REYNOLDS, J. 2023. *Mapping pipeline bundles for their repurposing used for hydrogen storage*. Presented at the 2023 Subsea expo, 21-23 February 2023, Aberdeen, UK.

Mapping pipeline bundles for their repurposing used for hydrogen storage.

REYNOLDS, J.

2023

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Mapping pipeline bundles for their repurposing used for hydrogen storage

Jemma Reynolds, Research Assistant

National Subsea Centre

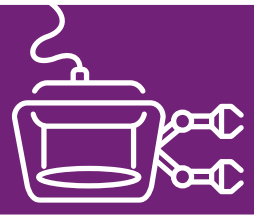
RGU ROBERT GORDON UNIVERSITY ABERDEEN

Net Zero Technology Centre

Technology Driving Transition

National Subsea Centre

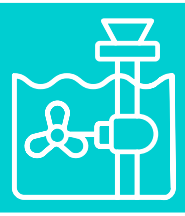
Our Research Programmes



Transparent Ocean:

Professor Jinchang Ren

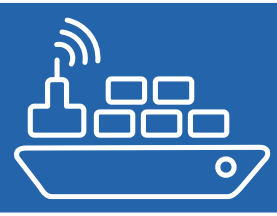
Aiming to develop cutting-edge capability to detect, monitor and understand subsea and marine, including conditions and activities of the infrastructures and the environments, using the full range of state-of-the-art platforms and sources for data acquisition, visualisation, analysis, interpretation and prediction.



Integrated Marine Energy:

Professor James Njuguna

Aiming to develop leading-edge capability to design, model, evaluate and construct an integrated marine energy grid to support the transition to decarbonized energy, using smart materials, digital twins, robotics and mixed energy vector power systems.



Net Zero Marine Operations:

Doctor Ciprian Zavoianu

Aiming to develop leading-edge capability to reduce carbon emissions, resource consumption and environmental footprint of marine industry operations using digital twins, machine learning and optimization for operations planning and management, workforce transition planning and supply chain re-design.

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Professor James Njuguna
Integrated Energy Lead

Integrated Energy

The Integrated Energy programme aims to develop leading-edge capability to design, model, evaluate and construct an integrated marine energy grid to support the transition to decarbonized energy, using smart materials, digital twins, robotics and mixed energy vector power systems.

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Project partner: Cygnas Solutions

- Extensive experience across a range of Industries
- Passion for Innovation with a wealth of Engineering Know-how
- Solutions for Companies transitioning to Industry 4.0 leveraging our multi-sectoral experience
- Experienced in Asset Integrity & Management, RBI, RAMS & Fitness For Service
- Advanced Engineering Analysis, AR, IOT and Consulting Services across a range of verticals

CYGNAS

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Project: Pipeline Bundles Repurposing for Hydrogen Storage

Key Task: Mapping pipeline bundles and offshore windfarms

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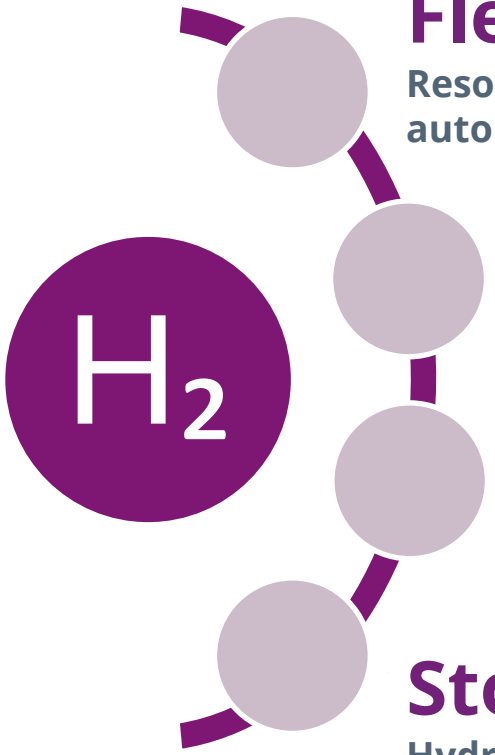
Hydrogen and its importance



Flexible

Resource that can be utilised in a number of different industries; aerospace, automotive and even house hold heating

Clean

Hydrogen can produce energy when required without any polluting by products to support decarbonisation

Abundant

Hydrogen is the most abundant energy source in the world contributing to 75% of the mass of the universe.

Storage Ability

Hydrogen can be stored, transported by pipelines and has a high energy density.

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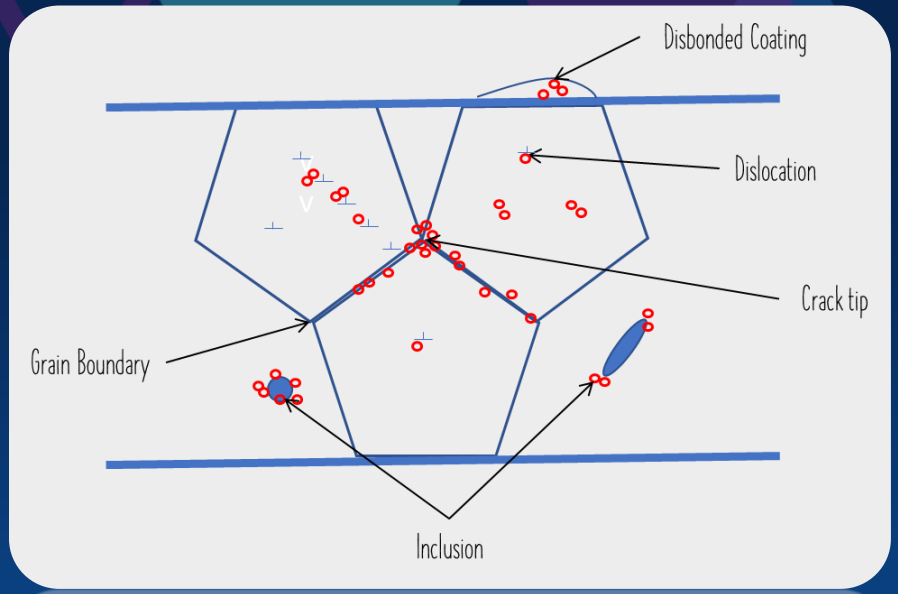
Challenges for Hydrogen Storage

- Hydrogen Embrittlement
- Permeability through porous media
- Safety of operating pressures
- Leakage detection



HE in Steel adapted from Hussein et al. 2021

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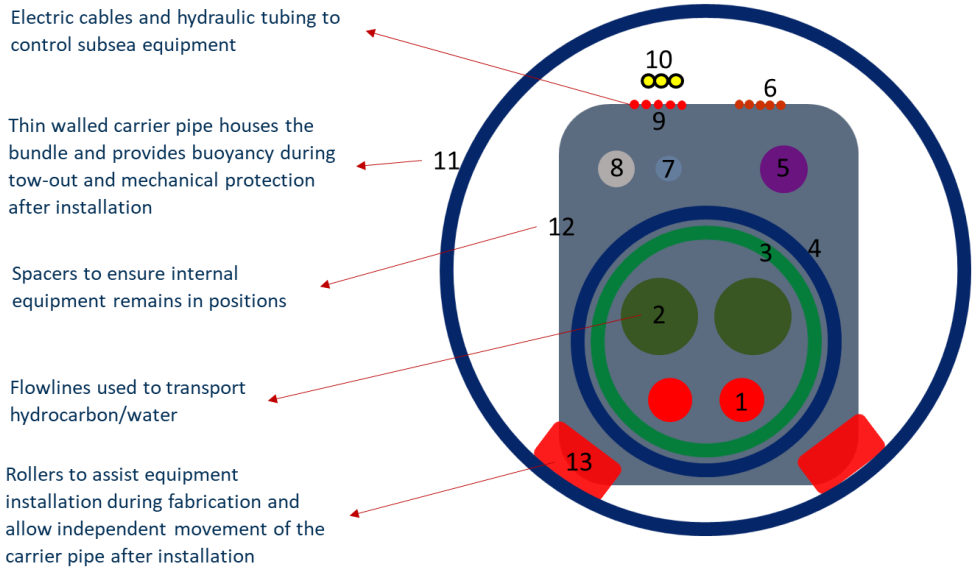
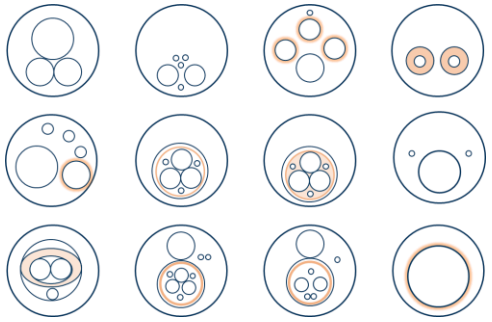
Pipeline bundles



1. Hot Water Heating
2. Production
3. Insulation
4. Sleeve Pipe
5. Gas Lift
6. Control Tubes
7. Methanol Injection
8. Scale Squeeze
9. Chemical Injection
10. Power & Signal Cables
11. Carrier Pipe
12. Main Spacer
13. Rollers



Subsea 7 2016

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Bundles Advantages

- Onshore welding and system integration tests
- Pipeline bundle installation
- Efficient insulation systems
- No need to trench or rock dump
- Protected from the outer environment with the carrier

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Bundles Decommissioning options

- Full removal to shore for disposal at landfill and/or material recycle
- Reuse at another site
- Removal for deep water disposal
- In place decommissioning

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Why bundles for hydrogen storage?

- Sustainable decommissioning option and potential to be profitable
- Bridge gap between wind farm energy production rates and energy usage
- Benefits of pipeline bundles is that by design they are commissioned as low stress and have high fatigue tolerances

Subsea 7 2016

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Offshore wind farms

- Wind power produces roughly 5% of the worlds electricity.
- Government ambition of adding up to 50GW by 2030 to offshore wind, of which 5GW from floating offshore wind in deeper seas is expected.
- Wind energy produced offshore is increasing in many countries around the north sea.
- One challenge is transporting the electricity back to shore.
- Potential to produce hydrogen.

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Bundles Project Overview

Developments in the H2 economy and need for hydrogen storage

Pipeline bundles being decommissioned

Surplus energy being produced from wind turbines

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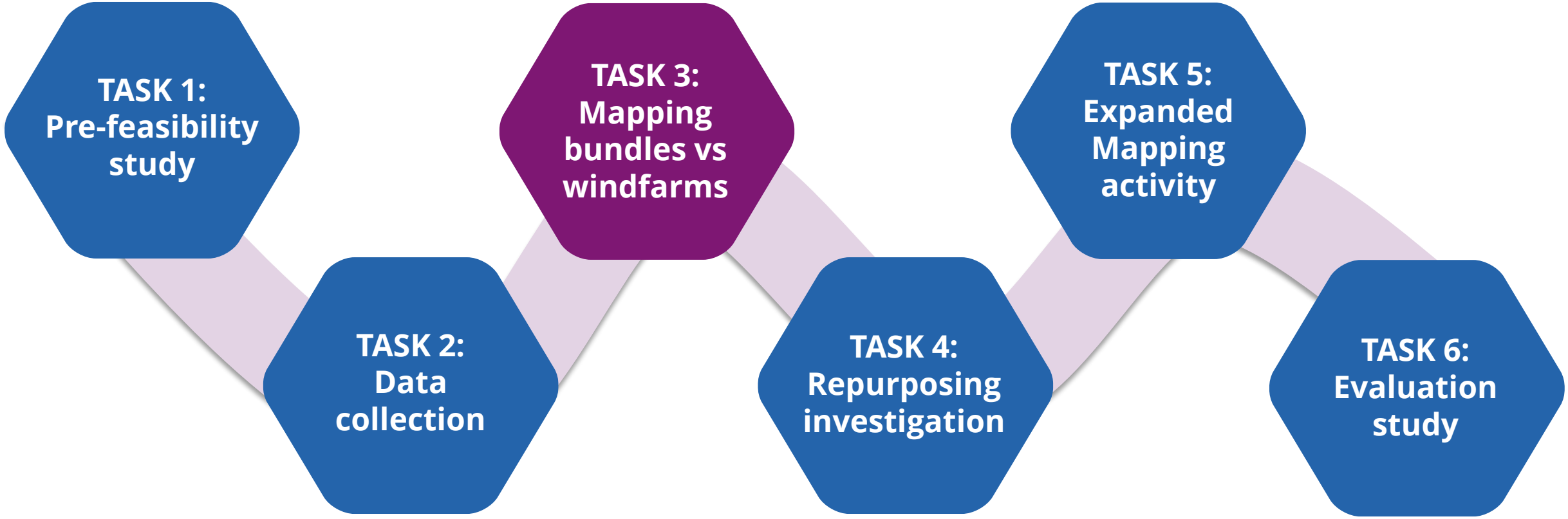
Project status:



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TASK1:

$P_{storage}$	207	*bara*	NPS	16		ID_{final}	325.494	*mm*	Length	7	km
Temp	4	*C*	Sch	Sch 160							
Density	15.9538	kg/m^3	$ID_{unpressurised}$	325.424	*mm*	A	0.083210273	*m^2*	Vol	582.4719139	m^3
Mass of H_2	10000	*kg*	Bundle Depth	50	m	$L_{required}$	7.532842856	*km*			
Vol	626.8099136	m^3	P_{sea}	6.034008	*bara*						
			DP	200.965992		Available H_2	9670.484806	kg			

Material Data			**Pressure Effects**		
E	207	GPa	σ_θ	80.76	*MPa*
α	1.58E-05	mm/mm/C	e_θ	3.902E-04	
$\sigma_{Fatigue\ Limit}$	300	MPa	**Thermal Effects**		
			e_θ	-1.738E-04	
			e_z	-1.738E-04	

Outcome based on 100% of fatigue limit	Pass

Calculation based on NIST data for H_2

Ambient temp at deployment assumed to be 15C

Average seawater density of 1023 kg/m^3 used

TASK 1: Pre-Feasibility Study

- The calculations were based on NIST data for H_2
- The ambient temperature at deployment was assumed to be 15C
- The average seawater density of 1023kg/m³ used

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TASK 2:

objectid	lease_desc	tenant_nam	lease_type	property_c	project_ph	capacity_m	shape_leng	shape_area
1	Robin Rigg East	RWE Renewables UK	Lease Marine	Wind Farm	Operational	84	0.174438309	0.001375732
2	Robin Rigg West	RWE Renewables UK	Lease Marine	Wind Farm	Operational	90	0.158276674	0.001182332
3	Inch Cape Offshore Wind Farm	Inch Cape Offshore Ltd	Agreement/Option for Lease	Wind Farm	Consented	1008	0.739036166	0.021772633
4	Moray East Met Mast	Moray Offshore Wind Farm	Lease Marine	Substation	Operational	0	0.008356256	4.79E-06
5	Methil Demo	ORE Catapult Ltd	Lease Marine	Wind Farm	Operational	7	0.00835391	3.44E-06
6	Inch Cape Met Mast	Inch Cape Offshore Ltd	Lease Marine	Substation	Consented	0	0.038869255	0.000101988
7	Forthwind Methil Demonstration	Forthwind Ltd	Agreement/Option for Lease	Wind Farm	Consented	12	0.052654485	5.45E-05
33	Broadshore	Orion Offshore Wind Farm	Agreement/Option for Lease	Wind Farm	Pre Planning	500	0.618858373	0.020447472
34	Bellrock	Gemini Offshore Wind Farm	Agreement/Option for Lease	Wind Farm	Pre Planning	1200	1.170430248	0.041105488
8	Beatrice Offshore Wind Farm	Beatrice Offshore Wind Farm Li	Lease Marine	Wind Farm	Operational	588	0.654697578	0.020103013
9	Beatrice OFTO	TC Beatrice OFTO Limited	Lease Marine	OFTO	Operational	0	0.016736646	9.60E-06
10	Aberdeen Offshore W/F	Aberdeen Offshore WindFarm Ltd	Lease Marine	Wind Farm	Operational	97	0.249356786	0.002975306
11	Buchan Deep Demo	Hywind (Scotland) Ltd	Lease Marine	Wind Farm	Operational	30	0.208187412	0.002305295
12	Pentland Floating Offshore Win Farm	Highland Wind Ltd	Agreement/Option for Lease	Wind Farm	In Planning	100	0.158027054	0.001547737
13	Robin Rigg OFTO	TC Robin Rigg OFTO Ltd	Lease Marine	OFTO	Operational	0	0.018747712	1.20E-05
14	Inch Cape OFTO	Inch Cape Offshore Ltd	Agreement/Option for Lease	OFTO	Consented	0	2.972066753	0.015254147
15	Moray West	Moray Offshore Windfarm (West)	Agreement/Option for Lease	Wind Farm	Consented	850	0.935495784	0.034285235
16	Berwick Bank Wind Farm	Berwick Bank	Agreement/Option for Lease	Wind Farm	Pre Planning	2300	1.424257229	0.094975421
17	Kincardine	Kincardine Offshore WF Ltd	Lease Marine	Wind Farm	Operational	50	0.26026987	0.003750704
18	Moray East OFTO	Moray Offshore Wind Farm	Lease Marine	OFTO	Under construction	0	1.633205752	0.003107417
19	Moray Offshore Windfarm (East)	Moray Offshore Wind Farm	Lease Marine	Wind Farm	Operational	953	1.456378324	0.044732569
20	Marr Bank Wind Farm	Marr Bank	Agreement/Option for Lease	Wind Farm	Pre Planning	1800	1.524123294	0.114222102
21	Neart Na Gaoithe Offshore Wind	Neart Na Gaoithe Offshore Wind	Lease Marine	Wind Farm	Under construction	448	0.71818202	0.014872928
22	Neart na Gaoithe OFTO	Neart Na Gaoithe Offshore Wind	Lease Marine	OFTO	Under construction	0	0.0120763	5.12E-06
23	Moray West OFTO	Moray Offshore Windfarm (West)	Agreement/Option for Lease	OFTO	Consented	0	1.883132572	0.060356619
44	Morven	Morven Offshore Wind Limited	Agreement/Option for Lease	Wind Farm	Pre Planning	2907	1.792697699	0.125365656
24	Seagreen Phase 1 OFTO	Seagreen Wind Energy Limited	Lease Marine	OFTO	Under construction	0	0.040511558	0.000114776
25	Seagreen Phase 1A OFTO	Seagreen 1A Limited	Agreement/Option for Lease	OFTO	Consented	0	3.452365169	0.017533142
26	Seagreen Phase 1 Windfarm	Seagreen Wind Energy Limited	Lease Marine	Wind Farm	Under construction	1140	1.692394668	0.048509635
27	Seagreen 1A Offshore Wind Farm	Seagreen 1A Limited	Agreement/Option for Lease	Wind Farm	Consented	360	0.463971567	0.008565016
28	Berwick Bank OFTO	Berwick Bank	Agreement/Option for Lease	OFTO	Pre Planning	0	3.530368568	0.11688525
29	Cluaran Deas Ear	Thistle Wind Partners Cluaran	Agreement/Option for Lease	Wind Farm	Pre Planning	1008	0.891787478	0.027625745
30	Scoprojco1 TBC	Ossian Offshore Windfarm	Agreement/Option for Lease	Wind Farm	Pre Planning	2610	2.022451172	0.125805704
31	Buchan Offshore Wind Farm	Floating Energy Allyance 1	Agreement/Option for Lease	Wind Farm	Pre Planning	960	0.95833232	0.050810197
32	Stromar	Northern Cross Offshore	Agreement/Option for Lease	Wind Farm	Pre Planning	1000	0.861862763	0.039473526
35	Marram	MarramWind Limited	Agreement/Option for Lease	Wind Farm	Pre Planning	3000	1.375839976	0.104323326
36	MachairWind	MachairWind Limited	Agreement/Option for Lease	Wind Farm	Pre Planning	2000	1.331892969	0.108540492
37	Campion	CampionWind Limited	Agreement/Option for Lease	Wind Farm	Pre Planning	2000	1.774414211	0.128105494
38	Cluaran Ear-Thuath	Thistle Wind Partners Cluaran	Agreement/Option for Lease	Wind Farm	Pre Planning	1008	1.38314575	0.031073324
39	Northland Sheena TBC	Northland Sheena Limited	Agreement/Option for Lease	Wind Farm	Pre Planning	840	0.832381654	0.024771895
40	Magnora TBC	Magnora Offshore Wind N3	Agreement/Option for Lease	Wind Farm	Pre Planning	495	0.554988175	0.016007227
41	Mara Mhor Offshore Wind Farm	Muir Mhor Offshore Wind Farm	Agreement/Option for Lease	Wind Farm	Pre Planning	798	0.75067669	0.029861689
42	Northland Mhairi TBC	Northland Mhairi Limited	Agreement/Option for Lease	Wind Farm	Pre Planning	1500	1.407979385	0.060663484
43	West of Orkney Wind Farm	Offshore Wind Power Limited	Agreement/Option for Lease	Wind Farm	Pre Planning	2000	1.570481375	0.102300202
45	Caledonia Offshore Wind Farm	Caledonia Offshore Wind Farm	Agreement/Option for Lease	Wind Farm	Pre Planning	1000	1.201315179	0.065488291
46	Shetland Offshore Wind	Shetland Offshore Wind Ltd	Agreement/Option for Lease	Wind Farm	Pre Planning	500	0.542831128	0.016320265
47	Ocean Winds Shetland	Ocean Winds Shetland Ltd	Agreement/Option for Lease	Wind Farm	Pre Planning	500	0.593952316	0.016217702
48	Arven Offshore Wind Farm	Arven Offshore Wind Farm	Agreement/Option for Lease	Wind Farm	Pre Planning	1800	1.076449234	0.058397889

TASK 2: Data Collection

- All data was taken as secondary data from various sources
- Data required formatting
- Low accuracy
- Requires more accurate mapping software for further investigation

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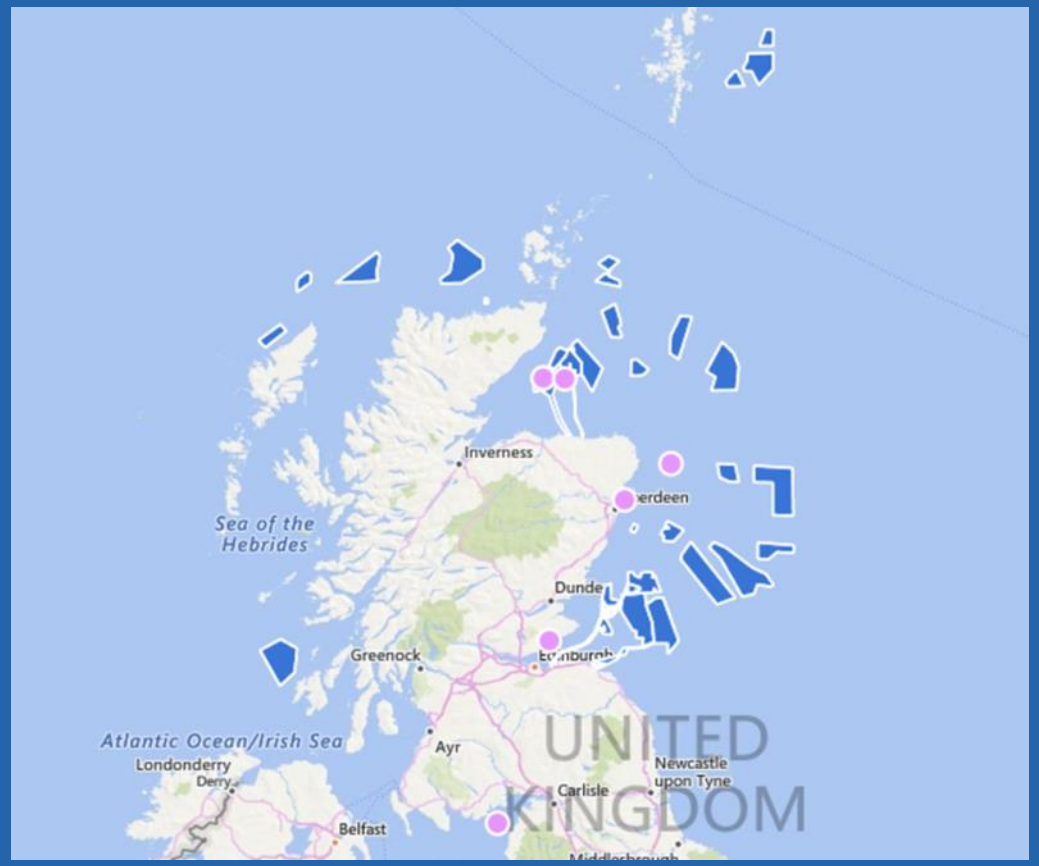
TASK 3:



TASK 3: Mapping activity

- Low accuracy
- Requires more accurate mapping software for further investigation
- Unable to obtain all data required at this point

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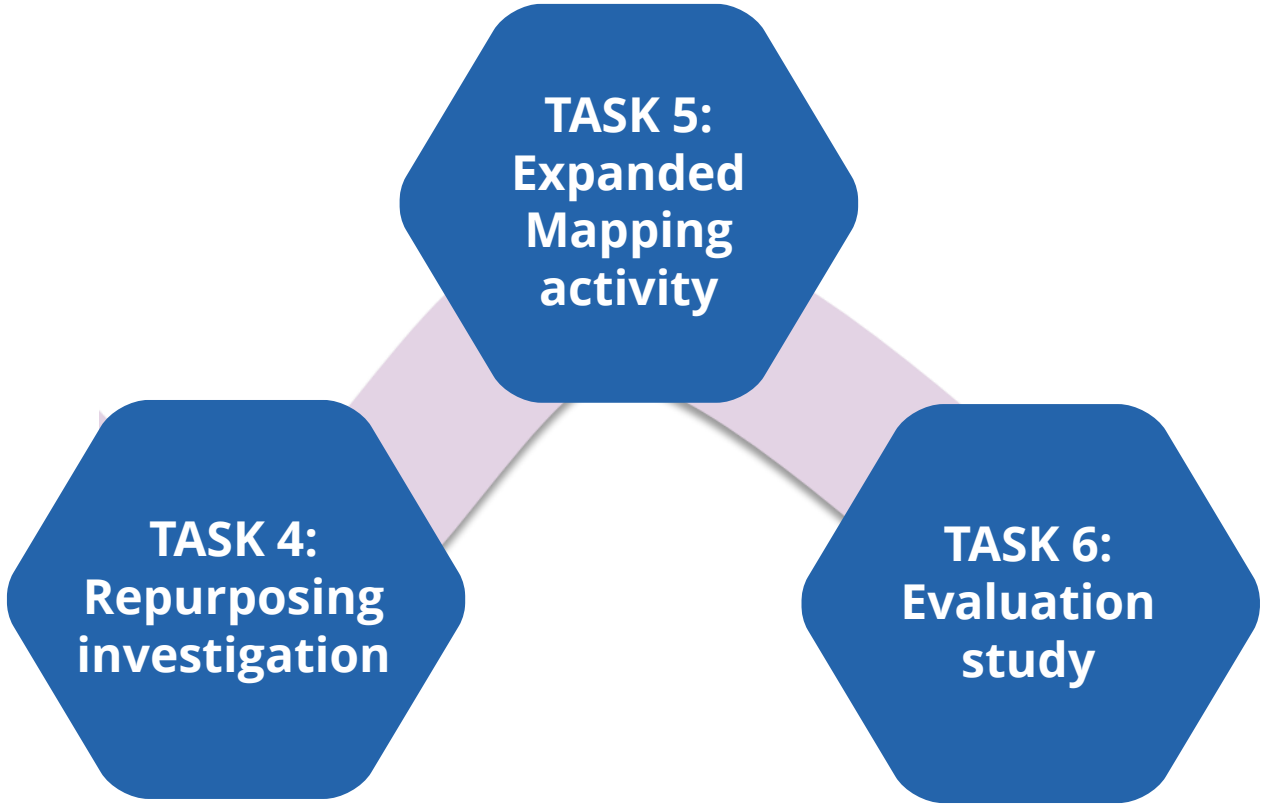
Future Project steps:



- Investigate coatings for pipeline repurposing
- Fatigue cycles
- Cleaning
- Services
- Hydrogen Compatibility with coatings
- All pipelines
- Costing evaluation

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Concluding remarks:

- Bundles have the potential to be repurposed for H2 storage for windfarms, but not just bundles
- Many bundles would be requiring decommissioning and a new and current wind farms might offer the best way forward
- Further work could be carried out on a real opportunity in the North Sea and further a field
- The inclusion of bundles might offer the platform to be repurposed to produce and process hydrogen

ALL THINGS HYDROGEN CONFERENCE

A COLLABORATION BETWEEN THE
NATIONAL SUBSEA CENTRE &
ROBERT GORDON UNIVERSITY

#ATH23

SUPPORTED BY:

GLOBAL MARITIME

SCOTTISH Hydrogen & Fuel Cell ASSOCIATION

Net Zero Technology Centre
Technology Driving Transition

CONFERENCE TOPICS:

HYDROGEN PRODUCTION DEVELOPMENTS

HYDROGEN STORAGE FACILITATING THE FUTURE

THE INTEGRATION OF HYDROGEN INTO THE ENERGY MIX

NIGEL HOLMES
SCOTTISH HYDROGEN & FUEL CELL ASSOCIATION

PROF. JAMES NJUGUNA
NATIONAL SUBSEA CENTRE

JOHN BUTLER
GLOBAL MARITIME

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Thank You