Green Growth

The Opportunity of an Accelerated Green Hydrogen Economy

October 2023

GREEN HYDROGEN ALLIANCE

Contents

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Executive summary

A robust low carbon hydrogen economy is key to the UK's energy security and Net Zero targets. The UK government has an ambition to produce 10GW of low carbon hydrogen, of which half will be green hydrogen, produced solely from renewable sources.

Green hydrogen will be key to the future of the industrial and mobility sectors, particularly within hard-to-abate industries, heavy-duty transport, and aviation, yet will need to grow one hundred times from today's levels to meet the Government's 2030 target. It is therefore imperative that the UK has a robust and holistic policy and regulatory environment which permits deployment at the scale and speed necessary to achieve its stated ambitions.

Green hydrogen supports the Government's wider policy priorities in five main ways:

- **Net Zero:** The development of low carbon fuel alternatives for transport and industry is an indispensable component of the Government's 2050 Net Zero aspirations.
- **Energy Security:** It would enable the rapid development of a baseline supply of renewable hydrogen, which would greatly diversify the UK's energy sources and thereby strengthen energy security and systems resilience.
- **Hydrogen Strategy**: It supports catalysing the UK Hydrogen market, which has yet to be established, to reach the 10GW target by 2030. This will probably require pump-priming both hydrogen supply and demand, necessary to give the UK overall a 'first mover' advantage in the emerging global hydrogen market.
- **Global Britain:** It develops the UK's port facilities and infrastructure in a way that ultimately positions it not as an importer of green ammonia, but ultimately as an exporter of green hydrogen, with ammonia imports merely part of a transition.
- **Levelling Up:** It contributes to UK congregations of hydrogen production i.e. agglomeration to bolster productivity through the supply side, including at Freeports.

In order to achieve these ambitions, this report offers a potential scenario whereby the initial development of a green hydrogen market is accelerated via importing renewable fuels to provide the feedstock for green hydrogen production. As there is not yet the requisite renewable energy infrastructure in the UK to support demand for green hydrogen, this report proposes the development of 3 green hydrogen production facilities generating 900MW of green hydrogen per annum. This would not counteract the growth of a domestic hydrogen sector, but rather provide a guaranteed supply, which would provide the investment certainty required for domestic firms to develop further production infrastructure.

Our modelling identifies **nearly £11 billion of socio-economic benefits**, spread over 30 years, to be gained from this scenario. Much of this social-economic benefit, £10 billion, is from reduced carbon dioxide emissions of over 1.7 million tonnes per year, making a significant contribution towards the UK's Net Zero targets.

There are significant further benefits including over £1.5 billion from reduced local air pollution and £500 million in redistributional (levelling up) benefits. The investment would create demand for 4,400 workers during project construction and 3,700 further jobs once the hydrogen production plants and distribution networks are operational. The hydrogen produced has the potential to remove 60,000 diesel HGVs from our roads.

These outcomes require significant policy interventions to 'pump-prime' a domestic green hydrogen market as soon as possible.

The Green Hydrogen Alliance's immediate policy recommendations are to:

- Allow a 'level playing field' for renewable feedstock imports to boost the UK's green hydrogen economy in the short-term.
- Attract capital by making the UK green hydrogen policy environment a more investable proposition.
- Streamline planning permission for renewable hydrogen production sites, classifying them as critical national infrastructure and making them eligible for capital subsidies.
- Begin work with industry to develop a roadmap for green hydrogen distribution networks of depots, refuelling stations and delivery networks branching out from production and import sites.
- Incentivise R&D into green hydrogen technologies to help spur innovation and drive down costs across the green hydrogen value chain and help to kickstart a domestically resilient market.

CHAPTER 1

Introduction

1.1 What is green hydrogen

Green hydrogen is hydrogen produced from 100% renewable energy, either via a process of electrolysis (the splitting of water molecules into hydrogen and oxygen), or by extracting hydrogen from renewable ammonia.

Green hydrogen can be used as a fuel for sectors that are difficult to electrify, including long distance and heavy-duty transport; in industrial processes and as a chemical feedstock. It can also be used as a storage fuel, converting excess renewable energy into hydrogen which can be stored in liquid or gas form, and deployed for use in fuel cells in times of high demand.

Hydrogen is not a new fuel - it is already produced and used in the UK, with total current demand representing 518,291 metric tonnes per year. To put this into perspective, this volume of hydrogen would fuel roughly 57 million long haul trucks to travel 100km.[1] However, most hydrogen production in the UK today tends to be carbon intensive, produced through carbon capture and storage methods (CCUS), usually on-site as part of an industrial process.[2] If all hydrogen produced was blue hydrogen via CCUS, UK hydrogen demand would result in up to 8m tonnes of CO2 emissions annually from the late 2020s, which would represent the equivalent of an average of 1.5m more fossil-fuel cars on UK roads by 2050.[3,4]

BOX 1: Green hydrogen production, storage and transport – the process

1. **Renewable energy generation** – Renewable fuels including solar, wind or hydroelectric power are used to generate renewable electricity. Renewable fuels such as ammonia can also be used as a base for hydrogen production.
2. **Electrolysis** – This electricity is used to power an electrolyser, which separates water into hydrogen and oxygen.
3. **Storage** – Hydrogen produced through electrolysis can be reacted to form suitable energy storage chemicals or hydrogen carriers which are more stable and more compact than gaseous hydrogen, and therefore able to be transported more easily.
4. **Usage** - hydrogen can be used in either liquid or gaseous form, piped in to existing gas grid infrastructure or employed to power fuel cells. Alternatively, the more stable hydrogen carriers can be safely transported around the world by sea, and provide a major export opportunity for the UK in the years ahead.

1.2 Why green specifically?

Following Russia's invasion of Ukraine in February 2022, the security of energy supply has become a central priority for the Government. Soaring fuel prices have highlighted the urgency of developing renewable fuels including hydrogen as an alternative energy source to oil and gas, providing greater national resilience against external supply shocks. Unlike other low-carbon forms of hydrogen, green hydrogen is not reliant on continuing fossil fuel production to

provide a fuel source, which itself seems antithetical to the wholehearted pursuit of a renewable energy mix. Furthermore, the recent House of Commons Science and Technology Committee report into the role of hydrogen in achieving Net Zero notes concerns around the large-scale use of blue hydrogen, given that CCUS technologies have yet to be proven at scale, and could come onstream much later than 2025.[5]

Currently, only around 4% of the 70 million tonnes of hydrogen produced globally each year are green, which is likely a factor of high production costs in the development of electrolysers, and complexity in production and transportation. However, having recognised the significant potential of green hydrogen in decarbonising some of the most energy-intensive sectors, the rapid development of a mass electrolyser market is bringing down costs significantly, and green hydrogen production looks likely to become cost competitive with blue hydrogen before the 2030s.[6]

That said, measures must be put in place now to incubate and build a fledgling green hydrogen market, to ensure that the requisite infrastructure is in place to enable us to meet these targets by 2050 and beyond. An entirely new energy market will not simply emerge overnight - it must be given time to develop, trialling new technologies and applications which can then be replicated at scale. If infrastructure is not built in the immediate term to support the production of green hydrogen in the UK, we are unlikely to meet the Hydrogen Strategy's ambitious targets, and risk missing out on the significant economic, environmental and strategic benefits that a thriving green hydrogen market could bring to the UK.

1.3 What is the opportunity for the UK?

This is precisely why the Green Hydrogen Alliance has come together, to ensure that the UK's green hydrogen economy is not left to chance whilst the Government focuses on more immediate priorities. We aim to demonstrate the commercial viability of a green hydrogen market in the UK, and shed light on the significant benefits that this could bring in supporting the UK's economic, energy security and Net Zero ambitions.

There are major opportunities for the UK:

- to become a global leader in decarbonisation;
- to develop system resilience and energy security through diversifying renewable hydrogen sources and routes;
- to develop a comparative advantage internationally as a renewable hydrogen producer;
- to develop more competitive energy costs resulting in lower energy bills for consumers and businesses;
- to grow key regional economic areas and become a net exporter of green hydrogen and associated technologies.

This paper will outline the opportunity of green hydrogen to the UK, making the case for an acceleration of current policy if the existing targets in the 2021 Hydrogen Strategy are to remain within reach.

CHAPTER 2

Moving to a UK hydrogen economy

2.1 Current policy

In its UK Hydrogen Strategy published in 2021, the UK Government signalled an ambition to become a "global leader" in hydrogen by 2030. This sets out a vision for the UK not only developing a domestic hydrogen economy, but to become an exporter of both hydrogen and associated technology.[7]

Analysis in the Hydrogen Strategy indicated that low carbon hydrogen may comprise 20–35 per cent of the UK's final energy consumption in 2050, and it is this potential that the Green Hydrogen Alliance seeks to recognise and ensure that the UK is best placed to maximise the benefits arising from this new fuel source.[8]

The UK's Hydrogen Strategy outlined a target for 5GW of low carbon hydrogen production capacity in the UK by 2030. This has since been doubled, to target 10GW of low-carbon hydrogen production, 5GW of which should be electrolytic (green) hydrogen. The strategy outlines that meeting the 5GW ambition would mean the creation of a thriving new hydrogen industry, supporting 9,000 jobs and £900 million of GVA by 2030. The Government's investment in hydrogen could provide further opportunities for businesses, with the potential to unlock over £4 billion of private sector co-investment up to 2030. Under a high hydrogen scenario, up to 100,000 jobs and £13 billion of GVA could be generated from the UK hydrogen economy by 2050.

There is clear political consensus behind green hydrogen's potential to support the UK economy and help the UK reach Net Zero. Green hydrogen is integral to one of Labour's Five Missions, to make the UK a clean energy superpower by delivering a zero-carbon energy system by 2030.[9] To achieve this mission, Labour has stated it will double the government's target on green hydrogen, with 10 GW of production for use particularly in flexible power generation, storage, and heavy industries. This new target will be funded by a 'National Wealth Fund', with the aim to create well-paying jobs by investing alongside the private sector in green hydrogen, gigafactories, heavy industry, renewable-ready ports and energy storage.

2.2 Green hydrogen's potential

The United Kingdom has significant geographical and economic potential in both the production and application of specifically *green* hydrogen technologies. The natural resources available in the form of wind and tidal energy are plentiful and can supply clean energy connected directly to local production plants, bypassing the need for grid connectivity, while the prevalence of natural salt caverns, which are currently utilised for natural gas storage, can be reappropriated for storing gaseous hydrogen. If capitalised on, these innate strengths have the potential to propel the UK to becoming a world leader in this industry, and in time, generate significant export potential, bringing sustained growth to the UK economy.

Renewable hydrogen has many potential advantages for the UK's national priorities, including:

Energy security

In the wake of the Ukraine invasion and its impact on global energy prices, governments around the world have prioritised a secure domestic energy supply. The UK is no exception, with the newly reconstituted Department for Energy Security and Net Zero encouraging moves away from imported natural gas, and towards a ramping up of domestic oil and gas production alongside renewable sources of energy.[10] There are a number of projects in the pipeline to produce green hydrogen domestically, from domestically-captured renewable energy, which removes any concerns around energy security.

Energy resilience

Hydrogen also demonstrates significant potential as a storage fuel, which could be used to plug gaps in renewable energy supply - when the wind is not blowing and the sun is not shining. Hydrogen is able to be stored for long periods relatively easily, so the development of hydrogen production would enable the UK to develop a ready cache of carbon neutral energy, to support both day-to-day energy resilience and in times of crisis.

The ability to store excesses of renewable energy means that infrastructure such as offshore wind farms can operate at full capacity, including overnight, providing even greater ROI on existing infrastructure investments as well as new projects.

This is one of the most promising long-term applications of hydrogen identified by the Secretary of State for Energy Security and Net Zero, enabling excess renewable energy to be stored and then released at times of peak demand.[11]

Energy costs

Diversifying sources and routes of renewable hydrogen help deliver more competitive costs, resulting in lower energy bills for consumers and businesses. Even before the Ukraine war, the industrial price of energy in the UK tripled between 2004 and 2021.[12] Lowering energy costs would therefore not only benefit the public facing cost-of-living pressures, but would also generally support economic growth across the country.

International comparative advantages

The UK already has a headstart in the requisite infrastructure to produce renewable fuels. In 2022, renewables generated a record 40% of the UK's electricity, with plans in place to reach over 50GW of offshore wind capacity by 2030. If these targets are met, this is a strong indication that in combination with existing power sources, the UK could be generating excess renewable electricity from 2030, which could be used in localised networks for the production of green hydrogen.

Already with a strong oil and gas sector, the UK is home to a skilled energy labour force, who can be retrained to support the hydrogen sector, as hydrocarbon production winds down.

Another boost to its fledgling hydrogen industry is the UK's world leading research and development capabilities and industrial clusters, derived from our world class universities. The UK is a global leader in the development of fuel cell technologies, and it is precisely this ingenuity that we should be seeking to capitalise on and develop into a successful leading industry.

Infrastructure challenges

This is not an outcome to be taken for granted, however. In 2018, the Climate Change Committee warned that "producing hydrogen in bulk from electrolysis [...] would entail extremely challenging build rates for zero-carbon electricity generation capacity".[13] Industry stakeholders such as EnergyUK have since warned that the UK is heading for an investment hiatus in renewable infrastructure, with inflation, high interest rates, supply chain difficulties and ongoing political and regulatory uncertainty causing some projects to be paused or relocated overseas.[14]

Overall costs for renewable energy projects have increased by up to 30%, with some developers reporting cost increases of up to 50% for specific projects. If these economic headwinds remain unaddressed, EnergyUK has calculated that this could result in a shortfall of 54GW of wind and solar energy generation - a capacity that could deliver generation each year to cover the current annual energy usage of every UK household.[15] Research from Oxford Economics has found that electricity output from renewables and nuclear power is set to grow by an average of 2.9% between 2023 and 2030 - the slowest rate among the G8 economies.[16]

It is clear that greater investment guarantees are required at all stages of the supply chain in order to maintain a strong renewable sector which has the potential to support low carbon hydrogen production, and is capable of maintaining its strategic advantage in an increasingly competitive global economic climate.

Economic stimulation

Many of our leading hydrogen industrial-research clusters, including in Teesside and South Wales, are situated in Category 1 Levelling Up areas - designated by the Government as areas most in need of investment. Many of these fall in the UK's former industrial heartlands, which have declined in recent years as flagship industries have relocated overseas. The development of hydrogen clusters therefore offers a route to revitalising these areas of the UK, drawing on the strengths of their industrial heritage to provide skilled workers and proximal offtakers for green hydrogen fuels. Supporting these areas to facilitate the green transition would also bring much needed socioeconomic benefits, including highly-skilled jobs, improved local infrastructure and investment in local services. In this way, a thriving green hydrogen economy would not only support the Government's environmental and energy security ambitions, but would also provide exciting opportunities for communities across the UK.

The UK's geography is also uniquely favourable to supporting a nascent hydrogen market. The prevalence of short-haul domestic travel routes, including in aviation and road haulage as two of the highest potential transport modes for green hydrogen specifically, makes the UK an ideal target market for early-stage trials of green hydrogen, which can be concentrated around smaller regional clusters. The small size of the UK relative to other developed hydrogen markets such as the USA or Germany, removes barriers within harder-to-abate sectors and facilitates distribution networks which can feasibly serve the whole of the UK.

Export potential

In time, these strengths can be developed to support a thriving export-based economy - not only of the final product of hydrogen fuels, but of technical equipment, expertise and highly skilled workers and companies who can help to develop global hydrogen supply chains, representing significant economic value-add to the UK. According to the UK's Hydrogen Strategy, around a quarter of UK jobs in the hydrogen sector, and around 30 per cent of economic opportunity could be driven by exports by 2030.[17]

2.3 Sector applications

Heavy industry

A widely recognised application of green hydrogen will be in decarbonising hard-to-abate sectors such as heavy industry. The International Energy Agency has noted global growth in industrial hydrogen use year on year. It further notes that *'There has been no significant progress in production of hydrogen from electrolysis [since 2022] with only three relatively small projects coming online in 2023"* indicating the major opportunity that the UK has to take a competitive approach.[18] Indeed, the UK's own Second National Infrastructure Assessment published this month identified industrial hubs such as Humberside and South Wales as key priorities for the country to develop a core hydrogen network.[19] The UK already funds innovation and deployment of industrial applications of hydrogen, but should go further.[20]

Aviation

Aviation will be a major demand sector for hydrogen in the coming decades. The EU's Clean Sky 2 report suggests that by 2050 the annual liquid hydrogen requirements of the average regional airport could be around 0.75 TWh, with larger hub airport possibly needing ten times that at 7.5 TWh - a significant demand when considered against the report's estimate of 75-140 TWh total demand from all other transport modes.[21]

Last year, a Project Napkin - a UK aviation consortium consisting of three airports, three manufacturers and three academic institutions and supported by Deloitte - published the most comprehensive study to date on the potential of a carbon free future for UK domestic aviation by 2040. It found that the Government's 'Jet Zero' 2040 target was achievable, but only by accelerating the supply of green hydrogen. It further found that developing distribution networks and airport's infrastructure requirements alongside upscaling supply would be crucial to deliver on this target.[22]

Case study: Airbus

Airbus is strengthening its UK research through the ZEROe Development Centre (ZEDC) for hydrogen technologies. A priority will be the development of a cost-competitive cryogenic fuel system required for the successful entry-into-service of Airbus' ZEROe passenger aircraft by 2035 and to accelerate UK skills and know-how on hydrogen-propulsion technologies.

End-to-end fuel systems development, a speciality of Airbus in the UK, is one of the most complex technologies crucial to the performance of a future hydrogen aircraft.

The ZEDC complements Airbus' existing Research and Technology footprint in the UK, as well as the work on cryogenic liquid hydrogen tanks being done at Airbus' existing ZEDCs in Madrid, Spain and Stade, Germany (composite structure technologies) and in Nantes, France and Bremen, Germany
(metallic structural technologies).

This facility will boost Britain's world-leading aerospace ecosystem, as Airbus working with the Jet Zero Council to drive forward research in the sector.

CHAPTER 3

The challenge: current policy will not deliver fast enough

3.1 Current trajectory

At the current pace of development, the UK Government's target to reach 10GW of low-carbon hydrogen production by 2030, of which 5GW is comprised of green hydrogen, seems out of reach.

This is not just the view of the Green Hydrogen Alliance and its industry members: independent analysis by Ember concludes that "full hydrogen generation is now ready, but deploying it will require government support and a source of green hydrogen".[23]

In August 2023, the 'Powering Up Britain' plan shortlisted 17 green hydrogen projects that would potentially be eligible for funding under the first hydrogen funding allocation round (HAR1), and could therefore become operational by 2025 - the first tranche of projects to contribute to that 5GW production target.[24]

In a climate of steadily increasing borrowing costs and rampant inflation, a number of larger electrolyser projects have since withdrawn from this funding round. The green hydrogen projects that have moved forward to negotiations comprise a collective production capacity of just 262MW, with the Government's stated aim to have 250MW of electrolytic hydrogen in production by 2025.[22] Even if the current scaled-back infrastructure were to be delivered, the speed and scale of escalation from 250MW to 5GW capacity in just 5 years would require a significant ramping up of direct investment, Government financial backing and planning approval for new projects. Illustratively, if 250MW of projects were awarded in Q4 of 2023, then it would take a 45% p.a. growth rate in awards in the subsequent annual rounds to get to the targeted 5GW green hydrogen production capacity by 2030.

The National Grid's 2023 Future Energy Scenarios acknowledge a similar shortfall in renewable supply, and the knock-on implications on the UK's nascent hydrogen economy. If we continue to miss targets and use National Grid projection, just 14Twh of Hydrogen would be required annually. If, however, we facilitate a supply side transformation to meet Net Zero commitments, 446Twh of hydrogen would be demanded in comparison. This is a 32x increase and indicates the significant potential that hydrogen has in decarbonising the UK's energy supply.

The current shortfall in renewable energy is already making the Government's ambition for a solely domestic hydrogen market unlikely in the short-term. Developing electrolysers at scale requires significant capital and with currently no guarantees of renewable electricity to power them, there is little incentive for firms to invest.

This gives rise to a 'chicken and egg' scenario, as without a consistent supply of renewable energy from which to produce green hydrogen, there is also little incentive to commit to hydrogen-based solutions to meet our Net Zero pledges and decarbonise crucial sectors such as transport and energy-intensive industries.

The primary funding mechanism for supporting UK hydrogen production, the Hydrogen Production Business Model, actively excludes any kind of imported renewable energy or feedstock for hydrogen production, maintaining that every element of the production process must be carried out in the UK.

However, the independent Climate Change Committee, who advise the Government on progress towards its Net Zero targets, concluded that "it appears unlikely that all [UK] hydrogen demand in 2035 can be met from domestic non-fossil fuel production, **on the basis of current Government commitments**." More favourable subsidy regimes have begun to spring up across our closest competitors, as governments across the world are beginning to recognise the economic and strategic gains available to them from being among the first to support a full green transition.

A continuation of current policy will therefore simply not deliver the requisite infrastructure for the UK to meet the 5GW target, nor to fully capitalise on the huge potential that a burgeoning green hydrogen economy could bring - including energy security, resilience and lower costs.

The additional value and benefits that we identify in the next chapter are framed against this base case, that on current policy trajectories, the UK will simply not deliver a green hydrogen market to match its stated targets.

The reality that renewable energy imports will be essential to kick-starting the global hydrogen market is becoming apparent; indeed, the EU has set target levels of 10 million tonnes of imported renewable hydrogen by 2030.[25] Independent analysis from the World Energy Council and PwC indicates that the UK is likely to be somewhat dependent on imports of green hydrogen by 2040, based on the Government's current hydrogen strategy. On a scale of 1 to 5, where 5 is an economy wholly dependent on imports of green hydrogen, the UK is currently ranked at a 4.[26] The most recent National Grid Future Energy Scenarios analysis also estimates that approximately 32 TWh of the UK's hydrogen would be imported by 2050, under the "Leading the Way" scenario.[27]

BOX 2: Barriers to hydrogen market expansion in the UK

The low carbon hydrogen market in the UK is at an early stage, and there are a number of strategic challenges that must be overcome in order for it to grow.

- **High production costs:** Low carbon hydrogen is currently much more expensive to produce than primary energy, but innovation and the introduction of new technologies are expected to reduce costs significantly.
- **Policy uncertainty:** The industry is looking to Government to provide support, incentives, and assurance of quality within the hydrogen market.
- **Technological uncertainty:** The technology required for hydrogen production and distribution is relatively mature. For low carbon hydrogen, the challenges are primarily ones of scale-up, adding significant risk for investors.
- **Planning timelines:** The infrastructure required to deliver on the Government's ambitions requires long lead-in times, and current planning regulation needs streamlining to get 'spades in the ground' as early as possible.

3.2 Demand

By 2050, the Government forecasts that between 250TWh to 460TWh of hydrogen will be needed, excluding imports.[28] With between 5 and 50% of this being green hydrogen, the central point of this range would see the need for approximately 26GW of green hydrogen production by 2050. [29]

The European Hydrogen Backbone study also gives an overview of expected industrial hydrogen demand per country, by 2030, 2040 and 2050.[30] **Figure 1** below shows the anticipated demand for hydrogen in the UK across various sectors, expressed in tonnes/day.

Figure 1 - Anticipated hydrogen demand in the UK (tonnes/day)

	Transport	Steel	SAF+HVC	Ammonia (NH3)	Ind Heat	Power	Grand total
2030	197	112	1,459	116	348	164	**2,396**
2040	1,337	235	4,120	619	1,018	4,592	**11,921**
2050	3,009	414	5,742	774	1,342	8,692	**19,974**

These figures, and the Government's own estimations, demonstrate that there is significant latent demand for green hydrogen within the UK economy as soon as 2030. If met, this could enable the UK to pioneer hydrogen-powered transport and industrial decarbonisation processes that could bring significant economic benefits to distinct regions of the country. The current supply of hydrogen to the UK market is 1,968 tonnes per day for all industries.[31] This means that by 2030, an additional 400 tonnes per day of supply would be required in order to meet this latent demand, at a minimum.

CHAPTER 4

A potential new approach

We modelled the development of production capacity for 900MW of green hydrogen based on three 300MW production facilities across the UK. These are:

1. **Humber Estuary** - where there are current plans to locate a green hydrogen facility;
2. **Thames Estuary** - an ideal location to serve domestic aviation, as well as other decarbonisation applications, with major local population benefits such as cutting air pollution;
3. **South Wales** - where heavy industries and downstream users such as construction can be decarbonised.

The hydrogen produced and distributed in these three projects will be principally for use in **heavy transport**, namely heavy goods vehicles (HGVs), **heavy industry** as well as, prospectively, commercial passenger aircraft as the next generation of aviation fuels following **Sustainable Aviation Fuels** (SAF).

Economic analysis illustrates that the combination of the three facilities would deliver 900MW of green hydrogen electrolysis capacity in the UK, capable of producing 18% of the Government's 2030 target. In addition to the environmental and economic benefits outlined in Figure 2 below, a tried and tested hydrogen production plant could also act as a blueprint and would be replicable in other parts of the UK, helping to support scaling up the UK's green hydrogen production capacity.

As previously indicated in this paper, the UK currently lacks the sufficient renewable infrastructure to deliver the electricity necessary for large scale green hydrogen production through electrolysis. As a result these first facilities will produce green hydrogen from ammonia at the Port of Tilbury in the Thames Estuary, a facility in South Wales, and Port of Immingham in the Humber Estuary. Each will have their own local hydrogen distribution network infrastructure. This will develop the UK's port facilities and infrastructure in a way that ultimately positions the UK as an exporter of green hydrogen, with ammonia imports just an initial cog in the pathway to becoming a global green hydrogen leader.

4.1 National benefits

Figure 2: The effect of 3 unique and strategic green hydrogen production facilities

Construction Phase 2025–2032	Operational Stage 2033 onwards	Environmental Benefits	Monetised Benefits over 30 years
4,374 workers employed in construction of the 3 facilities	**3,699** workers employed by facilities and distribution networks from 2033	The production benefits would equate to the equivalent of **60,000 diesel HGVs** taken off the roads	National CO2 reductions equal to **£9.9 Billion**
£382 million additional GVA would be generated every year during construction	**£532 million** GVA would be created annually after operations begin	In total, 1,734,000 Metric Tonnes of CO2 emissions would be cut per annum	Local air pollution reductions = **£490 million**
			Local redistribution Benefits (levelling up) = **£480 million**
			Total = **£10.8 Billion (NPV)**

Figure 2 (above) demonstrates the significant boosts that these sites would bring to the local labour market, economic growth and the environment, generating **£10.8 Billion** of monetised gains for the UK over 30 years. As a result, these production sites would help contribute not only to British decarbonisation but towards the levelling-up agenda and to strong and sustainable growth.

Looking purely at environmental benefits, it is estimated that the green ammonia to hydrogen production plants would deliver an annual reduction of over 1.7million Mt CO2 by 2033.

Figure 3: Green ammonia to hydrogen production plant, projected energy output, 2025-2033+

Year	2028	2029	2030	2031	2032	2033+
Output (MW)	300	420	540	660	780	900
CO2 saving (Mt)	578k	809k	1,040k	1,272k	1,503k	1,734k

In addition to economic benefits, fuel switching from diesel HGVs and coal-based production methods for industry brings significant environmental benefits in reducing local air pollution. Monetising the socio-economic benefit of this entails the use of 'air quality activity costs' published by the former BEIS department, which are evidence-based estimates of the cost in terms of reduced air quality of using different fuels such as combusting diesel in HGVs and burning coal.[32]

Figure 4: place lifetime monetised economic benefit of reduced air pollution, £ million (2023 money)*

Fuel switching in:	Thames Estuary, East, Southeast, London	Severn Sea, South Wales	Humber Estuary, Yorkshire & the Humber
HGVs	261	104	126
Total	260	1,145	125

*based on 30-year asset lifetime

4.2 Regional breakdown

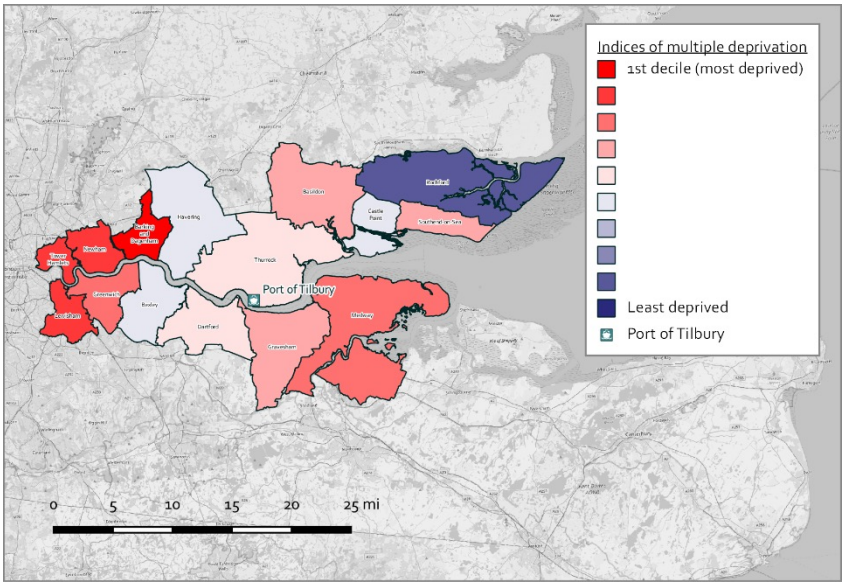
In what follows, a HM Treasury Green Book 'place-based approach' is applied to the hypothetical investments in the three local areas to ascertain local benefits.

Our modelling supports 'superplace' agglomerations of green hydrogen production in the UK, based around its Freeports. This, in turn, will create high productivity jobs in some of the areas most in need of investment across the country, supporting them to level up.

Most of the investment would be in the hydrogen production plants themselves, which make up around 75% of the capital expenditure. Hence the most significant economic impacts are focused on the local authorities in which these plants would be located, with the remaining 25% of capital expenditure for required distribution networks spread across the surrounding local authorities.

Agglomeration benefits including domestic supply chain development are not considered within our modelling, as these are very difficult to monetise. But they should be recognised as a potentially large non-monetised economic benefit, likely to improve productivity levels and growth. With agglomeration benefits taken into account, the national GVA and particularly the employment figures are likely to be significantly higher than our modelling can show, offering even greater opportunity for the UK's hydrogen economy.

THAMES CASE STUDY



The hydrogen produced in the study areas would be used mainly in hydrogen powered HGVs and, in the case of the Thames Estuary, a longer-term application could include hydrogen powered passenger aircraft based at London City Airport.

Direct Jobs: 688 (344 during construction phase; 344 during operational phase)

Growth: £3.548 billion

Air pollution reduction: Equivalent to £261 million[33]

Traffic congestion and local air pollution from traffic idling, including at the Dartford Crossing, are significant local issues, the majority of which derives from diesel engines, producing harmful emissions of carbon monoxide, particulate matter and nitrogen oxides, all of which have been linked to significant health concerns. It has been previously estimated that the mortality burden of the air pollution mixture based on both particulate matter 2.5 and nitrogen oxides (NOx) in the UK currently is equivalent to 28,000 to 36,000 deaths at typical ages.

Levelling Up: The **Thames Estuary** area has a patchwork of lesser and more affluent areas and taken as a whole is not significantly different to the England average. However, the prospect of additional, highly-skilled jobs as well as agglomeration effects centred around London City Airport as a hub for the development of hydrogen-based aviation fuels would bring significant benefits to a number of the local authorities most in need of investment, including Newham, Barking and Tower Hamlets.

Case study: London City Airport

Developing a green hydrogen hub in East London provide climate-friendly fuels to kickstart the future of zero-emissions flight by providing clean fuel for air travel that would emit no carbon.

London City Airport has already undertaken feasibility studies as part of Project Napkin, which found that within the next 20 years, passengers could be flying between all regions of the UK on climate-friendly aircraft.

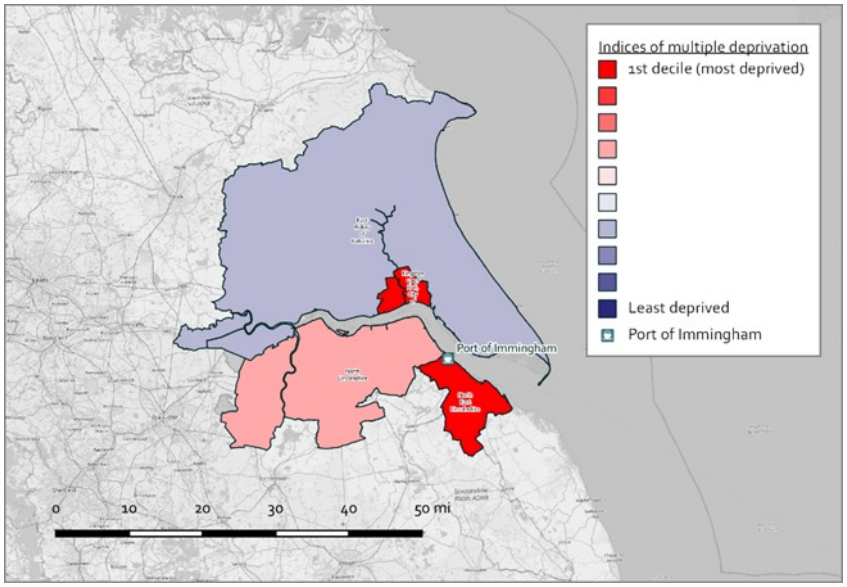
The airport's domestic route network makes the airport an ideal testing ground for the first short-haul, hydrogen powered flights, as the next generation of clean aviation takes off.

"By embracing and becoming a world leader in hydrogen technology, we can deliver high skilled jobs, secure investment, and tackle some of the most acute deprivation in the country.

The Thames Estuary is at the centre of that vision. The Growth Board is backing hydrogen as an alternative fuel for transport, logistics, construction, and heavy industry and we will drive demand and inward investment to ensure we create a hydrogen ecosystem that will unlock the vast untapped potential of the region"

- Thames Estuary Growth Board

HUMBER CASE STUDY



Enough hydrogen would be produced at both the prospective Thames Estuary and Humber Estuary plants to take 40,000 diesel HGVs off the local road networks.

Direct Jobs: 662 (348 during construction phase; 314 during operation)

Growth: £3.629 billion

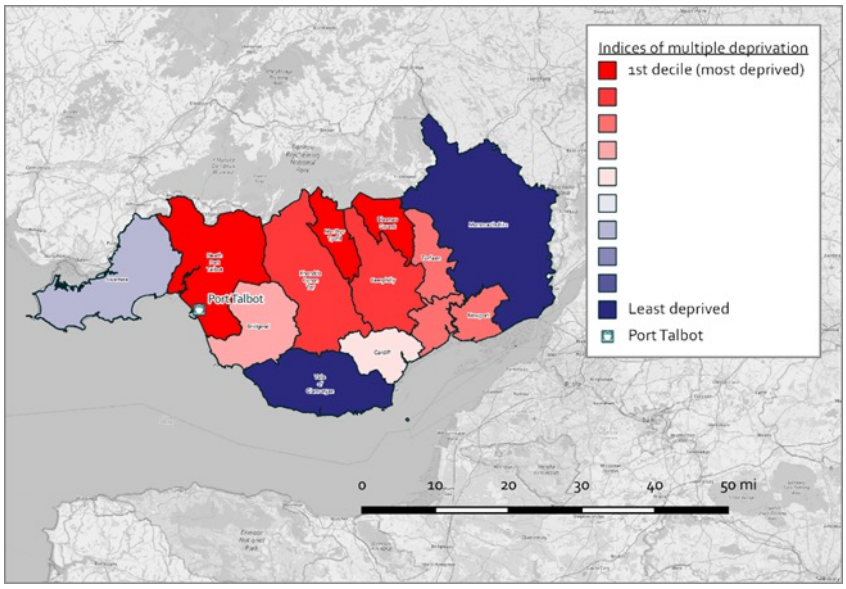
Air pollution: equivalent to £126 million[34]

Levelling Up: The **Humber Estuary** area is home to a number of communities that are most in need of levelling up, according to the Government's own indices, including North East Lincolnshire and the City of Kingston up Hull. The proposed plant location in North East Lincolnshire is ranked 29th on the Levelling Up index, with a below average employment rate of 71.7% (vs 75.6% GB), though it is noted that the City of Kingston Upon Hull ranks even lower than this on multiple levelling up indicators.

"This report illustrates the significant potential of green technologies, including hydrogen, to revitalise the Humber region. The Humber has a central role to play in supercharging the UK's green transition, but only if the Government take decisive action to support port areas like the Humber to develop into hydrogen hubs."

- Future Humber

SOUTH WALES CASE STUDY



The hydrogen produced in South Wales would be used half and half in hydrogen powered HGVs and in industrial fuel switching. **Enough hydrogen would be produced to take 20,000 diesel HGVs off the local roads,** or **decarbonise** industry.

Direct Jobs: 1,026 (542 in construction; 484 during operation)

Growth: £3.690 billion

Air pollution: equivalent to £104 million[35]

Levelling Up: South Wales (here defined as Glamorganshire and Monmouthshire) is a tale of extremes, home to some of the UK's local authorities most in need of levelling up, but also incredibly affluent parts such as the Vale of Glamorgan. Taken as a whole it is more deprived than the Wales average. The proposed plant location at Neath Port Talbot, ranks particularly low as the 4th highest category on Levelling Up measures of the 22 Welsh local authorities, and it has an employment rate significantly below the national average, at 69.6%.

This model offers just one way to accelerate the UK's green hydrogen economy, through the use of a limited amount of imported renewable fuels to catalyse supply and keep the Government's hydrogen targets within reach. Our model offers a feasible way of doing so which is within reach over the next few years, and seeks to demonstrate the significant benefits that the UK stands to gain from with acceleration of green hydrogen production.

CHAPTER 5

Moving to a green hydrogen economy: policy recommendations

5.1 The need for new policy

This paper has forecast the significant potential growth, jobs and decarbonisation benefits that would result from accelerating the UK's path to UK green hydrogen. Pump-priming the market would also be a major boost to the UK's energy security priorities, providing a ready supply of secure, low-carbon energy.

It has also considered the various applications that accelerating market growth would deliver, including decarbonisation of key industries, reduced air pollution and bringing skilled jobs to areas in need of 'levelling up'.

Current policy is not sufficient to drive the investment needed in renewable green hydrogen development, neither to meet current targets, nor to exploit the economic benefits a fully-fledged green hydrogen economy offers.

There is growing recognition that the original 2021 Hydrogen Strategy was drawn up in very different circumstances than those faced by the UK today. Not only before the Russian invasion of Ukraine, which has driven energy security up the agenda, but also before the $369 billion subsidies for green technology in the US Inflation Reduction Act[36] and the EU's $600 billion European Green Deal[37] and related initiatives.[38] It is clear that there is significant competition to develop an edge in green hydrogen internationally.

Existing policy is insufficient to service the UK's current ambitions. Without new policy to accelerate development of a green hydrogen market, the UK will fall behind in the global race.

A thriving green hydrogen industry in the UK will be an important component of our national energy mix - helping ensure that we do not miss our statutory Net Zero commitments, and supporting our domestic energy security in an uncertain geopolitical world. Looking to the century ahead, it is important to get these trajectories right as early as possible.

5.2 Policies to get there

In addition to imported renewable energy to kick start the market for green hydrogen, other ideas will be needed to help drive forward production and facilitate uptake. As an example, broader coordination across government will be essential, given that a comprehensive strategy is needed to align policies, incentives and regulations across transportation, industry, power and infrastructure. Targeted skills programmes in engineering and technical training will also be essential in building vital expertise to take forward this burgeoning hydrogen economy.

Preliminary findings from industry and official documents have outlined promising ideas to kickstart domestic production and create a thriving renewable hydrogen market:

(1) 'PUMP-PRIMING' THE MARKET THROUGH FEEDSTOCK IMPORTS

We believe the immediate lever available to the Government for accelerating the UK's hydrogen supply would be allowing a 'level playing field' of resilient feedstock imports to boost the UK's green hydrogen economy in the short-term. This would combat the domestic shortfall which has stifled the growth of this industry thus far, and would kick-start a British green hydrogen market to put us on a competitive footing against other emerging hydrogen economies. Imports would be capped at a level which does not crowd out the development of a domestic electrolyser market, and time-limited as a short-term stimulus measure.

Facilitating imports of renewable energy specifically earmarked for green hydrogen production can help overcome the current chicken-and-egg problem, where lack of production is stifling market creation and demand. Strategic partnerships and agreements with renewable-rich nations could secure reliable supplies for the UK.

(2) GIVE GUARANTEES TO INVESTORS

A major blockage to the development of a green hydrogen market in the UK is risk to investors, who need to see both a market and a path towards it in order to commit to investment decisions. A green hydrogen economy is not something that Government can build itself: investors will be asked to contribute billions in setting it up. The UK must be an attractive place to start production and there must be a specific deal for green hydrogen.

This is why initial imports will 'pump-prime' wider usage, enabling potential electrolyser investors to see a market to invest into. Separately, while the technology for renewable hydrogen is relatively mature, the primary problems are those of scale-up, for which greater investment certainty is required.

(3) SPEEDING PLANNING FOR PRODUCTION SITES

In tandem, concrete steps must be taken to catalyse domestic production. Streamlining planning approval processes through designating hydrogen projects as 'critical national infrastructure' would accelerate deployment timelines.

In Chapter 4 we modelled the expected benefits from three hypothetical 300 MW green ammonia to hydrogen production plants in strategic locations around the country, each with their own hydrogen distribution network infrastructure.

Each of the projects are self-contained and the hydrogen produced would come from additional renewable sources that would otherwise be curtailed. Its production does not therefore conflict with local or regional electrification and grid decarbonisation priorities.

Domestic production will be an important part of the UK's future energy resilience and security in an uncertain world.

The Green Hydrogen Alliance would therefore propose that the production sites would be classified as critical national infrastructure and eligible for capital subsidies.

(4) DISTRIBUTION INFRASTRUCTURE ROADMAP

Building out distribution infrastructure will be crucial - a UK-wide network of hydrogen distribution and storage facilities should be prepared urgently. Investors are likely to want to develop their own downstream distribution network and, in the case of fuel production, refuelling stations, across the UK.

Delivery of depots, fuelling stations and other regulations around hydrogen transportation will be a key priority to accelerate the UK's green hydrogen potential versus global competitors.

Policy solutions to shorten industry development and planning timelines for green hydrogen infrastructure is a critical goal if the UK is to realise the benefits. Industry and investors need to have confidence in the likely delivery dates of distribution and refuelling infrastructure, so that they can best prepare for the various applications and use cases once the 'tap is flowing'.

Given the complexities of creating multiple pieces of infrastructure in numerous locations - and the long-term nature of the infrastructure concerned - strategic oversight and coordination from Government, in addition to financial incentives, would be welcome. This was recognised in principle in the Hydrogen Strategy but needs to be set out in policy.

The Green Hydrogen Alliance would also suggest that Government should work with industry to develop a dedicated green hydrogen Distribution System Operation (DSO) roadmap for such infrastructure to be delivered and operated. This will help ensure that the supply chains for hydrogen transportation and refuelling infrastructure (for all types of transport) can be rolled out and get hydrogen energy where it is needed.

(5) INCENTIVISE PRODUCTION, RESEARCH & DEVELOPMENT, CONSUMPTION

Global competitors such as the EU and the US are ploughing major investment into their fledgling green hydrogen markets - the UK should take care not to be left behind.

We should create production subsidies or tax incentives for green hydrogen production. This could include implementing feed-in tariffs that guarantee long-term payments to producers of renewable hydrogen, enacting contracts for difference that pay producers the difference between the market price and an agreed strike price, or establishing tax credits that directly reduce the tax liability of companies producing green hydrogen.

These financial incentives would serve to make the cost of producing renewable hydrogen more competitive and help to kickstart a domestically resilient market.

The Government should fund R&D, and demonstration projects for green hydrogen technologies such as electrolyser efficiency improvements, renewable hydrogen production methods, hydrogen distribution infrastructure and storage, and end-use applications in transportation and industry. More R&D funding can help drive down costs across the green hydrogen value chain through technological innovations and demonstration of real-world applications.

CHAPTER 6

Conclusion

6.1 Topline summary of previous arguments, benefits & policies

The UK has the potential to lead in hydrogen production, capture lucrative export opportunities in technologies and services, deliver deep decarbonization across the economy, and create high-value jobs.

Our analysis has shown that building just three 300 MW hydrogen plants (servicing just 18% of the Government's current 2030 target) would generate **£10.8 Billion** of monetised gains for the UK over 30 years, an annual **reduction of over 1.7 million Mt CO2** by 2033, and over **8000 skilled jobs** across both the construction and operational phases. These benefits are only those directly associated with the plants, and the analysis does not take account of ancillary jobs, GVA and climate benefits downstream in the green hydrogen distribution chain.

Realising this requires ambitious policies to scale up production, distribution and end-uses. The window to establish a competitive position is narrow - strategic investment and partnerships now would enable long-term gains. With coordinated action, the UK can deliver on hydrogen's immense economic and environmental promise.

The policy suggestions listed above are the most immediate levers available to attract large-scale investment in the UK's green hydrogen market. Investors in subsequent domestic supply would also value these policies, creating a multiplier effect in benefits to the UK economy.

This policy framework could be constructed immediately to kick-start production of green hydrogen in the UK. This would create incentives for new entrants to the production market, allowing downstream distribution and consumption of green hydrogen to deliver major economic and environmental benefits. A strong domestic market would have the ambition to ultimately develop into a major export industry. The UK must act now to ensure it does not fall behind in the global race at this early stage.

6.2 Next report: Green Hydrogen manifesto

Having outlined these immediate short-term interventions available to the Government to kick-start a domestic market, the Green Hydrogen Alliance will offer further detail on more substantial policies to 'bed-in' the benefits, and how to deliver an export-ready green hydrogen market over the decades ahead. We will also be looking at the impact on specific sectors, in terms of high-value jobs in heavy industry, aviation, maritime, production and supply.

These more long-term policies will be outlined in our next report, the 'Green Hydrogen Manifesto' of ideas that policymakers can adopt. This will offer direct industry expertise to political parties and civil service officials developing policy programmes for delivery after the coming General Election.

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October 2023