Department for
Energy Security
& Net Zero

Enabling Industrial Electrification

A call for evidence on fuel-switching to electricity

Closing date: 20 October 2023

July 2023

Any enquiries regarding this publication should be sent to us at: industrialelectrification@energysecurity.gov.uk

Executive Summary

Powering up Britain: The Net Zero Growth Plan,[1] published in March this year, envisages that industrial emissions will need to fall by 62% to 75% on average over 2033-2037, relative to 2021 levels, to be on track to achieve net zero. To achieve this, we set out an ambition to replace around 50 TWh of fossil fuels with low carbon alternatives by 2035.[2] Industrial sites moving away from fossil fuels to electricity is likely to play a big part in meeting this ambition. Information gathered through this call for evidence will help us to:

- establish the role of electrification for industrial fuel switching;
- update our evidence base on electrification technologies;
- identify the issues sites are facing to electrify;
- understand whether there is a case for further intervention; and
- test early policy thinking.

The call for evidence is divided into two parts. **Part I** is for all stakeholders to complete and covers broader questions on electrification according to the following themes:

Chapter 1 tests our understanding of the benefits of industrial electrification and the technologies available to electrify, before moving on to set out the possible role of electrification across different industrial sites.

Chapter 2 sets out the barriers and enablers of industrial electrification. Our initial review indicates that industrial sites looking to electrify face several challenges. These include technology innovation and demonstration barriers, financial barriers linked to high fuel costs and high capital expenditure, infrastructure, and supply barriers such as electricity grid access, organisational barriers, and regulatory/policy uncertainty. This chapter looks to test this understanding, including how these barriers vary by site archetype, and whether there are other possible issues that may need to be addressed. Finally, we explore the role that private renewable generation and demand side response (DSR) could have in enabling electrification of industry.

Chapter 3 sets out our understanding of existing and upcoming policies and their expected impact on industrial sites switching to electricity. It looks to test whether these policies could be enough to enable electrification or whether further targeted support might be needed. It also outlines policy principles for any intervention and then high-level possible policies that could help with electrification. It looks to test which type of intervention stakeholders might prefer, how to structure a possible intervention, as well as whether there are other types of interventions that should be considered.

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[1] Department for Energy Security and Net Zero, (2023), Powering up Britain: the Net Zero Growth Plan https://www.gov.uk/government/publications/powering-up-britain

[2] Currently, 58% of total industrial energy consumption (185 TWh) is made up of fossil fuels (natural gas, coal and oil)

Part II is a site survey that asks detailed questions about electrification on industrial sites and is to be completed by industrial stakeholders only. The survey follows a similar structure to the main call for evidence. This information will be used to complement the responses received in Part I and will contribute to the evidence base needed to develop any further electrification policy.

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General information

Why we are calling for evidence

The Government is seeking evidence to understand how to enable industry to switch away from fossil fuels to electricity.

The UK Government and Devolved Administrations have set out ambitious climate targets, which require a significant reduction in industrial emissions. The Net Zero Strategy set out the ambition to replace around 50 TWh of fossil fuels per year in industry by 2035 with low carbon alternatives, such as electricity, hydrogen, and biomass.

We are calling for evidence to build our understanding of the role of electrification in industry, the challenges industry faces when considering electrification options and to test early-stage policy thinking. This will enable us to design an optimal policy framework to overcome barriers and manage interactions with the wider system, such as the review of electricity market arrangements (REMA) and future electricity networks.

Alignment with other government policy currently in development

Work is currently ongoing across several policy areas related to this call for evidence on Industrial Electrification. In particular, the Government accepted the recommendation from the Independent Review of Net Zero that Government should commit to outlining a clear approach to gas and electricity price rebalancing by the end of 2023/24 and should make significant progress affecting relative prices by the end of 2024. We recognise that any future policy changes to rebalance gas and electricity prices could change the economics of electrification for industry and any impacts will be taken into account when designing future electrification policy.

This call for evidence complements the study on the Future Opportunities for Electrification to Decarbonise UK Industry being conducted by the Directorate for Science and Innovation for Climate and Energy. The study seeks to evaluate industrial applications that have the potential to be electrified either with commercially available technologies or with technologies still in development, and those industry applications that do not have the engineering potential to be electrified and where alternative decarbonisation methods are more appropriate. Details of the project brief can be found here.

Call for evidence details

Issued: 19 July 2023

Respond by: 20 October 2023

Enquiries to:

Email: industrialelectrification@energysecurity.gov.uk

Industrial Electrification Team, Industrial Decarbonisation
Department for Energy Security and Net Zero
2 Floor, Spur 2
1 Victoria Street
London
SW1H 0NE

Call for evidence reference:

Enabling Industrial Electrification: A call for evidence on fuel-switching to electricity.

Scope:

The scope of this call for evidence follows the definition of industry as set out in the Net Zero Strategy. This defines industrial emissions as those arising from industrial processes, manufacturing, and production, including fuel combustion and product use in industrial buildings, as well as emissions from refineries and construction (including non-road mobile machinery). It also includes emissions from onsite generation of electricity and Combined Heat and Power (CHP) of non-major power producers.

The Industrial Decarbonisation Strategy defines electrification as 'Switching from using fuels such as gas or petroleum, to using electricity. For example, switching from a gas boiler to an electric boiler for raising steam in industry.'

Audiences:

We are keen to hear from industrial sites, trade associations, academics, technology providers, network companies, non-governmental organisations, electricity suppliers and anyone else with an interest in this area.

Territorial extent:

United Kingdom of Great Britain and Northern Ireland

How to respond

Respond online (preferred) at: https://beisgovuk.citizenspace.com/industrial-energy/industrial-electrification-call-for-evidence

or

Email to: industrialelectrification@energysecurity.gov.uk

Write to:

Industrial Electrification Team, Industrial Decarbonisation
Department for Energy Security and Net Zero
2nd Floor, Spur 2
1 Victoria Street
London
SW1H 0NE

Confidentiality and data protection

Information you provide in response to this call for evidence, including personal information, may be disclosed in accordance with UK legislation (the Freedom of Information Act 2000, the Data Protection Act 2018, UK General Data Protection Regulation and the Environmental Information Regulations 2004).

If you want the information that you provide to be treated as confidential, please tell us, but be aware that we cannot guarantee confidentiality in all circumstances. An automatic confidentiality disclaimer generated by your IT system will not be regarded by us as a confidentiality request.

We will process your personal data in accordance with all applicable data protection laws. See our personal information charter and privacy notice for further information.

This call for evidence has been carried out in accordance with the government's consultation principles.

If you have any complaints about the way this call for evidence has been conducted, please email: beis.bru@beis.gov.uk.

Part I – Call for Evidence on Enabling Industrial Electrification

Outline of 'About you' and 'About your site' section

The following sections are structured as follows:

- 'About you' section, which all stakeholders are required to answer. This will give us context behind your answers.
- 'About your site' section, which you should only answer if you are answering on behalf of an industrial site. This section seeks to gain some context behind your site, which will help us when analysing your responses to Part II (site survey) of this call for evidence.

About you

To be completed by all stakeholders:

1. **What is your name?**
2. **What is the name of your organisation?**
3. **What is the address of your organisation?**
4. **Do your views specifically relate to one of the Devolved Administrations?**

- Scotland
- Wales
- Northern Ireland
- Not related to a specific devolved administration

5. **Do you represent or hold expertise on a specific industrial sector? Please select all that apply.**

- Cement
- Lime
- Ammonia
- Ethylene
- Other Chemicals

- Food and drink
- Glass
- Ceramics
- Other non-metallic minerals
- Iron and steel
- Non-ferrous metals
- Vehicles
- Paper
- Refining
- Plastics
- Fabricated metal products
- Machinery and equipment
- Transport equipment
- Electrical and mechanical engineering
- Waste
- Construction (including non-road mobile machinery)
- Other industry (please specify)
- Industry as a whole

6. **Do you represent or hold expertise on a specific process or technology? If so, please select all that apply from the below.**

- Boiler
- CHP
- Reforming
- Dryer
- Furnace
- Kiln

- Metal Melting
- Metal Rolling
- Oven
- Primary Iron Production
- Motor-driven equipment
- Other (please specify)
- Not applicable

7. How did you hear about this call for evidence?

- Email from this department
- Email from elsewhere
- GOV.UK alert
- Newsletter
- Twitter
- Other (please specify)

8. If you are content to share your email address with us, for the purpose of being contacted relating to responses given, please share it below.

9. What type of organisation do you represent? Please select one:

- Industrial site
- Trade association or other industry body
- Academic institution
- Non-Governmental Organisation (NGO)
- Electricity network
- Technology provider
- Energy supplier
- Private individual
- Other, please specify

About your site

Please only complete this section if you represent an industrial site.

10. How many industrial sites does your company have? If your company has multiple sites, please choose a representative site based in the UK and answer the questions in Part II (site survey) with respect to that site only.

- Single site in the UK only
- Single site in the UK and one or more sites outside of the UK
- Multiple sites in the UK, no sites outside of the UK
- Multiple sites in the UK and one or more sites outside of the UK

11. Please provide the SIC code for your company.

12. What best describes your job role/background?

- Technical / Engineer
- Finance
- Management
- Business communication
- Sales & Marketing
- Other (please specify)

13. What 'product(s)' are the main output of your industrial site(s) (e.g. chocolate, ceramic tableware, aluminium, cardboard packaging)?

14. What is the operating temperature of the main piece of equipment or process that your site(s) mainly use?

- <100 degrees Celsius
- 100 – 240 degrees Celsius
- 241 – 500 degrees Celsius
- 500 – 999 degrees Celsius
- 1000+ degrees Celsius

15. Approximately what proportion (percentage from 0 – 100%) of your energy use is low temperature? For the purposes of our analysis, we define low temperature as 240 degrees Celsius or below.

16. How many people does your company employ?

- Less than 49
- 50 to 249
- More than 250

17. In which region is your industrial site located?

- North East England
- North West England
- Yorkshire & The Humber
- East Midlands
- West Midlands
- East England
- Inner London
- Outer London
- South East England
- South West England
- Scotland
- Wales
- Northern Ireland

18. Is the site physically located in one or more of the industrial clusters outlined in the BEIS Industrial Decarbonisation Strategy (i.e. within 25 km of Grangemouth, Teesside, Humberside, Merseyside, South Wales, Southampton, or Black Country)?

- Yes, the site is located within an industrial cluster
- No, the site is not located within an industrial cluster
- Not sure

1. The role of electrification in decarbonising industry

Chapter 1 tests our understanding of the benefits of industrial electrification and the technologies available to electrify, before moving on to set out the possible role of electrification across different industrial sites.

1.1 Background

In March 2021, the Government published the Industrial Decarbonisation Strategy.[3] The strategy set out how industry can reduce its emissions in line with net zero, including by replacing the use of fossil fuels with low carbon alternatives such as low carbon hydrogen, electricity, and bioenergy. One of its core principles is that Government has a ‘technology neutral’ approach to industry’s decarbonisation decision making, allowing industrial sites to choose the most suitable decarbonisation route for themselves.

Powering up Britain: The Net Zero Growth Plan,[4] published in March 2023, envisages that industrial emissions will need to fall by 62% to 75% on average over 2033-2037, relative to 2021 levels, to be on track to achieve net zero by 2050. The Net Zero Growth Plan also reiterated the ambition to replace 50 TWh of fossil fuels per year by 2035 with low carbon alternatives. Looking to net zero in 2050, fuel switching to electricity has the potential to reduce annual industrial emissions by between 7 and 19 $MtCO_2e$ per year cost-effectively, contributing between 15% and 40% of the (necessary) carbon abatement in industry by 2050.[5] The contribution will depend on the extent of fuel switching to low carbon hydrogen and bioenergy.

In their 2022 Progress Report, the Climate Change Committee recommended consulting on policy options to support industry with the additional costs of switching to electricity and allow low carbon hydrogen and electricity to compete on a level playing field.[6]

Electricity, low carbon hydrogen and bioenergy, all have an important role to play in decarbonising industry, and the exact mix of low carbon fuels in the future is still very uncertain. Significant progress is being made to support the development of a hydrogen economy, underpinned by strategic planning for the required transport and storage network. The build out of hydrogen network infrastructure will need to take account of several factors including likely industrial demand for hydrogen outside the clusters and the potential for repurposing the gas grid in given areas. Nonetheless uncertainty remains as to exactly where

[3] BEIS, (2021), Industrial Decarbonisation Strategy, https://www.gov.uk/government/publications/industrial-decarbonisation-strategy
[4] Department for Energy Security and Net Zero, (2023), Powering up Britain: the Net Zero Growth Plan https://www.gov.uk/government/publications/powering-up-britain
[5] DESNZ analysis (2023), ‘Net Zero Industry Pathway (N-ZIP) model’, https://www.theccc.org.uk/wp-content/uploads/2020/12/N-ZIP-Model.xlsb.
[6] Climate Change Committee (2022), 2022 Progress Report to Parliament, https://www.theccc.org.uk/publication/2022-progress-report-to-parliament/

and when hydrogen will become available, particularly for industrial users outside of the main clusters. We recognise, therefore, that failure to credibly address the barriers to electrification could result in some industrial locations lacking a viable route to decarbonise, putting them at a competitive disadvantage.

As such, we are looking to build our understanding of the role of electrification in industry, the barriers industry faces when considering electrification options and test early-stage policy thinking through this call for evidence. This will enable us to design the optimal policy framework to overcome barriers and manage interactions with wider systemic challenges such as electricity market arrangements and designing future electricity networks.

1.2 Potential for electrification of UK industry

Electricity is already used as an energy source across industrial sites, making up 32% of total industrial energy consumption in 2021 (Figure 1). Currently, electricity is used predominantly for driving machinery such as pumps and conveyor belts. However, to reach our Carbon Budget commitments and be on track to achieve net zero, industry will need to replace fossil fuel consumption with alternative low carbon fuels (along with the deployment of other decarbonisation measures, such as carbon capture, usage and storage (CCUS)). As grid electricity continues to decarbonise over the next decade,[7] electricity is an increasingly attractive low carbon energy source. Electrification offers several advantages as a decarbonisation option for industry:

- Many electrification technologies are already commercially available, for example, electric steam boilers and electric process heaters. Realising their potential in the 2020s would enable near-term carbon dioxide reductions, meeting Carbon Budget commitments and avoiding locking-in high carbon processes. Having a further, viable, low carbon energy option for industry will enable them to decide the optimal decarbonisation route to 'future-proof' themselves and open new green markets, securing viability and jobs.
- Electricity is already an established energy source with a widespread transmission and distribution network supplying industrial sites. Further electricity infrastructure is necessary to electrify sites without sufficient headroom in their electrical capacity. This would be an expansion and reinforcement of the existing network, compared with hydrogen, where new distribution networks still need to be built or gas networks repurposed.
- Some electrification technologies such as heat pumps and battery electric powertrains for Non-Road Mobile Machinery (NRMM) offer increased efficiency compared to incumbent fossil-fuel based technologies.
- Electrification technologies often have lower maintenance costs and, in some cases (such as the industrial boiler) lower capex cost.[8]

[7] In the Net Zero Strategy (2021), the UK committed to delivering a fully decarbonised power system by 2035.
[8] Industrial Fuel Switching Study (2019); McKinsey (2022)

- Electrification technologies offer environmental benefits, for example, reductions in noise and other pollutants such as nitrogen oxides, sulphur dioxide, and particulates compared to combustion technologies.
- The safety procedures for electricity on site are better established and its use does not introduce the additional safety assessment and mitigations associated with storing and using hydrogen.
- Increased electrification offers potential for sites to be rewarded for flexible operation that helps balance the grid at least cost. There are also additional synergies with onsite renewable generation which could reduce the total cost of electrification for a site. In Powering Up Britain: Energy Security Plan,[9] the Government announced that we would accept the recommendation in the Skidmore Review to explore onsite generation on manufacturing sites.
- Electricity does not face the same limitations as sustainable bioenergy in terms of availability. In theory, low carbon electricity generation can be scaled up to meet increased demand.
- Lastly, consuming electricity directly for heating industrial processes avoids the energy losses associated with first producing (green or blue) hydrogen and then using it to generate heat in an industrial process.

19. Do you know of any other advantages associated with electrification of industrial processes that have not been described here? If yes, please provide details.

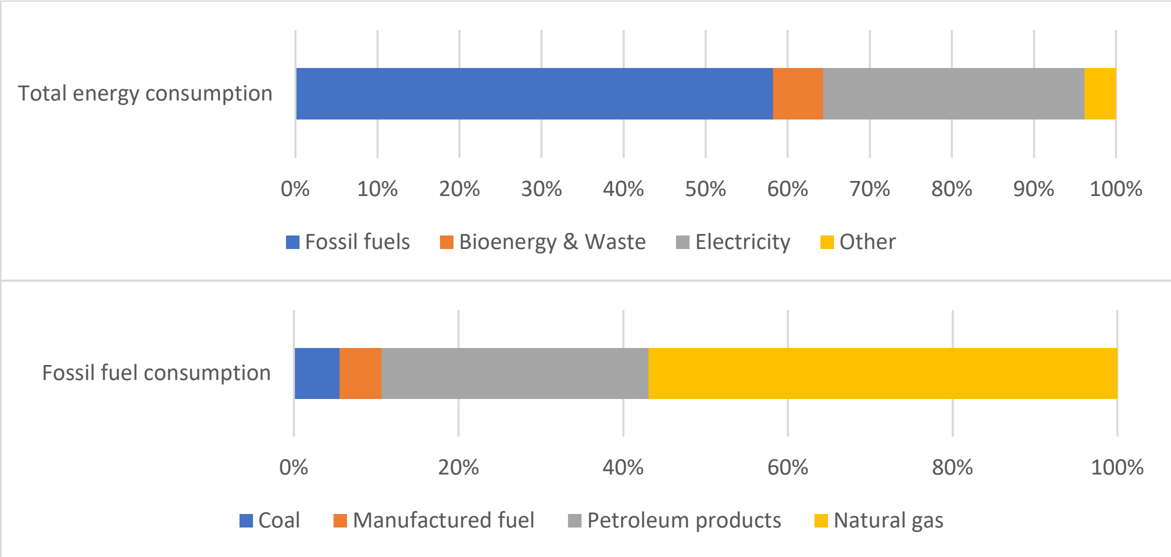
20. Are there any disadvantages of electrification of industrial processes? If yes, please provide details.

Currently, 58% of total industrial energy consumption (185 TWh) is made up of fossil fuels (natural gas, coal and oil), see Figure 1. The majority of fossil fuel consumption in industry is for generating heat for a variety of different purposes. This heat can be either **direct**, where heat is generated through the combustion of fuel in the same vessel as the reactants (e.g. a furnace or kiln), or **indirect** and transferred through heating steam, water, oil or air (e.g. boiler, dryer). The operating temperature also varies across industrial processes, ranging from 30-240°C for low temperature applications and 240-2000°C for medium-high temperature applications.[10]

[9] Department for Energy Security and Net Zero, (2023), Powering up Britain: Energy Security Plan https://www.gov.uk/government/publications/powering-up-britain
[10] Element Energy (2018), Industrial Fuel Switching Market Engagement Study

Figure 1: Share of total industrial energy consumption by fuel, 2021[11]

Figure 1 shows the proportion of industrial energy consumption of different fuel sources (first bar) including fossil fuels, bioenergy & waste, electricity, and other sources of energy. Fossil fuel consumption is further broken down into proportions by fuel type (second bar), this includes coal, manufactured fuels (fuels generated through industrial processes), petroleum products and natural gas.



Electrification is technically possible for a wide range of applications as shown in Table 1. The suitability of a process for electrification depends on the temperature of the heat required; low temperature applications are more easily electrified and many of these technologies, such as boilers and heaters, are commercially available today. Despite recent advancements, high temperature applications, particularly for processes greater than 1000°C, are more technically challenging to electrify. Electrification technologies for these processes are still in the research or development stage.

To drive decarbonisation of industrial sites in the 2020s and 2030s, we have initially chosen to focus on exploring options that would enable or incentivise the switch to technologies that are commercially available or almost commercially available. However, we are still interested in hearing about any views you may have on how we continue to address technology innovation and demonstration barriers.

[11] Digest of UK Energy Statistics (DUKES) (2022)

Table 1: Technology Readiness Level (TRL) and specifications of different electrification technologies[12],[13]

Development phase	Current TRL	Technology	Process	Sector	Efficiency	Reference size (MW)	Marginal Capex (£/kW)	Lifetime (years)
Commercial	9	Electric Steam Boiler (small)	Steam generation, space heating	Cross cutting	0.99	50	120	15
Commercial	9	Electrode Steam Boiler (large)	Steam generation	Cross cutting	0.99	50	120	15
Commercial	9	Electric Process Heater	Steam cracker, space heating	Chemicals, vehicles, Refining, other industry	0.99	4	120	15
Commercial	9	Electric Plasma Gas Heaters	Steel rolling, steel melting, sinter plant, high temperature kiln	Iron and steel; Non metallic minerals	0.90	7	262-387	15

[12] Element Energy (2018), Industrial Fuel Switching Market Engagement Study; Based on research at the University of Leeds as part of the UK Energy Research Centre, which has been submitted for publication as Gailani et al., (2023). Assessing the potential of decarbonisation options for industrial sectors. Unpublished manuscript; DESNZ analysis (2023), 'Net Zero Industry Pathway (N-ZIP) model', https://www.theccc.org.uk/wp-content/uploads/2020/12/N-ZIP-Model.xlsb.

[13] Marginal Capex represents the capex cost per kilowatt for a technology of the Reference size. It is scaled for a given size using the formula: $Capex = (Marginal\ Capex \times Reference\ Size) \times (Size/Reference\ Size)^{0.6}$

Development phase	Current TRL	Technology	Process	Sector	Efficiency	Reference size (MW)	Marginal Capex (£/kW)	Lifetime (years)
Commercial	9	OL Heat Pump (MVR) (Low temp)	Space heating	Other industry	4	1.6	300	20
Commercial	9	CL Heat Pump (Low temp)	Space heating	Vehicles, other industry	4	1	450	20
Commercial	9	Electric oven		Food and Drink	0.95	35	193	8
Commercial	9	Electric arc furnace	Secondary steel production	Iron and steel				
Deployment	8-9	Electrolyser (AEL/PEM)	Steam methane reforming	Chemicals				20-40
Deployment	8	Electric Infra-Red Heaters	Low temperature, drying	Vehicles, Non-metallic minerals, Other industry	0.95	0.006	233	15
Deployment	7	Microwave Heaters	Low pressure steam,	Food and drink, Paper, other industry	0.99	0.1	8,000	15
Deployment	7	Electric glass furnace		Glass	0.95	35	193	8

Development phase	Current TRL	Technology	Process	Sector	Efficiency	Reference size (MW)	Marginal Capex (£/kW)	Lifetime (years)
Deployment	7	Electric dryer		Food and drink	1	4	120	15
Development	6	Electric Ceramic Tunnel Kilns	High temperature kiln	Ceramics	0.95	20	1,000	15
Development	6	Med temperature heat pump						
Development	6	All Electric Smelters	Glass melting	Glass	0.95	35	193	8
Development	5-6	Iron ore electrolysis (direct electrification)	Primary iron production	Iron and steel				
Development	4	High temperature heat pump						
Research	3-4	Electric furnace - plasma	Furnace	Glass				

Development phase	Current TRL	Technology	Process	Sector	Efficiency	Reference size (MW)	Marginal Capex (£/kW)	Lifetime (years)
Research	3-4	Microwave drying	Drying	Food and drink				
Research	3-4	Electrical steam cracker	Cracking furnace	Chemicals				
Research	3-4	Electric furnace			0.95	35	193	8
Research	3-4	Electric kiln		Other minerals	0.95	20	1000	15
Research	3	Plasma torches	Kiln	Cement				
Research	2-3	Electric furnace - microwaves	Furnace	Glass				

21. Do you agree with the information presented in Table 1? If you disagree, please provide specific details and supporting evidence.

22. Is there any new evidence you would like to submit on electrification technologies, either in relation to the technologies listed in Table 1 or technologies that might be missing from Table 1? If yes, please provide details.

23. Listed below are the areas of focus for innovation of electrification technologies. Please rate their importance using the following scale: 0 = Don't know, 1 = Not at all important, 2 = Slightly important, 3 = Moderately important, 4 = Important, 5 = Extremely important.

- Reducing the cost of commercially ready electrification technologies

- Scaling up technologies to meet commercial production requirements

- Demonstration of electrification technologies on sites

- Research and development of high temperature electrification equipment (such as for glass, ceramics, and metals)

- Targeted innovation in a particular sector, technology or process.

- Improved reliability and/or performance of electrification technologies.

- Other, please provide details – including their ranking of importance.

24. If you rated "Targeted innovation in a particular sector, technology or process" at a 3 or above in the previous question, please provide details on your reasoning for this.

1.3 Site archetypes

For many industrial sites, electricity, hydrogen, and bioenergy are all possible options for replacing existing fossil fuel use. Carbon Capture Utilisation and Storage (CCUS) will also play an important role in decarbonisation of industry, particularly for sectors with high process emissions such as cement. The optimal fuel switching technology will depend on several factors such as: (1) the specific technical requirements or limitations of the industrial process, (2) the commercial readiness of a suitable low carbon technology, (3) site access to low carbon fuels, (4) the relative cost of each technology, (5) the physical space requirements and implications of introducing different technologies (e.g. larger plot space required larger units, hazards), and (6) the wider policy landscape.

To unpack the role of electrification of industry further, we have divided industrial sites into four "archetypes" as described in Table 2. The two main factors defining these archetypes are process temperature (i.e. low and high) and geography (i.e. clustered or dispersed). For the purposes of this analysis, we have defined low temperature processes as those less than 240°C. Table 2 lists the processes that fall into each temperature category. We recognise that some sites may have both high temperature and low temperature processes (such as auxiliary steam generation for example) on site, but for this analysis we focus on the temperature of the main production process. The definition of dispersed sites used in this analysis is industrial sites located more than 25 km from the likely CO_2 or hydrogen terminal point in an industrial cluster.[14]

Figure 2 and Figure 3 show the breakdown of current emissions from industrial heating for each archetype by sector and process, respectively. This shows that emissions from sites with low temperature processes in dispersed locations (Archetype 1) make up the largest share of emissions (~21 $MtCO_2$) today. These arise mainly from steam generation in boilers (including CHP) in the chemicals, food and drink, paper, and other industry sectors.[15] Ovens and dryers, mostly in the food and drink sector, make up the remaining share of emissions. Sites in Archetype 4 (high temperature processes in clusters) are the next largest emitters, making up around 18 $MtCO_2$. This is dominated by emissions from the Port Talbot and Scunthorpe steel plants. Emissions from Archetype 2 sites (low temperature processes in clusters) arise largely from boilers (including CHP) on chemicals and refining sites. Lastly, emissions from Archetype 3 sites (high temperature processes on dispersed sites) arise from furnaces or kilns in the cement,[16] glass and other minerals sectors.

[14] The following 11 industrial clusters are assumed: Teesside, Humberside (in-land), Humberside (terminal), Southampton, South Wales, Merseyside, Grangemouth, Peterhead, Peak District, Medway, and Londonderry. Note these are possible future clusters for analytical purposes only and do not reflect government policy on the definition of a cluster.
[15] "Other industry" is made up of range manufacturing processes such as plastic products, fabricated metal products, vehicles, machinery and equipment manufacturing and textiles.
[16] This analysis excludes process emissions. Electrification for cement kilns would not address process emissions.

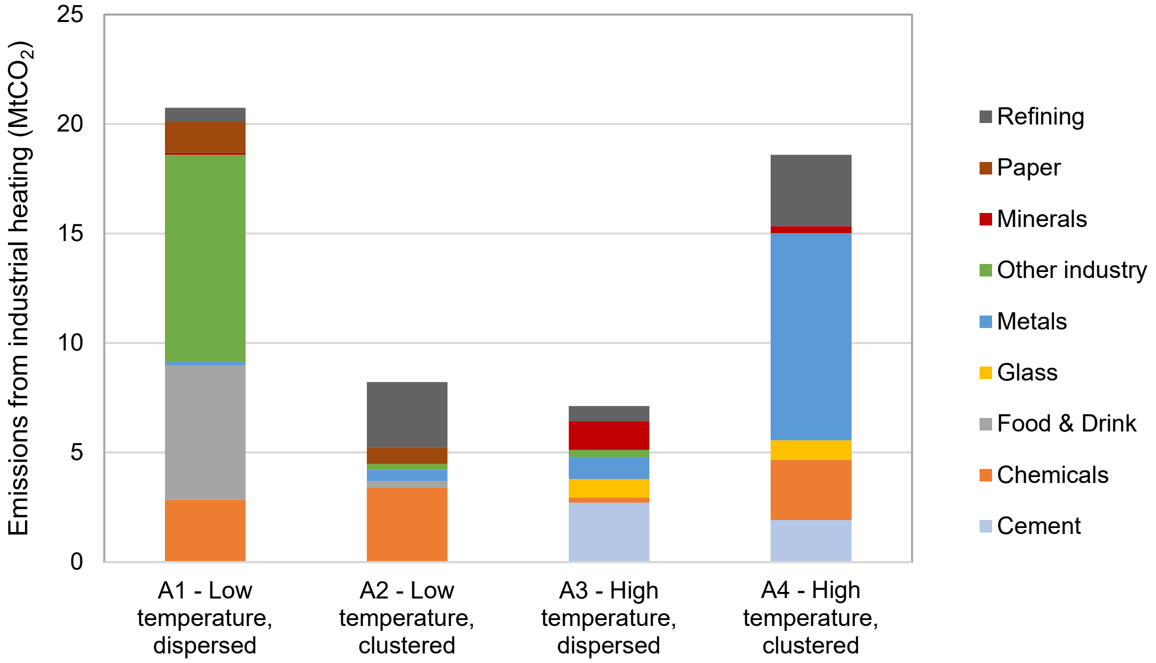
Table 2: Industrial site "archetypes" for electrification

Site archetype	Role of electrification	Processes/sectors
Archetype 1: Low temperature processes on **dispersed** sites	Electrification offers an opportunity for early decarbonisation of these sites since many of the electrification technologies for these processes are commercially available and access to low carbon hydrogen on these sites is uncertain. Hydrogen access will depend on rollout of hydrogen networks as well as localised electrolytic hydrogen production.	Boilers (including CHP), dryers and ovens in the refining, chemicals, food & drink, paper and other industry sectors such as vehicle manufacturing. Industrial heat pumps could also play a role for low temperature applications.
Archetype 2: Low temperature processes on sites in **clusters**	Sites will choose between electrification and hydrogen. Many of the electrification technologies for these processes are commercially available.	
Archetype 3: High temperature (particularly direct fired) on **dispersed** sites	The optimal fuel switching option for high temperature processes varies depending on the specific process. In some cases, hydrogen is preferred, owing to its similarity with natural gas. Whilst for other applications, water produced from hydrogen combustion can impact product quality, creating a technical challenge to roll-out of hydrogen for these processes. Access to low carbon hydrogen on these sites is uncertain and will depend on rollout of hydrogen networks as well as localised electrolytic hydrogen production. Electrification technologies for these processes are still in the research or development phase.	Furnaces (e.g. glass), kilns (e.g. ceramics), metal melting and rolling, chemical reforming, iron and steel production.

Site archetype	Role of electrification	Processes/sectors
Archetype 4: High temperature (particularly direct fired) on sites in **clusters**	Sites will choose between electrification and hydrogen depending in the suitability for their process (as described for Archetype 3). Apart from the Electric Arc Furnace for steel, electrification technologies for many processes in this archetype are still in the research or development phase.	

Figure 2: Breakdown of 2021 industrial heating emissions from archetypes by sector. Note: this covers emissions from fuel combustion only.[17],[18]

Figure 2 shows 2021 industrial heating emissions by sector grouped by archetype. Sectors are colour coded in the stacked columns. A1 low-temperature dispersed sites are responsible for the largest part of industrial emissions, with 'Other industry' playing a key role along with 'Food & Drink'. A2 high-temperature clustered sites is the second biggest contributor to industrial emissions, with Metals production responsible for most of the archetype's industrial heating emissions.

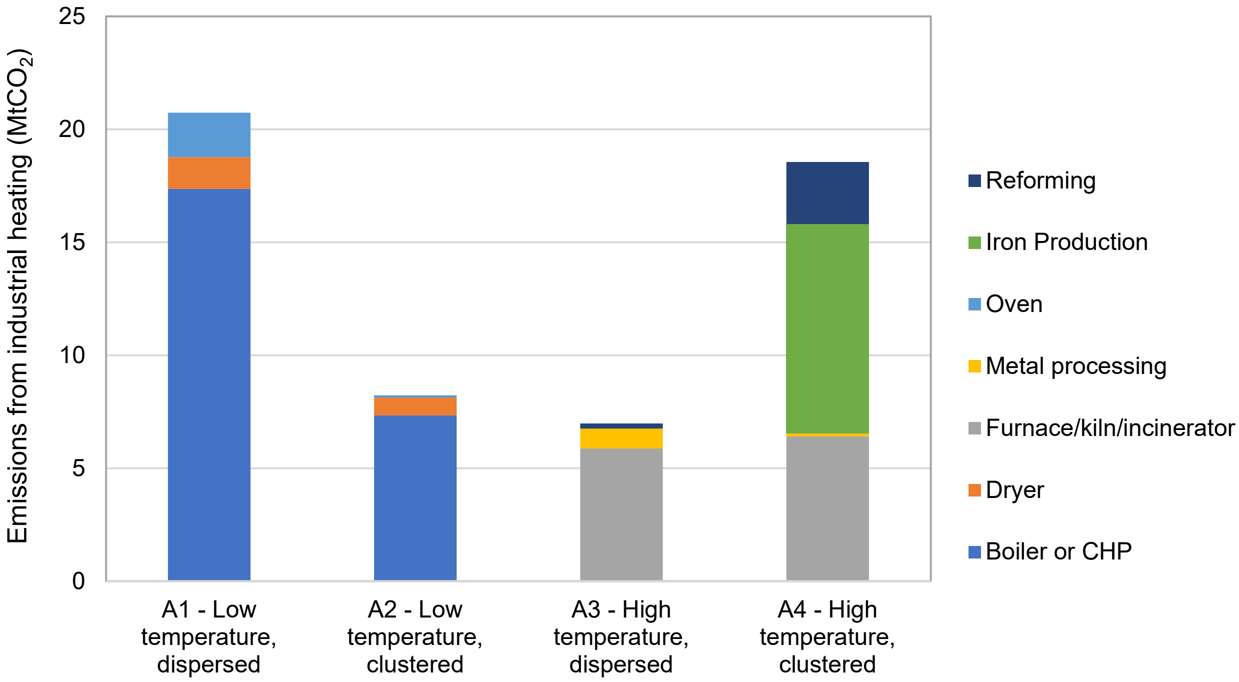


[17] Baseline Emissions sourced from NZIP model available at: https://www.theccc.org.uk/publication/deep-decarbonisation-pathways-for-uk-industry-element-energy/

[18] Does not include process emissions or emissions from NRMM, Iron & Steel combined with Non-Ferrous Metals into 'Metals' category for simplicity.

Figure 3: Breakdown of 2021 industrial heating emissions from archetypes by process.
Note: this covers direct combustion emissions only. NRMM and Process emissions are excluded.

Figure 3 shows 2021 industrial heating emissions by process grouped by archetype. Industrial processes are colour coded in the stacked columns. A1 low-temperature dispersed sites are responsible for the largest part of industrial emissions, with emissions from 'Boiler or CHP' processes accounting for over 75% of this archetype's heating emissions. A2 high-temperature clustered sites are the second biggest contributor to industrial emissions. Primary Iron production and Furnaces account for most of this archetype's heating emissions.



Box 1: Analysis of the potential for electrification across industrial archetypes

To examine the potential for electrification of these archetypes in more detail, we have run three different scenarios using the Net Zero Industry Pathway (NZIP) model.

NZIP uses a least cost approach to test the social economic value of different measures to decarbonise industrial processes across UK Industrial sites. Further details of the model, assumptions, and scenarios (excluding Maximum Technical Potential, discussed below) can be found in the Government's Net Zero Growth Plan Technical Annex.[19] The scenarios used in our analysis are detailed below:

- **High Electrification scenario:[20]** This is a socially cost-effective decarbonisation pathway in which access to hydrogen and CO_2 capture infrastructure is limited to clusters only. Electrification plays a major role in this pathway. Fuel and carbon value assumptions are based on central government projections.

- **Low Electrification scenario:[21]** This is a socially cost-effective decarbonisation pathway in which all industrial sites have access to hydrogen and CO_2 capture infrastructure. Fuel and carbon value assumptions are based on central government projections. This is a low electrification pathway and will not be discussed in the following analysis.

- **Maximum Technical Potential:** Unlike the above scenarios, this Maximum Technical Potential (MTP) scenario models the theoretical maximum uptake of electrification technologies across industry, where a process can electrify it does so irrespective of social optimality. Most of the model settings are the same as the High Electrification scenario with key changes to the assumptions being near zero electricity costs and removal of electricity supply constraints.

The socially cost-effective abatement potential for electrification of industry in 2050 ranges from 7 $MtCO_2$ per annum in the Low Electrification scenario and 19 $MtCO_2$ per annum for the High Electrification scenario. The maximum technical potential is even higher at around 27 $MtCO_2$ per annum by 2050. Figure 4 presents a breakdown of the modelled abatement potential for each archetype under the High Electrification and Maximum Technical Potential scenarios. These results are discussed in turn below.

Archetype 1: Low temperature processes in dispersed sites

Archetype 1 sites offer the largest potential for decarbonisation through electrification. Our Maximum Technical Potential scenario estimates that electrification of these sites could abate around 14 $MtCO_2$ per annum in 2050. The majority of this is through the replacement of natural gas boilers and CHP units with electric boilers and grid electricity

[19] DESNZ (2023), 'Powering Up Britain: Net Zero Growth Plan and Carbon Budget Delivery Plan', https://www.gov.uk/government/publications/net-zero-growth-plan-and-carbon-budget-delivery-plan-analysis-methodology
[20] Referred to in DESNZ (2023) as Cluster Networks Scenario
[21] Referred to in DESNZ (2023) as National Networks Scenario

supply. Electric dryers, heaters and ovens make up the remaining potential abatement. In the High Electrification scenario, where hydrogen access is limited to clusters only, we see early electrification of around 2 Mt CO_2 by 2035, increasing to almost 12 MtCO_2 by 2050.

Archetype 2: Low temperature processes in clustered sites

Our modelling estimates that the maximum technical potential for electrification of Archetype 2 sites is around 4 MtCO_2 by 2050, equivalent to electrifying most sites. Again, electrifying boilers (including CHP units) make up most of this abatement (~3.2 MtCO_2). With current modelling assumptions of electricity and hydrogen prices, and assuming that sites in clusters will have access to hydrogen within the next decade, our modelling indicates that the cost-effective potential for electrification of these sites is low and that hydrogen is the favoured option for fuel switching on these sites.

Archetype 3: High temperature processes in dispersed sites

From a purely technical perspective, it is possible to electrify most high temperature processes such as glass furnaces, ceramic kilns and non-ferrous metal production. Our modelling estimates that a maximum of almost 2 MtCO_2 could be abated through electrification of archetype 3 sites by 2050. However, these electric technologies are not yet commercially available, and more research and development is required. For industrial processes with significant process emissions, such as cement and lime, bioenergy in combination with CCUS is likely to be the favoured option. Hydrogen is likely to be more technically suitable for processes that require a reducing atmosphere such as ceramics. High temperature processes are very energy intensive, and, with current electricity cost assumptions, hydrogen is the more economically attractive fuel switching option for these sites, if it is available.

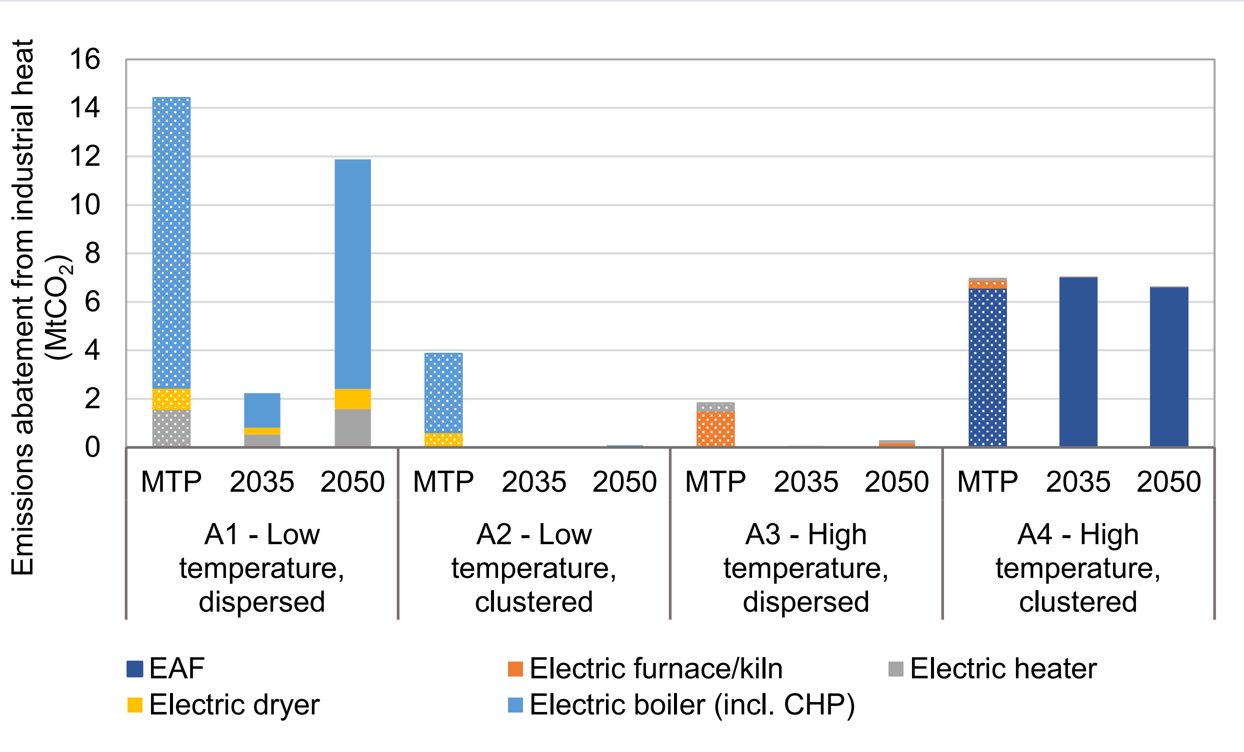
Archetype 4: High temperature processes in clustered sites

Emissions from Archetype 4 are dominated by the two iron and steel sites: Port Talbot and Scunthorpe. The Electric Arc Furnace is an established process for producing secondary steel from scrap or supplemented with Direct Reduced Iron.[22] As for Archetype 3, for the remaining emissions from sites in this archetype, a combination of hydrogen and bioenergy with CCUS are likely to be the favoured decarbonisation routes.

[22] Direct Reduced Iron is produced from reduction (i.e. removal of oxygen) of solid iron ore lumps, fines or pellets by using hydrogen and carbon monoxide derived from natural gas or coal gasification. Direct reduction of iron ore is less energy intensive as it does not require the iron ore to be melted.

Figure 4: Breakdown of emissions abated by electrification in the different archetypes. The Maximum Technical Potential (MTP) pathway models much higher electrification uptake than the socially optimal High Electrification pathway.

Figure 4 shows future abatement scenarios by electrification technology grouped by archetype. Electrification technologies are colour coded. The first hatched column in each archetype illustrates the 2050 Maximum Technical Potential (MTP) for abatement by electrification. 2035 and 2050 abatement by electrification from the socially optimal High Electrification pathway (Referred to in other publications as Cluster Networks scenario) is illustrated to the right of MTP. This chart demonstrates the gap between technically possible abatement by electrification and the socially optimal pathway.



25. Do you agree with the site archetypes defined in this chapter?

26. Do you agree with the role of electrification of these archetypes presented here? Please provide details.

2. Industrial electrification barriers and enablers

Chapter 2 sets out the barriers and enablers of industrial electrification. Our initial review indicates that industrial sites looking to electrify face several challenges. These include technology innovation and demonstration barriers, financial barriers linked to high fuel costs and high capital expenditure, infrastructure, and supply barriers such as electricity grid access, organisational barriers, and regulatory/policy uncertainty. The chapter looks to test this understanding, and how these barriers vary by site archetype, and finally whether there are other possible issues that may need to be addressed. Finally, we explore the role that private renewable generation and demand side response (DSR) could have in enabling electrification of industry.

2.1 Barriers

As outlined in Chapter 1, fuel switching to electrification is technically possible today in many instances. However, significant fuel switching to electricity is not happening. Table 3 sets out the barriers and their relevance to different industrial site archetypes.

Table 3: Overview of the barriers inhibiting the switch towards electricity.

Barrier	Detail	Description	Archetypes
Technology innovation and demonstration	Low technology readiness for some applications	Electrification technologies are not yet commercially available for some processes, particularly those that require a very high operating temperature or a reducing environment (see Table 1). Further innovation is required to develop and demonstrate these technologies. This presents a barrier to electrification of these processes in the near term.	High temperature operations (Archetypes 3 and 4)
	Technology integration	Integration of electric equipment into existing industrial facilities and processes can be difficult. Factors such as additional space requirements, incorporation of different equipment into the production process and lengthy	All

Barrier	Detail	Description	Archetypes
		pauses in production to accommodate new equipment can make decarbonisation costly and complicated.	
	Technology risk	For earlier TRL technologies there may be failures in operational and economic sustainability when they are deployed at scale. The risk of these failures discourages development and uptake of new technologies.	High temperature (Archetypes 3 and 4)
	Technology availability	New supply chains may need to be developed or strengthened to meet the demand for electrification technologies.	All
Financial & economic	High relative fuel costs	The high relative price of electricity compared with natural gas means that higher carbon technologies are currently more cost effective to operate than electric technologies.	All
	High non-fuel operational costs	Non-fuel operational costs may be higher for electric technologies, these may be technology or application specific.	All
	High capital costs and long-investment cycles	The costs of buying new equipment, supplementary equipment, and scrapping fossil fuel equipment can present an additional burden. Additional equipment needed for grid supply and conversion to electricity can also significantly increase the capital costs of switching.	All, but possibly more relevant for high temperature operations requiring bespoke technologies (Archetypes 3 and 4)

Barrier	Detail	Description	Archetypes
	Global competition from lower cost producers	Many producers are competing with others across the world that may have lower costs, including lower fuel costs. Any increase in costs could put them at a competitive disadvantage which could make it difficult to fund decarbonisation.	All
	Access to financing	High capital expenditure and long payback periods are a feature of development and demonstration of decarbonisation technologies as well as their deployment. Electrification technologies can be more costly than natural gas alternatives making financing more expensive and difficult to access. The UK does not currently have a formalised market for green finance that would be suited to these types of investments.	All
	Payback on investment	There is a possible mismatch between the payback required for site investments by shareholders with the payback that is achievable with fuel switching to electrification changes.	All
Infrastructure & Supply	Electricity grid access	Acquiring additional network access for increased electrification can often have long timescales and high costs. Electricity supply in certain regions may not be sufficient to support switching at scale.	All
Organisational	Management short-termism and risk aversion	Management may be focussed on the shorter-term projects with shorter payback periods and may be unwilling to invest in new technologies that disrupt	All

Barrier	Detail	Description	Archetypes
		production or could impact on cost base.	
	Lack of personnel, skills, and qualifications	Availability of qualified staff can be a barrier to introduction of new technologies, both from an advisory perspective to make initial choice, and for the actual installation. Early switchers may feel more acute staff and skill shortages as qualified personnel are not as common in the labour force.	All, but possibly more challenging for smaller sites many of which (but not all) fall into the lower temperature archetypes 1 and 2.
Regulatory/policy	Lack of certainty regarding Hydrogen or CCUS network access.	Many site operators are reluctant to choose a switching/decarbonisation route until there is more clarity on access to CCUS and hydrogen networks.	Dispersed sites (Archetypes 1 and 3)
	Lack of certainty about market for low-carbon goods	Product differentiation for industrial goods produced with low emissions is a promising way for firms to justify additional production costs, however, these markets are nascent and require clear and robust regulation from government. Site operators may be unsure about future profitability of low carbon goods and therefore reluctant to electrify.	All

27. Please rate the barriers to industrial electrification in terms of their severity using the following scale: 0 = Don't know, 1 = Not a barrier, 2 = low severity, 3 = moderate severity, 4 = severe, 5 = extremely severe, don't know.

- Technology innovation and demonstration
- Financial
- Infrastructure and supply
- Organisational
- Regulatory/policy

28. If you rated any of the above barriers as 4 or higher, please provide further details.

29. Are there any other barriers preventing the switch away from fossil fuels towards electricity? If yes, please provide details.

30. How do these barriers impact electrification of sites in each of the below archetypes? Archetype 1 – Low temperature, dispersed; Archetype 2 – Low temperature, clustered; Archetype 3 – High temperature, dispersed; Archetype 4 – High temperature, clustered.

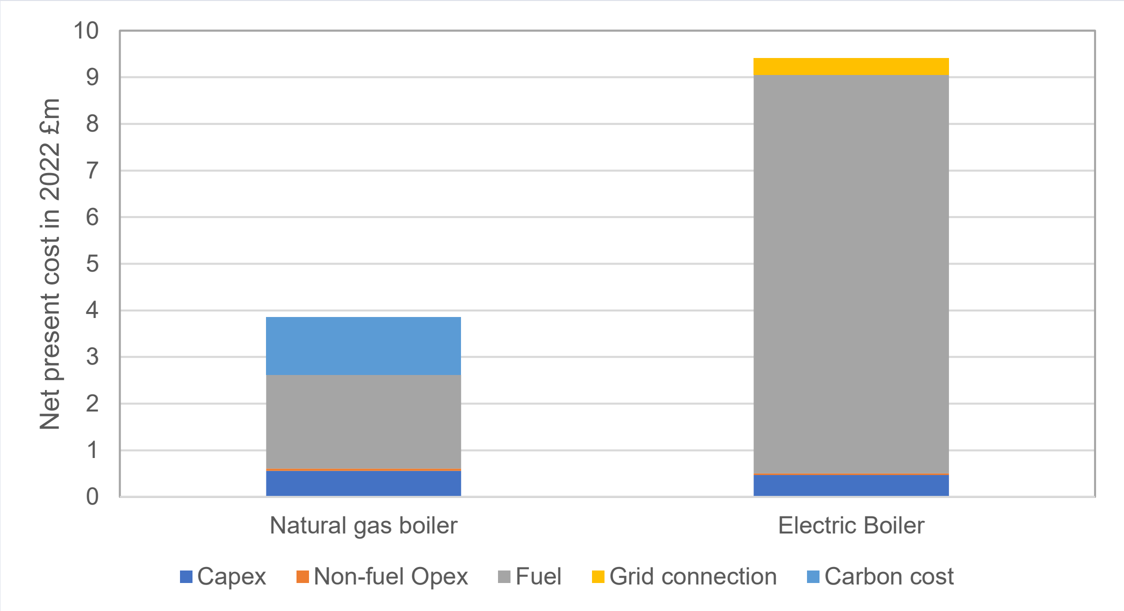
Over the last year, we have engaged with stakeholders to develop our understanding of the factors limiting the ability of businesses to switch away from fossil fuels towards electricity. This has highlighted that the main barriers for sites looking to switch to electrification in the short term are financial and infrastructure barriers. Therefore, we would like to unpack these further.

Box 2: Analysis of the cost of electrification for the case of an electric boiler

Our initial analysis suggests that the most significant financial barrier is the high relative fuel cost for electric technologies. Figure 5 below shows the breakdown of Net Present Cost over 15 years for a gas and electric boiler, assuming investment in 2030. For an electric boiler, even though the capital cost is approximately equal that of the gas boiler, higher electricity prices means that fuel costs make up 91% of the Net Present Cost. This results in overall costs that are more than double those of a natural gas boiler even when including the cost of carbon (from Emissions Trading Scheme permits).

Figure 5: Breakdown of the Net Present Cost over 15 years of different 2MW boiler technologies, assuming investment in 2030[23,24]

Figure 5 shows estimated private net present cost profiles of a 2 MW gas and electric boiler. Costs are broken down into Capex (capital expenditure), Non-fuel Opex (Operating costs not due to input fuel), and Fuel costs; for Electricity, 'Grid connection cost' is included at an assumed rate of £350/KW, for the Natural gas boiler, direct carbon costs arising from ETS participation are included as 'Carbon cost'. Future costs are discounted at a 10% discount rate over a 15-year appraisal period (the lifetime of an electric boiler) assuming a 2030 investment.



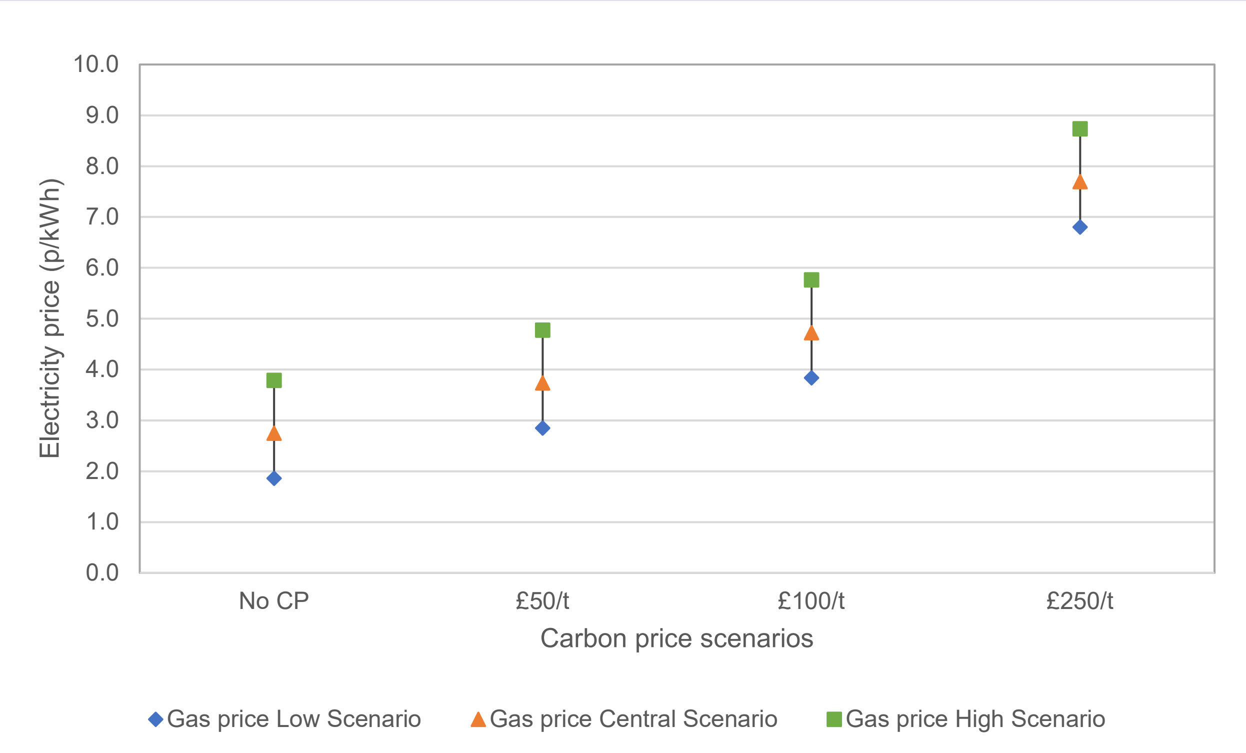
[23] Grid connection costs assumed to be £350/KW

[24] Figures 5 & 6 are based on Green book Tables 4-8, Industrial retail prices central scenario, https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

Figure 6 shows the average electricity price required for a 2 MW electric boiler to breakeven with a natural gas boiler (assuming a 15-year lifetime of the electric boiler) under different carbon and gas price scenarios, assuming a firm switches from a natural gas boiler to an electric boiler in 2030. Assuming a flat carbon price of £100 per tonne, electricity would need to cost less than 3.8-5.8 p/kWh in 2022 prices (depending on the gas price), to be cost competitive with a natural gas boiler. In the absence of a carbon price, the electricity price would need to be even lower at 1.9-3.8 p/kWh to achieve cost parity with the incumbent natural gas boiler. For comparison, the industrial electricity price in 2021 was around 14p/kWh, and around 20p/kWh in 2022.[25]

Figure 6: Average electricity price required to achieve cost parity over 15 years between a 2 MW natural gas boiler and 2 MW electric boiler under different natural gas and carbon price scenarios, assuming investment in 2030

Figure 6 shows required electricity prices (y-axis) to make a 2MW electric boiler cost-competitive with its natural gas counterpart over a 15-year appraisal period assuming a 2030 switch. A range of flat rate carbon prices (x-axis) are used to illustrate how higher ETS costs mean that an electric boiler becomes cost-competitive at a higher electricity price. This chart also captures uncertainty around future gas prices by incorporating high, central, and high scenarios and their impact on the required electricity price.

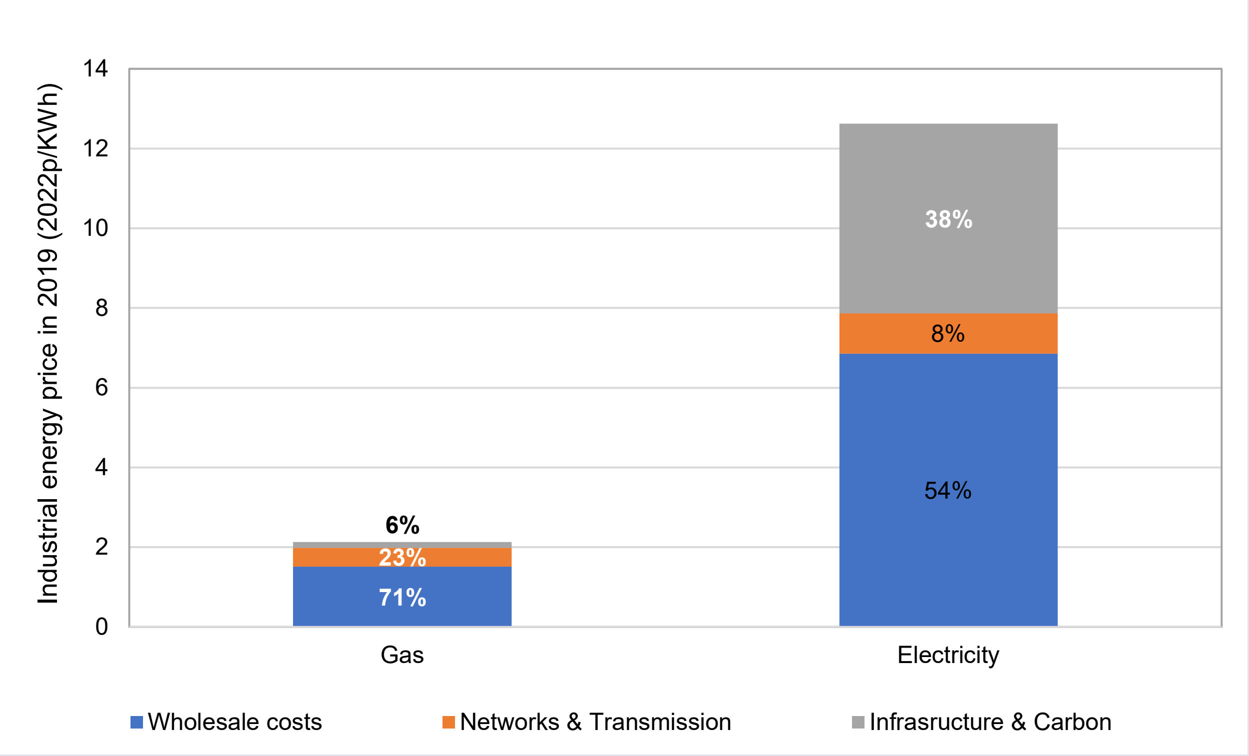


[25]BEIS Quarterly Energy Prices, Prices for a ‘Very Large’ electricity consumer, https://www.gov.uk/government/collections/quarterly-energy-prices

Figure 7 shows the breakdown of industrial and electricity prices in 2019. Of an 13p/kWh electricity price, wholesale costs account for around 50% while infrastructure and carbon costs contribute around 40% and network costs make up the remaining 10%. In the future, as the share of low-cost renewable generation increases, the wholesale price of electricity is expected to fall to around 5p/kWh by 2030.[26] This, combined with reforms to carbon and infrastructure costs,[27] could make electrification a more economically attractive option in the future.

Figure 7: Breakdown of Industrial Energy Price in 2019 (2022p/KWh)[28]

Figure 7 shows a breakdown of historic industrial gas and electricity prices in 2019. Gas and electricity prices are broken down into Wholesale costs (the price of energy set by the wholesale market), Networks & Transmission costs (costs of transport and distribution) and Infrastructure & Carbon costs (includes charges for funding the capacity market and renewable generation, carbon and environmental levies and carbon costs involved in electricity generation).



[26] BEIS Energy and Emissions Projections (2022), Annex M, https://www.gov.uk/government/publications/energy-and-emissions-projections-2021-to-2040
[27] These costs could cover schemes to support energy efficiency improvements in homes and businesses, help vulnerable people and encourage take-up of renewable technology, such as the Renewables Obligation.
[28] Electricity user band IF, or Very Large (70,000-140,000 MWh annually) and Gas user band I4, or Large – Very Large (27,778-1,111,112 MWh annually) Data taken from Eurostat, https://ec.europa.eu/eurostat/web/main/data/database

31. Please rank the following factors to describe the underlying reason(s) for fuel cost as a barrier to electrification using the following scale: 0 = don't know, 1 = not a factor, 2 = slightly important, 3 = moderately important, 4 = important, 5 = extremely important.

- High electricity price relative to gas
- Uncertainty about future electricity prices
- Uncertainty regarding other fuel options (e.g. future hydrogen price)
- Uncertainty of future energy prices
- High price relative to other countries causes competitiveness issues
- Other, please provide details

32. Please rank the following factors to describe the underlying reason(s) for capital cost as a barrier to electrification using the following scale: 0 = don't know, 1 = not a factor, 2 = slightly important, 3 = moderately important, 4 = important, 5 = extremely important.

- Capex is high relative to natural gas technology
- Capex is high relative to the hydrogen/biomass/CCUS alternative
- The payback period is too long to justify the higher Capex cost
- The project is too risky to justify the higher Capex cost
- Difficulties accessing finance
- The cost of retiring incumbent technology early
- Other, please provide details

33. Please rank the following factors to describe the underlying reason(s) for electricity grid access as a barrier to electrification using the following scale: 0 = don't know, 1 = not a factor, 2 = slightly important, 3 = moderately important, 4 = important, 5 = extremely important.

- Additional grid access takes too long
- Additional grid access is too costly
- Additional grid access application refused
- Other factors. Please provide details

2.2 Enablers: the role of private renewable generation

Industrial stakeholders are increasingly looking to private renewable generation to supply or supplement their electricity requirements. There is interest in solar (both rooftop and ground-mounted), wind, waste/biogas to electricity and small-scale nuclear (SMR).

The Independent Review of Net Zero included a recommendation (#70) to Government to "develop a policy proposal to incentivise on-site generation in Manufacturing by Q2 2024, with options to consult on the funding formula required by the public and private sector to reach the tipping point of adoption".[29] Any policy development in this area would need to be additional, affordable and provide value for money.

Private electricity generation can take on different forms. Broadly these can be grouped as:

- Private wire arrangements where there is a direct connection between two separate entities: a consumer and a generator. The consumer may or may not be connected to the licensed network, but generally will be. The generation facility can be located either on or off-site.
- "Behind the meter" or onsite generation where supply is generated by the consumer.

Private renewable generation could help to improve the overall economics of electrification technologies and create an attractive business case for this decarbonisation route. Industrial sites and other non-domestic buildings with high electricity demand can offer significant potential for solar deployment, which can rapidly pay for itself by means of energy bill savings. At present, and particularly during periods of high wholesale electricity prices, the cost of private generation can be lower compared to grid electricity, particularly for sites with high electricity demand, owing to:

- the per unit (MWh) price of renewable electricity generation having reduced significantly over the last decade, large-scale renewable generation is now competitive with (and significantly cheaper to develop and operate than) fossil-fuel based generation;[30]
- avoiding some of the legacy policy costs;
- possibly reduced network charges as these are proportional to a site's capacity/consumption;
- possibly reducing the need for grid connection reinforcements and avoiding the capital costs and connection charges associated with this;
- protection from gas price fluctuations.

[29] Rt Hon Chris Skidmore MP (2023), Mission Zero: Independent Review of Net Zero, https://www.gov.uk/government/publications/review-of-net-zero
[30] BEIS (2020), Electricity Generation Costs, https://www.gov.uk/government/publications/beis-electricity-generation-costs-2020

There is also potential for industry to sell excess renewable electricity back to the grid and to play a role in demand-side response. This is discussed on more detail below. These could generate additional revenue streams for businesses.

However, private renewable generation still faces barriers and does not solve all challenges. The regulatory landscape for renewable generation is complex which can prove costly and resource intensive for sites to navigate. In addition, most sites will still need a grid connection to ensure security of supply, which means that barriers in obtaining a grid connection may still exist. Changes to the network charging regime have been put in place by Ofgem from April 2023 that move some components of network charges from being based on consumption to connection capacity. This could make private generation with grid back up somewhat less financially beneficial for industrial sites.

34. Does private renewable generation act as an enabler for industrial electrification? Please provide details of your rationale.

35. Are there any barriers to deploying private renewable generation for industry? If yes, please provide details on how to overcome them.

2.3 Enablers: the role of demand side response

Flexibility in our energy system is essential to integrate high volumes of low carbon power, heat and transport. Demand Side Response (DSR) enables us to use electricity more flexibly, which bolsters our energy security and supports the cost-effective decarbonisation of our electricity system. It refers to action taken by consumers, in response to a signal (such as price) to reduce or increase the amount of electricity they take off the grid at a particular time. DSR can help large non-domestic consumers save money and create new revenue streams, by using electricity at times that are beneficial to the system and being rewarded for doing so. We are removing barriers to the increased participation of consumers in DSR, including through actions set out in the joint Government and Ofgem 2021 Smart Systems and Flexibility Plan, and through support for innovative initiatives like National Grid's Demand Flexibility Service.

36. Could demand side response (DSR) act as an enabler of industrial electrification? Please provide your rationale.

37. Are there any barriers to using DSR for industry? If yes, please provide details on how to overcome them.

3. Exploring policy options

3.1 Existing policy landscape and policies in development

Industrial decarbonisation, and electrification specifically, is a complex policy space where Government has been active over the years. Table 1A in the annex sets out the full suite of policies that impact electrification either directly or indirectly. Here, we focus on the main barriers to electrification and detail the existing policies and those in development that look to address these.

Technology barriers

- The **Industrial Fuel Switching Competition**, which is part of the **Net Zero Innovation Portfolio (NZIP)**, supports innovation in the development of pre-commercial fuel switch, and fuel switch enabling technology, to help industry switch from high to lower carbon fuels, including electricity.
- The **UKRI Industrial Decarbonisation Challenge** supports development of low-carbon technologies and infrastructure. The scheme is now closed. Successful projects have largely focussed on CCUS and hydrogen and the infrastructure needed to deliver these technologies. Electrification is likely to play a more significant role in some of the smaller clusters such as the Black Country.

Financial barriers

Current policies seeking to address the financial barriers to electrification include:

- The **Industrial Energy Transformation Fund (IETF) and the Scottish IETF** include capital support for businesses switching away from fossil fuels to electricity.
- The **UK Emissions Trading Scheme (UK ETS)** sets a long-term price signal for carbon which will increase over time, providing a financial incentive to energy intensive industries to switch to using lower carbon fuels.
- The **Energy Intensive Industry (EII) Exemption Scheme** reduces electricity costs for EII eligible businesses by exempting them from certain policy costs. Costs are redistributed to other energy consumers, increasing electricity costs for non-EII eligible industrial sites. This creates mixed signals across industry.
- The **EII Compensation Scheme** reduces electricity costs for eligible businesses by providing relief for the cost of the UK ETS and Carbon Price Support mechanism in their electricity bills, which could make it more attractive for these businesses to fuel switch.
- **Smart System and Flexibility Plans (2017 & 2021)** include actions making industrial participation in demand side response easier and improving the markets to provide better value for the provision of flexibility services. This could enable industrial sites to offset some of their electricity costs by securing revenues from the provision of flexibility services.

The Government is also working to address high electricity prices through the following policies currently in development:

- Department of Energy Security and Net Zero has committed to outlining a clear approach to **Fuel Price Rebalancing** by the end of 2023/24 and make significant progress affecting relative prices by the end of 2024. This will look to decrease the price of electricity relative to gas.
- Department of Energy Security and Net Zero is undertaking a **review of electricity market arrangements (REMA)** to ensure that that markets are fit for delivering a secure, affordable, net zero power sector. The review is considering several possible changes to achieve those aims.
- The proposed **British Industry Supercharger** is an extension of the EII exemption scheme. This could support EII-eligible businesses to electrify as their cost of electricity falls. However, this may make it more difficult for non-EII businesses to switch as these costs will be added to all other energy consumers, including industrial sites.
- The UK ETS Authority is considering several possible changes to **strengthen the UK ETS**, such as including more sectors and aligning the cap to net zero ambitions. Strengthening the UK ETS is likely to increase the incentives to switch to lower carbon fuels, which includes electricity.

Infrastructure and supply barriers

- The **Action Plan to Accelerate Connections** will set out the actions by Government, Ofgem and network companies to reduce connection timescales by releasing network capacity and improving the connections process. It is expected that these actions will result in earlier connection dates being offered to industrial electrification projects, amongst a range of others, including (but not limited to) renewable generation and battery storage.
- In response to the Independent Review of Net Zero, the Government is exploring policy options to increase the deployment of renewable electricity generation at manufacturing facilities. **Facilitating the process to secure onsite renewables** could help lower the cost of electricity for industrial sites, and in turn enable electrification.

38. Are there other policies (either current or in development) that could positively or negatively impact industry's ability to switch away from fossil fuels to electricity?

39. Considering the whole impact of existing policies and the exploratory/planned policies: is further electrification specific intervention needed to enable the electrification of industry in the 2020s and 2030s? Please provide evidence.

3.2 Possible approaches

While the policies above are expected to go at least some of the way to addressing the barriers set out in the Chapter 2, there is a possibility that further government intervention could be needed to enable electrification to deliver on our fuel switching ambition and Carbon Budget 6 targets. We intend to continue assessing the impacts of existing policies and policies in development on industrial electrification.

As we develop our approach to enabling industrial electrification, we are seeking views on an initial set of principles that would guide future policy. Policy should:

- drive decarbonisation of industrial sites in the 2020s and 2030s;
- be consistent with the wider industrial decarbonisation policy landscape;
- ensure value for money;
- provide confidence to those funding the electrification by allocating a proportionate level of risk;
- be affordable and fundable over time;
- be practical and simple, both from government and end user perspective.

40. Do you agree with these principles for a policy that enables industrial electrification? Are there other principles we should be considering?

There are a range of levers that could be used on their own or in combination to enable electrification in time for CB6. We are interested in hearing both about policies that could directly enable or incentivise electrification, for example a support mechanism for sites fuel switching to electricity or regulating to enforce switching; and policies that would indirectly enable or incentivise fuel switching, for example by removing barriers to the deployment of onsite renewables or developing a quality standard for a certain technology. Thinking about possible levers, Government could:

- **Regulate**. Government could develop regulation requiring owners of certain pieces of equipment to change to low carbon alternatives or have a plan for decarbonising these pieces of equipment.
- **Fund**. Government could develop funding options to address the financial barriers of electrification. Potential government support could be linked to abatement achieved through fuel switching or based on the additional costs that might be incurred.
- **Enable**. Government could create an enabling environment for businesses to be able to electrify with minimal or indirect government intervention looking to make the process easier, faster, and/or cheaper. For example, developing policy to address information barriers.

41. How could Government facilitate an enabling environment for electrification?

42. In your view, which of the two options is preferable: policy specifically for electrification or a broader "fuel switching" policy, that allows sites to choose their optimal decarbonisation route?

43. What regulatory approaches could the Government explore to incentivise or enable electrification?

44. How could a funding policy be structured effectively to incentivise or enable electrification while meeting the principles outlined above? Please provide evidence.

45. Are there any risks of a funding policy for electrification? If so, how could these be mitigated? Please provide evidence.

46. Are there smaller or indirect policy changes that could enable businesses to electrify? If yes, please provide details on what these might look like.

47. Are there policy options or international examples that could enable or incentivise electrification that we should be considering?

Further information

48. Is there anything further that you think we should be considering when thinking about policy options to enable electrification?

List of Part I call for evidence questions

About you

1. **What is your name?**

2. **What is the name of your organisation?**

3. **What is the address of your organisation?**

4. **Do your views specifically relate to one of the Devolved Administrations?**

- Scotland
- Wales
- Northern Ireland
- Not related to a specific devolved administration

5. **Do you represent or hold expertise on a specific industrial sector? Please select all that apply.**

- Cement
- Lime
- Ammonia
- Ethylene
- Other Chemicals
- Food and drink
- Glass
- Ceramics
- Other non-metallic minerals
- Iron and steel
- Non-ferrous metals
- Vehicles
- Paper

- Refining
- Plastics
- Fabricated metal products
- Machinery and equipment
- Transport equipment
- Electrical and mechanical engineering
- Waste
- Construction (including non-road mobile machinery)
- Other industry (please specify)

6. Do you represent or hold expertise on a specific process or technology? If so, please select all that apply from the below.

- Boiler
- CHP
- Reforming
- Dryer
- Furnace
- Kiln
- Metal Melting
- Metal Rolling
- Oven
- Primary Iron Production
- Motor-driven equipment
- Other (please specify)
- Not applicable

7. How did you hear about this call for evidence?

- Email from this department

- Email from elsewhere
- GOV.UK alert
- Newsletter
- Twitter
- Other (please specify)

8. **If you are content to share your email address with us, for the purpose of being contacted relating to responses given, please share it below.**
9. **What type of organisation do you represent? Please select one:**

- Industrial site
- Trade association or other industry body
- Academic institution
- Non-Governmental Organisation (NGO)
- Electricity network
- Technology provider
- Energy supplier
- Private individual
- Other, please specify

About your site

10. **How many industrial sites does your company have? If your company has multiple sites, please choose a representative site based in the UK and answer the questions in Part II (site survey) with respect to that site only.**

- Single site in the UK only
- Single site in the UK and one or more sites outside of the UK
- Multiple sites in the UK, no sites outside of the UK
- Multiple sites in the UK and one or more sites outside of the UK

11. **Please provide the SIC code for your company.**
12. **What best describes your job role/background?**

- Technical / Engineer
- Finance
- Management
- Business communication
- Sales & Marketing
- Other (please specify)

13. What 'product(s)' are the main output of your industrial site(s) (e.g. chocolate, ceramic tableware, aluminium, cardboard packaging)?

14. What is the operating temperature of the main piece of equipment or process that your site(s) mainly use?

- <100 degrees Celsius
- 100 – 240 degrees Celsius
- 241 – 500 degrees Celsius
- 500 – 999 degrees Celsius
- 1000+ degrees Celsius

15. Approximately what proportion (percentage from 0 – 100%) of your energy use is low temperature? For the purposes of our analysis, we define low temperature as 240 degrees Celsius or below.

16. How many people does your company employ?

- Less than 49
- 50 to 249
- More than 250

17. In which region is your industrial site located?

- North East England
- North West England
- Yorkshire & The Humber
- East Midlands
- West Midlands

- East England
- Inner London
- Outer London
- South East England
- South West England
- Scotland
- Wales
- Northern Ireland

18. Is the site physically located in one or more of the industrial clusters outlined in the BEIS Industrial Decarbonisation Strategy (i.e. within 25 km of Grangemouth, Teesside, Humberside, Merseyside, South Wales, Southampton, or Black Country)?

- Yes, the site is located within an industrial cluster
- No, the site is not located within an industrial cluster
- Not sure

CHAPTER 1

19. Do you know of any other advantages associated with electrification of industrial processes that have not been described here? If yes, please provide details.

20. Are there any disadvantages of electrification of industrial processes? If yes, please provide details.

21. Do you agree with the information presented in Table 1? If you disagree, please provide specific details and supporting evidence.

22. Is there any new evidence you would like to submit on electrification technologies, either in relation to the technologies listed in Table 1 or technologies that might be missing from Table 1? If yes, please provide details.

23. Listed below are the areas of focus for innovation of electrification technologies. Please rate their importance using the following scale: 0 = Don't know, 1 = Not at all important, 2 = Slightly important, 3 = Moderately important, 4 = Important, 5 = Extremely important.

- Reducing the cost of commercially ready electrification technologies

- Scaling up technologies to meet commercial production requirements

- Demonstration of electrification technologies on sites

- Research and development of high temperature electrification equipment (such as for glass, ceramics, and metals)

- Targeted innovation in a particular sector, technology or process.

- Improved reliability and/or performance of electrification technologies.

- Other, please provide details – including their ranking of importance.

24. If you rated "Targeted innovation in a particular sector, technology or process" at a 3 or above in the previous question, please provide details on your reasoning for this.

25. Do you agree with the site archetypes defined in this chapter?

26. Do you agree with the role of electrification of these archetypes presented here? Please provide details.

CHAPTER 2

27. Please rate the barriers to industrial electrification in terms of their severity using the following scale: 0 = Don't know, 1 = Not a barrier, 2 = low severity, 3 = moderate severity, 4 = severe, 5 = extremely severe, don't know.

- Technology innovation and demonstration
- Financial
- Infrastructure and supply
- Organisational
- Regulatory/policy

28. If you rated any of the above barriers as 4 or higher, please provide further details.

29. Are there any other barriers preventing the switch away from fossil fuels towards electricity? If yes, please provide details.

30. How do these barriers impact electrification of sites in each of the below archetypes? Archetype 1 – Low temperature, dispersed; Archetype 2 – Low temperature, clustered; Archetype 3 – High temperature, dispersed; Archetype 4 – High temperature, clustered.

31. Please rank the following factors to describe the underlying reason(s) for fuel cost as a barrier to electrification using the following scale: 0 = don’t know, 1 = not a factor, 2 = slightly important, 3 = moderately important, 4 = important, 5 = extremely important.

- High electricity price relative to gas
- Uncertainty about future electricity prices
- Uncertainty regarding other fuel options (e.g. future hydrogen price)
- Uncertainty of future energy prices
- High price relative to other countries causes competitiveness issues
- Other, please provide details

32. Please rank the following factors to describe the underlying reason(s) for capital cost as a barrier to electrification using the following scale: 0 = don’t know, 1 = not a factor, 2 = slightly important, 3 = moderately important, 4 = important, 5 = extremely important.

- Capex is high relative to natural gas technology
- Capex is high relative to the hydrogen/biomass/CCUS alternative
- The payback period is too long to justify the higher Capex cost
- The project is too risky to justify the higher Capex cost
- Difficulties accessing finance
- The cost of retiring incumbent technology early
- Other, please provide details

33. Please rank the following factors to describe the underlying reason(s) for electricity grid access as a barrier to electrification using the following scale: 0 = don’t know, 1 = not a factor, 2 = slightly important, 3 = moderately important, 4 = important, 5 = extremely important.

- Additional grid access takes too long
- Additional grid access is too costly
- Additional grid access application refused
- Other factors. Please provide details

34. Does private renewable generation act as an enabler for industrial electrification? Please provide details of your rationale.

35. Are there any barriers to deploying private renewable generation for industry? If yes, please provide details on how to overcome them.

36. Could demand side response (DSR) act as an enabler of industrial electrification? Please provide your rationale.

37. Are there any barriers to using DSR for industry? If yes, please provide details on how to overcome them.

CHAPTER 3

38. Are there other policies (either current or in development) that could positively or negatively impact industry's ability to switch away from fossil fuels to electricity?

39. Considering the whole impact of existing policies and the exploratory/planned policies: is further electrification specific intervention needed to enable the electrification of industry in the 2020s and 2030s? Please provide evidence.

40. Do you agree with these principles for a policy that enables industrial electrification? Are there other principles we should be considering?

41. How could Government facilitate an enabling environment for electrification?

42. In your view, which of the two options is preferable: policy specifically for electrification or a broader "fuel switching" policy, that allows sites to choose their optimal decarbonisation route?

43. What regulatory approaches could the Government explore to incentivise or enable electrification?

44. How could a funding policy be structured effectively to incentivise or enable electrification while meeting the principles outlined above? Please provide evidence.

45. Are there any risks of a funding policy for electrification? If so, how could these be mitigated? Please provide evidence.

46. Are there smaller or indirect policy changes that could enable businesses to electrify? If yes, please provide details on what these might look like.

47. Are there policy options or international examples that could enable or incentivise electrification that we should be considering?

Further information

48. Is there anything further that you think we should be considering when thinking about policy options to enable electrification?

Part II: Site survey on enabling industrial electrification

Introduction

The Department for Energy Security and Net Zero is working with industry to assess the feasibility, costs, and benefits of using electrification. The evidence generated will inform government analysis and strategic decisions for developing policy options to enable electrification.

Part I of the Call for Evidence on Enabling Industrial Electrification sought to gather views from all stakeholders with an interest in industrial electrification. **Part II** (this accompanying site survey) is specifically aimed at gathering more granular information from industrial sites, to further explore the opportunities and challenges of switching from natural gas to electrification in industrial sites across the UK. The Part II responses will be treated as commercially sensitive.

The questionnaire is mainly multiple choice and will cover (1) decarbonisation experience and planning, (2) barriers to electrification and (3) enablers to electrification. We are interested in hearing from sites irrespective of the progress towards decarbonisation, as all input will be valuable to us and will help scope and plan future phases of work with respect to electrification.

In Part I, we asked for your contact details so that we can follow up with companies that have agreed to being contacted by DESNZ with respect to information provided in the questionnaire, and/or that have expressed an interest in participating in future work. Please see our personal information charter and privacy notice for information on how we will handle this data.

Any enquiries regarding this publication should be sent to us at: industrialelectrification@energysecurity.gov.uk.

About you

1. **What is your name?**
2. **What is the name of your organisation?**

Decarbonisation planning

In this section we are looking to understand:

- Previous experiences of switching from a fossil fuel-based process to one using electricity.
- Current and future decarbonisation plans.

Previous experiences with electrification

If you have previous experience of switching from a fossil-fuel based process to one using electricity we would like to hear about this so that we can understand what is currently possible, the barriers you may have faced, and lessons learnt from this process.

3. **In the last 10 years, have you replaced any fossil fuel-based equipment with an electric alternative either on a UK site or on a site outside the UK that is owned by your company?**

- Yes. [If yes, please move to the next question in this section]
- No. [If no, please skip to the 'Current decarbonisation planning' section]
- Don't know [If don't know, please skip to the 'Current decarbonisation planning' section]

4. **Which technology was replaced? Please select all that apply.**

- Boiler
- CHP
- Reforming
- Dryer
- Furnace
- Kiln
- Metal Melting

- Metal Rolling
- Oven
- Primary Iron Production
- Motor-driven equipment
- Other (please specify)

5. **Why did you decide to change from fossil fuel to electricity? Please rank the following possible motivations using the following scale: 0 – Don't know, 1 - Not at all important, 2- slightly important, 3- moderately important, 4 - important, 5- extremely important.**

- Better financial performance
- Better performance efficiency
- Better operational performance (aside from efficiency)
- Environmental considerations
- Security of supply
- Fiscal support
- Other (please specify)

6. **If you experienced any key successes or challenges with the switch to electricity, please detail them here.**

Current and future decarbonisation plans

If you have a decarbonisation plan, or are developing one, we would like to hear about this so that we can gain an understanding of the level of decarbonisation planning across industry. Particularly, we would like to understand the role of electrification in your plan, along with which technologies you are considering.

7. **Does your site have a decarbonisation plan or are you working to develop a plan?**

- Yes. [If yes, please move to the next question]
- No. [If no, please give us some detail as to why your site does not have, or is not working to develop, a decarbonisation plan please give some detail as to why. Then, skip to 'Barriers to electrification' section]

- Don’t know. [If don’t know, please give us some detail as to why there is uncertainty around whether your site has, or is working to develop, a decarbonisation plan. Then, skip to ‘Barriers to electrification’ section]

8. **How well developed is your decarbonisation plan? Fully developed means that the plan is site-specific, process-specific and costed.**

- Initial ideas for the plan have been drafted
- Plan is partially developed, but is not yet site-specific, process-specific and costed
- Plan is developed, and has some elements of being site-specific, process-specific and costed, but further detail still needs to be added
- Plan is fully developed but is not yet being implemented
- Plan is fully developed and is being implemented

9. **Please detail your planned use for each type of fuel/technology using the following scale: 1 - Expect to use this for all processes, 2 - Expect to use for majority of processes, 3 - Expect to use for some of my processes, 4 - Don't expect to use, 5 - Ruled out / don't want to use, 6 - Don't know.**

- Electrification
- Hydrogen
- Biofuel
- CCUS

10. **If there is uncertainty around whether electrification is part of the solution for your site, please provide details on this.**

11. **If you plan to use electrification on your site, please provide detail on the main reasons that you consider electrification to be a good decarbonisation option for your site.**

12. **If electrification is part of the solution for your site, which electrification technologies are included in your decarbonisation plan? Select all that apply.**

- Electric Steam Boiler (small)
- Electrode Steam Boiler (large)
- Electric Process Heater
- Electric Plasma Gas Heaters
- OL Heat Pump (MVR) (Low temperature)

- CL Heat Pump (Low temperature)
- Electric oven
- Electric arc furnace
- Electrolyser (AEL/PEM)
- Electric Infra-Red Heaters
- Microwave Heaters
- Electric glass furnace
- Iron ore electrolysis (direct electrification)
- Electric Ceramic Tunnel Kilns
- Medium temperature heat pump
- All Electric Smelters
- Solid oxide electrolysis cells
- High temperature heat pump
- Electric dryer
- Electric furnace – plasma
- Microwave drying
- Electrical steam cracker
- Electric furnace – microwaves
- Plasma torches (Cement kilns)
- Electric furnace
- Electric kiln
- Other (please specify)

Barriers to electrification

In this section, we would like to hear from you on the barriers to electrification. The information you give us on barriers will help to inform future policy options to unblock the barriers and to maximise the opportunities for electrification. The main barriers we are collecting information on, reflecting those in Part I, are the following:

- Electricity costs.
- Capital costs.
- Electricity grid access and supply.
- Technology and technical capability.

In the 'Other barriers' subsection, you will have the opportunity to let us know any other barriers you may have faced which do not fit into these topics.

Electricity costs

13. Is your site eligible for energy exemptions or compensation? If so, please select all that apply.

- EII exemptions
- CCL reduction
- Other (please specify)
- No, my site is not eligible for exemptions or compensation. [If no, participants will skip to 'Please provide any further evidence to support your concerns around this barrier]

14. If your company is eligible for energy exemptions or compensation through which mechanisms are these provided for?

- Climate Change Agreements (CCA)
- Combined Heat and Power Quality Assurance Programme (CHPQA)
- Other, please specify

15. Is electricity price a barrier for electrifying your site? Please provide reasoning and any evidence for your above answer.

- Yes.
- No.
- Don't know.

Reasoning behind answer: [Free text]

Capital costs

16. How important are decarbonisation investments for your company relative to other investment priorities?

- Don't know
- Not at all important
- Slightly important
- Moderately important
- Important
- Extremely important

17. Please provide further reasoning behind your answer. Particularly, which priorities are above and below decarbonisation and why?

18. What are your payback and return expectations for your site's capital targeted at decarbonisation investments?

19. What would the spend profile be for the capital costs?

- Full payment in the year of investment
- Spread payment over several years
- Other, please provide details

20. How would you typically finance these costs?

- Loan
- Part loan, part company capital
- Company capital
- Other (please specify)

21. What sort of interest rates are you facing?

- 7% or lower
- 8%-9%
- 9%-10%
- 10%-11%

- 11%-12%
- 13% or higher

22. Is CapEx a barrier to investment in electrification technologies on your site? Please provide reasoning and any evidence for your above answer.

- Yes
- No
- Don't know

Reasoning behind answer: [Free text]

Electricity grid access and supply

23. Please describe how electricity is currently supplied to your site.

- Transmission network
- Distribution network
- Other (please specify)

24. Approximately, how much electricity does your site consume per annum (please specify units)?

25. Approximately, how much headroom do you have in your current electricity supply connection per annum (please specify units)?

26. Approximately, how much natural gas does your site consume per annum (please specify units)?

27. If you have plans to electrify, approximately what is the expected additional power requirement per annum (please specify units)?

28. If you have plans to electrify, is connection reinforcement required to meet the additional power demand?

- Yes
- No
- Don't know

29. Have you applied for an upgraded connection to the grid?

- Yes

- No
- Don't know

30. What is the cost (or potential cost) of this connection (in £)?

31. How long will you have to wait to be connected (in months)?

32. Are there any other challenges with obtaining this connection? If so, please provide details below.

33. Is electricity access and supply a barrier to electrification for your site? Please provide reasoning and any evidence for your answer.

- Yes
- No
- Don't know

Reasoning behind answer: [Free text]

Technology

34. Do you have any major equipment that is nearing the end of its lifetime? If yes, please provide details.

35. Are you able to use "off the shelf" electrification technologies on your site?

- Yes, 'Off the shelf' technologies are suitable for all of my site's processes
- Yes, 'Off the shelf' technologies are suitable for some of my site's processes, but some built to order technologies are also required
- No, built to order technologies are required for all of my site's processes
- Don't know

36. If there are specific requirements that would require built to order electrification technologies on your site, then please provide details on these required modifications.

37. Does the installation of electrification equipment require significant bespoke modification to other parts of your operation/process?

- Yes, significant bespoke modification is required
- No, significant bespoke modification is not required

- Don't know

38. If the installation of electrification equipment requires significant bespoke modification to other parts of your operation/process, then please provide details on these modifications.

39. Do you have concerns around the supply of electrification equipment?

- Yes
- No
- Don't know

40. If you do have concerns around the supply of electrification equipment, please provide further details.

41. Are technological limitations a barrier to implementing electrification on your site? Please provide reasoning and any evidence for your above answer.

- Yes
- No
- Don't know

Rationale behind answer: [Free text]

Technical capability

42. Do you have any concerns around workforce technical capacity to install, operate, maintain or decommission electric technologies (e.g. skill gaps as staff are trained to use combustion equipment)? Please select all that apply.

- Yes, I have concerns around workforce technical capacity to install electric technologies
- Yes, I have concerns around workforce technical capacity to operate electric technologies
- Yes, I have concerns around workforce technical capacity to maintain electric technologies
- Yes, I have concerns around workforce technical capacity to decommission electric technologies
- No, workforce technical capacity is not a problem
- Don't know

Please provide details of your concerns around workforce technical capacity below: [Free text]

43. Are technical capability limitations a barrier to implementing electrification on your site? Please provide reasoning and any evidence for your above answer.

- Yes
- No
- Don't know

Rationale behind answer: [Free text]

Other barriers

44. Thinking more broadly, are there other barriers to decarbonising your site through electrification?

Enablers of electrification

In this section, we aim to learn more about your site's use of, or plans to use, private renewable generation, demand side response and energy storage to enable electrification. Understanding the current use of these technologies, and potential future demand for them, will help us to plan future policy options.

Private renewable electricity generation

By private renewable generation, we mean both private-wire and onsite generation of renewable electricity to supply or supplement industrial site electricity requirements, including solar (both rooftop and ground-mounted), wind, waste/biogas to electricity and small-scale nuclear (SMR).

45. What is your site's current position on private renewable electricity generation?

- My site has private renewable generation. [If this option, please move to the next question]
- My site is planning on installing private renewable generation [If this option, please move to the next question]
- My site does not currently have private renewable generation but would like to explore/are exploring getting private renewable generation [If this option, please skip to 'Please rank the importance of the following benefits (or potential benefits) of private renewable generation to enable electrification for your site.']

- My site has no intention of investing in private renewable generation [If this option, please skip to 'What are the key barriers to installing, upgrading or planning for private renewable generation on your site?']

46. Which type(s) of technology does your site have, or is planning to get? Select all that apply.

- Wind
- Solar
- Bioenergy/waste
- Small scale nuclear (SMR)
- Other renewable generation (please specify)

47. Please provide details on the renewable generation technology you have or are planning to install (e.g. size, type, rooftop vs ground mount for solar)?

48. What were the determining factors that led you to invest in private renewable generation? If possible, please provide details of what incentives there were, why you chose the particular technology and what influenced the business case.

49. How did you access capital to build or install and at what rates?

50. Do you consume the majority of the electricity you generate on site as the end user?

- Yes
- No

51. Do you use Power Purchase Agreements (PPAs) or the Smart Export Guarantee (SEG)?

- Yes, PPAs and the SEG
- Yes, PPAs
- Yes, the SEG
- No, my site uses neither
- Other (please specify)

52. What are your financial arrangements behind this investment? If possible, please include details behind how you accessed the capital to build and at what rates, whether you consume the majority of the electricity on site as the end

user, and whether you use Power Purchase Agreements (PPAs) or the Smart Export Guarantee (SEG).

53. Please rank the importance of the following benefits (or potential benefits) of onsite low carbon generation to enable electrification for your site using the following scale: Not at all important, slightly important, moderately important, important, extremely important.

- Avoidance of costs from high wholesale electricity prices and network charges
- Better efficiency fuel to energy conversion
- Profit in long run by selling energy back to grid
- Other (please specify the benefit and its ranking of importance)

54. If you would like to explore a type(s) of technology further, please specify which type. Select all that apply.

- Wind
- Solar
- Bioenergy
- Small-scale nuclear (SMR)
- Other renewable generation (please specify)

55. What are the key barriers to installing, upgrading or planning for private renewable generation on your site?

56. Please provide views on how these barriers may be overcome at your site.

57. Aside from the barriers listed above, if you have no intention of investing (or investing further) in private renewable generation, why is this?

Demand side response

We define demand side response as participating in markets and offers to reduce, increase, or shift your demand of electricity.

58. Are you aware of demand side response, as defined above?

- Yes
- No
- Don’t know

59. What's your site's current position on demand side response?

- My site currently participates in demand side response [If this option, please move to the next question]
- My site is planning on participating in demand side response [If this option, please move to the next question]
- My site does not currently participate, or plan to participate, in demand side response but would like to engage with/learn more about it [If this option, please skip to 'What are the benefits, or potential benefits, of demand side response to enable electrification for your site?']
- My site has no intention of participating in demand side response [If this option, please skip to 'Do you consider that there are barriers to participating in demand side response for your site?'].

60. How do you participate or plan to participate in demand side response?

61. What are the benefits, or potential benefits, of demand side response to enable electrification for your site?

62. If you are interested in engaging with, and/or learning more about, demand side response, which aspects would you like to engage with/hear more about (if known)?

63. Do you consider that there are barriers to participating in demand side response for your site?

- Yes
- No
- Don't know

64. If so, what are those barriers to using demand side response to enable electrification for your site?

65. Please provide views on how these barriers may be overcome on your site.

66. Aside from the barriers listed above, if your site has no intention of participating in demand side response, why is this?

Energy storage

We define energy storage as the capture of energy produced at one time for use at a later time as electricity or as energy in other processes at sites. We are interested in the role electrical storage and heat storage types could play in enabling electrification, for example, through enabling flexible electricity demand.

67. What is your site's current position on onsite energy storage?

- My site has onsite energy storage [If this option, please move to the next question]
- My site is planning on getting energy storage. [If this option, please move to the next question]
- My site does not currently have or plan to get onsite energy storage but would like to engage with/learn more about getting energy storage [If this option, please skip to 'What are the benefits, or potential benefits, of energy storage to enable electrification for your site?'
- My site has no intention of getting energy storage [If this option, please skip to 'Please outline any key barriers with using these technologies?']

68. Which type(s) of energy storage technology does your site have or plan to get? Select all that apply.

- Mechanical
- Electrochemical
- Thermal
- Electrical
- Hydrogen based storage
- Other (please specify)

69. What are the benefits, or potential benefits, of energy storage to enable electrification for your site?

70. If you would like to engage with/learn more about getting energy storage, which aspects would you like to know more about (if known)?

71. Please outline any key barriers to using these technologies.

72. Please provide views on how these barriers may be overcome on your site.

73. Aside from the key barriers listed above, if you have no intention of getting (or getting further) energy storage, why is this?

Further information

74. Is there anything relating to your site that you think we should be considering when thinking about policy options to enable electrification?

Annex

Table 1A - Current policies and policies in development relevant to industrial electrification

Current/ New	Policy	Description	Impact on industrial electrification
Current policy	Industrial Energy Transformation Fund (IETF)	Fund designed to help businesses with high energy use to cut their energy bills and carbon emissions through investing in energy efficiency and low-carbon technologies.	The IETF includes capital support for businesses switching from fossil fuels to electricity.
	UK Emissions Trading Scheme	Cap-and-trade system which caps the total level of greenhouse gas emissions, creating a carbon market with a carbon price signal to incentivise decarbonisation.	UK carbon prices increasing over time encourages energy intensive industries to switch to using lower carbon fuels.
	ETS Free Allocations	Policy that sits within the UK ETS to mitigate the risk of carbon leakage for UK industry.	This may reduce the incentive to switch to lower carbon fuels in the shorter term but may also free up some of the capital to make the switch.
	Climate Change Levy (CCL)	Environmental tax on commercial energy uses aimed at promoting energy efficiency across industry.	The CCL currently has a higher cost/kWh for electricity than gas, contributing to electricity being more expensive than gas. This may negatively impact the switch towards electrification. However, these rates will equalise from 1 April 2024.

Current/ New	Policy	Description	Impact on industrial electrification
	Climate Change Agreements (CCAs)	These are voluntary agreements made between UK industry and the Environment Agency to reduce energy use and CO_2 emissions, in return for a discount on the Climate Change Levy.	This reduces the possible negative impact of the Climate Change Levy for the industries making changes to reduce their energy use and emissions. There is a higher discount available for CCL rates on electricity than there is on gas rates, encouraging electricity use over gas for high energy users. To be eligible for the CCA scheme, participants must meet agreed sectoral energy efficiency targets. Switching from fossil fuels to electricity can in some cases increase energy input required for the same output, disincentivising electrification in industries which are focused on energy efficiency targets.
	Energy Intensive Industry (EII) Exemption Scheme	The EII Exemption Scheme exempts around 300 EII eligible businesses from up to 85% of the costs arising from the renewable levies (Renewable Obligation, Feed in Tariffs, and Contracts for Difference).	The costs are redistributed to other energy consumers, including other industrial sites, therefore increasing electricity costs for non EII eligible businesses. This may positively impact the switch towards electrification for EII eligible businesses, and negatively impact the switch towards electrification for non-EII eligible businesses.

Current/ New	Policy	Description	Impact on industrial electrification
	Energy Intensive Industry (EII) Compensation Scheme	The scheme provides businesses with relief for the costs of the UK Emissions Trading Scheme (ETS) and Carbon Price Support mechanism in their electricity bills.	The helps to make electricity cheaper for eligible firms, which could incentivise them to switch to electricity from fossil fuels.
	Net Zero Innovation Portfolio (NZIP)	The £1 billion innovation fund aims to accelerate innovation in low-carbon technologies, systems and business models in power, buildings and industry.	This includes the Industrial Fuel Switching Competition, which supports innovation in the development of pre-commercial fuel switch, and fuel switch enabling technology, to help industry switch from high to lower carbon fuels, including electricity. It also includes the Energy Entrepreneur Fund which supports the development and demonstration of state-of-the-art technologies, products and processes in the areas of energy efficiency, power generation and heat and electricity storage.
	Smart System and Flexibility Plans (2017 & 2021)	The Plans have set out actions to facilitate flexibility from consumers, remove barriers to flexibility on the grid, and reform markets to reward flexibility through both policy and innovation.	This includes actions making industrial participation in demand side response easier and improving the markets to provide better value for the provision of flexibility services. This could enable industrial sites to offset some of their electricity

Current/ New	Policy	Description	Impact on industrial electrification
			costs by securing revenues from the provision of flexibility services.
New policy	Fuel Price Rebalancing	Department of Energy Security and Net Zero committed to outlining a clear approach to fuel price rebalancing by the end of 2023/2024 and make significant progress affecting relative prices by the end of 2024. This will look to decrease the price of electricity relative to gas.	The approach set out could have a significant impact on reducing the relative cost of electricity, reducing the fuel cost barrier and supporting industrial electrification.
	Review of Electricity Market Arrangements (REMA)	Department of Energy Security and Net Zero is undertaking a review of electricity market arrangements to ensure that markets are fit for delivering a secure, affordable, net zero power sector. The review is considering several possible changes to achieve those aims.	Better operating electricity markets are likely to bring the wholesale cost of electricity down, reducing the fuel cost barrier which would enable electrification.
	British Industry Supercharger	From Spring 2024, the Department for Business and Trade will be delivering an extension to the EII exemption scheme. In effect, exempting around 300 EII-eligible businesses from the costs of renewable energy obligations (including Feed in Tariff, Contracts for Difference, and the Renewable Obligation), exemption from Capacity Market charges, and reductions in network charges, subject to deliverability.	This could support EII-eligible businesses to electrify as their cost of electricity falls. However, this may make it more difficult for non-EII businesses to switch as these costs will be added to all other energy consumers, including industrial sites.

Current/ New	Policy	Description	Impact on industrial electrification
	Changes to the UK ETS	The UK ETS Authority is considering several possible changes to strengthen the UK ETS, such as including more sectors and aligning the cap to net zero ambitions.	Strengthening the UK ETS is likely to increase the incentives to switch to lower carbon fuels, which includes electricity.
	Action Plan to Accelerate Connections	Plan articulating actions by Government, Ofgem and network companies to reduce connection timescales by releasing network capacity and improving the connections process.	It is expected that these actions will result in earlier connection dates being offered to industrial electrification projects, amongst a range of others, including (but not limited to) renewable generation and battery storage.
	Onsite renewable electricity generation at manufacturing facilities	In line with the recommendation from the Independent Review of Net Zero, Government is exploring policy options to increase the deployment of onsite renewable electricity generation at manufacturing facilities.	Facilitating the process to secure onsite renewables could help lower the cost of electricity for industrial sites, and in turn enable electrification.
	Facilitating the deployment of solar generation	Again, in line with recommendations from the Independent Review of Net Zero, the Government will publish a Solar Roadmap in 2024 setting out a clear step by step deployment trajectory to achieve 70GW of solar needed by 2035. Alongside this, Government will establish a government/industry taskforce	As with the above, facilitating the deployment of solar generation could enable industrial sites to build onsite solar generation, lowering the costs of electricity, and in turn enabling electrification.

Current/ New	Policy	Description	Impact on industrial electrification
		to drive the actions to deliver on this ambition. Government is consulting on changes to permitted development rights aimed at simplifying planning processes for larger commercial rooftop installations.	

This consultation is available from: www.gov.uk/government/consultations/enabling-industrial-electrification-a-call-for-evidence

If you need a version of this document in a more accessible format, please email industrialelectrification@energysecurity.gov.uk. Please tell us what format you need. It will help us if you say what assistive technology you use.