Research paper

The potential of industrial electrification

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Authors: Liam Hardy and Kyle S Herman (research analyst at the American University of Sharjah)

Introduction

The UK's industrial sector is both a cornerstone of its economy and the third biggest contributor to its greenhouse gas emissions, after surface transport and buildings.[1] Despite decades of offshoring and decline, UK manufacturing industry still represents nine per cent of gross value added (GVA) and supports seven per cent of jobs nationwide.[2] Revitalising the UK's industrial base, while meeting ambitious greenhouse gas reduction targets by 2050, has driven the government to allocate substantial public funds, with billions earmarked, to support decarbonisation projects within industrial clusters.

Collectively, the six largest industrial clusters generate approximately half of all industrial emissions, making them a major focus for decarbonisation efforts. Government support is largely focused on the potential of clean hydrogen and carbon capture and storage (CCS) in these areas.[3] The other half of the UK's 73.5 $MtCO_2e$ per year of industrial emissions occur outside these clusters and have received much less attention.[4] The need for deep decarbonisation in industry, both inside and outside the major industrial clusters, is crucial to achieve the government's net zero ambition.

Much attention has been given to CCS and hydrogen, either blue hydrogen made using methane and carbon capture, or green hydrogen made using renewable energy and electrolysis, as solutions to drive industrial decarbonisation. Meanwhile, the government has provided less guidance and support for the electrification of industry, despite its potential to boost economic activity and make businesses more competitive. This report makes the case that electrification of industrial operations and sectors, especially given recent support in Europe, marks an important industrial opportunity that the UK should not miss.

What is electrification?

In this paper, we refer to electrification as the replacement of fossil fuel dependent processes with technologies powered by electricity; for example, the replacement of a boiler burning fossil gas with an electric boiler or heat pump. While fuel switching to green hydrogen could be considered a process of electrification, we define it as decarbonisation using hydrogen, rather than the use of direct electricity.

By replacing fossil fuels with electricity in processes ranging from steelmaking to chemical production, electrification offers a clear route to reduce emissions while enhancing the competitiveness of UK industries. This approach not only addresses greenhouse gas emissions reduction targets but would also position the UK as a leader in the unfolding industrial revolution based on electrification, enabling industries to thrive as electricity becomes cheaper, cleaner and more abundant. As such, electrification is not only a tool for decarbonisation but also a gateway to a modernised and resilient industrial economy.

Research on European industry suggests that 78 per cent of industrial energy demand could be met with existing electrification technologies, and up to 99 per cent may be possible with developing technologies.[5]

The potential for electrification, however, varies in cost and difficulty across sectors. For food and drink, and other sectors that only require low temperature heat, industrial heat pumps provide an efficient and scalable solution, serving as replacements for conventional fossil fuel boiler systems and enabling waste heat recirculation to enhance energy efficiency. Other examples include electric boilers, electric steam crackers, electric furnaces and microwave ovens.

The table below outlines a non-exhaustive selection of these options, their technology readiness levels (TRLs), and their potential industrial integration. Specific barriers to implementing processes and technologies are included.

Selected technology options for industrial electrification[6]

Sector	Example technology	Context	Implementation barrier	TRL
Cross sectoral	Electric boilers for steam generation	Gas-fired boilers dominate steam generation for low, medium and high pressure needs. Electric boilers (resistive and electrode) are commercially viable.	– Lack of awareness of technology and limited deployment in high pressure steam systems to date.	9
Cross sectoral, but especially paper and pulp	High temperature heat pumps	Combined heat and power (CHP) plants supply electricity and steam (150–180°C). High temperature heat pumps and mechanical vapour recompression technologies are emerging as replacements.	– Lack of awareness of technology and limited deployment to date. – Better refrigerants need to be explored, with lower global warming potential.	7-9
Chemicals	Electric steam crackers	Steam cracking furnaces for pyrolysis operate at 750–950°C. Electric resistance cracking furnaces are in early development.	– Technology is still in development. – Product yield and quality is still not fully understood. – Electrification can create a surplus of flue gases that would otherwise be combusted as fuel.	6
Glass	Melting furnaces	Glass melting occurs at around 1700°C. Electric furnaces are technically and commercially mature and can replace the use of gas.	– Larger furnaces are more technically challenging to develop. – Electric furnaces can't accept the highest fractions of recycled material – Electric furnaces have shorter lifespans.	9

Food and drink	Microwave ovens	Gas-fired ovens operate at 100–300°C. Microwave ovens offer a more efficient alternative that can bake products more quickly.	– Concern over replicating food quality. – Difficult to retrofit.	8-9
Steel	Electric arc furnace (EAF)	Traditionally, steelmaking uses coal to reach the high temperatures and provide the carbon needed to chemically reduce iron ore. Electric arc furnaces offer flexible production using up to 100 per cent scrap steel feedstock with much lower emissions.	– EAFs cannot produce virgin steel. – Requires very high electrical loads.	9

In contrast, sectors with high temperature demands, such as ceramics, cement and refining, face greater challenges in adopting electrification. These sectors may indeed need to rely on some combination of CCS and hydrogen for certain processes.

Electrification is the smart choice for many industries

There are many factors affecting any individual industrial site and its choice of decarbonisation technology, including differences in energy needs and production processes, existing assets and technical knowledge, appetite for innovation, access to relevant infrastructure and access to capital for investment. There are advantages to electrification in comparison to hydrogen fuel switching and CCS for both the individual business and the UK, including:

Immediate emissions reductions: While CCS and hydrogen need new supply pipelines and storage facilities, industrial electrification can use existing infrastructure, especially where there is already electricity network headroom in industrial clusters.

Energy independence: Unlike CCS or the use of blue hydrogen, which both tend to mitigate emissions without addressing fossil fuel dependency and associated geopolitical and economic risks, electrification offers a route to largely UK-sourced energy.

Cost stability: As electricity becomes cheaper, cleaner and more abundant, electrified industries can benefit from predictable, declining costs. In contrast, CCS and blue hydrogen face high, uncertain costs tied to volatile gas markets and unproven infrastructure.

Efficiency gains: Electrification technologies, like high temperature heat pumps, can achieve efficiencies several times higher than traditional gas boilers, lowering energy inputs and boosting productivity. Many electrified industrial processes can also be operated flexibly, helping to balance electricity grid supply and demand, reducing the overall size of the system.

Healthier communities: Electrification can deliver significant improvements in air quality and public health.[7]

Lower upstream emissions: Blue hydrogen and CCS entail significant methane emissions, and hydrogen's indirect warming potential is 12 times greater than CO_2 over a 100 year period.[8] In contrast, the carbon intensity of the current electricity system is falling rapidly, and low carbon electricity can have close to zero upstream emissions.

Scalability and flexibility: Electrification can sometimes be phased in incrementally, adapting to complex manufacturing processes. In contrast, hydrogen and CCS rely on large scale infrastructure, requiring significant time and investment on behalf of the business.

Suitable for dispersed sites: Dispersed industrial sites in the UK are responsible for around half of industrial emissions. Such sites are much less likely to be able to decarbonise through CCS and hydrogen.

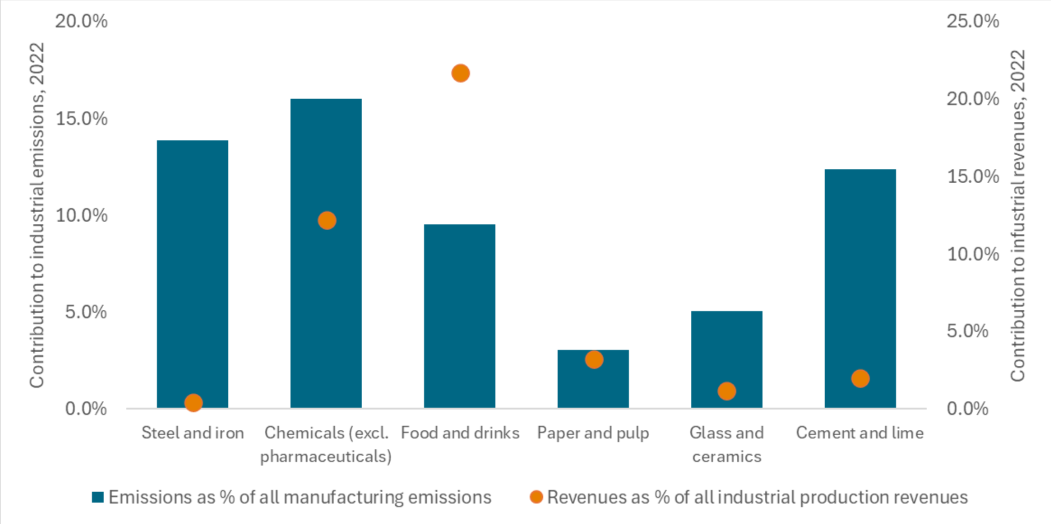
Certain industries are prime targets for electrification

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

In annex one at the end of this paper, we summarise seven of the biggest emitting sectors, including an overview of the emissions intensity (emissions per unit value of production), their energy consumption and heat demand, and their suitability for electrification. The refining sector is excluded as it expected to be much smaller in a net zero economy, and note that, in some datasets, glass and ceramics (and sometimes cement) are grouped together. It should be noted that the exact categorisation of emissions and revenues in each sector may not be universally comparable.

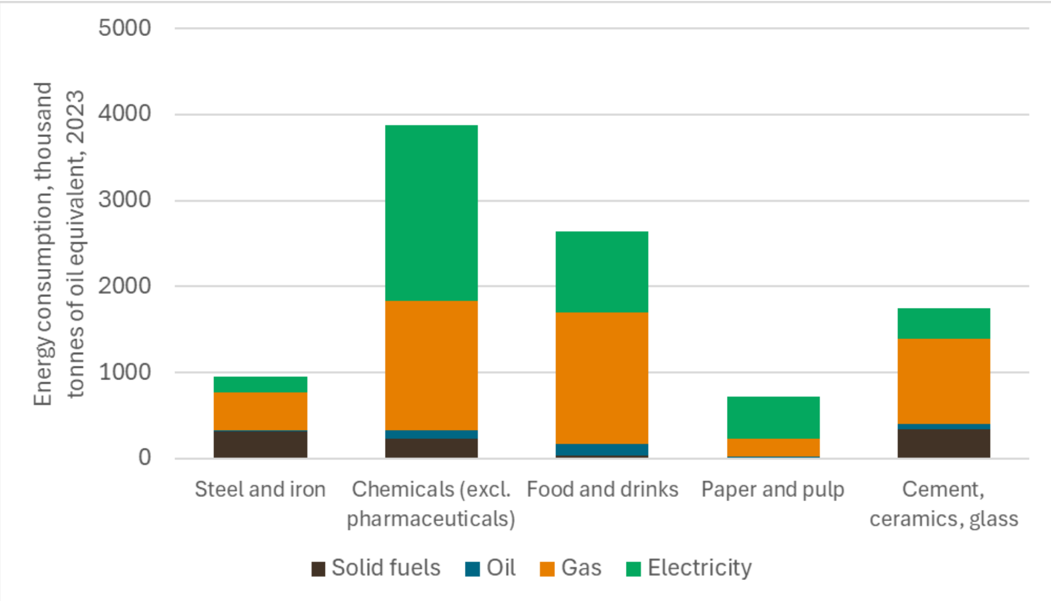
Emissions and economic impact of selected industrial sectors[9]

Steel and cement making are more emissions intensive than other sectors



Energy consumption of selected industrial sectors[10]

Most industries already use considerable electricity, with potential to electrify further



These sectors are responsible for significant emissions, whilst making critical contributions to the economy. Estimates for sector revenues do not capture their foundational importance to reliant sectors.

The second graph above shows that, whilst gas remains the most common source of energy across these sectors, there is already considerable electricity consumption. However, some of the electricity consumed is generated on site by combined heat and power (CHP) plants, and this is especially the case in the paper and pulp sector.[11]

Electrification technologies for low temperature heat are generally more mature and ready for deployment, compared to hydrogen. For high temperature heat, both have similar technological readiness levels and timelines, but hydrogen may be easier to integrate due to its compatibility with existing gas fired systems. However, hydrogen adoption is limited by cost and the availability of supply infrastructure.

Case studies in food and drink, paper and pulp, and glass manufacturing

Green Alliance has already explored the benefits of electrification over other decarbonisation measures for the UK steel and chemical industries.[12,13] The potential for industrial decarbonisation through electrification is further exemplified in sectors such as food and drink, paper and pulp, and glass. Below we outline the opportunities and some examples from each sector.

Food and drink manufacturing

- **Why electrify?** The food and drink sector is primarily composed of small and medium sized enterprises (SMEs) which are not, in contrast to larger facilities, subject to the UK emissions trading scheme (ETS). This means that there are few regulatory mandates to drive carbon emissions reductions, although this sector is one where consumer demand for green products is likely stronger than for others. Sites are also distributed across the country, making decarbonisation using hydrogen or CCS much more difficult. Notably, 65 per cent of the sector's heat demand comes from boilers, with an additional 16 per cent from ovens.[14] Suitable electrification solutions already exist for both. The modular nature of electrification technologies aligns well with the needs of these SMEs, allowing incremental upgrades without significant disruption or the need for large scale infrastructure changes.

- **For example:** The Britvic soft drinks plant in Beckton, London, was awarded a £4 million grant through the Industrial Energy Transformation Fund (IETF) to install heat pumps to turn waste heat from on site chillers into a hot water network supplying heat to other processes, replacing gas fired boilers. Similar projects could explore further efficiency gains, where the cooler air produced by heat pumps is used to support refrigeration units.
- **Barriers to electrification:** These include inertia, whereby companies fear a change to the taste of foods because of switching technologies, as well as upfront costs, running costs and access to electricity network upgrades. There are only a few activities in the food and drink sector that require very high temperatures, where hydrogen may be required, such as coffee roasting or sugar refining.

Paper and pulp manufacturing

- **Why electrify?** Most facilities in this sector rely on CHP plants to produce steam and hot air. While some CHP plants already use sustainable biomass, making immediate decarbonisation less pressing, the majority still depend on natural gas. Electric boilers, high temperature heat pumps and infrared dryers are suitable replacements.[15]
- **For example:** The James Cropper paper manufacturing project in Kendal was awarded £4.2 million in funding from the IETF, to replace its gas fired heat generation systems with electric heating.
- **Barriers to electrification:** These 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 decarbonisation progress in regions with the most ambitious climate policies. This underscores the importance of creating a supportive policy environment to attract investment in the UK.

Glass manufacturing

- **Why electrify?** While this transition is technologically challenging for higher temperature applications, the sector expects that around 80 per cent of the potential to reduce combustion emissions will come from electrification.[16]
- **For example:** Dartington Crystal in Devon is being supported by £500,000 from the IETF. The factory has been running gas furnaces

since 1967 but is now replacing them with new electric furnaces that will reduce overall energy consumption by around 80 per cent.

- **Barriers to electrification:** The sector faces the same core challenges as others, namely the price of electricity, upfront investment costs and inertia.

Electrification may offer a cheaper route to decarbonisation

The high price of electricity in the UK dissuades many industrial sites from exploring electrification projects. In 2023, the average price paid by industry for electricity was 4.6 times the average price paid for gas of equivalent energy value.[17] This factor is sometimes called the 'spark gap'.

That said, there is the potential for electrified activities to have lower overall costs than continued use of fossil fuels, as a result of:

Energy efficiency: technologies such as electric arc furnaces or industrial heat pumps operate more efficiently than fossil fuel systems.

Reduced maintenance and operating costs: electric systems generally have fewer moving parts than their fossil fuel counterparts, reducing maintenance costs and downtime.

Stability: electrification provides industries with more resilience against volatile fossil fuel markets. The 2021–2022 energy crisis highlighted the risks of dependency on gas. In contrast, an electricity system with an increasing proportion of renewables offers a more stable and predictable energy cost trajectory, ensuring long term cost stability.

Flexibility: for certain industries where batch processing is possible, matching demand with periods of low prices, or participating in demand side reduction schemes, can lower costs.

Electricity prices are expected to fall in the long term, and the spark gap will shrink, as gas sets the marginal price of electricity less and less frequently. Our analysis shows that the estimated lifetime costs of a high temperature heat pump producing steam are already comparable with the lowest estimated cost of using CCS with a gas boiler and are cheaper than a hydrogen boiler. This assumes access to a CO_2 transport and storage network, or a hydrogen supply, ie this comparison is relevant only in the planned CCS clusters and, crucially, only when the relevant infrastructure is in place.

Outside these clusters, the cost of supplying hydrogen or transporting away 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.[18]

The table below demonstrates this analysis and gives a sense of the economic factors affecting a business when deciding how to replace an ageing boiler, or when considering decarbonisation options.

Estimated costs of producing steam for industrial use via different technologies[19]

Cost component	Gas boiler (counterfactual)	High temperature heat pump (available today)	Electric boiler (available today)	Blue hydrogen boiler	Green hydrogen boiler	Gas boiler with CCS
Capex (£/kW)[20]	166	300	120	199	199	232
Expected lifetime (years)[21]	35	20	15	20	20	20
Expected load factor[22]	80%	80%	80%	80%	80%	80%
Capex (£/MWh)[23]	**1.62**	**3.85**	**1.83**	**2.56**	**2.56**	**2.98**
Fuel costs (£/MWh)[24]	48.59	190.27	190.27	73	216	48.59
Energy conversion efficiency[25]	90%	250%	99.9%	92%	92%	72%
Fixed opex (£/MWh)[26]	0.47	0.43	0.17	0.29	0.29	0.58
Variable opex (eg maintenance, £/MWh)[27]	0.21	0.40	0.20	0.30	0.30	0.26

Network costs (£/MWh)[28]	0.68	3.05	7.64	10.33	10.33	11.44
UK ETS costs (£/MWh)[29]	12.09	0	0	0	0	0.60
Opex (£/MWh)	**67.44**	**79.99**	**198.47**	**90.26**	**245.69**	**80.37**
Total (£/MWh)	**69**	**84**	**200**	**93**	**248**	**83**

The table above demonstrates that, whilst the capital investment in high temperature heat pumps might be more than double that of a new gas boiler, by far the biggest impact on overall economics is the cost of fuel. It also demonstrates that, at present, even with the UK ETS and the option of highly efficient heat pumps, businesses are unlikely to choose to electrify based on financial factors alone. If a gas fired CHP plant or steam boiler reaches the end of its life, right now businesses are likely to replace it with another fossil fuelled asset. This could change if the UK ETS carbon price rises beyond £100 per tCO_2.

To tip the balance towards decarbonisation, the government is offering businesses in the four proposed CCS clusters access to hydrogen or CCS infrastructure at a subsidised rate. To provide a technology agnostic level playing field for electrification and enable dispersed sites to decarbonise, the government must find a way to overcome the spark gap that deters industrial consumers.

By extension of the analysis above, we find that for an electric boiler to compete directly with a gas fired boiler, the effective price of electricity would need to approach £60 per MWh, a spark gap of 1.2. However, a heat pump could be cost competitive with a gas boiler at roughly £150 per MWh, a spark gap of around three. To drive widespread uptake with a clear financial incentive, the spark gap must be lowered to between 1.2 and three.

This could be achieved through a technology neutral carbon contract for difference, a specific electrification contract for difference (CfD), or through the government underwriting power purchase agreements, enabling industrial sites direct access to cheaper renewable electricity. Initially, support for those sites which can electrify with the use of a highly efficient heat pump would minimise any costs borne by government, as the difference in running costs between a gas boiler and a heat pump are small.

What's stopping faster uptake of electrification?

As well as the current spark gap, other factors are dissuading industrial sites from exploring electrification. Although policies exist to drive decarbonisation, they are skewed towards hydrogen fuel switching and CCS. This risks directing businesses away from electrification as the most efficient, resilient decarbonisation route, towards options that have the potential to induce higher emissions and higher long term costs.

Current policy favours hydrogen and CCS

The government's funding allocation for industrial decarbonisation highlights a stark disparity between investments in electrification technologies and those in CCS and hydrogen. While around £25 million has been awarded to electrification projects through the IETF, alongside support for energy intensive industries more broadly through the British Industry Supercharger, promised funding for CCS projects stands at a significantly larger £22 billion (over 25 years, with business models guaranteeing a subsidy for up to 15 years). Support for hydrogen may be unlimited, via a levy on consumer bills, on top of the £240 million provided so far, as part of the first hydrogen allocation round.[30]

UK emissions trading scheme – incentivises all technologies

Post-Brexit, the UK government introduced its own version of the EU ETS, the UK ETS. Energy intensive sectors must record their emissions, buying and retiring an equivalent number of credits under a set maximum or 'cap' on emissions. Any operations larger than 20MW (thermal energy consumption) or emitting more than 25,000tCO_2 per year must participate, though the government gives out some free allocations for sectors especially vulnerable to international competition from dirtier producers (carbon leakage).

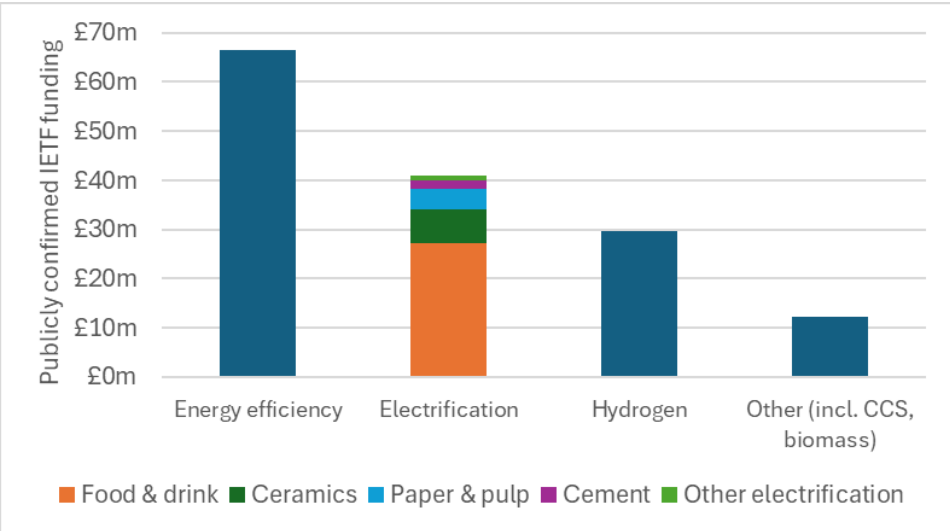
All sites covered by the UK ETS are, therefore, economically incentivised to cut emissions, with no particular technology favoured over others, although the signal is somewhat diminished for those receiving free allowances. The incentive is currently fairly weak, with a very low market price for carbon credits within the UK ETS since the middle of 2023.

Industrial Energy Transformation Fund – incentivises all technologies

Since 2020, the IETF has been awarding grants to help businesses build resilience and competitiveness by cutting their energy bills and carbon emissions, through investing in energy efficiency and low carbon technologies. Businesses need to match the grants with a similar amount of private investment. The fund is good example of a government intervention which boosts economic growth whilst cutting emissions.

The original fund totalled £315 million and some of this is still being spent, with around £150 million publicly allocated to competition winners (outside Scotland) in announcements to date. Almost half of this went to energy efficiency projects, and around £40 million went to electrification projects, as can be seen in the chart below.[31] Where funding was awarded for electrification projects, 67 per cent was for the food and drink sector. A further £100 million was opened for competition in 2024, but a second round of this extension fund was cancelled in December 2024. It is not clear if anything will replace it in future.

IETF spending (outside Scotland) leans towards energy efficiency measures and electrification



Industrial Decarbonisation Challenge – incentivises all technologies

This is part of the UK government's Industrial Strategy Challenge Fund. The programme has a £210 million budget to support the development of low carbon technologies and infrastructure in industrial clusters. The exact breakdown of project funding for each cluster is not available, and whilst the activities listed include electrification, CCS and hydrogen, the companies involved and the geographies covered suggest the vast majority has been spent on hydrogen and CCS projects.[32]

Climate Change Agreements – incentivise all technologies

The Climate Change Levy (CCL) is an environmental tax applied to energy supplied to businesses, designed to promote energy efficiency and lower carbon emissions. Energy intensive sectors can enter Climate Change Agreements (CCAs) with the government, whereby they agree to report and reduce their emissions according to set targets, in exchange for a discount on their CCL.

British Industry Supercharger – incentivises electrification

Announced in February 2023, the British Industry Supercharger (BIS) aims to boost the competitiveness of the UK's energy intensive industries by lowering electricity costs to align better with those in other comparable economies. The BIS exempts the largest industrial consumers of electricity from having to pay the renewables levies and capacity market charges, and it discounts the cost of network charges. In total, the BIS could reduce electricity prices by around £20 per MWh for around 400 of the most energy intensive businesses.[33] However, because exemptions are only available to businesses who can demonstrate high historic electricity consumption, it favours existing activities over proposed future electrified processes.

CCS funding – incentivises CCS and hydrogen

Reiterated in October 2024, the previous government's commitment to £20 billion for carbon capture and storage was solidified and enhanced to £21.7 billion over 25 years, almost a thousand times more than that awarded to electrification projects via the IETF. This funding primarily supports large scale projects in the East Coast and HyNet clusters, aiming to establish the UK as a leader in CCS technologies while driving private sector investment.

Although not yet finalised, it is expected that much of this funding will be allocated through the hydrogen and carbon capture business models, particular for hydrogen production and gas plants using CCS, as these are considered the anchor projects in the two initial CCS clusters. Some of this money will ultimately be passed on to CCS transport and storage companies.

Net Zero Hydrogen Fund – incentivises CCS and hydrogen

The Net Zero Hydrogen Fund has allocated £240 million to support the development and deployment of low carbon hydrogen production projects (both green and blue), facilitating the transition to hydrogen as a clean energy source. Going forward, it is expected that funding to subsidise the production of clean hydrogen will come from a levy on gas shippers. The hydrogen business models will enable industrial users to purchase hydrogen at effectively the same price as natural gas, incentivising the uptake of hydrogen fuel switching.

Steel strategy

The government has promised up to £2.5 billion of investment into the UK steel industry and promised a steel strategy. It is not clear what fraction of this would be invested in cutting emissions but, given the signals by Tata Steel and British Steel, this may fund the replacement of the last remaining blast furnaces with new electric arc furnaces.

National Wealth Fund – support for CCS and hydrogen

In its manifesto, the Labour Party promised £7.3 billion of capital investment, via the new National Wealth Fund, including £1 billion to accelerate CCS and £500 million to support green hydrogen production. So far, only £5.8 billion has been announced as part of the National Wealth Fund.

Investment for electrification is attracted elsewhere

Although there are thousands of small businesses involved in UK industrial activity, there are also many larger sites owned by multinational companies. Many of these have set science-based climate targets. Downstream buyers are also demanding lower carbon products. There is, consequently, growing momentum to decarbonise amongst the largest international industrial businesses.

Yet, as the UK has witnessed in the past two decades, in Teesside and Port Talbot, multinational industrial firms will naturally seek the best policy environments to invest in decarbonisation.[34] Low electricity prices and supportive policies are attracting investment away from the UK and towards other states, especially through the US Inflation Reduction Act, for example.[35] The closure of CF Fertilisers' ammonia production facilities in the UK in 2022 is a good example of this. The US-based company simply moved production to the US, where the cost of energy is much lower.

Investment in industrial electrification: a European comparison

Like the UK, the EU has been slow to recognise electrification as a priority route to industrial decarbonisation but is now working on an 'electrification action plan'.[36] Electricity prices in many parts of Europe are much lower than in the UK, and some countries have developed specific policies to support electrification efforts.

Germany, France, the Netherlands and Sweden stand out for their proactive approaches to industrial electrification, which leverage clean energy integration and supportive policy frameworks. Below, we review some of their relevant policies and projects.

Germany

What stands out in Germany is the introduction of carbon contracts for difference (CCfDs) to companies to effectively cover the costs of decarbonisation. Compensation for higher capital expenditure (capex) and operating expenditure (opex) costs of green technologies is available to companies of any size, thus including small and medium enterprises.

This is a truly technology agnostic approach which supports electrification, hydrogen fuel switching or other interventions, allowing businesses to choose the best technology for them. CCfDs, though a novel policy framework, can reduce investor uncertainty by guaranteeing a maximum cost for low carbon products.

At the Ludwigshafen chemicals complex, BASF are using recently awarded funds from a CCfD to install a large scale heat pump to recycle heat from a steam cracker.[37] This project could in future complement existing electrification progress at the site, where BASF, SABIC and Linde began demonstrating operations of an electrified steam cracker in 2024. That experiment tests the direct heating of cracking coils with electricity, and radiative heating from elements surrounding the furnace.[38]

France

France's industrial electrification efforts are bolstered by its plentiful supply of nuclear power. 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.[39]

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.[40]

The Netherlands

The SDE++ (Stimulation of Sustainable Energy Production and Climate Transition) programme provided subsidies for renewable energy projects and decarbonisation projects, including electrification of industrial processes. Technologies covered include heat pumps and electric boilers.[41] In 2024, the total budget available for the SDE++ was €11.5 billion, though in previous years this has been smaller. Importantly, the Netherlands could be the second European country to implement CCfDs, following Germany, as the SDE++ program is expected to be replaced by a new contract for difference mechanism.

The Netherlands is also demonstrating how to use and work alongside the EU ETS, to catalyse industrial decarbonisation in a technology neutral way. A carbon levy complements the EU ETS by effectively setting a carbon price floor for sites taking part in it, and some additional sites such as waste incineration.

Businesses are charged an additional fee for any emissions above a threshold, if the EU ETS price is below that set by the government. In 2024, the fee was €74 per tonne of CO_2e and will continue rising each year. This bolsters the impact of the EU ETS, driving investments in decarbonisation in a technology neutral way.[42]

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.[43]

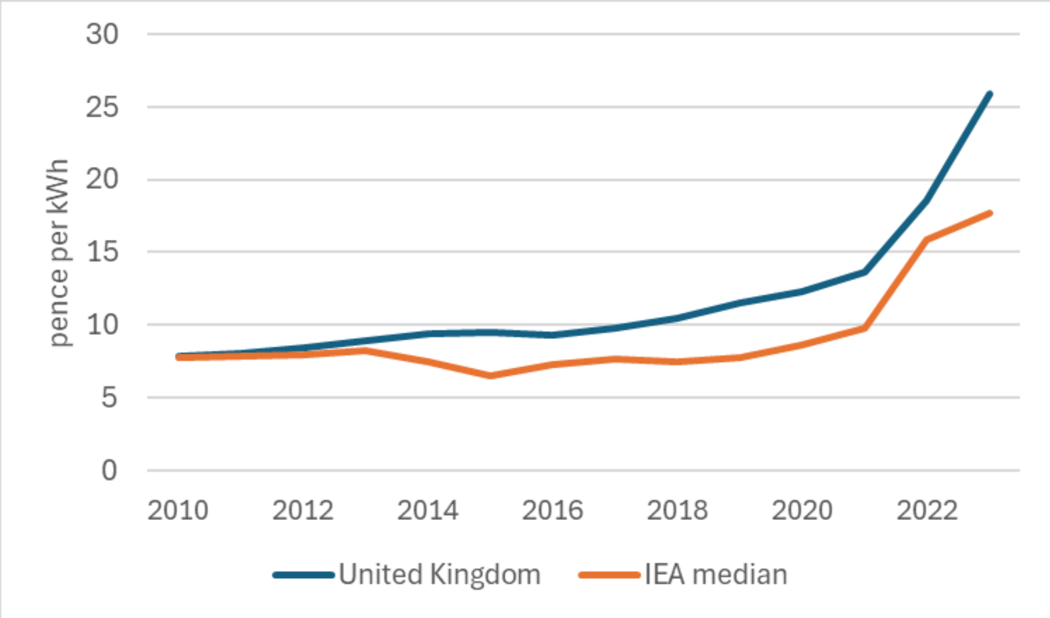
The Industrial Leap Initiative, first launched in 2018 and totalling around £420 million, supports large scale innovation projects aimed at greening industrial processes. A large fraction of funding has gone to carbon capture projects on bioenergy systems, but other technologies, including electrification, are supported. However, the Swedish national audit office recently reported that the scheme has several shortcomings, particularly in evaluating impact.[44]

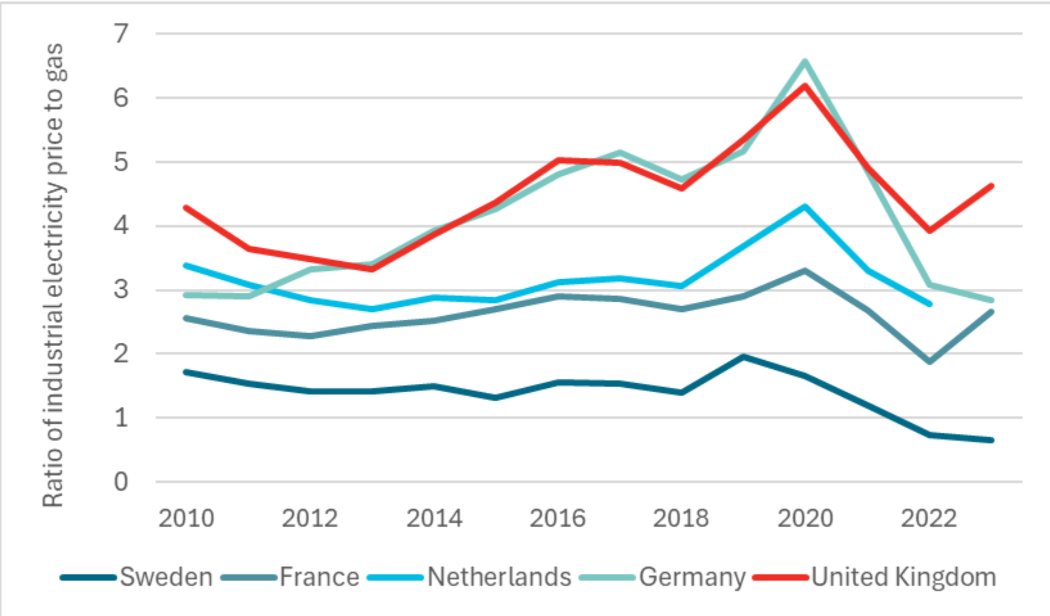
Swedish startup Cemvision has successfully demonstrated the production of cement using electricity and hydrogen. Plasma and resistive heating technology is combined with the combustion of hydrogen to reach the high temperatures required.[45] Sweden is also home to steel manufacturer SSAB's trial of green hydrogen steelmaking, demonstrating the attraction of low electricity prices.

Electricity prices and policies have an impact on the uptake of industrial electrification

Electricity prices and policy support significantly affect the adoption of industrial electrification. Countries with lower electricity prices or robust incentives are likely to attract more investment into electrification. The UK has some of the highest electricity prices in Europe, with industrial electricity costs consistently higher than the median of International Energy Agency (IEA) member countries since 2013.

UK industrial electricity prices since 2010 compared to the median of IEA member countries[46]





Industrial electrification faces multiple challenges

Despite the evidence that electrification of industrial processes can be cheaper, cleaner and more efficient than other technologies, there are several barriers in the UK preventing wider uptake.

- **High electricity costs:** As outlined above, UK industries pay some of the highest prices for electricity in Europe. The spark gap is around four at the moment, suggesting that electrified technologies would need to be around four times more efficient than fossil fuelled technologies. Some heat pumps can reach these levels of efficiency, but they are still considered novel technologies. Subsidies for the use of hydrogen and CCS enable companies to explore these options for decarbonisation, but equivalent support for high electricity costs is missing.
- **High capital expenditure:** Transitioning to electric equipment and upgrading grid infrastructure can require significant investment. As such, the replacement of fossil fuelled assets with electrified technologies is only like to happen when those assets reach the end of their lives. Even then, other complimentary components in the process may require alterations to allow for electrification, which can increase upfront costs. Grants and loans for capital expenditure may be required to attract investment.
- **Grid upgrades:** Even when a company commits to an electrification project and has the money available to purchase a new or enhanced grid connection, they cannot always access this quickly. Industries need access to a stable and sufficient power supply, which can require reinforcement or expansion of the local distribution network, and sometimes even the national transmission network. Much attention has been paid to the overloaded connection queue for new electricity generation projects, but much less attention has been said about demand side connection delays.

  Reforms to grid connection queue systems may unlock faster connection for generation and demand projects at the transmission level but will not solve regional disparities and delays at the distribution network level. Indeed, in 2023, the Department for Energy Security and Net Zero (DESNZ) conducted a call for evidence on industrial electrification. Of those who responded to this, 80 per cent indicated that financial and infrastructure barriers were the most severe.[48]
- **Resistance and inertia:** Many industrial operators have been using fossil fuelled technologies for decades, and their technicians are experts in those technologies. Some technologies, like CHP plants, are still considered the best available technology in sectors like paper and pulp. Workers and managers can fear widespread changes, especially for first of a kind projects where the proposed technologies are not yet widely adopted. Only the bravest companies want to be the first to switch.

Workforce training and education of the benefits of electric technologies is required.

- **Inconsistent policy support:** While initiatives like the IETF support electrification projects, these funds are undersubscribed because there is little ongoing opex support for electrified technologies. In comparison with business models for hydrogen and CCS, companies are discouraged from exploring electrification options. The UK ETS should offer a technology agnostic incentive to decarbonise, but the carbon price has remained stubbornly low since the middle of 2023, and it does not cover smaller industrial sites.

  In addition, there has been a lot of decarbonisation policy uncertainty in the UK in recent years, unlike in the EU where such policy has, in general, only been strengthened and added to. It is crucial that policy to support industrial electrification is put in place now, to enable better planning by all stakeholders, based on ambitious but realistic electricity demand expectations, especially as the national energy system operator (NESO) develops regional energy plans.

- **Technical readiness:** The total potential for electrification of industrial processes is wider than the sectors and applications we have outlined above. However, further research and development is required to enable the electrification of some of the highest temperature processes in the cement and ceramics sectors, for example.

Impact on electricity demand and electricity networks

Current energy consumption data suggests that full electrification of key industries - such as iron and steel, chemicals, food and drink, and paper and pulp - could double existing industrial electricity consumption. If these sectors replaced all fossil fuel use with electricity, annual consumption could rise by 42TWh, equivalent to approximately 15 per cent of the UK's 2023 electricity generation.[49]

Electrifying industrial sectors will inevitably lead to a substantial increase in electricity demand, necessitating major upgrades to grid capacity and infrastructure. At the distribution level, current capacity is expected to accommodate moderate industrial electrification through to 2030 but, beyond this date, significant network expansion will be required.[50] If greater uptake of electrification occurs, constraints will appear sooner. Even with lower rates of electrification, industrial processes demanding up to 71GW of grid capacity may face delays in electrification.

In 2022, it was estimated that to electrify all 46 paper mills in the UK, the overall cost of electricity network upgrades alone could be in the region of £330 million.[51]

Despite some capacity on the electricity grid at present, this capacity is not always located where it is needed. Even where upgrades are modest and affordable, as part of overall decarbonisation investments, some businesses have reported long delays waiting in the queue for grid upgrades.

In discussions with businesses and trade associations, it appears that there is sometimes an accidental deterrent to exploring electrification, whereby generic quotes for long lead in times and high costs are given before any detailed analysis of the precise situation for the site in question is undertaken. There is also a language issue for many demand users, especially smaller ones, who will struggle to engage with the energy industry jargon that permeates consultations and policy development.

Whilst network upgrades are a barrier for many businesses, a clear advantage for electrification efforts is that the bulk of the electricity grid already exists, and the technology is well established. In contrast, extensively transporting hydrogen or CO_2 by pipeline has not yet been demonstrated in the UK and developing that infrastructure is likely to incur significant costs.

Recommendations

To overcome these challenges and international competition, co-ordinated efforts are required by government, industry, regulators and research institutions, to achieve the following:

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

- An electrification CfD, in addition to the existing businesses models for hydrogen production and industrial CCS. All such business models could eventually be combined into a universal carbon CfD;
- Widening eligibility of the British Industry Supercharger, to enable more businesses to access discounts on electricity network costs;
- Government underwriting of power purchase agreements (PPAs) 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 industry and all consumers.

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. Larger projects with workforce transition risks must demonstrate careful planning and the close involvement of workers in 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 electrification technologies may be required.

Accelerate grid upgrades: Network operators should support industries to connect new projects to the grid at reasonable cost and without long delays. This may require more willingness by Ofgem to allow more investment, distribution network operators to enable customers to have flexible connections and a standardised customer journey for new grid connections. The national energy system operator (NESO) must engage industrial stakeholders early in its regional spatial planning process.

Do more research and development: Research and innovation funding for high temperature electric solutions will help to address the remaining technical barriers. This should reverse the historical bias towards hydrogen and CCS projects and prioritise cheaper, more efficient electrification technologies.[52]

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Endnotes

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[15] Confederation of Paper Industries, 2023, op cit
[16] British Glass, 2024, *Net zero strategy: progress update 2024*
[17] DESNZ, December 2024, 'Prices of fuels purchased by manufacturing industry', statistical dataset
[18] DESNZ, December 2023, *Hydrogen transport and storage cost report*
[19] This table compares the lifetime costs in £/MWh (in terms of the final heat delivered) for different steam generation technologies. Clearly the costs may vary from site to site, and these estimates do not consider the cost of any new infrastructure that would need to be deployed (e.g. new electricity grid capacity, hydrogen pipelines and storage, or CO_2 transportation pipelines), but it does include the ongoing costs for such connections. It may be expected that some of these types of infrastructure (e.g. CO_2 transportation pipelines) will mostly be paid for by the government. The capex calculation assumes an eight per cent interest rate paid back over the lifetime of the asset. Sources and assumptions are detailed in subsequent endnotes.
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Annex one:

Industrial sectors and their suitability for electrification

Sector	Heat processes	Heat demand (2023)[1]	Impacts	Challenges	Suitability for electrification[2]
Steel and iron	Blast furnaces, sinter plants, coke ovens, electric arc furnaces	100% of heat demand is for high temperatures	Recycling scrap steel in electric arc furnaces is up to 70% more energy efficient compared to traditional steel making in blast furnaces.[3]	Decarbonising primary steelmaking requires integrating hydrogen-based direct reduced iron (DRI) processes alongside EAFs to replace carbon-intensive blast furnaces	High, but need hydrogen DRI for any primary steel production
Chemicals (excl. pharmaceuticals)	Steam cracking, steam reforming, steam production, catalysis, reactors	12% of heat demand is high temperature, 88% is low temp, drying and separation, space heating	Electrified boilers and heat pump steam generation systems can replace natural gas in lower-temperature processes.	Electrifying high-temperature processes like steam cracking and reforming is currently limited by technological readiness, but trials are taking place	High, for all but the highest temperatures
Food and drinks	Boilers, ovens, fryers, driers, pasteurisers etc	100% of heat demand is for low temperatures, drying and separation	Electrification of ovens, pasteurizers, and dryers using industrial heat pumps offers efficient solutions for low and medium temperature processes.	Some applications such as frying may be harder to electrify	Very high, except in a few niche processes
Paper and pulp	CHPs supply steam for heated rollers, and hot air blowers	100% of heat demand is for low temperatures, drying and separation	Heat pumps and mechanical vapour recompression systems can replace combined heat and power (CHP) plants.	A longstanding dependence on fossil fuel or biomass CHP plants complicates the transition to fully electric systems	High, but hesitant, currently configured for CHP plants
Glass	Furnaces up to 1700°C	86% of heat demand is high temperature	Electric furnaces in container and flat glass manufacturing can replace natural gas furnaces.	High upfront costs and infrastructure requirements slow adoption	High, hydrogen may be needed for certain applications

Ceramics	Kilns and driers	(averaged across all sectors)	Processes such as drying and glazing are amenable to electrification, but electric high temperature kilns above 1,700°C are less well developed.	The sector is looking to hydrogen for use in high temperature kilns, especially tunnel kilns, where electric technologies are yet to be demonstrated	Moderate, may be possible for driers and smaller, specialist kilns, but otherwise most expect to use hydrogen
Cement and lime	Kilns		Electrification in this sector is limited due to the reliance on high temperature kilns, and the impact is limited due to significant process related emissions from calcination.	Cement production includes significant process emissions which are difficult to avoid. Electric cement kilns are not yet widely deployed, leaving CCS as the primary decarbonisation pathway.	Low

References

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[2] We have judged the suitability for electrification of different sectors on the technological readiness levels and deployment of different technologies and 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.

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