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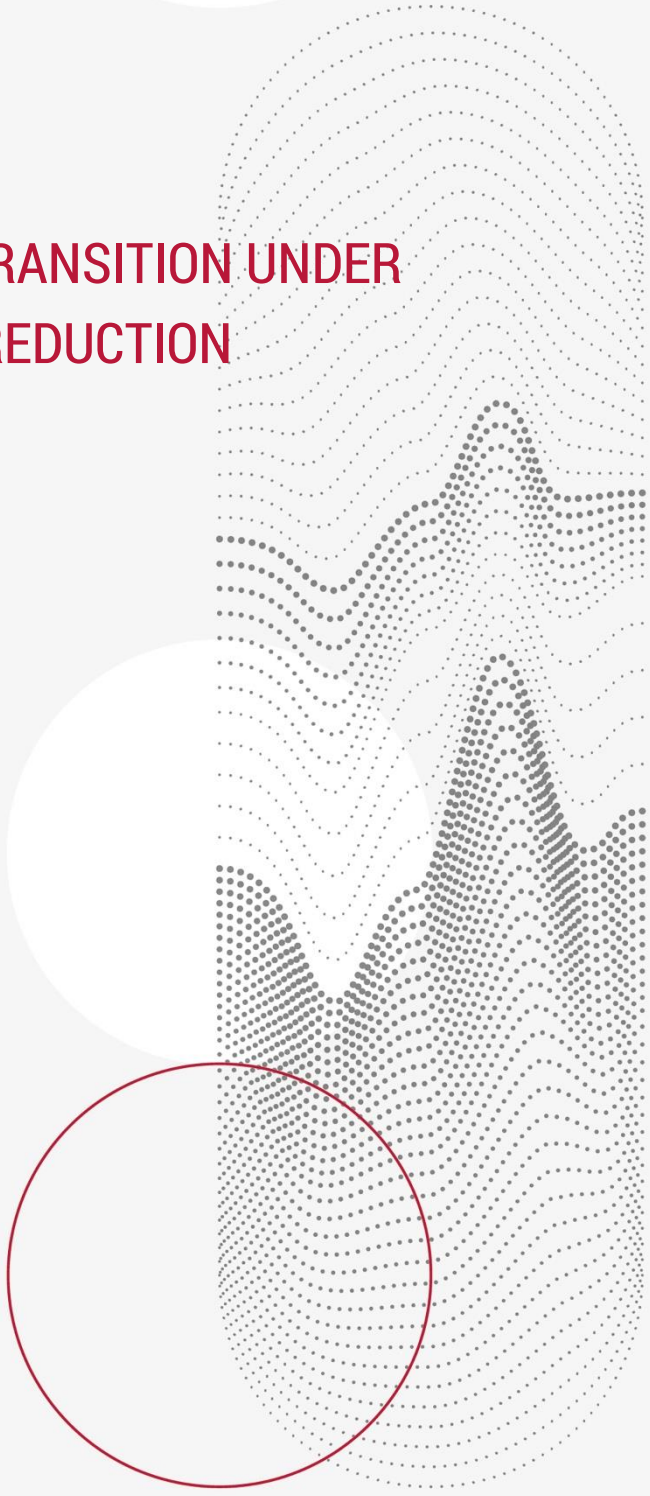

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Jan Witajewski-Baltvilks, Piotr Lewandowski, Aleksander Szpor, Jan Baran, Marek Antosiewicz[1]

Abstract

This report presents the main economic facts on the role of coal in the Polish economy, and analyses the implications of the transition away from coal for coal consumption and coal mining employment in Poland. Poland's energy mix relies on coal, most of which is domestically produced. We argue that issues related to job creation and the cushioning of negative shocks for workers are key for the phasing out of coal in Poland, especially at the regional and local levels. Our simulations show that achieving the Paris Agreement target is feasible in Poland provided hard coal consumption is cut by 20% between 2015 and 2030, and by 55% between 2015 and 2050. We estimate that this reduction in coal consumption would translate into a decline in mining employment of 47% between 2015 and 2030, and of 77% between 2015 and 2050. On the labour supply side, the reduction in employment can be achieved through natural attrition; i.e., through an outflow of workers to retirement and a moderate inflow of new workers. Training programmes, vocational courses, in-work benefits, and social policy instruments should be used to ease the transition.

Keywords: coal, mining, low-carbon transition, structural change, labour market

JEL: L71, J21, Q43

• The research leading to this paper was performed under the Coal Transition project that received funding from the KR foundation. The report extends the findings presented in the earlier report within the Coal Transition project (Baran et al. 2018, published by IDDRI and Climate Strategies) by adding a more detailed analysis of the labour market. This paper uses Statistics Poland data. Statistics Poland is not liable for the results and conclusions presented in the publication. We would like to thank Oliver Sartor and Jan Rutkowski for their valuable comments and suggestions as well as Agata Miazga for indispensable editorial support. The usual disclaimers apply. All errors are ours.

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Overview

If Poland is to participate as fully as other major economies in the global effort to minimise the risks associated with the global warming, it needs to substantially reduce its CO2 emissions. We show that in order to meet the Paris Agreement target, CO2 emissions per capita in Poland must reach the level of 2.80 Mt in 2050, which constitutes a 67% reduction from the 2010 level. Achieving this target is feasible provided hard coal consumption is cut by 20% between 2015 and 2030, and by 55% between 2015 and 2050. Most of this reduction can be achieved by replacing coal with alternative energy sources in the power sector. In the residential sector, coal consumption can be significantly reduced through the adoption of energy-saving technologies and measures.

This drop in coal consumption will lead to the phasing out of the coal mining sector in Poland, as most of hard coal produced in Poland is consumed domestically: in 2015, the Polish mining sector produced 72.2 million tonnes of hard coal, while the Polish economy consumed 71.9 million tonnes. By contrast, other major coal consumers in Europe import most of the coal they use.

The forthcoming cut in production will thus be associated with a reduction in the number of jobs in the coal sector, and particularly in the hard coal mining sector. We estimate that employment in that sector will need to be reduced from 94,000 jobs in 2015 to 63,000 jobs in 2030 (a 47% decline) and to 27,000 jobs in 2050 (a 77% decline). This approaching structural change poses a particular challenge for the Śląskie region. Although coal mining constitutes a tiny share of overall employment in Poland (0.6% in 2015), in Śląskie it provides a noticeable share of jobs (5%, and as much as 8% among males). This region previously experienced a substantial reduction in mining employment between the early 1990s and the mid-2010s. Although Śląskie has found new engines of growth in both manufacturing and services, and is one of the most affluent regions in Poland, large gaps in economic opportunities, jobs, and incomes are emerging between particular sub-regions and cities in the region. Moreover, as mining workers possess sector-specific technical skills which are of little use in other sectors of the economy, their employment prospects are likely to be limited. Since current jobs in the mining sector are well-paid, miners may have expectations regarding their working conditions that cannot be met in other sectors.

However, this coming transition is likely to be easier for the coal sector workers than the transitions many industrial workers have endured in the past. Given the ageing of the mining workforce, many current workers should be able to transition into retirement over the next dozen years or so. This natural attrition of workers, combined with moderate inflows of new workers, should result in a reduction of total employment in the sector, which is consistent with our scenario of the future demand for labour as coal use declines. Thus, the risk of mass lay-offs among this workforce is noticeably smaller than it was for workers in the past.

The strong performance of other industries in Śląskie opens another window of opportunity for the transition. Over the next dozen years or so, the demand for labour in the automotive, transport, and construction industries is expected to be strong in the region. In particular, there will be work in retrofitting buildings and implementing measures aimed at improving energy efficiency and air quality in Śląskie. Training programmes and vocational courses should be provided to prepare retiring or redundant miners, as well as individuals aspiring to work in mining, to work in other sectors. In-work benefits, social transfers, and support for commuting should also be provided to cushion the negative income shocks and ease the transition to existing jobs in other sectors and cities. These and other reforms must be accepted not only by the social partners, but by other stakeholders, such as NGOs and organisations working with local communities.

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1. Introduction

Weaning the Polish economy of its dependence on coal is increasingly on the agenda in Poland. To meet the GHG reduction targets established by the Paris Agreement, Poland must reduce coal's share in the energy mix. There are also internal pressures to speed up the transition away from coal. Challenges related to the financial problems of collieries and the low profitability of hard coal mining remain despite various forms of public support. Thus, there are economic incentives to close the unprofitable mines in order to re-establish the profitability of the sector. Moreover, coal deposits are gradually being exhausted. This is particularly the case for lignite mines, which account for almost half of Polish coal production, and are expected to be largely exhausted by 2030. It seems that the transition away from coal is inevitable, but it how it will be managed remains an open question.

A critical aspect of the coal transition is related to jobs. The share of the workforce employed in hard coal mining is still substantial, especially in the regions where this activity is clustered. The collieries are spatially concentrated, and most of them are located in the Śląskie region. This region will bear the largest economic and social burdens in the country's transition away from coal. Following reductions in coal mining employment in the 1990s in Poland, social problems and challenges related to persistent unemployment often arose, especially in places where the plant closure process was not sufficiently anticipated and addressed by public policies. However, the responses to negative labour demand shocks may be different this time because the characteristics of the labour supply in Poland have changed dramatically since the 1990s. Today, the workforce is better educated and more mobile. Moreover, because the Polish workforce is shrinking due to demographic changes, the competition for jobs is less fierce than it used to be.

In this report, we discuss the current role of coal in the Polish economy, how that role is expected to change in the future to meet the two-degree climate targets, and what implications the move away from coal will have for labour. In section 2, we describe the position of coal in Poland's energy mix, and outline the recent history of changes in coal production. We also discuss the condition of the coal mining sector, and the institutional settings that affect the sector. In section 3, we describe the mining workforce, the wage premiums offered by this sector, and the labour market status of workers leaving the mining sector. In section 4, we discuss lessons from the effects of past policies aimed at facilitating mining sector employment reductions and assisting the redundant workers. In part 5, we present simulations of Poland's future energy mix under the conditions needed to meet the two-degree climate targets. We also calculate the resulting demand for labour in mining, and juxtapose the results with simulations of the labour supply under various scenarios of inflows into the sector. Our conclusions and a discussion of the policy implications of this transition are presented in the final section.

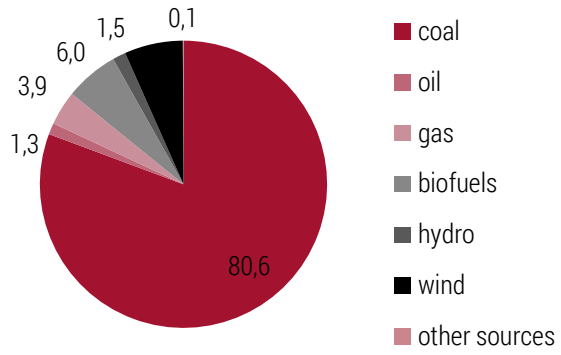
2. Coal use and coal production in Poland

In this section, we present the interlocking factors that make Poland the second-most coal-intensive economy in the EU. We show that Poland's abundant reserves of coal and extensive use of coal, particularly in energy sector, have had a large impact on the CO2 intensity of the country. We argue that the role of coal in Poland does not reflect the economic profits of this sector, which has struggled to remain competitive since the beginning of the country's transition to a market economy in the early 1990s.

2.1. Role of coal in the energy system

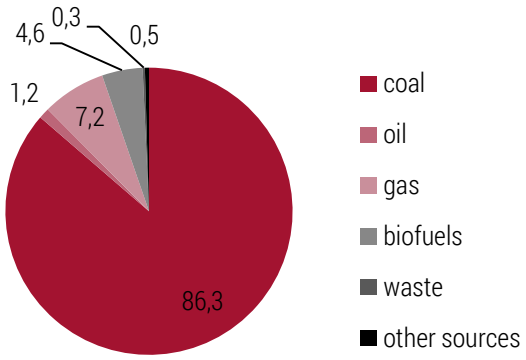
The role of coal in electricity and heat generation in Poland far exceeds that of any other energy source. Coal delivers 81% of the electricity and 86% of heat in the country. The next two most important sources of electricity production are wind (7%) and biomass (6%); while the next two most important sources of heat production are gas (7%) and biofuels (5%). The contributions of oil, hydro, and other sources to heat and electricity production in Poland are negligible (Figure 1 and Figure 2).

Figure 1. Production of electricity (%), 2015



Source: IEA

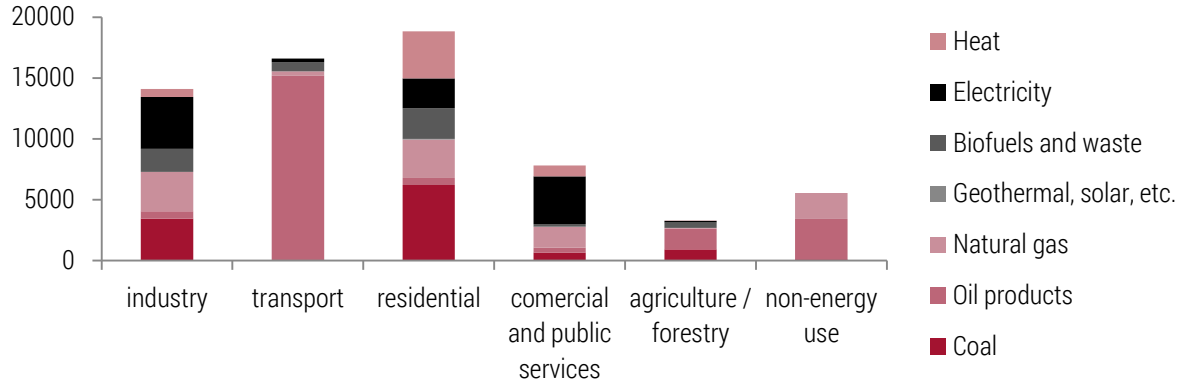
Figure 2. Production of heat (%), 2015



Source: IEA

The levels of coal use in sectors beyond energy generation are also large. The share of coal in total final consumption (TFC) in Poland is the largest among the EU member states. In the residential sector, coal directly provides one-third of TFC; and in the industrial sector, coal accounts for one-fifth of TFC. Coal is less important for TFC in the commercial, agricultural, and forestry sectors, and for non-energy use (Figure 3).

Figure 3. Total final energy consumption in Poland in thousand tonnes of oil equivalent (ktoe) on a net calorific value basis, 2015



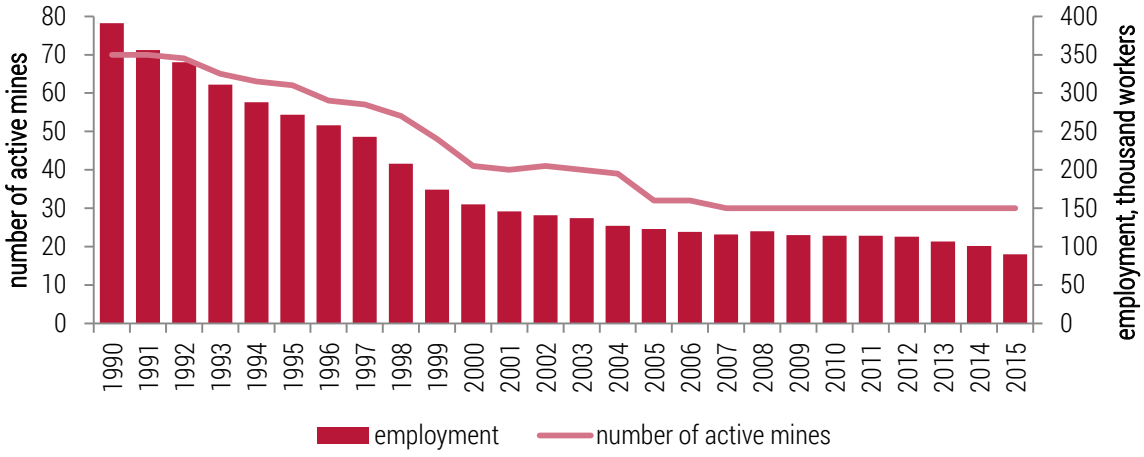
Source: IEA.

2.2. Role of coal in the economy

2.2.1. Trends in production in coal mining and recoverable reserves

After Poland's economy started transitioning in 1989 from being centrally-planned to being market-based, it was discovered that the coal mining sector was unprofitable and inefficient. At the beginning of the 1990s, coal production was very high, but the quality of the coal produced was low, and the cost of production was high (Czerwińska 2002, Dubiński and Turek 2017). To address the sector's problems, the government decided to close the least profitable mines and reduce employment. In the years that followed, the sector made gradual changes aimed at decreasing its excess capacities and reducing its high costs. Since 1990, the government has adopted several sectoral restructuring strategies. The number of active hard coal mines fell from 70 in 1990 to 30 in 2014 (Figure 4). In this period, employment in the hard coal sector decreased by more than 75%. The decline in coal sector employment was most pronounced in 1989-2000, when it decreased 60% (from 390,000 to 155,000 workers). In the 2000s and 2010s, employment in the sector shrank further, but at a much slower pace. In 2015, the number of coal jobs had fallen to 90,000 (Figure 4). At the same time, the annual production of hard coal was halved, from 147.7 million tonnes in 1990 to 73.3 million tonnes in 2015. Lignite mining is less labour-intensive than hard coal mining. Employment in lignite mining fell from 27,000 jobs in 1991 to less than 10,000 jobs in 2015. In this period, the number of mines remained unchanged and the annual production was roughly constant.[2]

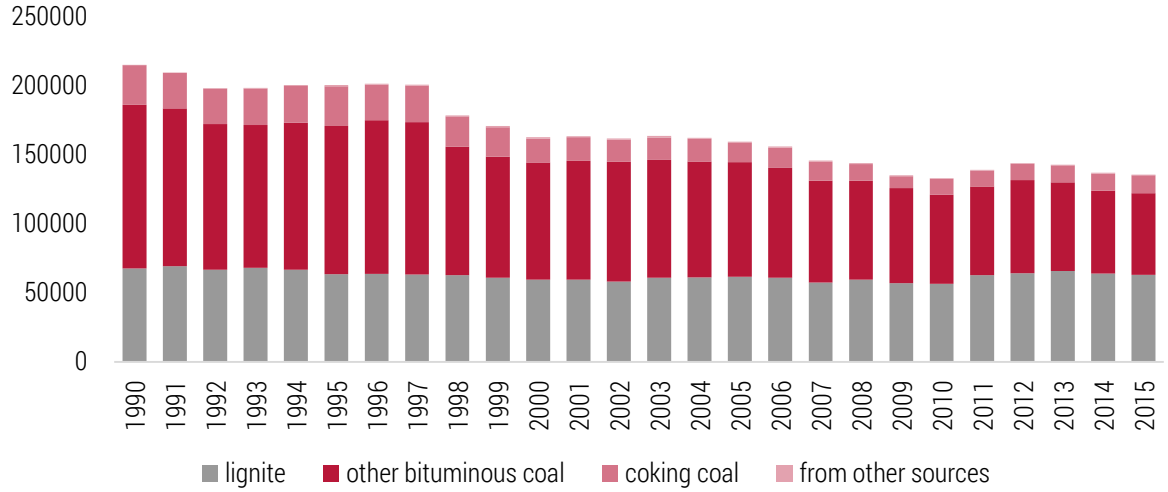
Figure 4. Number of active hard coal mines and jobs in hard coal mining in Poland, 1990-2014



Source: Data on the number of active mines from Kasztelewicz et al. 2015; data on employment from Bednorz 2015 (for 1989-2006); data from the Ministry of Economy and the Ministry of Energy for the rest.

[2] As a result, production per worker tripled from 12,000 to 37,000 m3 per person per year (Kasztelewicz 2015; Szczepiński 2017).

Figure 5. Production of coal and lignite in Poland, (1000 tonnes), 2015



Source: IEA.

Coal mining is geographically concentrated. Hard coal mining is restricted to three voivodships (NUTS-2 regions): Śląskie (most of the coal mines and 90% of employment), Lubelskie (one large coal mine), and Małopolskie (one medium-size coal mine). There are five lignite mines in Poland: Bełchatów (the largest one), which is located in Łódzkie voivodship; Konin and Adamów, which are located in Wielkopolskie voivodship; Turów, which is located in Dolnośląskie voivodship; and Sieniawa, which is located in Lubuskie voivodship. Four of these mines supply lignite coal to power plants located in their vicinity.

Three main types of coal are produced in Poland: thermal coal, coking coal (which we refer to later as a type of hard coal), and lignite[3]. The total volume of hard coal production in Poland in 2015 was 73 million tonnes, of which thermal coal accounted for more than 59 million tonnes and coking coal accounted for 13 million tonnes. Also in 2015, the production of lignite coal was 63 million tonnes. Between 1990 and 2015, the production of lignite coal remained at a constant level, whereas the production of hard coal was halved. It has been estimated that the recoverable reserves of hard coal (both thermal and coking) amount to 1.56 billion tonnes, and that the recoverable reserves of lignite coal come to 1.05 billion tonnes.[4] However, the governmental *Strategy for Hard Coal Mining* has acknowledged that these estimates are based on an outdated resource classification methodology that focuses on geological aspects, and that underestimates the economics of the exploration of possible reserves.[5]

[3] In this paper, the term "hard coal" refers to Polish classifications, and should not be confused with anthracite. In the IEA statistics, hard coal is also referred to as thermal coal or as bituminous coal. Other types of coal that are produced and consumed in Poland on a marginal scale, and that are referred to as coming "from other sources" in the IEA statistics, include low-grade coal and coal dust.

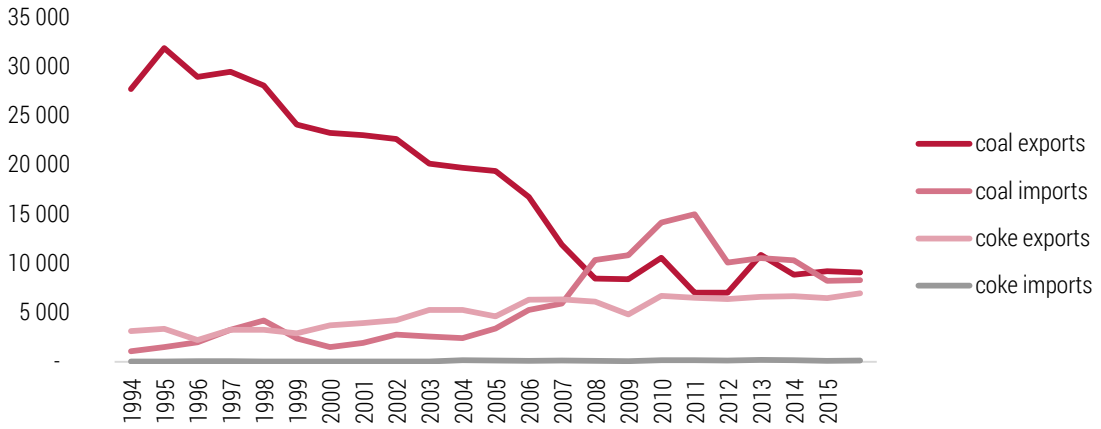
[4] These values refer only to the reserves for which concessions have been already granted. The value of the total recoverable coal reserves is estimated at 1.56 billion tonnes.

[5] For example, Canadian NI 431-01 or Australian JORC.

2.2.2. The coal trade

In the second half of the 20th century, Poland was a major exporter of coal. In recent years, however, the level of domestic production has been very close to the level of domestic consumption. In 2015, the balance of trade in thermal coal was slightly positive, with imports of 5.6 million tonnes and exports of 6.9 million tonnes. Considering the 2015 sales price of thermal coal (236 PLN (56.40 EUR)/tonne) and of coking coal (368 PLN (88 EUR)/tonne), these values were of marginal importance to Poland's overall economy and trade balance in that year. But for the coal mining sector, increasing the production of coking coal had become a strategic goal, mainly because of the higher profitability of and more stable demand for this type of coal. For coking coal, imports were at the level of 2.7 million tonnes and exports were at the level of 2.3 million tonnes in 2015 (Figure 1). For reasons related to the characteristics of lignite and the difficulties involved in transporting it, levels of imports and exports of this fuel in Poland remain marginal.

Figure 6. Exports and imports of coal in Poland, (1000 tonnes), 1994-2016



Source: Own elaboration based on data from Comtrade.

2.2.3. Profitability of the coal mining sector

Although efficiency indicators have improved and the average production per worker per day has increased from 1.87 t in 1990 to 3.72 t in 2015 (Dubiński and Turek 2017), coal production costs remain relatively high. The low competitiveness of hard coal production in Poland is reflected in a recent pattern of falling exports and rising imports (see Figure 6).

Despite relatively recent improvements in its competitiveness due to high coal prices in the world market, the sector is again unprofitable. After a period of positive net financial results that peaked at 3.0 billion PLN in 2011 (720 million EUR), the sector recorded negative financial results from 2013 to 2015. The largest loss was recorded in 2015, at 4.5 billion PLN (1.1 billion EUR). In 2016, the results were slightly positive, and were mainly attributable to a new restructuring programme that included investments of state companies in coal mining.

Excess employment and high personnel costs are among the factors that are frequently mentioned as obstacles to higher profitability for coal mines (Karbownik and Wodarski 2014). But because of collective wage agreements, it is difficult to reduce wages.[6] A reduction on the extensive margin (number of workers) is a more viable solution.

The other factors that contribute to the financial problems of the hard coal sector include high fixed costs; excessive production and increased competition from coal imports, mainly from Russia, which cause low-quality coal from Poland to remain unsold; and high production costs resulting from the unfavourable geological characteristics of deposits. In the future, the geological conditions could become even more problematic as more accessible deposits are depleted, and deeper pits need to be dug (Kasztelewicz et al. 2015).

Box 1. Support for coal mining and its contribution to public finances

Although it receives state support, the situation of the coal mining sector in Poland is unfavourable, mainly because of its obligations to fund pensions for retired miners. Between 2007 and 2015, the amount of the expenditures on miners' retirement pensions that were not covered by revenues from contributions was 7.4 billion PLN (1.8 billion EUR). However, it is important to keep in mind that this support is likely to be sustained even after the production of coal in Poland is phased out.

Other forms of state support the sector received in the 2007-2015 period included 1.6 billion PLN (0.4 billion EUR) for recapitalisation, 1 billion PLN (0.2 billion EUR) in state aid, and 0.5 billion PLN (0.1 billion EUR) for monitoring.[7]

The total amount the coal sector contributed in 2015 to Poland's public finances was 6.3 billion PLN (1.5 billion EUR). The largest share of this contribution, 3.2 billion PLN (0.8 billion EUR), was paid to the Social Insurance Institution and other public entities related to labour,[8] while 2.5 billion PLN (0.6 billion EUR) of this amount went to the state budget. The remaining shares were paid to the communes (0.3 billion PLN, 0.1 billion EUR), the National Disabled Persons Rehabilitation Fund (0.1 billion PLN, 0.02 billion EUR), and the national and regional funds for environmental protection and water management (0.1 billion PLN, 0.02 billion EUR).[9]

In 2007-2015, the balance of public support provided to the sector and the sector's contribution to public finances remained slightly positive. The sector's total contribution of 64 billion PLN to Poland's public finances was surpassed by the state support amounting to 65.7 billion PLN the sector received.

For the lignite mining sector, a similar analysis can be provided only in relation to the sector's contribution to Poland's public finances, which in 2015 amounted to 1 billion PLN (0.2 billion EUR). Of this amount, the Social Insurance Institution and other labour-related agencies received the largest share (3.7 billion PLN, 0.9 billion EUR), while the communes received the second-largest share (3 billion PLN, 0.7 billion EUR).

Source: 1) Supreme Audit Office report - in relation to hard coal mining and 2) Tajduś Z., Kasztelewicz A., Słomka T., 2017, Węgiel brunatny to paliwo przyszłości czy przeszłości? - in relation to lignite mining.

[6] Lower personnel costs are a key reason why private collieries are more profitable than state-controlled collieries.

[7] Supreme Audit Office (2017), p. 62.

[8] That includes three funds: Bridging Retirement Pension Fund, Labour Fund, Fund of Guaranteed Employee Benefits.

[9] Supreme Audit Office (2017), p. 65.

3. Labour market aspects of the coal transition

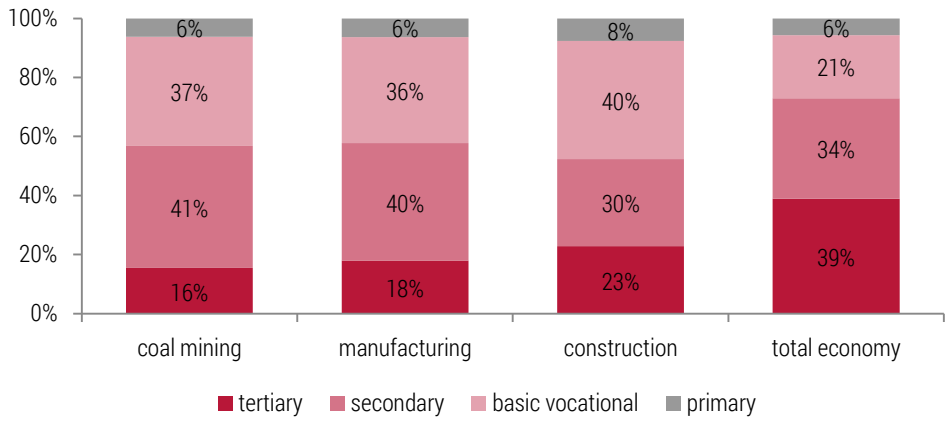
Workers in hard coal mining and lignite mining have similar characteristics. Employment in both sectors is highly masculinised and rather low-skilled. However, due to the broader spatial dispersion of lignite mining, the transition in the lignite mining sector will have different implications than the transition in the geographically concentrated hard coal mining sector. The concentration of hard coal mines in a limited area means that a single region will bear most of the costs of the phasing out of hard coal. It is therefore likely that the transition will have detrimental effects on local labour markets. Miners may be vulnerable to negative labour demand shocks for several reasons, including the large pay gap between mining and comparable sectors. Moreover, relative to other workers, miners are more likely to have low educational attainment and to be the sole earner in their household. In this section, we describe the employment patterns in hard coal mining in greater detail.

In 2015, 90,000 workers were employed in hard coal mining (Ministry of Energy 2016). This figure accounts for only 0.57% of total employment in Poland. However, role of this sector in employment in Śląskie voivodship is large because all but three of the hard coal mines in Poland, and 90% of all hard coal mining workers in the country, are located there.[10] In Śląskie voivodship, 5% of all workers (2014) and up to 8% of all male workers are employed in hard coal mining. The share of mining in the region's total value added is 6.8% (2014).

3.1. Low education of miners

Workers in the coal mining sector are, on average, less educated than the overall Polish workforce. In 2014, 6% of coal mining workers had primary education, 37% had basic vocational education, 41% had secondary education, and 16% had tertiary education. The share of coal mining workers with tertiary education was about half that of all workers, while the share of coal mining workers with basic vocational education was 16 pp. higher than the share of all workers (Figure 7).

Figure 7. Educational structure of employment in the coal mining sector and other sectors, 2014



Source: Own calculations based on the Structure of Earnings Survey 2014.

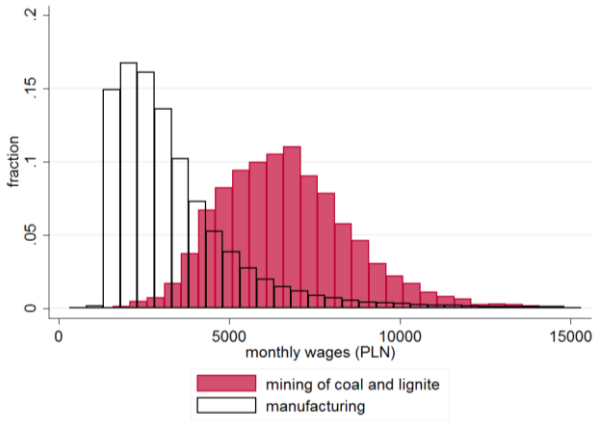
[10] Besides those in Śląskie, there are two coal mines in Małopolskie voivodship and one in Lubelskie voivodship.

The educational structure in the mining sector resembles the structures in construction and manufacturing. Hence, workers who leave mining tend to be more likely to find jobs in these two sectors than in other sectors where they would face education and skill gaps. Indeed, the evaluation of the Mining Social Package (which we discuss in more detail in section 4) showed that ex-miners often find new employment in occupations that require low levels of formal education, but that usually demand some specific competences. Individuals who found a job after retraining reported landing new employment in the following occupations: driver, builder, security worker, tradesman, entrepreneur, car mechanic, welder, plumber, warehouse worker, stoker, policeman, carpenter, locksmith (Turek and Karbownik, 2005).

3.2. Wage premiums in mining

Although coal miners are relatively low-skilled, earnings in the coal mining sector are far above the nationwide average. Workers in the hard coal and lignite mining sectors thus enjoy a significant wage premium compared to workers in the manufacturing sector (cf. Figure 8). In 2014, the average monthly wage in the hard coal and lignite mining sector was 6559 PLN, whereas the average monthly wage in manufacturing was 2907 PLN.

Figure 8. Distribution of monthly earnings in the hard coal and lignite mining sector and in the manufacturing sector, 2014



Source: Authors' own elaboration on Structure of Earnings Survey data.

Table 1. Wage premium for working in coal mining vs. working in manufacturing, obtained from wage regression

	based on October earnings	based on full-year earnings
hard coal and lignite	2412 PLN	3114 PLN

Notes: Only firms that employed at least 10 workers. Full-year earnings include bonuses, extra pay, etc. Monthly full-time equivalents. The control variables are: gender, age, age squared, specific tenure, specific tenure squared, education level, private/public sector, part-time employment, one-digit occupation group according to ISCO classification, voivodship.

Source: Own calculations based on the Polish Structure of Earnings Survey 2014.

The mining wage premium with respect to manufacturing is large even if the effects of other worker and job characteristics are accounted for. When we control econometrically for other factors that affect wages, such as age, tenure, gender, and education, the adjusted wage premium in coal mining amounts to 2400 PLN (monthly wages) to 3100 PLN (including bonuses, extra pay etc., cf. Table 1). This means that miners earn substantially more than workers with similar characteristics in manufacturing. These large wage differentials make voluntary

outflows from the mining sector unattractive, unless they are accompanied by financial compensation. Workers who leave the coal mining sector are likely to have higher wage expectations than other low-skilled workers, which may make them less willing to accept job offers available in other sectors and contribute to their tendency to have prolonged unemployment spells.

It should be acknowledged that to some extent, the mining wage premium is intended to compensate for dangerous working conditions. However, there are two other factors associated with wage premiums, especially among low-skilled workers: state control and high levels of unionisation. The mining sector remains largely under state control. Most of the coal mines in Poland are either directly owned or indirectly controlled by the state, and the number of coal mining jobs at private collieries is negligible.[11] At the same time, coal mining is the most unionised sector of the Polish economy. In 2015, the unionisation rate for the coal mining sector was 72% (GUS 2015), compared to only 11% for the total economy. High levels of unionisation and public ownership result in miners having more bargaining power than workers in other sectors.

3.3. Inactivity and early retirement among those who leave the mining sector

Workers in the mining sector have relatively high levels of work stability. Labour Force Survey data show that if an individual leaves the mining sector, it is usually because the person is moving to inactivity (seven in 10 individuals leaving the sector).[12] Two in 10 individuals leaving the sector find a job in a different sector, while one in 10 becomes unemployed. These figures are in a stark contrast to the employment patterns associated with outflows from the manufacturing sector: for each type of outflow (inactivity, unemployment, or starting employment in a different sector) the values are roughly three times higher in manufacturing than in mining. Hence, individuals who leave the mining sector are more likely than individuals who leave the manufacturing sector to end up in inactivity than in employment or unemployment.

Table 2. Yearly outflows of workers in the mining sector and the manufacturing sector, 2002-2015 average

	mining	manufacturing
employment -> employment (other sector)	1.4%	3.0%
employment -> unemployment	0.6%	2.9%
employment -> non-active	5.0%	3.0%
employment -> employment (same sector)	92.9%	91.1%

Notes: Numbers do not cover people who stopped being observed in the panel. Only data for Śląskie, Małopolskie and Lubelskie voivodships are used.

Source: Own calculations based on Polish LFS data.

The high incidence of outflows to inactivity observed among miners is related to their ability to take early retirement and availability of other passive social policy instruments. An official report on conditions in the sector found that the leading reason for outflows from the mining sector is retirement. In 2013-2014, 80% of the 17,000

[11] Only three collieries are private. They are: Silesia in Czechowice-Dziedzice, Siltech in Zabrze, and Ekoplus in Bytom. Together they employ about 2200 workers.

[12] The average for 2002-2015. The outflows are calculated based on Labour Force Survey data. Due to a lack of detailed data, the outflows are calculated for the whole mining sector in the regions with coal mines.

people who left the hard coal mining sector transitioned to retirement (Ministry of Economy, 2015a). Underground coal miners, who make up an average of 76% of workers in collieries (Supreme Audit Office 2017), are covered by early retirement provisions. They can retire at age of 50 if they have worked at least 25 years, including at least 15 years spent working underground. If the number of years spent working underground is 10 instead of 15, the retirement age is 55. In part, this early retirement option is compensation for the dangers associated with underground work and its potential negative impact on health, which includes a high risk of respiratory illness.[13] However, as the regular retirement age for men in Poland is 65, underground miners can retire 15 years earlier than most men.[14]

These early retirement provisions provide individuals with strong incentives to continue to work in mining, at least to the point at which they acquire eligibility rights. After 15 years of working underground, an ex-miner can work in any other sector without losing the right to take early retirement. Taking early retirement is not obligatory after the full right is acquired.[15]

3.4. Ageing of the coal mining workforce

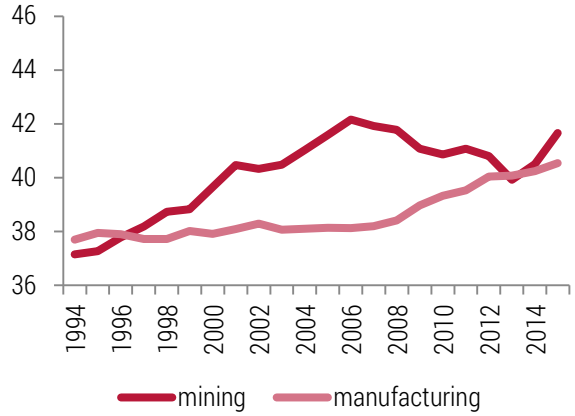
Between the early 1990s and the late 2010s, the average age of miners has been rising at a faster pace than the average age of workers in Poland, and at a faster pace than the average age of workers in manufacturing (Figure 9). This ageing process was due not only to population ageing, but to reductions in new hires. However, the trend was reversed in 2007, when the inflows of younger workers picked up. These developments are reflected in the age structure of the hard coal mining workforce, which is dominated by two groups (Figure 10). In 2014, the average (median) age of workers in the sector was 39 (40). About 25% of these workers were aged 40 to 45, while 15% were aged 28 to 32. The workers who were between the ages of 40 and 45 in 2014, and who have worked underground for a sufficiently long period of time, will start to reach (early) retirement age by 2020. The ongoing ageing of the hard coal mining workforce will result in an increase in worker outflows from the sector. This trend could provide an opportunity to implement a relatively painless but still noticeable reduction in hard coal mining employment in the coming decades. We discuss this possibility further in subsection 5.2.

[13] For instance, coal miners are at high risk of pneumoconiosis, which is the most common occupational disease among this group. Each year, an average of 400 new cases of pneumoconiosis are diagnosed among current and former miners (WUG 2017). Although there are no available data on life expectancy for different occupations, it is fair to assume that miners have a lower life expectancy than other workers because of the high accident risks and occupational disease risks associated with underground work.

[14] Other than in the mining sector, early retirement options are rather limited in Poland. The so-called bridging pension system introduced in 2008 allows workers in 51 occupations that involve working under dangerous or risky conditions to retire at the age of 55 (women) or 60 (men). Unlike mining pensions, bridging pensions are financed with revenue from a dedicated contribution.

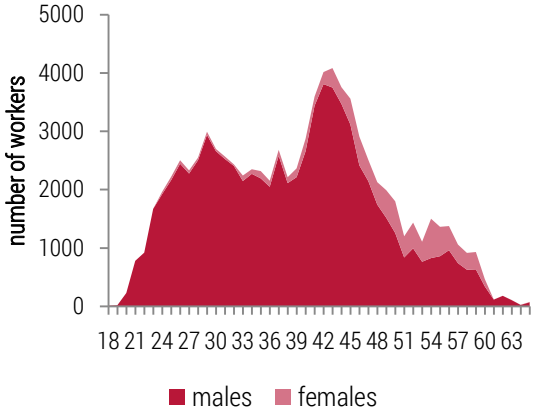
[15] At the end 2014, there were 3500 workers in hard coal mines who were eligible to retire, but who continued working. Miners with pension rights are usually referred as a "reservoir" that allows for a socially painless form of employment reduction. Nevertheless, these workers constitute a tiny share of total employment in the coal mining sector.

Figure 9. Average age of workers in mining and manufacturing in Poland, 1994-2015



Source: Own calculations based on Polish Labour Force Survey data.

Figure 10. Detailed age structure of employment in hard coal mining, 2014



Source: Own calculations based on Structure of Earnings Survey 2014 data.

The Śląskie region has been experiencing unfavourable demographic changes since the beginning of the 1990s due to a falling fertility rate and high levels of emigration. Although similar trends have been observed across Poland, they have been particularly pronounced in Śląskie. It is expected that these trends will continue in the future. Thus, Śląskie will experience further population shrinkage and a decrease in the share of the population who are of working ages (15-64). Since 1995, the region's population has already decreased by about 7% (350,000 people). According to demographic projections by Statistics Poland, the region's population will decline by another 310,000 people by 2030. Depopulation is accompanied by population ageing. The share of population who are of working ages is expected to decline from 69% in 2016 to 63% in 2030. At the same time, the share of the population who are aged 65 or older is expected to rise from 17% in 2016 to 25% in 2030. As a result, the labour supply in the region will decline and the workforce will become progressively older.

3.5. Regional labour markets in the Śląskie region

Śląskie is the second-largest Polish voivodship in terms of population, with 4.6 million inhabitants. Large parts of the region are occupied by the densely populated Silesian agglomeration, which includes Katowice, the region's capital and largest city. The region is highly urbanised, with a well-developed transportation system connecting the cities. Overall, the labour market conditions in the region are sound: in 2017, the unemployment rate (3.9%) was well below the national average (4.9%). Five out of the top 10 cities with the highest average wages in the Polish enterprise sector were located in Śląskie.[16] The total number of workers in Śląskie was 1.88 million.

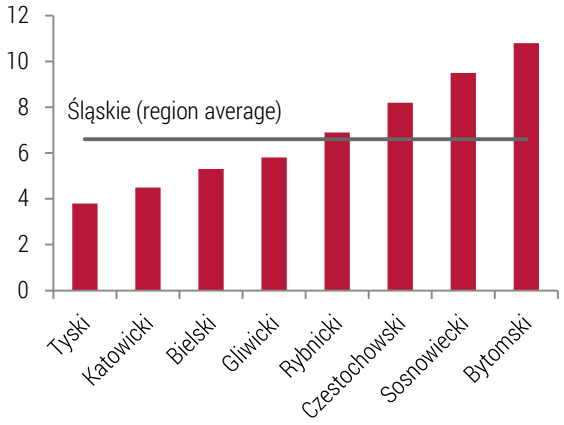
For statistical purposes, Śląskie voivodship is split into eight sub-regions (NUTS-3): Bielski, Bytomski, Częstochowski, Gliwicki, Katowicki, Rybnicki, Sosnowiecki, and Tyski. All of them except the Częstochowski sub-region have active collieries (Map 1). Coal mining is concentrated in the central part of the region, which is also the most urbanised part. In addition, there are two active collieries in the strip of Małopolskie voivodship, which is adjacent to Śląskie voivodship.

[16] According to the BDL data, these cities were: Jastrzębie Zdrój (first), Jaworzno (fourth), Katowice (seventh), Gliwice (eighth), and Dąbrowa Górnicza (ninth).

Map 1. Sub-regions of Śląskie voivodship and the location of active collieries

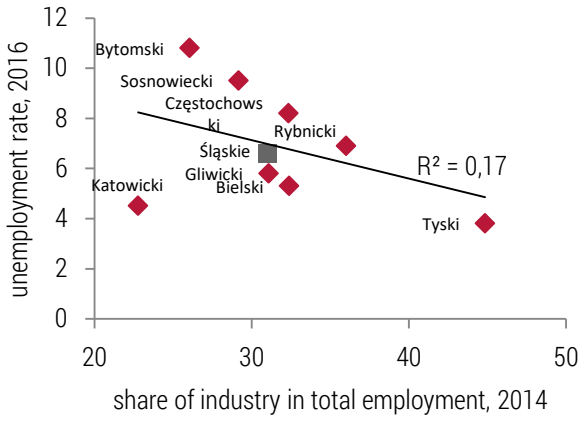
Source: Own elaboration.

Figure 11. The unemployment rate in the sub-regions of Śląskie voivodship, 2014



Source: Own elaboration based on BDL data.

Figure 12. The unemployment rate versus the share of industrial employment in the sub-regions of Śląskie



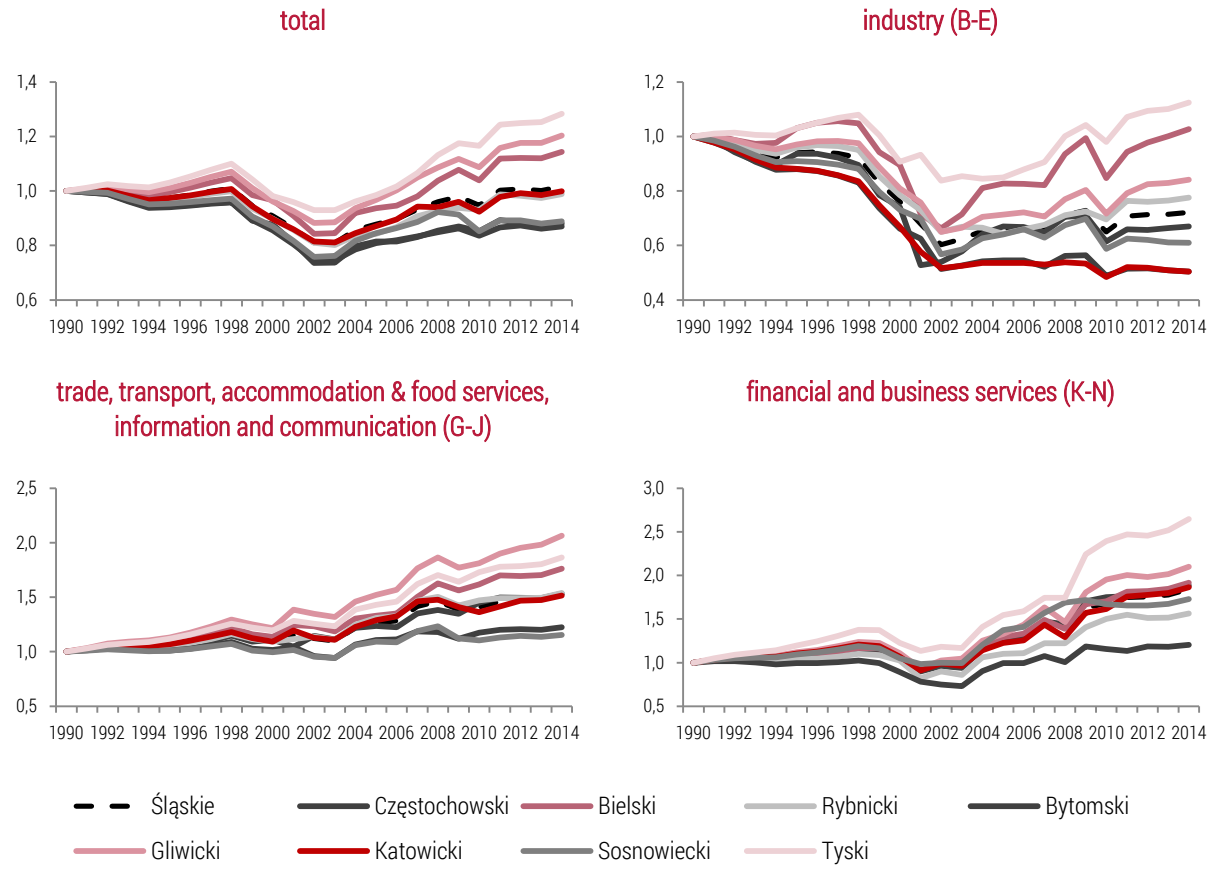
Source: Own elaboration based on data from the European Regional Database by Cambridge Econometrics.

Since 1990, the total number of jobs in Śląskie has increased despite the decrease in population. However, the labour market situations of the sub-regions vary (Figure 11). Four out of eight of the sub-regions have low unemployment rates: Tyski, Katowicki, Bielski, and Gliwicki. The worst labour market conditions and the highest unemployment rates are recorded in the Bytomski sub-region. The development patterns of particular sectors have also varied: heavy industry has shrunk in all of them, but other branches of manufacturing have grown and services have flourished to a various extent. The strong performances of particular sub-regions are largely attributable to their ability to rebuild their industrial structures. Manufacturing is the sector that is closest to

mining in terms of the educational structure of the workforce (Figure 7). Across the sub-regions, there is an apparent correlation between the unemployment rate and the share of industrial jobs in total employment.

In three of the most successful sub-regions (Tyski, Bielski, and Gliwicki), the industrial sector has retained a rather strong position, while employment in market services has expanded substantially. The total number of jobs has increased noticeably in these sub-regions: 28% in Tyski, 20% in Gliwicki, and 14% in Bielski (compared to just 2% in the region as a whole between 1990 and 2014). The expansion of employment in these sub-regions has been associated with the rebuilding of industrial employment after 2000, with the automotive industry playing an important role. The automotive industry has become the largest manufacturing branch in the region (54,000 workers in 2015), and a major car factory is located in each of these sub-regions. Moreover, there are factories that produce automotive parts (such as engines) in the Tyski sub-region.

Figure 13. Evolution of employment in the sub-regions of Śląskie voivodship, 1990-2014



Source: Own elaboration based on data from European Regional Database by Cambridge Econometrics.

The fourth of these relatively successful sub-regions, Katowicki, followed a different trajectory. It experienced substantial deindustrialisation (half of the sub-region's industrial jobs have been destroyed since 1990), but strong growth in market services has counterbalanced the decline in industrial jobs. Due to its capital functions, the Katowicki sub-region evolved towards a strong specialisation in market services. Katowice is not only the administrative capital, but a business, cultural, and educational hub. In 2014, this sub-region had the lowest share

of workers employed in industry (23%) and the highest share of workers employed in market services (46%) among all of the sub-regions of Śląskie voivodship.[17]

In contrast, the Bytomski sub-region is an example of an area that failed to adapt to changes in the economy. While the number of industrial jobs in this sub-region declined to the same extent as in the Katowicki sub-region (by 50%), no new branches of manufacturing or of market services have emerged to take their place. As a result, the number of jobs in this sub-region fell 13% between 1990 and 2014 – a decline that is unparalleled in the entire region. In the mid-2010s, this sub-region stood out for having the highest share of employment in non-market services (27% in 2014, compared to between 15% and 25% in the other sub-regions).

4. Lessons from past policies that apply to the coal transition

In this section, we discuss Poland's past experiences with social policies designed to facilitate the closure of hard coal mines. Previous policy efforts aimed at mitigating the negative social impact of previous coal transitions focused primarily on providing financial assistance to the ex-miners. Active policies aimed at increasing the employability of redundant miners in other sectors were rather scarce.

4.1. Assistance to individuals leaving the mining sector

In 1998, the government introduced the Mining Social Package to assist workers leaving the coal mining sector. The voluntary nature of the lay-offs was a key feature of the Mining Social Package. Between 1998 and 2002, 67,000 leavers received assistance under the Package (Faliszek 2011). Of these leavers, 36,900 used the *miners' leave* (*urlop górniczy*), which was the single most popular measure under the umbrella of the Mining Social Package (Bednorz 2015, p. 215); and a further 29,700 workers used *redundancy payments* (*jednorazowa odprawa pieniężna*). The other measures provided by the Mining Social Package were the *welfare allowance* and *retraining courses*. The welfare allowance played only a minor role, as just 419 individuals used this form of assistance.

The miners' leave was a form of early retirement. Workers with less than five years to work before retiring were eligible. During the leave, miners were paid 75% of their monthly wage. Individuals on the miners' leave were not permitted to receive other forms of assistance, but they were allowed to take up employment outside of mining. If they got another job, the amount they received under the leave would be reduced by a half (Karbownik and Bijańska 2000).

A redundancy payment was a one-time "golden handshake" that was taken up primarily by the miners who were not eligible for the miners' leave. There were two types of redundancy payments: conditional and unconditional. The conditional redundancy payment was offered to those miners who voluntarily left the mining sector and found a job within 24 months of leaving the sector. It was paid at the moment the individual started his or her new employment. If the worker started the new job by the end of 1999, the payment was the equivalent of a 14.4-monthly average wage in the mining sector. The payment was gradually reduced to the equivalent of a 7.2-monthly average wage for those started a new job by the end of 2002. This instrument could be used together

[17] The opposite was observed in Tyski: the sub-region had the highest share of employment in industry (45%) and the lowest share of employment in market services (30%).

with the welfare allowance. The unconditional redundancy payment was the equivalent of a 24-monthly average wage in the mining sector, but an individual who received it was required to give up other forms of assistance (Karbownik and Bijańska 2000).

The welfare allowance was a monthly financial benefit amounting to 65% of the miner's wage. Ex-miners could use the benefit until they found new employment, but for no more than 24 months after leaving mining. The welfare allowance was intended to assist individuals who were taking retraining courses. The take-up of the allowance turned to be very low.

The Mining Social Package was successful in facilitating significant reductions in mining employment through incentives, while avoiding forced group lay-offs. The miners who voluntarily left collieries were provided a level of financial support that shielded them from a significant deterioration in their standard of living. However, this programme represented a sizeable public finance expenditure. The total funds spent on assistance under the Mining Social Package in 1998-2002 amounted to 5.38 billion PLN (Turek and Karbownik 2005), or 0.75% of Polish GDP over that period.

The individual outcomes of the ex-miners who were given redundancy payments under the Mining Social Package have been evaluated. The assessment found that between 54% and 65% of individuals found a job within several months of leaving the mining sector (Turek and Karbownik 2005), while the rest failed to find employment. It was also shown that one-third of beneficiaries were economically inactive and had no interest in taking up employment. This finding is especially troublesome because the redundancy payments were given to individuals with more than five years to work before retiring, which suggests that a large share of the ex-miners with relatively long prospective careers stayed out of the labour market. This can be seen as a societal welfare loss. Moreover, the evaluation found that most of these individuals were unwilling to migrate.

The assessment further indicated that contrary to the government's original intention, relatively little of the financial assistance was spent on building skills. Instead, the evaluation showed, most of the redundancy payments were spent on repaying debts or consumption (Bednorz 2015, p. 188). This suggests that the assistance was not effective in improving the employability of the ex-miners.

The ideas that motivated the enactment of the Mining Social Package also influenced the assistance package introduced in 2015. This new assistance programme is aimed at helping the hard coal mining sector implement organisational changes and reduce their coal production. Again, encouraging workers to leave the coal mining sector voluntarily is a key principle. However, the number of measures has been reduced to two: miners' leaves and redundancy payments.

Under the terms of the new Package, the miners' leaves are offered to underground miners who are no more than four years short of the retirement age, and to workers of coal preparation units who are no more than three years short of the retirement age. Miners who use the leave cannot work in collieries, but they are free to take up employment in other sectors. As before, during the leave miners are paid 75% of their monthly wage. The important difference between this Package and the previous one is that taking a job outside the coal sector does not reduce the amount paid under the miners' leave. Hence, ex-miners have a stronger incentive to remain economically active after leaving a colliery.

Redundancy payments are available to surface workers, including administrative workers, who have at least five years' tenure in a colliery and are more than one year short of the retirement age. The payment can be up to 12

monthly average wages, but the amount depends on the time when the individual leaves the sector, with miners who leave the collieries later being given less money. The beneficiaries are banned from taking a job in a colliery, but there are no other restrictions on starting new employment. Those ex-miners who find a new job outside the collieries are given exactly the same amount as ex-miners who are inactive. Individuals can use only one instrument, either the miners' leave or the redundancy payment. The total amount of assistance provided in 2015-2017 for both the miners' leave and the redundancy payments was 850 million PLN.[18] By the beginning of 2018, 9000 workers had used the assistance, of whom 6000 were underground workers.

4.2. Support to local communes affected by the decline of coal mining

The municipalities affected by mine closures were also offered instruments aimed at spurring job creation, such as the option to be designated as a special economic zone. The experience of Wałbrzych, a city in the Dolnośląskie region where hard coal mines were closed in the 1990s, shows that such instruments were not sufficient to prevent economic malaise. A special economic zone in Wałbrzych was established in 1997. It granted tax exemptions and offered land plots for greenfield investment to attract new firms, especially FDIs. Although the city was successful in attracting new investment, the zone designation did not solve the problem of high joblessness. By the end of 2000, when the last colliery was closed, there were only 1500 jobs in the special economic zone (Hasińska and Sipurzyńska-Rudnicka 2008). Hence, just one-tenth of the jobs lost in the mining sector were replaced.[19] However, there is no proof that the new jobs in the special economic zone were taken up by redundant workers from closed collieries. The unemployment rate in the region remained at levels above the national average.

Box 2. The demise of mining in Wałbrzych

The closure of collieries might have strong negative effects on a local labour market, especially if it coincides with other adverse factors. Such a situation occurred in the Wałbrzych region, and led to persistently high unemployment rates and intensified social problems in the years that followed. The Wałbrzych coal region was one of three hard coal production regions in Poland. All of the coal mines in the region were closed in the 1990s, and the last colliery was shut down in 2000. The closure of the mines meant the loss of 14,000 jobs in the coal mining sector. At the same time, factories in other industries were shutting down in the Wałbrzych region. Moreover, the closure of the mines coincided with the deterioration of the general macroeconomic situation in Poland. With limited employment alternatives, it triggered a high and persistent unemployment rate in the region and intensified social problems of exclusion. (Dołzbłasz 2012). Poverty caused bootleg pits to appear. These illegal self-made coal pits, which started operating at the end of the 1990s, were characterised by a high risk of accidents. The bootleg pits were often dug by ex-miners who had run out of money from their redundancy payments and had failed to find new employment (Lorenz 2016).[20]

[18] Source: http://srk.com.pl/2018/02/23/oslony-socjalne-dla-9-tys-osob/

[19] By the end of 2006, the special economic zone had attracted 7000 jobs, but this was still half the number of jobs destroyed in coal mining.

[20] It has been estimated that around 300 individuals were working in bootleg pits around 2004 (see Lorenz 2016).

Special financial privileges granted to mining communes are another example of demand-side measures designed to indirectly stimulate job creation. In the late 1990s, the government acknowledged that local authorities play a key role in the process of restructuring local economies affected by the decline of hard coal mining. In 1998, the mining communes received privileges that included an increased share of tax revenues and access to preferential credits for the stimulation of local economic activity. These privileges were intended to equip local authorities with the means to develop alternative workplaces outside of the mining sector. However, a few years later the privileges were substantially limited. In 2003, the government withdrew the increased tax revenues; and in 2007, the programme of preferential credits was terminated. The latter instrument was withdrawn due to a lack of interest by local authorities in using the preferential credits. The Deputy Minister of Economy explained that the communes preferred to use European funding (Faliszek 2011).[21]

5. Scenarios for coal use and coal mining employment in Poland

In this section, we present projections of coal use in the Polish economy up to 2050. In section 5.1, we discuss the demand for coal and labour in the mining sector under two alternative scenarios: the baseline scenario and the scenario consistent with the two-degree climate change target[22]. In section 5.2, we present scenarios of labour supply in mining under two hiring scenarios, and compare them with the labour demand under the two-degree scenario.

5.1. Scenarios of coal use in Poland

5.1.1. Methodology

The baseline scenario

The baseline scenario is built on the assumption that the government does not set policies restricting emissions. The path of coal consumption in the power sector is constructed using the cost-minimising scenario with low ETS prices and no targets for RES or CO2 emissions. This scenario was prepared in 2015 by the Department of Strategic Analyses within the Polish Chancellery of the Prime Minister.[23] The path of coal consumption in the residential sector is computed using long-term trends in the consumption of coal per unit of GDP. For industry, the projections are made under the assumption that the path of coal consumption will converge with the long-term trends in Germany.

[21] The mining communes still retain some financial rights. They collect exploitation fees from collieries, which are seen as a form of compensation for the nuisances associated with the exploitation of coal (Olszowski 2010), rather than special funds aimed at assisting the transition. In 2014, the local authorities received 294 million PLN (70 million EUR) from exploitation fees and other minor local taxes (Ministry of Energy 2018). On average, the revenue from exploitation fees plays a minor role in the budgets of mining communes (1.2% in 2014; Czempas 2015). However, in a few communes, especially rural ones with small populations, the share of revenue from exploitation fees in total revenues exceeds 10%.

[22] These simulations are described at greater detail in the earlier report from the coal transition project, Baran et al. (2018).

[23] The dataset and the model is available online at https://www.premier.gov.pl/wydarzenia/aktualnosci/model-optymalnego-miksu-energetycznego-dla-polski-do-roku-2060-0.html

An important assumption in this scenario is that energy efficiency will increase quickly up to 2030. Since the 1990s, improvements in the fuel efficiency of vehicles, retrofitting efforts in the residential sector, and modernisation efforts in the industrial sector have led to a substantial drop in energy consumption in 1990s per unit of GDP. We assume that these trend will continue.

2°C-consistent scenario

In the two-degree scenario, we assume that the Polish economy will undergo a deep decarbonisation in accordance with the Deep Decarbonisation Pathways Project (DDPP).[24] The DDPP assumed that in 2050, emissions in the major economies will range from one to three tonnes of CO2 per capita depending on the degree of current development. In our scenario for Poland, the CO2 emissions per capita reaches the level of 2.80 Mt in 2050, which constitutes a 67% reduction relative to the 2010 level. This is achieved through the adoption of the following measures:

- A decarbonisation of the power sector by replacing coal with nuclear and renewables in the energy mix.
- An increase in the efficiency of the use of gas and coal in the industrial, residential, and commercial sectors.
- An increase in the efficiency of electricity use in the economy.
- The electrification of transport.

The pathway of power sector decarbonisation has been computed using the Model of Optimal Energy Mix, which was designed in the Department of Strategic Analysis of the Polish Chancellery of the Prime Minister, and made available to the public. While we use the original structure of the model, we introduce several changes in the parametrisation of the model. First, we have updated the costs of installations of solar PV, and we assume a relatively fast decline in these prices at a rate of 8% per annum between 2017 and 2027 and of 2% per annum between 2027 and 2050. Second, we assume that the amount of gas that could be imported is limited to 2 billion m3 per year, and that the total stock of home resources available for use in the power sector is 23 billion m3 (in the appendix we describe an alternative scenario that permits larger use of gas in the power sector). Third, we assume that the annual growth of demand for electricity oscillates around an average of 1%. Fourth, we assume that bioenergy is emission-neutral. Finally, we assume that the cap on emissions in the power sector decreases annually by 3.6 million t of CO2 by 2030, and by 2 million tonnes between 2030 and 2050.

Regarding the use of coal and gas in the residential, commercial, and industrial sectors, we assume that the efficiency in the use of these fuels (use per unit of GDP) follows or converges with the paths predicted for Germany in the DDPP project (Hillebrandt, K et al. (2015)).

We assume that the use of oil per unit of GDP decreases at a rate of 4% up to 2030 based on the long-run trends; and that after 2030, the consumption of oil will continue to decrease due to the electrification of transport. We assume that this process will allow oil consumption to decrease by 70% between 2030 and 2050. Note that in Poland, oil is used in the transport sector only.

[24] The project was convened under the auspices of the Sustainable Development Solutions Network (SDSN) and the Institute for Sustainable Development and International Relations (IDDRI). Information about the project can be found at: http://deepdecarbonization.org/wp-content/uploads/2015/06/DDPP_Digit.pdf

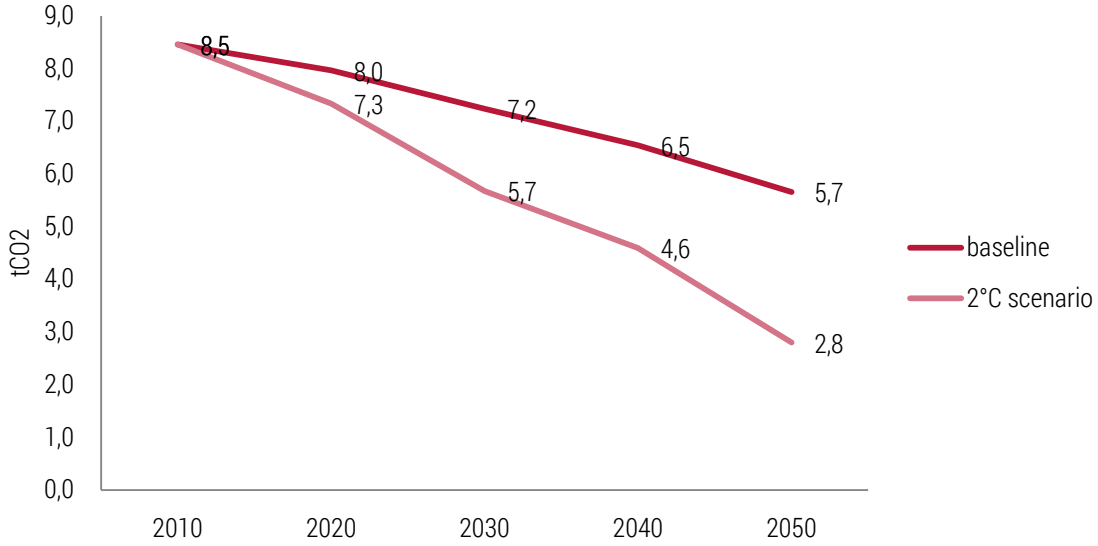
Since electric engines are highly efficient the amount of electricity required for the electrification of road transport in Poland will not be significant. According to the simulation in Barton et al. (2013), in 2050 a fleet of 24.7 million electric vehicles would require 37TWh. If we assume the target of 500 vehicles per 1000 people and the electrification of 70% of the fleet, the energy system in Poland would need to reserve 18.2TWh for this purpose, or 8.7% of electricity production in Poland in 2050.

We assume that between 2015 and 2050, the demand for electricity will increase at an average annual rate of 0.7%. The expected annual growth of GDP in the same period is 2%.[25]

5.1.2. Emissions and energy

While it makes a relatively optimistic assumption about increases in energy efficiency, the baseline scenario suggests that the decline in CO2 emissions will be modest and delayed relative to the ambitious two-degree scenario. In the baseline, the amount of emissions per capita will decline from 8.56 t in 2010 to 7.2t in 2030 and to 5.7t in 2050. In the two-degree scenario, emissions per capita will reach a level of 5.7t as early as 2030. By 2050, emissions will fall to 2.8t, or twice as much as in the baseline scenario (Figure 14).

Figure 14. CO2 emissions per capita from fuel combustion (tonnes per capita)

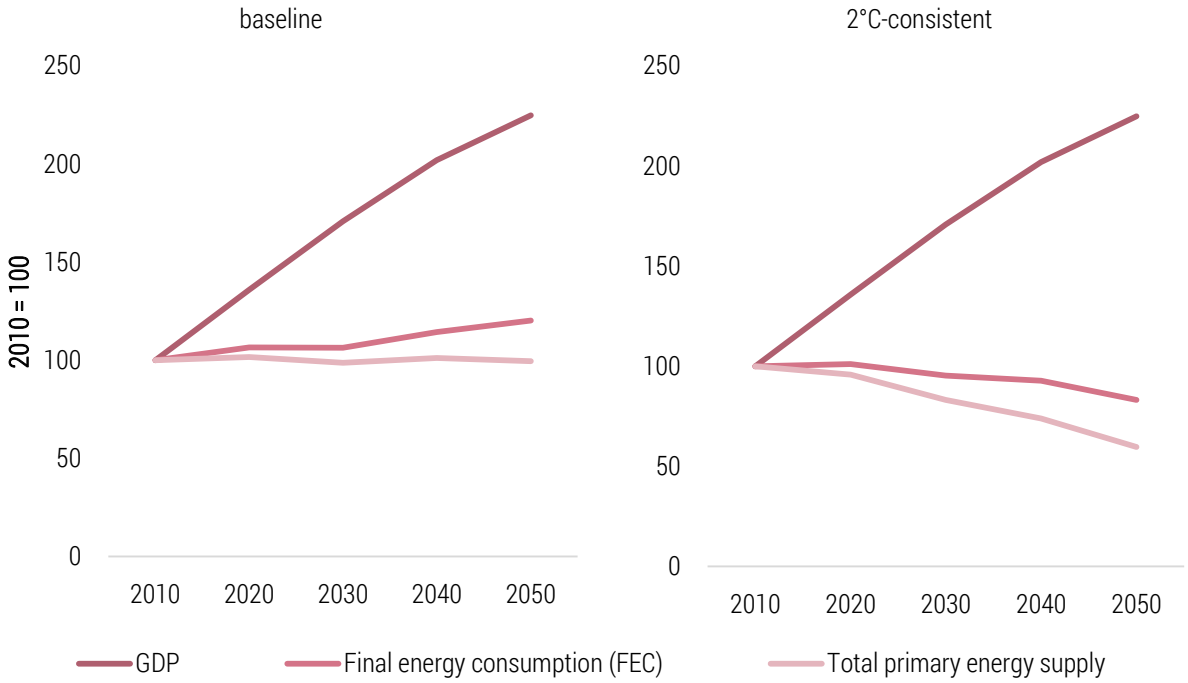


Source: Own calculations.

The path of final energy consumption will also be notably different in the two scenarios. In the baseline scenario, final energy consumption will continue to increase from the current level of 2.9EJ to 3.1 EJ in 2030 and to 3.5 EJ in 2050. In the two-degree scenario, it will peak in 2020 at 3.0 EJ. By 2050, final energy consumption will drop to the level of 2.4EJ, which is 17% below the level in 2010 (Figure 15). In both scenarios, the growth rate of final energy consumption will be lower than the growth rate of GDP due to a substantial increase in energy efficiency. In the two-degree scenario, the increase in energy efficiency will be large enough to fully offset the effect of growth in income.

[25] Between 2000 and 2010, the annual growth in the demand for electricity was 1.4%, and the annual growth in GDP was 3.6%.

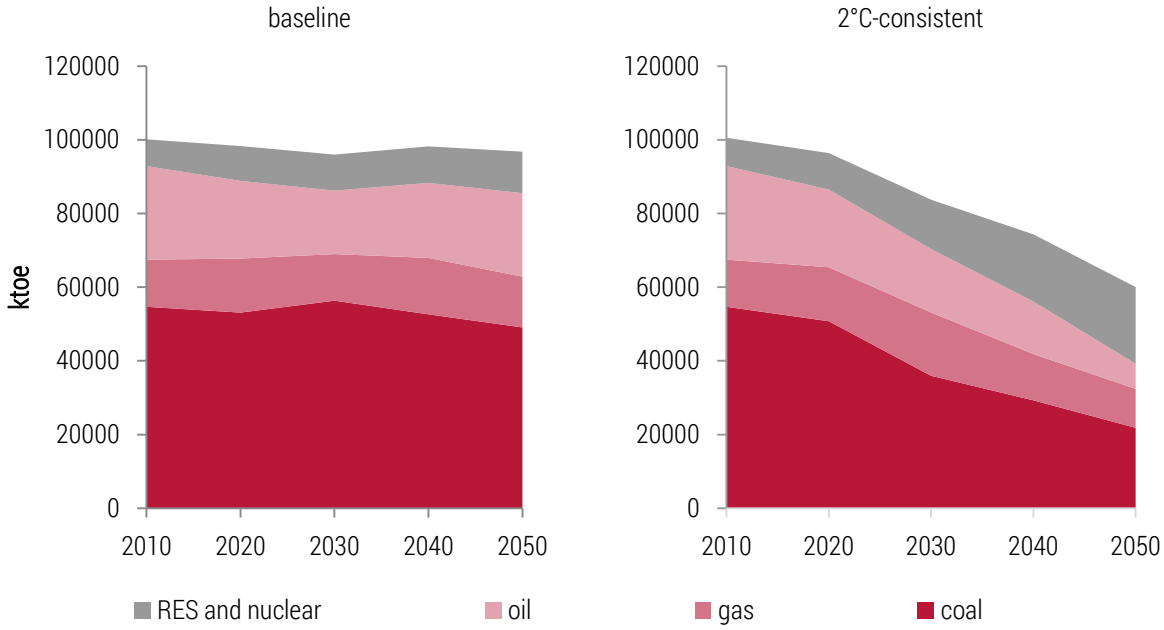
Figure 15. Final energy consumption and total primary energy supply



Source: Own calculations.

The total primary energy supply will remain roughly constant in the baseline and decrease 40% in the two-degree scenario. The difference in the trends for the primary and the final energy supply could be explained by an increase in the efficiency of the power sector, which is assumed for both scenarios. The decomposition of this trend by the source of energy is presented in Figure 16.

Figure 16. Total primary energy supply by the source of energy



Source: Own calculations.

5.1.3. Coal consumption

The reduction in coal consumption in the baseline scenario is small and delayed compared to the reduction in the two-degree scenario. The use of coal in 2030 at the baseline will be at almost the same level as in 2010. Only after this date will the use of coal drop, reaching the level of 2.21EJ in 2050 (vs. 2.55 EJ in 2010). In the two-degree scenario, the consumption decreases to the level of 1.43EJ in 2030 and of 0.76EJ in 2050, which is less than one-third of the consumption in 2010. If we take 2015 as the reference point, the two-degree scenario involves a 20% drop by 2030 and a 55% decline by 2050.

Below we discuss the evolution of the consumption of coal in the power, residential, and industrial sectors.

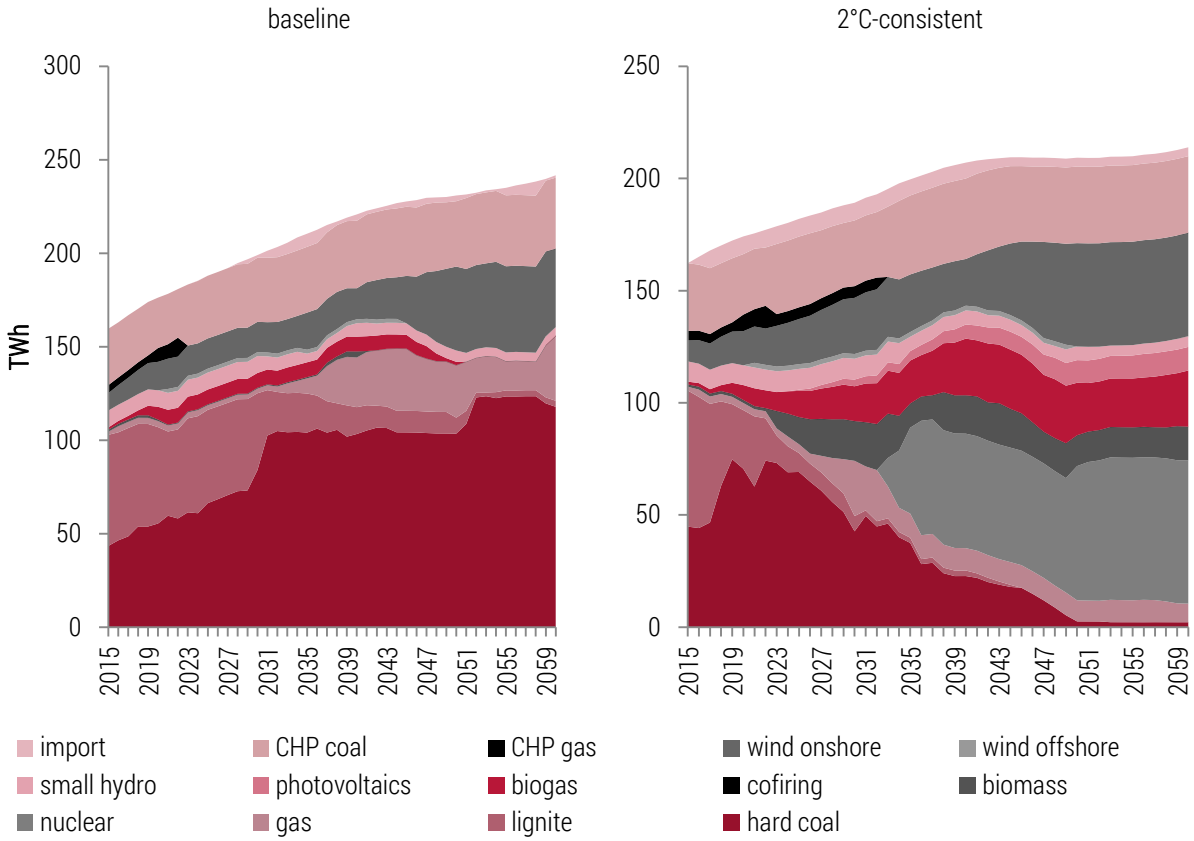
The power sector

The path of consumption of coal reflects the trends in the use of this fuel in the power sector. In the baseline scenario, the consumption of coal in the power sector will increase 5% between 2010 and 2030. Between 2030 and 2050, it will decrease 11%. In the two-degree scenario, the use of coal in the sector will be almost 50% lower in 2030 than in 2010. Between 2030 and 2050, our projection suggests there will be a further decline of 43%.

As a result of these changes, in the two-degree scenario the share of coal in the Polish electricity mix will decline from 87% in 2010 to 41% in 2030 and to 18% in 2050. In the first phase (taking place in the 2020s), coal will be replaced by gas, biomass, and biogas (Figure 17). In the second phase (taking place in the 2030s), coal will be replaced by nuclear power. In the last phase (after 2040), coal will be replaced by an increase in the capacity of onshore wind and solar power. The scenario assumes that between 2040 and 2050, 30% of coal power plants (2.25GW out of 7.50GW) will have installed CCS technology. If CCS technology is not available by that time, it could be replaced by negative emissions from new forests or the further replacement of coal power plants with biomass plants.

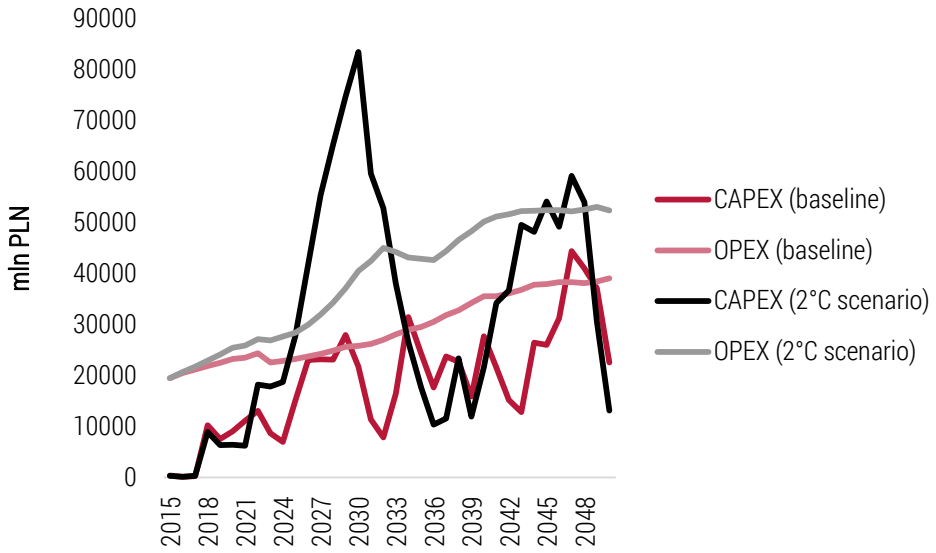
In both scenarios, the composition of coal consumption will change substantially: the projections indicate that lignite will be phased out completely and replaced by hard coal. The costs of operation (OPEX) and investment (CAPEX) required for the power sector in the two scenarios are shown in Figure 18. These costs do not include the costs of CCS installations. In the baseline scenario, there is no single investment peak, and the investment projects are spread across the entire period. In the two-degree scenario, most of the investment will take place in the 2025-2030 period; i.e., during the period when the use of coal in the power sector is declining the fastest.

Figure 17. Generation of electricity by source



Source: Own calculations based on the baseline scenario of the optimal energy mix model (see section 5.1.1.)

Figure 18. The total costs of operation (OPEX) and investment (CAPEX) required for the power sector



Source: Baseline scenario of the optimal energy mix model (see section 5.1.1.).

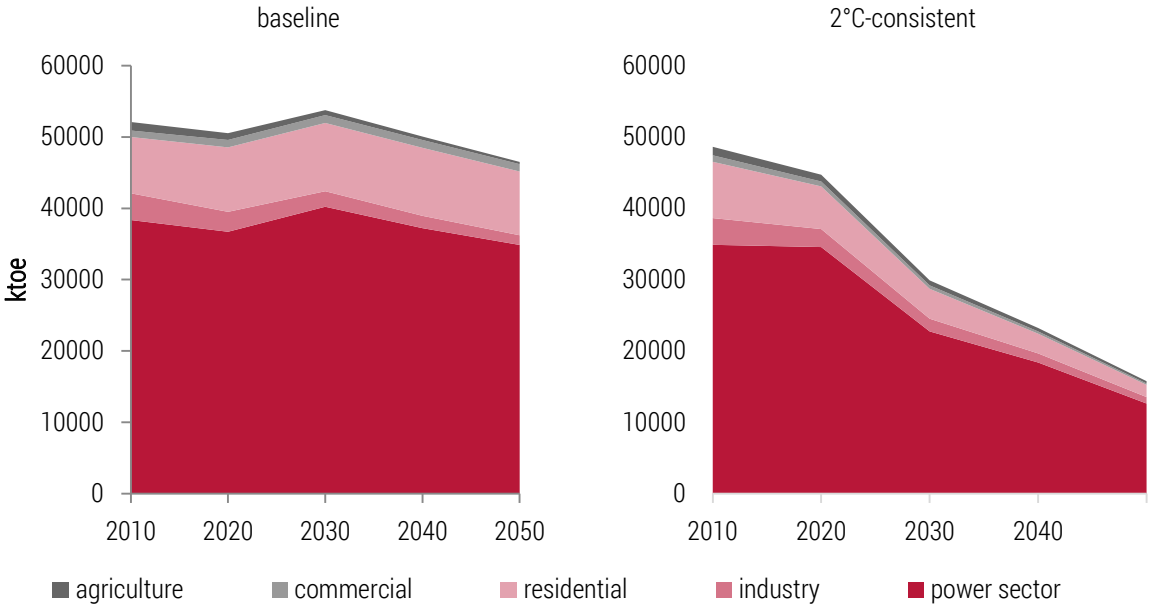
The residential and industrial sectors

The residential sector, which uses the second-largest amount of coal after the power sector, also contributes substantially to the differences between the two scenarios (Figure 19). In the baseline scenario, the consumption is projected to grow 21% between 2010 and 2030, and to return to its 2010 level by 2050. This projection assumes a substantial improvement in energy efficiency. Specifically, following the past trends in Germany, we assume that in the baseline scenario the use of coal per unit of GDP will fall at the annual rate of 2% per year.[26] This rate of progress can be achieved through the retrofitting of buildings, continued improvements in the construction technologies for new buildings, and an increase in the efficiency of coal burning.

In the two-degree scenario, the consumption of coal in the sector will fall steadily. Our results show a 24% reduction between 2010 and 2030 and a 78% reduction between 2010 and 2050. The decline in coal consumption could be achieved by a reduction in the demand for heat thanks to a higher rate of building retrofitting, the adoption of passive house technologies, and energy-saving behavioural changes (Forum Energii, 2018).

The consumption of coal in industry is projected to decline quickly in both scenarios. This reflects the assumption that steady progress will be made in technologies that allow for a reduction in energy use. Such improvements have occurred in recent history. For instance, in the 2004-2014 period, the use of coal in German industry decreased at a rate of 3% per annum, even though the share of industry in GDP in the same period increased.[27]

Figure 19. Coal consumption by sector



Source: Own calculations.

[26] In Poland, the rate of decline in consumption of coal per unit of GDP in the 2004-2014 period was 4%. In our view, it is overly optimistic to expect such a pace to be maintained. Thus, we make a more conservative assumption that the future decline in Poland will be at the same rate as in Germany in the 2004-2014 period.

[27] According to the World Bank data: https://data.worldbank.org/indicator/NV.IND.TOTL.ZS?locations=DE

5.1.4. Production of coal and employment in mining

In the baseline scenario, coal production remains constant until 2030, whereas it declines 44% in the two-degree scenario. Between 2030 and 2050, the changes in the total primary consumption of coal induce a decline in domestic coal production even in the relatively conservative projection of the baseline scenario. However, the decline in the two-degree scenario will be much stronger (Table 3).

In the baseline scenario, imports of coal will decrease insignificantly from 0.33EJ in 2010 to 0.29EJ in 2030 and to 0.31EJ in 2050. In the two-degree scenario, imports become negligible as early as in 2030.

The decrease in coal production is reflected in the decrease in employment associated with coal production under the assumption of constant productivity growth in mining (1.4% per annum in 2008-2015). In the baseline scenario, the number of workers employed in the mining, transport, and processing of coal will fall sharply from 131,000 in 2010 to 110,000 in 2030 and to 81,000 in 2050. In the two-degree scenario, the projection suggests that the number of workers employed in mining will drop to 70,000 in 2030 and to 30,000 in 2050 (Table 3). Hence, in 2050, the number of workers will be 52,000 lower in the two-degree scenario than in the baseline scenario.

Table 3. Production of coal and employment in mining

	Production (in EJ)		Employment (in thousands)	
	baseline	2°C-consistent	baseline	2°C-consistent
2010	2.5	2.5	131.2	131.2
2020	2.3	2.1	112.1	107.2
2030	2.4	1.4	109.8	68.4
2040	2.3	1.1	98.1	47.4
2050	2.1	0.7	81.9	29.3

Source: Own calculations

Employment in the coal power sector will decrease as well. In the baseline scenario, the number of workers will increase from 29,000 in 2010 to 32,000 in 2030 and then decrease to 25,000 in 2050. In the two-degree scenario, the number of workers employed in that sector will drop to 23,000 in 2030 and to 11,000 in 2050.

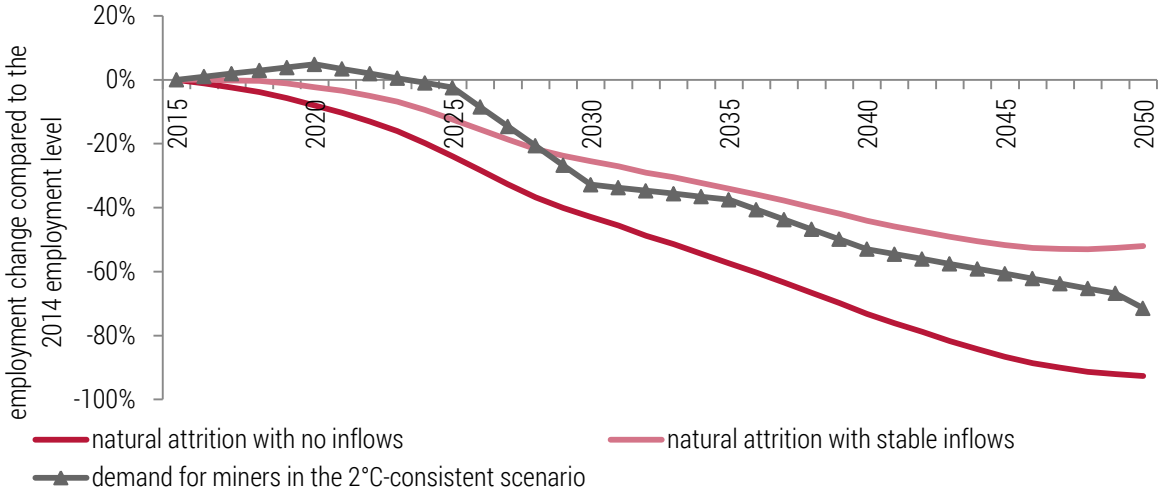
5.2. Projected supply of workers in hard coal mining

In this sub-section, we investigate how the supply of workers in hard coal mining would change in the future under two scenarios. The first scenario quantifies the effects of natural attrition; i.e., the outflows of workers due to retirement, under the assumption of a hiring freeze (no new workers enter the sector). The second scenario assumes that inflows of new workers to the sector will be stable and equal to the current number of graduates of mining classes (approx. 1000 people per year). Figure 20 presents the simulation results.

The scenario assuming no new entrants implies that employment will decrease 25% by 2025, and 44% by 2030 (compared to levels in 2014). The decline in employment accelerates in the mid-2020s, when 3000 to 4000 miners will reach the retirement age each year. The scenario with stable inflows of new workers implies that the employment reductions will be smaller: i.e., 12% by 2025 and 25% by 2030.

The decrease in the number workers in the stable inflows scenario is very close to the decline in the demand for workers predicted in the two-degree scenario (Figure 20). Hence, our simulations show that a noticeable reduction in hard coal mining employment is feasible in a dozen or so years without the need for additional layoffs. Population ageing will provide an opportunity for a relatively painless transition to occur.

Figure 20. Scenarios of employment changes in the hard coal sector between 2015 and 2050



Source: Own calculations using data from SES 2014.

Our scenarios show that the size of the employment reduction depends on the number of new entrants. Hence, it is important to coordinate educational policy with the coal transition goals. In recent years, there have been about 1000 graduates of mining classes each year. This number should be adjusted, and probably reduced, in line with the expected demand for workers with various skill levels. For labour market policy and public finance reasons, it is better to prevent workers from entering the sector than to reduce employment via lay-offs, as there are a number of costs associated with lay-offs, including the cost of financial assistance given to laid off workers, the cost of retraining, and the cost of disrupted career paths. An employment reduction that is largely driven by outflows to retirement, as in our scenarios, would be less costly than a reduction that requires group lay-offs or voluntary departures from the mining sector. Indeed, a review of the previous effects of the Mining Social Package, which facilitated cuts in mining employment in 1998-2002, indicates that voluntary departures can reach a large scale if they are combined with range of social policy instruments, like redundancy payments. However, that package was expensive (0.75% of GDP), and did little to keep ex-miners in the labour force.

6. Conclusions and policy implications

Meeting the objectives of the Paris Agreement will require an ambitious reduction in coal consumption in the coming decades. The Polish economy faces two major challenges in this process. The first challenge is to replace coal with renewable energy sources and adopt energy-saving technologies. The second challenge is to phase out a relatively large coal mining sector. In the EU, this second challenge is specific to Poland, since other major coal-dependent European economies import most of the coal they use rather than producing it domestically.

Replacing coal with other energy sources

Our simulations show that an ambitious reduction in CO2 in the Polish economy is feasible, but it requires a decarbonisation of the power sector. One possible pathway to decarbonisation is a gradual replacement of coal with a mix of nuclear energy, intermittent renewable energy sources (such as onshore wind), biogas, and biomass. However, the implementation of this solution may be difficult. Nuclear technology requires a substantial mobilisation of capital in short period of time, and it may be opposed by environmentalists. Onshore wind requires a complementary technology that can supply electricity during the days without wind. This function is often performed by electricity from natural gas, but the availability of large gas resources in Poland is uncertain. There is also a lack of certainty about how much of the biogas and biomass could be available domestically.

The following four measures could mitigate the problems that are expected to arise in implementing a decarbonised energy mix. Policy-makers should:

1. Identify the available resources.
2. Determine the optimal energy mix and the investment needed to implement it, and prepare strategies for dealing with the possibility that one of the technologies will cease to be feasible.
3. Monitor the implementation of investment progress in introducing the new energy mix, and coordinate the process to ensure that the supply of energy meets the demand.
4. Identify and monitor the changes needed in the related sectors for the implementation of new energy mix. These changes will likely include modifications in agriculture to ensure the availability of biogas; in forestry management to ensure that sufficient CO2 is absorbed to offset emissions from the use of biomass; and in electricity-intensive industries that affect the demand for electricity.

Our simulations also suggest that the decisions regarding the energy mix will have important consequences for the labour market. The demand for workers in the coal mining sector will decline more quickly in the scenario that involves replacing coal with natural gas than in the scenario that involves replacing coal with biofuels, even if the two scenarios assume the same reduction in CO2 emissions.

Coal sector phase-out

Coal mining employs a large share of the workforce in the Śląskie region, even though it generates only a small share of Polish GDP and plays a minor role in total employment nationwide. The phasing out of the sector will lead to a considerable reduction in coal mining employment in the coming decades. This reduction can be realised in two ways: (i) by laying off mining sector workers and moving them to other sectors of the economy; or (ii) by allowing for the natural attrition of mining sector workers, while imposing a hiring freeze and directing young people into other sectors of the economy.

Such lay-offs would be associated with substantial economic and political costs. First, current workers in the sector possess technical skills that are specific to that sector, and that will be of little use in other sectors of the economy. This limits their employment prospects. Second, since current jobs in the mining sector are well-paid, miners may have expectations regarding working conditions that cannot be met in other sectors. Because it may involve a loss of earnings for miners, the transition is likely to be opposed by trade unions.

However, our simulations show that lay-offs will not be necessary because most of the employment reduction could be achieved through natural attrition; i.e., through retirement and a hiring freeze. Natural attrition and a hiring freeze would reduce the supply of labour to a level that is very close to the decline in the demand for labour in the sector under our ambitious emissions reduction scenario. This result is obtained even under the assumption that productivity in the mining sector will grow at a fast pace. If the growth in productivity is slower, the need for lay-offs will be even lower.

Employment opportunities

To counteract the negative consequences of mine closures, the public authorities should consider implementing demand-side measures aimed at stimulating employment in the affected regions. Creating new pathways of development is a long process; for instance, it took decades for the Ruhr region to develop alternative pathways of development (Campbell and Coenen, 2017). Śląskie is in the middle stages of this transition process.

Retaining a strong position in the manufacturing sector is of key importance. The educational and skill requirements for manufacturing jobs are similar to those for jobs in mining. More than one-third of workers who move from mining to other sectors end up in manufacturing (based on LFS data). Moreover, the development of manufacturing in Śląskie can address the labour shortages resulting from both demand-side factors (strong growth) and supply-side factors (a demographically driven decline in the number of labour market entrants). According to the "Occupational barometer 2018" study,[28] plant and machine operators and assemblers, metal welders, ironworkers, and manufacturing labourers are among the most sought-after occupations in the region. However, technological progress will lead to automation, which will reduce future demand for labour, and for unskilled labour in particular. Hence, the next dozen or so years create a window of opportunity for making this transition, as the demand for low- and middle-skilled labour is projected to remain strong over this period. Jobs in transport and vehicle repair represent another group of occupations in high demand in Śląskie. Given the skill demands of these jobs, they can provide a viable alternative for many former miners or individuals who were considering a career in mining.

Construction is also a plausible destination for workers leaving the coal mining sector because some skills can be easily transferred between these sectors. Indeed, construction is already a destination sector for 10% of workers who leave mining and start working in another sector. Again, the demand for workers in construction is high, according to the regional occupational barometer.

A particular opportunity is created by current efforts in Poland to improve the energy efficiency of residential buildings and air quality. The acceleration of residential building retrofitting can create up to 100,000 new jobs nationwide, and more than 10,000 jobs in the Śląskie region (Lewandowski et al. 2018). Moreover, this work would

[28] https://barometrzawodow.pl/

help to improve living standards and air quality in local communities. Therefore, the status associated with these jobs may be higher than the status associated with regular construction jobs or with other unskilled jobs, which may be seen as degrading.

The spatial distribution of these opportunities is of key importance. Some sub-regions have vibrant manufacturing and service sectors, while others are lagging behind. Hence, some of the efforts to create new jobs should focus on the areas where mining jobs are likely to disappear, but where there are fewer job opportunities than in other sectors. At the same time, commuting should be treated as a crucial tool for matching workers with jobs, especially given that the Silesian agglomeration is a densely populated area with developed infrastructure.

Retraining and financial support for workers

Although there are several vibrant sectors in Śląskie that employ workers with skill structures similar to those of coal mining workers, the ex-miners who take up jobs in these sectors (as well as in other sectors) would still require some retraining. Equipping ex-miners with new skills should be an important component of public interventions. Before entering a retraining programme, each worker's skill gaps and skill advantages should be identified. Providing such individual skill diagnoses will ensure that workers receive tailor-made retraining that addresses their specific skill gaps and develops their relevant existing skills. If possible, the mastery of these skills should be verified and formally certified. Close cooperation between collieries, public employment services, and new employers is recommended to ease the transition to new employment. Job placements with on-the-job training might be effective in this context. The authorities could also subsidise job placements to encourage employers to hire ex-miners.

Miners who quit collieries and decide to work in other sectors are likely to be offered lower wages than they earned in mining. To incentivise former miners to work in other sectors, in-work benefits can be offered to workers who voluntarily leave mining and accept lower-paid jobs in other sectors. Such in-work benefits would also cushion a decline in the living standards of households of redundant miners. Moreover, even if they are working, ex-miners should be permitted to participate in publicly-funded training programmes, such as those provided by public employment services.

The social policy instruments that provide unconditional cash transfers should be offered only to workers close to retirement age. Two such transfers are currently in use in Poland: miners' leaves (equal to 75% of the previous wage) and redundancy payments.[29] Ex-miners receiving such payments have weak incentives to acquire new skills on their own, and a relatively high risk of prolonged joblessness – which can turn into worker "discouragement" (inactivity due to doubts that finding work is possible) and an early labour force exit. Many of the older workers receiving these transfers may find it hard to acquire new skills and change occupations. In order to keep them socially involved, and to prevent them from becoming discouraged and from losing social status as a result of losing a respected job, these workers should be offered the opportunity to participate in training and/or public works programmes, or be encouraged to volunteer with local NGOs or public services.

[29] These programmes can be treated as unconditional because the condition is that individuals cannot take a job in another colliery.

Educational policy

Since the 1990s, there has been a substantial shift in the educational structure of the population in Poland, including in the Śląskie region. In particular, the share of the population aged 25-64 with tertiary education rose from 8% in 2000 to 27% in 2016, which was the largest such increase in the EU. The educational structure of the population is expected to improve further, as the current tertiary education enrolment rate is 41%.

However, mining is still an important field of vocational education at the secondary level in Śląskie. In 2015, 4550 secondary school students in Sląskie voivodship were taking mining classes.[30] In the region, students in mining classes accounted for 3.5% of all secondary school students in vocational classes and 2.2% of all secondary school students, including those in non-vocational schooling.

The structure of education at the secondary and tertiary levels should be updated with the future labour demand in mind. In particular, the number of students accepted to secondary mining schools should be adjusted to align with the expected reduction in employment mining. Students willing to enrol in secondary vocational schools should be encouraged to take classes that prepare them to work in the growing manufacturing sectors.

Social dialogue

Successful industrial transitions require broad dialogue and the involvement of various stakeholders in the process of mapping out the challenges, identifying appropriate responses, and negotiating consensus. The coal mining sector in Poland has a long and established tradition of engaging in various forms of social dialogue, including industrial dialogue and tri-partite dialogue involving the local authorities and the central government. Thus, a platform on which the future of the sector can be discussed is already available. However, managing the transition away from a reliance on coal will require a cross-cutting agenda that goes well beyond the sector itself, and that has implications for the region's industrial, educational, social, environmental, and development policies. Therefore, it is important that the reforms are negotiated and accepted not only by the social partners, but by other stakeholders, including NGOs and organisations working with local communities.

[30] To minimise the risk of unemployment among young graduates of mining classes, schools and mines tend to cooperate closely, and students are usually guaranteed employment in coal mines after graduation.

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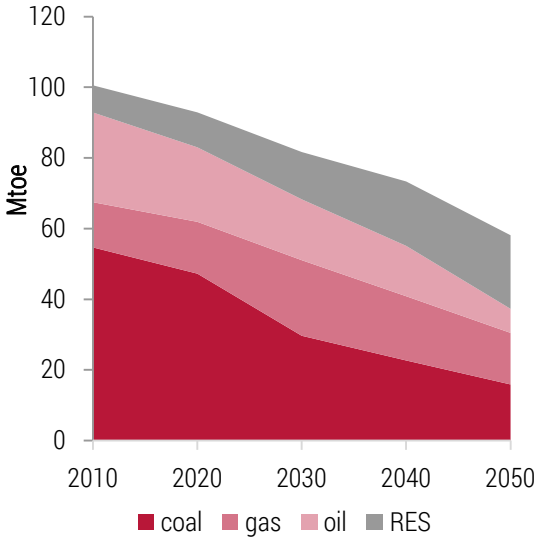
Appendix. Alternative two-degree scenario with the use of gas

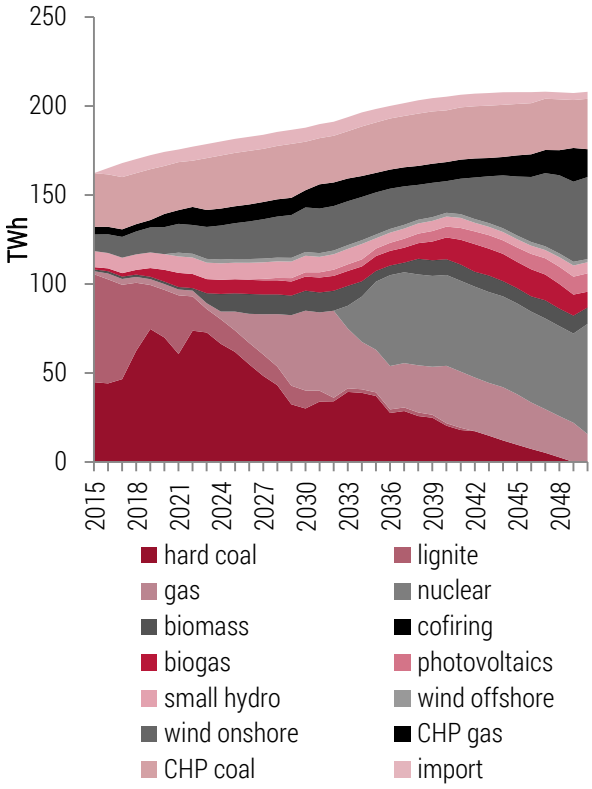
An alternative evolution of the energy mix may be sketched out in a scenario that permits the greater use of natural gas in the power sector. This scenario has been constructed using the model on the optimal energy mix by imposing the same constraints on emissions from the power sector as in the two-degree scenario, but relaxing the constraints on gas imports. The projections for the mix of fuels in the TPES (in the entire economy) is presented in Figure 21, and the projections for the electricity mix in the TPES are presented in Figure 22.

Figure 21. Total primary energy supply by the source of energy in the two-degree scenario with gas



Source: Own calculations.

Figure 22. Evolution of electricity mix under the alternative two-degree scenario with gas



Source: Own calculations.

In this scenario, the cost of the energy system is lower than in the two-degree scenario with a limited use of gas that was presented earlier, but the difference is small. The cumulated costs of investment and operation (including the costs of the fuel) for the 2015-2050 period are only 1% lower in the two-degree scenario with gas.

An important disadvantage of the scenario with gas is that it implies that coal production, and thus employment in mining, will decline more quickly. Given the expected challenges associated with this transition (which are explained in detail in section 3), the social costs may be higher in this scenario. Another disadvantage is that a dependency on imported fuel can undermine the country's energy security. Replacing coal with gas as the transition fuel may be unappealing for Poland because of political tensions with Russia, which would likely supply most of the imported gas. Increasing imports of gas from other countries is also unappealing from an economic perspective, as Russian gas tends to be less expensive than gas from alternative sources, such as Qatar.

The new investment in gas sector projects aims at increasing the capacity of the LNG terminal from five to 7.5 billion cubic meters and the construction of new gas transport routes with southern neighbours. In the long run, however, this will capacity not be sufficient to cover increasing demand, which – especially in the two-degree scenario with gas will occur in the period between 2025 and 2035. It certainly will not be sufficient to replace gas imports from Russia, with which Poland is due to renegotiate its current gas contract in 2022.

Given these challenges, the current government is planning to build a new gas pipeline (Baltic Pipe) to transport gas from its Norwegian fields. The project would include Denmark (as a recipient and a transit country) and Sweden (only as a recipient). The two Scandinavian countries would each receive 3 billion cubic meters, while Poland would be the main recipient, receiving 10 billion cubic meters. Even if the price of the supply through Baltic Pipe turns out to be higher than anticipated, the new pipeline is expected to place an upper limit on Russian gas prices, and thus to reduce the political vulnerability of this commodity for Poland.

It should also be noted that technological progress in the future could make it possible to build a stable energy system that does not involve the use of any natural gas. One such possibility is power generation based on a large share of intermittent renewable energy sources (solar and wind) and the use of hydrogen to store energy. Another possibility is the large-scale deployment of offshore wind farms, which tend to provide a more stable flow of energy than other intermittent renewable energy sources.

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