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Metal Hydride Storage Concept for Offshore Wind-derived Hydrogen

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Outline

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  - **Ocean REFuel Project**
- **Hydrogen Storage and distribution concept**
- **Experimental Studies**
- **Results**
- **Conclusion**

University of Nottingham
UK | CHINA | MALAYSIA

Hydrogen Research Group

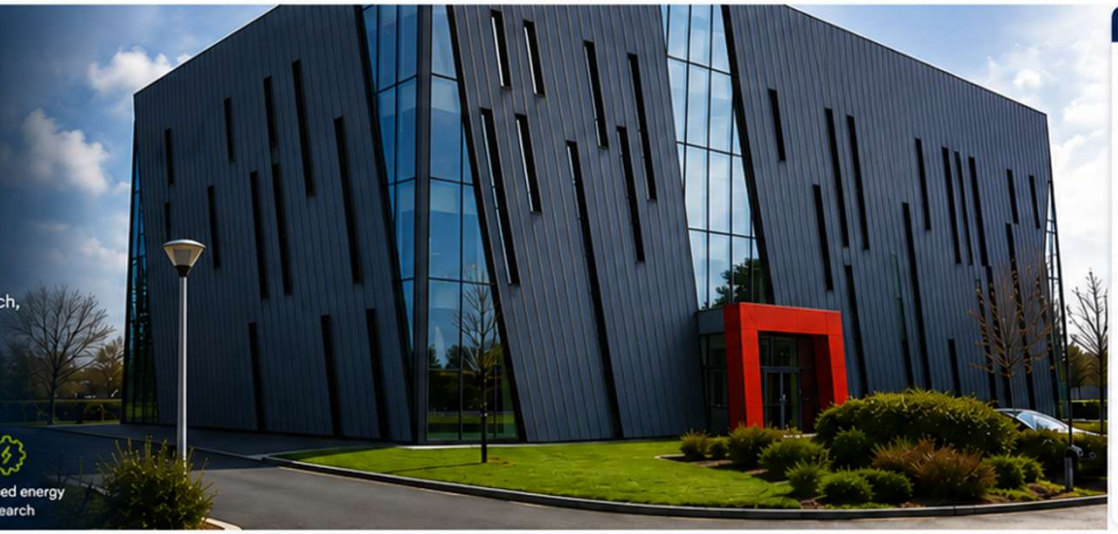
Engineering Faculty – University of Nottingham

H_2
CLEAN ENERGY FOR OUR FUTURE

Engineering research facilities

The RAD Building is the home of the Hydrogen Research Group at the University of Nottingham.

Purpose-built for advanced energy research, it provides state-of-the-art laboratories, workshops and collaborative spaces that enable cutting-edge research across the hydrogen value chain.



State-of-the-art laboratories | Collaborative spaces | Advanced energy research

CURRENT RESEARCH PROJECT

OCEAN REFuel

Ocean Renewable Energy Fuels

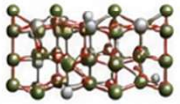
A five-year, £10 million research programme funded by the Engineering and Physical Sciences Research Council (EPSRC).

Ocean REFuel will establish a fundamental scientific and engineering understanding for the conversion of ocean renewable energy to liquid and gaseous fuels.

The project builds on offshore wind success to unlock new energy vectors, addressing energy storage, renewable heat and the decarbonisation of transport through high-energy-density fuels that can utilise existing storage and distribution infrastructure.

OUR RESEARCH THEMES

Hydrogen Storage Materials



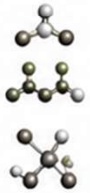
- Complex metal hydrides
- Solid state H_2 storage
- New alloy discovery
- High capacity & stability

Metal Hydrides We Work On

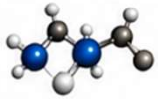
$NaAlH_4$ (Sodium alanate)

AB_2 type $TiMn_2$, $ZrCr_2$

AB_5 type $LaNi_5$, Mn_3Ni_6

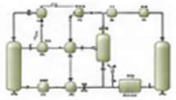


Catalysis & Hydrogen Production



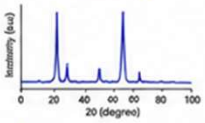
- Advanced catalysts
- Water splitting
- Reforming & ammonia cracking

Systems & Process Engineering



- Process modelling
- System integration
- Techno-economic analysis

Characterisation & Modelling



- Experimental techniques
- Computational modelling
- Structure–property relationships

Applications & Demonstration



- Transport
- Energy storage
- Decarbonisation strategies

RESEARCH PARTNERSHIPS

University of Nottingham UK | CHINA | MALAYSIA
University of Strathclyde Glasgow
Cardiff University / Prifysgol Caerdydd
Newcastle University
Imperial College London

OUR PEOPLE

~15 People
PhD Students & Postdocs
Multidisciplinary Experts

FUNDING

UKRI UK Research and Innovation
EPSRC Engineering and Physical Sciences Research Council

RESEARCH IMPACT

Enabling the UK hydrogen strategy and net-zero goals
Innovative solutions for a low-carbon energy system
Training the next generation of hydrogen experts

Ocean REFuel project

Project Scope

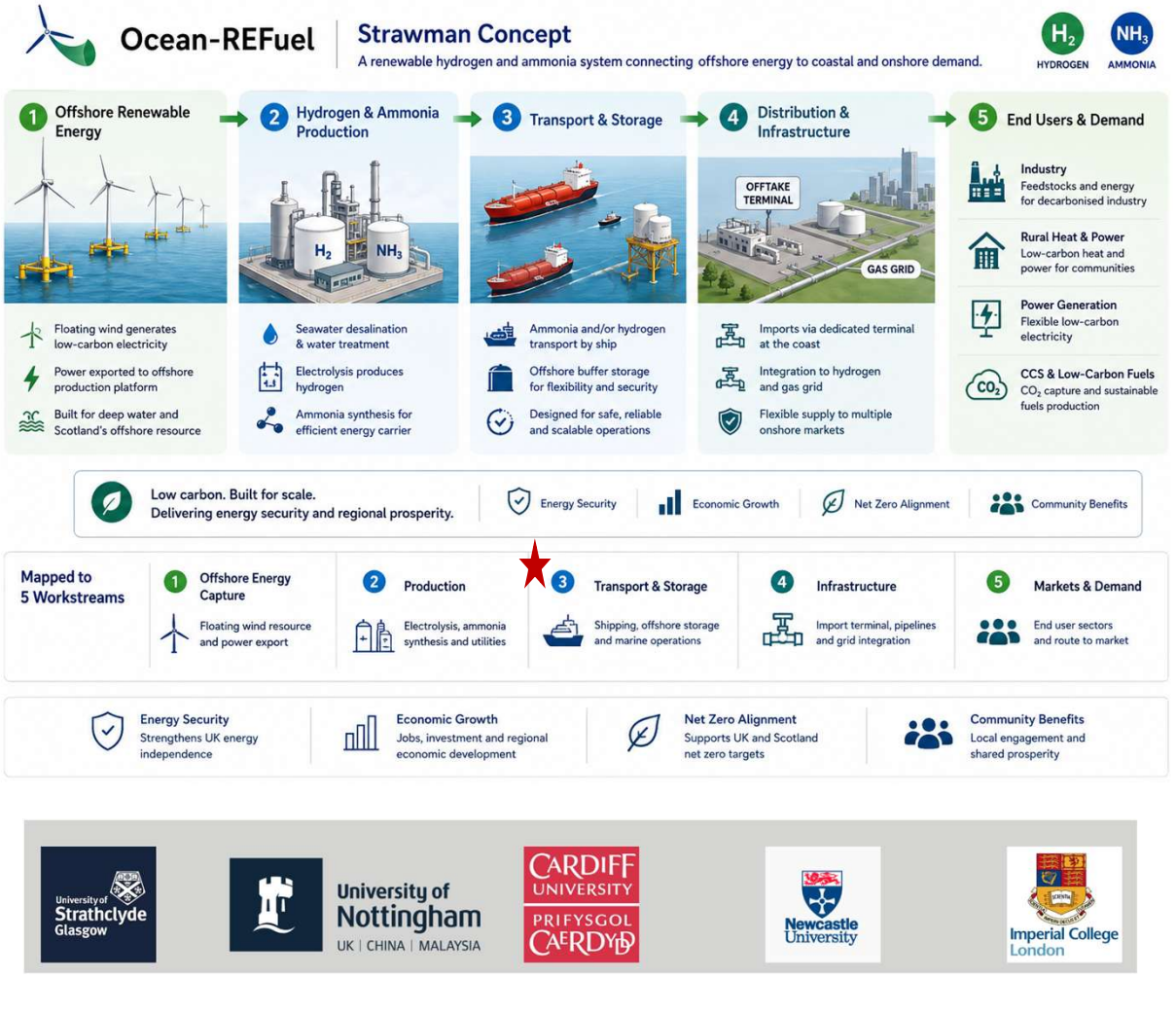
This project illustrates how offshore renewable energy could be converted into hydrogen and ammonia, transported and stored through candidate infrastructure pathways, and supplied to future end users.

UK-Wide Collaboration

A multidisciplinary research project involving five leading UK universities.

Our Contribution (WP3)

Design and development of a metal hydride-based hydrogen storage system.



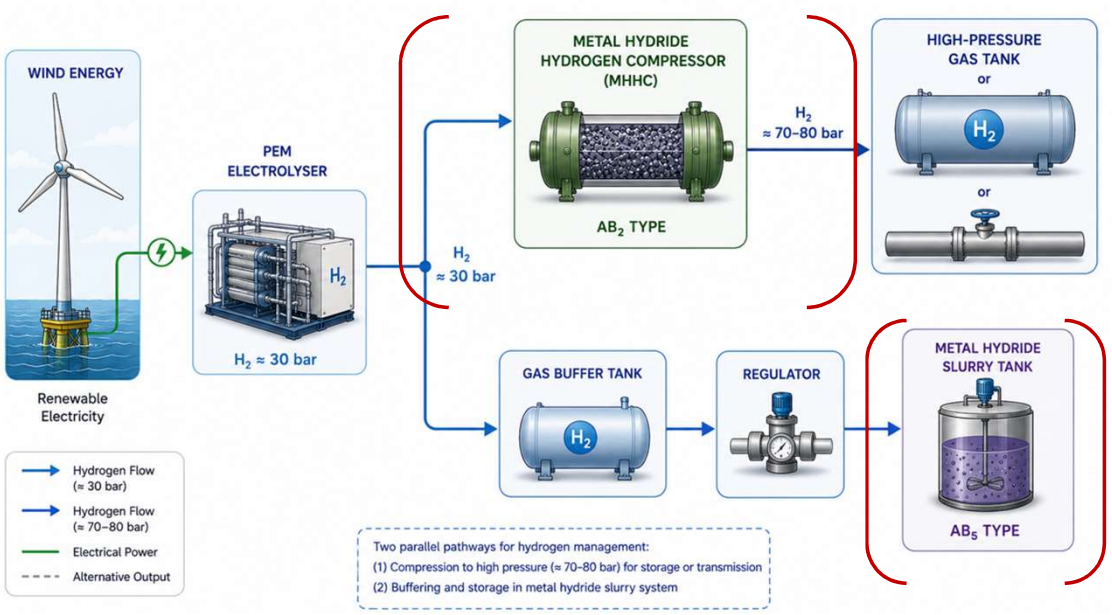
Hydrogen Storage and distribution concept

H_2 storage and transport (WP3)

Hydrogen storage is a key challenge within the Ocean-REFuel project.

At the University of Nottingham, our research focuses on the synthesis of metal hydrides, including AB_2, AB_5 and complex hydrides, and development MHHC and metal hydride slurry systems.

- Hydrogen storage and distribution concept-



- Metal hydrides for H_2 Storage-

CRITERIA	AB_2 (Laves Phase)	AB_5 ($CaCu_5$ Type)	COMPLEX HYDRIDES
EXAMPLES	$TiMn_2$, $TiCr_2$, ZrV_2-based alloys	$LaNi_5$, $MmNi_5$	$NaAlH_4$, $LiBH_4$, $Mg(BH_4)_2$
H_2 CONTENT	MODERATE	MODERATE	HIGH – VERY HIGH
KINETICS	FAST	VERY FAST	SLOW
REVERSIBILITY	GOOD	EXCELLENT	LIMITED / CHALLENGING
OPERATING CONDITIONS	MODERATE	MILD – MODERATE	OFTEN HIGH TEMPERATURE
TUNABILITY	HIGH (Tunable thermodynamics & equilibrium pressure)	MODERATE – HIGH	MATERIAL-DEPENDENT
TECHNOLOGY MATURITY	MATURE	HIGHLY MATURE	DEVELOPING
KEY STRENGTH	TUNABLE & BALANCED PERFORMANCE	RELIABILITY & CYCLING STABILITY	HIGH H_2 CONTENT
MAIN LIMITATION	ACTIVATION & IMPURITY SENSITIVITY	HIGH WEIGHT / MATERIAL COST	POOR KINETICS & REVERSIBILITY

AB_2 Tunable & Balanced — Fast kinetics, good reversibility, tunable thermodynamics

AB_5 Reliable & Stable — Excellent reversibility, very fast kinetics, mature

Complex Hydrides High-Capacity Potential — Very high H_2 content, but kinetically challenging

Experimental Studies

- Two different metal hydride materials were investigated for the proposed hydrogen storage systems.

Material	Type	Application
$Ti_{30}V_{15.8}Mn_{49.4}Zr_{0.5}Cr_{1.1}Fe_{2.9}$	AB_2 – $TiMn_2$ based	MHHC System
$LaNi_{4.7}Al_{0.3}$	AB_5 – $LaNi_5$ based	MH Slurry System

- H_2 storage properties of both materials were evaluated through Pressure-Composition Isotherm (PCI) measurements at different temperatures using a Sieverts-type apparatus.
- For MH slurry investigation, a slurry containing 5.0 wt% $LaNi_{4.7}Al_{0.3}$ was prepared with 40 mL of silicone oil and test was carried out via Ultrasound reactor.
- The raw-material cost for MHHC was calculated depending on hydrogen storage parameters of wind-powered electrolyser integrated system.



-Sieverts Line-

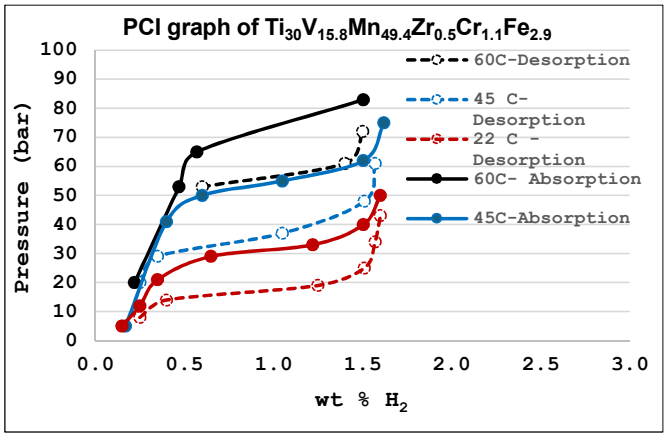


-Reactor for slurry test-

Results

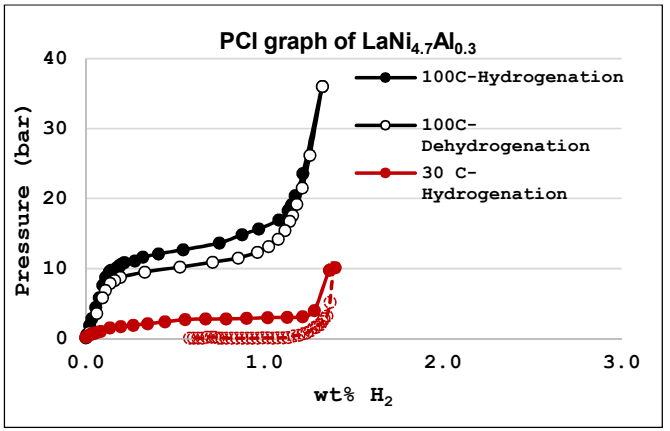
AB_2 Alloy, $Ti_{30}V_{15.8}Mn_{49.4}Zr_{0.5}Cr_{1.1}Fe_{2.9}$ – PCI Performance

~1.2 wt% H_2 at 22 °C / 30 bar, compatible with electrolyzer output (~ 30 bar).
Lower temperature increases storage capacity to ~1.6 wt% H_2.
Higher temperature promotes H_2 desorption and pressure boosting.
Promising for MHHC.



AB_5 Alloy, $LaNi_{4.7}Al_{0.3}$ – PCI Performance

~1.3 wt% H_2 at 30 °C / 5 bar.
Stable hydrogen storage under mild operating conditions.
Enables safe H_2 transport via metal hydride slurry pipelines.
H_2 can be released on demand for end use.



Results

Preliminary Cost Assessment

Following material selection and experimental validation, the MHHC was sized based on the electrolyzer H_2 production capacity defined within the Ocean-REFuel concept.

- H_2 storage parameters of wind-powered electrolyser integrated system-

PARAMETERS	MHHC system (Single-bed,batch-operated)
Electrolyzer Hydrogen Production Rate	2529.4 kg H_2 h^{-1}
Fraction of Hydrogen Supplied To The MHHC	50%
Hydrogen Flow Rate To The MHHC	1264.7 kg H_2 h^{-1}
Hydrogenation Temperature	15 °C
Hydrogenation Time	2 h
Dehydrogenation Temperature	60 °C
Dehydrogenation Time	0.5 h
Nominal Hydrogen Storage Capacity of the MH	1.6 wt%
Assumed Usable Fraction Of The Nominal Capacity	80%
Effective Hydrogen Storage Capacity	1.28 wt%
Hydrogen Stored Per Cycle	2529.4 kg H_2
Required Metal Hydride Inventory, Rounded	197.6 t

-Data For The Raw-material Cost Calculation-

Commercial raw material	Commercial Composition	Alloy (mol %)	Alloy (wt%)	Required amount (kg kg^{-1} alloy)	HS code	Representative price (USD kg^{-1})	Cost contribution (USD kg^{-1} alloy)	Price source # (2025 imports)
Titanium	Ti	30.0	27.51	0.2751	810820	12.85	3.535	UN Comtrade)
Ferrovanadium (FeV80)	81.4 mol% V + 18.6 mol% Fe	15.8	15.42	0.1928	720292	19.57	3.773	UN Comtrade
Manganese	Mn	49.4	52.00	0.52	811100	2.05	1.066	UN Comtrade
Zirconium	Zr	0.5	0.87	0.0087	810929	58.49	0.509	UN Comtrade
Chromium	Cr	1.1	1.10	0.0110	811221	11.58	0.127	UN Comtrade)
Total (1 kg alloy)	–	99.7*	100.00	1.0076 †	–	–	9.01	–

Representative unit prices were derived from **2025 UN Comtrade** import statistics using trade-weighted average import unit values. https://comtradeplus.un.org/TradeFlow?utm_source=chatgpt.com

Conclusion and Future Work

- Promising metal hydride materials were selected, prepared and experimentally characterised for integration into the proposed hydrogen storage and distribution system.
- The $Ti_{30}V_{15.8}Mn_{49.4}Zr_{0.5}Cr_{1.1}Fe_{2.9}$ alloy showed suitable performance for MHHC, enabling direct H_2 absorption at the 30 bar electrolyzer outlet pressure.
- Assuming 50% of the electrolyzer H_2 production is processed by the MHHC:
  Required MH mass: ~197.6 t
- Preliminary raw-material cost estimation based on 2025 UN Comtrade data:
  ~9.01 USD kg^{-1} → ~1.78 million USD total alloy cost

Future Work

- Additional experimental studies on the metal hydride slurry system.
- A comprehensive techno-economic assessment will evaluate CAPEX, OPEX and system optimisation, supporting further integration with the Ocean-REFuel concept.

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Ocean-REFuel

THANK YOU

for your attention

Advancing hydrogen storage
for a sustainable energy future



H_2

? QUESTION ?