Energy Partnership
Partenariat énergétique
Canada – Germany

Supporting just transitions in Canada and Germany

Lessons from sixty years of coal phase-out in Germany

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Executive Summary

In Germany and Canada, the energy transition is leading to structural change in the energy system. Policy-makers in both countries face the task of managing this structural change and achieving a just transition, which minimises disruptions for affected workers, industries, and communities, and leverages the opportunities of the transition. Through their Energy Partnership, Germany and Canada are collaborating on the just transition. Within this cooperation, this study aims to contribute to a better understanding of the challenges posed by structural change in the energy sector and the lessons-learned from previous structural and just transition policies. For that purpose, Germany's sixty-year experience in managing the decline of its coal sector is analysed and the lessons for policy-makers are highlighted.

Germany and Canada face different challenges in their transition due to distinct starting points in terms of natural resources, energy mix, energy trade balance, incumbent industries and policy pathways. In both countries, energy is central to the economy. In Canada, the energy sector directly employs 264,700 workers (1.4% of the workforce), who mostly work in oil and gas and the power sector. In Germany, the energy sector directly employs 230,000 workers (0.5% of the workforce), mostly in the power sector. The coal sector plays a relatively less significant role in both countries, employing 20,000 workers in Germany and 3,900 in Canada.

Germany's coal industry once used to be very significant to the national economy, however, employing 600,000 people at its peak in the 1950s. Taking a long-term perspective, Germany's coal sector thus offers an interesting case study of a modern energy industry having undergone far-reaching structural change over six decades. Many important lessons for policy-makers can be drawn from the decline of this industry as well as from the policy measures and strategies employed. These lessons are useful for policy-makers working on the coal phase-out in and outside of Germany. In addition, they are relevant for the transformation of other traditional energy sectors. This includes Canada's oil and gas industry, which shares similarities with Germany's historic coal industry in terms of economic significance, regional importance, challenges posed by changing markets, and the industry's response to these.

Germany's experience with structural change in the coal industry can be divided into three processes: the economically driven decline of hard coal mining in Western Germany over the 1958-2018 period; the restructuring of the energy sector of the former German Democratic Republic in the Eastern part of Germany after the reunification in 1990; and finally, the ongoing climate policy-driven nationwide phase-out of coal power generation and lignite mining by 2038, which was put into law in 2020. After a detailed analysis of each of these processes, the study presents several lessons-learned from selected best-practice (and less-good-practice) approaches and measures to manage and respond to structural change in Germany's energy sector, including experiences from stakeholder commissions, the topic of skill transferability of coal industry workers, and economic re-orientation and diversification.

Looking back at Germany's experience, a number of key lessons can be highlighted for policy-makers on how to deal with structural change in the energy sector and support affected workers, industries, and regions. First of all, policy measures should be anticipatory and forward-looking to enable a just and in-time transition. Indeed, there seems to be a first-mover advantage when responding to structural change in the energy sector. Push-back and attempts to delay the transition can hinder innovation and diversification. Second, regions following a more diversified approach tend to be more resilient and successful in managing the transition than those relying on fewer industries or employers. Third, successful policy approaches cross administrative boundaries, political levels, and policy fields, and rely on public participation. Fourth, labour market and social policies are important to cushion social hardships for those workers within the energy sector with fewer career alternatives. Lastly, each region is different and there is no one-size-fits-all solution. Successful just transition policy will need to be designed in cooperation with the affected regions and communities, taking into account their specific circumstances and leveraging their respective advantages and potentials in the energy transition.

Table of contents

1. Introduction

Global efforts to mitigate climate change are leading to structural change in energy systems, creating opportunities but also posing challenges for countries around the world. With almost 130 nations, which represent 92% of the global economy, having committed to reaching climate neutrality by mid-century (NZT 2022), energy sectors around the world will have to reduce energy demand, increase in efficiency and shift to renewables and climate-neutral energy carriers in only a few decades.

Structural change in the energy industry is not a new phenomenon, of course. Whether we look back at the shift from wood and charcoal to coal and later from coal to hydrocarbons, the increasing use of electricity instead of primary energy, or the development of nuclear energy – the history of energy use is one of continuous structural change (Smil 2004). Today's energy transition is different, given that it is mainly driven by climate policy and will have to be much faster in pace than historic energy transitions, which tended to take many decades or even centuries (Kern and Rogge 2016).

The energy transition offers many opportunities for countries around the world, in terms of new markets and industries in a climate-neutral global economy and the associated employment prospects, increased energy independence, and improvements in environmental quality and human health. At the same time, it poses new challenges to the world's energy sectors as well as to incumbent industries. This is particularly challenging for large energy producers and exporters such as Canada, where energy plays a significant role in the national economy. But it is also a challenge for Germany, having decided to phase out traditional energy industries such as coal and nuclear and transition to an energy system largely based on renewables. In dealing with structural change in the energy sector, Germany and Canada, as well as many other countries, made it their goal to ensure a 'just transition' – aiming to minimise the disruptions of affected workers, industries and communities caused by the transition (Gürtler et al. 2021, Piggot et al. 2019).

Canada has already gained experience in managing structural change in the energy sector. In 2018, after the decision on a nation-wide phase-out of coal-fired electricity by 2030, a 'Task Force on Just Transition for Canadian Coal Power Workers and Communities' was established. The Task Force's 2019 report helped to inform the Government's approach, which includes $185 million to support economic diversification and skills development for coal workers in 15 affected communities and economic regions in Alberta, Saskatchewan, Nova Scotia and New Brunswick. Provinces such as Alberta have also implemented provincial-level just transition measures and programmes that provide assistance to affected workers and municipalities (Piggot et al. 2019). Moving forward with its commitment "to support workers and communities while unlocking economic opportunities in the transition to a net-zero emissions economy", the Government of Canada released an interim Sustainable Jobs Plan[1] in February 2023 (Government of Canada 2023). It was followed by legislation ("Canadian Sustainable Jobs Act") in June 2023, requiring the publication of a Sustainable Jobs Action Plan every five years (starting in 2025), creating a Sustainable Jobs Partnership Council to provide independent advice to government and establishing a Sustainable Jobs Secretariat to coordinate federal action (NRCan 2023).

Germany's experience with structural change in the modern energy sector dates back much further. The decline of the country's coal industry spans over six decades, and there is much to learn from the associated structural transformation and structural policy responses. The coal sector's decline can be separated in three processes, described in detail in this study: the decline of hard coal mining in Western Germany from the 1960s, the restructuring of Eastern

[1] The term 'sustainable jobs' has been increasingly used by the Government of Canada, as well as certain provinces, territories and external organizations, in the context of work on achieving what the international community refers to as 'just transition' for workers and the jobs of a net-zero emissions economy.

Germany's energy sector after reunification, and the ongoing nation-wide phase-out of coal power generation and lignite mining ideally by 2030.

Taking a long-term perspective, Germany's coal phase-out can be considered as largely complete. Once very economically significant, Germany's coal industry employed 600,000 people at its peak. With the completed phase-out of hard coal mining and the still ongoing phase-out of coal-fired electricity and lignite mining, only around 20,000 employees remain today. Many relevant lessons can be drawn from this decades-long decline and the associated policy responses. These can not only serve policy-makers in Germany today, but also those in other countries phasing out coal. In addition, many of these lessons are relevant for the transformation of other traditional energy sectors.

Through their Energy Partnership, Canada and Germany are cooperating on achieving a just transition in their energy sectors. To share lessons-learned and forge connections, a virtual study trip on the topic of coal exit and structural change was organised in 2021 by the Energy Partnership for stakeholders from Alberta. This study is another step in this bilateral cooperation, aiming to contribute to a better understanding of the challenges posed by structural change in the energy sector as well as of key learnings from previous structural and 'just transition' policy responses. For this purpose, the decline of Germany's coal industry and the measures taken to manage and respond to it are analysed in view of today's energy transition. Further, the lessons-learned for policy-makers from Germany's experience are summarised.

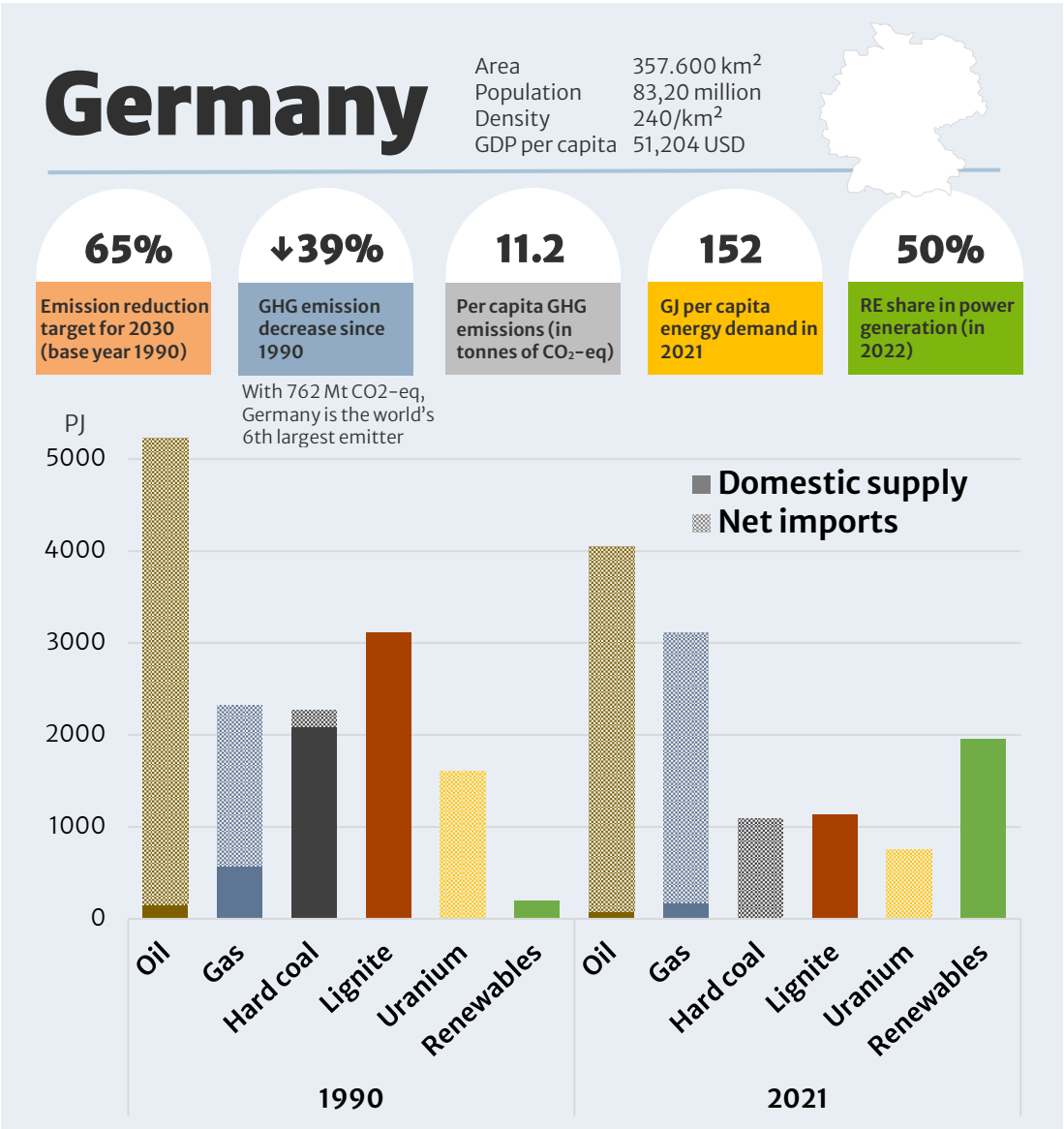
Setting the context for the discussion on structural change in the energy sector in Canada and Germany, the next chapter provides an overview of their respective energy landscapes, compares the energy sector's role in their economies and draws parallels between structural change processes in both countries. Chapter 3 analyses Germany's experience with structural change in the coal industry, Chapter 4 highlights several best- and worst-practice examples of policy measures taken. The final chapter provides an overview of lessons-learned from Germany's coal phase-out in light of today's energy transition, which is also relevant to policy-makers in other countries around the world, including Canada.

2. Energy in Germany and Canada: An overview

While structural change impacts energy sectors in all countries, challenges differ quite substantially depending on a country's economic make-up, resource assets, industry interests, and policy priorities. To better understand these, the next chapters will take a closer look at Canada's and Germany's energy sectors and their role within the national economy.

2.1 Germany's energy sector

Figure 1: Germany – energy facts and energy balance



Own depiction. Domestic supply = energy produced and consumed domestically. Net imports: energy imported minus energy exported. Both for lignite and renewables, there are negligible amounts of net exports not shown in the chart. Sources: AGEB 2022; BP 2022; UBA 2022b; BMWK 2022; Destatis 2022a.

Germany is the fourth-largest economy in the world, with a strong industrial sector and relatively few domestic natural resources. It is thus a large energy importer: Germany's net

import share was at 70% of total energy consumption in 2020, with 100% for uranium, 98% for oil, 93% for hard coal, 88% for natural gas. Small amounts of lignite were exported to the Czech Republic in 2020 (BMWK 2022). While Germany is increasing overall domestic energy production through renewables deployment, it is expected to remain an energy importer in the future. Given its climate targets and policies, it will mainly import climate-neutral energy carriers in the long-term (Piria et al. 2022).

Germany is the world's sixth-largest GHG emitter. Emissions reached 762 Mt CO_2-eq in 2021, a 39% decrease since 1990. 91% of emissions are energy-related (UBA 2022b). Per capita GHG emissions are at 11.2 tonnes of CO_2-eq (UBA 2021b). The country targets climate neutrality by 2045 and a 65% reduction of GHG emissions by 2030 compared to 1990. As part of its *Energiewende*, Germany phased out nuclear in 2023, and will phase out coal ideally by 2030 and eventually transition to an energy future largely based on renewables, as well as renewable hydrogen and its derivatives (IEA 2020). Renewables are to make up 80% of electricity generation by 2030. For this, renewable capacity is to be significantly expanded: 115 GW of onshore wind by 2030, 160 GW by 2040. 30 GW of offshore wind by 2030 and 70 GW by 2045. 215 GW of solar capacity by 2030, 400 GW by 2040. As an energy efficiency target, Germany aims to half energy demand by 2050 compared to 2008.

Germany is a large producer of renewable energy (RE), which represented the second-largest domestically produced energy source in 2020. In 2021, RE made up 19.7% of final energy consumption and 41% of gross electricity consumption (BMWK 2022). A smaller share of RE is used in heating (16.5%) and transport (6.8%). Biomass represents the largest source in Germany's RE production, followed by wind energy, solar, geothermal and hydro. Of the electricity generation mix, wind energy accounted for 21.5%, followed by solar PV (8.7%), biomass (5.8%) and hydro (3.6%) (Destatis 2022b). In 2021, wind energy capacity was at 63 GW, solar PV at 56 GW, hydro at 14 GW and biomass at 12 GW (BMWK 2022).

As one of the central targets of the *Energiewende*, Germany had decided to phase out nuclear energy by the end of 2022. Nuclear generation continuously increased between the 1970s and 1990s, plateaued afterwards and decreased from 30% of electricity generation in 2005 to 11.8% in 2021 (IEA 2020). Due to the energy crisis, two of the three last remaining operational nuclear plants were temporarily kept in reserve until mid-April 2023.

Germany is still among the world's largest producers of lignite, even though production has been declining in recent years. While existing lignite reserves are enough to last for a long time, coal-fired electricity production and coal mining will have to be phased out in 2038 at the latest according to Germany's coal exit law (BMWK 2023). Today, lignite still makes up 8% of primary energy consumption, being mainly used in electricity production (18.8% of power generation) and district heating. Germany used to be a large producer of hard coal, but domestic production could not compete with cheaper imports and thus declined over the past decades (IEA 2020). With the phase-out of subsidies for hard coal mining, production stopped completely at the end of 2018. Today, all hard coal consumed in Germany is imported, still representing 8% of primary energy consumption and 9.3% of power generation. Lignite and hard coal are responsible for 33% of Germany's energy-related CO2 emissions (BMWK 2022).

Germany's domestic production of hydrocarbons is small. Domestic natural gas production made up 6% of supply in 2020, having declined in the last decade from over 20 billion cubic metres (bcm) in 2007 to 5.7 bcm in 2020, with gas fields near depletion (IEA 2020, Wettengel 2022). While there are substantial reserves for unconventional production, Germany has had a ban on hydrologic fracturing (fracking) since 2017.

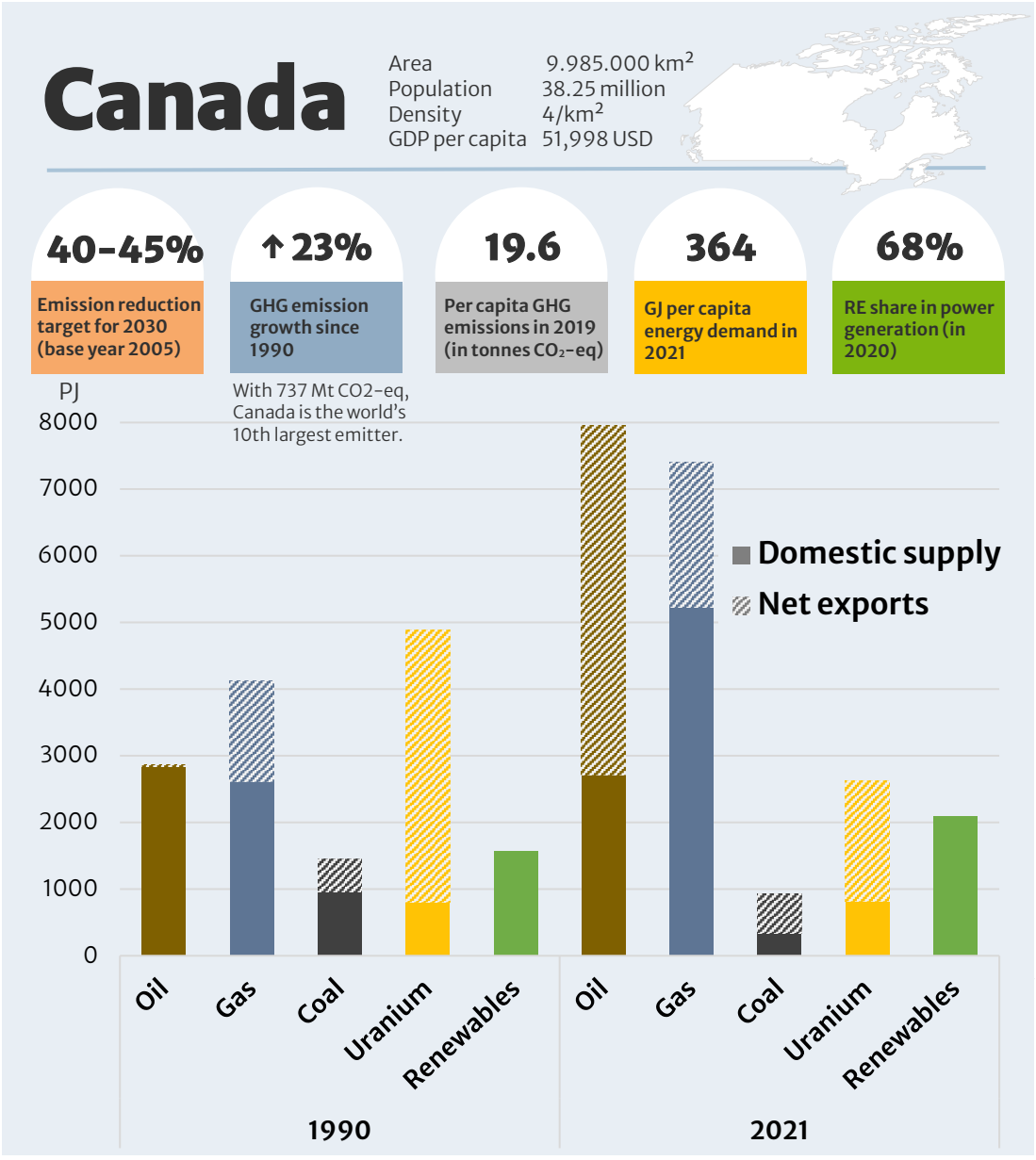
With domestic production insufficient to meet demand, imports are essential. In 2021, Russia was Germany's largest natural gas supplier, followed by the Netherlands and Norway. As a response to Russia's war on Ukraine, Germany has decided to wean itself off Russian gas in the short term. While Germany's gas demand is expected to fall in the medium- and long-term, Russian gas has to be replaced in the short term. For that reason, Germany is rapidly building up its LNG capacity. With no operational LNG terminals at the time of the invasion, seven floating LNG import terminals are to be completed, the first one went online at the end of 2022.

Three onshore LNG terminals are to be operational by 2025/2026 (Stratmann 2022). As scaling up domestic production through fracking would take several years and pose significant environmental risks, the Federal Government has excluded it as a potential solution to the current energy crisis (ZEIT 2022).

Domestic oil production makes up only 2% of Germany's supply and has declined by 27% between 2008 and 2018 (IEA 2020). Russia was the largest supplier of crude oil to Germany in 2021. Following Russia's invasion of Ukraine, Germany, as well as other EU member states, decided to cut Russian crude oil imports by December 2022. In addition, there has been an EU-wide embargo on refined oil products from Russia from February 2023. Other important oil suppliers to Germany are the United States, Kazakhstan, Norway, and the UK. Most of Germany's demand for oil products is produced in its 13 domestic refineries (IEA 2020).

2.2 Canada's energy sector

Figure 2: Canada – energy facts and energy balance



Own depiction. Domestic supply = energy produced and consumed domestically. Net exports = energy exported minus energy imported. For sources and details, see footnote[1] on next page.

Canada is the second-largest country by land area and the tenth-largest economy in the world. A resource-rich nation, Canada is the sixth-largest energy producer. Its uranium reserves are the third-largest in the world, its oil reserves the fourth-largest (NRCan 2022). Canada's per capita energy demand is among the world's largest, mostly as a result of its energy-intensive oil and gas industry and large demand from heating and transportation (IEA 2022). Canada is the world's tenth-largest GHG emitter. The country's emissions reached 737 Mt CO2-eq in 2019, a 23% increase since 1990. 84% of emissions are energy-related (Government of Canada 2022). Per capita GHG emissions were at 19.6 tonnes of CO_2-eq in 2019.

Aiming to reach net-zero by 2050 and to cut GHG emissions by 40-45% by 2030, Canada follows a technology-neutral approach based on fossil fuels combined with CCS, nuclear, renewables, and so-called 'clean' hydrogen, which can be either low-carbon or renewable (IEA 2022). The country wants to increase electricity generation from non-emitting sources (including nuclear) to 90% by 2030 and to transition to a net-zero electricity grid by 2035. In 2018, Canada regulated the phase-out of coal-fired electricity by 2030. Methane emissions from the oil and gas sector are to be cut by 75% by 2030 compared to 2012 levels. Zero emission vehicles are to make up 30% of new light duty sales by 2030 and 100% by 2040. In addition, Canada aims at increasing energy efficiency by 3% every year (IEA 2022).

The country is a net energy exporter. In 2021, Canadian energy products worth C$154.3 billion were exported to 142 countries. They accounted for 32% of total goods exports. Canada is the largest exporter of electricity, the 3rd-largest of crude oil, the 5th-largest of uranium, the 6th-largest of natural gas and the 7th-largest of coal. 91% of energy exports go to the US. North American energy trade goes both directions, however. Canada's energy imports make up 14% of total imports, 73% of energy imports come from the US (NRCan 2022).

Canada is the fourth-largest producer of crude oil, with 77% of production exported to the U.S. Oil production grew by 55% between 2010 and 2020 (IEA 2022). While production declined temporarily in the early phase of the Covid-19 pandemic, production reached pre-pandemic levels at the end of 2020 and saw strong growth again in 2021 (IEA 2021). Oil sands – where 97% of Canada's oil reserves lie – account for most of the production growth over the last decade (IEA 2022). In 2021, production from oil sands made up 65% of total output. Compared to conventional production, oil sands production is more cost-, energy- and emission-intensive (NRDC 2021). Emissions from Canada's oil sands made up 11% of total GHG emissions.

It is also the fifth-largest producer of natural gas, with the 17th-largest proven reserves in the world. At current output levels, reserves would last for over 200 years (IEA 2022). In 2021, 89% of natural gas was produced from unconventional sources, for which fracking is used. 46% of Canadian production is exported to the U.S. Yet, exports have been declining and imports increasing since 2007, due to the partial displacement of Canadian natural gas by cheaper US shale gas (IEA 2022). No LNG is exported, and while several LNG export projects have been announced, only one export facility is in construction in British Columbia. In New Brunswick, there is an operational LNG import facility.

Canada is the world's seventh-largest renewable energy producer, mostly due to its large hydropower capacity (82 GW in 2021) (IHA 2021). Installed capacity of onshore wind was at 14.3 GW in 2021, of solar at 3.6 GW. Most wind farms are located in Ontario and Quebec, almost all solar farms are in Ontario. Renewables made up 24% of total final energy supply and 67% of electricity production in 2019 (IEA 2022). Of the electricity mix, hydro accounted for 59.2%, wind for 5.1%, biomass for 1.7%, and solar for 0.6%. Canada is also the third-

[2] Data sources for the info boxes are Government of Canada (2022); BP (2022); and NRCan (2022). Supply and trade data for oil, gas, coal is based on IEA (2023a). Data for renewables in 2021 is from 2020, based on NRCan (2022). Data for renewables in 1990 is estimated, based on 1) data on RE electricity generation data from IEA (2023a) and 2) an estimate for biomass production based on current data, given the lack of historic data on biomass production in Canada and available information that production has remained relatively stable over time (NRCan 2020). No data on renewables trade was found for Canada.

For uranium, the data for 2021 is calculated based on a conversion rate of 1 tonne of Uranium = 0.56 PJ. In 2021, Canada produced 4700 tonnes of Uranium (NRCan 2022), equal to 2632 PJ. Data for 1990 is based on Chenoweth (1991), which specifies Canada's uranium output at 2.27 milllion pounds of U3O8. This is equal to 10,297 tonnes of U3O8, 8731 tonnes of Uranium or 4890 PJ. Data on uranium exports in 1990 is estimated by subtracting the energy value (803 PJ) of domestically generated nuclear electricity (72.5 TWh) (BP 2022).

largest producer of uranium, more than half of production is exported. Nuclear energy makes up 15% of the electricity mix.

The country is also a large producer and the seventh-largest exporter of coal. Between 2000 and 2020, the share of coal fell from 12% to 3.4% in energy demand, and from 19% to 4.8% in electricity generation (IEA 2022). In 2018, Canada decided to phase-out coal-fired electricity until 2030, leaving coal used for metallurgical processes unaffected. Coal is primarily mined in B.C. (53%), Alberta (31%), and Saskatchewan (16%), and also in Nova Scotia (0.4%). Coal-fired power capacity exists in Alberta (62%), Saskatchewan (22%), Nova Scotia (12%), and New Brunswick (3%). Coal accounted for 70% of electricity-related GHG emissions in 2019.

2.3 Energy's role in the economy: Comparing Canada and Germany

The previous sections show that the energy landscapes of Germany and Canada are quite distinct in terms of available natural resources, energy mix, energy trade balance, incumbent industries, as well as policy priorities and pathways. This section will now provide a brief overview of the energy sector's role in the two countries' economies.

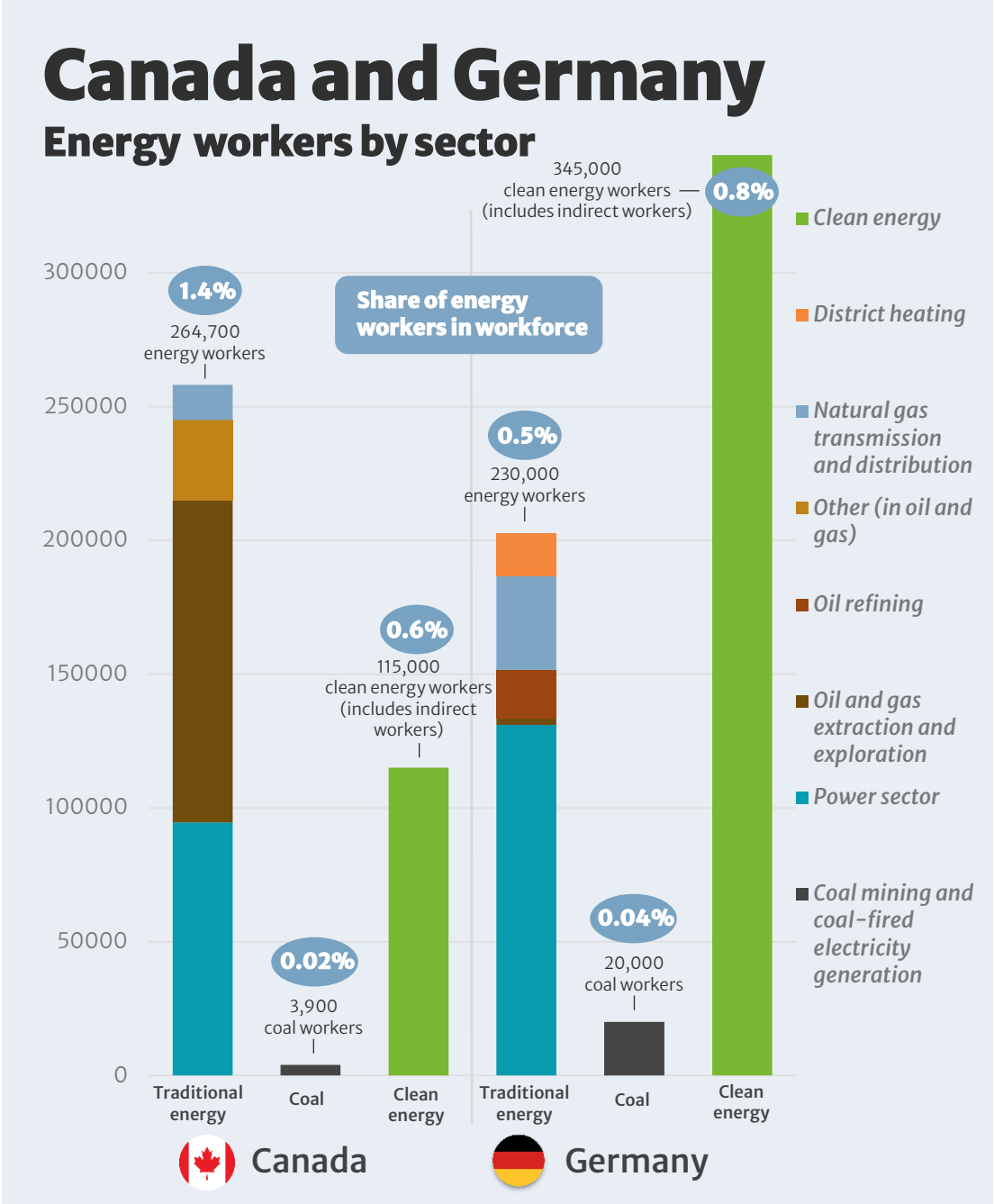
Canada's energy sector is central to its economy. With C$226 billion (€157 billion), the energy sector made up 9.7% of GDP in 2021. At C$14.9 billion (€10.3 billion) on a yearly average, 6.9% of the federal government's revenue from industry comes from the energy sector. Provincial governments benefit from royalties, too. These were estimated at C$18 billion (€12.5 billion) in 2022 – an increase of 50% from 2021 due to higher energy prices (Guldimann and Hussain 2022). In 2021, 3.4% of Canadian workers (634,600) were employed by the energy industry. 1.4% were employed directly (264,700) and 2% indirectly (369,900). 0.9% worked in the oil and gas industry (163,700) and 0.5% in the power sector (95,000). Of workers directly employed by the energy industry, 52% are in Alberta, 15% in Ontario, 12% in Quebec, 9% in British Columbia, 6% in Saskatchewan, and 5% in the Atlantic provinces. Canada's clean energy sector employed 115,000 workers in 2021, in the fields of renewable and nuclear electricity, biofuels, and carbon capture and storage (NRCan 2022).

Canada's oil and gas sector contributed C$168 billion (€117 billion) or a share of 7.2% to Canada's GDP in 2021. Exports amounted to C$140 billion (€97 billion), representing 29% of total exports. The oil and gas sector directly employed 163,700 people in 2021, of which 69% are located in Alberta. Of directly employed workers, 38% worked in extraction and exploration (62,100), 36% in support activities (58,300), 8% in natural gas transmission and distribution (13,100), and 2% in crude oil pipelines (4,000). Another 278,400 people were indirectly employed by oil and gas, mainly in Alberta (54%), BC (15%), and Ontario (13%). Around 10,400 Indigenous people are employed by the oil and gas sector (NRCan 2022). Due to low global oil prices and oversupply in North America, oil and gas employment fell by 22% between 2014 and 2019. The COVID-19 related demand decline led to further job losses, with employment in mid-2020 at 34% less than in 2014. By the end of 2022, employment was again at pre-pandemic levels (PetroLMI 2022).

Compared to oil and gas, Canada's coal industry has a much smaller role in the economy. Coal mining, processing, and related services account for 0.2% of GDP (C$4 or €2.7 billion), with half of the contribution from metallurgical coal. There are around 3,000 to 3,900 workers at Canada's coal-fired power plants and domestic thermal coal mines (ECCC 2019).

In Germany, too, the energy industry is an important sector of the national economy – with around 2,000 companies in the industry. While no recent data is available on the exact share of the energy sector in national GDP, the sector's contribution has ranged between 1.5-2.9% of GDP in the past decade (IFO 2011; OECD 2015; Prognos 2015). Revenues of Germany's energy supply sector totalled €589 billion in 2019 (BMWK 2022). The power supply sector accounted for most of these revenues (€509 billion), followed by gas supply (€75 billion) and district heating (€5 billion). Investments in energy supply totalled €16.1 billion.

Figure 3 – Energy and the economy: Canada and Germany



Own depiction based on ECCC 2019, NRCan 2022, BMWK 2022. Note: Indirectly employed energy workers are excluded for the traditional energy sector data. Coal data excludes Canada's workers in metallurgical coal mines. Clean energy data includes workers in the field of renewable energy for Germany (including those working in planning and project development, plant production and maintenance, sales, public administration, and research and development) and workers in the fields of renewable and nuclear electricity, biofuels, and carbon capture and storage for Canada (NRCan 2022, UBA 2022a).

At the end of 2021, around 230,000 workers were directly employed by the energy sector (Destatis 2022a). This represents 0.5% of Germany's workforce. Most of Germany's energy workers work in the power sector (131,000), followed by the natural gas sector (35,000), oil refining (18,000), district heating (16,000), coal mining (12,000), and oil and gas extraction

(2,600) (BMWK 2022). Germany's renewable energy sector employed around 345,000 workers in 2021 – including directly and indirectly employed workers in planning and project development, plant production and maintenance, sales, public administration, and research and development (UBA 2022a)

Direct employment in Germany's energy sector has fallen significantly over the past decades, from around 560,000 workers in 1991 to 220,000 in 2021 (BMWK 2022). This decline is primarily due to the large decrease in employment in the coal industry in the past decades, as well as employment decline in the power sector and to a lesser degree in oil refining.

In Germany's coal industry, the economic shift and associated structural change led to a large decline in employment over the past decades. In the hard coal industry, employment figures had shrunk significantly from the 1960s, with only a few thousand remaining when the last hard coal mine closed at the end of 2018 (Müller 2019). In the lignite industry, employment has declined since the 1990s. In 2020, there were around 20,000 workers left in lignite mining and processing and lignite-fired electricity production – representing only 0.04% of Germany's workers (UBA 2021a). Yet, while the lignite industry's role for the national economy is rather small, it is central for the economy in lignite-mining regions.

2.4 Structural change in the energy industry in Germany and Canada

While energy plays an important economic role in both Canada and Germany, the coal sector today only employs a few thousand workers respectively. In Germany, however, the coal industry once used to be very significant to the national economy. At its peak in the 1960s, it employed 600,000 people. Thus, taking a long-term perspective, the sector can be considered to be in the final stages of a transformation. This provides for an historic example of a traditional energy sector having undergone far-reaching structural change over many decades. The lessons-learned from that decline and its challenges, as well as from the more and less successful policy measures and strategies that were employed, are important for policy-makers in Germany and other countries today.

First and foremost, these lessons are useful for policy-makers and stakeholders managing structural change in the coal industry. But they are also relevant for the energy industry as a whole, including for fossil-energy energy sectors other than coal. Indeed, taking an energy-sector-wide perspective, we find a number of parallels between Germany's historic coal industry and Canada's modern oil and gas industry – including in terms of their strong significance for the national economy, their role as large employers offering high-paying jobs, and their importance for regional economies and identities.

Besides these economic characteristics, the two sectors share certain similarities in terms of external market challenges affecting the respective industries. In the case of Germany's hard coal industry, international market forces led to a decline in demand for the sector's product, with cheap imports increasingly displacing the more expensive domestic hard coal. Canada's energy sector is today also confronted by changing global markets, which will challenge the industry as demand for conventional energy products decreases in the long-term.

More importantly, today's challenges for Canada's energy industry include increasing climate policy ambitions and a global shift to sustainable energy. The global energy crisis has further accelerated this transition, with countries increasingly recognising that, besides the contribution to climate action, lower fossil fuel demand comes with higher economic and national security (Crawford 2022, IEA 2022b). Consequently, while still growing in the short term, global demand for all fossil fuels has now for the first time been forecasted by the IEA to peak around 2030 and to decline thereafter (IEA 2022b).

The energy transition will impact all major fossil fuel producers around the world. Still, certain studies and expert assessments have warned that Canada's oil and gas industry is particularly vulnerable to the transformation ahead (Le Billon and Kristoffersen 2019, Mercure et al. 2018,

Samson et al. 2021, Van de Graaf 2018). This is because the majority of Canada's oil reserves are non-conventional, largely in the oil sands, whose extraction comes with increased marginal production costs and higher GHG emissions (Le Billon and Kristoffersen 2019). Due to this cost gap, Canada's oil and gas industry is expected to be affected earlier by a global shift away from fossil fuels, being uncompetitive sooner than other conventional producers around the world (Mercure et al. 2018).

On top of that, the large investments needed to cut down the relatively higher emissions with CCS technology would further drive up production costs, increasing the risk of making extraction uneconomical (Guldimann and Hussain 2022). As a result, the stranded asset risk for Canada's oil and gas industry has been estimated at US$100 billion – among the highest in the world and much higher than that of Middle Eastern producers, whose sites remain profitable for longer (Semieniuk et al. 2022). Furthermore, this estimate only includes upstream oil and gas assets and would thus be even higher if assets such as pipelines or refineries were also considered. In addition, there are the environmental liabilities from oil and gas assets, including the costs for cleaning up orphaned wells and tailing ponds (Forman et al. 2022).

Interestingly, there are also parallels between coal in Germany and oil and gas in Canada in terms of how incumbent industries and involved stakeholders respond to the structural change ahead. Several Canadian experts and researchers have pointed out the long-term stranded assets risk of the country's oil and gas sector and have urged governments and industry to initiate a just and managed transition towards sustainable energy (Adkin and Davidson 2020; Mertins-Kirkwood 2022; Samson et al. 2021). Still, the energy industry itself and many surrounding actors still see a central role for fossil fuels both in the country's future energy system and in global energy markets and reject the notion that the industry will have to substantially change on the path to climate neutrality (CAPP 2022a, b; Rabson 2022).

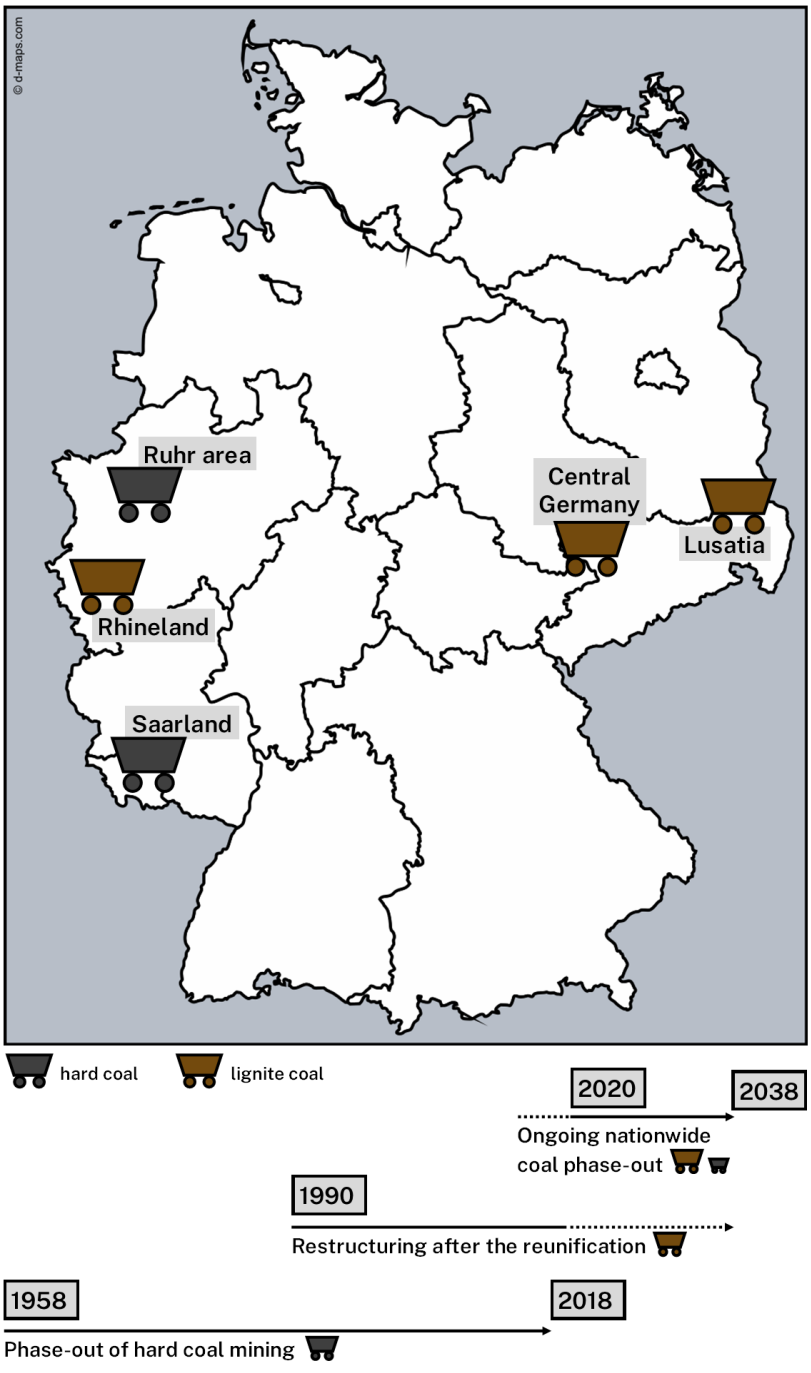
This reaction of Canada's oil and gas industry to the challenges of the global energy transition can be compared to the long-lasting push-back by government and businesses in Germany against the decline of the coal industry – described in more detail in the following chapters. A large number of subsidies was paid to Germany's coal industry over a long time period to prevent and later slow down its decline. Incumbent industries fought back and opposed the establishment of new, competing industries. All these attempts to stop the decline proved ultimately unsuccessful. Similar to Germany's experience, there is the risk that preservative policy responses and push-back against the energy transition in Canada could make the transition extremely expensive, cause institutional and economic lock-in effects, and hinder innovation and economic diversification.

Canada's modern energy industry is of large significance to the national economy and faces a number of challenges on the way to net-zero. Given the several parallels between Germany's traditional coal industry and Canada's energy industry, the lessons from the decline of the former are of relevance to the latter. Providing an overview of these lessons, the following chapters will analyse Germany's experience with structural change in coal industry and look at various best- and worst-practice examples of structural and just transition policy.

3. Structural change in Germany's coal industry

This chapter aims to appraise and analyse the German experience of structural change in the energy sector as a starting point to derive lessons learned relevant for other countries. We use the following three examples: the economically driven decline of hard coal mining in Western Germany over the 1958-2018 period, the restructuring of the energy sector of the former German Democratic Republic in the Eastern part of Germany after the reunification in 1990, and finally the ongoing climate policy-driven nationwide phase-out of coal power generation and lignite mining by 2038, which was put into law in 2020 (see Figure 1 for an overview).

Figure 1: Location of coal regions in Germany and timeline of phase-out processes. Own depiction using underlying map from d-maps (2022).



As these and other examples from other countries show, structural change has always been an issue in coal mining regions, where periods of growth are eventually followed by the closure of depleted mines (Dahlbeck et al. 2022). German structural policy (*Strukturpolitik*) aims to support coal regions in those periods of decline by combining industrial and regional development policies (Furnaro et al. 2021; Gärtner 2019). Including regional aspects is crucial for the success of structural policy as the phase-out of fossil fuels means not only a restructuring of the energy system, but also social consequences for coal industry workers and related regions (Oei, Brauers, and Herpich 2020).

Frequently mentioned in this context is the necessity of ensuring a 'just transition'. In the International Labour Organisation's original definition, this term refers to securing jobs and the alleviation of local social problems. The concept has since been expanded in literature to also include environmental, energy, and climate justice aspects (Heffron and McCauley 2018). The German Advisory Council on Global Change (WBGU) refers to a 'just and in-time transition', emphasising the importance of the temporal dimension to minimise negative effects on local communities and the natural environment (WBGU 2018).

Meeting the criteria for such a transition is a major challenge not only for Germany but for all countries faced with the phase-out of emission-intensive industries (Furnaro et al. 2021). So far, Germany's existing policies to phase-out coal are not sufficient to achieve decarbonisation at a pace to mitigate disastrous levels of climate change. To be in line with the 1.5°C target, the intended 2030 coal phase-out date needs to become law and the share of renewable energies must increase to 95% by 2030 (Climate Action Tracker 2022; DIW Econ 2021). While RWE has agreed to end coal in the Rhenish mining area by 2030, the company is still planning to expand its Garzweiler mine and is likely to exceed the amount of coal that would be compatible with the Paris Agreement (Rieve et al. 2022; 2021; BUND 2022).

Valuable lessons can be derived from Germany's experience, not only for other coal regions but also for the transformation of other sectors of the economy. However, it is important to keep in mind that there is no one-size-fits all solution. Each region and sector has its individual characteristics, challenges, and potentials that structural policy-making needs to take into account (Dahlbeck et al. 2022; Reitzenstein et al. 2022).

3.1 Phase-out of hard coal mining in Western Germany

Hard coal was the cornerstone of West Germany's post-war economic, social, and political reconstruction. The number of people directly employed in the industry peaked at around 600,000 in 1957 (Oei, Brauers, and Herpich 2020). The work of miners was physically very demanding but also comparatively well-paid with high levels of labour productivity (Dahlbeck et al. 2022).

European coal prices were liberalised starting in 1958, leading to a price drop that made coal from overseas and imported oil cheaper in comparison to domestic coal. As a result, Germany's hard coal production and employment entered a rapid decline. Through subsidies, however, the phase-out was drawn out over a long period of time as an attempt to ease the transition and cushion social hardships. It was only in 2007 that the growing influence of the EU forced Germany to implement a law which ended subsidising of hard coal mining by 2018. Subsidies for hard coal amounted to €289-331 billion from 1950 to 2018 (Meyer, Küchle, and Hölzinger 2010).

Most structural policies in the West German hard coal mining regions were aimed at solving (local) economic, social and, to a lesser extent, environmental problems.[3] Climate considerations did not yet play a role, hence, despite the mine closures, most coal-fired power plants kept operating and switched from domestic to cheaper imported hard coal.

[3] Hard coal mining was only located in West Germany. East Germany relied on lignite due to a lack of hard coal mines.

An important paradigm during the coal crisis was ‘no miner shall be left behind’. This goal was indeed achieved as, beginning in the 1970s, those who could not find alternative employment (e.g. in the metal industries) were offered retraining or early retirement schemes. However, this did not apply to up- and downstream industries, which were also significantly affected. Hence, structural policy also had to focus on diversification of the regional economy as well as the connectedness with neighbouring regions (Oei, Brauers, and Herpich 2020).

In the following, we present two hard coal regions: the Ruhr area and the Saarland. Located in different federal states, they differ in history, identity, representation at the political level, as well as economic and social characteristics. Their comparison can therefore help detect factors that contribute to the success or failure of transition policies.

Located in the state of North-Rhine-Westphalia (NRW), the **Ruhr** area is the larger of the two regions, with not only a larger number of mines and people who used to be directly employed in the hard coal industry, but also an overall higher population and population density. Due to its coal and steel industry, it was considered the ‘industrial heart’ of Germany for most of the 20th century (Petzina, 1984, quoted by Dahlbeck et al. 2022, 72).

The first structural policies aimed to halt the decline of the coal industry and to reduce the negative effects on workers, e.g. by subsidising hard coal and offering retraining and early retirement opportunities. Attracting new companies to increase economic diversification proved difficult, meeting resistance from mining companies, politicians, and unions. An example is the so-called ‘ground lock’: the refusal of mining companies to sell their brownfield sites since they feared new competing industries, which would ultimately lead to rising wages (Dahlbeck et al. 2022; Oei, Brauers, and Herpich 2020).

The transition proved especially complicated for the more northern parts of the Ruhr area. The southern areas were the first to close their mines and therefore also to benefit from structural policy measures, such as the establishment of the first university. When it was the northern Ruhr area’s turn, many subsidies and ideas were already taken, and to this day the North still suffers from high levels of (long-term) unemployment and lower economic power (Dahlbeck et al. 2022; Oei, Brauers, and Herpich 2020).

Starting in the 1980s, structural policy programmes became more inclusive and regionalised, including the establishment of ‘lead markets’ and more polycentric coordination. Ecological and cultural aspects received increasing attention as well. These factors allowed for increased entrepreneurial activity and diversification of the region (Oei, Brauers, and Herpich 2020). An example is the IBA Emscher Park. The 2010s were marked by a growing independence of the cities in the Ruhr area, each creating their individual development strategies (Oei, Brauers, and Herpich 2020).

The **Saarland**, itself a federal state, was the smaller of the two major hard coal mining areas in Germany. Unlike the Ruhr area, the Saarland’s coal mines were publicly owned. Therefore, the state and federal government had more influence over the transition process and the so-called ‘ground lock’ was not as much of an issue.

The Saarland mainly transitioned from coal and steel to the automotive industry. The automotive companies and their suppliers were seeking a workforce with a skillset similar to that of the former coal and steel workers. However, the Saarland was only able to attract companies at a large scale within a small window of time in the 1960s and 70s. After the 70s, the settlements of new companies declined significantly. In the 1990s, a number of research facilities connected to information technology (IT), medicine, bio- and nanotechnology were established, but the IT sector was the only one that managed to create a significant number of new jobs (Lerch 2007; Oei, Brauers, and Herpich 2020).

The shift to the automotive industry resulted in a new dependency on a single, large sector for job and income creation. An emission-intensive industry itself, the automotive sector will have to substantially transform over the coming years and faces challenges related to automation and digitalisation but also other forms of mobility, such as more railway transport. Moreover, as the automotive companies in the Saarland, such as Ford, operate globally, local

opportunities e.g. for R&D cooperation are limited since R&D departments often remain in the home country of the company and only production is outsourced. In 2022, the Ford company decided to produce its electric cars in Valencia, Spain, and not in the Saarland. Before, the Saarland was also competing for the production line of electric cars. With the decision of Ford, the future for the automotive in the Saarland is uncertain (Niewel 2022).

All things considered, neither region has yet completed a just and in-time transition. Only domestic mining was phased out, while power plants shifted to the use of imported hard coal. There has not been a phase-out plan for hard coal power plants until as recently as 2020 (see Section 3.3). Comparing the two regions' regional development, the Saarland was more successful initially at attracting large companies than the Ruhr area. However, while the Saarland developed a new dependency on the automotive industry, the Ruhr area's industry structure is more diversified in comparison.

There are differences within the Ruhr area, though: the Southern Ruhr area, where mines were closed first, benefited more from the structural change measures than the Northern Ruhr area did (Oei, Brauers, and Herpich 2020). Structural policy in the Ruhr area was mainly preserving and reactive. The policies aimed at reducing negative effects on coal workers but did not sufficiently focus on needs of future generations or other industries. As a consequence, the long period of subsidising hard coal made the transition extremely expensive and hindered economic diversification (Dahlbeck et al. 2022).

3.2 Restructuring the East German energy system after reunification

In the German Democratic Republic (GDR), domestic lignite was the most important energy source. It covered about two thirds of primary energy demand in the 1975-90 period, enabling East Germany to establish heavy industry and gain some independence from Soviet oil and gas imports (Hermann, Greiner, and Matthes 2017). Lignite coal is of lower quality than hard coal, having a higher moisture content that makes it impractical to transport over long distances. For that reason, lignite power plants are usually located in close proximity to the open-cast mining sites.

The world's largest producer of lignite, the GDR had two major mining regions: Lusatia (*Lausitzer Revier*) and Central Germany (*Mitteldeutsches Revier*). In the following, we are going to focus on Lusatia as the larger of the two. This region, located near the Polish border in today's federal states of Brandenburg and Saxony, experienced a period of strong population growth when the lignite and heavy industries were established (Wolle 2020).

In 1990, the German reunification led to a sudden system change in the former GDR from a centrally planned economy to a market economy. While the focus of the GDR had been on enabling a sufficient number of jobs, the market economy instead put profitability as the new main target. The resulting turnaround of formerly state-owned enterprises resulted in a large-scale de-industrialisation that affected many sectors, including large parts of the Lusatian lignite industry. Many East German industries were no longer able to keep up with the competition from the West, as they had lower levels of productivity, were based on outdated technology, or sold to external investors for short-term profits in the years after the reunification. These aspects in combination with the geological conditions in Lusatia made lignite mining and generation more expensive compared to lignite mines in western Germany. This was one of the main reasons for the closure of large parts of the coal industry and loss of jobs after 1990 (Ragnitz et al. 2022; Walk and Stognief 2021).

The result was a sudden structural break that left tens of thousands of people without employment. In 1989, the Lusatian lignite industry had still provided 80,000 jobs, but in the early 2000s, the number of jobs had reduced to less than 10,000 and unemployment rates rose to over 20% (Gürtler, Luh, and Staemmler 2020; Noack 2022; Öko-Institut 2017). Nearly a fifth of the region's inhabitants left over the 1995-2015 period, many of them young and with high levels of education (Schwartzkopff and Schulz 2015). The economic and social situation

in the ‘new federal states’ (*Neue Bundesländer*) became a major policy issue following the reunification. However, most major interventions applied to all of East Germany and were not specifically tailored to the regional characteristics or identity of Lusatia or other regions (Ragnitz et al. 2022).

Initially, the main policy was the so-called *Aufbau Ost* (‘development East’), which was mainly reactive and focused on labour market and social policy topics: early retirement schemes, retraining, and job creation programmes. The latter consisted of mostly temporary, low-skilled community service jobs intended to ease the transfer into regular employment. While these measures helped cushion social hardships, overall demand for labour remained too low for the job creation schemes to achieve lasting positive effects. Another cornerstone of the *Aufbau Ost* policy was investment funding by means of subsidies that brought the real capital costs below market level (Ragnitz et al. 2022). Investment loans, subsidies, and equity grants were available for investments in all sectors and were targeted both at external investors and companies already in the region (Pohl 2021; Ragnitz et al. 2022). These measures were successful in attracting private investment initially, but this development did not last and investment activity underwent a large decline once again, possibly because there were not enough profitable investment opportunities available (Ragnitz et al. 2022).

Starting in the late 1990s, structural policy became more forward-looking with the objective of supporting structural adaptation. The emphasis shifted towards solving the problems of skill shortages and out-migration by means of innovation funding and a stronger focus on technology. Whereas previous funding programmes had largely been open for investments in any sectors, there was now a stronger focus on research and development activities, cluster formation, as well as the economic viability and attractiveness of jobs (Ragnitz et al. 2022).

All in all, the post-reunification structural policies resulted only in partial successes for the region of Lusatia. Initial policies were mostly reactive and neglected the diversification of the economy. Another shortcoming is the lack of consideration for regional specifics and identity. Most labour market and social policies were targeted at the former GDR as a whole even though it was far from homogeneous. Compared to the state of Saxony, where spill-over effects from the city of Dresden were deemed sufficient for the regional development of the Lusatian coalfield, the state of Brandenburg implemented more regionalised policies, such as the establishment of regional development centres and, at a later stage, five planning regions, which were given some authority of their own (Ragnitz et al. 2022). Experiences from other structural change processes suggest that Lusatia might have developed more favourably, had its individual challenges and potentials been taken into account in more specific ways. A stronger focus on soft location factors could also have helped increase the overall attractiveness of the region and the quality of life.

Starting in the early 2010s, the discourse on lignite and the remaining jobs in the industry intensified as climate concerns became more prominent and more and more actors demanded a coal phase-out (Markard, Rinscheid, and Widdel 2021; Ragnitz et al. 2022). In 2020, thirty years after the reunification, a nationwide coal phase-out law was adopted by the German government. Lusatia is now facing the second major structural change process within a relatively short period of time while it still suffers from the consequences of the poorly handled post-reunification years (Walk and Stognief 2021). Despite the shrinkage that has already occurred and despite multiple changes to its ownership structure that have occurred since the reunification, the Lusatian lignite industry is still the largest employer in the region. As employment had already decreased from around 80,000 in 1989 to less than 8,000 in 2020 (Noack 2022), the number of jobs that had to be replaced was much smaller now than after reunification. Still, there are few alternatives that provide similarly stable, unionised, and well-paid jobs. At the same time, the region is facing major skill shortages and has only limited success in attracting skilled workers from other regions. The regional economy of Lusatia is overall less well prepared to handle the transformation than that of the Rhineland, the second major lignite mining region, which is located in western Germany. Reasons include the remote location of Lusatia within Germany as well as demographic and cultural factors, lower innovation capacity, and overall less favourable economic conditions (Stognief et al. 2019).

Lusatia's identity as an 'energy region' is still quite strong as well, and as recently as a few years ago this included the governments of the federal states of Brandenburg and Saxony insisting on maintaining the lignite industry despite its incompatibility with national and international climate goals. Had the eventual necessity of the coal phase-out been acknowledged and communicated earlier, it might have opened up opportunities for economic diversification (Ragnitz et al. 2022). Since the decision on the coal phase-out, there has been increasing interest in attracting alternative energy industries such as renewable energies, batteries, and hydrogen.

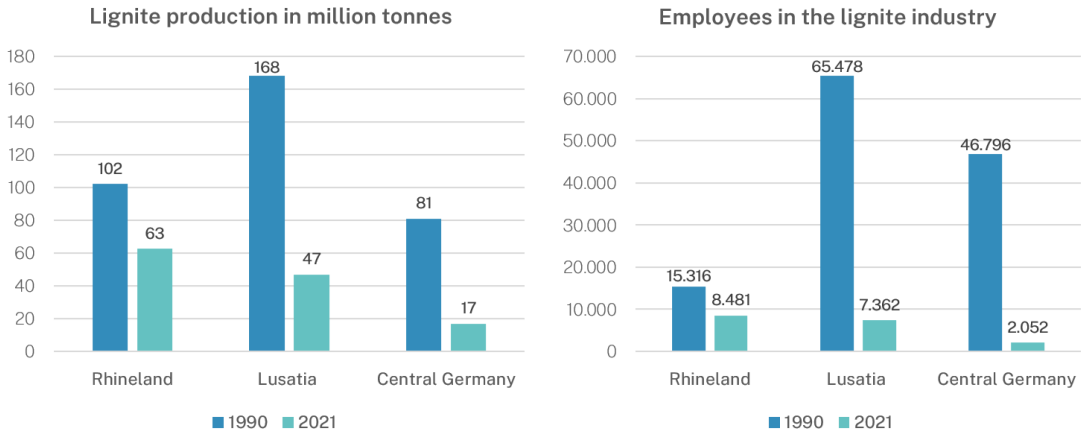
3.3 Germany's phase-out of coal-fired electricity and lignite mining

Since the last mine closed in the Ruhr area in December 2018, there is no more hard coal mining in Germany. However, hard coal is still being imported, especially for the use in power plants and the steel industry. Lignite mining, on the other hand, is still an active industry, as is generation. As it is not cost-effective to transport lignite over long distances, nearly all of the lignite mined in Germany is used to produce heat and electricity in power plants within the regions themselves.

As of 2019, there were still around 20,000 people directly employed in the lignite industry in Germany, though this number has declined significantly in the last thirty years, especially in the two Eastern coalfields (see Figure 2). Indirect and induced employment figures are significantly higher. In the respective regions, the lignite industry is still a major economic factor and a pillar of regional identity.

However, in recent years it has become clear both to the public and to policymakers that phasing out coal must be one of Germany's main contributions to meeting its climate targets. Against this backdrop, the topic of structural change in Germany's coal regions was once again put on the political agenda of the federal government as well as of affected state and local governments. Since the main driver of the transition is climate change mitigation rather than economic considerations, the debate is marked by a paradigm shift: Compared to, for example, the hard coal mining phase-out, there is now an awareness that the time frame for this transition will be much shorter than that for previous transitions. Moreover, there is a stronger emphasis on forward-looking, region-specific policies as well as stakeholder participation (Reitzenstein et al. 2022).

Figure 2: Lignite production and employment, 1990 and 2020. Own depiction based on DIW Berlin, Wuppertal Institut, and Ecologic Institut (2018), Statistik der Kohlenwirtschaft e. V. (2022).



This awareness of the necessity of structural change, however, is a rather recent development. As recently as the early 2010s, the option of phasing out coal was barely considered in the political debate (Furnaro 2022). It was mainly the 2015 Paris Agreement that increased pressure on the coal industry and meant that the reduction of coal use became inevitable

(Leipprand and Flachsland 2018). This resulted in a highly controversial debate involving diverse stakeholders such as utilities, mining companies, trade unions, environmental NGOs as well as heterogeneous stakeholders from the mining regions, ranging from people mainly worried about the loss of jobs and economic activity to local residents, who opposed the evacuation and finally destruction of their villages necessary to enable the expansion of the open-pit mining facilities. Considering how much these stakeholders' positions diverged, the federal government was hesitant to make a top-down decision, which would have likely been harshly criticized from all or most sides (Hauenstein et al. forthcoming; Löw Beer et al. 2021)

In order to solve this dilemma and find a societal consensus, the federal government set up the Commission on Growth, Structural Change and Employment (also referred to as the 'coal commission'), a stakeholder commission with the mandate to recommend a coal phase-out path and policies to support the transition and structural development in affected coal regions (Reitzenstein et al. 2022). The Commission was made up of four chairs and 24 stakeholder representatives with voting rights. The members were representatives from the coal regions, the energy sector, industry, science, unions, environmental NGOs, and administration. The Commission met ten times over the June 2018-Jan 2019 period. In addition to the regular meetings, three field trips to the mining regions were organized and around 70 experts were invited to speak in front of the commission (Hauenstein et al. forthcoming).

The Commission presented its final report on 26 January 2019. During the final vote, 27 out of 28 members voted in favour of the following recommendations: Germany was to phase out coal mining and generation by 2038, with the option to move it to an earlier date of 2035. As for the phase-out path, 12.5 GW of coal capacity were to already go offline by 2022 and renewable energy was to reach a share of 65% by 2030. The coal regions were to receive €40 billion in transition funding, and the operators of the mines and power plants were to be financially compensated as well. The Commission further recommended early retirement and adaptation allowance mechanisms modelled after the hard coal mining phase-out, as well as a policy programme on structural change in the affected regions (Kommission „Wachstum, Strukturwandel und Beschäftigung" 2019). For more information on the Commission see Section 5.3.

Largely following the Commission's recommendations, the federal government (a coalition of CDU/CSU and SPD) proposed a legislative package that was adopted by Parliament in July 2020: the coal phase-out law (*Kohleausstiegsgesetz*), the investment law for coal regions (*Investitionsgesetz Kohleregionen*), and the structural support law for coal regions (*Strukturstärkungsgesetz Kohleregionen*). The €40 billion will be paid from the national budget evenly until 2038, resulting in around €2 billion per year). Of this volume, €14 billion is directly given to the affected federal states Brandenburg, Nordrhein-Westfalen, Saxony Anhalt, and Saxony, while the remaining €26 billion are used by national bodies to directly finance specific projects within the coal regions. There is no complete project list which will be funded, but instead some autonomy is given to the regions to identify, propose, and develop fitting projects. For that governing period no additional money was made available by the financial ministry, but funds were redirected from other measures – e.g. restoring a rail line in coal regions, instead of investments in rail infrastructure in other regions in Germany. It is most likely that parts of the money will not only be invested within the heart of the coal regions but in adjacent regions, as especially the rural eastern regions are in need of additional investment to strengthen and improve living conditions and strengthen their (digital) infrastructure.

The federal Parliament elections in September 2021 resulted in a new government coalition led by the SPD with the Greens and the FDP. The new government has since expressed plans to move the coal phase-out date forward to 2030. However, the energy crisis caused by Russia's aggression war against Ukraine sparked a renewed debate about a runtime extension for coal power plants to ensure power and heat supply. To compensate for gas shortages, a number of hard coal power plants have been temporarily retrieved from the grid reserve. In September 2022, the federal government decided that these power plants will be allowed to produce until March 2024, a year longer than originally planned. In addition, lignite power plants are now allowed to return from security standby as well. The federal

government's intention to phase out coal by 2030, however, remains unaffected by these developments.

The distribution of the structural change funds is prescribed in the structural support law. The funds are to be distributed in several rounds until 2038. One portion of the money is administered by the federal level (*Bundesarm*) and the rest is shared among the federal states where the lignite mining regions are located (*Länderarme*). Local authorities and other project holders from the public sector can apply for the funds distributed through the *Länderarme*. Eligible for funding are investments in physical and immaterial infrastructures (that do not fall within the responsibility of the federal level), public welfare, regional development, the renaturation of former mining sites, and the protection of the climate, the environment, and nature (Bundesregierung 2020). The federal funding programme 'STARK' is open to both private and public applicants.

4. Measures for managing and responding to structural change in Germany's coal industry

In the following, we present lessons-learned from selected best-practice (and less-good-practice) approaches and measures to manage and respond to structural change in Germany's energy sector, including experiences from stakeholder commissions, the topic of skill transferability of coal industry workers, and economic re-orientation and diversification.

4.1 Best-practice examples: IBA Emscher Park and RAG Foundation

The **International Building Exhibition** (*Internationale Bauausstellung*, IBA) **Emscher Park** is a best-practice example from the Ruhr area. In the 1989–1999 period, various landscape planning and urban development projects were implemented in the area surrounding the river Emscher to support structural change in the region. The programme was financed mainly by the federal state of NRW, with additional support through federal and EU funds. IBA Emscher Park was the first structural change programme with the explicit objective to support ecology and regional identity (Dahlbeck et al. 2022). There were five main foci: (1) Working in the park, (2) new buildings and modernisation of housing estates, (3) ecological renewal of the Emscher system, (4) promotion of urban development, (5) social stimuli for urban development, and (6) the establishment of a regional park structure (Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR) n.d.). 'Working in the park' was the guiding principle for around 20 projects focusing on establishing attractive and modern locations aimed at small and medium-sized enterprises, such as technology parks (Metropole Ruhr 2010). The development of the Emscher landscape park was unique as not only the river itself was renaturated, but former industrial sites were turned into nature reserves and abandoned mining architectures became landmarks. For instance, the former mine Zeche Zollverein in Essen is today a centre for arts and culture (Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR) n.d.).

The specific success of the IBA Emscher Park was that it targeted an overarching perspective – beyond singular projects focusing only on creating alternative industry jobs in another factory. The purpose of the IBA instead lied on promoting the region as liveable and opening it up for a future beyond coal. Looking at the existing situation in German coal regions, the biggest challenge again does not lie in replacing coal jobs – as we already see an increasing shortage of skilled workers (in industry as well as service industries) with especially young people leaving these rural regions – calling once again for a more holistic approach to promote the region and create a new, more sustainable identity.

The environmental liabilities inherited from decades of hard coal mining operations have been, at least to a large extent, settled by the creation of the **RAG Foundation** (*RAG-Stiftung*) in 2007, following the decision to end subsidised hard coal mining in 2018. It is responsible for financing the "perpetual costs" to manage environmental liabilities, such as pit water management, polder measures, and ground water purification, as well as for supporting educational, scientific, and cultural projects in the former mining regions (Furnaro et al. 2021). These costs currently amount to around €300 million per year, but are expected to decrease in the future (RAG-Stiftung n.d.).

The RAG Foundation's initial capital stemmed from Ruhrkohle AG, the last hard coal producer in Germany, and profits from the chemical company Evonik AG. Its activities are overseen by a board of trustees including the federal states NRW and Saarland, the federal government, as well as the chair of the mining union IG BCE. However, there is no independent assessment of the full costs of the environmental liabilities caused by coal mining, so it is not entirely clear whether the foundation's financial resources will remain sufficient in the long-term (Furnaro et al. 2021).

4.2 Less-good-practice example: Policies to extend coal production

The first policy responses to the coal crises of the 1950s and 1960s consisted of economic rationalisation and subsidies for domestic hard coal in the Ruhr and Saarland regions. Mining companies received premiums and financial aid when they reduced the number of their collieries. Several laws were aimed at increasing the demand for domestic hard coal, e.g. through tax benefits for power stations using coal instead of oil. These subsidies were partly financed through a compensation levy (*Kohlepfennig*) on private consumers' energy bills (Dahlbeck et al. 2022).

Implemented in 1968, the *Entwicklungsprogramm Ruhr* ('Development programme Ruhr', EPR) was the first active structural policy. While it contained some reactive elements, such as attracting new industries and expanding infrastructure, one of its main foci was the modernisation of the mining companies. The follow-up policy, the *Aktionsprogramm Ruhr* ('Action programme Ruhr', APR), starting in 1980, contained preserving elements as well, such as a technology programme for mining (Dahlbeck et al. 2022).

All attempts to reactivate the coal economy in the Ruhr area and Saarland were ultimately unsuccessful. Resources that could have been invested in a more proactive structural transformation were instead used for policies that aimed at preserving the coal industry, which led to a continued dependence on coal and caused institutional, economic, and cognitive lock-in effects (Furnaro et al. 2021). In 2009, the Leibniz-Institute for Economic Research and University Duisburg-Essen recommended a phase-out by 2012 in order to avoid €4-10 billion in mining damages and subsidies, yet the last mine in the Ruhr area was not closed until December 2018 when EU regulations stopped Germany from continuing to subsidise hard coal (Frigelj 2009; Oei, Brauers, and Herpich 2020).

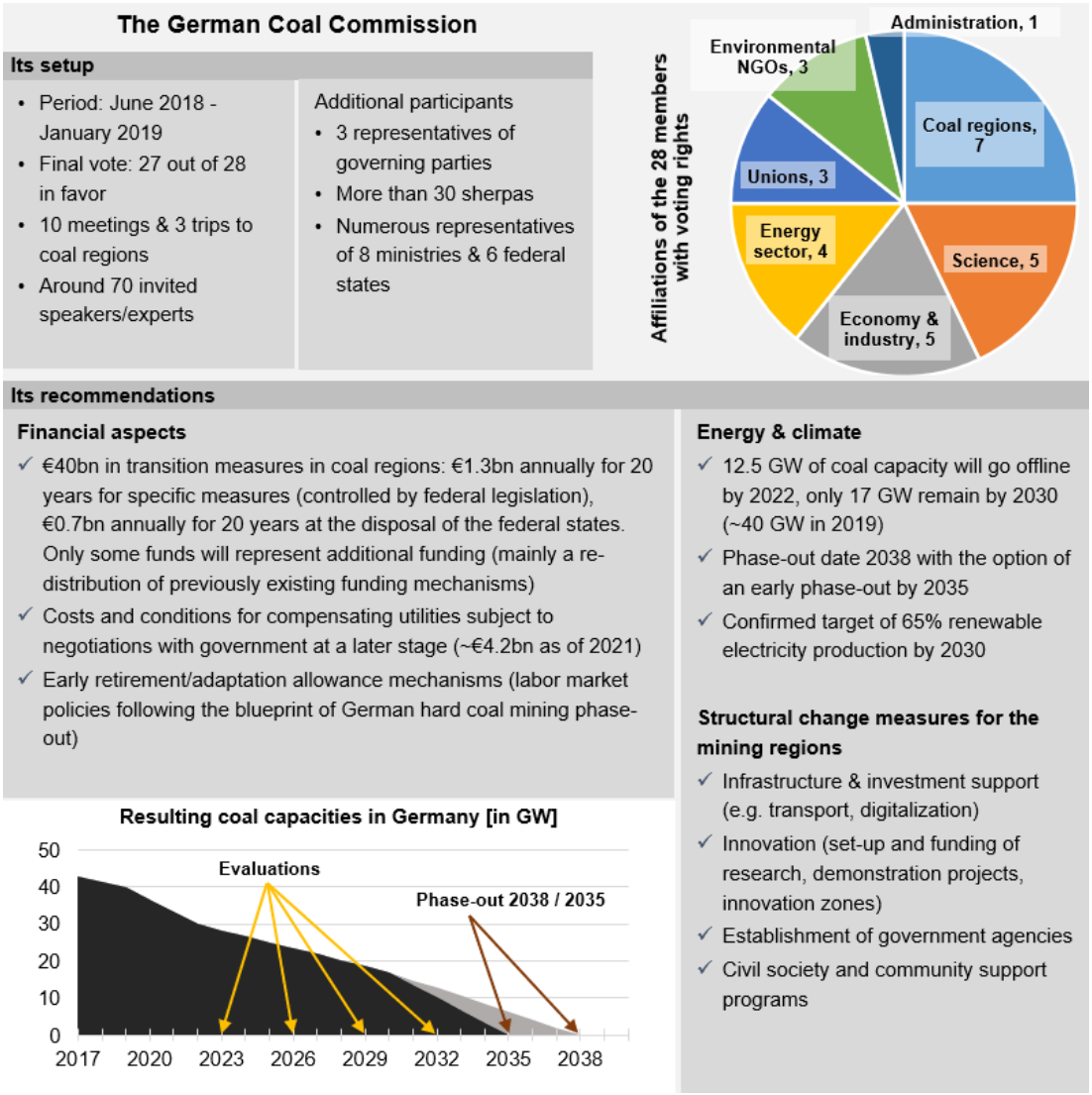
4.3 Stakeholder commissions

The Commission on Growth, Structural Change and Employment in 2018–19 was not the first commission implemented to support a structural transition in Germany. In the late 1980s, the **Coal and Steel Regions Commission** (*Kommission Montanregionen*) was established to oversee the Future Initiative for Coal and Steel Regions (*Zukunftsinitiative Montanregionen*, FICSR). The Commission, which consisted of representatives from the private and public sectors, labour, local organizations and research institutions, brought forward the collaboration of regional stakeholders in the Ruhr area and was generally well received by the local population. The Commission had the task to define priorities for the FICSR, to assess main challenges for the region, and develop a local network of partners. A novel aspect brought forward by the Commission was the idea of labour market policies specifically targeted at women (Furnaro et al. 2021). As experiences from historical coal phase-out processes show, coal transitions affect women differently than men, hence gender aspects need to receive increased attention when designing structural policies (Braunger and Walk 2022; Walk et al. 2021). The work of the Coal and Steel Regions Commission can overall be considered a positive example, though it was also subject to criticism for not always consulting all relevant stakeholders and for insufficient transparency of how it allocated funds (Furnaro et al. 2021).

Valuable lessons can be drawn from the experience with the **Commission on Growth, Structural Change and Employment** ('coal commission') in 2019-2019 (see also Section 3.3). The coal phase-out pathway recommended by the commission has been criticised by various stakeholders, including several from within the commission itself, as not being ambitious enough to be in line with existing climate targets in line with the Paris Agreement. This was partly due to the lack of climate ambition in the commission's mandate set by the federal government, and to trade-offs with economic, employment, and political objectives that were the priority of a large share of commission members. Power imbalances were not

sufficiently addressed in the commission, allowing incumbent actors to dominate the decision-making process. The alliance in favour of a more ambitious coal phase-out path only had limited negotiating power in comparison (Hauenstein et al. forthcoming).

Figure 3: The German Coal Commission: set-up and results. Hauenstein et al. (forthcoming) based on Kommission "Wachstum, Strukturwandel und Beschäftigung (2019). Reproduced with permission.



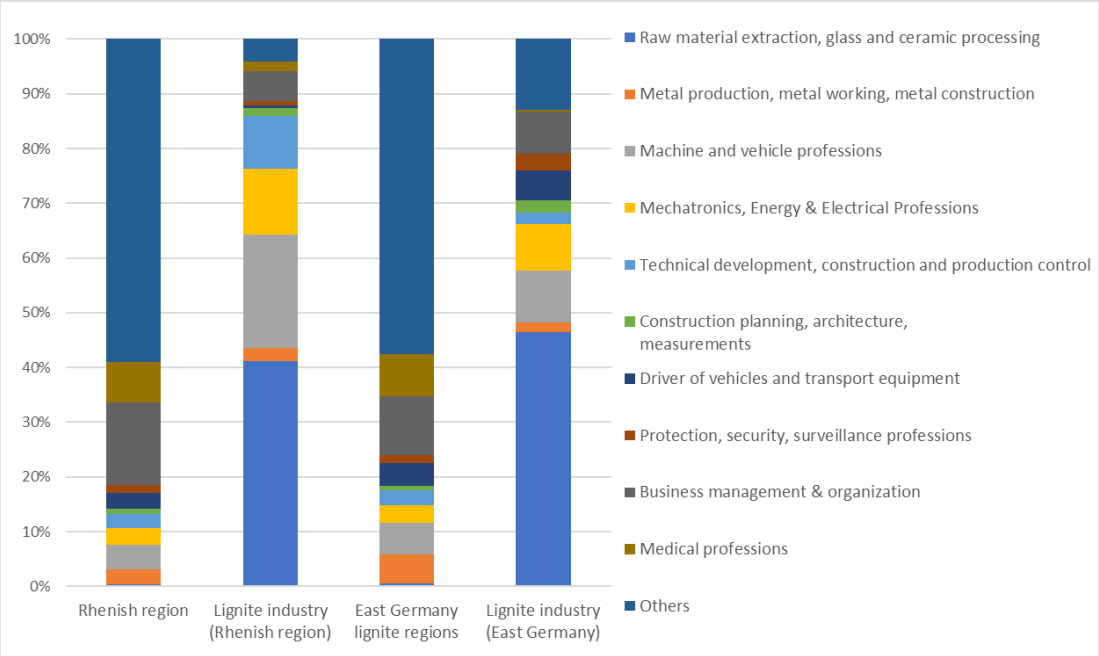
As a stakeholder commission tasked with solving an issue of largely incompatible interests and limited win-win situations, the coal commission would have needed a clearer political mandate that explicitly included appropriate climate targets. Despite this, the commission helped overcome a decades-long political stalemate and enabled the federal government to finally enact policies to limit the use of coal. However, the German coal compromise also comes with very high compensation payments at the taxpayer's expense, not only for the affected regions, but also for the coal industry itself (Hauenstein et al. forthcoming).

4.4 Transferability of skills of lignite industry employees

Germany has not yet concluded the transfer of all lignite workers into new professions, nevertheless, some lessons can already be drawn from the process. Generally, countries phasing out fossil fuels should focus their support for skill transfer on the people who will need it. In Germany, the age structure of the lignite employees leads to a natural decline of the workforce via retirement. This reduces the need for the transfer of workers. Additionally, countries should check whether the skills of the workers are needed for renaturation of the extraction sites. Often the skills needed for extraction are also needed for the renaturation after the extraction activities. For the remaining workers, who are not needed for renaturation, countries need to assess the skills and compare them with the skills needed within or outside the region. Based on this assessment, measures need to be implemented that encourage skilled people to stay in the region or ease their relocation to regions where they can apply their skills. For young people with skills that cannot be applied, suitable reskilling and education measures are needed to enable a transfer into new employment.

In Germany, comprehensive data is not publicly available of the skills and qualification of the lignite employees. Skills and qualification monitoring is mentioned in the final report of the coal commission (BMWi 2019, 99), however, this monitoring has not yet been carried out. Alternatively, aggregated data from the Federal Employment Agency are available from a special evaluation for the lignite regions (Oei et al. 2019, 145f.). Unfortunately, these data do not allow for conclusions about specific occupations, activities, and training levels. However, they provide an initial indication of how the employment situation is developing in specific fields of activity.

Figure 4: Fields of activity for lignite regions and the respective lignite industry. Own depiction based on Bundesagentur für Arbeit (2017). *Note: The share of employment of the lignite industry compared to the regions is 0.1% for the Rhenish region and 0.5% for the east German lignite regions.*



A subsequent analysis of the development of employment in the respective fields of activity provides some initial indications for which employment groups a transfer will likely be easier. The situation proves to be favourable for most fields of activity, such as mechatronics, energy

professions or machine and vehicle professions. The majority of activities have a positive trend in employment figures indicating a growing job demand and can thus provide alternative employment for lignite workers, who are laid off, especially when considering the long timeframe of the transformation (Oei et al. 2019, 145f.).

However, the situation of employees who work directly in opencast mining (falling under the activity category of "raw material extraction") is more difficult. This group of employees is by far the largest, and the lignite regions offer few opportunities for substitution (Oei et al. 2019, 145). Opportunities outside the region, i.e., in the rest of Germany, are also limited. Although alternatives exist in the mining sector, employment is not expected to grow enough to absorb the number of employees (Oei et al. 2019, 146).

For employees in the opencast mines, a transfer to other industries is therefore much more difficult than for other employees in the lignite industry. However, this problem can be mitigated in various ways. First, it is not necessary to find new employment for all of them. The high average age of these employees means that a significant share will reach retirement age before lignite mining is phased out. To this end, there are early retirement programmes for lignite employees that lower the retirement age to 57. For some of the remaining employees, the planned renaturation of the opencast mines offers possibilities for continued employment. Since the skills required for renaturation overlap to a large extent with the activities performed in the mines to date, it makes sense to continue employing the existing opencast mine workers. By continuing to work in renaturation, about a quarter of the workforce will be retained for approximately 4 years after termination of mining activities (Oei et al. 2019, 153). For the remaining employees, retraining measures are an option. If new jobs cannot be found in the region, there are support programmes that enable the temporary or long-term transfer to other regions by e.g. granting money for travel expenses, relocation costs or work and clothing equipment (Furnaro et al. 2021).

For employees in the lignite sector who do not work directly in the opencast mines, the energy transition offers employment options in the future. Renewable energies provide alternative employment opportunities, especially for employees in the fields of mechatronics, electrical engineering, energy professions, construction, and civil engineering. In addition to the deployment of renewables, these occupational groups will likely also have alternative opportunities for employment in the field of building efficiency, where there will be considerable demand for skilled workers in the future.

An example of a transfer plan of employees is the relocation of certain activities of the German railway company Deutsche Bahn in 2024, creating a total of 1,200 jobs in the Lusatian region. Around 100 employees have moved to transfer from the lignite company LEAG to their new jobs at the rail plant in 2022 (RBB 2022; Süddeutsche Zeitung 2021). In the future, such coordinated re-settlements will help transferring workers from the lignite industry into other sectors and keep the skilled workforce in the regions.

4.5 Economic diversification in the coal regions

Given the global imperative of climate action, today’s energy regions can only remain energy regions in the long-term if they successfully make the switch from unabated fossil fuels to renewable and climate-neutral energy. The example of the Saarland region shows that new industries can be successfully established in former coal mining regions if their development is planned in due time.

Like many rural regions, Lusatia suffers from unfavourable demographic developments, such as an aging population and outmigration especially of women. Women with a high level of education in particular tend to look for opportunities for personal and professional development elsewhere. An overall improvement of the quality of life in the region is therefore essential to reduce outmigration and attract new residents from outside the region. In this context, the provision of public services is a key aspect. Most of the burden of paid and unpaid care work,

e.g. professional healthcare, but also care for children and the elderly in private contexts, which is essential for social cohesion, is currently being shouldered by women. Economic sectors that are traditionally considered 'female' should receive more attention in the structural change process (F wie Kraft 2020). The current focus on creating industry jobs does not fully do the situation in the region justice, especially considering that there is already a shortage of skilled labour. The priorities of women, who tend to focus more on the overall quality of life in the region, are not adequately represented in the dominant structural change discourse (Walk et al. forthcoming).

Aspects of regional identity are important as well. Lusatia strongly identifies with being an energy region, hence one of the declared aims of structural policy is to strengthen the energy sector beyond coal. The lignite company LEAG is planning a number of "gigawatt factories", where 7-14 GW of solar and wind capacity are to be established by 2030, mostly on former lignite mining sites (Siegel 2022). While this large-scale project is not without controversy – the company is still not planning to reduce coal earlier than 2038 and only a small percentage of post-mining areas would remain available for other uses like forestry and agriculture (Umweltgruppe Cottbus 2022) – it does show that fossil fuel companies can develop new business opportunities in the renewable energy sector. In the Rhenish mining area, the state of NRW and 50 municipalities, utilities, and project holders have made a "gigawatt pact" (*Gigawattpakt*) to accelerate the expansion of renewable energies (Zukunftsagentur Rheinisches Revier and MWIDE NRW 2022). Unlike in the case of LEAG, local municipalities in the Rhineland are actively involved. Their participation in renewable energy projects can help increase public acceptance, as profits can be re-invested in local infrastructures. However, some actors have criticised the lack of concrete measures and bills to achieve the set targets (LEE NRW 2022; Schenk 2022).

Increased investment in research and development to decarbonise the energy and mobility sectors is an element of structural change policy in Lusatia. A battery materials factory and a prototype plant for battery recycling are being built at BASF's Schwarzheide site (Handelsblatt 2021; Inforadio 2020). The federal research institute German Aerospace Center (DLR) has founded the Institute of Low-Carbon Industrial Processes in Zittau and the Institute of Electrified Aero Engines in Cottbus (Albus 2022; dpa 2021). Outside of the energy sector, there has been a strong focus on research and development in past and current structural change processes as well. For example, before the start of the hard coal phase-out process, there was not a single university in the Ruhr area. Today, the various universities and research institutes located there have become important drivers for research, development, and innovation that have an impact far beyond the region itself. In Lusatia, too, there is a strong focus on universities, including a strong international orientation and a focus on future fields of research and technologies at BTU Cottbus-Senftenberg. A university medical centre is now also to be established in Cottbus with a focus on digitalisation of the healthcare system and the goal of addressing the shortage of doctors in rural areas (Antenne Brandenburg 2022).

A diversification beyond the energy sector can help making the transformation more sustainable. In Lusatia, tourism is an important focus with a lot of potential to make the region more attractive, both for visitors and residents. It is important to ensure, though, that long-term jobs with good conditions are created, as seasonal employment and low wages are quite common in the tourism industry.

5. Lessons for policy-makers from Germany's coal phase-out

Energy sectors around the world are impacted by structural change. This confronts different countries with the task of achieving a just and in-time transition that secures jobs, minimises social disruptions, and is in line with the objectives of the Paris Agreement. Looking back in Germany's history, the previous chapters show several important lessons on how to deal with structural change in the energy sector and support affected workers, industries, and regions.

As Germany's experience shows, a just and in-time transition must be actively shaped using appropriate policy packages that combine forward-looking policies (e.g. to attract new industries) and reactive interventions (e.g. retraining and early retirement programmes for workers). Both horizontal and vertical policy integration are key, as structural policy takes place across sectors of policy (e.g. labour market policy and regional development policy) and levels of government (from local to national). Structural policy interventions must consider not only economic, but also social, ecological, and cultural aspects. The regional context is important as there is no one-size-fits all solution. Still, diversification can generally reduce the risk of structural breaks (Dahlbeck et al. 2022; Oei, Brauers, and Herpich 2020; Ragnitz et al. 2022)

We observe that Germany has learned from past experiences and its policies now include different aspects of structural change, such as infrastructure, education, mobility of skilled workers, social policies such as early retirement, as well as aspects of regional identity. However, the current coal phase-out process shows that structural policy needs to be flexible and able to react accordingly, e.g., if the phase-out date is brought forward. If the current government puts its plans to phase out coal by 2030 instead of 2038 into action, it would be an important step towards meeting Germany's climate targets but at the same time create additional challenges for the affected regions. Current plans have been made with the assumption of the previous phase-out date, and inflexible funding structures and regulations can make it difficult to adapt to the new situation.

Germany's experience from sixty years of coal phase-out is valuable for policy-makers in and outside Germany – with respect to managing a coal phase-out but also with respect to going about the challenges of other energy sectors facing structural change. The lessons-learned from the decline of the once 600,000 workers strong industry are also valuable for Canada's energy transition. In the following, we summarise the key learnings from Germany's experience, which could inform structural and just transition policy in Canada and elsewhere.

Structural policies should be anticipatory and forward-looking to enable a just and in-time transition. Forward-looking policies help spurring innovative developments in affected regions and attract new industries. This ensures planning certainty for affected regions and strengthens their endogenous potentials (Ragnitz et al. 2022). The transition should not be prolonged through excessive subsidies for the affected energy industry as this hinders forward-looking measures and disincentivises innovation (Oei, Brauers, and Herpich 2020; Reitzenstein et al. 2022). Even in cases where an emission-intensive industry is still profitable without subsidies, an ambitious phase-out plan including an appropriate structural policy package needs to be developed as early as possible in order to allow for long-term planning in affected regions that is in line with climate targets.

Rather than benefitting from delaying, Germany's experience shows that there seems to be a first mover's advantage in responding to structural change in the energy sector. In Western Germany, the Southern Ruhr area, which at first closed its mines and benefitted from support programmes, economically performed much better than the North Ruhr area, which to this day suffers from lower development and high levels of long-term unemployment. In the east, Lusatia may be in a better economic position today, had the phase-out not been resisted for so long and economic diversification started earlier. It should be noted that, despite these

lessons, there continues to be political resistance in Germany today to decarbonising certain sectors of the economy, while public fossil fuel subsidies remain high.

Diversification increases regional economic resilience. Lock-in effects in old and unsustainable structures as well as dependencies on single industries should be avoided (Dahlbeck et al. 2022; Reitzenstein et al. 2022). Germany's experience shows that those regions that followed a more diversified development approach fared much better than those that became too dependent on one industry or employer such as the Saarland, which became heavily reliant on the automotive industry.

Canada already has an advantage here, given that its economy is quite diversified, with the energy industry making up a much smaller share of overall GDP than in other fossil fuel producing countries (Beedell and Corkal 2021). This means that Canada's economy is overall less vulnerable to the impacts of structural change in the energy sector and in a better position to manage the transition than those of other energy exporters around the world. At the same time, certain regions in Canada rely economically on energy production and face much larger challenges in the transformation than the economy as a whole.

Important factors for the settlement of new industries are location, timing, as well as the availability of skilled labour and space. Good transport connections with other (metropolitan) regions is crucial, however, this would need to be achieved through zero-emission modes of transport (Oei, Brauers, and Herpich 2020).

Successful structural policies cross administrative boundaries, political levels, and policy fields. Purposeful coordination of policy fields is key, such as structural policy, labour market policy, and education policy (Dahlbeck et al. 2022). Actors on the local, regional, national, and international level need to cooperate. In Canada, this cross-level coordination is particularly important, given the divided jurisdiction over energy, climate, labour market, and social policy between the federal government and the provinces.

Public participation can improve policy outcomes and increase public acceptance and legitimacy. As transitions are learning processes, uncertainties must be made transparent by policy-makers (Reitzenstein et al. 2022). Both Germany and Canada have gained experience with stakeholder participation for a just transition, each tasking a multi-stakeholder commission with developing ideas and strategies for successfully managing the coal phase-out and drafting legislation based on their suggestions. Germany's experience shows that the success of these commissions depends on a clear political mandate, good practical organisation and having a balanced and diverse selection of participants, including from government and administration, industry, science, the workforce, and NGOs, with no single group having excessive negotiating power.

Labour market and social policies are important to cushion social hardships. While energy workers have diverse skillsets that are technically transferable to many other professions, attractive employment opportunities need to also be created in the affected regions in order to prevent workers from relocating.

For traditional energy industry workers with fewer options for changing professions, frequently used successful measures in Germany were early retirement schemes and retraining (Oei, Brauers, and Herpich 2020). Structural policy intervention should also consider existing baseline policies. In Germany, the social security system, the labour system, and the regional equalisation system have been major factors supporting past and present transitions (Dahlbeck et al. 2022; Furnaro et al. 2021).

Each region is different and there is no one-size-fits all solution. Structural policies should be tailored to local circumstances, including the history, characteristics, identity, challenges, and potential of the affected region (Furnaro et al. 2021; Ragnitz et al. 2022; Reitzenstein et al. 2022). In Germany, capacities, knowledge, and institutions of the energy sector are often assets of coal regions (Reitzenstein et al. 2022).

Experiences with structural policy in Germany's Ruhr area show that once structural policy became more targeted and regionalised, it better supported entrepreneurial activity, the development of lead markets, and diversification of the region. In Lusatia, too, structural policy was more successful when more targeted measures, specifically aiming at R&D and cluster formation, replaced the earlier across-the-board approaches targeting all sectors. Soft location factors and environmental quality also play an important role for the attractiveness of a region. Hence, assessments of a region's strengths and weaknesses as well as the inclusion of the relevant stakeholders, e.g. through a commission, are necessary for finding suitable solutions. This can increase the acceptance and success of the transition within the regions.

Canada's conventional energy industry is – similar to Germany's coal industry – centred in specific regions and provinces. In many cases, the local energy industry is intertwined with rural communities, whose economies depend on it. Successful just transition policy will need to be designed in cooperation with these affected regions and communities, taking into account their specific circumstances and leveraging their advantages and potentials.

The good news for affected regions and communities is that the energy transition comes with enormous economic opportunities. The IEA expects the global market for clean energy technologies to triple by 2030 (IEA 2023b). Canada can benefit enormously here, given its many assets and advantages, which include great renewable energy and critical minerals resources, an advanced clean tech sector, and a highly-skilled energy workforce. Further, being a politically stable and democratic country, Canada is widely seen a reliable trading partner and potential climate-neutral energy supplier. This creates new trade opportunities with Germany, especially in the fields of hydrogen and critical minerals.

Overall, the transformation towards net-zero is expected to lead to significant job growth in Canada in the sectors of renewable energy, construction, and transportation (Mertins-Kirkwood and Deshpande 2019). Regions affected by structural change can benefit from these opportunities by leveraging their respective potential in the transformation.

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End Piece

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