

Scottish Government Hydrogen Policy Statement

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SCOTTISH GOVERNMENT HYDROGEN POLICY STATEMENT

Contents

Ministerial Foreword	Page 3
Executive Summary	Page 6
Chapter 1. Overview	Page 9
Chapter 2. Hydrogen within the Energy System	Page 14
Chapter 3. Economic Opportunity	Page 17
Chapter 4. Hydrogen Supply Chain	Page 22
Chapter 5. Scotland's Natural Resources, Infrastructure and Place	Page 26
Chapter 6. Hydrogen for Heat in Buildings	Page 31
Chapter 7. Hydrogen for Industry	Page 35
Chapter 8. Hydrogen in Transport	Page 39
Chapter 9. Hydrogen for Trade	Page 46
Chapter 10. Hydrogen Research, Innovation, and Demonstration	Page 51

MINISTERIAL FOREWORD



Scotland was amongst the first countries in the World to declare a climate emergency and we understand the urgency of moving our economy and society to generating net zero greenhouse gas emissions (or 'net zero').

Our world leading climate change targets, to achieve net zero greenhouse gas emissions by 2045 and a 75% reduction by 2030, against the 1990 baseline, mean that across our economy we will need to move at an unprecedented pace to deliver the innovation, investment, regulation and the market environment that will enable the required step change towards net zero.

Hydrogen, the most abundant element in the universe, is rapidly emerging as a sustainable solution for the decarbonisation of the economy and a key piece of the energy transition picture – a view now held in Scotland, Europe and around the world.

Hydrogen can be used as an alternative to natural gas to transfer and store energy, delivering that energy to end users in a form that emits no carbon dioxide when it is used. It is particularly relevant as a potential replacement for fossil fuel feedstock in industrial and chemical processes; in transport as an alternative to internal combustion engines, especially heavy-duty vehicles such as buses, heavy goods vehicles, trains and ships; and has the potential to be used for heat and cooking in our homes.

Scotland has in abundance all the raw ingredients necessary for the production of low-cost, clean hydrogen.

Our reputation for excellence in energy, our extensive oil and gas supply chain and our strong onshore and offshore wind sectors, are the key to our achieving a just transition to a low carbon and then net zero age. Both our oil and gas and renewable energy sectors will be critical to establishing stable and secure production of affordable large-scale hydrogen.

Scotland has an estimated 25% of all the wind resource in Europe, due to our location and climate. We also have one of the largest concentrations of offshore engineering expertise in the world. With 1 GW of installed capacity, rising to 11 GW by 2030, and rapidly decreasing costs, our offshore wind sector is forecast to grow significantly as Scotland and the UK progress towards meeting decarbonisation targets. This adds to our already significant onshore wind capacity of 8.4 GW which could also be deployed to generate clean hydrogen.

We are globally renowned for innovation in offshore wind, including the world's first floating offshore wind farm, 'Hywind Scotland', with a strong pipeline of planned projects to come. Scotland also has a strong track record for advancing hydrogen technologies and demonstrating its production and use in island and mainland projects.

As a nation, we have the opportunity and capability to benefit from the transition away from fossil fuels and produce large volumes of clean hydrogen which will not only help reduce Scotland's emissions and support meeting Scotland's challenging greenhouse gas emissions targets, but will also allow Scotland to develop a role as an exporter of hydrogen to other partner nations and to create and protect jobs and provide economic benefit for Scotland. We have the resources, the assets, the people and the ambition to achieve this.

In this policy statement we are committing to make hydrogen a key element of Scotland's decarbonisation plans. This document describes the roles that hydrogen could play in our vital energy transition and the scale of economic growth and supply chain development which hydrogen presents.

Economic impact scenarios developed this year as part of our Scottish Hydrogen Assessment Project suggest that in the most ambitious scenario, establishing Scotland as an exporter of green hydrogen to Europe, where there is already growing demand, could result in a £25 billion (bn) annual gross contribution to Scotland's Gross Value Added (GVA) with over 300,000 jobs supported by 2045. The report suggests that this would be achieved by unlocking Scotland's vast offshore wind potential, resulting in Scotland producing large-scale, 'green hydrogen' that is competitively priced within a growing European market.

Analysis tells us that Scotland could produce enough hydrogen to meet our demand and also support an export market to Europe. **Our policies will be focussed on support for the development of a low-cost hydrogen capability to meet an initial ambition of generating 5GW of renewable and low-carbon hydrogen by 2030.**

No one fuel or technology is by itself the solution to climate change, but hydrogen has the potential to be an important part of a decarbonised energy system and we are committed to supporting the emerging hydrogen sector in Scotland and also maximising the 'new-industry' benefits that the production of hydrogen may bring.

In 2021 we will publish our Hydrogen Action Plan which will set out the actions we will take to implement our hydrogen policies. This will be accompanied by £100 million funding to boost excellence in research, innovation development and demonstration of secure, low-cost clean hydrogen production between 2021 and 2026.

Our vision is for Scotland to become a leading Hydrogen Nation in the production of reliable, competitive, sustainable hydrogen and secure Scotland's future as a centre of international excellence as we establish the innovation, skills and supply chain that will underpin our energy transition.

Scotland's unique selling points, are its natural resources, infrastructure and skilled energy workforce which enable us to become the producer of lowest cost hydrogen in Europe by 2045.

This is our ambition. But Government can't achieve it alone. I hope now that our clear signal of intent, founded on evidence of demand, will allow industry and investors to respond with confidence. The global hydrogen market is developing rapidly, international partnerships are already being established and so, with shared ambition, co-ordination, collaboration and pace, we look toward to achieving a sustainable energy transition and realising our exciting hydrogen future.

Paul Wheelhouse MSP

Minister for Energy, Connectivity, and the Islands.

EXECUTIVE SUMMARY

Achieving Net Zero

It is becoming increasingly clear that hydrogen will play a major role globally in the transition to net zero, and Scotland's assets, natural, human and physical mean we can be a major player in this emerging global hydrogen market.

The International Energy Agency confirms clean hydrogen is currently enjoying unprecedented political and business momentum, with the number of policies and projects around the world expanding rapidly.

The European Union¹ published their hydrogen strategy in June 2020 with a strategic objective to install at least 6GW of renewable hydrogen electrolyzers producing up to 1 million tonnes of green hydrogen in the EU by 2024 and 40GW producing up to 10 million tonnes of green hydrogen by 2030. In 2020 Germany committed €9bn to their hydrogen strategy and France committed €7bn.

The UK Government will publish their Hydrogen Strategy in 2021 and have set a target of 5GW of low-carbon hydrogen by 2030.

Our world-leading targets for net zero emissions by 2045 will mean that our whole energy system will need to rapidly transform to meet the changing needs of consumers and society.

Combinations of demand reduction, energy efficiency and increasing uptake of electrification can take Scotland a good deal of the way towards our net zero future and the decarbonisation of our whole energy system. But reducing our demand for energy and electrification alone, are unlikely to be enough.

We believe that producing clean hydrogen and showing that it can be used to meet challenging energy demands (e.g. for heat, transport and industry) will also be part of the next stage of the Scotland energy transition pathway.

During 2020 we have carried out a hydrogen assessment and a range of other analysis to deepen the evidence base in order to inform our policies on hydrogen going forward. From our assessment, it is clear that hydrogen is not just an energy and emissions reduction opportunity; it could also have an important role in generating new economic opportunities in Scotland.

We are currently experiencing a period of economic turmoil with jobs and sectors at risk from the impacts of the coronavirus pandemic. The development of the hydrogen economy and supply chain will play an important role in our energy transition to net zero and are key components of the green economic recovery. The economic potential of hydrogen is explored throughout this document.

This policy statement is aligned to the Scottish Government's Climate Change Plan which sets out our long-term vision for Scotland to end our contribution to climate

¹ [European Commission Hydrogen Strategy 2020](#)

change by 2045. Our climate targets are underpinned by our commitment to a just transition, that supports sustainable economic growth and jobs.

Hydrogen development and deployment is a dynamic issue. Therefore, this policy statement should be regarded as a responsive document which will be regularly reviewed and refreshed by the Scottish Government as we continue to identify the challenges and opportunities for the full development of renewable and low-carbon hydrogen in Scotland.

Drawing on the evidence, we will set out policy positions on where things stand now; and the ways in which hydrogen can help to achieve a clean, secure and affordable energy future.

We will describe our next steps in our hydrogen journey and set out how we will implement our hydrogen policies when we publish our Hydrogen Action Plan in 2021 which will be supported by £100 million investment to support its delivery over the next five years.

In the Hydrogen Action Plan we will set out details of how we will take forward the necessary actions to implement the policy positions in this document. We will continue to engage those with an interest in establishing a hydrogen economy in Scotland and seek views on how best to deliver these policies through our Hydrogen Action Plan. The draft Hydrogen Action Plan will be subject to the necessary statutory and other impact assessments.

We recognise that we cannot achieve our hydrogen ambitions alone. Many of the regulatory and legislative levers required are determined at a UK level. We, therefore, require the UK Government work with us in building a flourishing hydrogen economy.

In this policy statement we:

- Confirm Scottish Government support for the strategic growth of a strong hydrogen economy in Scotland, focusing our efforts on supporting the development of Scotland's hydrogen production capability to meet an ambition of at least 5GW of renewable and low-carbon hydrogen by 2030 and at least 25GW by 2045.
- Commit £100 million funding towards the development of our hydrogen economy over the next five years as implemented through our Hydrogen Action Plan, due for publication in 2021.
- Confirm that both renewable and low-carbon hydrogen will play an increasingly important role in our energy transition to net zero in 2045 and the importance of establishing low-carbon hydrogen production at scale by the mid-2020s, linked to Carbon Capture and Storage (CCS).
- Set out how Scotland's abundant natural resources, skills and supply chain offer the potential for large scale production of renewable hydrogen from offshore wind to be a key driver of the longer term hydrogen economy in Scotland.

- Support the demonstration, development and deployment of hydrogen and its emergent role in the sustainable decarbonisation of critical industry functions and processes, transport and heat in buildings.
- Commit to drive technological progress and advance innovation by unlocking public and private funds for innovation development, and support demonstration for key hydrogen technologies, such as fuel cells and electrolyzers.
- Recognise the need for pace – the need to start now and grow quickly to capitalise on opportunities within the domestic and global hydrogen market.
- Commit to actively seek international collaboration in the development of our shared hydrogen economy and fully explore our hydrogen export potential.
- Support the transition and growth of Scotland’s existing supply chain, including in the development of skills and manufacturing capacity, that can play a significant role in the hydrogen economy both domestically and internationally.
- Commit to exploring the opportunities for negative carbon hydrogen, combining the potential to use bioenergy resources to produce hydrogen with CCS.
- Commit to engage with the UK Government on the development of a UK policy and regulatory framework for hydrogen, business models, market mechanisms, carbon pricing, feed in tariffs, fuel economy standards, renewable fuel standards and zero emission vehicle mandates – all of which are important for raising market certainty and investor confidence.

The Scottish Government is committed to providing a supportive policy and regulatory environment to support hydrogen production and use and to enable Scotland to take a pioneering role in a growing global industry. This means:

In the 2020s – Demonstration, accelerating market demand and getting the policy framework right: supporting research, innovation development and demonstration, building capability, and building partnerships with organisations and governments in Europe and beyond. Providing support for low-carbon hydrogen production and supporting the transition of existing supply chain companies in Scotland to develop and manufacture new technology in the hydrogen value chain. Establishing hydrogen demand in transport and industrial applications with supportive actions and investment, including access to public and private finance.

In the 2030s – Production at Scale: scaling up and bringing down costs, developing the value chain for renewable and low-carbon hydrogen; developing competitive, large scale, low-cost hydrogen for domestic use. Developing floating hydrogen production and an export industry for hydrogen and its derivatives.

By 2045 – Scaling up and global expansion: Enabling production of lowest cost green hydrogen for domestic use and for export, development of international hydrogen refuelling hubs, international transportation of hydrogen, including shipping and North Sea hydrogen pipeline infrastructure connecting Scotland to Europe.

Chapter 1. Overview

Hydrogen as a low carbon fuel

Hydrogen is of interest because it can be produced to act as an energy carrier that can be used directly for different purposes. The technology to produce hydrogen is well understood and already routinely applied in industry and when coupled with carbon capture and storage (CCS), large scale hydrogen production can be achieved with ultra-low carbon and even negative emissions when using biomass.

It could also be used to displace the direct use of methane in the heating of our homes and the provision of heat and industrial processes in our heavy industries. This is because domestic central heating systems and industrial applications can potentially be adapted to use hydrogen, making the conversion of existing gas networks to hydrogen and 'greening the gas grid' a serious consideration. (See Chapter 5: Heat in Buildings).

In addition to its use as a substitute for natural gas, hydrogen is used as an energy carrier as part of the electrification of energy systems and applications, mostly via fuel cells. This renewable and low-carbon hydrogen can be used to help displace the use of internal combustion engines that rely on petrol and diesel in the transport sector. (see Chapter 7: Hydrogen in Transport)

Hydrogen Production

In broad terms there are three types of hydrogen production:

- Grey Hydrogen – is produced from the reforming of natural gas. This process produces both hydrogen and carbon dioxide.
- Blue (or low-carbon) Hydrogen – is produced in the same way as grey hydrogen but the process is aligned with CCS systems which capture most of the CO₂ produced, preventing it from entering the atmosphere and storing it safely in deep geological formations.
- Green Hydrogen – is produced from the electrolysis of water, a process which splits water into its constituent parts of hydrogen and oxygen. When renewably sourced electricity is used this process is completely green.

Hydrogen and Negative Emissions Technology

When hydrogen is produced from a bio-energy feedstock and combined with CCS it can deliver negative emissions. This is an example of a Bioenergy with Carbon Capture and Storage (BECCS) technology.

The Scottish Government is exploring the potential of negative emissions technologies such as BECCS for hydrogen production, industrial applications, and electricity generation along with Direct Air Capture (DACCS). We are commissioning research into the development of negative emissions technologies across each of

these sectors, and how negative emissions, CCS infrastructure and hydrogen production can best support decarbonisation of the whole energy system.

Hydrogen as an Energy Store

Hydrogen also has a critical role to play in terms energy storage. Today, natural gas provides one of the largest energy storage mechanisms in the UK's energy system, with capacity for 17 TWh of energy storage providing critical flexibility for a wide range of energy system applications.

As we reduce our reliance on fossil fuels and aim for net zero hydrogen provides one of the most viable opportunity for large scale sustainable energy storage.

Key storage applications that hydrogen can deliver include:

- long-duration energy storage over months or longer in order to meet seasonal peaks in electricity and heat demand;
- medium term storage over days and weeks to manage the variability and uncertainty in the output of wind, solar and marine resources, and to balance the generation and use of energy;
- short term storage over hours, providing important services such as system balancing, inertia and voltage control on the electricity system.

Understanding hydrogen's role in decarbonisation

The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019² commits Scotland to reach net zero emissions of all greenhouse gases by 2045. It includes interim targets to reduce emissions by 75% by 2030, against a 1990 baseline, and to reduce emissions by 90% by 2040. These targets are required to meet Scotland's commitments under the 2015 Paris Agreement, which aims to limit global average temperature increases to 1.5 degrees Celsius.

To date, most of Scotland's emissions reductions have come from decarbonisation of electricity generation. Decarbonisation of heat, industry and transport are now priorities and require a broader range of technologies, strategies and energy systems.

There is consensus that hydrogen will play a critical role in decarbonisation of the energy system. Key publications such as the *Scottish Energy Strategy* (2017)³, *Committee on Climate Change Net Zero report* (2019)⁴, *National Grid ESO's Future Energy Scenarios* (2020)⁵ and, the *Offshore Wind Industry Council and Offshore Renewable Energy Catapults Offshore Wind and Hydrogen: Solving the Integration Challenge* (2020)⁶, have identified hydrogen as vital in decarbonising the energy system. Hydrogen is vital to decarbonising sectors where full electrification is

² [Climate Change \(Emissions Reduction Targets\) \(Scotland\) Act 2019](#)

³ [The future of energy in Scotland: Scottish Energy Strategy. Scottish Government \(2017\)](#)

⁴ [Net Zero - The UK's contribution to stopping global warming, Committee on Climate Change \(2019\)](#)

⁵ [Future Energy Scenarios, National Grid \(2020\)](#)

⁶ [Offshore Wind and Hydrogen - Solving the Integration Challenge, Offshore Wind Industry Council and Offshore Renewable Energy Catapult \(2020\)](#)

challenging, such as industry, transport and parts of the heat sector. A growing hydrogen economy, and the associated infrastructure required to support it, has the potential to provide cross-sectoral benefits.

The Committee on Climate Change has advised that demand for hydrogen across the UK is expected to increase significantly, from 27 TWh in 2017 to around 270 TWh by 2050 in its indicative pathway to reach net zero.

Identifying the unique Scottish context and understanding hydrogen's role in decarbonisation is critical to achieve Scotland's world leading decarbonisation targets. Therefore, the Scottish Government commissioned the Scottish Hydrogen Assessment, which sought to broaden and deepen our understanding of the potential offered by the production and use of hydrogen as we transition to net zero. This policy statement is a response to this assessment and should be read in conjunction with the assessment report.

The evidence gathered in the Hydrogen Assessment was complemented with the completion of a *Scottish Offshore Wind to Green Hydrogen Opportunity Assessment* and a *Deep Decarbonisation Pathways for Scottish Industries* study, which contributed to the comprehensive evidence base that now informs our future policies in support of the development of a hydrogen economy in Scotland.

Many of the regulatory and legislative levers required to enable the emergence of a hydrogen economy in Scotland are determined at a UK level. We welcome the UK Government's 10 Point Plan for a Green Industrial Revolution, published in November 2020, which set out a target to generate 5GW of low-carbon hydrogen production capacity by 2030 for industry, transport, power and homes, and an aim to develop the first town heated entirely by hydrogen by the end of the decade. A UK Government Hydrogen Strategy is expected to be published in the Spring of 2021.

Scottish Hydrogen Assessment

The Scottish Hydrogen Assessment was initiated in February 2020 and completed in October 2020. The assessment investigated how and where hydrogen may fit within the evolving energy system in Scotland, technically, geographically and economically.

From the assessment findings, and those of the Scottish Offshore Wind to Green Hydrogen Opportunity Assessment, we can determine the likelihood of sectors to transition to hydrogen and those most likely to be decarbonised by other means. The findings suggest that industrial and transport sectors are most likely to be the first takers of hydrogen in Scotland and could underpin market demand for low-cost hydrogen during the 2020s.

Initially, regional or local production of renewable hydrogen will play an important role in helping to build the domestic hydrogen market and these have the potential to scale up quickly. We are seeing regional efforts coming forward already in Scotland such as the clusters of activity in Aberdeen, Orkney, Glasgow and Dundee. Low-carbon blue hydrogen could supply relatively low-cost hydrogen at scale and be

used as a transition fuel in the medium-term, as developments like the Acorn Hydrogen project at St Fergus in North East Scotland become operational by 2025.

This may enable Scotland to establish a hydrogen economy relatively quickly in the near-term alongside the steady growth of large scale green hydrogen production in the medium-term. Scotland has an abundance of the ingredients in green hydrogen production: water and wind, both on and offshore.

A key part of the Assessment was the development of distinct viable scenarios for hydrogen deployment in Scotland and the economic assessment of those scenarios. Analysis of the potential economic impact in terms of Gross Value Added (GVA) and employment was undertaken for the purposes of understanding the relative scale of economic opportunities presented across and within the scenarios.

The most ambitious 'export' scenario in this assessment assumes that Scotland could credibly reach an installed capacity of 5 GW of renewable hydrogen by 2032 and over 25 GW by 2045. This is based on a high capacity of the ScotWind seabed leasing round for offshore wind projects and realistic subsequent future offshore wind developments being realised.

However, the scale of the hydrogen market depends on its cost. Driving down the cost of offshore and onshore wind electricity production will be key to cost-effective green hydrogen production.

If achieved, then Scotland's green hydrogen production will meet an expected growing domestic demand to help address decarbonisation of transport heat and industry sectors and also provide a surplus suitable for export according to the Assessment findings.

Further, this will provide opportunities along the whole hydrogen value chain in manufacturing and component and service supply chains as well as potential international collaboration opportunities with other nations and organisations seeking to decarbonise and invest in hydrogen production.

While headline figures for each scenario are presented, these should be treated as illustrative as they are not intended to be accurate depictions of what happens but possibilities based on a range of current views and assumptions. That said, the potential scale of the economic opportunity from the production of hydrogen has been calculated and the assessment scenarios attribute this in the main to future export demand from the UK and Europe. The gross impacts by 2045 across three scenarios modelled range from 70,000 to over 300,000 jobs protected or created and GVA impacts of between £5 billion and £25 billion p.a.

Global action

In less than a year's time, we will welcome to Glasgow the thousands of delegates to the United Nations Framework Convention on Climate Change 26th Conference of Parties (COP26). COP26 promises to be the most significant climate change summit since the Paris conference, five years ago. And it will potentially be one of the most important global gatherings of the century so far.

The fact that COP26 will take place here is obviously a huge honour for Glasgow – and for Scotland. But our ambitions for the conference extend well beyond simply being good hosts. We are determined as a country to play a full part – along with other cities, regions and states – in delivering a successful and ambitious outcome.

Last year, our country set world leading targets – to achieve a 75% reduction in emissions by 2030, and net zero by 2045.

We are now taking the action necessary to achieve our targets. As such, we are pursuing policies, including support for the development of alternative energy solutions such as hydrogen, which will help us to reduce emissions – while supporting a green recovery from COVID19, and enabling a just transition to a net zero world.

Many countries are seeking to build a hydrogen economy. Globally, hydrogen is expected to play a key role in a future decarbonised energy system. Many nations, as well as the European Union, are developing hydrogen strategies and policy frameworks which set out their national ambitions.

For a country to be a successful exporter of hydrogen, it must be able to produce and transport the hydrogen to the point of demand safely and securely. This must be done in a cost competitive way, competing in a global market.

Scotland has potential to produce significant quantities of green hydrogen from our offshore and onshore wind resources and our potential wave and tidal power which is vastly greater than our indigenous demand. We also have the potential to produce large scale blue hydrogen.

Scotland is keen to play its role in the development of UK, European and international markets. It is well placed in terms of proximity and infrastructure connectivity to several European nations that are unlikely to be able to produce enough green hydrogen to meet their own decarbonisation needs.

Scotland has recently been confirmed as European Co-Chair of the Under2 Coalition, a network of more than 200 Governments set up to drive climate action across the world and we see hydrogen as a key area of interest in this important body.

Scotland's access to low cost renewables, supplies of natural gas, carbon storage infrastructure, utilisation of existing transport infrastructure and proximity to demand, can all contribute to reducing the cost base. There is therefore an opportunity for Scotland to produce and export the lowest-cost clean hydrogen in Europe.

Chapter 2. Hydrogen within the Energy System

Policy Priorities: Hydrogen within the Energy System

We will support the continued development, use and production of hydrogen from renewable and low-carbon sources, i.e. green and blue hydrogen.

We will investigate the role of hydrogen in the development of Negative Emissions Technologies.

We recognise the potential for hydrogen to play a role in the decarbonisation of transport, heat, industry and also to potentially replace natural gas in the provision of back-up electricity generation and we will seek to fully explore these opportunities

We recognise the potential role for hydrogen in energy storage and will seek to explore this further.

Large scale renewable hydrogen production may provide an essential energy balancing and flexibility function to integrate the expected large increases in offshore wind into our energy system – under current constitutional arrangements, and recognizing our respective responsibilities, we will work with the UK Government to ensure alignment of policies and that market mechanisms are developed in tandem to reflect this system need.

We will produce a regulatory roadmap for hydrogen which will identify barriers to the use of hydrogen in the energy system and production at scale.

We also address challenges to deployment such as cost reduction and take forward findings in our Hydrogen Action Plan.

Whole Systems Approach

Hydrogen will be extremely valuable across the whole energy system, with the potential to help decarbonise a range of high emissions sectors such as buildings, power, transport and industry.

The introduction of hydrogen at scale creates a new energy carrier capable of capturing, transporting and storing energy. The benefits are potentially substantial. From the integration of renewables, to the large scale inter-seasonal storage of clean energy, hydrogen has the potential to change the way we think about energy.

With the breadth of applications for hydrogen, it will be critical that we plan for hydrogen using a systems-approach across all of our energy production, transportation and use sectors.

It is likely the most effective way to integrate hydrogen into our energy system, and our economy, is through the establishment of sector-coupling hydrogen production hubs capable of simultaneously servicing transport, heat and industry needs. It is a vision such as this that we are starting to develop through this policy statement and the Action Plan that will follow in 2021.

Once markets develop hydrogen can help address renewable intermittency as a commercial opportunity through its production by electrolysis at times of excess electricity supply – that is, when there is more renewable generation available than demand for electricity, or where our electricity networks are operating at their limit. Converting that wind power into hydrogen can provide developers with new routes to market, and may change the investment proposition for new and existing renewables generation.

Electrolysis can also lead to greater integration of the gas and electricity grids – subject to work currently being pursued into the capability of our existing gas network and pipelines to accommodate low carbon gases, including hydrogen (see example of the H100 Fife on page 31).

Hydrogen can also be used for direct power production – potentially displacing natural gas as a provider of back-up, flexible power generation on the system, and the vital technical qualities which generation of this kind provides for system stability.

Hydrogen may also provide the option of storing energy, either as hydrogen or ammonia, over extended time periods and, potentially, deployable at scale.

A stable, managed energy transition

Hydrogen is an important transition opportunity for Scotland's mature oil and gas industry, and a just transition that supports sustainable economic growth and jobs.

Hydrogen is mostly used as a gas. If it is to play a larger role in our future energy mix we will need the skills of people and companies that know how to produce, manage, compress, transport, store, and reconstitute gas. Many of the skills and the supply chain requirements for future hydrogen systems and infrastructures are to be found in our oil and gas industry today.

Scotland is a net exporter of electricity and in the past decade renewable electricity output has grown markedly. In 2018 more than 83% of the electricity generated in Scotland came from renewable or low carbon sources. Between now and 2032 we will see a further substantial increase in renewable generation, with the development of new offshore and onshore wind capacity supporting the increased electrification of transport and heating.

Our Offshore Wind Policy Statement⁷ set out our ambition for up to 11 GW of offshore wind generation in Scottish waters by 2030 – this is a key linked document to inform our Hydrogen Policy Statement and our proposed Action Plan.

⁷ <https://www.gov.scot/publications/offshore-wind-policy-statement/>

Our vast offshore wind resources, skilled technicians, and engineers, highly specialised technical companies and an experienced offshore workforce will be able to assist in bringing forward large scale green hydrogen production. There are gaps in the skills supply chain for hydrogen production that we need to understand and address, but we start from a strong base.

Case Study - Aberdeen Hydrogen Hub

The **Aberdeen Hydrogen Hub** is a regional collaboration proposal, involving Aberdeen City Council, Scottish Enterprise and Opportunity North East, taking a whole-system approach to hydrogen production and demand to drive scale and economic growth.

The 'Aberdeen Hydrogen Hub' aims to deliver a commercially scalable and investable, growth-focussed hydrogen production site making use of the region's offshore wind resources. This will kick start growth of the hydrogen sector in the region, initially for transport, with further opportunities for growth in heat, industry and beyond in the future. If successful, this is a model which could be suitable for replication in various regions of Scotland.

The Hub is among one of the projects being supported by Scottish Government funding via our £62m Energy Transition Fund (ETF), launched in June 2020.

The project has so far been awarded £4.5m enabling the procurement of an additional ten hydrogen double decker buses to add to the existing hydrogen bus fleet in Aberdeen to help anchor hydrogen demand and enable future buildout phases of the Hub.

Chapter 3. Economic Opportunity

Policy Priorities: Economic Opportunity

We will collaborate with industry, academia and government to ensure opportunities in the development of a hydrogen economy in Scotland are maximised.

Both renewable and low-carbon hydrogen will play an important role in our energy transition to net zero and are key components of the green recovery.

We support the development of commercial scale hydrogen production in Scotland, including:

- increased production of green hydrogen from existing surplus and dedicated renewable electricity generation;
- large scale low-carbon hydrogen from the reformation of natural gas aligned with CCS systems.

We also support the production of large scale green hydrogen for export both from existing surplus renewable and dedicated renewable electricity generation as well as low-carbon hydrogen from the reformation of natural gas aligned with CCS systems.

We recognise that innovation and Scotland's knowledge and people capital, alongside our skills and system integration knowledge and expertise, are also important and could hold export potential in their own right alongside a growing supply chain.

We will create a supportive policy environment to enable cross-cutting opportunities offered by hydrogen production and use, including sector coupling and hydrogen fuel cell deployment.

We will also explore the potential to produce hydrogen from bioenergy resources in combination with CCS to deliver negative emissions. Through this process we will pay careful attention to the ability of Scotland to grow or import bioenergy resources, making use of the expertise and evidence developed by the Bioenergy expert advisory group that we have announced in the update to our Climate Change Plan.

The development of a hydrogen economy is a substantial economic opportunity for Scotland.

From our hydrogen assessment, it is clear that hydrogen is not just an energy and emissions reduction opportunity, but it can have an important role in developing a sustainable economy in Scotland.

We know that a huge amount of both renewable and low-carbon hydrogen will be required to decarbonise our energy use as we move to 2045. We also know that we must work together with industry to ensure we secure maximum economic benefit from increasing hydrogen capacity and deployment in order to deliver a sustainable and just energy transition.

The Hydrogen Assessment points to ways in which this might be achieved. It sets out a range of scenarios, modelled to illustrate how Scotland could develop a future hydrogen economy. The scenarios help to frame and contextualise the uses of hydrogen in our energy system and the opportunities for Scotland as a key exporter of large scale green hydrogen to the rest of the UK and Europe, which the report concludes could result in new industrial opportunities of a significant scale. See Figure A.

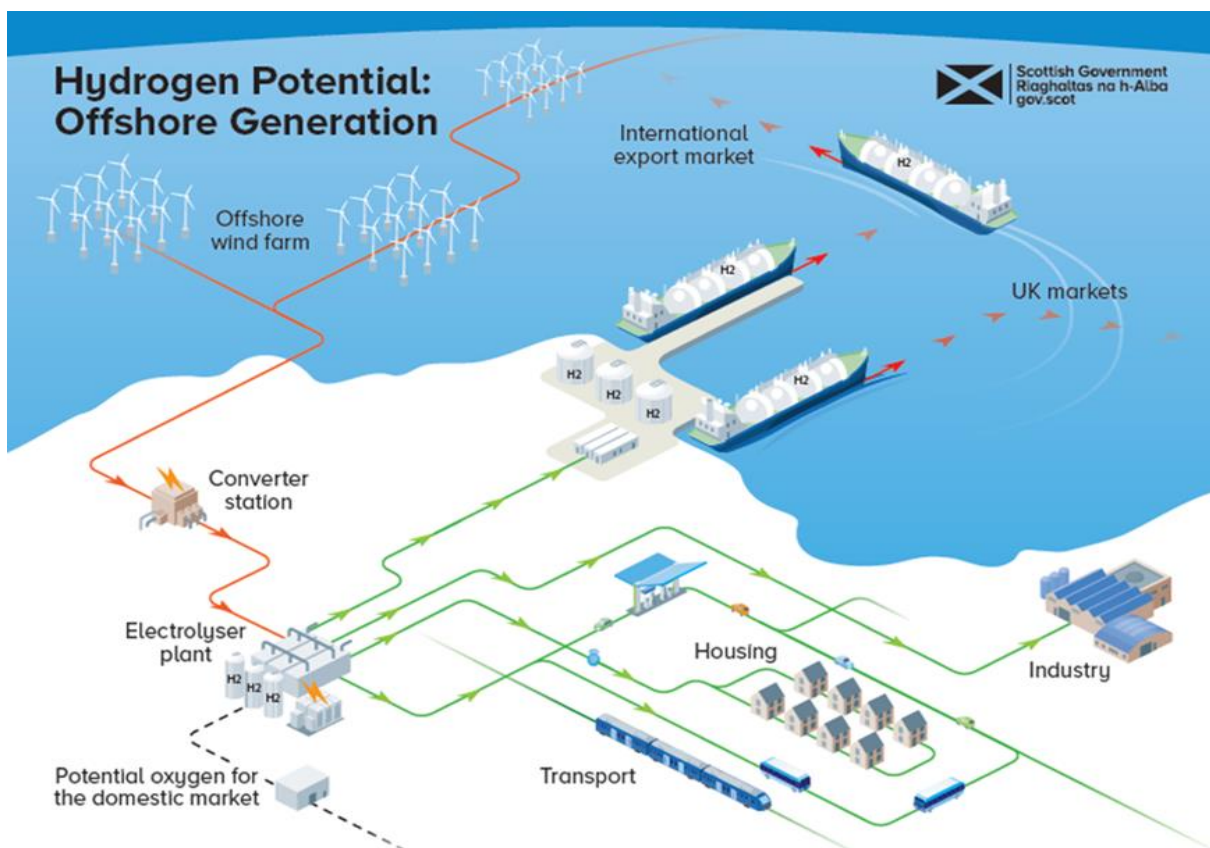


Figure A. Illustrative Hydrogen Export Hub

The report also identifies that the key driver of the hydrogen economy would likely be in the production of the renewable and low-carbon hydrogen itself (with other opportunities such as hydrogen for mobility etc. able to benefit from production capacity).

The gross impacts by 2045 across the three scenarios range from 70,000 to more than 300,000 jobs protected or created and GVA impacts of between £5 billion and £25 billion.

The three illustrative scenarios are designed to represent three possible future end states and as such allow the effect of different assumptions on the resulting GVA and jobs to be explored.

The most ambitious scenario with the largest estimated gross impacts is in establishing Scotland as a major exporter of green hydrogen to Europe by 2045, with significant opportunities from unlocking Scotland's vast offshore wind potential, but would be dependent on Scotland producing green hydrogen that is competitively priced in a European market.

Achieving the upper range of these scenarios will require a huge amount of effort and investment, both public and private. It will also require an aligned combination of reserved and devolved legislative and regulatory action to be developed to support hydrogen production and the enduring hydrogen economy. This will include the right levels of support, from the right design of market mechanisms and innovation support, skills and knowledge building, and the successful removal of barriers to deployment. The requirement to develop export markets for hydrogen as a key feature of the Scottish Government's hydrogen policy direction is explored further in Chapter 8: Hydrogen in Transport.

Sector Coupling

Hydrogen can be produced from surplus renewable electricity and utilised as a homogenous commodity across a variety of sectors such as transport, heat and industry, thereby joining up sectors which have traditionally remained separate parts of the energy system.

The Green Hydrogen for Glasgow project which aims to construct an "end-to-end" green hydrogen refuelling network in Scotland is a collaborative project led by a partnership including: Scottish Power Renewables, BOC/Linde and ITM Power. The project will develop a 10 MW electrolyser at Scottish Power's Whitelee Wind Farm near Glasgow to service the city and surrounding region with green, commercial hydrogen fuel within two years.

This particular project illustrates sector coupling between the electricity sector, hydrogen and gas technology leaders and the commercial transport sector working together to deliver key hydrogen infrastructure.

Other strengths for Scotland, beyond that of developing our export ambitions include our ability to move swiftly, connect opportunities across sectors, build on our academic expertise, and nurture expertise in areas where we have demonstrated strength, for example in the offshore oil and gas sector.

The extensive potential for renewable energy generation, the presence of major subsurface CO₂ storage sites and the availability of existing offshore pipeline infrastructure in the North Sea combine to offer a unique opportunity to develop a Scottish economy where renewables, hydrogen and CCS coexist and complement each other.

The emergence of a global hydrogen economy coincides with the tapering off of oil and gas production. The Scottish Government's continued support for oil and gas sector businesses operating in the North Sea is now conditional upon contributing to a sustainable, secure and inclusive energy transition. This presents transition opportunities for the oil and gas sector, particularly in establishing a hydrogen sector in Scotland.

The oil and gas sector continues to play an important role in our energy mix, in helping to ensure a secure energy supply; providing feedstock to support the petrochemical and fertilizer industries; and as a raw material providing finished products in fuel, plastic, industrial, chemical, and pharmaceutical industries.

The sector will help to design the diverse energy system we need for the future, including options such as hydrogen production and developing floating wind and marine energy, with many businesses already diversifying into these areas. Scotland's vast renewable resources, legacy oil and gas infrastructure, combined with its energy skills and supply chain focused on energy transition are critical to establishing a prominent role for Scotland in the emerging global hydrogen market.

Many companies who operate in the oil and gas sector already have direct involvement in developing and supporting the rapid growth in low carbon solutions, including development of hydrogen.

The creation of the OGTC Net Zero Solution Centre will look to rapidly accelerate technologies that will help not just to decarbonise operations and enable the gas sector to deliver the world's first net zero hydrocarbon basin. It will also look to draw across the range of companies operating across the energy sector, support the creation of an integrated offshore energy system, partnering with companies and R&D organisations on technology development projects including a direct focus on hydrogen production which has a significant international export opportunity.

The oil and gas and renewables sectors have well established supply chains which are positioned to benefit from the development of hydrogen domestically in Scotland and within international export markets. However, gaps remain in the supply chain for both green and blue production that will need to be filled in order to ensure that Scotland gets the most out of a transition to hydrogen. Opportunities for supply chain development in Scotland, such as fuel cell manufacture, are highlighted in the Hydrogen Assessment. The lack of an electrolyser manufacturer in Scotland is highlighted as a key issue. This is explored further in Chapter 4: Hydrogen Supply Chain.

Case Study – The Hydrogen Coast

The Hydrogen Coast is a cluster of projects that are delivering innovative hydrogen solutions along the east coast of Scotland. It is bringing together hydrogen projects to demonstrate full transition to the hydrogen economy, encompassing sector coupling for both blue and green hydrogen options.

The programme is being led by Scottish Gas Networks (SGN), National Grid and Pale Blue Dot along with the partners of the hydrogen projects that are already underway across the east coast of Scotland:

- **Acorn Hydrogen and Acorn CCS** – A blue hydrogen production plant producing hydrogen from natural gas landed at St Fergus, coupled with a CCS facility that will capture the CO₂ from hydrogen production, as well as other sources, and transport it for storage in the North Sea.
- **HyStorPor** – Investigating the requirements for the geological storage of hydrogen. This work will support the development of hydrogen storage for Acorn Hydrogen and other Hydrogen Coast projects.
- **Aberdeen Vision Project** – Using hydrogen from the Acorn Hydrogen project to support decarbonisation of the national and Aberdeenshire gas transmission systems. Phase 1 proposes all gas leaving St Fergus would be injected with 2% hydrogen by volume into the gas National Transmission Network. Phase 2 aims to inject up to 20% by volume hydrogen into the gas supply for Aberdeen and the Aberdeenshire region. Phase 3 aims to operate the low pressure gas distribution network on 100% hydrogen.
- **H100 Fife** – SGN are developing the first 100% hydrogen domestic network, in Fife. This project, to which we have committed £6.9 million in funding, is building an evidence base for domestic hydrogen use and will facilitate larger trials such as that proposed in the Phase 3 of the Aberdeen Vision Project.
- **Aberdeen Hydrogen Bus Project** – A fleet of fifteen new double decker buses in Aberdeen powered by green hydrogen, with Scottish Government funding support.
- **The Hydrogen Hub, Aberdeen** - Aims to secure a resilient and cost effective supply of green hydrogen, initially for a fleet of road vehicles, in support of the Hydrogen Bus Project and other fleet vehicles. Subsequent project phases are looking to supply marine and rail customers with green hydrogen.
- **Dolphyn ERM** – Project using deepwater floating offshore wind assets to produce hydrogen at sea and then pipe it to shore using existing oil and gas infrastructure, supplying additional hydrogen to the Hydrogen Coast projects. Currently in detailed engineering and consents phase, the 2MW prototype facility could be operational by summer 2024. A 10MW full scale pre-commercial facility is planned to follow by 2027, with full scale commercialisation shortly afterwards

Chapter 4. Hydrogen – Scotland’s Supply Chain and Skills

Policy Priorities: Hydrogen Supply Chain

We will complete a detailed review of our supply chain capability in order to identify strengths and weaknesses, opportunities and barriers to the transition to and growth of a hydrogen economy in Scotland.

We will work with our enterprise agencies to develop a programme of activity to support supply chain development, growth and transition in order to establish a stable and sustained hydrogen economy in Scotland.

We will build Scottish capability in the emerging hydrogen sector, supporting companies to grow and diversify across the whole hydrogen supply chain, but with a specific focus on manufacturing component parts required throughout the hydrogen value chain.

We will work with our existing supply chain to support access to funding and projects that will grow expertise, knowledge and revenue through the 2020s as the hydrogen economy matures.

We will work with innovative and emerging companies in Scotland to develop next generation technologies and components that help to reduce costs in a global hydrogen value chain and plug gaps in our supply chain.

By drawing on existing skills and capability we will play to our strengths and work to attract other companies to set up in Scotland. Where required, we will also work to attract inward investment in hydrogen supply chain with a particular focus on production, supply and manufacturing.

We will support collaborative projects that actively engage Scotland’s supply chain both domestically and internationally through demonstrators and commercial projects that can support supply chain transition and growth and leverage global export opportunities in terms of services, skills and manufacturing.

Building Supply Chain Capability

The expertise gained through over 45 years of experience of oil and gas sector operations in Scottish waters and an abundance of offshore wind skills means that Scotland should be well positioned to capitalise on the opportunities that the production of large scale hydrogen presents.

As we transition to a net zero economy, it will be increasingly important that these skills can be seamlessly transferred to our growing hydrogen sector – retaining, and growing the economic value of a new hydrogen production industry.

Capturing the Hydrogen Value Chain

While Scotland has a natural advantage in green hydrogen production, given the huge potential offshore and onshore wind resource, there are gaps in the supply chain which need to be explored and resolved.

The Scottish Offshore Wind to Green Hydrogen Opportunity Assessment, supported by the Scottish Government, identified over 100 companies in Scotland that are already involved or have an interest to be involved in green hydrogen production. The study also identified a number of strengths and weaknesses in Scotland's supply chain.

The current strengths of the Scottish hydrogen supply chain are in the areas of project development, installation, operations and maintenance and sector support where these capabilities can be transferred from Scottish companies with experience in similar industries. Scotland also possesses a wide range of engineering design and academic research capabilities that could be brought to bear.

However, gaps in the Scottish supply chain are predominantly in supply areas bespoke to the design, manufacture and maintenance of hydrogen generation plant. These would be high value added activities as would be the specialist extended supply chains that go with them.

To address these supply chain gaps we will support new and innovative indigenous companies as they develop next generation technologies as well as inward investment of manufacturing to Scotland which could not only generate direct jobs and value but may also lead to the establishment of a sustainable, long term local supply chain and stimulate wider supply chain opportunities.

Large Scale Production – (large scale investment)

Significant scale of investment is required to realise the green hydrogen production potential afforded by Scotland's vast renewable generation resources. Access to capital is critical to supporting energy investment.

The Just Transition Commission's report on green recovery (July 2020) states that leveraging private investment to help meet the cost of the transition to net zero is an 'absolute necessity'.

We will work with industry, the investment community, and the Scottish National Investment Bank and Scottish Futures Trust to fully explore the business models necessary to grow our hydrogen economy as well as innovations in finance to leverage and secure low cost investment opportunities to advance the hydrogen economy as part of the wider energy system thinking. The Scottish National Investment Bank is the UK's first mission-led development bank which is being capitalised by the Scottish Government with £2 billion over ten years.

Hydrogen supply chain in Scotland

The Scottish Hydrogen Assessment considered skills and capabilities in Scotland associated with our existing supply chain, including the renewable energy industry and the offshore oil and gas industry.

The supply chain capabilities are centred around development, construction including civil and electrical contractors, and operations. Scotland's oil and gas sector also has transferrable skills in the supply and service of process engineering kit.

While Scotland may have a limited indigenous manufacturing supply chain for provision of key plant like electrolyzers, it has existing and transferrable skills within the renewable and energy sectors, including a strong existing renewables sector with many onshore and offshore wind developers with locations and active projects within Scotland.

Companies are building capabilities to support the development of electrolysis projects. European Marine Energy Centre (EMEC) first procured a hydrogen electrolyser in 2015 and have since gone on to expand their portfolio of hydrogen projects. A number of small to medium enterprises (SMEs) in Scotland specialise in areas of the electrolyser supply chain. Examples include: the Pure Energy Centre, an electrolyser integrator or assembler located on Orkney and; Logan Energy a system integrator and operator based in Edinburgh.

Scotland's oil and gas sector also has transferrable skills in the supply and service of process engineering kit. Many of the supply chain elements required for the production of low-carbon hydrogen exist already in Scotland's oil and gas industry. SMR/ATR plants are typically bespoke and built at the installation site, with many of the components, such as pressure vessels, pipework and supporting steelwork, being items which could be manufactured in Scotland.

There is limited potential for the development of core intellectual property (IP) around SMR/ATR and Carbon Capture, Utilisation and Storage (CCUS) although the integration of these two elements for low-carbon hydrogen production may offer opportunities. These are high value added activities but at present much of this IP is being captured outside Scotland.

The extent to which Scotland is able to generate IP in this area will also determine the extent to which this sector could offer export potential in the same way that Scotland exports oil and gas expertise, recognising that there are strong incumbent players.

Further value added opportunities may exist in liquid fuels production. Hydrogen will mainly be used in gaseous or liquid form but in export scenarios hydrogen may be transported and ultimately used as ammonia, methanol or any number of synthetic hydrocarbons from methane to jet fuel.

If these fuels and energy carriers become established, then they are generally most economically co-produced in the same location as hydrogen. Scotland may therefore

be in a position to add further value to the hydrogen being produced by synthesising these fuels and chemicals.

The skills assessment from the hydrogen assessment work points to the presence of relevant skills in Scotland which could be exploited to realise this additional economic opportunity.

Skills

The development of training and skills associated with the deployment of solutions in the hydrogen sector will be considered as part of our Climate Emergency Skills Action Plan⁸. We will support reskilling and retraining skilled workers so that they can access the new, good quality jobs that become available. This is fundamental to delivering a just transition and ensuring people are able to access and benefit from the opportunities such as good, green jobs.

We are also investing in green jobs and skills as part of the green recovery including: £100m in a Green Jobs Fund to help businesses which provide sustainable and/or low carbon products and services to develop, grow and create jobs; £60m Young Person's Guarantee including increased opportunities for 'green' apprenticeships across public sector bodies; and, £25m National Transition Training Fund including focus on provision of green skills. The private sector has an integral role to play in the developing the hydrogen sector by joining Government in investing in the skills, the training and the infrastructure that will develop as local supply chains emerge.

In addition, the Scottish Government is a member of the Energy Skills Alliance (ESA), established in 2019 to develop an integrated skills strategy to create a net zero energy industry. The ESA is working to produce a clear forecast of energy skills in the short term, deliver an integrated energy apprenticeship scheme and develop a roadmap for aligning training and standards. The alignment of training and standards across energy sectors will be a key enabler in allowing renewables sectors to benefit from and utilise the skills and expertise of the oil and gas industry by removing the need for the workforce to obtain additional certification in order to transfer between sectors.

⁸ [climate-emergency-skills-action-plan-2020-2025.pdf](https://www.skillsdevelopmentscotland.co.uk/climate-emergency-skills-action-plan-2020-2025.pdf) (skillsdevelopmentscotland.co.uk)

Chapter 5. Scotland's Natural Resources, Infrastructure and Place

Policy Priorities: Scotland's Natural Resources, Infrastructure and Place

Scotland's natural resources, strengths and existing infrastructure provide the perfect combination of factors for large scale clean hydrogen production and we will promote these unique selling points to support the growth of a hydrogen economy in Scotland.

We support the establishment of regional clusters of hydrogen activity.

We support the aspirations of our islands communities to become hubs of energy innovation and climate change leaders, with an emphasis on energy transition, renewable energy and hydrogen production.

The key ingredients in green hydrogen production are renewable energy and water. Scotland has an abundance of wind, both on and offshore, tides, and reliable water resources within public control with which to support electrolysis. Scotland's water services are provided by Scottish Water, a publicly-owned company answerable to Scottish Ministers.

To-date, Scotland has seen a significant amount of offshore wind energy activity, with 15 offshore wind farms (including three floating wind farms) having received consent, five of which are currently operational. This equates to a total generating capacity of just over 5GW and our aim is this will rise to 11GW by 2030.

Scotland is in the process of running a further leasing round for commercial scale offshore wind energy projects in Scottish waters, the Crown Estate Scotland Scotwind leasing round. The development of deep water wind technology also provides an opportunity to further develop offshore wind supply chains and to lever existing infrastructure and supply chain capabilities from the offshore oil and gas industry and help create the requisite conditions to position Scotland as a world leader in deep water wind technologies.

Due to its extensive coastline, Scotland has an estimated one third of the UK's tidal stream resources and two thirds of the UK's wave resources. The UK as a whole is estimated to have around 50% of Europe's tidal energy and 35% of its wave energy potential. Scotland is a world leader in wave and tidal energy as a result of consistent and committed support from the Scottish Government together with the expertise, investment and innovation of the industry itself. Although wave and tidal technologies are at an early stage of commercial development, the scale of Scotland's natural resource offers significant opportunity for renewable energy generation in the future.

Scotland also has plentiful wave and tidal energy renewable resource at sites off our shores which are producing renewable energy for use in electrolysis.

While bulk green hydrogen from renewable electricity appears an attractive opportunity for medium to longer-term, in the near to medium-term, low-carbon hydrogen demand and infrastructure could be developed in Scotland by aligning hydrogen production from fossil fuels with carbon capture and storage (CCS).

Scotland's key CCS resource is our vast potential for CO₂ storage in the North Sea, estimated at 46Gt of CO₂ storage in Scottish waters. Legacy oil and gas infrastructure offers us rare access to these storage sites.

Hydrogen production via methane reformation aligned with CCS will require locations near to sources of natural gas. Approximately 35% of the UK's natural gas comes ashore from the North Sea at the St Fergus Gas Terminal in the North East of Scotland. This is where the proposed Acorn CCS and Acorn Hydrogen projects are located.

Infrastructure and Planning

Significant investment in infrastructure will be needed to support new emission reduction technologies such as CCS and hydrogen.

This is recognised in our draft Infrastructure Investment Plan (IIP) which was published on 24 September. The IIP delivers the National Infrastructure Mission – and sets a long term vision of infrastructure supporting an inclusive, net zero carbon economy in Scotland.

The Plan includes details of around £24 billion of major projects and national programmes – with more to be confirmed in future years, including: more than £8 billion for environmental sustainability and the transition to net zero emissions, including £250 million to support 18,000 hectares of forestry and restoring peatlands.

We expect that our draft National Planning Framework (NPF4) will confirm that climate change will be the overarching priority for our spatial strategy and planning policy and will confirm our view that the Global Climate Emergency should be a material consideration in considering applications for appropriately located renewable energy developments.

CCS infrastructure; on and offshore renewable energy generation and networks; and clean hydrogen production and distribution have been identified as strategically important development opportunities in Scotland that should be reflected in NPF4. Our analysis of candidate projects for national development status is ongoing. The draft NPF4 will be subject to Parliamentary scrutiny and public consultation from autumn 2021, and we expect to adopt it by summer 2022.

We already possess key infrastructure assets that can assist in the transition to a hydrogen economy. We have a wealth of oil and gas infrastructure (pipelines and offshore platforms) that could be repurposed for hydrogen transportation and storage. We also have a large number of deep water ports and harbours across

Scotland that could act as transportation and storage hubs for a future hydrogen industry.

Location

The importance of location in the development of a hydrogen economy in Scotland cannot be understated. Co-location of renewable energy generation, transport infrastructure, legacy oil and gas sector assets (including CCS infrastructure) and links to export markets, all contribute to lower production costs and growth in local use and export opportunities.

The deployment of hydrogen in Scotland is likely to be region and geography specific, reflecting the location of production resources, existing infrastructure and demand patterns.

This is a key goal of the Grangemouth Future Industry Board (GFIB), announced in the 2020 Programme for Government⁹. The Grangemouth cluster is responsible for approximately 30% of Scottish industrial emissions and comprises a range of businesses with significant expertise in oil refining, petrochemicals, engineering, ports/harbours and multi-modal transport (road, sea and rail).

The cluster already produces and consumes large quantities of hydrogen, positioning the region as a potential future hub of low carbon hydrogen supply and demand. There is substantial capacity for the industries in this area to capitalise on their location, skills and expertise, pooling their collective demand for low-carbon energy or working together to advance the early development of low-carbon infrastructure at scale. Grangemouth's advantages for CCUS linking and the capture of industrial emissions make for what could be a key asset in Scotland's transition to a net zero emissions economy by 2045.

GFIB will seek to enhanced public sector coordination around Grangemouth, leveraging this opportunity to help identify and progress growth/investment opportunities; streamline effort; identify barriers to economic development or decarbonisation and improve the collective public sector input to decisions affecting the cluster to drive a just transition to net zero.

Hydrogen also offers an opportunity for remote and rural and island communities, where a whole systems approach could allow effective decarbonisation, while also creating substantial local economic benefits. Support for hydrogen production and use in these areas would also assist in job retention and creation in these areas.

Scotland's island and rural locations have access to vast renewable resources. Despite this, they suffer from high fuel costs resulting in high levels of fuel poverty. This is the result of a combination of factors including constrained electricity grids, limited penetration and/or interconnection of gas grids and the high costs of transporting fuel. High fuel prices and carbon intensive fuels have a negative impact

⁹ [Protecting Scotland, Renewing Scotland: The Government's Programme for Scotland 2020-2021 - gov.scot \(www.gov.scot\)](https://www.gov.scot/publications/protecting-scotland-renewing-scotland-the-governments-programme-for-scotland-2020-2021/pages/100-to-109/)

on energy intensive industries and commercial activities, such as the whisky and distilling sectors.

An integrated energy system, that includes hydrogen, can allow better local management of supply and demand, allowing an increasing penetration of renewables in the system. Examples of this approach are emerging in the Western Isles and Orkney where hydrogen is being developed as a solution that can supply an increasing diversity of demand alongside increasing electrification.

In addition, proximity to large scale offshore renewables, may allow islands and rural locations to play a key role in production and export of hydrogen to the rest of Scotland, UK and Europe.

Our islands are microcosms of the rest of society. Many already have ambitious plans to be major renewable energy hubs, including establishing hydrogen production facilities to tap into the islands' wind, wave and tidal generation capacity. We wish to support and encourage this aided by the Islands Growth Deal which will target £100m funding to a range of areas including energy transition and local sustainable economic recovery and growth.

Case Study – Place based island projects

Islands offer the potential for valuable shared learning from pioneering hydrogen technology which could inform and accelerate decarbonisation in the hard-to-decarbonise sectors in Scotland, the UK and other carbon intensive countries. Recent Scottish Island projects include:

The **Scottish Western Isles Ferry Transport** ¹⁰using Hydrogen (SWIFTH2) - feasibility study conducted in 2019 sought to determine the viability of exploiting the isolated wind resource of the Western Isles to produce green hydrogen (isolated due to the size of the subsea connection cable, 33kV makes the Western Isles transmission network the weakest in the country).

- **PURE** (Promoting Unst Renewable Energy) – early demonstration of integrating local wind production with hydrogen storage and displacement of fossil fuels in islands.
- **H2Seed** (Hebridean Hydrogen Seed) – demonstration of renewable generation and AD biogas from municipal waste to produce hydrogen for a refuelling station.
- **Surf'n'Turf** – production of green hydrogen from wind and EMEC-based tidal energy in Orkney to provide green power to quayside Marine ferries.
- **BIGHIT** – building upon Surf 'n' Turf and implementing a fully integrated model of hydrogen production, storage, transportation and utilisation for heat, power and mobility with electrolysis from additional wind, based in Orkney.
- **OHLEH** (Outer Hebrides Local Energy Hub) Utilising increased levels of industrial fish waste and smart wind generation it produces both hydrogen and oxygen; with the hydrogen being used to provide fuel for both a council refuse lorry and heat and power to a salmon hatchery, which also utilises the produced oxygen to rear the young fish.
- **HyDIME** – the design and physical integration of a hydrogen injection system on a commercial passenger ferry.
- **HySPIRITS** – design of the world's first hydrogen fuelled distillery.
- **HyFLYER** – demonstration of the world's first hydrogen fuelled inter-island flight.

¹⁰ <http://www.pointandsandwick.co.uk/wp-content/uploads/2019/07/Scottish-Western-Isles-Ferry-Transport-using-Hydrogen-Feasibility-Report.pdf>

Chapter 6. Hydrogen for Heat in Buildings

Policy Priorities: Hydrogen for Heat in Buildings

We will ensure options for deploying hydrogen for heat are kept open, fully explored, evidenced and developed.

We will explore the potential that hydrogen may offer in helping to contribute to our ambitious heat decarbonisation targets and will investigate the system benefits of using hydrogen as part of our zero-carbon heating solutions.

We recognise the potential for hydrogen to replace direct use of natural gas for domestic and commercial space and water heating in Scotland. We will accelerate our efforts to understand more about the costs of hydrogen systems in comparison to other options and how hydrogen systems would be safely constructed, integrated and operated.

We will define, investigate and review potential barriers to the deployment of hydrogen for heat in Scotland.

We will support targeted research programmes and the demonstration of hydrogen for heat solutions, including continuing the hydrogen demonstration funding programme.

Using Hydrogen for the supply of decarbonised heat

Currently, natural gas via the mains gas network is used to supply in the region of four-fifths of the heat in Scotland's homes and businesses. Alongside energy efficiency improvements and the electrification of our future heat supply we are exploring the possibility of replacing the natural gas in our gas grid with hydrogen gas as a potentially significant part of our decarbonisation pathway in some areas.

There is the potential for hydrogen in our gas networks to begin decarbonising heat from the early 2020s. Initially this could take the form of blending small, but increasing quantities of hydrogen in with the natural gas delivered through the networks. Trials being carried out on the Keele University gas network are aiming to demonstrate that blending at up to 20% by volume in the gas distribution network can be accommodated within the network and used by existing gas boilers and other appliances. And one option for the Acorn Hydrogen project at the St Fergus gas terminal, near Peterhead in Aberdeenshire, is to blend hydrogen at 1 – 2 % by volume with the natural gas injected into the national transmission network from St. Fergus.

A more substantial intervention could see 100% hydrogen delivered through new and existing gas networks in future. This would mean replacing existing appliances with ones designed for hydrogen. To understand the potential for 100% hydrogen

networks we need further demonstration in the next few years to fully understand the various roles that hydrogen can perform in heating our buildings.

Alongside other research support, we have already provided £6.9 million funding towards the delivery of H100 project in Fife: a first-of-a-kind hydrogen heating network proposed by SGN which we believe will be a project of international significance. (See below for more detail on the H100 Fife Project).

Heat in Buildings Strategy

Decarbonising Scotland's heat supply, whilst maintaining affordability for customers, is a critical part of delivering a successful energy transition and a fundamental step towards achieving our net zero ambitions.

We have committed to £1.6 billion investment in heat and energy efficiency in our homes and buildings over the coming parliament (2021-26). Further actions are set out in the Climate Change Plan update and forthcoming Heat in Buildings Strategy.

To meet our 2030 emissions target, we will need to see mass switching to zero emissions heat in the next ten years. For homes, the transition will include by 2030 significantly increasing the amount of green gases (biomethane and hydrogen) blended into the gas network and switching around 1 million homes currently using mains gas to zero carbon heating systems by 2030.

Hydrogen for Heat

It is important to ensure the option of deploying hydrogen for heat is kept open, fully explored, evidenced and developed.

Our hydrogen policy positions will complement and support our wider Heat in Buildings Strategy to work with UK Government on product standards to require all new gas boilers to be hydrogen-ready and on their Hydrogen Energy and Utility Skills programme. This programme will develop a common competency framework for the training, accreditation, and registration of gas engineers working with hydrogen to ensure they are equipped to install hydrogen equipment into homes safely and efficiently.

As well as bringing forward and supporting demonstrator projects, we are working to better understand other heating options costs, performance and practicalities. We will identify areas of high potential for hydrogen and also which buildings would be most suitable for hydrogen as well as target areas of no- and low- regret during the 2020s until there is greater clarity over the future role of hydrogen as a replacement for natural gas.

UK Government Action Required

To drive further decarbonisation, including support for hydrogen, the UK Government must expand the scope of the Green Gas Levy, or a parallel scheme, and amend gas regulations to allow for greater blending of hydrogen. This is necessary to allow for the progressive reduction in emissions associated with the combustion of natural

gas, and to enable the demonstration of 100% hydrogen. Early clarity is needed, by 2025 at the latest, about the future of the gas network in order to deliver hydrogen at scale by the late 2020s.

We also call on the UK Government to continue the programmed support for the demonstration of hydrogen for heat and to step up support for stimulating further renewable electricity generation to meet the future demand from electrification of heat (and transport) and the production of green hydrogen from renewable electricity.

Research programmes

Further research will be required to investigate the energy system benefits of using hydrogen as part of our zero-carbon heating solutions and support the demonstration of hydrogen for heat solutions, including continuing the hydrogen demonstration funding programme.

We will support research programmes to undertake analysis, working with industry stakeholders and local authorities, of the particular areas in Scotland and the parts of our current heat system where hydrogen potential is greatest and also which buildings would be most suitable for hydrogen as part of our decarbonisation pathway. In addition we will identify no- and low-regret actions for hydrogen alternatives and target support for the demonstration of Hybrid Hydrogen/Electric heating systems.

Research will also be required to accelerate our understanding of the costs of hydrogen systems in comparison to other heat decarbonisation options, both at a systems level and for end consumers. We will define, investigate and review potential barriers to the deployment of hydrogen for heat in Scotland and engage the public in order to raise awareness and understanding of hydrogen.

Case Study - H100 Fife 100% Hydrogen Project

SGN (formerly Scotia Gas Networks) are partnering with other UK gas operators in this project to ensure the delivery of a world-first demonstration of an end to end 100% hydrogen energy system, to evidence the role that hydrogen can play in decarbonising heat, using the gas network. The project will construct and operate a hydrogen heat network system in Fife able to service around 300 houses and will be of UK-wide significance offering an important validation of the evidence base carried out by the UK Government in their Hy4Heat Programme.

The project will connect with the existing ORE Catapult 7MW offshore wind turbine situated off the coast of Leven in Fife to directly supply power to the electrolyser for hydrogen production evaluating the opportunity for grid integration systems between renewables and hydrogen production, and demonstrating the business case opportunities that offshore wind can offer for production of hydrogen at scale.

We have provided £6.9 million in funding support towards the cost of this ground breaking £27.7 million project. Other funders partnering in this project include Ofgem (Office of Gas and Electricity Markets), SGN themselves, Cadent, Northern Gas Networks Wales and West Utilities. The H100 Fife Project is recognised as a key building block in the strategic 'Gas Quality Decarbonisation Pathway' set out by UK gas distribution network operators and adopted by the Energy Networks Association (ENA).

The H100 Fife project is part of a larger phased programme proposed by SGN.

Phase 1 - H100 Fife (the project described above) will enable the decarbonisation of 300 homes saving 662 tonnes of CO₂/annum – only phase 1 is funded at present.

Phase 2 will offer opportunities to expand H100 Fife to 1000 properties providing annual emissions savings totalling 2,208 tonnes of CO₂/annum.

Phases 3, 4 and 5 progressively grow the hydrogen production capability to convert wider domestic, industrial and commercial gas demand of up to 5GWh in the region to eventually reduce emissions by 860,000 tonnes of CO₂/annum.

Chapter 7. Hydrogen for Industry

Policy Priorities: Hydrogen for Industry

Industrial use of hydrogen will be crucial in developing the initial market demand for low cost hydrogen production in Scotland.

We will work with the major point emitters in Scotland to assess applicable decarbonisation solutions, including opportunities for fuel-switching to hydrogen and the opportunities that large-scale hydrogen production can offer industry.

We support the deployment of the Scottish Net Zero Roadmap (SNZR) which will set out a pathway for industrial decarbonisation, including CCS and Hydrogen fuel switching.

We will support ambitious industrial applications for renewable and low-carbon hydrogen through support for studies and deployment via funds such as our £34 million Scottish Industrial Energy Transformation Fund.

We are particularly supportive of the roll-out of hydrogen hubs which bring together hydrogen production, CCS and transport in one place or hub. Our Energy Transition Fund is already enabling the development of one such hub: a Hydrogen Model Region in the North East.

Hydrogen's greatest medium to long-term potential may be in the industrial sector, which uses the majority of today's hydrogen, particularly in oil refining and in ammonia, methanol, cement production and steel milling.

There are four primary technological means to decarbonise industrial processes, including combustion processes – electrification, energy efficiency, CCS and hydrogen, and all will be required. Around half of Scottish industrial emissions come from combustion of fossil fuel, mainly natural gas and process gases. Substitution by renewable or low-carbon hydrogen may represent a practical option to reduce these emissions across all industrial sectors.

Scotland's industrial clusters represent numerous co-located and localised heavy industry units with diverse processes including chemicals, petrochemicals/refineries, metals, food and drink, cement, paper and pulp, and glass.

Industrial processes are often difficult and costly to decarbonise due to their complexity, their scale, and their specific technical requirements, which are in many cases based on fossil fuel inputs. This is particularly the case where a high temperature is required or a specific feedstock is essential for the chemical process. Hydrogen combustion offers a route by which industries can obtain high heat without direct greenhouse gas emissions.

Hydrogen is already produced in Scotland for use as a feedstock in chemical production. This hydrogen is currently 'grey', meaning it is produced from the reforming of natural gas with the process releasing unabated CO₂ into the atmosphere, and could switch to blue or green in the future.

Hydrogen could potentially replace natural gas for industrial users connected to the gas network in Scotland. As with domestic and commercial heating, this could initially be a blend of hydrogen with natural gas, before the full conversion to 100% hydrogen. Renewable hydrogen also has the potential to impact on the decarbonisation of industry in terms of space heating and for use in industrial processing and manufacturing.

Anchor loads of industrial use hydrogen can help bring hydrogen, more viably, to adjacent users such as for domestic heat, or non-domestic buildings. This could help to share the costs of infrastructure to enable a widening deployment of hydrogen.

Deep Decarbonisation Pathways for Scottish Industries

Earlier this year we commissioned an assessment of the viable pathways to deeply decarbonise Scotland's industrial subsectors by improving energy efficiency, replacing fossil fuels with hydrogen, electricity or, in limited cases, bioenergy (collectively termed 'fuel switching') and implementing CCUS.

Electrification is an option for some industrial processes, such as lower grade heating, but efficiency and technical constraints may be a barrier to electrifying higher grade industrial heat applications.

The use of hydrogen to displace fossil-based fuels and the application of carbon capture technologies present a significant opportunity to decarbonise sections of our industrial sector for which energy efficiency measures and electrification alone will not provide the required emissions savings.

The development of a CCS network is a critical enabler for the production of low-carbon hydrogen in industrial decarbonisation and negative emissions technologies such as BECCS and DACCS. The most ambitious scenario in the Scottish Hydrogen Assessment assumes that low-carbon hydrogen production aligned with CCUS could credibly reach an installed capacity of 200 MW by 2025, 2 GW by 2032 and 5 GW by 2045.

The industrial decarbonisation pathways analysis concluded that with extensive uptake of fuel switching and CCUS deployment it should be possible to reduce emissions from the industries in scope by over 80% compared to 2018 levels by 2045. Deep decarbonisation therefore hinges on the availability of CCS and the ability to electrify or switch to hydrogen feedstock, as well as the availability of

infrastructure to enable the early implementation of CCUS and low carbon fuel switching at Scotland's largest emission sources.

A Scottish Net Zero Roadmap for the decarbonisation of the Scottish industrial cluster is being developed by NECCUS, the Scottish Government supported industry alliance for decarbonisation. The SNZR is one of six UK industrial cluster plans intended to aggregate and inform a UK wide industrial decarbonisation plan.

The potential for hydrogen to be used to decarbonise Scottish industrial processes, must be carefully studied sub-sector by sub-sector. A partnership approach between government, agencies, energy-intensive industries and other relevant stakeholders will be crucial in planning for a just transition towards lower-carbon, and ultimately zero-carbon, industrial production. Sequencing the viable deployment of hydrogen infrastructural needs for industry will require long-term planning and collaboration.

We recognise the importance of fiscal support mechanisms and prompt deployment of enabling infrastructure and support for technology development needed by companies who are developing their decarbonisation plans and making long-term investment decisions. We have created the Advancing Manufacturing Challenge Fund, our Innovation Centres and the National Manufacturing Institute Scotland (NMIS), that are capable of fundamentally changing how companies harness the power of technology and innovation to drive growth.

We continue to engage with the UK Government on future carbon pricing arrangements for industry which in future could provide the price signal for investment in switching to hydrogen.

We also recognise the importance of ensuring policy decisions do not disadvantage Scottish companies competing in international markets and avoid the risk of carbon leakage. It is, therefore, key that the UK Government provide clarity on the business and regulatory framework to support the deployment of CCUS infrastructure to enable the production of low-carbon hydrogen.

The Scottish Government encourages fuel efficiency and the adoption of low-carbon technologies including hydrogen across all industrial sectors through our supportive policy environment and innovation and demonstration funding support including the Low Carbon Infrastructure Transition Programme, the Low Carbon Manufacturing Challenge Fund, and the Energy Transformation Fund.

Case Study - CCUS, the low-carbon hydrogen enabler

The Acorn CCS project at the St Fergus Gas Terminal in the North East of Scotland has the potential to store 10 million tonnes of CO₂ per annum by 2030, growing to 20 million tonnes per annum by 2035, and unlocking access to over 20 GT of CO₂ storage resource.

The Acorn Hydrogen project developing in parallel to Acorn CCS, will reform North Sea natural gas into clean-burning hydrogen. The CO₂ emissions created from generating the hydrogen will be safely removed and stored using Acorn CCS infrastructure. The project is scalable and will initially produce approximately 50,000t/y of clean hydrogen and 500,000t/y of CO₂ for sequestration by 2025.

Located at an injection point for the national gas transmission system low-carbon hydrogen could be produced for blending into the gas grid in increasing quantities until 100% hydrogen is established. It is also linked to large scale industrial emitters in the Grangemouth area via a network of existing onshore pipeline infrastructure and existing shipping facilities.

The project presents an economic opportunity for the deep-water port at Peterhead for potential import and export of CO₂ and Hydrogen.

It is anticipated Acorn CCS will be operational by 2024 and hydrogen production will start in 2025.

Chapter 8. Hydrogen in Transport

Policy Priorities: Hydrogen in Transport

Scotland has been an early adopter of hydrogen in transport, with Aberdeen being one of the first European cities to roll out hydrogen fuel cell buses. Over the past five years, more than £40 million has been successfully invested or earmarked for ground-breaking hydrogen transport projects.

We are now moving into a new phase. Having successfully demonstrated the technical viability of hydrogen in a range of transport applications, our focus is turning to scaling-up the potential for hydrogen by linking together opportunities across sectors and transport modes and building Scotland's potential for innovation and supply chain growth.

The recent creation of the Hydrogen Accelerator programme at the University of St Andrews, coupled with the Michelin Scotland Innovation Parc in Dundee have created a unique new focus and prospectus for innovation in hydrogen technologies and the supporting skills and knowledge base. Hydrogen also features strongly in the City of Glasgow's fleet strategy.

With the support of Transport Scotland and our enterprise agencies, underpinned by close collaboration between government and industry, we are now seeing the emergence of the next generation of hydrogen projects and investment, including in new areas such as rail, maritime and aviation.

Cities and regions across Scotland, including Aberdeen, Glasgow and Dundee, are also now driving forward coordinated strategies to harness the opportunities for linking up transport demand, green energy generation and innovation in product developments in the application of fuel cells to a growing range of vehicles types and transport modes.

Scotland is well positioned to be a global destination for development and deployment of hydrogen technologies in the transport system.

A sustainable transport system

Scotland's National Transport Strategy (NTS2) sets out four priorities for our transport system: reducing inequalities; taking climate action; supporting inclusive economic growth; and improving our health and wellbeing.

In line with the sustainable travel hierarchy, our priority is managing or reducing demand for travel, and supporting active travel and public transport. Where this is not possible, we must support a swift transition to new, low and zero emission modes of transport. This will require a mix of technology and behavioural shifts, all underpinned by fast-paced innovation and commitment.

In defining a Mission Zero for Transport (Programme for Government 2019-20¹¹), the Scottish Government has already established a visionary approach to these decarbonisation challenges and opportunities, setting us on a path to decarbonise our rail system by 2035; scheduled flights within Scotland by 2040; and removing the need for new petrol or diesel cars and vans by 2030. Our update to the Climate Change Plan has also affirmed our commitment to working across sectors so that the majority of new buses purchased from 2024 will be zero emission, and the need for new petrol and diesel heavy vehicles will be removed by 2035.

These stretching targets provide a clear policy landscape and a roadmap for one of the greatest transitions in mobility that we have seen for over a century.

Supporting this shift is about much more than just reducing carbon emissions. It is also an opportunity to reimagine mobility's place in society and to drive forward investment in and growth of new industries, skills and the innovation needed to underpin this transformation.

Hydrogen in the Transport Sector

Investment in electric vehicles globally is planned to reach \$300 billion over the next 5 - 10 years. The UK's share of the global market for low emission vehicles is estimated at £240 billion a year by 2050. Global market for other low emission vehicle products and services, including exhaust retrofitting, batteries, motor components, battery recycling, hydrogen fuel cells and integration of vehicle systems into energy systems could be worth a further £110 billion to the UK.

Although often viewed as competing technologies, battery electric and hydrogen systems are in fact complementary and could both become cornerstone technologies for the electrification of transport. The Scottish Government is supporting targeted investment in both technologies.

The Scottish Hydrogen Assessment indicates that the transport sector, alongside industry, will most likely form the initial areas of high demand for hydrogen in Scotland and could underpin a market of sufficient size to enable low-cost hydrogen production, with fuel cell markets developing or emerging in areas such as HGV's, buses, trains and shipping.

Hydrogen is already used internationally as a zero emission fuel for hydrogen fuel-cell electric vehicles (FCEVs) including passenger cars, buses, trucks, trains, and industrial machinery such as forklifts.

According to an International Energy Agency report in 2019¹², the Global FCEV market is expected to rise from \$830 million in 2018 to \$11.6 billion by 2025. A number of larger nations have announced targets to build a total of 1,000 hydrogen refuelling stations during 2025 – 2030. Front runner countries have also outlined national FCEV production targets with Korea committing to 1.8 million by 2030, China to 1 million and Japan to 0.8 million.

¹¹ [Protecting Scotland's Future: the Government's Programme for Scotland 2019-2020 - gov.scot \(www.gov.scot\)](https://www.gov.scot/publications/protecting-scotland-s-future-the-governments-programme-for-scotland-2019-2020/pages/100/index.aspx)

¹² <https://www.iea.org/reports/the-future-of-hydrogen>

There are also wider shifts in the automotive market that may be of importance to the emergence of hydrogen fuel cell technologies. Leasing continues to disrupt traditional models of vehicle ownership, across multiple market segments. Most of the major manufacturers have plans to move away from traditional sales and ownership models within the next decade. We have also seen energy companies enter the automotive market to offer leasing deals on cars, batteries and integrated energy products covering, cars, chargers, tariffs and energy storage and production.

Scotland's focus: Innovation, product development and infrastructure

Scotland has **specific research and innovation strengths to support our journey to a zero emission transport system**, including through the Michelin Scotland Innovation Parc, with its emphasis on sustainable and zero emission mobility technologies; the National Manufacturing Institute for Scotland and accompanying Light Weight Manufacturing centre; the Driving the Electric Revolution centre of expertise; and in energy system integration, (e.g. Power Network Demonstration centre).

In recent years, around £40 million has, or is, being invested in hydrogen mobility projects across Scotland, including refuelling infrastructure for Aberdeen, Dundee and Glasgow. This has seen the deployment of buses and other heavy vehicles which are assisting the development of drivetrain technologies, and demonstrating new ways to integrate hydrogen across transport and wider energy system applications.

Scotland now has an opportunity to support and strengthen its capabilities, encouraging the emergence of new hydrogen specialisms and commercial investments. Building on the strength of Scotland's early adopter and demonstration, the integration of hydrogen into the transport system at greater scale could also support the emergence of a local and regional markets for investment in green hydrogen.

Scotland's Automotive Industry Advisory Group (IAG) was established prior to COVID19, and brings together senior figures from across the industry, business and academia to advise on the steps to position Scotland as:

- a global player in supply chains for zero emission mobility for heavy duty and niche vehicles;
- an international centre of expertise in energy/transport system integration;
- a global destination for innovation in sustainable, zero emission mobility.

The Advisory Group's findings will be published at the conclusion of its work, and will provide important insights and actions to develop Scotland's capabilities and supply chains.

A sub group of the IAG - the Bus Decarbonisation Taskforce - has also been established to focus on the specific opportunities and challenges of scaling-up the deployment of battery and hydrogen fuel cell electric buses so that the majority of

new buses purchased from 2024 are zero emission, bringing this date forward if possible.

The Scottish Government, Transport Scotland and our enterprise agency partners are already supporting a range of initiatives and projects to build out Scotland's capabilities, with zero emission mobility now a key enterprise theme, and a priority inward investment theme¹³.

Example initiatives and action include:

- launching the Hydrogen Accelerator programme based at the University of St. Andrews. This links academic, public and commercial interests in the development and deployment of hydrogen technologies and provides expert advice and support to the design, development and implementation of transport initiatives across Scotland.
- supporting investment in new Scottish capabilities in areas such as zero emission drivetrain testing, and in energy system integration for future transport needs.
- supporting the Energy Technology Partnership to establish a new innovation network bringing together academia, sector specialists and companies to promote innovation in technologies to decarbonise the transport system.
- supporting the development and deployment of new zero emission vehicles and Scottish supply chain opportunities, building on the success of recent initiatives on refuse and emergency response vehicles.
- providing support for major demonstration projects to develop a commercial basis for investing in hydrogen refuelling and fuel cell vehicles, with current emphasis on Aberdeen, Dundee and Glasgow.
- funding the development of a hydrogen fuel cell rail vehicle to assess the potential for wider use on Scotland's railways.
- establishing a zero emission drivetrain testing facility to attract inward investment and support the development of the transport supply chain's capacity in hydrogen and other zero emission technologies.
- supporting Scottish companies and integration specialists introducing new zero emission vehicles into the market, with our Zero Emissions Heavy Duty Vehicle Programme co-ordinating activities between Scottish Enterprise and Transport Scotland to support the development of the zero emissions heavy duty vehicles sector in Scotland.

Local authorities and the wider public sector are also playing an important role in stimulating markets for green products and zero emission vehicles. The Scottish

¹³ <https://www.gov.scot/publications/shaping-scotlands-economy-scotlands-inward-investment-plan/pages/2/>

Government has committed to work with public bodies to phase out the need for any new petrol and diesel light commercial vehicles by 2025¹⁴ and to create the conditions to phase out the need for all new petrol and diesel vehicles in Scotland's public sector fleet by 2030.

Transport Scotland's Switched on Fleets programme has supported over 2,500 zero emission vehicles in Scotland's fleets to date. With partners such as Scottish Procurement and Scottish Futures Trust, Transport Scotland is establishing innovative new ways to help the public sector invest in zero emission vehicles at scale, whilst maximising opportunities to leverage commercial investment through aggregated demand for new products, vehicles and infrastructure.

Local authorities such as Glasgow City Council have invested in demonstrator and hydrogen fuel cell vehicles as part of their commitment to hydrogen in their own fleet decarbonisation plans.

Glasgow City Council's Fleet Decarbonisation Strategy, with its emphasis on hydrogen, is a living example of how this innovative approach to fleet renewal can leverage commercial markets and new investment opportunities. Green Hydrogen for Glasgow, is an "end-to-end" green hydrogen refuelling network led by a partnership including: Scottish Power Renewables, BOC/Linde and ITM Power. The project aims to develop a 10MW electrolyser at Scottish Power's Whitelee Wind Farm near Glasgow to service the city and surrounding region with green, commercial hydrogen fuel within two years.

Skills

Transport Scotland is working across sectors to build evidence and awareness of the skills and employment opportunities for Scotland as part of a just transition to new, zero emission technologies across the transport sector. This includes working with ESP (Energy Skills Partnership), Skills Development Scotland and the Skills Academy at the Michelin Scotland Innovation Parc. We will support colleges deliver training and accreditation in the skills to support a transition to a zero emission transport system, including in battery electric vehicles and hydrogen fuel cells.

Shipping and Aviation

The shipping and aviation sectors have limited low-carbon fuel options available and hydrogen or hydrogen-based fuels may represent an opportunity alongside battery electric options. Fuels such as ammonia (derived of hydrogen), hydrogen or related synthetic fuels have the potential to help address environmental targets in shipping, longer haul aviation and in ferries.

The use of hydrogen fuel cells in the aviation sector may hold promise and trials are taking place in Orkney. Orkney's European Marine Energy Centre (EMEC) has developed an end-to-end hydrogen refueling solution for ZeroAvia's pioneering hydrogen fuel cell powered electric test flight programme.

¹⁴ Programme for Government 2019-20.

Delivery of the refueling solution is a key milestone in the Aerospace Technology Institute (ATI) and Innovate UK funded “HyFlyer” project which aims to decarbonise medium range small passenger aircraft by demonstrating hydrogen fuel cell powertrain technology.

HyDIME Project

Scotland is home to the ground-breaking HyDIME (Hydrogen Diesel Injection in a Marine Environment) Project. The project is funded by Innovate UK and is trialing the use of green hydrogen as a fuel for a commercial ferry operating between Shapinsay and Kirkwall in Orkney.

The project design and physical integration of a hydrogen injection system on a commercial passenger and vehicle ferry will be the first of its kind worldwide.

We are closely engaged with this project and believe HyDIME to be an important proving initiative for the safe integration and use of hydrogen on vessels which could provide an important stepping stone to accelerating and de-risking future hydrogen marine projects.

Rail Sector

Scotland’s Rail Services Decarbonisation Action Plan¹⁵ recognises that although, initially, hydrogen fuelled trains are expected to have higher capital and operating costs than diesel trains, the growth and maturity of the market will drive down costs. Recent market engagement with rolling stock manufacturers suggests hydrogen fleets to replace diesel-powered trains are seen as a realistic and affordable option for Scotland in the second half of this decade. Those hydrogen fleets may be used to provide a transitional solution on parts of the network prior to the implementation of electrification infrastructure as well as providing a permanent solution on more remote, less intensively used sections of the network where full scale electrification is either not economic nor desirable for environmental reasons.

¹⁵ <https://www.transport.gov.scot/publication/rail-services-decarbonisation-action-plan/>

Case Study - Zero Emissions Train Project

The Zero Emissions Train project is an exciting hydrogen-focussed initiative currently being developed by Transport Scotland and Scottish Enterprise in response to the Scottish Government's Programme for Government commitment that; "Where we cannot electrify or it is inappropriate to do so, we will invest in battery powered trains and work with developers of hydrogen fuel cell trains to accelerate their development and deployment through practical trials in Scotland."

The project will convert a withdrawn ScotRail Class 314 electric train over to utilising hydrogen fuel cell (FC) traction. The project aims to demonstrate this technology by operating the train on closed rail network by autumn 2021. The project has six key objectives:

- prove we have the capability to modify an existing item of rolling stock to use hydrogen FC, batteries, control equipment, etc.;
- work with the regulatory bodies to develop the necessary standards and controls for the use of hydrogen FC power on passenger rolling stock;
- inform rail policy on the application of such technology on the Scottish passenger rail network in advance of the decarbonisation target of 2035 for Scotland's passenger rail services;
- demonstrate to Scotland's rail community through practical application the operation of hydrogen FC passenger rolling stock;
- provide the supply chain with the opportunity to develop their skills and knowledge of the application of hydrogen FC technology on passenger rolling stock and hydrogen supply and refuelling infrastructure; and
- provide educational institutions with the opportunity for research and practical application of hydrogen FC technology within the rail industry.

Chapter 9. Hydrogen for Trade

Policy Priorities: Hydrogen for Trade

Our vision is to establish Scotland as a 'Hydrogen Nation' that is recognised internationally for its expertise and capacity.

We will actively seek international collaboration in the development of our shared hydrogen economy and fully explore our hydrogen export potential.

We will fully explore the opportunities Scotland has to establish a new industry around the export of renewable hydrogen.

Scotland's Enterprise Agencies

Scotland's enterprise agencies: Scottish Enterprise, South of Scotland Enterprise, Highlands and Islands Enterprise and Scotland Development International, recognise that hydrogen is a significant economic opportunity for Scotland and are developing strategic programmes of activity to align with the Scottish Government's hydrogen policy position and Hydrogen Action Plan on its publication.

We will continue to work closely with our enterprise agencies to support the development of a strong pipeline of innovative projects and engagement with supply chain, industry and academia to maximise the economic potential of a future hydrogen industry in Scotland.

Scotland's place in the international hydrogen economy

Scotland has sufficient scale of renewable generation potential to meet domestic needs and to simultaneously satisfy the import requirement of others, thereby playing a key role in the creation of a European hydrogen market.

Based on the finding of the Hydrogen Assessment, we expect the conditions in Scotland to suit the large-scale production of low-cost hydrogen for export and for this to be a feature of our energy landscape in the future.

Europe has an ambitious Hydrogen Roadmap,¹⁶ and a number of countries have recently published hydrogen strategies. Countries such as Germany, which has declared it will need 90-110TWH and that its planned 5GW of domestic production could meet 14TWh of this. France and the Netherlands already have well developed plans to use hydrogen to decarbonise their heavy industries, for conversion of their gas networks and to build new distribution infrastructure to transport that hydrogen by pipe, truck and by ship.

Scotland is well placed in terms of proximity and infrastructure connectivity to several European import nations, such as Germany, the Netherlands, Belgium and Sweden, that are unlikely to be able to decarbonise wholly through their indigenous wind and

¹⁶ [Hydrogen Roadmap Europe, Fuel Cells and Hydrogen Joint Undertaking \(2019\)](#)

solar renewable energy supply. As large demand for green hydrogen develops in Europe, our challenge is to ensure Scotland becomes a primary centre of production to meet this need.

Our vision is for Scotland to become a Hydrogen Nation that is able to produce reliable, competitive, and sustainable renewable hydrogen and is recognised as a centre of international excellence as we establish the innovation, skills and supply chain that will underpin our energy transition.

We believe Scotland’s unique selling points, including its natural resources, infrastructure and skilled energy workforce, could enable us to become a producer of low-cost hydrogen in Europe by 2045. We are intent in developing our hydrogen capabilities as part of Europe, and as part of the European system that is now being actively pursued.

The Scottish Hydrogen Assessment considers in detail a broad range of scenarios, including one whereby Scotland becomes a centre for hydrogen production in Europe, exporting hydrogen across the rest of Europe and beyond.

If this ambition is to be realised, a significant ramp up in production of green hydrogen will be required as envisioned in this policy statement. The Hydrogen Assessment estimates that by 2045 Scotland could produce 37 GW of renewable generation producing 126TWh of renewable hydrogen, of which 94 TWh are produced to supply export demand. See figure B.

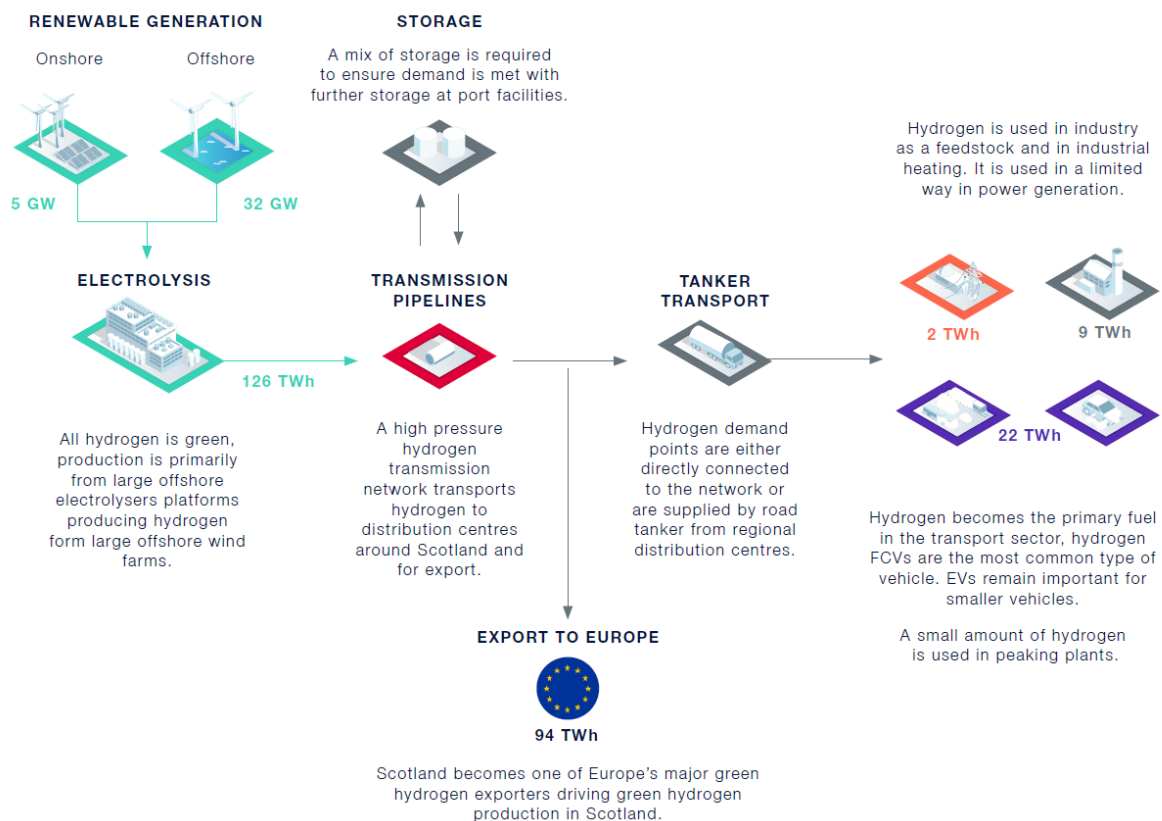


Figure B Scottish Hydrogen Assessment Report. Scenario: Green Export in 2045

Hydrogen can be transported in the same way as natural gas, via pipelines or vehicles, and wider imports and exports will need supporting port facilities and shipping vessels. We will therefore consider the infrastructure needed at our ports and harbours to support the transportation of gases including hydrogen and CO₂.

We are also working with partners on research to explore the safe and cost-effective options for the marine transport of hydrogen between Scotland and the UK and European ports. This work will evaluate the various Liquid Organic Hydrogen Carrier (LOHC) options to facilitate the large scale transport and storage of hydrogen.

International engagement and sharing expertise

Scotland's Energy Strategy recognises the importance of working with international partners to better understand the transition to a net zero economy. International engagement on hydrogen is a particular priority for Scottish Government, with international activity on hydrogen growing at pace in Europe and further afield. Scotland is the co-chair of the Under2 Coalition Industry Transition Platform, leading work on achieving a low carbon industry future via disruptive innovation and sustainable hydrogen.

Working with some of our overseas Hubs, we have acted promptly to ensure Scotland is engaged in the developing hydrogen economy. We are particularly interested in demonstrating Scotland's potential for green hydrogen export, our supply chain expertise and possible areas for collaborative development and future cooperation. These areas include sharing our expertise and learning from the many Scottish hydrogen projects to date, integrating different parts of the system as they develop, and providing an international centre for testing.

The emergence of hydrogen within the energy transition is part of a once-in-a-generation whole system change. Therefore we want to work with others on the development of the whole hydrogen value chain - within Scotland, within Europe, and making connections globally. This is an extension of Scotland's role as a global climate change leader, underlined by our absolute commitment to respond to the climate emergency and our statutory target of net zero greenhouse gases by 2045.

We want to work with others in mapping the full length of the supply chain from the multiple geographic energy sources and from hydrogen production, through local use, storage and transport, to where the bulk of hydrogen will ultimately be used. We recognise that this is a large complex system that will need to involve North Sea and continental pipeline systems, as well as shipping routes in northern and southern Europe, decisions on transit technology, and applications that range from the small scale and local to the large-scale industrial.

We also recognise there are a number of drivers that determine which countries are selected as import partners. We appreciate that there is a strong and valid international development dimension in some cases – which we would support. However, looking at the whole system, Scotland has a crucial contribution to make based on our resources; proximity to northern Europe; pipeline infrastructure; experience; and advanced stage of development in many areas.

Where there will be some change in the countries that are net energy producers, and many of Europe's new partners will need undergo a stage of extensive development, Scotland is one of the few countries that will be able to maintain its role as a net energy exporter, building on its 45-years of experience with oil and gas. We have already started the successful transition from oil and natural gas to offshore wind and hydrogen.

We know we're in a time of transition – which is why our Learning by Doing approach is so appropriate. We're keen to share our experience and to learn and work with others so that together we can develop the new hydrogen economy more efficiently, quickly, systematically and effectively.

Inward Investment and Export Opportunities

Shaping Scotland's Economy, Scotland's Inward Investment Plan¹⁷ was published on 27 October. It sets out our ambitions for Scotland as a leading destination for inward investment aligned with our values as a nation. Our strategic approach focuses on opportunities where Scotland can demonstrate an international comparative advantage mapped to strong global demand. The nine opportunity areas for focus identified include Energy Transition.

The Scottish Government is already working hard to support domestic businesses in light of the challenging operating environment as a result of the COVID19 pandemic with a package worth over £2.3bn. Inward investment complements such domestic investment due to a strong positive relationship with productivity, innovation and trade. It helps to transfer skills, support local supply chains and spur exports, creating a more open and outward facing economy.

Next steps

Producing the quantities of hydrogen required to support our domestic and export ambitions will be a challenge and will require significant amount of offshore wind deployment and electrolyser capacity. All indications are that this is feasible, though it will require further research and clear frameworks to make it happen.

If Scotland is to supply hydrogen at a low cost to compete with other potential hydrogen exporters, such as North Africa and South America, we will need to establish quickly what the price of hydrogen from Scottish offshore wind could be. This and building links with potential export markets will be the focus of further work.

We will continue to work with our enterprise agencies to ensure benefits from the growth in a hydrogen export market are captured for our domestic supply chain. This includes extensive engagement at strategic, sectoral and company level, promotion of Scotland's potential, and making Scottish companies aware of international opportunities in the hydrogen supply chain where these arise.

The Scottish Hydrogen Action Plan will focus on support for low-cost renewable hydrogen production and supply chain development at this early stage in order to

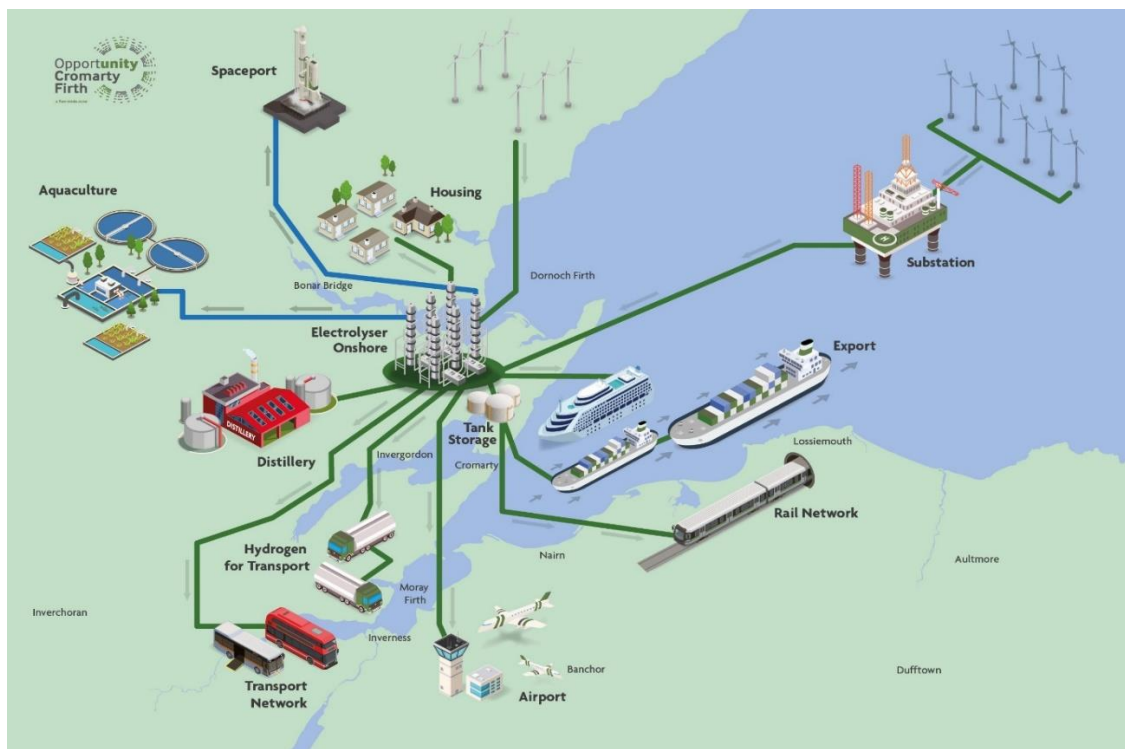
¹⁷ [Shaping Scotland's economy: inward investment plan - gov.scot \(www.gov.scot\)](https://www.gov.scot/publications/shaping-scotland-s-economy-inward-investment-plan/pages/1-100.aspx)

accelerate deployment, build market position and enable more of the value chain to be captured in Scotland.

Case study – North of Scotland Hydrogen

North of Scotland Hydrogen (NOSH) is a series of scalable green hydrogen projects based in the Cromarty Firth which will produce hydrogen from renewable energy for regional, national and export use. The Highlands is rich in renewable energy; producing more renewable energy for our country than any other region, and this energy can be used to meet Scottish Government's net zero obligations. The initial NOSH project will supply green hydrogen to distilleries in the region. It is a partnership between Pale Blue Dot Energy, Port of Cromarty Firth, Scottish Power, Glenmorangie and Whyte & Mackay. These distillers operate a number of distillery sites in the region and are keen to develop 'net zero' whisky for their customers around the world.

Future projects include the potential to decarbonise wider regional hydrogen transport applications, the decarbonisation of heat and industrial use in the north of Scotland (Invergordon sits strategically at the end of the gas grid,) and the potential for hydrogen export to other regions and countries, particularly Germany and the Netherlands. Port of Cromarty Firth is working with regional and national partners including HITRANS, The Highland Council, SGN and others, to realise the full potential from this opportunity and to position Scotland as global leaders in green hydrogen technologies. North of Scotland Hydrogen will create exciting skilled careers and business opportunities, and the technology and expertise developed will be exported around the world for many years to come, as other countries take action to meet their own climate targets.



Chapter 10. Hydrogen Research, Innovation, and Demonstration

Policy Priorities: Hydrogen Research, Innovation, and Demonstration

A focused programme of research, innovation and demonstration of technologies and systems along the entire hydrogen value chain will support the development of the hydrogen sector in Scotland. The strategic objective of this activity will be to decrease costs and improve the efficiency of robust and replicable hydrogen solutions which can be applied across our energy system.

Building on our strong foundations, we will stimulate hydrogen research, innovation and demonstration of technologies and systems which will help build domestic production and usage of renewable and low-carbon hydrogen, scaling up to full commercialisation in the late 2020s as demand grows.

Strong collaborative working between industry and academia, sharing innovation and knowledge of hydrogen technologies, will enable advances in the development of our hydrogen economy.

We will publish a Guidance Note on the development and consenting pathway for an offshore power to gas development model and commission research to further understanding of the technical, and environmental impact of geological storage of hydrogen.

We also recognise that public perceptions and consumer acceptance of hydrogen requires to be better understood so we will commission research and public engagement in this area.

In 2021, we will launch our new support framework for energy technology innovation with a strong focus on hydrogen.

Research, Innovation and Demonstration

Scotland has a long and proud tradition of innovation in the energy sector, with world class research institutions, testing facilities and businesses. Although many of the technologies required for hydrogen are already mature, as described elsewhere in this document, research and innovation still has an important role to play to reduce costs, improve safety and efficiency, and enable the production and use of hydrogen at scale.

Our support for innovation includes working closely with a number of research bodies including the Energy Technology Partnership (ETP) and the Scottish Research Partnership in Engineering (SRPe).

Our support of the ETP, an alliance of Scotland's world-class academic institutions includes funding for the Knowledge Exchange Network, and the Energy Industry Doctorate Programme, which supports PhD projects tackling innovation challenges across the energy sector, including hydrogen based projects.

Advanced manufacturing and energy are two strategic areas of research by the SRPe. This partnership of Scotland's universities works in collaboration with industry and government to future-proof Scotland's position as a world-class centre of research excellence and globally competitive driving force in engineering.

Our Energy Investment Fund (EIF) has made over £85 million of commercial investments across the energy sector. This has supported innovative technology companies to develop ideas and deliver projects, alongside support for community energy projects.

With the EIF now due to come to an end in its current form by the end of March 2021, work has already begun on its replacement. This will build on the success of EIF to date and, alongside partners, play an important role in supporting commercial investment into innovative low carbon technologies. We are developing a new framework of support for energy innovation. To underpin this, we will launch a call for evidence in early 2021 seeking views on how best to maximise Scotland's world-leading research talent and facilities for energy innovation.

Details of our new support framework will be announced by the end of 2021, outlining for the first time how we will build on our existing strong track record in investment in innovative energy technology through a comprehensive package of capital funding and wider support. We expect this framework to have a strong focus on technology development in the hydrogen sector, and help to accelerate the contribution that hydrogen can make to Scotland's low carbon economy.

We will create a community of interest which will include scientific advice from multiple disciplines to help inform our ongoing work on hydrogen. Key areas identified for further research and development include: integration of large scale hydrogen into the energy system; cost reduction opportunities for hydrogen production; hydrogen storage technologies and solutions; industrial 'blue-flame' processes; transmission and distribution; hydrogen from bioenergy and gasification, and increasing public awareness of hydrogen.

Investing in hydrogen focussed research will help develop robust technology solutions as part of new support framework for energy technology innovation and will help to unlock the expansion of the hydrogen economy, and also help develop Scotland's place in the growing global hydrogen market.



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