



HM Government

UK Hydrogen Strategy



August 2021

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UK Hydrogen Strategy

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by the Secretary of State for Business, Energy & Industrial Strategy
by Command of Her Majesty

August 2021

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Ministerial foreword

As the Prime Minister made clear when he launched his *Ten Point Plan for a Green Industrial Revolution* last year, developing a thriving low carbon hydrogen sector in the UK is a key plank of the government's plan to build back better with a cleaner, greener energy system. With the potential to overcome some of the trickiest decarbonisation challenges facing our economy – including our vital industrial sectors – and secure economic opportunities across the UK, low carbon hydrogen has a critical role to play in our transition to net zero.



Working with industry, our ambition is for 5GW of low carbon hydrogen production capacity by 2030 for use across the economy. This could produce hydrogen equivalent to the amount of gas consumed by over 3 million households in the UK each year. This new, low carbon hydrogen could help provide cleaner energy to power our economy and our everyday lives – from cookers to distilleries, film shoots to power plants, waste trucks to steel production, and 40 tonne diggers to the heat in our homes.

Meeting our ambition means rapid ramp up of production and use of hydrogen over the coming decade. In every country of the UK, there are ambitious, world-leading projects ready to deploy at scale, saving carbon and creating jobs. These trailblazers will help us fully understand the costs around hydrogen, its safety where hydrogen is being used in new ways, and just how far it can contribute to reducing our emissions.

The time for real world action is now. We have developed the first ever UK Hydrogen Strategy to set out clearly the key steps we need to take in the coming months and years to deliver against the promise that hydrogen presents – an exciting moment for technology providers, energy companies large and small, investors, innovators, and government at all levels.

Our ambition for hydrogen goes beyond decarbonisation. It also means a focus on supporting industry to develop sustainable, home-grown supply chains, create high quality jobs, and capitalise on British innovation and expertise. It means incentivising private investment and looking to increase export opportunities. It means strengthening our industrial heartlands, boosting our economy and driving national growth.

The Hydrogen Strategy builds on our national strengths. UK companies are already at the forefront of global hydrogen technology development. Our geology, infrastructure and technical know-how make us ideally positioned to be a global leader in hydrogen. We have a strong history of collaboration between government, industry and innovators to tackle climate change and grow our economy.

Alongside this Strategy we are also publishing a number of consultations – seeking views on our preferred Hydrogen Business Model, the design of our flagship £240m Net Zero Hydrogen Fund, and a UK Low Carbon Hydrogen Standard. These are policies that industry, including members of the Hydrogen Advisory Council which I co-Chair, have told us are key to drive early expansion of the UK hydrogen economy. This substantial suite of documents is supported by a detailed Analytical Annex and a report on Hydrogen Production Costs.

Taken together, the UK Hydrogen Strategy and supporting policy package lay the foundations for a thriving hydrogen economy, one that can support our trajectory to achieving our world-leading Sixth Carbon Budget and net zero commitments. I look forward to continuing to work closely with industry, innovators and investors to deliver real action on hydrogen, with real benefits for UK businesses and communities.

The Rt Hon Kwasi Kwarteng MP

Secretary of State for Business, Energy & Industrial Strategy

Executive summary

Hydrogen is one of a handful of new, low carbon solutions that will be critical for the UK's transition to net zero. As part of a deeply decarbonised, deeply renewable energy system, low carbon hydrogen could be a versatile replacement for high-carbon fuels used today – helping to bring down emissions in vital UK industrial sectors and providing flexible energy for power, heat and transport. The UK's vision, resources and know-how are ideally suited to rapidly developing a thriving hydrogen economy. Our world-class innovation and expertise offer opportunities for UK companies in growing domestic and global markets. The UK Hydrogen Strategy sets out how we will drive progress in the 2020s, to deliver our 5GW production ambition by 2030 and position hydrogen to help meet our Sixth Carbon Budget and net zero commitments.

The scale of the challenge is clear: with almost no low carbon production of hydrogen in the UK or globally today, meeting our 2030 ambition and delivering decarbonisation and economic benefits from hydrogen will require rapid and significant scale up over coming years. The work starts now.

The UK Hydrogen Strategy takes a holistic approach to developing a thriving UK hydrogen sector. It sets out what needs to happen to enable the production, distribution, storage and use of hydrogen and to secure economic opportunities for our industrial heartlands and across the UK. Guided by clear goals and principles, and a roadmap showing how we expect the hydrogen economy to evolve and scale up over the coming decade, the Strategy combines near term pace and action with clear, long term direction to unlock the innovation and investment critical to meeting our ambitions.

Chapter 1 of the Strategy sets out the case for low carbon hydrogen, briefly outlining how it is produced and used today before explaining its potential role in meeting net zero and in providing opportunities for UK firms and citizens to be at the forefront of the global transition to net zero. It explains how our 2030 ambition can deliver emissions savings to help meet our carbon budgets, as well as jobs and economic growth, helping to level up across the UK. It sets out our strategic framework, including our vision for 2030, the principles guiding our action, challenges to overcome and our key outcomes by 2030. Finally, it outlines the important role of the devolved nations in the UK's hydrogen story, and how government is working closely with the devolved administrations to help hydrogen contribute to emissions reductions and deliver local economic benefits across the UK.

Chapter 2 forms the core of the Strategy, setting out our whole-systems approach to developing the UK hydrogen economy. It opens with our 2020s roadmap, which sets out a shared understanding, developed in partnership with industry, of how the hydrogen economy needs to evolve over the course of the decade and into the 2030s – and what needs to be in place to enable this. The chapter then considers each part of the hydrogen value chain in turn – from production, to networks and storage, to use across industry,

power, buildings and transport – and outlines the actions we will take to deliver our 2030 ambition and position hydrogen for further scale up on a pathway to Carbon Budget Six and net zero. Finally, it considers how we will develop a thriving hydrogen market by 2030 – including the market and regulatory frameworks underpinning it and their interaction with the wider energy system, and the need to improve awareness and secure buy-in from potential users of hydrogen.

Chapter 3 explains how we will work to secure economic opportunities across the UK that can come from a thriving hydrogen economy – learning from the development of other low-carbon technologies and building this into our approach from the outset. It sets out how we will: build world class, sustainable supply chains across the full hydrogen value chain; create good quality jobs and upskill industry to drive regional growth and ensure that we have the right skills in the right place at the right time; maximise our research and innovation strengths to accelerate cost reduction and technology deployment, and to capitalise on the UK's world-leading expertise; and create an attractive environment to secure the right investment in UK projects while maximising the future export opportunities presented by a low-carbon hydrogen economy.

Chapter 4 builds on this to show how the UK is working with other leading hydrogen nations to drive global leadership on the development of low carbon hydrogen to support the world's transition to net zero. It sets out the UK's active role in many of the key institutions driving multilateral collaboration on hydrogen innovation and policy, and our ambition to actively seek opportunities for further collaboration with key partner countries to spur the development of thriving domestic, regional and ultimately international hydrogen markets.

Chapter 5 concludes the Strategy, setting out how we will track our progress to ensure we are developing a UK hydrogen economy in line with the principles and outcomes set out in Chapter 1 and our roadmap in Chapter 2. This chapter explains our approach – how we will be flexible, transparent, efficient and forward-looking in monitoring progress – and sets out the potential indicators and metrics we will use to track how we are delivering against our outcomes. This will help ensure that we can deliver our 2030 ambition and realise our vision for a low carbon hydrogen economy that drives us towards Carbon Budget Six and net zero, while making the most of the opportunities that hydrogen holds for the UK.



Chapter 1:

The case for low
carbon hydrogen



H_2
Hydrogen

A close-up, low-angle shot of a blue hydrogen fuel cell or station nozzle. The nozzle is made of a glossy, metallic blue material. In the center, there is a circular opening with a clear, textured glass or plastic cap. Above the cap, the chemical formula H_2 is embossed in a large, white, sans-serif font. Below the formula, the word "Hydrogen" is embossed in a smaller, white, sans-serif font. The background is a soft, out-of-focus blue sky.

Low carbon hydrogen will be critical for meeting the UK's legally binding commitment to achieve net zero by 2050, and Carbon Budget Six in the mid-2030s on the way to this. Hydrogen can support the deep decarbonisation of the UK economy, particularly in 'hard to electrify' UK industrial sectors, and can provide greener, flexible energy across power, heat and transport. Moreover, the UK's geography, geology, infrastructure and expertise make it particularly suited to rapidly developing a low carbon hydrogen economy, with the potential to become a global leader on hydrogen and secure economic opportunities across the UK.

Hydrogen is one of a handful of new low carbon solutions which can help the UK to achieve its world-leading emissions reductions target for Carbon Budget Six (CB6), and net zero by 2050. As set out in the Prime Minister's *Ten Point Plan for a Green Industrial Revolution*, working with industry, government is aiming for 5GW of low carbon hydrogen production capacity by 2030 for use across the economy. With virtually no low carbon hydrogen produced or used currently, particularly to supply energy, this will require rapid and significant scale up from where we are today.

The *Ten Point Plan* announced new funds and policies that will set us on the pathway to meet this ambition, including £240 million for government co-investment in production capacity through the Net Zero Hydrogen Fund (NZHF), a hydrogen business model to bring through private sector investment, and plans for a revenue mechanism to provide funding for the business model. Continued improvements in hydrogen technologies, enabled by pioneering UK research and innovation and international collaboration, will also be critical. The *Ten Point Plan* designated hydrogen as a key priority area in the Net Zero Innovation Portfolio, a £1 billion fund to accelerate commercialisation of low-carbon technologies and systems for net zero.

The 2020s will be critical for supporting energy users best suited to hydrogen as a low carbon solution to get ready to use it. We are accelerating work in this area. We are supporting fuel switching to hydrogen in industry through the £315 million Industrial Energy Transformation Fund and £20 million Industrial Fuel Switching Competition; establishing the evidence base for hydrogen use and storage in the power sector; rolling out demonstration competitions and trials (subject to funding) for the use of hydrogen in road freight, shipping and aviation; and pioneering trials of hydrogen heating – beginning with a hydrogen neighbourhood trial by 2023, followed by a large hydrogen village trial by 2025, and potentially a hydrogen town pilot before the end of the decade. We are working with the Health and Safety Executive (HSE) and industry to assess the potential for 20 per cent hydrogen blending into the gas network, and supporting the development of prototype 'hydrogen-ready' appliances such as boilers and cookers. The *Energy White Paper*, *Industrial Decarbonisation Strategy* and the recently published *Transport Decarbonisation Plan* set out further actions we are taking to bring forward hydrogen demand across industry, power, heat and transport.

This Strategy goes further, setting out a series of additional commitments and actions which show how government, in partnership with industry, the research and innovation community and wider civil society, will deliver our vision for a UK hydrogen economy.

By acting now we will be better positioned to stimulate domestic supply chains, enabling UK businesses to serve increasing international demand for hydrogen goods and services. Current evidence suggest that developing a UK hydrogen economy could also support over 9,000 jobs by 2030 – and up to 100,000 jobs by 2050 – across our industrial heartlands and across the UK.¹

1.1 Hydrogen in the UK today

The UK has a longstanding history with hydrogen. Since the discovery of ‘inflammable air’ by Henry Cavendish in the mid-18th century, hydrogen has played a role in our everyday lives, from helping to fertilise our fields to providing part of the ‘town gas’ that lit our streets and heated our homes until the late 20th century.

There are almost no abundant natural sources of pure hydrogen, which means that it has to be manufactured. The most common production route is steam methane reformation, where natural gas is reacted with steam to form hydrogen. This is a carbon-intensive process, but one which can be made low carbon through the addition of carbon capture, usage and storage (CCUS) – to produce a gas often called ‘blue hydrogen’. Hydrogen can also be produced through electrolysis, where electricity is used to split water into hydrogen and oxygen – gas from this process is often referred to as ‘green hydrogen’ or zero carbon hydrogen when the electricity comes from renewable sources. Today most hydrogen produced and used in the UK and globally is high carbon, coming from fossil fuels with no carbon capture; only a small fraction can be called low carbon.² For hydrogen to play a part in our journey to net zero, all current and future production will need to be low carbon.

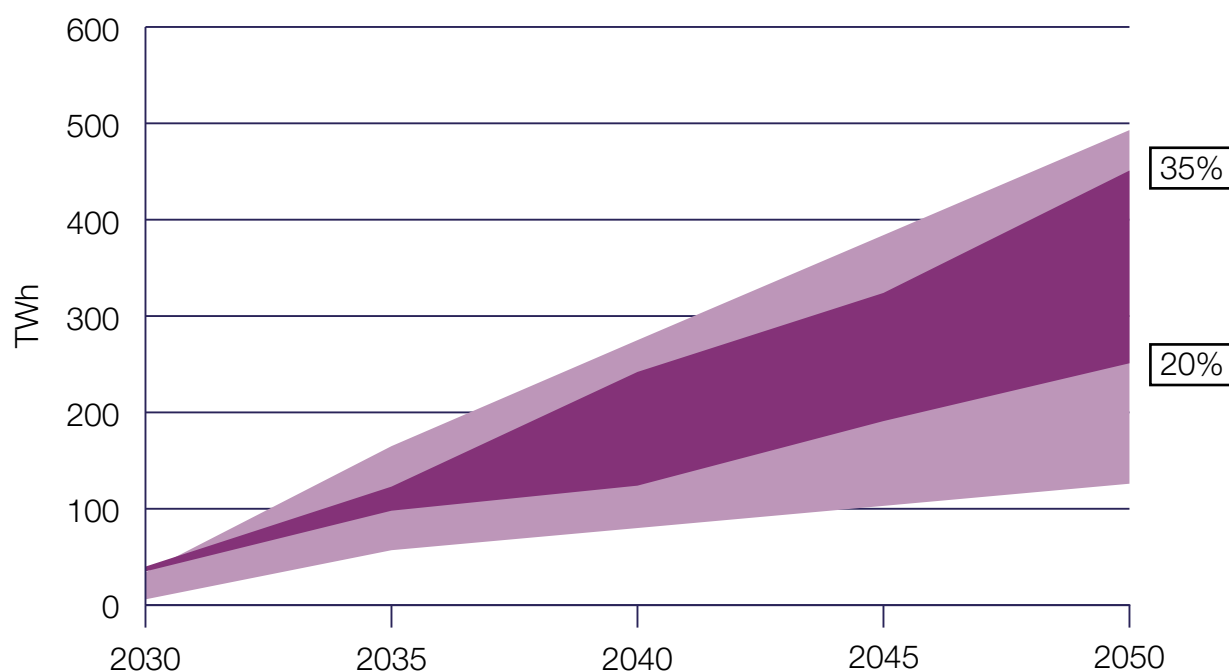
Current UK hydrogen production and use is heavily concentrated in chemicals and refineries.³ This hydrogen, largely produced from natural gas (without carbon capture), is used as a feedstock, or input, into making other chemicals and plays a variety of roles in refineries to convert crude oil into different end products. In these two sectors, production and use of hydrogen usually happen on the same site, often integrated into a single industrial facility. Hydrogen is also used as a fuel, in far smaller volumes, across the UK. Hydrogen cars, trucks, buses and marine vessels are already operating and supported by a network of refuelling stations, with plans for hydrogen trains and aircraft underway. Hydrogen will soon be blended with natural gas and supplied safely to over 650 homes as part of a trial in Winlaton in the north-east of England.

British companies such as ITM Power, Johnson Matthey and Ceres Power are already producing the technology for low and zero carbon hydrogen, and they and many others are pushing new innovations all the time. The Orkney Islands in Scotland have generated global interest in a range of projects that show how challenges in a local energy system can sometimes be overcome with hydrogen; here producing hydrogen from excess renewable electricity that would otherwise have gone to waste, and using it to support decarbonisation of road transport, heat and ferry related activities. Across the UK, pioneering production and use projects have provided lessons, stimulated further research and innovation, and pointed the way to what is needed to deploy production capacity at pace and scale, and to unlock hydrogen as a low carbon fuel for new applications across the energy system.

1.2 The role of hydrogen in meeting net zero

Low carbon hydrogen will be essential for achieving net zero, and ahead of that, meeting our world-leading CB6 target to reduce emissions 78 per cent on 1990 levels by 2035. Analysis by BEIS for CB6 suggests 250-460TWh of hydrogen could be needed in 2050,⁴ making up 20-35 per cent of UK final energy consumption (see Figure 1.2 below).⁵ The size of the hydrogen economy in 2050 will depend on a number of factors – including the cost and availability of hydrogen and hydrogen-using technology relative to alternatives, such as electrification, biomass and use of CCUS. Nonetheless, there is consensus, from the Climate Change Committee (CCC) and others, that we will need significant amounts of low carbon hydrogen on the system by 2050.

Figure 1.2: Hydrogen demand and proportion of final energy consumption in 2050



% = hydrogen as proportion of total energy consumption in 2050

Source: Central range – illustrative net zero consistent scenarios in CB6 Impact Assessment. Full range – based on whole range from UK Hydrogen Strategy Analytical Annex. Final energy consumption from ECUK (2019).

As a gas, hydrogen has a distinct set of characteristics. It can be used in a fuel cell or combusted in a boiler, turbine or engine to generate heat or electricity. It can also be stored in various ways, including at very large scales, and can be transported to different end users, in much the same way as natural gas or liquid fuels today. Hydrogen is also an essential input to a range of chemical processes and in industrial production.

Low carbon hydrogen will play an important complementary and enabling role alongside clean electricity in decarbonising our energy system. It is suited to use in a number of sectors where electrification is not feasible or is too costly, and other decarbonisation options are limited. This may include generation of high temperature heat, as in industrial furnaces, and long-distance and heavy-duty transport. Similarly it is useful in areas where

the flexibility and stability of a gas is valued, for example large scale or long duration energy storage and flexible power generation. However, hydrogen can only be considered as a decarbonisation option if it is readily available, at the right price, the right volume and with sufficient confidence it is low carbon. In addition, potential users must be able to purchase hydrogen-using equipment, with proper assurances about safety and reliability. This will be our focus for the 2020s, in order to deliver our 2030 ambition and set us on the pathway to CB6 and net zero.

1.3 The UK's hydrogen opportunity

As a result of its geography, geology, infrastructure and capabilities, the UK has an important opportunity to demonstrate global leadership in low carbon hydrogen and to secure competitive advantage. Building hydrogen production and enabling use across multiple sectors will be critical for developing domestic capacity and capabilities, and securing green jobs across the UK.

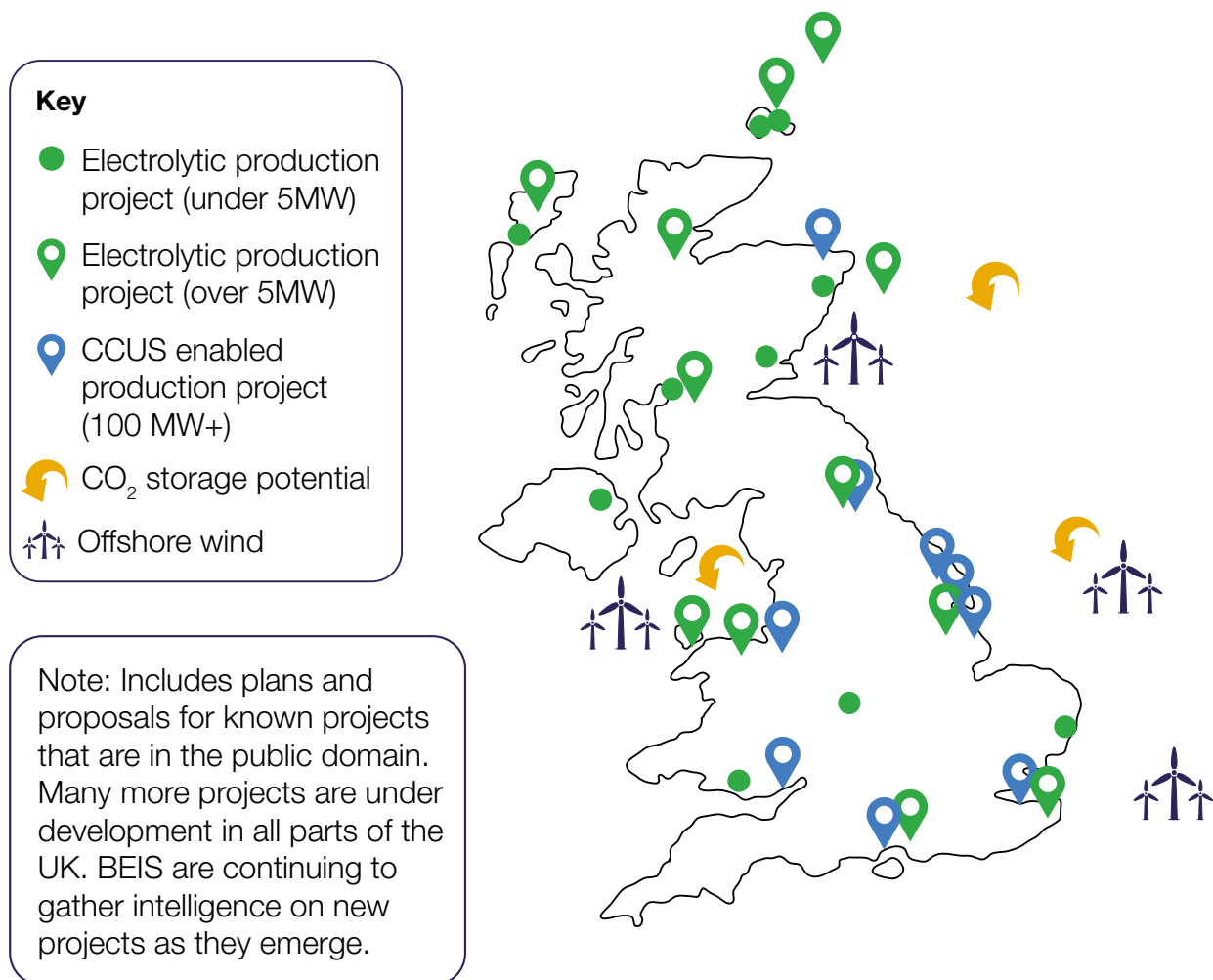
Developing a hydrogen economy requires tackling the 'chicken and egg' problem of growing supply and demand in tandem, and the UK offers favourable conditions for both to readily expand. When it comes to production, our 'twin track' approach capitalises on the UK's potential to produce large quantities of both electrolytic 'green' and CCUS-enabled 'blue' hydrogen. The UK reduced its power sector emissions by over 70 per cent between 1990 and 2019,⁶ and generates more electricity from offshore wind than any other country.⁷ The *Energy White Paper*, published in December 2020, sets out how we will expand renewable generation while decarbonising power sector emissions further, including through our ambition to quadruple offshore wind capacity to 40GW by 2030, and pursue new large-scale nuclear while investing in small-scale nuclear technologies. This low carbon electricity will be the primary route to decarbonisation for many parts the energy system, and will also support electrolytic production of hydrogen.

The *Energy White Paper* also sets out how the UK will deploy and support CCUS technology and infrastructure, with £1 billion of support allocated up to 2025 and a commitment to set out details of a revenue mechanism to bring through early-stage private investment in industrial carbon capture and hydrogen projects. The UK has the technology, know-how and storage potential to scale up CCUS across the country, unlocking new routes to CCUS-enabled hydrogen production.

Early deployment of CCUS technology and infrastructure will likely be located in industrial clusters. Many of these are in coastal locations, with important links to CO₂ storage sites such as disused oil and gas fields. Government aims to establish CCUS in four industrial clusters by 2030 at the latest, supporting our ambition to capture 10Mt/CO₂ per annum.

In turn, industrial clusters and wider industry are significant potential demand centres for low carbon hydrogen. Today, numerous industrial sectors from chemicals to food and drink are exploring the role that hydrogen can play in their journey to net zero. UK Research and Innovation's (UKRI's) Industrial Decarbonisation Challenge provides up to £170 million – matched by £261 million from industry – to invest in developing industrial decarbonisation infrastructure including CCUS and low carbon hydrogen.

Figure 1.3: Proposed UK electrolytic and CCUS-enabled hydrogen production projects



The UK also has decades of experience in production, distribution, storage, use and regulation of gas. Our widespread use of natural gas for power generation and for heat in industry and homes means that we have potential supply routes and numerous potential use cases for hydrogen gas. The UK also has favourable geology for large-scale storage of hydrogen, and is already storing hydrogen in salt caverns and exploring storage in disused oil and gas fields under the North Sea.

In addition, our well-developed North Sea oil and gas sectors and experience in renewables mean that the UK has developed supply chain strengths and innovative companies across the value chain poised to take advantage of the economic opportunities from developing low carbon hydrogen technologies. UK companies such as ITM Power, Johnson Matthey and Ceres Power are already recognised as being at the forefront of hydrogen technology development worldwide. Building on this strong base, we will draw on lessons from offshore wind and other low carbon technologies and aim to capitalise on our world-leading expertise in research and innovation and decarbonisation to put the UK at the forefront of emerging global hydrogen markets and opportunities.

The UK is well positioned to be a world leader in low carbon hydrogen production and use, delivering green jobs and growth to support levelling up across our industrial heartlands and across the UK. But we can only realise these economic opportunities if we act now to put in place the necessary environment and support to develop robust supply chains, upskill our people and secure high-quality jobs, and lay the groundwork to unlock investment and export opportunities. Our strategy seeks to maximise the economic benefits from a UK hydrogen economy and seize the potential of both domestic and international markets.

1.4 Our ambition for a thriving hydrogen economy by 2030

We recognise the importance of a clear goal alongside long term policy frameworks in bringing forward low carbon technologies. Our ambition for 5GW of low carbon hydrogen production capacity by 2030 is a signal of the government’s firm commitment to work with industry to develop a strong and enduring UK hydrogen economy. This ambition is a means to an end, rather than an end in itself – positioning the UK hydrogen economy for the scale up needed to support CB6 in the mid-2030s and net zero by 2050, and to deliver clean growth opportunities across the UK. We use “our 2030 ambition” in places throughout this strategy as shorthand for this wider vision for the UK hydrogen economy by the end of the decade.

It is not possible today, in 2021, to predict with certainty the size of the future hydrogen market in a net zero energy system, nor the best pathway to reach that. We recognise that the UK has huge potential to produce and use low carbon hydrogen, and that many in industry think we could go further and faster. We welcome this drive and ambition and will continue to work with industry to deliver the strategic direction and supporting policy environment to achieve our 2030 ambition and position the UK hydrogen economy for the future growth and scale up needed for CB6 and net zero.

