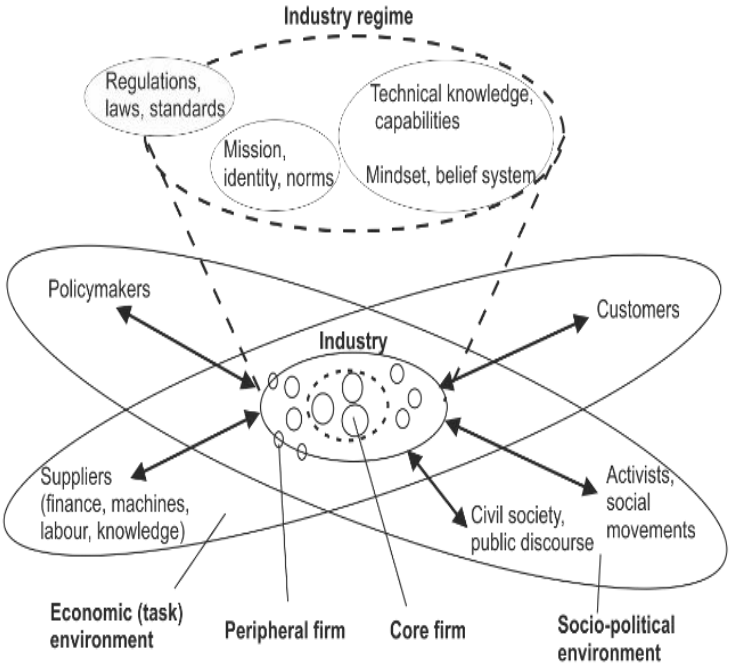
Low-carbon reorientation in steel, oil refining and petrochemical industries

Policy Briefing

November 2023

Steelmaking, oil refining and petrochemical industries are significant CO_2 emitters. To meet its net-zero obligations, the UK should quickly decarbonise these industries. Although the speed of change has been limited in all three industries, it accelerated in recent years and is now faster in oil refining and slowest in steel (until very recently). Drawing on a 2-year research project, sponsored by IDRIC, this policy brief aims to explain these differences and draw policy lessons.



Triple embeddedness framework of industries [1: p266]

Key Policy Findings

- The strengthening and expanding policy mix since 2019 has increased low-carbon reorientation activities in industrial firms.
- The policy focus on CCS and low-carbon hydrogen suits oil refining and petrochemical industries better than steelmakers. Other important decarbonisation pathways such as electrification, feedstock substitution, or demand reduction receive less attention than they should.
- The policy focus on four clusters disadvantages firms in the two other clusters, including a steelmaker and two refineries.
- Recent government deals with the two steelmakers partly alleviate these biases, but the intended shift to Electric Arc Furnaces faces practical obstacles, including: a) insufficient UK supply of high-quality scrap steel, b) grid challenges in supplying sufficient electricity, c) internationally high electricity prices, d) social acceptance problems because of layoffs
- As the cost of industrial reorientation may be £billions, past profitability of firms is important in shaping speed and commitment.
- Industrial decarbonisation policies need broadening to address other technologies, practical barriers, and social acceptance.

We analysed industrial low-carbon reorientation, using the Triple Embeddedness Framework - which sees industries as operating in both an economic environment and a socio-political environment, where industry responses to contextual pressures are shaped by an industry regime. Because low-carbon reorientation costs £billions, firms in industries are understandably cautious to commit to such expenditure, and therefore low-carbon reorientation requires an increase in external pressures for firms to respond. In response, firms tend to reorient through a sequence of steps: 1) denial, 2) incremental change, 3) exploration of radical innovations, 4) deployment of radical innovations, 5) deeper change in mindset and mission.

Three separate industry case study analyses carried out over the last two years [2, 3, 4] showed that oil refiners have moved from phase 3 to phase 4 since 2019, but that steelmakers and petrochemical firms are still in phase 3. This Policy Brief explains these differences focusing on five factors: a) policies, b) technical and practical feasibility, c) international competition, d) financial justifiability, e) mindsets. It will then offer lessons and advice.

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IDRIC

Industrial Decarbonisation Research & Innovation Centre (idric.org)

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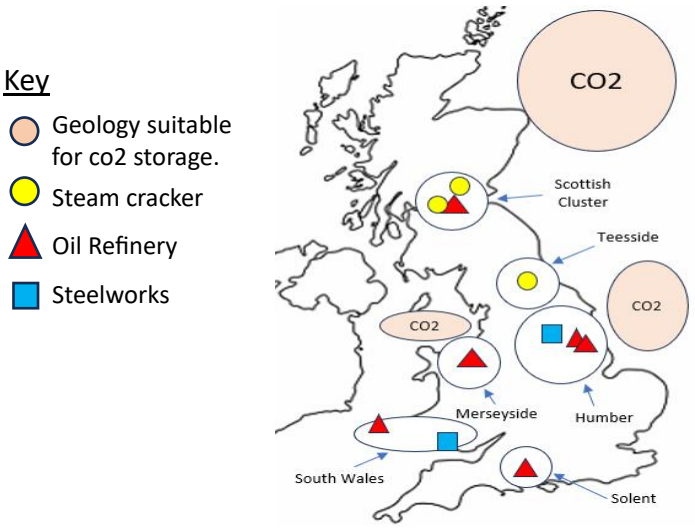
Industries in decline

All three industries have significantly reduced their scope-1 greenhouse gas emissions in recent decades: steelmakers by 56% between 1990 and 2021, oil refining by 46% between 1996 and 2021, and petrochemicals by 88% between 1990 and 2019. However, these reductions arose from incremental energy efficiency improvements, removal of two very strong climate-forcing chemicals (HCFC-22, N2O); and industrial decline, rather than low carbon reorientation. This decline was especially marked in the steel industry (73% since 1973) and oil refining (57% since 1973), and somewhat less in petrochemicals (32% since 2008). Deeper decarbonisation will require the implementation of radical innovations like carbon capture and storage (CCS), low-carbon hydrogen (for fuel switching or hydrogen direct reduction of iron ore), feedstock change, or electric arc furnaces (for steel).

The six principal UK cluster locations, with emitting assets and usable CCS geology highlighted



1) Variance in policy support

An important driver of these radical innovations is policy pressure, both through general targets (for net-zero, CCS, and hydrogen deployment) and specific policy instruments, including the £240m Net Zero Hydrogen Fund; the £140m Industrial Decarbonisation and Hydrogen Revenue Support Scheme; the 315m Industrial Energy Transformation Fund, the £1bn CCS Infrastructure Fund, and various business model support schemes, backed by a £20bn financial commitment. Although these policies have accelerated industrial low-carbon reorientation, they also introduced two biases. First, they focus on CCS and low-carbon hydrogen, which suit oil refining and petrochemicals far better than steelmakers. Second, they focus (through the Track 1 and 2 cluster sequencing process) on those industrial clusters that have nearby offshore CO_2 storage options, namely Merseyside, Humberside, Teesside, and Grangemouth (the Scottish cluster through the Acorn project). This mostly benefits the three petrochemical firms with steam crackers, and four of the six oil refineries in these clusters (see cluster figure above). Of these four, Essar Oil (Merseyside) and Phillips 66 (Humberside) have moved fastest to phase 4 of the transition, starting to deploy new CCS and low-carbon hydrogen technologies. Prax refinery (in Humberside) is following a bit more slowly, because of a recent (2021) take-over. The cluster policies disadvantage the Valero (South Wales) and the ExxonMobil (Solent) refineries and Tata's integrated steelworks (South Wales), as the South Wales and Solent clusters do not have good CO_2 storage options. These firms thus benefit less from the various support policies for CCS and low-carbon hydrogen.

It should not be assumed that either refinery will prefer low-carbon reorientation over withdrawing from the UK – particularly as both companies are American owned and managed, and the policy support for net-zero related investments within the USA is significantly greater.

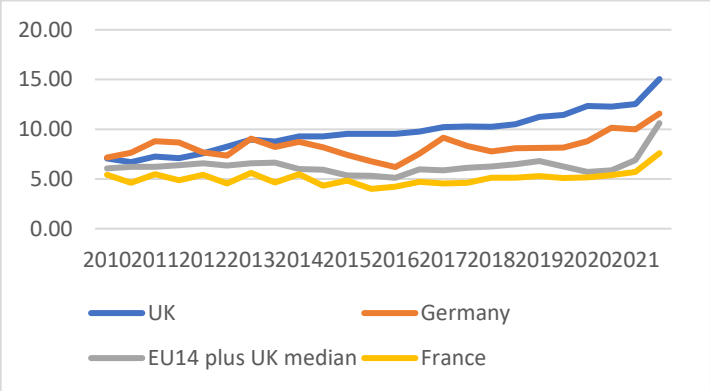
The owners of the two integrated steelworks have very recently (Fall 2023) made deals with the government to reorient towards Electric Arc Furnaces (EAFs), each receiving £500m policy support, which they will match with about £750m funding. Although this has the potential to transform UK steelmakers from the (comparatively) slowest to the fastest low-carbon reorienting industry, there are practical hurdles that may cause delays.

2) Technical and practical feasibility

CCS and hydrogen fuel switching are technologically feasible for the oil refining and petrochemical industries, which both already have relevant capabilities. These technologies also do not disrupt core operational processes, as they involve front-end or back-end changes (in energy supply or carbon capture add-on). Both industries thus prefer these low-carbon pathways.

CCS and blue hydrogen are unfeasible for Port Talbot in South Wales, as explained above. British Steel in Scunthorpe could have piggybacked on cluster-wide net-zero initiatives in Humberside but has (so far) decided not to. Hydrogen direct reduction of iron ore is still in early development stages with uncertain cost, and therefore less attractive for steelmakers. EAFs are a proven technology, but shifting the integrated steelworks to EAFs, which both firms recently agreed with policymakers, will likely encounter practical feasibility challenges: 1) electricity grids will struggle to provide the large amounts of power required (and grid upgrades are slow), 2) the required large amounts of high-quality scrap metal are not yet available, 3) recycled steel (from scrap metal smelting) has lower quality and cannot be used for all purposes, 4) high UK electricity prices may hamper international competitiveness (see figure below), 5) there will also be a significant loss of high-earning skilled employment, when

the blast furnace closes, as EAF technologies are far less labour intensive than blast furnace technology, and this is likely to create considerable political turbulence in the region. It remains to be seen if these hurdles can be overcome, or if the shift to EAFs will further reduce the UK's steel output.



Industrial electricity prices in pence/kWh (for January and July of each year) in selected European countries for extra-large electricity consumers including taxes (excluding VAT and other recoverable taxes and levies) (constructed using data from BEIS, 2022)

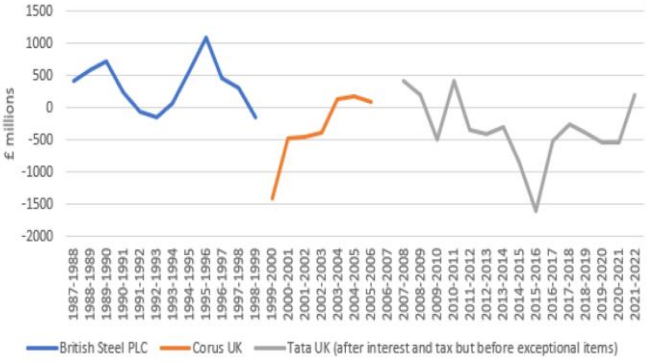
More generally, since both the South Wales and the Solent clusters are disadvantaged structurally by their location's geology, lack of industrial density and soon to be lack of CCS and blue hydrogen infrastructure, both these regions will remain handicapped in the future, in their ability to attract the 'green' businesses of the future. The politically discussed net-zero levelling up will not be open to them. This thus requires additional policy attention.

3) Variance in international competition

All three industries face varying degrees of foreign competition, which shapes their sensitivity to the effects of decarbonisation costs on competitiveness. UK steelmakers faced most international competition in both home and export markets, contributing to the industry's steep decline. Foreign imports overtook UK steel products in domestic markets in 2000, and by 2021 were almost twice as large. This competition has limited the industry's enthusiasm for low-carbon investments. Petrochemicals also faced increasing international competition in the past few decades, especially in the bulk chemicals segment. The industry has long used this as an argument for resisting low-carbon reorientation. UK oil refineries have been least impacted by international competition, as they mostly competed with each other. Imports increased from the 1990s, when existing UK refineries could not meet the changes in demand, notably increasing demand for kerosine and diesel and decreasing demand for petrol. This lower degree of international competition made the refining industry less worried about the competitiveness effects of decarbonisation costs.

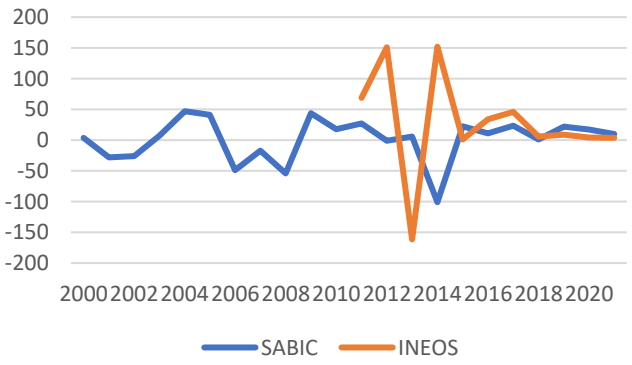
4) Financial justifiability

Deep decarbonisation can cost £billions, so the financial health of firms is an important factor shaping economic feasibility. Deep decarbonisation of the two remaining steelworks is estimated to cost around £6bn [3]. But Tata Steel, which purchased the UK's steel assets from Corus in 2007, has lost £5.8bn between 2009 and 2021 [3]. The firm has therefore not been keen to invest in decarbonisation and in 2016 tried to sell all its UK assets but could not find a buyer. It did, however, sell the Scunthorpe steelworks in 2016, which went bankrupt in 2019 and was purchased in 2020 by Jingye Group of China. We suggest that the poor financial health of both firms (and thus the risk of closure) as well as a deal between the government and the wider Tata Group (which also owns Jaguar Land Rover and agreed to build the UK's first battery manufacturing plant in exchange for support for Tata Steel) were reasons for the government to financially support the shift to EAFs.



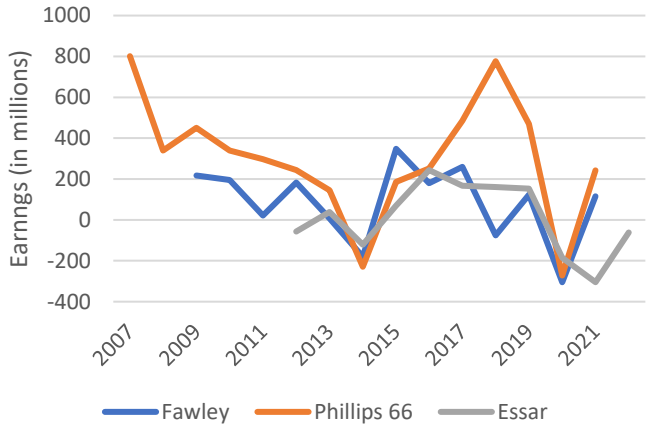
Annual consolidated financial earnings (in £ million) before tax for successive owners of UK steel industry assets (constructed using Annual report and accounts of British Steel PLC, Corus UK, and Tata Steel UK)

Decarbonisation plans of the two biggest petrochemical firms (INEOS and SABIC) are estimated more than £1bn for the Grangemouth site (Scottish cluster) and about £850m for the Teesside cracker complex [2]. Although both firms' financial performance has (mostly) been positive in the past decade, profit margins are low, so firms have been hesitant regarding low-carbon investment.



Annual consolidated financial earnings (in £ million) for SABIC UK Ltd (includes Huntsman Industries ownership - 1999-2005) and INEOS Chemicals Grangemouth.

Oil refineries' financial performance has (relatively) been better, with most firms making decent profits (except for 2014 and 2020/21). The four refineries in the selected clusters (with access to government funding for CCS and low-carbon hydrogen) thus have the financial ability to invest in deep decarbonisation, which is about £1bn per plant [4].



Earnings (in millions) for three UK refineries (Fawley in UK pounds and Essar and Phillips 66 in US dollars) (constructed using financial data from successive annual reports)

5) Wider corporate strategies and mindsets

Varying reorientation speeds also relate to wider strategies and mindsets. UK steelmakers have used retrenchment strategies (cost-cutting, divestment, asset closure) since 2008 to survive as their sales and production declined. This created a mindset that perceived decarbonisation as additional costs that hampered competitiveness, which explains their slow reorientation speed. However, if the recent EAF deals with government are realised (which is not guaranteed in our view), the industry might reorient fastest of the three. Petrochemical firms like INEOS and SABIC increased their fossil fuel investments in the past decade (e.g., ethane imports from the US and purchases of North Sea oil fields and pipelines), which means that their wider corporate strategy conflicts with low-carbon reorientation. Their mindset in the past decade has thus been to perceive decarbonisation as a threat to their new assets and wider competitiveness. This not only slowed their low-carbon reorientation, but also for many years led to active resistance strategies.

Some refineries have since 2019 started to see decarbonisation as offering economic opportunities. Essar Oil, for example, is actively participating in the HyNet cluster initiative, where it will become the main (blue) hydrogen supplier to other firms in the cluster. Phillips 66 has similarly moved into new economic areas such as biofuel co-refining, green hydrogen production (through the Gigastack project), and the production of speciality graphite coke for lithium-ion battery. This helps to further explain their (relatively) faster low-carbon reorientation.

Policy lessons and advice

Industrial decarbonisation is a challenging and expensive process, which is shaped by multiple factors. UK refineries are presently reorienting faster than petrochemical and steel industries, although the latter two have also increased their low-carbon activities. Based on our in-depth longitudinal case studies we offer the following policy lessons and advice.:

- The strengthening and expanding policy mix since 2019 has increased low-carbon reorientation activities in industrial firms.
- The policy focus on CCS and low-carbon hydrogen suits oil refining and petrochemical industries better than steelmakers. Other important decarbonisation pathways such as electrification, feedstock substitution, or demand reduction receive less attention than they should.
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