green alliance...

Plugging into industrial electrification

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This report is a summary of a more detailed research paper, available at bit.ly/4jZdzNv

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Summary

“Electrification is a missing piece in the puzzle of how to power industry in future.”

Cutting greenhouse gas emissions from industry is a major challenge for the UK. Industry is the third highest emitting sector behind transport and buildings. It has been considered one of the most difficult sectors to decarbonise.

The government has put great effort into developing supportive policy to enable some industrial sites to address climate impacts by switching to clean hydrogen or carbon capture and storage (CCS) technologies. But these cannot serve all industrial sectors well, nor will they be appropriate for many locations, especially those outside planned carbon capture clusters in Merseyside, Teesside, Humberside and Scotland.

Electrification is a missing piece in the puzzle of how to power industry in future, often overlooked in favour of the other, more complex, solutions. It can reduce overall energy consumption, improve resilience against fuel price shocks, reduce air pollution and enable greater power system flexibility. In fact, it could prove to be the strongest route to economic growth as the most affordable way to cut emissions in both the industrial clusters and elsewhere, especially in sectors like food and drink manufacturing and paper and pulp manufacturing.

Other European countries recognise the advantages of electrification and have developed supportive policies to accelerate it. Valuable lessons can be

drawn from these examples to exploit the untapped potential of electrification in UK industrial decarbonisation policy. Getting this right will unlock international investment in UK industries.

To make the most of this potential, industry must overcome different barriers, including: economic, current electricity prices are over four times higher than gas prices; infrastructure, new or enhanced electricity grid connections face extensive delays; and social, many businesses are still wary of new technologies having not yet seen widespread examples of their success.

> “Getting this right will unlock international investment in UK industries.”

Overcoming these requires co-ordinated effort across government, industry and regulators to:

- **Cut industrial electricity costs:** for example, through an electrification contract for difference subsidy scheme and a widened British Industry Supercharger. Underwriting power purchase agreements to sell cheaper renewable electricity direct to power hungry industries would also help. Shifting policy levies from electricity costs onto progressive taxation will cut energy bills for industry and all consumers.
- **Support and advise businesses:** a refreshed Industrial Energy Transformation Fund could be expanded with the addition of interest free loans. A dedicated advice and support service should also help businesses, especially small and medium enterprises, to develop and implement decarbonisation plans.
- **Accelerate grid upgrades:** network operators should support industrial consumers to connect to the electricity grid at reasonable cost and without long delays. This may require Ofgem to allow more investment, improvements in spatial

planning, with early industry involvement and standardisation of the customer journey to new grid connections.

- Do more research and development: funding more innovation in high temperature electric solutions will address the remaining technical barriers. This should avoid the hydrogen and CCS bias and prioritise cheaper, efficient electrification technologies.

This report summarises our more detailed analysis, which can be found at bit.ly/4jZdzNv

What is electrification?

> **“Seventy eight per cent of industrial energy demand could be met with existing electrification technologies.”**

Electrification is the replacement of fossil fuel dependent processes with technologies powered by electricity, such as replacing a traditional gas boiler with an electric boiler or a heat pump.

It is a straightforward way to reduce greenhouse gas emissions and enhance the competitiveness of UK industries in processes ranging from steelmaking to chemical production.

This not only helps to meet emissions targets, but also positions the UK as a leader in the electrification driven industrial revolution, enabling industries to thrive as electricity becomes cheaper, cleaner and more abundant. As such, it is the gateway to a modern, resilient economy.

Research in Europe suggests that 78 per cent of industrial energy demand could be met with existing electrification technologies.[1] This potential varies across sectors, depending on the costs and difficulty of switching.

For sectors that mostly require low temperature heat (typically below 200°C), like paper and pulp, industrial heat pumps are an immediate, efficient and scalable solution. Heat pumps can replace conventional fossil fuel boiler systems and boost energy efficiency by enabling waste heat recirculation. Other technologies, which can reach higher temperatures, include electric boilers, electric steam crackers, electric furnaces and microwave ovens.

Sectors with high temperature demand, such as ceramics, cement and refining, face greater challenges in electrifying. These sectors may have to rely on a combination of CCS and hydrogen for certain processes. Fuel switching to ‘green’ hydrogen (made using renewable electricity) is classed as electrification by some, but we class it as decarbonisation through the use of hydrogen, rather than direct electricity use.

Eight benefits of electrification

> “Electrification has distinct advantages for individual businesses and the wider UK economy.”

Many factors influence an industry’s choice of technology, including energy needs, processes, existing assets and knowledge, appetite for innovation, relevant infrastructure and investment capital available.

Electrification has distinct advantages over hydrogen fuel switching and CCS for individual businesses and the wider UK economy. These include:

1. Immediate emissions reductions

CCS and hydrogen need new pipelines and storage facilities. Electrification can use existing infrastructure, especially where there is already room in the network around industrial clusters.

2. Energy security

Unlike CCS or ‘blue’ hydrogen (made using natural gas), which fail to address fossil fuel dependency and its associated geopolitical and economic risks, electrification uses largely UK-sourced energy.

3. Cost stability

As electricity becomes cheaper and cleaner, electrified industries will benefit from more predictable declining costs. CCS and blue hydrogen will be subject to the high and uncertain costs of international gas markets and unproven UK infrastructure.

4. Efficiency gains

Electrification technologies, like high temperature heat pumps, can achieve efficiencies several times greater than gas boilers, lowering energy inputs and boosting productivity. Many electrified processes can also operate flexibly, helping to balance electricity grid supply and demand, helping to limit the overall size of the system.

> “Electrification can deliver significant improvements in air quality and public health.”

5. Healthier communities

Electrification can deliver significant improvements in air quality and public health.[2] The additional energy consumption associated with CCS could increase air pollution, and burning hydrogen can result in high levels of nitrogen oxide pollution.[3]

6. Lower upstream emissions

Blue hydrogen and CCS still result in significant methane emissions. Hydrogen is prone to leaks, and its indirect warming potential is 12 times greater than CO_2 over a 100 year period.[4] But the carbon intensity of electricity is falling rapidly and low carbon electricity will have almost zero upstream emissions.

7. Scalability and flexibility

Electrification can sometimes be phased in incrementally, allowing complex manufacturing processes to adapt step by step. Hydrogen and CCS rely on large scale infrastructure, requiring significant business time and investment in a single major upgrade.

8. More suitable for dispersed sites

Dispersed industrial sites are responsible for around half of the UK’s industrial greenhouse gas emissions, but they are much less likely to be able to use CCS and hydrogen because they cannot easily plug in to the planned hydrogen and CO_2 networks of CCS clusters.

Carbon capture and storage clusters

The government is supporting the development of two ‘Track 1’ CCS clusters which could be operational before 2030. These projects, in Merseyside and Teesside, will see a network of industrial and power generation plants connected by CO_2 pipelines to offshore storage sites. In some cases, hydrogen pipelines will also be installed to enable businesses to access low carbon hydrogen as well. ‘Track 2’ clusters, in Scotland and Humberside, are less well developed and less certain, but they could also be operational around 2030.

Which industries can benefit?

“For low to medium temperature heat processes, electrification is an immediate and scalable solution.”

For sectors which primarily require low to medium temperature heat processes, electrification is an immediate and scalable solution. Industrial heat pumps, electric boilers and advanced drying systems, in most cases, can replace fossil fuel-dependent equipment in these industries.

Opposite, we summarise seven major industrial sectors, their heat demand and their electrification challenges.[5] Their electrification suitability is indicated, colour coded from green (high suitability) to red (where there are major challenges). Oil refining is not included here because it is expected to be much a much smaller industry in a net zero economy, as demand for transport fuels declines.

Seven UK industrial sectors and their electrification potential[6]

Sector	Temperature of heat demand[7]	Challenges	Suitability for electrification[8]
Steel and iron	All high temperature	Fully decarbonising primary steelmaking requires integrating hydrogen based direct reduced iron (DRI) processes	High, but hydrogen DRI is necessary for primary steel production
Chemicals (excluding pharmaceuticals)	12% of demand is high temperature, 88% is low temperature	Electrifying high temperature processes, like steam cracking and reforming, is limited by technological readiness, but trials are taking place	High, for all but the highest temperatures
Food and drink	All low temperature	Some applications, such as high temperature frying, may be harder or more expensive to electrify	Very high, except in a few niche processes
Paper and pulp	All low temperature	Although technically simple, the industry has little experience with electrified technologies	Very high, but the sector is hesitant
Glass	86% of demand is high temperature (averaged across all three sectors)	High upfront costs and infrastructure requirements are leading to slow adoption	High, hydrogen may be needed for certain applications
Ceramics		The sector expects hydrogen will heat high temperature kilns, especially tunnel kilns, where electric technologies are unproven	Moderate, might be possible for driers and smaller, specialist kilns
Cement and lime		Electric cement kilns are not widely demonstrated, and significant process emissions are difficult to avoid, leaving CCS as the primary decarbonisation pathway	Low

> “Barriers include high upfront and running costs, and access to sufficient electricity network capacity. ”

Potential in the paper and pulp industry

We have previously explored the benefits of electrification over other decarbonisation measures in the UK’s steel and chemical industries.[9,10] The potential is also high in other industries, such as paper and pulp manufacturing.[11] Most facilities in this sector rely on combined heat and power (CHP) plants to produce steam and hot air. While some CHP plants use sustainable biomass, the majority still depend on natural gas. Electric boilers, high temperature heat pumps and infrared dryers are all suitable replacements.[12] One example of where this is already happening is the James Cropper paper manufacturing mill in Kendal, awarded £4.2 million in funding from the Industrial Energy Transformation Fund (IETF), to replace its gas fired heat generation systems with electric heating.

Barriers to greater electrification include high upfront and running costs and access to sufficient electricity network capacity. The sector’s largest sites are predominantly owned by multinational corporations, where internal competition for investment drives the most progress in countries with the most ambitious climate policies. This underscores the importance of creating a supportive policy environment to attract investment and secure the future of the UK’s paper and pulp industry.

A cost effective way to cut emissions

> **“Electrifying processes can incur lower overall costs than continuing to use fossil fuels.”**

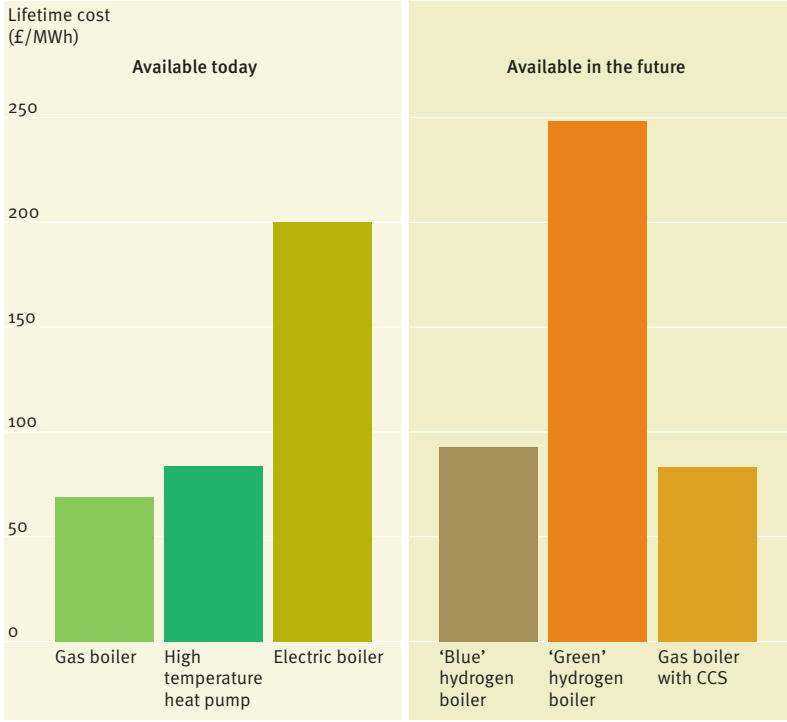
High electricity prices in the UK dissuade manufacturers from exploring electrification projects. In 2023, the average price paid by industrial sites for electricity was 4.6 times the average price paid for gas of equivalent energy value, while the same ratio in countries like Germany, France and Spain was less than three.[13] This is sometimes called the ‘spark gap’.

But electrifying processes can incur lower overall costs than continuing to use fossil fuels in a number of ways, eg energy efficiency (electric arc furnaces and heat pumps are more efficient technologies); lower maintenance and operating costs (fewer moving parts and downtime); price stability (renewables in the UK are not subject to the same market volatility as gas); and the potential for flexibility (by participating in demand reduction schemes or matching energy use to low price periods).

Electricity prices should fall in the long term, shrinking the ‘spark gap’, as gas prices will set the marginal price of electricity less frequently.[14] Our analysis shows that the estimated lifetime costs of a high temperature heat pump producing steam are comparable to a gas boiler with CCS and are cheaper than a hydrogen boiler. This assumes access to a CO_2 transport and storage network or hydrogen supply, so this comparison is most relevant in planned CCS clusters. Outside these clusters, the cost of supplying hydrogen or transporting captured CO_2 is likely to make those options prohibitively expensive. Transporting hydrogen by tanker is expected to be six to ten times more expensive than by pipeline.[15]

> “The biggest impact on the overall economics is the cost of fuel.”

Estimated lifetime costs of steam generation by different methods, using current energy prices [16]



Capital investment for high temperature heat pumps is higher than for gas and electric boilers, but the biggest impact on the overall economics is the cost of fuel. This is shown clearly above, whereby electric boilers have much higher lifetime costs than a heat pump which is assumed to be 2.5 times more efficient (higher efficiencies are possible, especially at lower temperatures).

What's stopping UK industries electrifying?

> “To create a level playing field for electrification the government needs to lower the cost of electricity relative to gas.”

When a gas fired CHP plant or steam boiler reaches the end of its life, businesses are still likely to replace it with a similar fossil fuelled asset. To make the shift to lower carbon technology, the government is offering businesses in the four proposed CCS clusters access to hydrogen or CCS infrastructure at a subsidised rate, roughly matching the expected costs of continuing with business as usual. This is steering businesses away from the most efficient, resilient way to decarbonise, towards options that could have higher greenhouse gas emissions and long term costs.

To create a level playing field for electrification and enable sites beyond industrial clusters to decarbonise too, the government needs to lower the cost of electricity relative to gas for industrial consumers.

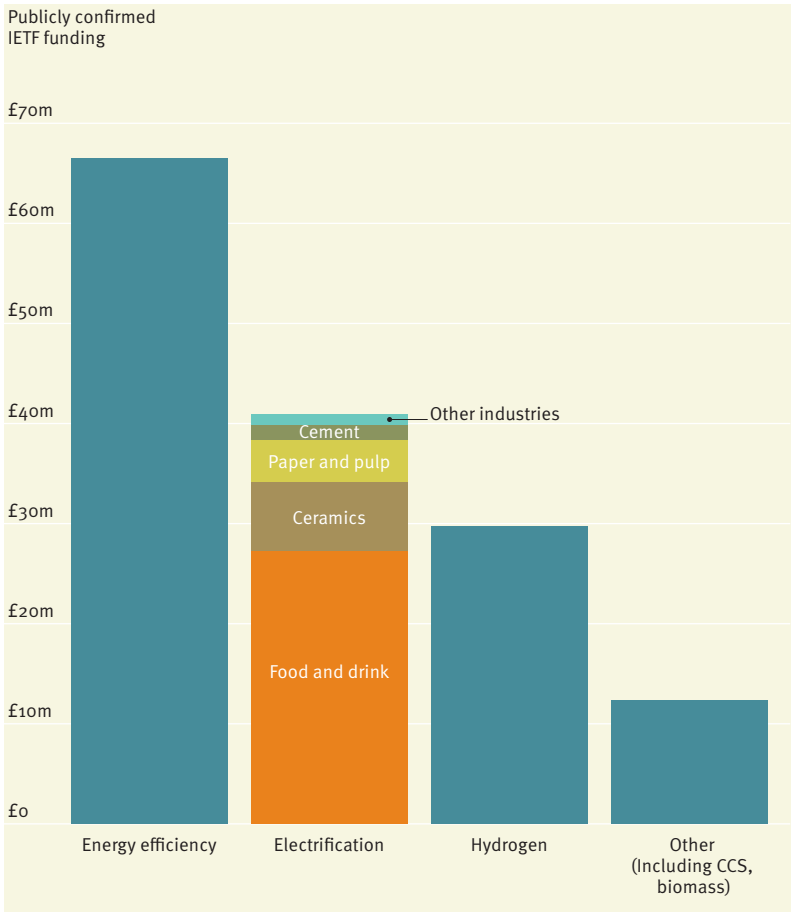
For an electric boiler to compete directly with a gas fired boiler, the price of electricity would need to approach £60 per MWh, 1.2 times the price of gas in 2023 (the latest full year for which data is available).[17] However, a heat pump could compete with a gas boiler at an electricity price of roughly £150 per MWh. This is £40 lower than 2023 electricity prices which averaged £190 per MWh for industrial consumers.[18]

The government's funding allocation for industrial decarbonisation shows a stark disparity between investment in electrification technologies and investment in CCS and hydrogen. Around £40 million has been publicly allocated to electrification projects through the Industrial Energy Transformation Fund so far, but the government cancelled the last promised round of funding in December 2024, and it is not clear if anything will replace it in future.[19] Broader support is offered to some energy intensive plants via the British Industry Supercharger.

Meanwhile, CCS projects have been promised a significantly larger £22 billion over 25 years, with guaranteed subsidies for up to 15 years, although the exact source of funding is as yet unclear. Support for hydrogen is also substantial, with unlimited funding available through a levy on gas shippers, on top of the £240 million already provided as part of the first hydrogen allocation round.[20]

> **“CCS projects have been promised £22 billion over 25 years, with guaranteed subsidies for up to 15 years.”**

The Industrial Energy Transformation Fund (IETF) has provided crucial investment support for electrification*, but its future is uncertain



*Not all IETF projects have been announced

Other countries are moving faster

> **“Lack of policy support for industrial electrification is damaging economic growth.”**

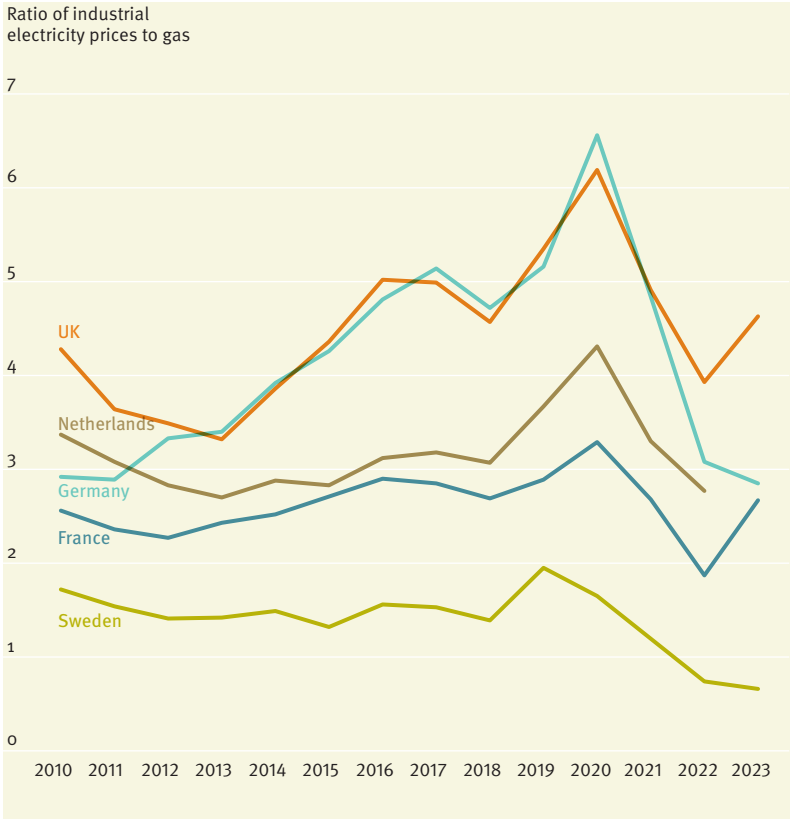
Momentum to decarbonise across all industries is building. Although thousands of small businesses are engaged in UK industrial activity, so too are many multinational companies which have set their own climate targets. And, in business supply chains, buyers are increasingly demanding lower carbon products.

Low electricity prices and supportive policies are attracting investment away from the UK towards other states. The US Inflation Reduction Act has had a tangible impact.[21] The US based company CF Fertilisers closed its UK ammonia production facilities in 2022 to move to the US where the cost of gas, a feedstock for ammonia, was lower. Similarly, industrial stakeholders tell us that the UK is at the back of the queue for international investment in electrification.

Lack of policy support for industrial electrification is damaging UK economic growth. Even compared to Europe, the UK stands out for its high electricity price and lack of policy support. Germany, France, the Netherlands and Sweden all have proactive approaches to industrial electrification, using clean energy integration and supportive policy frameworks. They also have a smaller ratio of electricity to gas prices. Unless this changes, global companies will invest in electrification in other countries rather than the UK.

> “Germany offers companies a carbon contract to cover the costs of decarbonisation compared to conventional processes.”

The UK has one of the least appealing economic environments for industrial electrification[22]



Germany

Germany offers companies a carbon contract for difference (CCfD) to cover the costs of decarbonisation compared to conventional processes. Compensation for higher capital expenditure and operating expense costs of all green technologies is available to all companies, including small and medium enterprises. This approach supports electrification, hydrogen fuel switching or other interventions, allowing businesses to choose the best technology for them. At the Ludwigshafen chemicals complex, BASF is using funds from a CCfD to install a large scale heat pump to recycle heat from a steam cracker.[23]

> “Sweden’s electricity prices have historically been less than half those in the UK.”

France

France’s industrial electrification efforts are bolstered by its plentiful supply of nuclear power. Therefore, it is in a unique position to leverage stable, low carbon electricity for its industrial sectors. The ‘regulated access to historic nuclear energy’ policy gives industrial consumers access to low cost nuclear energy supplied by older state owned plants.[24] The EU approved €4 billion in state aid for decarbonising French industry in 2024. These grants require steep cuts in emissions in return and can be spent on energy efficiency or electrification projects.[25]

The Netherlands

The Dutch SDE++ (Stimulation of Sustainable Energy Production and Climate Transition) programme has provided subsidies for renewable energy projects and decarbonisation projects, including the electrification of industrial processes.[26] In 2024, the total budget available for the SDE++ was €11.5 billion. A carbon levy complements the EU Emissions Trading Scheme (ETS) by setting a carbon price floor for sites taking part in the ETS, as well as some additional sites such as waste incineration. In 2024, the fee was €74 per tonne of CO_2 equivalent and this will continue rising each year.[27]

Sweden

Sweden’s electricity prices have historically been less than half those in the UK, with long established nuclear and hydropower sources creating a favourable economic environment for electrification.[28] The Industrial Leap Initiative, first launched in 2018 and totalling around £420 million, supports large scale innovation projects aimed at greening industrial processes. Swedish start up Cemvision has successfully demonstrated the production of cement using electricity and hydrogen.[29] Sweden is also home to the company SSAB’s trial of green hydrogen steelmaking, exploiting low electricity prices.

Barriers to UK industrial electrification

> **“Even when a company commits to electrify it is not always possible to achieve it quickly.”**

As we have shown, electrification has substantial benefits, including lower potential costs to the government, greater energy efficiency, long term price stability and lower climate and air pollution impacts. Yet, the following challenges need to be addressed before it can become a widespread choice for businesses:

High electricity costs

UK industries pay some of the highest prices for electricity in the world. Subsidies for hydrogen and CCS exist, but there is no equivalent support to bring down electricity costs.

High capital expenditure

Switching to electric equipment and upgrading grid infrastructure requires significant upfront investment. Some sectors may be more able to access such investment than others.

Grid upgrade delays

Even when a company commits to electrify and can afford a new or enhanced grid connection, it is not always possible to achieve it quickly. Some businesses have been quoted waiting times of over a decade. Industries need access to a stable and sufficient power supply. Attention has been paid to the overloaded connection queue for new electricity generation projects, but much less attention has been given to demand side delays. Welcome reforms are underway which could allow faster grid connection for both generation and demand projects at the transmission level, but they are unlikely to resolve regional disparities and delays at the distribution network level.

Wariness about new technologies

Many industrial operators have been using fossil fuel technologies for decades and their technicians are experts in them. Workers and managers can be wary of making major changes, especially where proposed technologies have not yet been widely adopted.

> “UK policy uncertainty in recent years has hampered progress.”

Inconsistent policy

While the Industrial Energy Transformation Fund supported some electrification projects, it did not reach its full potential because of the lack of support for ongoing costs of electrified technologies. It also ran funding rounds in an unpredictable way, because its own funding was provided piecemeal by the Treasury and it has now been discontinued. This discourages companies from exploring electrification options, pushing them instead towards the better supported hydrogen and CCS business models. Wider UK policy uncertainty in recent years has hampered progress.

Lack of R&D

The potential to electrify industrial processes is greater than the sectors and applications we have highlighted. However, further research and development is required to enable electrification of some of the highest temperature processes in the cement and ceramics sectors.

Four ways to speed up progress

> **“Bringing wholesale electricity costs more in line with prices across Europe would attract more domestic and foreign investment.”**

Industrial electrification should be the top choice for industries to decarbonise their processes, but it is not at present. Pursuing the four priorities below would give the UK’s government, industry and regulators, working together, the power to accelerate industrial decarbonisation and attract more international investment to grow the economy.

1. Cut electricity costs

Bringing wholesale electricity costs more in line with prices across Europe would attract more domestic and foreign investment and help businesses to choose the best route for them. This needs long term policy certainty. We recommend that the government explores:

- an electrification contract for difference (CfD), in addition to the business models for hydrogen fuel switching and industrial CCS; eventually, all such business models could be combined into a universal carbon CfD;
- widening eligibility of the British Industry Supercharger, to enable more businesses to access discounts on their electricity network costs;
- government underwriting of power purchase agreements with renewable electricity generators to reduce business risks and lower prices;
- permanently moving some policy levies from electricity bills onto more progressive general taxation, to cut energy costs for all consumers, including industry.

> “Network operators should support industries to connect new projects to the grid at reasonable cost and speed.”

2. Support businesses with finance and advice

A long term, stable replacement for the Industrial Energy Transformation Fund would encourage more businesses to invest in electrification. Although it may not be suitable for all businesses, the government could consider zero interest loans in addition to grants for some. Larger projects with workforce transition risks must demonstrate careful planning and the close involvement of workers in any changes made. As financial measures alone are unlikely to be sufficient, we also recommend a new advice and support service to help businesses, especially small and medium enterprises, to develop and implement their decarbonisation plans and access funding. Workforce training in the benefits of, and deployment of, technologies may be required.

3. Accelerate grid upgrades

Network operators should support industries to connect new projects to the grid at reasonable cost and speed. This may require more willingness by Ofgem to allow more investment, distribution network operators to offer flexible supply connections and a more standardised customer journey for new grid connections. The national energy system operator (NESO) must engage industrial stakeholders early in its regional spatial planning process.

4. Do more research and development

Research and innovation funding for high temperature electric solutions will help to address remaining technical barriers. This should aim to reverse the historical bias towards hydrogen and CCS projects and prioritise the cheaper, more efficient electrification technologies.[30]

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4 M Sand et al, 2023, 'A multi-model assessment of the global warming potential of hydrogen', *Communications earth & environment*, vol 4, 203

5 In some datasets, glass, ceramics and cement are grouped together.

6 A more detailed table is available in the accompanying research paper: L Hardy and K S Herman, February 2025, 'Research paper: the potential of industrial electrification', Green Alliance, available at bit.ly/4jZdzNv

7 Department for Energy Security and Net Zero (DESNZ), September 2024, 'Energy consumption in the UK 2024', see table U4. The methodology for this breakdown is now outdated (2014), but the majority of processes requiring heat are unlikely to have changed significantly.

8 We have judged the suitability for electrification of different sectors on the technological readiness levels and deployment of different technologies, as well as their relative consumption of high and low temperature heat. We have also used the decarbonisation plans produced by the sectors themselves, in conjunction with conversations with sector experts.

9 V Viisainen et al, 2022, *Building the future: a faster route to clean steel*, Green Alliance

10 V Viisainen et al, 2023, *A new formula: cutting the UK chemical industry's climate impact*, Green Alliance

11 Additional case studies on the glass and food and drink industries are included in the accompanying research paper: L Hardy and K S Herman, 2025, op cit

12 Confederation of Paper Industries, 2023, position paper, 'UK paper sector decarbonisation roadmap'

13 DESNZ, December 2024, 'Prices of fuels purchased by manufacturing industry', statistical dataset

14 The marginal price of electricity is the last unit of generation called upon to meet demand at any given moment. Currently, this is often expensive gas power generation, able to flex to meet demand and maintain balance on the electricity grid. As new technologies are installed, gas will set the marginal price less often, and overall wholesale costs of electricity should decrease.

15 DESNZ, December 2023, 'Hydrogen transport and storage cost report'

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17 Ibid

18 DESNZ, December 2024, op cit

19 Based on Green Alliance analysis of the published Industrial Energy Transformation Fund competition winners in England, Wales and Northern Ireland (not all projects have been finalised and published), as of January 2025, including any preliminary studies as well as capital spending, available at gov.uk/government/publications/industrial-energy-transformation-fund-ietf-competition-winners

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29 P Largue, 9 January 2025, 'Cement produced in fuelled electrified and fossil free rotary kiln', *Power engineering international*

30 In the following publication: UKRI, July 2024, *Industrial decarbonisation challenge: celebrating our impact*, electrification is mentioned only seven times. In contrast, hydrogen and CCS are mentioned around 80 times each.

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