Planning for Onshore Green Hydrogen

renewableUK

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Executive Summary

A thriving low carbon hydrogen economy is key to the UK's energy security and net zero ambitions. The UK government has an ambition to produce 10GW of low carbon hydrogen, of which half will be comprise of green hydrogen, produced solely from renewable sources. Green hydrogen's use extends to several parts of the energy sector, particularly heavy industry and transport, and will need to grow one hundred times from today's levels to meet the government's 2030 target. It is therefore imperative that the UK has a robust policy and regulatory environment which permits deployment at the scale and speed necessary.

Timely deployment is therefore critical; however this urgency is not reflected in the planning regime which has been criticised for being slow, complex and difficult to navigate for developers seeking consent. As such, RenewableUK has produced an industry-led report that will act as a comprehensive guide for green hydrogen developers seeking to navigate the planning and permitting regime all the way from conception to determination. It will then set out several sticking points and recommendations, of which a summary is provided below.

Sticking point	Recommendation	Lead
Unclear national guidance specific to green hydrogen • Green hydrogen does not benefit from the same guidance afforded by other renewable developments in national planning guidance, such as the National Planning Policy Guidance. • Lack of clarity as to whether a green hydrogen element of a renewables site can be considered as an associated development to an NSIP. • Unclear whether a co-located green hydrogen production facility can be included within the same planning application with a site's renewable generators, or instead requires a stand-alone application.	**Update guidance to include green hydrogen** • All national planning guidance on renewable energy generation across the UK should be updated to take account for green hydrogen. • Specific reference to green hydrogen production should be made in the NPPF and NPPG definitions of developments in flood risk areas. • Update Guidance on NSIP Associated Development to confirm that green hydrogen production may be an associate development of a primary renewable generator.	DESNZ (Department for Energy Security and Net Zero); DLUHC; Central and each devolved government[1]
Perceived negative impact on local water supply • Water scarcity is a major concern for regulators and the public, and therefore water abstraction for green hydrogen production should be managed sustainably. • This impact is particularly prominent within industrial cluster where a cumulative impact may arise from multiple developers using water. • Collectively this could be a major consenting risk if regulators are not satisfied that green hydrogen projects will not have a negative impact on local water supplies.	**Strategic approach to future water needs, including for electrolysis** • DESNZ should finalise its study on the impact of low carbon hydrogen on local water sources as soon as possible, with involvement across industry. • Explore options to mitigate water stress through, for example, water reuse, recycling systems and sustainable water withdrawal strategies. • Government and industrial clusters should work out how to reduce water abstraction in some areas through efficiency improvements and strategic approach to compensation. • Government to develop guidance and assurance on water supply impact.	DESNZ; Central and each devolved government; Industrial clusters

HSE and environmental regulators unable to process the pipeline of green hydrogen projects at pace • Insufficient resourcing and capacity at the HSE and environmental regulators impede their ability to deal with the at-pace rollout of new nascent technology, like green hydrogen. • The approach to permitting from the environmental regulators is currently unclear. • There is a lack of safety guidance form the HSE specific to hydrogen, which LPAs heavily rely on. • There is no statutory obligation on environmental regulators in the UK to deliver net zero in their decision-making. This means that low carbon generation faces challenges in gaining consents and positive statutory advice.	**Futureproof the environmental regulators and HSE for net zero** • Government and devolved governments to ensure there are sufficient mechanisms for the environmental regulators to get the funding they need. • The environmental agencies and HSE should develop guidance specific to green hydrogen setting out what is required. • Require environmental agencies to state clearly how their procedures, decision-making and advice will ensure alignment with net zero by 2050.	Central and each devolved government; Environmental regulators; HSE
The planning regime is not sufficiently prepared for green hydrogen production and pipelines • Green hydrogen projects are not always able to be brought forward as an NSIP. • Projects that require third party land, but do not need or want to go through the NSIP regime, are left in a potential ransom position because they are unable to realistically explore compulsory acquisition powers from alternatives. • Unclear whether EIA production facilities fall into the definition of an EIA development even if pipeline elements do.	**Modernise the planning regime for green hydrogen** • The upcoming updates to the NPPF should go further in their support for low carbon hydrogen and encourage them to go through section 35 process if they want to. This should include flexibility in multi-phase developments. • Amend the Gas Act 1986 to create a new category of licence called "gas producer" that would benefit from a new class of permitted development rights and is able to compulsorily acquire land. • EIA Regulations to be amended to create criteria by which appropriately sized hydrogen production facilities should be considered to be EIA development.	DESNZ, Central and each devolved government
Knowledge gap is hampering decision-making • Lack of understanding of green hydrogen projects and their planning and environmental impacts is likely to cause LPAs to be more cautious around the conditions and restrictions imposed on consents. • The above problem is exacerbated by the fact that existing assessment process Guidance, that LPAs use in reviewing environmental documentation, has not yet been updated to account for green hydrogen (e.g. IAQM, British Standards). • Planning decisions are influenced by the views of the general public who may be against what they consider an "industrial" style development, which they regard as hazardous.	**Educate relevant stakeholders about green hydrogen** • Industry stakeholders and trade bodies to build on messages of this document to LPAs, explaining that green hydrogen projects are primarily the new application of existing principles. • Industry should agree on standards and develop guidance to demonstrate that no issues or "likely significant effect" occur from green hydrogen developments, to assist with planning decision-making. • Industry and governments from across the UK should champion low carbon hydrogen projects and why they are key to net zero to the general public. This should include education around safety.	Industry-wide; Trade associations; Central and each devolved government; DESNZ

Introduction

Building a vibrant low carbon hydrogen economy is a critical part of the UK's route to achieving energy security and net zero emissions.[2] The development of this economy presents significant growth potential and the opportunity to attract investment, create jobs and decarbonise sectors that would otherwise be difficult to decarbonise.

The challenge is urgent; with a very limited amount of "low carbon" hydrogen produced today, UK government has set a target to install at least 10GW worth of low carbon hydrogen production capacity by 2030.[3]

At least half of this target will comprise what government refer to as "electrolytic" hydrogen, which is the process of using electrolysis to split water into hydrogen and oxygen. The electricity used to drive electrolysis can be produced from low carbon sources, including renewables and nuclear. Scottish Government have set their own target of 5GW installed renewable and low carbon hydrogen production capacity by 2030 and 25GW by 2045.[4]

"Green" hydrogen is the production of hydrogen via electrolysis using renewable power sources only. In addition to the benefits of energy security, decarbonisation and creation of a growth economy, the production of green hydrogen can increase the utilisation of the UK's present and planned renewable energy projects and make more efficient use of current and future energy infrastructure, while boosting the UK's energy security.

Timely deployment is critical if the UK is to capture this opportunity, however this urgency is not reflected in the planning regime which has been criticised for being slow, complex and difficult to navigate for developers seeking consent. Instead, changes to make the process simpler, faster and more predicable are required across the whole UK based upon clear guidance on how individual electrolytic projects are consented through the planning regime.

The aim of this report is therefore threefold:

For developers: Provide a go-to guide for green hydrogen developers seeking to navigate the UK's planning regime (sections 2 and 3).

For planners: Highlight sticking points of the current regime and myth busting to help planners understand key planning issues for green hydrogen projects (sections 1 and 4).

For government: Set out recommendations to government which make the process simpler and faster in line with targets (section 4).

Section 1: The Basics of Green Hydrogen

What is hydrogen?

Hydrogen is the simplest element, light and abundant.

When used in fuel cell applications hydrogen's only by-product is water. Fuel cells are devices that convert chemical energy into electrical and heat energy without burning fuel. This is a far more efficient process than the most common equivalent today: fossil fuel burning internal combustion engines. Hydrogen can also be burned as a thermal fuel in combustion engines where it produces no carbon dioxide, but it can produce a small amount of nitrogen oxide unless mitigated.

Hydrogen is not a new fuel, it is already produced and used in the UK with total current demand representing 518mt per year.[5] Hydrogen was also previously a major component in "Town Gas" (gas created from coal) during the 20th Century, which was used throughout the UK before the discovery of North Sea gas in the 1960s. Previous generations are therefore familiar with the use of hydrogen in a domestic context.

Nonetheless, most hydrogen production in the UK today tends to be carbon intensive (10kg of CO_2 per 1kg of H_2) and close to the point of demand, which is typically as part of an industrial process. These emissions can be mostly abated with carbon capture and storage, but this is energy-intensive and can have other environmental impacts. Green hydrogen is valuable because it is well-documented as the cleanest way to produce hydrogen, furthering our energy independence and progress towards decarbonisation goals.

Why is green hydrogen critical for net zero?

Thanks to its versatility, green hydrogen can be used as a fuel for sectors that are difficult to electrify (e.g. long-distance and heavy-duty transport); as a chemical feedstock (e.g. fertilizers and other chemicals) and in industrial processes as a reducing agent (e.g. steel) or thermal fuel (e.g. cement production, distilleries). As recognised in the Government's Hydrogen Strategy, green hydrogen can also support the integration of renewables with added benefits for energy security and resilience. For example, through balancing supply and demand through the provision of long-term, long duration energy storage, the provision of system flexibility services and reducing the curtailment of useful energy due to a lack of grid availability and battery storage.

Is hydrogen safe?

The priority for any green hydrogen developer is the safe construction and operation of their facilities. This includes adopting industry best practice and the highest standards of health and safety management.

Local planning authorities and the Health and Safety Executive (HSE) are typically the consenting bodies for all but the very smallest or largest hydrogen production facilities. Developers are required to produce robust and transparent evidence to these regulators that all risks to human health, habitats and property are controlled to a level that is "As Low As Reasonably Practicable" (ALARP). Regulators will closely scrutinise how any plant has been designed and how it is controlled, operated and monitored.

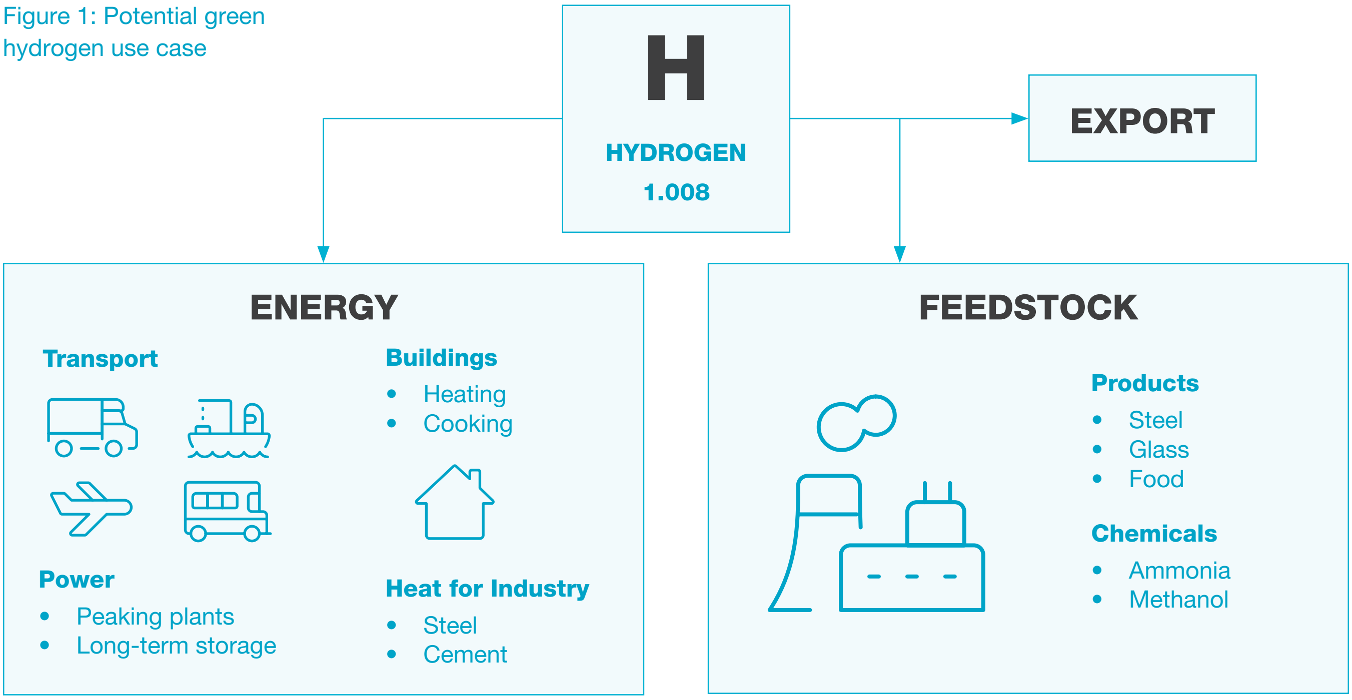
Sites storing larger quantities of hydrogen will additionally fall under the Control of Major Accident Hazards (COMAH) regulations. These sites' design and operation will be subject to further controls by the HSE and the environmental agencies.

A number of hydrogen's properties make it safer to handle and use than fuels commonly used today. For example, hydrogen is practically non-toxic by inhalation and carries no risk of contamination to soil, groundwater or surface water bodies. In addition, because hydrogen is much lighter than air, it dissipates rapidly upwards if it is released, allowing for quick dispersal in the unlikely case of a leak. Hydrogen has been produced and used on oil refineries, chemical manufacturing and metallurgical sites in the UK for many decades.

Additionally, transporting hydrogen through pipelines and using it in domestic or industrial appliances is very similar to present day transportation of natural gas, which is well understood and regulated for over 50 years, so the skills in managing this transition safely are already in place.

Section 1: The Basics of Green Hydrogen

Figure 1: Potential green hydrogen use case



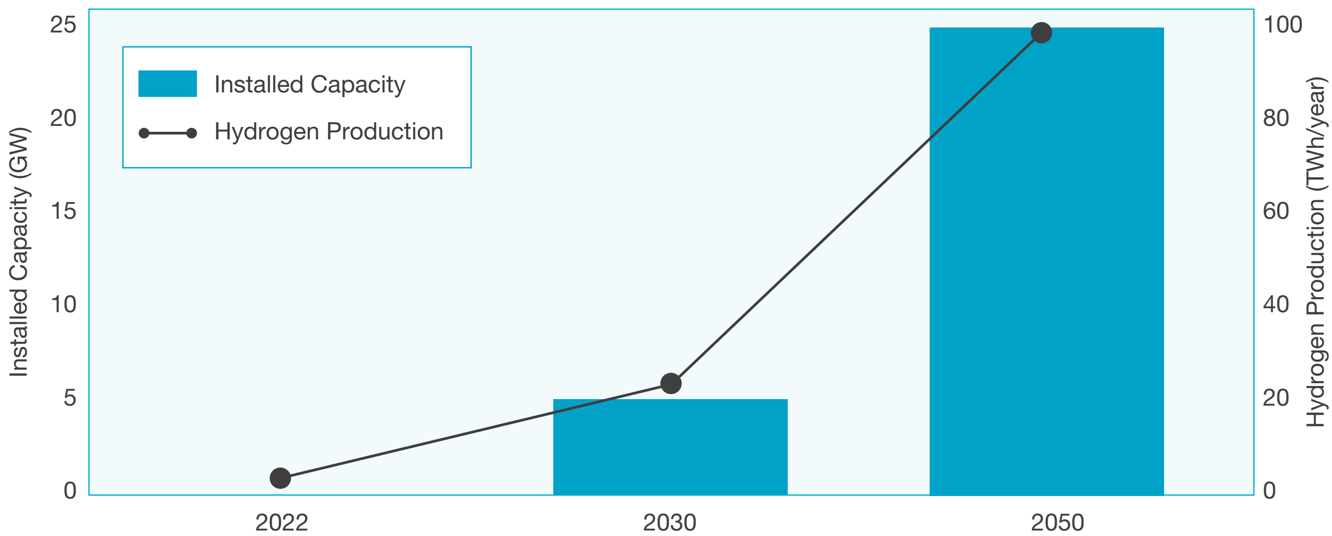
Source: RenewableUK

The creation of a green hydrogen economy, however, requires a step change from today's status quo which is reflected in the roadmap set out in the UK's Hydrogen Strategy and national targets for up to 10GW of low carbon hydrogen production by 2030, with a minimum of half of this capacity being green hydrogen production.[6]

By 2050, DESNZ forecasts that between 250TWh to 460TWh of hydrogen will be needed, with between 5% to 50% of this being green hydrogen. If we take the central point of these ranges, that will see the need for approximately 26GW of green hydrogen by 2050.[7]

The progression required to achieve this target is highlighted in the Figure 2 below.

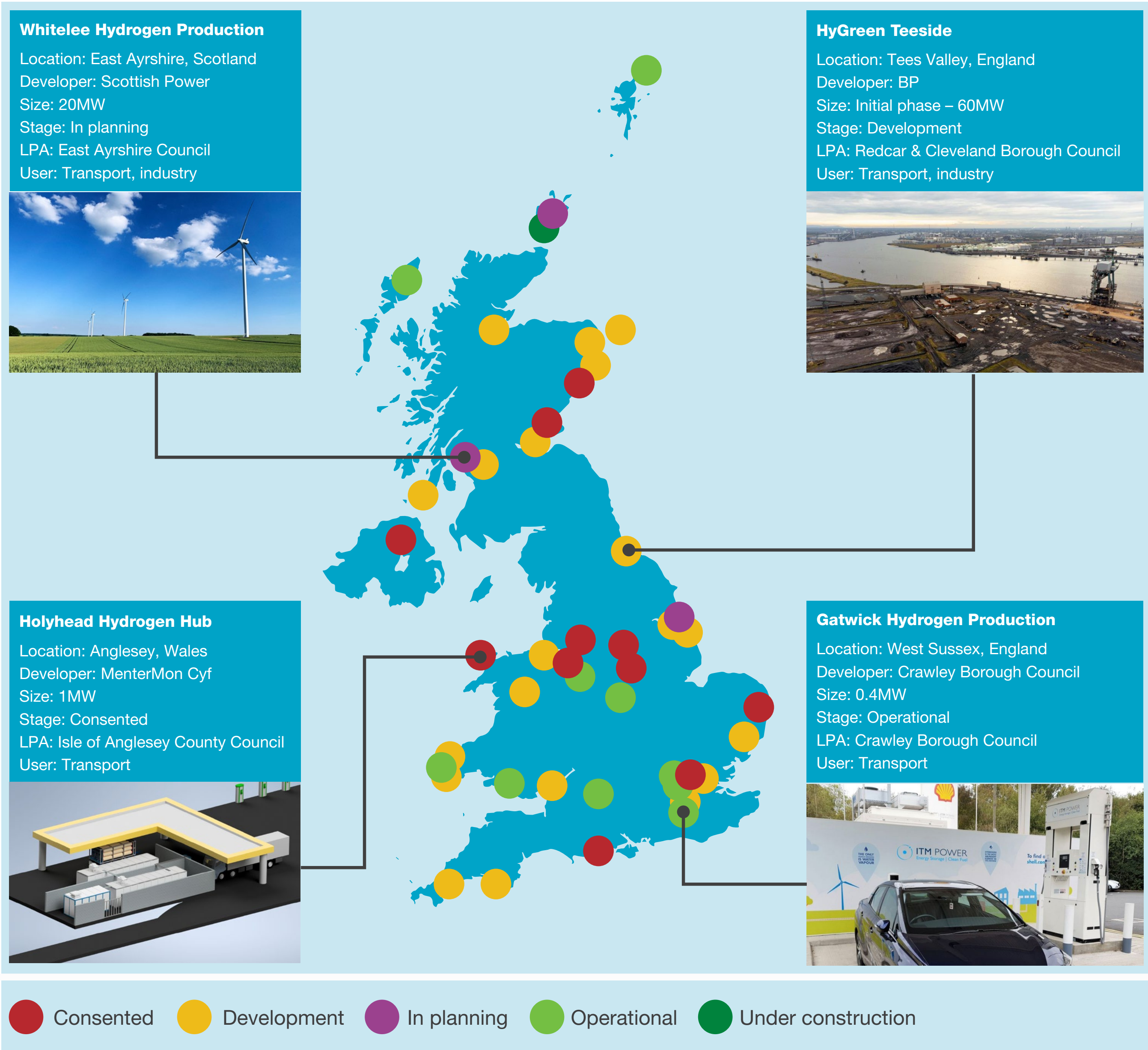
Figure 2: Estimated hydrogen production and installed capacity targets in the UK



Source: DESNZ, RUK

Meeting these targets will require timely development of multiple projects across the country. Figure 3 presents the location of a sample of UK low carbon hydrogen projects and demonstrates the spread across the country and, crucially, the range of local authorities that may be requested to host hydrogen projects.

Figure 3: Sample of green hydrogen production projects in the UK

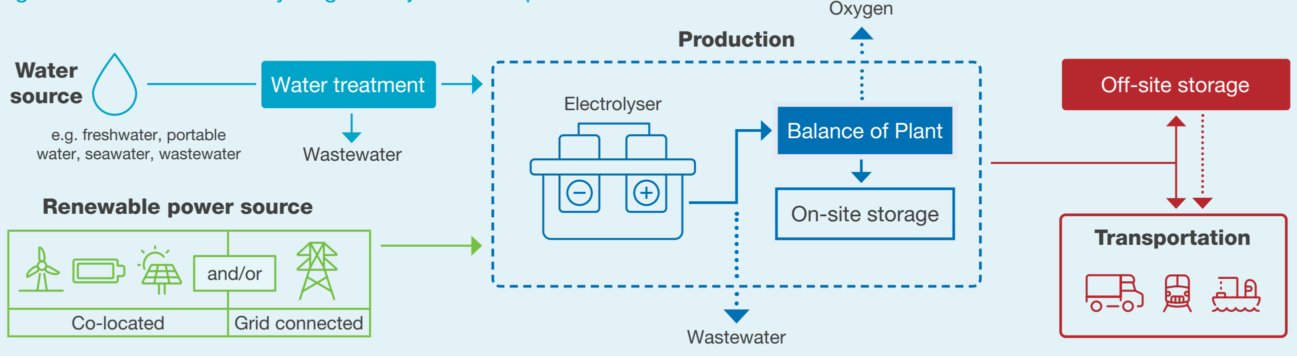


Source: EnergyPulse, RenewableUK

What does a green hydrogen production facility look like?

There are already multiple small-scale green hydrogen production projects in existence in the UK, and a number of larger scale projects currently at advanced stages of design and development. As the economy develops, projects are anticipated to take a range of varying sizes and types, depending on the business model and operating regime of the project owner. RenewableUK has previously described potential business models in *Renewable Hydrogen – Seizing the UK Opportunity.*[8] Despite the range of scenarios and sizes of projects, all projects tend to have the same key components of electricity and water supply, electrolysis and production of hydrogen. A generic green hydrogen project envelope is shown in figure 4 (overleaf).

Figure 4: Generic Green Hydrogen Project Envelope



The following sections describe the key components of a green hydrogen production project:

Electrolyser

Electrolyser "stacks" are the primary component of green hydrogen production. These stacks comprise several "cells" which are made up of two electrodes (positively charged anode, negatively charged cathode) that are separated by an electrolyte, commonly in the form of a liquid. The electrolyte is responsible for transporting the electrical charge from one electrode to the other, whereby hydrogen is produced at the cathode and oxygen is produced at the anode. There are currently three main types of electrolysers: alkaline electrolyte cell (AEC), proton exchange membrane (PEM), and solid oxide electrolyser (SOEC).

Technology	Description	Electrolyte	Operating pressure	Operating temp
AEC	Currently most mature and widely used in industry. The decomposition of water occurs in an electrolyte solution between the anode and cathode.	Potassium or sodium hydroxide	1-30 bar	100°C
PEM	Ionically conductive, solid polymer replaces the liquid electrolyte of the alkaline electrolysis design.	Solid polymer	70 bar	100°C
SOEC	Water vapour is used instead of liquid water as an input. Steam is fed to the cathode side of the electrolyser where it is broken down into hydrogen and oxide ions, which travel through the solid electrolyte towards the anode.	Solid ceramic	1 bar	500-850°C

Power source

Electrolysers operate at low voltage and use direct current which may be either supplied from the grid, dedicated renewables or a mixture of both. Electrolysers are flexible and can operate continuously or at times when electricity demand is low or when renewables-based power generation is high, helping to balance the supply and demand on the electricity grid. To demonstrate that a project is producing "green" hydrogen, it will require an explicit link to renewable electricity production to evidence that (e.g. compliance with the Low Carbon Hydrogen Standard).

Transformers are used to step down the voltage and a rectifier is used to convert the alternating current of the grid to direct current.

Water supply

Through the process of electrolysis, water is split into hydrogen and oxygen. This water can come from various sources, including ground or surface water; the sea; wastewater; or more commonly, a water utility's piped supply. Regardless of the source, the water will need to be cleaned and deionised (e.g. through reverse osmosis or desalinisation) to prevent it from damaging the equipment.[9] Moreover, desalinisation typically accounts of 1% of the electrolytic hydrogen production costs, enabling sea water to be utilised as feedstock in the future.[10]

Due to the concentration of brine, a portion of the water input is withdrawn and rejected from the system, and therefore will need to be collected and disposed of.

Oxygen

Green hydrogen production simultaneously produces oxygen which may be either vented into the atmosphere in a controlled manner or captured and stored for commercial use (e.g. sewage treatment works, medical).

Balance of Plant (Gas separation, treatment and compression)

Often referred to as "Balance of Plant", gaseous hydrogen requires treatment, gas separation and compression and in many cases storage ahead of transport.

- Separation units and gas treatment are used to separate the hydrogen from the oxygen.
- Drying equipment is used to remove traces of water.
- Compressors are used to increase hydrogen pressure for storage purposes if it cannot be done by changing the operating pressure of the electrolyser.
- Where vehicle transport is required, there needs to be storage and loading facilities to enable this.

Storage

The hydrogen may be stored on-site or off-site until it is needed. Compressed gas can be stored in pressure vessels or tanks for use in many applications, including vehicles, marine vessels, hydrogen refuelling stations and industrial heat. For long distances, liquid hydrogen may be stored in cryogenic vessels to increase energy density for transport. Alternatively, hydrogen carriers, such as ammonia, may be used or solid-state storage and sorption mechanisms (e.g. metal hydrides) to allow for more efficient use of space.

Transport and distribution

When required the hydrogen can be transported as a gas via new or repurposed pipelines, or as a gas or liquid via road, rail and marine transport. Subject to Government approval, hydrogen may in the future also be blended with natural gas in existing distribution networks, comprising up to 20% hydrogen. The government is expected to reach a decision on blending in late 2023.

CASE STUDY

Pembroke Green Hydrogen Project

Image is illustrative and an artist's impression of RWE's electrolyser project at Lingen, Germany.

RWE has plans for a number of green hydrogen projects in the grounds of its existing gas-fired 2.2GW power station, development of the initial phase is well advanced with a planning application expected in quarter 3 this year and commercial operation in 2026, subject to consents and funding decisions. Later phases of development are following behind.

Location: Pembrokeshire

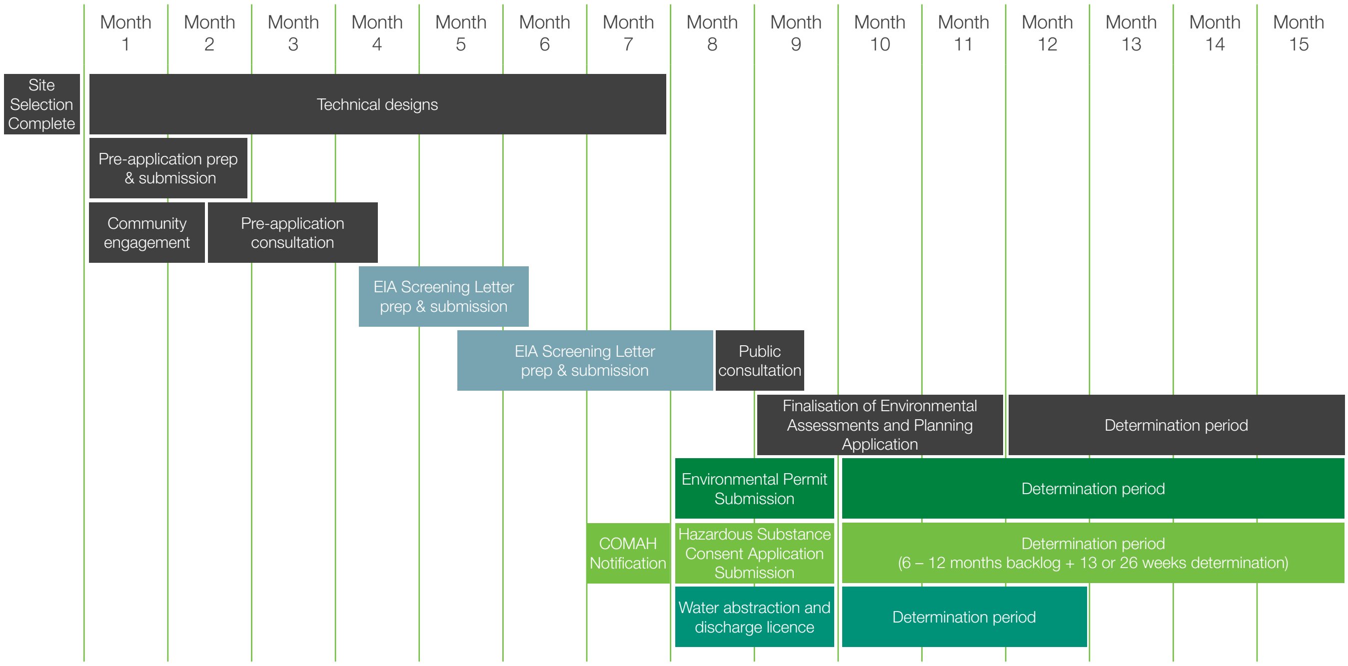
Developer: RWE

Size: Phase 1 (110MW), Phase 2 (~200MW), Phase 3 (GW-scale)

User: Industrial / Transport / 100% Hydrogen Backbone

Section 2: Planning Regime for Green Hydrogen

Having outlined the basic components and purpose of a green hydrogen facility, this section details a typical journey through the planning regime for an onshore green development in the UK. The diagram below has been developed as a representative schedule for a typical green hydrogen project, and it should be noted that both the structure, schedule and sequence presented below will vary from project to project. The breakdown of main tasks illustrated are not exhaustive and it is worth noting that environmental surveys across each season in a calendar year may be required, and therefore should be planned in sufficient time ahead of the planning application submission. Each represents the minimum time in each phase and there is a possibility of each major item causing delays to other items, and a statutory Environmental Impact Assessment (EIA) may not always be required.



Site selection

Before submitting a planning application, a developer must select a site where it wants to build the green hydrogen production facility. When selecting a site, the developer may want INITIAL discussions with the Local Planning Authority (LPA) and should consider local development plans. It will also need to consider the following issues:

- **Total land area required:** during construction: For example, road access, turning areas, construction laydown areas and room for landscaping.
- **Safety aspects of land use:** Including proximity to adjacent land uses (depending on project size) and truck and tanker movements.
- **Adequacy of surrounding road networks:** This must be adequate for larger vehicles accessing site during construction phase (HGVs, cranes) and the operational phase (delivery vehicles and users of any refueling facility that is created). Often the level of movements attributable to such a proposal are key issues which give rise to local concerns and so they should be given early consideration to seek to quantify and define the potential impact of the proposal by reference to existing traffic levels and the effect of the proposal on those levels.
- **Environmental considerations:** Selection of sites which avoid environmental sensitivity or designations as far as possible reduces the number and level of future planning issues to be addressed.
- **Amenity considerations:** Selection of sites which minimise effects on residential properties as far as possible, and address issues likely to cause concern for the population in the surrounding area. This could be any combination of noise, traffic, visual impact, or loss of amenity. These points must be considered early and addressed thoroughly.

Site selection (continued)

- **Demonstrating the need case:** The developer should be prepared to demonstrate the need case for the facility, even though any application will be viewed in the context of paragraph 158 a) of the National Planning Policy Framework (NPPF).[11] This advises that a LPA should not require applicants to demonstrate the overall need for renewable or low carbon energy development and should recognise that even small-scale projects provide a valuable contribution to cutting greenhouse gas emissions. There is further policy support for hydrogen in multiple Government policy documents, including the emerging National Policy Statement for Energy. Additionality, explaining the demand that is being met by the application, or its wider purpose helps create an understandable narrative for those weighing the benefits and impacts of an application. To which end, it would also be advantageous to demonstrate the sustainability of the proposal in terms of the obvious environmental benefits, but also the economic and social benefits of the proposals, versus any disbenefits.

Pre-application discussions with the relevant planning authority

Once the site is selected, the first step will be to meet with the relevant planning authority prior to submitting a planning application to understand their requirements and potential issues.

The proposals should be developed sufficiently to enable the officers and planning committee members to understand the general nature, scale, and design of the proposals, and should include considerations of traffic movements, visual impact, drainage and pollution control, noise, and any planned grid connection (electrical or gas). The initial proposals should also be sufficient to inform an accurate Environmental Impact Assessment (EIA) screening opinion, described in more detail below.

Each Authority may have its own pre-application procedure and requirements however, as a minimum, it is suggested that the following documents be made available for discussion purposes:

- **Location Plan** (suggested scale 1:1250 or 1:2500).
- **Existing and proposed Site plans** (suggested scale 1:500 or 1:1000).
- **Indicative elevations** (suggested scale 1:50 or 1:100).

Useful information may also be available by searching the LPA's webpage to see how similar applications in the local area progressed through the planning process. There are examples of green hydrogen related planning applications in both England and Scotland, such as Trafford Council in Greater Manchester, Highland Council and Fife Council in Scotland.

It should be noted that any advice received at this stage is not binding on the determining Authority and the local authority may charge for the provision of pre-application support.

If the Nationally Significant Infrastructure Project (NSIP) (NSIP) regime is sought to be used, a direction under Section 35 of the Planning Act 2008 to bring the development into that regime must be sought (which is only available in England). The rest of this section is based on the Town and Country Planning Act (TCPA) regime being used.

Preparation of initial proposals

Local planning documents: The initial proposals should be prepared considering the appropriate national and local planning policy and guidance. Local policies are contained within the borough's Local Development Plan. Detailed guidance may also be available from the local authority's planning department and will vary depending on the planning priorities in each Local Authority area.

National planning documents: National planning policy for England is available in the National Planning Policy Framework (NPPF) and the National Planning Practice Guidance (NPPG), although both require inclusion of the greater detail on hydrogen development. At the time of writing, reforms to the NPPF are being consulted on, however, the above remains unchanged under the current proposal.

Submission of a request for a formal EIA screening opinion

The planning application for a green hydrogen facility, depending on its scale and nature, may require the submission of an EIA in line with the Environmental Impact Assessment Regulations (England 2017, Scotland 2017, Northern Ireland 2017, or Wales 2017). In order to confirm whether an EIA will be required, a formal request may be made to obtain a screening opinion from the local planning authority, or screening direction from the Secretary of State. A screening direction from the Secretary of State would only be necessary if the applicant felt the local planning authority was incorrect in their screening opinion or if the request was taking an unjustifiably long time to be determined.

The screening request should be made in writing to the relevant planning authority and accompanied by a plan identifying the site, a description of the nature and purpose of the development and its potential impacts on the environment, and any other relevant information.

The regulations set out parameters for developments and split them into:

- **Schedule 1** developments which always require an EIA; and
- **Schedule 2** developments which are assessed against criteria to ascertain whether an EIA is required to accompany the application.

Where or whether green hydrogen production facilities fall within the Schedules is still unclear due to their novelty. Other energy projects of similar scales are generally assessed against Schedule 2 of the regulations, which include the Energy Industry Criteria, and specifically category 3a: "*Industrial installations for the production of electricity, steam and hot water*", which relates to sites over 0.5 hectares in size. However, hydrogen primarily involves the production of gas. Depending on the specific design of a project and some element of discretion in the interpretation of the Schedules, green hydrogen may be determined to fit within these criteria, although it could also fall under category 6a: "*Treatment of intermediate products and production of chemicals*". This question needs to also be considered in the context that pipeline elements of a hydrogen project would be considered under Schedule 2 under category 10(k) – a gas pipeline installation.

If an applicant is facing time constraints, it is possible to have an EIA screening opinion determined on submission of the full application. This would depend on the scale of the project, but this may make the submission process quicker but it also runs the risk that if it is determined that an EIA is required, this will significantly delay the determination of the application. This route should be used if the applicant's advisers are confident that an EIA is not required. In some areas the planning officer who issues the screening determination is highly likely to then be assigned the full application. This can often mean that they take the opportunity to offer useful guidance on the issues that are likely to be relevant to the determination of the application.

In any event, even if it was determined that an EIA is not required, it is sensible for environmental assessment and reporting to be undertaken to enable the local planning authority to understand the impacts of the scheme, even if this is not strictly an 'Environmental Statement'.

Planning for hydrogen transport & storage infrastructure

If the end-use will involve distribution of the hydrogen through new pipeline infrastructure (either to a customer, end-user or the gas network), the extent of that pipeline and the party responsible for constructing that pipeline will need to be understood. Depending on the length of the pipeline and the party delivering the pipeline (specifically if they are, or will be, a "gas transporter"), the pipeline may meet the thresholds for a NSIP pursuant to sections 20 or 21 of the Planning Act 2008.

Pipeline infrastructure is likely to include underground pipelines, above ground installations and block valve equipment.

Similarly, if the end-use will involve transportation, the work required to deliver any associated port, road or rail infrastructure for the onwards transportation of the hydrogen will need to be considered. This may necessitate consents under various other planning regimes such as a marine licence under the Marine and Coastal Access Act 2009, an order under the Transport and Works Act 1992 or the Harbour Act 1964. In some circumstances, the associated works may meet the relevant thresholds for an NSIP pursuant to sections 22 to 26 of the Planning Act 2008; or could be sought to be brought together and consented under the Planning Act, pursuant to a Direction under section 35 of that Act.

Underground hydrogen storage may also meet the thresholds for a NSIP pursuant to section 17 of the Planning Act 2008, depending upon its scale. Alternatively consent would be required under the TCPA.

Section 2: Planning Regime for Green Hydrogen

Scoping and production of the Environmental Statement (if it has been determined that an EIA is required)

If it is determined that an EIA is required, it is usual practice to then submit a formal request for an EIA Scoping Opinion to the planning authority in order to determine the required content for the EIA. In England and Wales, local planning authorities have a statutory period of 5 weeks to provide the formal scoping opinion which will also include responses from key statutory consultees such as the Environment Agency and Natural England.[12] Within Scotland, the LPA is required to provide an opinion within 8 weeks of receiving a request, and Northern Ireland specify a 30-day period for the LPA to provide a formal EIA scoping opinion.[13]

The EIA should include consideration of the aspects of the environment likely to be significantly affected by the development, which may include: ecology (in particular any protected species); surface water drainage and ground water impacts; noise; odour; transport; archaeology and heritage; landscape; and the inter-relationship between the above factors. The findings of the EIA process are set out in an Environmental Statement and supporting Non-Technical Summary document which are submitted with the planning application.

Depending on the underlying sensitivity of the site, and scope of works required the EIA (or environmental reporting otherwise) can take a long period to produce. For example, if relevant, some ecology studies may need to be undertaken during a particular season to enable a full evaluation of the impact on protected species. Generally speaking, however, a relatively uncomplicated, previously developed site with limited off-site impacts would be expected to take a minimum of 3 months to undertake the EIA process and prepare an Environmental Statement, should one be required at all. For sites with significant pre-existing sensitivities or development that have significant off-site impacts, 12 months is a more realistic estimate for preparation of an Environmental Statement. Depending on location and circumstances, a Habitats Regulation Assessment may also be required.

Public consultation

It is advised that public consultation is undertaken to establish and, where appropriate, address any concerns prior to the planning application being submitted (e.g. water impact, health & safety etc.). This can also help inform the project design to demonstrate how local feedback has been taken account of in the development process. It may highlight any local issues which need to be addressed as part of the planning application and help avoid or minimise objections through the formal consultation process. This may include consultation with local parish and town councils where relevant. Involving local councillors at an early stage can be beneficial both to anticipate any issues that are likely to develop and to demonstrate how the applicant wishes to work with the local community to develop the proposal. It can lead to local members being advocates in favour of an application.

Consultation can also be undertaken with statutory consultees and potentially with other interested parties (such as Wildlife Trusts). The local planning authority may provide advice on which organisations, individuals and/or communities should be consulted, and the consultation activities that should be carried out. The consultation activities, findings and any subsequent refinement on the proposals should then be presented in a Statement of Community Involvement (or Pre-Application Consultation Report in Scotland and Northern Ireland) accompanying the planning application.

Typical issues raised by consultees include:

Issue	Description	Examples of best practice
Noise	Potentially significant sources of noise include: construction of the site; noise associated with electrolysers (mostly that from the fan unit on the roof of a container), ancillary plant including compressors, vehicle movement on site up to 24 hours, including reversing alarms.	With the exception of vehicular movements, all of these sources can be addressed at the design stage – this may increase costs but can significantly reduce amenity impacts and help improve the community's perception of green hydrogen. Due to green hydrogen's relative novelty, more information is required on likely levels of noise generation from sites and a need for guidance on this issue, as suggested in our recommendations. If pre-application discussions have identified noise as an issue, it may be wise to engage an acoustic consultant to advise on the current noise climate on the site and to seek to predict the likely levels of noise to demonstrate that these are within acceptable limits.
Vehicle movements	Deliveries to and from the green hydrogen site can be of concern for residents. The environmental impact of transport is a key consideration in obtaining planning approval.	Although the number of truck movements can be difficult to predict with accuracy and may vary through the year, a good starting point to consider is the type of road that must be negotiated on the normal routes to and from the green hydrogen site. It would also be advisable to know the current level of traffic movement on the local highway network as the starting point against which the materiality of any traffic increase can be assessed. Consideration should be given to any need for imposing controls on hours of operation or operating procedures where there are residential properties near the proposal, where such controls are shown to provide necessary mitigation. Roads will require suitable access to major carriageways.
Drainage, water supply and water pollution	Processing of water produces a higher salinity output which will ordinarily be treated as wastewater (brine). A strategy for dealing with surface water from the plant area will be required, including containment measures for pollutants.	It will be important to ensure that appropriate surface water drainage and control measures are put in place to satisfy the environment agencies that there will be no unacceptable impacts to ground water or nearby water courses. Discharge or disposal methods for wastewater from the plants also needs to be considered. Due to increasing demand on water resources, it is recommended that green hydrogen developers engage with water utilities early on, particularly in areas where water is in short supply, to ensure its abstraction strategy aligns.
Odour	Gases released from green hydrogen production would primarily be hydrogen and oxygen, which are both naturally odourless. If the site is used for refuelling fuel cell vehicles (including HGVs) there will only be water vapour released by their use. Odour is likely therefore to be a negligible issue.	
Landscaping	The visual impact of the proposal may be a cause for concern for the local community, particularly where the facility is proposed on greenfield land.	Landscaping and planting schemes are the primary means of addressing these concerns. The most effective approach is to involve the site's neighbours in the development of the scheme and careful consideration when siting.

Section 2: Planning Regime for Green Hydrogen

Ecology	Irrespective of the pre-existing condition of the site, an application should be accompanied by an assessment of the impact of the application on ecological receptors. The exact requirement will vary depending on the location and footprint of the facility. This is likely to include a phase 1 habitat survey. If this reveals the potential for protected species to be present, then further surveys may be required. For example, ponds within 500m of the site should be surveyed for newts, while trees and buildings will be surveyed for evidence of bat roosts. There are different survey windows for different species. For example, the majority of pond survey methods for newts will only be effective from April to June. This does not mean all applications will involve pre-application surveying within those survey windows, but applicants must frame their approach in a careful and considered manner in consultation with the relevant statutory nature conservation bodies. Similarly, planning conditions based on the protection of certain species types may affect building methods in different ways at different times of the year, this will include nesting periods, and times of hibernation. Some impacts can be avoided with careful design. Examples include avoiding or minimising the removal of hedges in the design process and avoiding root protection zones of trees surrounding the development.	
Archaeology and Cultural Heritage	All applications should be accompanied by a Cultural Heritage and Archaeological Desk Based Assessment (DBA). This should consider the impact of the proposal on both potential archaeology and the built environment. If archaeological potential is considered likely then depending on the scale of the site, and the reason for the potential, further archaeological investigation work may be necessary, although in practice this will only apply to a small number of sites where there has been no previous modern development. Where additional work is necessary this could include Geo-physical Survey; Trial Trenching; production of a Written Scheme of Investigation; or an Archaeological Watching Brief, where a qualified archaeologist observes the critical ground works and excavations that may have an impact on potential archaeological remains. These can in most cases all be carried out post the determination of the application and linked to a pre-commencement planning condition. This reduces the risk of spending more money on the application, before it is known that it can be built, but can cause delays to the commencement of construction, when the applicant may need to ensure the project meets a specific subsidy-related construction deadline. Depending on the outcome of the consultation process, it may be appropriate and/or necessary to modify proposals to address concerns raised over archaeology to leave areas of archaeological interest undisturbed by development.	
Health and safety	Concern over safety, particularly from neighbouring occupiers, is likely to feature in most hydrogen planning applications. Safety regulations is addressed more fully in Section 3 of this report, with only brief comment here.	Safety, of those operating hydrogen plant and those close enough to a site to be affected by a safety incident, is primarily the responsibility of the Health and Safety Executive that operates under a well-established and highly effective body of regulatory law and policy. Planning decisions are required to recognise and not duplicate these controls, meaning the main engagement regarding safety in a planning application is to explain briefly but clearly how safe operation is ensured. Best practice in this area will recognise that public consultees and those taking planning decisions will understandably be concerned about safety and that an apprehension of danger may be present even if not based on evidence. Early engagement with the public on safety and the inclusion of a proportionate body of information relevant to the specific proposal can greatly assist with providing reassurance during the decision-making process, without making site safety an issue for the planning authority to manage in its decision or in the conditions it attaches to a permission.

Finalising the proposals and submission of the application

It is necessary to produce a detailed layout and site design to enable the planning application to be properly assessed. The basis for this will be a detailed topographical survey on which the proposed design can be based. The overall site design should take account of any planning or site constraints and operational requirements. This can include landscape, access or ecological factors or avoiding neighbouring uses.

Validation

Once an application is submitted, the LPA will check the documents submitted contain all the necessary information required to be considered value and processed for validation. This will be likely to focus on whether:

- The correct planning fee has been paid;
- All the correct documents have been submitted;
- Any additional component drawings the authority may require are included;
- Drawings are all at the correct scale;
- An accurate scale bar has been included on all drawings and plans, as this a standard requirement of a number of local authorities; and
- The technical details of the location plan are correct, with particular reference to vehicle access from the public highway and the required details for the red line boundary of the application and the wider blue line boundary of property ownership.

Until any outstanding validation issues are resolved an application will not be duly made, and the determination period will not have started. Most problems can be avoided with careful document review prior to submission. It is also worth noting that different Councils may have varying validation requirements.

Determination period

The finalised planning application is then formally acknowledged received by the planning authority. A planning application for a small-scale green hydrogen plant may be determined within 8 weeks; a major application may take up to 13 weeks, and a site subject to EIA regulations up to 16 weeks. These targets will usually be discussed at the pre-application stage. However, this determination target is not always met; for example, if any of the statutory consultees could be slow to respond to the officer, delaying the application's determination.

Where appropriate, the applicant may wish to secure a Planning Performance Agreement (PPA) with the local authority. The two parties will agree on timescales, actions and resources for development and can allow the applicant to understand the determination process for large projects. This agreement should cover the pre-application and application stages; however, it can also continue into the p ost-application stages. Most local authorities will not agree to PPAs being legally enforceable and they are therefore not a guarantee of efficient performance from them.

The majority of planning applications are determined by the Council's Head of Planning under delegated powers. Larger or more contentious applications are normally determined by locally elected members forming the Council's Planning Committee. Following consideration of the application by the Case Officer, taking into account any consultation responses received, a recommendation is made either to approve or refuse the application. Although not obliged, it is usually the case that the Planning Committee will support the recommendation of the Planning Officer. If the application is not determined within the statutory timescales or the application is refused, the applicant has a right to appeal to the Planning Inspectorate.

Post determination

A planning permission will typically include conditions (or reserved matters in the case of outline applications), which need to be addressed within a specified timeframe, often prior to commencement of the site works. For example, a planting scheme may need to be submitted to the planning authority and approved as part of a discharge of the planning conditions. In many cases, applicants can take action to satisfy pre-commencement conditions prior to the full determination of the application.

In addition, there is the potential for a legal agreement to be required – in England and Wales (Section 106 Agreement), Scotland (Section 75 Town and Country Planning (Scotland) Act 1997), and in the case of Northern Ireland (Article 10). These agreements allow local planning authorities to form legally binding planning obligations with the developer to ensure that the development is acceptable. These planning obligations must be related to the development itself and can deal with matters such as off-site works or improvements to the local road network (such as roundabouts or pedestrian crossings) and are generally required only where a planning condition cannot secure the same objective, such as works outside the application site or securing of financial contributions to secure necessary planning objectives related to the development.

Section 3: Safety and Environmental Consenting and Regulation

The previous section looked at the planning process and the related requirement for EIA. It is recognised that green hydrogen production projects will also require consents from, and be regulated by, other government agencies in addition to the relevant planning authority. In particular these requirements relate to the control of public safety and environmental protection, with the key authorities being the Health and Safety Executive (HSE)[14] and the respective UK environmental regulators.[15]

The HSE and environmental regulators are also statutory consultees to most planning applications and so have a direct role in advising planning authorities through the planning process. In addition to its statutory responsibilities for the regulation and enforcement of workplace health, safety and welfare, the HSE also advises on the protection of public safety. The environmental regulators each have a wide range of statutory functions with respect to environmental protection including the regulation of certain industrial processes and the licencing of water abstraction.

In addition to the planning regime, green hydrogen developments will likely fall into several important existing regulatory regimes. There is a comprehensive existing regulatory framework covering the safety of hydrogen production and storage. The primary regimes are:

- Hazardous Substances Consent
- Control of Major Accident Hazards
- Environmental Permitting
- Water abstraction and discharge licencing

There are many other secondary consents that may be required on a case specific basis, for example wildlife licences from the applicable statutory nature conservation body. However, this report is focused on the above four key regimes which collectively regulate some of the primary concerns that may be expected to be raised during the planning process.

Environmental regulators

There are several bodies responsible for regulating activities that can impact the environment across the UK, including air, land and water pollution. These are:

- England - Environment Agency (EA)
- Scotland- Scottish Environment Protection Agency (SEPA)
- Wales - Natural Resources Wales (NRW)
- Northern Ireland Environment Agency (NIEA)

Dealing with related applications for hazardous substances consent, an environmental permit, control of major accident hazards and for planning permission in parallel can assist with speeding up decision making and avoiding unnecessary duplication in providing information.[16]

There may be different considerations, and decisions, for related applications. It is important that related decisions are not inconsistent (e.g. conditions containing conflicting requirements) or duplicating controls in other regimes. For example, detailed control over the way a hazardous substance is to be kept or used is best addressed by hazardous substances consent conditions.

It is important to note that, in its role as the statutory regulator of health and safety, the Health and Safety Executive (HSE) has wide-ranging powers of inspection, enforcement and ultimately prosecution under the Health and Safety at Work etc Act 1974. The HSE will exercise these general responsibilities in ensuring the safety of a particular hydrogen production facility during both its construction[17] and operation.[18] There are also specific requirements which require an operator to provide information to the HSE prior to starting work.

Section 3: Safety and Environmental Consenting and Regulation

Hazardous Substances Consent[19]

The hazardous substances consent (HSC) process[20] ensures that necessary measures are taken to prevent major accidents and limit their consequences to people and the environment. The HSC is a planning consent and is required for the presence of, above controlled quantities, certain hazardous substances which could present a major off-site risk. The threshold for hydrogen is low, at 2 tonnes, and therefore it is likely that most green hydrogen developments will require consent. Depending on the electrolyser design, storage of a concentrated (alkaline) electrolyte may also be covered.

The relevant hazardous substances authority, which is typically also the LPA, has responsibility for deciding whether the risk of storing hazardous substances is tolerable for the community. As a form of planning consent, applications for an HSC are subject to publicity, consultation with both the public and statutory consultees and will most likely be determined by a planning committee in a public forum. The HSC is a specific consent regime addressing safety issues and the exercise of discretion by HSC decision-makers relates only to that range of safety issues that should all be determined on the basis of objectively justified evidence.

Separate health and safety law[21] ensures measures are in place for the safe use of hazardous substances. However, even after measures have been taken to prevent major accidents, there will remain the residual risk of an accident which cannot entirely be eliminated. Hazardous substances consent ensures that this residual risk to people in the vicinity or to the environment is taken into account before a hazardous substance is allowed to be present in a controlled quantity. The extent of this risk will depend upon where and how a hazardous substance is present; and the nature of existing and prospective uses of the application site and its surroundings. Public concern about safety is a legitimate consideration for a planning authority in the grant of planning permission or HSC; however, concern about residual risks that are not supported with robust empirical evidence would not be expected to be a decisive factor in decisions.

The COMAH Competent Authority (CA)[22] advises the hazardous substances authority on the nature and severity of the risk to persons in the vicinity and the local environment arising from the presence of a hazardous substance at an establishment. The CA is a statutory consultee and must be consulted by the hazardous substances authority before an HSC can be granted.

In view of its acknowledged expertise in assessing the off-site risks presented by the use of hazardous substances, any advice from the CA that hazardous substances consent should be refused should not be overridden without the most careful consideration. Similarly, advice from that CA supporting the grant of HSC would not be something to be overridden without identification of grounds of objection supported by a suitably authoritative source.

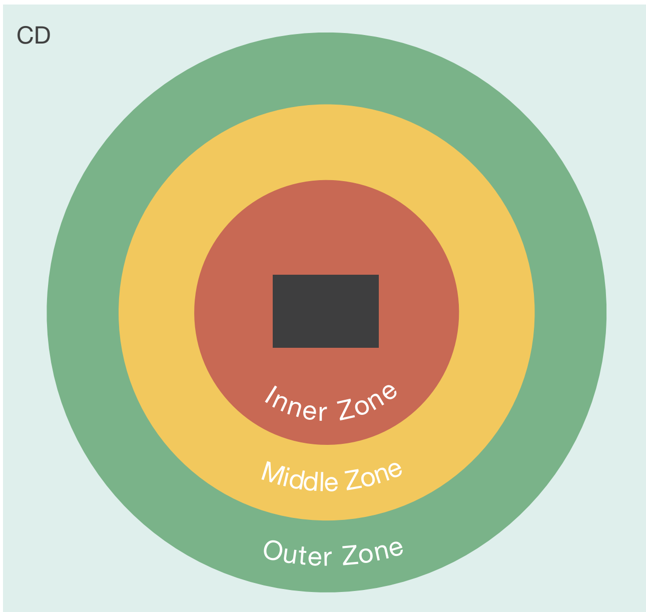
The HSE will advise a Consultation Distance (CD), or zone, around a major hazard site (and major accident hazard pipelines[23]). The HSE then becomes a statutory consultee for certain developments[24] within the CD. In assessing the application for consent, HSE will produce a map with three risk contours (or zones) as shown in figure 5, representing defined levels of risk or harm to which any individual would be subject.[25] Should the HSC be granted, this map defines the consultation distance within which HSE must be consulted over any relevant future planning applications. This process therefore provides protection to hydrogen pipelines once they are in place, from other development.

For an application to be made, information on the quantity of hydrogen to be held in any inventory on site (and any other prescribed substance) will be needed, together with a description of the process operations, details of how and where substances are to be stored and transferred, the site location and risks and consequences of a major accident, and the management systems and design control measures which will be implemented.

As mentioned above, there can be programme and cost advantages in applications for planning consent and hazardous substances consent being made and determined in parallel.

The public can be assured from the above that an HSC ensures safety is actively and effectively considered.

Figure 5: HSE consultation zones around a hazardous installation



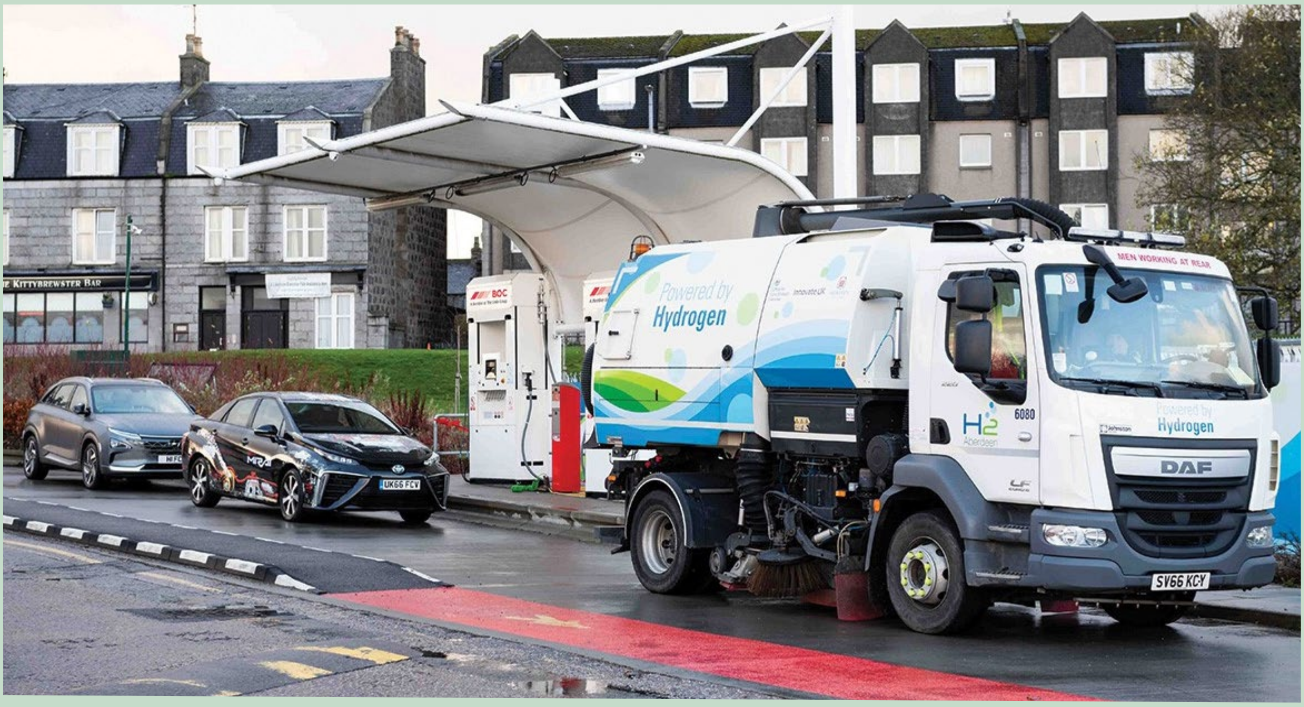
CASE STUDY

Kittybrewster Hydrogen Refuelling Station, Aberdeen

Press Archive / Aberdeen City Council

The Kittybrewster site in Aberdeen was set up by Aberdeen City Council, in partnership with BOC, primarily as a refuelling site for the council's hydrogen buses and now extended to its vehicle fleet, and open to the public.

The site has been operational since 2015 and was subsequently scaled up in 2018 to offer public access to refuelling, and is capable of producing up to 360kg per day. The site is centrally located within Aberdeen and is easily accessible for vehicles from the adjacent (A96) Powis Terrace, with existing access.



Abermedia / Michael Wachucik

Section 3: Safety and Environmental Consenting and Regulation

Control of Major Accident Hazards

The Control of Major Accident Hazards (COMAH) regime[26] aims to limit the consequences of a major accidents to people, local communities and the environment. It establishes a general duty that requires operators of COMAH sites to take “all measures necessary” to prevent major accidents and limit their consequences to people and the environment. This is achieved through appropriate plant design and construction, process control, mitigation measures and emergency procedures.

There are two levels of regulation within COMAH, known as Lower and Upper Tier, depending upon the number of dangerous substances held on site. For hydrogen the thresholds are 5 and 50 tonnes respectively. It is likely that many green hydrogen production facilities will be Lower Tier sites, but some may be Upper Tier as projects increase in scale.

Lower Tier sites must comply with the general duty and prepare a Major Accident Prevention Document (MAPP) setting out how the operator will prevent and mitigate major accidents. The MAPP is typically supported by documentation such as plant operating procedures, training records, job descriptions, audit reports, and a detailed safety management system.

For Upper Tier establishments, the duties are more onerous. A Safety Report must be prepared, including a MAPP; a management system for implementing that policy; information on the design safety precautions; details of firefighting and relief systems measures; and an on-site Emergency Plan, describing how they will respond to an incident and seek to minimise the consequences, which must be subject to periodic testing. In addition, for Upper Tier sites the local authority is required to prepare and test an off-site Emergency Plan, which all the emergency services work to in dealing with the wider consequences of an incident.

For both Lower and Upper Tier sites, the CA is required to provide the public with information regarding the COMAH establishment including detail on the dangerous substances involved. Operators of Upper Tier sites are required to provide the local population with information on safety measures and how to respond in the event of a major accident, written in straightforward and simple terms.

COMAH is enforced by a CA that comprises HSE acting jointly with the appropriate environmental agency.[27] The CA has statutory responsibility to regulate high-hazard industries using or storing specified quantities of dangerous substances. The objective of the CA is to assure the public that onshore major hazard businesses are meeting their responsibilities to control major accidents to people and the environment and to mitigate the consequences in the event of an industrial accident. The regulatory functions of the CA include the detailed review of COMAH Safety Reports, the agreement of Improvement Plans with operators and the periodic inspection of site operations.

The CA also carries out ongoing monitoring of sites, including regular audits at the expense of the operator and is empowered to make interventions, for example, where equipment is now considered out of date and requiring upgrade.

Planning authorities and the public can be assured from the above that COMAH sites are actively regulated to a particularly high standard.

COMAH Tiers for Hydrogen:

- Upper Tier: 50 tonnes
- Lower Tier: 5 tonnes

Environmental Permitting

The Environmental Permitting Regulations[28] require operators of “regulated facilities” to obtain an “environmental permit” and comply with its conditions. The aim of the regime is to protect the environment so that statutory and government policy environmental targets and outcomes are achieved.

Hydrogen production is a regulated activity under Environmental Permitting Regulations (EPR)[29] and the abstraction and treatment of waste waters and their discharge to the environment are regulated too, if undertaken.

Once obtained the environmental permit will contain conditions on management, operations, emissions, monitoring and record keeping/reporting. The permit may also include an improvement plan in relation to past activities, if required.

To obtain an environmental permit, operators must make an application to the regulator[30] and demonstrate they will be able to comply with the conditions of the environmental permit. The application will need to include risk assessments, management plans/procedures and a demonstration of the application of Best Available Techniques (BAT). The content of the application will depend on the technology employed, the risks associated with it, and the site’s setting. In determining the application, the EA/NRW/SEPA/NIEA will also need to apply Habitats Regulations considerations.

The UK environmental regulators are currently developing BAT guidance for the electrolytic production of hydrogen, and this is expected to be published for consultation in 2023.

Low impact installation standard rules environmental permits[31] are available for certain hydrogen production facilities where these are demonstrated to be low-risk operations and provided they can comply with a fixed set of conditions.

Natural Resources Wales has also recently consulted[32] on the proposed introduction online application system for certain types of small-scale hydrogen production, namely polymer electrolyte membrane/proton exchange membrane and alkaline electrolysers.

Planning authorities and the public may be reassured from the above that green hydrogen production sites with an environmental permit are regulated to a high standard.

Water abstraction and discharge licencing

Water, along with electricity, is an essential feedstock for the production of hydrogen via electrolysis. Although not directly regulated through the planning system, the planning authority will most likely want assurance that a proposed green hydrogen development has a sustainable source of water, and that there will no consequential downstream or upstream impact on water supply and water quality (the latter of which is a relevant planning consideration). Consultation responses from either the relevant environmental regulator or water company will therefore be important to provide this assurance.

In order to abstract water from a surface source (such as river, stream or canal) or from an underground source and take more than a prescribed volume[33], an abstraction licence is required from the relevant UK environmental regulator.[34] The regulator needs to ensure that water resources are safeguarded and that abstractions do not damage the environment. Unregulated abstraction could lead to water supply shortages, increased river pollution by reducing dilution, damage to wildlife habitats and ultimately to the loss of rivers. Abstraction licences are time-limited but, in principle, can be renewed.

In some parts of England and Wales, no new abstraction licences are being granted, such as the South Humber region. In these areas the only means of securing a new, year-round supply of water may, therefore, be through an abstraction licence trade (in England at least) or by purchasing it from a water company. The use of potable water will require a supply agreement with the relevant water supply company. Alternatively, water desalination or industrial wastewater re-use may potentially need to be considered.

If the site requires an Environmental Permit this will also regulate the discharge of wastewater to either the water environment (controlled waters) or the public sewer. A trade effluent consent will also be required from the relevant sewerage undertaker.[35] In the absence of an Environmental Permit, a separate discharge consent[36] will be required from the relevant UK environmental regulator.[37]

It is recommended that green hydrogen develop engage with and provide sufficient information to the environmental regulator early on to check whether water availability will be a constraint. Depending on the information provided, the environmental regulator may be able to provide advice on water sourcing strategies.[38]

CASE STUDY

Tees Valley Net Zero Project

Location: North Yorkshire, England

Developer: Protium

Size: 70MW

Stage: Pre-planning

LPA: Stockton Borough Council

User: Transport; Industry

Section 4: Sticking Points and Recommendations

As demonstrated, green hydrogen projects involve multiple components which require interaction with several planning bodies and different regulatory regimes. Due to the nascent stage of the industry, however, the current planning and permitting regime is not sufficiently prepared for this technology and could significantly impede the growth and success of a UK-based hydrogen economy. To accelerate the deployment of green hydrogen projects across the UK, simpler, faster and more predicable processes are required across the UK. RenewableUK has therefore identified five sticking points and proposed several recommendations to resolve these non-market barriers and streamline the planning process for green hydrogen projects.

STICKING POINT	RECOMMENDATION	LEAD
Unclear national guidance specific to green hydrogen In England, other forms of renewable developments (e.g. onshore wind) benefit from the NPPG on renewable energy generation, which provide guidance on how the policies and principles detailed within the NPPF apply in practice, and how key planning and environmental considerations should be dealt with, including matters such as site selection. Wales, Northern Ireland and Scotland have their own equivalent planning policies and guidance documents.[39] Guidance documents provide LPAs with a strong starting point and clear guidance to rely upon in considering hydrogen production projects in their area. However, the NPPG does not reference green hydrogen. In the absence of this clearly applying to hydrogen, the LPAs lose that direction and may feel like they are dealing with such project in a vacuum; leading to potential restrictions and controls being put in place that are not required. Furthermore, there is a lack of clarity for bringing forward green hydrogen elements of a wider project (i.e. co-location) where that wider project involves an NSIP. At the moment it is not clear that the green hydrogen site will be able to be considered as an "Associated Development"[40] given that it can be a means and end to itself; and hydrogen production is not itself currently able to be an NSIP. Moreover, it is unclear whether a co-located green hydrogen production facility can be included in the same planning application with a site's renewable generators (e.g. solar, wind farm), or instead requires a stand-alone application to the planning authority. In such instances the green hydrogen production facility is likely to be a key aspect of the generating plant's route to market and therefore certainty is required. In some instances, projects are forced between two consenting regimes. The Whitelee project, for example, was initially presented for EIA screening under the Electricity Act as a single project, comprising of an electrolyser, solar and battery storage. After much discussion it was deemed that neither the Scottish Government nor the council could determine the project as a whole. This was because the hydrogen production element was not electricity generation and could not be determined under the Electricity Act, and the solar and battery components exceeded 50MW and therefore could not be determined by the Council as part of the project. The result was the project being split over two consenting regimes which significantly complicated progress.	**Update guidance to green hydrogen.** • All national planning guidance (e.g. NPPG) on renewable energy generation across the UK should be updated to account for green hydrogen production. This should include objects that reflect approval in principle for hydrogen developments and the need for 10GW low carbon hydrogen by 2030 and beyond. • The review of the NPPF should ensure at a minimum, specific reference is made to green hydrogen equivalent to that made for other renewable energy technologies, including reference to the potential for green hydrogen co-location. • Specific reference to green hydrogen production should be made in the NPPF and NPPG definitions of development in flood risk areas to ensure that such development is treated as an essential development on par with renewable energy development.[41] • DLUHC to update Guidance on NSIP Associated Development to facilitate decarbonisation projects, confirming that green hydrogen production may be an associate development where multiple energy generation projects are proposed or where pipeline meet the NSIP criteria but need the production facility to be built to be utilised for green hydrogen purposes.	DESNZ; DLUHC; Central and each devolved government

Section 4: Sticking Points and Recommendations

STICKING POINT	RECOMMENDATION	LEAD
Perceived negative impact on local water supply Water scarcity in the UK is being driven by a range of factors including climate change, over abstraction and population. The deployment of green hydrogen could therefore cause water stress or degrade water quality in certain regions unless managed sustainably. Impacts on local water supply are further complicated by the cumulative effect of multiple projects and demand sites using water in clusters, which are likely to be attractive locations for the first wave of low carbon hydrogen projects. For example, a large part of the South Humber region is regarded as over abstracted. Collectively this could lead to consenting risks under the Habitats Regulations Assessment (HRA) and the Water Framework Directive Regulations (WFD). This is true even if a green hydrogen project is only making a small contribution to the issue and has a sustainable water abstraction plan.	**Strategic approach to future water needs, including for electrolysis** RenewableUK understands that Government is currently scoping out a study on the impacts of low carbon hydrogen on local water sources. We urge it to undertake this important industrywide study in a timely manner, and involves as many stakeholders as possible from across the industry. Government and industry should explore options to mitigate water stress through, for example, water reuse, recycling system and sustainable water withdrawal that minimises the impact on the local water balance. The Gigastack green hydrogen project, for example, has explored recycling effluent wastewater from the Humber Refinery and desalination based on a cost benefit analysis. This ensures that there is no increase to industrial water demand in the region, providing an innovative way of recycling refinery effluent water.[42] Furthermore, Government and industrial clusters should work out how to reduce water abstraction in some areas through efficiency improvements and optimisation from existing water users and transmission systems. This should be coupled with a strategic approach to compensation in the key decarbonisation clusters to ensure that the HRA and WFD does not become a blocker for crucial energy infrastructure. Finally, guidance and assurance on water supply impact will be useful as the volumes of water required for these projects seems significant and cumulatively, as more come forward, there will be increased demand on water supplies. However, the extent to the increase in demand for water from the energy sector (in particular, for hydrogen production) is highly uncertain and will depend on what net zero pathway is followed in practice during the transition to 2050.	DESNZ; Each devolved government; Industrial cluster body
HSE and environmental regulators unable to process the pipeline of green hydrogen projects at pace The environmental regulators and HSE lack the capacity and resources to be able to deal with the at-pace rollout of a new nascent technology while performing their regulatory duties in the wide array of spheres in which they are already involved. For example, the HSE have a considerable backlog which means that depending on the complexity of the application, it may take between 13 to 27 weeks to process an application. Additionally, as a developing technology, industry needs a clear picture from the environmental regulators about the approach to permitting, for example: • encouraging the use of staged applications so that promoters are able to engage and secure "buy-in" from the Agency to their developing approaches; • how it will deal with key issues such as hydrogen emissions to atmosphere; and • learning lessons from how the agencies have dealt with emerging carbon capture projects. Additionally, there is no statutory obligation on environmental regulators in the UK to take climate change mitigation and the delivery of net zero into their decision-making processes. This means that low carbon generation projects (and associated developments) face challenges in gaining consents and positive statutory advice, as there is no legal priority for climate change regulation over other environmental areas. Finally, LPAs heavily rely on the HSE for clear safety guidance to address potential safety concerns. However, there is a lack of safety guidance from HSE specific to hydrogen.	**Futureproof the environmental regulators and HSE for net zero** • Government and devolved governments to ensure there are sufficient mechanisms for the environmental regulators to get the funding they need. • The environmental agencies and HSE should develop guidance specific to green hydrogen setting out what is required. • In the current absence of a statutory duty, it would be prudent to require the environmental agencies to state clearly how their procedures, decision-making and advice will ensure alignment with the UK's binding target under the Climate Change Act 2008 to reduce net emissions of greenhouse gases to zero by 2050. Subsequent to this, and as soon as is feasible at the next available legislative opportunity, it is our view that a duty to take the transition to net zero into account in exercising their functions should be applied to the environmental regulators.	Central and each devolved government; Env. regulators; HSE

STICKING POINT	RECOMMENDATION	LEAD
The planning regime is not sufficiently prepared for green hydrogen production and pipelines **A.** Green hydrogen projects are not always able to be brought forward as a NSIP where they are of sufficient scale and have a need for a range of consents (including compulsory acquisition powers[43]). **B.** Hydrogen developers have the same needs and responsibilities as other utility operators and should be allowed the ability to seek Statutory Undertaker status[44] that would give them access to appropriate classes of permitted development rights and, as below, compulsory acquisition powers. However, projects that require third party land, but which do not want or need to go through the NSIP process are left in a potential ransom position because they are unable to realistically explore compulsory acquisition powers from alternative. • This is because hydrogen production promoters are not included within any of the existing categories of "undertaker" that are allowed to bring forward a Compulsory Purchase Order (CPO), and similarly would be unlikely to fall in the definition of a gas "transporter" that could be licensed under the Gas Act 1986. • It is also noted that for non-NSIP pipelines, hydrogen projects are left in a position of either seeking to obtain a gas transporter licence to get compulsory acquisition powers, which may be difficult if the pipelines are promoted alongside a production plant or may not be possible if, for example, they will supply a private network only; or seeking authorisation under the Pipe-lines Act 1962, a route which involves significant programme risk as it requires such CPOs to go through Special Parliamentary Procedure. **C.** It is not clear if hydrogen production facilities fall into the definition of an EIA development even if pipeline elements do. This can lead to uncertainty for all parties as to how to properly carry out environmental assessment and decision making.	**Modernise the planning regime for green hydrogen** **A.** At the moment, the majority of hydrogen projects are of sufficiently small scale that requiring hydrogen projects to be NSIPs will not be required, however that is beginning to change and is likely to accelerate in the future. However, it is considered that, given the nature of a hydrogen project, there is no need to mandate that a certain criterion be met to use the regime. Instead, we propose that the upcoming updates to the National Policy Statements go further in their support for hydrogen and encourage them to go through the section 35 process if they want to. For example by making it clear that the Energy National Policy Statement (NPS) will apply to hydrogen section 35 projects (in a similar way that the National Networks NPS does for local authority highways projects). The update to the NPS should also reflect that, given the changing commercial picture of large green hydrogen projects, developers may only know the detail of part of the project. Therefore, there should be greater flexibility in multi-phase developments. **B.** We suggest that the Gas Act 1986 is amended to create a new category of licence that can be sought called "gas producer" that would benefit from a new class of permitted development rights to be included in Part 15 of the General Permitted Development Order and is able to compulsorily acquire land in the same way as "gas transporters" under Schedule 3 to the Act (as separate from the various statutory requirements that fall upon a "gas supplier" under that Act). It is appreciated that promoters of such projects will need to be of sufficient "standing" to be given compulsory acquisition powers (and the licence application we recommend here would equate to the current scenario for energy companies of either obtaining a relevant licence from Ofgem; or undertaking the scrutiny of the Planning Act 2008 process). To that end, we propose that amendments are made to the Gas Act to provide that it must be a requirement that prior to seeking a compulsory acquisition order, promoters are required to provide and publicise a Funding Statement demonstrating how compensation liabilities are intended to be funded. **C.** EIA Regulations to be amended to create criteria by which appropriately sized hydrogen production facilities should be considered to be EIA development.	DESNZ; Each devolved government; Industrial cluster body

Section 4: Sticking Points and Recommendations

STICKING POINT	RECOMMENDATION	LEAD
Knowledge gap is hampering planning decision-making • The lack of understanding of hydrogen projects and their planning and environmental impacts mean LPAs are more likely to be cautious around the type of conditions and restrictions that are imposed on consents, particularly around ensuring that the effects of specific developments first put forwarded are tied down, potentially stifling innovation fand flexibility. Such an approach has the potential to stifle delivery and innovation in what is an emerging technology. • This lack of understanding is exacerbated by the fact that, in reviewing environmental documentation, LPAs will be looking to apply knowledge of existing assessment process Guidance which as of yet have not been updated to account for hydrogen development (e.g. Institute of Environmental Management and Assessment guidelines, Institute of Air Quality Management guidance or British Standards). In the absence of such updated Guidance, LPAs and Planning Inspectorate may impose more restrictions than are necessary. • Planning decision making will be influenced by the views of the general public who may be against what they might consider as “industrial” style developments. Specifically, they may regard these sites as hazardous with related transport movements, without appreciating the wider benefits of low carbon hydrogen within the wider decarbonisation agenda.	**Educate relevant stakeholders about green hydrogen** • Industry stakeholders and trade associations, such as RenewableUK and the UK Hydrogen Fuel cell Association, (potentially though PAS) to build on the messages of this document to LPAs, explaining that hydrogen projects are primarily the new application of existing principles. • As an emerging technology it would reassure LPAs if process could be seen as applying agreed industry standards to demonstrate no issues or “likely significant effects”. As such, industry should work with the relevant organisations that develop such guidance (and make available online) to consider where updates can be made to facilitate greater understanding of the impacts of hydrogen projects. • Industry and each Government to continue to champion low carbon hydrogen projects and why they are a key part of the decarbonisation agenda. Building on this document, launching a public education/ information campaign to show that hydrogen production and transport is safe and utilises demonstrable and proven technology.	Industry-wide; Trade associations; Central and each devolved government; DESNZ

CASE STUDY

H100 Fife

The electrolyser at the H100 site at Levenmouth in Fife is part of Scotia Gas Networks (SGN) demonstration project which will see the gas demands of 300 homes met by a 100% hydrogen supply. Located at the Energy Park Fife, the facility will use the existing neighbouring 7MW Offshore Renewable Energy Catapult Levenmouth Demonstration Turbine (LDT) as the primary electricity supply where possible. Key parts of the system will include:

- 5MWe Alkaline electrolyser producing around 2 tonnes of hydrogen per day
- Six above ground storage tanks, operating at 30bar with additional connectivity
- Pressure reduction
- Flow metering
- Hydrogen purity and odorisation
- Control system
- A hydrogen demonstration facility
- A polyethylene pipe distribution network passing 1000 homes

The site is yet to commence or about to commence construction with the plan to be operational and supplying homes in 2024.

Appendix

Defining key terminology

The absence of standard language for energy and power within the hydrogen production, transport and storage sectors complicates the roll-out of hydrogen projects during this nascent stage of the market development. The aim of this section is to highlight potential areas of ambiguity and raise awareness of variance in terms which may be observed.

First it is necessary to understand the basics of energy and power. Simply put, when work is done to an object "energy" is transferred, which is typically measured in watt-hours (Wh), joules (J), British Thermal units (Btu) or calories (cal). The "power" of a device, either input or output, is defined as the amount of energy transferred over time and may be measured in watts (W).

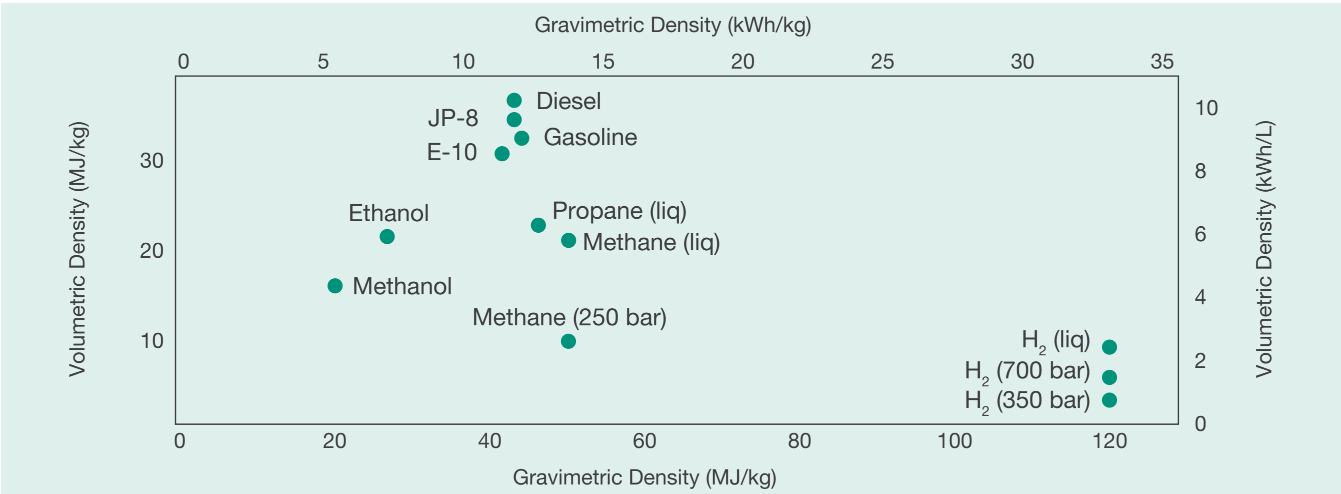
In the context of the hydrogen market these terms are ambiguous; however, there are some key concepts to understand:

- Devices such as electrolyser stacks will typically have their maximum electrical input power defined in megawatts (MW). For example, ITM Power's 3MEP CUBE electrolyser uses approximately 2MW to produce around 36kg/h of hydrogen.[45]
- Once the hydrogen is produced, it may be combusted for use as a fuel. When hydrogen (H_2) is burnt it produces water (H_2O) as a by-product, which is usually in the gaseous form of steam. This is important because a significant amount of energy is locked up in the gaseous steam, which can be returned by condensing it back into liquid water. Therefore, there are two figures used to quote the calorific value of the given fuel:
- The Higher Heating Value (HHV) assumes the steam is condensed back into liquid water therefore, this is defined as the amount of heat released during combustion minus the energy required to return the temperature of the combustion product to ambient temperature (25 °C). The HHV for hydrogen is 39.4KWh/kg and is typically used to quantify energy directed to high heat uses and industrial processes.
- The Lower Heating Value (LHV) assumes the steam is not condensed defined as the amount of heat released during combustion minus the energy required to return the temperature of the combustion product back to 150°C. For hydrogen it is 33.3KWh/Kg, and is commonly used to calculate the chemical energy stored in hydrogen for non-thermal uses.

When considering the usefulness of an energy source, the fuel is often described in terms of energy density, which is either measured by mass or weight. Hydrogen has a very high energy density by weight at 120MJ/kg, which is between 2.5 and 3 times lighter than fossil fuels and natural gas per MJ. This makes hydrogen very useful in larger vehicles (e.g. HGVs), for example, where payload is an important aspect of the business model. However, hydrogen has a low energy density by volume, at about a third of natural gas, meaning it takes up 3 times more space per MJ. Gaseous hydrogen may be compressed or liquified to increase the energy density per volume.

The volumetric and gravimetric (i.e. weight) relationship between different energy vectors is highlighted in the figure below.

Figure 3 - Fuels, Volumetric Density vs Gravimetric Density[46]



Appendix

Production example

A 1MW electrolyser would consume 1MWh of electrical energy per hour when operated at full load. Power output of the same device (i.e. thermal output of the hydrogen produced) would typically be quantified as either the lower heating value (MW_{LHV}) or the higher heating value (MW_{HHV}) depending on the use case.

An example and comparison of values for power, energy and mass/volume are provided in Table 2 for indicative 20MW and 300MW green hydrogen production facilities:

Quantification of hydrogen amount is most easily managed as a mass, either as tonnes (t) or kilogram (kg), because the mass of gaseous hydrogen is consistent regardless of whether it has been compressed. Both the volume and density of hydrogen change with variance in pressure and/or temperature. Volumetric measurements of hydrogen are typically expressed in normal cubic meters (Nm^3).[48]

Storage example

The same volumes of gaseous and liquid hydrogen stored within a one cubic metre tank at varying pressures and temperatures are included within Table 3, highlighted in both normal meters cubed and standard cubic feet. Table 4 shows an example of potential storage volumes that may be co-located with production facilities[49]

Table 2 – Input and output power ratings of indicative facilities.[47]

Electrical Input Power (MW_e)	Peak production per hour (kg/hr)	Higher Heating Value of hydrogen (MW_{HHV})	Lower Heating Value of hydrogen (MW_{LHV})
20	348	13.70	11.58
300	5,217	205.57	173.74

Table 3 – Equivalent hydrogen content of 1m³ of storage at varying temperature and pressure

State	Temperature [°C]	Pressure (Bar)	Density (kg/m³)	Assumes a 1m³ tank size
				Nm³ of H2 stored
Gas	0	1	0.08	1
	15	1	0.084	0.93
		35	2.87	31.9
		350	24.0	267
		700	39.2	436
Liquid	-252.9	1.01	70.9	788

Table 4 – Compressed hydrogen: indicative gaseous storage sizes for one day production at 100% utilisation[50]

Electrical Input Power (MW_e)	Peak daily Production of hydrogen (Te)	Peak Daily Production (Nm³)	Pressure (Bar)	Required volume of storage (m³)
20	8.352	92,924	35	2,912.99
			350	348.03
			700	213.13
300	125.208	1,393,064	35	43,669.72
			350	5,217.47
			700	3,195.10

Table 5 – Liquefied hydrogen: Indicative Liquid Storage Capacities for one day production at 100% utilisation

Electrical Input Power (MW_e)	Peak Daily Production (Te)	Peak Daily Production (Nm3)	Pressure (Bar)	Required volume of storage (m³)
20	8.352	92,924	1.01	117.92
300	125.208	1,393,064		1,767.85

References

1. Scottish Government; Welsh Government; Northern Ireland Executive.
2. UK Hydrogen Strategy. BEIS. August 2021. https://www.gov.uk/government/publications/uk-hydrogen-strategy.
3. Hydrogen Strategy Update to the Market: December 2022.December 2022. https://www.gov.uk/government/publications/uk-hydrogen-strategy
4. Hydrogen Action Plan: Draft. Scottish Government. https://www.gov.scot/publications/draft-hydrogen-action-plan/
5. Fuel Cells and Hydrogen Observatory. Hydrogen Demand. https://www.fchobservatory.eu/observatory/technology-and-market/hydrogen-demand
6. Presumed that all targets are defined as Higher Heating Value (HHV).
7. Central point is 355TWh and 27.5%. 26GW of green hydrogen is equivalent to 100TWh per year.
8. https://www.renewableuk.com/news/527257/Renewable-Hydrogen---Seizing-the-UK-Opportunity.htm#:~:text=The%20study%2C%20%E2%80%9CRenewable%20Hydrogen%20%2D,the%20course%20of%20this%20decade.
9. Low quality water can lead to faster degradation and shorter lifetime.
10. Humber Industrial Cluster Plan Water Supply. October 2022. Element Energy.
11. "When determining planning applications for renewable and low carbon development, local planning authorities should: not require applicants to demonstrate the overall need for renewable or low carbon energy, and recognise that even small-scale projects provide a valuable contribution to cutting greenhouse gas emissions…"
12. Town and Country Planning (Environmental Impact Assessment) Regulations 2017; The Town and Country Planning (Environmental Impact Assessment) (Wales) Regulations 2017.
13. The Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2017; The Planning (Environmental Impact Assessment) Regulations (Northern Ireland) 2012.
14. The Health and Safety Executive Northern Ireland (HSENI) in Northern Ireland.
15. The Environment Agency (EA) in England; Natural Resources Wales (NRW) in Wales; the Scottish Environment Protection Agency (SEPA) in Scotland; and The Northern Ireland Environment Agency (NIEA) in Northern Ireland.
16. There is however no strict statutory or policy provision that mandates the sequence in which multiple consents are pursued. Applicants may want to remain flexible to pursue applications at different speeds if local circumstances dictate, allowing progress in one area to help inform, but not duplicate, consideration in another; or seek to "roll up" consents by bringing the proposals into the Planning Act 2008 regime, through obtaining a section 35 Direction. Applicants may also be assisted by advocating the approach adopted by NSIP decision-makers in respect of any other necessary consents, of considering simply whether there is "any obvious impediments to the delivery of the Proposed Development arising from the need for these consents to be obtained".
17. The Construction (Design and Management) Regulations 2015.
18. The Control of Major Accident Hazards Regulations 2015.
19. Hazardous substances - GOV.UK (www.gov.uk).
20. The Planning (Hazardous Substances) Act 1990 and the Regulations made under that Act. The Planning (Hazardous Substances) Regulations 2015; The Town and Country Planning (Hazardous Substances) (Scotland) Regulations 2015; The Planning (Hazardous Substances) (Wales) Regulations 2015; The Planning (Hazardous Substances) (No. 2) Regulations (Northern Ireland) 2015.
21. e.g. The Dangerous Substances and Explosive Atmosphere Regulations 2002.
22. The Health & Safety Executive and relevant UK environmental regulator acting jointly.
23. Regulated under The Pipelines Safety Regulations 1996.
24. Proposals include residential development and large retail, office or industrial developments located in consultation zones and development likely to result in an increase in the number of people working in or visiting the relevant area.
25. The three contours represent levels of individual risk of 10 chances per million (cpm), 1 cpm and 0.3cpm per year respectively of receiving a dangerous dose or defined level of harm.
26. The Control of Major Accident Hazards Regulations 2015, which apply to Great Britain. The Control of Major Accident Hazards Regulations (Northern Ireland) 2015 apply in Northern Ireland.
27. In England this is the Environment Agency (EA); in Wales it is Natural Resources Wales (NRW); in Scotland it is the Scottish Environment Protection Agency (SEPA); and in Northern Ireland it is the Northern Ireland Environment Agency (NIEA).
28. The Environmental Permitting (England and Wales) Regulations 2016 (as amended) in England and Wales; The Pollution Prevention and Control (Scotland) Regulations 2012 (as amended) in Scotland; The Pollution Prevention and Control (Industrial Emissions) Regulations (Northern Ireland) 2013 (as amended) in Northern Ireland.
29. Being listed in Schedule 1 of the EPR under Section 4.2 Production of inorganic chemicals.
30. The Environment Agency (EA) in England; Natural Resources Wales in Wales; the Scottish Environmental Protection Agency in Scotland; and the Northern Ireland Environment Agency in Northern Ireland.
31. Standard rules SR2009 No2 – Low Impact. Part A Installation. Environment Agency. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/790718/SR2009_No2_Low_Impact_Part_A_Installation.pdf
32. Consultation on permitting small scale hydrogen production by electrolysis of water. Natural Resources Wales. https://ymgynghori.cyfoethnaturiol.cymru/regulatory-reform/consultation-on-permitting-small-scale-hydrogen-pr/#:~:text=We%20are%20changing%20the%20way%20we%20permit%20small,the%20process%20or%20the%20amount%20of%20Hydrogen%20produced.
33. In England and Wales, 20 cubic metres a day (m3/d). In Scotland, 50 m3/d. In Northern Ireland, 10 m3/d.
34. The Environment Agency in England under the Water Resources Act 1991; Natural Resources Wales in Wales under the Water Resources Act 1991; the Scottish Environmental Protection Agency in Scotland under the Water Environment and Water Services (Scotland) Act 2003; and the Northern Ireland Environment Agency in Northern Ireland under the Water (Northern Ireland) Order 1999.
35. The Water Industry Act 1991 in England and Wales; Sewerage (Scotland) Act 1968 and Control of Pollution Act 1974 in Scotland; The Water and Sewerage Services (Northern Ireland) Order 2006 in Northern Ireland.
36. The Water Resources Act 1991 in England and Wales; The Water Environment and Water Services (Scotland) Act 2003 in Scotland; The Water (Northern Ireland) Order 1999 in Northern Ireland.
37. In England this is the Environment Agency (EA); in Wales it is Natural Resources Wales (NRW); in Scotland it is the Scottish Environment Protection Agency (SEPA); and in Northern Ireland it is the Northern Ireland Environment Agency (NIEA).
38. Humber Industrial Cluster Plan Water Supply. October 2022. Element Energy.
39. In Wales it is the Planning Policy Wales (PPW) document; in Northern Ireland it is the Planning Policy Statements (PPSs); and in Scotland it is set National Planning Framework 4 (NPF4) and Scottish Planning Policy (SSP).
40. An "associated development" is a generator that relates to an existing primary development (e.g. onshore wind farm in England and Wales with 50MW+). The associated development is therefore considered to be part of the same planning application as the primary development.
41. Green hydrogen production facilities are not classified 'essential infrastructure' as per the National Planning Policy Framework (NPPF) definition because they require hazardous substances consent, which makes them 'highly vulnerable' in the NPPF definition. The NPPF and NPPG as currently written, if applied to the letter, and not allowing any consideration of mitigations by the developer, could be detrimental to the success of green hydrogen projects and other projects requiring hazardous substances consent in areas of high flood risk. This is because in such areas the Exception Test as currently written in the NPPG cannot be applied to 'highly vulnerable' developments.
42. Gigastack Phase 2: Pioneering UK Renewable Hydrogen. BEIS. https://gigastack.co.uk/content/uploads/2021/11/Gigastack-Phase-2-Public-Report_FINAL_.pdf
43. Compulsory acquisition powers refer to the legal powers to acquire privately owned land for the purposes of developing a project of national significance, even if the owner is unwilling to sell it.
44. i.e. legal status to carry out specific activities in the public interest.
45. https://itm-power.com/products/3-mep-cube
46. https://www.energy.gov/eere/fuelcells/hydrogen-storage, accessed 28/11/22
47. Assumes stack production of 1kg per 57.5kWh. The calculation is as follow: 20MW is 20000. 20000/57.5 = 348kg hydrogen per hour. This has a HHV thermal output of 13.70 (348 * 39.4 / 1000).
48. Nm3 is the amount of hydrogen present inside one cubic meter under defined normal pressure and temperature (P=1 atm, T=0 °C), Sfc is the amount of hydrogen present inside one square foot under the same conditions.
49. Required gaseous storage volume quoted at 15°C.
50. Required liquid storage volume quoted at -252.9°C.

Thank You

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H2 HYDROGEN POWER
CLEAN ENERGY OF THE FUTURE

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