UK energy security

The benefits of diversification

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Summary

> It undoubtedly makes sense to capitalise on the UK's abundant renewable energy capacity."

Rising geopolitical tensions have intensified the need to ensure UK energy security alongside delivering net zero and making energy affordable for consumers and businesses.

The government response to shocks which, in 2022, triggered a burst of inflation and a cost of living crisis has largely been to prioritise domestic energy supplies. It undoubtedly makes sense to capitalise on the UK's abundant renewable energy capacity. However, much of the discussion regarding energy security and independence has been simplistic, with little room to explore the trade-offs implicit in some strategies. With uncertainty over the energy needs of some sectors, the price trajectory and scalability of some types of supply, there are parts of the energy system where pursuing diversity of supply may prove more secure and cost efficient.

In this report, we explore this issue with two deep dives. The first looks at the challenge of meeting power demand during so called 'wind drought' periods, particularly in the context of increasing electrification of supply over the coming decades. In this case, it will be important to ensure renewables are spread across a range of locations, backed up with storage and better interconnection with Europe. But other technologies will be needed too.

The second considers how best to source green hydrogen and its derivatives, expected to fuel some heavy transport and industrial processes, and to help with power back up. On this, the conclusion is that there are complex trade-offs to navigate around cost, the best use of limited clean power sources, scalability and the difficulties of hydrogen transport and storage. There is no perfect solution but building a diverse supply could have strategic benefits.

> **"There is no perfect solution but building a diverse supply could have strategic benefits."**

Based on our analysis, and given ongoing geopolitical uncertainty, we recommend that the government develops a strategy in 2025 that defines more clearly what energy security means for the UK and assesses how different sources of supply in different locations, and their various trade-offs, can be navigated to match the country's needs.

This strategy should include:

- **more investment in energy efficiency** to reduce demand overall as a route to greater energy security, with links to the forthcoming Warm Homes Plan and Industrial Decarbonisation Strategy;
- **a comprehensive assessment of the energy sources required to meet demand** through the transition to a decarbonised energy system; for clean flexible power and green hydrogen, the government should actively pursue diversity as a route to resilience and security; policy mechanisms and supply chain support should be designed with this in mind, in particular:
    - **for flexible power**, the Clean Power Mission Control should focus on fast deployment of a range of technologies to balance the electricity grid when renewables cannot meet demand (whichever National Energy System Operator (NESO) recommended 2030 pathway is selected);

  - **for green hydrogen and hydrogen derivatives**, the viability of imports to supplement domestic production should be explored, including their integration into subsidy schemes, provided conditions around emissions and sourcing are met;

- **close co-operation between the Department for Energy Security and Net Zero (DESNZ) and the Foreign and Commonwealth Development Office (FCDO)** on energy diplomacy, with a network of existing and new energy allies around the world collaborating on energy and critical raw material sourcing;
- **alignment with the industrial strategy**, ensuring a range of clean energy technologies are supported as growth opportunities and that options to build components domestically and reduce regional economic inequalities are maximised.

Introduction

> "A system based around domestic renewables can avoid future price shocks."

UK energy security is a hot topic due to rising geopolitical tensions. Action on this priority risks clashing with other policy imperatives, such as meeting net zero and managing energy costs for industrial and domestic consumers.

The war in Ukraine has highlighted the danger of depending on a small number of potentially hostile states for energy resources. Even though the UK is less dependent on Russian gas than many other countries, this source is deeply embedded in European energy markets. The price shock which followed the invasion of Ukraine fuelled double digit UK inflation for a while and helped to stoke a cost of living crisis. Further global tensions have prompted a new emphasis on ensuring energy security.

This comes at a time when globalisation of trade and investment is in retreat, as major economic regions settle into protectionist blocs. The EU's Green New Deal and Joe Biden's Inflation Reduction Act (IRA) both aimed to secure foreign investment in supply chains and corner the global markets for essential goods, raw materials and energy supplies. While Donald Trump has threatened to cancel large parts of IRA, his imposition of an extensive tariff regime introduces further layers of uncertainty into the global trading environment and threatens to raise the price of many goods and components essential for the energy transition.

Six years ago, the business secretary argued that the energy trilemma – the challenge of making energy clean, cheap and secure – would come to an end.[1] Renewable power was zero carbon, located on UK shores and becoming cost competitive with other sources. This prediction was proved right. Although the cost of building renewable power has risen recently due to supply chain pressures, there is still a

> It seems unlikely that a country the size of the UK can achieve full energy independence.”

long term downward price trend. Solar and onshore wind are among the cheapest forms of energy and a system based around domestic renewables can avoid future price shocks.

But, as the UK’s clean energy transition progresses, trade-offs exist in some areas. For instance, should the UK manufacture its own renewables components, even if it costs more than buying them from overseas? Other activities dependent on fossil fuels, such as heating, cars and industry, will increasingly be electrified, but what about applications where electrification is not yet an option? And what about those periods when the wind does not blow, and the sun does not shine?

In response to the changing geopolitical situation, the previous government produced an integrated review of national security in 2021, which stressed national resilience to reduce the potential impact of overseas shocks on industry and consumers. It followed this, in 2022, with a British Energy Security Strategy, setting out moves towards energy independence, focusing on domestically produced oil and gas, hydrogen and electricity. The explicit assumption of this was that independence was the route to security, reliability and lowering costs in the energy system. In this report, we explore and test this assumption.

Although the government has not officially set out its stall on this question, Labour’s election manifesto made repeated references to the importance of security and resilience for economic stability and consumer welfare. Ed Miliband, secretary of state for energy security and net zero, promised in his speech to the 2024 Labour Party conference to “take back control of our energy”, highlighting the manufacturing opportunities clean energy offers.[2]

One problem with these discussions is that the terms ‘independence’ and ‘security’ are often used interchangeably, when they have different meanings and involve different trade-offs. It seems unlikely that a country the size of the UK can achieve full energy independence, not least because the technologies being developed rely on critical raw materials (CRMs) which can only be sourced at scale abroad. The UK is almost 100 per cent reliant on imports of all 24 materials acknowledged by the government as critical.[3]

Attempting to achieve greater energy security and affordability through diversification of supply, alongside domestic sources of energy, is likely to be more rational and achievable in an increasingly hazardous but still interdependent world.

Our exploration looks at two examples: the back up needed to support an electricity system based around renewables; and the deployment of 'green' hydrogen (produced using renewable energy), which is expected to replace fossil fuels in a variety of sectors. While not promoting any one energy source, we want to encourage debate about how best to achieve genuine energy security for the UK.

Key terms explained

The energy sector is awash with jargon. Here are explanations of some of the terms we use in this report.

Baseload power

Sources that operate all year round and include nuclear power, combined heat and power plants, and bioenergy with carbon capture (BECCS).

Carbon capture and storage (CCS)

A technology that captures carbon dioxide (CO_2) from industrial processes and power generation, and then stores it underground.

Dispatchable power

Sources that do not operate all year round but are turned on when needed, including hydrogen power generation and gas power plants, with or without carbon capture and storage (CCS).

Electricity curtailment

The deliberate reduction in output from a power source when the electricity system cannot transport, store or otherwise make use of it. For renewables, like wind, this results in a loss of potentially useful energy. This energy could be used before it reaches the system bottleneck.

Electrolyser

A technology used to split hydrogen from water using electricity.

‘Green’ ammonia

Ammonia is a gas used for a variety of applications, including agricultural fertilisers, and is typically made through a process which releases carbon dioxide. Green ammonia is instead made using a process that is carbon-free, most commonly using hydrogen from water electrolysis and nitrogen from the air, using renewable energy.

‘Grey’, ‘blue’ and ‘green’ hydrogen

Hydrogen is made by different methods; grey and blue hydrogen are both produced using natural gas, but carbon is captured and stored to make blue hydrogen; green hydrogen is made using renewable electricity and an electrolyser to split hydrogen from water.

Interconnectors

High voltage cables on land and under the sea connecting neighbouring countries’ electricity systems. Through them, surplus energy can be traded and shared between countries, helping to manage surges in demand.

Levelised cost

The average cost of producing one unit of energy output over the lifetime of a plant. This includes capital expenditure, operational, maintenance and financing costs.

Network charges

Fees electricity users pay for using the grid network. These include fees to maintain and expand the network, and policies that support low carbon energy generation and energy efficiency.

Power purchase agreement (PPA)

A long term contract between an electricity generator and a user. It is a common way of guaranteeing that renewable electricity is being used while connected to the grid.

The role of flexible power

> **“Demand on the electricity system will increase significantly as many areas of industry, heating and transport electrify.”**

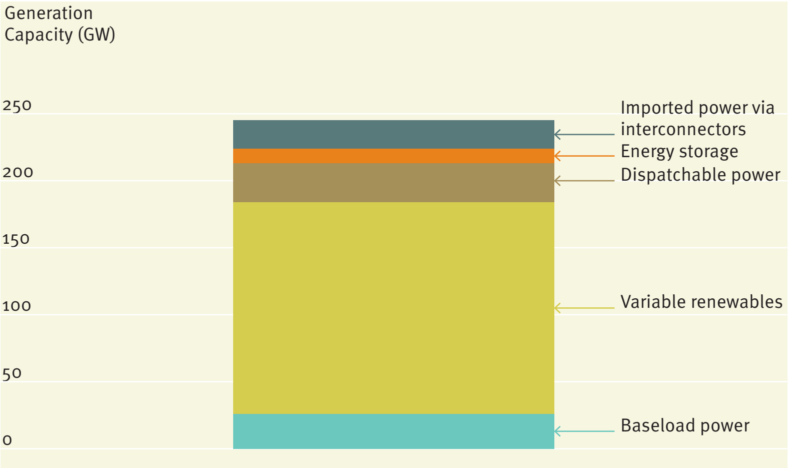
The UK is a global leader in decarbonising electricity. It was the first G7 nation to phase out coal power and it pioneered the use of contracts for difference (CfDs) to usher in a boom in renewable energy development.

The government has a goal to fully decarbonise the UK’s power system by 2030, with promises to double onshore wind capacity, triple solar capacity and quadruple offshore wind capacity.

However, even if these targets are achieved, they are only part of the picture. Wind and solar will generate the bulk of UK electricity by 2035, but some contribution from flexible clean generation technologies and energy storage will be needed to provide back up.[4]

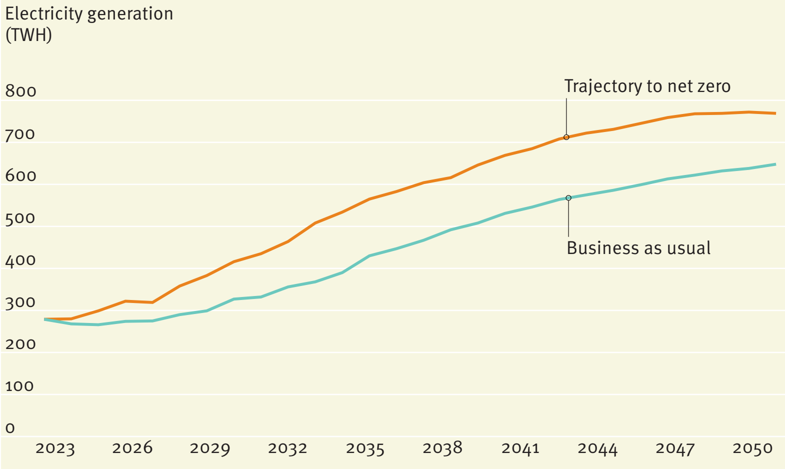
Demand on the electricity system will increase significantly as many areas of industry, heating and transport electrify. By 2035, annual demand could grow to 400-600TWh, from around 300TWh today.[5]

Renewables will dominate in 2035 but other technologies are still needed[6]



> **“Clean flexible power will be required in increasing volumes beyond 2030.”**

By 2050, UK projected electricity generation could be almost 800TWh[7]



Although it tends to be windier at night and in winter, when solar generation is lower, there will still be times when overall supply from renewable technologies cannot meet all the demand. Whilst energy system experts are confident blackouts will be avoided, it is difficult to predict the exact combination and necessary contribution of back up required.

On a daily basis, short duration energy storage can be provided affordably by grid scale batteries and, in the future, this could be supplemented by connected electric vehicle batteries feeding energy back into the grid. However, flexible low carbon power and long duration storage technologies will be needed to cope with week by week and seasonal variations. Pumped hydropower and compressed air energy storage could serve for several days, but other solutions are necessary for longer periods of high demand and low supply, most likely in the winter.

The National Energy System Operator (NESO) has published two potential pathways to achieve clean power by 2030.[8] One relies on faster rollout of renewables and more energy storage, while the other requires accelerated deployment of clean flexible power. Whichever path the government chooses, clean flexible power will be required in increasing volumes beyond 2030.

Power demand on a cloudy, windless winter day in 2035

How the shortfall could be met[9]

When renewable output is low, other energy sources are needed. Three technologies can fill the gap: gas with carbon capture and storage (CCS), hydrogen and interconnectors. The precise capacity potential of each will depend on costs and availability, but an indicative split, using Regen's 'A day in the life 2035' scenario, is shown above.

Dealing with the risk of wind droughts

> **A week long winter wind drought is of most immediate concern.”**

Some mitigation of extremely low wind scenarios is possible by building new windfarms along the west coast of Britain instead of relying on windfarms on the east coast. This might not significantly reduce the amount of back up supply needed but it would reduce the number and duration of very low wind energy supply events.[10]

There are three types of wind drought: frequent one day summer wind droughts, occurring a few times a year; winter wind droughts, lasting up to a week every few years; and infrequent summer wind droughts, lasting up to four weeks roughly once a decade.[11]

A week long winter wind drought is of most immediate concern. In 2035, the energy that might be needed during such an event, to cover for a lack of wind and solar, would be around 4TWh.[12] In these circumstances, there are only three feasible options, combined, that can supply enough flexible low carbon power:

- **Hydrogen power** has not been deployed at scale anywhere in the world, but several UK projects are in development, including the planned 1GW Keadby hydrogen power station in Lincolnshire. The fuel for these power plants could come from ‘green’ hydrogen, created and stored at times of excess renewable energy generation, ‘blue’ hydrogen, made from natural gas with CCS, or imported hydrogen and hydrogen derivatives.[13]
- **Gas with CCS** could supply electricity for longer periods. In fact, to achieve high carbon capture rates, and send the CO_2 for injection to storage sites at a stable flow rate, they would need to run for long periods, rather than ramping up and down to balance hourly variability.
- **Electricity interconnectors** are high voltage cables connecting the UK’s electricity grid to Ireland, France, Norway, Denmark, Belgium and the Netherlands. Currently, the UK is mostly a power importer but, in future, it could become a net exporter.

No solution is perfect: dispatchable power options and their limitations

	Cost	Residual carbon emissions	Availability	Potential capacity in 2035[14]
Hydrogen power	Likely to be higher than natural gas over the medium term, but avoids carbon costs and has the potential – given storage and diverse supply chains – to avoid market volatility.	Blue hydrogen production may have unacceptable emissions in the supply chain. All hydrogen needs to be handled carefully to avoid leaks, as hydrogen has an indirect global warming impact (see page 26).	Hydrogen is likely to be scarce in the UK until at least 2050. Diversity of sources would help, both in domestic production and imports. Blue hydrogen relies on imported gas.	10-15GW
Gas with CCS	May already compete with unabated gas, if carbon costs are high, but it is still not deployed on a commercial scale anywhere in the world, so there is high uncertainty.	Capture rates are unlikely to reach 100 per cent and can be much lower, especially on start up and shut down. Upstream methane emissions (another potent greenhouse gas) can also be significant.	Although a true shortage of gas is now unlikely, the entire global market still relies on a small number of countries' exports, which means there is a continued risk of price volatility.	4-6GW
Interconnectors	If renewable electricity production is low due to weather factors, it is likely that electricity prices in the rest of Europe would also be higher at the same time.	Climate impacts depend entirely on the carbon intensity of the interconnected grids, but these are trending downwards everywhere.	It is extremely unlikely that there will be low levels of generation everywhere.[15] But it will not be possible to rely on the rest of Europe to supply a lot of power when UK wind and solar generation is low.	18-22GW

“

Interconnectors already play a significant role in balancing the UK grid.”

Interconnectors already play a significant role in balancing the UK grid, with around 10GW capacity now and more being developed. Greater interconnectivity across north west Europe will provide additional capacity when UK renewables are not producing power, but there are trade barriers. The UK's exit from the single market and failure to implement efficient electricity trading was the source of an estimated extra £130-370 million in wholesale UK electricity costs in 2022.[16] The Trade and Cooperation Agreement's Domestic Advisory Group has argued that the UK and the EU must prioritise alternative day ahead electricity trading arrangements.[17]

Heightened tensions with Russia over the UK's support for Ukraine also raise the possibility of interconnectors being severed by hostile action. It is essential that this serious risk is analysed and countered in the government's forthcoming strategic defence review, due in summer 2025.

Storing large volumes of hydrogen as long duration energy storage is now almost universally considered to be the final piece of this puzzle. The Climate Change Committee (CCC) predicts that up to 5TWh of energy could be stored as hydrogen in salt caverns in the UK by 2035, equivalent to about three days of projected UK electricity generation.[18,19]

The economics of hydrogen storage are difficult to estimate, as costs depend significantly on how frequently the store is used and replenished. The Energy Storage Ninja calculator considers hydrogen to be the cheapest form of seasonal energy storage but, if such a store is only cycled ten times a year, it could cost up to £900 per MWh to deliver that power back to the system.[20] Most of this cost comes from upfront installation, with little sensitivity to the cost of electricity used to fill the store. The Royal Society assumes a similar storage cost but notes the impact on the average annual cost of electricity for the whole system is only around £5 per MWh.[21] By comparison, average wholesale electricity prices have been around £60 to £90 per MWh during 2024.[22]

Deploying more diverse clean flexible technologies

> “The most secure unit of energy is the unit that does not need to be consumed.”

The drive towards energy independence stems largely from the gas price shock of 2022, when spot prices for electricity were highly volatile and peaking at over £500 per MWh.[23] This was mostly driven by the high cost of gas, but future periods of low renewables production, coupled with high demand across interconnected countries, could result in similar volatility.

To minimise the impact of international energy price shocks and guard against blackouts, the UK needs to build diverse electricity sources to balance the variability of wind and solar. This should include expanded interconnection with other countries and accelerating the deployment of long duration energy storage.

The government and NESO must plan well ahead to achieve this. We have previously called for a ‘vaccine task force’ style approach to building clean flexible power generation as quickly as possible, taking the risk out of trying different options simultaneously to speed up progress.[24] The precise mechanism for ensuring deployment of clean flexible technologies depends on the government’s appetite for electricity market reform. A low carbon capacity market is being considered as part of ongoing reforms and could be the way to encourage deployment of clean flexible technologies.

In the context of security, it is critical that more is done to reduce energy demand. This would shrink the amount of capacity needed, saving costs, avoiding too many lengthy planning battles over electricity network developments and increasing security of supply. The most secure unit of energy is the unit that does not need to be consumed. Demand side flexibility, where the amount or timing of energy use can be changed, is another important way to reduce the volume of back up power required cheaply.

The role of hydrogen

> **‘Green’ hydrogen is expected to be the main source of future hydrogen production.”**

There has been significant hype around hydrogen’s role in decarbonising the economy. In 2021, Prime Minister Boris Johnson suggested the UK should become “the Qatar of hydrogen” and gas grid companies promised to transform their grids to supply hydrogen instead. Expectations have tempered since, especially in domestic heating where hydrogen is not considered to be a likely solution, but the first small scale clean hydrogen production and consumption projects are now coming on stream.

Alongside its crucial role in balancing the power system, hydrogen is likely to play a future role as shipping and aviation fuel. It could also be used in some high temperature industrial processes and to power the largest HGVs and offroad vehicles.

Currently, ‘grey’ hydrogen, produced from natural gas (without carbon capture), is used in oil refining and some chemical manufacturing. Blue hydrogen (from natural gas but with carbon capture) will be available when the first CCS clusters begin operation around 2030, but ‘green’ hydrogen, split from water with renewable electricity, is expected to be the main source of future hydrogen production and has the lowest emissions.[25]

Policy focuses on supply and production

The previous government’s 2021 hydrogen strategy was primarily interested in the domestic production of green and blue hydrogen, with only indicative suggestions of how it could be used, rather than working backwards from what it will be needed for. The focus on domestic production and self-sufficiency came with an explicit decision not to subsidise imported hydrogen.

The government has developed a hydrogen business model to subsidise the production of green hydrogen, based around a CfD style auction mechanism. On the demand side, there is capital support available for industrial fuel switching projects and some other applications, like buses, but no long term funding has been promised.

“Near term demand for hydrogen may have been overestimated.”

Hydrogen ambitions may be challenging

Our assessment is that near term demand for hydrogen may have been overestimated. Electrification will be preferred as a more energy and cost effective route to decarbonisation across much of the economy.

We estimate hydrogen demand of 70TWh in 2035, the equivalent of 12GW of production capacity.[26] This is at the low end of the latest government demand predictions of 50-175TWh in 2035 but is comparable to the 64TWh cited in the balanced ‘holistic pathway’ of NESO’s ‘Future energy scenarios’.[27] The CCC’s 7th carbon budget suggests an even lower figure of around 40TWh, with a heavy preference for industrial electrification over hydrogen.[28]

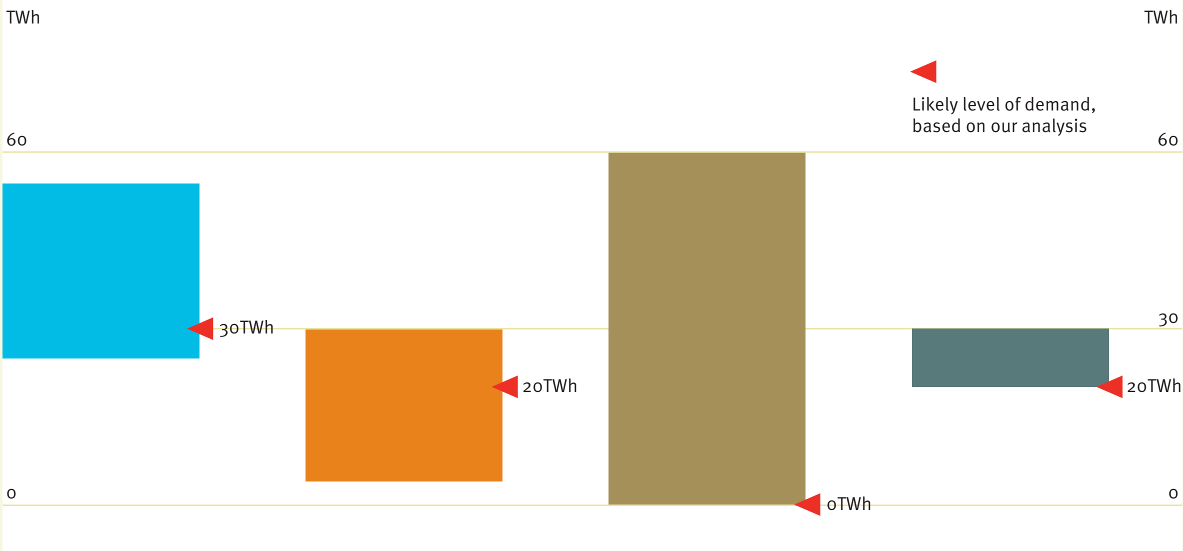
The previous government aimed for up to 10GW of hydrogen production capacity by 2030, including 6GW of green hydrogen. So far, there has been no indication of policy changes from the new government. A target of 10GW by 2030 would produce approximately 60TWh a year.[29]

In 2023, the first green hydrogen allocation round (HAR1) contracted 125MW (0.5TWh per year) of capacity. The short list from the second round has now been announced, falling a little short of its 875MW (4TWh per year) target.[30,31] From the third allocation round onwards the government intends to run annual auctions. Blue hydrogen projects are currently under negotiation to start building towards 4GW (33TWh per year) of capacity planned for 2030.[32]

The trade association Hydrogen UK’s project map suggests considerable further capacity may be available but it is uncertain how much of this could be on stream by 2030 or 2035.[33]

Future hydrogen demand may have been overestimated

Government prediction of potential range of 2035 hydrogen demand, by sector[34]



Industry
30 TWh

For use in high temperature processes, as a feedstock for chemicals, a fuel for heavy non-road machinery and potentially to manufacture green steel. A significant proportion of demand could be met with blue hydrogen where there is CCS infrastructure.

Power
20 TWh

Hydrogen is likely to be used to help balance variable renewables over long durations. Most may eventually be green hydrogen, produced using surplus renewable electricity but, in the medium term, some demand may be met with blue hydrogen.

Domestic heat
0 TWh

Hydrogen is unlikely to be used for domestic heating.

Transport
20 TWh

Use for zero emission flight is being explored and hydrogen derived from 'green' ammonia is expected to be used in shipping. It is also likely to be used for some HGVs and coaches. This is expected to be mostly green hydrogen.

Trade-offs and uncertainties

The growing hydrogen economy is complex, with different production routes and a variety of end users. Hydrogen production cost, need for transport and storage infrastructure, resource use (water and power) and the added strain on the power grid must all be considered.

> **Even if future auction prices come down, meeting the government's 6GW target will still not be cheap."**

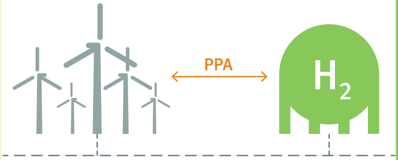
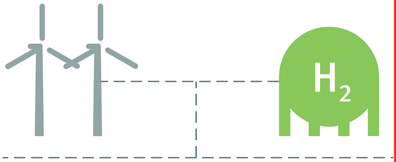
The HAR1 auction price of £241 per MWh is high but likely to fall in future as confidence in the market grows, reducing risks for investors. Initial projects will be located close to end users to minimise the need for larger scale transport and storage infrastructure, expected to be necessary beyond 2030. This will enable cheaper modes of production and will meet the needs of other users, like long term energy storage. However, even if future auction prices come down, meeting the government's 6GW target will still not be cheap. At an optimistic 30 per cent reduction, the total price would be approximately £4 billion a year, with up to around 80 per cent being a cost to government.[35]

Storing hydrogen in tanks is expensive and requires up to ten per cent of the energy stored to be used in maintaining low temperatures or high pressures.[36] Sub-surface storage in salt caverns is an effective and proven method, but is only suitable for large, long term, seasonal or inter-year storage.

Hydrogen production is an energy intensive process and direct electrification is generally a more energy and cost efficient way to reduce greenhouse gas emissions. Caution is needed to avoid competition for clean power during a critical period of renewable energy construction.

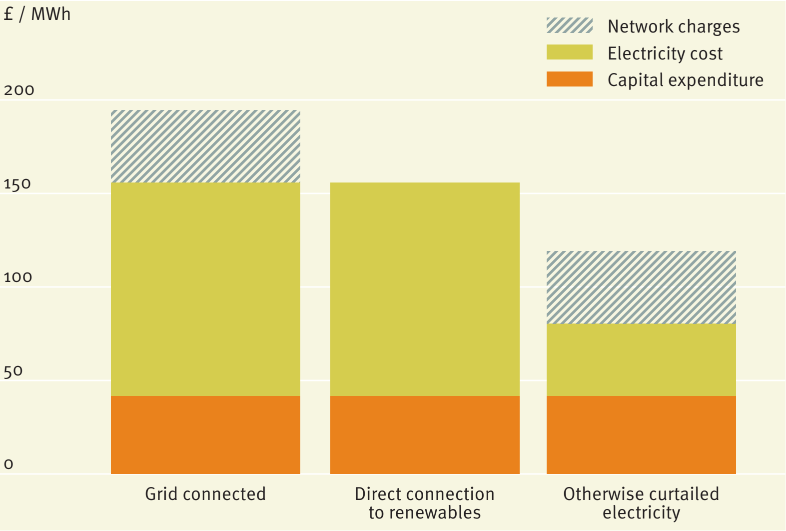
Our assessment of the different routes to domestic green hydrogen production shows there is no straightforward answer that avoids all these issues.

For comparison, a recent study estimated the levelised cost of blue hydrogen could be as low as £72 per MWh.[37] This will be conveniently located in industrial clusters close to sources of demand and can provide a constant supply, but it has a higher environmental footprint than green hydrogen because of upstream emissions associated with gas supplies and the incomplete capture of carbon dioxide emissions.

Mode of production	Transport and storage needs	Electricity demand	Production cost
Grid connection with a renewable power purchase agreement 	Can be located near the end use	Adds to electricity demand and contributes to the need for electricity grid upgrades	High electricity costs and electricity system charges
Direct connection to renewables 	Located next to renewable generators, which may be long distances from end use	Adds to electricity demand but, if renewables are also grid connected, electricity can instead be fed into the grid network when demand is high.	High electricity cost but no or low electricity system charges
Grid connection using electricity that would otherwise be curtailed 	Located in areas where grid curtailment occurs (eg Scotland) which may be long distances from end use	Most electricity used for production would otherwise be wasted through curtailment	Cheap electricity but there are electricity system charges for grid back up

“The use of otherwise curtailed electricity will be important for hydrogen production in the long term.”

Comparative cost of producing green hydrogen by different methods[38]



A grid connected electrolyser is the most common form of production as it produces hydrogen close to the end user and is, therefore, not dependent on extensive hydrogen infrastructure. However, it is expensive, with electricity and electricity system costs making up about 75 per cent of overall costs, neither of which are expected to fall in the near future. As shown in the table on page 21, while the other options considered would make production cheaper, they tend to be located away from sources of demand and would incur transport and storage costs.

The use of otherwise curtailed electricity will be important for hydrogen production in the long term. It is predicted that, in 2035, even with some export, energy storage and hydrogen production, 23-58TWh of electricity might be curtailed and wasted each year, representing four to ten per cent of domestic production.[39]

However, otherwise curtailed electricity is unlikely to be zero cost, and using it alone is thought to be too uncertain and too infrequent to offer an investible business case. This is why, in our cost calculations, we assume that the curtailed energy case includes a top up of low carbon grid electricity when the price is low.

Imports could be cost competitive

A nascent but growing global market in green hydrogen could take advantage of cheap renewable energy in areas of abundance, with the US, Australia, Brazil, Saudi Arabia and Egypt being potential exporters.[40]

> Other European countries rely more on imports in their hydrogen strategies.”

Long distance transportation to Europe can be achieved with low losses by turning hydrogen into other chemicals (known as carriers), with green ammonia being the most likely. Ammonia is a key ingredient for some chemicals, especially fertilisers, and is likely to be a future shipping fuel. The UK now imports 100 per cent of its ammonia and has the port infrastructure to support it.

Other European countries rely more on imports in their hydrogen strategies. Germany hosted the first global auction for green ammonia in 2024. The price reached was €1,000 per tonne or approximately £134 per MWh, including transport and import costs.[41] This is projected to fall to around £100 per MWh by 2030.[42] As shown in the graphs on pages 24 and 25, imports are expected to be significantly cheaper than domestic production of ammonia.

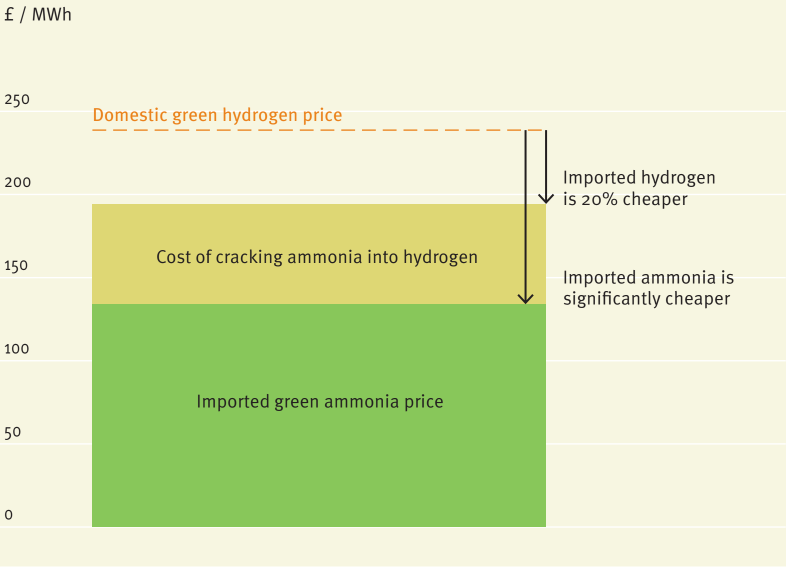
Ammonia can also be ‘cracked’ to produce hydrogen near its point of use. Despite being a costly, energy intensive process, this may still be cost competitive with domestic hydrogen production. Ammonia is much simpler to store, and so could be used as a way of ‘storing’ hydrogen.

The scale of this market is small. The first auction is only supplying two to three per cent of Germany’s ammonia consumption between 2027 and 2033. But it is expected to grow, with global projects announced totalling 200TWh per year by 2030.[43]

❝

Hydrogen produced from imported ammonia is still about 20 per cent cheaper.”

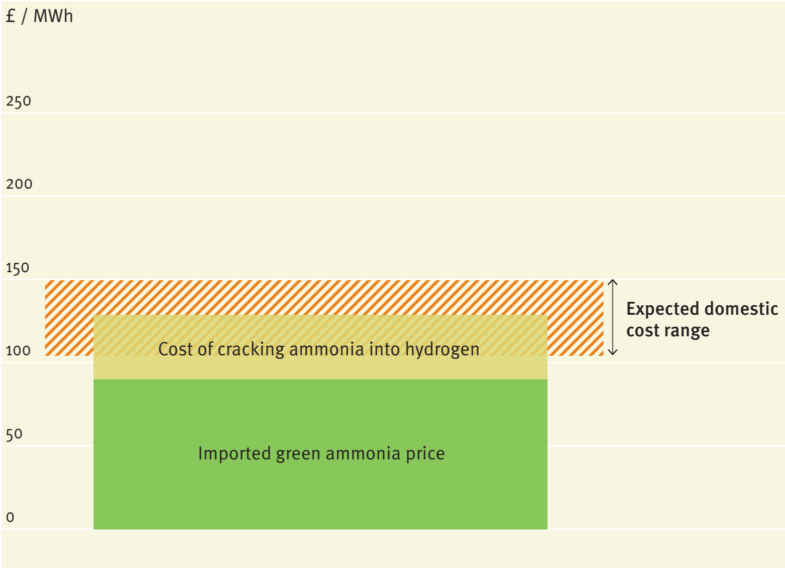
Today, imports are cheaper than domestic production



Producing ammonia uses hydrogen as a main ingredient and requires further energy and processing. Currently, imported green ammonia is significantly cheaper than producing it domestically.[44] Imported hydrogen, in this case sourced from cracking ammonia, is about 20 per cent cheaper than the UK’s first allocation round. This is despite the energy intensive cracking process increasing costs by about 45 per cent.[45]

> it is likely imported green ammonia will continue to be significantly cheaper than domestically produced ammonia."

By 2035, domestic and import costs will both fall



There is a high level of uncertainty in projecting costs forward to 2035, but it is likely imported green ammonia will continue to be significantly cheaper than domestically produced ammonia. After cracking, imported hydrogen is still likely to be cheaper in 2035 than hydrogen produced on-site using a grid connected electrolyser, which represents the top of the expected domestic cost range.

> **Transportation of hydrogen by pipeline has the lowest emissions."**

Environmental risks of hydrogen transportation

The transportation of hydrogen and its derivatives can have detrimental environmental effects. For example, hydrogen has an indirect global warming effect approximately 12 times stronger than CO_2 over a hundred year period, so its release into the atmosphere must be minimised.[46] Similarly, if ammonia leaks into oceans, it is a serious hazard to ecosystems and can be a source of nitrous oxide, another potent greenhouse gas.[47]

At each stage of transfer or conversion, there is increased risk of emitting hydrogen or ammonia, either via accidental leaks or deliberate purging for safety reasons. Therefore, it is preferable to minimise the distance hydrogen travels and the number of steps in the journey. Transportation of hydrogen by pipeline has the lowest emissions, at around one per cent, but other methods have unacceptably high leakage of one to four per cent for compressed hydrogen and ten to 20 per cent for liquified hydrogen.[48,49] Plans to transport hydrogen and its derivatives by any means must include deliberate actions to minimise emissions and the risk of leakage.

If these conditions are met, importing hydrogen derivatives, such as ammonia, should be seriously considered. Importing green ammonia as a route to meeting the estimated 15TWh of demand for UK shipping by 2035 will be much cheaper than producing it domestically. Though cracking ammonia into hydrogen is costly, it is still likely to be cost competitive. Hydrogen, via imported green ammonia, could act as a flexible source of supply to complement variable domestic hydrogen production in the short term, before larger hydrogen infrastructure is built. And, may be useful outside CCS-enabled clusters with access to blue hydrogen, in decentralised industry and transport, for example.

Building domestic supply chains

> **The UK has an advantage in clean technologies.”**

The cost, security and emissions of different energy sources are all critical considerations. But it is also important to consider wider impacts on the economy of choosing one energy source over another, including on supply chains.

Domestic production of clean energy components could add to energy costs, but this must be balanced against the potential for a domestic supply chain to play an important role in the government’s industrial strategy. Such new industries provide growth opportunities across the country and a secure energy supply for heavy industrial inputs, like steel and cement.

The EU has recognised the importance of linking the drive for lower energy costs with the development of domestic supply chains to maximise the positive economic spillovers for industry. The recent competitiveness report by the former European Central Bank President Mario Draghi called for a whole systems approach to energy and industrial policy.[50]

The government’s recent industrial strategy green paper sets out a basic policy framework for building up domestic supply chains across different sectors, based on various criteria. These include comparative advantage, growth opportunities in global markets and the contribution to broader goals such as net zero and tackling regional inequalities. However, it was not accompanied by detailed analysis of where the advantages and opportunities are.

Research by the Resolution Foundation indicates that the UK has an advantage in clean technologies, compared with some other economic sectors (as measured by the concentration of patents, a proxy for strength in innovation), but it is behind countries like France and Germany and is by no means a research leader in the field.[51]

“Companies need to invest as quickly as possible to achieve economies of scale.”

Estimates of the ability to turn research activity into economic value show the return on clean energy innovation exceeds that of any other technology. Commercial returns from research and development in offshore wind, tidal and CCS are well above biotechnology and AI, for instance, which feature prominently in the industrial strategy.

Returns from hydrogen are below other energy sectors but are still strongly positive. Investment in clean innovation outside the ‘golden triangle’ of south east England also tends to generate relatively high economic returns.

This suggests there is potential value in supporting the development of a domestic supply chain for clean energy infrastructure. However, this is hampered by a lack of policy to develop the sector. Industry stakeholders we interviewed for this report warned that companies need to invest as quickly as possible to achieve economies of scale.

The government’s recent decision to bring forward £300m of investment through GB Energy to help win global offshore wind investment is an example of the kind of action that is needed to leverage additional supply chain funding.[52]

The UK’s economic strengths tend to lie high up the value chain in technology. But government analysis of hydrogen supply chains suggests there are opportunities in the domestic supply of electrolysers and fuel cells.[53] In sectors such as wind and solar there is a strong rationale for investing in domestic manufacturing where there are supply constraints.[54]

The industrial strategy should also address the UK’s ability to access critical raw materials (CRMs), which could limit capacity to make key components. The three primary electrolyser technologies all rely on CRMs.[55] We argue that much more domestic recycling and reuse of these materials is vital, and that it is under exploited as a way to support business growth and energy security. The UK should also minimise reliance on CRMs through technologies and techniques that reduce the overall quantities needed.[56]

Making the most of these kinds of opportunities and managing any trade-offs requires a strategic approach.

Supporting the clean power mission through diversification

> “Geopolitical circumstances demand a strategic approach.”

Our analysis suggests that, while the UK’s clean energy transition is well underway, there is still a range of significant issues to resolve around the country’s energy needs and how best to secure economic benefits from the transition.

Discussions around energy independence and security often ignore trade-offs. The UK is unlikely to achieve true energy independence, at least in the short term, because of factors such as the rate at which infrastructure can be built, the need to keep energy bills affordable and reliance on imported CRMs. There is a role for imports to create a diverse energy system, prioritising security of supply and reducing costs, but geopolitical circumstances demand a strategic approach, building and maintaining good relationships with a range of countries.

An energy security strategy

A more nuanced conversation and more sophisticated planning around energy and the wider economy is needed, including the relevance to industrial and trade strategy

We recommend an energy security strategy that includes:

- **more investment in energy efficiency** to reduce demand overall as a route to greater energy security, with links to the forthcoming Warm Homes Plan and Industrial Decarbonisation Strategy;
- **a comprehensive assessment of the energy sources required** to meet demand through the transition to a decarbonised energy system; for clean flexible power and green hydrogen, the government should actively pursue diversity as a route to resilience and security; policy mechanisms and supply chain support should be designed with this in mind, in particular:

- **for flexible power**, the Clean Power Mission Control should focus on fast deployment of a range of available technologies to balance the electricity grid when renewables cannot meet demand (whichever NESO recommended 2030 pathway is selected);
- **for green hydrogen and hydrogen derivatives**, the viability of imports to supplement domestic production cost effectively should be assessed, through inclusion in subsidy schemes, provided conditions around emissions and sourcing are met;

“Clean Power Mission Control should focus on fast deployment of a range of technologies.”

- **close co-operation between the Department for Energy Security and Net Zero and the Foreign and Commonwealth Development Office** on energy diplomacy, with a network of existing and new energy allies around the world collaborating on energy and critical raw material sourcing;
- **alignment with the industrial strategy**, ensuring a range of clean energy technologies are supported as growth opportunities and that options to build components domestically and reduce regional economic inequalities are maximised.

Endnotes

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4 L Hardy and S Dossett, 2023, Green Alliance briefing, 'The building blocks of a secure 2035 zero carbon power system'

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6 Projected electricity generation capacity split by technology, according to: Climate Change Committee (CCC), March 2023, Delivering a reliable decarbonised power system

7 Projected electricity generation for the net zero transition and a counterfactual baseline in which the transition moves slowly and net zero is missed, according to: National Energy System Operator (NESO), Future Energy Scenarios 2024

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9 Regen and NESO, 2022, *A day in the life of 2035*

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12 The additional 36GW of flexible capacity, beyond short term energy storage, would be required for approximately two thirds of each 24 hour period, while in the middle of the night demand is lower. This equates to around 600GWh per day. For a week long wind drought, 4TWh might be required.

13 Ammonia may be a future fuel for power generation, with the development of Europe's first ammonia-fired power plant being explored in Ireland by Centrica and Mitsubishi Power. However, there are concerns over the creation of nitrous oxides in this process which need to be better understood.

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56 H Plumpton and L Peake, 2024, op cit

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