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REPORT MARCH 2021

BETWEEN HOPE AND HYPE: A HYDROGEN VISION FOR THE UK

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With special thanks to: Felix Heilmann, Simon Skillings, Eleonora Moro, Pedro Guertler, Ed Matthew, Ted Christie-Miller, Richard Lowes, Hywel Lloyd, David Cowdrey, Jess Whelligan

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About E3G

E3G is an independent climate change think tank accelerating the transition to a climate-safe world. E3G builds cross-sectoral coalitions to achieve carefully defined outcomes, chosen for their capacity to leverage change. E3G works closely with like-minded partners in government, politics, business, civil society, science, the media, public interest foundations and elsewhere.
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CONTENTS

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1. Summary of key recommendations

Zero emissions, 'green' hydrogen produced from renewable energy is likely to remain a premium commodity over the coming decades. It should be deployed where it adds the greatest value for climate, jobs, and a strong economic recovery. Used wisely, green hydrogen can support the decarbonisation of industrial hubs across the UK, helping tackle some of the greatest climate challenges for sectors where currently, there are no readily available pathways to zero emissions. 'Blue' fossil-based hydrogen is not zero emissions and risks a lock-in of high carbon infrastructure and jobs. Instead, the UK's competitive advantage can be secured if it chooses the green hydrogen path, sourced through harnessing the full potential of the country's offshore wind resources.

A focus on clean, green hydrogen within targeted sectors and hubs can support multiple Government goals – including demonstrating climate leadership, reducing regional inequalities through the 'levelling up' agenda, and ensuring a green and cost-effective recovery from the coronavirus pandemic which priorities jobs and skills. A strategic hydrogen vision must be honest and recognise where green hydrogen does *not* present the optimal pathway for decarbonisation – for instance, where alternative solutions are already readily available for roll-out, are more efficient and cost-effective. A clear example is hydrogen use for heating, where it is estimated to require around 30 times more offshore wind farm capacity than currently available to produce enough green hydrogen to replace all gas boilers, as well as adding costs for consumers.

Ahead of the publication of the Government's forthcoming Hydrogen Strategy, this paper considers the offer of hydrogen for key Government priorities. It assesses existing evidence and considers the risks and opportunities, and how they might inform a strategic vision for the UK. The table below sets out key expectations to maximise value through a strategic vision for hydrogen.

✓	**The UK should focus on green hydrogen** to show climate leadership and make gains in the international innovation race. Blue hydrogen is not zero emissions and should not be classed as 'low carbon'. We discourage the UK from taking a 'twin track' approach of pursuing both green and blue hydrogen. The UK can show leadership through introducing targets and standards which support green hydrogen and ensuring that public funding is only used to develop zero emissions fuel and technologies.
✓	**Scaling up green hydrogen requires parallel rapid growth in renewable energy – particularly offshore wind – as well as electrification, efficiency**

	and circular economy. These measures have strong social, economic and environmental co-benefits, and will be central pillars of any decarbonisation strategy, regardless of the role of hydrogen.
✓	**The UK should set out a vision identifying where green hydrogen production and use is likely to add most value,** ensuring a cost-effective use of public funding. A system-wide stock-take can help establish where hydrogen adds the most value for jobs, productivity growth and climate – focused on sectors that do not have alternative decarbonisation options, and regions which have access to abundant renewable energy sources. This is mainly applicable to high temperature heat in industry, shipping and aviation, and long-duration storage in the power sector.
✓	**Governance mechanisms are needed for risk-managing delivery and avoiding a 'lock in' of fossil fuel derived energy sources.** These should ensure a switch away from fossil-based fuels, and could include clear timelines and targets, transparency and accountability mechanisms, and regulations and standards which support a phase-out.
✓	**Hydrogen pipelines should be built around secure hydrogen demand and supply**; not around the question of how existing gas assets can best be kept functioning. The future hydrogen grid is likely to be significantly different than today's gas grid, clustered around industrial end users rather than nationwide. As such, nationwide 'blending' of fossil gas and hydrogen is not appropriate.
✓	**For the decarbonisation of heat in buildings, the UK should focus on making rapid gains on energy efficiency, heat pumps and renewable heat networks**. A growing body of evidence suggests that green hydrogen for heating is likely to only play a small role in industrial clusters where there is a surplus. Waiting for long-term progress on hydrogen must not act as a blocker to action that can be taken today.
✓	**A large focus on jobs, skills and supply chains is required to ensure a just transition and support the "levelling up" agenda to reduce regional inequalities.** The UK must focus on supporting new green skills and jobs to address transition risks as the country phases out fossil gas energy and infrastructure, engaging closely with workers and unions.
✓	**The Government must promote evidence-based and society-wide decision making.** This requires including all sectors of society in decision-making and advisory bodies such as the Hydrogen Advisory Council, and rooting choices in independent science. The Government should engage the most vulnerable workers and households to ensure the approach works for everyone, as well as ensuring a central role for Local Authorities and city councils.

2. Background: Hope in Hydrogen?

There is a growing conversation around the role that hydrogen can play in the future of the UK, and how to best harness its potential to secure jobs, show climate leadership, promote industrial competitiveness and drive innovation. The Government's 'Ten Point Plan for a Green Industrial Revolution' included hydrogen as one of its ten actions, targeting 5GW of 'low carbon' hydrogen production by 2030. Britain is thus joining the EU, US, Japan, Germany and a host of other countries seeking to be part of the hydrogen economy of the future.

A strategic vision for hydrogen development and deployment should be based on an understanding of its strength and limitations. This requires analysing the risks associated with certain uses and applications, and calculating the costs of different decarbonisation pathways to ensure we select the ones which deliver best value for consumers and support the UK's agenda to reduce economic inequalities across the country ("levelling up"). In particular, there could be opportunities to drive green economic growth and support jobs in industrial clusters and hubs strategically located to benefit from the vast renewable potential of North Seas offshore wind.

Green hydrogen production is starting from a low baseline – with less than 0.1% of global dedicated hydrogen production coming from water electrolysis[1] –and is likely to be a scarce and premium resource for decades to come. Deployment must be focused on where it adds most value in light of the Government's social, environmental and economic goals. This should be grounded in an honest, critical examination of the evidence and research. Currently, the hydrogen agenda is in part driven by vested interests of those with stakes in high-carbon infrastructure and systems, not all of which align with the Government's goals.

The Hydrogen Strategy, expected from the Department for Business, Energy and Industrial Strategy (BEIS) in mid-2021, will offer a vision for how the UK can get on track to meet its new target. This paper considers the offer of hydrogen and sets expectations ahead of the Strategy's publication. We propose a vision centred around people, places and planet; targeting development and deployment choices that secure best value, support the levelling up agenda, and boost the UK competitiveness to achieve leadership status in key markets and industries. Distinguishing between hope, hype and reality will be key to putting the UK on the right track.

[1] IEA (2020) **The Future of Hydrogen**

TERMINOLOGY:

1. **‘Green’ or ‘renewable hydrogen’** describes hydrogen produced via electrolysis from renewable electricity.
2. **‘Grey hydrogen’** describes hydrogen produced from fossil gas through steam methane reformation (SMR), without carbon capture and storage (CCS).
3. **‘Blue hydrogen’** describes hydrogen produced from fossil gas through steam methane reformation in combination with CCS. An alternative technology is pyrolysis, but this is at very low levels of maturity and encounters many of the same issues as SMR.

E3G has published a more in-depth analysis of these three options in light of net-zero in 2018, available **here**.

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3. Unpacking key considerations for a hydrogen strategy

BEIS is developing a strategy to decarbonise and scale-up the hydrogen economy to get on track to meet the goal to achieve 5GW of 'low carbon' hydrogen (defined as green hydrogen and blue hydrogen with CCS) by 2030, and set the context for further scale-up. This paper considers the offer of hydrogen for key Government priorities – including an inclusive and resilient economic recovery from the pandemic, demonstrating climate leadership, and delivering for all of society across the UK. It assesses existing evidence and considers the risks and opportunities, and how they might inform a strategic vision for the UK. The following section considers additional, core factors that should underpin the development of hydrogen strategy and subsequent decision-making.

Balancing supply to demand

The strategy must consider what the future demand for hydrogen is likely to look like, and whether and how the supply-side can accommodate for this. A successful strategy would be one that effectively identifies and populates the best niche for hydrogen (if the scale of supply is limited); or one that properly resources and supports a mass roll-out of hydrogen to match supply to demand across the different sectors where hydrogen can support decarbonisation. The race for hydrogen innovation is also a race against time to limit climate breakdown. While there is scope for a staged approach that focuses on niche applications in the near-term, then supporting a longer-term vision to deliver hydrogen on a greater scale, it is essential that this does not delay action on deploying alternatives to hydrogen which are already available today.

The demand-side will depend on whether customers (industrial and individuals) will prefer to use hydrogen compared to the alternatives. This choice will be driven by Government decisions through standards that phase out emissions-intensive alternatives and the provision of infrastructure, with consumer perceptions and consent critical in driving these decisions.

A system wide stock-take to understand the potential

Understanding likely future supply and demand requires analysis of the technical options and likely cost implications of hydrogen in comparison to other pathways for decarbonisation. The significant energy losses associated with hydrogen production, transport and conversion[2] mean that it is not always the most efficient pathway where direct electrification is possible. However, technology does not currently exist to electrify every sector (e.g. some industrial processes). In some cases, it is the nature of hydrogen as an energy vector (enabling energy to be carried and converted back into other forms of energy) that is important, and so it is not competing directly with electricity (e.g. long-term storage). Hydrogen also acts as a chemical feedstock.

Since current evidence suggests that hydrogen will not be the most cost-effective nor efficient decarbonisation pathway for every sector and application, there is rationale for ensuring the strategy presents a vision for hydrogen as a premium resource, which needs to be carefully developed and deployed in instances where it adds most value.

Separating the industrial and individual components

It is important to separate industrial and consumer markets. In the former, choice will be driven (almost) entirely by technical and economic factors and can be thought of as a classic industrial strategy. Individuals bring a wide range of other considerations to bear that can have significant political implications. Understanding these issues, and how they can be managed, will be central.

The industrial component of the strategy should focus on driving down costs of green hydrogen – alongside potential alternatives – to create competitive advantages for UK industry. The North Sea presents opportunities for large-scale production of renewable electricity, with benefits of existing infrastructure in place. Alongside rapid progress on renewables, the successful development and deployment of green hydrogen needs parallel scaling of electrification, efficiency, flexibility and circular economy measures. These measures offer wider social, economic and environmental co-benefits, and should be pursued regardless of action on hydrogen.

There are credible electrification or other decarbonisation routes for industry which do not involve green hydrogen. Innovation in these areas will also determine the ultimate demand for hydrogen.

4 The process of converting hydrogen into electricity has a poor energy efficiency, ranging from around 30% to 60%. Combined with the energy penalty from using electrolysers and storing hydrogen, these re-electrification losses result in a round-trip efficiency ranging from 20 – 48%. Source: **Energy Transition Institute**.

The individual, residential consumer side is different. The strategy relating to home heating depends on consumer consent as well as reliable technical and real economic advantages, or disadvantages.

A fair innovation race

The strategy must trigger a race in innovation, while maintaining options until more has been learnt about the feasibility of different decarbonisation pathways. Given the 'need for speed' to limit global temperature rises to 1.5°C, there is a need to push forward at pace with all available solutions, learning how to increase demand for them. When dealing with uncertainty, it is key to ensure:

1. The innovation race is fair, and does not detract from making rapid progress on other key technologies for decarbonisation (e.g. heat pumps)
2. There is the right governance in place to direct innovation spend and identify which options should be kept open and which should be closed.

4. A hydrogen strategy for an inclusive and resilient economic recovery

A well-targeted framework for green hydrogen could support a competitive future for certain industries, such as steel and freight, and support the decarbonisation of the power sector. Clustered around northern industrial hubs, this could support the levelling up agenda, delivering high-skilled green jobs to communities, and support a just transition for high carbon industries where alternative pathways for decarbonisation do not currently exist – such as steel. Achieving this potential requires a realistic stock-take of where green hydrogen can add value, and where alternative pathways provide cheaper and quicker options to advance an inclusive and resilient economic recovery.

The role of green hydrogen in a cost-effective economic recovery, supporting green employment

Under current economic conditions owing to the pandemic, it is vital the Government focuses on the most cost-effective pathways to decarbonisation, seeking those that offer the greatest social and economic co-benefits, delivering value to the public purse and targeting key regions and sectors.

The efficiency of producing and using green hydrogen is low, due to conversion losses.[3] From a system's efficiency perspective**,** hydrogen is best deployed where electrification, efficiency or circular processes are not possible. This is mainly applicable to high temperature heat in industry, shipping and aviation, and potentially seasonal storage. In many sectors, alternative solutions are already available – e.g. electrification of heat or transport and often have the potential to further reduce operating costs for the end user. Currently, 40% of current gas use in industry is for heat under 100°C and could be replaced with electrification – and even for higher temperature requirements, a range of power-to-heat options can be more energy-efficient than hydrogen.[4]

Focussing on deploying green hydrogen in sectors where electrification and efficiency cannot currently offer a pathway to decarbonisation offers the greatest prospect for a cost-effective recovery, helping ensure the long-term viability of these industries and the communities and workers they support.

The success and scalability of hydrogen is closely tied to rapid progress on renewable electricity needed to source zero emissions green hydrogen.[5] In

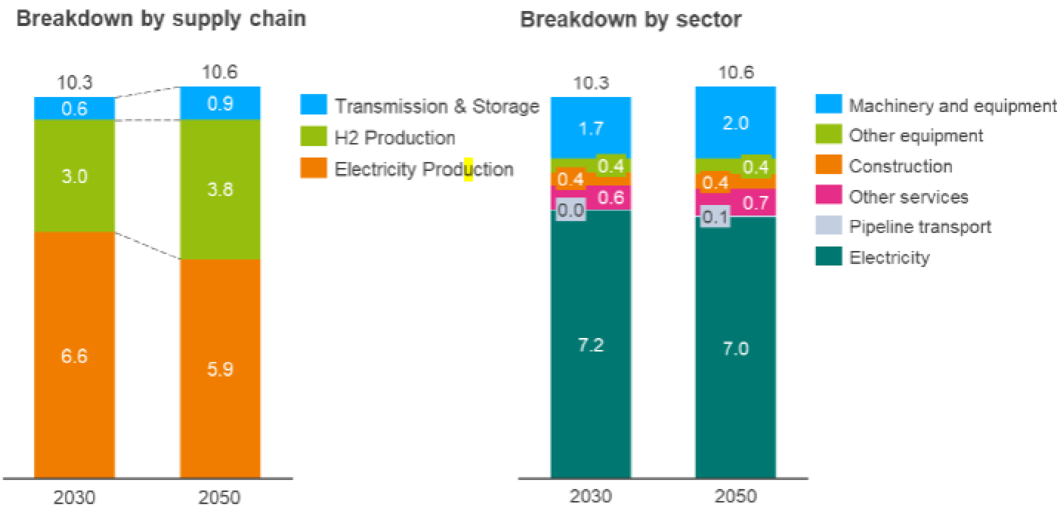
3 E3G (2018), **Renewable and decarbonised gas renewable gas – options for a zero emissions society.**

[4] Agora Energiewende (2021) **No regret hydrogen infrastructure for Europe**

[5] CCC (2018), **Hydrogen in a low carbon economy**

particular, the UK must focus on securing its full offshore wind potential,[6] in parallel to making strides on grid flexibility, energy efficiency and circular economy – all measures which support lower cost pathways to decarbonisation. This offers significant opportunities for green employment and skills, with a recent study highlighting that most jobs are generated in the electricity component of green hydrogen production – see Figure 1.[7]

Figure 1: Number of jobs created per billion EUR invested.



Source: Report prepared for the European Commission

[6] E3G and Imperial College London (2021) **Offshore win in the North Seas: from ambition to delivery**

[7] Directorate-General for Energy (European Commission), Guidehouse (2020) **Hydrogen generation in Europe: Overview of costs and key benefits**

Efficiency, flexibility and circular economy key for cost effective decarbonisation

Measures to reduce demand for energy and materials, as well as avoiding 'peaks' in demand, will be central for reducing costs and should be central to all decarbonisation strategies. Enhanced efficiency of buildings, technologies and processes is critical for both industrial and individual consumers. **Analysis of UK household** energy demand scenarios shows that combining energy efficiency and heat pumps can deliver energy savings of around 25%. Grid flexibility refers to the capability of a power system to maintain the balance between generation and consumption and is critical for renewables, which are more variable than conventional electricity generation. **Reducing peak demand through flexibility** will reduce the network and generation capacity required to meet that peak, thereby lowering emissions and overall system costs. **Circular economy measures** enhance the efficiency of resource-use over the lifecycle of materials and products, reducing energy use, emissions and costs.

Calculating the costs

It is essential to consider the costs and challenges related to scaling hydrogen, as these will inform decision-making about where it can add most value. Key costs relate to production and infrastructure, and parallel investments needed to support this (i.e. renewables, efficiency, electrification, etc). These costs are currently uncertain and rapidly evolving, and can differ between suppliers, applications and technologies.[8]

Key costs
Generation of hydrogen: Electrolysis (for green); steam methane reforming and gasification (for blue). Producing green hydrogen requires parallel scaling of renewable energy. Blue hydrogen costs need to factor gas imports, the elimination of methane leakages, scaling CCS and carbon taxes. Low-cost wind and solar can provide hydrogen at a cost comparable to that of hydrogen produced from fossil fuels, with likely further reductions as renewables decrease in cost.[9]

[8] E4Tech (2019) **Study on Value Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cells Technologies**

[9] IRENA (2019) **Hydrogen: a renewable energy perspective**

Transmission pipelines and distribution networks: There will be costs associated with upgrading the gas grid and infrastructure in clusters and hubs where green hydrogen is being deployed. For hydrogen use for heat decarbonisation, analysis undertaken on behalf of the CCC found that the cost savings from reusing gas grids do not give hydrogen a cost advantage over electrification.[10]
Costs for end-user: There will be upfront costs for both industrial consumers and households to upgrade equipment and technology for hydrogen usage – many of which currently have niche status as technology is not yet mature. The energy costs associated with hydrogen are higher than fossil gas or direct electrification, given the inefficiencies in hydrogen production.

The deployment of green hydrogen requires infrastructure transformation**.** While estimates of the costs for refurbishing the gas grid are uncertain, a study for the EU concludes that the costs of fully converting distribution networks and appliances for hydrogen are prohibitive.[11] For decisions over keeping the current gas network running for future repurposing, the costs of conversion and the process for conversion (including end-use appliances) need to be better understood. The Climate Change Committee (CCC) found that the sunk costs of having an extensive gas grid do not automatically mean that it will be lower cost to switch it over to hydrogen and use it in boilers.[12]

Hydrogen pipelines should be built around secure hydrogen demand and supply; not around the question of how existing gas assets can best be kept functioning.[13] Supply and demand patterns will likely look different compared to the current gas network, with a different network shape. Localised production of renewable electricity, hydrogen production and end-use consumption of hydrogen is most cost-effective through "clustering", which in turn drives down infrastructure costs.[14] The future hydrogen network could be much more localised compared to the current gas network, around industrial clusters and hubs that benefit from offshore wind. It is essential that Local Authorities and bodies are involved in decision-making, with hydrogen considered within the context of energy decentralisation and heat zoning.

Another key challenge is integration of hydrogen into the grid – with costs of building new hydrogen grids or switching existing gas grids. This is currently an

[10] Climate Change Commission (2018) **Hydrogen in a low carbon economy**
[11] Gas for Climate (2020), **Gas Decarbonisation Pathways**
[12] Climate Change Committee (2018) **Hydrogen in a low carbon economy**
[13] Agora Energiewende (2021) **No regret hydrogen infrastructure for Europe**
[14] Artelys (2020) **Energy Infrastructure Needs**

area of uncertainty, with trials and pilots ongoing. The Ten Point Plan states the Government will work with industry to complete testing necessary to allow up to 20% blending of hydrogen into the gas distribution grid [15] - with blending presumably needing to rise to 100% hydrogen over time. It will be challenging to gradually increase the share given current infrastructure, [16] and necessary to consider the transition risks if blending trials fail, or the quantities of green hydrogen that would be required never emerge. Some fear this could result in a technological dead-end similar to biodiesel dosing of diesel.[17] There will be further transition risks in the switch from 20% to 100% green hydrogen blending relating to jobs and infrastructure – potential stranded assets – as the supply and production changes. As such, nationwide 'blending' of fossil gas and hydrogen is not appropriate.

The investment propositions of an all-electric switch for domestic heating compared to a gas network transformation are fundamentally different. For the electrical switch over, private investment largely funds new wind power generation based on falling capital costs with relatively low operating costs, providing proven investment returns. On the other hand, hydrogen operating costs will be inherently higher than natural gas and are at a higher investment risk level given the unproven technology and up-scaling needed. This could result in a higher burden to the taxpayer, given that passing this scale of costs directly through to consumers is unlikely to be acceptable.[18]

Levelling up through green industrial clusters

The most efficient way to produce and consume green hydrogen is in clusters focused on industrial consumers, developed "bottom up".[19] North Seas renewables modelling shows that the most cost-effective way to produce hydrogen is on offshore hubs with green hydrogen piped ashore in repurposed gas infrastructure – where these geographically match.[20] This suggests clusters are best located near this landing infrastructure or where it can be moved inland using existing network.[21]

The industries – and jobs they support – in these clusters and hubs are heavy users of fossil fuels; with industrial clusters representing around 20% of Europe's greenhouse gas emissions (excluding transport).[22] Recent analysis from think tank

[15] UK Government (2020) **Ten Point Plan for a Green Industrial Revolution**
[16] Agora Energiewende (2021) **No regret hydrogen infrastructure for Europe**
[17] LETI (2021) **Hydrogen A decarbonisation route for heat in buildings?**
[18] LETI (2021) **Hydrogen A decarbonisation route for heat in buildings?**
[19] World Economic Forum and Accenture (2020) **Industrial Clusters can be a key lever for decarbonisation: Here's why.**
[20] E3G and Imperial College London (2021) **Offshore win in the North Seas: from ambition to delivery**
[21] E3G (2020) **The return of the north seas grid**
[22] World Economic Forum and Accenture (2020) **Industrial Clusters can be a key lever for decarbonisation: Here's why.** .

Onward highlights that the UK's least prosperous regions disproportionately rely on heavily emitting industries for jobs.[23] The East Midlands has the highest proportion of jobs in high emitting industries (42%), followed by Yorkshire and the Humber (38%) and the North West (38%).

A strategic focus on boosting North Seas offshore wind power to produce green hydrogen can help support a just transition in line with the levelling up agenda. There is a density of companies in localities previously dependent on fossil fuels that supply the offshore wind industry.[24] For example, clusters exist in Teesside and the East Anglia coastal regions, and Aberdeen Bay and the Firth of Forth in Scotland. New jobs supporting offshore wind deployment will help boost local economies as demand for fossil fuels declines.

Case study: A green boost for the Humber and north-east supply chains

Humberside, the UK's largest cluster by industrial emissions, (12.4Mt of CO_2 per year), contributes £18bn to the national economy each year and has access to a large renewable resource from offshore wind in the North Sea.[25] Sheffield-based company ITM Power is working with Orsted and Phillips 66 to develop a 100 MW industrial-scale electrolysis system to convert electricity produced by Orsted's 1.3 GW Hornsea Two wind farm off the Yorkshire coast into green hydrogen. The hydrogen will be used as feedstock in Phillips 66's Humber Refinery, replacing grey hydrogen produced by fossil fuels.[26]

Industrial leadership and export opportunities

With an international race for leadership in developing green hydrogen economies, the UK can stride ahead through focusing on innovation to support the decarbonisation of sectors where alternative zero emission pathways are not readily available, considering where it can add value in international markets. There is potential for productivity growth in hydrogen production and technology; as well as gains for industries that use the fuel to produce low emissions products – such as green steel.

Timing will be critical as markets develop, underscoring the need for a framework which is focussed on strategic deployment. The greatest export opportunities and

[23] Onward (2021) **Getting to Zero**
[24] E3G and Imperial College London (2021) **Offshore win in the North Seas: from ambition to delivery**
[25] ITM Power (2020) **Green hydrogen for Humberside project deployment survey**
[26] Energy Voice (2020) **UK needs a clear strategy before green hydrogen energy can take off**

added value might be found where the UK already has access to existing markets it can tap into, such as for green steel, low carbon ammonia for maritime use, and low carbon chemicals – all resources that will be also be sought domestically.

The UK can also focus on boosting green production technologies, such as electrolysers, which will be sought both domestically and in international markets. An early example is ITM Power selling a 24MW electrolyser to be installed at the Leuna Chemical Complex in Germany to produce green hydrogen to supply Linde's industrial customers through the company's existing network.[27]

The decarbonisation of the power sector should be another priority. Many challenges in the power sector revolve around grid stability. Short-term challenges can be mitigated through demand side response and smart electrification, and seasonal swings can be greatly mitigated through energy efficiency. Long periods of low wind and solar will provide future challenges – with interconnection and hydrogen providing potential backups. This opportunity needs to be better understood as National Grid ESO is preparing Britain's electricity system to be able to run on purely zero-carbon electricity by 2025.[28] A holistic approach should be pursued which also considers efficiency and flexibility measures to reduce overall power requirements.

Green finance: leveraging markets and innovation

The UK can show leadership with financial innovation supporting new products and services to underpin the development and deployment of green hydrogen where it adds value. Taxonomies defining sustainable finance are setting the bar to ensure only green hydrogen might be considered a sustainable investment. There is an opportunity for the UK to race to the top through an early focus on scaling markets for zero emission green hydrogen. For example, the draft EU taxonomy sets thresholds for the manufacturing of hydrogen to limit direct CO_2 emissions to 5.8 tCO_2e/t, and requires electricity use for hydrogen produced by electrolysis is at or lower than 58 MWh/t hydrogen[29] - effectively barring fossil-based hydrogen.

Meanwhile, increasing concern regarding the financial risks associated with investing in high carbon fuels and energies could expose investments in fossil-based hydrogen. S&P Global Ratings has recently placed several of the biggest oil

[27] ITM Power (2021) **Sale to Linde of World's Largest PEM Electrolyser**
[28] National Grid ESO (2021) **Zero Carbon Explained**
[29] Nordea (2020) **EU Taxonomy Final Recommendations**

companies on negative watch, signalling it may cut credit ratings due to "greater industry risks" associated with climate change.[30] Signals could steer markets away from fossil-based hydrogen and instead support the scaling of zero emissions green hydrogen. The UK can seize opportunities and attract international investors by focusing on green hydrogen, which will be essential to meet the ambition set out in the 10 Point Plan to leverage £4 billion of private investment in the period up to 2030.[31]

[30] As reported in Seeking Alpha (2021) **S&P Puts big oil names on negative watch due to climate risk**
[31] UK Government (2020) **10 Point Plan for a Green Industrial Revolution**

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5. A hydrogen strategy for climate leadership

Ahead of COP 26, the UK can use the Hydrogen Strategy to demonstrate its commitment to climate action through focus on building up renewables for a strategic deployment of green hydrogen. This will come with economic advantages and opportunities as the international innovation race moves ahead at pace – moving away from fossil gas imports and towards a future powered by domestic renewables. The UK's peers are making a big bet on green hydrogen, with Germany and others setting targets to ensure a proportion of future supply is met through renewable sources.[32]

Green hydrogen can help the UK achieve its net zero goal and make progress towards interim carbon budgets, if deployed as part of a mix of solutions which also recognises the importance of renewables, efficiency, flexibility and circular economy principles. The UK's world-leading climate framework means that it will need to deploy all options to get on track, with a 'need for speed' in areas – such as heat decarbonisation – where solutions already exist.

A need for green leadership

A commitment to climate leadership requires the UK to double-down on green hydrogen, and carefully navigate the risks that blue hydrogen present to net zero and a cost-effective transition.

Hydrogen derived from fossil fuels is not zero emissions, due to methane leakages along the value chain. The International Energy Association (IEA) estimates that the oil and gas sector emitted around 70 Mt of methane in 2020 –over 5% of global energy-related greenhouse gas emissions.[33] Methane is over 80 times more powerful, though shorter-lived greenhouse gas than CO_2.[34] Leakages are historically underestimated and underreported, with satellite technologies and site studies regularly revealing large, previously undetected plumes.[35] The full costs of eliminating methane leakages is unknown, and the IEA estimates that even if all options were to be deployed across value chains, 25% of total oil and gas methane emissions would remain unaddressed.[36]

[32] S&P Global (2021) **Germany agrees hydrogen strategy to kickstart electrolyzers for 2030s**
[33] IEA (2021) **Driving down methane leaks from the oil and gas industry**
[34] UNECE (2020) **Methane management**
[35] For example see Reuters (2020) **Satellites reveal major new gas industry methane leaks** and Clean Energy Wire (2020) **Large amounts of methane leak into North Sea from abandoned oil and gas wells – study**
[36] IEA (2020) **Methane Tracker: Abatement Options**

Developing blue hydrogen does not accelerate development of green hydrogen on the supply side, since these are fundamentally different technologies. Unprecedented progress would be needed on Carbon Capture and Storage (CCS) within the next decade if it is to play any meaningful role in the transition period. While carbon capture efficiencies are hoped to reach 85-95%, current flagship CCS projects achieve far lower capture rates. The Petra Nova project in the US captures just over a third of the flue gas from one of four coal-fired units, while the Boundary Dam project in Canada has an overall capture rate of 31%.[37] There are also questions around current practices in Carbon Capture Usage and Storage (CCUS), with the oil industry using captured CO_2 gas injections as part of the enhanced oil recovery process. There need to be controls over how CO_2 will be used and where it will be stored, so that it will not be used to extract more oil.[38]

The Government announced that it will set up a £1bn CCS Infrastructure Fund and will help establish four CCS clusters by 2030, capturing up to 10 mega-tonnes of carbon dioxide a year by 2030. [39] Since CCS is an expensive means of decarbonisation which is yet to be proven at scale, it makes sense to ensure it is deployed strategically where it is essential and other pathways to zero emissions are not readily available.

As well as being essential for climate targets, there is also a strong economic case for a focus on green hydrogen from the start. A recent study found that hydrogen from renewables will be cheaper than blue in the long run.[40] Furthermore, the UK can take a leadership position and establish market advantages, with export opportunities to other major economies focusing on green hydrogen. On the other hand, a focus on blue could leave the UK dependent on fossil gas imports – with the CCC's 'full hydrogen' pathway seeing gas imports at around double today's levels.[41] Instead, a focus on North Seas offshore wind could enable spending to be redirected into the domestic economy, supporting UK jobs, communities and supply chains.

Hydrogen's prospects rely on scaling renewables, efficiency and electrification

Hydrogen from electrolysis is as clean as the power that goes into it. According to data by National Grid ESO, the average carbon intensity of Britain's electricity

[37] IRENA (2019) **Hydrogen: A renewable energy perspective**
[38] National Energy Technology Lab, US Department of Energy (2010) **Carbon Dioxide Enhanced Oil Recovery - Untapped Domestic Energy Supply and Long-Term Carbon Storage Solution**
[39] Science Business (2020) **UK Government funds four CCS clusters**
[40] Agora Energiewende (2021) **No regret hydrogen infrastructure for Europe**
[41] Climate Change Committee (2018) **Hydrogen in a low carbon economy**

system was 181g CO_2/kWh – continuing a trend which has seen the system decarbonise by 66% in the last seven year.[42]

The successful scaling of green hydrogen requires a parallel increase in renewable energy sources to supply the electricity required for the electrolysis process. The 'winners' in green hydrogen will be those who can produce at scale and transport at least cost to demand centres. The UK's big competitive advantage is the North Sea. Other countries, particularly those with lots of solar, also have advantages – with Saudi Arabia building a $5bn plant to make green hydrogen for export, powered entirely by sun and wind.[43] We note that hydrogen transport and export at global scale, i.e. via ship, is likely not to occur in its pure form and cannot be done with existing infrastructure. To liquify hydrogen, extremely low temperatures (-252.87°C[44]) are needed which are expensive and difficult to achieve.[45]

The UK's vast renewables potential has a two-fold advantage: Not only does it provide access to hydrogen production that is likely to become the cheapest option within the next decade,[46] but it also means domestic access to a zero emissions fuel, reducing reliance on international energy imports. This will rely on a high deployment of offshore wind to meet electricity demand, with the UK developing an integrated and interconnected electricity grid in the North Seas to unlock the significant wind resources, zero emissions energy sources and grid flexibility that will be needed.[47] A hydrogen strategy for climate leadership should also prioritise efficiency, grid flexibility and circular economy principles to reduce overall energy demand and 'peaks' in usage (see section 4).

Protecting from transition risks

The UK Government has indicated it will pursue a 'twin track' approach of supporting both green and blue hydrogen *"to enable production to be brought forward at the necessary scale during the 2020s, to grow the supply chain and build confidence in the sector",* whilst scaling up green hydrogen which is likely to dominate the global market in the long term.[48]

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[42] National Grid (2020) **Record breaking 2020 becomes greenest year for Britain's electricity**
[43] Bloomberg (2021) **Saudi Arabia plans to rule $700 billion hydrogen market**
[44] Air Liquid (2021) **Storing Hydrogen**
[45] Frontier Economics (2020) **Role of LNG in the energy transition**
[46] Hydrogen Council (2020) **Path to hydrogen competitiveness: A cost perspective**
[47] E3G and Imperial College London (2021) **Offshore win in the North Seas: from ambition to delivery**
[48] UK Parliament (2020) **Ministerial question answered by Kwasi Kwarteng Secretary of State for Business, Energy and Industrial Strategy**

Blue hydrogen presents transition risks and regulatory challenges which the Government must carefully consider. There is growing recognition among academics and experts that fossil-based blue hydrogen will only have a limited role to play in the low carbon transition.[49] Pursuing a 'twin track' approach carries a significant risk of lock-in to high carbon technologies, infrastructure and jobs. Key governance questions will include:

- How to decide upon infrastructure investments, as production sites for green and blue hydrogen do not necessarily coincide and volumes may differ.
- Is a transitionary role for blue hydrogen enough to justify additional costs from CCS and elimination of methane leakages? Who should bear those costs – the polluter or the taxpayer?
- How to ensure incentives and tax structures ensure the smooth transition from one to the other? By when should that switch occur?

Governance mechanisms are needed to avoid a 'lock in' of fossil fuels and ensure a switch away from fossil gas and blue hydrogen, including clear timelines and targets, accountability and transparency mechanisms, and regulations and standards which support the phase-out – for example, through a rising carbon intensity limit. A 'twin track' approach should not divert public funding resource away from the development of green hydrogen the scale and speed needed to get on track to zero emissions, and the Government can commit to ensure all public support for hydrogen development and deployment are focused on green.

Supporting – and not delaying – exit from unabated fossil fuel use

Given the speed of the UK's necessary transformation, fast and focussed deployment of green hydrogen will be key to success. Hydrogen is not expected to get to scale until after 2030, whereas the UK's new Nationally Determined Contribution requires a reduction of emissions by 68% by 2030, compared to 1990 levels.[50] To achieve this, scale and pace need to be achieved this decade for sectors where available decarbonisation pathways already exist.

The ultimate goal of deployment of green hydrogen should be to facilitate the exit from unabated fossil fuels. The CCC's "balanced net-zero" pathway in the sixth Carbon Budget states that by 2033, fossil gas should be phased out in any areas

[49] Fraunhofer Institute for Energy Economics and Energy System Technology (IEE) (2020) **Hydrogen in the Energy System of the Future: Focus on Hydrogen**
[50] UK Government (2020) **The UK's Nationally Determined Contribution under the Paris Agreement**

not designated for low-carbon district heat or hydrogen-conversion areas.[51] Progress with the phase-out of fossil gas in buildings – achievable today through energy efficiency and electrification solutions – cannot be delayed, or carbon budgets risk being exceeded.

Case study: Pipeline dreams – hydrogen for heating

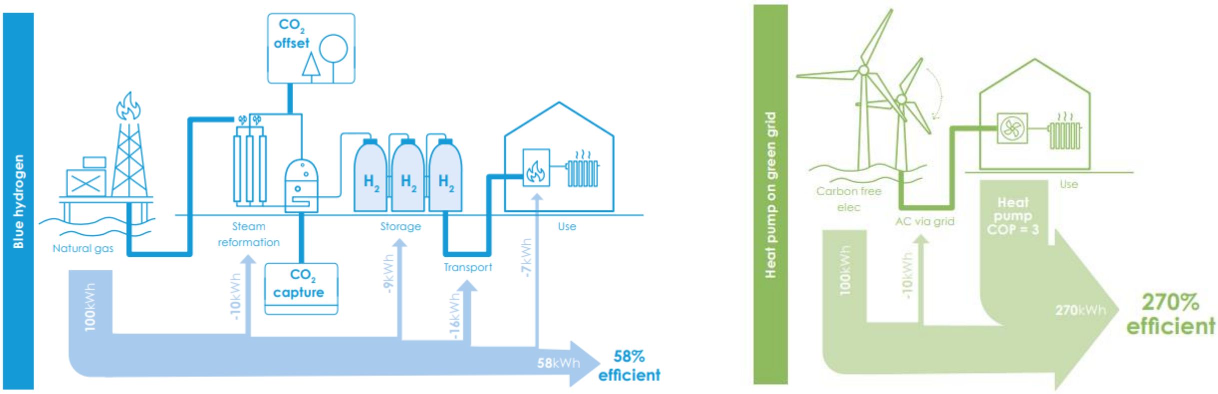
A strategic framework for hydrogen will identify where its development and deployment will add the most value – and where it will not. Claims of widespread applicability of hydrogen within the heating sector are unproven and potentially misleading**.** Analysis for the CCC found that the sunk costs of having an extensive gas grid do not automatically mean that it will be lower cost to switch it over to hydrogen and use it in hydrogen-ready boilers. It also found that the costs of a range of pathways for heat decarbonisation are similar, including those in which the gas grid has a much-reduced role or is decommissioned.[52] Furthermore, full conversion of gas distribution networks to hydrogen would lead to a very high demand for hydrogen by 2050 (470 TWh, even allowing for substantial improvements to energy efficiency), increasing costs for other hydrogen users.[53]

A strong evidence-base backs the claim that hydrogen for heating is not an effective solution for most of the country. Research from the London Energy Transformation Initiative (LETI) shows that hydrogen conversion, delivery and combustion has between a third and one sixth the efficiency of clean heat alternatives such as electrification and heat pumps (see Figure 2).[54] The research added further doubt to the prospects of hydrogen for heating, noting that a national energy grid upgrade – incorporating new infrastructure technology unproven at scale – is a major delivery risk. A study for the German Government found that the amount of green electricity needed to produce green hydrogen is up to 600% greater than needed to power an equivalent number of heat pumps.[55] The CCC's chief executive suggests that 30 times as much offshore wind farm capacity than currently available would be needed to produce enough green hydrogen to replace all UK gas boilers.[56]

While there may be a small role for green hydrogen heating, this will likely be concentrated in industrial clusters that have produced surplus that can be used in local homes.

[51] Climate Change Committee (2020) **Sixth Carbon Budget**
[52] Climate Change Committee (2018) **Hydrogen in a low carbon economy**
[53] Aura Energy (2020) **Hydrogen prices rise sharply without electrifications for heating and transport**
[54] LETI (2021) **Hydrogen A decarbonisation route for heat in buildings?**
[55] Fraunhofer Institute for Energy Economics and Energy System Technology (2020) **Green hydrogen or green electricity for building heating?**
[56] Chris Stark, Chief Executive of the Climate Change Committee, quoted in The Times (2020) **Switching all boilers to hydrogen 'is impractical'**

Figure 2: Efficiency of blue hydrogen for heat vs renewable electrification (images from LETI)



6. A hydrogen strategy that delivers for all

A hydrogen strategy that works for everyone must be cost-efficient for the taxpayer, offer the best option for households – including the most vulnerable – and provide the best boost for green employment and skills. Understanding what that looks like requires a system-wide analysis of the costs and benefits of different decarbonisation pathways, in parallel to society-wide consultation to understand and integrate the concerns of different stakeholders into decision-making.

Good governance and science-based decision making

The Hydrogen Strategy and associated decision-making must be underpinned by robust governance principles and aligned with climate science, if it is to reflect the best long-term interests of the country. Given the likely infrastructure costs – and impact on the public purse –associated with scaling hydrogen development and deployment, this is particularly pertinent.

There is concern that currently the discussion is dominated by those with vested interests in existing high carbon infrastructure. The UK Government's Hydrogen Advisory Council is chaired by Shell, and the membership contains a limited balance of views from across society.[57] A more nuanced discussion on hydrogen is required, with greater transparency on the mandate and selection criteria of bodies close to Government decision-making. Society-wide engagement must be baked into the decision-making process, engaging with trade unions, civil society, consumer interest groups, fuel poverty organisations and many more. This could include the input of citizens climate assemblies, and a new Heat Council to help bring together local and national actors.

Research from Exeter University's Energy Policy Group found that incumbent industry actors with vested interests in fossil fuel heat were "overselling" the idea of converting the UK's existing gas infrastructure to run on hydrogen, detracting from the importance and value of electrification.[58] The research highlights a concern that if the political influence by incumbents affects the policy process and slows down the deployment of known low carbon heat options, the UK's climate change goals are at risk of being missed.

[57] UK Government (2020) **Hydrogen Advisory Council**
[58] Richard Lowes, Bridget Woodman, Jamie Speirs (2020) **Heating in Great Britain: An incumbent discourse coalition resists an electrifying future https://www.sciencedirect.com/science/article/pii/S2210422420300964?via%3Dihub**

As part of an approach which promotes more nuance and transparency, the UK should refrain from classifying blue hydrogen as 'low carbon', as this is misleading given the continued emissions associated with fossil fuel derived hydrogen (see section 5).

Hydrogen and households

The cost implications for households will be ultimately determined by the question of 'who pays' for the costs of transition, and how these are distributed across society. Hydrogen is expected to cost more than natural gas, particularly if the cost of building pipework and appliance conversion is amortised within it.[59] It is estimated that it would cost over £22 billion to transform the entire gas network for hydrogen distribution.[60]

Consumers have flagged concerns associated with price hikes associated with a conversion and safety risks.[61] The small size of hydrogen molecules may increase the chance of leakage, and there are additional risks associated with explosions which are still to be fully understood. Research undertaken for BEIS found that hydrogen has a significantly higher flame speed, greater flammability range and is likely to burn at a higher temperature than natural gas; with further concerns regarding light-back (propagation of flames back through burner), higher NOx emissions and the potential explosion of unburned gas.[62]

Appliances that would need to be replaced with "hydrogen-ready" alternatives include boilers, hobs and ovens, and gas fires.[63] It is also likely that external pipework that delivers the hydrogen to homes and boilers will need to be changed in order to have sufficient energy content, as hydrogen is often compressed and stored under high-pressure. New meters will need to be developed and installed to ensure people are billed correctly, and billing methodologies will also need to change to reflect the energy used in a home. If hydrogen boilers are more efficient operating at lower temperatures, additional changes may be needed, such as installing over-sized radiators or underfloor heating, in addition to a water tank[64] - similar to the changes that might accompany a heat pump installation.

[59] LETI (2021) **Hydrogen A decarbonisation route for heat in buildings?**
[60] Prepared by Element Energy Ltd for the Department for Business, Energy & Industrial Strategy (2018) **Hydrogen supply chain evidence base**
[61] Networks (2019) **Consumers back hydrogen for heating but fear cost hikes**
[62] Frazer-Nash Consultancy Prepared for the Department of Business, Energy & Industrial Strategy (2018) **Appraisal of Domestic Hydrogen Appliances**
[63] Citizens Advice (2020) **Discussion paper Questions about how hydrogen might work for homes in Great Britain**
[64] Citizens Advice (2020) **Discussion paper Questions about how hydrogen might work for homes in Great Britain**

Impact on fuel poverty

The Government is committed to addressing fuel poverty, which currently leaves thousands of people with cold and unhealthy homes, exacerbating unnecessary winter deaths and putting unnecessary pressure on the NHS. The UK's new Fuel Poverty Strategy, *Sustainable Warmth,* reconfirms the Government's commitment to increase the energy efficiency of homes, reduce the cost of bills whilst also contributing to net zero targets.[65] Statistics indicate that over 13% of households in England are in fuel poverty,[66] and the impacts of the pandemic are likely to exacerbate this further.

There is growing evidence that hydrogen for heating will be a highly inefficient option for most of the country (see section 4). There are concerns that hydrogen gas would also, at present rates, be about twice as expensive as natural gas.[67] Instead, new academic research by UKERC finds energy efficiency, heat pumps and district heating comprise the most effective investment pathway for heat decarbonisation for the next 10 years.[68] It is deployment of these measures that E3G recommends the Government must scale within this Parliament, in order to get on track to meet climate and fuel poverty targets.[69]

A just transition for high carbon sectors

For certain high-carbon industries located in industrial clusters, green hydrogen may present a way to support jobs and a just transition in industries such as steel and chemicals. A good example is the steel industry. With 15% of greenhouse gas emissions from British industry produced by the UK steel sector in 2018, decarbonising this sector – which employs 32,000 people directly in Wales and Yorkshire and the Humber, as well as over 40,000 more in wider supply chains – is key for reaching climate targets and making progress on the levelling up agenda.[70] Hydrogen-based steelmaking uses hydrogen instead of coal, both as an energy source and reducing agent, with pilots and demonstration projects underway.

Steel is a vital component of low-carbon infrastructure and manufacturing, demand is expected to grow 10% this decade, creating a £6 billion annual market for low-carbon steel. With unions at the heart of the steel sector, a thriving steel

[65] BEIS (2021) **Sustainable Warmth Protecting Vulnerable Households in England**
[66] BEIS (2021) **Annual Fuel Poverty Statistics**
[67] As quoted in The Times (2020) **Switching all boilers to hydrogen is impractical**
[68] **UKERC (2020) The pathway to net zero heating in the UK**
[69] E3G and Regulatory Assistance Project (2021) **A policy package for a heat pump mass market in the UK**
[70] Common Wealth (2021) **A test of mettle: Securing a future for a green UK steel industry**

industry can support worker voice and good work; underpinning resilient communities which are well positioned to benefit from the zero carbon transition.[71] Green steel production can benefit as the cost of green hydrogen falls. As international trade regimes increasingly favour zero carbon and sustainable production standards, the UK can gain competitive advantage through supporting this sector.

Re-skilling and the future of fossil fuel supply chains

The low carbon transition threatens high carbon industries, including those along the fossil fuel supply chain. Engagements between government, industry, unions and workers are needed to ensure a just transition that supports skills, jobs and retraining for the green technologies of the future – while avoiding potential transition risks associated with blue hydrogen.

A recent survey of 1,383 people employed in North Sea oil and gas investigated their thoughts on climate change, green energy and their industry and its future.[72] In written responses, some workers referenced CCS as a potential decarbonisation route for oil and gas, but predominantly with caveats such as: *"CCS and Hydrogen, with offshore wind to produce clean hydrogen"* or "*CCS technologies exist to some extent but they are still unrealistic to be applied on a large scale. They are too expensive to be justified."* Other key findings of the survey included that 81.7% said they would consider moving to a job outside of the oil and gas industry, and given the option of retraining to work elsewhere in the energy sector, more than half would be interested in renewables and offshore wind.

The discussion on jobs is particularly prominent in the debate around the decarbonisation of heat, with 'hydrogen ready' boilers seen as less disruptive for the industry. The costs of infrastructure transformation of gas networks, as well as the likelihood that green hydrogen production and deployment will be localised in clusters, means that hydrogen for heat is not a simple switch for most of the country or for most employees in the gas sector. Instead, the mass roll out of heat pumps is estimated to require up-skilling around 100,000 domestic gas and oil engineers to fit them, requiring a mass scaling-up of skills and supply chains. Organisations like the Heat Pump Association[73] and NIBE Energy Systems[74] are working on schemes to simplify the process for training and upskilling installers to introduce heat pumps, getting more people on track to meet the needs of a zero

[71] Common Wealth (2021) **A test of mettle: Securing a future for a green UK steel industry**
[72] Platform (2020) **Oil & Gas workers report**
[73] PHPI (2020) **Heat Pump Association launches Training Strategy**
[74] H&V News (2021) **NIBE rethinks heat pump training to tackle industry's skills shortage fears**

emissions economy. There is an opportunity for the Government to support these initiatives as part of its ambitions for a green recovery, such as through training programmes such as the Lifetime Skills Guarantee and Green Homes Grant skills training competition.[75]

A focus on green hydrogen, and the parallel need to scale up North Seas offshore wind, offers another large boost for green jobs. The offshore wind sector employed around 10,000 people in 2018 in a broad supply chain that involves companies across the UK.[76] This can be expected to increase significantly if growth aspirations from the sector are fulfilled. There is a concentration of companies in localities previously dependent on fossil fuels that supply the offshore wind industry. These include clusters exist in Teesside and the East Anglia coastal regions in England, and Aberdeen Bay and the Firth of Forth in Scotland. These are key regions for the existing offshore oil and gas industry and new jobs supporting offshore wind deployment will help boost local economies as demand for fossil fuels declines. The UK's low carbon sector already supports more jobs than the oil and gas industry, employing more than 430,000 people in 2018[77] compared to 259,000 jobs in oil and gas.[78]

[75] UK Government (2020) **Green Homes Grant skills training competition**
[76] 3 ECITB (2019) **Industry 4.0: The impact of technological change on the Engineering Construction Industry** p.33
[77] BEIS (2019) **Industrial Strategy: Offshore Wind Sector Deal**
[78] Oil and Gas UK (2019) **Workforce Report 2019**v

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7. Conclusion

In order to realise the positive benefits that hydrogen can offer for climate targets, jobs and levelling up, the UK Government should focus on green hydrogen development – wherein the greatest gains in the international innovation race can be reaped. A 'twin track' approach that pursues both green and fossil-based, blue hydrogen risks a lock-in of high carbon technologies and infrastructure. Instead, the UK's competitive advantage lies with its offshore wind potential, which can support green hydrogen development and deployment in key industrial clusters and hubs. A system-wide stock take is required to identify where green hydrogen does – and does not – add value and provides the most cost-effective route for decarbonisation.

This paper has considered the key factors that should underpin BEIS's forthcoming Hydrogen Strategy, and presented evidence to inform a strategic vision that supports key Government priorities – including an inclusive and resilient economic recovery from the pandemic; demonstrating climate leadership and progressing towards emission reduction targets; and reducing regional inequalities through the 'levelling up' agenda. Key recommendations are summarised below.

A hydrogen strategy for an inclusive and resilient economic recovery

There is role for zero emissions green hydrogen to support competitive industrial clusters, located across the country to support the 'levelling up' agenda, with successful delivery strongly dependent on a rapid upscaling of renewable electricity generation and efficiency gains to reduce overall energy demand. To take this opportunity, green hydrogen must be strategically developed and deployed in sectors and regions where it adds most value, i.e. where other decarbonisation pathways are not currently available.

- We recommend that the Government focuses on deployment of **green hydrogen within sectors that do not have alternative decarbonisation options.** This should be enshrined in the forthcoming Strategy through ensuring targets focus on green, and underpinned by a supportive policy framework, principles, regulations, and incentives.
- It is essential that the Government clarifies **its focus in terms of production and end-use in the Hydrogen Strategy**, to ensure a cost-effective use of public funding, in line with a zero emissions pathway. A fair, market-led innovation race can be supported; while the Government focuses support where it adds most value for climate and jobs. This requires a systems

approach to identifying regions and sectors where support is targeted, which is then reflected in policy and funding prioritisation.

A hydrogen strategy for climate leadership

The UK's competitive advantage can be secured if it chooses a green hydrogen path, sourced through harnessing the full potential of the country's offshore wind resources. Blue, fossil-derived hydrogen depends on continued imports of fossil gas, whereas a focus on green can be supported through the UK's enormous offshore wind potential.

Fossil hydrogen with Carbon Capture and Storage (CCS) – blue hydrogen – is not zero emissions, due to limitations of CCS, and methane leakages during gas production and transportation. Developing blue hydrogen does not accelerate development of green hydrogen on the supply side, since these are fundamentally different technologies. Governance mechanisms are needed to avoid a 'lock in' of fossil-derived fuels, with clear timelines and targets, accountability mechanisms, and regulations and standards which support the phase-out – for example, through a rising carbon intensity limit.

Rather than a 'twin track' approach, the UK should focus on pursuing green. Doubling down on green hydrogen could play a significant role in addressing the next generation of deep climate challenges – including the decarbonisation of industry, freight and balancing the electricity system.

- **The UK should show leadership on green hydrogen ahead of COP 26,** in parallel to seeking rapid growth in renewable energy. This could be demonstrated through setting targets and legal requirements around the relative levels of green and blue hydrogen, and committing that public funding only goes towards supporting the development and deployment of green hydrogen. This will allow the UK to play an international leadership role on climate innovation, as other countries race to develop sustainable hydrogen solutions. In particular, the success of scaling green hydrogen will rely on the buildout of offshore wind, with a need for a joined-up approach between Government departments and teams working on different parts of the energy transition.

- **The success and scalability of green hydrogen are closely tied to rapid progress on efficiency and renewable energy** needed for sourcing zero emissions green hydrogen. The UK must focus on securing the full potential of offshore wind, in parallel to making broader strides on renewables, grid flexibility, energy efficiency, and circular economy – all measures which support lower cost pathways to decarbonisation. These have strong social, economic and environmental co-benefits, and should be central pillars of all decarbonisation strategies.

A hydrogen strategy that delivers for all

Understanding how and where hydrogen can most add value requires a system-wide analysis of the costs and benefits of different decarbonisation pathways, understanding which ones are most cost-efficient for the taxpayer, which offer the best option for consumers – including the most vulnerable – and which provide the best boost for green employment and skills.

For example, a growing evidence base suggests that hydrogen does not present a strategically credible option to decarbonise heat,[79] and could lead to higher bills.[80] Instead, to get on track for net zero heating, a sustained effort must be made this decade to deploy heat pumps in a way that make the most of the inherent cost advantages and improve people's lives. In light of the evolving science and potential conflicts of interest of market players, rigorous and independent analysis and systems governance must be ensured.

- **The Government must ensure its decisions on hydrogen are rooted in independent science and evidence.** Government discussions should not conflate blue and green hydrogen and should stop using ambiguous terms like 'low carbon' hydrogen. The Government must consult widely – and not just with industry – when developing its Hydrogen Strategy, and in the decision-making processes that follow, including by expanding the membership of the Hydrogen Advisory Council.

- **Decision-making on hydrogen must consider and consult citizens – in particular the most vulnerable workers and households** to ensure the approach works for everyone and can gain public acceptability. Where deployment of hydrogen is likely to increase costs for households compared to other decarbonisation avenues – such as with heating – consumers should be enabled to choose alternatives.

[79] UKERC (2020) **The pathway to net zero heating in the UK**
[80] As quoted in The Times, (2020) **Switching all boilers to hydrogen is impractical**

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- **The Hydrogen Strategy must be accompanied by a robust jobs and skills agenda** which involves and is shaped by workers and their unions. The Government must act to ensure that jobs that are retained and created by hydrogen development are well paid and of high quality, as well as guaranteeing a 'just transition' for workers who may be negatively impacted by a decline in fossil fuel infrastructure and supply chains.

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About E3G

E3G is an independent climate change think tank accelerating the transition to a climate-safe world. E3G builds cross-sectoral coalitions to achieve carefully defined outcomes, chosen for their capacity to leverage change. E3G works closely with like-minded partners in government, politics, business, civil society, science, the media, public interest foundations and elsewhere.

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