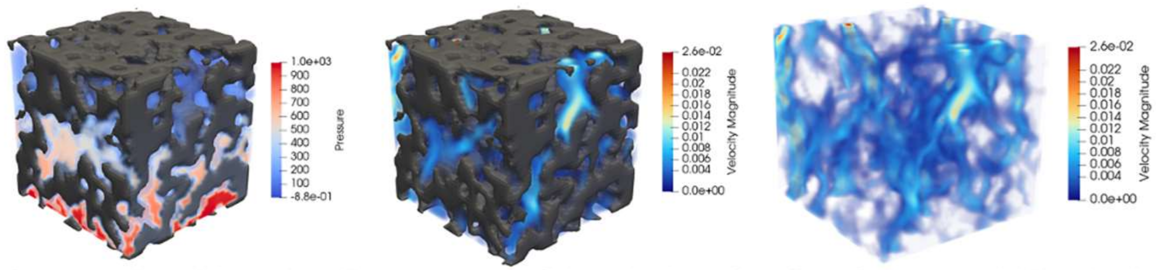
Runs	Bubble Point Pressure [Pa]	Max Pore Size [µm]	Min Pore Size Pressure [Pa]	Min Pore Size [µm]	Mean Pore Pressure [Pa]	Mean Pore Size [µm]	Median Pore Size [µm]	Maximum Relative Permeability [m²]
Run 1	11440	6.59	44440	1.70	26820	**2.81**	3.47	**3.27E-13**
Run 2	13470	6.01	44440	1.82	27350	**2.96**	3.56	**3.08E-13**
Run 3	10600	7.64	39960	2.03	24410	**3.32**	3.85	**2.95E-13**

1.5 mm stainless steel plate (30% porosity)

Runs	Bubble Point Pressure [Pa]	Max Pore Size [µm]	Min Pore Size Pressure [Pa]	Min Pore Size [µm]	Mean Pore Pressure [Pa]	Mean Pore Size [µm]	Median Pore Size [µm]	Maximum Relative Permeability [m²]
Run 1	8700	9.31	22220	3.64	19470	**4.16**	5.23	**2.27E-13**
Run 2	8730	9.27	23900	3.39	20040	**4.04**	5.63	**2.21E-13**
Run 3	9660	8.38	22240	3.64	19380	**4.18**	5.27	**2.20E-13**



Permeability also predicted by 3 ways: LBM, pore network model and Kozeny Eqn:

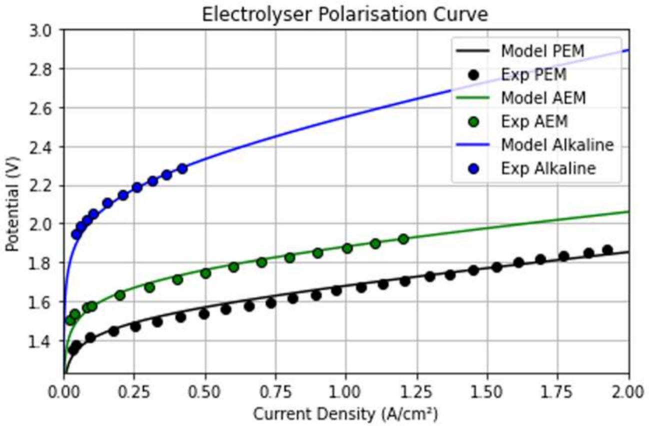


Customised Lattice Boltzmann Simulation for flow/permeability built within our software tool (Porous Microstructure Generator) – 4 minutes

Power to Electrolyser Coupling

https://github.com/DNiblett/powerToElectrolysis

PowerToElectrolysis: Developed simple electrolyser model (python) for converting power to produced hydrogen with options of: stack number, stack size, minimum load and electrolyser type (PEM, AEM, Alkaline).



Predicted polarisation curves for each electrolyser in model

$$\frac{P_{stack}}{A_{cell}V(i)i} = N_{cells}$$

Fixed rated stack power consumption, Fixed cell area, potential and current set to find number of cells.

Solve non-linear predictive model for electrolyser for every power timestep

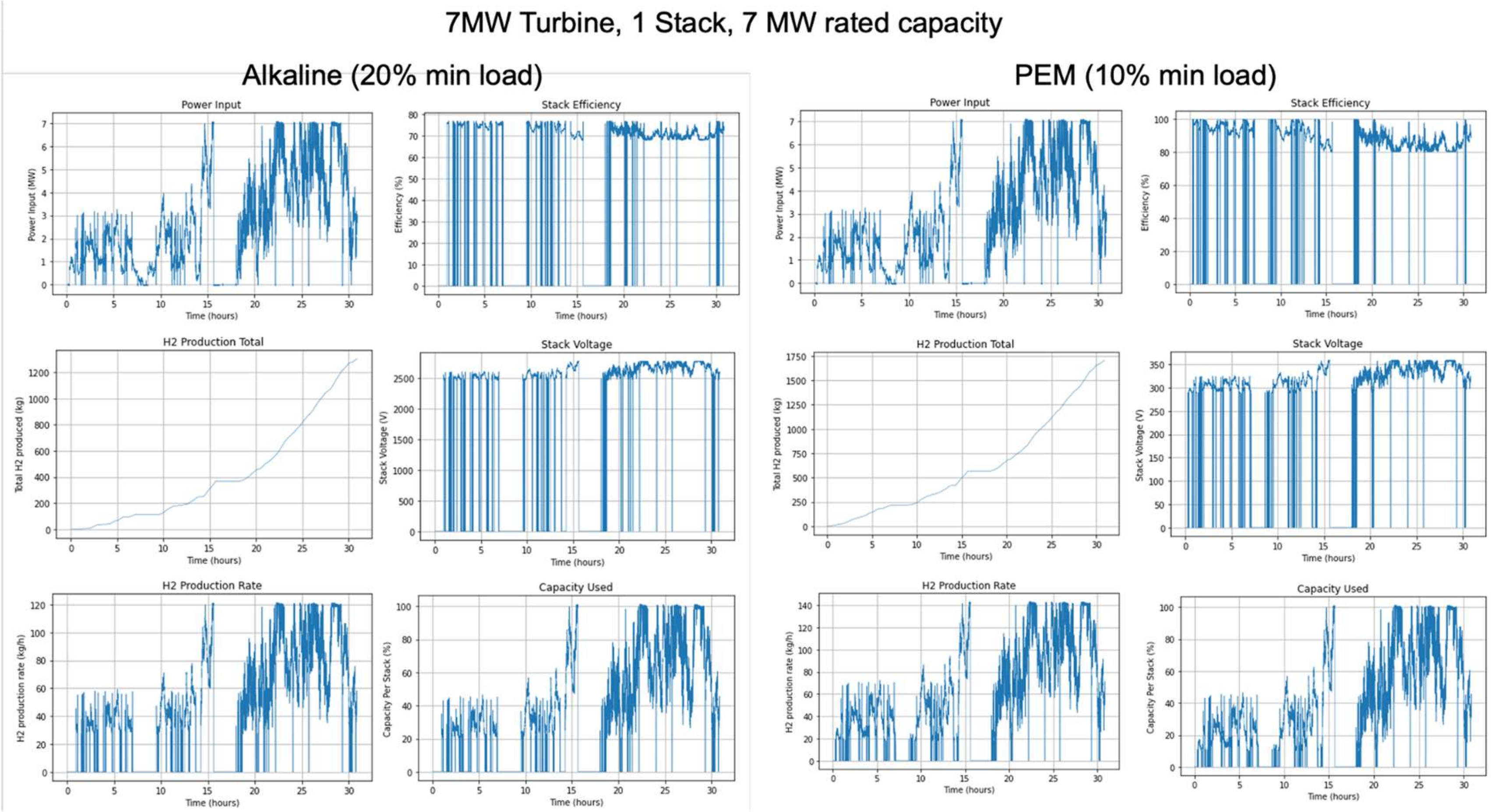
$$f = N_{stacks}N_{cells}A_{cell}\left(2b\ln\left(\frac{i}{i_{0a}r_f}\right) + \frac{i\delta}{k}\right)i - P_{turbine}$$

Hydrogen production rate from Faraday's law of electrolysis:

$$\dot{m} = \frac{j A_{cell} N_{cell} M_{H_2}}{2F}$$

Power to Electrolyser Coupling

https://github.com/DNiblett/powerToElectrolysis



Overview

1. Membrane-less electrolyser
2. AEM based Electrolysers
3. Rotating cells and MFIE
4. Electrolyzer in floating Offshore simulation
5. Questions and open discussion

Ramakrishnan Shanmugam

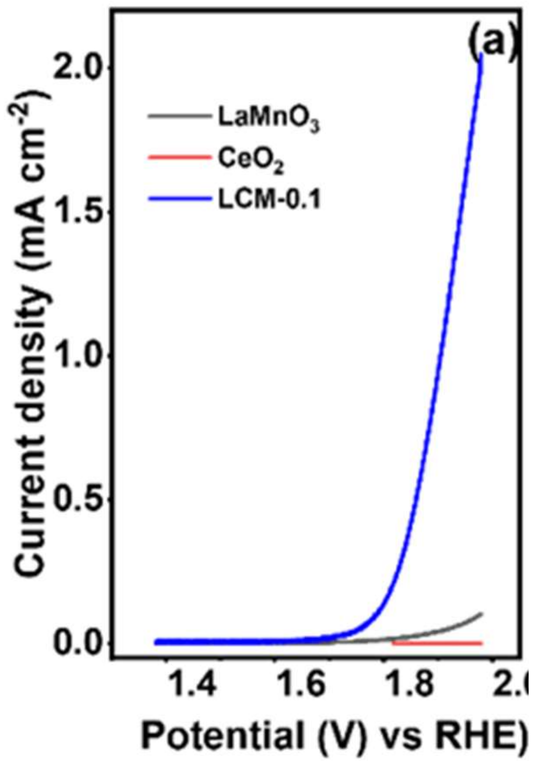
Publication

Title : **Enhanced oxygen evolution reaction activity of Cerium oxide modified lanthanum manganese oxide perovskite catalyst in anion exchange membrane water electrolyser**

Journal Name : Energy & Fuels (ACS)

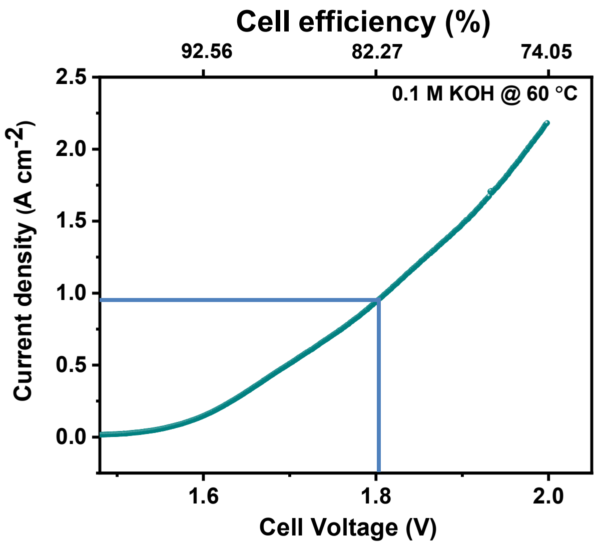
Status : Revision Submitted (Manuscript Id ef-2025-03080b.R1)

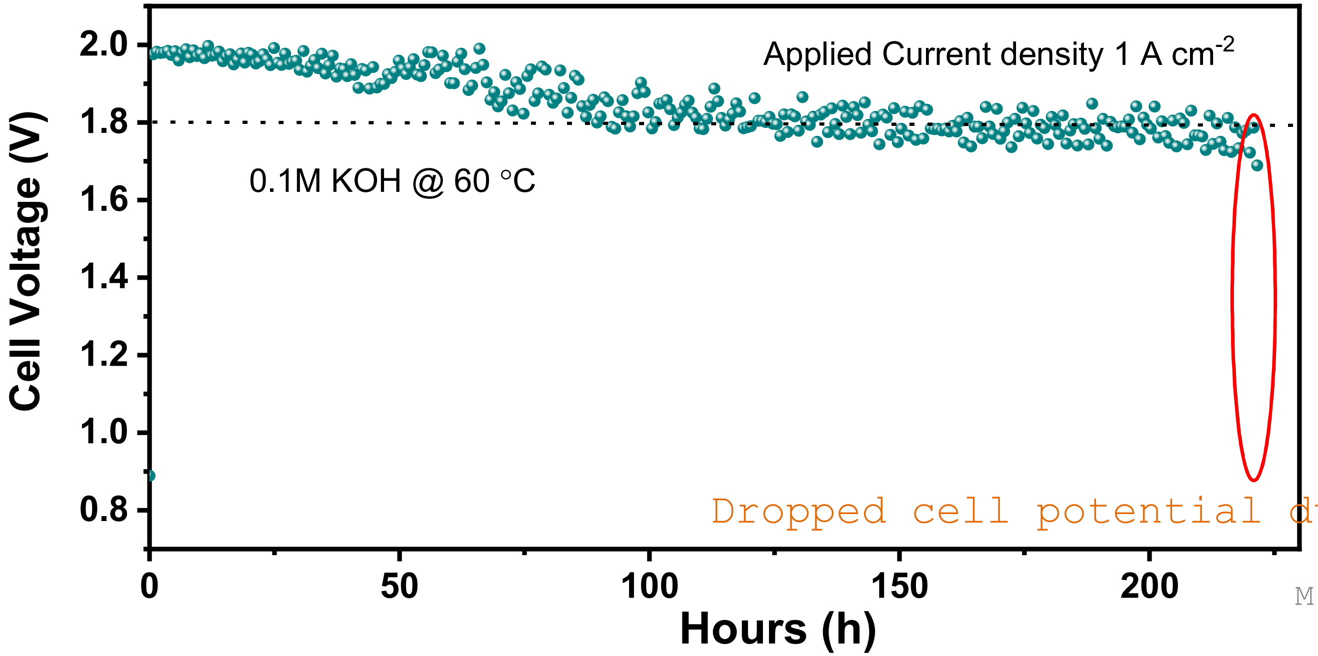
Finding : The optimised electrocatalyst of 10 wt% of CeO_2 added lanthanum manganese perovskite (LCM-0.1) showed improved OER activity, achieving a greater than 22-fold increase in generated current density at 1.9 V vs. RHE (reversible hydrogen electrode) in 0.1 M KOH compared to pure $LaMnO_3$



Stability test for AEM Electrolyser

MOx-LDH @ NF // Pt-C at 0.1M KOH at 60 °C





Dropped cell potential due short

Overview

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Mostafa Delpisheh

Multi-physics modeling of the SDR

- ✅ Electromagnetism
- ✅ Tertiary Current Distribution (with transport phenomena)
- ✅ Magnetohydrodynamics
- ✅ Multibody systems
- ✅ Two-phase flow
- ✅ Multi-physics Coupling
- ➤ Experimental validation
- ☑ Designs exploration

Objective : Validating the magnetic field from the simulation model with those from experiments using Gaussmeter

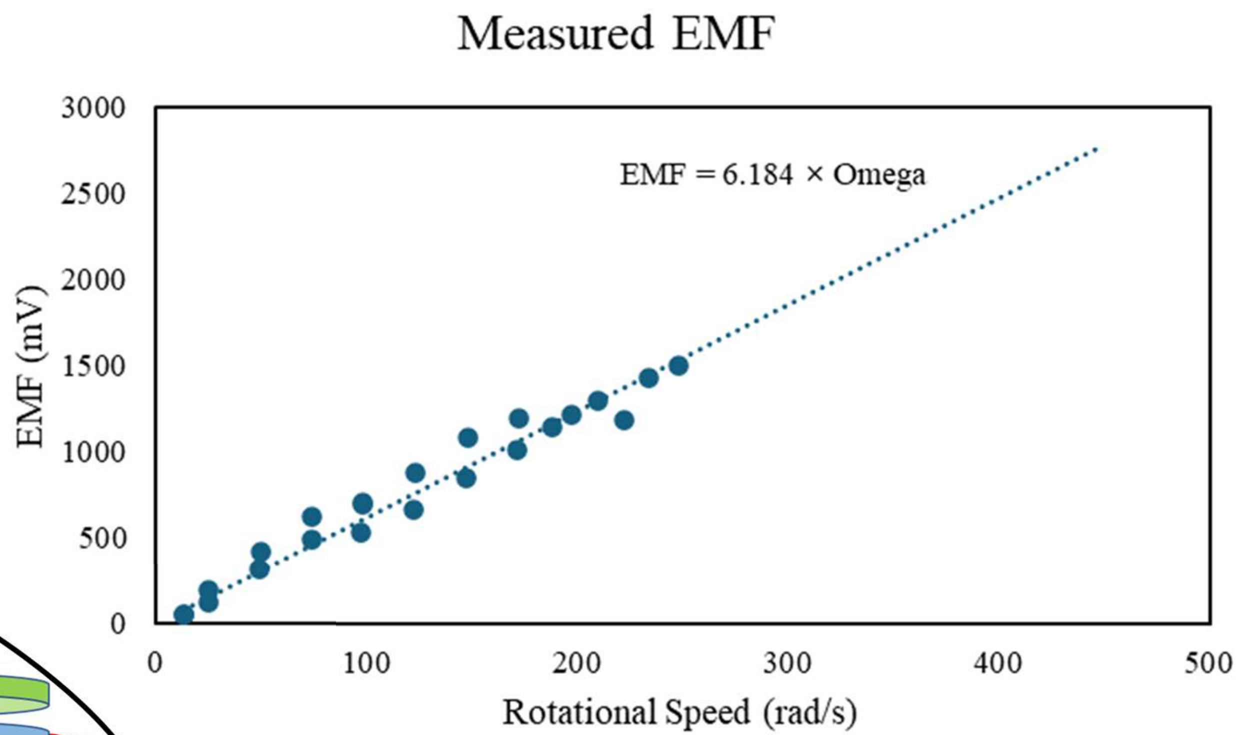
Objective : Calculating the energy losses from bearing, minor shaft misalignment, pulley, etc.

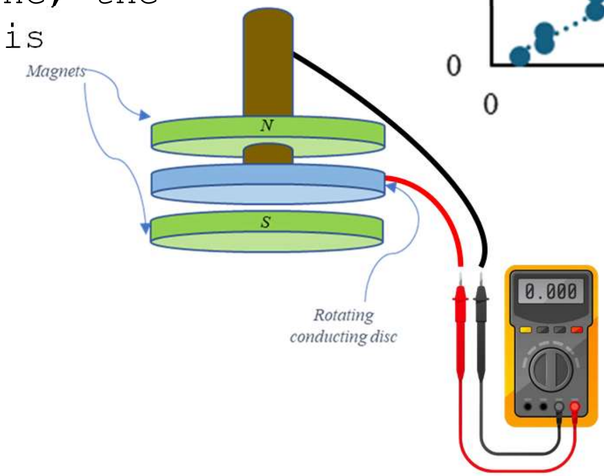
Voltage measurement in SDR

The voltage is measured between the rim of the disk and the shaft, under the exposure to two magnets, as displayed in the schematic below.
Theoretically, it can be calculated as:

$$EMF = -B \times \frac{dA}{dt} = -\frac{1}{2}B\omega r^2$$

Where r is disc radius, with a rotational speed of ω, within a magnetic field of strength B.
Using the formula and the measure EMF and relevant trend line, the effective magnetic field is calculated at 766.82 mT.

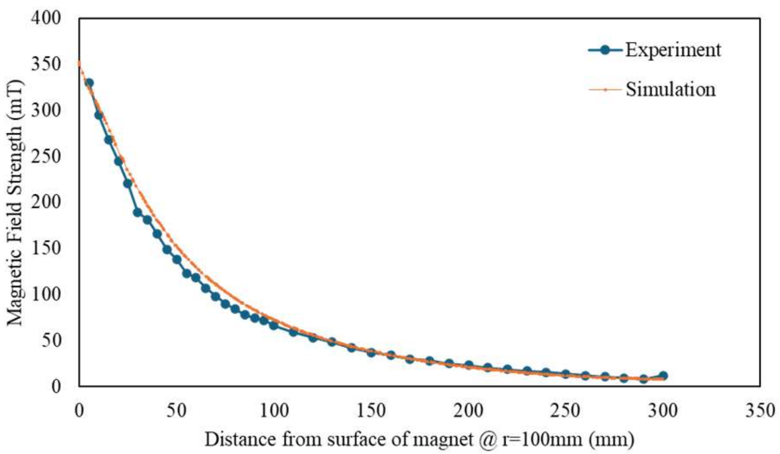


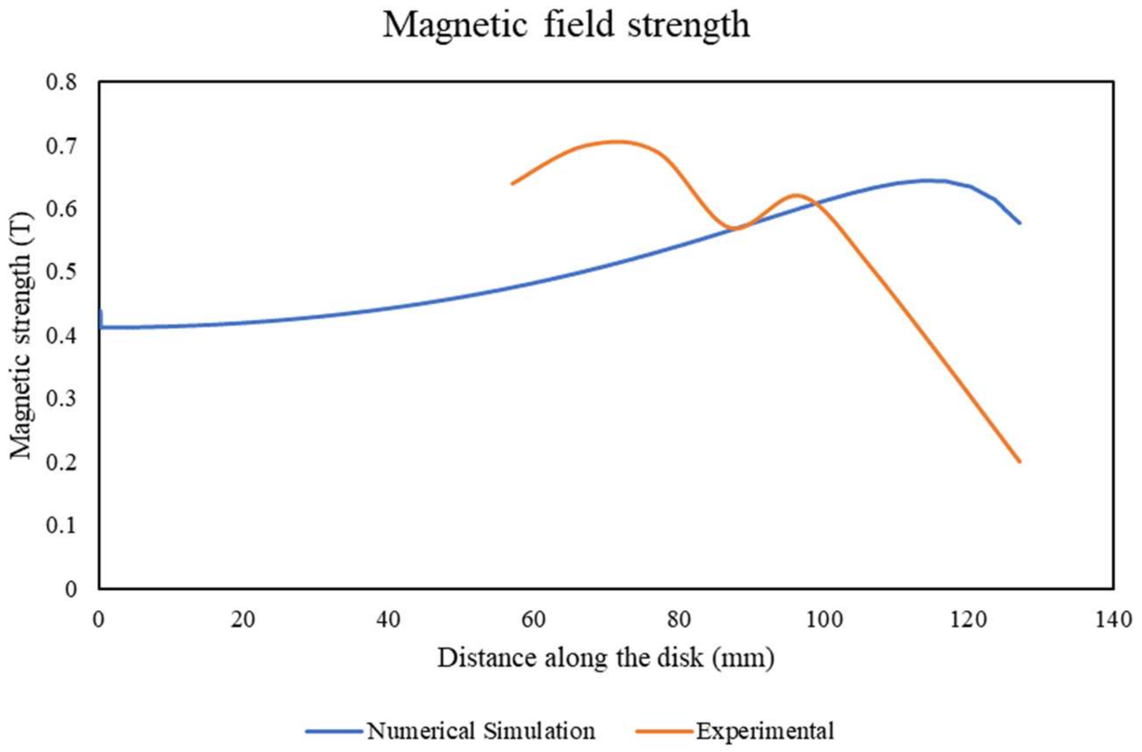


Magnetic field strength

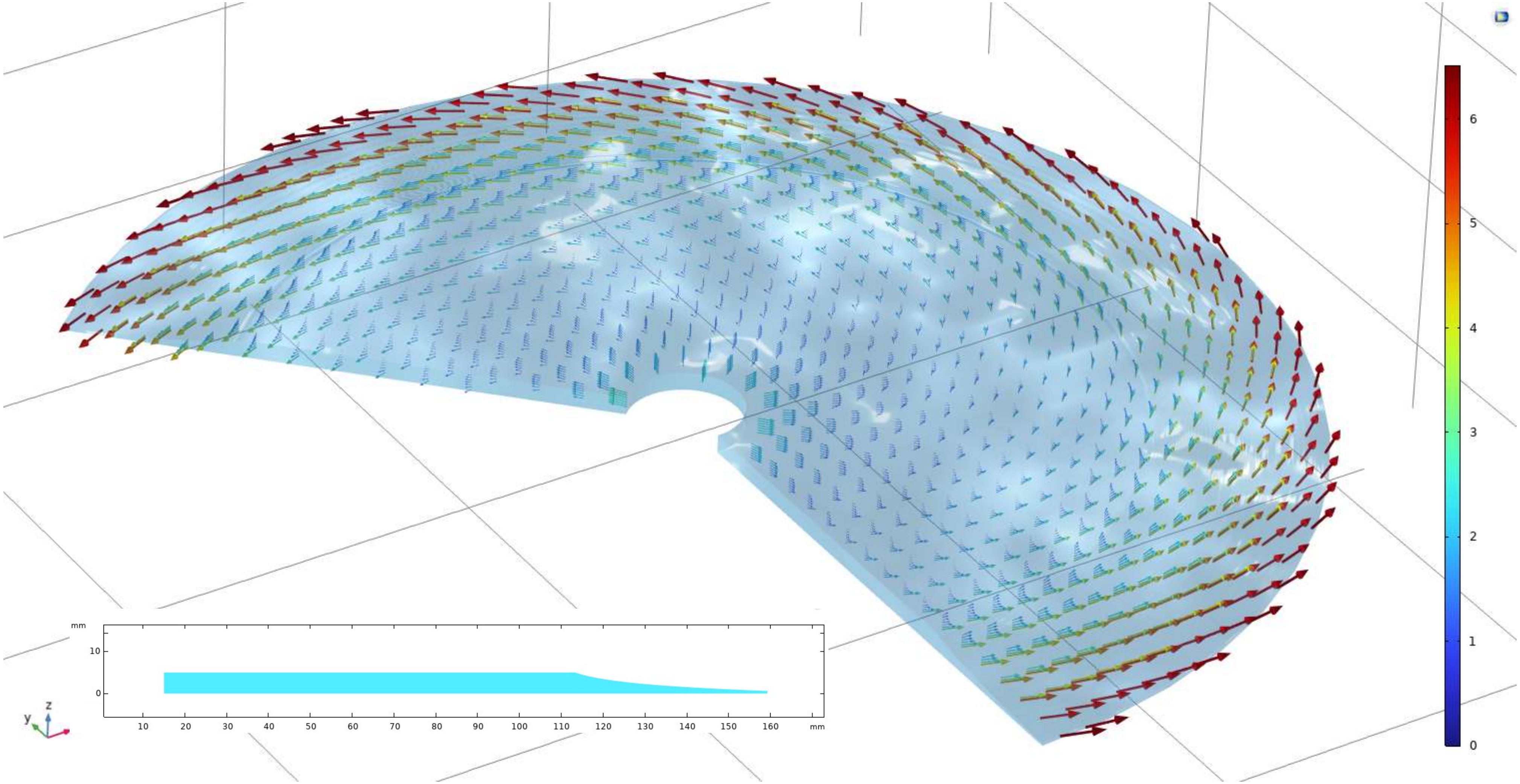
The magnetic field strength in the space between is measured using Gaussmeter and compared to numerical simulation in COMSOL.

Average values (mT) from 60 mm onwards	
Numerical Simulation (COMSOL)	570
Experimental (Gaussmeter)	560





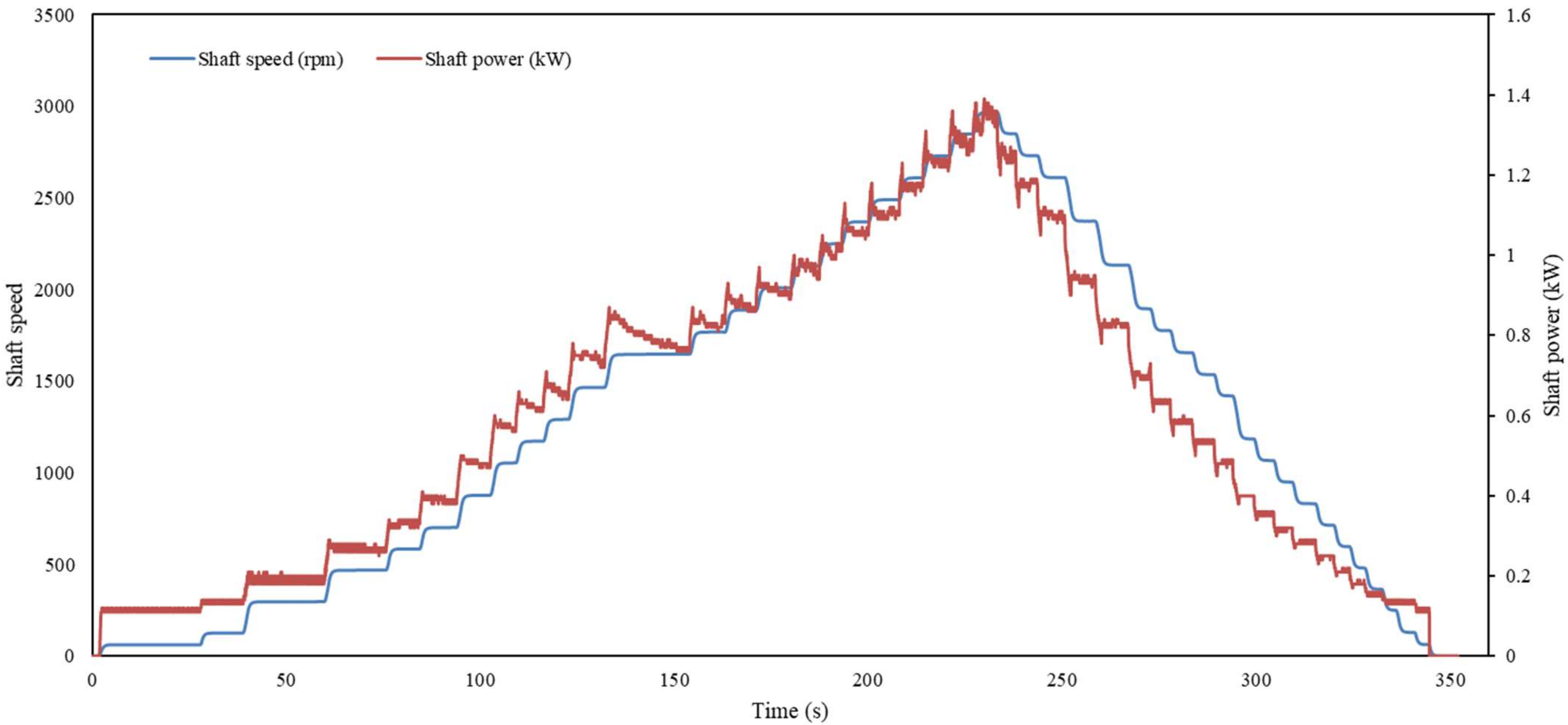
Two-phase flow physics of SDR



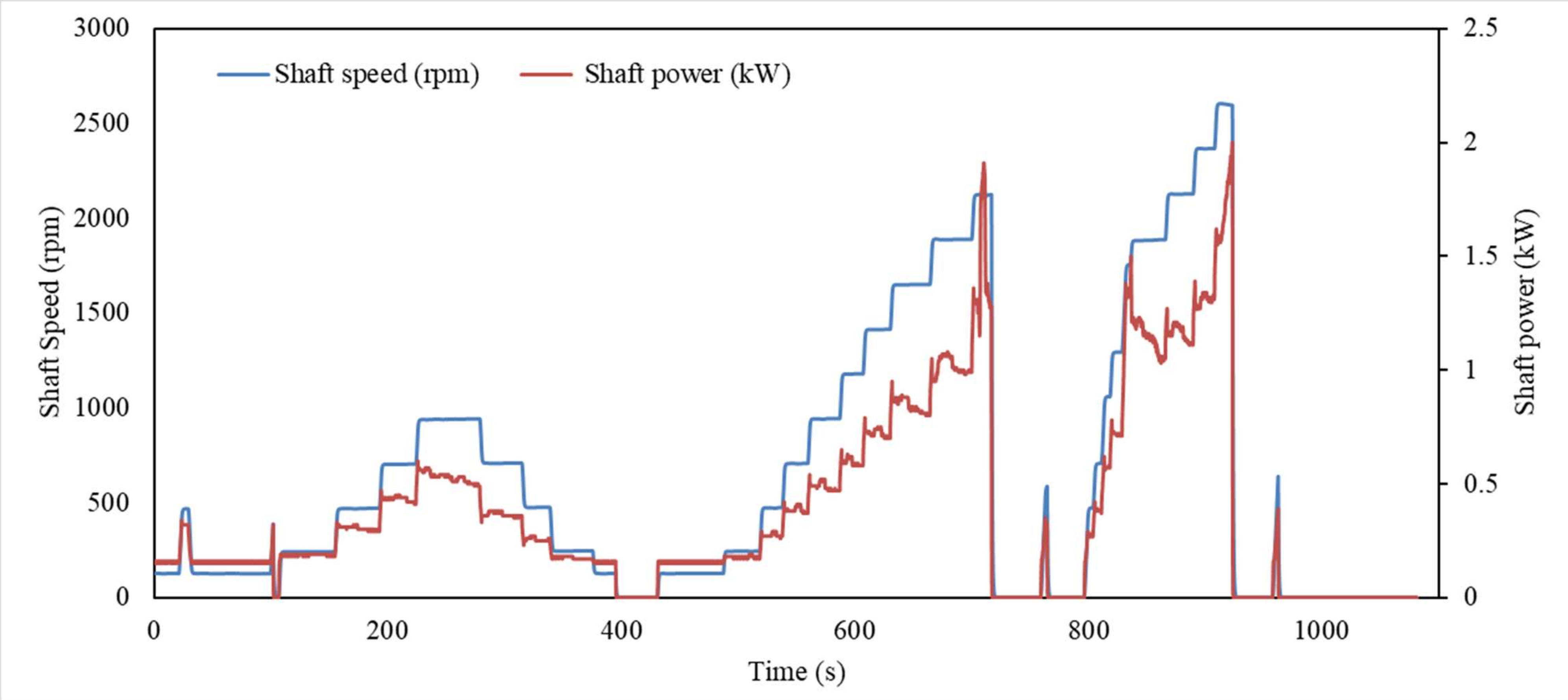
Magnetic field strength

- 407 rpm of shaft
- 134 SLPM purge air
- 33 LPM (2 m^3/h) water circulation

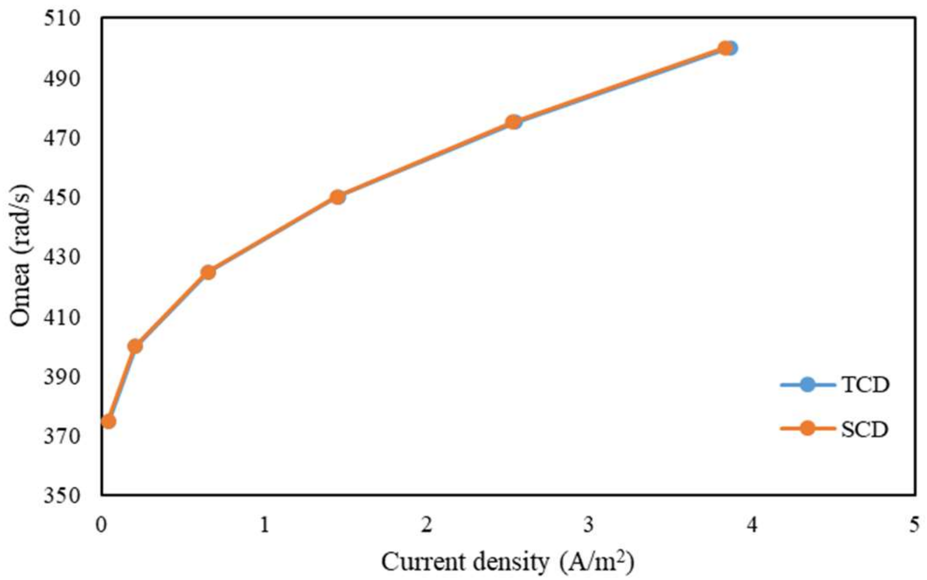
Energy losses in SDR – Without disk



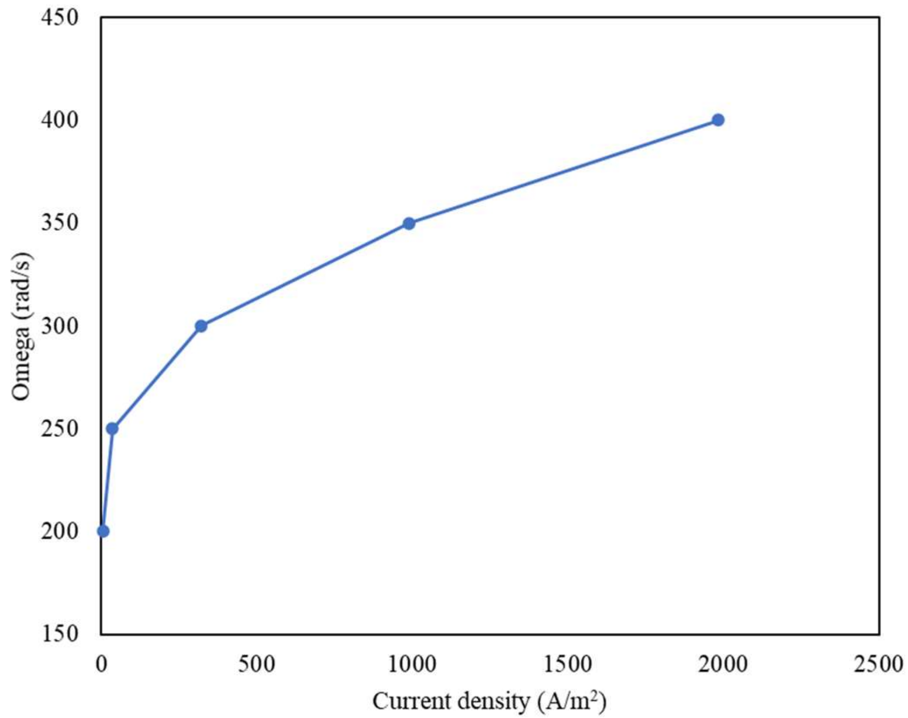
Energy losses in SDR – With disk



Current electrolzyer performance and projected design



Present system



Projected future Design

Overview

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Majid Rahgoshay

AWE Electrolyser Modification

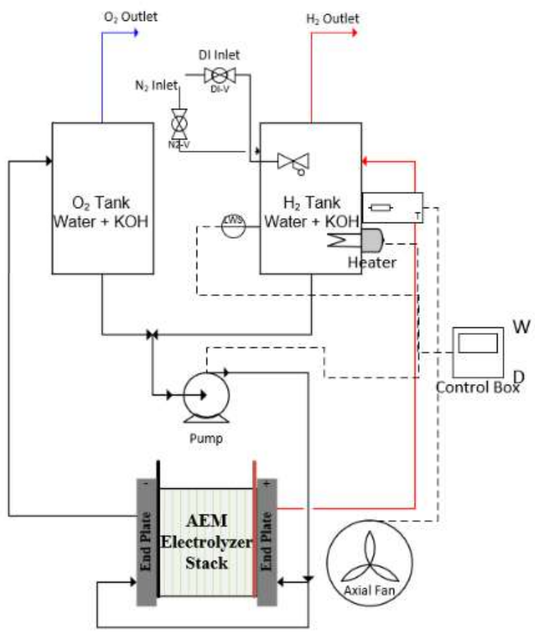
Modify AWE electrolyser system to test condition:

- **Add chiller line** for better gas–liquid separation *(by S.H2 & NCL)*
- **Shortened electrolyser system** to fit test bay size *(by NCL)*
- **Reinforced mechanical connections** to withstand motion platform movements *(by NCL)*
- **Changed water feeding feedback** from flowmeter to conductivity meter *(by S.H2)*
- **Omitted water heater and reduced electrolyte tank volume** *(by S.H2)*
- **Added baffle inside electrolyte tank** to reduce bubbling and splashing *(by S.H2 & NCL)*

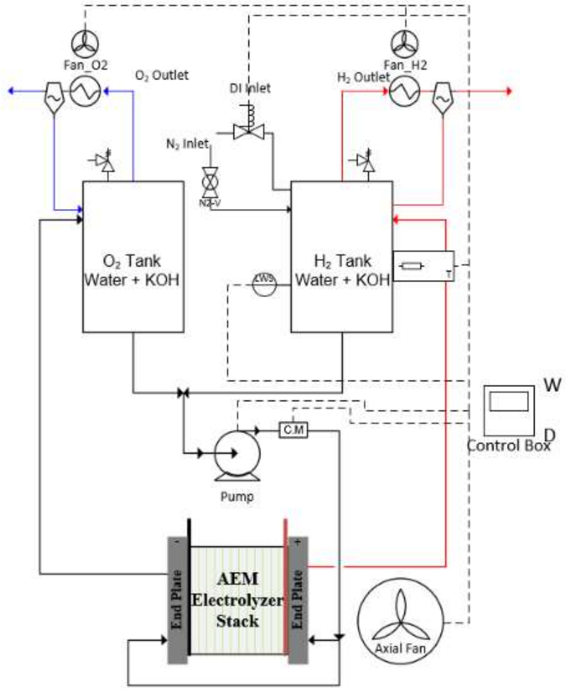
SungreenH2 Electrolyzer

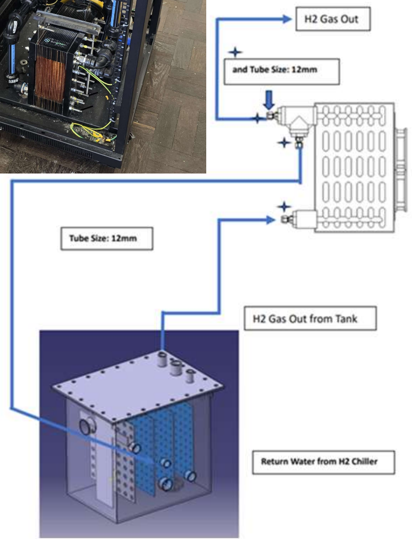
Globe Valve	Ball Valve
Check Valve	Relief Vavle
Float Valve	Solenoid Vavle
Pump	Flow Meter
Gas Filter	Water Filter
Separator	Low water Switch
Flow Meter	Conductivity Meter
Deionized Water	Heat Exchanger
Dryer	Temp Sensor
Mass Specs	
N2	KOH
O2	H2
Wiring	

Before



After Modification

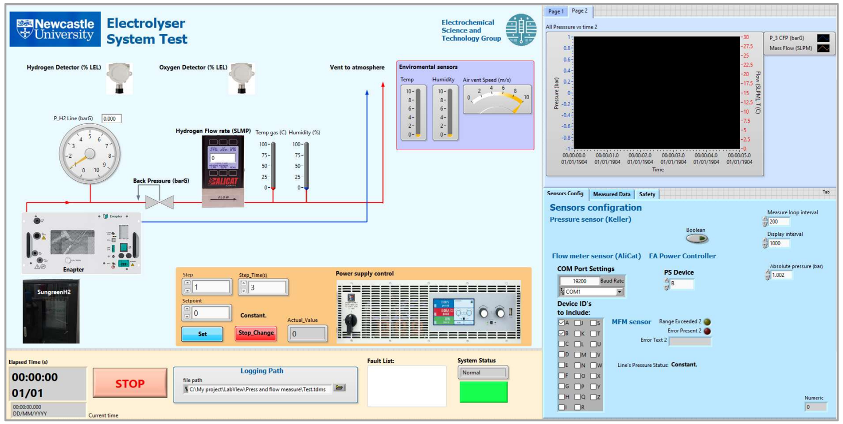


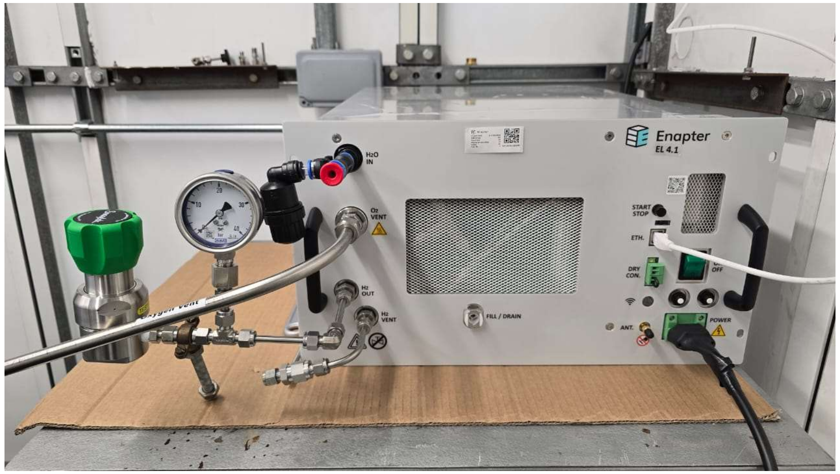


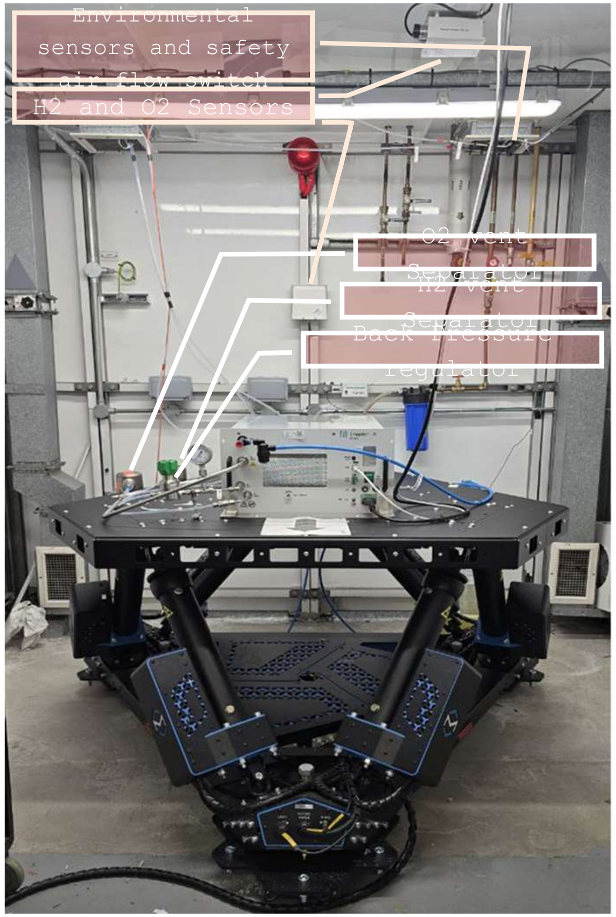
Preparing test bay

Preparing test bay for testing both electrolyser system

PS-6TL-350 Motion Platform (x 1)







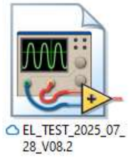
Preparing test bay

Upcoming work for preparing test bay for testing both electrolyser system

- ✓ **Testing Motion Platform:**
  - Changing Yaw, Pitch and Roll degree.
  - Changing Heave, Sway and Surge displacement.
- ✓ **Applying motion profile to platform with computer**

- **Preparing LabVIEW code for control and monitoring sensors in test bay with new NI datalogger**
  - **UI Design of Test bay for WE testing**
  - **Cell Voltage monitoring of electrolyzer Stack**

Compact DAQ Chassis	cDAQ-9174
Datalogger Module	NI-9202 - 784400-01
	NI-9205



- **Appling power profile**
  - ✓ **Using EA software (Done)**
  - **Integrating applying current profile with LabView (InProgress)**

Electrolyser Testing

Defining test protocols.

- ❑ AEM 35 barg H_2
- ❑ AWE near ambient pressure

1. Static Baseline Performance Characterization

Variable Load Simulation (Wind Fluctuations)

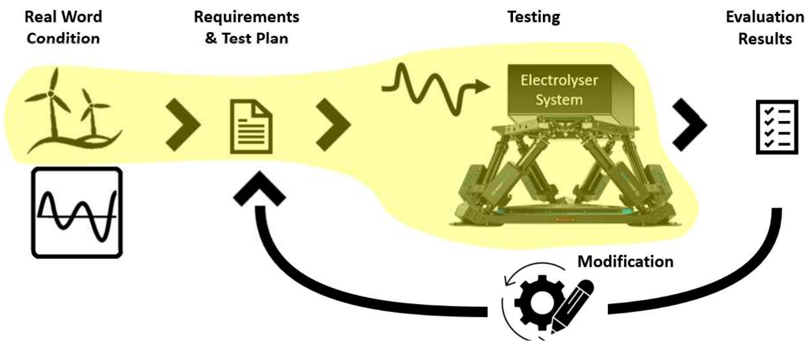
Mechanical Motion (Rocking & Pitching) Simulation

Long-Term Durability & Lifetime Testing (on normal and stressors situation)

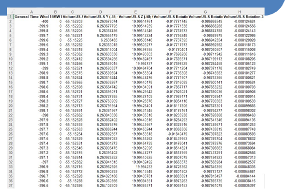
REF: [JRC Technical Report, EU harmonised protocols for testing of low temperature water electrolysers (2021)]

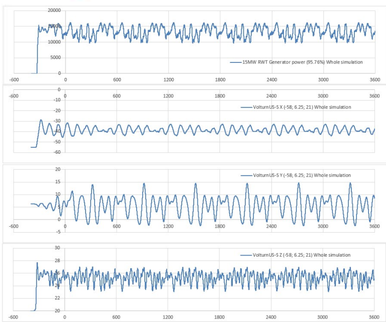
Applying Motion profile

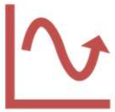
All steps for applying motion profile from real world to Electrolyser system was done!

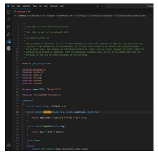


Strathclyde Simulation Data → Evaluate range limitation → Find Best equivalent curve → Make C++ code to ForceSeatPM → Applying Normalized wave on the motion platform









- ✓ DLC1_3_0deg_v2 (mild environment)
- DLC1_6_0deg_v2 (harsh environment)
- DLC1_6_0deg_v2 (extreme condition)

Applying Motion profile

Ocean REFuel | Newcastle University

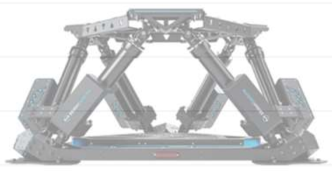
Evaluating Profile Range under mild environment

DLC1_3

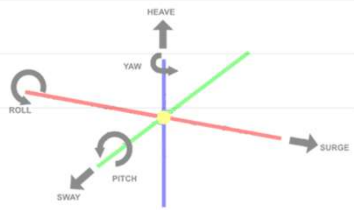
	Min-displac(m - Deg)	Max-displac(m - Deg)	Min Vel(m/s - Deg/s)	Max Vel(m/s - Deg/s)	Min Acc(m/s2 - Deg/s2)	Max Acc(m/s2 - Deg/s2)
X	-55.162	-28.563	-0.50628	0.63873	-0.26925	0.27306
Y	-2.4131	14.614	-0.58348	0.57115	-0.1115	0.147
Z	19.99	27.702	-0.42409	0.62584	-0.27702	0.26527
roll_deg	-0.3075	1.1134	-0.14249	0.1668	-0.12809	0.12363
pitch_deg	-0.99071	6.8704	-0.40857	0.63828	-0.27754	0.25801
yaw_deg	-5.2601	5.4015	-0.40425	0.35444	-0.08448	0.080508

SYSTEM PERFORMANCE

	EXCURSION SINGLE DOF	VELOCITY	ACCELERATION
SURGE	-0.3, 0.272 m | -11.81, 10.62 in	0.68 m/s | 33.86 in/s	6.4 m/s²
SWAY	-0.26, 0.26 m | -10.23, 10.23 in	0.7 m/s | 27.56 in/s	5 m/s²
HEAVE	-0.168, 0.187 m | - 6.14, 7.36 in	0.37 m/s | 14.57 in/s	5 m/s²
ROLL	-20.6°, 20.6°	45°/s	600 °/s²
PITCH	-19.9°, 18.1°	50°/s	650 °/s²
YAW	-27.8°, 27.8°	60°/s	700 °/s²



PS-6TL-350 Motion Platform (x 1)



(6.40 m/s2)
(5.00 m
(5.00 m
(6
(6
(

Factor_Relax = 0.9;
For Motion Platform range

	Min centralized	Max centralized	Min Course	Max Course
X	-5.6472	7.1822	-0.27	0.243
Y	-7.992	9.0355	-0.234	0.234
Z	-2.1149	1.8496	-0.1503	0.1683
roll_deg	-0.3075	1.1134	-18.54	18.54
pitch_deg	2.0761	6.1213	-17.91	16.29
yaw_deg	-5.2601	5.4015	-25.02	25.02

Normalised Factor (length scale): **Min For Y: 0.0259 (38.6),** For Z: 0.071 (14) - 0.09 (11)

Applying Motion profile

Normalized with Froud scaling
Find Best equivalent

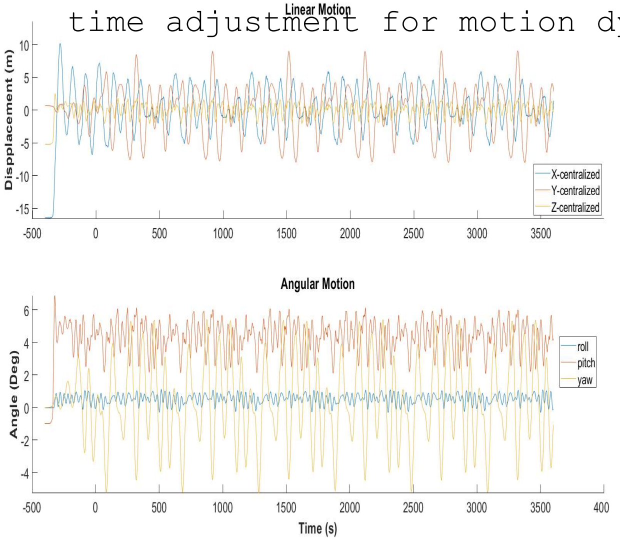
Froude Scaling (gravity-dominant) is suitable for normalizing real-world profiles to lab scale, particularly because wave motion is significant, especially concerning the separators.

$\lambda_L = L_{model} / L_{real}$, $\lambda_T = \sqrt{(\lambda_L)}$

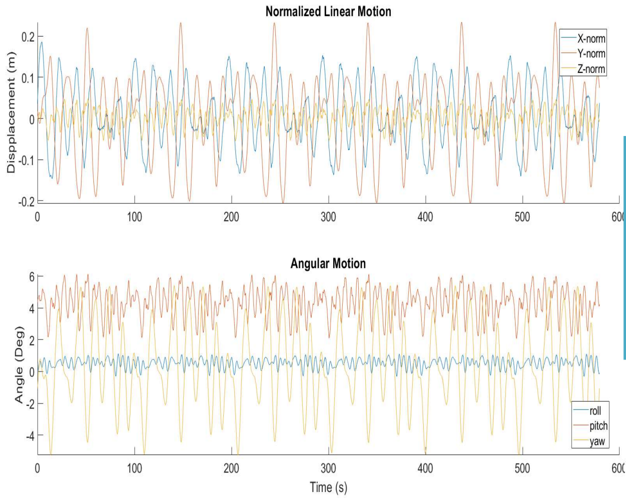
- ❑ Length scale (λ_L):
  ratio of model length to real-world length.
- ❑ Time scale (λ_T):
  time adjustment for motion dynamics.

Table C2 presents the scaling factor for the model to the prototype of important parameters at a scale of 1:λ.

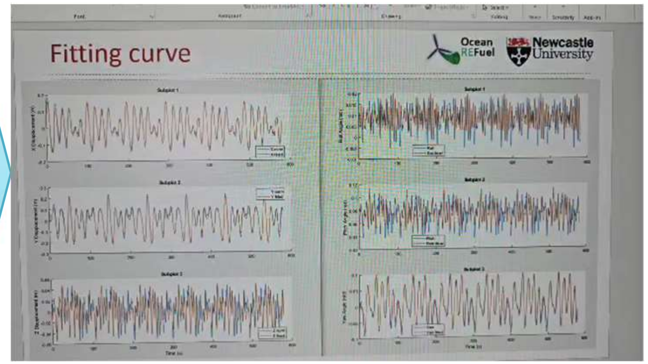
Magnitude	Unit - SI	Dimension	Ratio
Length	m	L	λ
Time	s	T	$\sqrt{\lambda}$
Velocity	ms^{-1}	LT^{-1}	$\sqrt{\lambda}$
Aceleration	ms^{-2}	LT^{-2}	λ^0
Angular velocity	$rad.s^{-1}$	T^{-1}	$\lambda^{-1/2}$
Angular acceleration	$rad.s^{-2}$	T^{-2}	$1/\lambda$
Angle	rad	1	λ^0
Mass	kg	M	$(\rho_{wp}/\rho_{wm})\lambda^3$
Force	N	MLT^{-2}	$(\rho_{wp}/\rho_{wm})\lambda^3$
Pressure	Pa	$ML^{-1}T^{-2}$	$(\rho_{wp}/\rho_{wm})\lambda$
Moment	Nm	ML^2T^{-2}	$(\rho_{wp}/\rho_{wm})\lambda^4$
Power	W	MTL^3	$(\rho_{wp}/\rho_{wm})\lambda^{7/2}$
Frequency	s^{-1}	T^{-1}	$\lambda^{-1/2}$
Mass moment of inertia (J)	$Kg.\,m^2$	ML^2	$(\rho_{wp}/\rho_{wm})\lambda^5$



Normalized



Function fitting



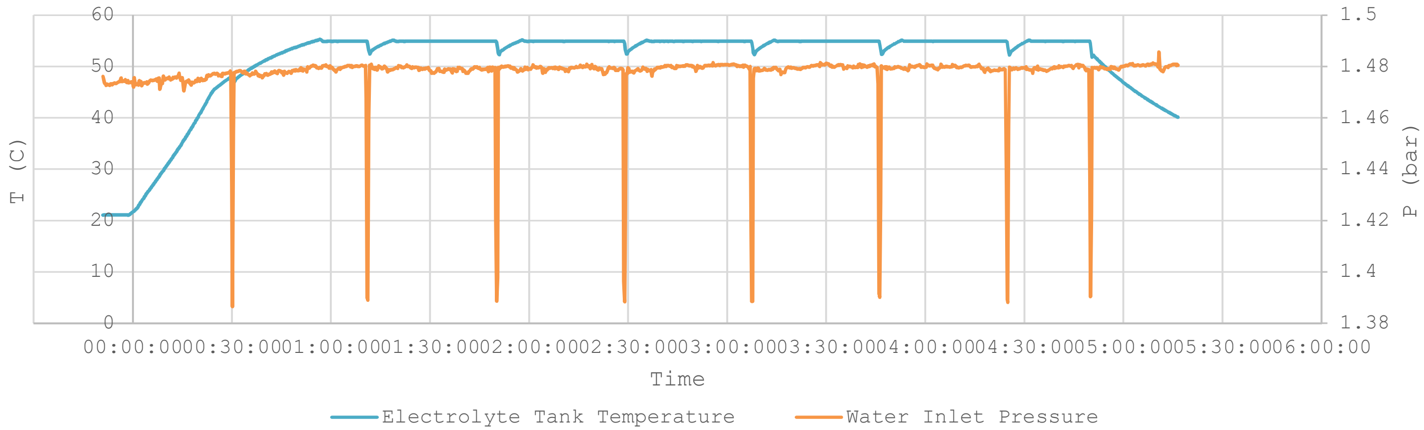
Electrolyser testing

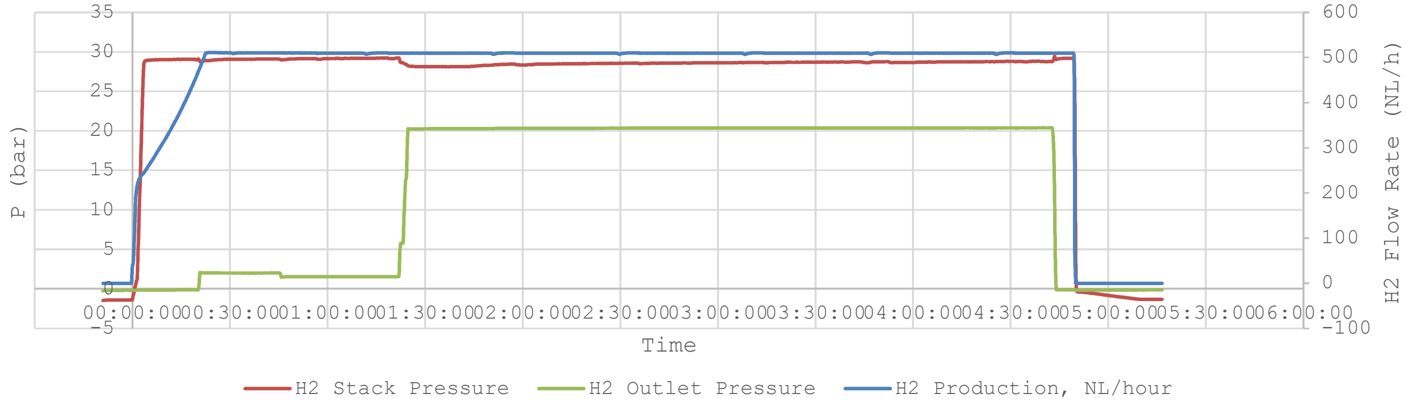
Enapter AEM Electrolyser testing start-up and shut-down

Enapter AEM Electrolyzer System

Some useful notes from electrolyser’s company(cold start):

- **Warm-up time (time taken for the electrolyte to heat up to 55 °C**1 °C/min.
- **Ramp up time (time to reach nominal production rate):** 22 min.
- **Build pressure time:** 4 min.

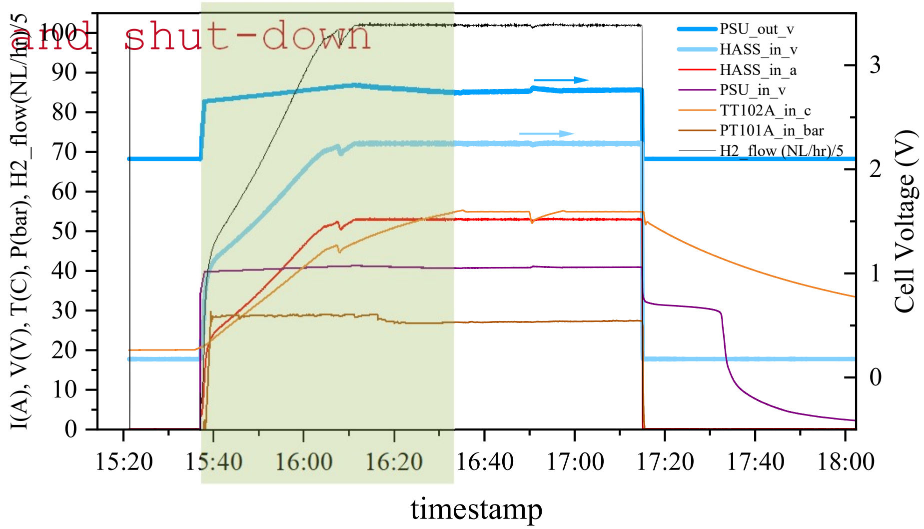




Electrolyser testing

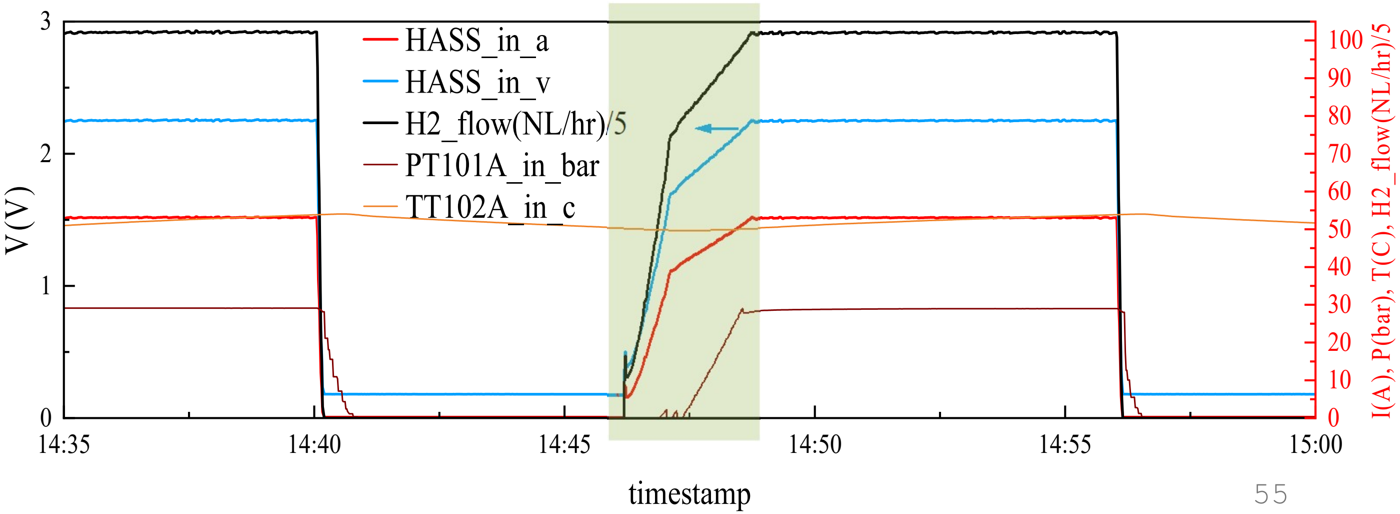
Enapter AEM Electrolyser testing start-up and shut-down

Enapter AEM Electrolyzer System



Start-up after shut-down (warm start):

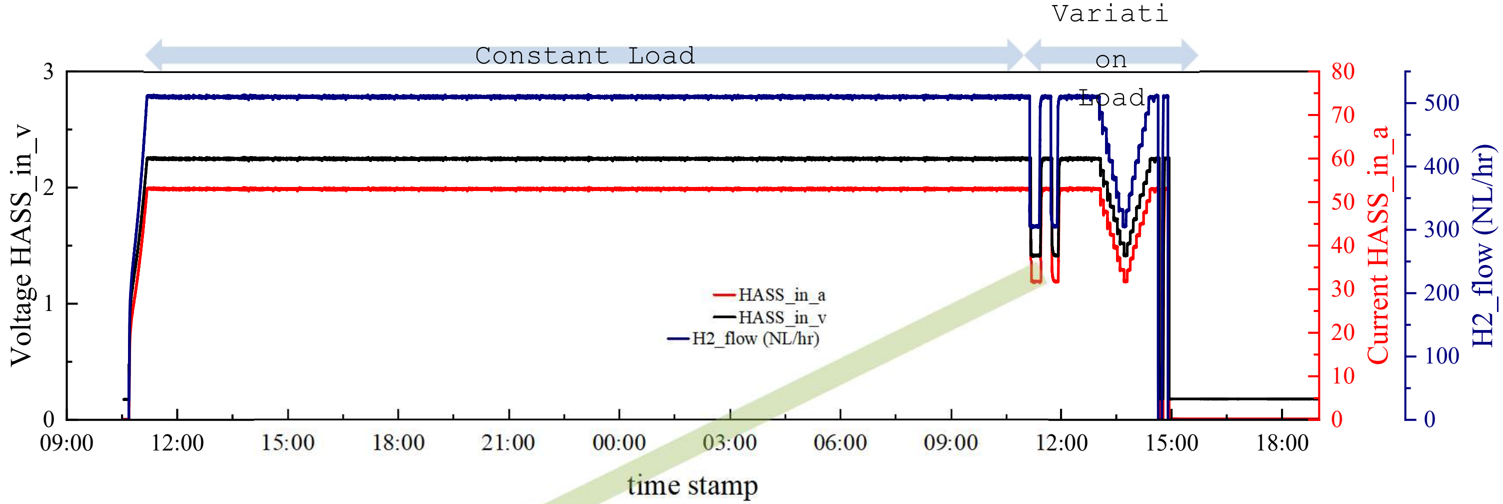
- **Warm-up time (time taken for the electrolyte to heat up to 55 °C):** No need.
- **Ramp up time (time to reach nominal production rate):** less than **3 min.**
- **Build pressure time:** Immediately. Less than **1min**

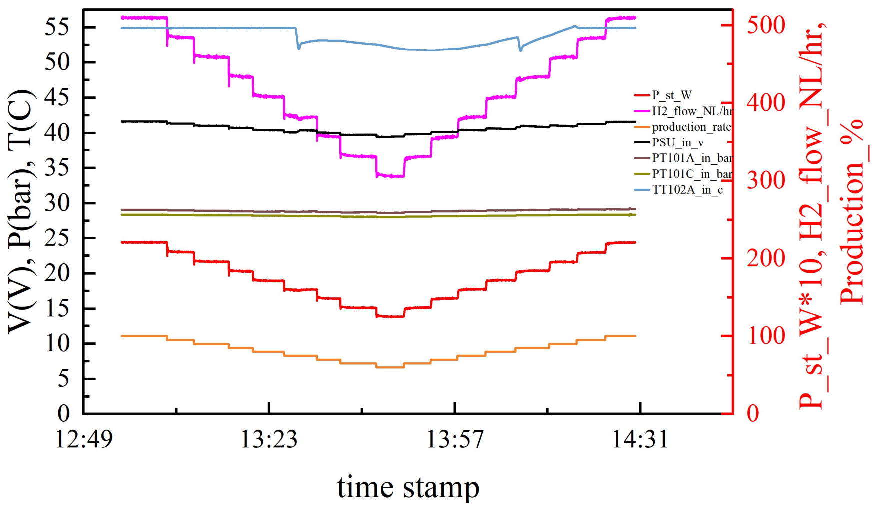


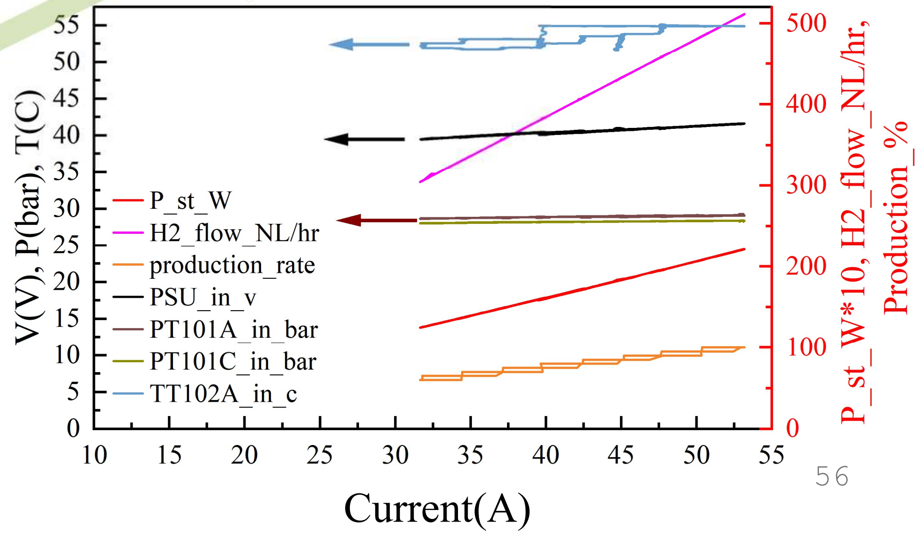
Electrolyser testing on stable condition

Test period: 48 hr

Enapter recommends:
limiting the device's maximum operative cycles to a maximum of **five on/off cycles per day,** and **one on/off cycle per hour.** This helps to ensure the longevity of the device.
However minimum load is capped at 60%







THANKS FOR YOUR ATTENTION

Questions and discussion

Ocean Refuel funded by
EP/W005204/1

UK Research and Innovation

Questions and discussion

Ocean Refuel funded by EP/W005204/1

UK Research and Innovation

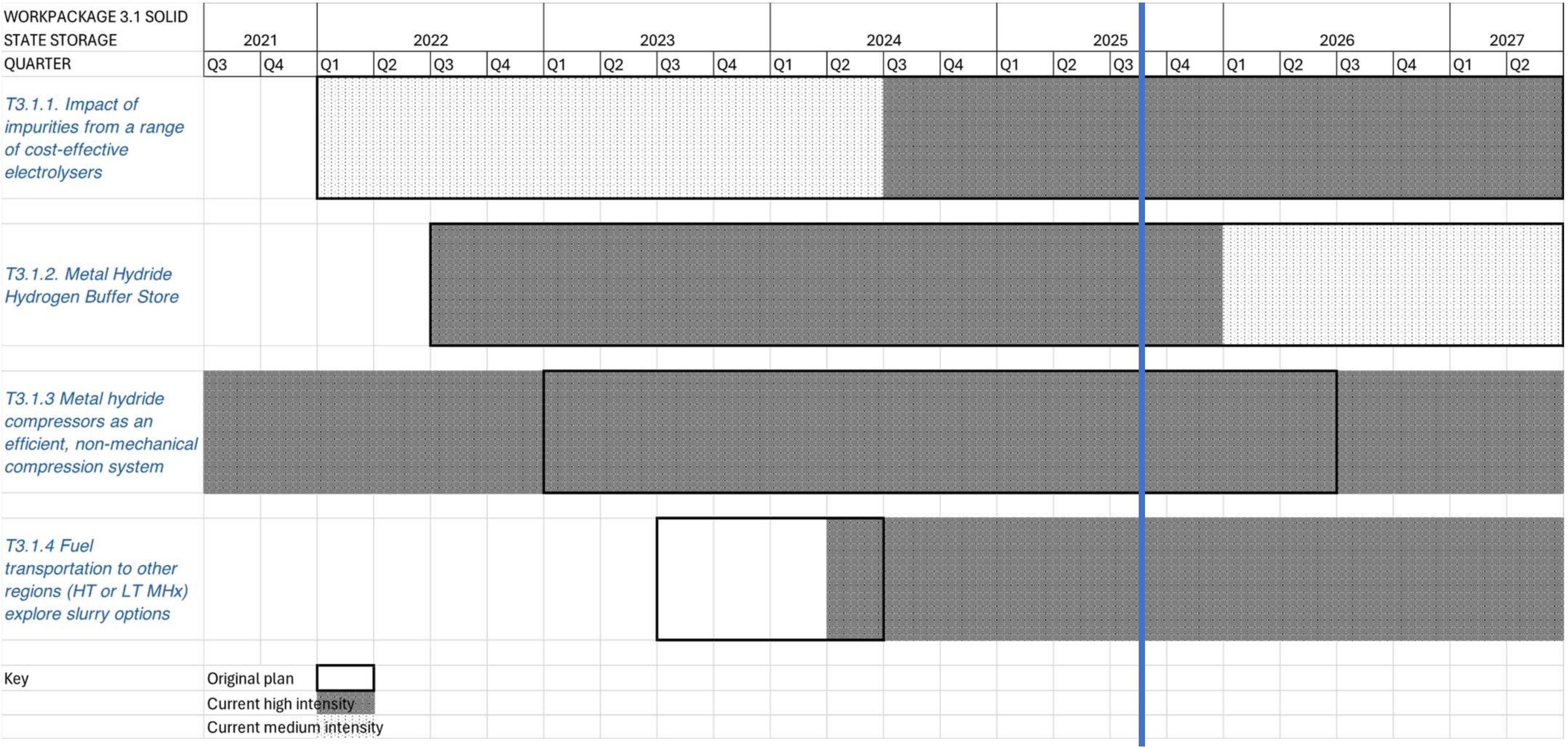
University of Nottingham
Energy Institute

UoN Hydrogen Research

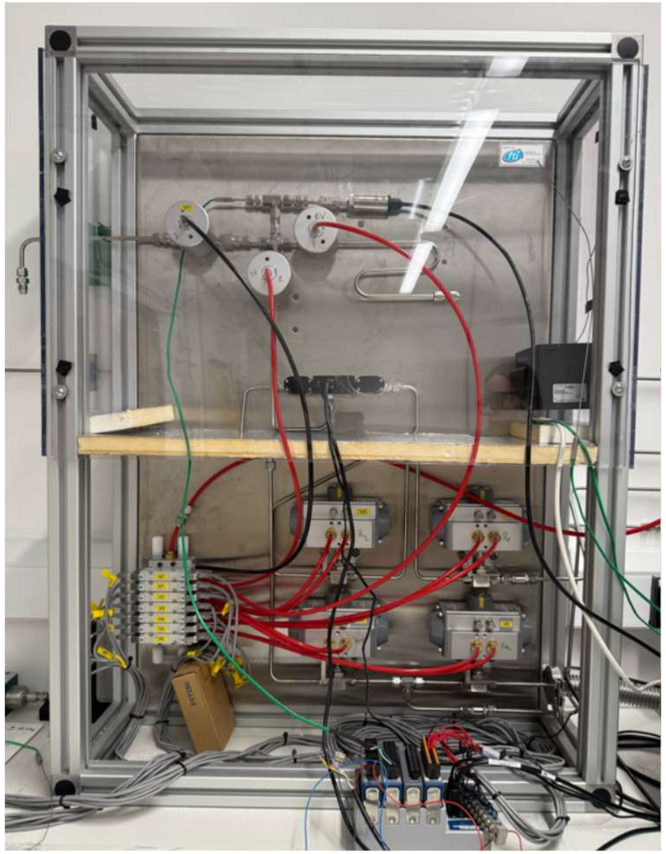
Work Stream 3 Update

Marcus Adams, Amelia-Rose Edgley, Ramas Al Qudah, Jorge Montero Banuelos, David Grant

Workstream 3.1 tasks



WP 3.1.1 Impurity cycling tests



- Impurity testing rig now completed. Commissioning underway.
- Planned cycling up to 200 ppm moisture levels consistent with undried gas stream (source Oort Energy)

Investigate the resistance to impurities in different forms

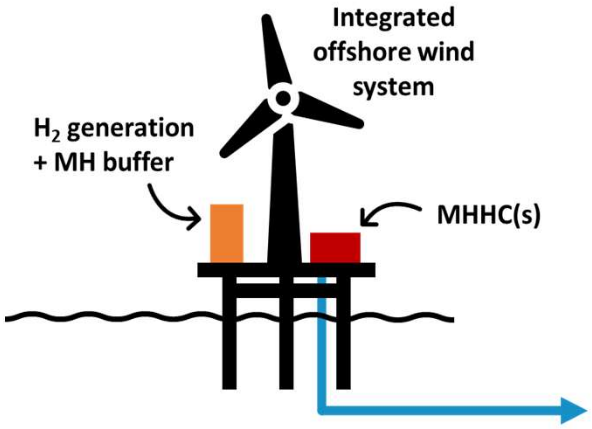
- Powder
- Pellatised

Semi automatised pellatiser installed

WP 3.1.2 Hybrid Buffer store

University of Nottingham Energy Institute

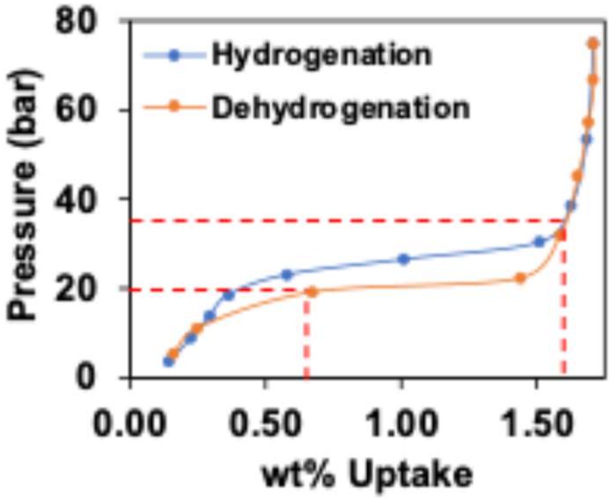
UoN Hydrogen Research



- 250 kg hydrogen store
- Tank volume from 194 m^3 to 38 m^3
- 14 tonne of hydride material

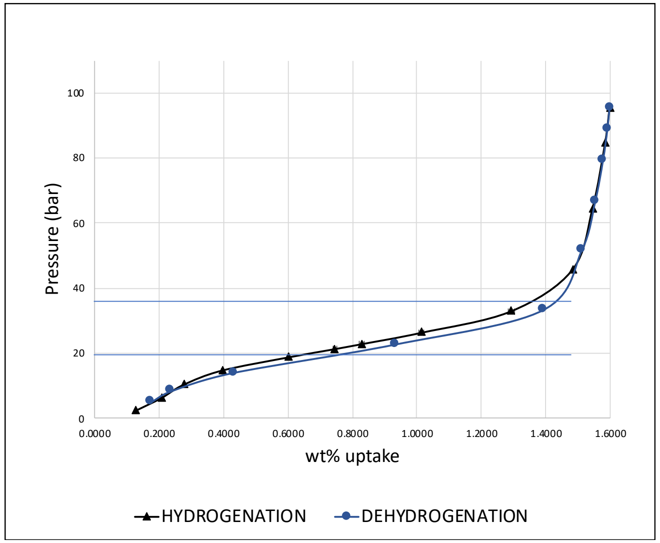
Feasibility Assessment Into the Use of Hybrid Gas-Hydride Tanks for Improving the Flexibility of Offshore Hydrogen Production Amelia-Rose Edgley, Timothy Cooper, Marcus J Adams, David M. Grant *Accepted 6th Sept 2025 IJHE*

3.1.2 MATERIALS SELECTION



PCI for Hydralloy-C5 at 50 °C

Flat plateau and/or minimal hysteresis to maximise usable stored hydrogen



UoN alloy (Ti,Zr)CrMnFeX at 25 °C

Fast reaction kinetics based on AB2 alloys to match system response

3.1.3 Metal hydride compression

Metal hydride compressor built and tested. Next steps improve the kinetics via a new design and exploring higher pressures and new materials under test

Suitability of metal hydride compression in offshore hydrogen generation for use in pipeline transmission

Authors: Marcus J. Adams[1], Jorge M. Banuelos[1], Andrew Gray[1], Ramas Al Qudah[1], Alastair Stuart[1], Martin Dornheim[1], David M. Grant[1]

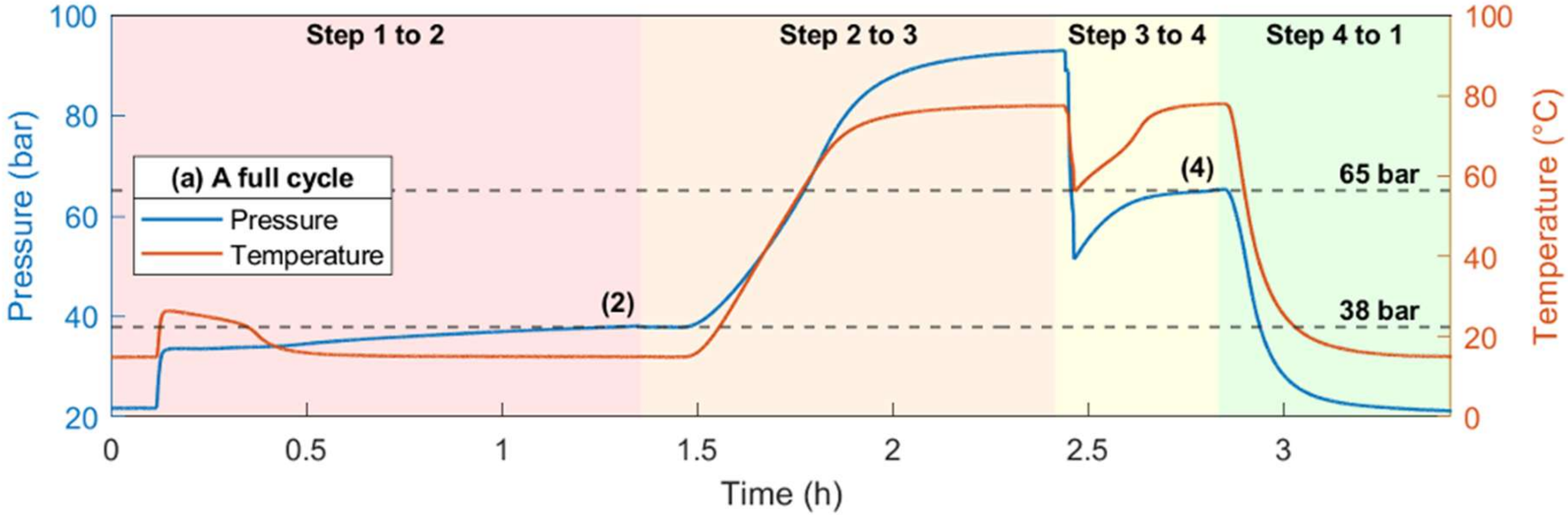
[1]Advanced Materials Research Group, Faculty of Engineering, University of Nottingham, University Park, Nottingham, NG7 2RD, United Kingdom

Keywords: Metal hydride hydrogen compression, hydrogen pipeline transmission, electrolyser waste heat, offshore hydrogen generation

Submitted

Result of paper: it is possible to pressurise hydrogen from electrolyser outlet pressures (30 bar) to pipeline transmission pressures (80 bar) operating the metal hydride compressor between North sea seawater temperatures (5 to 15 °C) to electrolyser waste heat temperatures (max 80 °C)

Integrated MH single stage compressor: Using sea water 15˚C and electrolyser 80˚C



No HTF mitigation

Temperature range 15 °C - 80 °C

Sample mass 320 g
Poor heat exchange
Hard to swap samples

$Ti_{30}V_{15.8}Mn_{49.4}(Zr_{0.5}Cr_{1.1}Fe_{2.9})$

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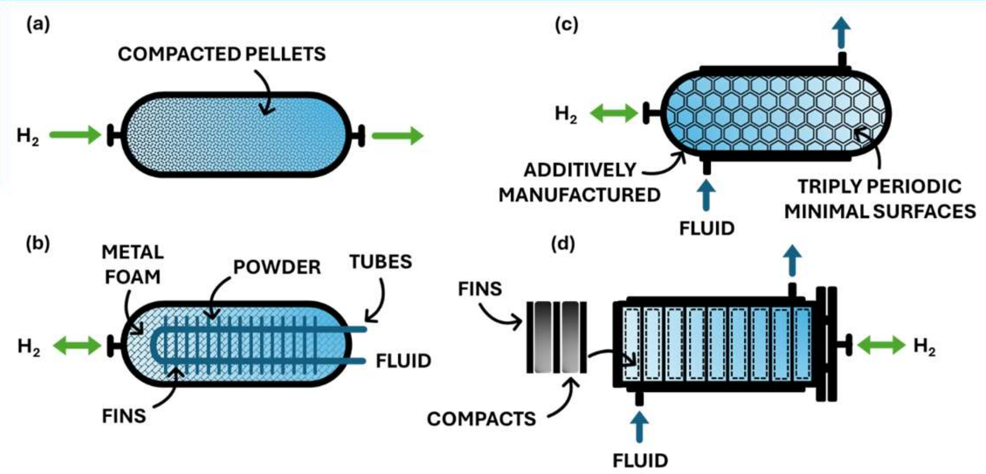
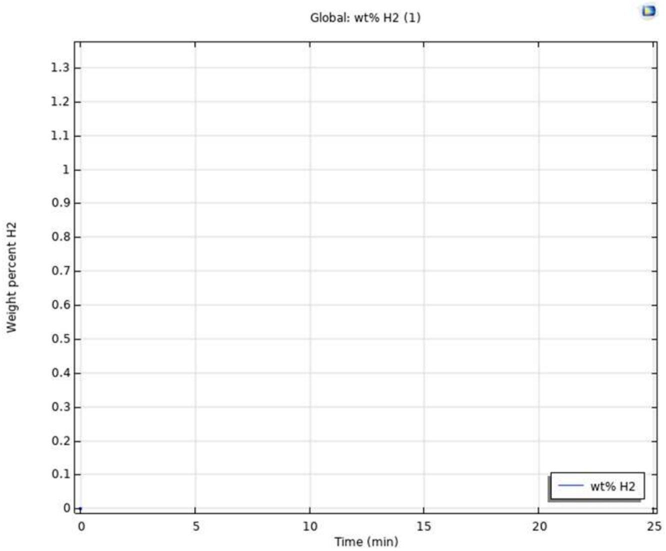
Alternatives:

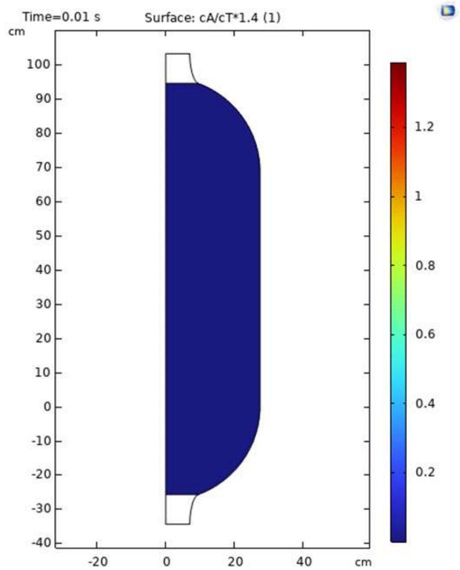


Circulating hydrogen: simulation

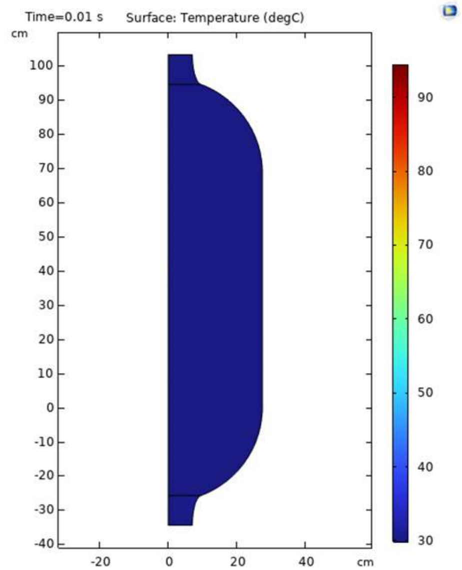
wt% H_2 profile



wt% H_2 profile



Temperature profile



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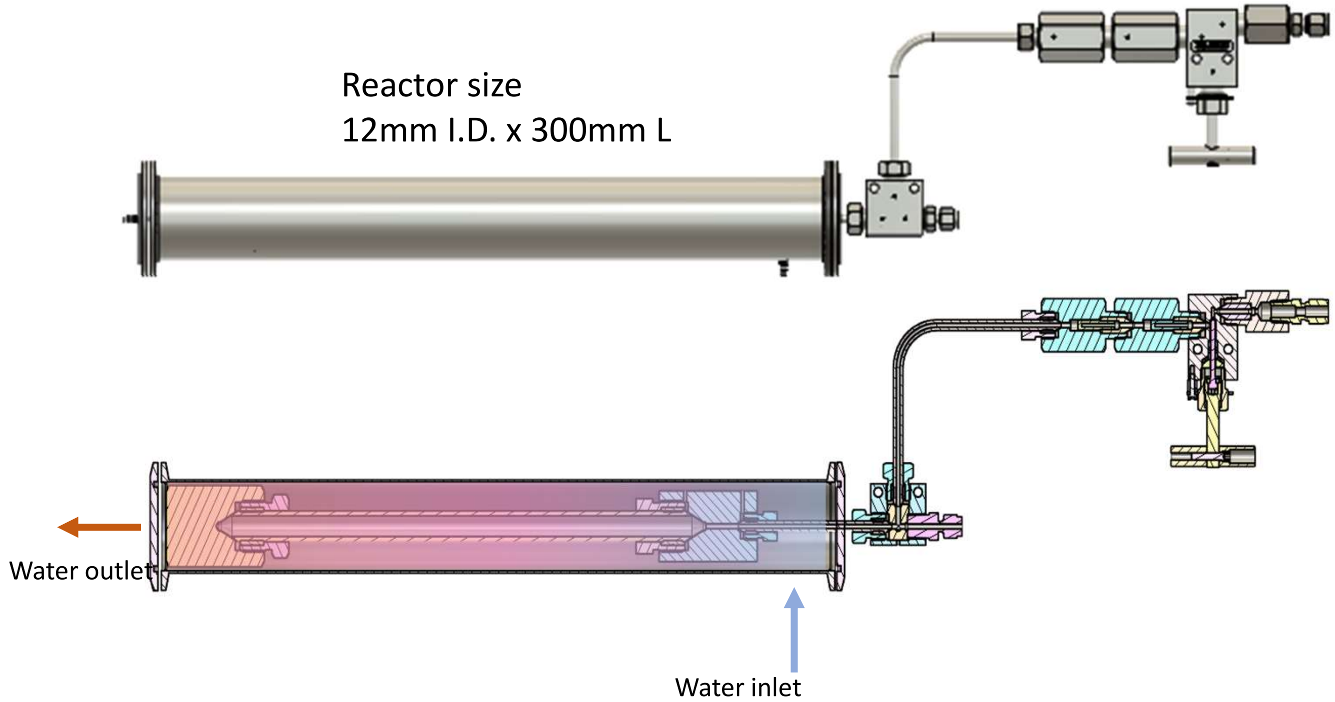
NEXT GENERATION REACTOR

UoN Hydrogen Research

Pressure rating 1400 bar
Temperature range -30°C – 150 °C

Sample mass 50-80 g
Improved thermal efficiency
Swapping samples inertly
Powder and pellet form
Multi-stage configuration
Increased pressure rating



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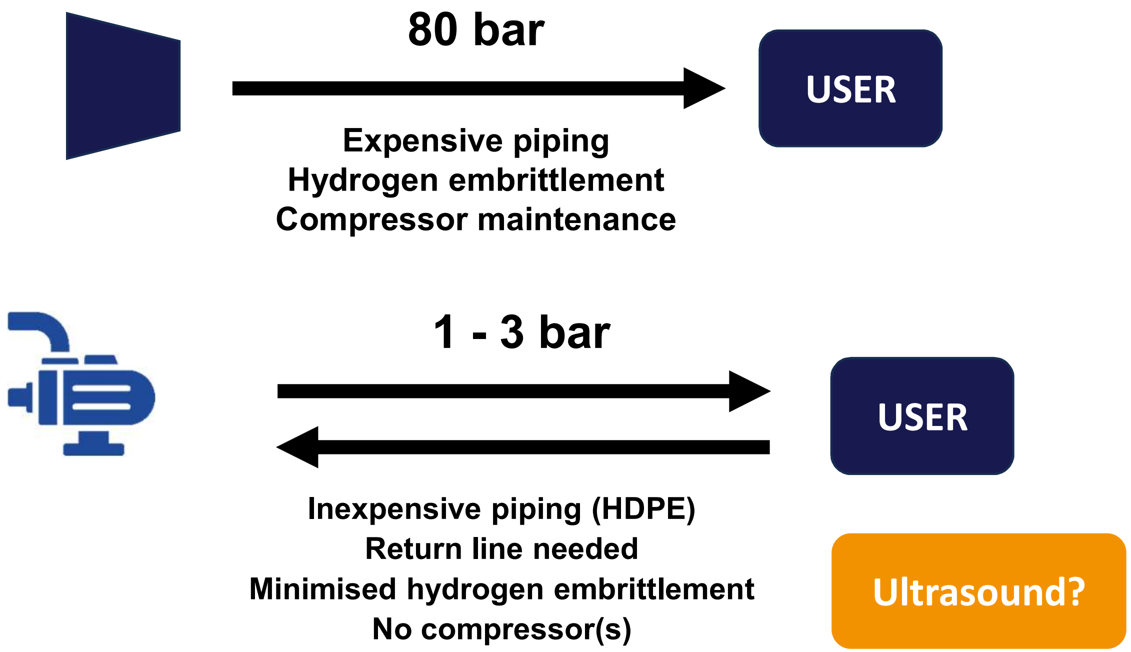
3.1.4 Pipeline transmission

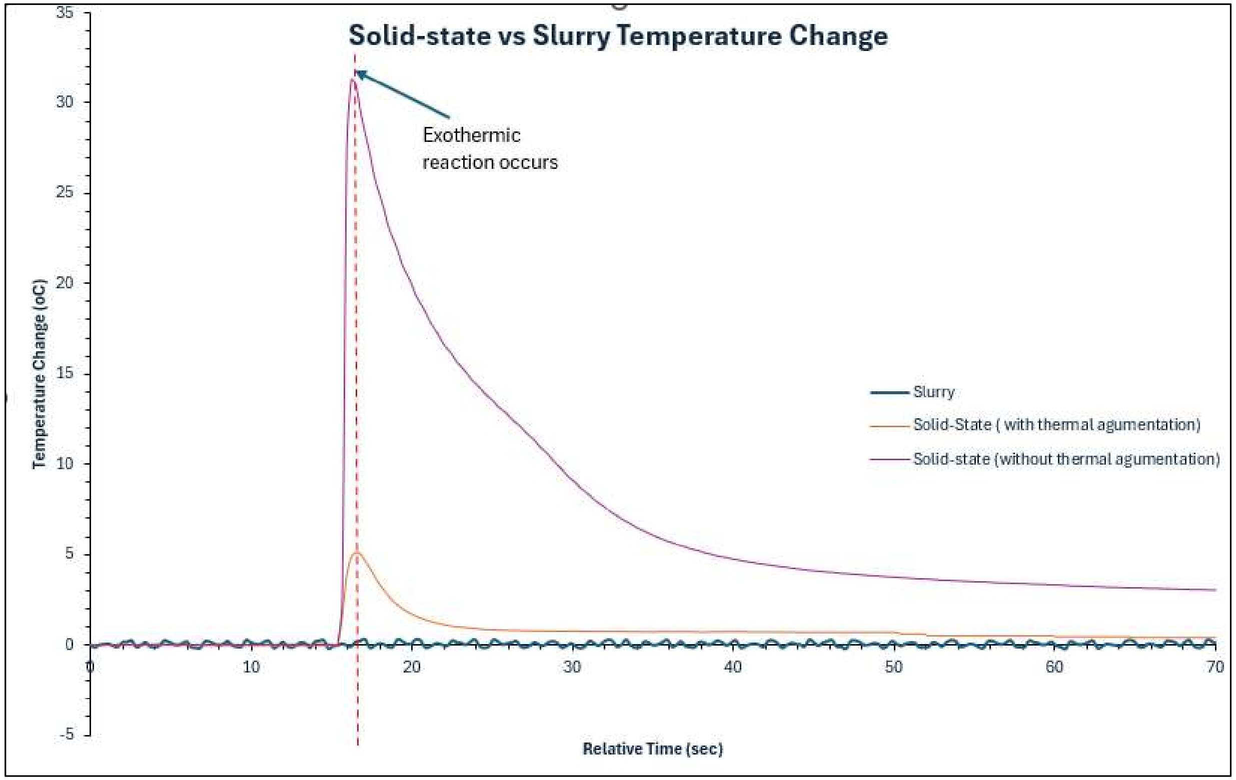
UoN Hydrogen Research

- 3.1.4 Alternative - transport hydrogen efficiently using a metal hydride slurry. Investigating ultrasound hydrogenation and dehydrogenation of the hydrides in fluids. Potential novel hydrogen transport system.



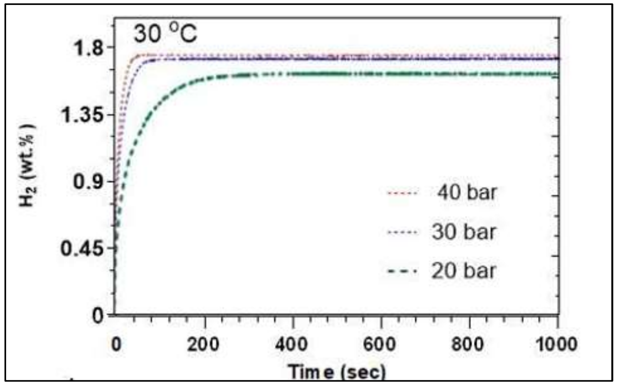
Preliminary technoeconomic analysis done

Challenge is the kinetics of slurries…



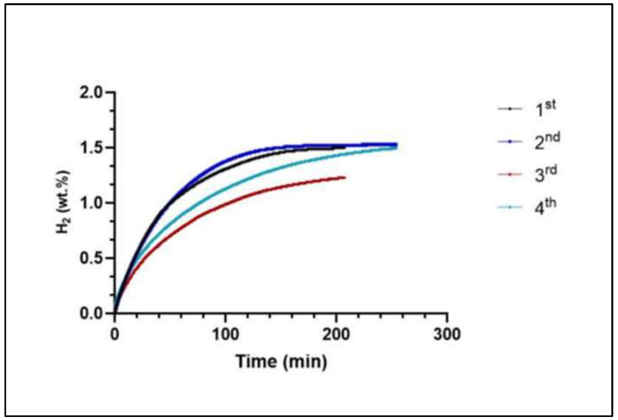
Advantage of slurries: heat management

(1)



HydralloyC5 in powder

(2)



HydralloyC5 in slurry – slower kinetics

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Experimental setup modifications

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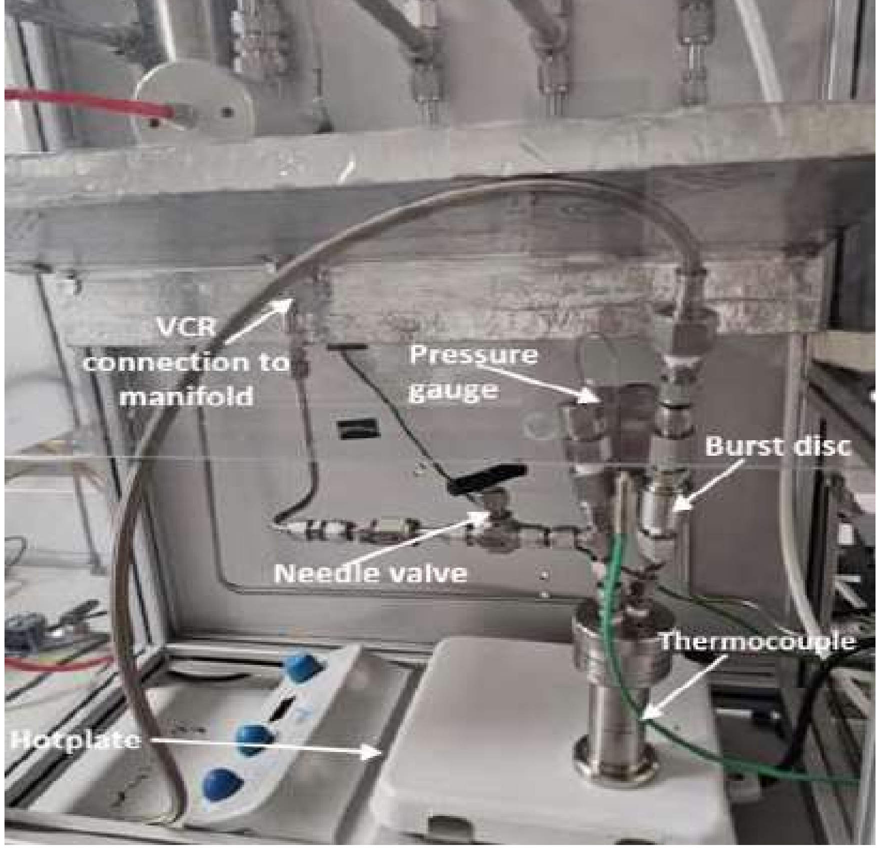
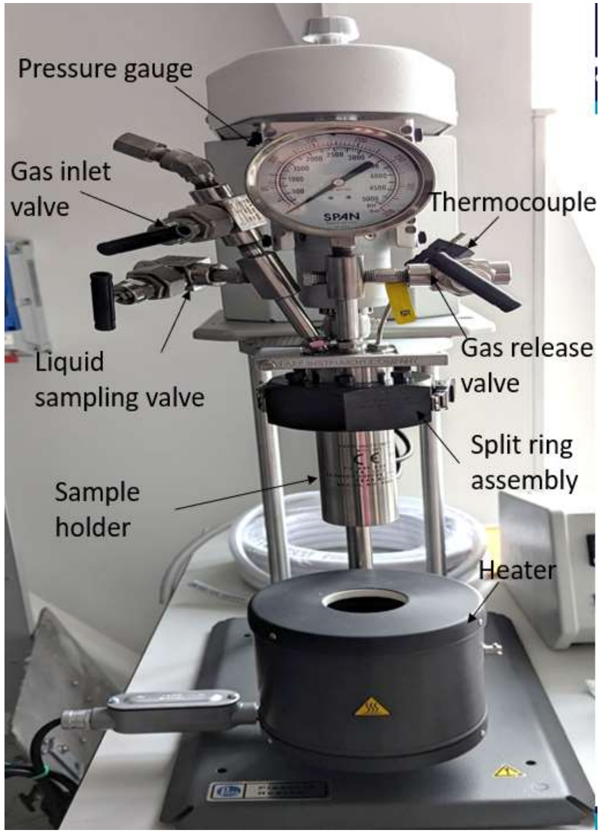
Tinyclave Assembly (10 mL):



Parr reactor Assembly (100 mL):



…unlock superior hydrides

Current room temperature hydrides are:

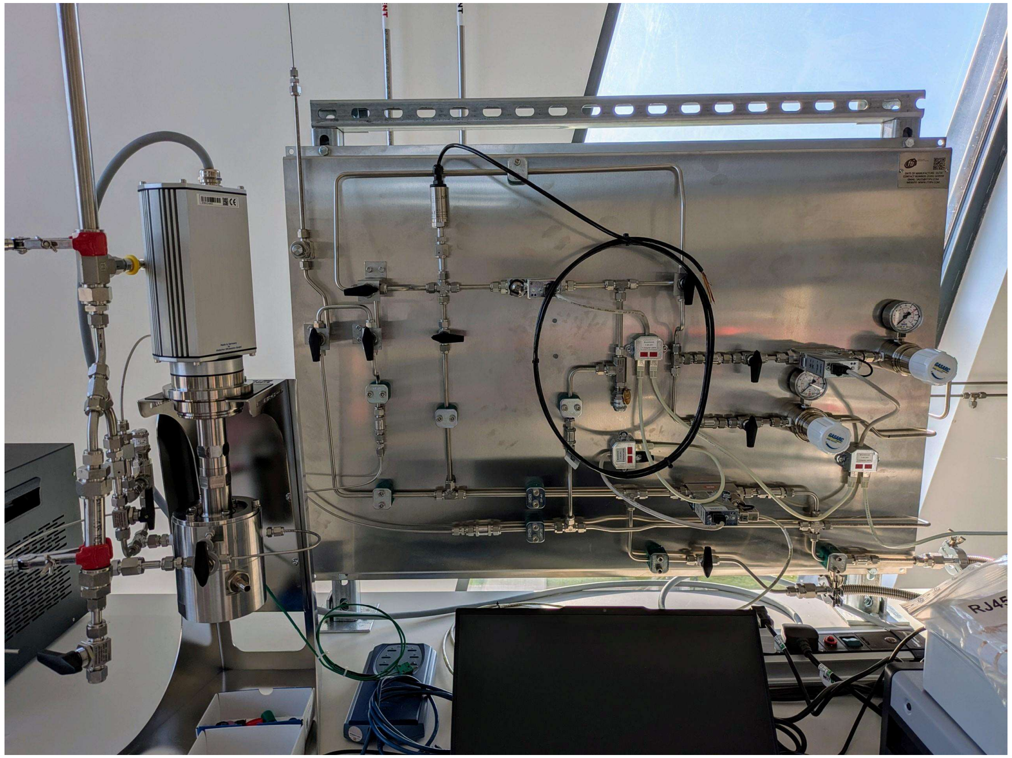
- Expensive, heavy
- Low H_2 weight percent (1.5 wt% H_2)

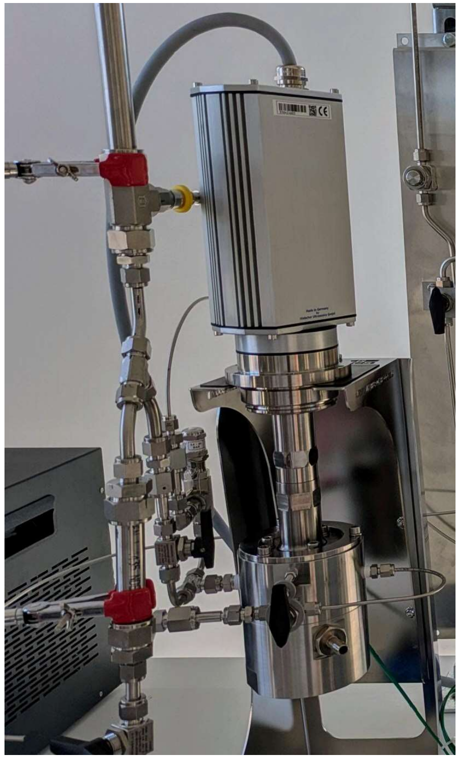
If we can unlock higher H_2 weight percent materials

- More H_2 transported in pipeline
- Unlock low pressure H_2 storage

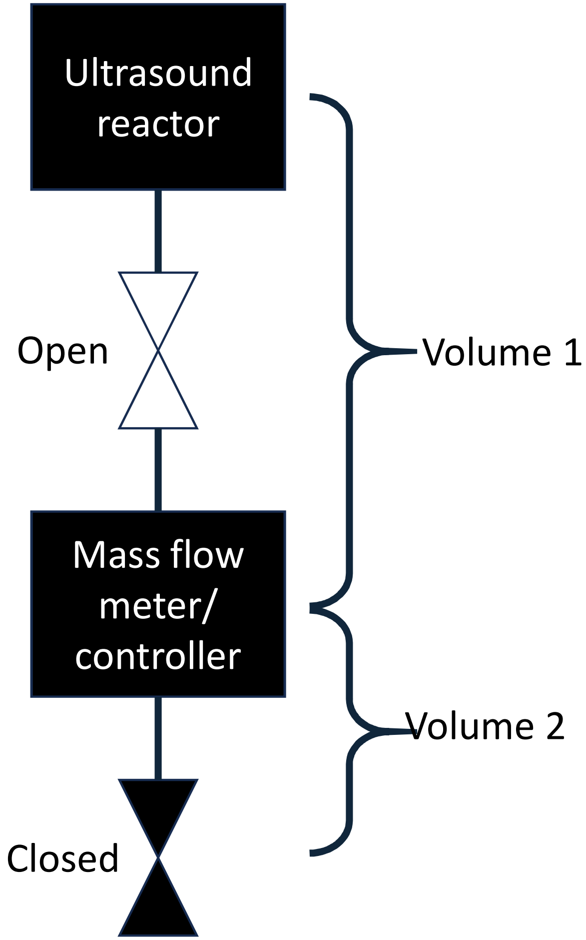
- For example,
- $3NaAlH_4 \rightleftharpoons Na_3AlH_6 + 2Al + 3H_2$ (3.7 wt% H_2)
- Needs 150 °C and 100 bar
- Thermodynamics says can be done at near room temperature at 1 – 3 bar.

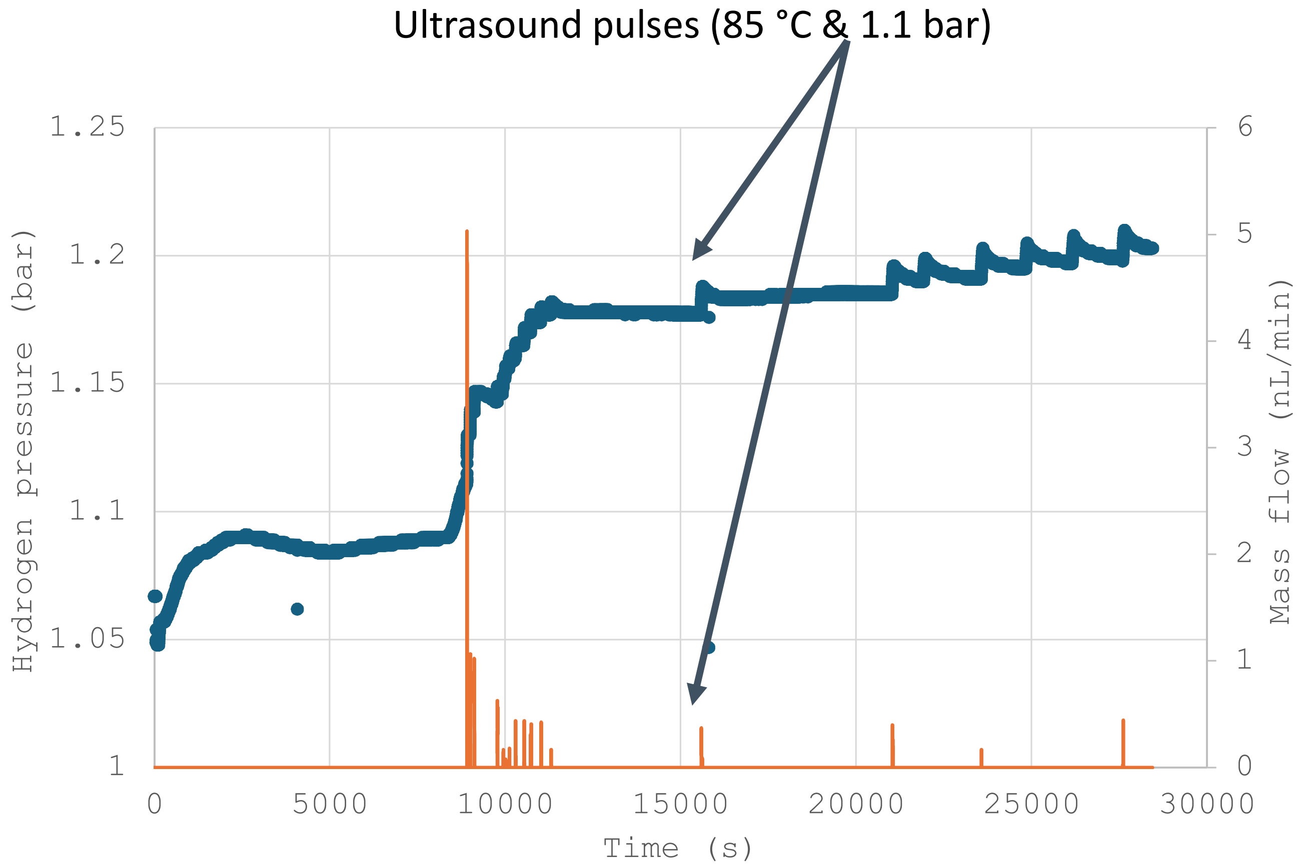
Ultrasound rig





POC Preliminary results





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Journal of Magnesium and Alloys 13 (2025) 2009–2022

www.elsevier.com/locate/jma

Full Length Article

Improving kinetic modelling of magnesium hydrogenation by including interfacial polarisation and interstitial hydrogen clustering behaviour within the site availability model

Marcus J. Adams[a,*], Alastair Stuart[a], Gavin S. Walker[b], David M. Grant[a]

[a] *Advanced Materials Research, University of Nottingham, Nottingham, NG7 2RD, United Kingdom*
[b] *Aria Sustainability Ltd, Unit 7 Wheatcroft Business Park Landmere Lane, Nottingham, NG12 4DG, United Kingdom*

Received 17 October 2024; received in revised form 4 January 2025; accepted 10 March 2025
Available online 4 April 2025

Comfort Break

WP4 - Ammonia, Carboniferous H2, Overall System Optimisation

H2 may be transported in its pure form, transformed into a different energy carrier and/or blended to form part of a gas stream to be transported. Ammonia can support the concept, whilst methane produced from capture CO2 and H2 could mitigate the impact of excessive carbon dioxide emissions.

This WP addresses:

WP4.1. Use of NH3 as an alternative long-term/long-distance energy vector

WP4.2. ‘Carboniferous’ Hydrogen Supply

WP4.5. Overall System Optimisation

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Centre of Excellence on Ammonia Technologies

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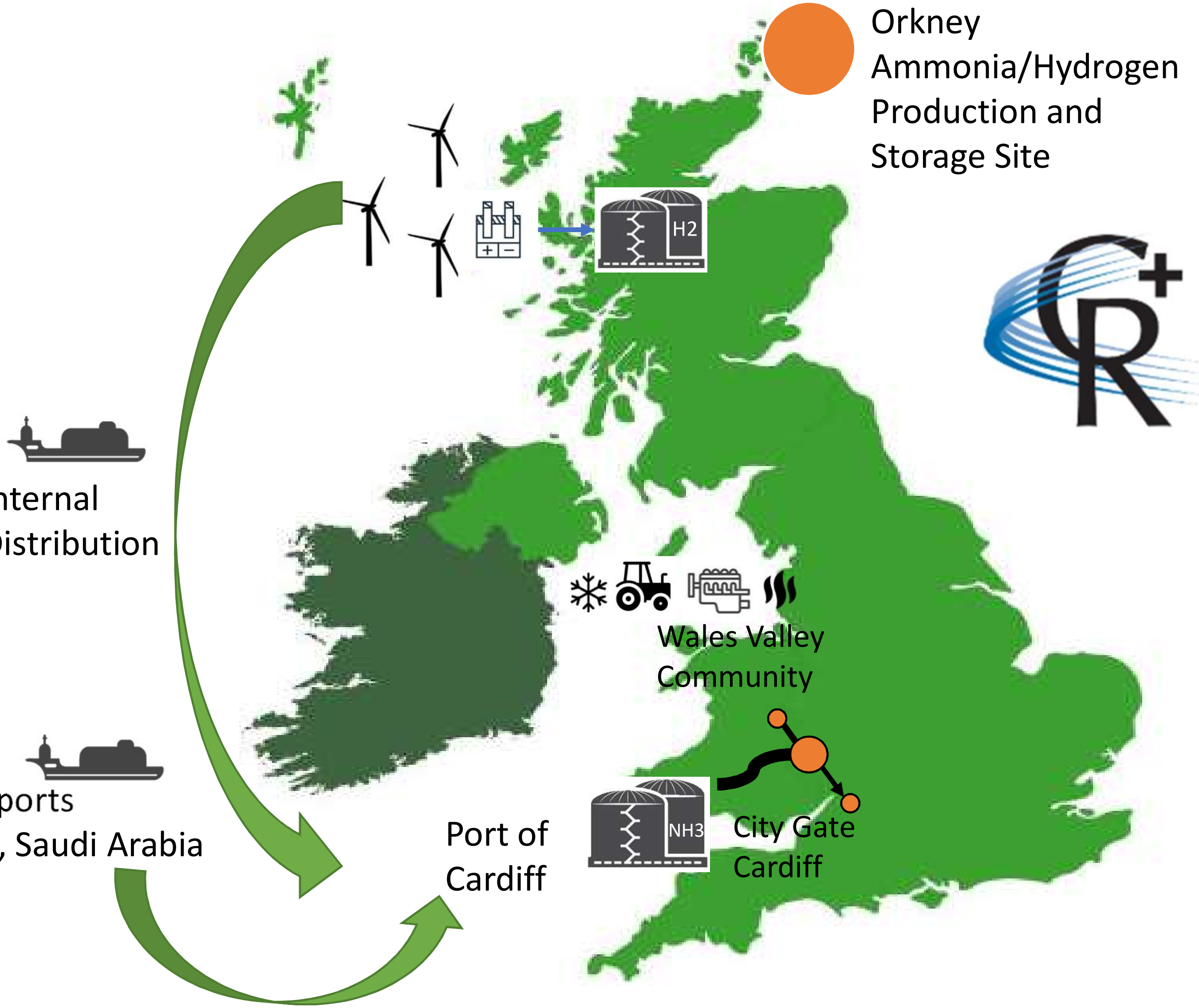
UK SCENARIO FOR AMMONIA UTILIZATION



WALES&WEST UTILITIES

celsa

Prifddinas Ranbarth Caerdydd | Cardiff Capital Region

GW-SHIFT

UKRI Engineering and Physical Sciences Research Council

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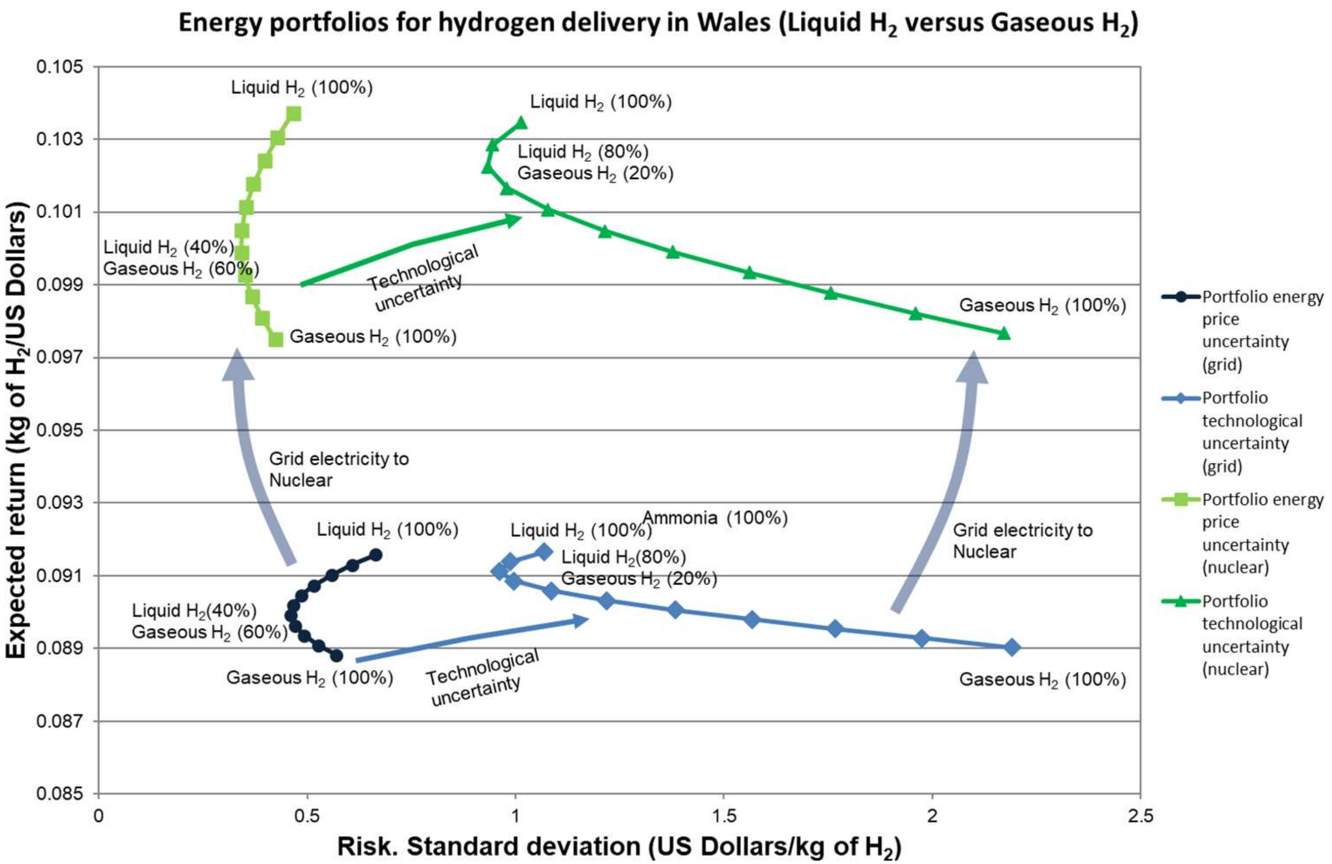
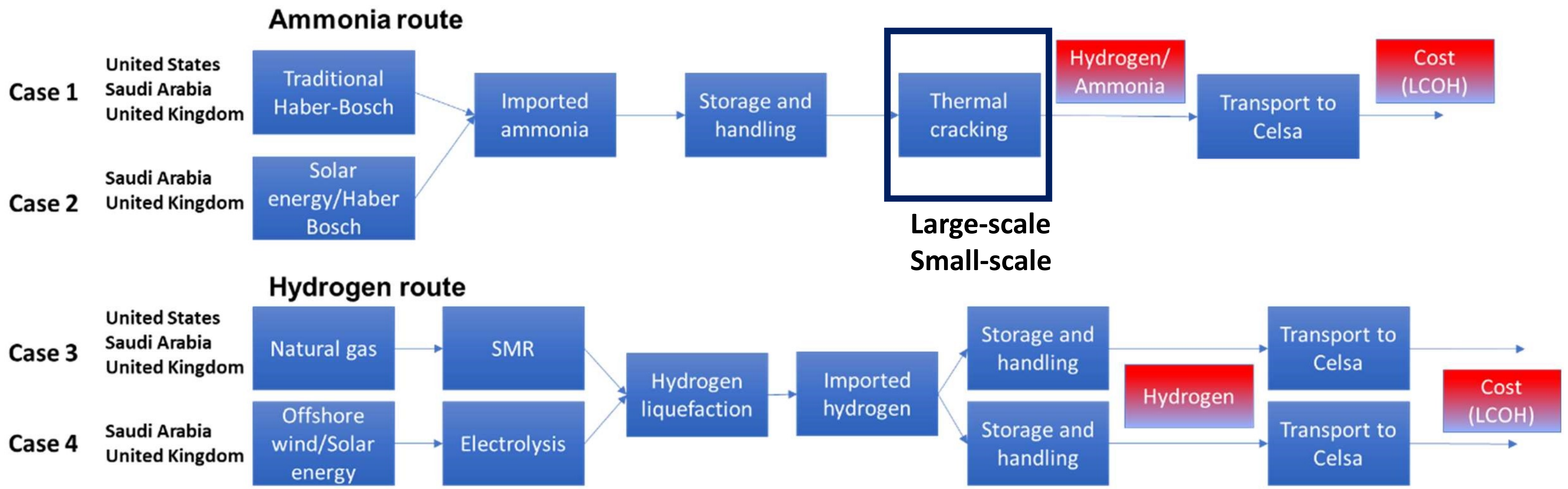
UK SCENARIO FOR AMMONIA UTILIZATION

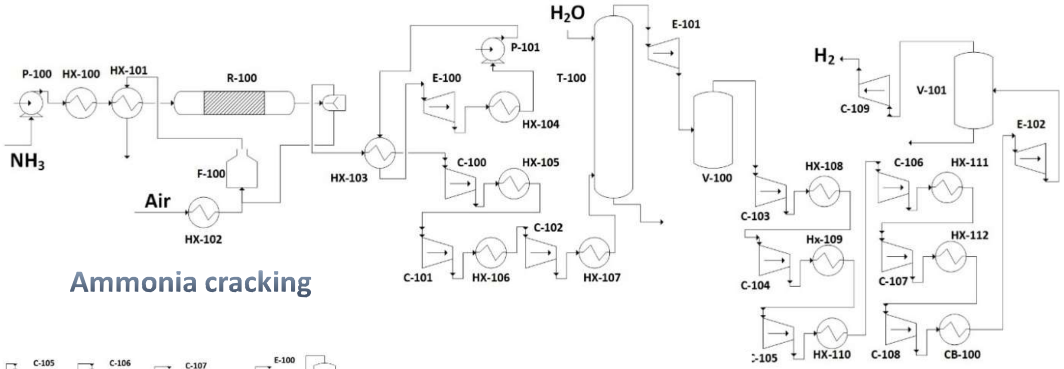


- ❑ If **gaseous H_2** is compared to **liquid H_2**, portfolios contain a **higher amount of gaseous H_2** production.
- ❑ This **trend reverses** as **technological risk** increases.
- ❑ The first case is due to **higher sensitivity of liquid H_2** production to **energy price** volatility (large energy consumption) while the second case highlights the **impact of pipeline capital costs**.

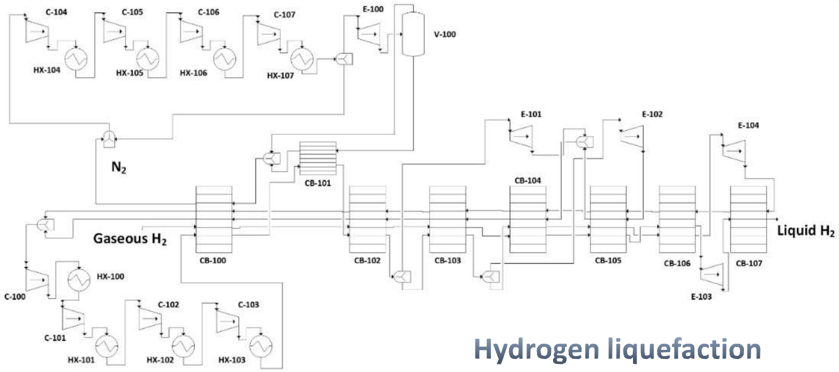
UK SCENARIO FOR AMMONIA UTILIZATION



UK SCENARIO FOR AMMONIA UTILIZATION

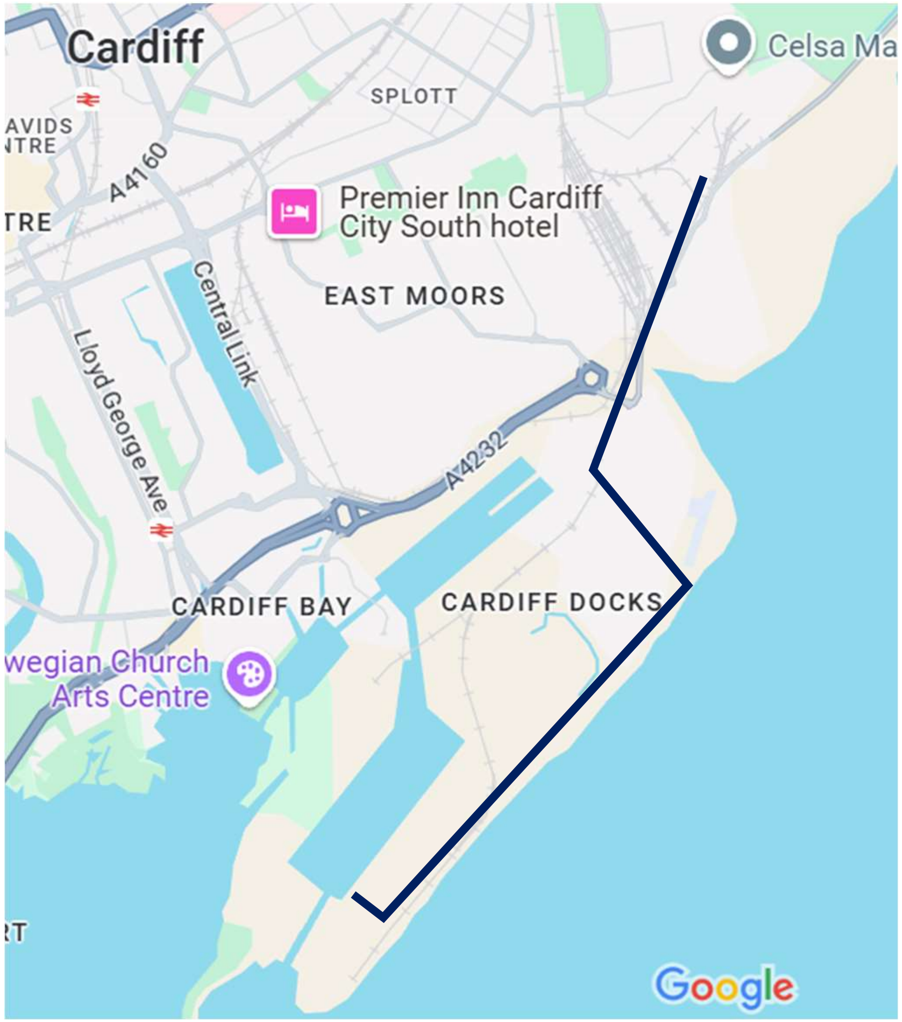


Ammonia cracking

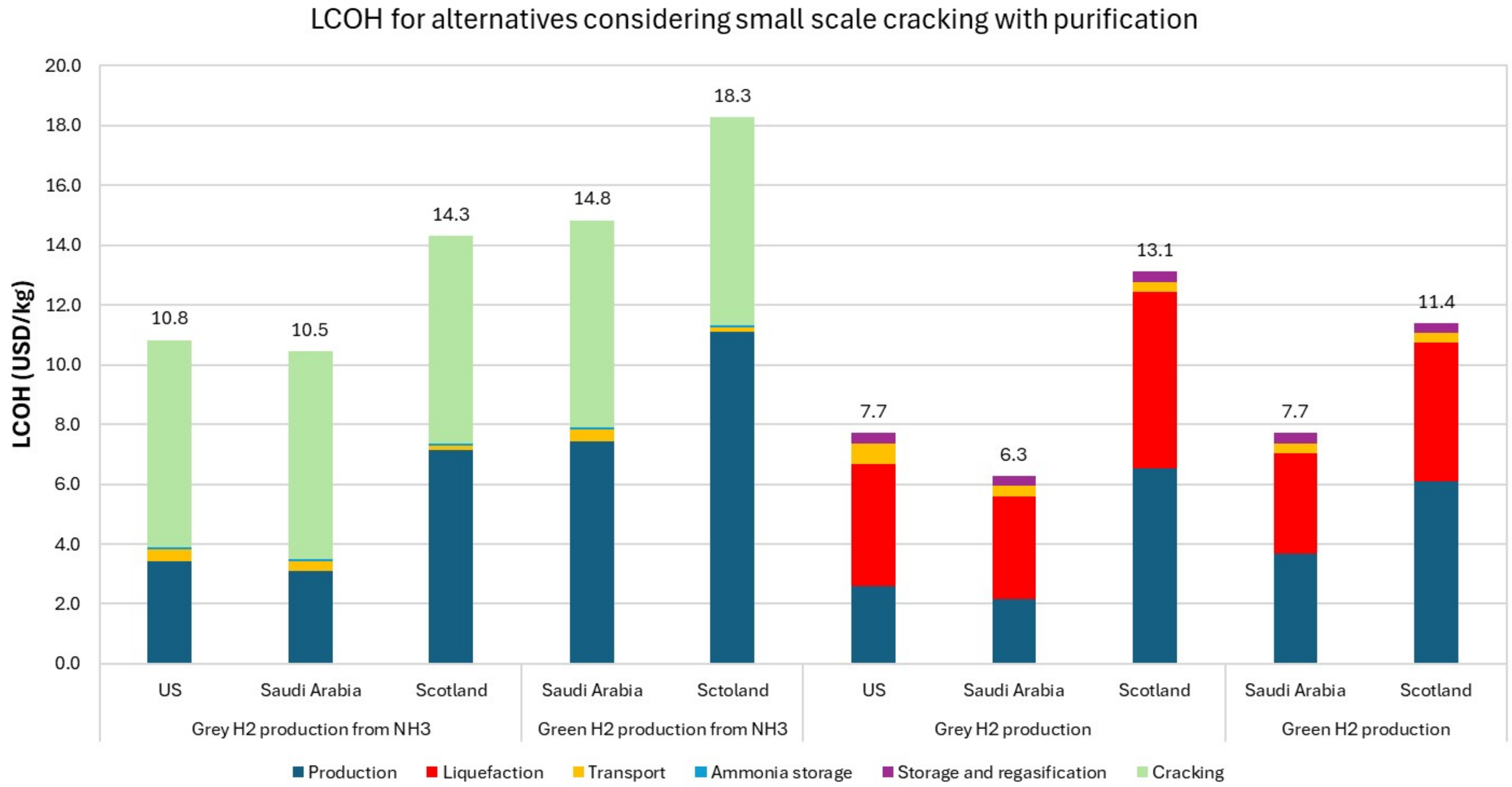


Hydrogen liquefaction

- **Engineering and economic analysis.**
- **Support from Celsa and WWU for technical requirements.**



UK SCENARIO FOR AMMONIA UTILIZATION



- **The lowest cost alternative is the import of liquid hydrogen from Saudi Arabia.**
- **The difference between grey and green hydrogen from Saudi Arabia is 22%.**
- **Green hydrogen from Saudi Arabia can be comparable to grey hydrogen from the US.**

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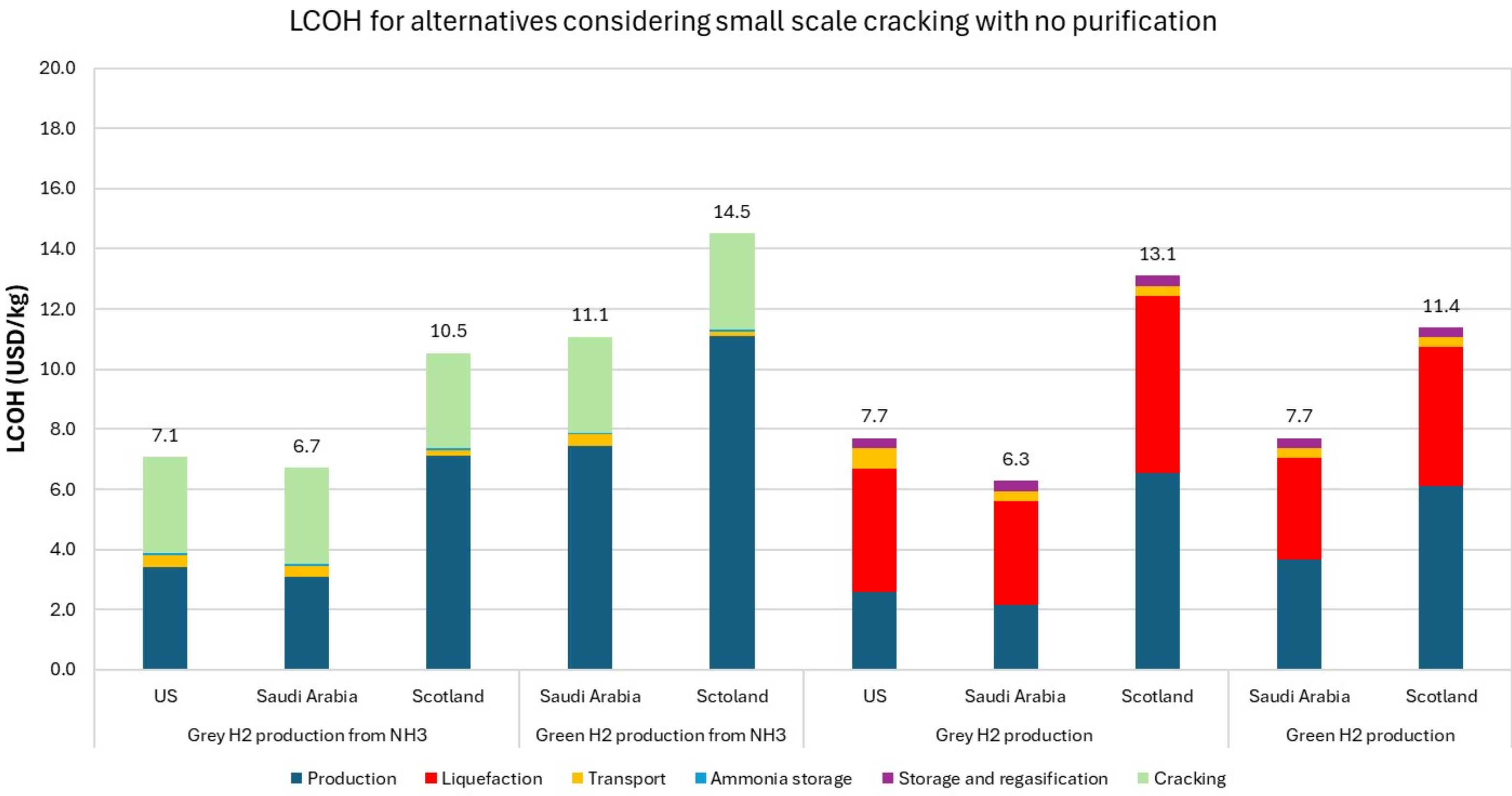

- **Liquid hydrogen has the lowest cost. However, grey ammonia costs are similar**
- **The difference between ammonia and hydrogen (US and Saudi Arabia) is based on electricity prices.**

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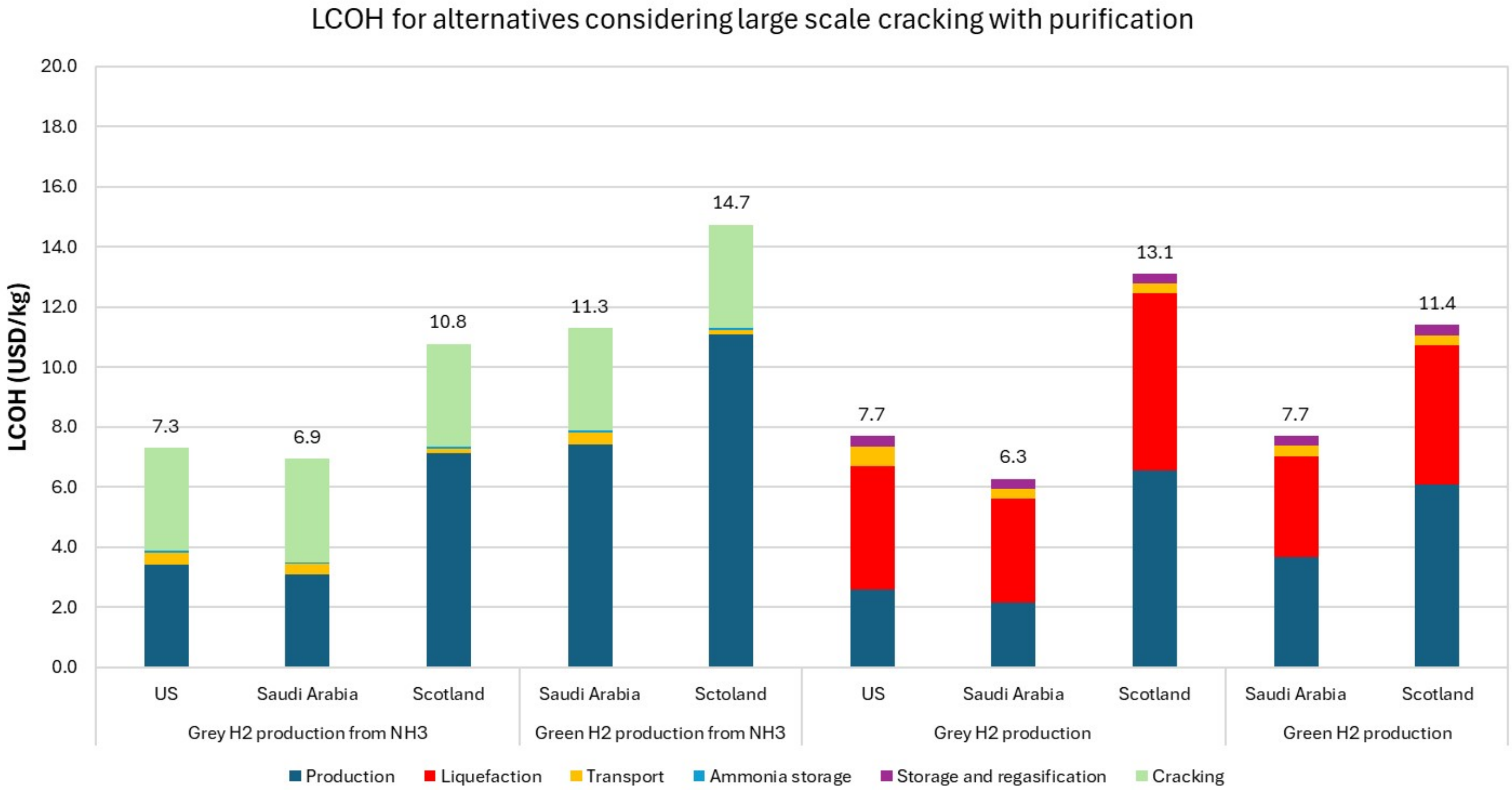

- **There are economies of scale (cracking).**
- **The lowest-cost alternative is liquid hydrogen from Saudi Arabia.**

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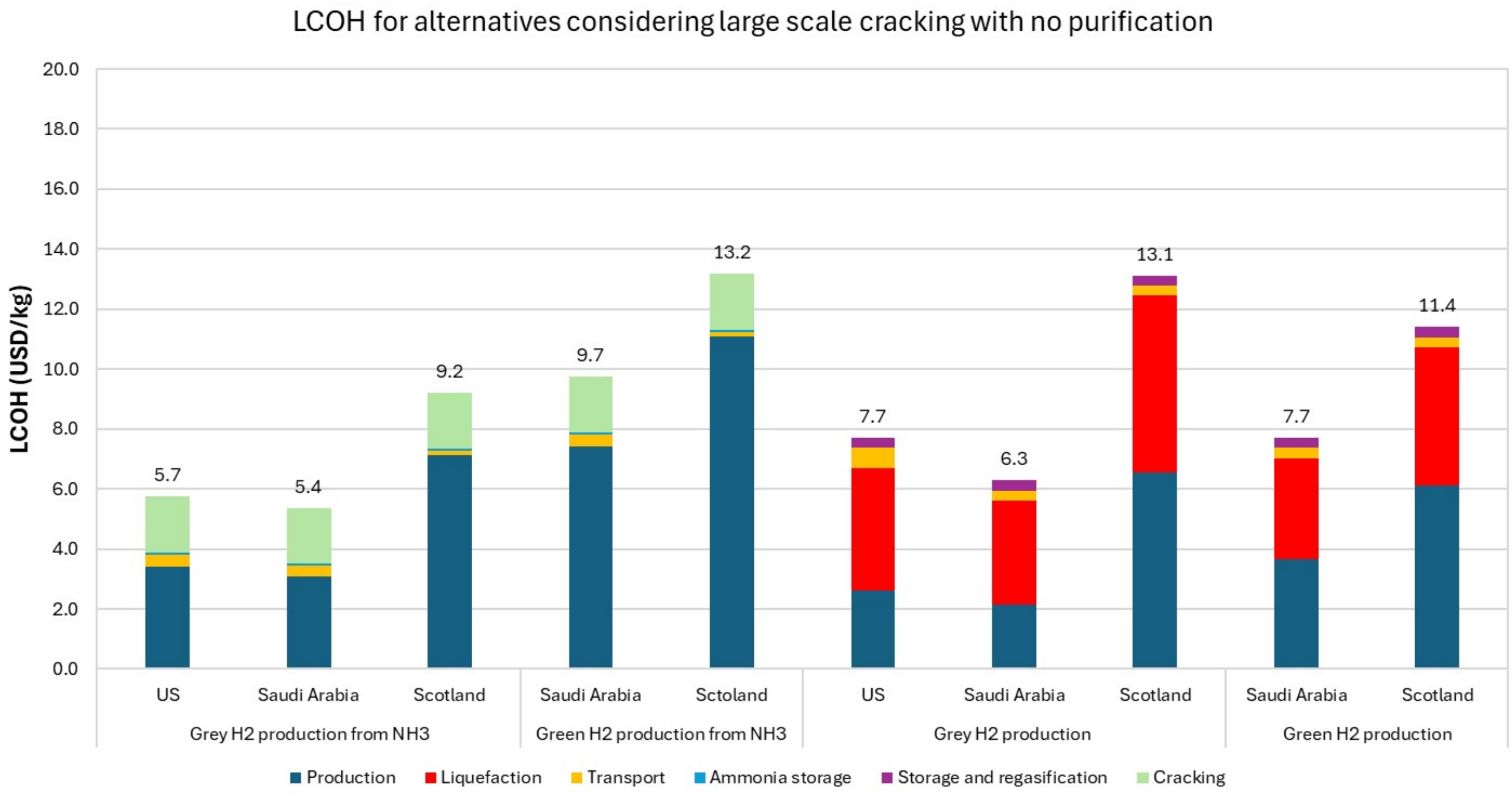
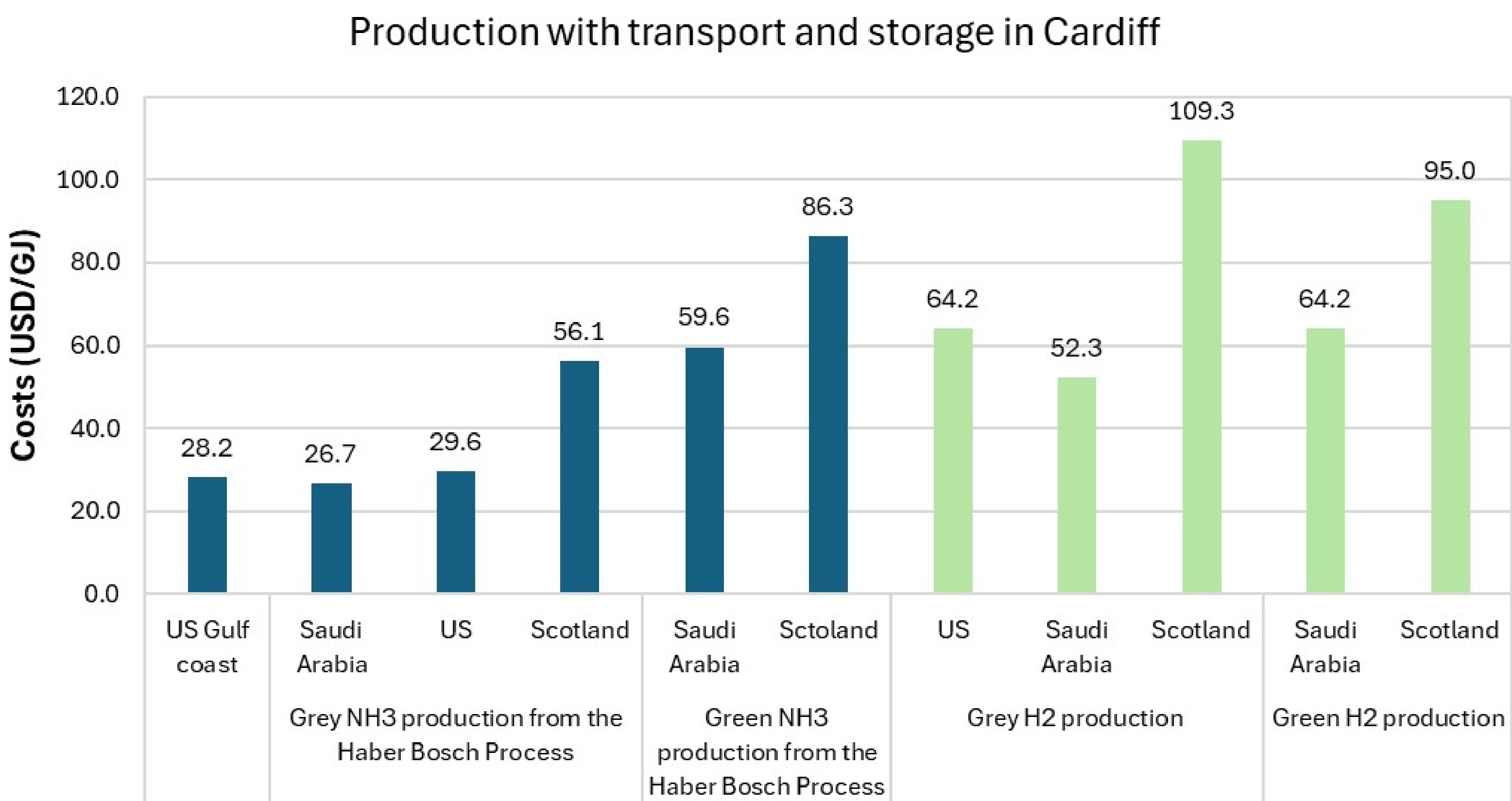


- **Grey ammonia is the lowest-cost alternative.**
- **Electricity and natural gas prices have an important impact.**

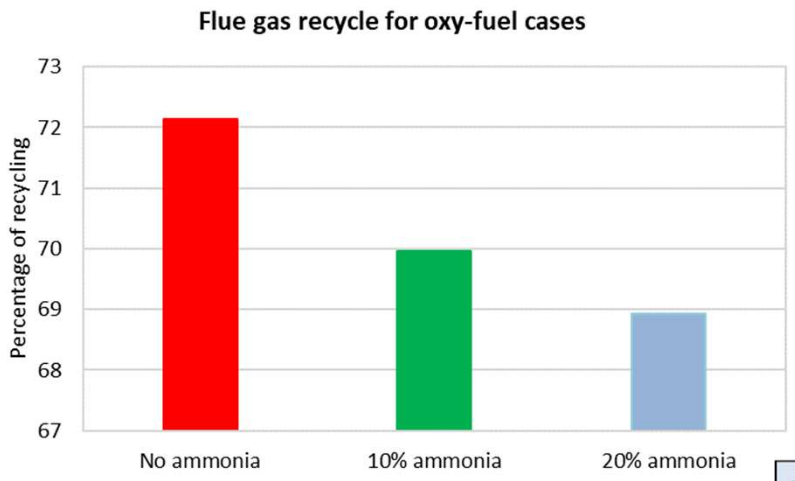
UK SCENARIO FOR AMMONIA UTILIZATION



- **If directly used, ammonia is the lowest-cost alternative.**

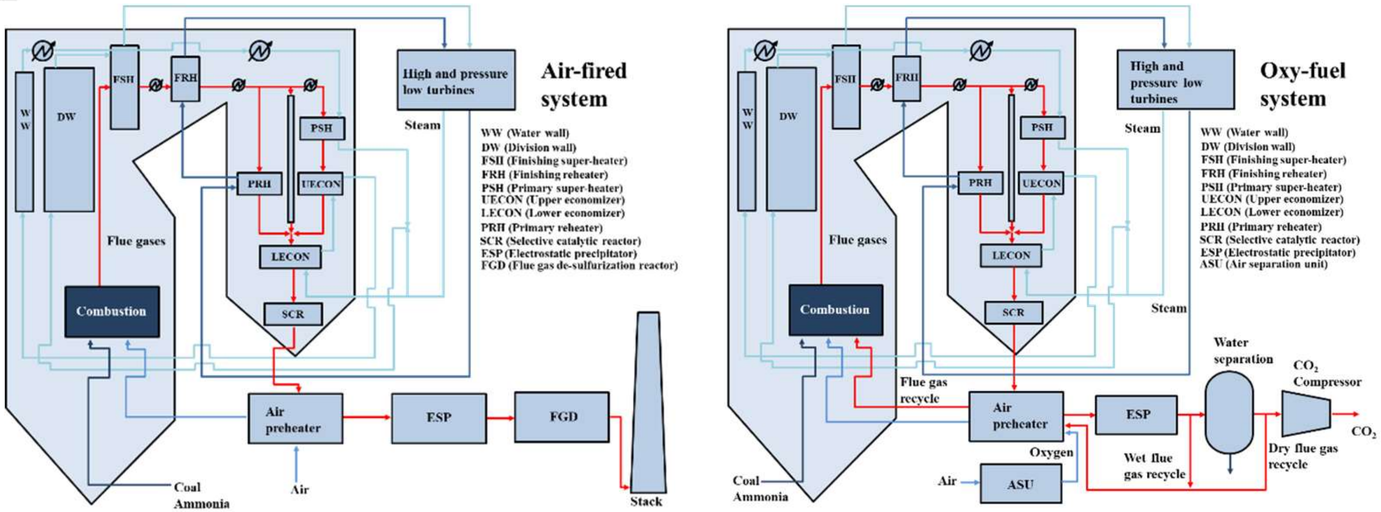
UK SCENARIO FOR AMMONIA UTILIZATION

Ammonia Co-firing with coal



- The oxygen that may be produced in electrolysers could be used for oxy-fuel combustion.
- Ammonia co-firing could reduce CO_2 emissions in both air-fired and oxy-fuel combustion and process conditions are important to improve the performance of boilers.

The increase in the concentration of nitrogen for the oxy-fuel combustion cases is within the 10% mole limit that could be allowed for CO_2 transport and geological storage.



Source: Taken from: Jano-Ito, Reed and Millan-Agorio (2014).

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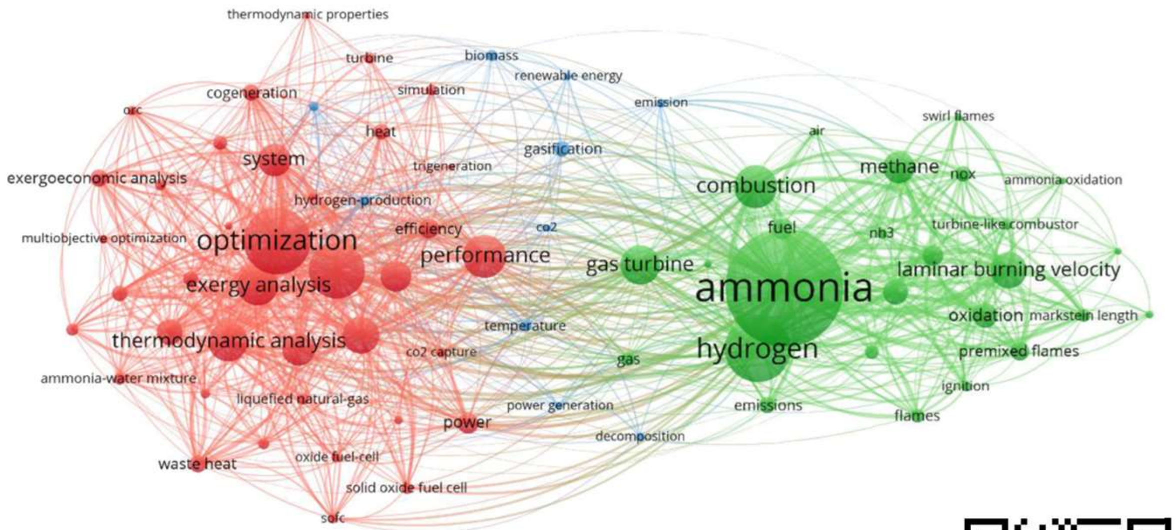
NH3–H2 Engine Development



Dr Mo Alnajideen

AlnajideenMI@cardiff.ac.uk

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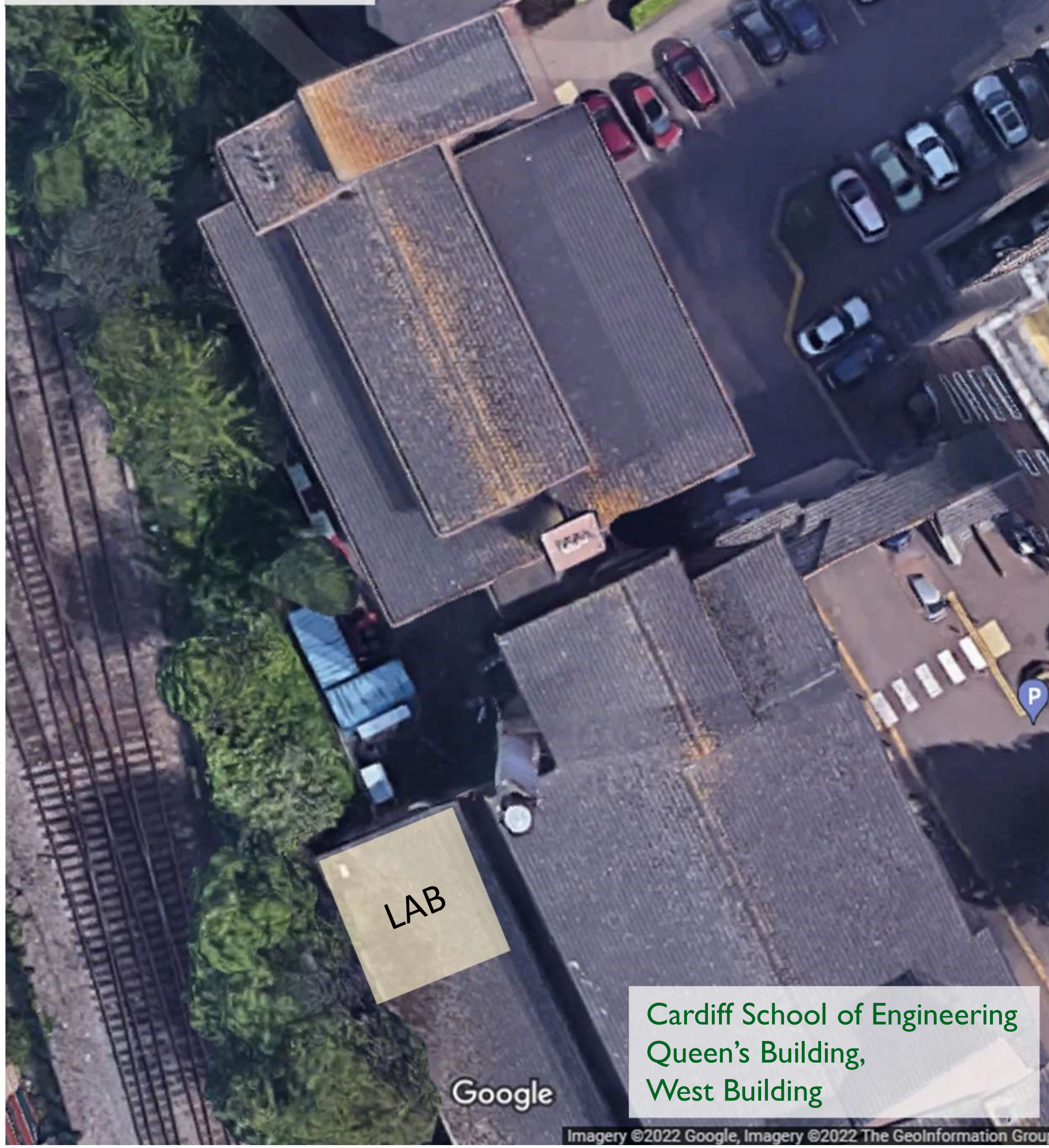
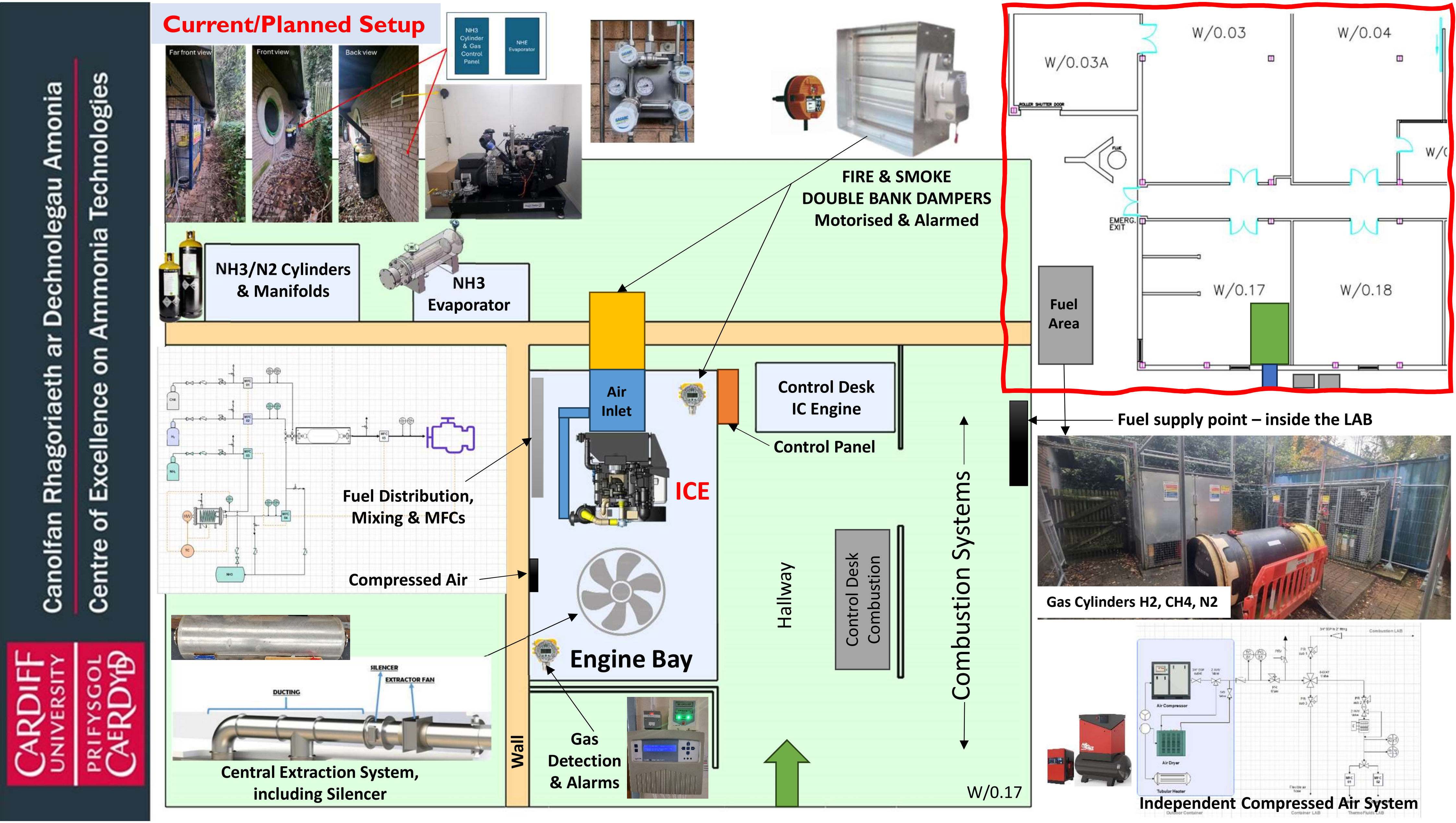
CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

Commissioning of new canopy to host NH3 evaporator outside of the lab – A new NH3 Supply.

Site & Planning



Cardiff School of Engineering
Queen's Building,
West Building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CARDIFF UNIVERSITY
PRIFYSGOL CAERDYD
Current/Planned Setup
Far front view
Front view
Back view
NH3 Cylinder & Gas Control Panel
NHE Evaporator
NH3/N2 Cylinders & Manifolds
NH3 Evaporator
FIRE & SMOKE DOUBLE BANK DAMPERS Motorised & Alarmed
W/0.03A
W/0.03
W/0.04
EMERG. EXIT
W/0.17
W/0.18
Fuel Area
Air Inlet
ICE
Control Desk IC Engine
Control Panel
Fuel supply point – inside the LAB
Fuel Distribution, Mixing & MFCs
Compressed Air
Engine Bay
Hallway
Control Desk Combustion
Combustion Systems
Gas Cylinders H2, CH4, N2
SILENCER
EXTRACTOR FAN
DUCTING
Central Extraction System, including Silencer
Wall
Gas Detection & Alarms
W/0.17
Independent Compressed Air System

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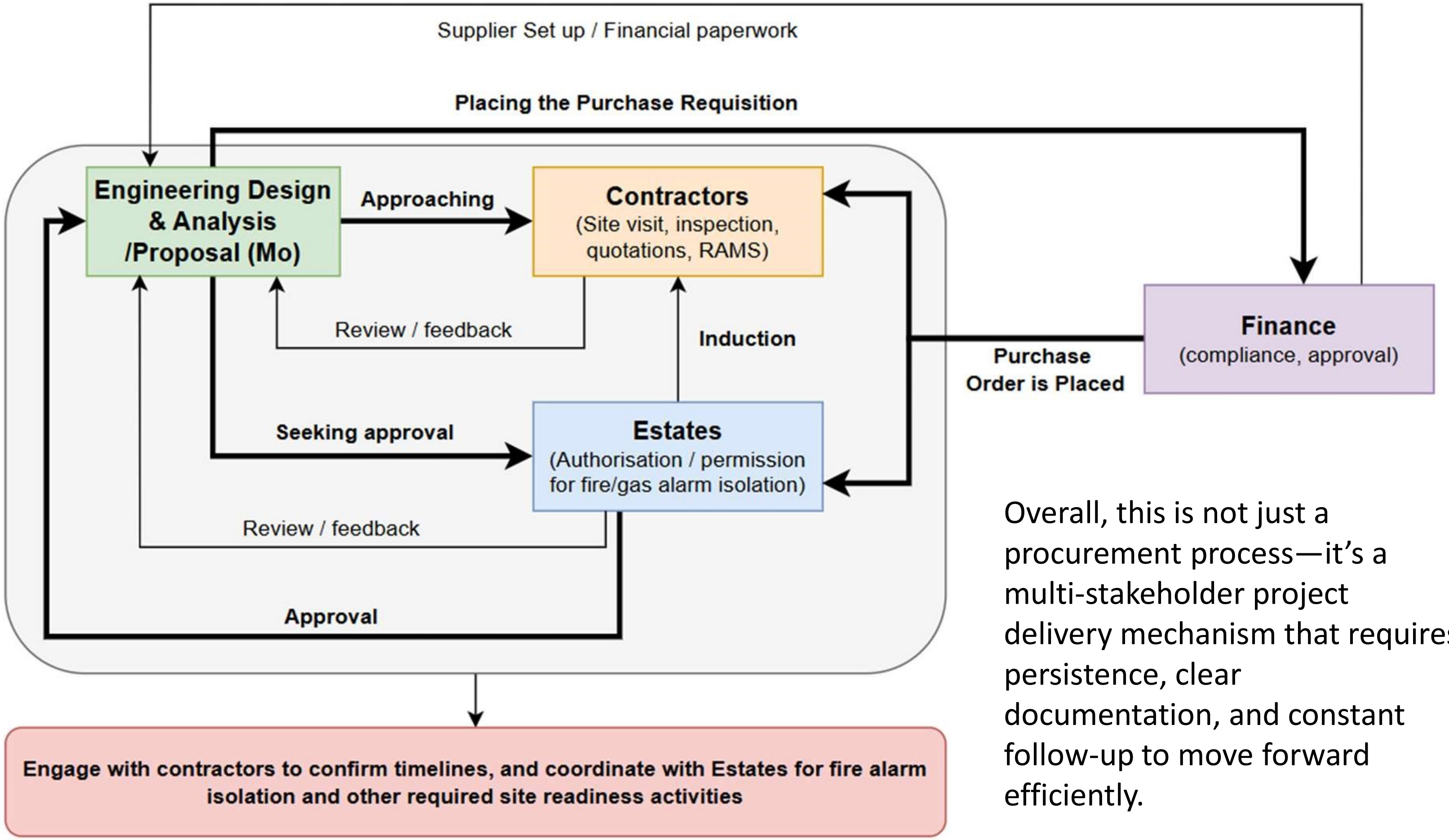
The diagram illustrates the intricate and resource-intensive process required to implement any engineering procurement or site-based modification.

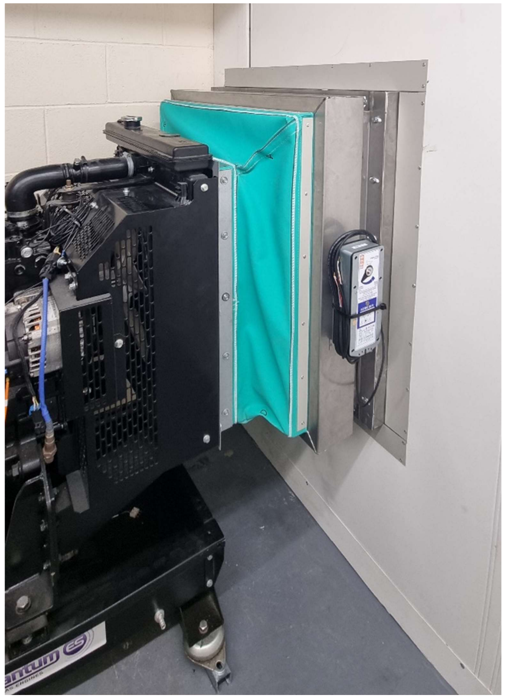
Despite appearing linear, the workflow involves multiple interdependent stages, each demanding extensive coordination and formal approvals across various departments.



Overall, this is not just a procurement process—it's a multi-stakeholder project delivery mechanism that requires persistence, clear documentation, and constant follow-up to move forward efficiently.


Quantum ES
GAS ENGINES
31 July 2025 4:35 pm


CORE




CORE

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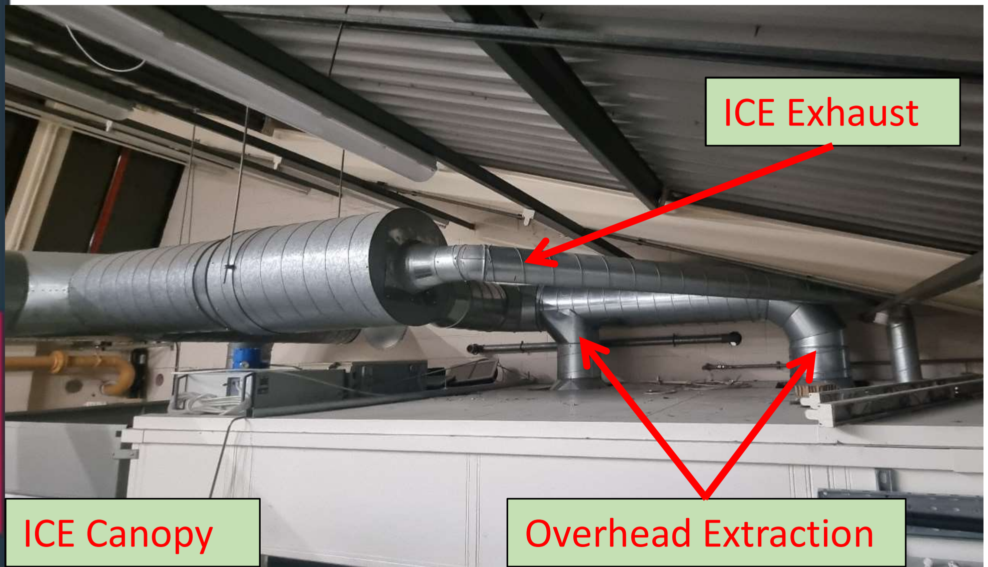

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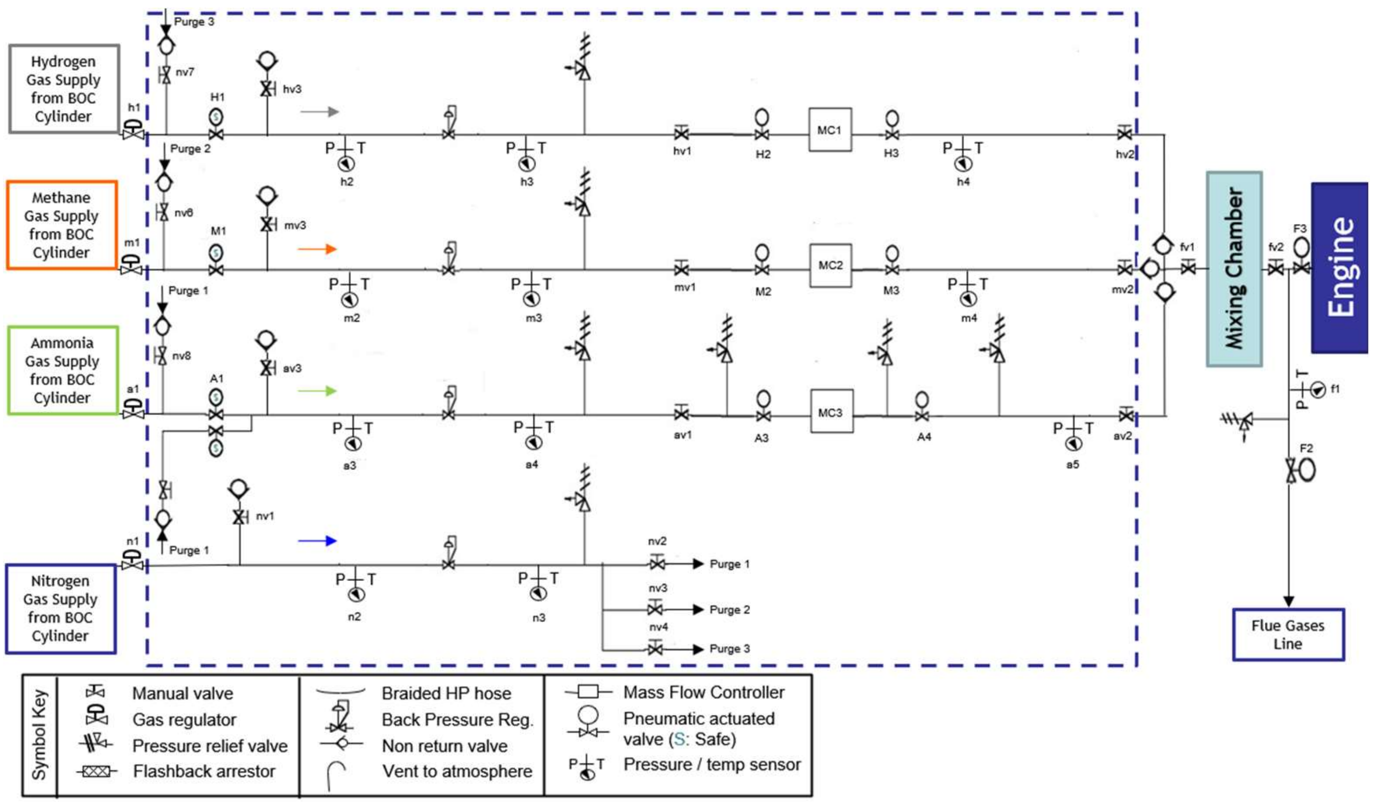


Customer Ref: ENGIN 31406484

Certificate No: JC155217-01

Test records:

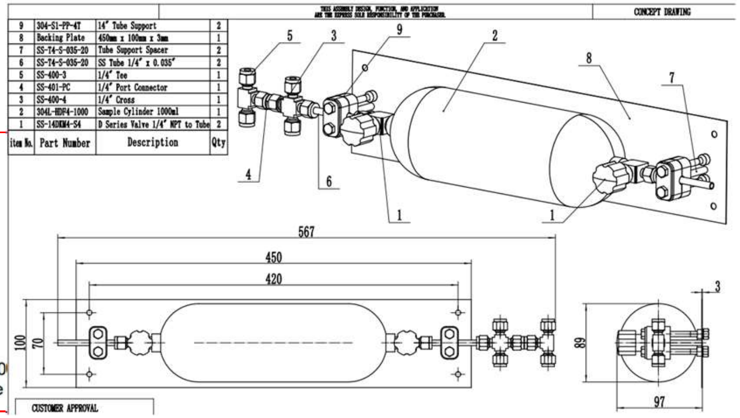
Stainless steel tube coil: Type: 8mm coil Serial No: N.A.

Type of Test: Hydrostatic Pressure Test – 8 Bar / Duration 30 mins

Bronkhorst MFCs
(NH3, H2, N2, CH4, Air)

Terms and Conditions

Total goods	:	£ 22,524.00
Discount	:	£ 3,378.60
Subtotal	:	£ 19,145.40
Shipping cost	:	£ 287.18
Total amount (excl. VAT)	:	**£ 19,432.58**
VAT 20%	:	£ 3,886.52
Total incl VAT	:	**£ 23,319.10**
Lead time	:	Ca. 4 working weeks after receipt of order
Validity quotation	:	30 days from date of offer
Delivery	:	1.5% of order value (CIF, UK mainland) £20.0
Payment	:	30 days net, approved accounts, from invoice



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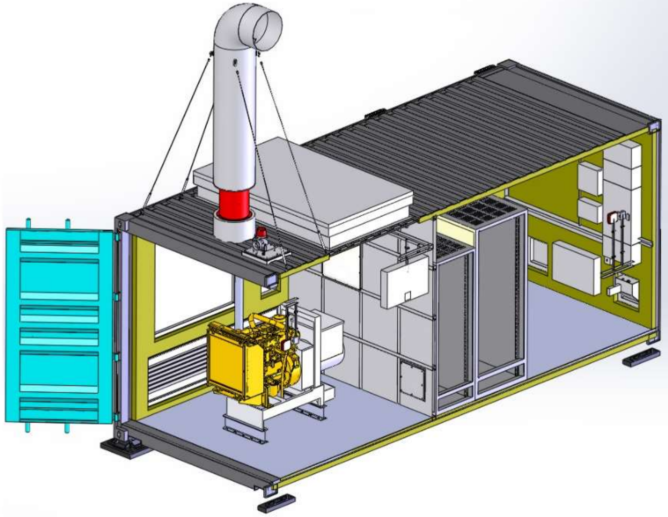
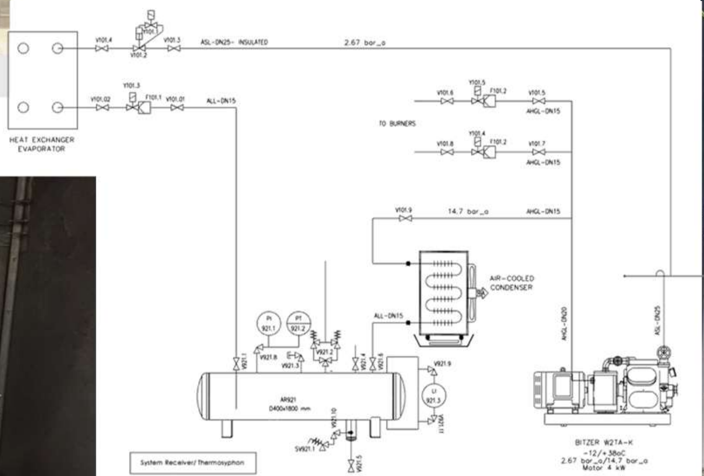
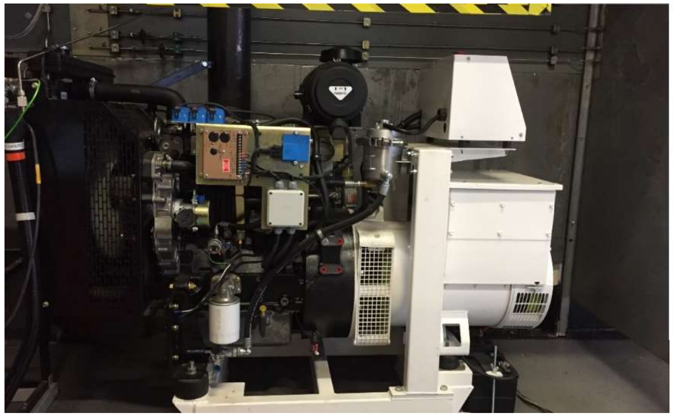
World first Green Ammonia power demonstrator developed by Siemens, Cardiff and Oxford University

12 February 2019

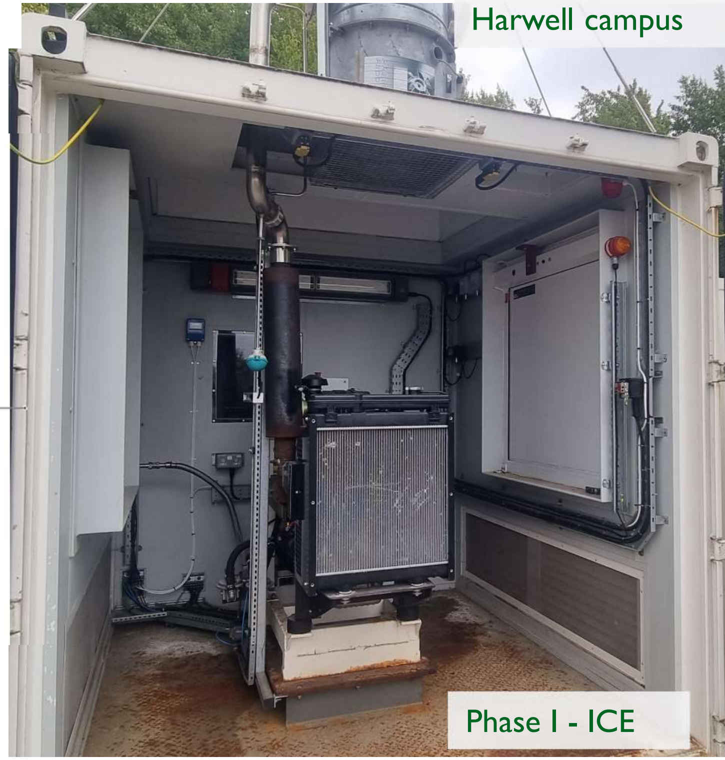
Flexis team







STFC Project
Harwell campus



Phase I - ICE

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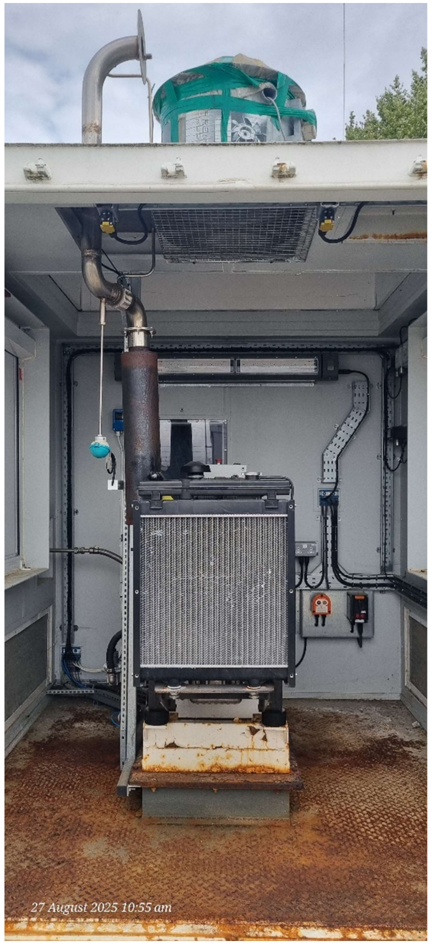
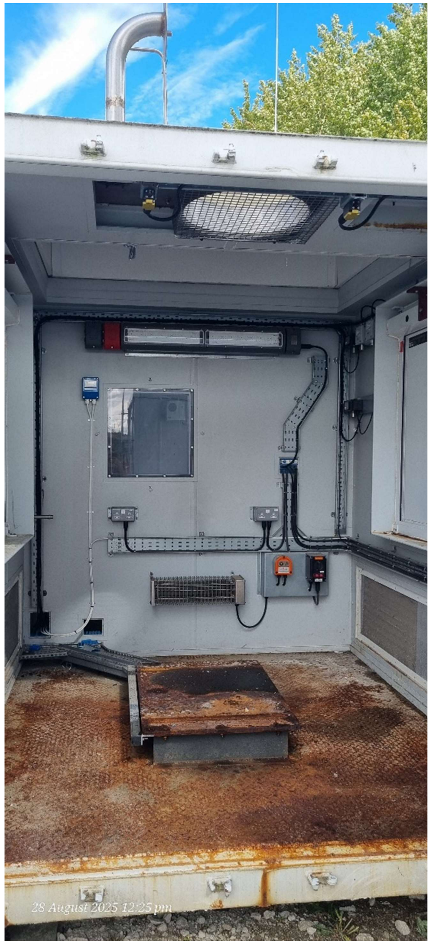
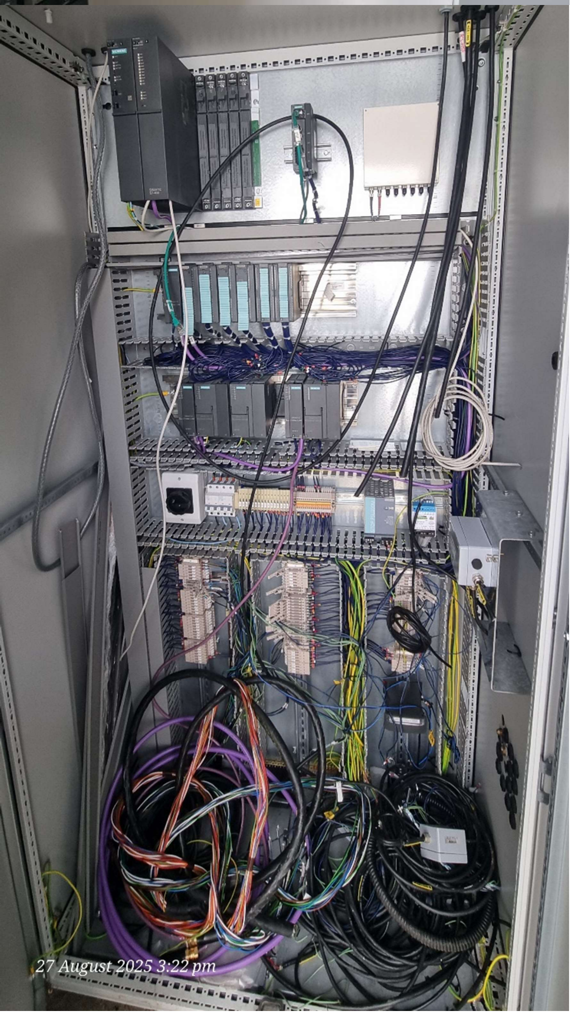
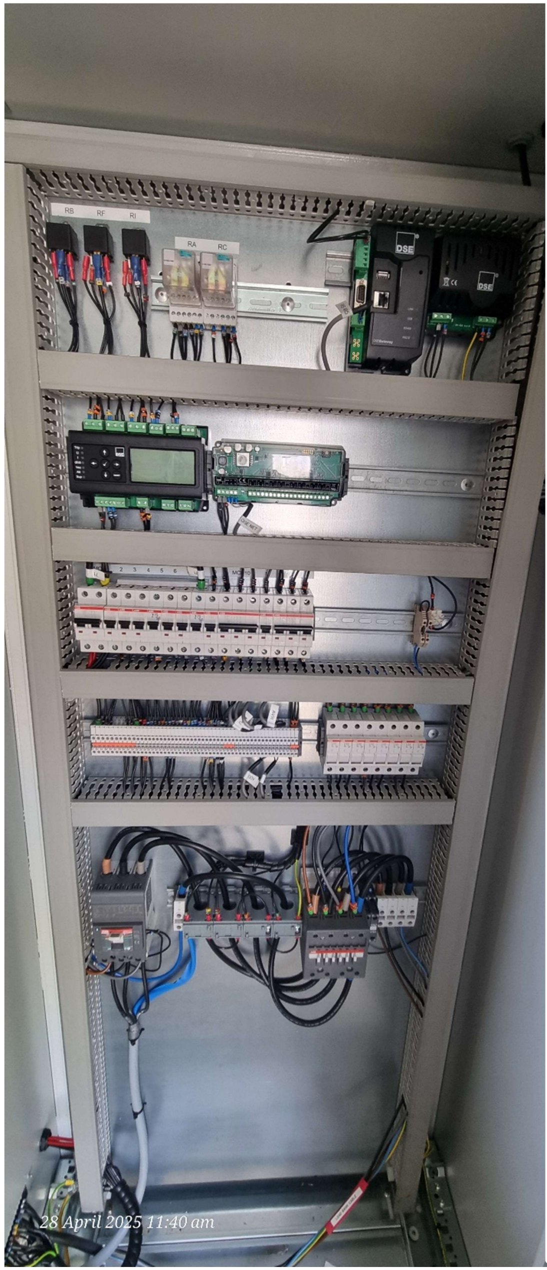
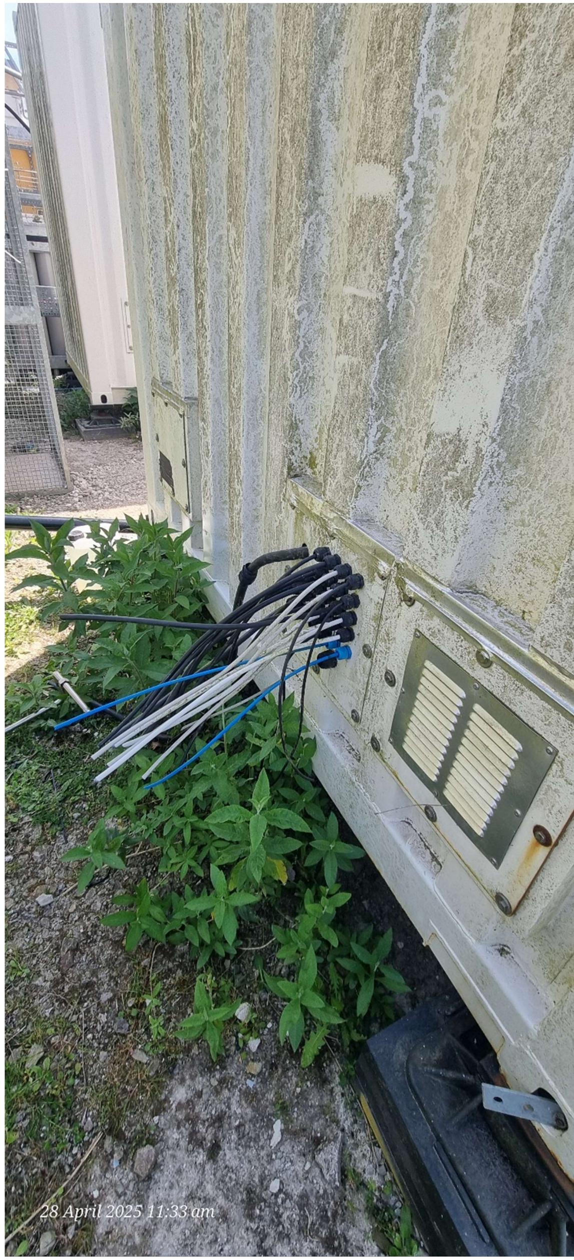





27 August 2025 3:22 pm


RB
RF
RI
RA
RC
DSE
DSE
28 April 2025 11:40 am


H2
METHANE
27 August 2025 2:57 pm


28 April 2025 11:33 am

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Quantum Q3.3 TSI Spark Ignited Gas Engine – Experimental Test

General Installation

Designation	Units	Type of Operation			
		Prime	Stand-by	Prime	Stand-by
		Hz	Hz	Hz	Hz
		1500	1500	1800	1800
Gross engine power	kWm	31.9	36.2	35.1	40.0
Brake mean effective pressure	kPa	773	878	710	807
Engine coolant flow 35 kPa restriction	l/min	48	48	88	88
Combustion air flow	m^3/min	2.5	2.9	3.1	3.7
Exhaust gas flow (max)	m^3/min	5.5	6.3	6.6	7.5
Exhaust gas outlet temperature (max at standby)	°C	503	496	486	476.2
Cooling fan air flow (200kPa external restriction)	m^3/min	53	53	70	70
Overall thermal efficiency (net)	%	35.6	36.4	34.6	35.5
Genset electrical output	kWe	28	32	31	35
	kVA	35	40	39	55
Power factor		0.8	0.8	0.8	0.8
Actual alternator efficiency	%	90.4	90.4	91.8	91.5
Fuel consumption	m^3/hr	8.8	9.8	9.8	10.9
Energy balance					
Power in fuel (Fuel heat of combustion)	kW	87.1	97.0	96.7	107.8
Power output (gross)	kW	31.9	36.2	35.1	40.0
Power to cooling fan	kW	0.9	0.9	1.7	1.7
Power output (net)	kW	31.0	35.3	33.4	38.3
Power to coolant and lubricating oil	kW	22.2	24.8	26.8	27.4
Power to exhaust	kW	23.5	26.7	27.6	31.3
(Recoverable power, exhaust cooled to 120 °C)	kW	18.6	21.0	21.5	24.0
Power to radiation	kW	9.5	9.2	7.2	9.2

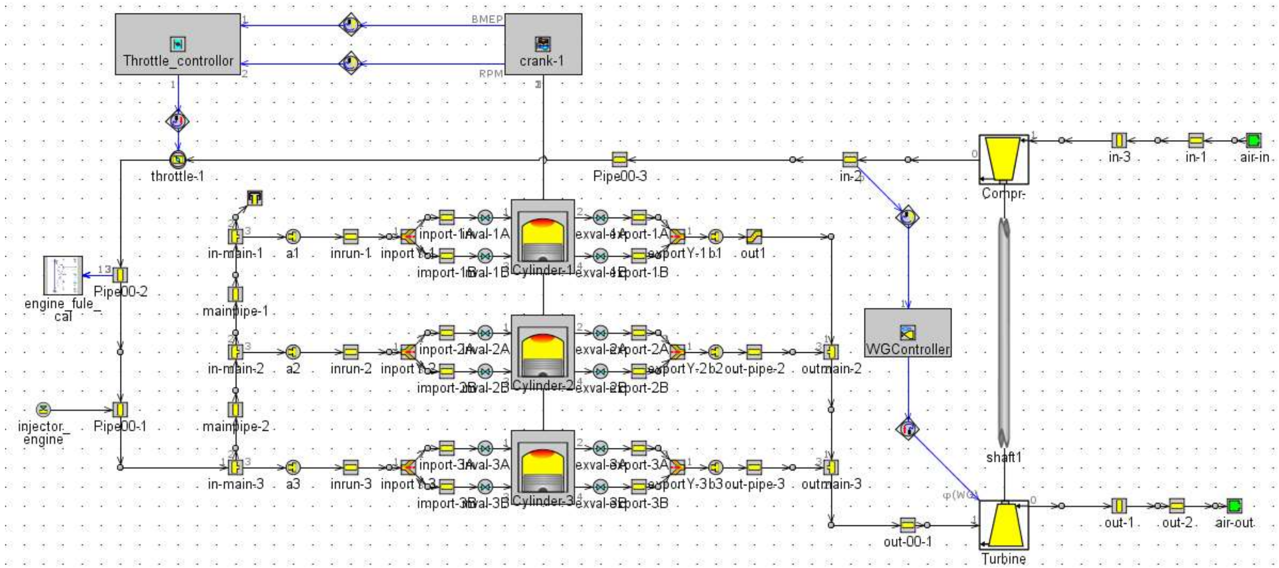
Basic technical data

Number of cylinders. 3
Cylinder arrangement ... ... Vertical in-line
Cycle. ... ... Four stroke
Induction system... ... ... Turbocharged
Compression ratio. ... ... .13 : 1
Bore .. .. 105 mm (4.13 in)
Stroke .. .. 127 mm (4.99 in)
Cubic capacity .. .. 3.3 litres
Direction of rotation... ... ... Clockwise view from front
Firing order 1,2,3

LOAD	Ambient°C	engine speed	Timing	Mains Gas pressure (mb)	MAT	MAP	Coolant temp °C	Top hose	Bottom hose	Phi	EFR position	Throttle pos	Fuel consumption kg/hr	Oil Temp	Oil pressure (Bar)
0	19	1500	27	28	51.4	31	78.4	72	28	1	21.5	8.5	3.82	69	3.6
5	19	1500	26.8	28	43.4	36.7	79.2	73.2	33.7	1	23.2	10.6	4.57	85	3.45
10	19.5	1500	26.6	28	43	43.3	79.4	75	39.7	1	24.9	12.2	5.48	87	3.45
15	19.5	1500	25.8	28	43.8	52	80	75.8	41	0.998	27	14.1	6.81	88	3.41
20	19.5	1500	24.7	28	47.3	64.8	80.5	76.6	44.9	0.914	28.8	18.1	8.37	89	3.42
25	20	1500	24	28	52.7	75.2	80.7	77.4	50.1	0.875	29.9	21.6	9.61	91	3.42

EMISSIONS							EXHAUST TEMPS			
LOAD	NO(ppm)	Nox(mg/m³)	CO(ppm)	02(%)	CO2(%)	Lambda	Exhaust temp	Cyl 1	Cyl 2	Cyl 3
0	23	64	67	19.9	0.18	0	347	549	555	553
5	230	604	389	18.2	0.88	7.64	460	584	585	585
10	518	1360	729	16.9	1.5	5.13	499	593	601	593
15	931	2525	996	15.1	2.29	3.69	527	605	630	611
20	1088	2992	1025	15.9	1.86	4.11	539	593	630	604
25	343	2778	956	16.4	1.66	4.61	542	589	631	602

Combustion & Emission Characteristics of a Q3.3 TSI Engine



Item	Value
Engine speed（rpm）	1500
Power（kW）	31.9
Bore	105
Stroke	127
Cylinder	3
Compression ratio	13
Gas consumption（m^3/h）	8.8

Item	Value	Error
Rated power	31.9kW	-
Simulated power	32.1kW	0.63%

- Using **GT-POWER** to build a 1D simulation model of the engine, including intake and exhaust system model, cylinder model, turbocharging model, injector model, crankshaft drive module, and system boundary conditions (pressure, temperature, etc.);

- By adjusting ignition timing, intake pressure, compression ratio, and other parameters, the model calibration is completed. With a test data error of 0.63%, the model meets the requirements for subsequent calculations.

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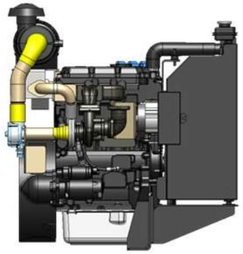
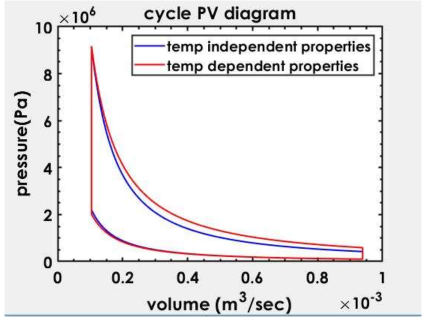
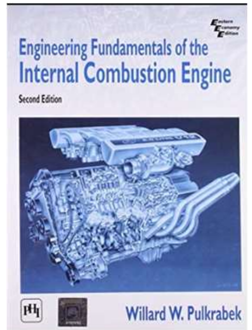
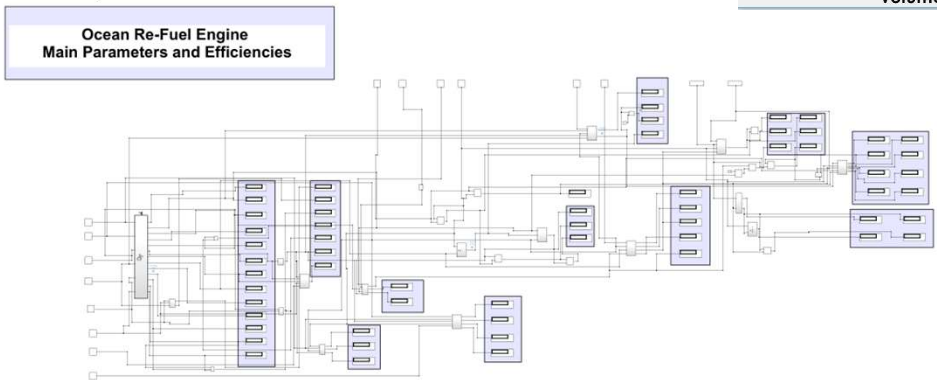
A MATLAB/Simulink is designed to simulate ICE performance by calculating various engine parameters and efficiencies based on user-provided inputs.

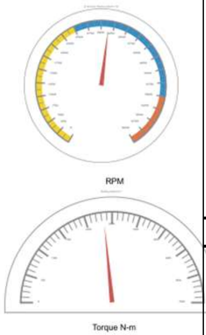


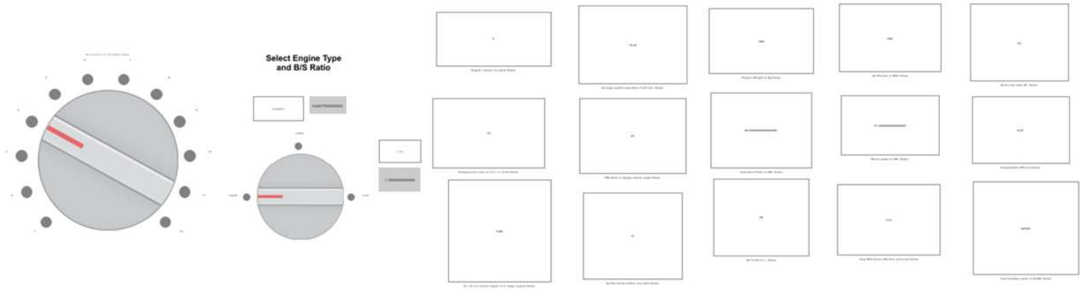




Input Parameters (Required for Calculation)
Engine Specifications:
Engine type (SI/CI, 2-stroke/4-stroke)
Bore (mm)
Stroke (mm)
Number of cylinders
Compression ratio (CR)
Connecting rod length (mm)
Cylinder head surface area (cm²)
Crank angle (°) at TDC
Fuel type
Fuel heating value (kJ/kg)
Air-fuel ratio (AFR)
Volumetric efficiency (%)
Combustion efficiency (%)
Operating Conditions:
Engine speed (RPM)
Intake air temperature (°C)
Intake air pressure (kPa)
Fuel mass flow rate (kg/s)
Air mass flow rate (kg/s)
Ambient pressure and temperature
Combustion pressure curve
Fuel and Combustion Parameters:
Fuel heating value (MJ/kg)
Fuel-air equivalence ratio







Output Parameters (Computed from Inputs)
Geometric & Operational Parameters:
Bore (mm) & Stroke (mm)
Displacement volume (L)
Compression ratio (CR)
Clearance volume (Vc)
Piston speed (m/s)
Crank radius (mm)
Connecting rod-to-crank ratio
Instantaneous volume at crank angles
Engine speed (RPM)
Mean piston speed (m/s)
Crankshaft torque (Nm)
Performance Parameters:
Indicated power (kW)
Brake power (kW)
Friction power (kW)
Indicated mean effective pressure (IMEP) (kPa)
Brake mean effective pressure (BMEP) (kPa)
Friction mean effective pressure (FMEP) (kPa)
Brake thermal efficiency (%)
Indicated thermal efficiency (%)
Mechanical efficiency (%)
Volumetric efficiency (%)
Specific fuel consumption (kg/kWh, g/kWh)
Brake specific fuel consumption (BSFC) (g/kWh)
Indicated specific fuel consumption (ISFC) (g/kWh)
Exhaust gas composition (CO_2, CO, NO_x, HC, O_2) (%)
Specific emissions (g/kWh)
Exhaust temperature (°C)

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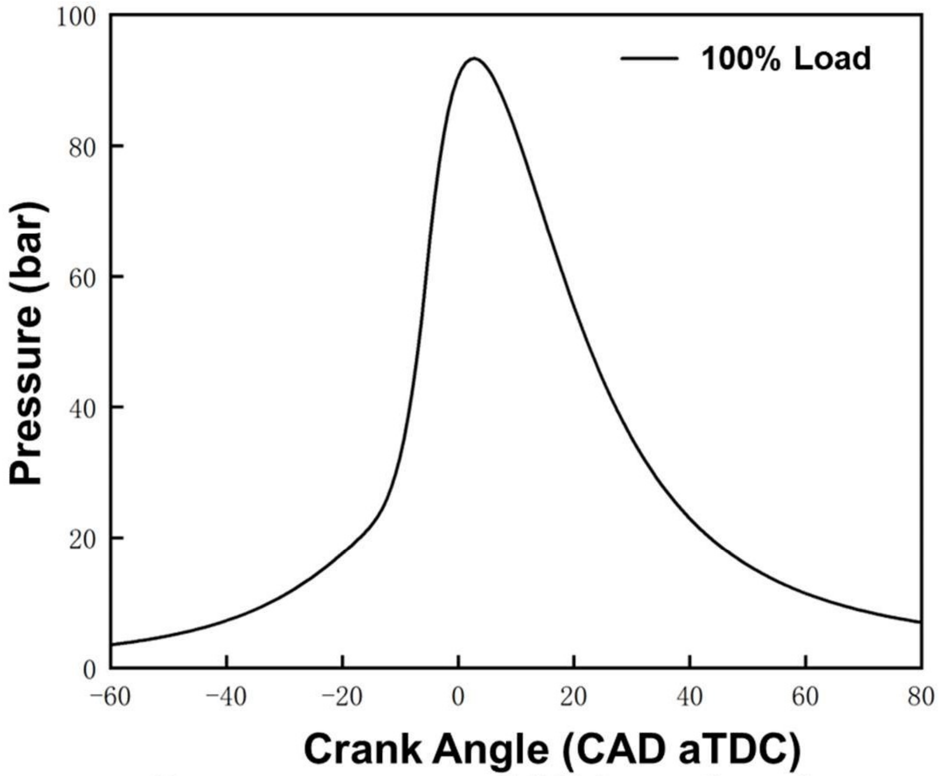
Natural Gas Engine Combustion Characteristics



Pressure curve of CH_4 combustion

Parameter	Value
Ignition Timing (CAD aTDC)	-26.00
Turbo charging (bar)	1.60
λ	1.15
Intake Pressure (bar)	1.00
Intake Temperature (K)	298.15
Compression Ratio	13

Simulation Results	Value
Power (kW)	32.1
Peak Pressure (bar)	93.3
Fuel Consumption Rate (g/kWh)	231.6
NOx (ppm)	4775

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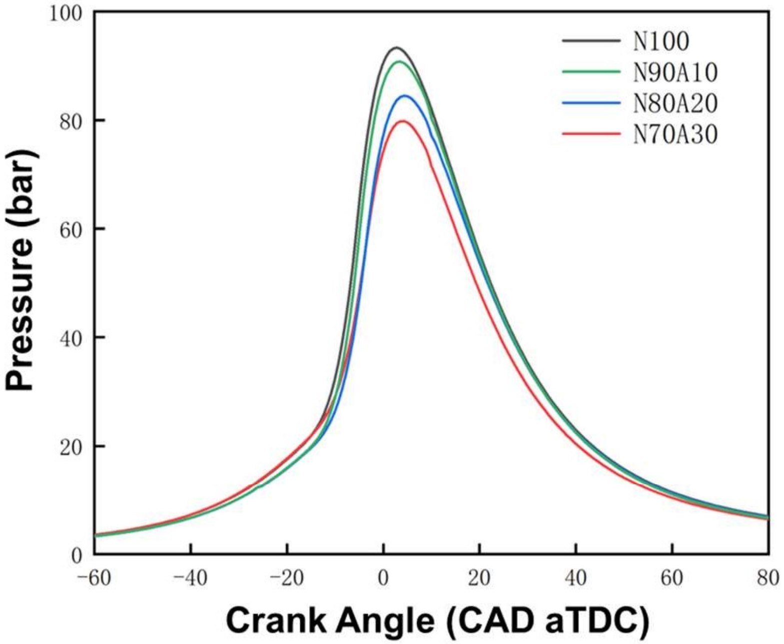
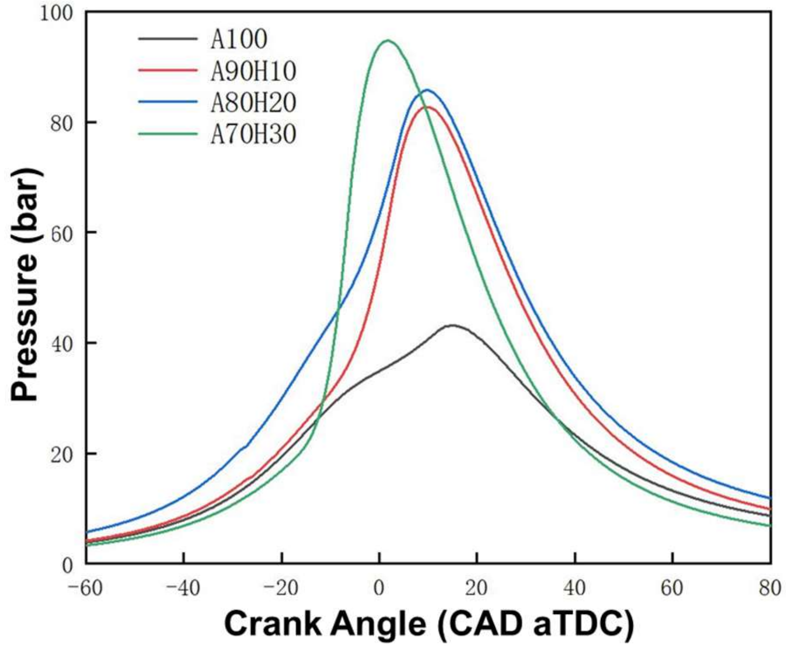
NH3/CH4 Combustion & Emission Characteristics



Pressure curve of NH3/CH4 combustion

Fuel Mixture	Power (kW)	Peak Pressure (Bar)	Fuel Consumption (g/kWh)	NOx (ppm)
N100	31.2	93.3	231.6	4775
N90A10	30.7	90.8	226.8	8222
N80A20	30.4	84.5	240.2	8197
N70A30	28.6	79.7	367.8	7982

NH3/H2 Combustion & Emission Characteristics



Pressure curve of NH3/H2 combustion

Fuel Mixture	Peak Pressure (Bar)	Fuel Consumption (g/kWh)
A100	42.8	691.4
A90H10	82.6	576.3
A80H20	85.93	521.3
A70H30	94.5	429.8

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Parameter Group	Input Parameter	Value	Notes
Engine Geometry	Number of cylinders	3	Vertical in-line
	Bore	105 mm	
	Stroke	127 mm	
	Compression ratio	13	
	Crankshaft rotation direction	Clockwise	From front view
	Firing order	1–2–3	
Operating Conditions	Engine displacement (capacity)	3.3 L	Calculated from bore/stroke and cylinder count
	Engine speeds	1500 rpm / 1800 rpm	Prime and standby
	Intake air temp	25 °C	Standard test condition
	Barometric pressure	100 kPa	
	Relative humidity	30%	
Induction	Induction type	Turbocharged	Forced induction
	Max air intake restriction	2–4 kPa	Clean to dirty filter
	Combustion air flow rate	2.5 – 3.7 m^3/min	Varies with speed and load
Fuel Properties	Fuel type	Natural Gas	LHV = 35.66 MJ/m^3
	Fuel consumption	8.8 – 10.9 m^3/hr	Load and speed dependent
	Supply pressure	Min 25 mbar	Contact OEM if lower
Combustion & Ignition	Combustion type	Spark-ignition	Otto cycle
	Ignition system	Electronic, 1 coil per cylinder	Inductive
	Lambda or equivalence ratio	Required input	Based on AFR and fuelling strategy
Exhaust	Max back pressure (at 1800 rpm)	15 kPa	
	Exhaust gas flow rate	5.5 – 7.5 m^3/min	
	Exhaust temp (max)	476 – 503 °C	
Cooling System	Coolant flow rate	48 – 88 L/min	
	Coolant system capacity	10.2 L (with radiator)	
	Coolant temp range	82 – 105 °C	
	Fan characteristics	457 mm, 7-blade, pusher type	
Lubrication	Total oil system capacity	8.3 L	
	Oil pressure	276 – 470 kPa	
Mechanical	Flywheel moment of inertia	1.14 kg·m^2	
	Engine rotational inertia	0.141 kg·m^2	
Installation	Dry/Wet weight	398 / 416 kg	
	Engine dimensions (L x W x H)	1010 × 640 × 1050 mm	
	Max installation angle	25°	All directions

Notes

Fuel Properties (changeable; see Tab "INPUTS-1 (Fuel Blends)"

Power in fuel (Fuel heat of combustion) is fixed at 100kW

Basic technical data

Number of cylinders. 3
Cylinder arrangement .... Vertical in-line
Cycle. .... Four stroke
Induction system.................... Turbocharged
Compression ratio. .... 13 : 1
Bore .... 105 mm (4.13 in)
Stroke .... 127 mm (4.99 in)
Cubic capacity .... 3.3 litres
Direction of rotation.................... Clockwise view from front
Firing order 1,2,3

Q3.3TSI Engine – Technical Data (collected from the Datasheet)

Designation	Units	Type of Operation			
		Prime	Stand-by	Prime	Stand-by
		Hz	Hz	Hz	Hz
		1500	1500	1800	1800
Gross engine power	kWm	31.9	36.2	35.1	40.0
Brake mean effective pressure	kPa	773	878	710	807
Engine coolant flow 35 kPa restriction	l/min	48	48	88	88
Combustion air flow	m^3/min	2.5	2.9	3.1	3.7
Exhaust gas flow (max)	m^3/min	5.5	6.3	6.6	7.5
Exhaust gas outlet temperature (max at standby)	°C	503	496	486	476.2
Cooling fan air flow (200kPa external restriction)	m^3/min	53	53	70	70
Overall thermal efficiency (net)	%	35.6	36.4	34.6	35.5
Genset electrical output	kWe	28	32	31	35
	kVA	35	40	39	55
Power factor		0.8	0.8	0.8	0.8
Actual alternator efficiency	%	90.4	90.4	91.8	91.5
Fuel consumption	m^3/hr	8.8	9.8	9.8	10.9

Gross thermal power (kW) 'fuel heat of combustion'	89.61	99.45	101.45	112.68	~ 100 kW_{avg}

INPUTS-1 (Fuel Blends) | INPUTS-2 (Engine Parameters) | Expected Results | Results (Plots)

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Fuel Blend	Blend Ratio (vol%)	AFR (Φ=0.6)	AFR (Φ=1.0)	AFR (Φ=1.4)	LHV (MJ/kg)	Mechanism
CH_4	100%	28.67	17.20	12.29	50.00	GRI-Mech 3.0
H_2	100%	57.17	34.30	24.50	120.00	San Diego Mechanism, or AramcoMech 3.0
NH_3	100%	10.08	6.05	4.32	18.60	Okafor et al. (2018) or Konnov v2019
CH_4/H_2	30%:70%	44.03	26.42	18.87	65.87	
CH_4/H_2	50%:50%	38.18	22.91	16.36	57.82	GRI-Mech 3.0 or AramcoMech 2.0 or 3.0
CH_4/H_2	70%:30%	33.70	20.22	14.44	53.58	
CH_4/NH_3	30%:70%	12.52	7.51	5.36	27.63	
CH_4/NH_3	50%:50%	14.92	8.95	6.39	33.83	Konnov + GRI-Mech merged, or Okafor et al. modified
CH_4/NH_3	70%:30%	18.47	11.08	7.91	40.18	
$CH_4/NH_3/N_2$	30%:30%:40%	24.87	14.92	10.66	15.88	
$CH_4/NH_3/N_2$	40%:40%:20%	18.65	11.19	7.99	23.76	Same as above + treat N_2 as inert in thermodynamic model
$CH_4/NH_3/N_2$	50%:30%:20%	21.18	12.71	9.08	26.48	
$CH_4/H_2/NH_3$	30%:30%:40%	18.05	10.83	7.74	35.97	
$CH_4/H_2/NH_3$	40%:40%:20%	24.52	14.71	10.51	45.25	HyChem/Aramco + Konnov/Okafor merged
$CH_4/H_2/NH_3$	50%:30%:20%	23.52	14.11	10.08	44.63	
$CH_4/H_2/NH_3/N_2$	25%:20%:50%:5%	16.18	9.71	6.94	28.42	
$CH_4/H_2/NH_3/N_2$	25%:25%:25%:25%	26.40	15.84	11.31	21.56	Same as above + N_2 as inert
$CH_4/H_2/NH_3/N_2$	30%:30%:20%:20%	28.13	16.88	12.06	26.10	
$CH_4/H_2/NH_3/N_2$	40%:20%:20%:20%	26.82	16.09	11.49	27.33	
NH_3/H_2	30%:70%	23.82	14.29	10.21	40.55	
NH_3/H_2	50%:50%	17.15	10.29	7.35	29.33	Okafor et al. (2018)
NH_3/H_2	70%:30%	13.40	8.04	5.74	23.50	

INPUTS-1 (Fuel Blends) | INPUTS-2 (Engine Parameters) | Expected Results | Results (Plots)

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Source	Mechanisms
GRI-Mech 3.0 / AramcoMech 2.0 or 3.0	CH_4/H_2
Konnov Mechanisms	CH_4/NH_3
Okafor et al. (2018)	NH_3/H_2
San Diego Mech	H_2
San Diego Mech	$H_2/CO/CH_4$

Cracking NH3 Cases [2 NH3 → 3H2 + N2]								
Fuel Blend	Blend Ratio (vol%)				AFR (Φ=0.6)	AFR (Φ=1.0)	AFR (Φ=1.4)	LHV (MJ/kg)
	CH4	NH3	H2	N2				
CH4/**NH3** - 0% cracked NH3	100	0.00	0.00	0.00	28.67	17.20	12.29	50.00
CH4/**NH3** - 5% cracked NH3	95	4.52	0.36	0.12	26.53	15.92	11.37	48.52
CH4/**NH3** - 10% cracked NH3	90	8.18	1.36	0.45	25.15	15.09	10.78	47.36
CH4/**NH3** - 15% cracked NH3	85	11.09	2.93	0.98	24.30	14.58	10.41	46.46
CH4/**NH3** - 20% cracked NH3	80	13.33	5.00	1.67	23.82	14.29	10.21	45.78
CH4/**NH3** - 25% cracked NH3	75	15.00	7.50	2.50	23.62	14.17	10.12	45.27
CH4/**NH3** - 30% cracked NH3	70	16.15	10.38	3.46	23.67	14.20	10.14	44.95
CH4/**NH3** - 35% cracked NH3	65	16.85	13.61	4.54	23.95	14.37	10.26	44.78
CH4/**NH3** - 40% cracked NH3	60	17.14	17.14	5.71	24.43	14.66	10.47	44.77
CH4/**NH3** - 45% cracked NH3	55	17.07	20.95	6.98	25.13	15.08	10.77	44.92
CH4/**NH3** - 50% cracked NH3	50	16.67	25.00	8.33	26.08	15.65	11.18	45.26
CH4/**NH3** - 55% cracked NH3	45	15.97	29.27	9.76	27.28	16.37	11.69	45.81
CH4/**NH3** - 60% cracked NH3	40	15.00	33.75	11.25	28.78	17.27	12.34	46.62
CH4/**NH3** - 65% cracked NH3	35	13.79	38.41	12.80	30.67	18.40	13.14	47.76
CH4/**NH3** - 70% cracked NH3	30	12.35	43.24	14.41	33.03	19.82	14.16	49.36
CH4/**NH3** - 75% cracked NH3	25	10.71	48.21	16.07	36.00	21.60	15.43	51.58
CH4/**NH3** - 80% cracked NH3	20	8.89	53.33	17.78	39.80	23.88	17.06	54.78
CH4/**NH3** - 85% cracked NH3	15	6.89	58.58	19.53	44.82	26.89	19.21	59.63
CH4/**NH3** - 90% cracked NH3	10	4.74	63.95	21.32	51.62	30.97	22.12	67.54
CH4/**NH3** - 95% cracked NH3	5	2.44	69.42	23.14	61.32	36.79	26.28	82.45
CH4/**NH3** - 100% cracked NH3	0	0.00	75.00	25.00	76.22	45.73	32.66	120.00

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Engine Performance Results

Metric	Unit	Description
Brake Power	kW	Net output at the crankshaft
Indicated Power	kW	Power developed in cylinders
Brake Torque	Nm	Torque output at the crankshaft
Brake Mean Effective Pressure (BMEP)	bar	Engine loading measure
Indicated Mean Effective Pressure (IMEP)	bar	Gross pressure-based indicator
Brake Thermal Efficiency	%	Efficiency of fuel-to-power conversion
BSFC (Brake Specific Fuel Consumption)	g/kWh	Fuel use per unit brake power
Volumetric Efficiency	%	Intake air filling effectiveness
Mechanical Efficiency	%	Ratio of brake to indicated power

Emissions Predictions

Emission	Units	Description
NO_x	ppm or g/kWh	Nitric oxides from high-temperature
CO	ppm or g/kWh	Incomplete combustion indicator
HC	ppm or g/kWh	Unburnt hydrocarbons
CO_2	g/kWh or %vol	Fuel carbon balance
Particulate Matter	mg/m^3	(If soot models applied)

Figures Generated:
- Emissions vs. load/rpm
- NOx vs. equivalence ratio or boost
- Emissions breakdown per cylinder

In-Cylinder Combustion Analysis

Output	Description
Cylinder Pressure vs. Crank Angle	Combustion pressure trace
Heat Release Rate	Energy release timing
Cumulative Heat Release	Total chemical energy released
Ignition Delay / Burn Duration	Combustion phasing metrics
Pressure Rise Rate	Used to predict knock tendency
Peak Cylinder Pressure & Location	Max pressure and its crank angle

Figures Generated:
- Pressure vs. Crank Angle plot
- Heat Release Rate vs. Crank Angle
- P-V (Pressure-Volume) diagrams

Thermal Management Results

Output	Description
Wall Heat Transfer	Heat loss from combustion to walls
Coolant Temperature	Circuit temperature and flow rates
Oil Circuit Temperature	Engine oil thermal performance
Heat Rejection Breakdown	By coolant, oil, exhaust, etc.
CHT Wall Temperature (if 3D included)	Conjugate heat transfer maps

Figures Generated:
- Heat rejection vs. time
- Coolant temperature vs. time
- Wall heat transfer vs. crank angle or cylinder index

Transient and Drive Cycle Outputs

Metric	Description
RPM vs. Time	Speed profile tracking
Torque vs. Time	Load-following characteristics
Turbo Lag, Throttle Response	Transient behaviours
Temperature vs. Time	Coolant, oil, component temps
Emissions vs. Time	Instantaneous or integrated

Figures Generated:
- Torque/RPM vs. time
- Transient thermal response plots
- Emissions vs. time

Flow Dynamics & Gas Exchange

Result	Description
Mass Flow Rate (air, fuel, exhaust)	At engine ports and system boundaries
Boost Pressure & Turbocharger Speed	For turbocharged engines
Intake & Exhaust Valve Flow Coefficients	Valve operation and timing effects
Manifold Pressure & Temperature	For flow wave analysis
Pumping Losses	Work lost in moving gases in/out of cylinders

Figures Generated:
- Mass flow vs. crank angle or time
- Intake/exhaust pressure wave diagrams
- Turbocharger performance maps
- Valve lift vs. crank angle profiles

Fuel & Chemical Energy Balances

Output	Description
Fuel Energy Input	LHV × mass flow
Energy Recovered as Brake Work	Useful output
Waste Heat via Coolant, Exhaust, etc.	Thermal loss analysis
Combustion Efficiency	Based on energy balance and emissions

Acoustics

Sound Pressure Level (SPL)	For intake/exhaust/muffler
Transmission Loss	Silencer effectiveness
Frequency Spectrum	FFT of pressure signals

Figures Generated:
- Frequency response plots
- SPL vs. frequency for different locations
- Transmission loss vs. frequency

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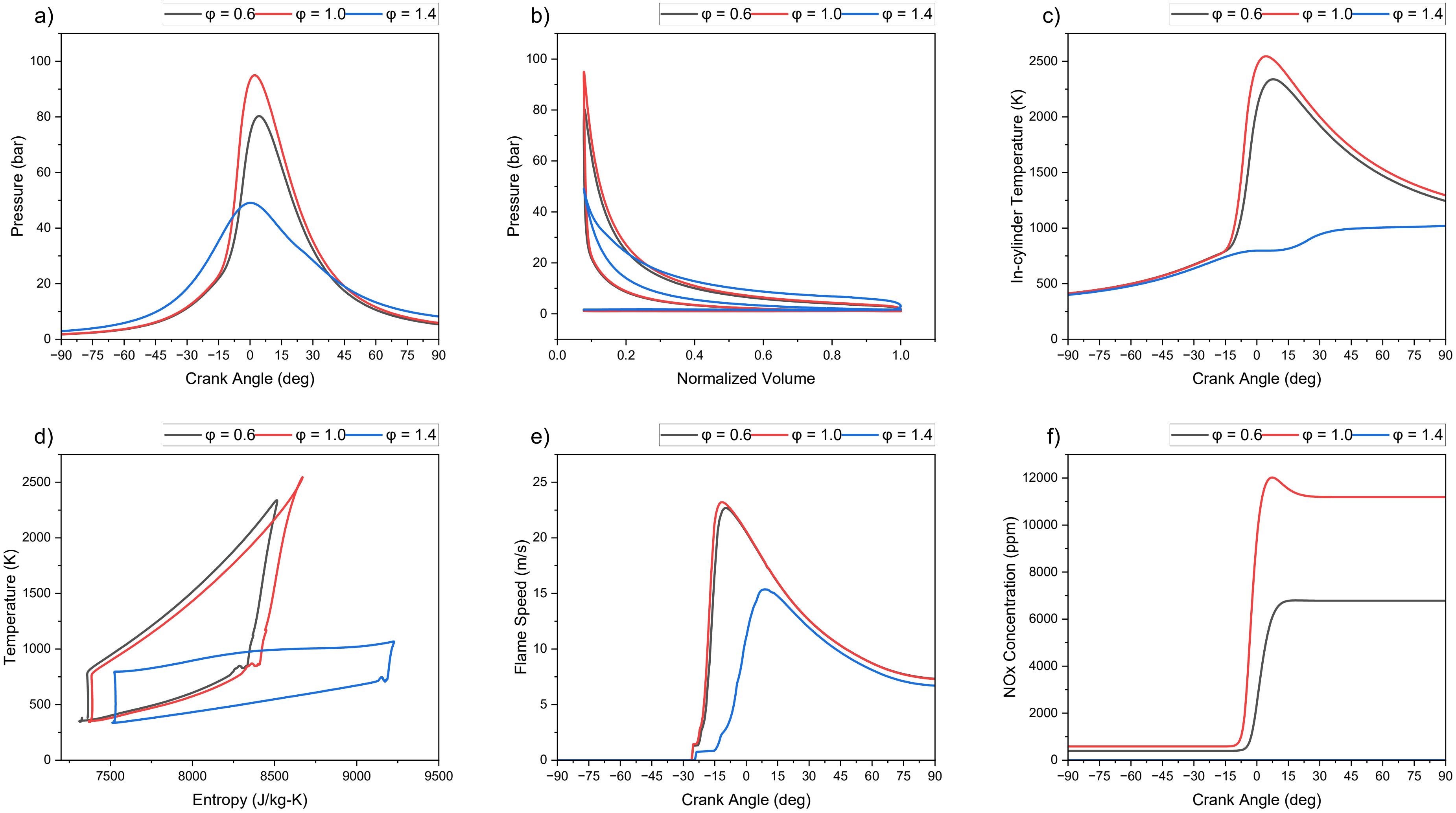
CH4 - RPM = 1500 | Throttle Angle = 50 | Phi = 0.6 to 1.4

	φ = 0.6	φ = 1.0	φ = 1.4
Engine Speed (rpm)	1500	1500	1500
Brake Torque (N-m)	180.08	202.95	110.80
Brake Power (kW)	28.29	31.88	17.40
BMEP (bar)	6.86	7.73	4.22
Air/fuel ratio	23.63	18.67	8.66



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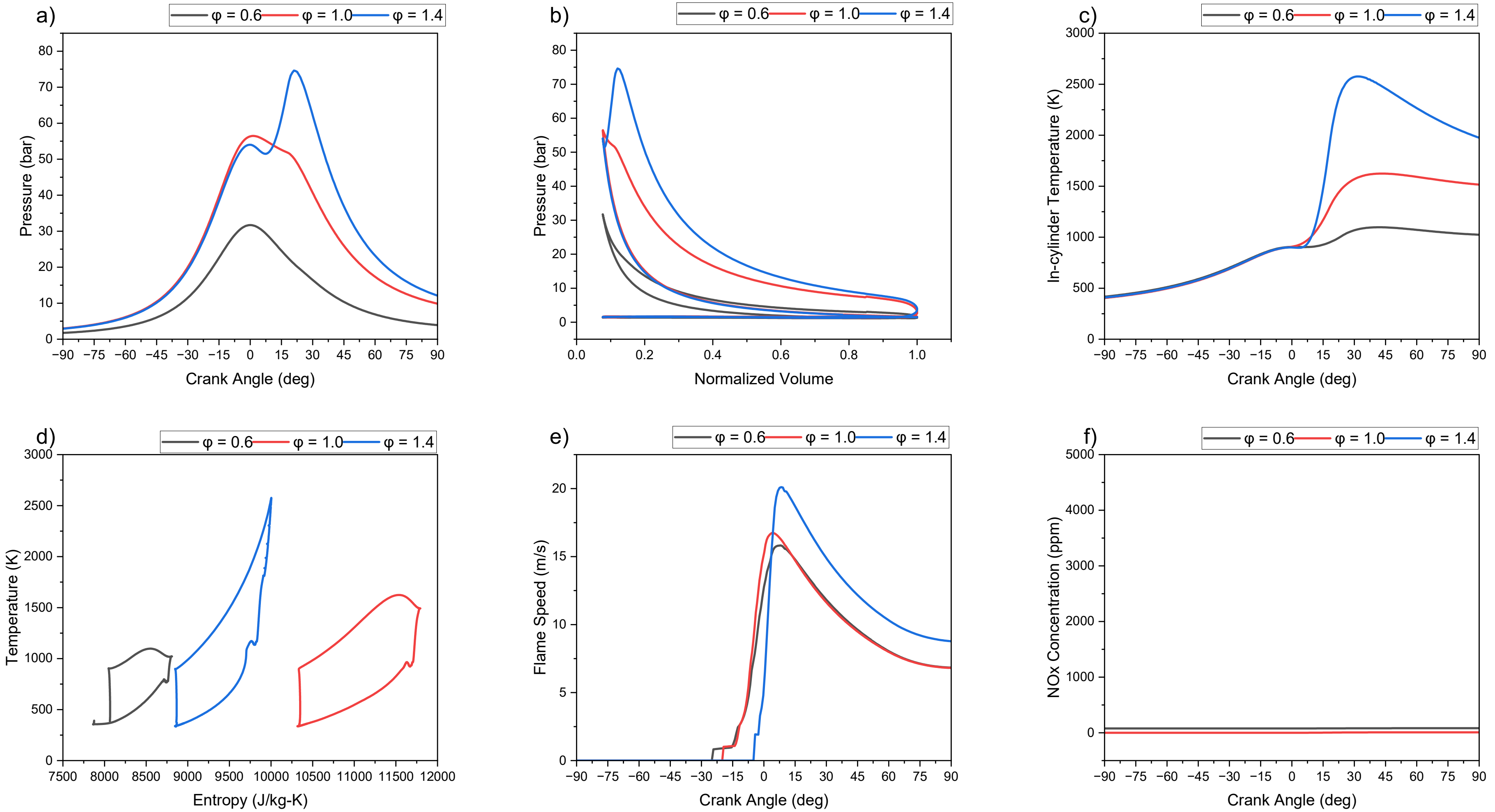
H2 - RPM = 1500 | Throttle Angle = 50 | Phi = 0.6 to 1.4

	φ = 0.6	φ = 1.0	φ = 1.4
Engine Speed (rpm)	1500	1500	1500
Brake Torque (N-m)	33.22	173.70	370.15
Brake Power (kW)	5.22	27.29	69.77
BMEP (bar)	1.27	6.62	14.10
Air/fuel ratio	94.94	16.79	30.89



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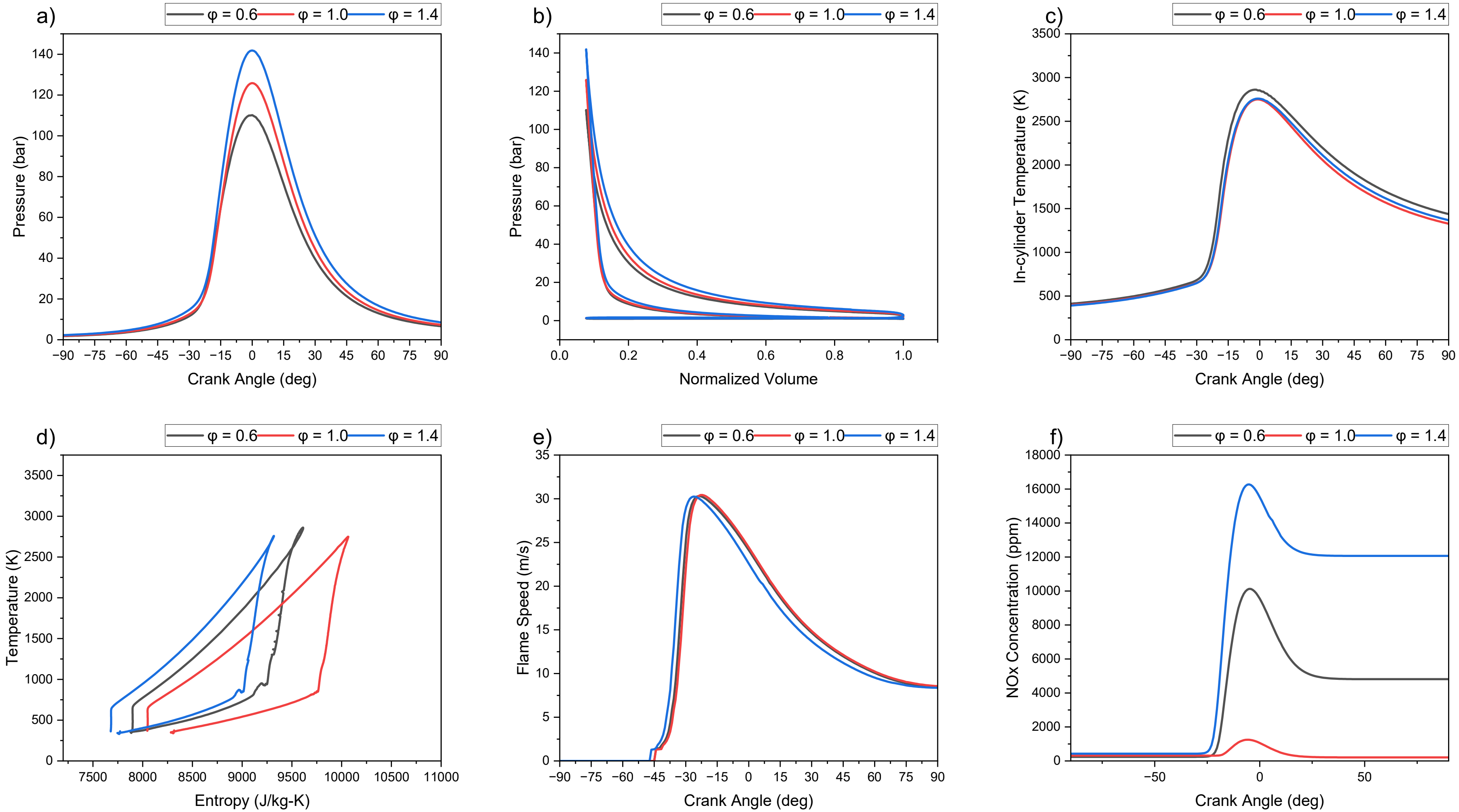
NH3/H2 70%:30%vol - RPM = 1500 | Throttle Angle = 50 | Phi = 0.6 to 1.4

	φ = 0.6	φ = 1.0	φ = 1.4
Engine Speed (rpm)	1500	1500	1500
Brake Torque (N-m)	195.07	321.59	173.21
Brake Power (kW)	32.68	50.52	27.21
BMEP (bar)	7.43	12.25	6.60
Air/fuel ratio	7.88	5.18	6.78



Recent Publications

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IET The Institution of Engineering and Technology

Ammonia Combustion Applications for Energy Systems

Edited by Agustin Valera-Medina, Yuyang Li, Hao Shi, Dongsheng Dong, Mara de Joannon and Daria Bellotti

Chapter Item | 31 December 2024

Chapter 5

Ammonia-fueled internal combustion engines

Authors: H. Shi, E. Boulet, D. Dong, M. Alnajideen, S. Mashruk, Z. Zhang, and A. Valera-Medina | Authors Info & Affiliations

Publication: Ammonia Combustion Applications for Energy Systems • https://doi.org/10.1049/PBPO224E_ch5

Chapter Item | 31 December 2024

Chapter 6

Combustion systems for ammonia-fuelled gas turbines and other propulsion devices

Authors: H. Shi, S. Mashruk, M. Alnajideen, and A. Valera-Medina | Authors Info & Affiliations

Publication: Ammonia Combustion Applications for Energy Systems • https://doi.org/10.1049/PBPO224E_ch6

THE JOURNAL OF Ammonia Energy

Reading: Techno-economics of ammonia as an energy carrier. Exporting wind from the North Atlantic Ocean/North Sea to Wales

Taxonomy: Techno-economics and Life Cycle Analyses

Research and Development

Techno-economics of ammonia as an energy carrier. Exporting wind from the North Atlantic Ocean/North Sea to Wales

Marco Jano-Ito, Agustin Valera-Medina

ELSEVIER

Green Energy and Resources

Volume 1, Issue 4, December 2023, 100046

Research Article

Emission reduction and cost-benefit analysis of the use of ammonia and green hydrogen as fuel for marine applications

Yunfan Wu [a], Aiguo Chen [a], Hua Xiao [a], Marco Jano-Ito [b], Mustafa Alnaeli [b], Mohammad Alnajideen [b], Syed Mashruk [b], Agustin Valera-Medina [b]

energies

Open Access Article

Economic Feasibility of Using Municipal Solid Waste and Date Palm Waste for Clean Energy Production in Qatar

by Ahmad Mohamed S. H. Al-Moftah [1,2], Mohammad Alnajideen [1,*], Fatima Alafifi [3,4], Pawel Czyzewski [5], Hao Shi [1,6], Mohammad Alherbawi [3], Rukshan Navaratne [1] and Agustin Valera-Medina [1]

Alnajideen et al. Carbon Neutrality (2024) 3:13

https://doi.org/10.1007/s43979-024-00088-6

Carbon Neutrality

REVIEW Open Access

Ammonia combustion and emissions in practical applications: a review

Mohammad Alnajideen[1*], Hao Shi[2], William Northrop[3], David Emberson[4], Seamus Kane[3], Pawel Czyzewski[5], Mustafa Alnaeli[1], Syed Mashruk[1], Kevin Rouwenhorst[6], Chunkan Yu[7], Sven Eckart[8] and Agustin Valera-Medina[1]

ELSEVIER

International Journal of Hydrogen Energy

Volume 49, Part B, 2 January 2024, Pages 1597-1618

Ammonia combustion in furnaces: A review

A. Valera-Medina [a], M.O. Vigueras-Zuniga [b], H. Shi [a], S. Mashruk [a], M. Alnajideen [a], A. Alnasif [a c], J. Davies [a], Y. Wang [d e], X. Zhu [d], W. Yang [f], Y.B. Cheng [d e]

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- Mo is currently conducting system simulations and drafting a journal manuscript focused on an ammonia-based solar–geothermal heat pump for residential heating and cooling applications. In parallel, Mo is also working on a comparative study assessing the performance, efficiency, and environmental impact of various refrigerants in low-temperature heat pump systems.

- Two targeted funding calls are currently under development:
  - Clean Farm Energy – WalesFocus: Deploying ICE technology in agricultural combined heat and power (AgriCHP) systems.
  - Interregional GreenTrack Programme (Consortia-based)Focus: Decarbonising industrial locomotives using clean ammonia/hydrogen ICE systems.

Modelling study of a novel dual heat source ammonia-based heat pump system

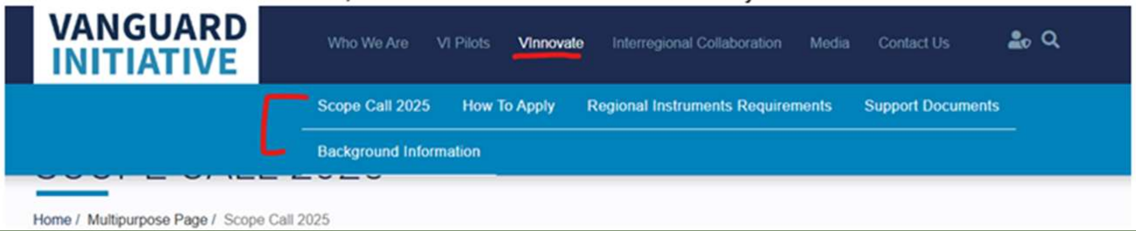
Hao Shi[a,b], Mohammad Alnajideen[a*] and Agustin Valera-Medina[a]

a. Cardiff University, Queen's Building, Cardiff CF24 3AA, United Kingdom

b. Reactive Flows and Diagnostics, Department of Mechanical Engineering, Technical University of Darmstadt, Darmstadt 64287, Germany

1. **Regional (Welsh Government):**
   SMART Flexible Innovation Support (via SMART FIT – Circular Economy theme)
   Funding: £200k per year for 2 years
   Deadline: ASAP – before the end of the year.
   Proposal: AgriCHP- Clean Farm Energy

2. **Interregional (EURO):**
   Vinnovative Call 2025. This call requires alignment with regional instruments (the SMART FIT programme).
   Deadline: September 2025, but we should begin establishing the consortium as soon as possible.
   Proposal: GreenTracks- Decarbonising Industrial Locomotives
   Funding starts from £200 per year for 3 years. We can claim higher through one of our EURO SMEs or Research Partners.
   Please have a look at the website, as shown below. I also attached the flyers for both calls.



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Next Steps: Project Delivery Plan [Sep – Dec]

- Gibbson (Contractor) – Complete the installation of NG pipeline & Inclusion of the gas interlock.
- M&M (Contractor) - Installation of the fuel delivery system to the canopy area [Start on 22 Sept 2025 – for 3 weeks]
- GDS (Contractor) - Installation and commissioning of new gas detection units
- Finalise the engine installation by completing the electrical, fuel, and silencer connections
- Publishing 2 journal paper by the end of this year.
- Targeting two funding calls
- 4th SoAE – USA
- RUN the ENGINE – 1st trial by November 2025

Ocean REFuel

Investigating the potential of offshore wind & marine renewable energy to produce zero-carbon hydrogen & ammonia fuels

Services for Renewable Energy · Cardiff · 44 followers · 10K+ employees

Sven & 8 other connections follow this page

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Ocean REFuel
44 followers
1w • Edited •

🔍 New Review on Ammonia as a Fuel

This paper explores the latest advancements in using ammonia as a fuel substitute, focusing on the key challenges that must be addressed for commercial deployment. Uniquely, it includes insights from industry partners actively working on green ammonia technologies, and tackles the fundamental complexities of ammonia combustion critical for real-world applications.

📄 Read the full article at:
https://lnkd.in/epsMT34t

Agustin Valera Medina Will Northrop Sven Eckart Kevin Rouwenhorst Paweł Czyżewski

#AmmoniaFuel #Decarbonisation #EnergyTransition #GreenAmmonia #Combustion #SustainableEnergy #EnergyResearch

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Overview

Overview
=========
Ocean REFuel is an innovative £10M research project which will investigate the potential of harnessing offshore wind and marine renewable energy to produce zero carbon hydrogen and ammonia fuels.

Led by the University of Strathclyde, in collaboration with a world-leading team of researchers from the Universities of Nottingham, Cardiff, Newcastle and Imperial College London, the multi-disciplinary project will explore ways of converting ocean energy into fuels for use in heating, energy storage and difficult to decarbonise transport applications.

The five-year collaboration, which involves 28 industrial partners, including BP, Scottish Power, National Grid, ENI along with the UK Health & Safety Executive, will also produce a blueprint for the first integrated Ocean Renewable Fuel production facility.

Through economic modelling and wider analysis of political economy outcomes and narrative development, CEP researchers will bring crucial understanding of the economy-wide impacts of green hydrogen production through ocean renewable energy to the project.

By looking at the broader socio-economic picture, CEP research can help bring understanding of what investments in ocean renewable energy and green hydrogen production could mean for GDP, jobs and earnings, and in turn the long-term prosperity, as well as sustainability of the UK.

This understanding will be critical to building consensus across government, industry and citizens on the contribution that ocean renewable energy and hydrogen production can make economically, politically and socially. This consensus will be crucial to ultimately delivering feasible and robust pathways to net zero targets.

Partners
=======
Lead partner – University of Strathclyde
Other partners – Cardiff University, University of Nottingham, Newcastle University and Imperial College London

Website
https://www.oceanrefuel.ac.uk/

Industry
Services for Renewable Energy

Company size
10,001+ employees

Founded
2021

Specialties
Energy, Offshore renewable, Green hydr
infrastructure , Economic and policy mo
conversion , and Floating platform

Commitments

Featured
Social impact
Environmental sustainability
Career growth and learning
Diversity, equity, and inclusion

Social impact

Economic modelling & policy analysis: To assess macroeconomic impacts—GDP, jobs, earnings—of green hydrogen deployment via ocean renewables and develop policy narratives. Building consensus: Work across government, industry, and public spheres to foster understanding and consensus on ocean-based fuel pathways to Net Zero.

Company pledge

Home | Ocean REFuel
oceanrefuel.ac.uk

Environmental sustainability

From inception, the project targets offshore wind and marine platforms that are safe, sustainable, resilient, affordable and environmentally sensitive, ensuring minimal disturbance to marine ecosystems and landscapes. Throughout its technical workstreams—such as fuel conversion, storage, infrastructure, and logistics—the project includes environment… See more

Company pledge

Home | Ocean REFuel
oceanrefuel.ac.uk

ng work involving offshore engineering,
rironmental policy. Technical upskilling: Researchers
newable energy platforms Hydrogen/am… See more

gen Hub • Industrial Decarbonisation Research and
h Centre) • Faraday Institution • EPSRC Decarbonising
and Solutions) • Catapult Offshore Renewable Energy •

Ocean REFuel
44 followers
2d •

🌊 Attention to all followers! 🌊

🙏 Please help this page grow by inviting your network to follow and engage. Your support can amplify the impact of this important work.

🔗 Ocean-REFuel Project is a cutting-edge collaboration exploring how offshore renewable energy can be harnessed to produce green hydrogen and ammonia — powering ships and ports with zero emissions.

💡 If you're passionate about clean energy, climate action, or maritime innovation, this is a project worth following.

Let's build a cleaner, more sustainable future — together. 🌍 ⚓

#OceanREFuel #CleanShipping #GreenHydrogen #SustainableFuels #NetZero #MaritimeInnovation #EnergyTransition

1

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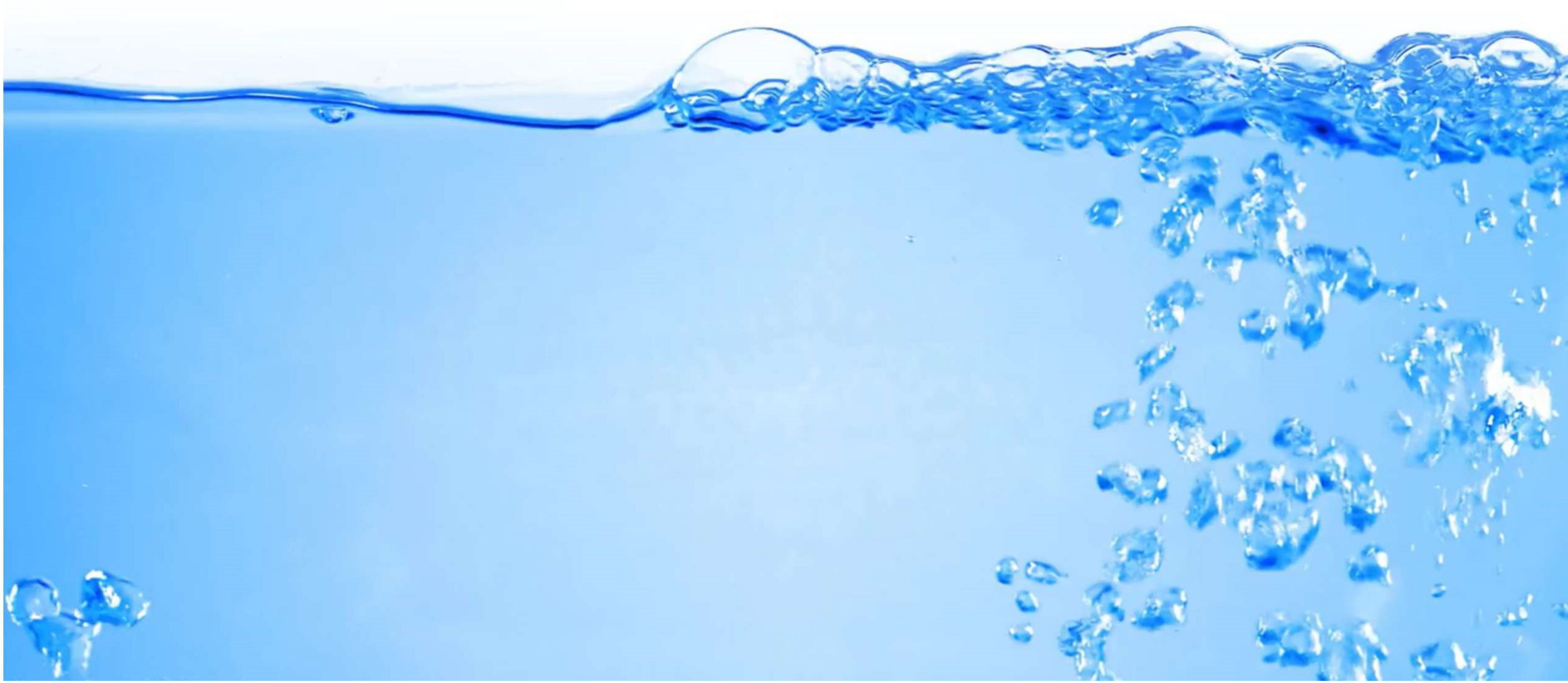

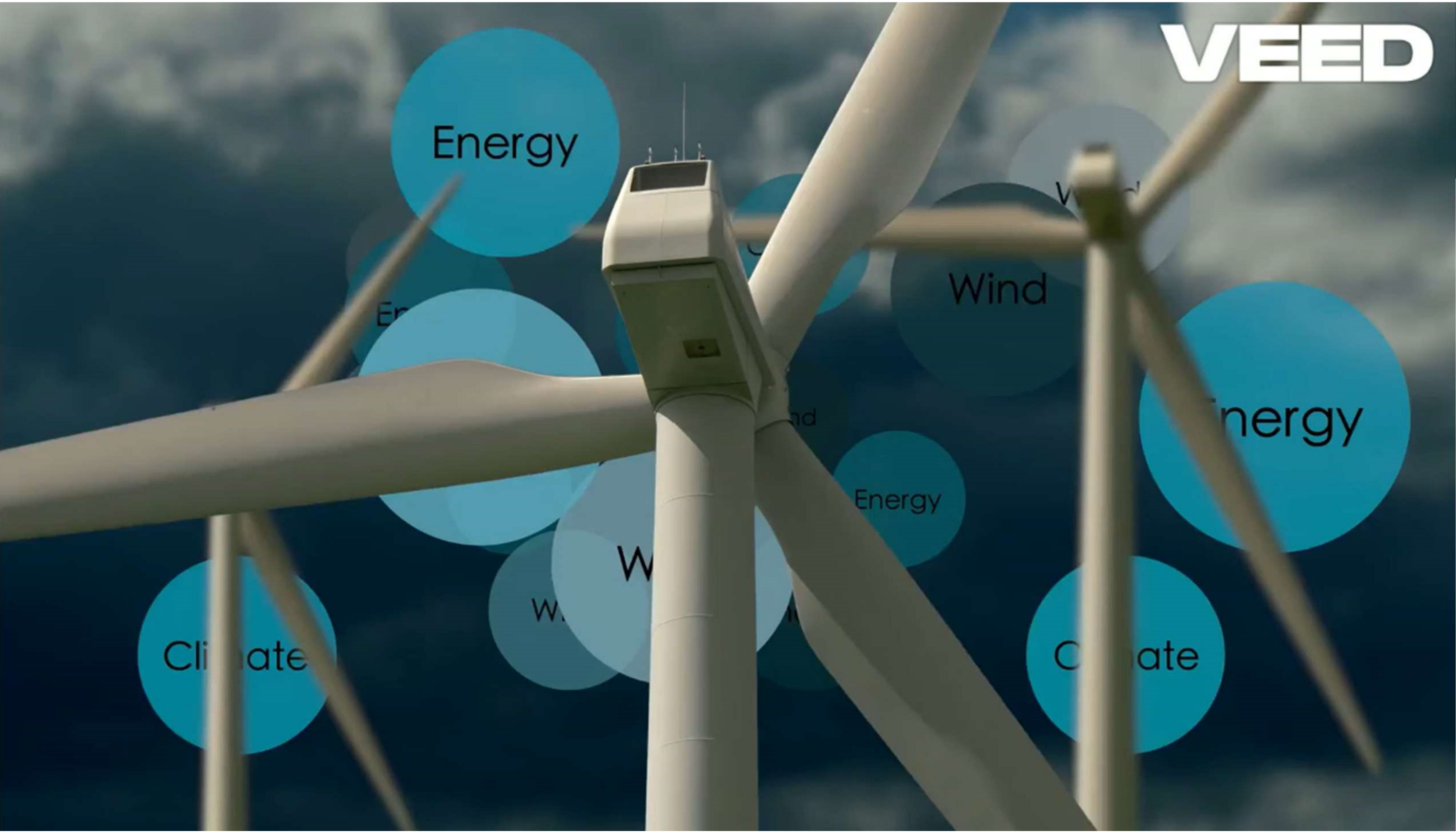
VEED
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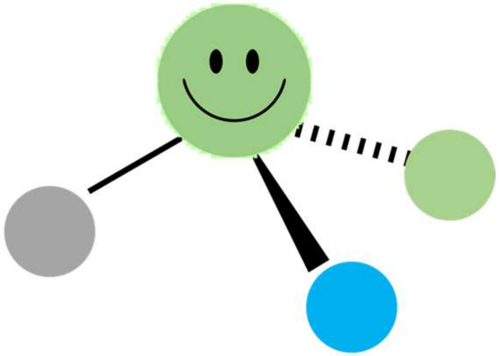
Thank you

Diolch



School of Engineering

Ysgol Peirianneg

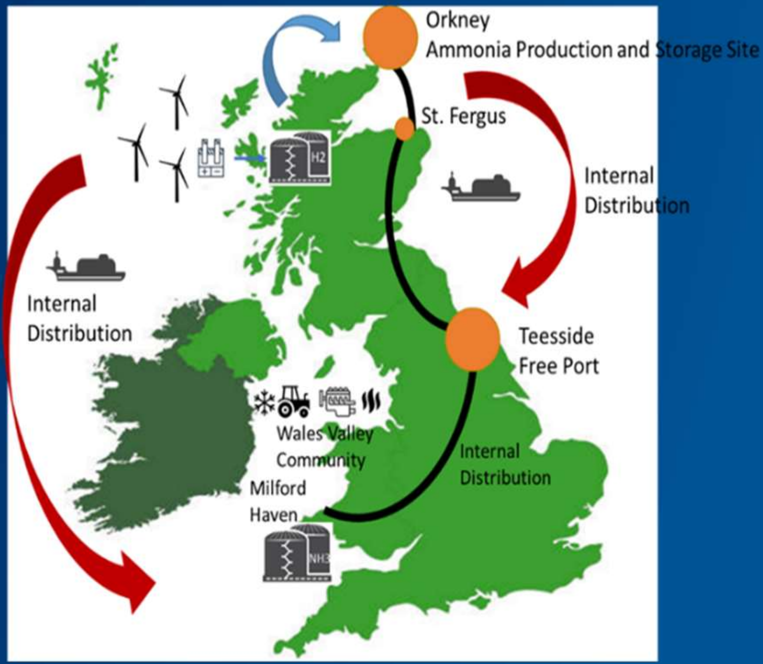
WP4.2 – 'Carbonaceous' H2

H_2-based systems may be able to move to 100% initially but other scenarios may favour the use of intermediate (high) blends in early operation.

Most likely in regions with one main gas feeder.

What range of operation is possible for burners designed/optimized for one gas, when operated on a different blend.

Previous work is on low H_2 percentages. We are exploring the higher ranges



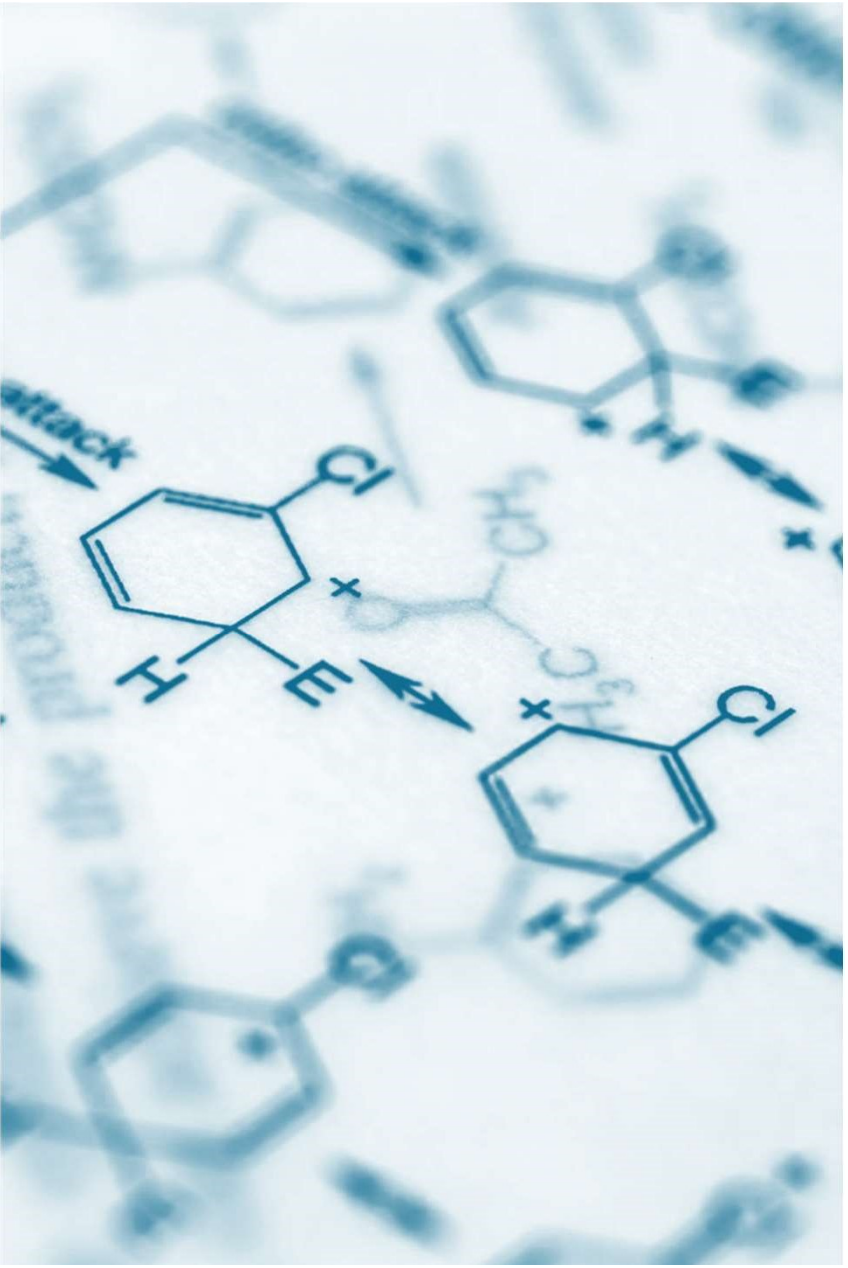
Robin Irons and Haiqin Zhou

Ocean REFuel

WP4.5. OVERALL SYSTEM OPTIMISATION

Introduction

- UK is the second-largest offshore wind market globally, with 15.9 GW grid-connected capacity (2024).
- 2030 target range: 43–50 GW offshore wind under the Clean Power 2030 plan.
- North Sea offers excellent resource, with modern projects achieving capacity factors near or above 50%.
- Strategic role: essential for decarbonising industry, transport, and power generation while enhancing energy security.



From Electrons to Molecules: Challenges and Opportunities

The intermittency challenge: Variable offshore wind generation creates periods of surplus and deficit that limit grid integration

Chemical storage solution: Converting electrical energy to molecular carriers (H_2, NH_3) decouples production timing from consumption demand

Electrolytic conversion: Water splitting transforms curtailed wind electrons into storable hydrogen molecules with 70-80% efficiency

Molecular flexibility: Hydrogen enables direct storage/transport, while ammonia conversion provides enhanced density and existing infrastructure compatibility

System integration opportunity: Offshore chemical production eliminates transmission bottlenecks while creating new export value streams

Multi-Scenario Analysis of Offshore Hydrogen Production Pathways

Research Objective: Comprehensive techno-economic assessment of diverse offshore hydrogen production and distribution configurations and technologies

Analytical Framework: Levelized Cost of Hydrogen/Ammonia (LCOH/LCOA) methodology

Scope: 12 distinct scenarios encompassing varied infrastructure configurations, transport mechanisms, and storage solutions

Expected Outcome: Identification of optimal pathways for industrial-scale offshore hydrogen/ammonia production with minimum economic barriers

Methodology: Mixed-Integer Optimization Programming

- **Superstructure Formulation**: Comprehensive network superstructure encompassing all potential production-transport-storage configurations
- **Mathematical Approach**: Mixed-integer programming for simultaneous optimization of:
  - Binary Selection Variables (Network Topology and Technology Selection)
  - Continuous Parametric Variables (Economic and Operational Parameters)
- **Decision Variables**:
  - **Wind Turbine Foundation Types**: Fixed, Floating, and Hybrid configurations
  - **Electrolysis Placement**: Onshore, Offshore Hub, Wind Turbine Integrated
  - **Energy Carrier Conversion**:
    - Direct Hydrogen Transport (Compressed/Liquefied)
    - Chemical Conversion (NH_3 via Haber-Bosch)
  - **Transport Mechanisms**: Pipelines (H_2), Marine Vessels (Liquefied H_2, NH_3)
- **Objective Function**: Minimization of LCOH/LCOA incorporating CAPEX, OPEX, capacity factors, and system lifetimes

Pathway Optimization Formulation:

Mixed-Integer Optimization Framework

Objective: Levelized costs of hydrogen or ammonia

Decision Variables: Technology investments, capacities, operations

Key Constraints:

- Power balance: generation = consumption + export + losses
- Hydrogen balance: production = demand + losses + storage
- Capacity limits: electrolyser turndown ratios, storage bounds
- Network connectivity: wind farms ↔ terminals ↔ demand centers

Case Study - UK North Sea System

Wind Farms: 6 sites, 9.922 GW total capacity

Fixed: Teesside (62 MW), Dogger Bank (3.6 GW), Sofia (1.4 GW)

Floating: NE6 (900 MW), NE7 (3.0 GW), NE8 (960 MW)

Onshore Terminals: Middlesbrough, Bridlington, St Fergus

Demand Center: Milford Haven and Teesside (seaborn and/or inland transport)

Three Electrolysis Placement Strategies

Onshore Electrolysis: Electricity transmitted via HVDC cables

Offshore Hub Electrolysis: Centralized platforms with H_2 pipelines

Turbine-Integrated Electrolysis: H_2 production within wind turbine towers

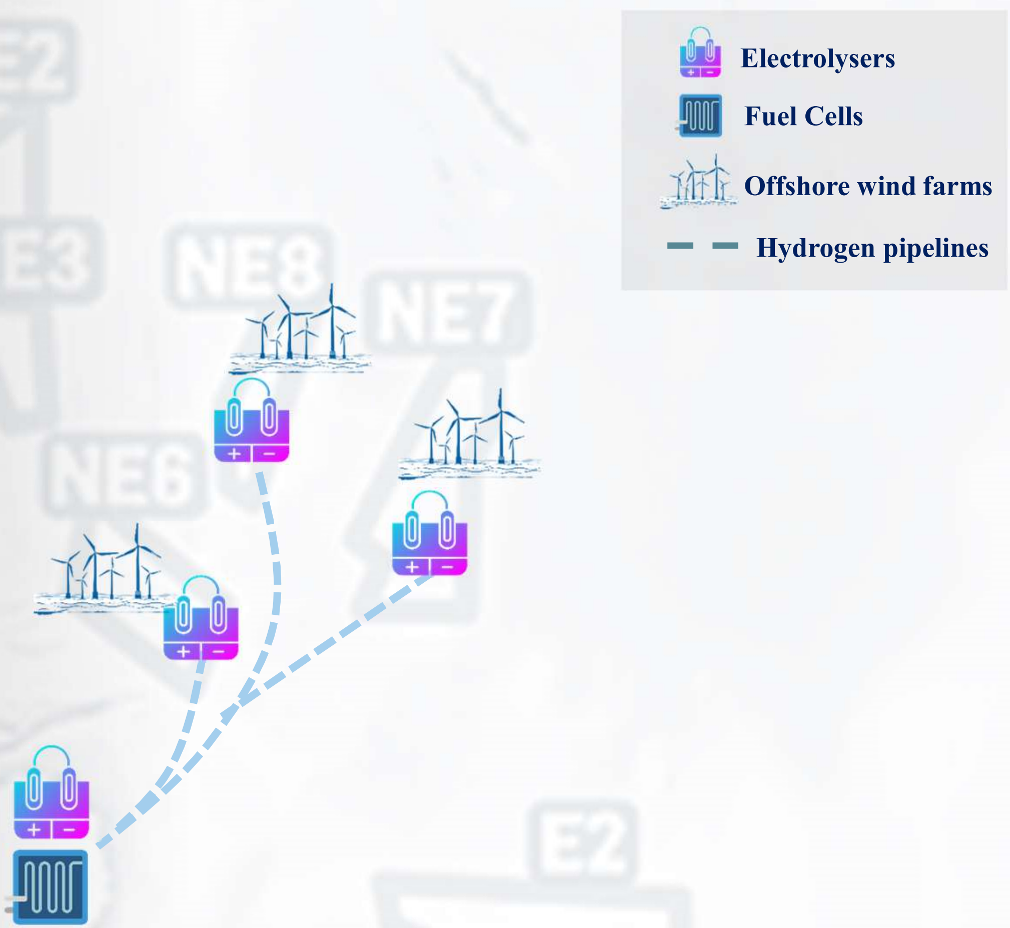
Foundation Types: Fixed-bottom vs floating wind platforms

Energy Carriers: Compressed H_2, liquefied H_2, ammonia production

Production sites: Teesside

https://thecrownestate.maps.arcgis.com/apps/webappviewer/index.html?id=b7f375021ea845fcabd46f83f1d48f0b

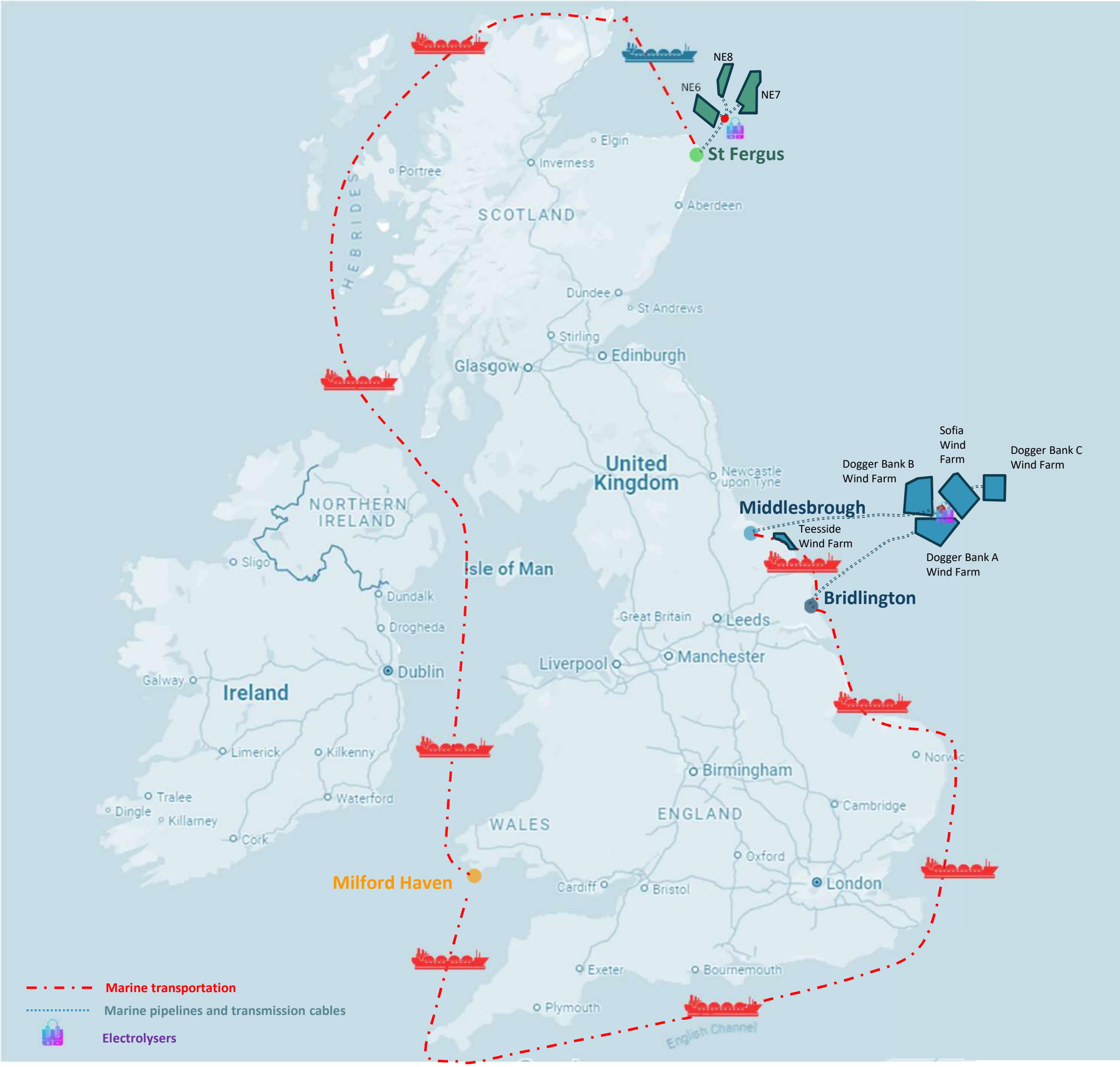
Production sites: St. Fergus



Energy Network Superstructure

#12

Example: Scen#7 H2 production



Three Fundamental Configuration Strategies

Configuration 1 - Onshore Electrolysis Hub:
Scale Advantage: Maximum economies of scale for electrolysis and ammonia conversion
Transport Trade-off: High marine cable costs but leverages proven HVDC technology
Optimal for: Large-scale centralized production with established grid infrastructure

Configuration 2 - Offshore Electrolysis Hub:
Balanced Approach: Moderate scale economies while reducing electrical transmission distances
Infrastructure Trade-off: Offshore platform costs offset by hydrogen pipeline economics
Optimal for: Systems where hydrogen transport costs favor pipelines over electrical cables

Configuration 3 - Wind Turbine Integrated:
Scale Disadvantage: Limited unit sizes reduce equipment efficiency and increase per-MW costs
Transport Advantage: Eliminates electrical transformation losses and cable infrastructure
Optimal for: Remote locations where transmission costs become prohibitive or grid connection is technically challenging

Energy Transmission and Transportation Modes

Electrical Energy Collection and Transmission:

- **Inter-Array Cables:** Collect electricity from individual wind turbines within offshore wind farms
- **Export Cables (HVDC/HVAC):** Transmit consolidated power from offshore collection points to onshore terminals
- **Onshore Terminal Integration:** Connection point for direct electrolysis facilities

Hydrogen Energy Transport:

- **Offshore-to-Onshore Pipelines:** Dedicated infrastructure avoiding electrical conversion losses, suitable for medium-to-long distances
- **Onshore Pipeline Networks:** Integration with existing or planned hydrogen backbone infrastructure for inland distribution

Energy Carrier Transportation:

- **Compressed Hydrogen:** Pipeline-based distribution requiring specialized materials and compression stations
- **Liquefied Hydrogen:** Cryogenic shipping enabling long-distance transport but with additional processing complexity
- **Ammonia (Liquid State):** Leverages existing global chemical shipping infrastructure with ambient pressure storage capabilities

Mode Selection Rationale: Distance economics, infrastructure maturity, end-use compatibility, and storage requirements determine optimal transport pathway for each supply chain segment.

Scenario Classification Framework

	Offshore WT Platform	Offshore Hub	Electrolysis	Hydrogen liquefaction	NH_3 Production	Transition to Offshore Hub	Transition to Onshore	Transition to end-user	Storage Method	LCOH/ LCOA (£/kg)
Scenario#1	Fixed/ Floating	No	Onshore	No	No	NA	Cable	In-land H_2 Pipeline	Compressed H_2 /MH	**12.026**
Scenario#2	Fixed	Yes	Offshore Hub	No	No	Cable	H_2 Pipeline	In-land H_2 Pipeline	Compressed H_2 /MH	**8.652**
Scenario#3	Fixed	Yes	Offshore Hub	Yes	No	Cable	H_2 Pipeline	Ship	Liquefied H_2	**7.702**
Scenario#4	Floating	Yes	Offshore Hub	No	No	Cable	H_2 Pipeline	In-land H_2 Pipeline	Compressed H_2 /MH	**11.971**
Scenario#5	Floating	Yes	Offshore Hub	Yes	No	Cable	H_2 Pipeline	Ship	Liquefied H_2	**11.291**
Scenario#6	Fixed/ Floating	Yes	Offshore Hub	No	No	Cable	H_2 Pipeline	In-land H_2 Pipeline	Compressed H_2 /MH	**9.449**
Scenario#7	Fixed/ Floating	Yes	Offshore Hub	Yes	No	Cable	H_2 Pipeline	Ship	Liquefied H_2	**9.246**
Scenario#8	Fixed/ Floating	Yes	Offshore Hub	No	Haber–Bosch (onshore)	Cable	H_2 Pipeline	Ship	NH_3 in Liquid state	**1.187**
Scenario#9	Fixed/ Floating	Yes	Onshore	No	Haber–Bosch (onshore)	Cable	H_2 Pipeline	Ship	NH_3 in Liquid state	**1.372**
Scenario#10	Fixed/ Floating	Yes	WT integrated	No	No	H_2 Pipeline	H_2 Pipeline	In-land H_2 Pipeline	Compressed H_2 /MH	**9.024**
Scenario#11	Fixed/ Floating	Yes	WT integrated	Yes	No	H_2 Pipeline	Ship	Ship	Liquefied H_2	**8.820**
Scenario#12	Fixed/ Floating	Yes	WT integrated	No	Haber–Bosch (offshore)	NA	H_2 Pipeline	Ship	NH3 in Liquid state	**1.312**

Key Research Findings:

NH_3 pathways demonstrate minor energy-equivalent advantage:

- **H_2 optimal (Scenario #3):** £7.702/kg for LHV of 120 MJ/kg = **£0.0641/MJ**
- **NH_3 optimal (Scenario #8):** £1.187/kg for LHV of 18.6 MJ/kg = **£0.0638/MJ**

NH_3 strategic advantages beyond cost:

- **Storage Operating Condition:** Liquid at 8 bar vs. 350-700 bar for H_2, or -253°C for LH_2
- **Transport infrastructure:** Existing global shipping network (8M tonnes/year)
- **Industrial integration:** Direct feedstock for fertilizers, chemicals, steel production

Offshore hubs emerge as optimal configuration: Balance of cost, scale, technical feasibility across both H_2 and NH_3 pathways

Floating wind integration feasible: 30% capacity factor premium justifies 15-25% CAPEX premium at scale

System integration critical: Progressive integration yields 15-25% cost improvements from distributed to centralized configurations

Cross Cutting Themes

Economic Modelling

Public Perception of technologies

LCA and System Metrics

Ocean-REFuel (Ocean Renewable Energy Fuel)

"Next generation Renewable Ocean Energy"

Cross-cutting themes Policy/Economic Modelling & Public Perceptions

2024-2026: A focus on Shetland

- **Exploring how potential harnessing Shetland's extensive wind power and marine energy resources may impact the prosperity and sustainability of the local economy and affect the lives and livelihoods of its residents.**
- Focus on the **transition of the Sullom Voe Terminal from oil and gas processing to the production of low carbon fuels including green hydrogen**, with the support of Veri Energy, starting with focus on the counterfactual of 'do nothing' and capacity being freed up.
- Also, investments Shetland supply chain capacity to service offshore wind developments at NE1 Scotwind sites – starting with collaboration with Lerwick Port Authority to investigate **how a £34 million investment in deep water port at Dales Voe is likely to impact Shetland GDP, employment, income generation and prices.**
- In partnership with Shetland Islands Council (SIC), via additional ESRC Impact Acceleration funding, we have developed a **Shetland Economy Model User Tool** to enable decision makers to draw on full bank of economy-wide scenario simulation results from the regional computable general equilibrium (CGE) model we have begun developing via Ocean REFuel.
- The **Policy/Economic Modelling and Public Perceptions team are collaborating to investigate how understanding of economy-wide impacts may impact public attitudes to green energy developments**

The transition away from oil and gas at SVT

- Investigating **how the energy transition may affect critical Shetland infrastructure, local supply chains, service changing local demand,** all in terms of realising benefits and community wealth creation
- Key focus on the [transition of the Sullom Voe Terminal (SVT),]from a facility providing oil & gas services to one where low carbon fuels could be produced. Key challenge: **timing of what is declining and what is emerging in terms of retaining skills and high value activity in the (highly constrained) local economy**
- Going forward we will explore how the transition of the SVT can lead to a broader **transformation of the Shetland economy from one that imports fuels to meet its energy needs, to one where it consumes locally produced energy goods**.
- Initial focus – what is declining/capacity being freed up

How much worker capacity will be freed up at Sullom Voe Terminal (SVT) and the Shetland supply chain by the decline in servicing oil and gas activity?

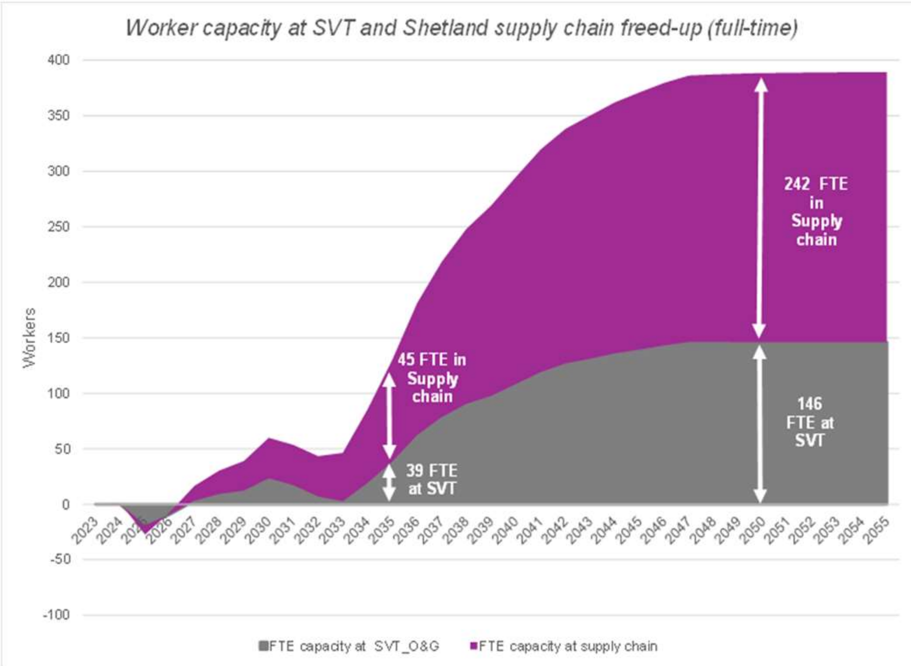
The decline in oil and gas activity at SVT could free up skilled labour capacity. Future plans involve producing low carbon fuels, including green hydrogen, transporting and storing captured carbon (from elsewhere in the UK and overseas)

Key Finding 1

- The planned closure of East of Shetland oil field (by 2035), and the continued decline of West of Shetland could **free up +140 skilled workers at SVT and around 240 workers across the Shetland supply chain.**
- Freed-up workers could be absorbed by low-carbon fuel production and storing carbon emissions services.

Key Finding 2

- The pace of freed-up capacity varies over time; slower in earlier stages and accelerated beyond 2035.
- Veri Energy and Statkraft developments can create **demand for the freed-up labour capacity**.
- The question is whether the near-term freed-up capacity will be sufficient to support these developments. Or if the new developments will exacerbate existing challenges in the Shetland labour market?



https://doi.org/10.17868/strath.00093862

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New port and harbour activity to support the transition

- Another key focus is the **development of an Ultra-Deep-Water Quay at Dales Voe to support the decommissioning of oil and gas infrastructure and the deployment and operation of offshore wind**.
- We are running scenario simulation analyses using our Shetland Economy Model (SEM) around how different scales of either/both activities can be supported by the planned investment at Dales Voe and by local supply chain responses.
- Across all our analyses, we investigate the **potential displacement of other activities and workers and explore how these could be mitigated** by changing the conditions in the local labour market.
- We continually strive to make our analyses as useful as possible for a wide range of stakeholders. To that end, our **Shetland work serves as the basis for developing an accessible reporting tool** for our modelling work.

How will the creation of the new Dales Voe Ultra-Deep-Water Quay impact the Shetland economy?

Key Finding 1

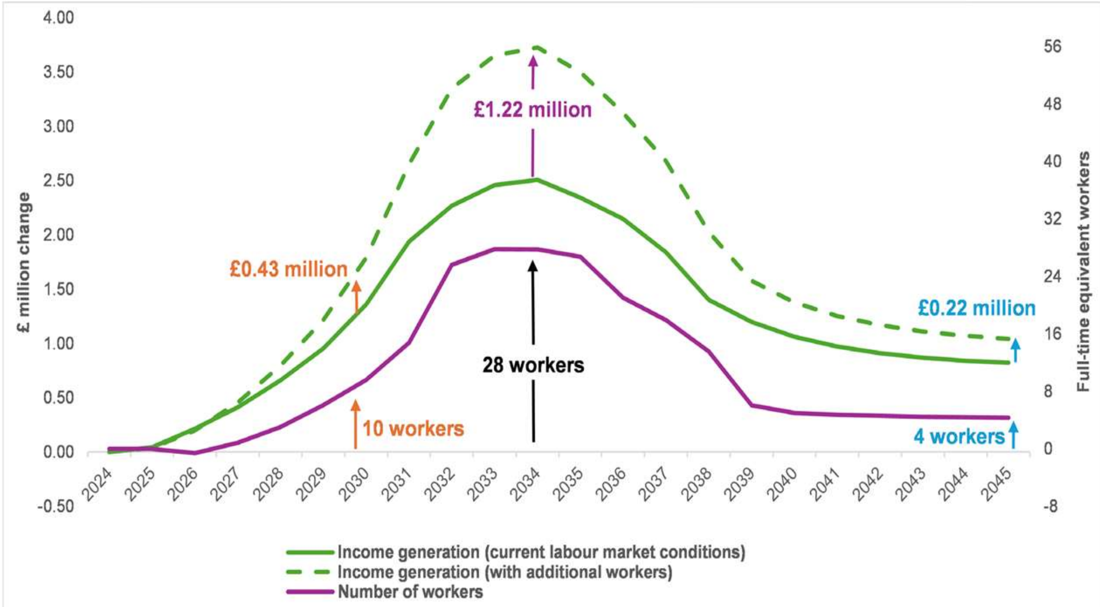
- Despite the worker and skills challenges in Shetland's labour market, the Dales Voe facility will boost income generation in Shetland (measured as regional GDP, GRDP). Even without any additional workers attracted to Shetland:
  - Peak GRDP gains of £2.4 million in 2034, and a sustain long-term boost of £0.8 million is possible.

Key Finding 2

- Operating the new facility will require only 2-3 additional workers. However, increased supply chain activity within Shetland will require sourcing workers from other sectors.
- This is likely to create **competition for labour between sectors**, driving up wages and the (already high) cost of living and doing business in Shetland.

Key Finding 3

- If sufficient additional workers can be attracted to fill vacant supply chain jobs at different points in time, Shetland's income boost will increase (on average 27%). With additional workers:
  - GRDP peaks at £3.7 million in 2034.
  - Long-term GRDP gains of £1 million per year, with almost no upward pressure on wages and prices.



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Next steps with the Shetland Economy Model (SEM)

- **Continue with scenario simulation work and stakeholder engagement** – both on the scenarios we're looking at so far and building out to others; supporting interaction with the SEM User Tool.
- **Including initial results for nascent hydrogen production activity**, both Statkraft new development at Scatsta and Veri plans to transition activity at the Sullom Voe Terminal. Activity here will include but not be limited to green hydrogen production, which is likely to at least initially involve onshore wind turbines on site, rather than linking to Shetland's evolving electricity grid or offshore wind.
- **We need to expedite our investigation of evolution of Shetland's electricity sector**, in economic terms linked to technology and interconnection developments.

Continuing to answer 3 broad research questions:

1. How similar or different will the islands' economic picture come to look compared to what it is now, with extensive midstream oil activity on Shetland – WHAT, WHY and WHEN?
2. What generic lessons emerge for other regional cases (Shetland as a microcosm)?
3. How will the emerging economic picture affect PUBLIC ATTITUDES?

Public Perceptions

Deliberative Workshops

- Qualitative
- N = 60
- Shetland Islands
- April 2025 & 2026
- Exploring Diverse perspectives

Survey

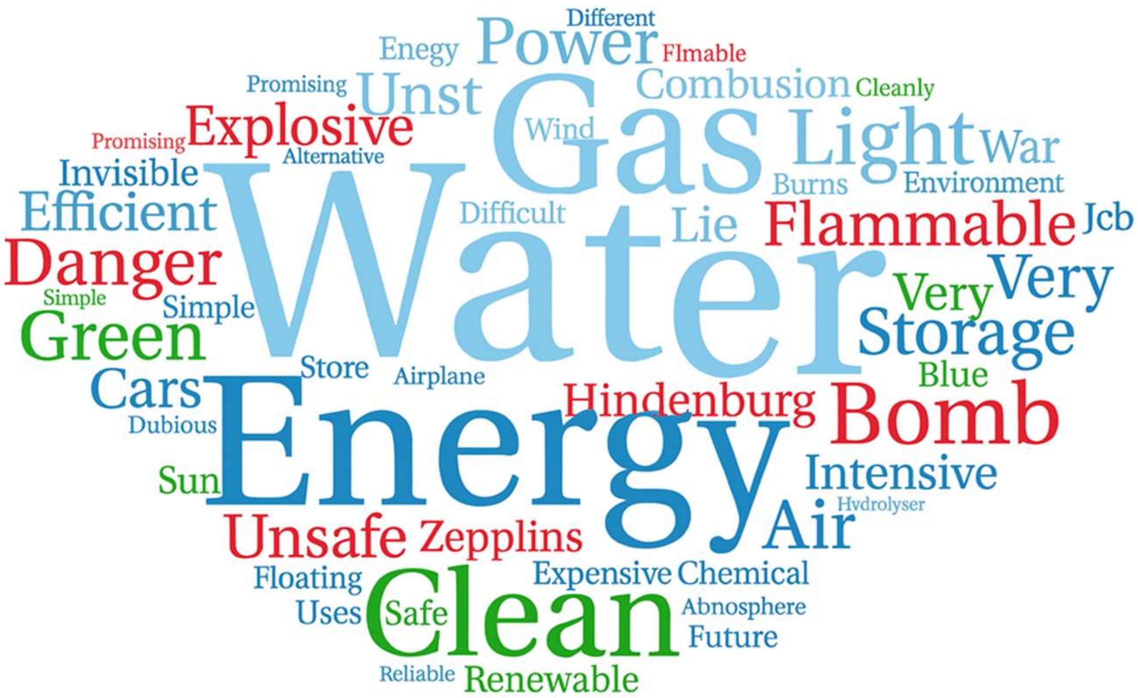
- Quantitative
- N ~ 1500
- Nationwide
- September/October 2025
- Measuring prevalence
- Testing Associations
- Generalizable conclusions

Deliberative Workshop

April 2 & 3, 2025
2:00 PM – 6:00 PM
Islesburgh Complex, Lerwick, Shetland

Session 1:	Hydrogen & Ammonia: First Impressions
Session 2:	Hydrogen & Ammonia – Feelings, Benefits, Concerns, Information
Session 3:	Hydrogen & Ammonia Applications
Session 4:	Envisioning Shetland's Future: What matters most
Session 5:	Energy Projects in Shetland (Onshore vs Offshore)
Session 6:	Community Benefits – Priorities & Concerns
New Session:	Economic Impacts / Benefits of Energy Development

Hydrogen

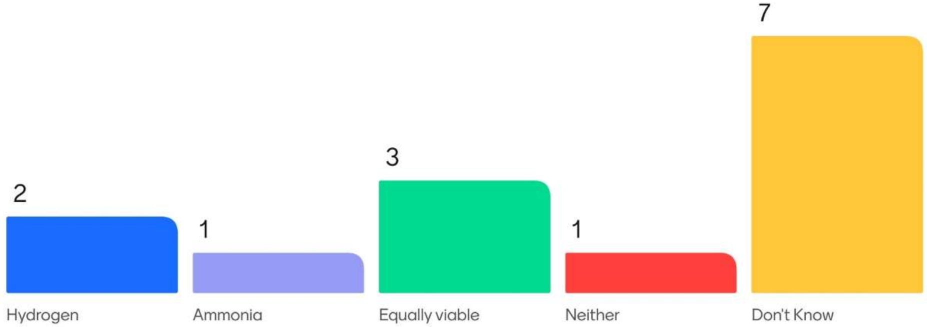


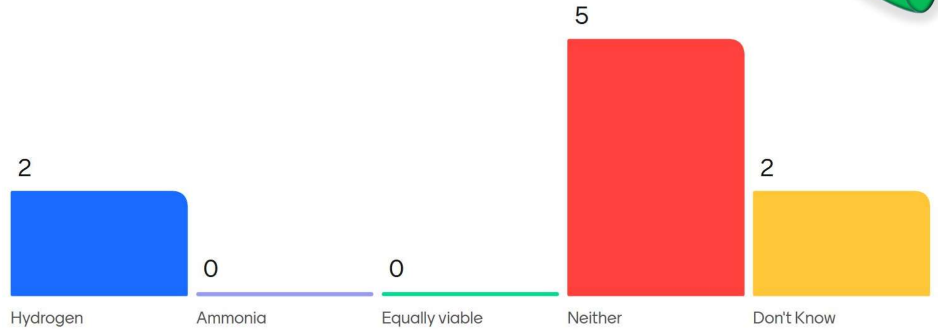
Ammonia

Day 1

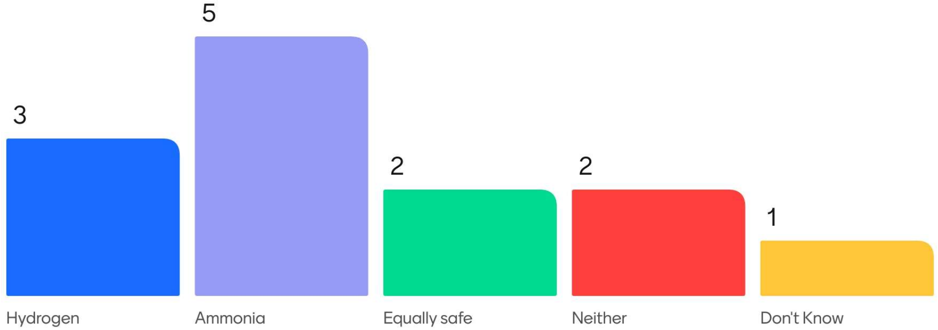
Day 2

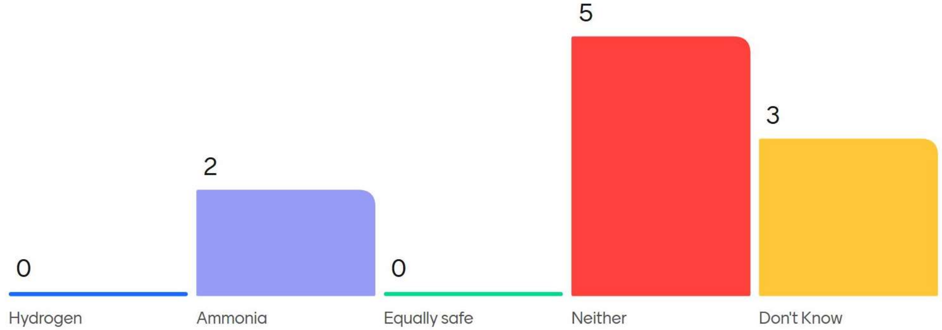
Viable



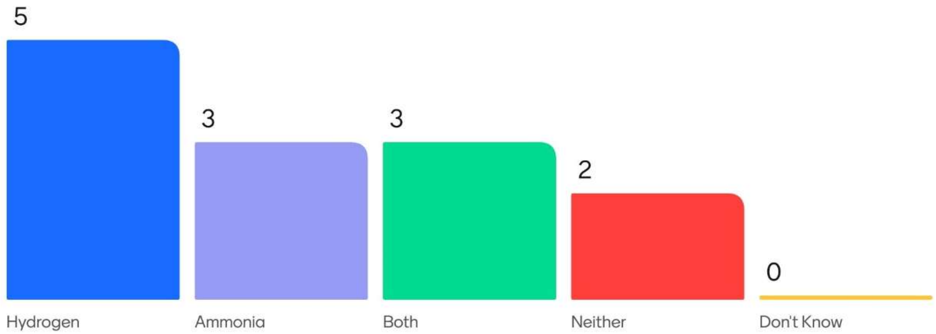


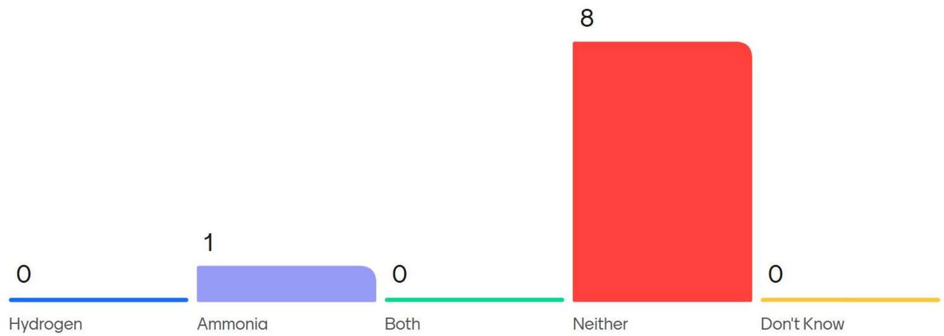
Safer





Prefer





Broad Takeaways

- Participation marked by motivation, curiosity, caution, and occasional confusion
- Preference for ‘green’ hydrogen production, though with important caveats
- Stronger acceptance of applications in heavy transport and industry
- Key concerns: environmental impacts and scale of development
- Mistrust linked to information gaps and limited transparency
- Perceptions of lost control shaped by experiences with past projects
- Scepticism over local benefits vs. fears of becoming an ‘energy dumping ground’
- Community acceptance influenced by:
  - Honest, accessible information from trusted local sources
  - Early, meaningful community engagement
  - Fair and just benefit sharing
  - Careful management of scale
  - Sensitivity to location and visibility

Survey

- Demographics
- Factors associated with social acceptance and policy support for both Hydrogen and Ammonia
  - Environmental values and climate change concerns
  - Energy concerns
  - Technology Optimism
  - Subjective perceptions of knowledge
  - Information seeking (interest, sources, trust)
  - Misinformation and conspiracy mentality scale
  - Place attachment
  - Trust and fairness perceptions
  - Affect
  - Risk/Benefit Perceptions
  - Safety concerns
- Conjoint Experiments
  - Project preferences
  - Community benefit agreements
  - Energy policy orientation

Ocean-REFuel (Ocean Renewable Energy Fuel)

"Next generation Renewable Ocean Energy"

Thank you!

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University of Nottingham
UK | CHINA | MALAYSIA

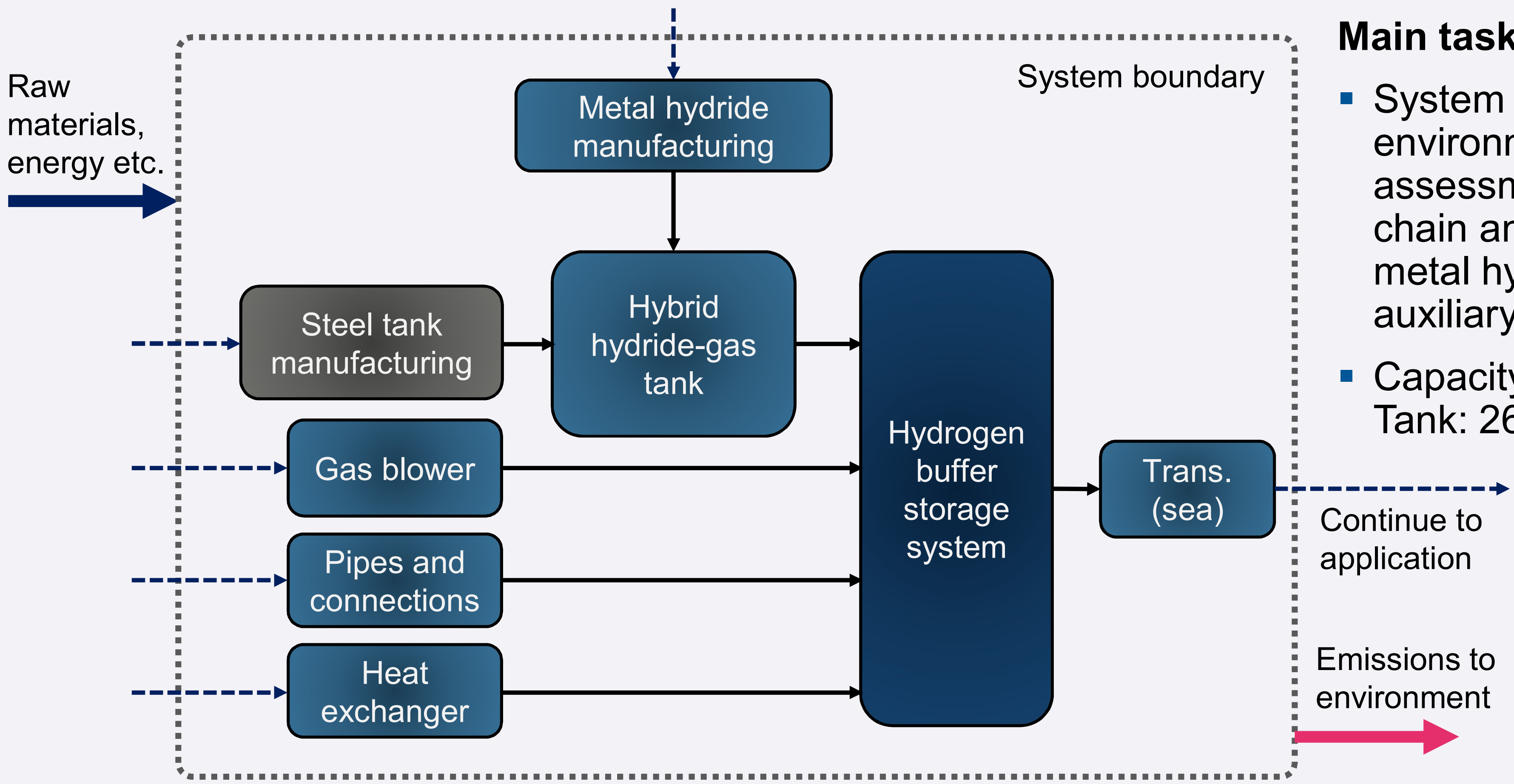
Cross Cutting themes LCA

Akos Cseke, Jorge Llamas, Cheryl Duke, Ben Davies, Jon McKechnie

Life Cycle Assessment: Metal Hydrides and Offshore Hydrogen Storage Tanks

Akos Cseke

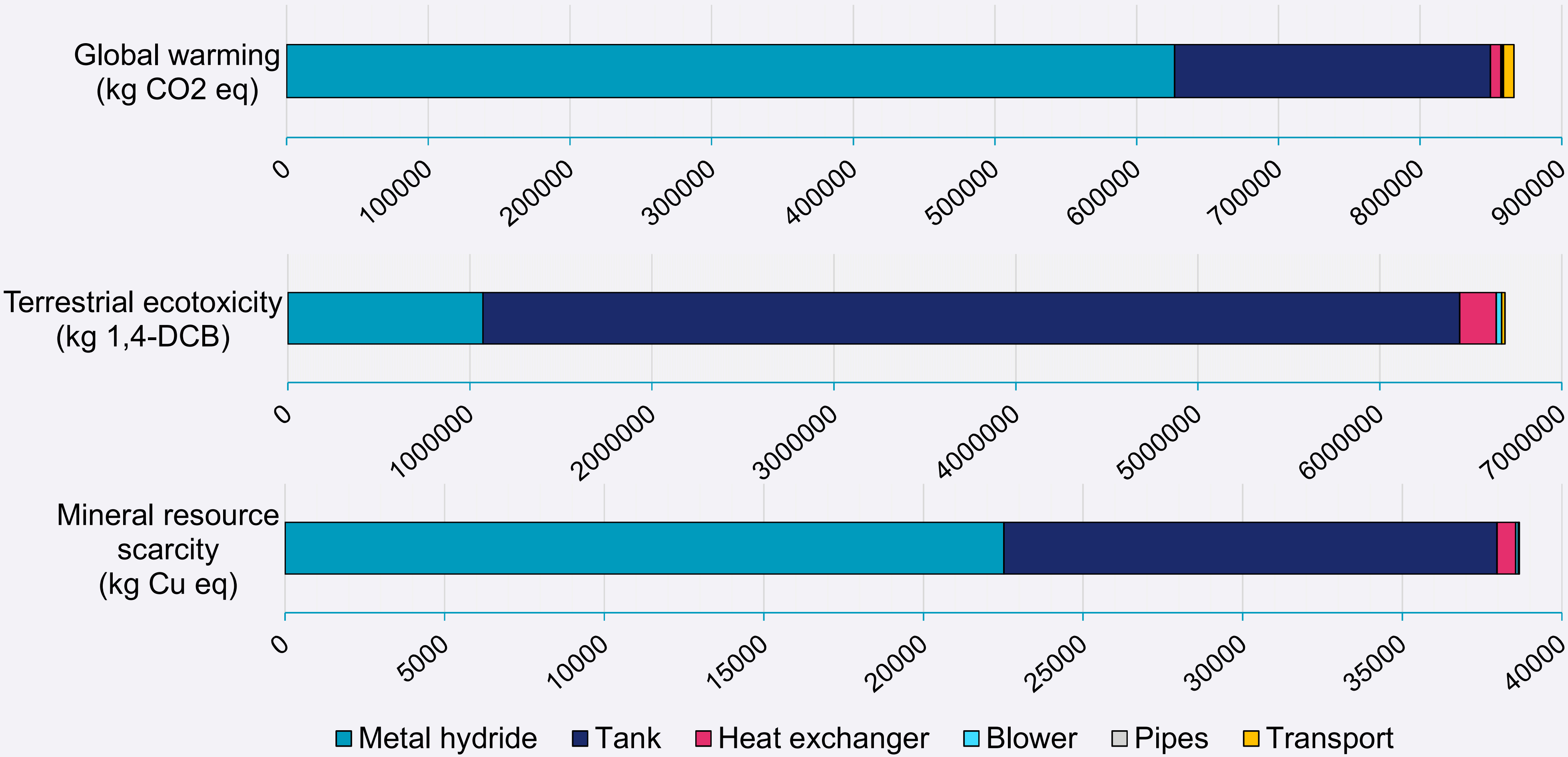
LCA: Hydrogen buffer storage system



Main tasks

- System modelling and environmental impact assessment of the supply chain and manufacturing of metal hydrides, tank and auxiliary systems.
- Capacity: 250 kg H_2
  Tank: 26400, MH 16500 kg

LCA: Impact assessment



LCA: Next steps

- System modelling and impact assessment of different metal hydride alloys.
- Investigation of the relative performance of the metal hydride alloys and relative importance of the tank and ancillary equipment.
- Review and screening of metals for metal hydride alloys: combination LCA with other factors, such as cost and criticality. Creation of a scoring system to indicate relative impacts and risks of various metals.
- Integration of sustainability and technical parameters: bringing together capacity, degradation, lifetime, heat balance, etc. into sustainability analysis to evaluate and compare the most promising options.

Ocean ReFuel Updates

Ben

- Has been integrating the wind turbine and electrolyser material flows from Jorge and Cheryl, with the hydrogen production network modelling completed by Mahdi from Imperial. The goal is to supplement the network model output (optimised for cost of production) with LCA results.

Jorge

- Finalising paper draft on future UK offshore wind material requirements with aim to submit for review in Autumn.

Cheryl

- Paper on material requirements and supply risks for future PEM deployment has been resubmitted following positive reviewer comments and we hope to have it published in very near future.

Thank you

Questions and discussion

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UK Research and Innovation


LUNCH TIME