MILFORD HAVEN: ENERGY KINGDOM

Investment Brochure

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Investment context

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The case for change

"Climate change is real, and it is happening all across the world and **impacting on local communities in Pembrokeshire**.

Sir David Attenborough in 2019 called climate change *'our greatest threat in thousands of years'*, adding, *'while Earth has survived radical climactic changes and regenerated following mass extinctions, it's not the destruction of Earth that we are facing, it's the destruction of our familiar, natural world and our uniquely rich human culture.'*

It is up to us all to change this."

Cllr Joshua Beynon, Chair of the Net Zero Carbon 2030 Group, Pembrokeshire County Council

The Case for Change –net zero by 2050

The UK and Welsh Government net zero targets by 2050 require whole system decarbonisation at scale and at pace.

Everyone has a role to play as individuals, local communities, private organisations, industry, public sector actors and financiers to ensure we reach these targets.

This will require technological adoption and innovation, economic, financial and regulatory innovation, business transformation, and behavioural change.

The fastest and most effective way to deliver against country level decarbonisation targets, is to decarbonize the energy sector as a priority.

Pembrokeshire and more specifically Milford Haven, Pembroke and Pembroke Dock are uniquely positioned to take a leading stance on this decarbonization journey.

The Port of Milford Haven is the UK's largest energy port, with associated industrial processes, jobs and skilled workforce, and Pembrokeshire has significant offshore and onshore renewables potential.

The Case for Change –energy sector decarbonisation as a priority

Whole energy sector decarbonisation is establishing behaviours, processes and infrastructure that bring about net zero emissions across all electricity, heat and transport.

The UK Government has set a more ambitious target for the electricity sector of reaching net zero by 2035, in support of whole system decarbonisation by 2050. This will need to be met with significant additional renewables as part of the UK electricity network than exists today, as well as some degree of carbon capture & storage in order to meet:

- Decarbonisation of current electricity demand,
- Increasing electricity demand linked with expected population growth,
- Shifts in locational demand as urban centres grow,
- Increasing electricity demand linked to electrification of heat and transport.

There is a shared commitment across Government and industry to deliver against these targets as evidenced by the presence and contributions of the private sector at COP26 and through many collaborative industry studies that are referenced throughout this report.

"We believe decarbonising energy is possible but also that it will be complex, not least because there are many ways to reach net zero, each with their own trade-offs." National Grid ESO

Amongst the many ways to reach net zero, Smart Local Energy Systems (SLES) are expected to have a significant role in supporting decentralisation of the energy system, greater local balancing and through enabling a greater number of (new) actors to engage.

"Smart Local Energy Systems can help to achieve these targets. Smaller scale, decentralised energy systems utilising smart technologies can be delivered at a local level to offer a route to net zero, while providing considerable market opportunities associated with the transition." EnergyREV

Pembrokeshire County Council Net Zero 2030 action plan

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Global hydrogen economy is projected to grow significantly

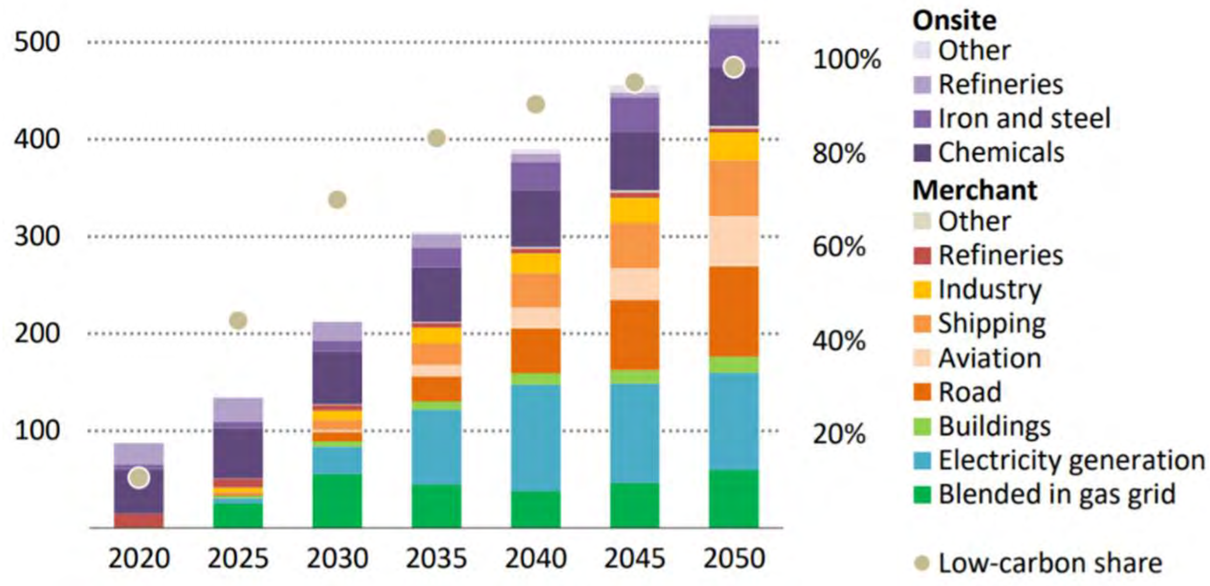
Hydrogen is expected to play a significant role in the UK energy mix with the UK government aiming to produce up to 10 GW of hydrogen by 2030, with at least half of this being from electrolysis (Department of Business, Energy & Industrial Strategy, 2022). Around 70 million tonnes of hydrogen is produced today with three-quarters of it from natural gas and the rest from coal. Only close to 2% of the global hydrogen production is through electrolysis. With the expectations of hydrogen playing a vital role in global net zero ambitions and in decarbonising the energy system, it is expected that many more players would be involved in hydrogen production in the UK and in green hydrogen production from offshore renewables in particular.

Global hydrogen use expands from less than 90 Mt in 2020 to more than 200 Mt in 2030; the proportion of low-carbon hydrogen rises from 10% in 2020 to 70% in 2030. Hydrogen is blended with natural gas in gas networks: the global average blend in 2030 includes 15% of hydrogen in volumetric terms,

These developments facilitate a rapid scaling up of electrolyser manufacturing capacity and the parallel development of new hydrogen transport infrastructure. This leads to rapid cost reductions for electrolysers and for hydrogen storage, notably in salt caverns.

After 2030, low-carbon hydrogen use expands rapidly in all sectors in the NZE.

Global hydrogen and hydrogen-based fuel use in the Net Zero Economy
Mt



Source: Net Zero by 2050 A Roadmap for the Global Energy Sector, IEA, 2021

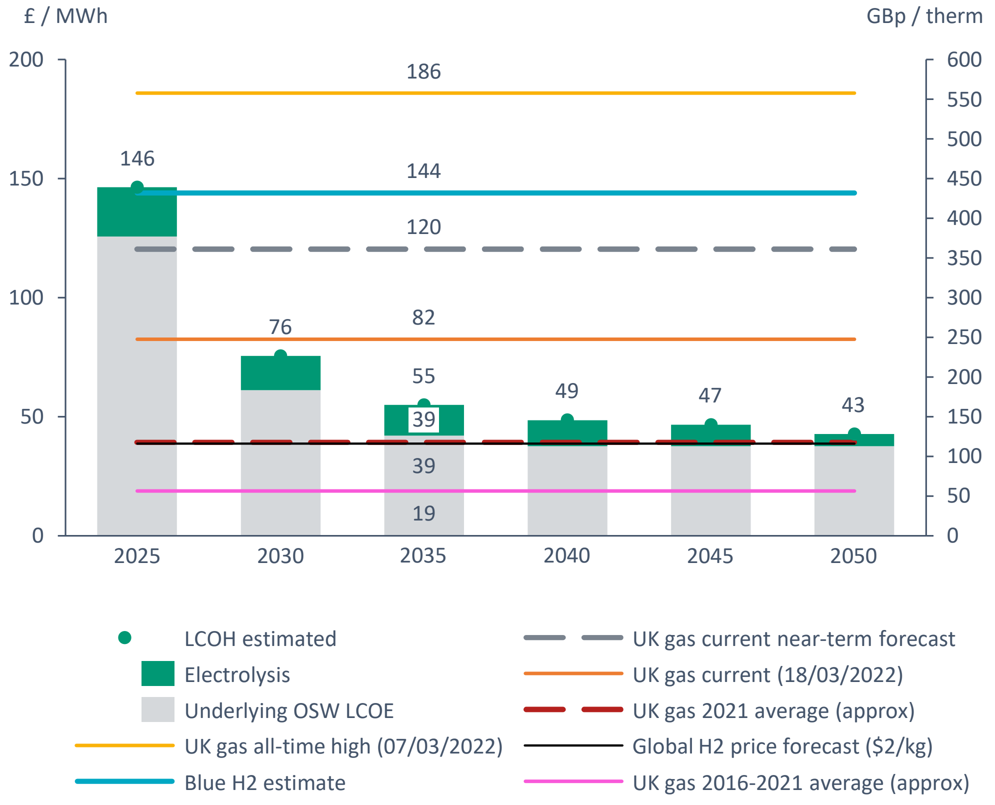
Affordability of green hydrogen from UK offshore wind

Increasing volumes of floating offshore wind will be well suited to UK production of green hydrogen. Co-location of hydrogen with offshore wind will enable an increase in usable energy from individual projects as well as providing long-term storage and alternative fuel source for increased UK electrification. There is ongoing debate about the merits of green vs blue hydrogen in terms of environmental impact and project economics. Over the last decade, record low gas prices have made the economics of blue hydrogen look attractive, though the environmental merits are not clear, with large uncertainty over the potential efficiency of carbon capture in the process. For the foreseeable future, with gas prices subject to huge uncertainty and climbing to record high levels, the economic argument no longer carries the same weight. The cost of supplying blue hydrogen is tied to gas prices, which is likely to remain around £145/MWh (£5.70/kg) in the short to medium term, based on an underlying gas price of £3.53/therm.

In comparison, as shown in the figure below, we forecast the cost of producing green hydrogen from floating offshore wind to reduce from around £146/MWh for early commercial projects around 2025-2027 to £76/MWh by 2030 and reducing below £50/MWh by 2040. This cost reduction is driven by the major cost reductions in FLOW as well as swift cost reductions in the cost of electrolysis – both driven by a combination of technology innovation and large-scale deployment.

Global benchmark pricing for green hydrogen (reported F.O.B. prices in Western Australia, Saudi Arabia, etc.) is $2 per kg H2, equivalent to £39/MWh. Shipping to UK and mainland Europe might add around £10/MWh, according to estimates.

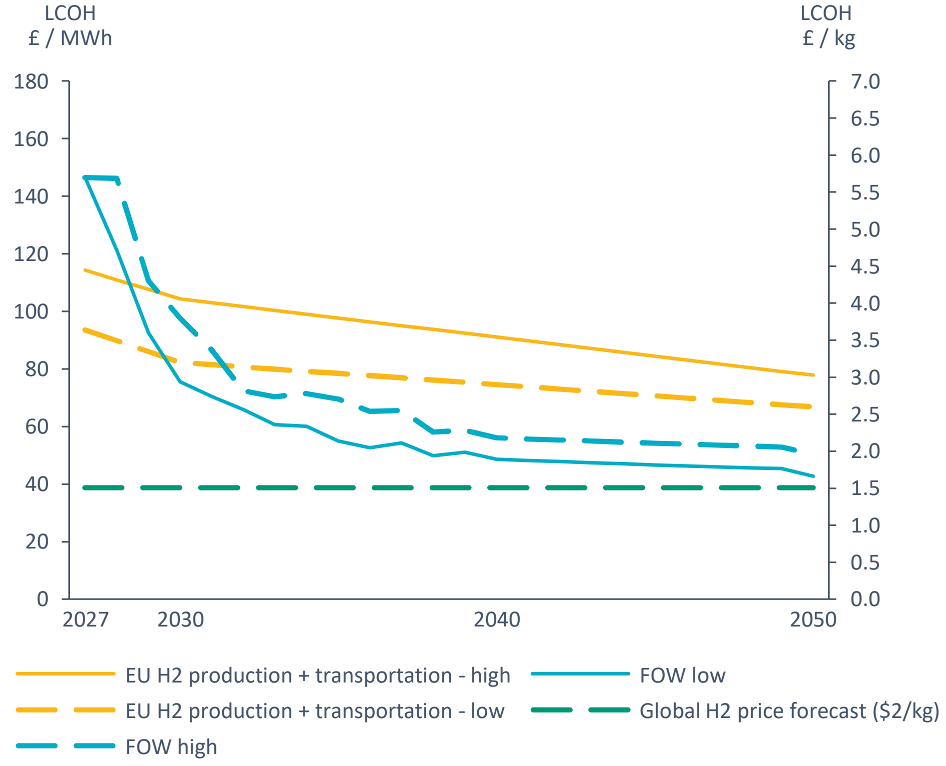
Forecast UK FLOW green hydrogen vs various UK gas price benchmarks (ORE Catapult, 2022)



Opportunities in offshore green hydrogen production

Comparing the cost of UK FLOW-produced green hydrogen with the cost of green hydrogen imported from overseas, in the long-term, by 2050 (and potentially earlier), UK FLOW-produced hydrogen should be at cost parity with the cheapest global cost for green hydrogen, around the £40/MWh (£1.60/kg) mark. As markets and infrastructure mature, global hydrogen prices may become a valid comparison but, in the near-term, the comparison with hydrogen imported from Europe is more relevant. ORE Catapult forecasts that UK FLOW-produced hydrogen should reduce below the cost of green hydrogen imported from Europe around 2030 and continue to track below European prices for the foreseeable future. As well as benefitting from low costs due to the best European wind resource, UK-produced hydrogen will also incur lower transportation costs. In addition to the benefits of using UK-produced green hydrogen domestically, the scale of the UK's offshore wind resource and ambition mean that there is huge potential to export UK green hydrogen to Europe and beyond. This opportunity was valued at £48bn per year in ORE Catapult's Solving the Integration Challenge (StIC) study with hydrogen forming 25% of Europe's energy needs by 2050. This opportunity will only accelerate and increase as demand grows even faster than previous predictions, given the imperative faced by an increasing number of countries to reduce reliance on Russian gas.

UK FLOW H2 vs European and global Hs imported into UK (ORE Catapult, 2022)



The role of hydrogen

"As the UK's largest energy Port, we are responsible for the supply of 25% of UK energy needs. It is becoming increasingly clear that to achieve net zero by 2050, we need renewable electrons and molecules. Gas plays a very significant role in the UK's energy mix and the gas network is able to be used for hydrogen transportation and storage. As a vital component of the energy system, the gas network can support the already-constrained electricity grid when at capacity with renewable energy or when renewable energy is unavailable."

Tam Bardell, Port of Milford Haven

A national transition from natural gas to hydrogen is increasingly seen as a necessary component of full decarbonisation by 2050.

Large scale hydrogen markets may provide essential cross-vector system balancing and inter-seasonal energy storage for an energy system dominated by the UK's abundant renewables, especially high-capacity factor, offshore wind and marine resources.

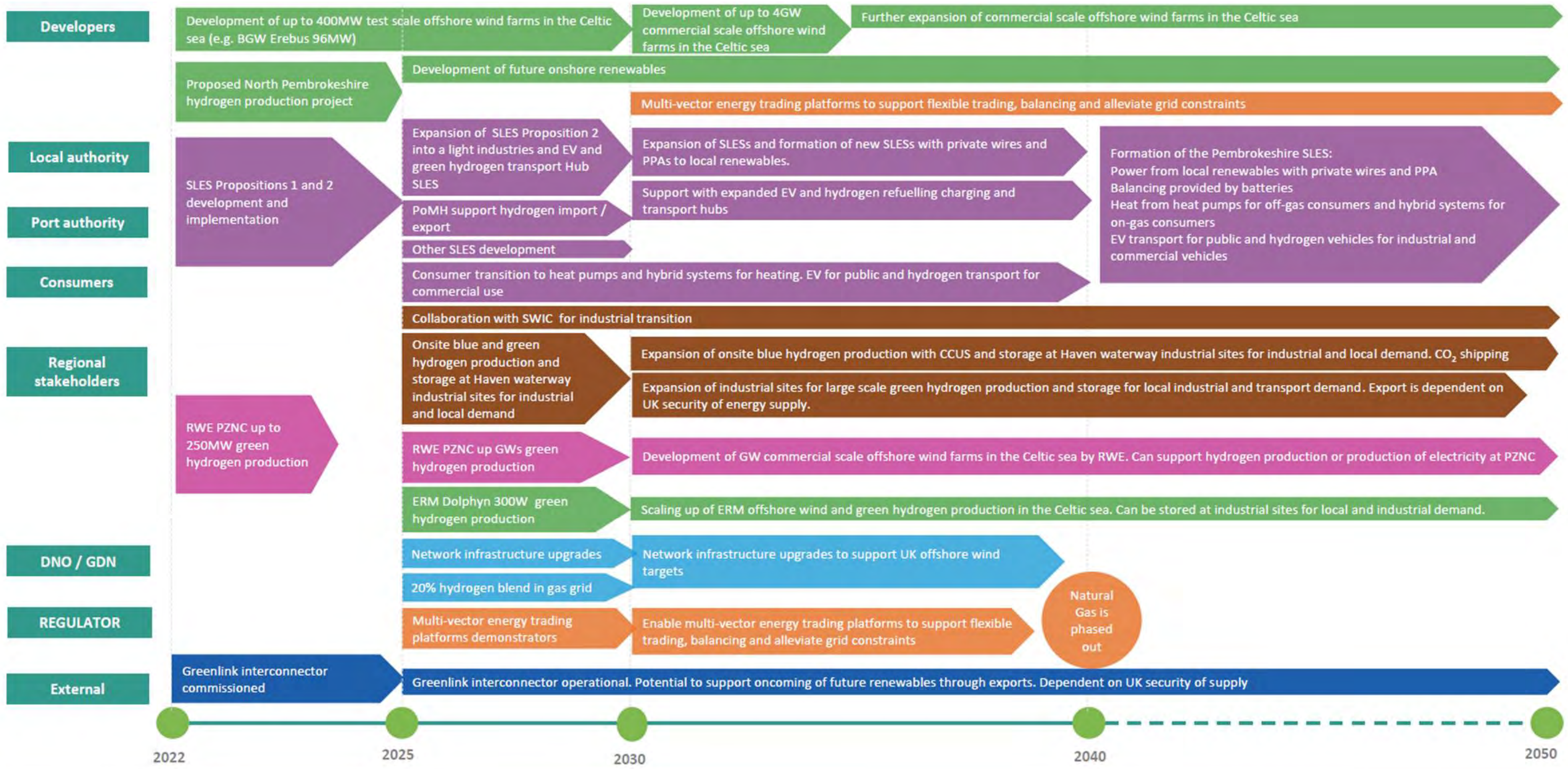
The reason for the focus on hydrogen within this project is threefold:

1. The Milford Haven boundary is uniquely located around the Port of Milford Haven, the UK's largest energy port, with an associated highly skilled workforce in the fossil fuel industries – people who understand about dealing with hydrocarbons, the processes involved, and safe working practices. We need to harness their skills for hydrogen. It is critical that we develop new skills and transition communities, in parallel with the changes to the physical components of our energy systems.

2.The MH:EK boundary includes other significant national energy assets, which will continue to retain a supporting role in the transitioning energy sector such as the Pembroke Power Station which is central to RWE's proposed Pembroke Net Zero Centre (PNZC). Similarly, Pembrokeshire is considered to have a key role in new renewables developments both onshore and with offshore wind in the Celtic Sea, as well as being the site of the nationally significant Greenlink interconnector which will support balancing of the GB energy system with Ireland.

3. Hydrogen can be created using excess electricity generated by renewable technologies, and then it acts as a chemical energy store, releasing energy when needed to support electricity grid balancing which will be increasingly important as the energy sector decarbonises and electricity demand increases. What we need to look at is how to make using hydrogen financially viable within the different energy vectors of heat, power and transport, and doing so both at scale and at a local level; whether it's putting in a hydrogen-fuelled heating system, running a hydrogen vehicle, or building a hydrogen manufacturing facility. This is something that the project aims to explore in detail.

Timeline of events for the Milford Haven Green Hydrogen longer-term pathway



Summary of the investments and returns from near-term propositions

Milford Haven Energy Kingdom project

The Milford Haven: Energy Kingdom project

The Milford Haven: Energy Kingdom(MH:EK) project is part of the Prospering from the Energy Revolution (PfER) programme funded by Innovate UK (IUK) as part of the UK research and Innovation (UKRI) Industrial Strategy Challenge Fund (ISCF).

MH:EK has reviewed the current energy landscape in the local area, to investigate options for a future Smart Local Energy System (SLES) by identifying proposition (opportunities) that are investible in the short-term and could provide the initial smaller steps towards larger scale decarbonisation and realisation of a Pembrokeshire wide SLES.

The project team consists of ORE Catapult, Port of Milford Haven, Wales & West Utilities, Riversimple, Energy Systems Catapult, Arup; led by Pembrokeshire County Council. Project non-funded collaborators and supporters include Western Power Distribution (WPD) and RWE; and Welsh Government Energy Service, Simply Blue and Community Energy Pembrokeshire respectively.

Routes to net zero

This research has explored a range of different scenarios, or possible pathways, to net zero across both immediate actions that could be taken now, out to decisions across the period to 2050. The study has drawn on the existing literature base, previous studies, extensive stakeholder engagement and Arup analysis to inform the scenarios considered. The scenarios are not intended to present a recommended outlook but to enable exploration of a wide spectrum of outlooks that future decisions will influence, to support 'no regrets' decisions in the short-term.

The role for SLES

Smart local energy systems are shown to have significant benefits in terms of costs and carbon emissions.

This is the case where there is strong interplay between the demand energy vectors (heating, cooling, electricity and hydrogen) supporting system balancing and greater flexibility of supply.

The study has highlighted a strong case for a hierarchy of energy usage as the system transitions to net zero. Energy should be used locally where possible and unnecessary transition between vectors should be minimised.

However, SLESs and heat networks are not always the preferred solution, this is dependent on the mix and scale of demand energy vectors**.**

The role for hydrogen

Electricity is shown to be more cost and carbon effective for power and heating in the SLES propositions modelled, with locally produced hydrogen playing a role in absorbing excess electricity to create green hydrogen for local transport. The case for hydrogen in transport is seen to be most viable in heavy goods vehicles, particularly whilst the market is nascent, as highlighted by other studies.

Short-term propositions

This feasibility study has focused on three shortlisted 'propositions' to assess their viability as a SLES and set out recommended 'no regrets' opportunities that if pursued would kickstart the journey to decarbonisation. A 'proposition' is defined as a project or development opportunity to make an intervention to the existing energy system of the local area that results in a linked multi-vector (power, heat, and transport) system where there is (potential for) smart connectivity between assets or component parts resulting in better balancing of local energy supply and demand.

To answer the overarching question of how 'best' to integrate hydrogen into the energy system to decarbonise energy supply, To understand the Economic case for a decarbonised multi-vector energy system, we have undertaken whole systems energy modelling considering technical, economic, and carbon emission factors.

The three shortlisted propositions from the long list of sixteen propositions:

- Proposition 1: The Milford Haven Marina SLES;
- Proposition 2: The Pembrokeshire Food Park SLES;
- Proposition 3: The Pembroke Schools, Leisure Centre and Dock SLES

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Near term propositions modelled by ARUP

The propositions

Proposition 1 – The Milford Haven Marina SLES

Proposition 1 focuses on the assets owned by the Port of Milford Haven (PoMH). The proposition considers the existing Liddeston Ridge Solar farm as a key supply asset alongside prospective PV and wind extensions, as well as the potential for rooftop PV on the PoMH buildings. The demand assets across the heat, power and transport vectors include the existing and proposed buildings and the commercial vehicle fleet owned by PoMH.

The analysis showed that further expansion of renewable assets and closer integration between those assets and the demand at the waterfront would be beneficial. The preferred option for expansion is a 2.5MW wind turbine with a 3.5MW solar PV expansion as second preference. Either a power purchase agreement (PPA) or a private wire connection to the waterfront demand is also recommended.

*Modelling for proposition 1 has been undertaken to a greater level of detail due to additional funding and therefore has only been run for the 2020 scenario at this higher level of detail.**

2020 CAPEX with 66% Optimism Bias (£million)	2050 CO_2 emissions (kg/kWh)	2020 LCOE (£/kWh)	MCA Score
16.4	0.002*	0.081	3.4

Figure 1: Map overview of the Milford Haven Marina and Liddeston Ridge site with the proposition boundary.

*CO_2 emissions are shown adjusted to a 2050 view and excluding gas heating emissions in order to compare like-for-like with proposition 2 and 3

Proposition 2 – The Pembrokeshire Food Park SLES

Proposition 2 is centred around the Pembrokeshire Food Park, a planned development for a food distribution centre in Haverfordwest, alongside the planned 10MW Haverfordwest airfield solar PV, and PCC transport hub plans in Haverfordwest. There is strong interplay between the demand energy vectors (heating, cooling, electricity and hydrogen) and a significant opportunity to utilise local waste products to fulfil this demand.

As a new-build proposal, the food park could be designed to take advantage of no regret technologies, particularly anaerobic digestion, biogas cold climate heat pump and polyvalent heat pumps. These can be integrated via heating and cooling distribution networks.

Utilising excess PV generation to electrolyse hydrogen locally would be a cost-effective method of meeting some transport demand. If local hydrogen transport demand grows this proposition could form a local hydrogen transport hub.

2050 CAPEX with 66% Optimism Bias (£million)	2050 CO_2 emissions (kg/kWh)	2050 LCOE (£/kWh)	MCA Score
24.1	0.003	0.074	3.9

Figure 2: Visualisation of the proposed Pembrokeshire food park (©hacerdevelopments.com/)

Proposition 3 – The Pembroke Schools, Leisure Centre and Dock SLES

Proposition 3 is located in Pembroke and is geographically closer to the hydrocarbon-based energy industries on the Haven waterway. As such, this proposition promotes a geographical spread with prospects on stepping up to a wider SLES in the long term as the industrial partners on the Milford Haven waterway seek to decarbonise.

The project considers potential incorporation of existing solar generation assets into the SLES and identifies opportunities for additional renewable generation.

The outcome of Proposition 3 suggests that it is not a strong SLES candidate as modelled. The outcomes mainly consist of a large capacity of solar PV that predominantly exports its generation to the national grid for income. There is little to no district-level integration between the buildings' heating systems and very limited interaction between energy vectors.

2050 CAPEX with 66% Optimism Bias (£million)	2050 CO_2 emissions (kg/kWh)	2050 LCOE (£/kWh)	MCA Score
22.2	0.001	0.030	2.1

Figure 3: Pembroke Ysgol Harri Tudor School (© https://www.ysgolharritudur.cymru/)

The propositions recommendations

The propositions

- It is recommended that the MH:EK project pursues both Proposition 1 and Proposition 2.
- Further work and more detailed analysis of both propositions is required, as these propositions progress along their development journeys.
- Both present real opportunities for a catalytic stepping-stone SLES that could result in a longer term larger SLES for the Pembrokeshire region, through expansion over time to include a broader boundary of residential and industrial demands.
- These two propositions present differences in 'flavour' with Proposition 1 being more focused around local community demand and Proposition 2 encompassing more commercial / light industrial use.

Proposition 1 recommendations

The analysis shows that further expansion of renewable assets and closer integration between those assets and the demand at the waterfront would be beneficial. The preferred option for expansion is a 2.5MW wind turbine with a 3.5MW solar PV expansion as second preference.

The preferred method of integrating waterfront demand with Liddeston Ridge supply is via a private wire. However, a private wire would cost an estimated £4.4m (without OB) which accounts for most of the CAPEX in all private wire scenarios. This would pay for itself over the 40-year lifetime, but the initial investment could be challenging.

If the commercial, legal and managerial challenges associated with a private wire prove insurmountable, the virtual PPA option could be preferrable to the business-as-usual operation, if it can be achieved at the 33kV scale.

Proposition 2 recommendations

This proposition represents a viable opportunity for a SLES. There is strong interplay between the demand energy vectors (heating, cooling, electricity and hydrogen) and a significant opportunity to utilise local waste products to fulfil this demand.

A core aspect essential to each scenario is a solar farm located at Haverfordwest airfield connected to the food park via private wire. The renewable energy is beneficial to minimise the amount of electricity purchased via the national grid. However, it does account for a significant proportion of the CAPEX (£9.5m-£10.5m) for every scenario.

Given that Proposition 2 represents a new-build proposal, the food park could be designed from the beginning to take advantage of no regret technologies, particularly anaerobic digestion, biogas CCHP and polyvalent heat pumps. These can be integrated via heating and cooling distribution networks with no disruption to existing services or replacement of legacy assets unlike Proposition 1 and 3.

Utilising excess PV generation to electrolyse hydrogen locally would be a cost-effective method of meeting some of the hydrogen transport demand although the majority would still be imported.

If local hydrogen transport demand becomes a reality and regular, consistent, consumers are identified, this proposition could begin to form the core of a local hydrogen transport hub. Further work on the Hydrogen refueller costs and business case would be required.

When a clearer understanding of end user demands is available, further analysis is required to understand the feasibility of the proposed solution and adjust efficiencies if necessary. We would also recommend to undertake a more detailed level of modelling to model different system configurations (as with Proposition 1).

Short term next steps

Further work and more detailed analysis of both propositions is required, including:

- taking the **whole system energy modelling** undertaken to date to the next stage of detail to support a more detailed design;
- exploration and **use case testing of the SPV / partnership commercial model**;
- specific **stakeholder engagement** to explore their appetite for such a model, and to better understand what risks or barriers there might be in implementing;
- exploring in more detail **how the ESCo model would work in practice**, what the relationship would be with other project partners, and the commercial relationship with entities outside of the SPV partnership perimeter;
- **financial modelling** to further understand the potential pay-back or revenue to different parties; and
- establishing a **detailed management plan**, including: an implementation programme, data management, risk management and contract management approaches.

Modelling outcomes

Summary of the propositions optimised outcomes

Table provides a summary of the CAPEX, OPEX, LCOE and carbon emissions for each proposition. The CO2 emissions have been scaled to the size / capacity of the proposition to allow for ease of comparison between propositions.

The upfront capital cost (CAPEX) for the recommended system for each proposition is provided in a separate report. In line with the HM Treasury Green book guidance, an optimism bias (OB) of 6-66% should be allowed for non-standard Civil Engineering projects. At this stage of the project, the upper bound 66% is applied, as there is not enough information to reduce the optimism bias. This total CAPEX represents the upfront budget for each proposition.

Carbon emissions from Proposition 1 are relatively high when compared to Proposition 2 and 3 across the same year. This is because all scenarios for Proposition 1 are based in 2020, so they still have significant carbon for electricity imports, and remains a predominantly natural gas-based heating system. The carbon emissions shown for Proposition 1 with a 2050 view in Table 4 have been adjusted to exclude gas heating emissions that are present in 2020 in order to compare 'like-for-like' with Proposition 2 and 3.The three propositions are then broadly comparable.

It should be noted that these quantitative outputs present only part of the picture, and the following notes should be considered alongside the recommendations. A key component of project funding will be revenues from the sale of electricity generated – either through savings by using the energy within the system or exports to the national grid.

For proposition 1, the Milford Haven Marina SLES, the annual benefit of the preferred scenario, wind expansion with private wire, against the business-as-usual scenario is estimated to be £2.8m which led to a simple payback of around 3 years for PoMH. This would require private waterfront tenants to agree to be supplied by the Port's resources (or likely an ESCo operating on the Port's behalf). To encourage this, the cost of that supply would have to be competitive against existing external utility providers. Therefore, the estimated £2.8m annual benefit to the system is likely to be split between private tenants and the Port. Assuming a local electricity sale price of £0.18/kWh, annual revenue from this sale and external export would be approximately £1.8m.

A core aspect of Proposition 2, the Pembrokeshire food park SLES, is a solar farm located at Haverfordwest airfield connected to the food park via private wire. The renewable energy is beneficial to minimise the amount of electricity purchased via the national grid. However, it does account for a significant proportion of the CAPEX (£9.5m-£10.5m). Compared to the baseline counterfactuals, optimised scenarios led to an uplift in CAPEX but a reduction in OPEX. Payback periods compared to counterfactuals varied based on the year but range between 5 and 8 years.

The above summary represents potential funding and revenue streams for the project anchor; however, these propositions present wider investment opportunities for a broad range of investors which should be reviewed in detail by interested parties.

Proposition		1 – Milford Haven Marina SLES		2 – Pembrokeshire Food Park SLES		3 - Pembroke Schools, Leisure Centre and Dock SLES	
Scenario		Onshore wind expansion with private wire	Onshore wind expansion with private wire and no gas*	Hybrid	Hybrid	Hybrid	Hybrid
		2020	2050*	2020	2050	2020	2050
KPI	CAPEX (£million)	8.12	9.87*	15.6	14.5	13.6	13.4
	CAPEX with 66% OB (£million)	13.5	16.4*	25.9	24.1	22.6	22.2
	OPEX (£m/year)	1.704	2.204*	0.765	0.705	-0.176	-0.236
	CO_2 emissions (kg/kWh)	0.076	0.002*	0.01	0.003	0.102	0.001
	LCoE (£/kWh)	0.061	0.081*	0.079	0.074	0.024	0.03

Table 4: Summary of the CAPEX, OPEX, LCoE and carbon emissions for each proposition scaled to the size / capacity of the proposition. *CO_2 emissions are shown adjusted to a 2050 view and excluding gas heating emissions in order to compare like-for-like with proposition 2 and 3.

Modelling outcomes

Figure 4: Graphical representation of the CAPEX, OPEX, LCOE and carbon emissions for each proposition scaled to the size / capacity of the proposition. *CO_2 emissions are shown adjusted to a 2050 view and excluding gas heating emissions in order to compare like-for-like with proposition 2 and 3.

Factors affecting the propositions

What could change the picture?

Delivering energy system transformation at the scale and pace needed to reach net zero by 2050 will require balancing multiple complex factors. Our work has consolidated the current evidence base to help build an understanding of the 'no regrets' first steps that could support broader system level change, whilst meeting a broad range of key objectives and critical success factors.

However, there are still several unknowns, uncertainty and gaps in the evidence base, and different assumptions, or higher quality datasets, could create different outputs.

This analysis was conducted before the spike in the gas prices. The propositions were based on high Hydrogen prices and considering the market volatility of natural gas these may look different now. For investors interested in a particular proposition we can rerun the analysis to reflect the latest price developments.

The impact of hydrogen import prices

Our sensitivity analysis showed that current hydrogen prices of 0.135 to 0.18 £/kWh (£4.50 to £6.00/kg based on a lower bound heating value of hydrogen of 33.3kWh/kg) are close to a tipping point in making electrolysis viable. If the grid export price decreases slightly, or the hydrogen import price increases slightly, electrolysis is a good use of excess electricity after local electrical demand is met.

No natural gas

With no natural gas supply, heat is largely electrified with air-source heat pumps with a small amount from hydrogen boilers. Electrolysis and electricity exports were decreased with renewable electricity for heat being prioritised. This led to very large decreases in carbon emissions, but an inevitable increase in cost. This suggests that electrification of heat is preferable to hydrogen boilers if gas was removed from the system and for any new buildings, air-source heat pumps are likely to be cost competitive.

Lower electricity price, higher gas price

In this sensitivity analysis, the system started to switch over to electrification of heating via air-source heat pumps resulting in lower national grid exports and higher national grid imports. This result suggests a prioritisation of meeting the heating demand with the local renewable generation rather than only the electrical demand.

Lower battery prices

With lower battery capital costs, batteries were selected by the WSEM optimisation process to be part of the optimised system in every scenario, but with varying capacities. Higher capacity batteries resulted in less national grid electricity import and export and instead promoted self-consumption. These changes produced a very marginal decrease in annualised costs and carbon emissions. With grid price fluctuations, it may be possible to buy low-cost electricity at certain times to be stored for periods of higher demand.

Techno-economic conclusions: short-term actions on the roadmap to net zero by 2050

What are the short-term actions within the Milford Haven project boundary to deliver net zero by 2050?

Across all the propositions, scenarios and sensitivity testing modelled, the resulting optimum hierarchy of the energy supply-demand relationship has been:

1. Use locally generated electricity locally where possible, first for power and then to satisfy heating (using heat pumps) and EV transport.
2. If excess electricity is generated beyond the power and heat demand baseload, this is used to support local electrolysis and green hydrogen production, where there is a local hydrogen transport demand, in preference to exporting excess electricity to the national grid.
3. Any remaining excess electricity (or where an electrolyser is not sized to the maximum seasonal excess such that it is not underutilised) is exported to the regional or national grid.
4. Imported electricity is used to support balancing of fluctuations for both power and electric-heating, where new technologies have been installed.
5. Where existing buildings are connected to the gas network (2020 scenarios), these remain until gas boilers are phased out. In 2050 scenarios, where natural gas is no longer an option electric heating systems dominate with hydrogen boilers featuring to a lesser extent and dependent on the scenario. Hybrid heating systems can provide resilience to future system but the timescales of system level transfer from natural gas to Hydrogen (including 20% hydrogen blend to 100% transition over time) are unknown.
6. Locally produced hydrogen is not favoured for heating demand. New hydrogen boilers are generally a much lower proportion of the overall heating mix due to their lower efficiencies, even once gas is phased out, in the current market context.
7. If electricity export prices decrease, a greater proportion of locally generated electricity may be used to produce hydrogen to satisfy a greater proportion of any hydrogen transport demand (though generally not heating).
8. Where there is a significant proportion of hydrogen transport demand, this is only partially met locally with hydrogen imports. This presents an opportunity for greater local hydrogen production if hydrogen transport demand does develop in the region.
9. Batteries feature in all scenarios, but are not a strong 'no regrets' option, we suggest they are kept in review. Based on the battery price assumptions taken in the model across 2020 (higher cost) and 2050 (lower cost), batteries are at a price tipping point and are expected to feature more predominantly and be a more favourable balancing solution soon.

Additional low carbon generation is adopted in most scenarios, with the cost-benefit and pay-back demonstrated as part of a whole systems view.

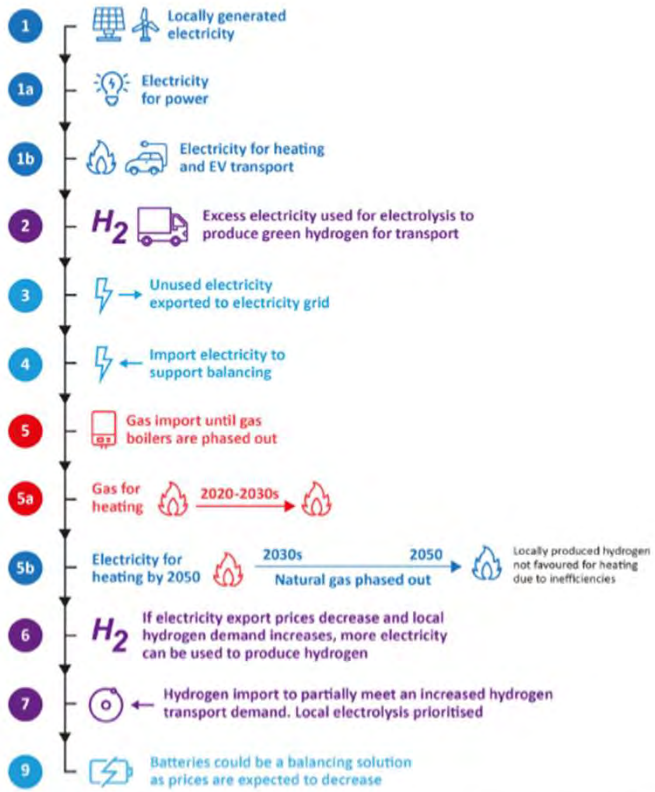
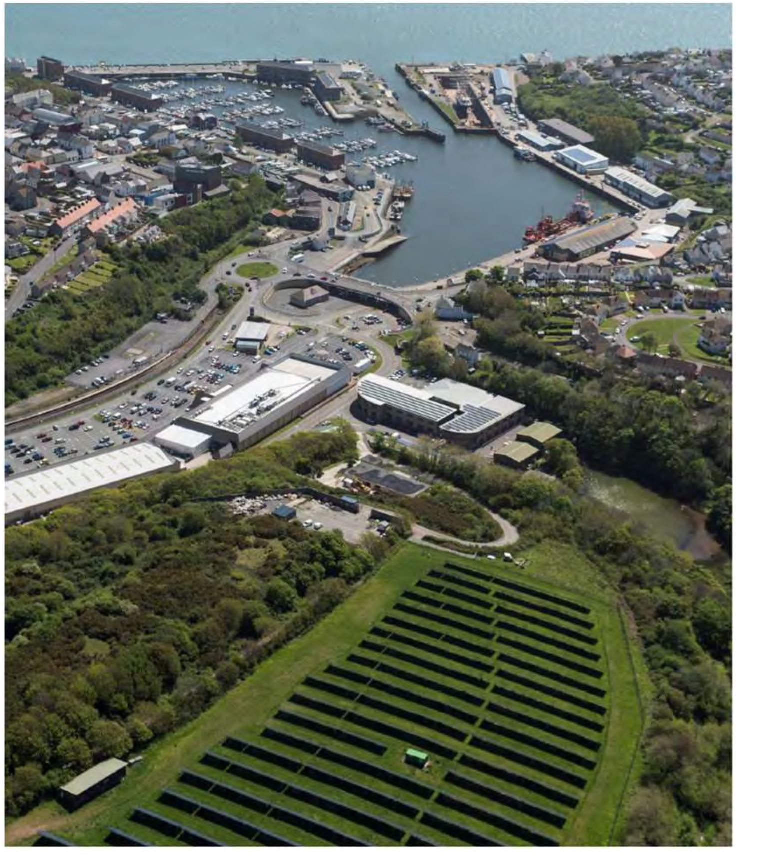


Figure 28: Hierarchy of energy supply-demand relationship based on a 2020 world view and short-term actions to support reaching net zero by 2050

Key messages from the study

The study has highlighted:

- The need for whole system energy modelling at a wider scale that optimises across supply and demand, and balances between energy vectors. Doing this will enable informed decision making around the level of renewables development required, alongside storage technologies (batteries or hydrogen) so that utilisation of assets remains high and losses within the system are minimised.
- Electricity is likely to be the dominant low carbon energy vector, preferred for power, heat and a proportion of transport demand. As new renewable generation assets are developed locally supporting decentralised low carbon electricity options and the UK electricity grid continues to decarbonise, as back-up to decentralised local systems, the emerging hierarchy is to use low carbon electricity first ahead of green hydrogen generation.
- Hydrogen will play a role, but the degree to which it does, and to which it presents an efficient, low carbon, cost effective alternative will depend on external factors and policy and regulatory decisions.
- Future decisions made around the UK's transmission network will be significant in influencing development of new renewable generation, balancing, flexibility and trading. Regulatory barriers currently present a significant challenge to local trading platforms.
- The most significant regulatory risks arise from "Newer Market Entrants", particularly those with an undeveloped regulatory framework (e.g., networked hydrogen, heat networks), market access, and asset co-ownership.
- Establishing a robust data ecosystem at a local level, that integrates beyond the local boundary, is key to benefit from and support the national modernising energy data access (MEDA).
- The transition to net zero should put the community, stakeholders and wider aims at the centre and ensure a just transition for all. Through continual stakeholder engagement and adopting a theory of change approach, MH:EK should develop a roadmap for everybody to understand their role to get to net zero by 2050.



MILFORD HAVEN: ENERGY KINGDOM

Medium to long term vision for the region

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Milford Haven Waterway
Future Energy Cluster

Delivering an accelerated transition to a Net Zero future

The Milford Haven Waterway aims to support the UK by achieving...

20% of UK Government low carbon hydrogen production target by 2030

At least **10%** of UK Government floating offshore wind target by 2035

ENERGY KINGDOM
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Milford Haven hosts key energy infrastructure making it an ideal location for a green hydrogen hub

The Milford Haven Waterway is a critical national energy asset, attracting billions of pounds in investment for over 60 years and supplying 20% of the UK's annual energy demand.

The Waterway has a pivotal role to play in delivering the UK's net zero ambitions, offering a whole energy cycle solution that will unlock accelerated transition, while stimulating economic growth. This is an opportunity that will repurpose existing assets, skills, rail connectivity, transmission and pipelines to deliver a future focused on hydrogen (blue and green), floating offshore wind (FLOW), marine renewables, sustainable alternative fuels, CO2shipping, and energy storage.

The benefits are clear. Continued investment and support will create and stabilise thousands of jobs and supply chain opportunities, levelling up the coastal communities across South Wales. It will strengthen UK energy resilience while establishing new export opportunities. And, it will stimulate inward investment providing clear line of sight on returns for investors, ensuring the Milford Haven Waterway remains a major energy innovation hub capable of competing globally.

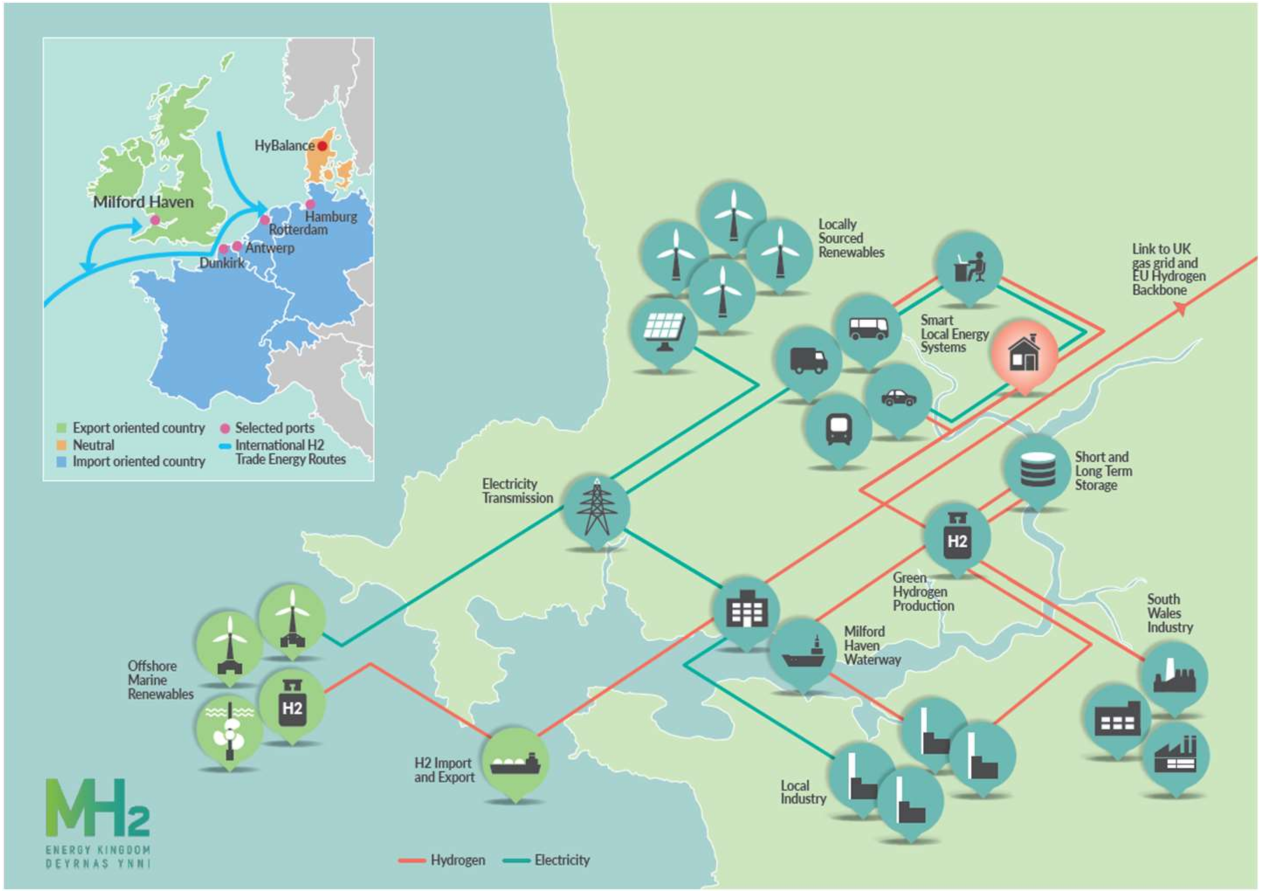
Milford Haven is an ideal location to be a green hydrogen pioneer

A global 'gold rush' for green hydrogen has begun. Milford Haven Waterway has perhaps the best potential in the UK to become a global green hydrogen port/hub, using local Floating Offshore Wind. Green H2 can meet energy demand growth and bolster energy security for the UK and Europe

Existing energy infrastructure is a tremendous platform for growth into green hydrogen

Gas industry on the MH Waterway has capacity to develop infrastructure for imports of affordable green hydrogen and to receive and process local offshore renewable hydrogen. A proposed green hydrogen pipeline 'backbone' for GB can be built out from Milford Haven.

The public's acceptance of hydrogen is unusually high, due to familiarity with having a major energy industry cluster on the Haven for decades.



We are proposing a globally outward-facing programme to develop Milford Haven Hydrogen Kingdom (MH2K)

Milford Haven Hydrogen Kingdom (MH2K) is a proposed consortium to develop green hydrogen production at sea, with a vision of achieving 8GW of production capacity for green hydrogen from offshore wind energy and transporting it to land by 2035.

Initiatives to facilitate market roll-out would include:

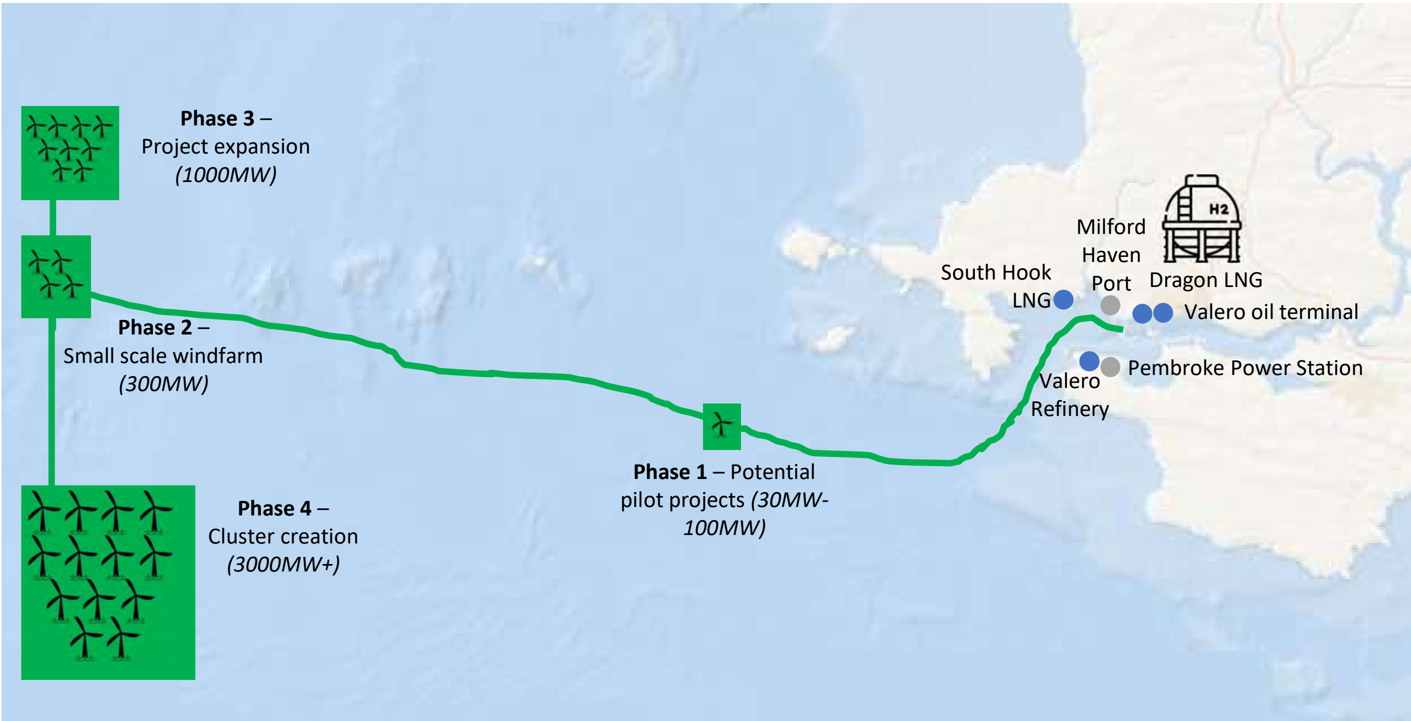
Alpha HK - the development of offshore wind turbines with integrated hydrogen production

Network HK - a central supply pipeline

Port HK - infrastructure for harbours

Research HK - a testing facility and a research platform

Omega HK - a large-scale offshore hydrogen park



Potential H2 off-takers (hydrogen demand and the scale of wind capacity required to support this)

Offtake option	Offtake Use	Hydrogen (Te / day)	Wind Capacity (MW)
Short term (2022 – 2025)			
Pembroke Council	Vehicle fleet and hydrogen refuelling hub in Milford Haven	1-2	6
Local Gas Network (Wales & West)	20% blend into local gas network	9	36
Medium term (2025 – 2032)			
Milford Haven Port	Transport and heating requirements	2-3	10
Pembroke Refinery (Valero)	Industrial heat / grey hydrogen replacement	>200	800
Power Station (RWE)	Blend into single gas turbine (trial)	20	80
Local Gas Network (Wales & West)	100% hydrogen gas into regional distribution system	45	180
National Grid	Potential to inject directly into 100% 'backbone'	>250	>1,000
Long term (2032 – 2040)			
Pembroke Dock	Supply of hydrogen to marine vessels	4-8	25
Pembroke Refinery (Valero)	Low Carbon Synthetic Fuels	>1,500	>6,000
Pembroke Oil Terminal (Valero)	Bulk Scale production & storage of LOHC/Ammonia for export	>1,000	>4,000
Power Station (RWE)	Fuelling future hydrogen gas turbines	>1,500	>6,000

Source: ERM *Dolphyn's 'South Wales Dolphyn Feasibility Phase 1 Presentation'* and own analysis

Milford Haven can fulfil key success factors for the preparation phase of a Hydrogen Valley

In the report "Hydrogen Valleys - Insights into the emerging hydrogen economies around the world" commissioned by FCH 2 JU, 30 projects developing Hydrogen Valleys gave an insight on topics ranging from fundamentals such as investment and production volumes, technologies deployed to project development and financing activities as well as hurdles and barriers along the way

Milford Haven's achievements so far

Building a successful business model for the hydrogen valley through SWIC and MH:EK

MH:EK focus on finding investment partners and future ways to fund hydrogen projects in the region

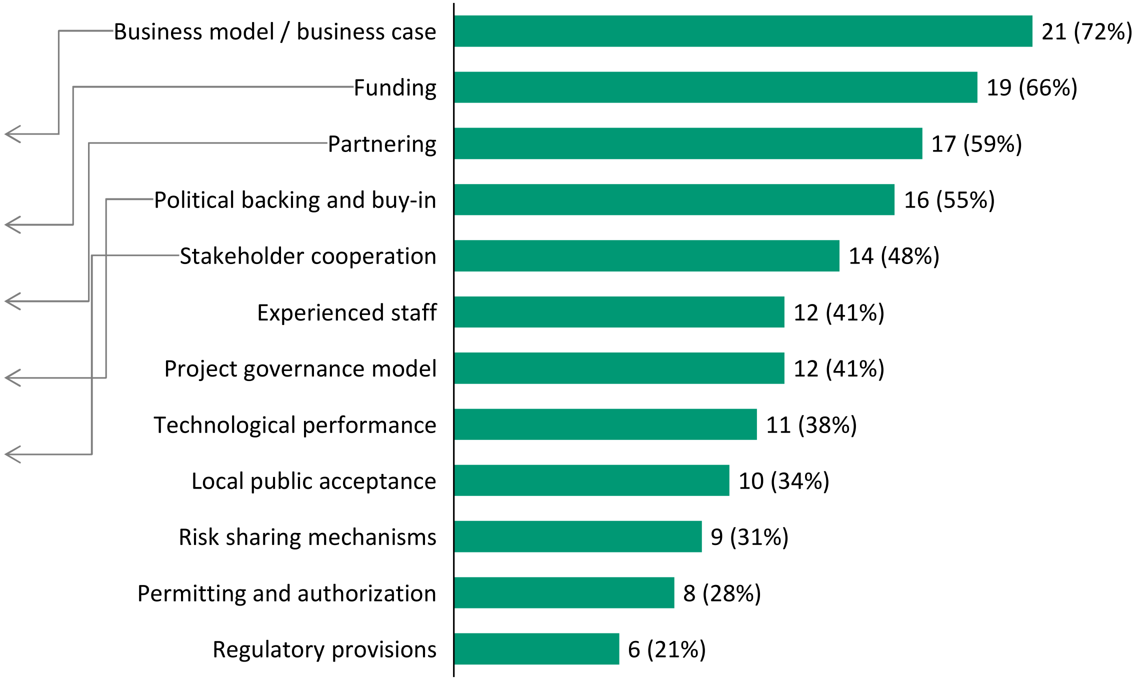
A strong group of partners forming SWIC

Good working relationships with the local government established through MHPA and good Welsh Government links

Stakeholder cooperation is already happening within MH:EK and SWIC

Key success factors for a Hydrogen Valley

Question: "What are the key success factors for the preparation phase?" (n=29)



Source: FCH 2 JU, Inycom, Roland Berger

Multiple answers possible

Project Union and the European Hydrogen Backbone

Project Union National Grid's Project Union vision was published in May 2022 and presents how it will connect hydrogen production, storage and demand to enable net zero and empower a UK hydrogen economy. Repurposing existing transmission pipelines will create a low-cost hydrogen 'backbone' for the UK by the early 2030s and connect to the proposed European Hydrogen Backbone

It also describes the other projects National Grid is undertaking to grow the evidence base for both a blended and 100% hydrogen transmission network. The report also considers the range of ways in which the market, policy and regulatory framework will need to adapt to enable investment in hydrogen.

National Grid will carry out the feasibility stage of Project Union, which will involve considering which pipelines from the current gas transmission system can be repurposed to support hydrogen and whether any new assets are required.

Through the phased repurposing of existing assets alongside new ones, a hydrogen backbone of around 2,000km will be created, representing around 25% of the UK's current natural gas transmission pipelines. This approach of primarily repurposing assets is up to five times more cost effective compared to new build. It also minimises the additional environmental impact of new build.

The backbone will initially link strategic hydrogen production sites, including the industrial clusters, across the UK by the early 2030s and provide the option to expand beyond this initial hydrogen transmission network to connect additional consumers.

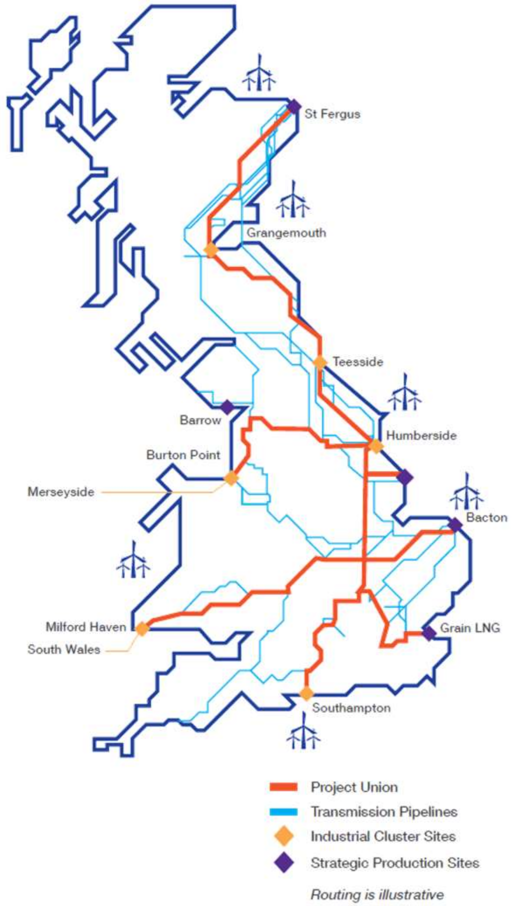
The project will explore how and when to convert existing pipeline infrastructure for a hydrogen backbone by connecting Teesside, Humberside and Grangemouth as well as linking up Southampton, the North West and South Wales. The backbone will also connect to strategic hydrogen production sites including Milford Haven, St Fergus and Bacton.

Project Union is linked to another recently announced initiative – The European Hydrogen Backbone

The European Hydrogen Backbone (EHB) initiative has unveiled an accelerated vision in light of the European Commission's REPowerEU plan and developments in the hydrogen market.

Published in May 2022, the vision includes 31 energy infrastructure companies, spanning 28 countries which, by 2030, could see five pan-European hydrogen supply and import corridors emerge, connecting industrial clusters, ports and hydrogen valleys to regions of abundant hydrogen supply. It would be mainly based on repurposed existing natural gas infrastructure. One of those corridors is North Sea.

Realising such a vision would call for an estimated total investment of around €80-143bn, with this including subsea pipelines and interconnectors to link countries to offshore energy hubs, as well as potential export regions.



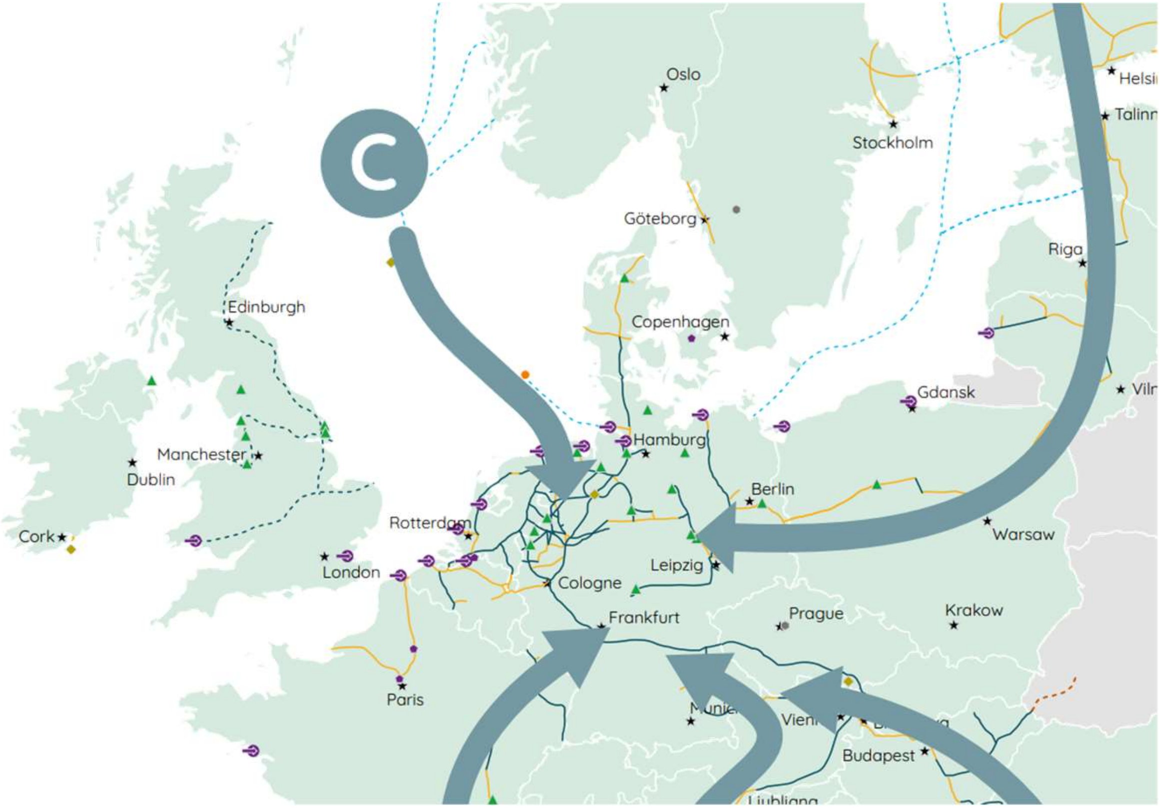
Source: Project Union, Gas Transmission and Metering

Project Union will feed into the European Hydrogen Backbone shown on the map

The announcement further set out how the EHB presents an opportunity to accelerate the decarbonisation of the energy sector by efficiently integrating substantial volumes of additional renewable and low carbon energy, and by connecting regions with abundant supply potential to centres of demand

The report set out a series of levers to facilitate the implementation of the development of each corridor by 2030, including:

- Introducing the establishment of hydrogen supply & import corridors as front-running infrastructure, including all infrastructure requirements, as a political objective.
- Fostering development of new and repurposed hydrogen infrastructure, for example, by unbundling rules facilitating the efficient use of TSO expertise and services and by allowing the adoption of different vertical unbundling models in the EU, as is the case with natural gas
- Unlock financing to fast-track hydrogen infrastructure deployment by applying regional regulatory flexibility
- Simplify and shorten planning and permitting procedures for the full value chain of renewable energies and hydrogen infrastructure projects
- Facilitate integrated energy system planning of hydrogen, natural gas, and electricity infrastructure supporting the accelerated deployment and integration of renewable energy resources



Source: The European Hydrogen Backbone

Summary of notable near-term funding mechanisms

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Competition timings for BEIS Hydrogen funds launching 2022 and 2023

	NZIP Proposed Industrial Hydrogen Accelerator (IHA)	NZIP Industrial Fuel Switching (IFS) Phase 2	Industrial Energy Transformation Fund (IETF)	Net Zero Hydrogen Fund (NZHF) Strand 1	Net Zero Hydrogen Fund (NZHF) Strand 2	NZHF and Hydrogen Business Model[2] Strand 3 (proposed)	NZHF and Hydrogen Business Model[2] Strand 4
AIM	Demonstrate end-to-end industrial fuel switching to hydrogen to provide evidence on feasibility, cost and performance.	Support development of fuel switching and fuel switch enabling technologies, including hydrogen, for UK industry	Support the development and deployment of technologies that enable businesses to transition to a low carbon future.	Support development of new low carbon hydrogen production to grow the pipeline of projects in the UK.	Support low carbon hydrogen projects to take FID and begin deployment in the early 2020s, kickstarting the hydrogen economy.	Support electrolytic hydrogen projects to take FID and deploy at scale at the earliest opportunity.	Support for CCUS-enabled hydrogen projects. Must be able to connect to Track-1 clusters, as part of cluster sequencing
ACTIVITY	Feasibility and demonstration	Demonstration	Feasibility, FEED and permanent deployment	FEED and post-FEED costs	Permanent deployment	Permanent deployment and operation	
FUNDING	Innovation funding	Innovation funding up to £6m/project	CAPEX grant co-funding, Total grant funding provided is: Feasibility studies, up to £7m Engineering Studies, up to £14m Deep Decarbonisation Deployment, up to £30m	DEVEX grant 50% co-funding for FEED and post-FEED studies, Grant awards of £80k–£15m	CAPEX grant 30% co-funding, Grant awards of £200k–£30m[3]	CAPEX grant co-funding and ongoing revenue support via the hydrogen business model	
MATURITY	Innovation projects	TRL 4-7	TRL 7 +	TRL 7 +			
LOCATION	UK wide	UK wide	Within England, Wales or N. Ireland[1]	UK wide			
SCOPE	End-to-end project	Industry end-use	Industry end-use	Low carbon hydrogen generation		Low carbon hydrogen generation via electrolysis	CCUS-enabled low carbon hydrogen generation
LINK	nzip.hydrogen@beis.gov.uk Industrial Hydrogen Accelerator https://bit.ly/H2NZIP	industry.innovation@beis.gov.uk Industrial Fuel Switching https://bit.ly/IFSH2	ietf@beis.gov.uk Industrial Energy Transformation Fund https://bit.ly/P2IETF	HydrogenProduction@beis.gov.uk Net Zero Hydrogen Fund https://bit.ly/H2NZHF			

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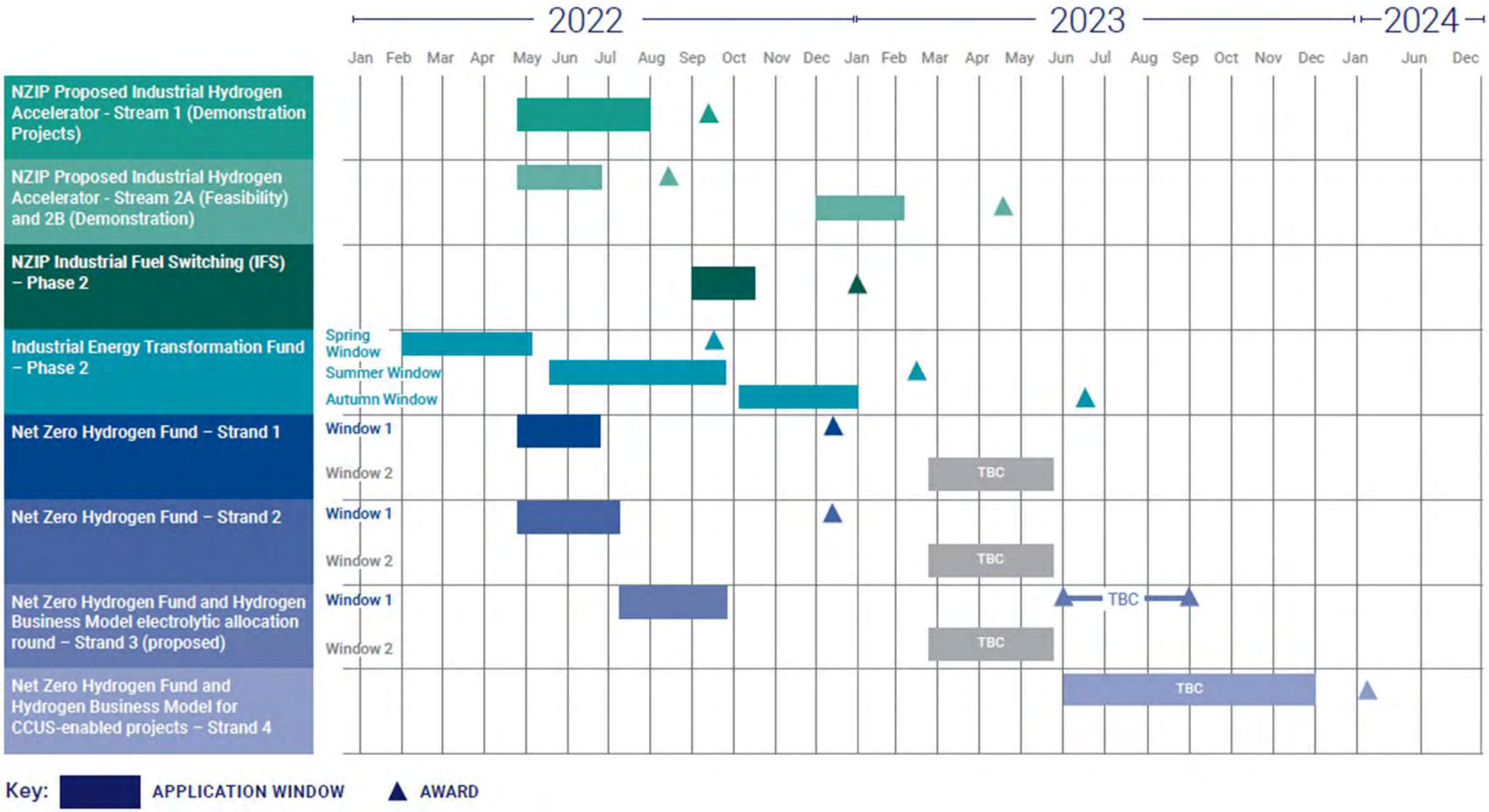
Competition timings for BEIS Hydrogen funds



MILFORD HAVEN: ENERGY KINGDOM

Local and national political support for the vision

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Summary of the wider context

The local context

The Milford Haven Waterway is at the centre of nationally important energy infrastructure, with major energy related investment underway, targeting efficiency and decarbonisation. Facilities include South Hook LNG terminal, Dragon LNG terminal, RWE's 2.2GW CCGT, and National Grid's NTS pipeline that connects the Milford Haven Waterway with other assets like Grain LNG terminal, in Kent, and St Fergus gas terminal, Aberdeenshire.

This project has focused on developing diverse, local seed markets to support the transition, to hydrogen and renewables, of the cluster of major energy infrastructure along the Milford Haven Waterway.

This transition will occur via a mixture of pathways available locally - meeting heating and transportation needs of local communities, including via fuel cell vehicles; creating transport solutions for Pembrokeshire's 4.2 million annual tourists; hydrogen production from curtailed onshore wind and solar generators; and improving off-take markets for offshore renewables in the South-Western Approaches, including the consented Pembrokeshire Demonstration Zone (PDZ).

The regional context

There are various, and ongoing, regional initiatives that aim to contribute to the growing evidence base to support not just the case for change in the region, but what change could look like for South Wales and Pembrokeshire and include:

- South Wales ZERO 2050
- Regen Net Zero South Wales
- The Future role of gas in transport
- South Wales Industrial Cluster (SWIC)
- RWE Pembrokeshire Net Zero Centre
- Offshore wind renewable generation –Celtic sea cluster
- ERM Dolphyn project
- Greenlink Interconnector

Other upcoming studies such as the Pembrokeshire Local Area Energy planning (LAEP) which will include whole system energy modelling and optimization of the Pembrokeshire local authority energy system, LAEP delivery pathways and local energy decarbonization routemap are also key to inform the development of the local decarbonization roadmap.

The South West Wales Regional Energy Strategy is a regional energy strategy aiming at developing a strategic pathway identifying key interventions to deliver on the region’s ambitions for decarbonising its energy system. The vision is *"Harnessing the region’s low carbon energy potential across its on and offshore locations, to deliver a prosperous and equitable net zero carbon economy which enhances the well-being of future generations and the region’s ecosystems, at a pace which delivers against regional and national emissions reduction targets by 2035 and 2050”*

The national context

Whilst the journey to decarbonization of the UK energy system by 2050 is uncertain, there is a shared commitment across Government and industry to deliver against net zero targets. This was recently evidenced by the presence and contributions of the private sector at COP26 and through many collaborative industry studies.

The Climate Change Committee (CCC) ‘Balanced Pathway’ to maintain the 6thCarbon budget and achieve net zero by 2050 includes recommendations across varying levels and sector innovation.

The balanced pathway features strong contribution of take-up of low carbon solutions (boilers, transport and carbon capture and storage) and expansion of low-carbon energy supplies (renewables and at scale hydrogen production).

The CCC balanced pathway has assumed key phase out dates for gas boilers by 2033, fossil fuel powered vehicles by 2032 and the switch of HGVs to low carbon transport by 2040 which is in line with our assumptions.

The CCC balanced pathway energy system moves almost entirely to low-carbon energy sources by 2050. Low-carbon electricity becomes the dominant energy vector; a hydrogen economy is formed comparable to the existing electricity by 2050; domestic demand is met by more efficient EVs and heat pumps; a modest growth in bioenergy and waste use; carbon capture and storage is applied to the industrial sector.

The National Grid Future Energy Scenarios (FES) set scenarios under which the UK energy system could achieve net zero by 2050 -with differing level of societal, sector level and policy changes required.

Three of the four FES 2021 modelled scenarios meet the net zero target. However, to achieve this target, immediate action to enable deployment of new technologies at scale, demand flexibility, trading flexibility, digitalisation whilst taking a whole energy systems approach is needed.

By applying this UK wide view to a local context, the MH:EK project aims to develop a conceptual proposal for what a 2050 decarbonised Milford Haven energy system could look like and provide a roadmap for short-to mid-term steps to reach net zero by 2050.

Regional support

"The Council is proud to lead the Milford Haven: Energy Kingdom project which is positioning the Milford Haven Waterway as a frontrunner for breakthrough renewable energy and hydrogen technologies to provide increased flexibility to the way we consume electricity and gas, as we deliver greater amounts of green, affordable onshore solar, and offshore wind, tidal and wave generation in the Celtic Sea and beyond.

Having already established itself as the UK's Energy Capital, the Milford Haven Waterway is now at the centre of a renewable energy revolution, with huge potential to become the low carbon energy capital of the UK, safeguarding thousands of local jobs and creating thousands more new ones.

The projects heating and transport demonstrators showcase what can be achieved through collaboration with our partners and Pembrokeshire can use these innovations as we work to become a net zero carbon local authority by 2030.

To get to Net Zero, we must deliver Net Zero power, transport and heat across a smartly connected whole energy system with progression to regulatory & policy frameworks to support truly multi-vector trading platforms.

We have all the necessary components here on our doorstep in Pembrokeshire to act as a vital cluster of national significance and to provide opportunities in the green energy sector for both current and future generations".

Steve Keating, Energy & Sustainability Team Manager, Pembrokeshire County Council.

In the aftermath of Covid-19 and in the shadow of its resurgence Pembrokeshire faces an unprecedented level of economic uncertainty. My team deserve full credit for their response to the immediate crisis and I know through the feedback I've received just how vital that support has been for our businesses. With those immediate actions now behind us, it's the right time to look to the future.

Long before Covid-19 our strategy was to build on Pembrokeshire's reputation as a fantastic place to visit and ensure it became a fantastic place to live and work too. The significance of our main comparative disadvantage (remoteness) has been eroded by technology but needs a corresponding shift in attitudes before we see its full impact. The pandemic and society's response to it has delivered a more radical cultural shift than we could possibly have anticipated. Working from home is now a reality for millions and has opened up a world of possibilities for living in one location and working somewhere quite different.

That provides us here in Pembrokeshire with a unique opportunity but one we need to work at to realise. The people we need to attract here won't just discover Pembrokeshire all on their own, nor will they consider it a viable place to live while we lack some of the key ingredients needed in this new world. Our strategy, is focussed on ensuring we deliver everything our county needs to become the great place to live and work that I know it can be. That means us:

- Reshaping our built environment – through substantial investments to kick start transformation and regeneration of our County and key towns.
- Working with our partners to deliver the next generation of clean, green engineering jobs focussed around the Milford Haven Waterway.
- Ensuring our world class tourism offer becomes even stronger, releasing the industry from the shackles of a public sector run tourism offer and empowering providers and business to lead in managing and marketing that destination to the world.

For too long, supporting Pembrokeshire's economy hasn't had the focus it deserved. I, together with my Cabinet Colleagues, am committed to ensuring that the strategy set out here is delivered and to providing the people and resources we need to ensure Pembrokeshire's economic success.

Paul Miller – Cabinet Member for Economy, Tourism, Leisure and Culture

Pembrokeshire Recovery and Regeneration Strategy 2020 - 2030

British Energy Security Strategy

In April 2022, the UK Government published the British Energy Security Strategy, which aims to secure, clean and affordable British energy for the long term.

The strategy outlines that the first step is to improve energy efficiency, reducing the amount of energy that households and businesses need. It also states that government is investing over £6 billion on decarbonising the nation's homes and buildings. But the long-term solution is to address our underlying vulnerability to international oil and gas prices by reducing our dependence on imported oil and gas.

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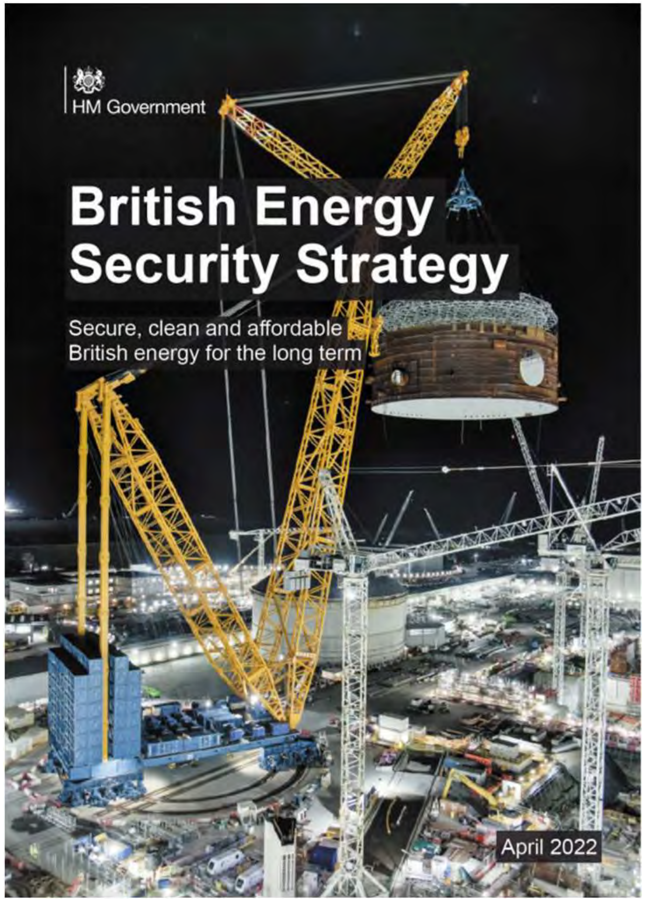
The strategy states that accelerating the transition from fossil fuels depends critically on how quickly we can roll out new renewables.

Major highlights from the Energy Security Strategy include:

- Government will double the UK ambition for hydrogen production to up to 10GW by 2030, with at least half of this from electrolytic hydrogen
- Aiming to run annual allocation rounds for electrolytic hydrogen, moving to price competitive allocation by 2025, so that up to 1GW of electrolytic hydrogen is in construction or operational by 2025;
- Increase in offshore wind installed capacity ambition to 50GW by 2030, including 5GW floating wind
- Ambition to reach 95% low carbon power by 2030
- Government will consult on limited changes to allow onshore wind in areas with local support
- Expanding nuclear energy in the UK with up to 24GW of capacity by 2050
- New FSO role that could be established by 2024
- No new announcements to improve the energy efficiency of the UK's housing stock, which ranks among the worst in Europe



Analysis of external political, economic and social factors

Political

Pro - The greatest political backing that surrounds MHEK and green hydrogen is that of the British Energy Security Strategy, with the UK Government aiming to have at least half of UK hydrogen production come from electrolysis (~5GW) by 2030. Furthermore, there are ambitions to have as much as 1GW of green hydrogen capacity at RWE's Pembroke Net Zero Centre, which includes the Pembrokeshire Demonstration Zone, by 2030.

Additionally, as of June 2022, the Welsh Government published a consultation response on how to develop the Welsh hydrogen sector. In the publication it seeks to enable pathways to meet objectives such as fuel cell T&D, large-scale clean hydrogen production planning, industrial decarbonisation via skills development and R&D, and the implementation of a "place-based" approach.

Con – Despite clear targets being set within the British Energy Security Strategy, the change of Prime Minister is causing uncertainty as to what direction the government will take over the next few years with regards to its hydrogen strategy and funding agenda.

Economic

Pro – Rising wholesale gas prices have consequently closed the gap in LCoH between green hydrogen and blue hydrogen. While there is still uncertainty in the long-term trajectory of gas prices, this short-term spike has led to reducing reliance on fossil fuels which bear greater market volatility than wind energy production.

Con – More needs to be done to increase the performance and reliability of large-scale electrolyser units that are to be used in harsh offshore environments. Whether proton exchange membrane or alkaline electrolyser are selected, far more R&D and T&D is required to validate a range of system components that will aid in reaching the crossover point where green hydrogen becomes competitive with grey and blue hydrogen.

Social

Pro – By making progress towards the development of a smart local energy system, steps can be made towards safeguarding thousands of local jobs and creating thousands of new ones as the industries present at Milford Haven progress along their respective decarbonisation pathways in the low carbon energy transition. Furthermore, there are opportunities to make apprenticeships available to local young people so that much of the benefits of job creation are experienced by people who are from the region.

Cons – By failing to address concerns of the local community and relevant stakeholders, there may be more opposition to further development associated with MHEK. Creating and maintaining a constructive dialogue is crucial to ensure all stakeholders are satisfied with current developments and proposals for future developments to ensure the notion of a just transition is maintained.

Analysis of technological, environmental and legal factors.

Technological

Pro – Reduction in the cost of individual electrolyser units is crucial in allowing green hydrogen to become cost competitive with traditional forms of hydrogen production. With the UK Government having aiming to have ~5GW of installed electrolytic hydrogen capacity by 2030, this creates demand which will require volume manufacturing and subsequent cost reductions can be achieved as a result. Cost reductions can be brought as automated manufacturing processes become more economically feasible when higher order volumes of electrolyser units are made.

In addition to cost reductions via faster, more efficient manufacturing processes, targeted R&D which focuses on higher round trip and material efficiencies in electrolysers will also aid in reducing LCoH.

Con – Compared to potential floating offshore wind sites in the North Sea there is no gas transportation networks to accommodate offshore green hydrogen production in the medium to long-term. Because of a lack of infrastructure, arrangements as to where green hydrogen is produced in terms of onshore, nearshore, or further from shore is more likely to be limited when considering green hydrogen production from floating wind projects in the Celtic Sea.

Environmental

Pro – With the development of a smart local energy system centred around renewables, steps can be taken to drastically reduce emissions in the region. Within the port of Milford Haven there are specific facilities that can be considered low hanging fruit such as the Pembroke refinery. By enabling the Pembroke refinery to produce hydrogen using CCUS, significant emission reductions can be made in the operations of the refinery which account for 0.5% of UK emissions at present. Furthermore, this hydrogen production can be used to produce other synthetic low carbon fuels which can be used for a range of industrial and transport applications.

Con – N/A

Legal

Pro – The UK government has taken steps to grow the hydrogen sector via regulatory reform. They have set out various actions to support smart local energy systems and reward providers of flexibility. For local energy systems, it was recommended that government work extensively with local energy hubs to “support projects which are tailored and delivered to meet local needs”. Regarding flexibility provision, continued work is required to ensure appropriate price signals and ancillary service options are given to flexibility providers so that multiple revenues streams from hydrogen an energy storage are made available to increase the competitiveness of flexibility technologies in the wider electricity market. However, it is stressed that caution must be taken so that the playing field remains even between larger providers of flexibility and smaller, more distributed assets.

Con – In the constantly evolving innovation landscape new technological solutions can emerge at a pace in which regulation cannot keep pace, leading to solutions with a high technology readiness but a low commercial readiness. Action needs to be taken between relevant governments and innovators to ensure regulatory reform allows for a more streamlined route to commercialisation for emerging smart grid solutions such as networked hydrogen.

MH:EK's view on needed government support

Expand South Wales grid capacity by 10GW by 2030

To facilitate the transmission requirements of FLOW and other new green developments, we need an additional 10GW for South Wales by 2030.

Implement a fast-tracked consenting regime

Speed and certainty of marine licencing and national planning consenting is essential to encourage large-scale global investment. We need increased case officer support to ensure that any future DCO, DNS, planning, marine licensing or environmental permit application is delivered at speed. Valero's Pembroke Refinery Cogen Project is an exemplar for the DNS process. We also need to add a net zero remit to environmental regulators and planning bodies. While also providing guidelines on how electrolysers interface with a renewables-based power Grid to ensure all terrestrial planning regimes are aligned.

Back a South Wales Green Freeport bid

To ensure Wales maximises the economic opportunity from the development of floating offshore wind and other industries, creating jobs and cleaner energy we need support for a South Wales Green Freeport.

Back a South Wales Floating Offshore Wind (FLOW) infrastructure bid

To maximise green manufacturing, operations and maintenance opportunities from a £5 billion industry taking shape in the Celtic Sea, we need to secure public funding to improve and expand port and manufacturing infrastructure. Ports need guaranteed project pipeline to ensure efficiency of asset utilisation in the medium to long term. Domestic manufacturing capacity will be essential if the British supply chain content target is to hit the £1bn of benefit per 1GW installed. By building significant domestic manufacturing capacity, we can turn Welsh green industrial content into an export opportunity to markets across Europe.

Introduce mechanisms to de-risk the Celtic Sea FLOW opportunity

Uncertainty in securing a Crown Estate seabed lease, grid connection and Contracts for Difference auction means developers, ports and supply chain invest at significant risk. We need mechanisms that manage this risk to support long term, stable growth and maximised security of investment.

Support the Milford Haven Waterway SuperPlace ambition

To deliver the national 10GW hydrogen target, supported by capital co-investment and revenue business models, we need to unlock strategic infrastructure and create enduring domestic supply-chains for hydrogen and offshore renewables. This will encourage demand side uptake of low carbon hydrogen. Alongside the speed of consent, we must define and harmonise standards and use cases; introduce OPEX support mechanism for electrolysers and refuelers, based on uptime and hydrogen delivery volumes; exempt electrolyser facilities from environmental levies as an energy-intensive industry; and create a mechanism for National Grid Gas Transmission to be an off-taker of last resort for green hydrogen, up to a 20% blend or 100% in trial areas.

Support prioritisation of South Wales in National Grid's Project Union

Under 'Project Union', National Grid is developing a new hydrogen backbone for the UK. We need to ensure that the Milford Haven pipeline route is prioritised to unlock this opportunity or risk significant delays to the development of the hydrogen economy for the whole UK south west region.

Support a BEIS Cluster Sequencing Track 2 bid

With no obvious Carbon Capture and Storage (CCS) sites in the south of the UK, we need an even playing field between pipelined CO2 and shipped CO2, whether through regulatory or charging regimes. Support for a BEIS Cluster Sequencing Track 2 bid will help ensure CO2 shipping and the hydrogen economy can grow and ensures compliance with a decarbonised electricity system policy by 2035.

Incentivise the production and use of low carbon fuels

Clean-burning, renewable fuels can support widespread emissions reductions, particularly for hard-to-abate sectors such as transport. We need policies and incentives for the production of fuels from sustainable feedstocks (such as Sustainable Aviation Fuel) that can cut GHG emissions.

Back a Skills Accelerator programme

To support the exploration of new technologies and incubator schemes for sustainable energy and fuels, we need to harness and grow the existing skills base. The current workforce is highly productive and many roles to support a hydrogen economy and CO2 shipping are already in situ (such as trained process operators, engineers with technical, operational, maintenance and storage expertise). We need a skills accelerator programme that will bring local education providers and employers together to ensure a new generation can capitalise on these career opportunities.

Back a Supply Chain Accelerator programme

The Milford Haven Waterway has an extensive, high skill supply chain with a wealth of knowledge and experience in delivering the needs of the energy sector. As the industry continues to innovate and evolve, we need an Accelerator Programme to ensure the facilities, spaces and services within the supply chain evolve in time to support this large-scale industrial opportunity.

MILFORD HAVEN: ENERGY KINGDOM

Local economic development green energy opportunities

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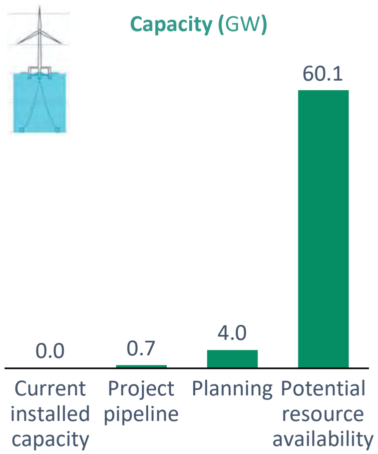
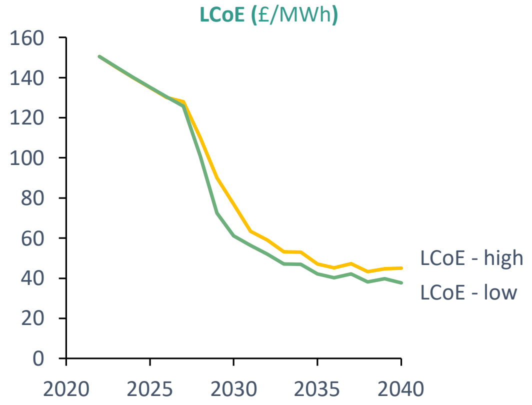
Opportunities in floating offshore wind





There is a large region of high wind resource with suitably deep water in Wales. Given the interest and the relative maturity of wind turbine technology it can be expected that the regional pipeline of floating offshore wind projects will grow the most of any form of offshore renewable energy in the near term.

All developers are currently working towards a steppingstone approach of incrementally larger projects in order to grow regional supply chain capacity and learning alongside the projects themselves and at present 300 MW is the maximum size of a floating offshore wind project under The Crown Estate's seabed leasing framework.

In November 2021 The Crown Estate (TCE) has published further detail on its leasing plans in the Celtic Sea, confirming its ambition to unlock up to 4GW of new floating offshore wind capacity by 2035.

In July 2022, TCE has identified and published five broad 'Areas of Search' for the development of floating offshore wind in the Celtic Sea. The areas have been identified following technical analysis and extensive engagement between The Crown Estate, the UK and Welsh governments and key agencies, and specialist stakeholders. Further stakeholder and market feedback will be used to refine the areas of search into smaller project development areas, within which the first generation of commercial-scale floating wind farms could be built. The project development areas will be offered to the market via competitive tender, to be launched in mid-2023.

The Crown Estate will be tendering larger, 1GW-scale projects which may be developed in a phased or 'stepping stone' approach. This approach is deliberately intended to provide further opportunities for investment in the supply chain and to facilitate the co-ordination of supporting infrastructure.

Subject to the outcome of the plan-level HRA, The Crown Estate will in 2023 also confirm seabed rights for three separate 'Test and Demonstration' sites in the Celtic Sea. Experience from these smaller-scale developments will inform the rollout of larger projects in the Celtic Sea and elsewhere.

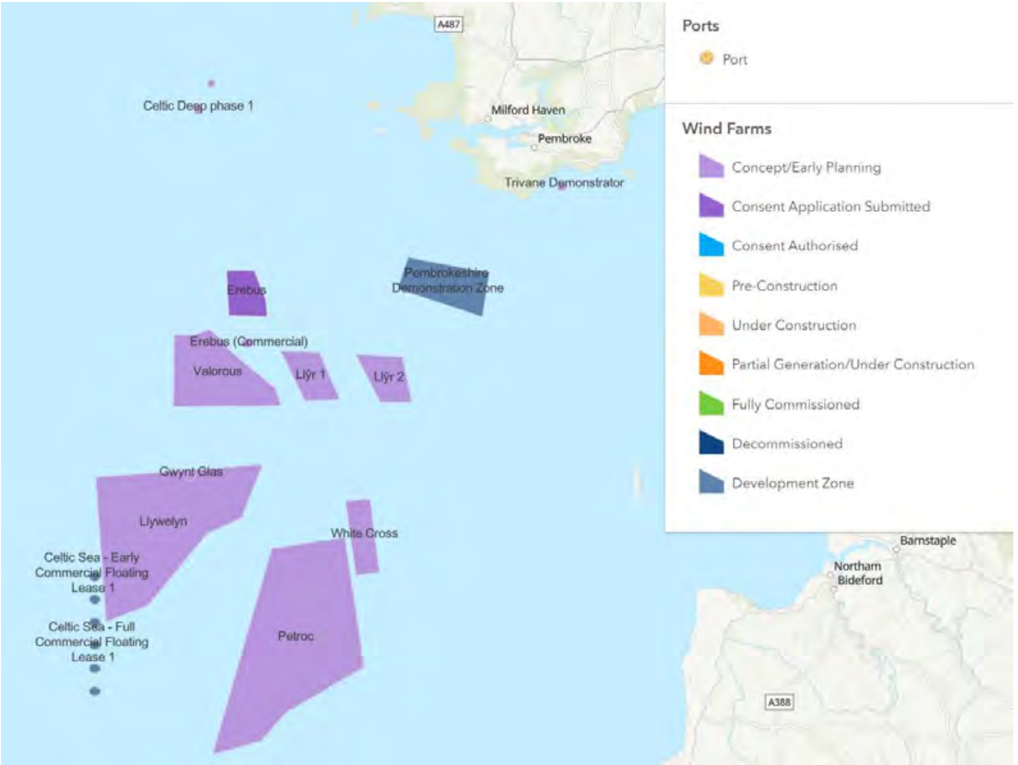
TCE will also work with Electricity System Operator and others to support a coordinated grid solution, in line with the work underway through the Offshore Transmission Network Review, to accelerate grid development. They also plan to assess the longer-term potential for further market growth, beyond 2035, in the Celtic Sea; and prepare for future leasing rounds to bring viable further capacity to market.

To support a growing pipeline of projects in the region significant infrastructure will need to be put in place to transport electricity to the grid. Pembrokeshire already has high voltage grid infrastructure put in place to export power from Pembroke power station. Both PDZ and Blue Gem Wind's project plan to utilise this infrastructure but significant upgrades may be needed to support multi gigawatt scale power production from the Celtic Sea.

The follow-up study Strategic Infrastructure & Supply Chain Development – Deployment Scenarios has calculated feasible deployment of offshore wind within each DNO zone. Assuming deployment density and a number of additional constraints (including shipping lanes, Marine Protected Areas (MPAs), Fishing activity and clustering effect of existing and planned wind farms it concluded that up to 60.1GW could be deployed in the Celtic Sea.

Opportunities in floating offshore wind

The current list of planned and announced floating offshore wind projects in the region are summarised in Table 9. This highlights a total capacity of around 2.2 GW have been planned in the Celtic Sea. The layout of some of these projects are shown on the map below



Floating wind projects in planning in Celtic Sea

Name of the project	Capacity	Developer
TwinHub	32MW	Hexicon (contracted)
Erebus	96 MW	Blue Gem Wind (a joint venture between Total and Simply Blue Energy)
Valorous	300 MW	Blue Gem Wind
Llyr 1	100 MW	Floventis (a joint venture between SBM Offshore and Cierco)
Llyr 2	100 MW	Floventis
Whitecross	100 MW	Cobra and Flotation Energy
PDZ	180 MW	Wave Hub
Llywelyn	300 MW	Falck Renewables & BlueFloat Energy
Petroc	300 MW	Falck Renewables & BlueFloat Energy
Gwynt Glas	300 MW - 1,000 MW	EDF Renewables UK & DP Energy
Celtic Deep 1	98 MW	AWC Technology Ltd.
Celtic Deep 2	300 MW	AWC Technology Ltd.
Celtic Sea – Early Commercial Floating Release	Contender 1: 300 MW	Contender 1: Morwind Ltd. Contender 2 & 3: Celtic Sea Offshore Wind Farm Ltd
Celtic Sea – Full Commercial Floating Release	Contender 2: 350 MW	Contender 1, 2 & 3: Simply Blue Energy Ltd.

Summary of future regional plans and developments – floating offshore wind

Hexicon

In July 2022, the UK government awarded its first CFD for a floating wind project to developer Hexicon through a special pot in the UK Round 4 renewable energy auction. Hexicon secured a 15-year contract at a highly competitive strike price of 87.3 £/MWh for its 32 MW TwinHub project,

Hexicon will deploy its floating foundations that allow two turbines to be placed on a single foundation at the Wave Hub` demonstration site 16 km off the north coast off Cornwall. The project is expected to be completed between 2025 and 2027.

Blue Gem Wind

Blue Gem Wind is a partnership between Simply Blue Energy and TotalEnergies to develop floating wind projects in the Celtic Sea. Their 'Erebus' 96MW project is currently the only project with an agreed Crown Estate lease (planned for 2026-2027). Blue Gem Wind will initially focus on the Erebus demonstration project which is 45 km offshore. Delivering the Celtic Sea's first offshore floating wind project will provide green energy to 90,000 homes per year and will utilise Principle Power's Windfloat technology as the foundation. Blue Gem Wind also plan the development of the commercial scale 300MW Valorous project, which will be sited 50km off the south-west coast of Pembrokeshire by 2029. DP Energy and EDF Renewables are scoping floating offshore wind and Green H2 opportunities in Pembrokeshire and the Celtic Sea.

Other projects announcing planned installation dates by 2030 include SimplyBlue / Shell project Emerald and other developers, like RWE, looking to develop large scale floating offshore wind sites by 2040.

ERM Dolphyn project

The ERM Dolphyn project is a planned 100-300MW commercial project for a hydrogen wind farm in the Celtic sea using the ERM Dolphyn technology.

The ERM technology comprises of an offshore electrolyser sited on a floating offshore wind substructure, producing green hydrogen from generated electricity and desalinated sea water. The deployment phase is set to have a 2MW prototype facility by 2024 followed by 10MW full scale pre-commercial project by 2027.

The Celtic sea 100-300MW project plans to have a single hydrogen pipeline to Pembroke / Milford Haven, where there are options to supply green hydrogen at scale for industrial use to industries around the Haven waterway, for port marine operations, storage or to other future hydrogen off-takers. The project is planned to be in operation by 2030 with plans to expand to the GW scale by mid 2030s. ERM have agreed to trial their device in the Pembroke Dock Marine City Deal META (Marine Energy Test Area).

Floventis (a joint venture between SBM Offshore and Cierco)

The Llŷr projects are exploring the potential of two innovative floating offshore wind technologies. Llyr 1 and Llyr 2 (100MW each) have secured Crown Estate lease and are subject to HRA assessment.

Both sites will use different floating foundation technology. One is believed to use SBMs technology with the other being from the open market.

Greenlink Interconnector

The Greenlink Interconnector is a proposed 500MW subsea and underground electricity interconnector cable that will provide a new grid connection between then EirGrid's Great Island substation in County Wexford, Ireland and the National Grid's Pembroke substation in Pembrokeshire in Wales. The interconnector will provide additional grid capacity and therefore deliver increased energy security, increased opportunities for low carbon renewable energy generation and regional investment. Greenlink is planned to be commissioned in 2023.

In the Milford Haven context, the interconnector represents an opportunity for renewable electricity export should grid capacity or network improvement costs be a hindrance to large scale renewable energy production in the shorter term (up to 2030).

Offshore Wind Ltd (a joint venture between Cobra and Floatation Energy)

White Cross is a 100MW Test and Demonstration floating wind farm located in the Celtic Sea. The project will look to utilise new substructure technologies at pre-commercial scale and support the development of the local supply chain.

They have secured Crown Estate lease and are subject to HRA assessment.

Summary of future regional plans and developments – agriculture

'Deep Green' Hydrogen & The New Carbon Economy

The proposal developed by Clo Carbon Cymru seeks to position the dairy sector in Pembrokeshire at the forefront of establishing foundations for the New Carbon Economy.

Generating hydrogen-based energy from slurry, parlour-washings and wastewater, combined with more effective approaches to manure management, presents an opportunity for dairy farmers to build resilience into their business models and farming systems. Ultimately, this should help to steer the sector through the challenging times ahead.

Approach

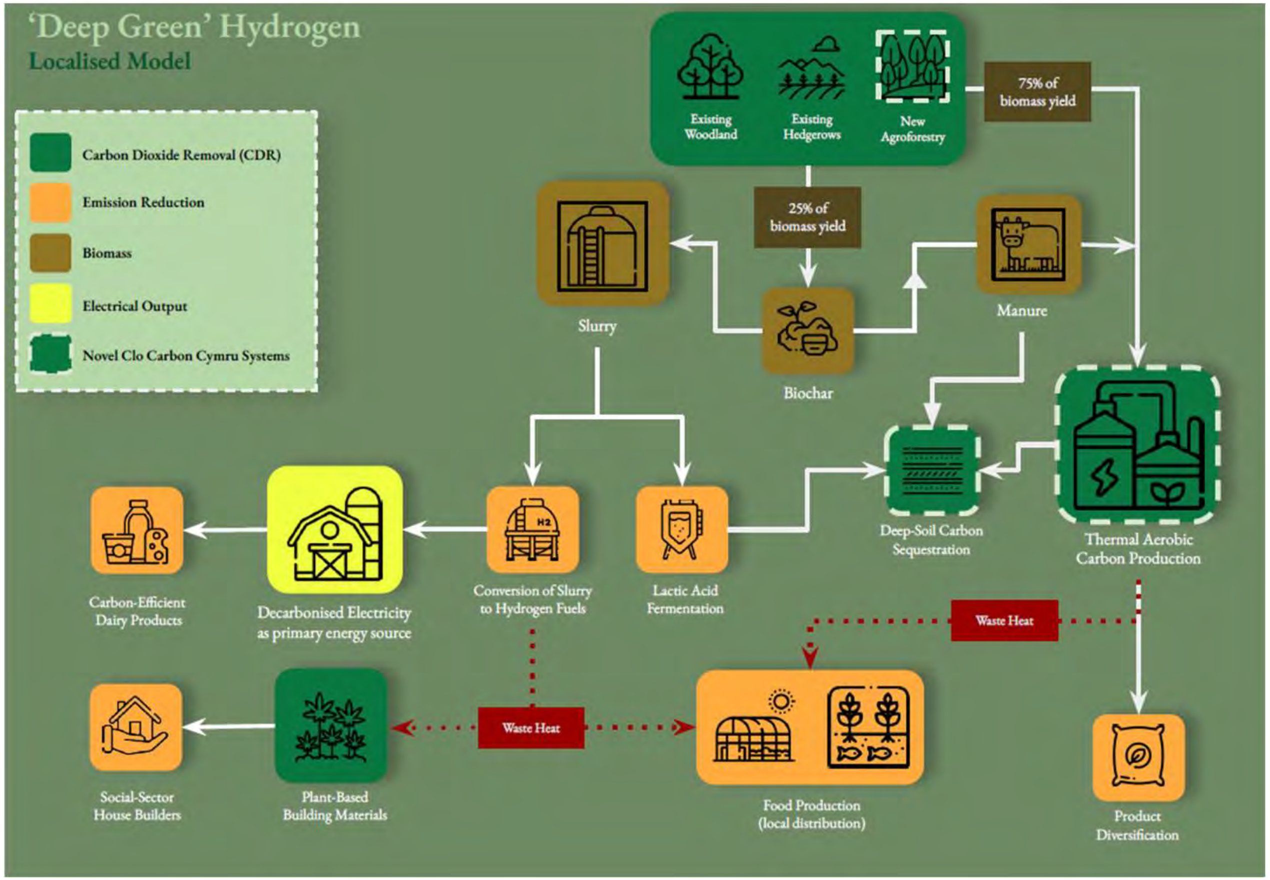
Agroforestry - Our model includes 7,000 trees per hectare (Welsh Govt standard is 2,500 trees per hectare).

Deep Soil Carbon Sequestration - Increase capacity of soil to store long-term carbon by up to 20% via addition of mycorrhizal and melanotic fungi.

Biochar - Strategic utilisation of biochar to enhance water retention and microbial activity in soil & to sequester carbon as a long-term strategy.

Thermal Aerobic Carbon Production (TACP) - Conversion of low-value hardwood (thinnings/ residual streams) into carbon-rich replacement of peat-based products.

Improved management of slurry and manure from dairy farms, through lactic acid fermentation and generation of hydrogen gas. Locally produced high-protein food-crops, replacing imports and avoiding associated up/ downstream CO2 emissions. 90% reduction of gaseous emissions from slurry and manure. Converts raw slurry to a nutrient-rich fertiliser. This replaces synthetic chemical imports, increasing self-reliance and drastically reducing carbon inputs.



Summary of strategic sites in the region and future plans

Confidential, planned 20 MW green H2 electrolysis project in Milford Haven (1)

A significant 15 MW green hydrogen electrolysis project located on the Haven Waterway to develop the production, storage and distribution of green hydrogen for refueling stations for road and maritime transport. It is estimated to produce ~4 tons of h2 daily. The project is expected to reach FID in 2023 and be commissioned by 2025.

Confidential, planned 10 MW green H2 electrolysis project in Milford Haven (2)

A significant 10 MW green hydrogen electrolysis project located in North Pembrokeshire planning to make fuel for buses, HGVs, trains, and industry in Wales. More details are expected to be announced in October 2022.

Valero

Pembroke's refinery is one of Europe's largest and most complex refineries, with a total capacity of 270,000 barrels per day. The refinery is responsible for 10% of Wales GDP, works in a strong export market and supports many local jobs. Valero is one the UK's top ten largest single point emitters at 0.5% of total UK emissions (2.2million tonnes CO2 in 2019). Using figures from ERM study, Valero could make around 1700 tonnes of H2 per day (which would take 6800 MW of wind power to produce the H2) for industrial processes and low carbon synthetic fuels (potentially to service the aviation industry).

South Hook and Dragon LNG

South Hook LNG terminal is an LNG regasification terminal near Milford Haven and is the largest LNG terminal in Europe. Together with the smaller Dragon LNG terminal it can handle up to 25% of the UK's gas requirement. During the C-19 lockdown these terminal supplied 80% of UK gas. Construction of the LNG terminals unlocked access into the gas network via the extension of the national transmission system (NTS) into Pembrokeshire.

It is believed to be working with WWU regards H2 blending into local gas distribution grid. No details available due to NDA.

Shell & Dragon LNG have entered a JV for blue hydrogen production and CCuS , but there is no details available due to NDA.

Lightsource / BP

It is understood that a JV has been formed to produce green H2 from photovoltaic solar farms in the SWIC region.

Blackbridge

Classified as regionally important strategic site, Blackbridge is a potential 350MW biomass energy generation site. The owner is looking to sell it after planning application has been refused. It is Ex Gulf refinery site and currently inactive. Prosperity Energy reported they have agreed purchase price with no details on the plans for future use.

Statkraft (Trecwn)

Statkraft is a generator of renewable energy and is preparing planning application for 50 MW Solar PV to support 10 MW green H2 electrolysis to produce 2,000-4,000 kg H2/day. It is planned to be operational around 2024 dependent on planning application.

PNZC RWE'S PEMBROKE NET ZERO CENTRE

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RWE Pembrokeshire Net Zero Centre

> "RWE is looking to deliver 2GW of hydrogen projects by 2030, including a green hydrogen project in Pembrokeshire. Key to this is the economic viability of projects producing hydrogen for use across a wide variety of sectors such as transport, power and industry. RWE welcomes the work of MH:EK in helping to make the storage, use and distribution of hydrogen cost effective."
>
> Jeremy Smith, RWE

RWE operates Europe's largest Combined Cycle Gas Turbine – 2200 MW in Pembroke. It is a key industrial player on the Haven waterway, owning and operating the Pembroke natural gas-fired power station. To transition to carbon neutrality, RWE is looking at wide-scale investment in decarbonisation technologies which includes transforming the Pembroke power station to the Pembrokeshire Net Zero Centre (PNZC) – a decarbonisation hub linking innovative low carbon technologies such as hydrogen production, CCUS and floating offshore wind.

The construction of a 100-250MW electrolyser at the Pembroke power station site is assumed to be completed by 2025 and scaled up to the GW scale by 2030. By 2040, the Pembroke Power station is assumed to be fully decarbonised, alongside RWE deploying GW scale floating wind and establishing large-scale hydrogen production.

PNZC will develop and implement three distinctive pillars:

Decarbonisation of Pembroke Power Station

Activities in this pillar include assessing the options to decarbonise further through SWIC: Partial replacement of natural gas with hydrogen to reduce CO2by up to 15%; 100% replacement of natural gas by hydrogen. Over the next months pre-FEED studies will be conducted as part of the SWIC Phase 2 Deployment project.

Floating Offshore Wind development in the Celtic Sea.

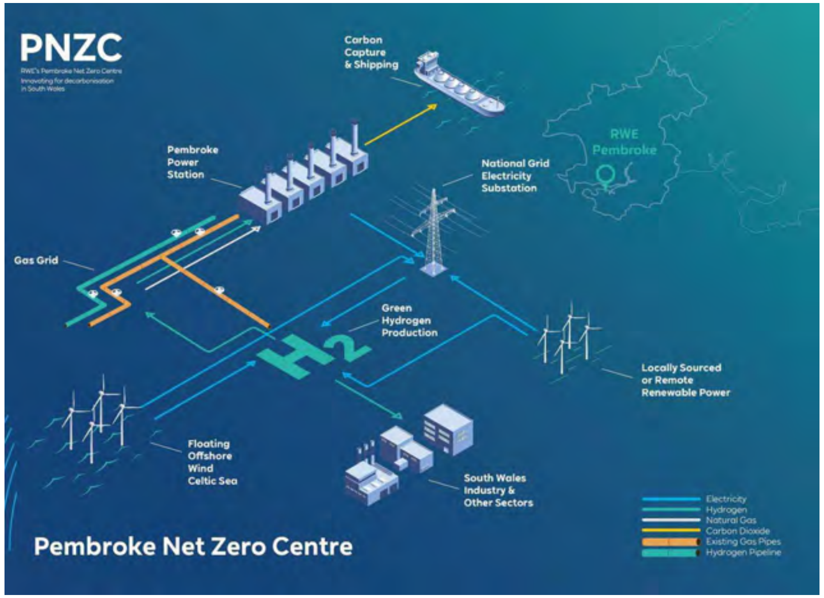
Early ~100MW floating wind projects are being developed in the region but significant deployment is only likely to in the late-2020s/early-2030s and beyond. By 2050, total deployment could be up to 10GW

In March 2021, The Crown Estate announced it will be undertaking a process for 'early commercial scale' floating wind opportunities in the Celtic Sea -further details are to be announced imminently. RWE plans to respond to expected Celtic Sea Floating Wind tender.

Green Hydrogen production, including feasibility studies for the development of an electrolyser on the Pembroke site;

RWE is investigating the feasibility of developing a Lighthouse Green Hydrogen Production project at the Pembroke Power Station site to include long-term large-scale production connected to offshore floating wind in the Celtic Sea.

Next steps include conducting Green Hydrogen Production Feasibility Study and consideration of renewable power connection associated with the Green Hydrogen project.



South Wales Industrial Cluster (SWIC)

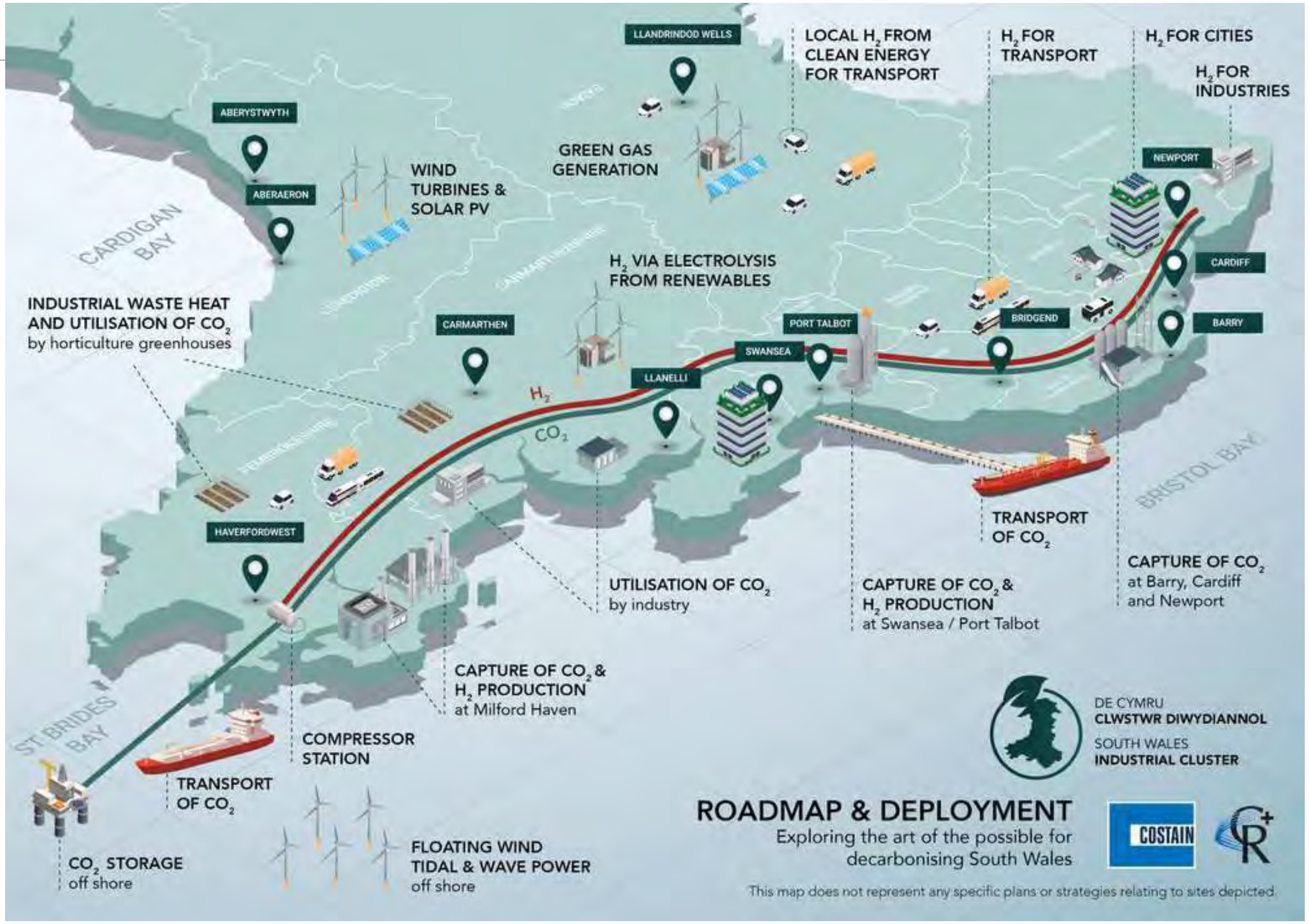
SWIC is a partnership between Welsh Industry, energy suppliers, infrastructure providers, academia, legal sector, service providers and public sector organisations, working to map what is needed to support South Wales in becoming a net zero carbon region by 2040.

The project is jointly funded by the project partners and UKRI. The project entered its deployment phase in February 2021 and over a period of 26 months aims to create pathways and opportunities to promote Wales as a leading global player in decarbonised industrial and economic growth, with a goal of net zero carbon by 2040.

The project brings together various industries such as energy, oil refining, paper, nickel, chemicals, LNG import, steel and cement to research, investigate and develop solutions and a plan to decarbonise the industrial sector in South Wales. Topics or options being investigated include blue hydrogen production, CCUS, carbon dioxide transportation and shipping, and green hydrogen production.

The phase one Deployment project focuses on four anchor projects at sites that are responsible for a significant portion of the economic activity in South Wales:

- Tata Steel's integrated steelworks at Port Talbot,
- Tarmac's Cement Works at Aberthaw
- Valero Energy's Refinery,
- RWE's CCGT Power Plant at Milford Haven.



Summary of future regional plans and developments

City Deal Pembroke Dock Marine (PDM)

The £60 million Pembroke Dock Marine programme aims to place Pembrokeshire at the heart of global zero carbon marine energy innovation.

Pembroke Dock Marine will deliver the facilities, services and spaces needed to establish a world-class centre for marine engineering. Led by the private sector and supported by Pembrokeshire County Council, Pembroke Dock Marine is made up of four elements:

- Marine Energy Engineering Centre of Excellence (MEECE) - Research, development and demonstration support, driving innovation in the supply chain and reducing cost of energy.
- Pembroke Port developments - Creating spaces that help industry fabricate, launch and maintain devices.
- Marine Energy Test Area (META) - Facilitates component, sub-assembly and device testing through pre- consented test areas in order to reduce the time, cost and risks faced and accelerate growth in the sector.
- Pembrokeshire Demonstration Zone (PDZ) - Enabling offshore renewable infrastructure to catalyse the Celtic Sea floating offshore wind and marine energy opportunities.

South Wales ZERO 2050

The Zero 2050 study considers how net zero greenhouse gas emissions for the whole energy system in South Wales can be achieved. Pembrokeshire was one of the 14 local authorities in South Wales covered by the project with Milford Haven featuring as a major energy use location in South Wales.

The study identifies low regret options that would accelerate the transition to net zero by 2050 including:

- increasing the capacity of onshore wind and solar;
- piloting hydrogen production from both autothermal reformation and electrolysis;
- undertaking network studies to understand feasibility and cost of transitioning networks to hydrogen; and
- investigating options for CCUS and CO2 export from South Wales (which are of particular relevance to MH:EK).

The study recognises the uncertainties around the route to decarbonisation and recommends to take an adaptive pathway approach by monitoring tipping points that will enable future decision making.

Regen Net Zero South Wales

The Regen Net Zero South Wales project undertook an integrated net zero Distribution Future Energy Scenarios (DFES) analysis in South Wales. Regen along with Wales and West Utilities (WWU) and Western Power Distribution (WPD) explored three scenario pathways for the gas and electricity networks to 2050 to explore what the future could look like in the region and develop a methodology that can be used for future integrated DFES analysis. The DFES approach created bottom-up, stakeholder led, locally relevant decarbonization pathways for licence areas and regions. The DFES data produced was then used by the distribution networks to plan how the network might need to evolve and where and when network investment or flexibility solutions might be needed. Three net zero scenario pathways: High Electrification, Core Hydrogen and High Hydrogen were used in this study.

The recommendations from the study are particularly relevant to how to integrate DFES (local & regional distribution pathways) to National Grid FES. The study recommends that a scenario approach is critical to delivering a cross-vector DFES which allows the gas and electricity networks to agree on a set of possible futures.

Technology acceleration opportunities

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Longlist to shortlist appraisal

i. Introduction

To develop a detailed concept design of a SLES for MH:EK that is investable in the short-term (2030) and in transition towards Milford Haven being fully decarbonised by 2050, we adopted a bottom-up approach of identifying a longlist of opportunities for SLESs within Milford Haven, Pembroke and Pembroke Dock based on the project objectives and critical success factors. This was then refined to a shortlist through a multi-criteria assessment, expert & stakeholder review for further techno-economic modelling.

ii. Data gathering and review

The project boundary and data gathering (Phase 1)

The project boundary for MH:EK is designed to be sufficiently large to allow the study to identify key opportunities while also remaining focused on the local area. The boundary includes major generation assets along with areas that have potential for renewable generation in the future.

To build up a picture of the physical energy supply and demand assets and the existing energy distribution network within the MH:EK project boundary, we undertook an extensive first phase of data gathering, to enable us to build a deep understanding of the local energy infrastructure and system.

We gathered demand data for key energy demand centres and buildings owned by Pembrokeshire Country Council and the Port of Milford Haven as well as data and insight on planned developments and opportunities by engaging directly with asset owners and undertaking literature review of various studies around future developments and opportunities within the project boundary.

We consulted publicly available databases such as BEIS Renewable Energy Planning Database *[21]* to gather data on existing and planned renewables generation and supply assets.

We engaged with the local gas network operator Wales & West Utilities (WWU) and electricity network operator, Western Power Distribution (WPD) to gather data on the network infrastructure, constraints and management.

We have further engaged with the MH:EK project team to identify any critical energy demand or supply asset and opportunities for renewables and hydrogen generation.

Note that the propositions include planned developments with high level planning and masterplanning details; the propositions are based on the details of the proposed phases of developments available at the time of shortlisting and modelling, assuming the whole schemes go ahead. However, each build / phase will be subject to review and may or may not proceed.

Stakeholder Engagement

Due to the breadth of data required and the range of stakeholders involved, a structured and considered approach to data collection and stakeholder engagement is fundamental in the efficient delivery of techno-economic modelling and meeting the project objectives.

Our stakeholder engagement process is as follows:

I. Identify stakeholders
II. Stakeholder mapping
III. Stakeholder engagement
IV. Document engagement activity and data received
V. Measure effectiveness and review

Summary of key stakeholder engagement activities

We primarily engaged with Pembrokeshire County Council (PCC) and the Port of Milford Haven (PoMH) as key data holders to build a comprehensive picture of the energy demand and supply assets, existing and planned, within the MH:EK project boundary. Examples of key data gathered from PCC and PoMH include:

- List of properties owned by PCC and PoMH and associated electricity and heat demands
- PCC and PoMH vehicle and freight fleet information to inform the transport demand
- NHS vehicle fleet information (through PCC)
- PoMH owned renewable asset information including installed capacity, generation, curtailment information
- PoMH land ownership information
- List of planned developments or prospective energy generation projects within the MH:EK boundary

We engaged with the gas and electricity network operators – WWU and WPD respectively to gather data on existing energy infrastructure. Information requested included data on the gas pipelines and grid and substation capacities. We also held further discussions with WWU and WPD to gather insight on the constraints and pressures on their system and the barriers to increasing capacity, which is summarised in section 5/ii.

Energy Revolution Integration Service (ERIS) – LEAR study

We collaborated with the ERIS team to make use of their Local Area Energy System Representation (LEAR) tool to extract residential demand loads for our project boundary.

However, due to data confidentiality, the data from LEAR could only be provided in an aggregated form with a granularity that therefore was insufficiently informative as an input to the MH:EK modelling process and analysis.

Longlist to shortlist appraisal

ii. Data gathering and review (continued)

The Milford Haven energy network infrastructure

A key use case of hydrogen as a vector is to act as a storage mechanism for excess electricity that may otherwise be curtailed or lost if the electricity network has no available capacity to carry all the locally generated supply.

It is important to understand the constraints on the electricity network and how new applications to connect to the electricity network are managed in the Milford Haven and Pembroke area.

To understand the local picture, we engaged with WPD at various points in the project. We gathered data on the substations and their capacities within the project boundary. The Milford Haven area is in an active network management (ANM) zone.

> *WPD uses the ANM system to continually monitor the limits on the local network capacity and allocates available capacity based on the date of their grid connection application. New renewable projects risk being constrained with a requirement to wait for capacity to be available to progress their projects and without compensation. This represents an undesirable situation when compared with non-ANM areas where they would be compensated for the networks inability to accommodate electricity export. Alternatively, there is the option to pay for reinforcement of the network, but this is likely to be prohibitively costly for individual developments.*

The implication of ANM within the MH:EK boundary is that new renewable energy generation projects are currently stalled which doesn't align with, and could be a hindrance to, the need to increase renewable energy generation to reach net-zero by 2050. This context highlights the case for development of a SLES or decentralised clusters that are less dependent on the regional and national electricity network and support balancing to bring greater resilience and energy security.

The gas network infrastructure in the region is generally considered to be hydrogen "ready". The Energy Networks Association (ENA) *[22]* announced that the British gas grid is set to be ready to deliver gas blended with 20% hydrogen by 2023. So, if large scale hydrogen heating or blended hydrogen, with either future or existing boilers is shown to be commercially viable then the network itself should not present a blocker.

There are still many other considerations around the integration of hydrogen into the existing gas network that would need to be considered before wide scale adoption, for example injected gas quality. To enter the gas network, gas must meet certain criteria including achieving a Wobbe number in a specific range for the Gas Safety (Management) Regulations. Hydrogen has a very low Wobbe number and often needs to be mixed with propane to reach the required specification. This proved too expensive on a previous PoMH project.

Literature review

Several previous studies were undertaken on potential opportunities within the project boundary. These were reviewed to inform the longlisting process.

To identify future opportunities and understand the feasibility of the developments and constraints, and to gather information on potential demand and timescales, we reviewed multiple local studies as well as key regional policy documents.

The final longlist was established through combination of data gathering and review, stakeholder engagement, and literature review which supported identification of focal areas and clusters of potential SLES development.

To build up a better understanding of the longer-term plans and developments in the area including larger scale national energy assets that could integrate into the local energy system, we considered future opportunities such as the Greenlink interconnector, the ERM Dolphyn offshore hydrogen production project and the Celtic Sea offshore wind project pipeline and engaged with other groups such as SWIC (South-West Industrial Cluster). The longer-term energy transition opportunities are further explained in the 'MH:EK strategic outline case for a smart local energy system' report *[28]*.

Future energy scenarios

The future direction of the energy system, the energy mix and energy supply is uncertain. Any SLES identified through this project should therefore perform well when placed in the external context of a range of future energy system environments. Several industry studies explore the various driving factors and possible pathways. We reviewed these scenarios to inform the scenarios taken for analysis in this study. The scenarios are further discussed in section 8.

A list of the key documents we reviewed to inform the techno-economic modelling and other references are provided in the References section. A summary of the key documents reviewed and the implication on the MH:EK project is given in Appendix A.

Longlist to shortlist appraisal

iii. The physical energy infrastructure map

The data gathered, and insights drawn from stakeholder engagement and literature reviews were recorded in a database alongside metadata where available. The database acts as a single source of truth and to visualise this data, we developed a digital, dynamic and interactive energy infrastructure map.

The GIS based geospatial map enables users to view the existing energy supply and demand assets, alongside additional asset information such as capacity, asset ownership, status, commissioned year, technology type, planning details etc. We also mapped the energy distribution network and local information such as energy capacity, gas pipe pressures or electric line voltages and substations. We used the map to identify constraints and opportunities for future potential energy generation and used the tool to connect assets and networks to form clusters that could be opportunities for a SLES and so formed a longlist of propositions.

The map has provided a dynamic and live picture of the MH:EK energy system and kept evolving as we progressed through the data gathering, literature review and techno-economic modelling.

The methodology, process and tools used to develop the energy infrastructure map is a key step in the development of SLES opportunities that can be replicated and scaled elsewhere.

The map and the inbuilt data is accessible and interactive, supporting the move to open data and a modern digitalised energy future with the opportunity to continue to evolve beyond this first phase of MH:EK.

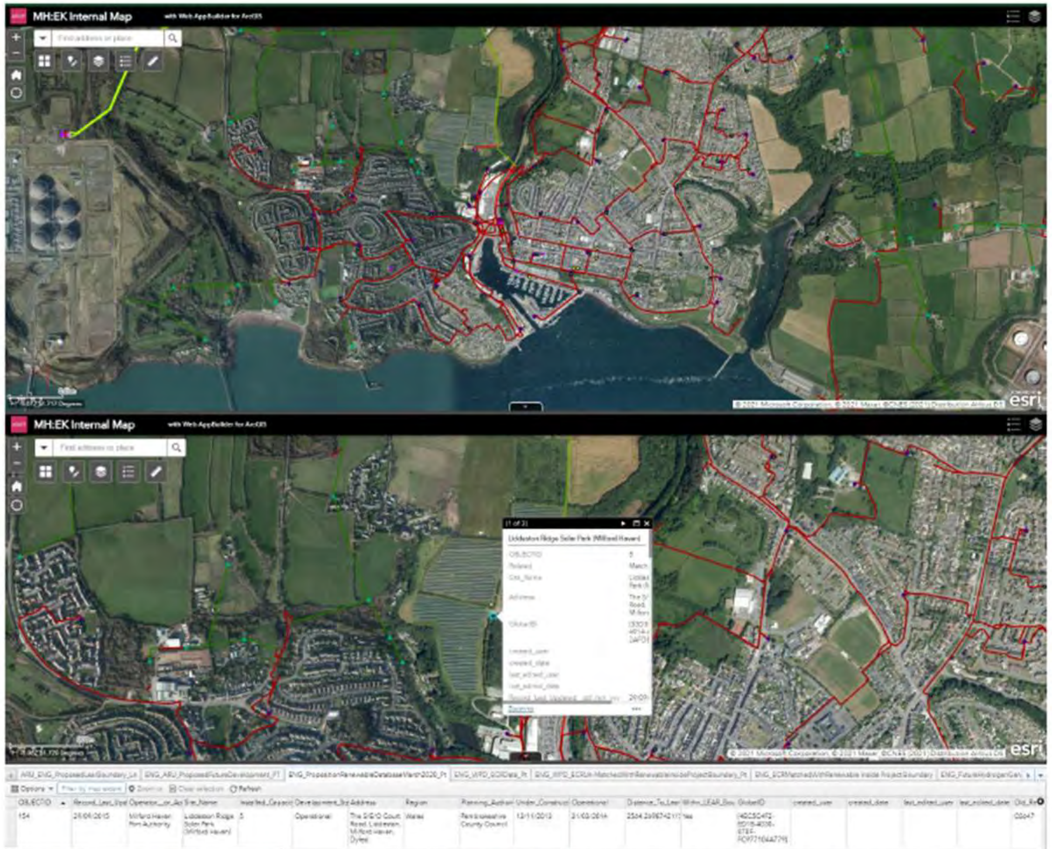

Figure 9: Top - extract of the energy infrastructure map for energy asset and network mapping. Bottom - Energy asset metadata information is accessible through a 'pop-up' or full attribute table at the bottom by clicking on the asset icon.

Longlist to shortlist appraisal

v. The critical success factors

The critical success factors (CSFs) are key criteria that are used to assess the longlist of propositions against the project objectives and enable the shortlisting process using a strategic approach.

The list of CSFs are grouped in three main categories:

- the MH:EK project objectives

  These CSFs directly address the MH:EK objectives and the benefits of developing SLESs including benefits in accelerating the transition to net-zero, the associated social and community benefits.

- the technical, commercial and economic viability

  These CSFs ensure that the solution contributes to ensuring energy security & resilience, is technically, economically and commercially viable and addresses other development risks such as the broader need, investment, policy & regulatory considerations, planning and other development risks.

- wider benefits in line with the Welsh Future Generations Act (WFGA) *[24]* and wider sustainability objectives

  These CSFs consider how MH:EK should contribute to wider regional and global sustainability goals. The WFGA seven wellbeing goals stem from the United Nations Sustainable Development Goals and have been translated into the Welsh context to ensure public bodies and projects think about the long-term impact of their decisions, to work better with people, communities and each other, and to prevent persistent problems such as poverty, health inequalities and climate change.

Critical success factors	Icon
Key objective: Achieves emissions reductions, significant contribution to net-zero 2050 pathway	
Key objective: Catalyst / First of a kind & supports future expansion *Potential to develop seed markets for hydrogen in the fields of heat, transport, gas & power.*	
Key objective: Jobs & Prosperity *Stimulate growth in local community,* *Potential for job creation/upskilling,* *Decarbonises heating or transport for local community,* *Contribute to the alleviation of fuel poverty*	
Key objective: Optimises social value (social, economic and environmental), in terms of the potential costs, benefits and risks	
Key objective: Stakeholder / Community Acceptability & Awareness raising	
Viability: Technical: Balance of supply & demand	
Viability: Technical: Technology maturity *Existing vs novel technologies* *Supply chain - availability / investment required*	
Viability: Contributes to Energy Resilience	
Viability: Immediate Need / Opportunity Readiness	
Viability: Commercial Opportunity	
Viability: Commercial: Capex investment required	
Viability: Investor Interest / Funding Streams	
Viability: Complexity / Asset ownership / Number of parties	
Viability: Policy & Regulatory Considerations	
Viability: Development Risks & Scheme Constraints	
Wider benefits: WFGA Goals *Prosperous / Resilient / Healthier / More equal / Cohesive communities / Vibrant culture / Globally responsible*	
Wider benefits: WFGA Ways of Working *Long term / Prevention / Integration / Collaboration / Involvement*	
Wider benefits: Waste Reduction / Circular Economy	

Table 2: The critical success factors of MH:EK

Longlist to shortlist appraisal

vi. The longlist of propositions

We used the energy infrastructure map to identify the critical or central energy assets, to form the longlist of investable propositions. These are either demand or supply assets that have a stronger opportunity to be part of a SLES. For example, it could be a significant building (school, library, leisure centre) with the opportunity to transition its heating or electricity demand to a net-zero technology within a SLES, or a renewable energy asset that has the opportunity of feeding the generated energy to a SLES rather than fully exporting to the grid.

We clustered a broader mix of assets around a central or critical asset (as defined above) considering feasible geographical links to form propositions that are broadly in line with the CSFs and key success criteria.

We undertook a high-level demand and supply assessment using the gathered data to determine the overall scale of the proposition. This supported a first pass assessment of technical viability. We carried out a qualitative 'triage' of the longlist against the CSFs using a RAG assessment to further consolidate the longlist, and either group or remove weaker propositions from the longlist.

An example of a proposition card is shown in Figure 10 which gives a summary of the proposition and shows how each component (defined within a hexagon) can be clustered to form a proposition.

The card provides information about each proposition including title and description; the value of the proposition; the scale of the energy supply-demand; the demand, supply and conversion components of the proposition; the timeframe considered; the energy vectors represented; the network distribution systems; asset ownership and a qualitative triage RAG assessment against the CSFs.

Proposition summary cards for each longlisted proposition are provided in Appendix B.

An initial longlist of 13 propositions was developed in line with the CSFs (Table 2) and SLES success criteria (Table 1). These were identified geographically across the project boundary as well a temporally from short-, mid-, and longer-term time horizon propositions.

Figure 10: Example of a proposition card

A longlist review workshop was held with the MH:EK project team to identify gaps such as assets or proposed projects / opportunities that may have been missed and to confirm that the initial longlist were in line with the project objectives. In the workshop, an additional three critical assets were identified:

- The PCC recycling centre
- The Haverfordwest Riverside shopping centre
- The Pembrokeshire food park

We formed three new propositions around these critical assets and reviewed these using the high-level supply-demand assessment and qualitative triage against the CSFs, as per the other longlisted propositions.

This assessment concluded that they were strong propositions and were included in the longlist to form a final longlist of 16 propositions. The full longlist and a description is provided in Table 3 and shown in Figure 11.

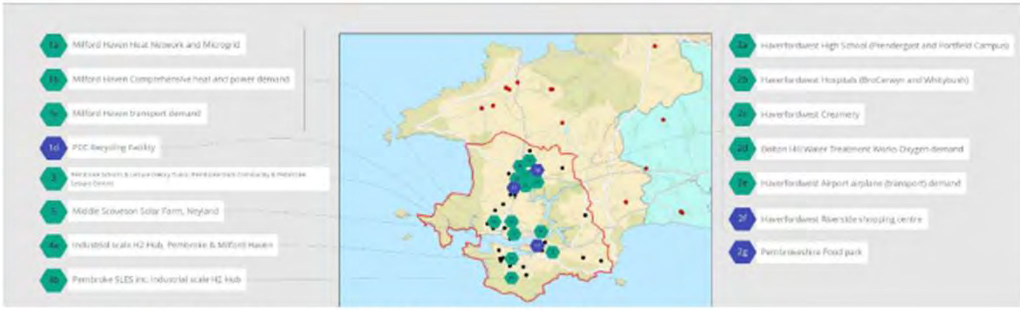

Figure 11: Overview of the longlist proposition within the MH:EK project boundary

Longlist to shortlist appraisal

Proposition Number	Proposition Name	Proposition Description
1a	Milford Haven Heat Network and Microgrid	Feasibility of developing a heat network and microgrid for Milford Marina for heat and power supply through electrolysis of excess energy from PoMH energy supply assets.
1b	Milford Haven Comprehensive heat and power demand	Feasibility of meeting the existing and future heat and power demand of the Milford Haven Comprehensive school by Hydrogen through electrolysis of excess energy from PCC and PoMH owned assets.
1c	Milford Haven transport demand	Feasibility of meeting the existing and future PCC and PoMH transport demand from Hydrogen through electrolysis of excess electricity from PCC and PoMH owned assets.
1d	PCC Recycling Facility	This proposition integrates a proposed recycling centre at the current Milford Haven Puma Energy site with existing local renewable energy supplies.
2a	Haverfordwest High School (Prendergast and Portfield Campus)	Meeting power demand of Haverfordwest High School campuses from nearby renewable energy assets and heat demand through the electrolysis of excess renewable energy.
2b	Haverfordwest Hospitals (BroCerwyn and Whitybush)	Providing Hydrogen for heat and transport demand as well as potential oxygen demand for Haverfordwest hospitals through the electrolysis of excess renewable energy from nearby assets.
2c	Haverfordwest Creamery	Meeting heating/cooling demand of Haverfordwest creamery using hydrogen from biomass conversion of sewage sludge and power demand from nearby renewable energy assets.
2d	Bolton Hill Water Treatment Works Oxygen demand	Proposition to supply oxygen to the Bolton Hill sewage water treatment works through the electrolysis of excess energy from nearby renewable assets.
2e	Haverfordwest Airport airplane (transport) demand	Longer term proposition to supply blue hydrogen for airplane refuelling at Haverfordwest airfield and general heat demand within the MH boundary through reformation of natural gas.
2f	Riverside Shopping Centre	Proposition to provide heat and power to Riverside Shopping Centre in Haverfordwest. This will most likely be via a microgrid due to current electric heating infrastructure.
2g	Pembrokeshire Food Park	Electricity from potential new ground PV farm at Haverfordwest airfield used to meet future heating/cooling and power demand of the planned food park and to create hydrogen to supply freight/HGV transport demand from Pembrokeshire Food Park hub.
3	Pembroke Schools & Leisure (Ysgol Harri Tudor, Pembroke Dock Community & Pembroke Leisure Centre)	Feasibility of meeting the existing and future heat and power demand of existing PCC school and leisure assets from renewable assets and by Hydrogen through electrolysis of excess energy.
5	Middle Scoveson Solar Farm, Neyland	Heat demand of Neyland Health centre through the electrolysis of excess energy from existing and proposed renewable energy assets.
4a	Industrial scale H2 Hub, Pembroke & Milford Haven	Transition of the Haven waterway industrial energy sector towards being a major UK H and CO_2 hub. Includes H production, storage, import/export and CO_2 storage and export in the longer term.
4b	Pembroke SLES inc. industrial scale H2 Hub	Transition of the Pembroke area to a smart interconnected local system balancing electric or hydrogen supply based on availability & seasonality. Import of green H for UK transmission.

Longlist to shortlist appraisal

vii. Multi-criteria assessment (MCA)

To evaluate the longlist of propositions against the project CSFs in a consistent manner, we adopted a multi-criteria assessment approach. This approach enables explicit evaluation of the propositions against multiple criteria that may have conflicting or differing levels of priority or weighting.

We developed an MCA tool specific to the review of SLES, the assessment is carried out as per the following process:

1. Criteria definition
2. Relative criteria importance defined by a weighting factor
3. Scoring of the propositions against each criterion
4. Weighting factor applied to each proposition criterion score
5. Proposition ranking based on the final sum of the weighted scores

Criteria definition: A list of 35 criteria was used to evaluate the propositions built from the CSFs and provide greater granularity through specific criteria to enable a robust assessment. The criteria were split into nine categories: key objectives; technical viability; environmental impact; financial viability; funding streams; deliverability; resilience; wider wellbeing & future generations and sustainability goals. Health, safety and welfare as a topic is not considered as a criterion on the basis that it should not be assessed on relative importance; health, safety and welfare should be considered through all aspects of the project.

Relative criteria importance: To assess the relative importance of different criteria against one another, we used a tool to capture the perspective of each project partner and combined to give an overall weighting. Whilst it is recognised that the relationship between criterion is in most cases not linear and easy to distinguish relative importance, the tool captures the views of a project team based on project knowledge and the local context. Overall, the 'catalyst' criterion resulted as the most important followed closely by 'achieving carbon emissions', 'stakeholder acceptability', 'water bodies' and 'WFGA Goals'.

The full list of the criteria, their categorisation and description and the resulting weighting factor is provided in Table 5 overleaf, with the top 5 criteria highlighted in **bold.**

Proposition scoring: Using the MCA tool, we scored each proposition against the criteria using a scale of 1 to 5: a score of 1 being a negative or no contribution and 5 being a positive contribution to the criterion. Rationale of the scoring against each criteria is also recorded in the tool.

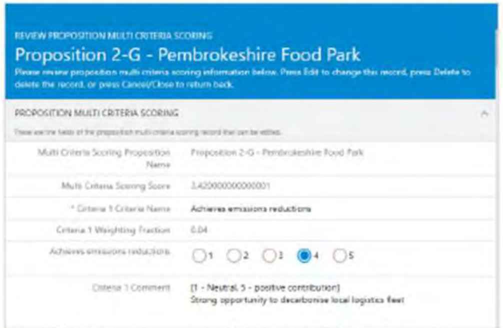

Figure 12 shows an example of the scoring for a proposition against criterion 1: Achieves carbon emissions reduction.

Proposition ranking: Once the scoring of each proposition against each criterion is completed, the tool applies the weighting factor to the score to give an overall score out of 5 for every proposition. The propositions were then ranked from the highest to lowest score to show how best they contribute to the project CSFs.

The emerging shortlist

The MCA process provides a robust and consistent approach to aid decision making, but has some limitations linked to the subjective nature of the scoring. Output is always recommended to be reviewed by technical experts familiar with the local context.

We conducted an expert peer review of the top 10 propositions from the MCA to support the shortlisting process. This review identified emerging focal points and clusters that were recommended to be taken forwards to shortlisting:

A. The Milford Haven cluster
B. The Haverfordwest cluster
C. The Pembroke & Pembroke Dock cluster
D. Longer term industry transition
E. Longer term whole system energy transition.

The project team and expert review confirmed the top 10 propositions as shown in Table 4.

Rank	Proposition Name	Score	Cluster
1	Proposition 4-B Pembroke SLES inc. industrial scale H2 Hub	3.62	D
2	Proposition 1-A - Milford Haven Heat Network and Microgrid	3.54	A
3	Proposition 2-G - Pembrokeshire Food Park	3.43	B
4	Proposition 2-F - Riverside Shopping Centre	3.43	B
5	Proposition 3 - Pembroke Schools & Leisure (Ysgol Harri Tudor, Pembroke Dock Community & Pembroke Leisure	3.41	C
6	Proposition 4-A - Industrial scale H2 Hub, Pembroke & Milford Haven	3.34	E
7	Proposition 2-D - Bolton Hill Water Treatment Works Oxygen demand	3.32	B
8	Proposition 1-C - Milford Haven transport demand	3.27	A
9	Proposition 1-D - PCC Recycling Facility	3.18	A
10	Proposition 1-B: Milford Haven Comprehensive heat and power demand	3.14	A

Table 4: The top 10 propositions after the MCA.

Longlist to shortlist appraisal

Number	Criteria Category	Criteria Name	Notes	Weighting
Criteria 1	Key Objectives	**Achieves emissions reductions**	Achieves emissions reductions, significant contribution to net-zero 2050 pathway	**4%**
Criteria 2	Key Objectives	**Catalyst**	Catalyst / First of a kind & supports future expansion Potential to develop seed markets for hydrogen in the fields of heat, transport, gas & power.	**5%**
Criteria 3	Key Objectives	Jobs & Prosperity	Jobs & Prosperity Stimulate growth in local community, Potential for job creation/upskilling, Decarbonises heating or transport for local community, Contribute to the alleviation of fuel poverty b) enabling the development of a mixed, zero carbon energy system for the city region c) providing clean, reliable and competitively priced energy for current and future local businesses and communities	3%
Criteria 4	Key Objectives	Social Value	Optimises social value (social, economic and environmental), in terms of the potential costs, benefits and risks	3%
Criteria 5	Key Objectives	**Stakeholder acceptability**	Stakeholder / Community Acceptability & Awareness raising	**4%**
Criteria 6	Technical	Design	Design – known technology & approaches, appropriateness and balance of supply & demand	2%
Criteria 7	Technical	Construction	Construction – known methods, supply chain skills & technical capability, local supply of materials and construction support facilities, installation programme & weather downtime vulnerability, construction of environmental mitigations	2%
Criteria 8	Technical	Operation	In-use phase – operation & maintenance requirements, schedule, access & safety considerations, supply chain availability and material supply for significant maintenance events	1%
Criteria 9	Technical	Decommissioning	Decommissioning - known technology & approaches, timeframe & likely changes to supply chain and technologies, design life & potential extension, environmental mitigation, safeguarding of other benefits. How robust is the scheme to external scenarios.	2%
Criteria 10	Environmental	Impact	The scheme will be capable of avoiding, reducing the effects to and/or compensating for the loss of European designated sites.	2%
Criteria 11	Environmental	Mitigation	The scheme will be capable of mitigating its environmental effects to acceptable levels.	2%
Criteria 12	Environmental	**Water Bodies**	The scheme will be capable of either maintaining the ecological status of a water body or capable of supporting a case for derogation under the Water Framework Directive.	**4%**
Criteria 13	Environmental	Biodiversity	The scheme will be capable of achieving a net biodiversity gain.	2%
Criteria 14	Financial Viability	Commercial Opportunity	The scale of the commercial opportunity the scheme presents	3%
Criteria 15	Financial Viability	Capital Cost	The upfront cost of the solution to the point of installation or commissioning	3%
Criteria 16	Financial Viability	Maintenance Cost	The annual costs of operating and maintaining the proposed scheme	2%
Criteria 17	Financial Viability	Price Resilience	The resilience of the scheme to energy price volatility	3%
Criteria 18	Financial Viability	Levelised Cost of Energy	The anticipated LCOE	3%
Criteria 19	Financial Viability	Supply Chain	The opportunity for investment in the supply chain to realise the delivery of the scheme, if any. And if so, the scale of investment.	3%
Criteria 20	Funding Streams	Investor Interest / Funding Streams	The scheme will be capable of unlocking funding streams where possible. This should also consider to what degree it relies on these streams to be economically viable.	3%
Criteria 21	Proposition Deliverability	Immediate Need / Opportunity Readiness	Is there an identified immediate need or opportunity associated with the proposition? E.g. planned (re)development.	2%
Criteria 22	Proposition Deliverability	Complexity of asset ownership	Number of parties or direct stakeholders involved	3%
Criteria 23	Proposition Deliverability	Policy & Regulatory Considerations	Critical barriers or obstacles presented by current policy & regulation to the scheme	3%
Criteria 24	Proposition Deliverability	Development Risk	The risk associated with the proposition from planning through to installation and commissioning	3%
Criteria 25	Proposition Deliverability	Scheme Constraints	The number of significant constraints associated with the scheme	3%
Criteria 26	Proposition Deliverability	Future Expansion	The scheme will be capable of connecting to additional loads, and bring benefits to the wider area. The scheme will be capable of supporting future expansion of energy capacity / be adaptable to future new technologies.	3%
Criteria 27	Proposition Deliverability	Visual Impact	The visual impact of the scheme in the landscape and the possibility of raising objections.	3%
Criteria 28	Proposition Deliverability	Low-Carbon Technologies	The scheme will allow for low-carbon technologies to be on display	3%
Criteria 29	Resilience	Energy Resilience	The scheme will provide a secure supply of energy	3%
Criteria 30	Resilience	Innovation	The scheme will demonstrate innovation in the energy sector	3%
Criteria 31	Wellbeing & Future Generations Act	**WFGA Goals**	The scheme will promote wider benefits to wellbeing goals in terms of: Prosperous / Resilient / Healthier / More equal / Cohesive communities / Vibrant culture / Globally responsible	**4%**
Criteria 32	Wellbeing & Future Generations Act	WFGA Ways of Working	The scheme will promote wider benefits to ways of working in terms of: Long term / Prevention / Integration / Collaboration / Involvement	3%
Criteria 33	Sustainability	Waste Reduction / Circular Economy	The scheme will include efficiencies or waste reduction within or across sectors E.g. Energy + Water	3%
Criteria 34	Sustainability	Aur Quality	The impact of the chosen technology solution on local air quality	3%
Criteria 35	Sustainability	Education	The scheme will support education about energy and the environment	2%

Proposition 1-A - Milford Haven Heat Network and Microgrid

Feasibility of developing a heat network and microgrid for Milford Marina for heat and power supply through electrolysis of excess energy from PoMH energy supply assets

Core Value	Potential Value	Core Supply (MW)	Core Supply (GWh/year)	Core Demand (GWh/year)
Provides more efficient & resilient local system	Enables development of additional renewables on the system	16.9MW solar 2.5MW wind	21.0	26.8

Proposition Elements

Criteria Satisfied

Time Horizon

2025 2030 2040 2050

Development Readiness Level

25% 50% 75% 100%

VECTORS

POWER

HEAT

TRANSPORT

NETWORK & TRANSMISSION SUMMARY

WPD DN
Potential for private wire connection

OWNERSHIP OF ASSETS

PoMH

QUALITATIVE TRIAGE RAG MATRIX

Criteria	Criteria Icon	Benefit	Constraint
Key Objective: Achieves emissions reductions, significant contribution to net-zero 2050 pathway			
Key Objective: Catalyst / First of a kind & supports future expansion *Potential to develop seed markets for hydrogen in the fields of heat, transport, gas & power.*			
Key Objective: Jobs & Prosperity *Stimulate growth in local community, Potential for job creation/upskilling, Decarbonises heating or transport for local community, Contribute to the alleviation of fuel poverty*			
Key Objective: Optimises social value (social, economic and environmental), in terms of the potential costs, benefits and risks			
Key Objective: Stakeholder / Community Acceptability & Awareness raising			
Critical Success Factor: Technical: Balance of supply & demand			
Critical Success Factor: Technical: Technology maturity *Existing vs novel technologies Supply chain - availability / investment required*			
Critical Success Factor: Contributes to Energy Resilience			
Critical Success Factor: Immediate Need / Opportunity Readiness			
Critical Success Factor: Commercial Opportunity			
Critical Success Factor: Commercial: Capex investment required			
Critical Success Factor: Investor Interest / Funding Streams			
Critical Success Factor: Complexity / Asset ownership / Number of parties			
Critical Success Factor: Policy & Regulatory Considerations			
Critical Success Factor: Development Risks & Scheme Constraints			
Wider Benefits: WFGA Goals *Prosperous / Resilient / Healthier / More equal / Cohesive communities / Vibrant culture / Globally responsible*			
Wider Benefits: WFGA Ways of Working *Long term / Prevention / Integration / Collaboration / Involvement*			
Wider Benefits: Waste Reduction / Circular Economy			

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Proposition 1-B: Milford Haven Comprehensive heat and power demand

Feasibility of meeting the existing and future heat and power demand of the Milford Haven Comprehensive school by Hydrogen through electrolysis of excess energy from PCC and PoMH owned assets.

Core Value	Potential Value	Core Supply (MW)	Core Supply (GWh/year)	Core Demand (GWh/year)
Linking up local supply-demand, releasing grid capacity for future renewables development.	Greater renewables development - growth of SLES.	10MW solar 2.5 MW wind	14.8	1.4

Proposition Elements

Criteria Satisfied

Time Horizon

2025 | 2030 | 2040 | 2050

Development Readiness Level

25% | 50% | 75% | 100%

VECTORS

POWER

HEAT

TRANSPORT

NETWORK & TRANSMISSION SUMMARY

Potential to isolate gas network connection to Milford Haven Comprehensive and replace with hydrogen connection (either via hydrogen pipeline or tanks).

OWNERSHIP OF ASSETS

PCC and PoMH

Criteria	Criteria Icon	Benefit	Constraint
Key Objective: Achieves emissions reductions, significant contribution to net-zero 2050 pathway			
Key Objective: Catalyst / First of a kind & supports future expansion *Potential to develop seed markets for hydrogen in the fields of heat, transport, gas & power.*			
Key Objective: Jobs & Prosperity *Stimulate growth in local community. Potential for job creation/upskilling. Decarbonises heating or transport for local community. Contribute to the alleviation of fuel poverty*			
Key Objective: Optimises social value (social, economic and environmental), in terms of the potential costs, benefits and risks			
Key Objective: Stakeholder / Community Acceptability & Awareness raising		Opportunity to demnstrate benefits through education	
Critical Success Factor: Technical: Balance of supply & demand			Supply could exceed demand significantly, at this scale is Hydrogen economical?
Critical Success Factor: Technical: Technology maturity *Existing vs novel technologies Supply chain - availability / investment required*			
Critical Success Factor: Contributes to Energy Resilience			
Critical Success Factor: Immediate Need / Opportunity Readiness		Redevelopment - need to understand timeframe but proposed giving opportunity for move to zero carbon heating / power.	
Critical Success Factor: Commercial Opportunity			
Critical Success Factor: Commercial: Capex investment required			
Critical Success Factor: Investor Interest / Funding Streams			
Critical Success Factor: Complexity / Asset ownership / Number of parties			
Critical Success Factor: Policy & Regulatory Considerations			
Critical Success Factor: Development Risks & Scheme Constraints			
Wider Benefits: WFGA Goals *Prosperous / Resilient / Healthier / More equal / Cohesive communities / Vibrant culture / Globally responsible*			
Wider Benefits: WFGA Ways of Working *Long term / Prevention / Integration / Collaboration / Involvement*			
Wider Benefits: Waste Reduction / Circular Economy			

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MH2 ENERGY KINGDOM / DEYRNAS YNNI

Proposition 1-C - Milford Haven transport demand

Feasibility of meeting the existing and future PCC and PoMH transport demand from Hydrogen through electrolysis of excess electricity from PCC and PoMH owned assets.

Core Value	Potential Value	Core Supply (MW)	Core Supply (GWh/year)	Core Demand (GWh/year)
Transport considered most commercially viable across H and electric.	Transport hub - potential seed market.	10MW solar 2.5MW wind	14.8	2.1

Proposition Elements

Criteria Satisfied

Time Horizon

2025 · 2030 · 2040 · 2050

Development Readiness Level

25% · 50% · 75% · 100%

VECTORS

POWER

HEAT

TRANSPORT

NETWORK & TRANSMISSION SUMMARY

Hydrogen to be elctrolysed at renewable assets and transported by tanker to point of vehicle refuelling

OWNERSHIP OF ASSETS

PCC & PoMH

Criteria	Criteria Icon	Benefit	Constraint
Key Objective: Achieves emissions reductions, significant contribution to net-zero 2050 pathway			
Key Objective: Catalyst / First of a kind & supports future expansion *Potential to develop seed markets for hydrogen in the fields of heat, transport, gas & power.*			
Key Objective: Jobs & Prosperity *Stimulate growth in local community, Potential for job creation/upskilling, Decarbonises heating or transport for local community, Contribute to the alleviation of fuel poverty*			
Key Objective: Optimises social value (social, economic and environmental), in terms of the potential costs, benefits and risks			
Key Objective: Stakeholder / Community Acceptability & Awareness raising			
Critical Success Factor: Technical: Balance of supply & demand			
Critical Success Factor: Technical: Technology maturity *Existing vs novel technologies Supply chain - availability / investment required*			
Critical Success Factor: Contributes to Energy Resilience			
Critical Success Factor: Immediate Need / Opportunity Readiness		There may be an intermediate need to have electric vehicle fleet in the transition to Hydrogen vehicle fleet. Hydrogen for shipping is less ready considering refuelling of vessel is usually done at different ports.	
Critical Success Factor: Commercial Opportunity			
Critical Success Factor: Commercial: Capex investment required			
Critical Success Factor: Investor Interest / Funding Streams			
Critical Success Factor: Complexity / Asset ownership / Number of parties			Opportunity to expand to vessel/hydrogen for shipping and individual/public transport demand but with asset ownership complexities
Critical Success Factor: Policy & Regulatory Considerations			
Critical Success Factor: Development Risks & Scheme Constraints			
Wider Benefits: WFGA Goals *Prosperous / Resilient / Healthier / More equal / Cohesive communities / Vibrant culture / Globally responsible*			
Wider Benefits: WFGA Ways of Working *Long term / Prevention / Integration / Collaboration / Involvement*			
Wider Benefits: Waste Reduction / Circular Economy			

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ENERGY KINGDOM
DEYRNAS YNNI

Proposition 1-D - PCC Recycling Facility

This proposition integrates a proposed recycling centre at the current Milford Haven Puma Energy site with existing local renewable energy supplies.

Core Value	Potential Value	Core Supply (MW)	Core Supply (GWh/year)	Core Demand (GWh/year)

Proposition Elements

Criteria Satisfied

Time Horizon

2025 2030 2040 2050

Development Readiness Level

25% 50% 75% 100%

VECTORS

POWER

HEAT

TRANSPORT

NETWORK & TRANSMISSION SUMMARY

Hydrogen to be elctrolysed at renewable assets and transported by tanker to point of vehicle refuelling

OWNERSHIP OF ASSETS

PCC & PoMH

Criteria	Criteria Icon	Benefit	Constraint
Key Objective: Achieves emissions reductions, significant contribution to net-zero 2050 pathway			
Key Objective: Catalyst / First of a kind & supports future expansion *Potential to develop seed markets for hydrogen in the fields of heat, transport, gas & power.*			
Key Objective: Jobs & Prosperity *Stimulate growth in local community, Potential for job creation/upskilling, Decarbonises heating or transport for local community, Contribute to the alleviation of fuel poverty*			
Key Objective: Optimises social value (social, economic and environmental), in terms of the potential costs, benefits and risks			
Key Objective: Stakeholder / Community Acceptability & Awareness raising			
Critical Success Factor: Technical: Balance of supply & demand			
Critical Success Factor: Technical: Technology maturity *Existing vs novel technologies Supply chain - availability / investment required*			
Critical Success Factor: Contributes to Energy Resilience			
Critical Success Factor: Immediate Need / Opportunity Readiness			
Critical Success Factor: Commercial Opportunity			
Critical Success Factor: Commercial: Capex investment required			
Critical Success Factor: Investor Interest / Funding Streams			
Critical Success Factor: Complexity / Asset ownership / Number of parties			
Critical Success Factor: Policy & Regulatory Considerations			
Critical Success Factor: Development Risks & Scheme Constraints			
Wider Benefits: WFGA Goals *Prosperous / Resilient / Healthier / More equal / Cohesive communities / Vibrant culture / Globally responsible*			
Wider Benefits: WFGA Ways of Working *Long term / Prevention / Integration / Collaboration / Involvement*			
Wider Benefits: Waste Reduction / Circular Economy			

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Proposition 2-A - Haverfordwest High School (Prendergast and Portfield Campus)

Meeting power demand of Haverfordwest High School campuses from nearby renewable energy assets and heat demand through the electrolysis of excess renewable energy.

Core Value	Potential Value	Core Supply (MW)	Core Supply (GWh/year)	Core Demand (GWh/year)
Redevelopment opportunity & stepping stone to wider cluster.		65MW solar	58.1	3.7

Proposition Elements

Criteria Satisfied

Time Horizon

2025 2030 2040 2050

Development Readiness Level

25% 50% 75% 100%

VECTORS

POWER

HEAT

TRANSPORT

NETWORK & TRANSMISSION SUMMARY

OWNERSHIP OF ASSETS

Demand assets PCC ownership

Multiple supply assets private owners

QUALITATIVE TRIAGE RAG MATRIX

Criteria	Criteria Icon	Benefit	Constraint
Key Objective: Achieves emissions reductions, significant contribution to net-zero 2050 pathway			
Key Objective: Catalyst / First of a kind & supports future expansion *Potential to develop seed markets for hydrogen in the fields of heat, transport, gas & power.*			
Key Objective: Jobs & Prosperity *Stimulate growth in local community. Potential for job creation/upskilling. Decarbonises heating or transport for local community. Contribute to the alleviation of fuel poverty*			
Key Objective: Optimises social value (social, economic and environmental), in terms of the potential costs, benefits and risks			
Key Objective: Stakeholder / Community Acceptability & Awareness raising			
Critical Success Factor: Technical: Balance of supply & demand			
Critical Success Factor: Technical: Technology maturity *Existing vs novel technologies Supply chain - availability / investment required*			
Critical Success Factor: Contributes to Energy Resilience		Multiple independent energy supply points	
Critical Success Factor: Immediate Need / Opportunity Readiness		High School - need to understand timeframe and scale of proposed works, giving opportunity to move to zero carbon heating / power as well as more low carbon energy generation.	
Critical Success Factor: Commercial Opportunity			
Critical Success Factor: Commercial: Capex investment required			
Critical Success Factor: Investor Interest / Funding Streams			
Critical Success Factor: Complexity / Asset ownership / Number of parties		Multiple Renewables asset owners	
Critical Success Factor: Policy & Regulatory Considerations			
Critical Success Factor: Development Risks & Scheme Constraints			
Wider Benefits: WFGA Goals *Prosperous / Resilient / Healthier / More equal / Cohesive communities / Vibrant culture / Globally responsible*		Local and multiple energy supply points.	
Wider Benefits: WFGA Ways of Working *Long term / Prevention / Integration / Collaboration / Involvement*			
Wider Benefits: Waste Reduction / Circular Economy			

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MH2 ENERGY KINGDOM DEYRNAS YNNI

Proposition 2-B - Haverfordwest Hospitals (BroCerwyn and Whitybush)

Providing Hydrogen for heat and transport demand as well as potential oxygen demand for Haverfordwest hospitals through the electrolysis of excess renewable energy from nearby assets.

Core Value	Potential Value	Core Supply (MW)	Core Supply (GWh/year)	Core Demand (GWh/year)
Integration of multiple vectors.		59MW solar 2MW wind	56.4	20.8

Proposition Elements

Criteria Satisfied

Time Horizon

2025 2030 2040 2050

Development Readiness Level

25% 50% 75% 100%

VECTORS

POWER

HEAT

TRANSPORT

NETWORK & TRANSMISSION SUMMARY

Hydrogen delivered via tanker to hospital and ambulance base sites

OWNERSHIP OF ASSETS

Demand assets PCC & NHS ownership. Welsh Water required further engagement for potential transport demand

Multiple supply assets private owners

QUALITATIVE TRIAGE RAG MATRIX

Criteria	Criteria Icon	Benefit	Constraint
Key Objective: Achieves emissions reductions, significant contribution to net-zero 2050 pathway			
Key Objective: Catalyst / First of a kind & supports future expansion *Potential to develop seed markets for hydrogen in the fields of heat, transport, gas & power.*		Using oxygen for hospital demand is an opportunity to reap more benefits from electrolysis	
Key Objective: Jobs & Prosperity *Stimulate growth in local community, Potential for job creation/upskilling, Decarbonises heating or transport for local community, Contribute to the alleviation of fuel poverty*			
Key Objective: Optimises social value (social, economic and environmental), in terms of the potential costs, benefits and risks			
Key Objective: Stakeholder / Community Acceptability & Awareness raising			
Critical Success Factor: Technical: Balance of supply & demand			
Critical Success Factor: Technical: Technology maturity *Existing vs novel technologies Supply chain - availability / investment required*			Are there any additional processes to ensure oxygen from electrolysis can be used for medical purposes?
Critical Success Factor: Contributes to Energy Resilience			
Critical Success Factor: Immediate Need / Opportunity Readiness			
Critical Success Factor: Commercial Opportunity			
Critical Success Factor: Commercial: Capex investment required			
Critical Success Factor: Investor Interest / Funding Streams			
Critical Success Factor: Complexity / Asset ownership / Number of parties		Multiple supply and demand assets owners	
Critical Success Factor: Policy & Regulatory Considerations			Regulation around medical use of oxygen
Critical Success Factor: Development Risks & Scheme Constraints			
Wider Benefits: WFGA Goals *Prosperous / Resilient / Healthier / More equal / Cohesive communities / Vibrant culture / Globally responsible*			
Wider Benefits: WFGA Ways of Working *Long term / Prevention / Integration / Collaboration / Involvement*			
Wider Benefits: Waste Reduction / Circular Economy			

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ENERGY KINGDOM
DEYRNAS YNNI

Proposition 2-C - Haverfordwest Creamery

Meeting heat demand of Haverfordwest creamery using hydrogen from biomass conversion of sewage sludge and power demand from nearby renewable energy assets.

Core Value	Potential Value	Core Supply (MW)	Core Supply (GWh/year)	Core Demand (GWh/year)
Integration of multiple vectors.		23MW solar	20.6	3.3

Proposition Elements

Criteria Satisfied

Time Horizon

2025 2030 2040 2050

Development Readiness Level

25% 50% 75% 100%

VECTORS

POWER

HEAT

TRANSPORT

NETWORK & TRANSMISSION SUMMARY

Hydrogen delivered by tanker or hydrogen pipelines from point of electrolysis to demand centres

OWNERSHIP OF ASSETS

PCC owned housing

Creamery is privately owned (First Milk)

Multiple supply asset private owners

Sewage water treatment owned by Welsh Water

Criteria	Criteria Icon	Benefit	Constraint
Key Objective: Achieves emissions reductions, significant contribution to net-zero 2050 pathway			
Key Objective: Catalyst / First of a kind & supports future expansion *Potential to develop seed markets for hydrogen in the fields of heat, transport, gas & power.*			
Key Objective: Jobs & Prosperity *Stimulate growth in local community, Potential for job creation/upskilling, Decarbonises heating or transport for local community, Contribute to the alleviation of fuel poverty*			
Key Objective: Optimises social value (social, economic and environmental), in terms of the potential costs, benefits and risks			
Key Objective: Stakeholder / Community Acceptability & Awareness raising			
Critical Success Factor: Technical: Balance of supply & demand			
Critical Success Factor: Technical: Technology maturity *Existing vs novel technologies Supply chain - availability / investment required*			
Critical Success Factor: Contributes to Energy Resilience			
Critical Success Factor: Immediate Need / Opportunity Readiness			
Critical Success Factor: Commercial Opportunity			
Critical Success Factor: Commercial: Capex investment required			
Critical Success Factor: Investor Interest / Funding Streams			
Critical Success Factor: Complexity / Asset ownership / Number of parties			
Critical Success Factor: Policy & Regulatory Considerations			
Critical Success Factor: Development Risks & Scheme Constraints			
Wider Benefits: WFGA Goals *Prosperous / Resilient / Healthier / More equal / Cohesive communities / Vibrant culture / Globally responsible*			
Wider Benefits: WFGA Ways of Working *Long term / Prevention / Integration / Collaboration / Involvement*			
Wider Benefits: Waste Reduction / Circular Economy			

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Proposition 2-D - Bolton Hill Water Treatment Works Oxygen demand

Proposition to supply oxygen to the Bolton Hill sewage water treatment works through the electrolysis of excess energy from nearby renewable assets.

Core Value	Potential Value	Core Supply (MW)	Core Supply (GWh/year)	Core Demand (GWh/year)
Integration of multiple vectors.		23MW solar 2MW wind	51.2	3.3

Proposition Elements

Criteria Satisfied

Time Horizon

2025 2030 2040 2050

Development Readiness Level

25% 50% 75% 100%

VECTORS

POWER

HEAT

TRANSPORT

NETWORK & TRANSMISSION SUMMARY

Hydrogen delivered by tanker or hydrogen pipelines from point of electrolysis to demand centres

OWNERSHIP OF ASSETS

PCC owned housing

Creamery is privately owned (First Milk).

Water treatment works owned by Welsh Water

Multiple supply asset private owners

QUALITATIVE TRIAGE RAG MATRIX

Criteria	Criteria Icon	Benefit	Constraint
Key Objective: Achieves emissions reductions, significant contribution to net-zero 2050 pathway			
Key Objective: Catalyst / First of a kind & supports future expansion *Potential to develop seed markets for hydrogen in the fields of heat, transport, gas & power.*		Using oxygen for hospital demand is an opportunity to reap more benefits from electrolysis	
Key Objective: Jobs & Prosperity *Stimulate growth in local community, Potential for job creation/upskilling, Decarbonises heating or transport for local community, Contribute to the alleviation of fuel poverty*			
Key Objective: Optimises social value (social, economic and environmental), in terms of the potential costs, benefits and risks			
Key Objective: Stakeholder / Community Acceptability & Awareness raising			
Critical Success Factor: Technical: Balance of supply & demand			
Critical Success Factor: Technical: Technology maturity *Existing vs novel technologies Supply chain - availability / investment required*			*Are there any additional processes to for use of oxygen for water treatment works?*
Critical Success Factor: Contributes to Energy Resilience			
Critical Success Factor: Immediate Need / Opportunity Readiness			
Critical Success Factor: Commercial Opportunity			
Critical Success Factor: Commercial: Capex investment required			
Critical Success Factor: Investor Interest / Funding Streams			
Critical Success Factor: Complexity / Asset ownership / Number of parties			
Critical Success Factor: Policy & Regulatory Considerations			
Critical Success Factor: Development Risks & Scheme Constraints			
Wider Benefits: WFGA Goals *Prosperous / Resilient / Healthier / More equal / Cohesive communities / Vibrant culture / Globally responsible*			
Wider Benefits: WFGA Ways of Working *Long term / Prevention / Integration / Collaboration / Involvement*			
Wider Benefits: Waste Reduction / Circular Economy			

MH2 ENERGY KINGDOM DEYRNAS YNNI

Proposition 2-E - Haverfordwest Airport airplane (transport) demand

Longer term proposition to supply blue hydrogen for airplane refuelling at Haverfordwest airport and general heat demand within the MH boundary through reformation of natural gas

Core Value	Potential Value	Core Supply (MW)	Core Supply (GWh/year)	Core Demand (GWh/year)
	Future transport opportunity.			

Proposition Elements

Criteria Satisfied

Time Horizon

2025 2030 2040 2050

Development Readiness Level

25% 50% 75% 100%

VECTORS

POWER

HEAT

TRANSPORT

NETWORK & TRANSMISSION SUMMARY

Milford Haven boundary is isolated and gas network is reconfigured to become an isolated hydrogen distribution network.

OWNERSHIP OF ASSETS

Complex asset ownership including industrial, commercial and residential for the future heat demand of MH

QUALITATIVE TRIAGE RAG MATRIX

Criteria	Criteria Icon	Benefit	Constraint
Key Objective: Achieves emissions reductions, significant contribution to net-zero 2050 pathway			
Key Objective: Catalyst / First of a kind & supports future expansion *Potential to develop seed markets for hydrogen in the fields of heat, transport, gas & power.*			
Key Objective: Jobs & Prosperity *Stimulate growth in local community. Potential for job creation/upskilling. Decarbonises heating or transport for local community. Contribute to the alleviation of fuel poverty*			
Key Objective: Optimises social value (social, economic and environmental), in terms of the potential costs, benefits and risks			
Key Objective: Stakeholder / Community Acceptability & Awareness raising			
Critical Success Factor: Technical: Balance of supply & demand			
Critical Success Factor: Technical: Technology maturity *Existing vs novel technologies Supply chain - availability / investment required*			
Critical Success Factor: Contributes to Energy Resilience			
Critical Success Factor: Immediate Need / Opportunity Readiness			
Critical Success Factor: Commercial Opportunity			
Critical Success Factor: Commercial: Capex investment required			
Critical Success Factor: Investor Interest / Funding Streams			
Critical Success Factor: Complexity / Asset ownership / Number of parties			
Critical Success Factor: Policy & Regulatory Considerations			
Critical Success Factor: Development Risks & Scheme Constraints			
Wider Benefits: WFGA Goals *Prosperous / Resilient / Healthier / More equal / Cohesive communities / Vibrant culture / Globally responsible*			
Wider Benefits: WFGA Ways of Working *Long term / Prevention / Integration / Collaboration / Involvement*			
Wider Benefits: Waste Reduction / Circular Economy			

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Proposition 2-F - Riverside Shopping Centre

Proposition to provide heat and power to Riverside Shopping Centre in Haverfordwest. This will most likely be via a microgrid due to current electric heating infrastructure.

Core Value	Potential Value	Core Supply (MW)	Core Supply (GWh/year)	Core Demand (GWh/year)

Proposition Elements

Criteria Satisfied

Time Horizon

2025 2030 2040 2050

Development Readiness Level

25% 50% 75% 100%

VECTORS

POWER

HEAT

TRANSPORT

NETWORK & TRANSMISSION SUMMARY

Hydrogen produced on site or delivered by tanker or hydrogen pipelines from point of electrolysis to demand centres

OWNERSHIP OF ASSETS

PCC owned housing and shopping centre however, multiple tenants within shopping centre

Water vehicle hub owned by Welsh Water

Multiple supply asset private owners

Criteria	Criteria Icon	Benefit	Constraint
Key Objective: Achieves emissions reductions, significant contribution to net-zero 2050 pathway			
Key Objective: Catalyst / First of a kind & supports future expansion *Potential to develop seed markets for hydrogen in the fields of heat, transport, gas & power.*			
Key Objective: Jobs & Prosperity *Stimulate growth in local community, Potential for job creation/upskilling, Decarbonises heating or transport for local community, Contribute to the alleviation of fuel poverty*			
Key Objective: Optimises social value (social, economic and environmental), in terms of the potential costs, benefits and risks			
Key Objective: Stakeholder / Community Acceptability & Awareness raising			
Critical Success Factor: Technical: Balance of supply & demand			
Critical Success Factor: Technical: Technology maturity *Existing vs novel technologies Supply chain - availability / investment required*			
Critical Success Factor: Contributes to Energy Resilience			
Critical Success Factor: Immediate Need / Opportunity Readiness			
Critical Success Factor: Commercial Opportunity			
Critical Success Factor: Commercial: Capex investment required			
Critical Success Factor: Investor Interest / Funding Streams			
Critical Success Factor: Complexity / Asset ownership / Number of parties			
Critical Success Factor: Policy & Regulatory Considerations			
Critical Success Factor: Development Risks & Scheme Constraints			Risks due to requirement of river crossing
Wider Benefits: WFGA Goals *Prosperous / Resilient / Healthier / More equal / Cohesive communities / Vibrant culture / Globally responsible*			
Wider Benefits: WFGA Ways of Working *Long term / Prevention / Integration / Collaboration / Involvement*			
Wider Benefits: Waste Reduction / Circular Economy			Would need to replace all electrical heating systems which would increase waste

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Proposition 2-G - Pembrokeshire Food Park

Electricity from the nearby airport is used to create hydrogen to power freight from Pembrokeshire Food Park.

Core Value	Potential Value	Core Supply (MW)	Core Supply (GWh/year)	Core Demand (GWh/year)

Proposition Elements

Criteria Satisfied

Time Horizon

2025 2030 2040 2050

Development Readiness Level

25% 50% 75% 100%

VECTORS

POWER

HEAT

TRANSPORT

NETWORK & TRANSMISSION SUMMARY

Private wire or new hydrogen pipes used to transport energy from airport to nearby food park. Potential for hydrogen to be tankered to Creamery.

OWNERSHIP OF ASSETS

QUALITATIVE TRIAGE RAG MATRIX

Criteria	Criteria Icon	Benefit	Constraint
Key Objective: Achieves emissions reductions, significant contribution to net-zero 2050 pathway			
Key Objective: Catalyst / First of a kind & supports future expansion *Potential to develop seed markets for hydrogen in the fields of heat, transport, gas & power.*			
Key Objective: Jobs & Prosperity *Stimulate growth in local community. Potential for job creation/upskilling. Decarbonises heating or transport for local community. Contribute to the alleviation of fuel poverty*			
Key Objective: Optimises social value (social, economic and environmental), in terms of the potential costs, benefits and risks			
Key Objective: Stakeholder / Community Acceptability & Awareness raising			
Critical Success Factor: Technical: Balance of supply & demand			
Critical Success Factor: Technical: Technology maturity *Existing vs novel technologies Supply chain - availability / investment required*			
Critical Success Factor: Contributes to Energy Resilience			
Critical Success Factor: Immediate Need / Opportunity Readiness			
Critical Success Factor: Commercial Opportunity			
Critical Success Factor: Commercial: Capex investment required			
Critical Success Factor: Investor Interest / Funding Streams			
Critical Success Factor: Complexity / Asset ownership / Number of parties			
Critical Success Factor: Policy & Regulatory Considerations			
Critical Success Factor: Development Risks & Scheme Constraints			
Wider Benefits: WFGA Goals *Prosperous / Resilient / Healthier / More equal / Cohesive communities / Vibrant culture / Globally responsible*			
Wider Benefits: WFGA Ways of Working *Long term / Prevention / Integration / Collaboration / Involvement*			
Wider Benefits: Waste Reduction / Circular Economy			

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Proposition 3 - Pembroke Schools & Leisure (Henry Tudor, Pembroke Dock Community & Pembroke Leisure Centre)

Feasibility of meeting the existing and future heat and power demand of existing PCC school & leisure assets from renewable assets and by Hydrogen through electrolysis of excess energy.

Core Value	Potential Value	Core Supply (MW)	Core Supply (GWh/year)	Core Demand (GWh/year)
Significant local renewables, increasing localised use.	Relieving network locally creates greater opportunity for renewables development.	44MW solar	38.9	2.0

Proposition Elements

Criteria Satisfied

Time Horizon

2025 2030 2040 2050

Development Readiness Level

25% 50% 75% 100%

VECTORS

POWER

HEAT

TRANSPORT

NETWORK & TRANSMISSION SUMMARY

Hydrogen delivered by tanker or hydrogen pipelines from point of electrolysis to demand centres

OWNERSHIP OF ASSETS

PCC owned demand assets
PCC owned supply asset with potential for expansion
Multiple other supply assets, private owners

QUALITATIVE TRIAGE RAG MATRIX

Criteria	Criteria Icon	Benefit	Constraint
Key Objective: Achieves emissions reductions, significant contribution to net-zero 2050 pathway			
Key Objective: Catalyst / First of a kind & supports future expansion *Potential to develop seed markets for hydrogen in the fields of heat, transport, gas & power.*			
Key Objective: Jobs & Prosperity *Stimulate growth in local community, Potential for job creation/upskilling, Decarbonises heating or transport for local community, Contribute to the alleviation of fuel poverty*			
Key Objective: Optimises social value (social, economic and environmental), in terms of the potential costs, benefits and risks			
Key Objective: Stakeholder / Community Acceptability & Awareness raising			
Critical Success Factor: Technical: Balance of supply & demand			
Critical Success Factor: Technical: Technology maturity *Existing vs novel technologies Supply chain - availability / investment required*			
Critical Success Factor: Contributes to Energy Resilience			
Critical Success Factor: Immediate Need / Opportunity Readiness			
Critical Success Factor: Commercial Opportunity			
Critical Success Factor: Commercial: Capex investment required			
Critical Success Factor: Investor Interest / Funding Streams			
Critical Success Factor: Complexity / Asset ownership / Number of parties			
Critical Success Factor: Policy & Regulatory Considerations			
Critical Success Factor: Development Risks & Scheme Constraints			
Wider Benefits: WFGA Goals *Prosperous / Resilient / Healthier / More equal / Cohesive communities / Vibrant culture / Globally responsible*			
Wider Benefits: WFGA Ways of Working *Long term / Prevention / Integration / Collaboration / Involvement*			
Wider Benefits: Waste Reduction / Circular Economy			

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Proposition 4-A - Industrial scale H2 Hub, Pembroke & Milford Haven

Transition of the Haven waterway industrial energy sector towards being a major UK H and CO2 hub. Includes H production, storage, import/export and CO2 storage and export in the longer term.

Core Value	Potential Value	Core Capacity	Potential Capacity	Core Demand	Potential Demand
Provides transition for existing industry and job security.	MH as UK H Hub - creating greater regional prosperity & job growth.				

Proposition Elements

Criteria Satisfied

Time Horizon

2025 2030 2040 2050

Development Readiness Level

25% 50% 75% 100%

VECTORS

POWER

HEAT

TRANSPORT

NETWORK & TRANSMISSION SUMMARY

Hydrogen and natural gas pipelines into the port area, hydrogen pipelines or repurposed gas network to transport hydrogen to point of use

OWNERSHIP OF ASSETS

Valero
Dragon LNG
RWE
Blue Gem Wind

QUALITATIVE TRIAGE RAG MATRIX

Criteria	Criteria Icon	Benefit	Constraint
Key Objective: Achieves emissions reductions, significant contribution to net-zero 2050 pathway			
Key Objective: Catalyst / First of a kind & supports future expansion *Potential to develop seed markets for hydrogen in the fields of heat, transport, gas & power.*			
Key Objective: Jobs & Prosperity *Stimulate growth in local community, Potential for job creation/upskilling, Decarbonises heating or transport for local community, Contribute to the alleviation of fuel poverty*		Securing jobs for the Hydrocarbon workforce	
Key Objective: Optimises social value (social, economic and environmental), in terms of the potential costs, benefits and risks			
Key Objective: Stakeholder / Community Acceptability & Awareness raising			
Critical Success Factor: Technical: Balance of supply & demand			
Critical Success Factor: Technical: Technology maturity *Existing vs novel technologies Supply chain - availability / investment required*			
Critical Success Factor: Contributes to Energy Resilience			
Critical Success Factor: Immediate Need / Opportunity Readiness			
Critical Success Factor: Commercial Opportunity			
Critical Success Factor: Commercial: Capex investment required			
Critical Success Factor: Investor Interest / Funding Streams			
Critical Success Factor: Complexity / Asset ownership / Number of parties			
Critical Success Factor: Policy & Regulatory Considerations			
Critical Success Factor: Development Risks & Scheme Constraints			
Wider Benefits: WFGA Goals *Prosperous / Resilient / Healthier / More equal / Cohesive communities / Vibrant culture / Globally responsible*			
Wider Benefits: WFGA Ways of Working *Long term / Prevention / Integration / Collaboration / Involvement*			
Wider Benefits: Waste Reduction / Circular Economy			

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Proposition 4-B Pembroke SLES inc. industrial scale H2 Hub

Transition of the Pembroke area to a smart interconnected local system balancing electric or hydrogen supply based on availability & seasonality. Import of green H for UK transmission.

Core Value	Potential Value	Core Capacity	Potential Capacity	Core Demand	Potential Demand
Provides stimulus for greater renewables deployment, contributing beyond MH.	Green recovery / growth & replicable model.				

Proposition Elements

Criteria Satisfied

Time Horizon

2025 2030 2040 2050

Development Readiness Level

25% 50% 75% 100%

VECTORS

POWER

HEAT

TRANSPORT

NETWORK & TRANSMISSION

Greenlink Interconnector

Upgrade of DN locally to enable better use / balancing of additional renewables

H international import / national export as UK hub

OWNERSHIP OF ASSETS

Valero

Dragon LNG

RWE

Blue Gem Wind

QUALITATIVE TRIAGE RAG MATRIX

Criteria	Criteria Icon	Benefit	Constraint
Key Objective: Achieves emissions reductions, significant contribution to net-zero 2050 pathway			Is the energy supplied from RWE power station low carbon?
Key Objective: Catalyst / First of a kind & supports future expansion *Potential to develop seed markets for hydrogen in the fields of heat, transport, gas & power.*			
Key Objective: Jobs & Prosperity *Stimulate growth in local community. Potential for job creation/upskilling. Decarbonises heating or transport for local community. Contribute to the alleviation of fuel poverty*			
Key Objective: Optimises social value (social, economic and environmental), in terms of the potential costs, benefits and risks			
Key Objective: Stakeholder / Community Acceptability & Awareness raising			
Critical Success Factor: Technical: Balance of supply & demand			
Critical Success Factor: Technical: Technology maturity *Existing vs novel technologies Supply chain - availability / investment required*			
Critical Success Factor: Contributes to Energy Resilience			
Critical Success Factor: Immediate Need / Opportunity Readiness			
Critical Success Factor: Commercial Opportunity			
Critical Success Factor: Commercial: Capex investment required			
Critical Success Factor: Investor Interest / Funding Streams			
Critical Success Factor: Complexity / Asset ownership / Number of parties			
Critical Success Factor: Policy & Regulatory Considerations			
Critical Success Factor: Development Risks & Scheme Constraints			
Wider Benefits: WFGA Goals *Prosperous / Resilient / Healthier / More equal / Cohesive communities / Vibrant culture / Globally responsible*			
Wider Benefits: WFGA Ways of Working *Long term / Prevention / Integration / Collaboration / Involvement*			
Wider Benefits: Waste Reduction / Circular Economy			

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Proposition 5 - Middle Scoveson Solar Farm, Neyland

Heat demand of Neyland Health centre through the electrolysis of excess energy from existing and proposed renewable energy assets.

Core Value	Potential Value	Core Supply (MW)	Core Supply (GWh/year)	Core Demand (GWh/year)
Localised use of existing assets.	Potential to isolate area of network & develop early SLES.	10MW solar 8MW wind	0.1	28.3

Proposition Elements

Criteria Satisfied

Time Horizon

2025 2030 2040 2050

Development Readiness Level

25% 50% 75% 100%

VECTORS

POWER

HEAT

TRANSPORT

NETWORK & TRANSMISSION SUMMARY

Hydrogen delivered by tanker or hydrogen pipelines from point of electrolysis to demand centres

OWNERSHIP OF ASSETS

PCC owned demand assets

Privately owned supply assets

QUALITATIVE TRIAGE RAG MATRIX

Criteria	Criteria Icon	Benefit	Constraint
Key Objective: Achieves emissions reductions, significant contribution to net-zero 2050 pathway			
Key Objective: Catalyst / First of a kind & supports future expansion *Potential to develop seed markets for hydrogen in the fields of heat, transport, gas & power.*			
Key Objective: Jobs & Prosperity *Stimulate growth in local community, Potential for job creation/upskilling, Decarbonises heating or transport for local community, Contribute to the alleviation of fuel poverty*			
Key Objective: Optimises social value (social, economic and environmental), in terms of the potential costs, benefits and risks			
Key Objective: Stakeholder / Community Acceptability & Awareness raising			
Critical Success Factor: Technical: Balance of supply & demand			
Critical Success Factor: Technical: Technology maturity *Existing vs novel technologies Supply chain - availability / investment required*			
Critical Success Factor: Contributes to Energy Resilience			
Critical Success Factor: Immediate Need / Opportunity Readiness			
Critical Success Factor: Commercial Opportunity			
Critical Success Factor: Commercial: Capex investment required			
Critical Success Factor: Investor Interest / Funding Streams			
Critical Success Factor: Complexity / Asset ownership / Number of parties			
Critical Success Factor: Policy & Regulatory Considerations			
Critical Success Factor: Development Risks & Scheme Constraints			
Wider Benefits: WFGA Goals *Prosperous / Resilient / Healthier / More equal / Cohesive communities / Vibrant culture / Globally responsible*			
Wider Benefits: WFGA Ways of Working *Long term / Prevention / Integration / Collaboration / Involvement*			
Wider Benefits: Waste Reduction / Circular Economy			

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