Coal phase-out and just transitions

Lessons learned from Europe

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NEW CLIMATE INSTITUTE

November 2022

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Project number
220013

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Summary

All scenarios compatible with meeting the Paris Agreement's 1.5°C temperature limit require a rapid decline in coal use. This transformation requires an enormous shift in resources and employment, creating the risk of stranded workers, communities, and corporations. Governments should allocate sufficient resources to support the groups who bear the greatest risk of the transition.

Countries that are now planning a just transition away from coal can learn from experiences of historic and ongoing coal transitions in Europe. This report examines the impact of coal transitions on the workers, communities, and corporations in several European countries and explores the processes, policies, and programmes implemented to manage the transition. Lessons are distilled from the case studies with consideration of case-specific contexts.

The decline of the coal industry has, especially in monolithic economies, left a massive gap in the labour market. Countries have experimented with a broad range of policies and programmes to manage this structural change, with many similarities across cases. This experimentation provides valuable insights into which measures worked, which didn't, and why.

Ultimately, former coal regions still lag behind national statistics for health, economic growth, and employment. Economic regeneration depends on the ability to attract new businesses and retain the region's youth and skilled workers. This has been particularly challenging in rural areas with poor transport and educational infrastructure.

Measures to support workers succeeded in limiting increases in poverty and unemployment but widely failed to reorientate workers to secure jobs. Early retirement has been one of the main instruments used to manage the labour market shock both in cases of faster, unplanned transitions and slower planned transitions. Careers services were generally poor in quality and coverage. Valuable lessons can be learned from the Skills Development Scotland service, which provides a comprehensive careers service that is also reactive to regional labour markets and integrated into regional development planning.

Visioning and participation were key to the process of managing structural change in coal regions. Approaches with bottom-up project identification and implementation, and top-down financing and coordination, have shown the greatest success in Europe. Local and regional expertise is used to identify opportunities and implement projects, which in turn fosters a sense of ownership of the transition.

Investment in education and transport infrastructure were key enablers for economic restructuring, particularly in rural regions. Investment in transport infrastructure also created short-term jobs and allowed people to commute greater distances, thus increasing the chance of finding employment. Investment in education laid the foundation for innovative new business streams that created secure, high-wage jobs.

Environmental restoration was paramount to just transition efforts and had several cross-cutting benefits – it improved quality of life, reduced outward migration, attracted new businesses, and created temporary jobs suitable for ex-miners, and in the case of the Ruhr and Lusatia it was the foundation of a new core industry in environmental services.

Due to the planned nature of China's coal phase-out, the prospects for a just transition are greater than in the historical cases seen in Europe. Historical coal transitions in Europe were driven by strong economic forces and resulted in the rapid decline of the coal industry in a number of years, in communities that were heavily dependent on coal in terms of GDP and employment. China has the opportunity to proactively plan its just transition from coal and can learn from experiences from both historical and ongoing coal transitions in Europe.

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1 Introduction

The global momentum for phasing-out coal is increasing. One of the core objectives of the United Nations Framework Convention on Climate Change 26th Conference of Parties (UNFCCC COP26) was "consigning coal power to history" (UK Government, 2021). The conference saw more than 40 countries pledge to end all investment in new coal-fired power generation domestically and internationally, and phase-out coal in the 2030s for major economies and in the 2040s for developing countries. This is an important step but falls short of what was agreed internationally.

All scenarios compatible with meeting the Paris Agreement's 1.5ºC temperature limit require a rapid decline in coal use (IEA, 2021d). The International Energy Agency estimate that global unabated coal use in the energy sector must fall by 55% by 2030 and be phased out entirely by 2040 to reach net zero emissions by 2050 (IEA, 2021c).

The transformation from fossil-fuels to renewables and other decarbonised energy sources in our energy systems requires an enormous shift in resources and employment. While this transition has huge potential for new jobs and economic growth, the new opportunities are not necessarily available to those who will lose their jobs in the fossil-fuel industry (IEA, 2021c). The transition therefore creates significant risk of stranded workers and communities.

The discourse around phasing out coal has increasingly involved the concept of justice. Justice literature broadly concerns the access to resources, involvement in decision-making processes, and fair distribution of benefits and burdens (Fraser, 1999). The term "just transitions" emerged in the 1980s from organised US labour and environmental groups that advocated for public policy that protects both workers and the environment.

A just transition must ensure environmental sustainability and facilitate sustainable development, while providing access to decision-making processes and fairly distributing the benefits and risks like shifting employment (Just Transition Initiative, 2020). Governments should allocate sufficient resources to support these workers and communities who bear the greatest risk of the transition (Just Transition Centre, 2017). The focus on these groups can come at the expense of the bigger picture: Sustainability transitions aim to address the myriad of injustices caused by the fossil fuel regime, concerning intergenerational, social, health, environmental, and gender justice.

While the concept was initially confined to domestic policy-making, it later became widely used at the international level in the context of global climate change mitigation efforts and the energy transition. The concept entered international climate negotiations at COP15 in Copenhagen and was later incorporated into the historic Paris Agreement at COP21 in 2015. Just transition declarations were made at COP24 in Katowice and at COP26 in Glasgow, aiming to support "green growth, decent work, and economic prosperity in the transition to net zero" (UNFCCC, 2018, 2021).

Countries that are now planning a just transition away from coal can learn from experiences of historic and ongoing coal transitions in Europe.

This report examines the impact of coal transitions on the workers, communities, and corporations in several European countries and explores the processes, policies, and programmes implemented to manage the transition. The analysis considers both the production and consumption of coal where possible, mainly in the energy and industry sectors. Lessons are distilled from the case studies to provide valuable insights for two partner provinces in China - Shandong and Inner Mongolia. The main research questions are as follows:

- How have coal transitions impacted regions in Europe? What structural change has been observed and how has it been managed?

- What kind of policies, programmes, and processes have been used to support workers, communities, and corporations? What are the success and failure factors?
- What are the key lessons that can be drawn from experiences with historical and planned coal transitions at the regional/ local level in Europe, that may be useful in the context of the challenges faced in Shandong and Inner Mongolia?

The experiences from Europe are embedded in specific technical, economic, political, social, and cultural contexts. Case study regions are chosen based on data availability, and where possible aim to represent a range of contextual dimensions. The first phase of research will investigate coal transitions in the Ruhr area (Germany), Lusatia (Germany), the United Kingdom, and Spain. The cases of Germany and the UK are particularly interesting due to the large body of research on coal transitions and structural change at the subnational level. In the second phase we will add several cases from Poland and Eastern Europe. Together these cases will cover planned and historical transitions across a range of economic, social, and political contexts, providing a broad overview of experiences with coal phase-out in Europe.

The report is structured as follows: Chapter 2 provides background information on the status of coal use, coal phase-out plans, and just transition measures in several European countries and China, leading to the selection of case study regions. The methodology is then discussed in Chapter 3. Several case studies are described in Chapter 4, followed by an analysis of common lessons in Chapter 5 and conclusions and outlook in Chapter 6.

2 Background

2.1 Coal use, phase-out, and just transition in Europe and China

European Union

The EU is still a major consumer of hard coal and lignite, which are predominantly used for power generation - 53% of the hard coal and 93% of the lignite consumed by the EU in 2019 were used to generate power (Eurostat, 2021). Germany is the largest consumer of lignite in the EU, accounting for 44% of total EU consumption in 2020, followed by Poland (19%), Czech Republic (12%), Bulgaria (9%), and Romania and Greece (both 6%) (Eurostat, 2021). Many member states produce lignite for domestic consumption, while relying entirely on imports for hard coal as Poland and Czech Republic are the only two EU member states to still produce hard coal.

The share of coal-fired power generation dropped from 40% in 2015 to 20% by 2020 (Agora Energiewende and Ember, 2021). The EU has made positive steps in halting new coal capacity – by 2021 Poland was the only EU member state with new coal capacity in development, with two small plants in the commissioning phase and one in the planning phase (EMBER, 2021).

Three member states, Austria, Belgium and Sweden, phased-out coal-fired power generation by 2020, bringing the total to nine member states (six member states never installed coal plants: Cyprus, Estonia, Latvia, Lithuania, Luxembourg, and Malta). Coal phase-out plans have been announced in 14 member states and are under discussion in the remaining four member states (Table 1).

The European Green Deal aims to accelerate the EU's transition to net-zero emissions by 2050, while facilitating continued economic growth and ensuring that no people or communities are left behind (European Commission, 2020). The Just Transition Mechanism (JTM) aims to mobilise at least €65-75 billion between 2021 and 2027 to support the structural transformation of the carbon-intensive regions most affected by the transition (European Commission, no date b). The JTM has three pillars: the Just Transition Fund (JTF), the InvestEU "Just Transition" scheme, and a new public sector loan facility.

Table 1: Coal phase-out in the EU and United Kingdom

Phased out (3)	Phase-out decided (14)	Phase-out in discussion (4)
Austria (2020)	Denmark (2028)	Bulgaria (draft proposals for 2035, 2038, 2040)
Belgium (2016)	Finland (mid 2029)	Croatia (2040)
Sweden (2020)	France (2022)	Czech Republic (2038)
	Germany (end 2038)	Slovenia (draft proposals for 2033, 2038, 2042)
	Greece (2028)	
	Hungary (end 2025)	
	Ireland (2025)	
	Italy (2025)	
	Netherlands (end 2029)	
	Poland (2049)	
	Portugal (end 2021)	
	Romania (2032)	
	Slovakia (2030)	
	Spain (2030)	
	United Kingdom (2024)	

Germany

Until 2020 Germany was the world's second largest producer of lignite (after China), producing around 100 Mt in 2020 (European Comission, 2021). Production is concentrated in three mining districts: the Rhenish district in North Rhine – Westphalia (NRW), the Lusatian district in Brandenburg and Saxony, and the Central German district in Saxony and Saxony-Anhalt (Clean Energy Wire, 2019). Hard coal mining was concentrated in two districts: the Ruhr and Saarland. Hard coal production declined continuously since the 1960s due to increasing costs and the removal of subsidies in 2007 (Oei, Brauers and Herpich, 2019). Germany's last hard coal mines were closed in 2018.

The coal phase-out in Germany has been a very slow process, in part due to Germany's decision to phase-out nuclear power following the Fukushima nuclear disaster. The strong growth in renewables offset the decline in nuclear power generation and left a significant role for coal, which accounted for 26% of the mix in 2020 (IEA, 2020).

The Commission on Growth, Structural Change and Employment was introduced to envisage the coal phase-out in Germany under increasing pressure from the EU and civil society to strengthen climate mitigation efforts, and from coal regions demanding financial support (Federal Ministry for Economic Affairs and Energy (BMWi), 2019). The resulting plan was enshrined in law in 2020 through the Coal Phase-Out Act, which enforces the gradual reduction of coal-fired power generation, with a complete phase-out by 2038 at the latest (Die Bundesregierung, 2021). This was accompanied by the Structural Support for Coal Regions Act, which provides up to €40 billion to support just transition efforts.

Spain

Spain's production of hard coal was concentrated in the provinces of Asturias, Palencia, Teruel, and Leon, while lignite production, which ceased in 2007, was concentrated in Galicia. Coal production has been declining steadily since its peak of around 40 Mt/year in 1986 (BP, 2021). By 2020, coal supplied just 3% of Spain's total energy and 2% of its electricity (IEA, 2021b).

Spain's Just Transition Strategy was announced in 2019 and aims to address the negative outcomes of the coal phase-out. This is a reactive, participatory process, that outlines measures and plans for the economic development of previous coal regions (MITECO, 2019).

The United Kingdom

Coal production in the UK has been declining since its peak of 292 Mt/year in 1913 and stood at just 2.17 Mt in 2019. In the power sector, the share of coal in the generation mix declined steadily from over 60% in 1990, to around 40% in 2012, and then declined steeply to 2% in 2020 (IEA, 2020).

The phase-out of coal in the UK was not a purpose-driven process but the result of declining export markets, shifting political and public support, and worsening economics in the face of competition from renewables and the carbon tax that was introduced in 2010 (Fothergill, 2017). In 2015 the UK became the first country to agree to phase-out unabated coal power generation. Ahead of COP26, the UK government announced that the coal phase-out deadline will be brought forward from 2025 to 2024.

The British coal industry began its steep decline far before the idea of 'just transitions' entered public and political dialogue. Coal mining communities were hit very hard by sudden mine closures and received very little immediate support from the government. Efforts to manage the negative impacts of the declining coal industry were purely reactionary and have had varying degrees of success. Former coal mining communities still show significantly lower welfare than the rest of the country (Beatty, Fothergill and Gor, 2019).

China

China is the largest producer of coal in the world, accounting for over 50% of global production in 2020 (81 EJ) (BP, 2021). Coal plays a major role in China's electricity sector, accounting for around 64% of the mix in 2020 (IEA, 2020). As of late 2021, China had 1,047 GW of coal capacity in operation, 97 GW under construction, and a further 153 GW in the planning phase (EMBER, 2021). The capacity under construction accounts for almost 53% of the global capacity under construction, while the planned capacity accounts for 55% of the global pre-construction pipeline (EMBER, 2021).

Due to China's scale, provinces are the most comparable level to European countries. China has a comparable area to Europe (around 10 million km^2) but has around double its population at 1.4 billion people in 2020 (World Bank, 2021).

At the provincial level, Shandong and Inner Mongolia have the two largest capacities of operational coal-fired power plants, at 98 GW and 93 GW in 2021, respectively (Inner Mongolia Autonomous Bureau of Statistics, 2021; Shandong Provincial Bureau of Statistics, 2021).

Coal phase-out is part of China's target to become carbon neutral by 2060. Coal consumption is planned to peak before 2025 and by 2060 all unabated coal will be completely phased out. In April 2021, President Xi Jinping announced at the Biden Leaders Climate Summit that China will "strictly control coal consumption" over the next 14th Five-Year Plan (FYP) period (2021-2025) and will "phase down coal consumption" in the next 15th Five-Year Plan (FYP) period (2026-2030) (Climate Action Tracker, 2021).

2.2 Context of Shandong and Inner Mongolia

Shandong is a densely populated urban region with 101.5 million inhabitants (larger than Germany) at 646 inhabitants/km^2, while Inner Mongolia is a sparsely populated rural region over three times the area of Germany with 24 million inhabitants at 20.7 inhabitants/km^2. The GDP per capita of both Inner Mongolia and Shandong reached around 72,000 CNY in 2020 (around €10,000) (Inner Mongolia Autonomous Bureau of Statistics, 2021; Shandong Provincial Bureau of Statistics, 2021).

Inner Mongolia is China's second largest coal producer – production here is an order of magnitude greater than in Shandong. In 2020, Inner Mongolia and Shandong produced 1,026 Mt and 74 Mt, respectively (Inner Mongolia Autonomous Bureau of Statistics, 2021; Shandong Provincial

Bureau of Statistics, 2021). Coal accounts for over 95% of energy production in Inner Mongolia and 62% in Shandong.

Despite the scale of Inner Mongolia and Shandong's coal industries, neither region have monolithic economic structures (Table 2). For both regions, around 10% of the GDP comes from the agriculture sector, 40% from industry, and 50% from the service sector. Nonetheless, coal-related industries like mining, power generation, and coal chemicals make up a significant portion of regional GDP.

Table 2: GDP per sector for Inner Mongolia and Shandong in 2019 (Inner Mongolia Autonomous Bureau of Statistics, 2021; Shandong Provincial Bureau of Statistics, 2021)

Sector	Inner Mongolia		Shandong	
	GDP (billion CNY)	Share (%)	GDP (billion CNY)	Share (%)
Agriculture	1863	11	5117	7
Industry	6763	39	28172	40
Services	8586	50	37252	53
Total	17213	100	70541	100

The mining and the electricity, heat, gas, and water supply sectors do not account for a large share of employment in either province – these sectors each account for 5% of total employment in Inner Mongolia and just 3% in Shandong. Sectoral employment shares follow a similar distribution - the service sector is the largest employer, followed by the industry and agriculture sectors, where agriculture account for just a few percent of the work force in Inner Mongolia and less than a percent in Shandong (Table 3).

Coal is the dominant source of energy consumption in both provinces. Most of the coal consumed in Shandong is used for electricity (77%) and the remainder is used in industry (23%) (Shandong Provincial Bureau of Statistics, 2021). No data is available for the split of coal end uses in Inner Mongolia.

Shandong has a relatively strong base for economic restructuring. Economic and technological development areas (EDAs) were introduced in early 1990s to encourage growth in new sectors including IT, new energy, advanced equipment manufacturing, new materials, biotechnology, and medicine. In 2019, Shandong and Inner Mongolia had 152 and 54 institutions offering higher education, equivalent to 1.5 and 2.6 knowledge institutes per million inhabitants, respectively (Inner Mongolia Autonomous Bureau of Statistics, 2021; Shandong Provincial Bureau of Statistics, 2021).

The phase-out of unabated coal in Shandong and Inner Mongolia is driven by national climate change mitigation efforts and is core to achieving China's target to become carbon neutral by 2060. The "phase-down" of coal consumption is outlined in the 14th FYP (2021-2025) and 15th FYP (2026-2030) (Climate Action Tracker, 2021).

Finally, the business environment in China's heavy industries is a mix of large state-owned companies, their subsidiaries, SMEs, and private companies. Activities of local state-owned enterprises (at the provincial and municipal level), private companies and SMEs are not closely tied to the national level of governance. In Shandong and Inner Mongolia, SMEs and private companies provide a significant portion of industrial employment.

Table 3: Employment by sector in Inner Mongolia and Shandong in 2019 (Inner Mongolia Autonomous Bureau of Statistics, 2021; Shandong Provincial Bureau of Statistics, 2021)

Sector	Inner Mongolia		Shandong	
	Employment (10,000)	Share (%)	Employment (10,000)	Share (%)
Agriculture	8.6	3.1	1.2	0.1
Industry	72.8	25.9	479.8	44.8
Mining	14.5	5.2	29.7	2.8
Manufacturing	30.8	11.0	271.7	25.3
Electricity, heat, gas, and water production and supply	14.6	5.2	27.9	2.6
Construction	12.9	4.6	150.5	14.0
Services	199.7	71.0	591.0	55.1
Total	281.1	100.0	1072.0	100.0

3 Case study methodology

The just transition cases are structured along four main elements: context, measures, process, and outcomes. Each of the four elements include several dimensions as set out in Table 4 and further described below.

Table 4: Case study framework

Context	Measures	Process	Outcomes
Economic Social Political Transition drivers	Workers Communities/regions Corporations	Approach Participation Vision	Quantity & quality employment Economic restructuring Process-related

Context

The economic, social, and political context of each case shapes the drivers, challenges and opportunities for the just transition. A key challenge of this research is how to distil valuable insights from transitions embedded in the developed country context, to inform the just transition planning in the context of China, which can be characterised by fewer economic resources and limited social safety measures.

Experiences and lessons learned from coal phase-out in European regions must be carefully discussed in relation to their specific contexts, while also understanding the specific contexts of Shandong and Inner Mongolia.

A typology, based on the work of Reitzenstein *et al.* (2021), is developed to capture some of the key framework conditions of cases and support the high-level understanding of similarities and differences between case study regions (Table 5). Relevant elements that fall outside of this typology are discussed where necessary.

The type of coal determines the level of dependency of mines on regional consumers – lignite mines are dependent on local consumption as lignite transport is uneconomical – this interlinking increases the risks of job losses (see (Reitzenstein *et al.*, 2021)). Population density strongly influences the options for attracting new businesses and skilled workers. We consider three dimensions of coal dependency where possible – GDP, employment, and energy. The 'knowledge base' element aims to capture the 'readiness' of a region to restructure towards innovative, future-oriented sectors. The number of universities and the expenditure on R&D are two widely available indicators. Finally, the 'transition intensity' element aims to capture the time and scale dimensions of coal transitions by measuring the rate at which coal production declined (or is planned to decline). This is calculated by dividing the decline in annual coal production by the length of the transition (Mt/year^2).

Table 5: Typology

Coal type	Population density	Coal dependency	Knowledge base	Transition intensity
Hard coal Lignite	Population/area	GDP Employment Energy	# Universities Research expenditure	Decline in production/ time

Measures

This element refers to policies and programmes implemented to support the transition. We organise the policies and programmes by their target group - workers, communities and regions, and corporations (Fothergill, 2017; Brauers *et al.*, 2018; Green and Denniss, 2018).

Process

This element considers the nature of the approach (top-down/bottom-up) and who is included and excluded from the measures identified (participation). Where possible, the underlying vision behind periods of policies and programmes will be discussed – this was identified as a key lesson from the Ruhr case (Fischedick, 2021).

Outcomes

This research will focus on the just transition outcomes, looking at the impact on workers, communities and regions. The number and quality of jobs created are key indicators. While high-level figures can provide useful insights into the overall structural change process, attention needs to be given to who benefits from the creation of new jobs – whether ex-miners are able to gain employment with decent wages and job security. This analysis, however, is dependent on the availability of detailed case studies.

High-level figures of employment level, GDP per capita, and population, are useful indicators for the general outcome of the transition process – whether the collective set of policies and measures have been able to foster the economic restructuring necessary for the long-term health of the region. Where possible, the outcomes of specific measures will be discussed, and used to draw lessons learned from each case.

4 Case studies

4.1 Case 1: Ruhr area, Germany

4.1.1 Context

The Ruhr region in northwest Germany is characterized by significant reserves of hard coal (Figure 1). The region has been a hub for European coal and steel production since the mid-1800s, growing from just 400,000 inhabitants in 1850, to over 5 million today. The Ruhr area can be classified as a high-density industrial area with 1,150 inhabitants/km^2 in 2017 (Stognief *et al.*, 2019).

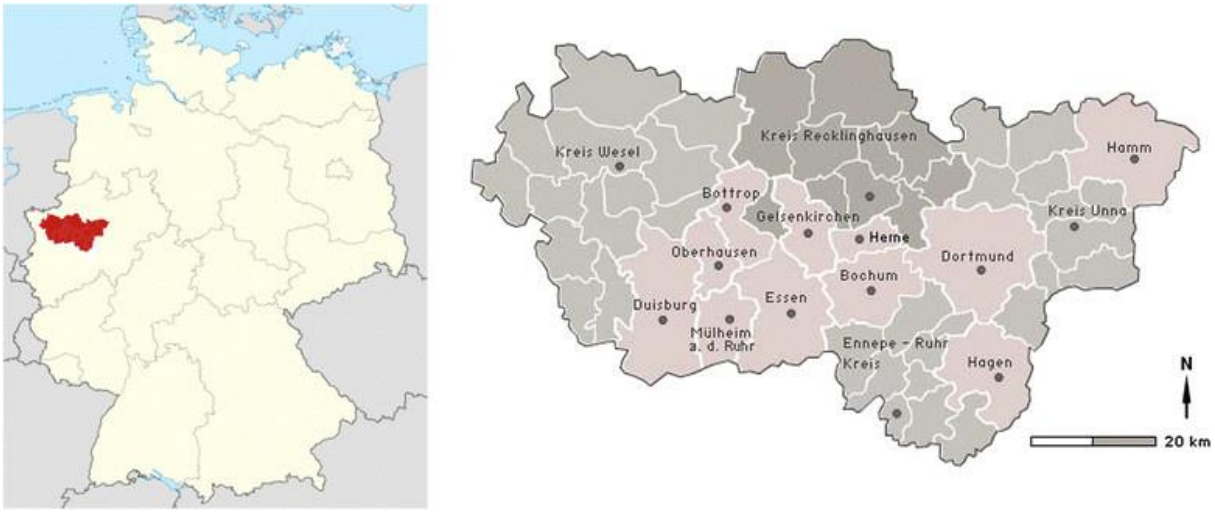

Figure 1: Map of Ruhr area (Viétor, Hoppe and Clancy, 2015)

Hard coal was central to West Germany's economic, social, and political reconstruction after the Second World War. In 1957, around 600,000 people were directly employed in the hard coal mining industry, while many more benefited from indirect employment opportunities (Figure 2). **Employment in the Ruhr's coal and metal industries amounted to over 800,000 in 1957, accounting for around 70% of total employment in the region** (Schepelmann, Kemp and Schneidewind, 2016; IRRC, 2019). Hard coal production was concentrated in four regions, of which the Ruhr was the largest, producing over 120 Mt/year (Oei, Brauers and Herpich, 2019).

Coal provided more than 70% of primary energy consumption in 1950 and over 60% of electricity generation by the late 1950s (AG Energiebilanzen e.V., 2017).

The region's economy developed a monolithic structure around coal production and coal consuming heavy industries. These production industries accounted for around 50% of the regional GDP in 1980 (Dahlbeck *et al.*, 2021).

Coal mining became a central aspect of the Ruhr area's identity due to the importance of the sector during Germany's rebuilding after the war and the dominance of the sector in the regional economy in terms of revenue and employment.

The Ruhr had a weak base for economic restructuring in 1960 – the region was dominated by a few very large companies related to the coal industry and had very few SMEs. The education system in the region was also weak, with no higher-level technical schools or universities prior to 1961.

The rapid decline in hard coal production was driven by economic factors – the liberalization of coal prices in 1958 started the 'coal crisis', where hard coal production and employment fell rapidly due

to intense competition from the global coal market and from oil, which began to substitute hard coal in the heating sector. While significant shocks were experienced, the full transition was slow, lasting around 60 years, with an average annual decrease in coal production of 2 Mt/year.

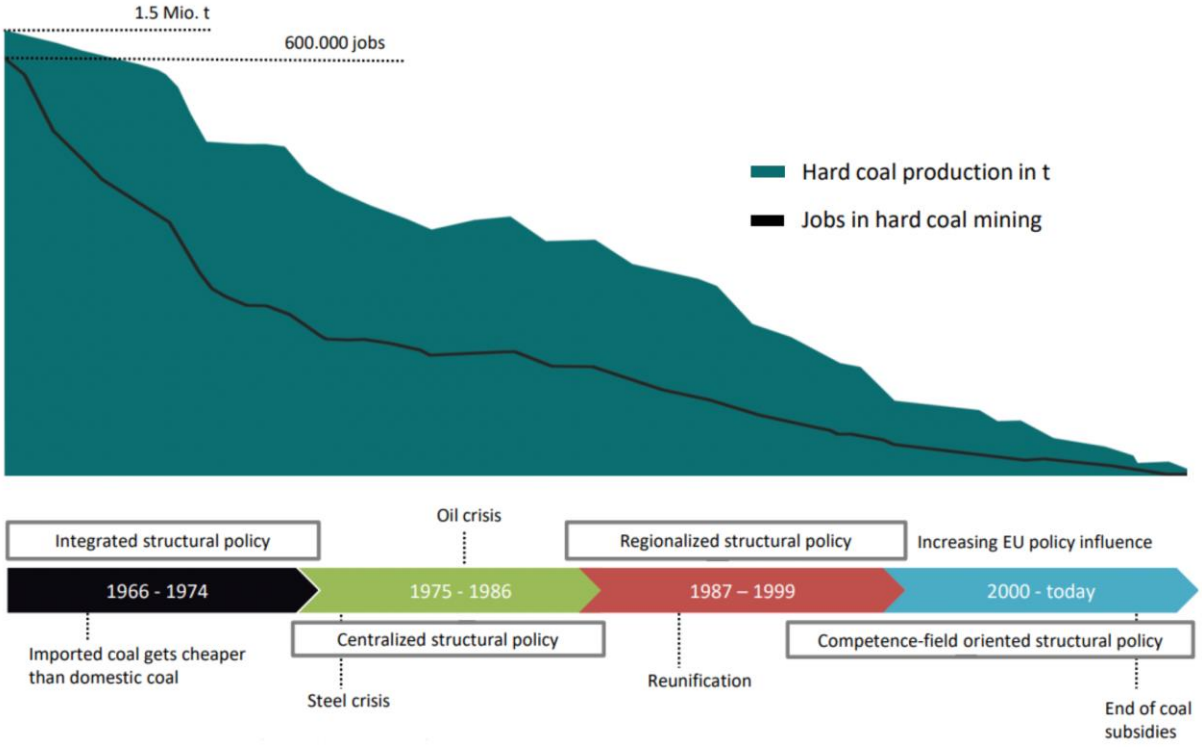

Figure 2: Coal production and employment in the Ruhr area throughout changing structural policy regimes (Fischedick, 2021)

The cost of hard coal production continued to increase throughout the 20th and early 21st century – between 1950 and 2008, subsidies to support the industry amounted to €289-331 billion (Meyer, Küchle and Hölzinger, 2010). In 2007, under increasing pressure from the EU, Germany agreed to end subsidies for hard coal production. By 2018, the last hard coal mine in the Ruhr was closed.

4.1.2 Measures

Many measures have been implemented since the hard coal mining industry started to decline in the mid-20th century. Over time the strategy has shifted from supporting the industry, believing in a future rebound, to supporting the structural transformation of the Ruhr's economy. An overview of measures is shown in Table 10 (Annex).

Workers

During the rapid decline of the coal industry in the 1960s, many workers were able to gain employment in the expanding coal-consuming metal industries that were unaffected by the shift from domestic to imported coal (Nonn, 2001). Workers who lost their jobs were supported by a variety of social protection programmes that were introduced by national and regional policy. **The programmes included redundancy payments, compensation programmes, re-adaption programmes, early retirement, and pension contributions.** These programmes amounted to €18 billion between 1968 and 2020 (see Table 10 in the Annex) (Taylor, 2015). Regional unemployment was successfully limited in the 1960s due to the availability of work in related sectors, coal subsidies, and social support measures.

The coal and steel industries were hit hard in the 1970s by the world oil and steel crises. Measures in this period aimed to create jobs in both the declining coal and steel industries, and new sectors (see *Corporations*).

The gradual phase-out of hard coal mining ensured that the majority of workers had reached retirement age by the time of the final mine closure in 2018. Early retirement and pension contributions have been the largest support programmes for former coal miners (Storchmann, 2005). This financial support is managed through the instrument of adjustment money (APG).

Communities/regions

Integrated structural policy was introduced at the national level in 1966, focusing on education, research, mobility, and leisure. **In the case of the Ruhr area, improved connectivity to neighbouring cities not only prevented the migration of workers, but also increased the region's attractiveness to new industries** (Bogumil *et al.*, 2012). The region's first universities were founded in Bochum, Dortmund, and Duisburg-Essen in the 1960s. **The establishment of universities was key to facilitating the innovation programmes that drove the economic restructuring in the following decades**.

⟩⟩ Investment in transport and educational infrastructure are key to facilitating economic restructuring

From 1987 structural policy became increasingly regionalised, focusing on programmes in line with the regional vision of ecological reconstruction (Fischedick, 2021). **The creation of innovation centres, like the Dortmund Technology Park in 1985, supported economic restructuring by bringing technology-based activities to the area.** The Park started as a start-up incubation hub at Dortmund university and hosted manufacturing firms across several new sectors including IT, logistics, and environmental management technology. By 2013, the Park had 300 companies and employed around 8,500 people (Taylor, 2015). However, older workers who lost their jobs from the declining coal and steel industry did not benefit greatly from this programme since most opportunities were offered to the younger generation, particularly university graduates (Hospers, 2004).

The Emscher River development programme is often cited as a key example for economic restructuring in the 1980s and 1990s. **The programme sought to regenerate the region's landscape that was characterised by heavily polluted and degraded land and water systems, abandoned mines, and vacant factories** (Schepelmann, Kemp and Schneidewind, 2016)**.** Over 120 projects were implemented under the programme, totalling around €2.5 billion, of which around one third was from the private sector. Crucially, the programme successfully implemented the new bottom-up development approach, which has been the core of subsequent programmes (discussed below).

⟩⟩ Environmental restoration increases the attractiveness of the region, which can help to attract new businesses and prevent outward migration, while creating short-term employment opportunities

Since the 2000s, programmes have been focused on the creation of 'clusters' - networks of companies, NGOs, research institutions, and political actors, across the entire value chain of new business streams (competence-based structural policy). **Clusters connect industry and academia, and channel the economic and political support to drive innovation in these new business streams.**

Economic restructuring was also driven by the private sector. InitiativKreis Ruhr, an alliance of 70 of the largest companies in the region, was founded in 1989 with the goal of sustainably strengthening

the future prospects and competitiveness of the region. InnovationCity Ruhr (2010) is one of its hallmark projects, aiming to develop innovative ideas on how to meet the challenges of climate and structural change in urban areas. The competition-based tender was won by Bottrop city, which aimed to halve carbon dioxide emissions in 10 years and reorientate the local economy away from coal, which had been central to the economy for the past 150 years. The city became Germany's first city lab for experimental solutions to climate-friendly urban development. Over 300 projects were implemented, focusing on energy efficiency and renewable energy. After successful results, the NRW state Ministry of Economic Affairs, Innovation, Digitalisation and Energy are channelling resources through the ERDF to support a rollout of the InnovationCity model in 20 other districts in the Ruhr area.

The increasingly collaborative approaches are exemplified by the 'In4climate.NRW' initiative (2018), a **multi-stakeholder collaboration between the NRW state government, industry, and academia, aiming to develop strategies and technologies for sustainable, climate-neutral industry in the long-term, thereby aligning regional development activities with national objectives** (State of North Rhine-Westphalia, 2019). Innovation teams jointly develop ideas on how production processes and value chains from major industries (including steel and metals, chemicals, and cement) can be made climate-neutral in the long-term. Research is conducted by six research institutions under the guidance of the Wuppertal Institute. The four-year project is funded by the NRW state, however, the project will also mobilise significant funds from the federal government and EU for individual projects.

⟩⟩ Multi-stakeholder innovation networks (clusters) drive innovation by connecting government, industry, and academia

Heritage projects that preserved and celebrated the region's industrial history were important for easing social resistance to structural change processes. A large part of the Ruhr area's identity relates to its history with the coal industry and its importance for Germany's rebuilding after the war. Old industrial sites, like the "Zeche Zollverein" (former coal production site) have been repurposed into work spaces for research institutes and start-ups, museums, tourist attractions, and venues for cultural events (Reitzenstein *et al.*, 2021).

Corporations

Coal subsidies were introduced at the start of the 'coal crisis' in 1958 to compensate domestic coal consumers for the difference between the increasingly costly domestic hard coal supply and cheaper imports. The subsidy was relatively small in 1960 but increased constantly throughout the late 20th century and by 2002 the total cost of coal subsidies amounted to €158 billion (Storchmann, 2005). Coal subsidies were unable to limit the rapid decline in employment in the domestic hard coal industry. The demand for coal in Germany fell due to the continued substitution of coal for oil in end-use sectors like heating, and due to decreasing demand for coal in the domestic steel industry that was under pressure from the growing global market.

From the 1970s, technology programmes were introduced to improve the competitiveness of the declining coal and steel industries through technological modernisation (see Section 4.1.2 (Dahlbeck *et al.*, 2021)). A core objective of this structural policy was to address the rising unemployment in the Ruhr by creating jobs in the sectors that were experiences losses.

While most technology programmes in the 1970s and 1980s were focused on modernising the coal and steel industries, the 1978-1984 'technology programme for the economy' aimed at improving the innovative ability of SMEs in all sectors.

4.1.3 Process

The Ruhr's structural transformation was a strongly steered process where structural change measures were embedded in clear visions and narratives. The "Blue Sky Vision" of the 1960s underlay policies aimed at end-of-pipe pollution control, rather than any structural change. From 1989 the vision shifted to "Ecological Reconstruction", supporting the green rebuilding along the Emscher river. Finally, in 2010 the vision shifted to "Green Energy", fostering public-private initiatives for green technology (Fischedick, 2021).

⟩⟩ Clear visions and narratives provide important framing for transitions

Germany has a vertically integrated multi-level governance structure, where policies are largely driven by national and EU development objectives. Policies and programmes prior to 1980 followed a top-down approach, where resources were directly allocated to activities pre-defined by the national and regional governments, while local actors were afforded a very limited role. The lack of success of these top-down approaches led to experimentation with new bottom-up approaches in the 1980s and 1990s. Local groups designed and implemented programmes with the planning and financial support of regional and national institutions (Taylor, 2015). **This blended bottom-up approach is widely regarded as a key success factor in the Ruhr and has since remained the dominant approach in Germany** (Taylor, 2015; Oei, Brauers and Herpich, 2019).

⟩⟩ Blended bottom-up/top-down approach shown success. Bottom-up project identification and implementation, combined with top-down financing and coordination.

4.1.4 Outcomes

The decline of hard coal mining impacted the population growth and age distribution in the Ruhr area. The Ruhr's population declined in waves from 5.6 million in 1961 to 5.1 million in 2015. During this period the German population increased by around 3%. In this period the share of population over 60 years old increased from around 16% to 28% while the share of working-aged people fell by 1.6% to 54% (Dahlbeck *et al.*, 2021). **Projects that improved soft location factors (cultural, leisure, environmental) like the Action Program Ruhr (1980) and IBA Emscher River (1989), had a positive impact on population dynamics – total net migration increased from -158,000 between 1977 and 1986 to +247,000 between 1987 and 1995** (Oei, Brauers and Herpich, 2019).

⟩⟩ Soft location factors (cultural, leisure, environmental) play an important role in the perception of a region – improving these can increase the net migration.

Despite the strong impact of the coal crisis in 1958, **unemployment levels in the Ruhr remained low throughout the 1960s (Figure 3), partly due to the social protection measures, but also due to the availability of work for ex-miners in the booming steel industry**. However, unemployment rates increased rapidly from less than 2% in 1972, to around 10% in 1982 due to the steel crisis and two global oil crises in the 1970s.

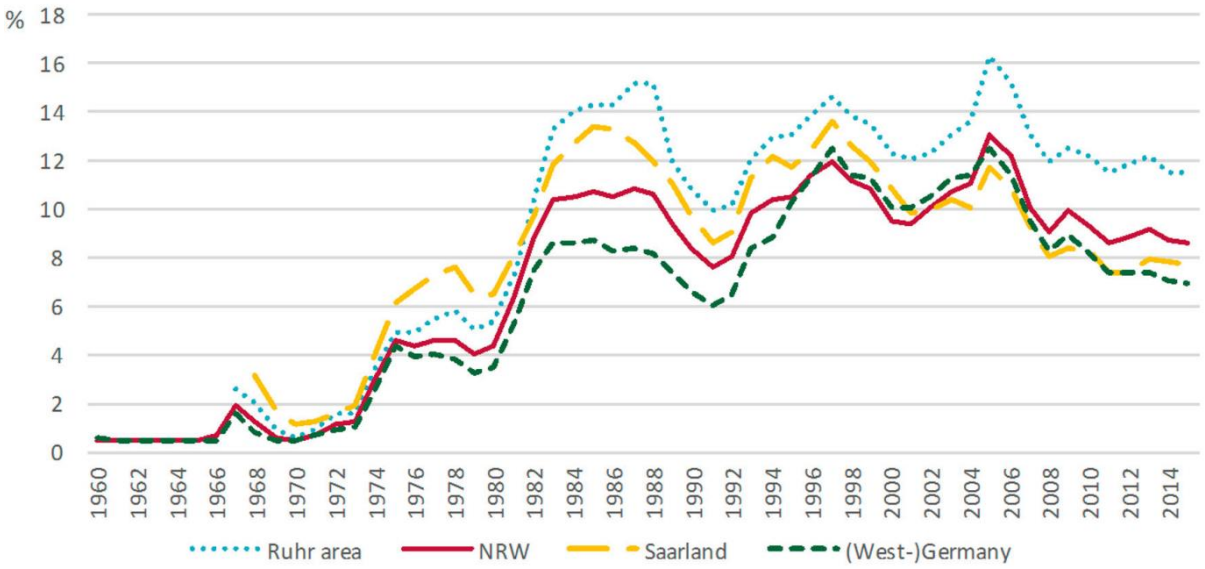

Figure 3: Unemployment rates in the Ruhr, NRW, Saarland, and (West-)Germany (Oei, Brauers and Herpich, 2019)

Employment in the coal and steel industries decreased from 720,000 in 1958, to just 60,000 in 2005 (RVR, no date). However, **structural policies were able to support the rapid growth of the service sector, in which almost one million jobs were added in the same period.** While the employment in the production sector decreased from 61% to 21% in this period, the service sector's share of employment rose from 38% to 78%.

Measures to foster higher education and innovation clusters led to the creation of high-wage, highly skilled jobs in new sectors, including energy and environmental management. Regional strength, experience, and global market potential were key success factors for new industries. Proximity to the problem was a key success factor for the growth of the environmental management sector in the Ruhr – around half of national investment in this sector was directed to NRW and the Ruhr (Taylor, 2015).

- Measures to foster higher education and innovation support the creation of high-wage and highly skilled jobs.
- New sectors should be aligned with regional strengths, weaknesses, and the global market.

However, the growth of new industries did not create many opportunities for ex-miners and unemployment in the region remained high (10-16%) between 1982 and 2014 (Oei, Brauers and Herpich, 2019).

Persisting unemployment levels were compounded by the fact that the economic performance of new industries was below that of the coal industry - new jobs generally showed lower productivity, added value, and incomes, in comparison to the coal industry (Taylor, 2015).

Economic restructuring was stalled for around 20 years following the coal crisis by structural policy aimed at preserving the coal industry and only pursuing singular replacement sectors (Taylor, 2015). Incumbent players from the coal industry were able to obstruct structural transformation beyond economic and ecological reason through strong networks with politicians and trade unions (Oei *et al.*, 2020). This is a key reason that the southern Ruhr area has progressed significantly more than the northern Ruhr area, which is characterised by higher unemployment and weaker economy (Bogumil *et al.*, 2012).

4.2 Case 2: Lusatia, Germany

4.2.1 Context

The Lusatia region in the east of Germany is characterised by large lignite reserves (Figure 4). Lusatia is a sparsely populated rural area with 1.2 million inhabitants in 2017 (103 inhabitants/km^2) (Stognief *et al.*, 2019).

Figure 4: Map of Lusatia (Institute for Climate Protection Energy and Mobility (IKEM), 2020)

Lusatia underwent an intense period of structural transformation following the reunification of Germany in 1990. In 1989 the sector produced around 200 Mt coal and employed 80,000 people (Figure 5). By 2017, direct employment dropped to 8,639 people, accounting for around 2% of regional employment. Direct, indirect, and induced employment was much higher, at 13,245 in 2016 (over 3.3% of regional employment) (Stognief *et al.*, 2019).

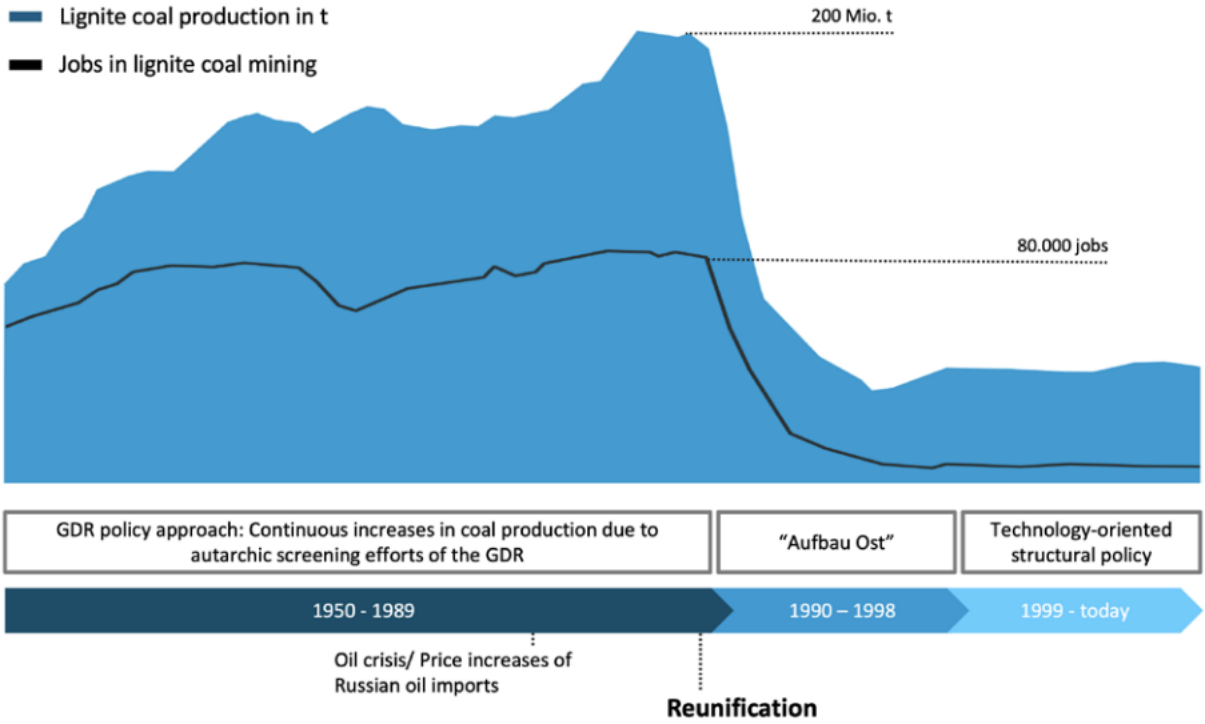

Figure 5: Coal production and employment in Lusatia (Ragnitz et al., 2021)

The coal industry still plays a major role in the Lusatian economy and the national energy system. In 2020, coal accounted for 16% of Germany's primary energy supply and 26% of its electricity supply (IEA, 2020). In 2016, the coal industry accounted for 30% of Lusatia's GDP (Wehnert *et al.*, 2018)**.**

Indicators for education infrastructure in Lusatia lag behind national averages. Lusatia's R&D expenditures amounted to around 0.5% of its GDP in 2015, less than a quarter of the national average. The share of school leavers with university qualification was also below the national average, at less than one third between 2011 and 2013 (Stognief *et al.*, 2019).

Two distinct transition periods can be distinguished in Lusatia: the first is the rapid decline of all economic sectors, including the coal industry, following reunification. Between 1989 and 2000 coal production dropped from 195 Mt/year to 55 Mt/year, an average annual decrease of 13 Mt/year (Statistik der Kohlenwirschaft e.V., 2021).

The second period is the slower, planned phase-out of lignite mining and power generation driven by EU and German climate policy. The initial phase-out date is set at 2038 and implies an average annual reduction of 3 Mt/year, from 60 Mt/year in 2018 to zero in 2038 (Statistik der Kohlenwirschaft e.V., 2021). This timeline is constrained by coal dependency in the power sector, but may be brought forward to 2030 by the new German government with increasing support for renewables (Amelang and Wehrmann, 2021).

We focus on the second transition period in Lusatia as valuable lessons can be learnt regarding the planning of coal transitions. The first period is interesting due to its intensity but is highly contextualised in the collapse of East Germany's economy following reunification.

4.2.2 Measures

Workers, communities, and corporations in Lusatia are supported by national and EU just transition policies, programmes, and processes. An overview of measures is shown in Table 11 (Annex).

The EU Just Transition Mechanism provides targeted support to coal regions in Europe, aiming to mobilise around €55 billion between 2021 and 2027 through three main pillars: the Just Transition Fund, InvestEU Just Transition scheme, and a new public loan facility (European Commission, no date b). Complementary to this is the Just Transition Platform, which provides comprehensive technical and advisory support for coal regions, including detailed case studies of coal transitions, analysis of successful projects, and toolkits for specific policy objectives such as environmental rehabilitation (European Commission, no date a).

Workers

The Innovationsregion Lusatia association (iRL) aims to **ensure that old industrial jobs are replaced by new jobs in the industrial sector by supporting specialised SMEs with reorientation based on the alignment of existing skills and future markets**, particularly concerning automation (Agora Energiewende, 2018).

Early retirement is the main measure to support workers in the transition. The age structure of the industry means that by 2038 most of the workers will be at retirement age. Financial support is managed through the instrument of adjustment money (APG), that was developed over many years during the hard coal phase-out in Western Germany. Early retirement is offered up to 5 years with no reduction in the pension amount. Opportunities for additional earning and several other benefits, such as tax exemptions and contributions, are offered to compensate for the reduction of wages due to the disproportionately high wages in the coal industry. Payments may extend until 2048, 10 years beyond the initial coal phase-out date, and amount to €4.8 billion (Matthes, 2021).

Communities/regions

Current structural policy in Germany aims to secure the long-term attractiveness of the region for young people through new business streams focusing on six areas:

- Economic promotion and development
- Infrastructure development
- Strengthening of municipalities in the area of services of general interest
- Promotion of science, research, and development
- Education and the development of skilled labour
- Regional anchoring and participation of civil society

National programmes since the announcement of Germany's coal phase-out have sought to identify future opportunities for economic diversification in coal regions like Lusatia. Programmes have included the development of the region's tourism sector, establishment of institutions for entrepreneurship and innovation, and long-term energy projects that aim to preserve the region's identity as an energy region through the development of renewable energy infrastructure (Institute for Climate Protection Energy and Mobility (IKEM), 2020). Two key programmes are the 'HyLand – Hydrogen Regions in Germany', implemented by the Federal Ministry of Transport and Digitalisation, and the WindNODE project – a 'reality-lab' for smart energy systems support by the Ministry of Economic Affairs and Energy.

Many of the programmes seek to capitalise on regional expertise and opportunities related to its history in the coal industry. For example, in the tourism industry, around 140 km^2 of former open-cast lignite mines is being converted into a chain of artificial lakes to form the Lusatian Lake District (LMBV, no date).

Binding commitments for the future development in coal regions in transition is legislated through the Coal Regions Structural Strengthening Act of 8 August 2020. The law provides an extensive list of measures and programmes to be implemented under the Coal Regions Investment Act (InvKG). The law defines nine areas for investments, including environmental protection, research, tourism, digitalisation, and public services, and sets the following objectives:

- Strengthening innovation activities in the field of energy and climate protection
- Founding of scientific institutions with a focus on specific innovation focal points
- Call for tenders for two large state-funded research institutes with an open thematic focus in the Lusatian and Central German lignite mining region
- Programmes or individual measures to strengthen education, culture and sport in the coal regions
- Creation of 5,000 new jobs in federal government facilities in the coal regions over a period of 10 years.

The law provides around €40 billion in support for coal regions, consisting of a €14 billion investment package for regional governments to implement projects and €26 billion in funding for federal measures such as R&D funding and investment in transport infrastructure (Federal Ministry of Economics and Climate Protection (BMWK), 2020b). **Lusatia will receive €17 billion of the fund, Saxony and Brandenburg will receive one third, while the remaining two thirds will be used by federal ministries for various regional development programmes and investments.**

Corporations

The phase-out of coal-fired power generation and compensation measures is set out in the Coal-fired Power Generation Cessation Act (KVBG). Compensation for hard-coal-fired power plants is managed through tendered decommissioning premiums until 2027. During this process the government defines a specific capacity of coal-fired power plants to be decommissioned and issues tenders which companies can bid for. If awarded, companies receive the accepted bid (€/MW) and must phase-out the capacity in a specified period. The maximum level of these premiums was set at €165,000/MW in 2020 and decrease annually. If the tendered decommissioning capacity fails to meet target for capacity

reduction, the mechanism is based on plant age. The second round of Germany's decommissioning auctions was held in April 2021 for 1,500 MW coal capacity and a total of 1,514 MW bids were accepted. The power plants ranged from 67-757 MW and bids ranged from €0-59,000/MW. High competition drove the value of the awarded decommissioning premiums well below the maximum set by law (Bundesnetzagentur, 2021).

Compensation for lignite-fired power plants and open mines was subject to an extensive multi-stakeholder negotiation process (discussed below).

The total compensation for the coal industry is estimated as €5-5.4 billion, with €4.35 billion aimed at lignite mines and power plants. **Compensation payments are structured so that they are used to remediate damaged and contaminated land.**

Power plants are also given the opportunity to apply for conversion to combined heat and power (CHP) under the Combined Heat and Power Act (KWKG). Coal CHP plants are also given the opportunity to convert to gas and can receive €390/kW capacity from the government.

4.2.3 Process

In contrast with the unplanned, sometimes rapid decline of the coal industries in the Ruhr, UK, and Lusatia following reunification in 1990, the **current coal phase-out in Lusatia is a slow, planned and negotiated process with a clear vision.**

Germany communicated its intention to phase out coal in the 2016 Climate Protection Plan. **The Commission on Growth, Structural Change and Employment (KWSB, also known as the Coal Commission) was founded and tasked with designing Germany's coal phase-out plan.**

The commission comprised of 28 members with voting rights, from a wide variety in background, including business, energy, trade unions, environmental organisations, academics, regional authorities, former ministers of East German coal states, and people affected by the lignite mining industry. **The diverse composition of the Coal Commission was meant to ensure that the coal phase-out planning process was inclusive, where each stakeholder group could participate in the negotiation process.**

> Diverse multi-stakeholder commissions can facilitate fair, inclusive decision making and ensure that the needs of each stakeholder group are considered

The commission had six focus areas aimed at developing a plan for sustainable regional development aligned with national and EU climate mitigation efforts and support for coal communities.

- Perspectives on creation of new and secure jobs in coal regions
- Create perspectives of renewable energy regions in context of energy transition
- Development of mix of instruments with requirements of economic development, structural change, social compatibility, and climate protection
- Development of investment programme
- Development of plan for gradual reduction and phase-out of coal-fired power generation in Germany
- Measures to assess consequences of emissions reductions target and to close emissions gap to meet 2030 target

Climate, energy, and labour market policy, in addition to monitoring strategies, are determined through a process of fact-finding, discussion, and negotiation between the Coal Commission

and the federal government. The closure of hard coal capacities and compensations are set in the law, while for lignite capacities this is set in a public-private contract that was the result of untransparent negotiations between the federal government and coal plant operators (Federal Ministry of Economics and Climate Protection (BMWK), 2020a; Heilmann and Popp, 2020).

Structural policy is determined through direct negotiation between affected states and the federal government, where affected states develop a list of measures and projects necessary for restructuring. The entire process is also subject to comprehensive and regular review so that adjustments can be made if necessary.

4.2.4 Outcomes

Due to the timing of Germany's coal phase-out, it is currently only possible to assess the planning process of Lusatia's current coal phase-out, which is centred around the work of the Coal Commission. The commission resulted in the Coal Phase Out Act, which set the end date for coal in Germany in 2038 (with the option to move to 2035 pending reviews in 2022, 2026, 2029, and 2032), and the Structural Strengthening Act for Coal Regions, which provides extensive financial support to coal regions. **The 2038 phase-out has been criticised for failing to agree a phase-out plan compatible with the Paris Agreement, for which unabated coal use in major economies should be phased out by 2030** (Greenpeace International, 2019; IEA, 2021c).

⟩⟩ Coal phase-out and just transition plans should not jeopardise climate change mitigation efforts that aim to protect the 'common good'

The process and outcome of the compensation agreements have also been subject to criticism and review (European Commission, 2021). The Öko Institute found that compensation payments should be at least €2 billion lower due to the poor economic outlook of the plants involved (Matthes, Hermann and Mendelevitch, 2020).

A recent review of the Coal Commission by the Institute for Advanced Sustainability Studies (IASS) highlighted shortcomings regarding the inclusivity and transparency of the decision-making process. The review used available literature, media reports, statements from participating organisations, and interviews with 14 of the 28 commission members (Beer *et al.*, 2021).

While the commission represented a broad range of stakeholders, some groups, such as citizens of coal regions, were excluded from the decision-making process. Furthermore, the process failed to compensate for the differences in expertise, experience, and access to resources, and lacked professional moderation services to facilitate inclusive discussion and decision making that fairly accounts for the diverse interests of affected parties. In addition, the study revealed that the final negotiations were held in a smaller informal group, excluding other members of the commission.

⟩⟩ Participation is dependent not only on the composition of the group but also the mechanisms in place to facilitate inclusive discussion and decision making

4.3 Case 3: United Kingdom

4.3.1 Context

The UK coalfields extend throughout central England, Scotland, and South Wales (Figure 6). Coal reserves are dominated by hard coal that has been mined from deep mines since the late 19th century. The coalfields cover a range of population densities, from more rural regions like Ayrshire (91 inhabitants/km^2), to urban centres like North Staffordshire (332 inhabitants/km^2).

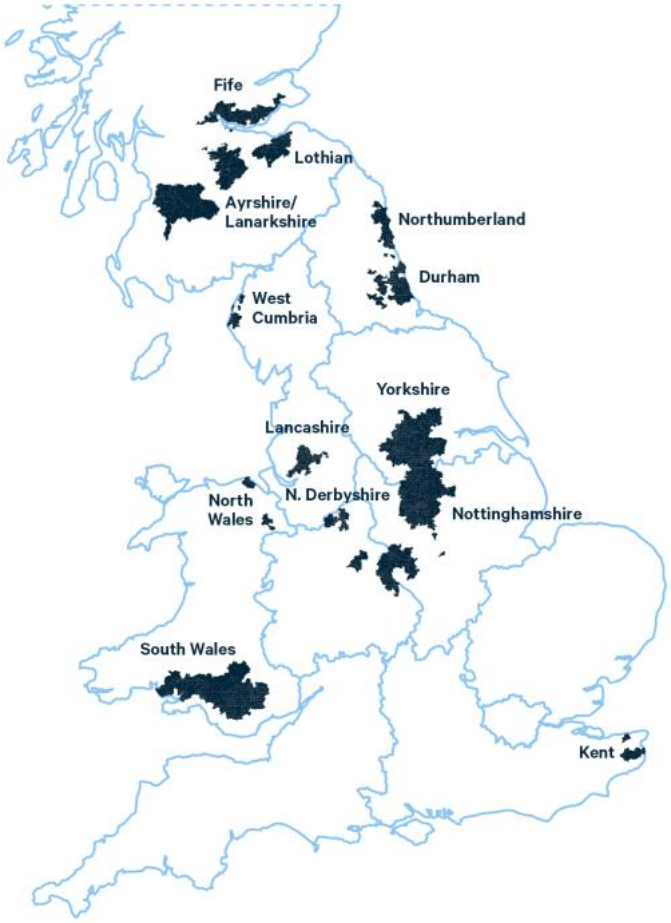

Figure 6: Map of UK coalfields (Beatty, Fothergill and Gor, 2019; Rising et al., 2021)

There is also significant variation in terms of economic dependency on coal. At its peak in 1913 the coalfields produced 300 Mt of hard coal and employed 1.1 million people (Figure 7). In more urban settings like North Staffordshire and Lancashire, coal mining employed around 10% of the male workforce in the 1980s. However, in more rural areas like South Yorkshire, this could be as high as 70% (Fothergill, 2017).

The UK's energy system was hugely dependent on coal at the industry's peak – in 1920 it accounted for over 95% of primary energy supply and over 99% of electricity generation (UK Department for Business Energy & Industrial Strategy, 2021).

The coalfields had relatively weak knowledge bases to support economic restructuring and the creation of high-wage jobs due to the few universities and SMEs (Rising *et al.*, 2021).

The decline of coal mining in the UK was not a planned process – it was motivated by worsening economics of hard coal production from deep mines and increasing competition from low-cost imports.

The collapse of the coal industry was rapid, sometimes mines closed within a number of days and very few measures were in place to support the workers (Fothergill, 2017).

The UK's liberal market economy had important implications for the decline of the coal industry. In comparison to Germany's more coordinated market economy, where there is significant joint decision making between state and social actors, market forces drive economic activity in the UK. The coal industry was privatised in the 1990s. Thereafter, coal companies were simply allowed to go bankrupt during further declines of the industry (Fothergill, 2017). This was particularly prevalent during the rapid expansion of new gas-fired power plants in the late 1990s.

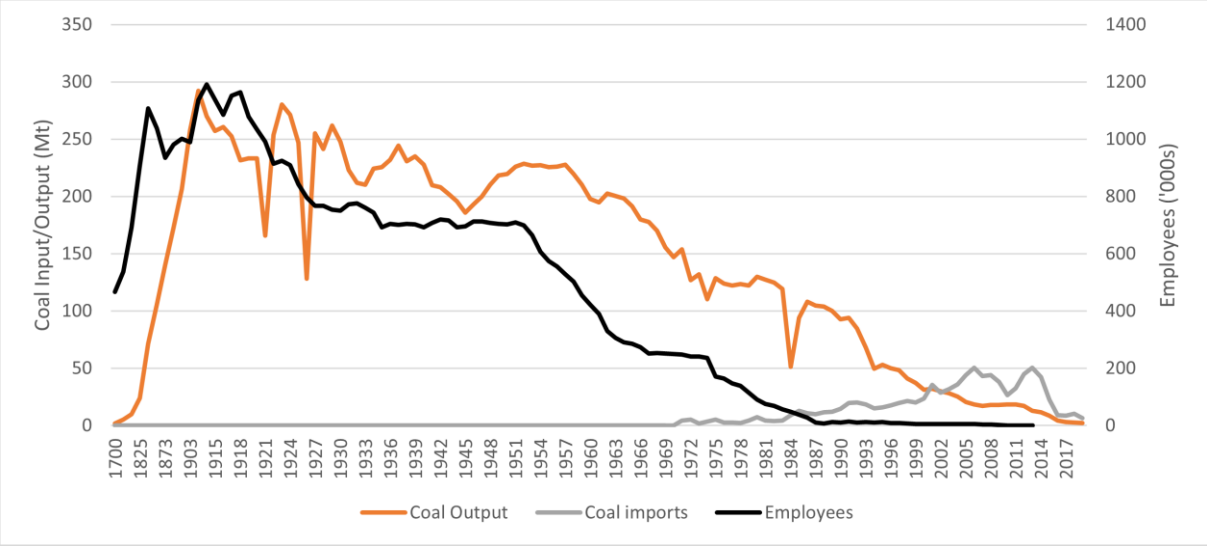

Figure 7: UK coal production and employment (own figure). Source (UK Department for Business, 2021).

The public finance system in the UK is highly centralised. The central government controls the budget for skills, regeneration, housing, employment, and business support. The UK does not have a regional level of government. Budgets are decided at the central level and distributed to regional or local bodies – prior to 2008 these were regional development agencies, which were replaced by local enterprise partnerships.

The UK's welfare system is a subsistence level means-tested benefit system that is aimed at preventing poverty. It is not a social security system like seen in Germany. The main objective of labour policy in the UK is for people to re-enter the labour market, low priority is given to human capital investment and training (Bonoli, 2013).

4.3.2 Measures

Workers were mainly supported through early retirement and welfare benefits. Several long-term programmes supported regeneration of communities, many using EU funds. Support for corporations was mainly limited to inheriting debt for pensions and environmental restoration. A timeline of major measures is shown in Figure 8 and an overview of the financial scale of the main measures is shown in Table 12 (Annex).

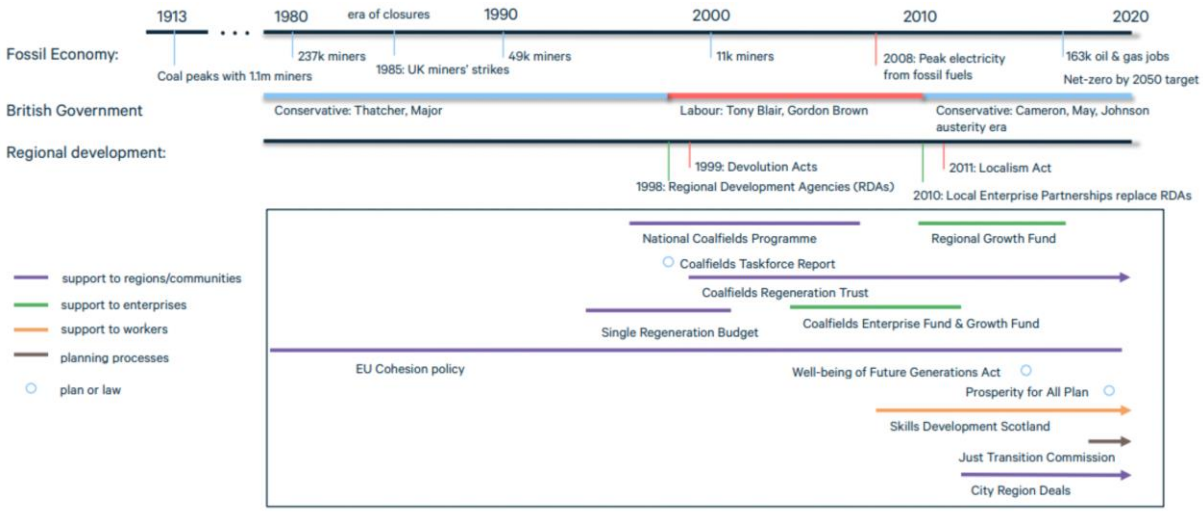

Figure 8: Timeline of transition policies in the UK (Rising et al., 2021)

Workers

The rapid decline of the coal industry led to the disappearance of over one million jobs since its peak in 1913, and around a quarter of a million since the 1980s (Figure 7). Miners from closed mines were first offered to transfer to open mines to reduce increases in unemployment and soften the shock to the labour market. This was only possible while the number of open mines remained high and was facilitated by the high level of car ownership in the UK allowing people to commute in rural areas.

Workers were also supported with redundancy payments, early retirement, and a range of welfare benefits, including unemployment and incapacity benefits. As with the German cases, the age structure of the mining industry meant that many miners were within 5-10 years of retirement. Redundancy payments were typically 6-12 months' wages.

The government also provides financial support to charities like the Coal Industry Social Welfare Organisation (CISWO), which supports ex-miners, their families, and coal communities, through the provision of personal welfare services, educational grants, and the creation of local recreational facilities.

Career advice and training services were typically available for the first 6-12 months and in some cases, training could only be accessed after being on unemployment benefits for 6 months. Interviews show that many miners did not receive career advice, assistance with job searches, or retraining (Murray *et al.*, 2005). Some workers were able to find jobs, but these were mainly low-wage jobs in haulage, warehouses, and call centres.

The British Coal Enterprise (BCE), a subsidiary of the state-owned British Coal Company (BCC), was established in 1984 and tasked with creating jobs by supporting SMEs and assisting miners in job searches and training. A review found that the BCE was only able to replace one of every 14 jobs lost (Fothergill and Guy, 1994).

Skills Development Scotland (SDS) is an example of a proactive, accessible service that offers a wide range of support people workers facing redundancy (see (Rising *et al.*, 2021) for more details)**.** The organisation was created in 2008 as a centralised public agency with board members from both public and private sectors that are appointed by Scottish ministers. Apart from high-level guidance from ministers, the organisation operates independently, with an annual budget of £264 million in 2019 (Government of Scotland, 2021).

By 2018, around 40% of people facing redundancy used a service within the SDS, the Partnerships Action for Continuing Employment (PACE). A quarter of users undertook training courses and 80% were employed within a year, most within the first 6 months (PACE, 2018).

Two elements of the SDS are particularly important for its success: first, its broad coverage of services including apprenticeships, application support, career management workshops, numeracy and literacy courses, and help understanding unemployment benefits. **Second, the SDS is an adaptive service – it conducts regular regional skills assessments to identify mismatches between supply and demand.** The adaptive nature of the SDS allows it to integrate into the regional development planning that is currently coordinated by the Growth deal partnerships in the UK.

⟩⟩ Careers services should be comprehensive in coverage and responsive to regional labour demand and development objectives

Community/region

The UK was part of the EU until 2020. Many of the policies and programmes identified below were supported through either the European Social Fund (ESF) or the European Regional Development Fund (ERDF) – two main structural funds of the EU Cohesion policy. In the last funding period 2014-2020 the UK received €11.8 billion (European Commission, 2014).

A revenue support grant system was used to compensate local authorities for loss of property tax revenue due to the closure of mines and power plants (Fothergill, 2017).

By the 1990s, former coalfields were experiencing high levels of poor health and unemployment. The national Coalfields Task Force was established by the government in 1998 to advise the regeneration of these regions. In the short-term the task force identified the need for a dedicated charity to support social projects and create opportunities for their people.

The Coalfields Regeneration Trust is a government-funded charity founded in 1999 to support communities through social projects. Over a period of 20 years the charity dispersed £150 million in small grants to social enterprises, community organisations, local training agencies, community-based renewable energy infrastructure, and other initiatives (The Coalfields Regeneration Trust, no date).

Remediation of coal mines is another important part of the structural change process in former coal mines that improves the attractiveness of the region and improves the health and wellbeing of the local people. The National Coal Programme was mandated to remediate and convert abandoned and contaminated coal mining sites throughout the UK to housing and commercial spaces. The program covered 107 sites across 7 regions and received £880 million in public funds and £1.1 billion in private funds (Industrial Communities Alliance, 2020). All sites were brought under public ownership so that sites with higher economic potential could subsidies less profitable sites.

Lottery funding is provided for heritage projects that showcase the history of coal mining in the area, such as the revitalisation of the North of England Institute of Mining and Mechanical Engineers in central Newcastle (Heritage Fund, 2018).

Corporations

Financial losses of coal companies prior to the privatisation of the sector were absorbed by government. Private companies thereafter were supported through subsidies, but these were limited under EU rules. Many coal companies went bankrupt during the late 20th and early 21st century, their financial obligations regarding miners' health compensation and environmental restoration were inherited by the government (Fothergill, 2017).

Structural reorientation of the business environment was difficult due to the dearth of SMEs in former coalfields (Rising *et al.*, 2021). The Coalfields Enterprise Fund (2004-2014) and the Coalfields Growth Fund (2009-2014) are venture capital funds that were established to support SMEs and by 2009

the Coalfields Enterprise Fund had created 482 direct jobs with an average cost of £16,500 per job (NAO, 2009). For comparison, regional development agencies created 178,000 jobs between 2002-2007 at a cost of £60,000 per job (Rising *et al.*, 2021).

Companies that invested in creating and safeguarding jobs in the deprived former coalfields were able to access regional aid (Regional Growth Fund) through the government's Assisted Area programme. By 2015, the programme had created or safeguarded 141,000 jobs at an average cost of £11,000 per job, making it the most cost-efficient programme assessed in this way (Rising *et al.*, 2021).

Measures also supported coal consuming corporations. Electricity consumers absorbed the higher costs that resulted from the introduction of the carbon tax in 2013. Energy-intense industries were compensated through exemptions from green charges on electricity consumption.

4.3.3 Processes

The decline of the British coal industry was not a planned or negotiated process.

There was a shift from top-down to bottom-up process in the UK. The regional development agencies that represented the central government were replaced by local enterprise partnerships (LEPs) in 2008. **Local authorities and businesses were invited to bid to form these new bottom-up partnerships that would be tasked with advocating for local development needs and coordinating the vision and projects for local economic development.** LEPs set regional investment priorities, coordinate proposals for funding from the EU (ESF, ERGF) and national government (Regional Growth Fund, Local Growth Fund), and participate in national policy discussions.

Other programmes such as the CISWO implemented this blended approach of top-down funding and coordination, with local project identification and implementation.

4.3.4 Outcomes

In general, employment figures in coalfields throughout the UK still lag far behind the national averages, however there is some variation in outcomes due to differing framework conditions.

Regeneration efforts were able to create around 180,000 new jobs in the English and Welsh coalfields between 1981 and 2005. However, in this time over 225,000 were lost. A review of the state of the coalfields found that by 2012, there were just 50 jobs for every 100 inhabitants in former coalfields across the country (Beatty, Fothergill and Gor, 2019). **The new jobs created in the coalfields were mainly in call centres, distribution centres, and warehouses. These jobs were low-wage (7-8% below UK average) and low security due to the threat of automation.**

Unemployment statistics hide the issue in former coalfields as many ex-miners of working age were transferred from unemployment benefits to incapacity benefits – 2.5 million adults on incapacity benefits, while 800,000 were on unemployment benefits. **The number of working-age men 'economically active' was 150,000 greater than in the 1980s** (Fothergill, 2017).

Several factors exacerbated the labour market conditions in the case of the UK coalfields. The liberalised market economy led to massive positive and negative shocks due to the rise and fall of industries like the coal industry. The coalfields' long history of unemployment was intensified by growing working population, increasing women participation in the workforce and in recent years migration and immigration.

The coalfields are still lagging behind national averages in indicators for health, wellbeing, and education - around 42% of coalfield neighbourhoods are in the most deprived 30% in Britain (Beatty, Fothergill and Gor, 2019). The report identified the need for further investment in education

systems, apprenticeships, entry-level opportunities for those who do not pursue high education, and opportunities to enter education throughout life.

The population of the coalfields has increased steadily between 2001 and 2017, but at around 60% of the national average and less than half the rate in main regional cities (Beatty, Fothergill and Gor, 2014, 2019). The age distribution in the coalfields has been diverging from the national average, with a higher share of older people (65+) and fewer of working age (16-64). The population dynamics reflect the outward migration of the young and qualified – a trend that has been exacerbated by the expansion of higher education which has further diverted young people from the coalfields where there are few opportunities for higher education (Beatty, Fothergill and Gor, 2019).

The National Coal Programme successfully remediated and converted 107 coal mines across the UK. The project took a total of 20 years (10 years longer than planned) and received a total of £880 million in public funds and £1.1 billion in private funds (Industrial Communities Alliance, 2020).

The business stock and formation rate in the coalfields are still much lower than the national average. Former coalfields had on average 262 private enterprises per 10,000 population in 2018 – around two-thirds of the national average (Beatty, Fothergill and Gor, 2019). This represents a growth of 19% since 2012, compared to the national average of 25%.

Experiences with structural transformation efforts in the UK's coalfields highlight the wider issue of rural development in the absence of extractive industries. Outcomes are embedded in the context of the UK's 'trickle down' approach to development, where rural regions benefit from investment that is concentrated in highly populated growth centres.

4.4 Case 4: Spain

4.4.1 Context

Coal mining in Spain is mostly concentrated in the north-western provinces of Asturias and León (Figure 9). The population density of Spanish coal regions in 1960 varied from less than 100 inhabitants/km^2 in Fabero to almost 800 inhabitant/km^2 in Langreo (INE, 2021a).

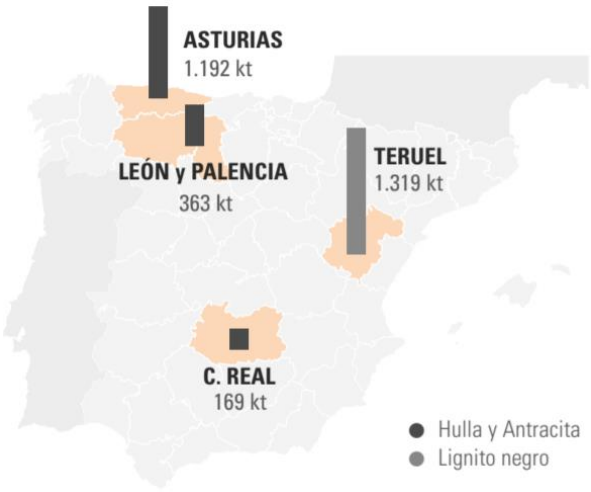

Figure 9: Map of coal regions in Spain (CARBUNION, 2015)

Spain is endowed with anthracite (hard coal), bituminous coal, and sub-bituminous coal (also known as black lignite) and brown lignite. Prior to the 1980s, most of the coal produced in Spain was bituminous. Lignite production began to increase dramatically in the late 1970s due to the global oil crises, growing

its share of production from just under 30% in 1976 to over 60% in 1984. Over this period overall production grew by 170% and reached a peak of 40 Mt in in 1984 (Figure 10).

Employment in the coal industry peaked in the 1950s and 1960s, reaching levels of around 100,000 employees, while production peaked two decades later in 1984, by which point employment had fallen by almost half. Coal production decreased in the 1960s with the introduction of oil but later increased during the 1970s as the result of the two global oil crises, the introduction of surface mining, and greater mechanisation of the production process. The latter also drove decreasing employment in the sector (Herrero and Lemkow, 2015).

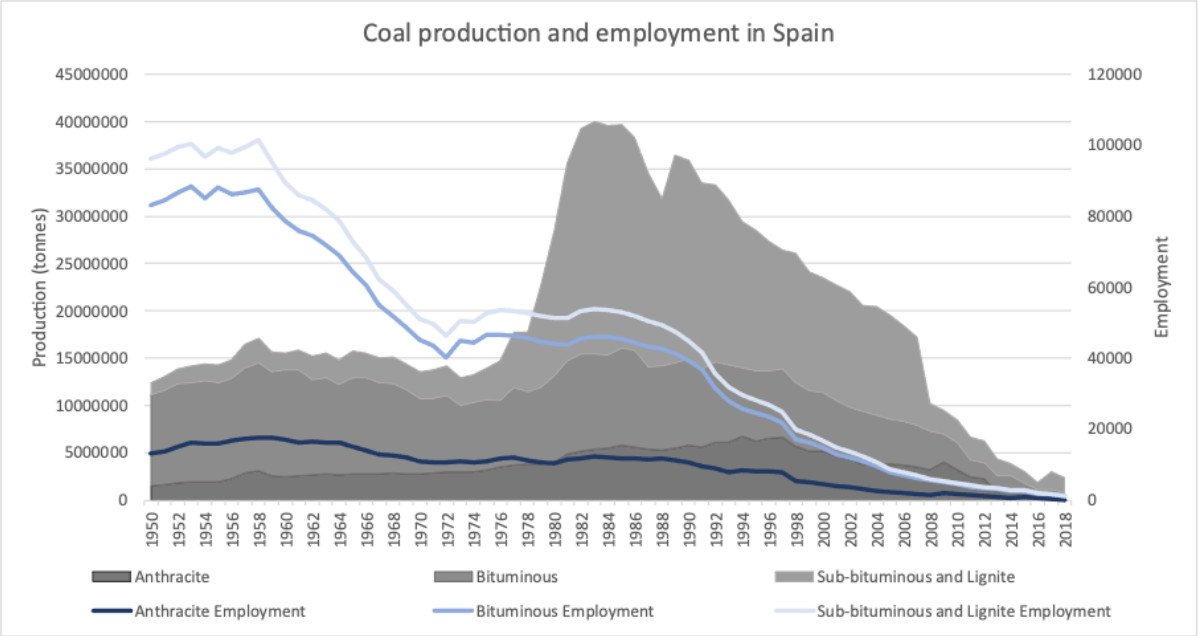

Figure 10: Annual mining statistics on production and employment (Gobierno de España, 2021)

Spain's energy system showed moderate levels of coal dependence in the early years of its coal transition. Coal accounted for 21% of primary energy supply and 40% of electricity supply in 1990.

Coal regions in Spain showed a relatively low level of coal dependence in terms of the share of regional GDP and employment. By 2000, industry (including coal) accounted for 13% of the regional GDP in Leon and 6% in Asturias. In the same year, industry accounted for just 2-3% of total employment in these regions (INE, 2021a). Lignite provided the least employment among the varieties of coal mined. During the periods of greatest production, lignite mining provided around 13% of the total employment in the sector while bituminous coal mining provided around 64%.

The coal transition in Spain was relatively gradual - annual coal production declined at an average annual rate of 1 Mt/y from its peak of 40 Mt in 1984 to 2.5 Mt in 2018. While coal production declined rapidly from the mid-1980s onwards in terms of physical units, the largest decline came from low energy density lignite; coal supply, in terms of energy units, saw a much less pronounced decline (BP, 2021).

4.4.2 Measures

The Spanish government introduced the New Thermal Coal Contracting System in 1987 which created a legal distinction between public and private mining companies with regards to allocation of subsidies and procurement of coal for power generation. This distinction served as the basis for the government's plans put forth from 1990 and helped to ensure compliance with the EU's regulatory framework (González Rabanal, 2005).

Beginning in 1990, the Spanish government put forth a series of plans to restructure the coal mining industry. These plans were intended to keep the industry viable by reducing employees and production and involved compensation to coal mining regions and companies, incentives for early retirement of workers, and subsidies to coal-fired power plants. An overview of the financial scale of the main measures is shown in Table 13 (Annex).

Plans to restructure the coal mining industry were primarily a response to economic forces, rather than concerns over environmental degradation or air pollution. The Spanish government was responding to calls to liberalize the economy, including the energy sector, to align itself with EU rules requiring that member states phase-out government subsidies to domestic industry to not create an advantage over competitors in other member states (Bridle *et al.*, 2017).

Although Spain's domestic coal has become increasingly uncompetitive throughout the periods of the plans, it is still seen as critical to the country's security of supply and as providing stability to the grid (Del Río, 2017). As stated in the Coal Activity Framework 2013-2018, the government sought to maintain a competitive indigenous supply of coal which allows a certain level of electricity generation to support the development of renewable energy resources (MINETUR, 2013).

Early coal restructuring plans focused on reducing costs and improving productivity at mines to bolster the industry's competitiveness. For example, the Coal Reorganisation Plan 1990-1993 sought to improve underground mining productivity by 15% while consolidating the production capacity of open-pit surface mining (González Rabanal, 2005). The result was a reduction in the production of lower value lignite and an increase in the production of higher value anthracite.

As mines closed, the plans began to give greater priority to the reactivation of coal mining regions. The funding amounts and allocations are indicative of this process. The plan covering the period 1994-1997 allocated around €11.5 million/year for "reindustrialisation support" (roughly 11% of total subsidies granted). During the period 1998-2005, €390 million/year was granted to mining regions for business projects, infrastructure, and training. Support for these activities continued at around the same level through the 2006-2012 plan (Tribunal de Cuentas, 2020). Support payments were drastically cut in 2012 as part of austerity measures.

Workers

In October of 2018, the Spanish government and coal mining unions agreed on a Just Transition Plan for the sector and its employees covering the period 2019-2027. At the time of the deal, 12 coal mines, directly employing 2,000 workers, were still active. Since this time, the number of workers has decreased by half.

Subsidy payments for retirements and redundancies had been included in coal industry restructuring plans prior to the 2018 deal. For example, redundancy and retirement payments made up 37% of total allocated funds in the 1994-1997 plan. Far less support was given for miners who continued working in other industries. This aid fell within the category of reindustrialisation, which in this plan made up 11% of the total (González Rabanal, 2005). Even in later plans where worker training was explicitly included as a support area, far less funding was allocated compared to other aspects of "economic reactivation". For the period 1998-2005, worker re-training made up 7.6% of the €3.12 billion set aside for economic reactivation. For the period 2006-2012, in which €2.88 billion in support for this purpose was allocated, the share for re-training was around 10% (Del Río, 2017).

Support for workers was given greater priority since the 1998-2005 plan. This included not only the re-training mentioned, but also loans to establish job-creating SMEs in the affected coal mining regions, and financing for the necessary infrastructure to support these new businesses.

Community/regions

Subsidies for economic reactivation of coal mining regions have figured largely in the government's plans since 1990. A recent inquiry for the Spanish Court of Auditors shows that between 1990 and 2012, a total of €4.8 billion of public funds were allocated for these purposes. Note however, that the actual provision of support has not in all cases matched the planned allocations. For example, the reactivation plan for 1998-2015 envisioned a total of €3.12 billion in support for coal mining regions, for the development of infrastructure, assistance for job creating entrepreneurial activities, and professional training. The Court of Auditors found that €1.64 billion was provided over the planned period (Tribunal de Cuentas, 2020). This discrepancy has been attributed to slow administrative processes (Del Río, 2017).

In both their 2006-2012 and 2013-2018 coal plans, the Spanish Government explicitly acknowledges that previous restructuring plans had failed to prevent depopulation of coal mining regions or to provide the adequate alternative economic and employment opportunities necessary to meet the structural socioeconomic changes from mine closures (MINETUR, 2006, 2013). It appears to be a long-standing issue however as this acknowledgment was also given as a motivation for the earlier 1998-2005 plan (Maurín Álvarez, 1999).

Several closed mines have been converted into museums and tourist destinations to acknowledge and celebrate the long history of coal mining in Spain and the social status of miners. The employment arising from these activities pales in comparison with that previously known from mining. For example, a proposal has been put forth to convert a former mine in Fabero in the Province of León into a geological adventure park. The estimated 20 which would be employed at this facility is 4% of the number who once worked the mine. However, several in the town are wary that such a facility will be constructed, as an earlier plan from 2010 to invest €8 million for a theme park in the town never materialized (Carmona, 2020).

In general, funds for economic reactivation of mining towns have been inefficiently managed with serious issues in monitoring and accountability – as detailed in the recent report from the Spanish Court of Auditors (Tribunal de Cuentas, 2020).

Corporations

Spain closed the vast majority of its coal mines, located in the provinces of Asturias, Palencia, Teruel, and Leon, in 2018. These closures were motivated in part by the EU's decision 2010/787/EU calling on Member States to cease financial support of uncompetitive coal mines and close them by 31st December 2018. Mines deemed to be economically competitive, and which chose to remain open after this date would be compelled to reimburse the state for subsidies received during the period 2011-2018 (Del Río, 2017). Direct subsidies for the 26 mines (property of 15 companies) was estimated to be €504 million (Planelles, 2018).

Spain provided subsidies to coal mining companies in the form of price augmentation for coal sold to domestic power plants. This support was reduced in line with efforts to increase the competitiveness of mining companies, as outlined in the Coal Activity Framework 2013-2018 (Table 6). The prices shown in Table 6 reflect changes in the calorific value of the coal as they are given per thermal unit (thm).

Spain's Ministry of Industry, Energy, and Tourism had previously estimated that between 1992 and 2014, Spanish coal mining firms received €22 billion from the government (Del Río, 2017). The IEA estimates that in 2010, the government provided €314 million in direct subsidies for the country's uncompetitive domestic coal production (€37/tonne). By 2019, and in line with EU directives, these subsidies had ended (IEA, 2021a).

Table 6: Support for coal corporations in Spain (MINETUR, 2014)

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total (€cent/thm)	1.478	1.466	1.496	1.58	1.568	1.544	1.597	1.565	1.732	1.782	1.932	1.91	1.963	2.439	2.041	2.361	1.852
Revenue (%)	52%	50%	52%	52%	52%	51%	52%	58%	56%	56%	61%	67%	58%	55%	71%	70%	86%
Support (%)	48%	50%	48%	48%	48%	49%	48%	42%	44%	44%	39%	33%	42%	45%	29%	30%	14%

4.4.3 Processes

The management of Spain's coal phase-out shifted from top-down to more participatory approaches. To the extent that it has been planned, the phase-out process began with a top-down approach driven by EU directives, which the country was obliged to comply with when they joined the union in 1986. As the phase-out proceeded, and the eventual complete shutdown of coal production became more of a reality, the planning process took on a more participatory character.

Coal miners, as part of larger national labour unions UGT and CCOO, hold a substantial influence in Spain, both culturally and politically (Herrero and Lemkow, 2015). Consequently, mining unions have played a significant role in the formulation of coal mining restructuring plans, particularly as signatories to the plans commencing in 1998. Indeed, a main motivation of the 1998-2005 plan was to respond to demands from miners regarding the future wellbeing of themselves and their communities. However, unlike those commencing from 2006, this plan was not agreed upon by either coal or power companies (González Rabanal, 2005).

4.4.4 Outcomes

From the time that Spain joined the EU in 1986, coal production began to decline. On average, total coal production declined by 8% per year during the period. The largest drop in production, and consumption, was a result of the financial crisis which began in 2008 and coincided with the end of brown lignite mining.

Coal consumption for power generation declined due to both market conditions, and EU and national policy. The decline in coal's share of generation from 17% in 2017 to 2% in 2020 was largely driven by EU's decision 2010/787/EU, while the decline occurring between 2007 and 2010 (from 24% to 8% share of total generation) was primarily a consequence of the financial crisis.

Declines in coal consumption resulted in power plant closures. Power generation from coal has declined from 40% of the total in 1990 to 2% in 2020 (IEA, 2021a). That year, the country shut down seven of its 15 operational coal plants, totalling around 4,360 MW (around half of the total coal capacity at the time) and providing around 1,100 jobs. A further four plants, totalling 3,092 MW, filed for permission to shut down in 2020, putting another 800 workers at risk of unemployment. As indicated in the country's National Energy and Climate Plan 2021-2030, which was approved in January 2020, Spain expects that their coal power plants will cease operation by 2030 (Planelles, 2020).

Coal production and employment decreased throughout the planning periods, often at much higher levels than targets and estimates put forth in the plan. For example, the Coal Activity Framework 2013-2018 stated that as per mining company estimates, employment in the sector would be reduced by 15% over the plan's period (MINETUR, 2013). In reality, employment saw a 15% annual reduction during this time leading to a 58% reduction between 2013-2018.

Former coal regions have seen rapid declines in population since the industry's peak in the 1950s and 1960s. Fabero (León), Mieres (Asturias) and Langreo (Asturias) provide good examples of this phenomenon (Figure 11).

Coal phase-out has resulted in significant demographic shifts in former coal regions (Figure 12). The average age in former coal regions has increased significantly due to outward migration of youth and an influx of retirees (Bridle *et al.*, 2017). This is a consequence which the early-retirement provisions in the government's coal plans intended to avoid. Women also make up a larger portion of the older demographic. For example, in 2020 55% of Fabero's population was 50 or older. Women aged 65 or older accounted for 16% of the total population compared to 11% for men. This is in contrast to Spain as a whole, where 40–50-year-olds make up the largest portion of the population.

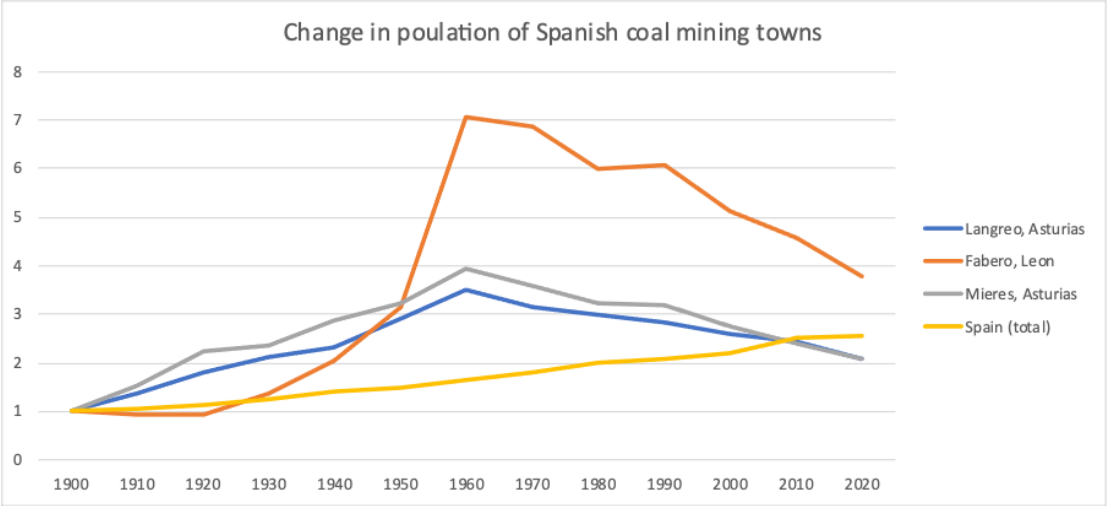

Figure 11: Population changes in three towns located in Spain's prominent coal mining regions: Fabero (area 82.5 km^2), Langreo (area 82.46 km^2), and Mieres (area 146 km^2) Changes in total population of Spain are given for comparison. Changes are relative to population in 1900.

Over the last decade annual deaths have been on average 3 times greater than births in Fabero. Births have not outnumbered deaths in the town since 1998. Although natural population growth is currently negative in Spain as well, this has only been the case since 2015 and the magnitude of the discrepancy is far less than what is observed in Fabero (INE, 2021b).

In former coal mining towns like Fabero, ex-miners have voiced concern over the lack of opportunities for their children (Del Río, 2017). The poor outlook for future opportunities is exacerbated by the rural setting of these towns, which makes attracting modern industry difficult (Martínez, 2016).

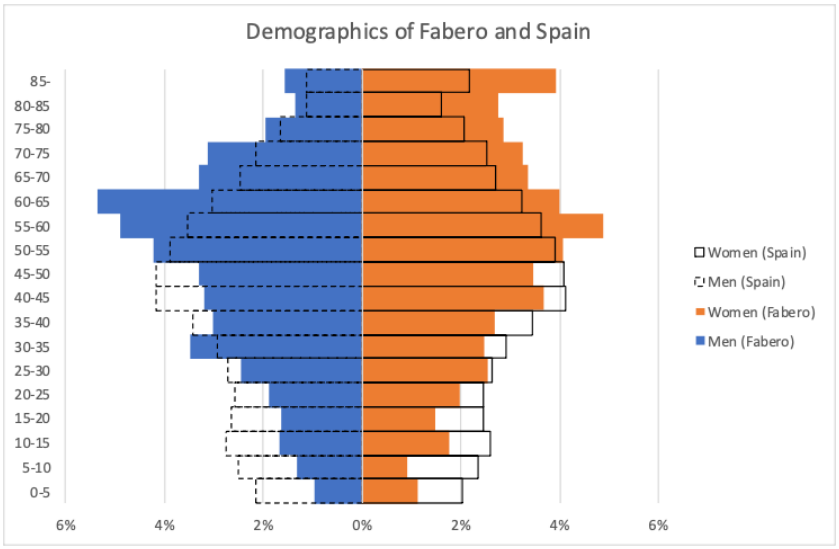

Figure 12: Demographics of Fabero (Province of León), and Spain. Source: (INE, 2021b) and (Foro-Ciudad, 2022)

5 Key lessons learned

Before discussing the relevance of specific lessons and insights from the cases studies for the selected Chinese provinces it is important to understand potential differences and similarities between the regions. Experiences with coal transitions are highly dependent on the specific context and hence their transferability needs to consider regional circumstances. Table 7 provides an overview of the similarities and differences in context between the Ruhr area, Lusatia, the UK coalfields, Spain, Shandong, and Inner Mongolia according to the typology discussed in the methodology section (Table 5).

The historical case study regions all exhibited a similarly high dependency on coal in terms of the share of regional GDP, employment, and energy when compared to Shandong and Inner Mongolia. While the employment dependency on coal mining in Shandong and Inner Mongolia is relatively low, concerns over job losses have been a blocker for transformational change at the subnational level in China (Nilsson, Smit and Kuramochi, 2021). Important insights from the case studies will relate to how highly dependent coal regions managed (or failed to manage) economic shocks, where the dominant source of employment, energy, and revenue declined rapidly in some periods. This will include aspects of managing the transition for the affected workers and communities, and of fostering economic restructuring along new business streams.

Table 7: Comparison of case contexts

			Ruhr area	Lusatia	UK coalfields	Spain	Shandong	Inner Mongolia
Type of coal			Hard coal	Lignite	Hard coal	Both		
Population density (inhabitants/km²)			1150	100	90-350	100-800	650	20
Coal dependency	GDP coal mining (%)			30		6-13		
	Employment coal mining (%)		50	2	10-70*	2-3	3	5
	Energy from coal	Primary energy (%)	>70	16	>95	21	67	>95
		Electricity (%)	>60	26	>99	40		
Knowledge base (at start of transition)			Low	Low	Low	Low	Medium - high	Medium
Transition intensity (Mt/y²)			2	3	3	1	2	26

Coal mining and coal consuming heavy industries accounted for around 50% of regional GDP in the Ruhr area in 1980 (Dahlbeck *et al.*, 2021), while the industrial sector including coal mining, coal power generation, and coal chemicals accounted for around 40% of regional GDP in Shandong and Inner Mongolia (Inner Mongolia Autonomous Bureau of Statistics, 2021; Shandong Provincial Bureau of Statistics, 2021).
* Share of male population employed by coal mining

All case study regions had a weak knowledge base for economic restructuring, with few institutions for higher education and low R&D expenditure. Shandong and Inner Mongolia currently have 152 and 54 institutions offering higher education, equivalent to 1.5 and 2.6 knowledge institutes per million inhabitants, respectively (see background section).

Due to its rural context, key lessons for Inner Mongolia will relate to how sparsely populated coal regions in the UK, Lusatia, and Spain attempted to foster economic restructuring by attracting new businesses and preventing the migration of skilled workers. Fundamental to this question is the nature and timing of transport and educational infrastructure.

China recently set the ambitious targets to peak GHG emissions by 2030 and reach carbon neutrality by 2060. While a long-term coal phase-out is yet to be planned, the phase-down of coal will be outlined in China's 15th Five Year Plan (Climate Action Tracker, 2021).

A potential 2060 phase-out date would imply very different transition intensities in Inner Mongolia and Shandong. **A 2060 coal phase-out in Shandong would imply a similar transition intensity to historical coal transitions in Europe. However, this is not the case for Inner Mongolia, where a**

2060 coal phase-out would imply a transition an order of magnitude more intense. The average annual decline in coal production in European coal transitions was 1-3 Mt/year. In comparison, an average reduction of 2 Mt/year would be needed to phase out coal in Shandong by 2060, while a reduction of 26 Mt/year would be needed in Inner Mongolia – this is almost twice the intensity experienced in Lusatia during the economic collapse of Eastern Germany following reunification in 1990 (Table 8).

Table 8: Comparison of transition intensity across regions

	Ruhr area	Lusatia (hist)	Lusatia (current)	UK coalfields	Spain	Shandong	Inner Mongolia
Transition start (year)	1958	1989	2018	1913	1986	2020	2020
Initial production (Mt/y)	120	195	60	292	40	74	1026
Transition end (year)	2018	2000	2038	2019	2018	2060	2060
Transition period (years)	60	11	20	106	32	40	40
Final production (Mt/y)	0	55	0	2.2	2.5	0	0
Transition intensity (Mt/y²)	2	13	3	3	1	2	26

Key lessons are extracted from the four case studies focussing on the measures to support workers, communities, and regions, and the processes observed in the planning and implementation of transition measures.

5.1 Measures

Workers

- Offering redundancy or transfer to open mines softened impacts on labour markets. This lesson is also applicable to other sectors.
- Good coordination of government programmes can avoid missed opportunities to boost employment (e.g., mine regeneration projects that did not employ ex-miners).
- Just transition policies should actively support the reskilling and reorientation of workers to new industries. Narrow compensation policies, such as severance pay and unemployment benefits, fail to address the need to reorientate the workforce – focus on these policies can contribute to long-term deprivation of former coal regions.
- Singular, centralised organisations can streamline support for workers facing redundancy. Key success factors are the broad coverage of services and capacity of the organisation to understand and adapt to the regional skills market, which allows alignment with development objectives.
- Comprehensive all-in-one careers services show the greatest success in reintegrating workers into the workforce. These services have included skills development, application support, and assistance understanding benefits.
- Skills development should be immediately available for redundant workers and open to all ages (lifelong learning opportunities). Comprehensive services have included apprenticeships, workshops, and courses in numeracy and literacy.
- Careers services can be reactive to the labour market and regional development objectives by performing regular skills assessments and collaborating with regional development agencies.

Communities/regions

- Economic restructuring takes a long time. The disappearance of the coal industry leaves a large gap in the labour market, some regions will be particularly impacted. Miners were often able to find employment in other sectors, however, without expansion of these sectors, others lost jobs and unemployment persisted.

- In general, former coal mines still lag behind national averages on socio-economic indicators and have suffered from outward migration of skilled workers and youth. Early investment in transport and educational infrastructure is key for regional development, particularly in rural areas.
- Development plans should address the contextual constraints of regions such as poor transport infrastructure and limited institutions for further education and R&D.
- Coordinating regional development plans with education and skills development policy is important for creating future employment opportunities for youth in the region and can help reduce outward migration and declines in regional working population.
- New business streams were most successful when aligned with regional strengths and opportunities, and with the global market (e.g., environmental services).
- Innovation hubs strengthen the link between academia and industry, ensuring that research objectives are aligned and enable recent graduates to benefit from employment opportunities in future industries, thereby reducing the risk of outward migration of skilled workers.
- Repurposing former coal mines and power plants creates short-term temporary jobs suitable for ex-miners. This increases the attractiveness of the area to new businesses and increases quality of life in the area, which can reduce the risk of outward migration.
- Improving soft location factors through investment in cultural and leisure facilities, and environmental restoration is important for reducing outward migration and attracting new industries and businesses.

5.2 Process

- Clear visions and timelines are important for guiding the structural change processes resulting from phasing-out coal.
- Economic restructuring requires the coordination between many stakeholders. Policies should build strong processes for coordination, experimentation, and engagement.
- Phase-out plans must not only focus on the compensation of corporations, communities, and workers, but also meet overarching national climate change mitigation goals that are founded on protecting the common good.
- If implemented well, diverse commissions can facilitate joint agreement on coal phase-out plans, lower prejudices towards the transition and foster ownership. Clear boundaries must be set to ensure phase-out timelines are aligned with the Paris Agreement.
- Multi-stakeholder processes like the Coal Commission (as in the German case) need binding criteria for composition to ensure each stakeholder group is represented and need measures to facilitate public participation.
- These processes require measures to ensure meaningful participation of all stakeholders, such as professional moderation.
- Blended top-down financing and coordination with local project identification and implementation was a key success factor for structural projects.
- Knowledge sharing platforms like the EU Just Transition Platform allow people across the world to learn from past experiences with coal transitions. National platforms can be even more valuable considering the transferability of lessons.

Table 9 provides an overview of the outcomes, success factors, and failure factors of the policies and programmes used to support workers, communities, and corporations during coal transitions in the case study regions.

Table 9: Experiences with transition policies and programmes

Measures	Outcomes	Success factors	Failure factors/risks
Workers			
Transfer to open mines	- Softened labour market impact (UK)	- Phased mine closures - Nearby mines - Good transport infrastructure to ease commute	
Wage subsidies	- Limited rate of unemployment increase		
Compensation programmes (incl. pension contributions)	- Supported recently unemployed miners and their families, limited increases in poverty levels		- Create culture of joblessness that contributes to long-term regional deprivation (UK) - Reduce incentive to re-enter labour market
Early retirement	- One of the main measures used due to age structure of industry - Limited increase in unemployment figures and reduced gap in labour market	- Workers within 5-10 years of retirement	- Can significantly decrease labour workforce in region
Careers service (incl. retraining, careers advice, job search assistance)	- Unable to improve employment prospects in Ruhr, Lusatia, or UK (historical cases) - Re-orientation often to low-wage jobs vulnerable to automation (UK) - Comprehensive programmes able to reintegrate workers into the labour force within a year (Skills Development Scotland, UK)	- Comprehensive service incl. apprenticeships, applications support, and workshops (see SDS, UK) - Assessment of regional skills supply and demand - Workers should immediately eligible for retraining (UK required workers to be on benefits for at least 6 months) - Longer-term support required	- Poor alignment of skills development to labour demand - Short duration of service
Regions/ communities			
Cross-sector regional development programmes	- Regional development agency in UK created 178,000 jobs 2002-2007 at £60,000/job - CRT channelled £300 million into small grants	- Distribution of funds across region (not concentrating) - Programmes account for strengths and weaknesses of a region (e.g., lack of educational and transport infrastructure)	- Lack of measurable objectives - Lack of evaluation of regional capital needs
Investment in transport	- Enabled workers to commute for new job opportunities - Attracted businesses to region - Created temporary jobs		
Investment in education and research institutions	- Increased knowledge base for economic restructuring - Facilitated creation of innovative new sectors, creating high-wage, highly skilled jobs in future-orientated markets	- Good coordination of education and skills development policy to align with regional development objectives to ensure youth employment in the region	- Poor alignment of education and skills development with future regional development objectives can lead to outward migration
Creation of innovation centres	- Attracted new industries - Created high-wage, highly skilled jobs	- University research agenda aligned with regional plans for future industry	
Restore degraded environment	- Increased attractiveness of region for new businesses (indirect job creation) - Improved quality of life and prevented/ slowed outward migration - Employment for thousands of people, short-term in Ruhr, long-term in UK	- Bottom-up project identification and implementation, top-down financing and coordination - Mine regeneration projects can employ ex-miners - Public ownership of mines can allow those with high economic potential to subsidies those with low potential	- Poor coordination of government activities can lead to missed opportunities (ex-miners not employed in UK to regenerate mines)
Investment in culture and heritage	- Increased attractiveness of the region, helping to prevent outward migration - Programmes relating to the coal industry appeased local resistance to the transition through recognition of past regional identity		
Corporations			
Coal subsidies	- Slowed decline of industry and resulting increasing in unemployment (Ruhr, UK) - Delayed economic restructuring process - Huge cost (Ruhr €165 billion 1968-2018)		
Technology programmes	- Created temporary jobs in declining industries - High cost (Ruhr €1.3 billion 1974-1984)		
Decommissioning bonuses	- Implemented in Lusatia to incentivise decommissioning		
Support for SMEs (venture capital funds)	- Increased share of SMEs, supporting economic restructuring - Growth of SME network created jobs, sometimes at very low cost (£11,000-16,500/job in UK)		

6 Conclusion

Several European countries have gained experiences with structural change caused by the decline of the coal industry. This decline has, especially in monolithic economies, left a massive gap in the labour market. Countries have experimented with a broad range of policies and programmes to manage this structural change, with many similarities across cases. This experimentation provides valuable insights into which measures worked, which didn't, and why.

Former coal regions still lag behind national statistics for health, economic growth, and employment. Economic regeneration depends on the ability to attract new businesses and retrain the region's youth and skilled workers. This has been particularly challenging in rural areas with poor transport and educational infrastructure.

Measures to support workers succeeded in limiting increases in poverty and unemployment but widely failed to reorientate workers to secure jobs. Early retirement has been one of the main instruments used to manage the labour market shock, both in cases of faster, unplanned transitions and slower, planned transitions. Careers services were generally poor in quality and coverage. Valuable lessons can be learned from the Skills Development Scotland service, which provides a comprehensive careers service that is also reactive to regional labour markets and integrated into regional development planning.

Visioning and participation were key to the process of managing structural change in coal regions. Approaches with bottom-up project identification and implementation, and top-down financing and coordination, have shown the greatest success in Europe. Local and regional expertise is used to identify opportunities and implement projects, which in turn fosters a sense of ownership of the transition.

Investment in education and transport infrastructure were key enablers for economic restructuring, particularly in rural regions. Investment in transport infrastructure also created short-term jobs and allowed people to commute greater distances, thus increasing the chance of finding employment. Investment in education laid the foundation for innovative new business streams that created secure, high-wage jobs.

Environmental restoration was paramount to just transition efforts and had several cross-cutting benefits – it improved quality of life, reduced outward migration, attracted new businesses, and created temporary jobs suitable for ex-miners, and in the case of the Ruhr and Lusatia, it was the foundation of a new core industry in environmental services.

The transition intensity facing China's largest coal producing provinces is far greater than experienced in Europe. While coal production in some Chinese provinces like Shandong is comparable to European countries, coal production in China's largest coal producing provinces like Inner Mongolia is an order of magnitude greater. In these provinces, the average annual decline in coal production required to phase out coal by 2060 is an order of magnitude greater than historic and planned coal transitions in Europe.

However, due to the planned nature of China's coal phase-out, the prospects for a just transition are greater than in the historical cases in Europe. Past coal transitions in Europe were driven by strong economic forces and resulted in periods of rapid decline in the coal industry, in communities that were in some cases heavily dependent on the industry for employment. China has the opportunity to proactively plan its just transition from coal and can learn from experiences of historic and ongoing coal transitions in Europe.

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Annex

6.1 Case 1: Ruhr area, Germany

Table 10: Financial scale of main measures, Ruhr

Measure	Years	Funds	Description
Social policies	1968-2020	€18bn National	- Retraining, financial aid to support new employment, liberation of unemployment insurance, early retirement
Subsidies for domestic coal sales	1968-2018	€165bn National	- Subsidies to close gap between domestic and international coal prices - Phase-out initiated in 2007
Technology programmes for steel, coal, and energy	1974-1984	€1.3bn State/ National	- Creation of jobs via aids for existing companies. Modernisation of companies.
Development program Ruhr and NRW	1968-1975	€16bn National	- Settlement of new companies without any sectoral specification (economic reorientation) - Education (est. universities) - Transport infrastructure
Action program Ruhr	1980-1984	€83.5bn State/ National	- Technology transfer and innovation - Culture and environment - Refurbishment of old industrial sites
Technology programs	1985-1988	€200m State/ National	- Support for development of new products in 8 fields (e.g., environment and technology)
Future initiative coal and steel regions	1987-1989	€1bn State/ National /EU	- Innovation and technology funding - Education of workers - Support for soft location factors
IBA Emscher Park	1989-1999	€2.5bn Public/ private	- Financial support for individual projects for economic reorientation and better living conditions - Coordination - Consulting
EFRD & public funding for individual projects	1989-2006	€3.7bn National /EU	- Investment and research support - Development of education and research facilities - Environmental measures - Creation of business centres
EFRD & public funding for individual projects	2007-2013	€2.5bn National /EU	- Entrepreneurship - Higher living conditions - Improvement of innovation activities
EFRD & public funding for individual projects	2014-2020	€2.5bn National /EU	- Subsidies for innovation and technology - Support for SMEs - Support for renewables and energy efficiency

6.2 Case 2: Lusatia, Germany

Table 11: Financial scale of major transition measures, Lusatia

Measure	Years	Funds	Description
Social policies	2020 - 2048	€4.8bn National	- Early retirement, pension contributions, retraining, additional earning opportunities, and other benefits
German Federal Government support for coal regions (incl. Lusatia)	2020 - 2038	€40bn National/ EU	- Investment package for regional governments (€14bn) - Federal measures incl. R&D funding, infrastructure investment, and establishment of federal facilities within coal regions (€26bn)
German Federal Government support for Lusatia (with support of EU JTM)	2020 - 2038	€17bn National/ EU	- Immediate investment in new infrastructure projects such as transport and broadband - Establishment of new clusters for research, university, and agencies - Establishment of federal agencies
Coal-fired Power Cessation Act	2020 - 2038	€5-5.4bn National	- Decommissioning premiums of €165,000/MW, decreasing from 2020 - Support for conversion to CHP and from coal CHP to gas CHP €390,000/MW
Mine reclamation	2018 -	€2.2bn National	- Conversion of 140 km² former open-surface lignite mines into 24 artificial lakes, connected by 70 km of canals

6.3 Case 3: United Kingdom

Table 12: Financial scale of major transition measures, United Kingdom

Measure	Years	Funds	Description
Single Regeneration Budget	1994 - 2001	£713m/y (£5.7bn total) Local/national/ EU/private	- Competition-based funding supplement for partnerships working on regeneration schemes.
National Coalfields Programme	1996 - 2017	£37m/y (£880m public, £1.1bn private)	- Remediation of coal mining sites and conversion to housing and commercial spaces. Funded by public-private partnerships.
Coalfields Regeneration Trust	1999 - 2019	£150m National/EU	- Small grants for social enterprises, community organisations, local training agencies, renewable energy infrastructure, and other initiatives.
Coalfields Funds (Enterprise and Growth)	2004 - 2014	£2.3m/y National/EU	- Venture capital initiatives for SMEs
Regional Growth Fund	2010 - 2017	£425m/y National	- Non-interest loans to initiatives in “assisted areas”
City Region Deals (England, waves 1-2)	2012 - present	£127m/y National	- Provision of funding and devolution of decision-making powers to local/regional level.
City Region Deals (Scotland)	2014 - present	£104m/y National	
City Region Deals (Wales)	2016 - present	£62m/y National	
Skills Development Scotland	2008 - present	£264m/y (2019) National	- Comprehensive unemployment service, incl. retraining, application support, and help with understanding benefits.

6.4 Case 4: Spain

Table 13: Financial scale of major transition measures, Spain

Measure	Years	Funds	Description
Coal reorganisation plan	1990 - 1993	- Reindustrialisation: €150m	- Reduce production cost of domestic coal through reduction in state aid - Improve underground mining productivity by 15% - Consolidate open-pit mining capacity to 600 kt - Improve mining safety - Promote industrial transition in areas affected by mining closures
Coal industry modernisation plan	1994 - 1997	- Retirements: €113m - Redundancy: €46m - Debt restructuring: €94m - Reindustrialisation: €47m - Business loans: €133m	- State aid continued on condition of increased productivity and competitiveness - Economic fund for reindustrialization activities - Aid for mines limited <5% electricity revenue - Aid for economic reactivation of mining regions limited to <0.5% electricity revenue - Aid for mining regions aimed at alternative job creation, supporting business infrastructure, mitigating problems of social marginalisation, and the environmental, urban, and cultural transformation of affected communities.
Coal mining plan	1998 - 2005	- Infrastructure: €2.4bn - Training: €240m - Business loans: €480m	- Business development leading to direct employment creation (15% total funds allocated) - Retraining (7.5% funds allocated) - Infrastructure investment (77.5% funds allocated)
Coal strategic reserves national plan	2006 - 2012	- Infrastructure and business projects: €2.6bn - Training: €280m - Coal production subsidies: €2.5bn	- Continuation of support from previous plan - Greater priority for reactivation measures - First to support adaptation of the coal mining industry to environmental requirements (financing R&D cleaner combustion and carbon capture technologies and rehabilitation of closed mines.
Coal activity framework	2013 - 2018	- Environmental rehabilitation: €15m/y (2014 - 2021) - Retirement: €158m - Redundancy: €124m	- Support for coal used in domestic power plants - Workers: compensation for voluntary redundancy, healthcare support (silicosis), early retirement packages, and training support - Reactivation of former coal mining areas and development of job-creating alternative industries - R&D activities around cleaner combustion and carbon storage technologies
Just transition plan	2019 - 2027		- Environmental rehabilitation of closed mines - Financing for economic reactivation of mining communities, alternative industries and CCS

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