Comparing coal phase-out pathways: The United Kingdom's and Germany's diverging transitions

Hanna Brauers [1,2], Pao-Yu Oei [1,2] and Paula Walk [1]

[1] Workgroup for Economic and Infrastructure Policy (WIP), TU Berlin. Straße des 17. Juni 135, 10623 Berlin, Germany
[2] Department of Energy, Transportation, Environment, DIW Berlin. Mohrenstraße 58, 10117 Berlin, Germany

Abstract

Political decisions and trends regarding coal use for electricity generation developed differently in the UK and Germany, despite being subject to relatively similar climate protection targets and general political and economic conditions. In 2015, the UK agreed on a coal phase-out by 2025. In Germany, a draft law schedules a coal phase-out by 2038 at the latest. This paper investigates reasons for the different developments and aims to identify main hurdles and drivers of coal phase-outs by using the Triple Embeddedness Framework.

The comparative case study approach reveals that policy outcomes regarding coal consumption are deeply influenced by several actor groups, namely, coal companies, unions, environmental NGOs, and the government. The most discussed aspects of a coal phase-out in both countries are energy security concerns, whether coal is mined domestically, (regional) economic dependence, as well as the relative power of actors with vested interests in coal consumption.

Keywords:

Coal phase-out, energy transition, Triple Embeddedness Framework, Germany, the United Kingdom, energy policy, climate policy

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1 Introduction

To meet the Paris Agreement target of limiting global warming to at most 1.5°C to 2°C, coal consumption needs to be reduced drastically (UNEP 2017, chap. 6; Rockström et al. 2017). The European Union (EU) would have to cut its coal consumption to almost zero by 2030 to fulfil its already agreed upon climate protection commitments (Rocha et al. 2016; Climate Analytics 2017a).

Some major EU coal producing and consuming countries have agreed on a coal phase-out, while others still plan further expansions in coal generation capacity. This paper aims to identify the main hurdles and drivers of coal phase-outs on a country-specific level. It contributes to the literature by investigating and comparing the current state regarding coal consumption for electricity generation of two (former) EU states, namely the United Kingdom (UK)[1] and Germany over the 1960 to 2019 era. Both countries have a long history of coal production and consumption, being heavily dependent on coal for electricity supply. At the same time, they are (still) subject to the same EU climate and energy market regulations as well as the Paris Agreement (UNFCCC 2015), being required to reduce the amount of coal consumed. However, they are undertaking two contrasting strategies: namely a relatively rapid coal phase-out plan in the UK, compared to a strategy of conserving and delaying in Germany.

This paper aims to contribute to the literature by analysing why the developments in two major (formerly) coal producing and consuming countries are diverging so widely. It questions which actors and interests supported a continuation of coal's importance and which ones destabilised the coal regime.

Academic attention has shifted from the phase-in of renewables and support for so called niches, to the complementary analysis of how incumbents influence policy outcomes and how they can be destabilised (Kivimaa and Kern 2016; Kungl and Geels 2016; Turnheim and Geels 2013; Stirling 2018; Heyen, Hermwille, and Wehnert 2017; David 2017; Lockwood, Mitchell, and Hoggett 2019).

Resistance to a shift away from coal originates from various actors – namely, coal companies, unions, parts of civil society, and the government, albeit for different reasons. These actors and their coalitions have shaped, and are still influencing, policy measures affecting the coal industry (Leipprand and Flachsland 2018; Kungl 2015; Turnheim and Geels 2012; 2013; Oei, Brauers, and Herpich 2019; Mayer 2018; Brauers and Oei 2020). A transformation cannot be planned and then implemented by decision makers. It is rather a "*product of competition and interaction between a number of pathways, supported by diverse social actors with highly uneven political power*" (Scoones, Leach, and Newell 2015, 3). Other important elements influencing energy transition include, among others, the economic development and technological innovation of a country or region (Cherp et al. 2018). Hence, looking at the various actors in and around the coal regime, their interests, relations, and their influence is important for explaining why a coal regime is able to uphold its position, or not. A framework suitable for including all these factors is the Triple Embeddedness Framework (TEF) (Geels 2014).[2]

[1] Despite the Brexit decision, the UK remains part of the analysis as the focus of the analysis is on past developments. Further, the February 2020 decision to bring forward the phase-out of coal from 2025 to 2024 is not explicitly included in the analysis.

[2] Using the more commonly applied multi-level perspective (Geels and Schot 2007), would have diverted the attention to the niche part of the analysis. Instead, we focus on the coal regime and incumbency, as well as the politics and power around a reduction in coal consumption.

The outline of the paper is the following: Section 2 introduces the TEF as methodology for the analysis, the case study selection and data sources. The status-quo of coal and the historical analysis of each country's coal regime is elaborated in two different parts of Section 3: Section 3.1. focuses on the UK, while section 3.2. analyses the situation in Germany, including direct comparisons to the UK. Section 4 concludes.

2 Methodology

2.1 The Triple Embeddedness Framework

The TEF, a conceptual framework developed by Geels (2014), is part of the socio-technical transitions literature. Industries suitable for this framework are reluctant to change, hold a high political influence, and are scale-intensive with many sunk investments, which is true for the coal sector. It recognises institutional change and includes strategic behaviour as well as the power of actors. By enabling the analysis of the co-evolution and the bi-directional relationships between an industry regime and its environments, it addresses shortcomings of previous methodologies (Kungl and Geels 2018).

Thereby, the framework refers to the situation of firms within an industry regime, which is itself embedded in two external environments – the socio-political and the techno-economic [3] environments. An industry regime is under selection pressures from its *socio-political environment*, where the criteria include, among others, legitimacy and social fitness, and the *techno-economic environment,* which demands economic competitiveness, efficiency, and financial performance. The TEF acknowledges the ability of firms to respond to their environments and influence them through strategic actions. The responses of the coal regime (adaptation strategies) are both externally-oriented (toward the economic and the socio-political environment) and internally-oriented (toward changing the firm's set-up to fit better to the environments). Hence, the framework includes bi-directional relationships and co-evolution of the regime and its environments (Geels 2014). It can be used as a tool for analysing the destabilisation of industry regimes.

In the analysis included actor groups are the firms of the incumbent coal regime, non-governmental organisations (NGOs), governments, labour unions, civil society and competitors for coal (this selection is based on Hess (2014) and Turnheim and Geels (2013) and the actors influence on coal transitions). Additional background on the Triple Embeddedness Framework is presented in the Appendix.

2.2 Case selection and research design

To analyse drivers and hurdles away from coal, two EU countries, where coal mining and using coal for electricity generation played or still plays a major role for the economy, were chosen. In 2015, the UK decided to phase out coal by 2025 (subsequently bringing the phase-out date forward to 2024 in 2020). In Germany, the implementation of a phase-out plan is still under discussion; however, a coal phase-out by no later than 2038 is included in a draft law. The paper considers the 1960 to 2019 era, as the destabilisation of a regime is a long-term process and historic events can reveal broader societal and economic trends, creating path dependencies and lock-in effects (see also Kungl and Geels (2016)).

[3] In the original framework from 2014, the environment is called "economic" and not "techno-economic".

However, as most data (especially for East Germany) is only available post-1989 and climate concerns were only perceived as more pressing after 2000, the paper focuses on 2000 to 2019. In addition, information from earlier periods is included within the analysis to provide context for both case studies. In Germany, the installation of the so-called “coal commission” and its proposed phase-out plan is considered, but the implementation process of the phase out law is not analysed as it is still ongoing at the time of writing. Due to the close connection of coal use for downstream electricity generation and upstream coal mining, both are included in the coal regime analysis. The paper focusses on the usage of coal in the electricity sector, as heat, until now, is of lesser importance for coal companies.

2.3 Data sources

Data-collection is guided by the conceptual framework focusing on the relevant actors and contexts rather than on dependent and independent variables (Kungl and Geels 2016, 2018). Our data collection is based on a triangulation of document analysis, regular visits to the German coal regions, and a series of workshops. The document analysis uses primary data from databases regarding coal production, consumption, employment, and share of GDP, etc. as well as secondary sources from scientific peer-reviewed journals, other articles, and books. Additionally, we draw on a wide range of grey literature including daily newspaper articles, blogs, company press reports, annual reports, and various website information, written in English or German and referenced throughout the text.

Informal background interviews with regionally affected stakeholders, while visiting German coal regions[4] during three different research projects between 2012 and 2018, allows us to test and complement the acquired information. We study the German context to highlight resistance against the phase-out. A first draft of different socio-political and techno-economic aspects of the coal phase-out, including response strategies of the coal regime, allowed us to organize ten thematic workshops in Germany between 2015 and 2019 to acquire additional information on specific aspects as well as the underlying narratives of affected stakeholders within the coal phase-out process. Participants varied between 10-20 representatives from governmental bodies, the (conventional and renewable) energy industry, unions, academia, and civil society. Each workshops focused on a different set of topics, either touching more socio-political (e.g. health concerns, climate and environmental regulation options) or techno-economic (e.g. number of job losses and possible replacements, technical replacement of coal with renewable energies, grid stability, affordability) aspects as well as the response strategies of the coal regime (e.g. modelling phase-out pathways, liability issues). We did not do fieldwork in the UK; instead ongoing exchanges with academic experts on the UK validated the quality of our case study findings. The triangulation of this gathered information was used to develop the TEF, mapping socio-political and techno-economic aspects of the coal phase-out including response strategies of the coal regime for each country. In addition, intermediate results of the TEF were regularly refined following presentations and discussions with stakeholders at five international academic conferences.

The main aim of the paper is to provide an overall picture of the political economy of coal in both countries in a novel way. Many of the single elements included in the TEF are studied by other authors. Our main contribution is to bring these results into the descriptive framework to better understand the

[4] The Ruhr area for hard coal and Lusatia as well as the Rhineland for lignite.

complexities influencing the political economy of coal. Additionally, new findings are generated by comparing the diverging developments of these two countries.

3 Coal-regime Analysis

Figure 1 provides a broad overview of coal mining and the total number of employees in coal mining (hard coal and lignite) in the UK and Germany since 1958. It is apparent that coal's importance is in decline in both countries – but at different speeds. Despite the strong reduction in coal mining and employment since the 1960s, the share of electricity generated by coal is still 28% in Germany in 2019 (BDEW 2020), whereas it constitutes only 2% in the UK (Department for Business, Energy & Industrial Strategy 2020c)[5].

Figure 2 shows the development of the electricity mixes for the two countries.[6] It illustrates that the main substitutes for coal in the UK have been natural gas and renewables; in Germany, renewable energy. This is also due to the fact that levelised costs of energy for renewables have fallen below the costs for conventional energy in both countries, especially due to falling capital costs and improving technologies (see for example Johnstone and Stirling (2020) for an analysis of energy prices in Germany and the UK). The resulting strong increase of renewables has also resulted in new employment options for around 300,000 people for Germany and slightly more than 100,000 for the UK (IRENA 2019; Oei, Hermann, et al. 2020).

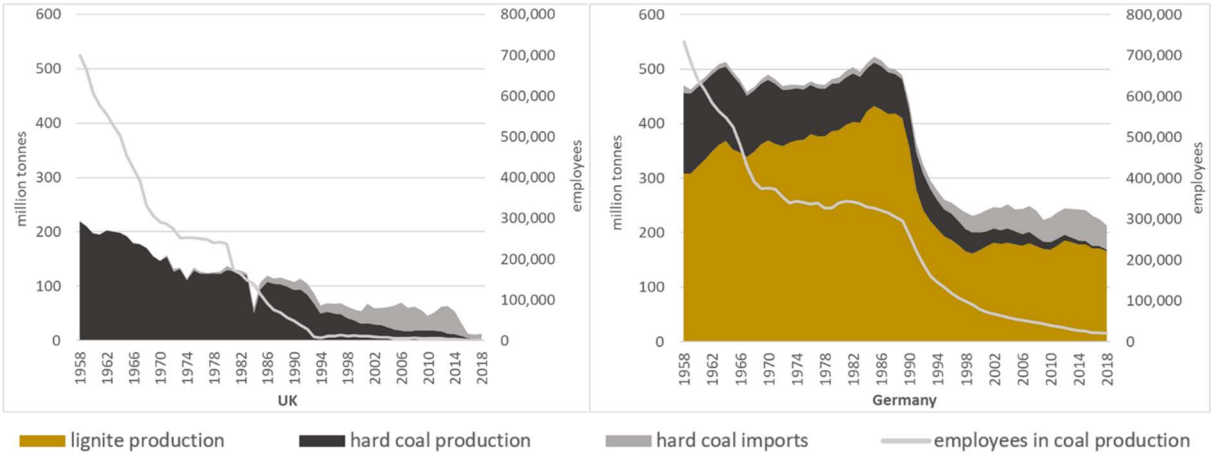

Figure 1: Coal mining, coal imports, and number of direct employees in the UK and Germany from 1958-2018

Own depiction based on Department for Business, Energy & Industrial Strategy (2018; 2019a), Statistik der Kohlenwirtschaft e.V. (2018b; 2018a; 2019b; 2019a), Verein der Kohleimporteure (2017; 2019) World Bank DIW Berlin et al. (2018), and own calculations. Note: The values for coal production and imports are displayed as stacked areas, while employment figures are depicted as individual lines.

[5] The numbers for the electricity mix in Germany in 2019 are preliminary. The numbers for the electricity mix in the UK in 2019 constitute the average of the first three quarters 2019.

[6] For an overview of the longer term electricity trends in the UK and Germany see Figure 5 and Figure 6 in the Appendix.

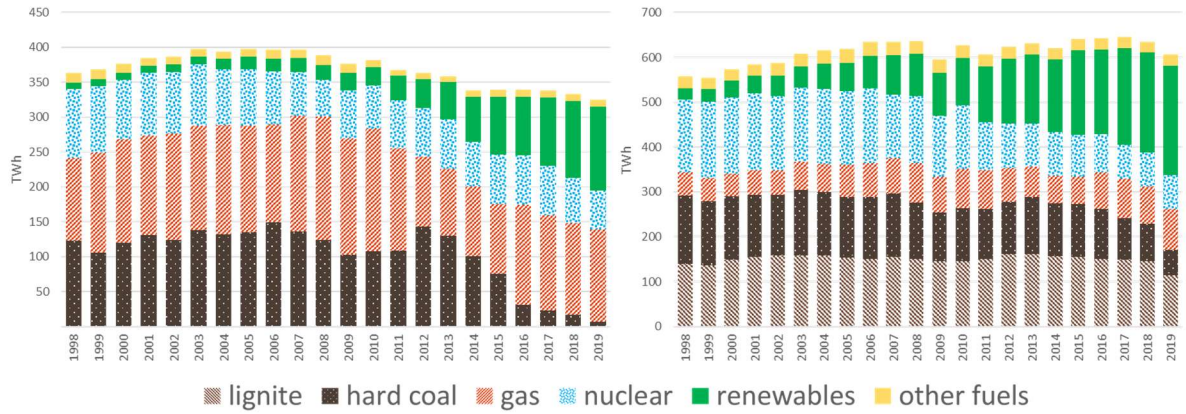

Figure 2: Gross Electricity Generation for the UK (left) and Germany (right) in TWh.

Own depiction based on the Department for Business, Energy & Industrial Strategy (2020), Umweltbundesamt (2020), AG Energiebilanzen (2020); numbers for 2019 are preliminary.

3.1 Coal regime analysis: United Kingdom

The UK is one of the few EU member states where coal played an important role in the energy sector, but which nevertheless announced a coal phase-out by 2024/2025 and is a founding member of the Powering Past Coal Alliance (Department for Business, Energy & Industrial Strategy 2017). The role of coal has changed dramatically since the 1980s, especially in the last few years. While coal accounted for almost 80 percent of the UK's electricity generation at the beginning of the 1980s, it reached an all-time low in 2018, as shown in Figure 2 (Department for Business, Energy & Industrial Strategy 2020c).[7] Coal was not needed at all to meet the UK's electricity requirements on 83 days in 2019 (Evans 2020), and is even further reduced in 2020 due to reduced energy demand because of COVID-19. Coal production in the UK is almost eliminated with the closure of the last large deep mine in 2017.

3.1.1 Socio-political environment analysis of the UK

The influence of the UK's coal unions on political decisions has changed over time. Margaret Thatcher fought against the power of unions during the 1980s. Reasons for this were the government's aspirations for power as well as the aim to liberalise the energy market and to increase competition (Gouiffes 2009; Pollitt and Haney 2013). After the end of the violent labour dispute (in 1985), the union's influence had been reduced substantially (Gouiffes 2009; Johnstone and Stirling 2020).[8] Nevertheless, all major unions supported coal and lobbied against mine and power plant closures.

Following the strikes, hard coal production and employment continued to decline substantially (see also Figure 1), while overall coal consumption declined more slowly (Department for Business, Energy &

[7] Since the opening of an interconnector with France in 1986, the UK has been a net electricity importer. At its peak in 2015, electricity imports were responsible for less than 0.9% of total primary energy supply and 6.6% of UK electricity generation (Bolten 2018). ~95% of the electricity imports come from France and the Netherlands (Bolten 2018). As both countries have a lower electricity carbon intensity than the UK, the phase-out of coal in the UK electricity mix did not lead to substantial additional emissions elsewhere.

[8] The strike resulted in more than 11,000 arrests, 7,000 wounded, 200 imprisoned and more than 8,000 convicted (Gouiffes 2009, 179).

Industrial Strategy 2020a). An accelerated coal phase-out process, steered by the government, started much later. In 2005, the socio-political environment in the UK observed a major shift in the perception of climate change, triggered by the 'Big Ask' campaign of the NGO Friends of the Earth (FoE). An extensive media coverage of the campaign increased public and political awareness of climate change. The Conservative Party supported the 'Big Ask' campaign and adopted climate change accordingly as a major point of its strategy to modernise the party. Within a month of this decision, 412 Members of Parliament (out of 646) signed the FoE motion for a bill that would make emission reduction targets a law. The big three parties (Conservatives, Labour, and Liberal Democrats) started to compete by being greener than the others (Carter and Jacobs 2014). This made it more difficult for parties to openly support coal.

Starting in 2006, the cross-party 'green' competition created opportunities for politics prioritising the environment. Another main influence on climate friendly political decisions were inter-departmental institutions, e.g. the Office for Climate Change (with members from all the main departments related to greenhouse gas (GHG) emissions (energy, business, transport, treasury, etc.)) and the Committee on Climate Change. By bringing different interests together and by being more independent, they managed to create consensus around integrated approaches that undermined pure economic considerations that had previously dominated (Carter and Jacobs 2014).

The UK can be considered as a "liberal market economy" with a preference for market-based and non-technology specific policy instruments like the CPF (Hall and Soskice 2001). The focus on cost efficiency – and not on e.g. supporting new entrants – also explains the preference for large-scale technologies (see section 3.1.2). Furthermore, the UK's 'liberal market economy' is characterized by "close-knit policy networks that are relatively open to incumbent industry actors but remain closed for outsiders and new entrants" (Geels et al. 2016, 910). As a mostly top-down policy style prevails, broad stakeholder engagement is limited (Geels et al. 2016).

In general, there was a broad public consensus among civil society and NGOs within the UK that tackling climate change was crucial (Gillard 2016; Parkhill et al. 2013). The declining role of coal combined with widely appreciated and available alternatives like local natural gas, nuclear energy, and renewable energy helped to generate public support for climate change policies. Media coverage can shape public opinion and has also influenced the transition in the UK. Isoaho and Markard (2020) find in their discourse analysis of the Guardian that incumbent actors first tried to legitimise coal until 2015. However, as they had already started to shift to alternatives, there was little resistance in public media when the government announced its coal phase-out pledge (see also Antal and Karhunmaa (2018) for a comparison of reporting of the Guardian and the Times on the German energy transition). In 2019, the government further increased its goals, deciding to target net-zero greenhouse gas emissions by 2050 (Department for Business, Energy & Industrial Strategy 2019b).

3.1.2 Techno-economic environment analysis of the UK

Several factors of the techno-economic environment facilitated the reduction of coal in the UK. Compared to other countries (e.g. Colombia, South Africa or Russia), coal resources were deeper in the ground and labour costs were higher, such that international imports were much cheaper than domestic mining. Instead of subsidising coal mining like other countries, e.g. Germany (see section 3.2.1), the UK

started weaning itself off its dependence on coal mining. By taking the decision not to use public funds to support domestic mining in the 1980s, international competition led to a quick decline of domestic coal production and related employment.

Several policies introduced after 2006 constrained coal's business opportunities long before the final phase-out decision in 2015, especially the Carbon Price Floor (CPF), the Renewables Obligation (RO), the Emissions Performance Standard (EPS), as well as more in general the Climate Change Act and the related carbon budgets.[9]

The Climate Change Act[10] of 2008, a main cornerstone of its climate policy, commits the UK to reducing greenhouse gas emissions by at least 80 percent by 2050 compared to 1990 levels, setting legally-binding carbon budgets. Additionally, timetables for compliance with stricter EU pollution control regulations have required a response from all power plant operators and contributed to the closing decision of seven non-compliant and ageing power plants (~10 GW) between 2010 and 2015 (Littlecott, Burrows and Skillings 2018). Older power plants are mostly more polluting (in terms of CO_2 and other emissions) and less efficient, which leads, next to higher amounts of pollution, to higher specific costs per MWh. In May 2020, the four still operating coal plants have reached an average lifespan of 43 years (Power Stations of the UK 2020).

The CPF and the EPS, on the other hand, have restricted potential construction of new coal units (without carbon capture) (Mendelevitch and Oei 2017). Renewable electricity policies, especially the Renewables Obligation, which required utilities to meet annual renewable electricity targets, incentivised incumbents to deploy a certain amount of renewable energies themselves, rather than enabling new market participants to enter the electricity market. Entry barriers for new non-specialist market participants were high due to the complexity of the mechanism and related revenues were too uncertain for civil society actors (Hall, Foxon, and Bolton 2016).

On the demand side, falling wholesale electricity prices, especially in the period after 2015, put pressure on the coal industry (Littlecott, Burrows, and Skillings 2018). However, the coal industry is subsidised by the government through various policies: A capacity market was introduced in 2014 and serves to guarantee idle power plants a steady income. Other policies in 2017 included various tax benefits, inherited liabilities[11] related to coal mining, the Supplementary Balancing Reserve[12] (2014-2017), and others. The inherited liabilities related to coal mining amounted to annual average subsidies of €48.6 million in the years 2006-2014. Estimates for the annual average budgetary support for the Supplementary Balancing Reserve are €94.3 million in 2016 (van der Burg 2017). In addition, subsidies for renewables were cut back heavily in 2015 (Johnstone, Stirling, and Sovacool 2017). Renewable projects are, in most cases, smaller than conventional units and face problems in acquiring loans within

[9] The EPS was part of the 2013 Energy Act and it sets a limit of 450gCO_2/kWh for new power plants of more than 50 MW. The Carbon Price Floor was introduced in 2013 with £9/tCO_2; the price of £18/t CO_2 (~21€/t CO_2) was frozen in 2015 until 2021 (House of Commons 2018).

[10] *Climate Change Act* 2008, Chapter 27, Parliament of the United Kingdom.

[11] The Coal Authority takes charge of inherited liabilities, for which coal-mine operators were not held responsible (Van der Burg 2017).

[12] The Supplementary Balancing Reserve puts generation capacity into a reserve. The reserve is kept outside the electricity market and can be used when there is a shortage in supply (Van der Berg 2017).

a market based financial environment, such as the UK. This results in additional barriers for small scale renewable energy projects (especially with civil society ownership) to borrow funds from mostly centralised and internationalised private investment capital (Hall, Foxon, and Bolton 2016). This contributed to the fact that most installed renewable generation capacities in the UK are owned by firms that are already present in the energy market.[13] Additionally, the slowing down of renewable energy investments increases the need to use natural gas as a replacement fuel for coal. So far, coal for electricity generation has been continuously replaced by cheaper electricity from both natural gas and renewables. However, in contrast to most EU countries, no renewable energy targets have been set for 2030 nor 2050 in the UK (Geels et al. 2016). This might further hinder renewable energy expansion and, therefore, increase the use of natural gas and potentially nuclear energy. [14]

3.1.3 External and internal response strategies of the coal firms in the UK

Lockwood et al. (2019) find that large electricity generators have structural power in relation to decision makers. This enabled companies' ideas and related lobbying to influence the design of the capacity market policy and other subsidies in the UK. Additionally, high hopes among all incumbents were placed on CC(T)S (Carbon, Capture, (Transport), and Storage) as a 'silver bullet' to allow for emission free coal combustion. The political decision to implement the EPS and the CPS, accelerating the coal phase-out might have been different, if it had been clear for all actors that carbon capture, (transport,) and storage (CCS or CCTS) would not be available as a so-called 'clean coal' alternative, potentially leading to more resistance (Littlecott, Burrows, and Skillings 2018).[15]

The coal industry used several framing techniques to influence public opinion and political decision makers. A main narrative was that without cheap coal, electricity prices would rise, which in turn would lower competitiveness of other British firms and hit households hard. The question of whether prices actually do increase because of climate policies or because the old power plants would have to go offline after ~50 years in operation anyways, has been avoided. Other powerful frames repeatedly pushed into the public debate by the coal regime are job losses and blackouts. An example for this is a report by the British Infrastructure Group saying that coal power station closures would lead to a "*sustained danger of intermittent blackouts for the foreseeable future*".[16] The report was immediately refuted by several research institutes and NGOs.

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[13] Background talks with energy experts and see also https://www.gov.uk/government/publications/renewable-energy-planning-database-monthly-extract.

[14] The government reduced its support for onshore wind and solar PV substantially, and signals on support for tidal power and biomass are unclear. Nuclear power is struggling with opposition, the long planning and construction times, high costs, and ever-increasing problems with Hinkley Point C (The Guardian (2019): Hinkley Point nuclear plant building costs rise by up to £2.9bn. https://www.theguardian.com/uk-news/2019/sep/25/hinkley-point-nuclear-plant-to-run-29m-over-budget).

[15] In 2009, a new regulation stated that no coal power station would get a permission without CCTS (Carter and Jacobs 2014). This prevented new coal-fired power plants from being built, as CCTS never became technologically available.

[16] Philpott, Tim. 2016. 'Electric Shock: Will the Christmas Lights Go out next Winter?' A British Infrastructure Group (BIG) Report. https://www.theguardian.com/environment/2016/dec/19/campaigners-dismiss-christmas-electricity-blackout-report-as-laughable.

3.1.4 Lessons-learned from the UK

Figure 3 summarises the Triple Embeddedness Framework analysis' results for UK. The aging infrastructure, uneconomic mining, and climate policies led to the unfavourable (economic) conditions for coal in the electricity sector. When coal mining became uneconomic in the 1980s, state support was withdrawn, reducing the power of the unions. Reducing the amount of domestic coal lowered further resistance to implement policies reducing coal's dominance in the electricity sector in subsequent years.

The added focus on environmental protection and climate change by the government during the 2000s led to the implementation of crucial policies like the CPF and the EPS. Together with EU emission reduction targets, the coal industry's business was further weakened, and finally the coal phase-out by 2024/2025 announced. The EPS prevents new coal-fired power plants (without carbon capture) from being built, the CPF made electricity generation by coal less competitive and air pollution regulations forced older power plants to be closed. The policies incentivised incumbents to change their strategy: Invest in renewables and natural gas projects instead of further holding on to coal as their main business model. However, policies in the UK did not support the entrance of new (small-scale renewable) generators but instead continued support for the incumbent energy companies. For an in-depth analysis of parallel developments regarding nuclear power, see Johnstone and Stirling (2020).

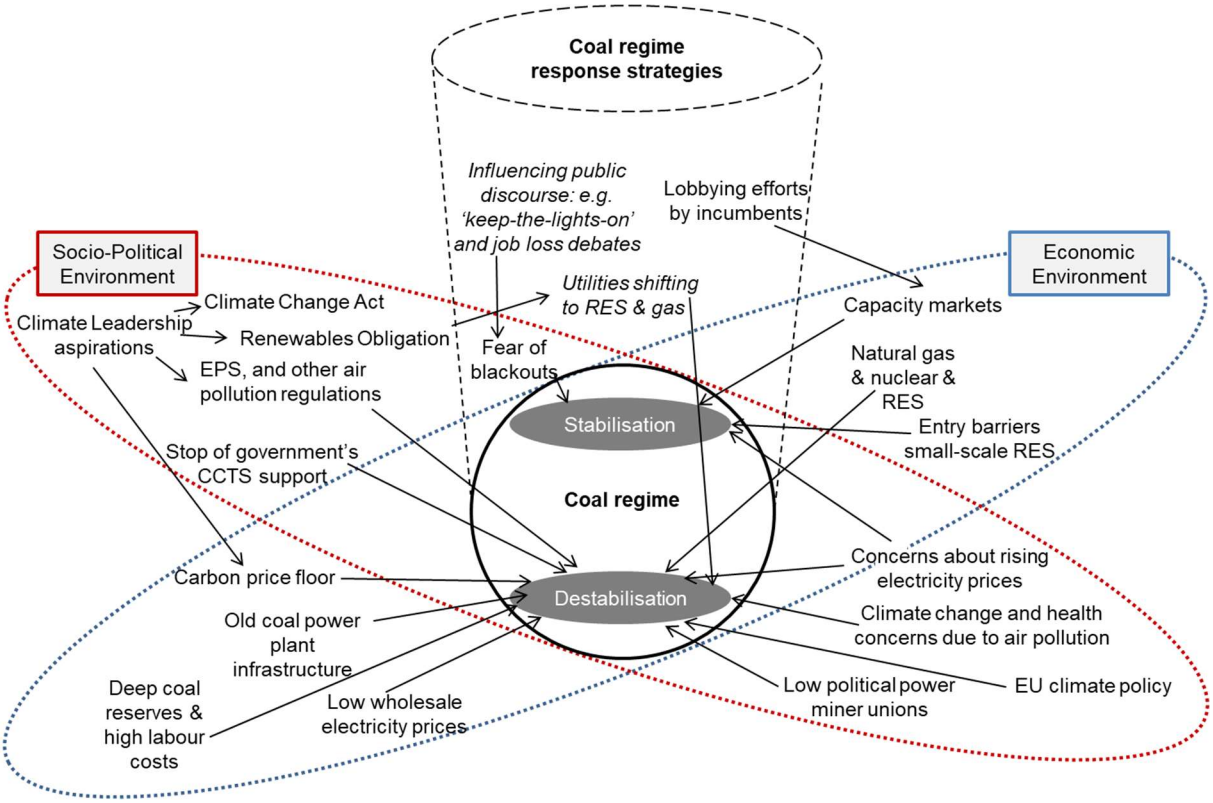

Figure 3: Coal regime analysis UK.

3.2 Coal regime analysis: Germany

The characteristics of coal in Germany are similar to the UK: In both countries hard coal mining has been uneconomic for decades, coal infrastructure is mostly old and hard coal import dependence is rising (Oei, Brauers, and Herpich 2019a). The consequences for the coal regime, however, have been very different due to a different political direction. The German government subsidised domestic mining from the 1950s onwards so that it could stay competitive with cheaper imported hard coal (Matthes 2017).[17] These numerous direct and indirect subsidies continued until they were forbidden by European regulation in 2018 (Gençsü et al. 2019). As a consequence, hard coal mining experienced a continuous 60 year controlled decline – compared to the abrupt collapse in the UK – and ended in December 2018 (Oei, Brauers, and Herpich 2019). The consumption of hard coal stayed relatively constant over time, while power plants switched from domestic coal to imported hard coal. Retired coal power plants were replaced with new units even after 2000 (Pahle 2010). Reasons for this were the underestimation of renewables and false hopes of operators to profit from the phase-out of nuclear energy. By the late 2010s, the share of hard coal within the electricity mix was cut in half, reaching 9 percent in 2019, resulting in very low utilisation rates (Oei, Hermann, et al. 2020).

The biggest drop in lignite production (and employment) already happened in the early 1990s following the reunification of Germany as mines in Eastern Germany were adopted to Western standards (e.g. higher environmental standards and higher labour productivity), enforcing several closures (Stognief et al. 2019). In 2020, lignite continues to be mined in three open cast mining regions in Germany (Oei, Hermann, et al. 2020). The adjacent power plants profit from relatively low operating costs and, therefore, contributed 19 percent of German electricity generation in 2019 (AG Energiebilanzen 2020). Rising civil society pressure, as well as from the coal regions demanding financial support, pushed the government to introduce a 'Commission on Growth, Structural Change and Employment' in 2018 – often also referred to as 'coal commission'. The commission included representatives of various social groups, such as unions, energy companies, industry, NGOs, and residents of coal regions. It proposed a coal phase-out plan in January 2019 that foresees shutting down a total of 12.5 GW (27% of the active installed coal capacity at the end of 2017) of coal-fired power plants by 2022. All coal-fired electricity should be phased-out by 2035 or by 2038 the latest (BMWi 2019). The planned instrument to phase-out hard coal is an auction mechanism. In late 2019, the government started negotiations with the lignite operators about the timing of decommissioning and the magnitude of compensations. In May 2020, more than one year after the commission presented its recommendations, it is still not implemented as a law, and criticized by many actors previously involved in the negotiations of the commission (Oei, Kendziorski, et al. 2020). The following analysis focuses on historical hurdles that prevented an earlier coal phase-out in Germany (compared to the UK).

[17] Cumulative subsidies between 1958 and 2008 of €295 billion supported hard coal, while lignite received a total of €57 billion (Meyer, Küchler, and Hölzinger 2010). Next to the capacity payments for lignite power plants, there were several other state subsidies still in place in 2017. These include royalty exemptions and reductions for resource extraction, support for the rehabilitation of mines, energy tax and electricity tax exemptions for power generation, and early retirement schemes for workers. For example, there were still €1,863 million subsidies every year only for coal mining in North Rhine Westphalia until 2014. There are interesting parallels to the UK, as there is a relatively newly introduced capacity reserve running in both countries until 2020, costing €230 million in Germany and €138 million in the UK (van der Burg 2017).

3.2.1 Socio-political environment analysis of Germany

Public opposition to coal began in the 1960s due to high-stack emissions causing acid rains and forest diebacks. Until the 1980s, however, concerns and protests against coal remained a local issue. Instead, the main focus of national protests by civil society and NGOs was nuclear power, which was perceived as a more direct threat by the broad public. Consequently, organizing anti-nuclear protests was the principal focus of environmental NGOs like FoE, Greenpeace, and WWF (Renn and Marshall 2016).

The German government slowed the decline of the coal industry since the 1950s, lowering the negative impact on firms, workers, and regions, but also prolonging the difficulties of reducing the dependence of coal until this date. For a detailed description of government policies to support the hard coal industry from the 1950s through 2018, see Oei, Brauers, and Herpich (2019). Internationally, Germany is known as a strong supporter for climate change action. The focus on climate change protection and careful steps toward a government planned coal phase-out increased in 2011. Since then, Germany's energy strategy has been called 'Energiewende' (often translated as energy transition). It is based on the goals of a nuclear phase-out, the reduced consumption of fossil fuels, and an increase in energy efficiency (Renn and Marshall 2016; von Hirschhausen et al. 2018). However, the government fails to achieve its domestic emission reduction targets due to continued coal consumption. Germany aimed to reduce emissions by 40% in 2020 compared to 1990. In 2019, Germany was on track to reduce emissions only by 33.2% (BMU 2019).[18]

Germany can be characterized as "coordinated market economy" (P. Hall and Soskice 2001). This can result in close interactions between the government and powerful incumbents, as well as civil society organisations. While coal incumbents received continuous governmental support (Oei, Brauers, and Herpich 2019; Stognief et al. 2019), Germany also has a relatively strong and organized civil society with active cooperatives, citizens' groups, and a strong environmental tradition. Therefore, civil society protests were already an important lever enabling the phase-out of nuclear power in Germany (Johnstone and Stirling 2020).

From 2011, the agreed upon nuclear phase-out relieved (human) resources of environmental actor groups. In parallel, concerns about coal intensified as knowledge about the impacts of climate change and human health impacts grew. Tackling coal is more difficult for NGOs, as it is not sufficient to simply address the risks of the energy technology (as in the nuclear case), but need to include also the potentially negative socio-economic aspects for coal workers and regions in their argumentation. Rising international awareness of the climate crisis increased the pressure on the coal regime and the German government. Consequently, NGOs and activists managed to increase public attention, e.g. organizing a protest march in 2018 with more than 50,000 people into the Hambach forest, which was planned to be cut down for the enlargement of an adjacent lignite mine (Oei et al. 2018).

[18] A paradox in Germany is that despite big successes in growing wind, solar, and biomass capacities, greenhouse gas emissions remained relatively constant between 2011 and 2017 at around 900 million tonnes of $CO_{2\text{-eq}}$. The target for 2030 is 543 million tonnes of $CO_{2\text{-eq}}$ (Umweltbundesamt 2017; 2020b). New estimations indicate that Germany might achieve its 2020 target due to the recession caused by the COVID-19 pandemic. This short-term decrease, however, will be evened out by the uptake of the economy in the following years and, therefore, does not reflect the desired structural reduction.

People living in the lignite mining regions have split opinions on a coal phase-out: One part of society fights against new mines to prevent their villages from being destroyed and to protect the environment. The other part lobbies to keep lignite as a main energy source in Germany, mainly to protect their jobs and cultural heritage. Both sides, however, believe that democratic processes have failed to make them actual stakeholders and part of the decisions shaping their energy futures (Morton and Müller 2016).

The biggest unions in Germany, representing workers of hard coal and lignite mines and power plants, are the IG BCE and ver.di. Both have a high influence on political decisions and were strong supporters of the gradual phase-out of coal in Germany (compared to the UK) (Renn and Marshall 2016). The IG BCE's position has been the most rigid, as they also represent workers in the energy intensive industries sector, which profits from low wholesale prices of electricity. Before 2017, a coal phase-out before 2050 was characterised as impossible. Any measure to reduce coal consumption was seen as direct attack on their represented workers (IG BCE 2016). Ver.di also lobbied against tighter air pollution controls and in favour of capacity payments to keep the coal industry alive. Their focus, however, put benefits and retraining programs for affected workers as the highest priority, rather than only trying to postpone the phase-out date (Enervis 2016).

3.2.2 Techno-economic environment analysis of Germany

The German electricity market was liberalised in 1998, but competition remained limited resulting in continuously high market power of the four incumbent companies (RWE, EnBW, E.ON, and Vattenfall). The Renewable Energy Sources Act (EEG), implemented in 2004, substantially changed the dynamics of the electricity market. Feed-in-tariffs were available for all electricity market participants and were especially attractive to, and supportive of, new market participants. The German green industrial policies were more stable, financially certain, and less bureaucratic than the British policies (Geels et al. 2016; Hall, Foxon, and Bolton 2016). The Green Growth discourse – that Germany with its substantial manufacturing sector could profit financially from the energy transition, building wind turbines and solar modules – further pushed the transition (Geels et al. 2016).

The EEG also resulted in a reduction of the market share of the formerly 'Big Four' electricity generating companies as well as to a shift within their production portfolio (Renn and Marshall 2016; Johnstone et al. 2020). In 2018, the domestic market share of the biggest five electricity generating companies ('Big Four' and LEAG – a new company having bought all lignite assets from Vattenfall) was reduced to 74% (BNetzA and Bundeskartellamt 2019). This is comparable to the development of the wholesale electricity generation market share by the eight largest companies of the UK (EDF, RWE, SSE, Drax, Uniper, EEX, ScottishPower, and Orsted) summing up to 72% (ofgem 2019).

In Germany, big energy utilities face increasing re-municipalisation strategies as well as strong public support for nuclear phase-out and increasing renewables. In addition, many local small savings banks allocate capital to small and medium scale energy providers, like municipality owned Stadtwerke (local public utilities), through an established framework of citizen investment to support regional development (Hall, Foxon, and Bolton 2016). This regional financial support, paired with national renewable electricity policies of guaranteed feed-in tariffs, incentivised new small and community-based providers of renewable energies to enter the electricity market.

Continual market pressures on the coal business included overall decreasing energy demand due to the financial crisis, the rising market shares of renewables, and, consequently, decreasing wholesale electricity prices (Kungl and Geels 2016). In addition, the increasing price for allowances in the European Emissions Trading System, ~25 Euro/per tonne of CO_2 in 2019, in combination with shrinking gas prices made coal combustion increasingly uneconomic. Consequently, older hard coal units observed greater variable costs than gas units, resulting in lower utilization rates. This is the principal reason underlying the decline of coal's share in the electricity mix since 2017 (Sandbag 2020; Agora Energiewende 2020).

3.2.3 External and internal response strategies of the coal firms in Germany

The main strategy of the incumbent coal firms was to lobby for coal friendly regulation and further (financial) state support: This is visible in their success at opposing the first attempt by the German government in 2015 to introduce a 'climate contribution' (Klimaabgabe) (Morton and Müller 2016). The 'climate contribution' would have led, similar to a carbon tax, to closures of mostly older coal units (Goodman 2016). Instead, a so-called 'carbon reserve' mechanism was introduced: Old lignite-fired power stations were paid compensation while providing only a very small, if any, contribution to Germany's climate goals. "*The defeat of the 'climate contribution' is one clear example of how the politics of coal can undermine the policy aims of the energy transition*" (Morton and Müller 2016, 10).

Another example illustrating the coal industry's power over German politics is air pollution regulations. In 2017, Germany lobbied with a small group of other (mostly eastern) EU countries against tighter EU air pollution rules[19], which set stricter emission limits (best available techniques (BAT) requirements) for large combustion plants as part of the Industrial Emissions Directive (Climate Analytics 2017b). Nevertheless, a slim majority of European countries voted in favour of the stricter emission limits, taking effect for all EU member states in 2021[20]. However, in May 2020 Germany is still not complying with European regulation not having transferred the new regulation into a corresponding law.

The incumbent regime used several strategies to maintain the status quo of coal for as long as possible. One strategy was to misrepresent the effect of renewables on electricity prices for the general public. Renewable feed-in-tariffs are mostly paid for by households and small industries, explicitly stated as such on all electricity bills. However, the increase of renewables actually lowered wholesale electricity prices - which especially benefited energy intensive industries. Subsidies for conventional electricity, on the other hand, are directly paid for by the state budget and, thusly, are not clearly visible to consumers (Lauber and Jacobsson 2016).

To save their business, electricity corporations additionally claimed that renewables threaten energy security because their fossil fuel plants would be rendered unprofitable and argued that renewables would make German industries uncompetitive by increasing energy costs. These claims were being made despite various studies showing that grid stability is not threatened by increasing amounts of

[19] DW (2018): Environmental groups hit back as German coal companies try to sue EU. https://www.dw.com/en/environmental-groups-hit-back-as-german-coal-companies-try-to-sue-eu/a-42801965

[20] European Commission (2017): News Release - Commission to review permits of Large Combustion Plants. July 31. http://ec.europa.eu/environment/pdf/31_07_2017_news_en.pdf

renewables in the system and most energy intensive companies being freed entirely or at least partly from the EEG-surcharge (Egerer, Oei, and Lorenz 2018).

The entanglement of RWE and municipal actors within the lignite region is a good example for the complexity of the coal regime in Germany: Traditionally, several city and regional governments in North-Rhine Westphalia are financially dependent on revenues of the RWE shares and have difficulties financing public services otherwise. Municipal shareholders had little expertise (and belief) in renewables and consequently prevented a strategic reorientation of RWE away from coal, wanting to protect their regional coal interests (Geels et al. 2016). Additionally, regional actors helped exert pressure on the national government to protect the overall coal regime – to safeguard local jobs and municipal services dependent upon the companies' financial success (Oei 2018).

RWE as well as the other members of the 'Big Four' in Germany underestimated the fast growth of renewables and missed the opportunity to invest in non-fossil-fuel generation technologies. Being used to large-scale projects, these companies did not want to participate in small-scale renewable projects and, additionally, they did not want to take some of their own profits from their conventional fleet away (Kungl and Geels 2016). Consequently, medium-sized new actors formed, influencing and profiting from integrating renewable energy into the existing conventional wholesale power markets (Wassermann, Reeg, and Nienhaus 2015). This was strengthened through an overarching German trend toward re-municipalisation and the re-establishment of municipal utilities (Stadtwerke). These served as key actors to promote structural change within the energy sector (Berlo, Wagner, and Heenen 2017).

Johnstone et al. (2020) find that disruption in ownership in the electricity sector can help to support changing beliefs and practices. They distinguish between the "incumbent-led" energy transition in the UK and a "new-entrant-led disruptive" energy transition in Germany. Incumbents in the UK acted more strategically than incumbents in Germany, saw change coming toward low carbon energy transition earlier, and deployed large-scale renewable energies themselves. Nevertheless, incumbents in both Germany and the UK lobbied for policies that supported their coal business activity.

Since 2015, Germany's 'Big Four' have also started to diversify their strategies (though not necessarily their portfolio): Vattenfall sold all its lignite assets and is promoting a target of carbon neutrality within a generation; EnBW wants to align its strategy according to the Paris Agreement; E.ON sold all of its electricity assets (to RWE and Fortum); and RWE aims at carbon neutrality by 2040. Furthermore, the BDEW, the federal association of energy and water, which also represents the 'Big Four' together with most municipal utilities and renewable energy companies, was represented in the coal commission agreeing together with coal union representatives to the coal phase-out plan by 2035/38 (BMWi 2019).

3.2.4 Lessons-learned from Germany

Figure 4 summarises the TEF analysis results for Germany. This includes contextual information regarding the socio-political and economic environments as well as those forces (de-)stabilizing the coal regime. The long continuation of government subsidies for coal mining enabled the continuation of power generation and steel production with domestic energy sources. Despite substantial pressure by international competition due to cheaper coal imports and climate protection measures, the political power of the coal regime limited changes to the status quo. Climate change or air pollution concerns have not been strong enough to stop subsidies for the coal industry or to implement policy instruments

similar to those that forced closures in the UK. Instead, concerns about high electricity prices, import independence, grid stability, as well as the implementation of the nuclear phase-out have resulted in a more gradual coal phase-out process. In 2010, shortly before Germany decided to phase out nuclear energy, the share of coal and nuclear energy in gross electricity generation was still 64%. To replace both energy carriers posed a substantially larger challenge than replacing the 28% share of coal generation in the UK in 2010 (see Figure 2). Thus, CO_2 emissions were not reduced in a similar manner as in the UK.

Germany's example powerfully demonstrates that only incentivising and expanding renewable energies is not enough to diminish coal's importance. However, small scale renewable energy deployment and citizen ownership has created broad civil society support for the German *Energiewende*, providing a valuable lesson for other countries and an important basis for a future coal phase-out. Furthermore, prices for renewables have been brought down with the help of deployment in Germany, which helped other countries in their renewable energy investments, including the UK (Morris 2016).

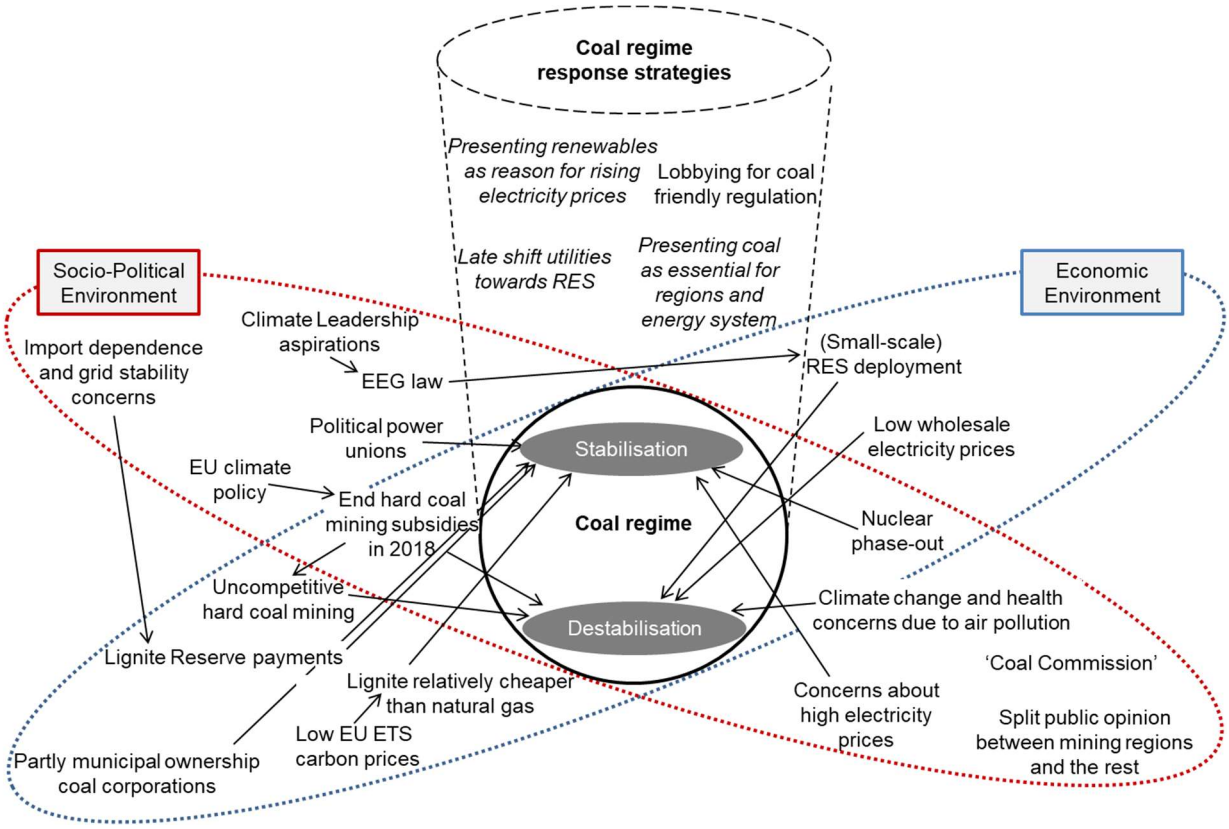

Figure 4: Coal regime analysis Germany.

4 Conclusions

The aim of this paper is to analyse which actors and interests prevented or, in contrast, enabled a reduction of coal's importance. The comparative case study of the UK and Germany employs the Triple Embeddedness Framework. For both countries, it is apparent that socio-political and techno-economic environment pressures influence the coal regime and that powerful incumbents exist. Another commonality for these two countries is that incumbents successfully prevented policies reducing their business opportunities for several decades while also securing financial support. Common frames used to generate this support are claiming disadvantages in e.g. domestic competitiveness, energy security,

import dependence, rising energy prices, black-outs, and unemployment. However, the decline of coal happened at different speeds and under different policy tools, influenced by varying contextual national factors, diversity of actor power within the coal regime, and those opposing coal. Table 1 summarises the findings and highlights differences.

In the UK, opposition of miners was already suppressed in the 1980s – not for climate reasons but other political reasons. Having to import coal lowered opposition to reducing coal's importance in the power sector over the following decades. A driving force was NGO campaigns influencing public opinion on climate change and health aspects, which facilitated a competition between political parties for 'green' policies and the implementation of policy instruments like the carbon price floor and emission performance standards in the 2010s. This coincided with a point in time when, due to the age of coal-fired power plants, a decision between either major investments or a shutdown was necessary. Furthermore, the decision for companies was comparatively easy as they were able to diversify into other domestic large-scale natural gas and renewables projects.

In Germany, since the 1950s, coal unions and influential coal companies slowed the decline of coal. Thereby, reductions within hard coal mining and related employment happened in a linear manner until 2018 with the help of large governmental subsidies. The lignite sector, on the other hand, observed a rapid structural break in the early 1990s following German unification. A primary objective of East German mining was to create employment possibilities – leading to 'inefficiencies' when having to compete with Western mines optimized for capital return. After unification, this resulted in closures and layoffs as mining adapted to West European norms.

Our analysis shows that in Germany the incumbent coal regime was able to uphold the status quo for a longer time than in the UK: In 2020, regional governments as well as municipalities that are shareholders of energy corporations in mining areas in Germany are still supportive of coal due to ongoing employment concerns. Additionally, energy intensive industries have built a coalition with the coal regime as they perceived it as a means for achieving lower wholesale electricity prices. Coal mining in the UK, on the other hand, was reduced to a negligible amount since the 2000s, while Germany still mined almost 200 million tonnes of coal. Therefore, the UK was less dependent on jobs and regional income generation related to coal.

Germany's previous nuclear phase-out decision, following the 2011 Fukushima accident, made the coal phase-out more difficult due to concerns about sufficient installed electricity generation capacities. This, however, also released more human and financial capacities for NGOs to put pressure on the coal industry. Phasing-out coal and nuclear energy simultaneously meant having to replace the majority of electricity generation capacities both for Germany as a whole and for those companies owning the power plants. Moreover, in contrast to the UK, Germany could not increase domestic natural gas production and were dependent on comparatively expensive imported gas. Most large electricity corporations in Germany underestimated the potential for renewable energy and did not change their strategy to investing in renewables until much later. Other main reasons for the earlier reduction in coal production and consumption include the relatively old infrastructure of coal-fired power plants in the UK, requiring major investments in refurbishment or new capacities, as well as the stronger opposition to any decision restricting coal by miners' unions in Germany.

Table 1: The socio-political and techno-economic environments of the coal regimes in the UK and Germany and their respective responses

		UK	Germany
Socio-political environment	**Civil society**	NGO campaigns influenced public opinion on climate change, especially in the 2000s	Historically strong civil society, but focused more on nuclear phase-out until 2011
	Government	Policies like carbon price floor and emission performance standards restricting coal use for electricity generation Liberal market economy → focus on market approaches, preference on cost-efficiency and large-scale technologies Close policy networks between government and incumbent industries, but not new market entrants; limited stakeholder engagement	Regional and national governments preserving coal mining to protect jobs Feed-in-tariff supported new market actors to invest in renewables Coordinated market economy → close connections not only between industries and government, but also between government and unions as well as civil society
	Unions	Miners unions lost influence in 1980s due to Thatcher's policies	Strong miners and energy intensive industries unions
Techno-economic environment	**Coal infrastructure**	Necessary investment decisions due to old infrastructure End of domestic mining due to low coal import prices, and end of mining subsidies	Coal infrastructure with broad age structure, domestic coal mining for a longer period (due to hard coal subsidies and lignite deposits)
	Energy Market	Availability of domestic natural gas production	Simultaneous nuclear phase-out, little domestic natural gas production
		Technologically advanced renewables and falling prices	
External strategies of coal regime	**Political influence**	Successful lobbying: E.g. capacity markets and cap on the carbon price floor Fostering concerns that ending coal would lead to rising electricity prices and black-outs	Successful lobbying: E.g. hard coal mining subsidies since the 1950s and lignite capacity reserve payments Criticizing renewables as 'over subsidised', and highlighting energy security and job losses concerns
Internal strategies of coal regime	**Strategic (re-) orientation**	Investments in large-scale renewables and natural gas	Little reorientation, effort to keep the old business model as long as possible

These experiences show that different actor groups have significantly more influence on political decisions than others, contributing to the diverging decisions regarding coal in countries otherwise comparatively similar and subject to the same EU energy and climate regulations. Accepting this

influence can make policy sequencing approaches more attractive (introducing policies that face little initial resistance, to upscale stringency and introduce more controversial policies later) (Pahle, Michael et al. 2017). This appears more feasible than simply targeting most efficient policy instruments that go against the interest of a regime with close ties to policymakers. We show that the diverging situations regarding coal arise due to a complex interplay of pressures by the socio-political and techno-economic environments as well as the response strategies of the incumbent regime. Without efforts to limit the influence incumbents have on policy making, or at least balance it with other civil society actors, more ambitious energy transitions seem unlikely, or will at least be significantly slower. Some overarching policy recommendations that can be drawn from these past experiences are the following:

- Support for large scale renewable energy investments can either come through a Renewables Obligation, such as in the UK, or through the entrance of new renewable energy actors, like in Germany.
- However, supporting renewable energies is not sufficient to enable a coal phase-out in line with (inter-)national climate targets. This is reflected in the struggle of the German government to implement the agreement of the coal commission against continuing opposition of incumbents. Importantly, the achieved compromise is neither in line with the Paris Agreement nor Germany's climate targets (Oei, Kendziorski, et al. 2020). It is also slower than what citizens desire (Rinscheid and Wüstenhagen 2019).
- Compatibility with the goal of GHG neutrality by 2050 needs to be included in transition planning. Although the UK managed to achieve substantial GHG emission reductions with its shift from coal to natural gas, this will not be sufficient to achieve the upcoming more stringent climate targets for most countries. Policies should be considered that prevent this next fossil fuel lock-in and instead create investments directly in renewables and energy storage as well as efficiency measures.
- Weakening the existing coal regime as well as showing them alternative business models enables change. Margaret Thatcher's political actions reduced the influence of the unions, but also resulted in other negative socio-economic consequences for mining regions still visible today. These impacts can be averted with targeted just transition policies, stopping coal use, and simultaneously providing social security for workers and new economic opportunities for dependent regions.
- Opportunities for change exist whenever larger investment decisions for plants or mines need to be taken. Enforcing stringent climate and environmental regulation for new investments, as in the UK, can prevent stranded investments. Missing such points in time can lead to ongoing legal debates regarding potential compensation payments, an ongoing discussion in Germany.
- Phasing-out coal is not only about the replacement of coal with renewable energies within the energy system. For coal mining countries, like the UK and Germany, the biggest challenge actually lies within the needed adjustments for the affected regional economies. Past experiences show lessons of hardly managing (UK) or to passively delaying (Germany) this process. Current debates of the EU Green Deal try to reflect this by focusing on a "just transition" for all regions that will be affected by upcoming phase-out pathways. Thereby, solutions strongly depend on regional contextual factors and must be adopted individually, as no single blueprint for a socially acceptable coal phase-out exists.

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5 Appendix

5.1 Additional background on the Triple Embeddedness Framework

The TEF conceptualises industry environments and is based on evolutionary economics, neo-institutional theory, and economic sociology. It accommodates interactions between incumbent firms of a specific industry and a broader set of environments, including the economic and socio-political environments. The framework is based on Schumpeter's idea to include social institutions relevant to economic behaviour in economic analyses (Schumpeter 1942). It recognises institutional change and includes strategic behaviour and power of actors. "Embeddedness" means that the economy is embedded and not independent of social, political, and cultural dynamics.

The TEF framework builds on both selection theories and adaptation theories. It aims to integrate the two streams, not to choose either/or. The focus is on co-evolution, embeddedness, and bi-directional interactions (of industries and their economic, political, cultural, and social environments), which can only be analysed by combining the different theories and approaches. As Geels (2014) states himself in the paper explaining the framework:

> 'Lewin and Volberda (1999) suggest that selection theories and adaptation theories represent two levels of analyses, with the former emphasizing selection pressures that *populations* face from their environments, and the latter emphasizing (differences in) *firm-level* strategies, capabilities and perceptions. […] "single-theme explanations for the adaptation-selection phenomenon have reached their limit. Progress in the field requires combining and recombining multiple lenses instead of increasing fragmentation. We should consider the joint outcomes of managerial adaptation and environmental selection"' (Geels 2014, 262).

The TEF framework is appropriate for our question and the coal industry, as it focusses on incumbent firms and the necessary pressure by policy makers and civil society to generate change (environmental selection). Firms-in-industries are defined as "large, politically powerful, and scale-intensive with many sunk investments" (Geels 2014, 261). Further, the framework enables the analysis and comparison of coal phase-outs - non-linear processes involving a wide variety of actors - as it includes both lock-in and path dependence hindering reorientation of firms-in-industries and entire industries – as well as the reorientation of them, that means the change in the directionality of innovation. It includes insights from neo-institutional theory about the influences from the institutional environment, where "organizations compete for social fitness rather than economic efficiency" (Geels 2014, 264). Important is that firms-in-industries do "not only adapt to institutional pressures, but also respond strategically to shape them" (Geels 2014, 265). Aspects included from economic sociology highlight 'embeddedness', (cognitive, cultural and political). Therefore, an important notion is "that economies and markets are underpinned by government regulations and institutions" (Geels 2014, 265). Another important contribution is also the recognition that "firms and industries use power and politics to shape formal institutions to their advantage" (Geels 2014, 265) and that "market elites and governmental elites often cooperate and that their voices are louder than those of labour unions, consumer groups and environmental groups" (Geels 2014, 265), and that they can exert more political power than "ordinary citizens".

The adaptation theory part acknowledges that firms act with deliberate and intentional strategies, rather than being mostly passive. Both externally- and internally-oriented strategy schools are included. Importantly, it is acknowledged that firms, in some contexts, have substantial scope to influence regulations and political environments. They use information strategies (e.g. setting up think tanks), financial incentives strategies (e.g. contributions to politicians and political parties), organize pressure strategies (e.g. creating industry associations, lobbying directly, confront using litigation, or threaten policymakers with layoffs), and discursive strategies (e.g. arguing that solutions are costly or technologically unfeasible). Increasing pressures (from the economic and socio-political environment) and related performance problems can then incentivize actors to overcome lock-in mechanisms and tackle increasingly more foundational regime elements (Geels 2014).

5.2 Additional background information on long-term trends in electricity generation

The following two figures display long-term trends of electricity generation in the UK and Germany. The effect of the miners' strikes in 1984 are clearly visible in the data for the UK. For Germany, only data since its unification was available.

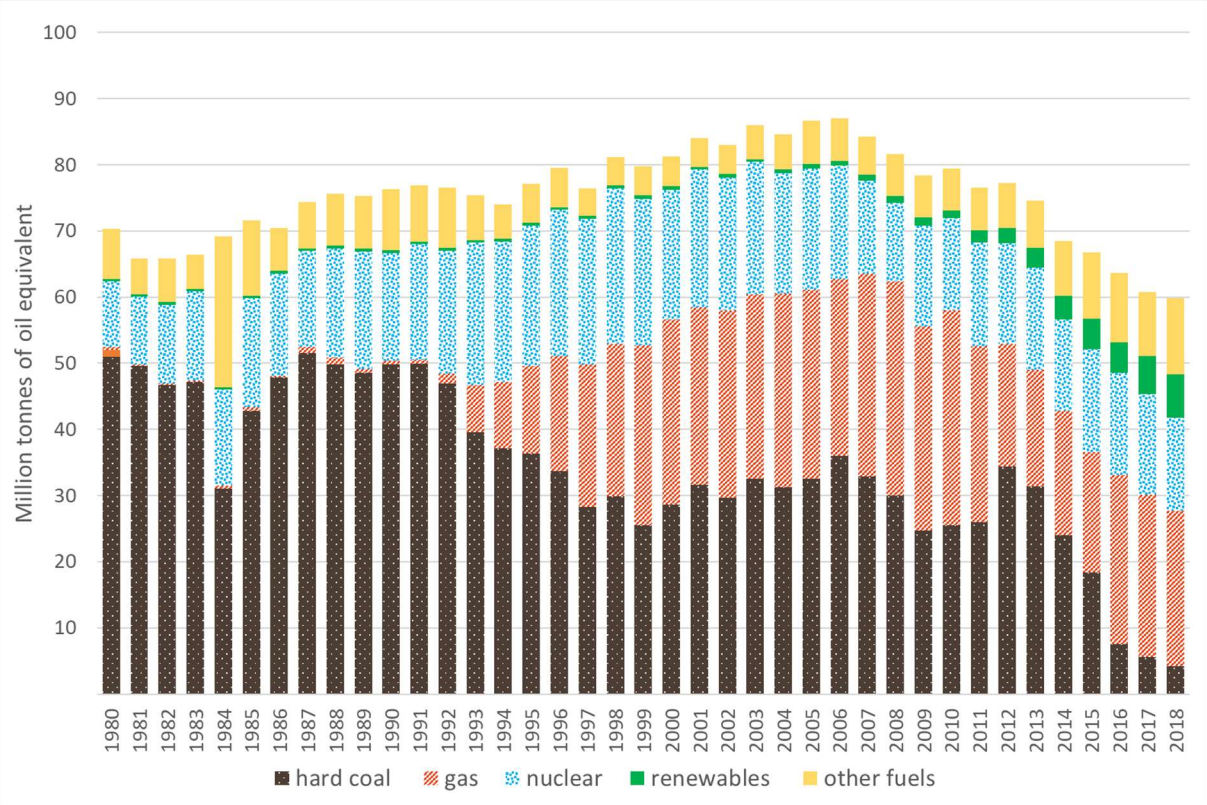

Figure 5: Fuel Input for Electricity Generation in the UK from 1980-2018 in million tonnes of oil equivalent.

Own depiction based on Department for Business, Energy and Industrial Strategy (2020b).

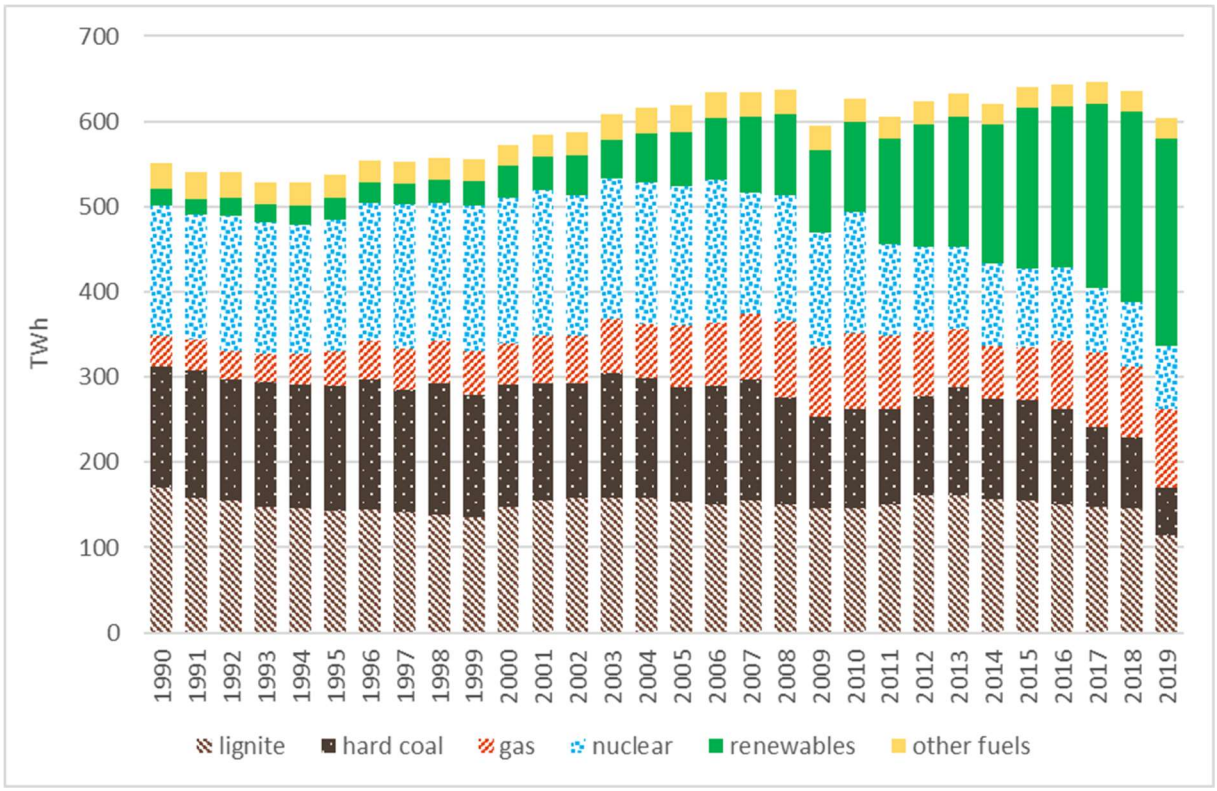

Figure 6: Gross Electricity Generation in Germany from 1990-2019 in TWh.

Own depiction based on Umweltbundesamt (2020a), AG Energiebilanzen (2019) and AGEB (2018).