

Ymddiriedolaeth
Elusennol Ynys Môn
*Isle of Anglesey
Charitable Trust*



Ynys Môn Hydrogen Island

Adroddiad Rhan 1



Stage 1 Report

i/for

Menter Môn

Gorffennaf / July 2019

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Hoffai Guto Owen, Cyfarwyddwr Ynni Glân, ddiolch yn fawr i Menter Môn am eu cymorth arbennig wrth llywio'r prosiect ac i'r holl gyfranddalwyr a roddod eu hamser hael ac am fwydo eu syniadau gwerthfawr, sydd wedi arwain at yr adroddiad hon.

Executive Summary

This 1st stage of the Ynys Môn Hydrogen Island project has:

- involved a research and consultation exercise with stakeholders in order to formalise the Ynys Môn Hydrogen Island concept, to assess relevant local expertise and local appetite for projects and to subsequently map and identify a specific project pathway for the 2020s;
- involved a soft market testing exercise with international hydrogen technology companies and related services in order to gauge interest in Ynys Môn Hydrogen Island;
- learnt from the many, swiftly-emerging international developments taking place around hydrogen and which have helped to inform and shape the work.

The stakeholder research and consultation has proved very positive with a strong appetite for pursuing hydrogen projects on Ynys Môn being conveyed, building on the island's many relevant advantages, as explained below.

The specific project opportunities which have been identified are:

- Holyhead "Hydrogen" Port
- Large-scale power to gas
- Hydrogen for transport
- Community hydrogen
- Hydrogen for heat

The project now seeks additional funding to prepare business cases for these identified project opportunities as the next stage of Ynys Môn Hydrogen Island.

The soft market testing amongst international hydrogen technology suppliers was a valuable, initial exercise in both placing Ynys Môn on the "hydrogen map" of emerging opportunities and in establishing a firm, positive response from these potential suppliers and collaborators. Indeed, responses from some companies went beyond the expected by eliciting a keen desire to immediately discuss collaboration, based on experience which is very relevant to the specific project opportunities.

“Unfair advantage”

The 1st stage identified green hydrogen production from renewable energy as being particularly suitable for Ynys Môn, due to the abundant resource - tidal, wind, solar - on and around the island. Such power-to-gas technologies are suitable at both community-scale as well as GW-scale deployment (as evidenced by proposals for the North Sea which could potentially be emulated in the seas around Ynys Môn).

It became clear during the work that the prospects of developing a strong hydrogen focus for Ynys Môn was entirely in-step with and could provide considerable added value to the existing Energy Island concept of economic development based on energy. For example, hydrogen production can release the full potential of renewables and can also be produced as a by-product of advanced nuclear reactors.

The Energy Island framework therefore proved hugely advantageous in quickly gaining stakeholder interest and enthusiasm for hydrogen; and in reaching consensus on the recommended next steps.

The building blocks to advance hydrogen on Ynys Môn - as a complement to not only the Energy Island project but also the North Anglesey Economic Regeneration Plan and the Enterprise Zone - are in place locally. The primary renewable energy resource is bountiful; the infrastructure (road, rail, strategic sites, electricity and gas grids) is extensive although incomplete (hydrogen can be applied in both contexts); and there is a very strong network of skilled people who can steer and control developments.

Coupled with wider initiatives including the North Wales Growth Deal and the connections which can be made with Ireland and NW England, Ynys Môn is in a unique position to be a major player in the emerging hydrogen economy. At the crossroads between Ireland and Wales and the rest of the UK, Ynys Môn is at geographical sweet-spot.

Or, as Dafydd Gruffydd, Managing Director at Menter Môn perfectly summed it up, Ynys Môn has an unfair advantage.

The next, project development stage will enable the preparation of high-level studies and business cases for each identified project - in effect the creation of a prospectus; which will aim to lead to formal project partnerships being forged between stakeholders, technology companies, investors and others but underpinned by the need to establish local ownership of hydrogen under the control of Menter Môn.

1 Introduction

In May 2019, Ynni Glân was commissioned by Menter Môn to co-ordinate and deliver Phase 1 of Ynys Môn Hydrogen Island under a set of clearly defined work packages, drawing-on Ynni Glân's expertise in the field of hydrogen and an extensive network of potential collaboration partners.

The work packages being:

- WP1 Engagement** - Stakeholder engagement
- WP2 Evidence** - Review of current, relevant hydrogen-related activities
- WP3 Identification** - Identifying specific project opportunities
- WP4 Report** - Presenting the results of Phase 1

Ynys Môn (Anglesey) is Wales' largest island with a population of 70,000. It is strategically located; connecting Ireland with Wales and the UK via Holyhead port and major road and rail links. There are sizeable electricity and gas networks (although incomplete) which connect Ynys Môn to the rest of Wales and the UK; together with strategic sites on the island which have been identified for major economic development.

Ynys Môn has high renewable energy potential which is under-exploited and, as an alternative to connecting to an electricity grid which may be constrained, primary renewable energy can be used to produce green hydrogen via electrolysis for multiple applications and for sector-coupling - between power, heat and transport sector networks. The project can therefore fully complement and add value to the goals of Anglesey Energy Island.

A prime example of the resource potential is Menter Môn's Morlais tidal energy project which has mapped 240MW of tidal energy potential around the north-west coast of Anglesey but constraints may prove a barrier to connecting all this resource to the electricity grid.

Therefore, Menter Môn has identified hydrogen production as an alternative to connecting to the grid, so forming the basis for undertaking this study. But the potential is not limited to tidal and extends to the island's extensive renewable resources in wind (especially offshore) and solar.

This renewable resource has now been further underlined by the August 2019 publication of the Welsh Government's draft National Development Framework which, under Policy 10, identifies a large central portion of Ynys Môn as a Priority Area for Wind and Solar Energy. The Policy states that within Priority Areas: *"There is a presumption in favour of development for these schemes and an associated acceptance of landscape change."*¹.

Together with the November 2019 launch of the Crown Estate's Offshore Wind Leasing Round 4², which is expected to include waters to the north of Ynys Môn, this serves to emphasise a probably significant expansion of renewable energy projects through the 2020s; and which could be suitable for (part-)hydrogen production under local ownership on Ynys Môn.

As well as the practical energy applications, the hydrogen economy can create and sustain long-term jobs, with forecasts of up to 5.4 million jobs forecast in the EU by 2050³. Hydrogen production on the island can therefore complement the goals of Energy Island and the North Anglesey Economic Regeneration Plan⁴, the draft of which was published in April 2019.

The results of Phase 1 of Ynys Môn Hydrogen Island are set-out in this report.

1 <https://gov.wales/sites/default/files/consultations/2019-08/Draft%20National%20Development%20Framework.pdf>, pp38-42

2 <https://www.thecrownestate.co.uk/en-gb/media-and-insights/news/2019-the-crown-estate-presents-revised-round-4-tender-design-ahead-of-launch-later-this-year/>

3 <https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition>

4 <https://www.anglesey.gov.uk/documents/Docs-en/Council/Consultations/2019/Business/North-Anglesey-Economic-Regeneration-Draft-Plan.pdf>

2 Hydrogen - Global Activities

A review of the rapidly emerging hydrogen-related activities at a European and global level has been conducted in Wales, UK and international level (both strategic and deployment) which can help shape and inform the project.

A presentation was prepared for the stakeholders which highlights these key activities. The presentation is included as Appendix I.

But it must be stressed that the sector is evolving rapidly, with frequent new project announcements and policy initiatives in several countries. The presentation should therefore be considered as a snapshot of the scale of activity. Its purpose was to stimulate interest about hydrogen amongst stakeholders and to subsequently inform and shape suitable project opportunities on Ynys Môn.

As a result of this fast-moving sector, a further set of new projects and policy announcement are set out below....

3 Illustrative Hydrogen Resource Calculations

Several stakeholders requested figures which could illustrate the scale of opportunity relevant to Ynys Môn.

For example, how much hydrogen would be required to service a fleet of buses and how much hydrogen could be produced from renewable energy sources to meet such a demand?

Table 1 below provides a selection of such calculations for a fleet of 50 buses in order to inform the project.

Table 1 Speculative Hydrogen Bus Calculations

Parameter	Value	Unit	Notes
Hydrogen tank capacity per bus	40	kg	Typical value, please see more information: https://www.hydrogeneurope.eu/hydrogen-buses
Hydrogen required for 50 buses	2,000	kg	
Electricity required to produce hydrogen for 50 buses	120,000	kWh	Via electrolysis and assumes 60kWh to produce 1kg/H2
Hydrogen Bus Range	400	km	Typical value, please see more information: https://www.hydrogeneurope.eu/hydrogen-buses
Total annual distance covered by 50 hydrogen buses	6,000,000	km	Assumes 300 journeys per bus per year
Hydrogen consumption rate	10	km/kg	
Total annual hydrogen required for 50 buses	600,000	kg	
Annual value of hydrogen produced	6,000,000	£	Assumes £10/kg for hydrogen but unit price is expected to fall.
Total annual electricity required for 50 buses	36,000,000	kWh	
Onshore Wind Installed Capacity Required for a fleet of 50 buses	12	MW	Assumes 33% Capacity Factor for Onshore Wind
Offshore Wind Installed Capacity Required for a fleet of 50 buses	10	MW	Assumes 40% Capacity Factor for Offshore Wind
Tidal Energy Installed Capacity Required for a fleet of 50 buses	21	MW	Assumes 20% Capacity Factor for Tidal
Solar pv Installed Capacity Required for a fleet of 50 buses	37	MW	Assumes 11% Capacity Factor for Solar pv

Two striking results emerge from the calculations:

1. the relatively small installed capacity required from a range of renewable technologies in order to serve a fleet of 50 hydrogen buses. (A combination of sources could be used in practice.)
2. the large financial value of the hydrogen fuel produced and which would stay in the local economy. Compare this with diesel which holds little value to the local economy.

4 Stakeholder Engagement & Soft Market Testing

A consultation exercise with key local stakeholders was undertaken which aimed to develop the Ynys Môn Hydrogen Island concept and to map project opportunities towards a strategic action plan. Details of the stakeholder engagement are provided in section 4.1 below.

A further soft market testing exercise was undertaken with international hydrogen technology companies and those who could provide related, project development services in order to gauge their appetite for being involved in any future project opportunities. The results of this soft market testing exercise are detailed in Section 4.2.

4.1 Stakeholder Engagement

This stakeholder engagement exercise constituted the main body of work during Phase 1 and involved the local authority, local enterprises, government, business & industries, educational bodies, utilities and community organisations.

The purpose of the stakeholder engagement exercise was to:

- bring stakeholders up to speed by means of a presentation (see Appendix I) and discussions on the rapid emergence of national and international hydrogen projects and initiatives which could influence developments on Ynys Môn;
- seek stakeholders views on specific areas of interest and expertise which could be applied to hydrogen project development and from which they could benefit;
- identify specific project opportunities which could be taken forward for detailed assessment and the preparation of business cases.

During May and June 2019, individual stakeholder meetings and calls were conducted and a questionnaire was distributed (See Appendix II for the completed questionnaires). The stakeholders are listed in Table 2 below.

To complete the stakeholder engagement exercise, a workshop was held at M-SParc on 15 July 2019 in order to reach consensus on the specific project opportunities to be taken forward.

Table 2 Stakeholders

Sector	Mudiad / Organisation
Lleol / Local	<ul style="list-style-type: none"> - Menter Môn - Morlais - Cyngor Sir Ynys Môn - M-SParc
Llywodraeth / Government	<ul style="list-style-type: none"> - Welsh Government - Cyngor Gwynedd - NWEAB - Politicians - Local Partnerships - Natural Resources Wales
Addysg / Education	<ul style="list-style-type: none"> - Coleg Llandrillo Menai - Prifysgol Bangor University
Strategol / Strategic	<ul style="list-style-type: none"> - Holyhead Port - Horizon - Ynni Cymunedol
Isadeiledd / Infrastructure	<ul style="list-style-type: none"> - Wales & West Utilities - SP Energy Networks - National Grid - Arup
Tîr / Land	<ul style="list-style-type: none"> - Treysgawen Hall (Chair of Anglesey Enterprise Zone)
Allanol / External	<ul style="list-style-type: none"> - Institute of Mechanical Engineers - South Wales Low Carbon Industrial Cluster - NW England HyNet Project - Hydrogen Ireland

Highlights from the consultation questionnaire responses are provided below but it is also particularly worth reading the full questionnaire response from Cyngor Ynys Môn, see Appendix I.

"Anglesey's Enterprise Zone status alongside its Energy Island Programme is driving the island's growth into a world-renowned centre of excellence in low carbon power generation and ten key sites have been designated."

"Any Hydrogen projects would require external support."

"Think big scale."

"The port could therefore become a hydrogen hub for transport application in particular."

"Carwn weld orsaf danwydd ar gyfer moduron yma ar y Parc Gwyddoniaeth maes o law, wedi ei gysylltu i ddatblygiad Morlais a/neu waith y Brifysgol."

"The IACC is aware and has knowledge of the 'Smart Local Energy Project' which sits underneath the Low Carbon Energy Programme of the North Wales Growth Deal."

The project aims to support low carbon renewable energy development in North Wales. The project will:

- a. Work in partnership with private sector energy developers to increase generation capacity;*
- b. Work with SPEN and National Grid to remove barriers to investment;*
- c. Deliver 4 pilot projects to support the long term decarbonisation of energy networks (network & storage, rural low carbon heating, hydrogen networks and clean transport);*
- d. Establish a Regional Energy Hub with skills and capacity to work with partners.*

As part of the project, Snowdonia National Park are introducing 4 hydrogen buses."

"This would be an area of interest for the plumbing and heating sector, with work being generated at many levels, both civil engineering and gas service engineering."

"This particular event [Egni 2018] was very beneficial to increase knowledge and awareness on the topic area."

"Hoffwn wybod fy hun pa waith mae'r Brifysgol yn ei wneud yn y maes."

"it is emphasised that any proposed low carbon energy related project must provide environmental, supply chain, employment, community benefits where possible."

"The connection of Stena Danica to the district heating grid in Gothenburg is a ground breaking project to demonstrate that district heating can be used for other purposes than just buildings."

"There is strategic justification to secure external funding to pilot a development in Anglesey due to its designation as an Enterprise Zone alongside the Energy Island Programme in driving the island's growth into a world-renowned centre of excellence in low carbon generation."

"Through the IACC's Energy Island Programme there is an established Strategic Forum which provides opportunities for industry and developers to present potential projects or pilot activities."

4.1.1 Stakeholder Workshop

After these individual stakeholders sessions and the receipt of the questionnaires, a key stakeholder workshop for Ynys Môn Hydrogen Island was subsequently held at M-SParc on 15 July 2019 and which was attended by the following organisations:

- Menter Môn
- Morlais Energy
- Cyngor Ynys Môn
- Wales & West Utilities
- Ynni Cymunedol
- SP Energy Networks

- Port of Holyhead (Stena Group)
- Welsh Government (Local Partnerships)
- Natural Resources Wales
- Bangor University
- Coleg Llandrillo Menai
- M-SParc

The purpose of the workshop was to focus stakeholders' attention on Ynys Môn's hydrogen potential following the 1-2-1 sessions over the preceding weeks; and to reach consensus on the specific projects which could be taken forward for further assessment.

The ensuing result, therefore, of the workshop was to shape the next stage of the Ynys Môn Hydrogen Island project, being the preparation of business cases for the following specific, recommended projects:

- **Holyhead "Hydrogen" Port**
- **Large-scale power to gas**
- **Hydrogen for transport**
- **Community hydrogen**
- **Hydrogen for heat**

It was recognised that some of the above projects may evolve to be mutually complimentary and this would be addressed in the next stage business cases.

A number of cross-cutting themes were also identified at the workshop, namely:

- Research
- Jobs and skills

- Public awareness

These cross-cutting themes may form the basis of establishing a centre of excellence for hydrogen on Ynys Môn, and this is explored in Section 5.6; as well being valuable in themselves in steering the preparation of the specific project business cases.

The results of the workshop, including details of the 5 specific, identified projects, are shown in Section 5.

4.2 Soft Market Testing with Hydrogen Technology Companies

A soft market testing exercise was also conducted with international hydrogen technology companies and related services in order to test their appetite for potential supply opportunities or collaborative partnership opportunities as Ynys Môn Hydrogen Island develops.

The responses were very positive and those companies who responded to the consultation are listed in Table 3 below.

It should be noted that there are many more hydrogen technology companies in operation and which could be pursued at a later date; but within the short-period of this exercise those listed in Table 3 represent a very good cross-section of some of the leading international players.

The encouraging - and in some cases enthusiastic - responses provide grounds for optimism for when it comes to delivering specific projects; and also the potential for creating a cluster of hydrogen technology companies on Ynys Môn.

Such a cluster should also extend to providing opportunities for local start-ups to emerge and for existing local companies to extend their expertise into hydrogen-related fields. Such local opportunities could be in both the development of technology products and also in providing the services (e.g. development companies, energy systems designers and engineers, consultancies etc) which will support the growth of Ynys Môn's hydrogen economy and which can serve opportunities beyond Ynys Môn.

Table 3 Soft Market Testing : Responding Companies

Sector	Mudiad / Organisation	Speciality	Location
Fuel Cells	Doosan	Large stationary fuel cells but also EPC & complex energy/engineering	South Korea; UK subsidiary
	SolidPower	Micro stationary fuel cells. Installed by Gwynedd CC.	Italy with UK base.
	Sunfire	Small fuel cells but also power to gas & synthetic fuels.	Germany
	Ballard	Vehicle fuel cells.	Canada but European base.
	Proton Motor	Small fuel cells & stand-alone energy systems.	Germany
Electrolysers / Power to Gas	ITM Power	Electrolysers & hydrogen filling stations.	England
	NEL Hydrogen	Electrolysers & hydrogen filling stations.	Norway
	Hydrogenics	Electrolysers	Canada but European base.
	McPhy	Electrolysers & hydrogen filling stations.	France
Transport	Alstom	Hydrogen Trains	France but UK base.
	Riversimple	Small hydrogen car; circular economy.	Wales
	Toyota	Hydrogen car	Japan but UK base.
	H2 Energy	Hydrogen filling station networks.	Switzerland
Projects / Solutions	Logan Energy	Design and implementation of complete hydrogen systems.	Scotland
	Nilsson Energy	Off-grid containerised hydrogen systems.	Sweden
	Arcola Energy	Engineering and design for hydrogen systems.	England
	Engie	Large projects.	France but UK base.
Waste 2 Energy	Powerhouse Energy	Plastic waste to hydrogen.	England

The positive responses from a wide-range of established hydrogen companies (and related services), coupled with the very encouraging stakeholder engagement exercise, provide a good base or further dialogue with the companies and to explore commercial opportunities between them and Menter Môn.

It is also worth considering holding a dedicated funders/investors/tech companies event which will further raise the profile of Ynys Môn Hydrogen Island once the business cases for the select projects are completed, and possibly as soon as Autumn 2019.

But, in parallel, it became clear during discussions with some of the companies that they are very keen to quickly engage with Menter Môn on a 1-2-1 basis on Ynys Môn Hydrogen Island, in order to present their expertise in the field and to discuss the prospect of developing commercial partnerships which can advance projects. These companies are listed in Table 4 below with a brief commentary against each.

Those listed in Table 4 do not constitute an exclusive list and Ynni Glân will update the table as additional responses are received from other companies. In other words, there is fluidity between Tables 3 & 4 and room for others to be involved.

Table 4 Extended Company Responses to Soft Market Testing

Company	Sector	Commentary
ITM Power	Electrolysers; Power to Gas (P2G)	<p>Quote: <i>"The Ynys Môn Hydrogen Island sounds a really exciting study that you are undertaking, and I very much hope ITM can be considered as the electrolyser partner for the Ynys Môn , bringing the benefits of a UK supply chain, as well as global leading scale, knowledge, know-how and experience for delivering projects."</i></p> <p>ITM are involved with several international and large-scale P2G projects. They are expanding their factory in Sheffield and have invited Menter Môn to visit the factory.</p>
Doosan	Fuel cells; Distributed Energy; EPC	<p>Doosan are partners in the Orkneys hydrogen energy project and are also designing a hydrogen port at Belfast. Interests extend to large fuel cells for data centres, EPC (Engineering, Procurement and Construction) services and in engineering and deploying fully integrated distributed energy systems. Doosan are suppliers of fuel cells to power a large data centre development in Connecticut, USA, which is expected to create more than 3,000 direct and indirect jobs over the course of the next 20 years⁵. Senior personnel are keen to meet Menter Môn.</p>
Alstom	Hydrogen Trains	<p>Interested in discussing how a small fleet (of say 10 trains) could serve the island (and beyond) and spur the re-opening of the Gaerwen to Amlwch line. A likely focus would be establishing a depot at Holyhead.</p>
Logan Energy	Hydrogen Systems	<p>Logan Energy presented at Egni 2019 at M-Sparc. They are consultants on the Orkneys hydrogen projects and experienced in designing and implementing complete hydrogen systems.</p>
Arup	Consultancy	<p>Arup has detailed local knowledge of Ynys Môn's grid infrastructure. They wish to bring this knowledge to advise on hydrogen developments.</p>
Proton Motor	Fuel cell systems	<p>Systems suppliers for the Orkney Surf & Turf project and recently teamed up with MTSA to supply large fuel cell systems and power to power solutions.</p>

5 <https://microgridknowledge.com/fuel-cell-microgrid-data-center-connecticut/>

The comments in Table 4 above do not constitute any pre-judging of the partnership opportunities nor either preclude against pursuing partnerships with the companies listed in Table 3 and others besides. But they serve to illustrate the specific offerings from each company and their willingness to either travel to Ynys Môn at this early stage or to host visits at their operations.

It should also be noted that most of the companies listed in Table 4 have UK bases, which may explain their eager responses. But there is no reason to doubt that such responses may also emerge from international companies, including those in Table 3, as Ynys Môn Hydrogen Island develops. Ynni Glân will update Menter Môn on any new responses.

The enthusiasm conveyed by the companies helps to support the idea of creating a hydrogen centre of excellence on Ynys Môn, which was a topic which also emerged during the stakeholder engagement exercise, and which would act as a high-profile focal point for the island's hydrogen activities in partnership with universities and others. This is further explored in Section 5.6.

4.3 Conclusion

Throughout the stakeholder engagement exercise and in discussions with the hydrogen-related companies, it was clearly expressed that the headline aim of Ynys Môn Hydrogen Island was to develop hydrogen production capacity and fuel cell applications on and for the island (plus leading to export) - and to embed the resultant economic benefits (i.e. full/part ownership of the assets, the revenue potential, skills & jobs etc) on the island under the guidance and control of Menter Môn and partners.

The exercise therefore helped to establish common ground between the stakeholders and to connect this with international hydrogen-related expertise relevant to the Ynys Môn Hydrogen Island and which can lead to commercial opportunities.

The exercise has established a strong appetite and consensus for pursuing business cases for five specific projects under the next stage of the project, full details of which are provided in Section 5 below.

5 Specific Project Opportunities

Five projects were identified during the stakeholder engagement exercise for further assessment and these are listed below from 5.1 to 5.5 together with representative comments from the stakeholder workshop. There is no order of project preference.

A number of cross-cutting themes were also identified which, together with the strong, relevant research expertise at Bangor University, may lend themselves to establishing a hydrogen centre of excellence on Ynys Môn. This is explored in Section 5.6.

5.1 Port of Holyhead

Strategically located, Holyhead Port connects Ireland with Wales and the UK.

This study will prepare a plan for the development of a Hydrogen Port at Holyhead which will include the Port's logistical operations, road and rail transport infrastructure, the emergence of hydrogen shipping and other areas.



Figure 1 - Port of Holyhead. This key transport hub between Wales and Ireland is the second busiest roll-on, roll-off port in the UK. 500,000 trucks pass through the port of Holyhead every year and it is connected to the mainline rail service.

The following representative comments on the Port of Holyhead project are taken from the stakeholder workshop:

"Key opportunity due to strategic importance of port."

"Fully support this idea and suggest linking with Parc Cybi transport plans."

"Engage with haulage industry locally (e.g. Huws Gray), nationally and in Ireland via Irish Haulage Association"

"Internal market potential within Stena's operations at Holyhead and its wider (port to port) logistics, as well as connecting with external transport users."

"Hydrogen Hub in Parc Cybi to attract industries that use a lot of electricity such as data centres"

"This appears to be the main unique for hydrogen on Anglesey and it would benefit from merging with the large-scale power-to-gas project."

"The economics of the other projects/spin-offs would be dramatically changed if we had the port of Holyhead/large-scale power to gas project up and running"

Conclusion

This study gained most support due the clear, strategic focus; its multiple (and scaleable) applications; the high-impact potential in the short-term; and the buy-in from Stena Group, the port operator.

The potential to forge close ties with Ireland's emerging hydrogen activities was also identified as a clear, strategic opportunity.

5.2 Large-scale Power to Gas

Strategic sites, especially in the north of the island, present opportunities to produce green hydrogen at scale from renewables via electrolysis. This is the basis of power to gas; and once the hydrogen is produced it can also be synthesised into other valuable fuels.

This study will:

- assess the practical and economic viability of establishing large-scale power-to-gas sites on Ynys Môn which can be coupled with existing networks and infrastructure;
- assess the skills training and supply-chain opportunities from the deployment and servicing of such developments;
- assess other markets for hydrogen including ammonia production for agriculture.

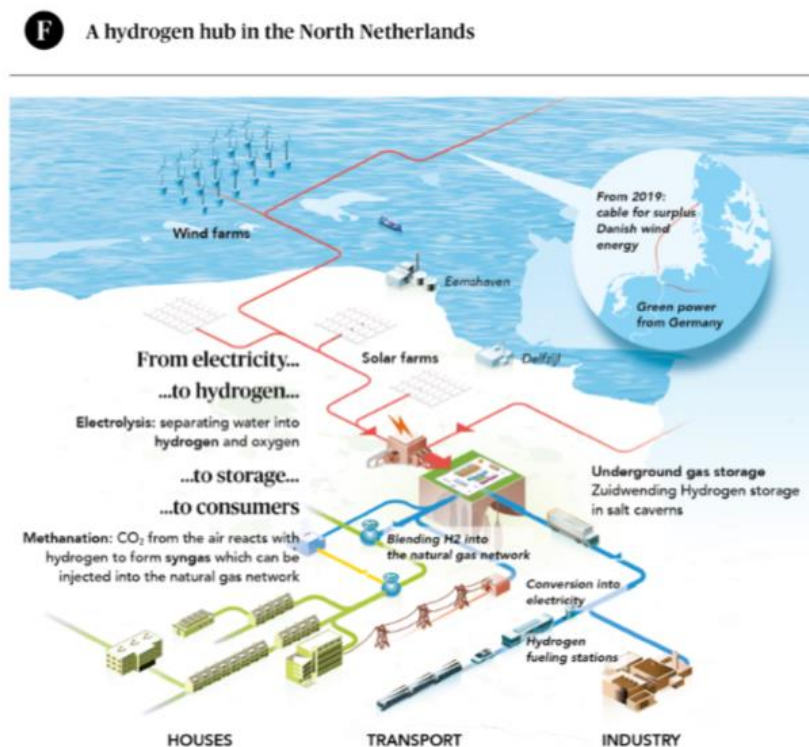


Figure 2 - North Netherlands GW-scale power to gas project. The North Sea's wind resource is being assessed as part of a 2020s pathway to produce hydrogen at scale via electrolysis for transport, heat and industrial applications. This could serve as an example for Ynys Môn and the region.

The following representative comments on the Large-scale Power to Gas project are taken from the stakeholder workshop:

"Understanding what has already been done at scale is key"

"Need to identify market before moving forward"

"Scale-up production as demand rises"

"10 sites identified as part of enterprise zone"

"Parc Cybi emerging as a good candidate site"

"fertilizer issues [nitrates] with ammonia production"

"With Wylfa Newydd on hold and the closure of Rehau and previously Octel - a strategic site in the north of the island with economic benefits (jobs/skills) would be an attractive proposition (and opportunity for WG funding)"

Conclusion

Falling renewable costs and economies of scale with electrolyzers provide optimism that, in the 2020s, large-scale green hydrogen production can reach cost parity with the market incumbent of hydrogen produced via steam methane reformation (SMR) of natural gas; whilst avoiding the potential pitfalls of fugitive methane emissions and the speculative nature of carbon capture and storage technologies, which are being touted in support of the proposed large-scale expansion of SMR.

5.3 Public Sector Transport

Transport is a difficult to decarbonise sector with few available technology solutions. Hydrogen can meet the requirements of all scales of transport, from small cars to buses and large lorries.

This study will assess the adoption of hydrogen vehicles for a consortium of public (and other) stakeholders.

The focus will be on fleet operations which can justify the investment in infrastructure to match hydrogen supply with demand.

Partnerships beyond Ynys Môn will be further explored in order to build capacity; to join-up with any emerging network of filling stations; and to serve a larger geographical area.



Figure 3 - Hydrogen van and filling station, France. Public sector organisations in France and elsewhere are forming consortia to develop projects which combine infrastructure and vehicles, including buses, vans and cars, in order to address air pollution and decarbonisation goals.

The following representative comments on the Public Sector Transport project are taken from the stakeholder workshop:

"Hydrogen use in transport is well established and presents a short term opportunity"

"Under Welsh Government's Prosperity for All, Public Sector vehicles need to be Carbon Neutral by: 2025 LGV, Buses 2028, 2030 HGV."

"Cyfle am gyllid LEADER Cyfwedithredol ar gyfer teithiau bysiau hir e.e. Traws Cymru"

"Link to Holyhead port and Parc Cybi development"

"There are fleet opportunities."

Conclusion

With only two realistic zero emission technologies to choose from (being battery and/or hydrogen vehicles, which are complementary in any case) and given the clear policy direction of the Welsh Government's Prosperity for All policy document, the public sector is primed to take a leading role in advancing hydrogen transport initiatives. Many hydrogen transport examples are emerging across the UK and Europe which can inform such projects on Ynys Môn and also connect with the rest of North Wales. Hydrogen transport will address both decarbonisation goals and also air quality issues. The huge value to the local economy of producing green hydrogen which can serve transport (trains, buses, fleets etc) is illustrated in the calculations in Section 3.

5.4 Hydrogen blending into the Gas Grid

Decarbonisation of gas is subject to intense analysis and project assessment in the UK. Gas utilities are preparing roadmaps and undertaking pilot-projects which can comply with the Welsh and UK Government's stated Net Zero commitments, especially for decarbonising heating.

This study will assess opportunities for injecting hydrogen directly into the gas pipeline network at a dedicated site, with particular focus on the scope for developing a closed-loop 100% hydrogen network on a private site.



Figure 4 - Gas pipeline replacement programme from Wales & West Utilities, Cardiff. All metal gas pipes are being replaced by plastic pipes for safety reasons under a UK roll-out programme. The new plastic pipes are also hydrogen-ready, allowing for a key infrastructure asset to be repurposed for hydrogen as a substitute for natural gas.

The following representative comments on the Hydrogen Blending project are taken from the stakeholder workshop:

"considered a longer term (10-15yr) initiative"

"Could create an independent site at Coleg Menai for a hydrogen loop"

"Major issues over how you present this idea to the customer"

"Wales and West Utilities are the key stakeholder"

Wales and West Utilities have shared valuable information around existing barriers to the transportation of Hydrogen in gas networks and this is provided in Appendix III Wales & West Utilities: Advice on Hydrogen in the Gas Network.

Wales and West Utilities have also highlighted a collaborative Gas Distribution Networks 'Pathways' project which is looking at the decarbonisation pathway for gas networks⁶.

Conclusion

Wales & West Utilities will not consider any project which duplicates existing hydrogen initiatives amongst the UK's other gas utilities. But interest is strong in pursuing an innovative closed-loop hydrogen project on Ynys Môn which would establish a proving ground and provide supporting evidence towards the potential wider roll-out of hydrogen in the gas grid on Ynys Môn and beyond through the 2020s and into the 2030s. Strong candidate sites are emerging on Ynys Môn, including Coleg Menai at Llangefni. Such a project would also ideally complement Coleg Menai's skills and training programme in highly relevant energy engineering disciplines.

⁶ https://www.smarternetworks.org/project/nia_sgn0144.

5.5 Community-scale Hydrogen - “Off-grid”

Large numbers of properties, including farms and tourist accommodation, are not connected to the gas grid on Ynys Môn. Electricity grid connections can prove problematic as well, especially in stormy weather.

This study will assess the development of a green hydrogen-based, resilient off-grid solution which can serve a site’s energy needs. This can release more renewable energy generation sites on Ynys Môn and act as a pilot which could be replicated across the island and further afield.



Figure 5 - Off-grid Alpine Chalet, Austria. Hydropower is the primary energy source. An electrolyser, solid hydride hydrogen storage, battery, fuel cell CHP and controls complete the energy system to provide year-round, zero emission energy capability.

The following representative comments on the Community-scale Hydrogen project are taken from the stakeholder workshop:

"Benllech is all off-grid"

"Start at property level and scale-up to village level"

"Perhaps better applied to a specific use in e.g. agriculture"

"Datrys problem tlodi tanwydd mewn ardaloedd heb gyflenwad nwy trwy'r grid yn flaenoriaeth"

"Could produce a great USP and PR for the right tourist location"

"Not sure about the efficiency for electric generation to then convert back to hydrogen."

"Halen Môn could be a good site"

Conclusion

Many of Ynys Môn's properties are off the gas grid, including farms and tourist accommodation. And being off the gas grid extends to whole villages, such as Benllech, in some parts of the island. Whilst highly valuable in an individual building setting, there is a clear and scaleable carbon reduction and economic development opportunity to be made from piloting a community hydrogen project and by developing the skill base which can subsequently meet local and regional demand in this area. Resilience of hydrogen systems is also a vitally important benefit, given the frequent power cuts to properties on Ynys Môn as a result of stormy weather which can knock-out power lines.

5.6 Hydrogen Centre of Excellence

Emerging during the stakeholder consultation exercise, including the workshop, were a number of cross-cutting themes surrounding the development of hydrogen projects on Ynys Môn. These themes may provide grounds for establishing a central focus for project activities and to stimulate further project growth in the shape of a hydrogen research, development and demonstration centre of excellence on the island; and possibly in partnership with Bangor University.

Such a concept could learn from the experience of the HydroHub centre in The Netherlands which involves a public-private partnership centred around large-scale electrolysis. But a centre on Ynys Môn could address other areas and benefit from Bangor University's expertise in, for example, nuclear, materials, economics and public awareness; and set against a platform of building skills and economic capacity with other partners

A centre of excellence Could provide a focus for the identified project opportunities and also provide a platform for other project opportunities as they emerge. The concept is illustrated in Figure 6 below.

Ynys Môn Hydrogen Island

Cross-cutting themes

- Research - e.g. Nuclear, Materials at Bangor University, new VC
- Skills - building local capacity
- Jobs - building local capacity & companies
- Public Awareness



M-Sparc, Menai Science Park, www.m-sparc.com



.....a model for Ynys Môn?

Bundling alliances to get sustainable production of hydrogen off the ground quickly

Figure 6 Cross-cutting themes and a Hydrogen Centre of Excellence

6 Conclusions

The study has:

- learnt from and been steered by the rapidly emerging and international momentum behind hydrogen as a crucial technology for achieving decarbonisation goals at scale and across all sectors;
- established that Menter Môn represents a strong, local renewable energy and enterprise presence which can serve as a platform for hydrogen activities;
- consulted with and established strong stakeholder appetite (including Cyngor Ynys Môn, utilities, Bangor University, Coleg Menai etc)for specific hydrogen projects to be taken forward for assessment
- established that the international fuel cell and hydrogen technology and related business community are keen to be involved in emerging project opportunities
- recognised that Ynys Môn has large RE potential but other sources may emerge in the 2020s inc W2E & SMR
- assessed that green hydrogen is a no-regrets option with costs falling and in avoiding the unproven nature of blue carbon carbon's reliance on speculative carbon capture and storage technology and the fugitive emissions from steam methane reformation,
- recognised the economic development opportunities including connecting to Energy Island, North Anglesey, Enterprise Zone, strategic sites, Coleg Menai skills etc
- assessed cross-cutting themes which mat support the establishment of a R,D&D centre of excellence, spin-offs & incubator cf M-Sparc but themed on hydrogen and building on the research expertise of BU inc nuclear, economics, materials, public awareness, safety
- recognised that considerable energy expertise and capacity already exists on Ynys Môn, which can be fine-tuned toward H2 opps
- recognised the superb resource, geographical and infrastructure advantages of Ynys Môn, especially the Port of Holyhead.

- assessed the strategic, national (to the rest of north Wales) and international opportunities (connecting to Ireland, the rest of the UK and Europe via technology companies' interest) are already emerging
- identified 5 projects which can be taken forward for the preparation of business cases and which present good, realistic opportunities to swiftly establish Ynys Môn as a major hydrogen hub
- concluded that Ynys Môn has an unfair advantage which can provide a pathway for prosperity centred on hydrogen through the 2020s.

It is therefore recommended that the next stage of Ynys Môn Hydrogen Island:

- should deliver the business cases for the 5 identified projects being:
 - **Holyhead "Hydrogen" Port [including port logistics, shipping, rail & heavy transport applications and which can help forge close ties with Ireland]**
 - **Large-scale power to gas**
 - **Hydrogen for transport [public sector-led]**
 - **Community hydrogen**
 - **Hydrogen for heat;**
- while being steered by the cross-cutting themes and the prospect of establishing a high-profile centre of R, D & D excellence for hydrogen;
- by advancing the prospects of entering into formal partnerships with relevant stakeholders, technology companies, investors and others;
- and should consider a funders/investors/tech companies event once the business cases for the select projects are completed, and possibly as soon as Autumn 2019;
- but should also conduct 1-2-1 discussions with those companies who have shown the most appetite to date and may have unique commercial offerings;

- and will be underpinned by the need to establish local ownership of the emerging projects and commercial opportunities under the control of Menter Môn and local partners [add Council?].

Appendices

I Ynni Glân Stakeholder Presentation

[Please see attached]

II Stakeholder Questionnaire Responses

Coleg Menai

Cyngor Sir Ynys Môn

Horizon

M-SParc

Port of Holyhead

[Please see attached]

III Wales & West Utilities: Advice on Hydrogen in the Gas Network

Appendix III

Wales & West Utilities: Advice on Hydrogen in the Gas Network

1 Gas Quality and Capacity

The current limit for hydrogen according to GS(M)R Part 1 is $\leq 0.1\%$ (molar). This restriction significantly restricts the quantity of hydrogen you would be able to inject at low demand periods (overnight and during the summer). Seasonal storage would be required in order to manage the flows into the network. The key implications of this are financial in terms of storage plant although arrangements would need to be confirmed in terms of ongoing operations and maintenance.

Changes to regulations would mean that in the future it may be possible to inject hydrogen at higher percentage rates. The Health & Safety Laboratory released a report indicating that in theory, concentrations of up to 20% (volume) would have limited impact from a safety perspective, especially with regard to domestic consumers.

Further field research work, such as that conducted at Oban, to understand the impact of widening the GS(M)R gas quality ranges would need to be conducted, but work being instigated by the Institution of Gas Engineers and Managers is examining opportunities in this area. There is an option to apply for site specific exemptions in some cases..

2 Local Distribution Zone Billing CV

Current regulations for gas quality and billing within GS(M)R and the Thermal Energy Regulations mean that the calorific value (CV) used for billing in any Local Distribution Zone (LDZ) is determined based on actual CVs of gas which is input to the LDZ.

Actual flows and CVs are used to determine the flow weighted average CV (FWACV) each day so the smaller the injection point the smaller the influence on FWACV. This process produces a representative CV for the network. However, in order to protect customers within the LDZ from local variations the billing CV can never be more than 1MJm³ above the lowest CV injected and so the billing CV is always capped at 1 + lowest source CV.

On days when the cap takes effect there is CV shrinkage on the National Transmission System (NTS) which can have significant financial implications on NTS shippers. In order to minimise NTS Shrinkage currently all input points on our network are required to add an appropriate gas e.g. propane, to their source gas so that it meets a target CV provided by us. This adds costs to producers and takes up part of the allowed input capacity.

In order to remove this requirement we would need to either gain acceptance from OFGEM that a site does not feed into CV calculations OR wait for the outcome of a project being led by National Grid Distribution to look at alternative CV billing arrangements .

3 Blending

In order to ensure an appropriate blend of hydrogen with source gas we would need to discuss the blending equipment it's ownership and operation.

There are a number of questions around the measurement of gas injection to be used for billing and invoicing. We would need to understand the treatment of the gas that is used for the blending and how it is accounted for. There is a risk that it is considered as gas exiting our system (with associated exit charges) and subsequently as gas entering the system (with associated entry charges).

The work required in this area will depend on the outcome of the work in section 2 – LDZ Billing CV

4 Measurement and Monitoring

The design for injection plant would need to include gas quality measurement before and after blending which we would deem essential in order to for us to be able to prove that gas entering the network met requirements in being GS(M)R compliant. Additional measurement and monitoring equipment will have implications for total cost.

5 Operational Requirements

A Network Entry Agreement (NEA) would be required between ourselves and the operator. This is a detailed document setting out obligations. Our current NEAs include details of communication routes during emergencies and requirements for a remotely operable valve (ROV) which can be closed from the WWU control centre in order to protect our network.

As part of our funding arrangements (RIIO) all UK Gas Distribution / Transmission Networks are incentivised to deliver innovations to promote efficiency in all aspects of operation with a particular focus on de-carbonisation. These projects can be delivered by one or more Networks but a requirement of the funding is that all learning is shared in order to ensure the investment is efficient. A number of the issues listed above are being addressed by existing projects with fixed timescales.

The documentation referred to above can be accessed as follows:

GS(M)R: <http://www.legislation.gov.uk/ukxi/1996/551/contents/made>

Thermal Energy
<http://www.legislation.gov.uk/uksi/1996/439/contents/made>

Regulations:

Network Innovation Projects: www.smarternetworks.org