

Challoch ENERGY

Hydrogen in rural energy systems

How to Guide

August 2023

HyRES

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Purpose and scope

This How to Guide will help and assist those developing plans for small scale green hydrogen production and delivery in rural villages across Wales and the wider UK.

The main objective of the guide is to offer a clear and comprehensive understanding of the technology, component infrastructure, and regulatory processes involved in the development of green hydrogen. By doing so, the Guide aims to provide a useful resource for a range of stakeholders who are involved in the development of such schemes, including local authorities, decision making bodies, and consultees.

The Guide covers a wide range of topics, including the scope and relevance of guidance and legislation, the relevant technologies and potential markets as well as the importance of community engagement. The guide offers a shared understanding of the procedures and requirements to anyone who is interested in the development of green hydrogen.

This guide derives from the HyRES SBRI project funded by the Welsh Government Smart Living HyBRID (Hydrogen Business Research & Innovation for Decarbonisation) scheme. HYBRID supports innovative and research solutions to deliver the Wales Hydrogen Pathway and Net Zero Wales CB2 2021-2025, speeding up the deployment of hydrogen as a key energy vector, and helping Wales realise its national commitment to achieve net zero emissions by 2050.

Concept and rationale for cleaner energy

The UK Government has committed to achieving net zero carbon emissions by 2050. The Welsh Government is aligned with the UK Government in committing to reach this target. Achieving the net zero target will require significant changes in the way that the UK produces and consumes energy, as well as changes in all sectors including energy supply, residential, transport, agriculture, and industry.

Scale of the problem

Domestic heating is a significant source of greenhouse gas emissions in the UK. According to the UK Committee on Climate Change, the use of natural gas for heating and cooking for homes accounted for approximately 16 of the UK's total greenhouse gas emissions 2021.

Transportation accounted for 26 of total GHGs in the UK, whilst industry was responsible for 18% and agriculture 11%.

Achieving the net zero target will require a combination of policy, technology and behavioural changes, with both individuals and organisations playing an important role in creating a sustainable future.

Green hydrogen, in addition to electrification, will have an important role to play in decarbonisation across all sectors through its potential for use as a fuel, a feedstock, energy storage and load balancing.

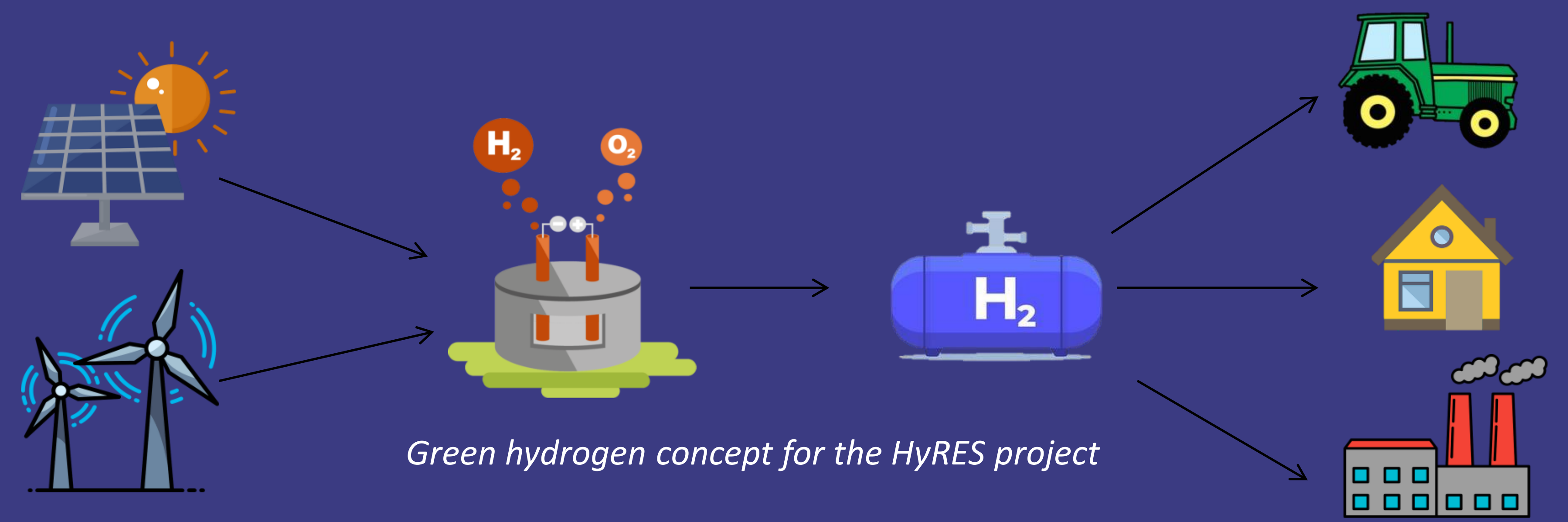
Concept and rationale for cleaner energy

Hydrogen for Rural Energy Systems (HyRES) is a project aiming to decarbonise rural areas through the development of an integrated energy system, comprising a local energy market with distributed rooftop PV energy shared amongst the community, a local energy operating system (LEOS) to manage and optimise energy flows, and a green hydrogen facility with dedicated onsite wind-turbine and solar farm providing long-term energy storage and greater flexibility to the community. The first location to be developed is a village in South Wales.

The localisation of energy production and the control of its use through a community-based energy network will provide potential financial benefits to the community through affordable renewable energy as well as the local market, providing hydrogen as a fuel for agriculture and as a feedstock for industry. The concept is designed to be replicable in rural communities across the UK, providing greater penetration of renewables and system-wide flexibility across the national grid.

Core components of a typical project for the purpose of rural supply

- On-site renewable electricity source (wind and/or solar) or private wire energy supply directly from an off-site renewable electricity generator.
- On-site electrical infrastructure, an electrolyser, hydrogen storage, off-site supplies for hydrogen, gas network infrastructure and fueling trucks.



Green hydrogen concept for the HyRES project

Technologies
Electrolyser

An electrolyser uses electricity to split water molecules into hydrogen and oxygen through a process called electrolysis. It can be considered 'green' if the electricity used in the process is generated from renewable sources such as wind or solar power, which ensures that the production of hydrogen is free of greenhouse gas emissions.

The electrolyser consists of two electrodes (a positively charged anode and a negatively charged cathode) separated by a membrane (a solution that conducts electricity). When an electric current is passed through the water, the hydrogen is produced at the cathode, while oxygen is produced at the anode. The hydrogen can then be captured and stored for later use as a clean energy source for things like heating and fuel for vehicles.

These are the main components of a hydrogen production facility:

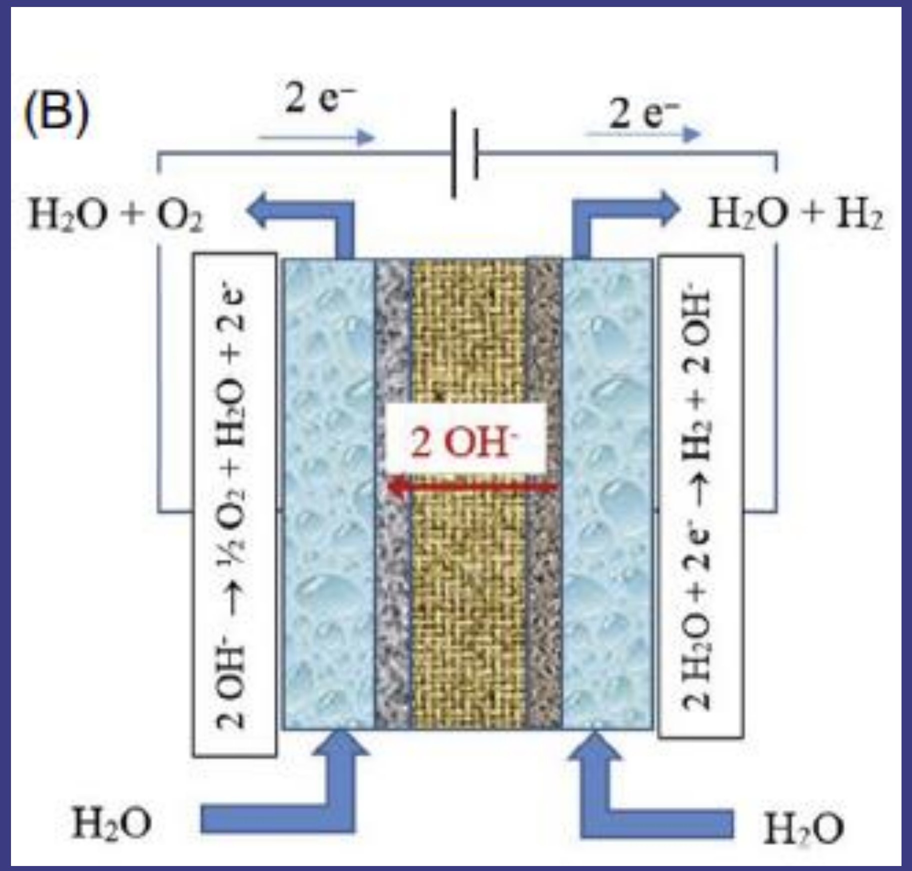
- An electrolyser
- Hydrogen storage
- Compressors
- Gas blending unit (if blending into the local gas network)
- HV/LV substation for bringing power from renewables
- Provision for odourisation unit (if injecting into the local gas network)

Technologies
Electrolyser

AEL (Alkaline Electrolysis): Developed and implemented in the 1920s, alkaline electrolysis is the oldest industrial electrolyser technology. This system reduces water at the anode producing H2 gas and oxidises OH- anions at the cathode producing oxygen and water.

AEL uses a conductive diaphragm for the selective crossing of OH- anions and a strong alkaline solution – 20-40% aqueous potassium hydroxide – to promote their flow due to water's poor conductivity. AEL also requires additional downstream purification steps to achieve high quality hydrogen.

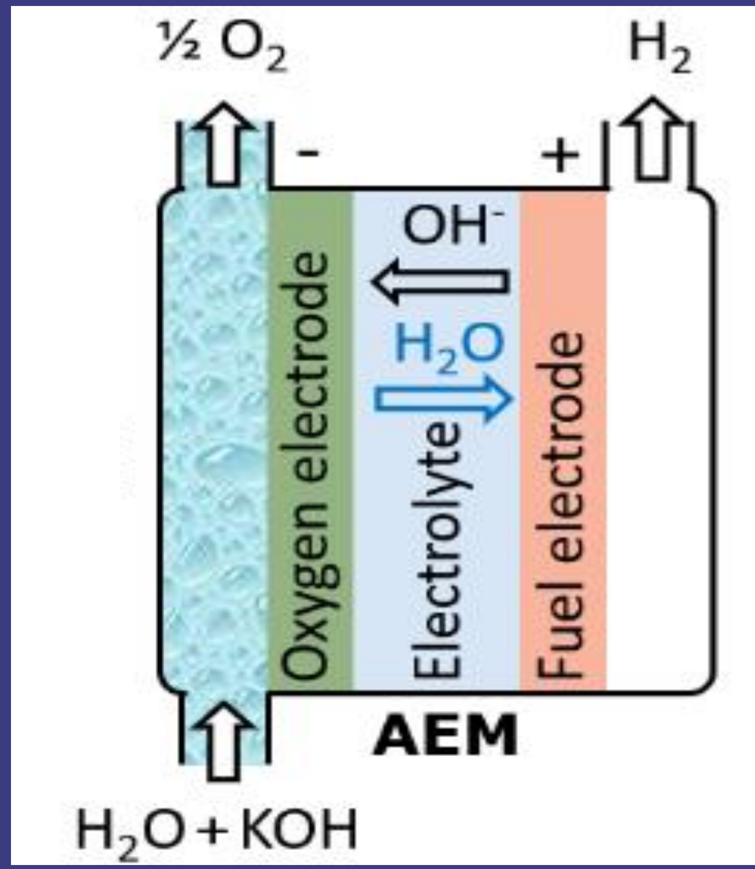
Key advantages of AEL are its technological maturity, the absence of any precious metals and its much cheaper costs compared to others. Still, the technology is not as efficient and does not operate at the same pressures as PEM or AEM though this is improving.



AEM (Anion Exchange Membrane): These electrolysers use an anion exchange membrane instead of a diaphragm to selectively pass anions while blocking cations, allowing for the use of a wider range of electrolytes and the direct production of high-purity hydrogen without the need for additional purification.

Like AEL, the system reduces water at the anode, producing oxygen and OH- anions. These are conducted through the AEM membrane to the cathode, where they are oxidised to generate hydrogen gas. AEM electrolysis is a promising technology to produce green hydrogen due to its high efficiency, low operating temperatures and pressures, and ability to use a variety of electrolytes. Moreover, this technology requires few precious metals and a smaller concentration of electrolyte solution.

Still, it is at initial development stages and comparatively expensive.

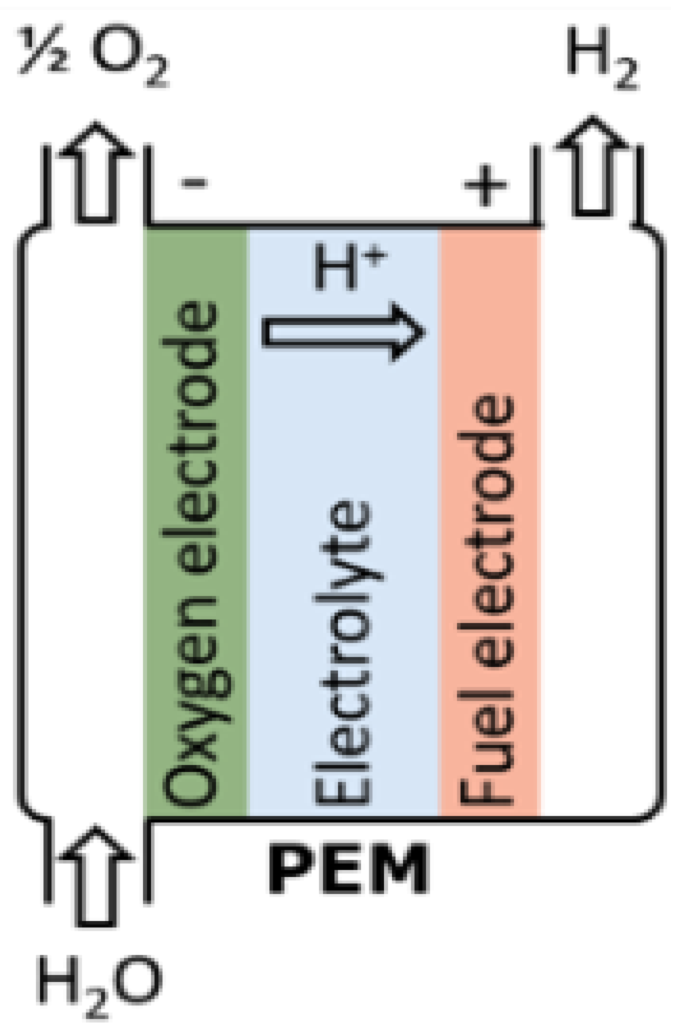


Technologies

Electrolyser

PEM (Proton Exchange Membrane): This electrolyser uses a solid polymer electrolyte membrane to separate the anode and cathode compartments and conduct protons from the anode to the cathode. The process involves water being oxidised at the anode, releasing electrons and protons that are conducted through the PEM membrane to the cathode, where they are reduced to generate hydrogen gas.

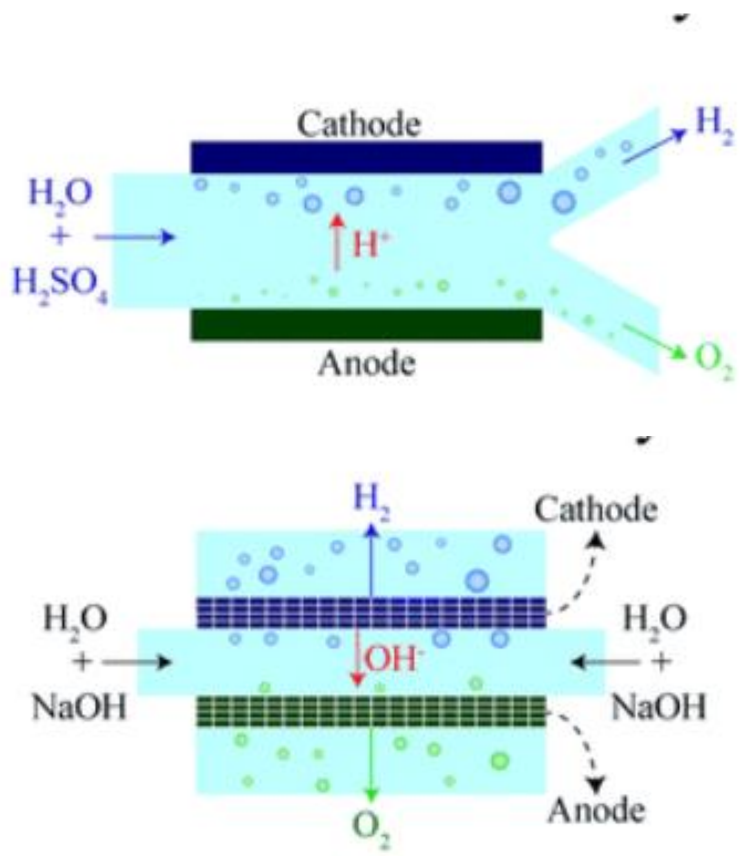
PEM electrolysis is more efficient than other electrolysis technologies, operates at lower temperatures and pressures, and can be more easily scaled for small-scale applications. Still the technology requires several expensive platinum group metals, increasing costs and requires additional purification steps to achieve fuel-cell grade hydrogen.



MFE (Membrane Free Electrolysis): This system utilises the same principles as PEM or AEM systems. The key difference is that no membrane is used to promote the selective passing of anions/cations in the system. Instead, the fluids flow freely across the electrolyser and the hydrogen and oxygen gases flow out of the electrolyser's cathode and anode. This product stream, however, is not pure and will typically be a mix of water, oxygen, and hydrogen. To separate these components, the electrolyser uses cryogenic units which sequentially separate, water and oxygen from the product streams. This yields ultra-pure oxygen and hydrogen product streams.

MFE's main advantage is the absence of a membrane. This eliminates the need for this part's eventual replacement and increases the cells overall ionic conductivity as membranes create a source of resistance. Also, both acidic or alkaline electrolytes can be used, mimicking either the PEM or AEM principles.

Still, this is a relatively new technology and cryogenic separation is expensive.



Technologies

Electrolyser

How to pick the right size of electrolyser:

- **Determine the required hydrogen production**. The first step is to determine how much hydrogen is needed for the specific application. This will depend on factors such as the type of hydrogen application, the required hydrogen output, and the daily or annual hydrogen demand. For a 20% blend the hydrogen demand can be best calculated by finding the peak heat demand of the village based on utilities data.

- **Calculate the required electrical power supply**. The amount of electrical power required to operate the electrolyser will depend on the hydrogen production need and the efficiency of the electrolysis process. This will also help to determine the size of renewables needed to power the electrolyser.

- **Consider the available power supply**. The size of the electrolyser should be chosen based on the amount of available electrical power supply. If the power supply is limited, then a smaller electrolyser may be required.

- It should be noted that the size of the electrolyser should be future-proofed against potential increases in demand to minimise costs.

Technologies
Renewables

For the electrolyser to run on 100% green electricity the following options must be considered:

- On-site renewables generation (wind and solar).
- Private wire electricity imports from neighbouring wind and solar farms.
- A combination of both, to ensure an uninterrupted electricity supply.

When assessing on-site renewables, you will need to consider:

- The number/size of renewables will be based on the size of the electrolyser.
- The land available around the site.
- Land profile (especially wind) – distance from highways/roads, residential housing, overhead electrical infrastructure.

It is crucial to evaluate the usage of private wire electrical connection if you want an uninterrupted power supply to the electrolyser, especially on days with little wind or sunlight, when onsite renewables may produce less electricity.

Location is the most significant consideration; if the off-site renewables are too far away, the cost will rise, more private wire length will be required, and wayleave costs may rise depending on how many individual landowners' lands must be routed through.

Planning & Policy

General

- If the area is above 1 hectare, then an Environment Impact Assessment will be needed.
- It is advisable to carry out early land surveys on the designated site, ecology, archaeology and mining history especially if project is in South Wales.
- For standard grid connection, infrastructure outside the site is covered by the utilities company.
- However, onsite work such as a substation will require planning permission.
- Checks with statutory bodies such as Natural Resources Wales or Natural England are advised, to assess impact on forestry or water courses.

Site Specific

Control of major accident hazards regulations (COMAH)

- Applies to facilities that store potentially hazardous substances above specified thresholds, for hydrogen.
    - Lower Tier greater than 5 tonnes and less than 50 tonnes.
    - Upper Tier above 50 tonnes.
- You will need to notify the competent authority (HSE/NRW) 3-6 months before construction of the facility begins if the site is in either of these COMAH tiers.

Trade effluent consents (TECs)

- Required to discharge process waters into the public sewer.
- A TEC will contain a number of conditions related to the volume, flow rate and nature of the effluent that are set to protect the environment and water company assets.

Planning & Policy

Site Specific

Environmental Permit - The production of hydrogen falls under Schedule 1 Part 2, Section 4.2 a(i) of the Environmental Permitting Regulation.

Natural Resources Wales would potentially consider production of hydrogen from electrolysis as a low impact installation dependent on installation capacity and location. Early contact with the local NRW office is recommended.

To establish if a facility is low impact NRW has defined criteria that need consideration. These include:

- Management techniques
- Aqueous waste generation
- Abatement systems
- Emissions to groundwater
- Waste production
- Energy use
- Accident prevention
- Noise impacts
- Emissions of polluting substances
- Odour impacts
- Operator compliance history

For more information

- The Environmental Permitting (England and Wales) Regulations 2016
- NRW Standard Rules SR2009 No2- Low Impact Part A Installation

Planning & Policy

Local Area Energy Plan (LAEP)

A LAEP is a strategic plan developed at the local or regional level to guide the management, development, and transition of energy systems within a specific geographic area and will serve as a tool to assess the feasibility of hydrogen integration. This can refer to hydrogen as a clean energy carrier into various energy systems such as power generation, transportation, heating and industrial processes.

By including the elements below in a LAEP, communities can develop a comprehensive strategy for incorporating hydrogen as a clean energy source, driving the transition to a low-carbon energy system.

- **Resource Assessment:** Assess local hydrogen availability and production potential.
- **Infrastructure Planning:** Identify infrastructure needs for hydrogen production, storage, and distribution.
- **Sector Integration:** Explore opportunities to use hydrogen in transportation, industry, power generation, and heating.
- **Regulatory and Policy Frameworks:** Advocate for supportive regulations, incentives, and funding for hydrogen infrastructure.
- **Stakeholder Engagement:** Engage stakeholders, industry experts, and community organisations for input and collaboration.

Planning & Policy

Water Supply

Water quantity

The water consumption of an electrolyser needs to be evaluated and an application for water supply will need to be made to the regional water company, in the case of South Wales this is Welsh Water. The water volume required is dependent on the size of the electrolyser, the type used and the number of operating hours. For example, a 2.5MW electrolyser will need +/-600l/h with a disposable rate of around +/-200l/h.

Water quality

Most electrolysers will be able to use town's water which is of sufficient quality. If this is not available and a borehole or other water source is to be used, then further water treatment will be needed.

Water disposal

Most electrolysers need a wastewater drain which will require an application to the regional water company and a permit for operation. This permit will come with limits to the water content. Electrolysers will be compliant with these requirements.

Surface water discharge

As per Schedule 3 of the Flood and Water Management Act 2010, it is a mandatory requirement of all new developments to incorporate a sustainable drainage system (SuDS). This natural drainage system is incorporated to receive rainwater to help reduce flood damage, protect and improve the environment and protect health and safety, along with a wealth of other benefits.

Planning & Policy

Connection to the Electricity

In order to meet the energy demands of the green hydrogen production facility, a robust and efficient electricity supply needs to be established. Ideally, this supply should harness the power of renewable energy sources, such as wind, solar, or both, to ensure a reliable and sustainable supply of electricity.

There are a number of ways in which you can supply renewable electricity to your electrolyser:

- Via off site renewables with a private wire.
- Via on-site renewables.
- Via the grid.

Any of these options can be considered when constructing a green hydrogen facility but will depend on location and size of facility. It is important should the electrolyser need a grid connection or need the grid as back-up electricity that it should be supplied at 11kV or 415V unless the electrolyser is over 7.5MW for which a supply of 33kV or greater will be required.

Private Wire

Ideally, the maximum distance from the private wire supply to the hydrogen plant should be no more than 5km, to avoid high infrastructure costs.

Consider a well thought contingency plan as in most cases a private wire connection is a non-firm connection, meaning any maintenance needed on the line will put it out of action and temporarily unable to supply electricity to the hydrogen facility.

A substation will be needed on site to drop the high voltage down to low voltage to run through the local network.

The routing of the private wire should be carefully considered, to minimise the cost. Overhead wiring is highly recommended but where undergrounding is required it should be kept to as short a distance as possible. The number of wayleaves should be looked at as these will also come with their own costs.

Planning & Policy

On-Site Renewables

- Assess site suitability and available renewable resources. This may not always be possible but should be considered to maximise energy generation to meet the hydrogen facilities energy needs.
- Use energy storage to manage fluctuations, this will help harness energy at peak generation times and release it when renewable generation is low. This helps to ensure there is a stable energy supply to the electrolyser.
- Integrate with the grid to sell surplus energy if applicable.
- Develop an energy management system to optimise usage. This will help to effectively balance energy generation, hydrogen production and facility energy consumption.
- Comply with regulations and permits.
- Normally on-site generation requires a grid connection from the Distribution Network Operator (DNO). Timelines and costs can make this impractical, so consider whether the project can operate in isolation from the grid or with a small connection for essential loads. If this is the case very careful design will be required to meet the requirements of the DNO.

Grid Supply

Electricity from the grid can be obtained via a PPA from a green energy supplier, this should be used as a backup to the private wire and on-site generation to help keep a consistent energy flow to the hydrogen facility.

This option requires a standard power contract, which includes an energy component, network charges, and environmental and other taxes. A basic green-PPA or a more direct link with a renewable electricity provider via a sleeved supply contract are both options.

For a standard grid connection, an application will be required to your local DNO. This will need to include:

- A site map
- Single line diagram
- A letter of authority dated within the last 12 months signed by the landowner
- G99 ENA form

To help find your local GNO & DNO please follow the link: [Who's my network operator? – Energy Networks Association (ENA)]

Planning & Policy

Gas Connection

You must consult your local gas utility to confirm the processes for connection and to choose a connection point for your hydrogen plant. It would be advisable to minimise the distance between your facility and the injection point to help reduce the cost of constructing new pipeline.

Process for connecting to the grid are still under development but will include:

- Feasibility Assessment: Conduct a feasibility assessment to determine the suitability and viability of connecting hydrogen gas to the grid. This includes evaluating the existing gas infrastructure, available capacity, and the compatibility of the infrastructure with hydrogen.
- Infrastructure Upgrades: Assess the necessary upgrades or modifications required for the gas grid to accommodate hydrogen. This may involve retrofitting or replacing components, such as pipelines, compressors and meters to ensure they can safely handle hydrogen.
- Regulatory Compliance: Understand and comply with regulatory requirements related to hydrogen injection into the gas grid. Consult with relevant regulatory authorities to ensure adherence to safety standards, quality specifications, and reporting obligations.
- Hydrogen Purity and Quality: Ensure that the hydrogen gas meets the required purity and quality standards for injection into the gas grid. This may involve purification processes, removing impurities, and verifying the hydrogen composition to ensure it aligns with grid specifications.
- Blending or Direct Injection: Determine whether hydrogen will be blended with natural gas or directly injected into the grid. Blending involves mixing hydrogen with natural gas in controlled ratios, while direct injection involves injecting hydrogen separately into the grid.
- Injection Points and Grid Management: Identify suitable injection points within the gas grid for hydrogen integration. Determine the optimal locations to inject hydrogen while ensuring safe and efficient gas flow, grid stability, and reliable supply to consumers.
- Monitoring and Control Systems: Implement monitoring and control systems to monitor hydrogen injection, gas quality, and grid performance. This includes metering, pressure regulation, and real-time monitoring to ensure the safe and efficient operation of the hydrogen injection process.

Planning & Policy

Below are Welsh Government common policies and guidance for consideration in relation to hydrogen schemes.

Future Wales - The National Plan 2040

The Welsh Government strongly supports the principle of developing renewable and low carbon energy from all technologies and at all scales to meet our future energy needs.

In determining planning applications for renewable and low carbon energy development, decision-makers must give significant weight to the need to meet Wales' international commitments and its target to generate 70% of consumed electricity by renewable means by 2030 in order to combat the climate emergency.

UK Department for Energy Security and Net Zero (DESNZ) - Hydrogen Strategy update to the market

DESNZ are continuing to coordinate a range of projects with industry, regulators and other stakeholders to assess and prepare for hydrogen's potential use for heating, ahead of strategic decisions on the role of hydrogen for heating being taken in 2026.

However, it should be noted that a number of steps have already been taken to improve the clarity of hydrogen for heating. During 2023 a meeting will take place to discuss blending strategies, with the intention to enable blending.

Net Zero Wales Carbon Budget 2 (2021-2025)

The Welsh Government outlines a strong commitment to the future use of hydrogen in Wales to support a shift away from natural gas use in homes for heating. With the backing of financial support and clear hydrogen regulations the Welsh Government seeks to trigger a strong momentum shift towards the uplift of Welsh hydrogen in the medium to long term.

Community Engagement

Stage 1 – Awareness

- When embarking on a new project, potential customers typically start by becoming aware of their problem and seeking a solution.
- During this awareness phase, customers primarily look for educational content that can help them understand how services can address their issues.
- It is crucial to present information in a simple and engaging manner to keep customers interested.
- Customers in this phase prefer educational thought leadership content rather than promotional or product-focused insights.
- Organisations should prioritise providing value to customers instead of aggressively pushing their products, as this approach can be counterproductive.
- The focus should be on demonstrating how hydrogen can meet customer needs, emphasising its benefits through educational resources, and showcasing its potential positive impact on the community.

Stage 2 – Consideration

- When evaluating options, customers tend to compare the offerings of different organisations, such as hydrogen, heat pumps, or natural gas solutions.
- To consistently engage and foster trust with the audience, organisations can employ various strategies, including dedicated website content, showcasing success stories from previous hydrogen projects, implementing email nurturing campaigns, and hosting webinars or events.
- Customer Engagement teams play a crucial role in reinforcing the unique features and advantages of their products and services, enabling consumers to better grasp their benefits.
- Prospective customers in this phase are likely to actively interact with brands they are already considering.
- It is important to proactively address the major concerns and issues prospects have by actively listening to them during events, utilising questionnaires for engagement, and ensuring prompt and thorough responses to demonstrate empathy and attentiveness.
- During this phase, marketing teams should adapt the tone and messaging of their content, transitioning from high-level and educational to a more detailed and specific approach.

Community Engagement

Stage 3 – Decision

To capture the interest of those ready to commit, present an appealing hydrogen offering that covers all necessary details. By this stage, provide comprehensive information to the community, including pricing details, site locations, and any potential disruptions during the construction phase that may impact them.

Source: TechTarget

Customer journey plan for the HyRES project

Stage	Awareness		Consideration				Decision
Customer Goals	No goals at this point		Aim to be in a position to make an informed decision				Decide best option
Customer Activities	Need to consider energy options	Read HyRES leaflet delivered to door	Research HyRES online resources	Attend Event 1	Further ad-hoc interactions	Event 2	Homeowner 'buy-in' to 20% blend
Touchpoints / Experience	No touchpoints at this stage	Read leaflet Engage tel Engage email	Read website Read BCBC info? Compare options	View stands etc View brochures Speak to Team Take aways	Engage email Engage tel Visits by Team Event2 leaflets	View stands etc View brochures Speak to Team Take aways	
HyRES Goal	Identify target customer area	Raise awareness	Raise interest and educate	Make Hydrogen attractive	Reinforce message	Make Hydrogen match expectations	Deliver an attractive Hydrogen offering
KPIs	Number of homes targeted	Number of leaflets delivered to door.	Number of visits to web site	Number of attendees leaving details.	Number of 'follow on' interactions.	Number of attendees leaving details.	Number 'signing up' to Hydrogen offer
Organisational Activities	Develop engagement plan	Prepare/deliver leaflets.	Develop online resources, FAQs etc.	Prepare/deliver event	Respond to queries via email, tel & visits	Prepare/deliver event	Proactively emailing, telephoning, visits

Hydrogen Markets

There are a number of potential off-takers that can use green hydrogen for fuel or feedstock in their operations. These include:

- Industry - companies in sectors such as steel production, chemical manufacturing and refining are exploring the use of green hydrogen as a replacement to their fossil fuel use.
- Transport – both private vehicles and public transportation are exploring the use of hydrogen fuel vehicles as an alternative to conventional combustion engine vehicles.
- Agriculture – this can be used for farm machinery or heating of livestock sheds.
- Heating – initially through blending up to 20% hydrogen into the local gas network, potentially up to 100% depending on government strategy.

JCB hydrogen powered vehicles

Hydrogen fuel cell bus


Hydrogen use in industry

Oxygen Markets

As part of the hydrogen production process, there will be a considerable amount of heat and oxygen, so to increase overall efficiency of the process, determining any potential offtakes should be considered.

Potential offtakes for waste oxygen:

	Oxygen valorisation options	Special requirements for oxygen
1	Fish farming	Pure oxygen
2	Oxy-welding/oxy-cutting	High purity (>99.5%); 200bar, bottled supply
3	O2 delignification	Pressures around 4-8b
4	Wastewater treatment	Pure oxygen (>90%)
5	Laboratories	High degree of purity; +/-200bar, bottled supply
5	Healthcare	Several purity levels : 90-99%; different pressures: 24bar - 200bar

Source: Valorisation of O2 by-produced via H2 production from electrolysis – UCLouvain, Belgium

Heat Markets

Type of heat network	Supply temperature	Characteristics
High temperature heat network (HT-network)	>75℃	Direct supply of high-temperature heat for both space heating and hot tap water
Medium temperature heat network (MT-network)	55-75℃	Direct supply of medium-temperature heat for both space heating and hot tap water
Low temperature heat network (LT-network)	30-55℃	Direct supply of low-temperature heat for space heating. Reasonable insulation and LT delivery system needed; domestic hot water by means of a booster heat pump
Ultra low temperature heat network (ULT-network)	10-30℃	No direct heat supply; very low temperature heat for a combi heat pump that produces heat for space heating as well as for hot tap water. Reasonable insulation and LT delivery system required.

Source: Utilisation of Heat Released During the Production of Green Hydrogen Using Alkaline Electrolysis – F.S Le Coultre

The expected heat recovery temperature from an electrolyser is 75-80℃. However, the amount of recovered heat and its temperature are dependent on electrolyser technology and the distance between the electrolyser and the end user (the shorter the distance the lower the heat loss). On average 20% heat will be lost.

Some end uses for low temperature heat recover include:

- Domestic hot water and space heating
- Process heating
- Greenhouses/Vertical Farming

HyRES Team

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