



HM Government

UK Hydrogen Strategy



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UK Hydrogen Strategy

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by Command of Her Majesty

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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.

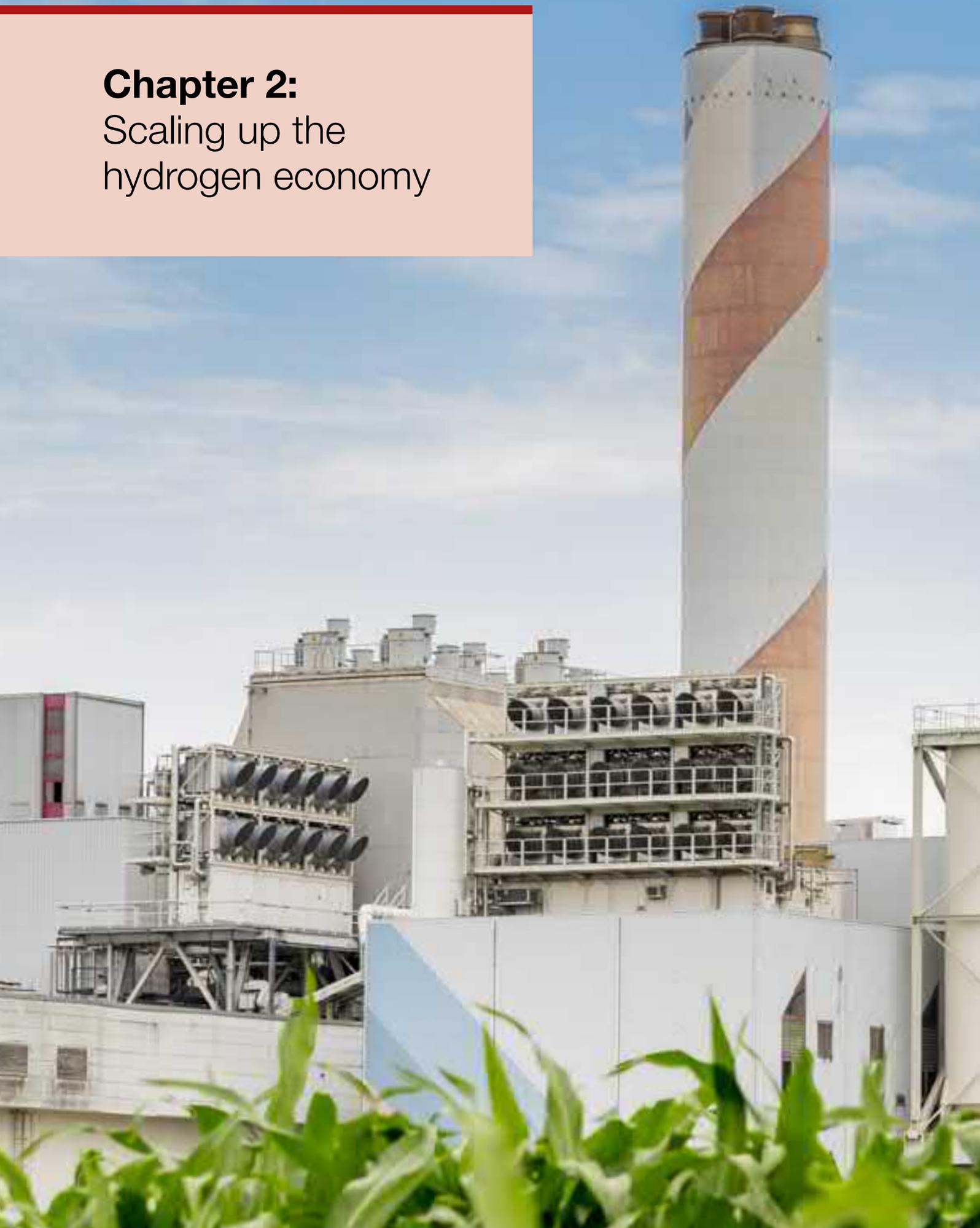
Chapter 3 explains how we will work to secure economic opportunities across the UK that can come from a thriving hydrogen economy – learning from the development of other low-carbon technologies and building this into our approach from the outset. It sets out how we will: build world class, sustainable 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 2: Scaling up the hydrogen economy



We expect that industry will form a lead option for both early hydrogen use and in the longer term, with demand from hydrogen fuel switching picking up from the middle of this decade and hydrogen playing a key role in further decarbonisation of industry by the mid-2030s under CB6 and on the pathway to net zero.

Hydrogen is likely to play an important enabling role in a fully decarbonised power sector, through the system flexibility that electrolytic production and hydrogen storage can provide and the potential for flexible power generation using hydrogen as a fuel – helping to balance a more variable renewables-based electricity grid. We could see use of hydrogen in power in this way by the late 2020s with further scale up by the mid-2030s.

Hydrogen could also provide an important low carbon alternative – alongside electrification – to the UK’s largely natural gas-based domestic heating sector, and government is supporting major studies and testing projects, including first-of-a-kind heating trials, to fill important evidence gaps on the costs, benefits and feasibility of using hydrogen for heating. This will be used to inform broader strategic decisions on heat decarbonisation in the middle of this decade. We are also exploring the option of blending hydrogen into the gas grid, with a decision to be taken in 2023 following testing of the safety, technical and economic case (see gas blending box in Chapter 2.5).

Finally, hydrogen is likely to be fundamental to achieving the full decarbonisation of transport, with particular potential in areas of heavy transport ‘that batteries cannot reach’. Hydrogen buses are already in use in some UK towns and cities, and feasibility studies are underway for the use of hydrogen and other zero emission technologies in heavy goods vehicles (HGVs) with the aim of undertaking future years trials (subject to funding). We expect hydrogen to play a significant role in decarbonising international shipping and aviation, with demonstration and trials already underway, potential for early stage uses in shipping and aviation by the end of the decade, and an increasing role from the 2030s.

Given the wide range of applications and the strategic enabling role that hydrogen can play in an increasingly decarbonised economy, the 2020s will be critical to developing, testing and scaling up the use of low carbon hydrogen in the UK. The following sections set out how government and industry will work together to unlock the potential that hydrogen holds to decarbonise these important UK sectors.

2.4.1 Use of hydrogen in industry

It is clear that UK industrial sectors will play a vital role in developing a hydrogen economy over the next decade. Industry produced 16 per cent of UK emissions in 2018,⁴³ and hydrogen will be critical to decarbonise industrial processes that would be hard to abate with CCUS or electrification. The *Industrial Decarbonisation Strategy* published earlier this year sets out the policy and technology principles to decarbonise industry by 2050, including the installation of deep decarbonisation infrastructure such as hydrogen and CCUS networks in the 2020s.

Our industrial heartlands will likely lead the way for large scale low carbon hydrogen supply, and industrial users are expected to provide the most significant new demand for hydrogen by 2030 through industrial fuel switching. Today’s hydrogen economy will need to scale up from its current base in the oil refining and chemical sectors, to enter other

parts of industry and the wider energy system. We will develop policy to support and deliver this change, and to drive the decarbonisation of existing industrial hydrogen use.

Decarbonising current hydrogen production and use in industry

To meet our net zero ambition and develop the new low carbon hydrogen economy, we need to decarbonise existing industrial production of carbon intensive hydrogen. Today, hydrogen is mainly produced by steam methane reformation (without CCUS) for use as a feedstock, or as a by-product of other industrial processes. The most appropriate option to decarbonise existing production will vary for different types of industrial sites and will depend on factors such as the life cycle of current assets and the production method used. As the oil refining and chemical sectors are today often both producers and consumers of hydrogen, they could be important drivers of the transition to a low carbon hydrogen economy.

We will support hydrogen producers to decarbonise through, for example, the Industrial Carbon Capture and Hydrogen Business Models. Furthermore, we will finalise the design elements of a UK standard for low carbon hydrogen by early 2022.

We will also publish within a year a call for evidence to explore with industry the further interventions needed to phase out carbon intensive hydrogen and transition to low carbon production methods and sources, at the required pace to meet net zero.

Switching to low carbon hydrogen as an industrial fuel

Low carbon hydrogen can also provide an alternative to natural gas and other high carbon fuels currently used for industrial heating. This includes both indirect heating applications,



for example, using hydrogen to fuel steam boilers and combined heat and power (CHP) systems, and direct heating processes, such as melting glass in a furnace. Low carbon hydrogen is a good option for processes that are more expensive or harder to electrify, given its potential to replace natural gas.

The *Industrial Decarbonisation Strategy* set out that we expect, at a minimum, 20TWh per year of fossil fuel use to be replaced with low carbon alternatives, including hydrogen, electrification and biofuels, in 2030. Our latest analysis suggests that by 2030 demand from industry for low carbon hydrogen as a fuel could range from around 10TWh per year if supply is limited to clusters, up to around 20TWh per year if some dispersed sites are connected to pipelines.⁴⁴ Further demand could be realised from sites sourcing hydrogen from local electrolytic production. Fuel switching to low carbon hydrogen could yield carbon savings of around 3MtCO₂e per year by 2030, equivalent to taking 1.4 million cars off the road.

To meet CB6, we anticipate that industrial demand for low carbon hydrogen would need to continue to grow, reaching up to 45TWh by 2035. This increase would be driven by a growing number of sites with access to low carbon hydrogen, continued technology development to expand the range of processes capable of using hydrogen, and a shift in associated costs, such as the price of carbon, to make hydrogen an increasingly competitive fuel option. By 2050, in a scenario with widespread access to low carbon hydrogen across the UK, consumption in industry could be as high as 105TWh by 2050.

This strategy covers the full range of UK industrial sectors: metals and minerals, chemicals, food and drink, paper and pulp, ceramics, glass, oil refineries, and less energy-intensive manufacturing.⁴⁵ The greatest potential demand for low carbon hydrogen in 2030 arises from sectors such as chemicals and steel.

As set out in the *Industrial Decarbonisation Strategy*, decarbonising the steel sector will be essential to the decarbonisation of UK industry. The main options for doing so include using electric arc furnace technology coupled with hydrogen direct reduced iron, or CCUS. In collaboration with the Steel Council, we are considering the implications of the recommendation of the CCC to “set targets for ore-based steelmaking to reach near-zero emissions by 2035” and will provide an update in the forthcoming Net Zero Strategy.

Hydrogen could also be used to help abate the 6MtCO₂ emissions associated with the use of industrial non-road vehicles such as excavators and diggers used in a range of sectors. Machinery manufacturers are already developing equipment capable of using hydrogen, which alongside electrification may be an important way to decarbonise this sector. The adoption of hydrogen as a solution will depend on the development of wider hydrogen infrastructure.

We recognise that industry faces several barriers in fuel switching to low carbon hydrogen, even where it may offer the best decarbonisation option. These include the higher cost of low carbon hydrogen supply compared with fossil fuels; the capital cost of retrofitting or replacing equipment to be hydrogen-ready; the operational disruption of conversion and the subsequent costs associated with optimising new processes using hydrogen; and the operational risks associated with the security of supply of low carbon hydrogen, particularly in the short term while the market develops.

Demonstrating the technical performance of hydrogen, without compromising process efficiency or product quality, is also essential. As hydrogen has a distinct chemical composition and physical characteristics compared to current fuels, further research and testing will be needed in the 2020s. This will help industry to better understand how hydrogen transfers heat, how to limit any pollutants released during combustion (including NOx) and how this might impact materials and end products. In practice this will involve building on existing research with more lab-based studies, followed by at scale trials for distinct industrial processes.

What are we doing to deliver?

Given the scale of industrial emissions and the likely importance of hydrogen in replacing high-carbon fuels used in industry, it is critical that we demonstrate and scale up fuel switching to low carbon hydrogen on industrial sites during the 2020s. Government is already providing a range of funding opportunities that could support industry to switch to low carbon technologies including hydrogen, which complement the existing academic and private sector led initiatives in this area:

- The **£315 million Industrial Energy Transformation Fund** is supporting the uptake of technologies that improve efficiencies and reduce the carbon emissions associated with industrial processes. Hydrogen projects, subject to contract, were supported as part of Phase 1 of the competition.⁴⁶ The Fund aims to de-risk key technologies including hydrogen fuel switching by providing support for feasibility and engineering studies, and capital support for first movers to upgrade their industrial equipment. It will increase readiness for the hydrogen economy by building demand for hydrogen in industry and helping to develop the commercial case for low carbon hydrogen projects.
- The **£20 million Industrial Fuel Switching Competition** has allocated innovation funding to stimulate early investment in fuel switching processes and technologies. It has been highly successful in progressing the development of new fuel switching technologies across a range of sectors, including cement, refineries, glass and lime. The latest round of funding was awarded in winter 2019, with four projects moving from feasibility studies to demonstration, including the Mineral Products Association's world first demonstrations of firing hydrogen at commercial fuel supply scale for the manufacture of cement and lime.
- The **Green Distilleries Fund is providing £10 million of new innovation funding** to help distilleries go green. The programme is taking a portfolio approach and aims to fund a range of different solutions which could include electrification, hydrogen, biomass or waste. Nine of the 17 feasibility studies funded at Phase 1 are for projects using low carbon hydrogen.



Case study: Unilever demonstrates a hydrogen-fired industrial boiler

As part of the BEIS funded HyNet Industrial Fuel Switching competition, Unilever, working alongside Progressive Energy, is running a trial to switch an onsite natural gas fired boiler to hydrogen. The boiler, located at the Port Sunlight facility on the Wirral, raises steam needed for the manufacture of home and personal care products.

Switching to low carbon hydrogen allows the site to cut carbon emissions, with no change to manufacturing operations. This trial will provide Unilever with the evidence and confidence to convert existing boilers to run on low carbon hydrogen, once a supply is available. It seeks to demonstrate consistent steam production at the required temperature and pressure, reliable boiler operations, and adherence to NOx emissions limits.

Following successful trials on a representative boiler system at Dunphy Combustion's test site in 2021, a new 7MWth dual fuel (hydrogen and natural gas) burner will be installed in Unilever's boiler. The proportion of hydrogen fuel gas will be increased from 0 to 100 per cent over four days, with verification of steam quality and NOx emissions performance taking place, followed by several weeks of 100 per cent hydrogen firing for up to eight hours a day, providing steam for the Port Sunlight works.

Building on these successes, later this year we will launch a number of further funds to support industry to switch to hydrogen and other low carbon fuels:

- **We will provide further grant funding to support fuel switching technologies, including low carbon hydrogen, through Phase 2 of the £315m Industrial Energy Transformation Fund.**
- **We will launch a new £55m Industrial Fuel Switching 2 Competition to develop and demonstrate innovative solutions for industry to switch to low carbon fuels such as hydrogen.**
- **We will launch a new £40 million Red Diesel Replacement Competition to fund the development and demonstration of innovative technologies that enable Non-Road Mobile Machinery (NRMM) used for quarrying, mining, and construction to switch from red diesel to hydrogen or other low carbon fuels.**

Throughout the early 2020s, we will also be supporting the engineering and technical design elements of decarbonisation projects across the UK's industrial clusters through UKRI's **Industrial Decarbonisation Challenge**, to accelerate the deployment of technologies such as CCS and hydrogen fuel switching.

Building on this substantial existing industrial decarbonisation support, we will need additional dedicated support for fuel switching to hydrogen, including for further research and innovation, and demonstration and deployment of early use cases in the 2020s. To accelerate fuel switching to low carbon hydrogen, **we will seek to support research and innovation through the existing Net Zero Innovation Portfolio and initiatives led by the Industrial Decarbonisation Research & Innovation Centre (IDRIC). We will also**

engage with industry later this year on possible requirements for a research and innovation facility to support hydrogen use in industry and power.

Due to infrastructure requirements, demand will likely be concentrated in large industrial clusters during the 2020s, a significant proportion of which could arise from a small number of sites. These sites could act as ‘pathfinders’, proving the viability of hydrogen as a fuel at commercial scale, and helping to foster an initial market for low carbon hydrogen close to supply. **We will work with cluster projects to better understand the opportunities that pathfinder sites present, so to maximise the benefit to the sites themselves and the associated clusters.**

Initially, hydrogen will likely be used to fuel indirect heating technologies such as steam boilers and CHP units. Given the range of sectors that use steam as part of an industrial process, our analysis indicates that boilers and CHPs could make up around two thirds of demand for hydrogen fuel switching by 2030. We will therefore focus on policies to unlock the fuel switch potential for these technologies, taking into account replacement cycles of existing equipment. Work is ongoing to establish the role of hydrogen in decarbonising CHPs, and **by the end of this year we will launch a new call for evidence on ‘hydrogen-ready’ industrial equipment.**

Later in the decade, hydrogen could replace methane in different parts of the gas grid, either partially through blending or fully with 100 per cent hydrogen (see Chapter 2.5 for further detail on blending). Among the current users of the gas network, industry has the most variation in terms of types of equipment and uses of natural gas. Government is working with industry and with regulators to identify the changes that would be necessary to transition to full or blended hydrogen in the gas grid, and how this could impact industrial settings. **We will work with industrial end users to ensure their needs and the potential impacts of a full or partial transition to hydrogen via the gas grid are well understood.**

Collectively, this extensive set of measures will help UK industrial sectors better understand the challenges and opportunities of switching to low carbon hydrogen. Unlocking demand for low carbon hydrogen in industry will deliver significant carbon savings and help scale up the hydrogen economy. Demand from industry can act as an anchor to stimulate production, which will in turn help decarbonise other end use sectors in both industrial clusters and dispersed sites across the UK.

2.4.2 Use of hydrogen in power

As set out in the *Energy White Paper*, government is aiming for a fully decarbonised, reliable and low-cost power system by 2050, which will require the rapid growth in renewables which has been a key driver of emissions reductions to date. To meet CB6 on the way to this, we must aim for a largely decarbonised power sector by the mid-2030s. Deployment of renewables and other forms of low carbon generation is projected to further scale up, demand for electricity will increase as more sectors shift to electrification, and power generation will become more decentralised, variable and intermittent as we become increasingly dependent on wind and solar. To support this transition, we will need more flexible, low carbon generation and flexible technologies such as energy storage and demand-side response to manage demand peaks and to balance electricity supply and demand.