An historical case study on previous coal transitions in GERMANY

Part of the project “Coal Transitions: Research and Dialogue on the Future of Coal”

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An historical case study on previous coal transitions in Germany

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Abstract

Subsidies for German hard coal production will end in 2018, resulting in a final shutdown of domestic hard coal production. This paper looks back at the 60 years of steady decline and transition of an industry that once employed more than 700,000 people. One focus of this historic case study therefore lies on the Ruhr area—Germany’s largest hard coal mining area that was hit by this economically driven transition. The second focus lies on the politically driven reduction of lignite production in Eastern Germany due to the reunification in 1990.

The analysis is hereby divided into the quantitative consideration of the significance of coal for the energy system and the regional economies, as well as an evaluation of implemented political instruments accompanying the reductions in the coal sector. The political instruments on regional, national and supranational level can be differentiated between measures for the conservation of coal production, the economic reorientation in the regions as well as easing negative social impacts.

Upcoming challenges for regions facing a coal phase-out in the future differ depending on various aspects e.g. the type of coal (lignite or hard coal), its usage (domestic or exported; electricity; heat; industry); regional characteristics (rural or urban); as well as the political and institutional situation (governance; ownership). This analysis of past transitions of mining areas and energy systems in Germany might, however, provide other countries and regions with valuable lessons of how to structure their upcoming coal phase-out period and therefore provides a useful addition to the existing literature.

Keywords: Coal phase-out; just transition; energy transition; Germany; structural policy
Introduction

Looming climate change requires the end of unabated coal combustion, the most greenhouse gas emission intensive energy carrier. In the Paris climate agreement, the world community committed to keeping the global temperature rise to well below 2°C compared to preindustrial levels. In 2017, at the COP 23 (23rd Conference of the Parties) in Bonn, several countries founded the “Powering Past Coal Alliance”, pledging to end coal consumption. The hosting country Germany did not participate in the new alliance against coal and has until now no explicit plan to phase out coal. Despite being seen as an ambitious country in climate protection negotiations, it is one of the countries with active coal mines and a large coal-fired power plant fleet.

Structuring the transition away from coal

Germany is, hence, facing the challenge of structuring the upcoming transition away from coal. The transition away from coal is, however, not only due to climate policies. The large scale deployment of renewable energy threatens the economic viability of coal-fired power plants, as renewables increase competition and lower whole-sale electricity prices. The existing (economic) situation in Germany will prevent the construction of new coal-fired power plants. Therefore, eventually, coal would be phased-out at the latest at end of the power plants’ lifetimes. To achieve a coal phase-out in line with climate protection commitments, climate policy measures need to be introduced to accelerate the decline of coal.

The good news for Germany is, a large share of coal’s decline has already been managed. It therefore serves as a case study to analyze the history of the phase-out of hard coal mining in the Ruhr area and the reduction of lignite mining in East Germany as a result of Germany’s reunification. Germany’s two examples of reducing coal mining provide valuable lessons learned but also illustrate the difficulties of structuring a phase-out without negative consequences for employees, companies and entire regions. The Ruhr area serves as an interesting example since it shows how the shift away from coal was delayed by the powerful influence by coal mining and steel industries. However, it shows that a phase-out is possible and that potential negative effects can be managed effectively: The perception of the Ruhr area changed from the old industrial area towards a region with a more diversified and strong economy with an increasing quality of life.

An important lesson is, that it is not only necessary to have policies addressing unemployment, the economy and the energy system, but also measures to improve former coal regions’ infrastructure, universities and research facilities as well as soft location factors like culture and ecology. The German case study suggests that implementing a fair and realistic transition from a fossil fuel-based economy can be managed when city, regional, national and supranational governments work together on designing a phase-out and multi-level polycentric structural policy mix. Despite having specific regional characteristics, Germany’s experience provides valuable lessons learned for other regions with a phase-out ahead. Learning from the past could help to prevent the repetition of mistakes, and ensure that previously successful policies might be implemented in a similar fashion. The upcoming transition can succeed by considering past experiences with structural policies and social security systems, along with the incorporation of affordable alternative forms of energy generation and other promising innovative sectors providing new job opportunities.

Germany’s new “coal commission”

In June 2018, Germany has installed a commission which is called “growth, structural change and employment”. By the end of 2018, the commission is supposed to submit concrete proposals on the future of coal in Germany regarding:

- an end date for coal based electricity generation.
- to develop a pathway for a structured decline of coal, taking into account the sectoral emission reduction targets for 2030 (a reduction of greenhouse gas emissions by 61-62 % compared to 1990).
- additional decisions on coal-fired power plant shut-downs by 2020 to close the remaining gap to Germany’s 2020 emission reduction target to be presented at the upcoming COP24 in Katowice, Poland.
The commission’s focus is, however, not only on the decline of coal but also on how to manage the implications for the coal regions. The commission is therefore supposed to propose additional concrete measures on how to create new jobs fit for the future. A mix of instruments is meant to jointly address the economic development, social acceptability as well as climate protection targets. A new national fund will be created that is specifically earmarked for investments in the (former) coal mining regions.

The commission is mandated by the four German ministries for the economy, environment, employment as well as the ministry of the interior; under the management of the economics ministry. The “coal commission” consists of 4 board members and 27 other members across the political spectrum, representatives of industries, unions, science, environmental organisations and the affected regions. The commission will meet on a monthly basis and consists, next to the plenary, of two parallel working groups focusing on “structural change” and “climate, energy, and energy security”. Concerns exist that certain members of the commission could try to focus and decide on social implications and measures first, postponing and possibly attenuating ambitions to reduce coal consumption in line with climate protection targets. The outcome of this coal commission, therefore, still remains uncertain, but it can be seen as a positive signal that Germany has turned from discussing the necessity of a coal phase-out to how to structure it. This paper aims to contribute to this discussion by exploring insights and lessons from past German coal transitions.

Structure of the paper

The remainder is structured as follows: Section 2 describes the role hard coal played in the energy system and economy of the mining areas in Germany from the 1950s until 2017. Since the hard coal production was based in West Germany during Germany’s separation, the analysis of hard coal focusses on West Germany. Section 3 describes the role of lignite in Germany, focusing on the drastic decline of lignite in East Germany after reunification. The following section analyzes the implemented political measures which accompanied the decline in hard coal and lignite production. Section 5 concludes with lessons learned on how to structure coal phase-outs in a socially responsible way.
History of hard coal in Germany 1950-2017

After the Second World War, Germany was divided into West and East Germany. The entire production of underground hard coal was based in West Germany. For West Germany, the domestic hard coal reserves were more than just an energy carrier for West Germany since it helped to rebuild its industry and enabled its "economic miracle". Furthermore, coal helped to reintegrate Germany into an international union: The European Coal and Steel Community (ECSC), the predecessor of the European Union, was founded in 1951 together with Italy, Belgium, France, Luxemburg and the Netherlands.

**Hard coal as energy carrier – primary energy consumption and electricity generation**

Hard coal was the backbone of West Germany’s energy supply after the war. Its importance can be illustrated by the fact that Germany introduced the so-called Hard Coal Units (HCU) to measure energy, analogue to the oil equivalent (OE). In 1950, hard coal provided 98.7 million t HCU (2,893 PJ), or more than 70% of primary energy consumption (PEC) (AG Energiebilanzen e.V. 2017a). Hard coal was eventually substituted, mainly with imported mineral oil, and its share dropped to 19% in 1990 and 12% in 2016. Absolute consumption of hard coal declined in the same period from 74 million t HCU (2,169 PJ) in 1990 to 55 million t HCU (1,612 PJ) in 2016. From 1950 to 1990, the PEC trippled to 392.2 million t HCU (11,494 PJ). After Germany’s reunification, PEC increased further to 455 million t HCU (13,335 PJ) in 2016. The decrease in coal consumption was covered mainly by imports of oil and natural gas. In 1950, mineral oil provided only 5% of PEC; which increased to a share of 41% in 1990. Gas had a negligible share in 1950, by 1990 it contributed 18% and in 2016 22%.

**Figure 1** displays the primary energy consumption for West Germany in 1950 and 1990 and for the reunified Germany in 2016, illustrating the increasing diversification of the energy system: Before the reunification, mineral oil, natural gas and nuclear energy consumption increased drastically while hard coal consumption decreased. The main change after 1990 is the increased usage of renewable energy, while hard coal consumption decreased and lignite consumption (as well as total PEC) continued to grow.

In contrast to the development in the energy sector, during the German separation hard coal consumption in-
increased in the electricity sector of West Germany (with the exception of the years shortly before the first oil crisis in 1973). Hard coal reached its highest share with over 60% at the end of the 50s and has been fluctuating around 30% since the reunification.

Gross electricity generation (GEG) in general increased tenfold from 44 TWh (1950) up to 440 TWh by 1990 [Statistik der Kohlenwirtschaft e.V. 2017a]. After 1960, mineral oil and natural gas gained in importance in the electricity sector, but after the two oil crises the electricity sector started to shift away from mineral oil.

In order to increase security of supply, nuclear energy gained importance and covered 30% of gross electricity generation since the 1980s. After the accident in Fukushima in 2011, Germany decided to phase-out nuclear power by 2022. Figure 2 displays West Germany’s electricity generation from 1950 to 1990 and Figure 3 for the reunified Germany from 1990 to 2016. Coal consumption for electricity generation has increased until the 1990s and has been on a gradual decline since the 2000s. However, coal’s share in PED has declined more strongly (see Figure 1), due to varying competition over time from oil, natural gas, nuclear power and renewable energies.

**Figure 2.** Gross electricity generation in West Germany 1950-1990

**Figure 3.** Gross electricity generation in Germany 1990-2016

Source: Statistik der Kohlenwirtschaft e.V. 2017a.
**Hard coal production and employment**

After the end of the war, underground hard coal production rose until the year 1958—the first year of the coal crisis, which led to an end of the “economic miracle” in West Germany. After the Suez crisis and the liberation of the energy sector in the mid-1950s, cheap import oil gained in significance and so the hard coal demand began to decline. Before, the government had set the price for coal on a low level for the reconstruction of Germany, but in 1956, the ECSC demanded a market based price in Germany (Nonn 2009, 97–98). The sales and production figures started to strongly decline in the mining as well as the steel industry, one of the biggest consumers of German hard coal. Germany did not only import oil but also comparably cheap foreign hard coal, which additionally decreased the demand for domestic coal. In order to protect domestic production, the hard coal industry received subsidies to level-out the price difference between domestic and imported coal since 1968. Since 1964, the prices for domestic coal exceeded the ones of imported coal. The coal and steel industry formed a powerful network together with influential unions and politicians (especially the social democratic party), protecting domestic coal production. Besides its regional significance, hard coal production and employment were a crucial aspect of the country’s economy.

**Figure 4.** Prices for domestic and imported hard coal

![Graph showing prices for domestic and imported hard coal from 1957 to 2014. The graph demonstrates a steady increase in prices for both domestic and imported coal, with a notable rise in the 1960s and 1970s.](source: Verein der Kohleimporteure e.V. 2017, 111.)

**Figure 5.** Domestic hard coal production, imports and employees (mining only) of West Germany

![Graph showing domestic hard coal production, imports, and employees from 1957 to 2014. The graph illustrates a decline in domestic production and an increase in imports and employees, indicating a shift in the coal industry’s reliance on imported coal.](source: Own calculations based on Statistik der Kohlenwirtschaft (2017b, 2017c) and Verein der Kohleimporteure (2017).)
coal was considered important for other political and strategic reasons: Coal guaranteed a certain level of supply security, making Germany less dependent on foreign oil, coal and later natural gas imports. Additionally, hard coal was a gateway for Germany into international affairs. Being a member of the ECSC was beneficial in forming strong relations with other European nations. Therefore, and to prevent structural disruptions at the regional level, the government provided the hard coal sector with various subsidies for more than 60 years.

Besides the increasing amount of imported energy carriers, the ongoing mechanization of the mining sector led to a lower employment which had an additional impact on the total number of employees in the Ruhr area. At the peak of production, right before the coal crisis in 1958, over 600,000 people were employed. Within ten years, 320,000 people had lost their jobs. Figure 5 shows the development of employment in hard coal mining as well as produced and imported hard coal.

The majority of German hard coal production came from the Ruhr area, which is located between Dortmund and Düsseldorf. Therefore, this study focuses on the development in the Ruhr area. The coal mining and steel industry (in German ‘Montanindustrie’) made this area the most densely populated area in Germany—until today. The region depended strongly on the economic circumstances of this industry and suffered repeatedly from high unemployment rates over the years. Figure 6 displays the development of the unemployment rate for (West-) Germany, North Rhine-Westphalia (NRW) and the Ruhr area from 1960 to 2015. The figure does not display the years before 1960 for NRW and West Germany and before 1967 for the Ruhr area due to a lack of yearly data. However, total unemployment in West Germany fell from around 1.9 million in 1950 to just 150,000 in 1962 (Bundesagentur für Arbeit 2018). The rising development of the metal industry was able to cover most of the job losses in the mining sector (Nonn 2001, 179f). Yet, in the following years, the “economic miracle” ended in Germany and the Ruhr area as Germany suffered from global macroeconomic changes like the oil crises in 1973 and 1979. The induced economic recessions led to a doubling of the unemployment rates in the Ruhr area within only a few years (1973: 1.6% › 1974: 3.3% and 1979: 5% › 1982: 10.3%). A peak in unemployment was reached with 15.1% in 1987, which dropped to around 10% in the early 90s. In 2005, the maximum was reached with 16.4%. In the past 10 years, the region’s average unemployment rate equates to approximately 11%. The development of the unemployment figures corresponded with the trends of NRW and the rest of Germany; however, unemployment rates of the Ruhr area were always higher. The gap widened especially in the 1980s, were they were between 5 and 7% higher than the West German average. The gap was reduced to only about 2% in 2002 and remains at a level between 4 and 5% since 2010 (Regionalverband Ruhr 2017b).

Figure 6. Unemployment rates in the Ruhr area, North Rhine-Westphalia and (West-)Germany from 1960 to 2015

Note: The depicted (West-)Germany values are only for West Germany from 1960 until 1990 and from then onwards for the reunified Germany. Data for the Ruhr area was available only for the years after 1966.

Source: Regionalverband Ruhr 2017b.
History of lignite in Germany 1950-2017

Besides hard coal, lignite is the only energy carrier mined in a significant amount in Germany. Unlike hard coal, lignite was available in both parts of Germany during the separation. Lignite contains a higher share of water than hard coal, which makes the transportation over large distances uneconomic. Therefore, lignite production and power plants are clustered in the mining regions. A phase-out of lignite production, would thus also lead to a phase-out of lignite-fired power plants. In 2017, lignite is produced in Germany in the open pits of the Rhineland (West Germany, close to the Ruhr area), Lusatia (East Germany) and Central Germany (East Germany) region. The eastern coal mining regions are mostly rural areas with low population figures, unlike the lignite and hard coal mining areas in West Germany.\(^2\)

**Lignite in East Germany’s energy system**

East Germany covered around 90% of its primary energy consumption via domestically produced lignite in the years right after the second world war (Kahlert 1988, 10). Its PEC almost tripled in the years from 1950 to 1990 from 51 million HCU (1,495 PJ) to closely 130 million HCU (3,810 PJ). In 1960, lignite contributed 88%, in 1970 it had dropped to 75% of the primary energy consumption and continued to decrease until the end of the 1970s. The reasons were increasing imports of mineral oil and share of nuclear power. The decline of lignite production stopped when the oil crises from 1973 and 1979 raised the prices of oil, and the ambitious plans for the deployment of nuclear power plants could not be realized (Matthes 2000, 53). East Germany started to increase the share of lignite in its energy system again in the 1980s. On the one hand, this increase led to a state where East Germany was able to cover 70% of its PEC by domestic energy carriers in 1986. On the other hand, East Germany’s economic stability was threatened by high consumption of expensive and uncompetitive lignite (Kahlert 1988, 10). From the mid-1980s, annual investments into lignite and energy summed up to GDR-Mark 9 to 10 billion\(^3\) (East Germany’s currency, equivalent to ~€1.15-1.28 billion), which corresponded to approximately one quarter of total industrial investments (Matthes 2000, 54). Figure 7 displays East Germany’s primary energy consumption in 1960 and 1990. In 1950, the amount of hard coal and lignite combined

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\(^2\) During the last 150 years, coal production was also located in other regions but with an accumulated production of 4% of total production, the contribution is rather insignificant (Öko-Institut 2017, 23).

\(^3\) The exchange rate from Deutsche Mark (DM) to GDR-Mark in 1987 was 1:4 (Baltensperger and Deutsche Bundesbank 1998, 648). Exchange rate for € to DM = 1:1.95583.

**Figure 7.** Primary energy consumption in East Germany 1960, 1990 and in Germany 2016

![Figure 7](image-url)

Source: AG Energiebilanzen e.V. 2017b; Kahlert 1988, 10.
exceeded 99% of the PEC\(^4\) (Kahlert 1988, 10). The third column shows the PEC in 2016 not for East Germany but the reunified Germany.

**Figure 8** displays the development of gross electricity generation (GEG) in East Germany from 1979 to 1990\(^5\). From 1955 until 1977, lignite contributed around 90% of GEG. After 1978, it declined to around 80 to 85% due to the deployment of nuclear power. The absolute amount of lignite increased from 25 TWh in 1955 to around 100 TWh in 1990 (Matthes 2000, 67). Shortly before the reunification, East Germany's power plant fleet consisted of two thirds lignite-fired power plants with a capacity of 15 GW (Kahlert 1988, 13). The share of lignite peaked in East Germany right after the reunification with 91%, when East Germany phased out nuclear power. The total GEG increased to 118 TWh in 1990 (Statistik der Kohlenwirtschaft e.V. 2017a). After the reunification, the lignite sector broke down, because it was less productive and more expensive compared to the West German lignite sector. Additionally, citizens and regions started to develop ecological concerns (Matthes 2000, 238). Both figures on PEC and GEG show a strong dominance of lignite in East Germany until 1990 (see **Figure 7** and **Figure 8**). However, in 2016 lignite plays a much smaller role in Germany’s PEC, both in absolute and in relative terms.

\(^4\) The available data does not differentiate between both energy carriers.

\(^5\) Natural gas is listed in “others”.

Lignite’s contribution to the energy systems of West Germany and Germany after the reunification

Compared to East Germany, lignite was not as substantial in the energy system of West Germany. At the beginning of the 1950s, lignite contributed only 15% to the PEC (AG Energiebilanzen e.V. 2017b). The share of lignite declined to only 8% by 1990—in absolute figures it rose from 21 to 32 million HCU (607-938 PJ). The amount of lignite used in the generation of electricity increased eightfold from 11 to 83 TWh in the same period of time. In the years after the first oil crises, when hard coal contribution was at a low, lignite reached its highest share of one third. By the time of the reunification, the share was only 18.1% due to the high shares of hard coal (32%) and nuclear power (34%) (Statistik der Kohlenwirtschaft e.V. 2017a). Since the reunification, the share and the total amount of the three technologies decreased, while simultaneously the electricity production rose. In 2016 lignite-fired power plants generated around 23% of GEG, with 150 TWh, making it the largest producer in the system before hard coal with only 110 TWh (compare **Figure 3**).

In 2017, Germany produced 648 TWh of electricity of which more than 50 TWh were exported. The increase in the renewable energy consumption has not yet led to a decrease of fossil fuel-fired generation, but instead has turned Germany into a large electricity exporter.
Lignite production and employment

Until the reunification, the total production of lignite continuously increased, mainly in East Germany, in order to cover the increasing PEC. The supply rose almost throughout the time of separation. The peak was reached in 1985 when around 140,000 employees produced 312 million tons of lignite. The total production of Germany in 1985 equaled to 430 million tons with almost 160,000 employees of which 90% worked in the mines of East Germany. As a reaction to the oil crises in 1973 and 1979, East Germany tried to use political means to increase production, even though its economic condition was not able to sustain it (Matthes 2000, 56). Its maximum level of 1985 slowly decreased in the following years. East Germany was globally the biggest lignite producer, extracting one quarter of the total amount of lignite and doubling the production of the second largest producer—the Soviet Union (Kahlert 1988, 10). 70% of the production in Germany was concentrated in East Germany (Meyer, Kuchle, and Hölzinger 2010, 8). The lignite production in East Germany was characterized by high overcapacities (Kahlert 1988, 15). Right before the reunification the average production in tons per worker in West Germany was three times higher than in East Germany. This resulted in a drastic reduction of the lignite production in East Germany after reunification when all mines were forced into inner German competition. In East Germany, between 1989 and 1994 over 100,000 employees lost their job and production decreased by about 200 million tons. Unlike the hard coal decline, lignite broke down within just a few years, leading to a structural disruption in some regions. Since the mid-90s, lignite production and employment has stayed almost constant, however, at only a fraction of the pre-reunification time. Despite this, Germany is still the largest lignite producing country in the world. Figure 9 displays the lignite production and employees in Germany from 1950-2016.

Figure 9. Lignite production and employees in Germany 1950-2016

Note: The values for lignite production are displayed as stacked areas for East and West Germany, while employment figures are depicted as individual lines. Since 2002, the employees of lignite-fired power plants are included.

Source: Statistik der Kohlenwirtschaft e.V. 2017d.
Section 2 and 3 gave an overview of the historical importance of the fossil fuels hard coal and lignite in Germany and the phase-outs from a production and energy systems point of view. The following section points to the social consequences of the hard coal phase-out and lignite reduction especially in affected mining areas. It highlights policy instruments on regional, national and supranational level which accompanied the decline of both energy carriers. The description starts chronologically with the hard coal decline in the Ruhr area after the 1950s and covers the reduction in lignite production of East Germany. The latter analysis hereby focusses on the Lusatian region.

The coal crisis in 1958 and the first structural policy program of North Rhine-Westphalia (NRW)

German hard coal production and consumption has been declining since the coal crisis in 1958 (see section 2). Since cheap oil was one of the main causes of the crisis, some politicians, especially in the Ruhr area, urged to implement a protectionist import tax on oil. The income of that tax was partly used to compensate around 16,000 workers for a shortening of their shifts, which were implemented as reaction to the quickly lowering coal demand. Additionally, early retirement in the mining industry was financially supported by the state (Farrenkopf 2009, 81, 94). In the short-term, these measures were able to alleviate negative consequences for affected workers, however, the measures did not succeed in addressing the structural problems of the hard coal sector. Between 1957 and 1967, over 300,000 out of 600,000 workers lost their job in hard coal production—most of them in the Ruhr area. The first years of the reduction in coal production due to the oil crisis overlapped with the last years of the “economic miracle” in Germany. The majority of the workers were therefore able to transfer into other jobs, mainly in the metal industry (see Figure 10) (Nonn 2001, 179f).

Thus unemployment payments were only necessary for workers close to their retirement. In 1962, the economic situation changed again, especially in the steel sector (Nonn 2001, 183). It had become apparent, that the mining industry would not be able to recover, hence the law for rationalization and decommissioning was implemented in 1963: causing 51 out of 141 coal mines to be shut down by 1967. In order to be able to initiate a controlled decline of coal production, mining companies were forced to combine their production in a newly dounded company called RAG AG (Goch 2009,

Figure 10. History of hard coal and structural policy programs in the Ruhr area since 1951

- 150 Mt hard coal production
- ~ 600,000 employees in hard coal mining

1951 Foundation of the ECSC

“Economic miracle”

1956 Suez crisis & liberation of coal price

1958 Begin of the coal crisis

1964 Import coal cheaper than domestic coal

1980 “Action program Ruhr” → End of “Bodensperre”

1989 Begin of “IBA Emscher Park”

1999 Reunification & EU influence in structural policy grows

~ 2000 Growth orientation of EU structural policy, focus on “lead markets”, increased decentralization & participation

2007 Law to end hard coal subsidies

2018 End of hard coal subsidies → end of production

2018 End of production
Additionally, in 1968, the coal sector concluded sale contracts with the energy and steel sector which included state subsidies for domestic coal, paying the price difference between domestic and imported hard coal. This framework enabled a structured and slowed down decline in coal production and employment. As the decline in domestic coal production and related employment accelerated, the government of NRW started to address the need for an economic reorientation in a more strategic way: it launched its first structural policy program called “Development Program Ruhr” in 1968 with a volume of 17 billion Deutsche Mark (DM) (€8.7 billion) (Goch 2009, 146), which bundled hitherto individual and isolated measures. The program intended to neo-industrialize the area by attracting new enterprises from other sectors. In order to achieve that, the government needed to convince the mining companies to sell the land they owned to the new competition. The fear of losing qualified workers to the potential newcomers made them hold onto the land, so only few enterprises were able to settle in the Ruhr area. The behavior of the mining companies was later referred to as “ground lock” (“Bodensperre”). Besides the economic reorientation, which mostly failed, the program improved both education and traffic infrastructure to accompany the economic changes (Goch 2009, 146). Before, there existed no university in the area and the cities within the Ruhr area were not sufficiently connected by transport routes. The economic reorientation needed a higher mobility of workers since the distances between their homes and jobs were likely to increase. Homes had previously been in close distance to the work places and therefore the need for an infrastructural connection between the cities was neglected (Bogumil et al., 2012, 15).

The oil crisis 1973 and the re- & neo-industrialization of the Ruhr area

In the Ruhr area, unemployment figures rose from 12,000 in 1970 to almost 100,000 in 1976 (see also Figure 6) (Regionalverband Ruhr 2017c). The strategy of settling new industries in the Ruhr area of the previous structural policy program had failed due to the “ground lock”. Therefore, the new strategy intended to exploit the endogenous potentials of existing industries via investments of DM2 billion (€1 billion) into the modernization of the coal mining, energy and steel sectors (Goch 2009, 150). This re-industrialization was partly driven by the hopes of a renaissance of coal as an energy carrier due to the oil crisis. In 1974, steel production, which was one of the biggest consumers of domestic hard coal, reached its peak. However, the following steel crisis further aggravated the situation for the Ruhr area one year later. Policy makers realized that this development was not due to the economic cycle but structural, which required adjustments on the production level. The rising unemployment figures in the 1970s and the development in the steel sector revealed the problems associated with the high sectoral specialization of the Ruhr area. The structural policy, namely the “Action Program Ruhr” from 1980 until 1984, therefore focused on an economic reorientation or neo-industrialization of the Ruhr area. Furthermore, the program intended to improve the technology transfer between universities and companies as well as to increase the tertiarization of the Ruhr area. The program used a new approach by including elements of participation of regional stakeholders, since previous programs had faced their resistance (Goch 2009, 152). The “Action Program Ruhr” with a volume of DM6.9 billion (€3.5 billion) combined several individual measures for technology and innovation support, ecology, culture and the labor market. One goal of the program was the better coordination of the various measures by the federal government, the state and municipalities. Although a majority of the measures was still implemented in an isolated way, the result was a more dialogue oriented policy making. The program improved the Ruhr area’s situation in terms of soft location factors (e.g. improving the regional image, more cultural activities, etc.). Although it led to the creation of several new technology centers, it was not able to substantially diversify the economy, as large part of subsidies still went to the coal and steel industry.

The implementation of the property fund Ruhr and the “State development society” (“Landesentwicklungsgesellschaft”), which bought and restored former industrial sites, led to an end of the so-called “ground lock” (metropoleruhr 2010). Hence, the action program Ruhr was able to remove one of the barriers that prevented reorientation in the area. Nevertheless, the program’s focus on slowing down the decline of the coal industry impeded a more rapid establishment of new industries.
Policy makers had realized that there was no industry likely to replace the steel and coal sector in a way so that it could stabilize the Ruhr area’s economy. Therefore, each city within the Ruhr area needed its own strategy of economic reorientation. Previous programs did not take the individual strengths and weaknesses of the cities into account. The new approach regionalized the structural policy, mainly via regionally planned development strategies including individual strength and weakness analyses (Goch 2009, 156). The need for a new structural policy program increased after the second oil crisis in 1979 (see Figure 10). The unemployment rate almost tripled within 6 years to 14.2% in 1985—significantly above the rate of 8.7% in the rest of the country (Regionalverband Ruhr 2017c). The government of NRW implemented the so-called “Kommission Montanregionen” (“Commission for Coal and Steel Regions”), which elaborated strategies with the regional stakeholders. In 1987, the program “Zukunftsinitiative Montanregionen” (“Future Initiative Coal and Steel Regions”) with a volume of 2 billion DM (1.0 billion €) was launched. Hereby, the state declared fields of development, namely innovation and technology funding, education of workers, infrastructure and improvement of the environment as well as energy matters. It further granted financial resources to regional decision makers: In order to receive funding, the regions had to submit projects that had been developed together with regional stakeholders such as the chamber of crafts, unions or environmental organizations. The program itself did not introduce new measures but marked the shift to more regionalized structural policy approach (Goch 2009, 159).

Another example for the consent-based regionalized policy is the so-called “International Building Exhibition Emscher Park”. Between 1989 and 1999, this program with a volume of DM5 billion (€2.6 billion)—of which two thirds came from the public budget—combined over 120 small projects aimed at improving soft location factors in order to create a new identity of the Ruhr area. These projects included measures to implement an underground sewage system, improving water quality and opening up new areas for both citizens and nature alike. The cultural and touristic attractiveness of the region was increased by transforming former industrial sites into touristic landmarks, preserving the regions coal history and increasing tourism. Furthermore, 17 technology centers were created while mining damages were remediated as far as possible (Goch 2009, 162).

The structural policy programs caused an image change of the Ruhr area beyond the mining and steel industry, helped to create several universities and research institutions and improved the attractiveness of the region. However, only a limited number of new companies, and hence employment opportunities, was attracted into the Ruhr area, as financial support was focused on preserving the old industries and a powerful network of the coal and steel companies, unions and politicians resisted more rapid changes.

East Germany’s reduction in lignite production due to the reunification

In 1990 West and East Germany were reunified. As a result, the political and economic system of East Germany broke down and with it the majority of its lignite production (see also section 3). The main reason was the comparably low development in labor productivity in East Germany as Figure 11 displays. The Figure shows the labor productivity development for lignite mining in East and West Germany from 1957 to 2016, relative to labor productivity in 1957. Note that the drop in labor productivity in 2002 is due to a statistical change: From 2002 onwards employees in lignite-fired power plants are included in the statistics. Labor productivity in East Germany remained nearly constant from 1957 until 1990, while it increased 2.5 fold in West Germany. Only after the Reunification did labor productivity in East Germany catch up with the levels of West Germany. The labor productivity for hard coal does not include workers in the power plants.

Within five years after Reunification, 86,000 workers lost their jobs in the former East German lignite sector. The policy in the following years was not exclusively for the lignite sector and regions but for the whole former East Germany. East Germany needed to be integrated in the common currency union with West Germany, to open itself to the market economy and to initiate a process of privatization of large parts of its economy. When creating the common currency union, the exchange rate was 1:1. This secured the interests of the population, but caused a difficult competition situation for companies in East Germany (Schroeder 2000, 128). Additionally, the internal market broke down, partly because people
preferred buying western products. The living conditions in East and West Germany were very different, which caused many people to migrate from East to West Germany after the opening of the border. The structural policy focused on creating the same standards of living in both parts of Germany to stop the migration. Due to the weak economic situation of East Germany before the reunification, the government neglected investments in infrastructure, education, buildings as well as an efficient production especially in the lignite sector. The political measures in the first years intended to erase those deficits. As some kind of “first aid kit”, the counties of East Germany received DM12 billion (€6.1 billion) via the so-called “joint effort upturn east” (“Gemeinschaftswerk Aufschwung Ost”) in 1991 (Bundespr esseamt 1991). The money was distributed with minimum bureaucratic delay on the regional level in order to fix the deficiencies from the time before the reunification. In the following years many programs followed, which were later gathered under the term “Reconstruction East” (“Aufbau Ost”). The implemented measures for East Germany focused on investment support, infrastructure and labor market interventions.

Depending on the sector and size companies were granted investment support of up to 50% of total investments. Furthermore, companies could receive loans with low interest rates. These measures had a positive effect on investments and employment in East Germany but created a capital intensive production, which prevented further job creation (Brenke, Ludwig, and Ragnitz 2011, 7f). In some sectors it even led to overcapacities. The investment support strategy intended an assimilation within the regions, and therefore funded companies in the peripheral areas. Often the regions did not implement sufficient measures to supply educated worker and research facilities, so that companies had few reasons to stay in the periphery (Brenke, Ludwig, and Ragnitz 2011, 18).

The programs for infrastructure connected East and West Germany as well as the regions within. Often the projects were implemented on a regional level and due to a lack of a sufficient planning phase some projects did not take the demographic and economic changes of the region into account. The result was that many infrastructure projects have a low utilization rate due to a lack of traffic (Brenke, Ludwig, and Ragnitz 2011, 11).

The infrastructure projects and restorations in the private and public housing sector (schools, hospitals, etc.) in combination with the investment support measures created a boom in the building sector, which created jobs but also resulted in the already mentioned overcapacities (Brenke, Ludwig, and Ragnitz 2011, 8).

Due to the transformation of the economic system in East Germany many people lost their jobs. This created high tensions on the labor market, especially in the mining areas. The government intervened with different policy measures, one of them being an option of early retirement. At an age of 55, people could receive a so-called “age transitioning payment” (“Altersübergangs-geld”) of 65% of their last net income, if they became unemployed (Buchholz 2008, 136). At the age of 60 they could receive a pre-pension payment until they

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**Figure 11. Development of the standardized labor productivity in the German mining industry**

Note: The drop in labor productivity for lignite in 2002 is due to a statistical change, as from 2002 onwards employees in lignite-fired power plants are included.

Source: Own calculation and depiction based on Statistik der Kohlenwirtschaft (2017b, 2017c, 2017d).
entered the pension fund. Furthermore, the government implemented measures of active labor market policy such as programs for retraining which 400,000 people used in the first half of the 1990s. The high demand for those programs arose due to their included social security aspects: During the retraining program, former coal workers were granted special unemployment payments and after completing the program, those who were still unemployed were able to claim further unemployment payments. Additionally, the government financed so-called “job creation measures” (“Arbeitsbeschaffungsmassnahmen”) for 360,000 unemployed people during the same period of time (Brenke, Ludwig, and Ragnitz 2011, 12). Job creation measures were low-paid jobs in order to prepare people for a regular follow-up employment. The social security aspect of the program can be evaluated as positive. However, the measures that were supposed to reintegrate the unemployed into the regular labor market mostly failed due to insufficient amount of available work as well as the perceived stigmatization for people who participated in these kind of measures and the related reduced willingness to apply actively for a regular employment (Brenke, Ludwig, and Ragnitz 2011, 12).

In East Germany, the “polluter pays” principal for the renaturation of old mines was not applied after the closure of several lignite mines. Germany—as the legal successor of East Germany—privatized the lignite production, while the responsibility for the renaturation of the former mining sites stayed with the state. Germany created the so-called “Lusatian and Central German Mining Administration Company”, which is responsible for renaturation and reuse. For a future phase-out of the rest of the lignite production, the renaturation process is supposed to be financed by the mining companies themselves. Studies, however, have contested the ability of companies to cover all upcoming costs due to too low existing provisions. Most mining companies in Germany are facing economic problems as the value of their assets as well as possible future income flows experience a downward trend. As soon as these companies generate too little income, e.g. due to the upcoming coal phase-out, it will be very difficult if not impossible for them to pay all costs associated with the renaturation. Measures on how to safeguard sufficient provisions as long as the mining companies are solvent are currently being discussed but not yet in place. They include the introduction of a public fund, foundation or laws to protect the provisions from insolvency (Oei et al., 2017).

**Directional shift in the structural policy and growing influence of the EU since the turn of the century**

In the 1990s, the German structural policy aimed at equalizing regional disparities. The main focus was on funding projects in rural areas and the periphery, neglecting an emphasis on strengthening specific sectors. Especially in East Germany, this funding strategy was not sustainable since a plan on how to develop future oriented sectoral economic structures was missing. Around the turn of the millennium, structural policy became more growth oriented, due to growing influence of the EU. Cohesion and structural funds are central instruments of EU policy and represent around a third of the EU budget (Kambeck and Schmidt 2011, 369). Cohesion policies target the reduction of disparities between various EU regions. The European Regional Development Fund (ERDF) was central for the support both in Eastern and Western mining regions. The ERDF provides the financial resources for cohesion projects in the EU, focusing on increasing the competitiveness of regions, on developing and distributing technologies and products, and the creation and preservation of jobs. Attention was shifted from independent large scale industrial projects to improving competencies in the networks of promising sectors or clusters. Cluster policy addresses the fact that there is no one-size-fits-all solution, focusing on particular strengths of the regions. Clusters are networks of enterprises, associations, research facilities and other institutions within a region (Weingarten 2010, 81). They are meant to strengthen the vertical and horizontal link of companies, suppliers and universities/research institutions. The Ruhr area, for example, declared eight so-called “lead markets”, namely health, resource efficiency, mobility, urban building & living, sustainable consumption, digital communication, education & knowledge, leisure time & events as its competencies. Money obtained though ERDF is distributed by the regions themselves to individual projects. After 2007, ERDF shifted its focus towards increasing competition and innovation. Financial support changed from being divided between regions to state-wide support schemes, which meant for the Ruhr Area that funds are now allocated by its federal state NRW.
Progress has been made in the aforementioned lead markets, and especially the southern part of the Ruhr area has experienced a positive economic development. In general, structural policy has led to new employment, increased investments, improved competitiveness and innovativeness, and investments in renaturation that have improved both living standards and environmental quality (Untiedt et al., 2010). However, a clear empirical evaluation of the successes of a single cluster and policy measure is difficult (Rehfeld 2013). For some regions it might be more helpful to break with old pathways and strengths more rapidly, building up expertise in new sectors to enable an economic system fit for the future (Rehfeld 2013). As a general lesson, cluster oriented structural policy needs to be embedded in a broader, more coherent strategy for the development of a region to be successful in the long term (Rehfeld 2005).

**End of subsidies for domestic hard coal production**

In 2007, after 40 years of hard coal production subsidies with a total volume of between €289 to 331 billion from 1950 to 2008, the federal government passed a law to end the subsidies by 2018 (Meyer, Küchle, and Hölzinger 2010, 10). The subsidies were no longer in accordance with EU law that forbids such kind of distortion of competition.

The subsidies, which initially were spent to secure the supply with domestic coal and later to prevent an economic disruption in the Ruhr area, rose from €13,500 in 1980 to €75,000 in 2005 per employee in the mining industry. These annual costs exceeded the average yearly salary of an employee (Frigelj 2009, 230). In the negotiations regarding the end date of the subsidies, the “social compatibility” stood in the center. This term paraphrased, that the exit pathway had to secure that every worker in the hard coal production either entered retirement or got a new job. None of the workers should be threatened by unemployment through the law that ended the hard coal subsidies and implicitly the hard coal production in Germany (“Steinkohlefinanzierungsgesetz”). Even after the massive decrease in the hard coal production since the 1950s, around 5 to 10% of the regularly employed in Ruhr area were still working in the mining sector. Therefore, stakeholders like the IG BCE union emphasized the disruptive effects of a too early end date. In order to decide on an appropriate end date for coal subsidies, hearings were held in 2007. The mining industry, unions and social democrats pleaded for 2018 in the debate, referring to the “social compatibility” and the time needed in the Ruhr area to adjust to the changes. The IG BCE union stated that 11,000 employees would lose their job, if the end date was 2012 (Frigelj 2009, 229). Research facilities like University Duisburg-Essen and the RWI-Leibniz Institute for Economic Research on the other hand stated, that the 2012 end date could have saved between €4 and 10 billion due to lower mining damages and less years of hard coal subsidies. The RWI proposed that those savings could be used to reeducate former employees and give them a new job in the decommissioning of the mining infrastructure (Frigelj 2009, 230). With an end in 2012 there could have been €1 million per worker to create a “socially compatible” phase-out.

Nevertheless, the powerful network of unions, the mining industry and the social democrats achieved that the end date of coal mining subsidies was set to 2018. Every worker with the age of 42 or older was secured by law against unemployment. After the end of their employment in coal mines, workers would work three years in decommissioning and then receive payments for 5 years to bridge the time until they enter the regular pension fund at age 62 in 2027 (Frigelj 2009, 229). The federal parliament estimated the total costs for the phase-out period from 2006 to 2018 at around €38 billion (Bundesregierung 2007, 11). The parliament estimated around €2 billion for pensions and mining damages and additional €7 billion for the so-called eternity costs (Frigelj 2009, 214).

Eternity costs (“Ewigkeitskosten”) are the follow-up costs of the mining activities, especially resulting from water management in the mines. As it is still unclear how many decades these costs will occur, they are called eternity costs. According to German mining law, the polluter-pays principle must be applied. Since the last mining company (RAG AG) will most likely have difficulties to pay for the eternity costs after the end of public subsidies, a foundation was established to assume the task. Therefore, the RAG AG transferred its promising chemical industry—namely the Evonik AG—into the RAG foundation. The revenues of Evonik AG and the sale of its shares is supposed to generate sufficient funds to cover the costs for the eternity burdens of coal mining. This solution is connected with a high risk, since it strongly depends on the economic liability of the Evonik AG.
Furthermore, the data to calculate the amount of eternity burdens of coal mining was supplied by the RAG AG itself, without the possibility to verify the assumed costs independently. In the case that the foundation does not manage to generate sufficient funds, the government guarantees to pay the costs.

The Ruhr area experienced a long process of decline of its coal and steel industry, beginning with the coal crisis in 1958 and the following steel crisis in the mid-70s. Over the past 50 years many different structural and societal policy measures were implemented in order to control the rate of necessary structural changes. At first, the small, locally concentrated structures around the mines needed to be cracked up. This meant, amongst other factors, investments in modern transport infrastructure to interconnect the cities within the Ruhr area. These investments were meant to increase citizens’ mobility, to enable them to travel between their homes and potential new workplaces outside the mining industry. Additionally, the opening of the first university in the Ruhr area was an important part for the region’s reorientation. However, the intended economic reorientation done by attracting new companies to the area was slowed down substantially by the resistance of the network between mining companies, politicians and unions.

The inability of industrial regions to enable an economic reorientation has been termed “lock-in” (Hospers 2004, 151; Campbell and Coenen 2017, 6f). The institutional lock-in (network of companies, politicians and unions), the economic lock-in (high dependency on the mining and steel industry) as well as a cognitive lock-in (belief that the crisis was cyclical not structural) led to persistent attempts to modernize the old structures of the Ruhr area, instead of turning to new economic possibilities.

The Ruhr area case study shows that economic reorientation worked best when new projects were related to the existing industries in the cities of the Ruhr area. Large projects from distant sectors did not prove as successful. An important step was therefore the inclusion of local stakeholders and increased regionalization in structural policy decision making. This enabled the region to benefit from its endogenous potentials and at the same time, in comparison to top-down decision making, reduced local resistance. In order to achieve that, especially in a federal state like Germany, it was necessary to create an organizational structure that represents the different cities of the Ruhr area as one entity with respect to the different political levels.

The following structural policy programs focused more on ecological and cultural aspects and increased the entrepreneurial activity in the Ruhr area (Hospers 2004, 154f). These efforts changed the perception of the Ruhr area from the outside as well as from the inside and helped it move beyond the image of a dirty industrial area. The share of people working in the secondary sector decreased from 58% in 1976 to 26% in 2014, whereas the share in the tertiary sector increased from 42% to 74%, respectively (Regionalverband Ruhr 2017c).

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6 Own calculations based on the provided data.
Lessons learned

The case study Germany illustrates that even in one country coal reduction pathways vary strongly and require different measures. Table 1 lists some of the main differences between the reduction in hard coal and lignite production in Germany. Even though the circumstances are different, the German historical experience, however, also shows that regardless of the specificity of each reduction, certain identical dimensions need to be addressed to enable a “just transition” (based on the concept by the International Labour Organization, in order to create social justice (ILO 2015, 6)). Figure 12 illustrates important aspects following the concept of the “just transition”, which need to be addressed when a region transitions from a fossil fuel-based economy to a low-carbon society in a just way. They can be divided into aspects that account mainly for the mining regions and others that have to be dealt with on a national or even supranational level. The figure lists important areas that should be addressed by policy makers in future transitions, while actually implemented measures will vary for each case study depending on regional specifics. In both the Ruhr area and Lusatia some of the aspects were addressed successfully while others were neglected. While important lessons can be identified through the two transition pathways, room for improvement is left and neither

Table 1. Differences between the Ruhr and Lusatian mining regions.

<table>
<thead>
<tr>
<th></th>
<th>Ruhr area</th>
<th>Lusatian region</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main energy carrier</strong></td>
<td>Hard coal</td>
<td>Lignite</td>
</tr>
<tr>
<td><strong>Type of mining</strong></td>
<td>Deep mines</td>
<td>Open cast mines</td>
</tr>
<tr>
<td><strong>Follow-up costs</strong></td>
<td>High costs over a long time period with an uncertain end date (“eternity costs”); mainly for water management in the former mines</td>
<td>Costs for renaturation and reuse of the vast areas of destroyed land (cost and time period easier to predict compared to hard coal)</td>
</tr>
<tr>
<td><strong>Environment/Population</strong></td>
<td>Most densely populated area in Germany, &gt;5 million people</td>
<td>Rural/peripheral area, ~1.1 million people</td>
</tr>
<tr>
<td><strong>Phase-out consequences for energy system</strong></td>
<td>Limited; coal demand covered with imports from overseas 1957-2018</td>
<td>No imports, mining and power plants are coupled; potential “domino-effects” Since 1989</td>
</tr>
<tr>
<td><strong>Time period phase-out</strong></td>
<td>Long, continuous process</td>
<td>Rapid reduction in only a few years with follow-up consequences</td>
</tr>
<tr>
<td><strong>Employment in mining</strong></td>
<td>1957: ~600,000 1967: ~290,000 1977: ~190,000 2016: ~6,000</td>
<td>1989: ~139,000 1999: ~11,000 2016: ~8,000</td>
</tr>
<tr>
<td><strong>Civil society</strong></td>
<td>Protests against coal reduction in the mining regions; Strong connection and identification with jobs in hard coal production</td>
<td>Very little ecological concerns before reunification; Reduction in coal dominated by reunification effects</td>
</tr>
<tr>
<td><strong>Reasons for mining reduction</strong></td>
<td>Comparably cheap imported oil and hard coal</td>
<td>Reunification, inefficient and costly production compared to West Germany</td>
</tr>
<tr>
<td><strong>Labor productivity</strong></td>
<td>Increased more than 4-fold since 1950</td>
<td>Almost constant from 1950s to 1990; then steep increase catching up with Western German standards</td>
</tr>
<tr>
<td><strong>Replacement of jobs</strong></td>
<td>Focus on education, the service industry and becoming a “knowledge society”; strong social security net, however, also a strong increase in unemployment</td>
<td>Replacement of coal jobs difficult due the economic and political breakdown also outside the lignite sector</td>
</tr>
</tbody>
</table>

A just transition needs to guarantee social security of the mining workers and give them and the regions a perspective away from coal mining. That means that lost jobs in the mining industry need to be replaced with new comparable jobs in other industries and sectors. In the Ruhr area, the strong influence of mining companies and the energy and steel sector resulted in high subsidies which slowed-down the decline in coal production. All employees entered either new employment or the pension fund (in combination with early retirement measures). Additional anticipative measures included retraining of the workers.

Regardless of the success of policies to ensure a more moderately-paced decline, the Ruhr area struggled for a long time to create new jobs, especially due to the coal and steel crises coinciding with the end of a period of strong economic growth. The inability to create new jobs was mainly caused by the resistance of the mining companies (compare “ground lock” in section 4.1), problems for the domestic industries caused by increasing competition due to globalization and the misjudgment of the true nature of the coal and steel crises, which prevented action towards a transition.

The Lusatian region faced and still faces the challenges of demographic changes and migration (to West Germany), which is a common problem for rural areas. The situation for Lusatia was aggravated as not only the employment in the mining sector broke down but the whole economic and political system. Also, the reduction was not accompanied by direct subsidies for the mining sector to enable a moderate decline, as it had been the case for hard coal in the Ruhr area. Instead, measures like early retirement were implemented to ease tension on the labor market in the entire East Germany. Consequently, Lusatia faces even stronger problems than the Ruhr area to attract new businesses providing local jobs.

Anticipative elements like retraining and an early communication of phase-out plans can ease the disruptive-ness of upcoming changes, by helping former coal miners to stay in the labor market and to prevent future erroneous education and employment choices. A consideration of the age structure in the German lignite sector for example shows that over 50% of the employees are older than 50 in 2017. The job decrease in an up-coming phase-out could hence be organized along the age
structure, without causing high numbers of unemployment (Sachverständigenrat für Umweltfragen 2017). Furthermore, early retraining and different education choices can alleviate problems for phase-outs not only in Germany, but also other countries. The case study of the Ruhr area further shows that at the beginning of the coal crisis, the job losses could be covered by new jobs in the metal sector, which was in a comparatively good economic condition at the time. The close relation of these industries was an important factor for the success of this shift of workers. Germany now has the possibility to shift workers from the fossil-fuel sector to the related renewable sector, the development of energy storages or the construction of electric vehicles. A move to renewable energies poses not only a challenge for the mining regions but might also be an opportunity. In 2016, the German renewable energy industry employed around 334,000 people, compared to only around 160,000 in 2004 (Burger et al., 2015; IRENA 2017). Although not all former coal workers will simply be able to transition to the renewables sector, it can enable regions to continue to play an important role in the energy sector (Agora Energiewende 2017). Especially in Lusatia, people feel left behind and not taken seriously of (inter-)national policy. Therefore, a stronger participation of various stakeholders including civil society is necessary to achieve better policy outcomes and public acceptance.

**Economy & industry**

The just transition should transform an economy which strongly relied on mining and related industries (e.g. suppliers or steel production) into a sustainable economy that ensures a decent life for people by including elements of participation and consent-based decision making. In the Ruhr area, the economy shifted from the primary sector to the tertiary sector (“knowledge society”), although, the necessary developments were prolonged for a long time in the Ruhr area, especially due to the strong resistance of coal corporations to any changes. In the beginning, mining and steel companies blocked developments by not selling their land to new enterprises. Additionally, a substantial financial amount of the structural policy packages was spent on the coal and steel industry, instead of focusing on new sectors. Nevertheless, the economy in the Ruhr area is now more diversified thanks to a reorientation towards a more participative approach in structural policy making, the polycentric coordination of national, state and regional policy making, and the majority of subsidies going to industries and sectors other than the coal and steel industries. In particular, the Ruhr area experimented with different structural policy instruments and governance structures, as previously only a limited amount of experience with structural change existed. The current approach focuses support on projects and companies within promising “lead markets” (see section 4.5). Within the Ruhr area, cities are now more independent and able to create their own development strategies. This change was necessary to reflect the individual needs of each city. For example, the city Dortmund has constructed a technology center, specializing successfully on microsystem technologies, using synergies of research and innovative companies. However, a closer look reveals that these individual and competitive strategies of the cities can result in redundant industries and projects in the Ruhr area, which prevents further growth and limits the exploitation of the regions’ economic potential (Bogumil et al., 2012). As a contrary example, the Ruhr area succeeds in coordinating different cities’ efforts in the health sector with the joint initiative “MedEcon Ruhr” (Büter 2012). The health sector in the Ruhr area employs more than 300,000 people and creates more than €5 billion in yearly revenues, focusing on applying new technologies and services. Future transitions should consider coordinating plans of cities at an early planning stage, to prevent or coordinate redundant or similar developments. A struggle during the developments of structural policy in the Ruhr area, was to identify the right system of governance to lead the transition. The first large projects initiated on a federal level were ineffective and faced regional and local resistance. Over time, decision making and planning shifted to a more regional level, to include the endogenous local potentials and to enhance approval of the transition by increasing participation of the stakeholders. The implementation of an institution representing the Ruhr area as an entity has helped to coordinate national funding but is still not fully capable of creating a coherent strategy for all cities in the Ruhr area, possibly leading to further exploitation of its (economic) potential. The Lusatin economy still suffers from the structural break which occurred after the reunification, when many industries collapsed. The region additionally faces the challenges many rural areas have (demographic changes, a lack in infrastructure, emigration, etc.). Due to a failure
to develop alternative industries, the local economy in some communities still heavily depends on lignite production. Investment support for new businesses often comes from outside the region. As a result, over the decades, projects have heavily relied on this financial and intellectual support, resulting in repeated closures of projects that cannot sustain themselves when the support ends.

The East German mining regions need additional measures besides job creation measures and investment support in order to create a sustainable economy beyond mining. Experience and knowledge with new projects and structural policy is needed to build up within the regions themselves. Additionally, the regions need modern infrastructures (transport, internet, etc.), as well as a network of education and research facilities. Attractive living conditions (cultural opportunities, leisure time possibilities, low air pollution levels, etc.) are essential not only keep its citizens but to attract new ones. In order to reverse current migration trends it is necessary to further local corporations that provide jobs fit for the future, but in a much more broad sense it is also vital that cities provide attractive places for younger people to live in. How to make local cities and villages more livable is a task that needs to be structured by local stakeholders, however, with the opportunity of (financial) support from other governance levels.

Infrastructure

In the Ruhr area, infrastructure investments were a crucial aspect of the first structural policy program “Development Program Ruhr”, since the “new economy” beyond the mining industry relied on an enhanced mobility of the people. The area now plays a major role in the logistic sector due to its links to economic centers within Europe. However, on a regional level, there is still room for improvement in the public transportation systems, as each city still possesses its own transportation company, limiting regional effectiveness (Bogumil et al., 2012). A major part in the programs of “Reconstruction East” after reunification consisted of infrastructure programs. Due to the condition of the existing infrastructure and the urgency to renew it, many projects were realized without a sufficient planning phase (demographic changes and economic development were not taken into account properly). This has resulted in a situation where many infrastructure projects are now not being used to their full potential. These failures were caused by the unique situation of the reunification and are not likely to be repeated in future infrastructure projects. Besides the traffic infrastructure, the regions (especially Lusatia) need high-speed data connections in order to create an attractive environment for companies.

Education/Research institutions

Education and research institutions can play an important role in order to enable a shift from a mining area towards a more knowledge based society. In 1965 the Ruhr area was devoid of a single university; the opening of several new universities enhanced the attractiveness of the region for companies as well as for citizens, constituting an important location factor. In 2014, 22 universities existed with more than 250,000 students (Kriegesmann, Böttcher, and Lippmann 2015). The deployment of the universities enabled a shift from the mining economy towards an economy which is based on high-value adding sectors (such as the lead markets in the Ruhr area) with increased demand for highly skilled workers and research-based innovation. The universities and research facilities need to be integrated into networks of companies and other institutions in order to create competitive and resilient structures which keep companies in the region and attract new ones. In Lusatia, only two universities exist, concentrating skills in these cities. However, due to a lack of related skilled jobs, migration after completing a degree remains a problem.

Soft location factors

Soft location factors like cultural and leisure time possibilities, but also environmental issues (air pollution levels, clean rivers, etc.) play an important role in the public perception of a region. They increase the quality of life in the region and can convince people to stay in or to move to a region. Migration is not only caused by better job options but also because of higher cultural potential of regions. In the Ruhr area, the aspect of soft location factors was neglected for a long time but with the “Action Program Ruhr” and the “IBA Emscher Park” these issues were addressed. Former industrial sites were transformed into landmarks and cultural sites in order to conserve the identification with the region but also to enable a shift towards a new, more future oriented perception. The entire migration effect is not likely to be due to soft location factors, but must be seen as a combination with job and study opportunities, trends
coinciding with the new focus on living quality: Net mi-
genrification turned after the “Action Program Ruhr” and the
“IBA Emscher Park”. Within 8 years (1987–95) 247,000
people migrated (net) to the Ruhr area, whilst net mi-
genrification stabilized after a new downward trend after IBA
Emscher Park. As a comparison, net migration from 1977
until 1986 was minus 158,000 (Regionalverband Ruhr
2017). For Lusatia, the pending renaturation, hence, not
only poses a challenge but also an opportunity to in-
crease the attractiveness of the region.

National and supranational level

Energy system
In Germany, the decline in coal production affects elec-
tricity and heat generation. The reduction in hard coal
production starting in the 1950s was replaced (and also
caused) by comparatively cheap hard coal and oil im-
ports. The decrease in the domestic production therefore
had little immediate consequences for hard coal-fired
power plants. However, the reduction of lignite mining in
East Germany caused a decline in lignite based electricity
generation of almost 40 TWh between 1989 and 1995
(which corresponds to a decline of approximately 40% of
the East German gross electricity generation). In 2017,
Germany generated more than 35% of its electricity with
renewable energies and exported more than 50 TWh of
electricity. To prevent lock-ins and resistance to a coal
phase-out, timely investments in alternative electricity
and heat generation are crucial, guaranteeing energy
security, grid stability and affordable energy prices. The
deep integration of local electricity markets into national
and EU markets facilitates the transition where not every
region needs to be energy self-sufficient. It can be attrac-
tive for former coal regions to use their expertise in the
energy sector and to move towards renewable energies,
energy storages or other innovative energy solutions.

Finance
A just transition requires financial resources and a fair
distribution of the responsibilities for the costs. Ger-
many therefore financed most of the subsidies for the
Ruhr area with the national budget. As future coal-phase
outs are mostly a political decision due to global climate
cchange concerns, costs should not be born only by the
regions but by the whole country or even the suprana-
tional level.

The consideration of the finances includes, besides the
structural policy and social policies, sufficient measures
to guarantee the polluter-pays principle, also in line with
the German mining law. In both the hard coal and lignite
phase-out, the state is at risk to bear shares of the (eter-
nity) costs. For hard coal mining, a foundation to secure
the provisions was implemented, however whether the
funds will be sufficient remains to be seen. In East Ger-
many, the state bore the full costs for the recultivation.
After the reunification of German, the responsibilities for
environmental damages were socialized whereas the lig-
nite companies were privatized. In a future lignite phase-
out, Germany (and other countries) need to implement
measures which secure the polluters-pay principle. Possi-
bilities include the introduction of a public fund (analog
to the nuclear sector in Germany), a foundation (analog
to hard coal sector in Germany) or laws to protect at
least the provisions which mining companies have built
up so far from insolvency. Securing sufficient funds needs
to be ensured as fast as possible before the regular min-
ing business ends (see also Oei et al., 2017).

Transfer to other countries and future phase-outs
As the hard coal and lignite reduction have shown, the
situations are different from case to case and therefore
policies guiding the transformation need to be adjusted
to the respective circumstances. In East Germany the
circumstances were unprecedented since the drastic re-
duction in lignite mining was accompanied (and caused)
by the German reunification, resulting in a breakdown of
the whole economic and political system. This should be
taken into account when assessing the consequences of
the lignite reduction and the effect of structural policies.
The case of the Ruhr area is special, as future reductions
in coal mining are not likely to be granted a similarly
long time period for a phase-out. Germany conserved (a
shrinking share) of its hard coal production for more than
60 years with subsidies. The implementation of subsidies
on a similar scale in other countries and future phase-
outs is unlikely for several reasons. Firstly, in principle,
such a market interference is forbidden after 2018 at
least for all EU countries by European law. Secondly, the
total amount of subsidies for domestic hard coal is diffi-
cult to quantify as they consist of direct subsidies, infra-
structure investments, labor market interventions, etc.
Nevertheless, Germany spend more than € 330 billion
on direct and indirect hard coal subsidies, to an extent
that will be hard for other countries to replicate. Thirdly,
the subsidies in the Ruhr area supported a German company that was interconnected on the regional level, since politicians were holding positions within the firm and cities were shareholders of the company. The acceptance of change among the citizens of the Ruhr area (and Germany) might therefore have been somewhat more difficult than for other countries where foreign mining companies often exploit the resources and export them abroad. Fourthly, ecological consciousness and especially concerns about potentially devastating consequences of climate change are widespread, making subsidies to extend the lifetime of fossil fuel exploration (like in the beginning of the transition in the Ruhr area) more difficult.

In the past, a strong identification and pride existed among workers (and entire regions) with the manly, tough and often dangerous mining job, thought to be essential for economic development. This, along with the influence of powerful unions, helped to prevent a faster transition away from coal. However, the perception of coal mining as an attractive and necessary job is fading, which might facilitate the transition away from coal in other countries, especially when other well paid jobs are available.

The structural policy of the Ruhr area showed that single large projects were not able to replace the mining (and steel) industry and instead faced resistance within the region. Former mining cities had individual needs that needed to be addressed independently. Therefore, the level of decision making shifted more and more from a centralized national level to a regional one. Today, there exists an institution which conceptualizes development strategies for the entire region, coordinating bottom-up strategies from within the various cities themselves. Such an institution might help to guide future phase-outs as well to limit the bureaucratic friction (especially in a federal state like Germany when mining areas cross borders) and improve the participation of relevant stakeholders. The endogenous potential of the region might be exploited better and the transformation as such becomes more consent based.

From an energy system’s point of view, the transformation has become easier and cheaper for other countries than it was for Germany in the past. The cost of renewable energy technologies has decreased significantly in the last decade, and is now just a fraction of the price compared to when Germany started deploying photovoltaics and onshore wind on a large scale. The ongoing development and installation of renewables in Germany threatens the economic and technical feasibility of its coal-fired power plants. The inflexibility of coal-fired power plants limits their application in energy systems mainly based on volatile renewables. Many studies have successfully modelled energy systems that are entirely based on 100% renewables not only for Germany but for the global energy system (Fraunhofer ISE 2012; Jacobson et al., 2017; Löffler et al., 2017).

Germany’s two examples of reducing coal mining provide valuable lessons learned but also illustrate the difficulties of structuring a phase-out without negative consequences for employees, companies and entire regions. An important lesson from Germany’s past experience is that it is not only necessary to have policies addressing unemployment, the economy and the energy system, but also measures to improve former coal regions’ infrastructure, universities and research facilities as well as soft location factors like culture and environmental health. The German example suggests that implementing a fair and realistic transition from a fossil fuel-based economy can be managed when city, regional, national and supranational governments work together on designing a phase-out and a multi-level polycentric structural policy mix. The historical case study further shows that the majority of coal’s decline in Germany (but also in many other European countries) has already happened. The upcoming remaining transition can succeed when past experiences with structural policies and social security systems are considered, along with the incorporation of affordable alternative forms of energy generation and other promising innovative sectors providing new job opportunities for people in the affected regions.
References

COAL TRANSITIONS: RESEARCH AND DIALOGUE ON THE FUTURE OF COAL

*COAL TRANSITIONS* is a large-scale research project leaded by Climate Strategies and The Institute for Sustainable Development and International Relations (IDDRI) and funded by the KR Foundation.

The project’s main objective is to conduct research and policy dialogue on the issue of managing the transition within the coal sector in major coal using economies, as is required if climate change is to be successfully limited to 2°C.

**THIS PROJECT BRINGS TOGETHER RESEARCHERS FROM AROUND THE GLOBE, INCLUDING AUSTRALIA, SOUTH AFRICA, GERMANY, POLAND, INDIA AND CHINA.**

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