European Commission

Research Fund for Coal and Steel

Raising awareness of small local communities in the process of coal mining transition

Deliverable 2.1

Instrat Policy Paper with review of

the current state of hard coal and lignite mining

Grant Agreement number: 101216335

Document Control Page Deliverable name:	INSTRAT Policy Paper with review of the current state of hard coal and lignite mining
Deliverable number:	D2.1
Work-Package no and title:	WP2: Identification of the main premises determining the process of coal transformation
Work Package Leader:	INSTRAT
Deliverable:	INSTRAT
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Due date of deliverable:	31/03/2026
Language:	English
Dissemination Level1:	PU
Audience:	Public
Status:	Final

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1. Key events on the EU level and impacting coal phase-out and just transition in coal regions

Coal used to play a significant role in the European economy, serving as the primary fuel for the electricity sector and many energy-consuming industries. However, over the recent years, a confluence of environmental regulation and economic factors contributed to a decline in coal's role, leading to a transformation of coal regions in Europe. Germany, Czechia and Poland, as the EU's current biggest coal producers and consumers, are particularly affected by this transformation.

The regulatory shift began with the 1997 Kyoto Protocol, which established the first legally binding CO_2 emissions reduction targets for industrialised nations. In response, the European Commission came up with the EU Emissions Trading System (ETS) in 2005, and it became the world's first international carbon market. Since its introduction, the volume of emission allowances available on the market has decreased. Therefore, carbon prices have risen, amplifying the impact of the ETS on the operating costs of CO_2-intensive sources.

The economic burden placed on fossil fuels, especially coal, by the ETS system is severe. Throughout 2025 and early 2026 the cost of an ETS allowance hovered around 80 EUR/MWh (Energy Instrat, 2026)[1]. Because of the high carbon content in solid fuels, the emission intensity per each unit of energy produced is significant (ARE, 2024):

- Hard coal: 840 kg CO2/MWh
- Lignite: 1037 kg CO2/MWh

This means that **for every megawatt-hour of electricity generated from these fuels, producers must spend 67 EUR/MWh for hard coal and 83 EUR/MWh for lignite just to cover the cost of emissions**. With wholesale prices oscillating around 100 EUR/MWh in the same period in all the analysed countries, coal-fired power plants are often rendered uncompetitive.

However, the ETS Directive is not the only legislative act affecting the coal sector. The EU has been setting emissions reduction targets for itself since 2008, when the Climate and Energy Package was adopted. Following the 2015 Paris Agreement — which aims to limit global warming to well below 2°C, and preferably to 1.5°C — the European Green Deal (2021) and specifically the European Climate Law, adopted in 2021, established legally binding targets of EU climate neutrality by 2050 and at least a 55% reduction (vs 1990) in greenhouse gas emissions by 2030. In 2023, the Fit for 55 packages operationalised the 2030 climate target into specific propositions. In March 2026 the Council of the European Union adopted the new binding climate target for 2040 - namely emissions reductions by 90% compared to 1990 - putting even more pressure on the carbon intensive industries.

Additionally, many of the hard coal mines must face the EU regulation on the reduction of methane emissions in the energy sector. To limit emissions of this potent greenhouse gas to the atmosphere, it has introduced reporting measures and might force companies to invest in costly abatement technology.

To meet the EU targets, a set of legislative changes aimed at reducing the role of fossil fuels in the energy mix came about. A clear example is the internal market for electricity directive. On the one hand, fossil-based power plants can be uncompetitive on the energy market due to high emission allowance cost. On the other, they are still required in the system as dispatchable sources to provide security of supply. Through capacity mechanisms they can be provided the "missing money" to reach profitability. But the EU's capacity mechanism

[1] yearly averages for 2025 and 2026 (as for 20th of February 2026).

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set out in the directive establishes a strict emissions limit: any electricity-generating unit emitting more than 550 g CO_2/kWh cannot receive capacity payments (European Parliament, 2019). In practice, this favors gas-fired units as it is the only fossil fuel that meets the criteria. The combination of cutting off vital subsidised revenue streams and high variable costs imposed by the ETS effectively pushes coal out of the energy market.

2. Regional Production Amounts: Hard coal, lignite and coking coal (CZ, DE, PL)

2.1. Long-term trends in coal production (1990-2024)

Since 1990, the energy landscape across the three neighbouring countries (Poland, Germany and the Czechia) has already undergone a profound transformation. It was characterised by a sharp decline in fossil fuel extraction. **Collectively, total coal production (hard coal, lignite and coking coal) in these three states has decreased by approximately three-quarters over the last three decades.**

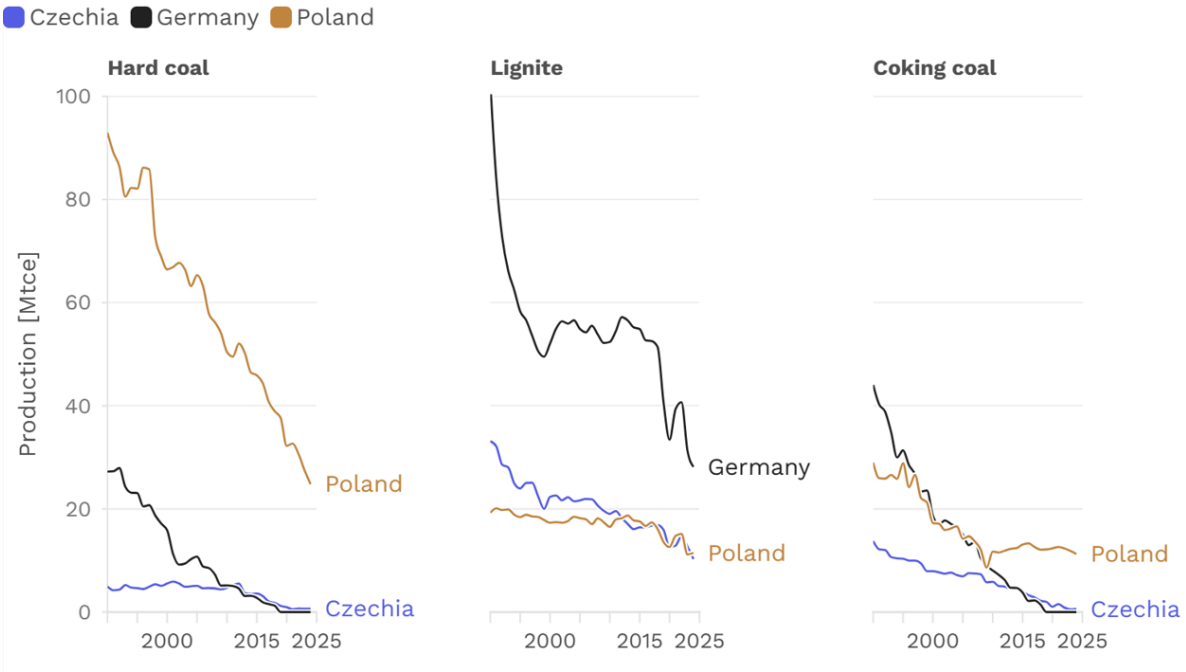

Figure 1 Annual coal production 1990-2024 [Mtce]*

Source: Instrat's own analysis based on Eurostat data
Note: Hard coal does not include coking coal

* 1 tonne of coal equivalent (tce) is the energy content equivalent to one tonne of standard coal ~29,3 GJ

This downfall is particularly evident in the hard coal sector. As of February 2026, Poland is the only producer amongst the analysed countries and the EU as a whole. However, even in Poland, domestic extraction has fallen by over 70% to nearly 25 Mtce over the last 3 decades.

Lignite production follows a similar downward trajectory, although with notable national nuances. **Germany, the European leader in lignite extraction, produced 28 Mtce in 2024 – a drop of over 70% compared to 1990**.

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Poland and Czechia continue to extract lignite too, producing approximately 10 Mtce each in 2024. Yet, both of them have experienced significant reductions since 1990 – 40% and 69% respectively. It is worth noting that the three countries in question are the EU's leading lignite producers.

Lignite's relatively slower decline despite higher associated emissions can probably be explained by the fact it is not a tradeable commodity, unlike hard coal. There, gap in production costs between the regional producer, i.e. Poland and leading global players is wide enough to justify imports.

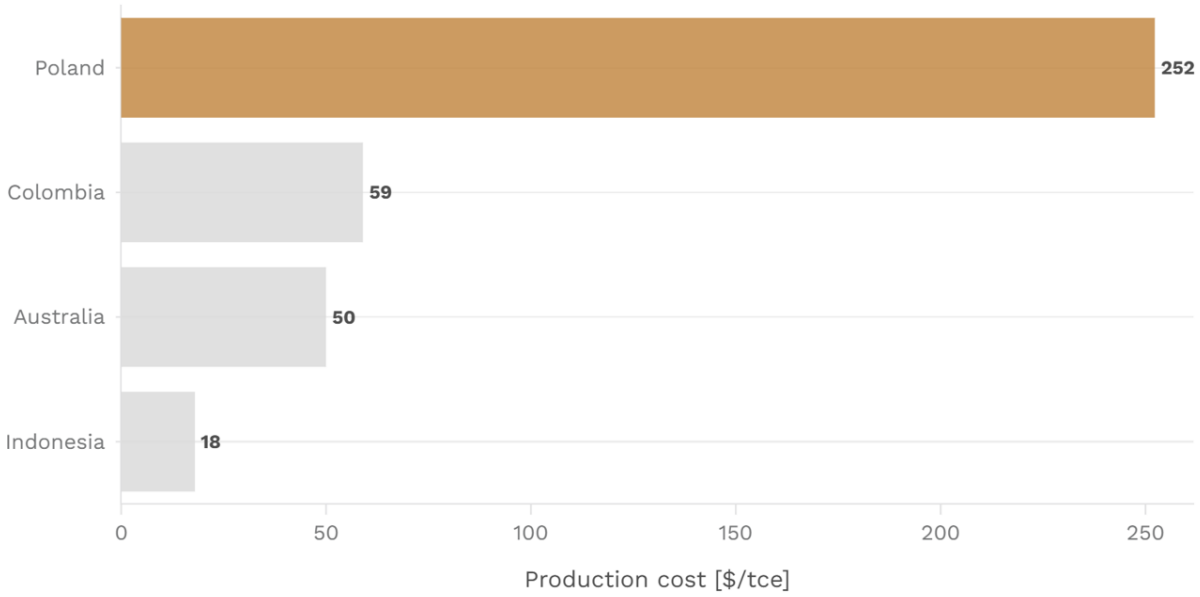

Figure 2 Average cost of hard coal production [$/tce]*

Source: ARP Katowice (Poland) and IEA (Other)

*Cost for Poland expressed in dollars according to the average annual exchange rate in 2025 of the National Bank of Poland

Finally, regarding coking coal, Germany's transition from a major producer (44 Mtce in 1990) to a complete cessation of production by 2019 should be highlighted. While Czechia finished coking coal extraction in early 2026, Poland remains, conversely, an essential supplier, producing over 11 Mtce in 2024 despite a 60% decrease from its 1990 volumes. In this context, it is important to remember about the special role of the coking coal. **Since 2014, hard coking coal has been recognized at the EU level as a critical raw material for the European economy, particularly due to its key role as an input in steel production** (in turn essential for the energy transition, e.g. for wind turbines).

Employment remains one of the key dimensions of coal mining, closely linked to declining production levels. In Poland, hard coal mining employed 71,411 people at the end of 2025 - nearly 3,000 less than a year earlier and almost 5,000 less than two years ago (Energy Instrat, 2026). It is the only country among the three analysed where employment in hard coal mining still persists at a significant scale. By comparison, lignite mining employs around 10 times less, i.e. approximately 7,000 people.

Amendments to the Polish Hard Coal Mining Act, in force since January 2026, will allow workers from 4 state-owned Silesian mining companies (PGG, Węglokoks, PKW and JSW) to benefit from earlier retirement schemes and one-off lump sum payments. Over 8,000 workers are expected to leave the sector in 2026 using those social

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protection mechanisms, according to the Polish Deputy Minister of Energy Konrad Wojnarowski (BusinessInsider, 2026) .

In Czechia, 4,659 people were employed in hard coal mining in 2024 (the last Czech hard coal mine was closed in early 2026). Lignite mining, in turn, employed 4,329 workers. Until 2021, hard coal mining had employed more people than lignite (MPO, 2025).

In Germany, employment is also concentrated exclusively in the lignite sector, which employed 15,268 people as of June 2025 - over 5,000 less than in 2019[2]. Since 2011, lignite mining has employed more workers than hard coal mining, the latter having been phased out at the end of 2018, when approximately 4,900 people were still employed in its final year of operation (Kohlenstatistik, 2025).

2.2. Recent developments around coal production in the EU & countries of the region

In February 2026, the last hard coal mine in Czechia ceased production. The state-owned OKD deemed the production in the ČSM mine to be uneconomic. It was the only active mine in the country since 2021. Given Germany closed its last hard coal mines in 2018, the geography of hard coal mining in the EU has effectively consolidated into a single active market. Poland has shifted from being a dominant producer (holding over 50% share in 1990) to the EU's solitary supplier. The general trend seen across the European countries reflects broader market forces, including rising extraction costs, decreasing demand for coal, and the EU`s accelerating environmental and industrial transformation.

Despite its monopoly status within the bloc, the Polish mining sector is facing major difficulties. The Silesia-based Polska Grupa Górnicza (PGG), which controls 38% of the market, expects a net loss of 5 billion PLN (1.18 billion EUR[3]) for 2025. While the company's leadership expressed pride in this result due to significant operational cost reductions compared to the previous year, every year the financial gap is being bridged by state aid that has not received formal approval from the European Commission yet.

In contrast, **LW Bogdanka, located in the east of the country, far from Silesia, remains a profitable outlier.** It is operating without public subsidies and reported a net profit of 263.8 million PLN (62.2 million EUR) for 2025. Its operations are characterised by very limited amounts of methane, so methane regulations are less of a challenge for it.

[2] Data includes employees in own lignite-fired power plants.

[3] All currency values are converted using an average yearly (2025) rate at 1 EUR = 4,241 PLN from the NBP (National Bank of Poland).

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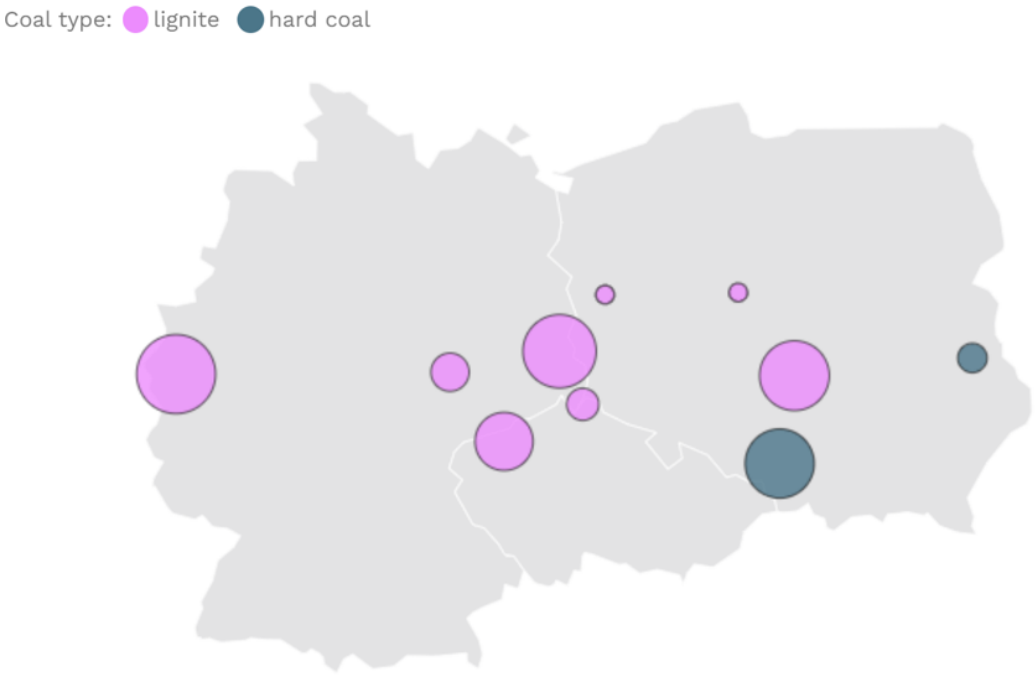

Figure 3 Map of active (as of 2026) lignite and hard coal mining areas in Poland, Germany and Czechia. Circle size corresponds with the net extraction in 2024 [Mt]*

Sources: Database of coal mines in Poland. Instrat; Bundesnetzagentur; Czech Ministry of Environment

*Hard coal extraction in Czechia is not shown on the map as hard coal mines are no longer active.

Some of the circles aggregate mines belonging to the same region (and their production in 2024):

Upper Silesia (Poland) - 16 mines produced a total of 33.6 Mt of hard coal.

Central Germany - 2 mines produced a total of 10.2 Mt of lignite.

Rhineland (Germany) - 4 mines produced a total of 43.9 Mt of lignite.

Lusetia (Germany) - 3 mines produced a total of 37.8 Mt of lignite.

Czechia - 4 mines produced a total of 23.7 Mt of lignite.

2.3. Overview of mine closure plans in the analysed countries

Outside of Poland, extraction is now limited almost exclusively to lignite open-cast mines in Germany and the Czechia, as hard coal has been completely phased out in both nations.

In Czechia, lignite will be mined until 2033 according to the Ministry of Environment. The Bílina mine in North Bohemia will be the last one to close, while Vršany, Nástup - Tušimice (Libouš) and Jiří will be closing earlier, depending on the closing dates of co-located power and heat plants.

In Germany, mining operations are centered around eight lignite-fired power plants. The decommissioning of these mining and power plant complexes is phased: the Jänschwalde and Weisweiler are set to close in the 2020s, majority of the remaining fleet is to be closed between 2030 and 2035. The Boxberg and Schwarze Pumpe sites are scheduled to remain operational until the **final 2038 coal phase-out date** (Bundesnetzagentur, 2026).

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The terminal date for German lignite production is set for 2038, though recent government negotiations have successfully advanced the phase-out in the Rhenish mining district to 2030 (DEBRIV, 2026).

In Poland, there is no agreed uponlignite phase-out timeline. The Bełchatów lignite mine, Europe's largest carbon emitter, will have finished its operation by 2038, with some of the surrounding open pit mines closing earlier. The situation of the Turów mine is more complex. Although it holds a mining license until 2044, its extension was challenged by Czechia before the CJEU in 2021 over environmental impacts, leading to daily penalties of EUR 500,000 for non-compliance. The legal dispute was ultimately resolved through a bilateral Polish Czech settlement in 2022. (CJEU, 2026; Świsłowski, 2026).

For the hard coal sector, the roadmap is set out in the Social Contract Regarding the Transformation of the Hard Coal Mining Sector in Poland (2021), which outlines a gradual exit strategy designed to prevent mass unemployment and social tensions. Under this agreement:

- the majority of active mines are scheduled to conclude their operations during the 2030s and 2040s.
- four hard coal mines are designated to remain operational until the final deadline of 2049: Bogdanka, ROW (Ruch Chwałowice and Ruch Jankowice), Sobieski and Janina[4].

3. Hard coal and lignite consumption

3.1. Role of coal in electricity mix – current share

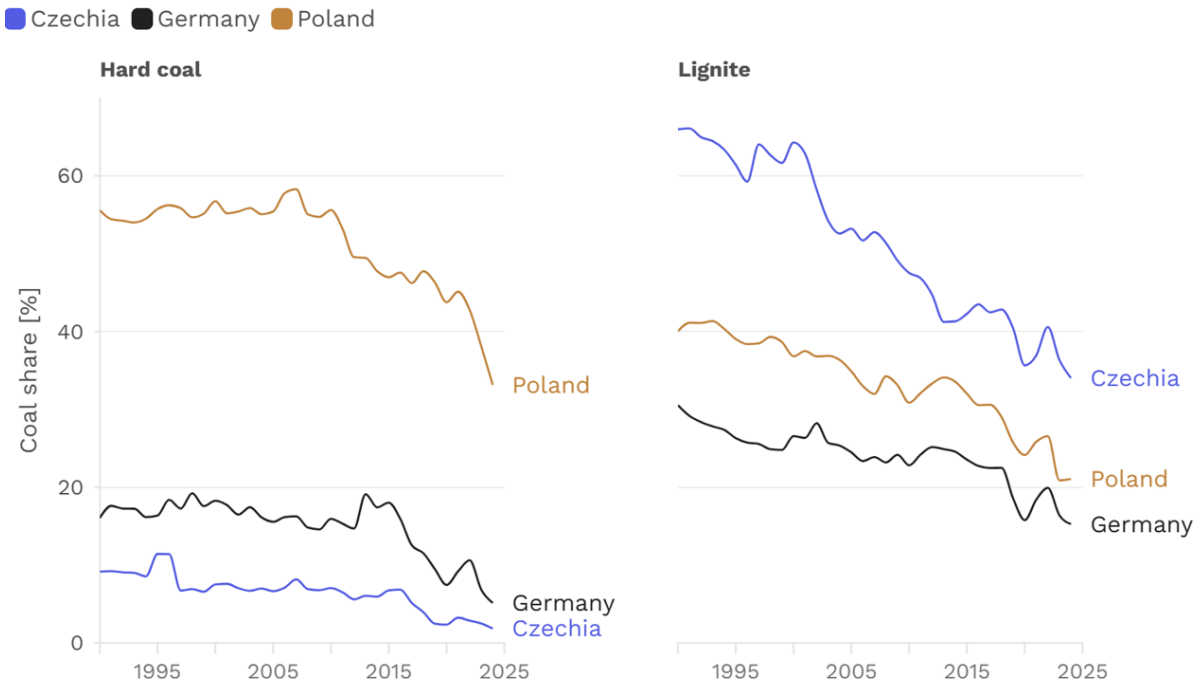

Figure 4 Annual coal share in total electricity production 1990-2024 [%]

Source: Instrat's own analysis based on Eurostat

[4] Further information on particular mines in Poland together with the expected timeline of their functioning are to be found in the coal mining database available on the energy.instrat platform: https://energy.instrat.pl/en/mining/database/.

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While the dominance of solid fossil fuels has been diminishing across the region, coal remains a distinct, albeit shrinking, component of the electricity mix. The trend is most pronounced in Poland, where the share of hard coal has dropped rapidly below 40% in recent years. Despite this sharp decline, Poland remains heavily reliant on solid fossil fuels, which collectively accounted for over 50% of total electricity production in 2024[5].

In Germany and Czechia, the decline of hard coal has been less significant recently, largely because its role had already been minimised. It accounts for just 5% of the German mix and less than 2% in Czechia (in 2024).

Lignite, however, shows a more persistent presence despite a long-term downward trend since 1990 in all three nations. It continues to be a significant part of the Czech electricity mix with a substantial 34% share. In Germany it accounts for 15% of generation. In Poland lignite-fired units still generate around 20% of total electricity on a yearly basis[6].

3.2. Plans regarding future share based on NECP and other strategies.

National Energy and Climate Plans (NECPs) outline countries' pathways for the final phase-out of coal in the region. **Germany has legally mandated a complete phase-out by 2038 at the latest** (Coal Phase-out Act from 2020), with capacity targets set to reduce to 8 GW for hard coal and 9 GW for lignite by 2030 (BMWK, 2024). While a 2030 lignite phase-out was agreed for North Rhine-Westphalia, new ruling coalition (2025) notes that a complete coal exit in Western Germany is "increasingly unlikely" (Amelang, 2026) due to delays in building alternative gas-fired units. Consequently, while the strict 2038 deadline remains, the shutdown timetable depends on alternative infrastructure.

According to its National Energy and Climate Plan, **Czechia aims to phase-out coal for electricity and heat generation by 2033**. Strategic objectives target reducing the share of coal and its derivatives in primary energy consumption to 10% by 2030, and further to 3% by 2040 and 2050. In the electricity sector specifically, coal's share is projected to drop to 9% by 2030 and go down to 0% by 2040. It is worth noting that the complete phase-out by 2033 is possible only according to the ambitious scenario. The WEM scenario, in turn, forecasts less sharp decline in coal use for heat production - from 34.4 PJ in 2025 to 5.5 and 5.1 in 2035 and 2040, accordingly.

Poland's latest draft version of the NECP published in December 2025 (yet to be approved by the Polish Government) **maintains 2049 as the final deadline for hard coal extraction. The role of lignite in the electricity mix is expected to be very limited by 2035**, though closure decisions will factor in system balancing and agreements between the mining companies and the government. The plan adopts a flexible approach - coal units may be retained as a "system reserve" depending on the development of nuclear, gas and renewable sources. Given Poland's dependence on coal it is worth taking a deeper look at how the pace of decarbonisation varies between scenarios:

- WAM Scenario (ambitious): Coal's share in electricity falls to 23% (2030), 6% (2035), and 0% (2040). In district heating, the share drops to 22% in 2035 and 0% in 2040. When it comes to individual heating, it falls to 5% and 2% in 2035 and 2040, respectively.
- WEM Scenario (base): Coal remains more important, with electricity shares of 29% (2030), 18% (2035), and 5% (2040). District heating relies heavily on coal (>40% in 2035, >20% in 2040), and individual heating maintains a 10-15% coal share in the years 2035-2040.

[5] And for 2025 (as preliminary data suggests).
[6] 21% in 2024 and 19% in 2025 (ARE, 2026).

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It is worth noting that, as electricity generation from coal-fired units becomes increasingly costly, the capacity market is expected to become one of their main sources of revenue in the coming years. As emissions from both hard coal and lignite vastly exceed the capacity mechanism threshold (550 gCO2/kWh), coal-fired power plants were originally excluded from participating in the capacity market from July 2025. However, the Regulation 2024/1747 provided the legal basis for the 2028 derogation regarding capacity mechanisms for the Member States (European Parliament, 2024). Then the formal 2025 approval granted Poland the specific right to use this derogation for its coal fleet (European Commission, 2025).

4. Decarbonisation impact on local economies and labor markets: case study of selected Polish coal counties

The ongoing decline in coal and lignite extraction profoundly impacts regional and local economies traditionally dependent on the coal industry for income, jobs, and tax revenue. In this chapter, we aim to assess the adaptive capacity of these regions, and, more specifically, that of the coal-dependent counties - by analysing selected socio-economic and demographic factors that are likely to shape their transition.

Our approach is informed by resilience frameworks, though we note a key distinction: while resilience is usually studied post-shock, many Polish coal localities are still actively dependent on coal or – despite being located in coal basins – exhibit different economic characteristics. Consequently, we examine how their current socio-economic baselines might shape their future resilience to the ongoing extraction phase-out detailed in Chapters 1 - 3.

4.1. Resilience framework: how can we measure a county's ability to endure a crisis?

Resilience is defined as the ability of individuals, systems, or collectives to adapt to changing conditions and to maintain or regain equilibrium in the aftermath of a crisis (Abłażewicz, 2025; Norris et al., 2008, p. 130).

While the concept of resilience most frequently refers to sudden economic shocks or disasters, its significance is equally vital in the context of "slow burn" processes that gradually undermine regional resilience (Cainelli, 2019). A prime example of such a long-term challenge is the deindustrialization, currently observed in many European (coal) regions, including those in Poland, occurring as a result of the energy transition and the shift away from fossil fuels.

In the face of slow-burn structural changes, it is worthwhile to adopt a perspective in which regional systems affected by deindustrialization exist in a permanent state of transformation, renewal, and adaptation (Hassink & Gong, 2020; Hassink, 2009). This process is defined as the economy's capacity to withstand and recover from shocks by modifying economic structures as well as social and institutional arrangements. The objective of these actions is to maintain the existing development trajectory, or more importantly, to transition toward a new, sustainable development path characterized by a more effective/optimal utilization of local resources (Martin & Sunley, 2015; Giannakis & Bruggeman, 2017, p. 2).

In practical terms, this requires the development of innovative business models and economic diversification, understood as avoiding the "lock-in" trap of excessive specialization in a single sector (Cainelli et al., 2018; Giannakis & Bruggeman, 2017). However, it should be emphasized that the process of seeking a new equilibrium is strongly historical in nature (path-dependency). This means that current adaptive capacities are the consequence of cumulative decisions made over a long-term horizon (Hassink & Gong, 2020).

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The resilience framework has already been used to assess the situation in Polish coal regions. For example, the Polish Economic Institute (PIE) (Juszczak & Szpor, 2020) constructed a Mining Region's Vulnerability Index and performed a cluster analysis to group them accordingly. The study was later repeated in 2024 on a smaller sample, although without clustering (Żelisko & Ogórek, 2024). Both studies used counties as units of analysis - the same approach we take in our analysis. A recent research paper by Jonek-Kowalska used cluster analysis to assess the need for just transition funding in 12 coal-dependent Silesian cities (Jonek-Kowalska, 2024).

4.2. Selection of counties for analysis

The analysis is conducted at the county level. This is a level of granularity that is a compromise between NUTS3 statistical division (not enough nuance) and communes (sample too large). Our study encompasses 66 coal counties from 11 voivodeships.

- We chose the counties included in Just Transition Territorial Plans (JTTPs):
    - those that had been approved by the European Commission and are connected with Just Transition Fund (JTF)
    - those that were drafted but were not approved by the European Commission because of weak extraction reduction targets.
- Additionally, we added counties where coal power plants operate (5 in total), as well as Świebodziński county, where a small lignite mine still operates (this county was not a candidate for JTF).

As we showed in chapter 3, the Polish NECP envisages a significant reduction in electricity generation from coal. This means that counties where coal power plants are currently operating may face a similar need to diversify as those where mines are important job providers. Choosing counties with coal power plants is our contribution to previous studies assessing the adaptive capacity/vulnerability of Polish coal localities.

4.3. Diagnostic pillars:

Our indicator selection process began with a review of the literature on measures of regional resilience. Key influences included Jonek-Kowalska's socioeconomic cluster analysis of the Upper Silesian Coal Basin cities at various stages of mine closure, from complete liquidation, partial closures to fully operational facilities (Jonek-Kowalska, 2024). We also drew significantly from the two PIE's reports (2020; 2024) examining coal counties' vulnerability to decarbonization. While many existing studies on resilience focus on post-shock regional performance (e.g. Giannakis & Bruggeman, 2017), we aim at a more proactive assessment.

Therefore, our analysis includes a suite of socioeconomic indicators reflecting economic diversification, labor market dynamics, and the broader regional context through demographic measures. To capture the current state of regional readiness towards transition, we primarily use the most recent available data, typically from 2024. In some cases, after analysing the historical data, we decided to calculate two- or three-year averages, to account for annual volatility and ensure a more stable representation of regional dynamics. Where possible, we relate our data to national averages to benchmark trends beyond the regional level and to improve comparability between indicators.

4.3.1. Economic diversification: entrepreneurship dynamics (firm births/deaths), HHI concentration, mining & energy employment share

As previously noted, economic diversification is a key element in building regional resilience. To capture its level in coal counties, we employ five key indicators.

Entrepreneurship dynamics/replacement index (2022-24 average): It calculates the ratio of new business

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registrations to closures (the number of newly registered firms per 100 liquidations). It allows us to assess the structural integrity and stability of the local business environment.

Herfindahl-Hirschman Index (HHI): This popular index measures market concentration of an industry (Eurostat Glossary) or - as in our case - at territorial level. Following Obrębalski & Walesiak (2015) we chose to use the proportion of employees working in each sector as the input data for calculating the HHI index. We decided to calculate the index for both:

1. employees by registered office (2022-24 average)
2. place of residence (2024 average)

The rationale for this distinction is that the former tells us about the concentration of economic activity and workplaces in a given county, while the latter captures possible dependence of local residents on specific sectors of employment, regardless of where the workplaces are actually located.[1] A lower HHI indicates lower market concentration, which reflects a higher degree of economic diversification.

Employment share in the mining and electricity generation sectors (2024 average): This indicator helps us to identify the counties in which a high proportion of workers rely on the coal sector[7].

Share of total employment in large enterprises, with 1,000 or more employees (2024 average): This variable was used initially but we removed it at later stages of the analysis due to its strong correlation with the share of workers in the coal and energy industry (see the correlation matrix in the Annex).

4.3.2. Labor market: employment rate, wage levels, long-term unemployment, female employment rate

Current conditions of the labor market help us to assess the potential to absorb future employment reductions in mining and energy sectors as well as potentially reduced incomes (PIE 2020, Jonek Kowalska, 2023). To measure the condition of labor markets in coal counties, we take the following indicators.

Employment rate among the working-age population (2024 average relative to national average): This simple indicator gives an overview of the general condition and strength of the local labor market. Eventually, we removed it from the cluster analysis due to its strong correlation with long-term unemployment.

Female employment rate (2024 average relative to national average): in the past, mining households often relied on the relatively high, single-stream wages of male miners (Baran et al., 2018). Shutting down coal facilities may have a particularly strong impact on these households. Additionally, upon the closure of extractive industries, women are left to compete in a local labor market where service-sector opportunities are often more limited and lower paid than the industrial positions previously held by men (Jonek-Kowalska, 2023; 2026). We presume that a higher share of women on the labor market may strengthen the resilience of a given locality, even if female wages remain lower (GUS 2025).

Long-term unemployment (2024 average relative to national average): This is the share of people who remain unemployed for more than one year in the total economically active population. It reflects structural unemployment on local labor markets more accurately than the overall unemployment rate.

Average monthly gross wages (2024 average relative to national average): This helps us assess the quality of jobs and wealth level in coal counties as well as - in extrapolation - their contribution to local economies via income taxes.

[7] There is also a technical reason for choosing both measures. Data on employment by registered office was not complete, with several gaps, particularly in the mining sector. Therefore, we decided to calculate averages based on data from December 2022, December 2023, and December 2024.

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4.3.3. Demography: migration rates, old people dependency ratios, higher education attainment

Beyond economic diversification and labor market characteristics, we aim to capture the broader regional context through demographic indicators.

Net migration per 10,000 inhabitants (2023-24 average): This indicator allows us to capture the perceived local prospects available, particularly to younger generations, who are statistically the most mobile demographic (Masso et al., 2018). However, as youth out-migration is a pervasive trend across many rural areas and medium-size cities in Poland - not just coal regions - we supplement this data with other demographic variables.

Old-age dependency ratio (2024 average relative to national average): Depopulation trends are currently observed also at the national level therefore comparison with the national benchmark is crucial. Unlike net migration, which focuses on population flows, the dependency ratio reflects the resulting demographic structure. This provides a clearer picture of the proportion of the youth population remaining within the total population, which is particularly relevant in the context of the long-term sustainability of the local labor market (ILO,2022). Given high correlation between this indicator and the firm replacement indicator, we decided to remove the former from the cluster analysis.

Share of employed persons with tertiary education (2021, relative to the national average): As highlighted in the literature (Stępka, 2021; Berkes & Ross, 2013), building local resilience also depends on social capital. In the context of coal regions, educational level is a factor related to adaptation capacities during structural change, as higher levels of education increase the likelihood of transitioning into alternative occupations in the local economy (Jonek-Kowalska, 2026).

4.4. Method

To grasp the diverse realities and uncover the characteristic profiles of the analyzed counties, we employed a statistical method known as cluster analysis. Rather than examining each region in isolation or relying on broad generalizations, this approach enables us to group individual counties into relatively cohesive clusters. These groups are formed based on shared socio-economic features, revealing which areas may face similar transitional challenges and share a common current situation.

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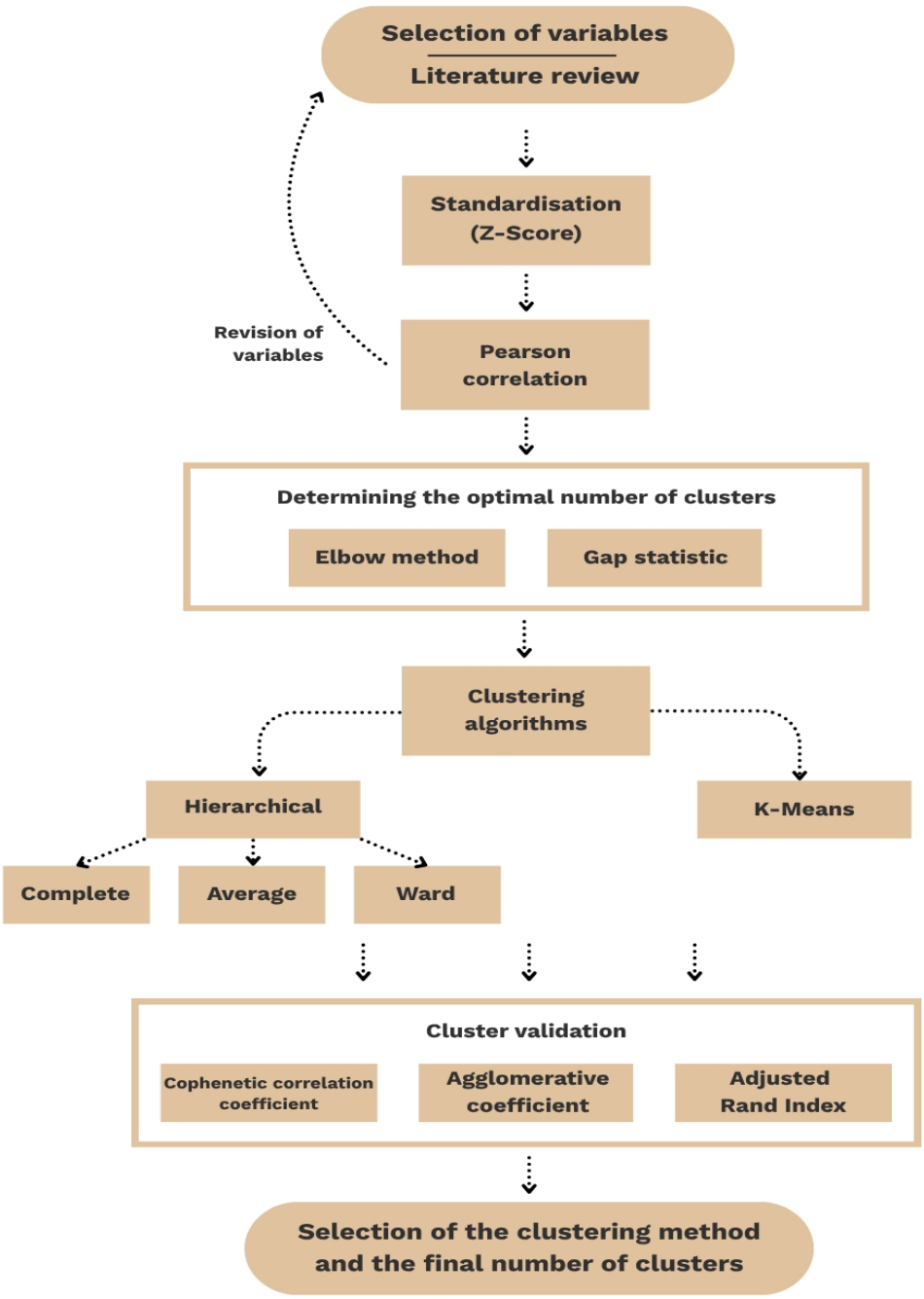

Figure 5 Clustering methodology. Own work.

As a first step in the multi-stage clustering methodology (see Figure 5), all indicators have been standardized (Z-score) to ensure an unbiased comparison across different social and economic dimensions. We also analyzed a Pearson correlation matrix to ensure that each indicator provides unique value and to prevent multicollinearity (see Annex). Consequently, we excluded four indicators that were highly correlated with other variables in the dataset: the old-age dependency ratio, HHI by residence, employment in large enterprises, and the employment rate (more details on the rationale in chapters 4.3.1-4.3.3).

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The primary segmentation was performed using Ward's hierarchical clustering method based on Euclidean distance (Ward, 1963); in the process, we also used complete and average linkage algorithms for comparative purposes (see Charts 1-3 in the Annex). To check which clustering method best approximates the original relationships between data points, we calculated the cophenetic correlation coefficient (CCC) (Everitt, 2011) and the agglomerative coefficient (AC). This also allowed us to validate the choice to exclude certain indicators by comparing the impact of different sets of variables on the quality of clustering.

To guarantee the utmost reliability of our insights and eliminate the risk of algorithmic bias, this initial structure was cross-validated using the non-hierarchical K-means algorithm (MacQueen, 1967). The consistency between both clustering approaches (hierarchical and K-means) was measured using the Adjusted Rand Index (ARI), which gives the proportion of correct groupings (Rand, 1971; Ferreira & Hitchcock, 2009). While Ward's method and k-means generated very similar clustering results, particularly in the five-cluster solution, we ultimately opted for Ward's hierarchical clustering due to its greater reproducibility. We determined the optimal number of clusters through statistical testing, specifically applying the Elbow method and the Gap Statistic, which both supported a partition into five clusters (see Charts 4-7 in the Annex). Ultimately, we proceeded with Ward's hierarchical clustering with five distinct clusters. This choice was supported by a cophenetic correlation coefficient of 0.51, an agglomerative coefficient of 0.86 and an Adjusted Rand Index between Ward's and K-means clustering of 0.54. This approach allowed us to unveil nuances between the 66 counties while identifying several analytically rich commonalities.

4.5. Regional typology: results of cluster analysis

Cluster analysis is a useful method for exploring similarity and dissimilarity patterns amongst members of a given group - coal counties in our case. However, the results need to be treated carefully as many combinations are possible and different algorithms suggest slightly different groupings. Our final choice is based on a combination of statistical test results, our experience and knowledge of the regions, since various combinations of input variables yielded broadly similar results.

	firm_repl	emp_mining_ener	HHI_firm	lt_unemp_toPL	wages_toPL	emp_female_toPL	edu_tertiary	migr_balance
Beyond coal potential	0.14	0.85	-0.36	-0.48	0.16	-0.23	0.25	1.05
Peripheral and rural belts	0.81	-0.58	0.60	0.87	-0.75	-1.32	-0.83	-0.39
Post coal counties sustained by women	-0.56	-0.25	-0.43	0.11	-0.19	0.57	-0.15	-0.29
Mining core	1.32	2.93	2.39	-0.46	3.70	-0.54	-0.57	-0.67
Big cities with mining ties	0.12	-0.54	0.77	-0.91	0.78	0.74	1.78	-0.13

Figure 6 Average indicator values for each cluster, standardized data. 0 = average value amongst all counties, 1 = 1 standard deviation

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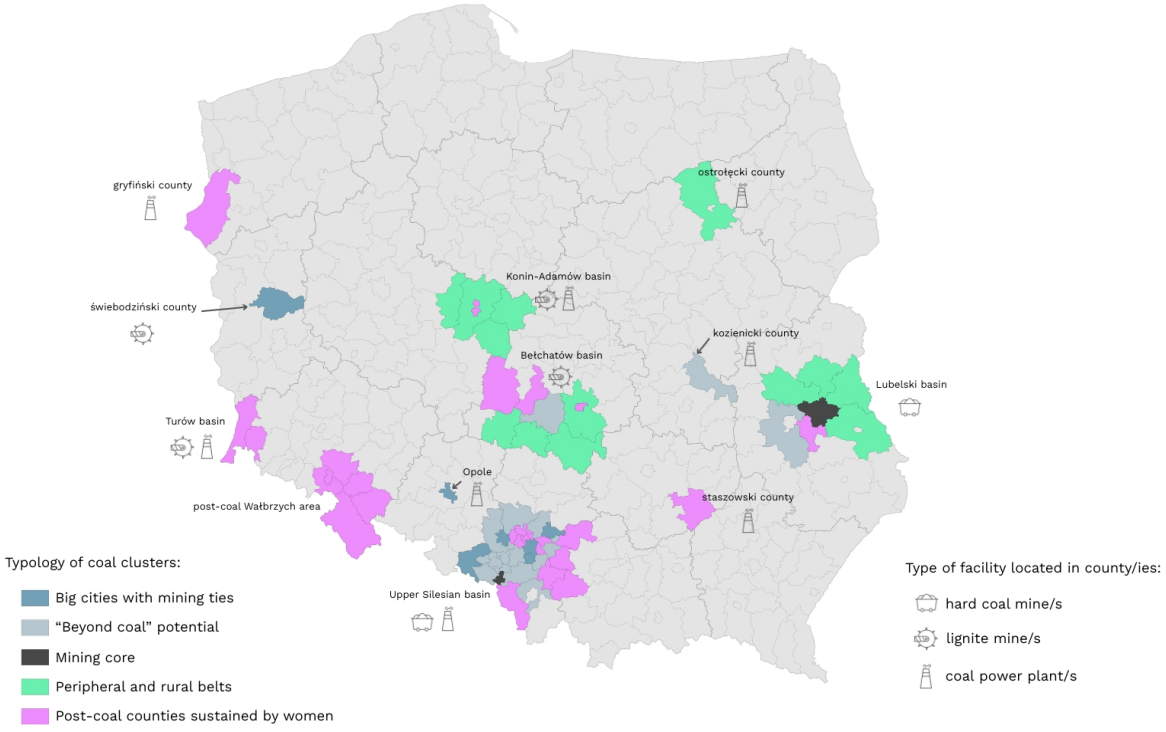

Figure 7 Map of cluster division. Own work based on the cluster analysis.

CLUSTER 1: Stable mining and energy counties with a "beyond coal" potential (15 counties, mix of urban, urban-rural and rural)

Counties: bełchatowski, będziński, bielski, bieruńsko-lędziński, gliwicki, kozienicki, lubelski, m. Jaworzno, m. Rybnik, m. Żory, mikołowski, pszczyński, rybnicki, tarnogórski, wodzisławski

Economic diversification	**Labor market**	**Demographics**
• Second highest economic diversification • Below average firm replacement	• Second highest share of employees in mining and energy sector • Above average long term unemployment (-29% compared to PL average) • Below average wages (-8% compared to PL average) • Slightly below average women share in employment (same as PL average)	• Above average tertiary education levels (-40% compared to PL average) • Highest positive migration balance

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This cluster is mostly characterised by positive demographic trends (migration, education) and a job structure still significantly relying on the coal sector, average diversification and firm replacement, mostly average labor market indicators apart from long-term unemployment (second lowest average value).

This cluster includes core mining and energy counties as indicated by the above-average employment in mining and electricity production sectors. High employment in these sectors is particularly prominent in hard coal Silesian counties and cities, but also in bełchatowski (a lignite-producing area) and kozienicki (home to a major coal power plant).

This is also a unique cluster with a positive migration balance on average. This in-migration trend is the strongest in lubelski county (overall leader, probably because of Lublin's strong suburbanisation trends), with mikołowski and tarnogórski as frontrunners as well. Given that coal sectors are not increasing employment (on the contrary), this lack of depopulation may be a predictor of potential resilience to coal phase out trends.

The roughly average values for labor market and economic indicators suggest a stable situation currently, which may, however, be negatively affected by the (future) employment reduction in the coal sector. The labor protection mechanism offered by the government for coal workers may help sustain current standards of living and the diversified local economies, while a greater share of tertiary educated workers may help absorb ex-coal workers into different sectors (greater than in most coal counties, but still below Polish average).

Outliers in this cluster

Kozienicki: while having a high employment share in the coal energy sector and high average wage (ranking 5th best among 66 counties), this county has a very high long term unemployment rate (ranking 4th worst among 66 counties). This means that the benefits of the coal industry are not equally shared and that a sudden reduction in employment may have very negative consequences for this locality. Currently it hosts the largest hard coal power plant in Poland.

Lubelski: this is not a coal county but given its proximity to Bogdanka hard coal mine it has been included in the draft Just Transition Territorial Plan. Its socio-economic indicators differ from other counties neighbouring the mine, therefore it had to belong to a different group. It has the highest positive migration balance among all 66 counties and ranks 2nd in terms of firm renewal.

Bełchatowski: neighbouring the biggest coal power plant in the EU, this county has the highest earnings in the entire cluster.

Conclusions for this cluster: Relatively high economic diversification, wages close to the national average, and a mostly positive migration balance suggest significant resilience potential in the majority of counties forming this cluster. While these counties are yet to experience a coal phase-out, the socio-economic indicators used in our analysis suggest their adaptive capacity is above average; they may successfully absorb the challenges resulting from the reduction of employment in the mining sector, as their labor markets offer viable alternatives.

Recommendations for this cluster: To maintain and grow their economic potential, these counties should further develop sectors that are independent of the coal industry. The strong economic condition of this cluster could justify accelerating the coal phase-out. Their labor markets—as well as those of neighbouring cities from the "Big Cities with Mining Ties" cluster—should be able to accommodate workers leaving the industry. Given the still-significant employment in the coal mining and energy sectors, these counties should

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prioritize the implementation of reskilling and upskilling programs. This is especially important for workers in mining value chains who will not benefit from the social protection mechanisms provided by existing legislation. Kozienicki county will need a special approach to address its high unemployment.

CLUSTER 2 - Peripheral and rural belts (13 counties, mostly rural)

Counties in this cluster: chełmski, kolski, koniński, lubartowski, ostrołęcki, pajęczański, parczewski, piotrkowski, radomszczański, słupecki, turecki, wieluński, włodawski

Economic diversification	**Labor Market**	**Demographics**
● Average economic diversification ● Above average firm replacement	● Lowest share of employees in mining and energy sector ● Highest long term unemployment (+75% compared to PL average) ● Lowest wages (-19% compared to PL average) ● Lowest share of employment of women (-6% compared to PL average)	● Lowest tertiary education levels (-53% compared to PL average) ● Second lowest (negative) migration balance

This cluster of counties is not or no longer benefitting from the coal industry and is characterised by low values of labor market indicators: the highest long-term unemployment, the lowest wages, the lowest education and the lowest share of women in employment.

It is formed by mostly rural counties located around/near large mining centers such as Bogdanka hard coal mine, as well as lignite basins near Bełchatów and in Eastern Wielkopolska (generally less developed parts of Poland). Three counties in Lubelskie voivodeship (chełmski, lubartowski and włodawski) have particularly high levels of long-term unemployment suggesting structural difficulties and little benefit from the adjacent mining center.

While these counties have the smallest share of mining and energy workers (only pajęczański and włodawski have near average employment in mining), their economies have slightly below average diversification, with some highly agricultural counties (chełmski, ostrołęcki and parczewski[8]) belonging to the least diversified in the whole 66 counties group. On a potentially positive side, there is a relatively high firm replacement rate, but it may also be a sign of instability and business rotation. New businesses are emerging in the service sector, and, to some extent, in industry. The outmigration trend is not particularly strong.

Just Transition Fund

2 out of 3 geographic areas covered by the peripheral/rural cluster are benefiting from the Just Transition Fund (JTF): Konin and Bełchatów lignite basins. The effects of projects implemented with JTF will not be immediately visible, but the weak socio-economic condition of these areas supports the argument to renew the just transition funding in the new multiannual financial framework. Coal counties in Eastern Poland should definitely benefit from this funding as well to prevent a larger socio-economic decline if Bogdanka mine also reduces its extraction.

[8]In 2024, the average share of the working population employed in agriculture was equal to 50% in chełmski county, 42% in ostrołęcki, and 40% in parczewski (based on the employment data by registered office).

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Case of Eastern Wielkopolska

All counties from Eastern Wielkopolska lignite area - except the city of Konin - fall into the rural/peripheral cluster. According to the Institute of Urban and Regional Development (IRMiR), Konin acts as a sub-regional balancing center; while its full economic potential remains to be unlocked, it maintains a crucial nodal position capable of driving polycentric development (Sobala-Gwosdz, 2023).

Counties in Eastern Wielkopolska are already benefitting from **Job After Coal** - the largest job outplacement program dedicated to, amongst others, former mining workers and their families. While the firm replacement value remains similar across all counties in the peripheral cluster, koniński county has the highest number of new firms in absolute values and is in the top 10 across the whole 66 counties (1160 new firms registered in 2024, GUS 2026). It remains to be seen how many of them remain after 2 years, which is a minimum survival period demanded by the Job After Coal program.

Conclusions for this cluster: Given its weak socio-economic standing relative to other clusters, these counties should greatly benefit from just transition funding. They seem already "left behind" while the coal industry continues nearby. Although Eastern Wielkopolska has been transitioning rapidly since late 2017, Bełchatów and Bogdanka have yet to scale down extraction. Despite low direct employment in the mining and energy sectors, factors such as low wages, a limited share of tertiary-educated labor, and higher unemployment make this cluster vulnerable to external shocks.

Recommendations for this cluster: Support should target labor market challenges while simultaneously fostering new job opportunities. Just transition funds (both current and future under the new MFF) should prioritize reskilling and upskilling to improve labor market outcomes and address educational gaps. However, these efforts may trigger the outmigration of skilled residents unless accompanied by investments that stimulate job creation. Counties with exceptionally high long-term unemployment require tailored interventions, and programs increasing the economic activity of women should be prioritized. Finally, while entrepreneurship levels are healthy, local authorities should focus on guaranteeing the long-term survival rates of new firms.

CLUSTER 3: Average, mostly post-coal counties sustained by women (29 counties, including 12 cities)

Counties: chrzanowski, cieszyński, dzierżoniowski, gryfiński, kłodzki, lubański, łaski, Bytom, Chorzów, Konin, Mysłowice, Piekary Śląskie, Piotrków Trybunalski, Ruda Śląska, Siemianowice Śląskie, Sosnowiec, Świętochłowice, Wałbrzych, Zabrze, olkuski, oświęcimski, sieradzki, staszowski, świdnicki (dolnośląskie), świdnicki (lubelskie), wadowicki, wałbrzyski, ząbkowicki, zgorzelecki.

Economic diversification	Labor Market	Demographics
● Highest economic diversification ● Lowest firm replacement	● Average employment in mining and energy sector (4%) ● Average long term unemployment rate (+17% compared to PL average) ● Average wages (-12% than PL average) ● 2nd highest share of women	● Average tertiary education levels (but -45% compared to PL average) ● Average migration balance

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	in employment (same as in PL average)	

This is the largest cluster in our analysis and what is unique about it is that it presents mostly average values across a range of indicators. It comprises both rural and rural-urban counties in the vicinity of former or existing mines and energy plants. We find here medium-sized cities from Lower and Upper Silesia, Piotrków Trybunalski and Konin (subregional centers in two lignite basins).

This cluster exhibits the highest geographical variation: Silesian (post)mining counties and towns, those with operating coal power plants (gryfiński, staszowski), the lignite complex in Turów, as well as post-coal counties from Lower Silesia that experienced a rapid coal phase out in the 1990s, leading to unprecedented unemployment and social precarity.

In terms of economic diversification and activity it has the lowest firm replacement rate, suggesting a low level of entrepreneurship and potential economic stagnation. Wałbrzych, gryfiński, Piotrków Trybunalski and ząbkowicki are presenting the lowest values across all 66 counties. On the other hand, its low average HHI value suggests that the economic structure of these counties is more diversified than in other clusters and does not highly depend on single, large employers. While the employment in the mining sector remains average in this cluster, there are a few exceptions where the coal industry is still a significant job provider: zgorzelecki (Turów lignite complex), Mysłowice, chrzanowski, oświęcimski and Ruda Śląska (hard coal mining and energy areas in the south of Poland).

Among all 66 counties, the cluster presents average values in terms of wages and long-term unemployment, however it has a higher share of women in the working population. When we compare these results with Poland's average, it turns out that the average wage in this cluster is 12% lower than the national average. The long-term unemployment is average across all coal counties within the cluster and it is still higher than the Polish average by 17%. While women's employment in this cluster is higher than the study average, it aligns with the national average. This may result from the fact that the cluster contains a lot of post-mining cities where traditional male jobs have declined. Women's economic activity could potentially smoothen the economic shocks in those counties that are yet to undergo a coal phase out (such as zgorzelecki).

Lastly, demographic trends present average values for all mining localities. These values remain below the Polish average. The share of workers with tertiary education is 45% lower than in Poland on average (unsurprisingly the leaders are medium-sized cities), while migration balance remains negative (-1.8 per 10 000 inhabitants; Poland showed a slightly positive migration trend in 2024 of 0.1 per 10 000).

Outliers in this cluster

Zgorzelecki: while it remains similar to other counties in terms of firm replacement, unemployment, wages, female employment, education or migration it has an almost 4 times higher employment share in the mining and energy sector than this cluster's average (14% compared to 4%). Interestingly, despite the presence of the Turów lignite mining and energy complex, the county is characterised by a low HHI index (0.03) which means that its economy remains diversified. While the HHI index measured by employer's residence address could be low as PGE GiEK is registered in Bełchatów and not in Turów, the HHI measured by employees residence addresses is equally low (0.03).

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Conclusions for this cluster:

Average socio-economic indicators and the ongoing presence of the coal industry suggest that, without external funding, the phase-out could prove challenging. This cluster has little room to absorb potential shocks, as it already performs at or below average relative to other coal counties. On the positive side, high economic diversification, female economic activity, and wages approximately 20% below the national average enhance its adaptive capacity. The fact that counties are still rebuilding decades after the 1990s closures—remaining only average performers today—underscores the need for continued support for these areas, while highlighting the necessity of better safeguarding those currently facing phase-outs to ensure more successful long-term outcomes.

Recommendations for this cluster:

This cluster requires measures to improve its socio-economic indicators and better prepare it for the upcoming coal phase-out—or to "build back better" following previous industry closures. Interventions should focus on reducing unemployment and enhancing the skills and education of the local population, providing them with better labor market opportunities, and limiting outmigration. Finally, subregional centers and small cities within this cluster need economic stimuli to ensure their development benefits the surrounding areas.

CLUSTER 4: Big cities with mining ties (7 counties, including 5 big cities)

Counties: m. Dąbrowa Górnicza, m. Gliwice, m. Katowice, m. Opole, m. Tychy, raciborski, świebodziński,

Economic diversification	**Labor Market**	**Demographics**
● Second lowest economic diversification ● Average firm replacement	● Second lowest employment in mining and energy sectors ● Lowest long term unemployment (-60% compared to PL average) ● Second highest wages (same as PL average) ● Highest share of women in employment (same as PL average)	● Highest tertiary education levels (-24% compared to PL average) ● Second lowest migration (although still negative)

This cluster of counties is characterized by a stable labor market, with the highest share of women in employment, the lowest level of long-term unemployment, and above-average wages. Demographic trends are also in favour with the highest educational level and above average migration balance.

This cluster comprises largest cities of Silesia, as well as Opole - the largest city in the Opolskie Voivodeship - and two urban-rural counties: raciborski county in the Silesian region and a świebodziński county in the Lubuskie Voivodeship, where the private Sieniawa lignite mine is located.

The strength of the labor market in this cluster does not appear to be driven by the mining sector, as employment in mining and energy is relatively low - ranging from just 1% in świebodziński county to 4% in Katowice. Although economic diversification is below average, the counties in this cluster vary most in this dimension. Notably, Gliwice, Opole, and Katowice exhibit low levels of economic concentration. In particular, Katowice (together with the zgorzelecki county) records the lowest HHI index among all 66 counties. This is somewhat surprising given that PGG - the largest employer in the coal sector - is headquartered in Katowice (it is important since the HHI is calculated based on employment by firm location). However, the presence of PGG does not translate into

high concentration, suggesting that employment is distributed across a wider range of firms. On the other hand, Tychy (with large automotive sector), Dąbrowa Górnicza (steel sector), raciborski and świebodziński county have one of the lowest economic diversifications of all counties, suggesting that their relatively concentrated economic structures may pose risks in the event of sector-specific shocks.

This cluster, along with its positive demographic trends and stable market conditions, reflects broader national patterns. Specifically, small and medium-sized cities are experiencing depopulation in favor of larger urban centers. Cities that are part of the Upper Silesian–Dąbrowa Basin Metropolis - particularly its largest urban centers - belong to this cluster and are recognized as supra-regional growth poles[9]. These are dynamic urban centers that attract capital, including human capital, as well as innovation, and exert a positive influence on surrounding areas. Through these processes, they are also considered to exhibit high levels of economic resilience (Sobala-Gwosdz, 2023).

Conclusions for this cluster:

This cluster reflects broader national patterns, where large cities function as centres with strong labor markets and abundant opportunities. In mining regions, these are primarily urban areas in Silesia. Their economic strength allows them to act as buffers, mitigating the negative effects of closures in surrounding areas (growth poles). Low unemployment rates indicate a strong capacity to absorb additional workers compared to other clusters, highlighting their resilience. Therefore, mine closures are unlikely to have a substantial direct impact on these cities, given the relatively small share of mining employment and their otherwise stable labor markets. At the same time, cities within this cluster differ significantly in terms of economic diversification, largely due to the strong presence of industry in some locations. However, these industries are generally distinct from coal mining, suggesting that a coal phase-out should not substantially affect them. A potential exception is more industrially specialised cities, such as Dąbrowa Górnicza, where sectors like steel production could be indirectly impacted by disruptions in mining companies (e.g. JSW)

Recommendations for this cluster:

Funding should not be disproportionately directed toward these cities, as they are already in relatively strong economic condition. Instead, greater emphasis should be placed on strengthening their surrounding areas - particularly neighbouring clusters that might otherwise face depopulation as residents are anyways drawn toward these urban centres. At the same time, it is important to pay close attention to the aforementioned outliers, which exhibit relatively high levels of economic concentration and whose activities are directly or indirectly linked to the coal sector.

CLUSTER 5: Mining core (2 counties)

Counties in this cluster: m. Jastrzębie-Zdrój, łęczyński

Economic diversification	**Labor Market**	**Demographics**
● Low economic diversification ● Varied firm replacement rate	● Highest employment in mining and energy sector (19,7%) ● 2nd lowest long-term unemployment rate (-26% compared to PL average) ● High average wages (+35 compared to PL average)	● Low tertiary education levels (-50% compared to PL average) ● Very negative net migration (more people leaving than arriving)

[9] Opole is likewise regarded as a growth pole but at the regional level (Sobala-Gwosdz, 2023).

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	• Low female employment (-3% compared to PL average)	

This cluster is highly reliant on the coal mining industry, which conditions its economic diversification, the labor market and demographics. It comprises only two counties – Jastrzębie-Zdrój and łęczyński – from different parts of the country: Lubelskie and Śląskie voivodeships. These counties are home to two large mining companies: Bogdanka and JSW.

The mining industry dominates the local economies in this cluster, evidenced by a very high employment rate in mining and limited economic diversification as measured by HHI. Interestingly, the two counties differ in terms of their firm replacement rate: while łęczyński county has a higher-than-average firm replacement rate, Jastrzębie-Zdrój's rate is marginally below average. In this regard, Jastrzębie-Zdrój resembles other mining cities, which are characterised by an average replacement rate.

The present-day strength of the labor market in this cluster is visible through high average wages compared to the national average and the second-lowest long-term unemployment rate among the five clusters. However, because employment is highly concentrated in the mining sector, the low-carbon energy transition in these counties must be managed carefully to concurrently create productive and attractive workplaces for affected workers and their families. Łęczyński county will be particularly vulnerable to the coal exit, due to its focus on thermal coal mining.

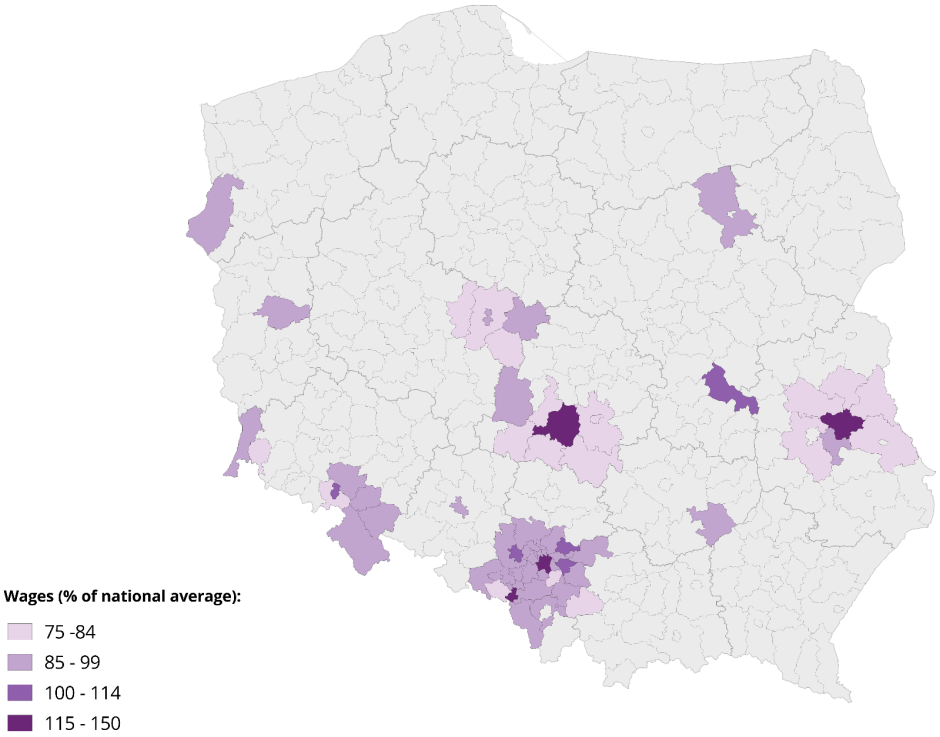

Figure 8 Average gross wages in coal counties as % of national average (PL average = 100%). Own work based on GUS BDL.

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Conclusions for this cluster:

Counties in this cluster may face the greatest challenges in adapting to the structural changes associated with the energy transition, due to their high dependence on the mining sector. This is particularly the case for łęczyński, which is largely surrounded by poorer rural areas, limiting regional diversification and support networks. Despite seemingly favourable labor market conditions, such as high wages and low unemployment, these counties experience a negative migration balance. For example, Jastrzębie shows one of the highest net outflows among all counties, reflecting limited alternative employment opportunities and low resilience to economic shocks. Moreover, the share of workers with higher education is relatively low, which may further constrain the capacity to diversify the local economy and adapt to change.

Recommendations for this cluster:

It is important to invest in upskilling and reskilling programs, however, in these counties highly dependent on coal, this alone will not be sufficient. Without well-paid local job opportunities, higher qualifications could simply become a reason for people to leave - an issue already evident in some of the fastest depopulating counties. Therefore, skills development must be accompanied by the economic diversification of local labor markets in sectors beyond mining. This is particularly crucial in the case of łęczyński county, which is surrounded by counties from the "Peripheral and rural belts" cluster. Here, reducing dependence on coal while simultaneously strengthening neighbouring counties is essential to ensure balanced regional development and long-term resilience.

Figure 9 Radar charts illustrating indicator profiles for each cluster based on normalized data (range 0–1). Source: own work.

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5. General conclusions

Cluster specific conclusions are included in chapter 4, in sections describing specific clusters.

The cluster analysis revealed that Upper Silesia, the Lublin Coal Basin, and the Bełchatów Lignite Basin exhibit the most variation, comprising counties that fall into three or even four different clusters.

In the Lublin and Bełchatów area, the results suggest an uneven distribution of benefits from the existing coal activities. Well-performing mining counties – with exceptionally high wages and still ahead of coal phase out – are surrounded by rural counties with low labor market indicators.

Upper Silesia has the most variance – it hosts representatives of all four clusters apart from "Rural belts" – and is generally characterized by better performance across socio-economic indicators used in this analysis. This is in part due to the presence of several big cities in this region.

Several coal-dependent or coal-adjacent counties that are not receiving the Just Transition Fund (e.g. zgorzelecki, kozienicki, rural belt near Bogdanka mine) are demonstrating similar characteristics to those that are already benefitting from it. This may indicate that the socio-demographic differences between counties receiving support from the fund and those that do not are yet significant enough, but could become so in the future, making it important to introduce such support before the differences are too wide. It is therefore crucial that mine and energy facility owners declare ambitious reduction or phase out plans so that these counties may apply for just transition funding (under new MFF or e.g. Modernization Fund).

Eastern Wielkopolska, a region that is most advanced on its decarbonization path, sits almost entirely in the Rural and Peripheral Belt cluster, with the exception of Konin. This city remains key to unlocking a new post-coal development potential and, according to IRMiR, it has the potential to be a subregional balancing pole. This region requires careful attention from researchers as it is currently implementing a very large outplacement and reskilling program - Job After Coal.

The variation in employment share in the coal mining and energy sector is demonstrated by a difference between the average employment share in the mining and energy sector across all 66 counties - it stands at 5.2% - **and the median value** which stands at only 2.9%. The difference is due to the presence of outliers such as Jastrzębie Zdrój (19.7%), łęczyński (19.7%) and rybnicki (18.8%).

While a few counties boast wages above both the coal-group and national averages, the overall wage distribution is relatively narrow. The median wage across all 66 coal counties stands at 87% of the national average, positioning them among the country's wealthier areas. However, some coal regions—such as the area near the Bogdanka mine—demonstrate a more uneven wage distribution. Keeping up with this level of wages may pose a challenge especially in counties that are still significantly coal dependent such as the Mining Core cluster or the Average, Post-Coal Counties Sustained by Women cluster.

The share of women in total employment remains close to the national average across most clusters, though it falls slightly below in the Rural and Peripheral Belt (95%), Mining Core (97%), and Beyond Coal Potential (99%) clusters. High female labor participation strengthens the resilience of coal counties by reducing household reliance on a single male income. However, high economic activity does not necessarily translate into wage parity with men.

While the majority of counties are experiencing depopulation - consistent with national trends observed in small and medium-sized towns and rural areas - **approximately one-quarter maintain a positive migration**

balance. This trend primarily applies to Silesian counties and cities contributing positively to their adaptive capacity and bolstering their ability to navigate the upcoming transition.

Economic diversification, as measured by the HHI index, remains relatively high across most counties, with a few notable exceptions such as Łęczna, Jastrzębie-Zdrój, Tychy, raciborski and chełmski. This diversification serves as an important factor that can enhance their resilience in the event of economic shocks.

6. General recommendation

Cluster specific recommendations are included in chapter 4, in sections describing specific clusters.

The results of this cluster analysis may inform policy makers' and regional/local governments decisions on planning new interventions and financial support within the just transition framework. It could be specifically useful in the context of the new Multiannual Financial Framework or the deployment of the Modernisation Fund for just transition.

On one hand **several counties analysed here are already experiencing significant socio-economic challenges** - e.g. long-term unemployment, low entrepreneurship, strong dependence on a single large company, low tertiary education levels. On the other hand, **there is a significant variance among counties that can be characterised as coal dependent**, which we tried to highlight using cluster analysis. One region can encompass counties that will need different forms and directions of support. The **future just transition planning will have to include this complexity.**

Regionally, the most favourable conditions are found in Upper Silesia. Conversely, the total absence of Beyond Coal Potential counties in Eastern Wielkopolska and Lower Silesia remains a significant concern.

Counties belonging to the Rural and Peripheral Belt cluster may greatly benefit from just transition programs and funds, as they currently demonstrate the weakest performance, especially in terms of labor market indicators. Although they have historically gained little from the adjacent mining industries, their inclusion in the transition process may strengthen the resilience of a given region.

Jastrzębie-Zdrój and łęczyński county are clear outliers in the whole group of the 66 counties. They are home to Jastrzębska Spółka Węglowa, 2nd largest coal company in Poland, and to LW Bogdanka, a large hard coal mine. They require special attention of decision-makers as their extreme dependence on the coal industry (especially in terms of employment share) can make their adaptation to the coal phase out difficult. This is especially true for Bogdanka, which is surrounded by several underperforming rural counties. The shock may, however, be attenuated by the presence of Lublin, considered as one of two development poles in Eastern Poland (together with Białystok). The cluster analysis also demonstrated that the effects of Bogdanka's economic activity do not translate into a wider subregional wealth.

The share of workers with tertiary education remains significantly below the national average across all 66 counties, standing at just 57%. This gap is most pronounced in the Rural and Peripheral Belts, Post-coal Counties, and Mining Core clusters. While many mining and energy workers may adapt to the coal phase-out through their technical specialties, this is not the case for everyone - particularly those in mining value chains and with lower qualifications. Targeted reskilling and upskilling programs would greatly benefit these counties by aligning workers' skills with existing or planned industries.

Lastly, just transition programs should support a greater participation of women in the labor market, especially in Rural and Peripheral Belt, Mining Core and Beyond Coal Potential clusters.

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6. Bibliography

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7. List of figures

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8. Annex

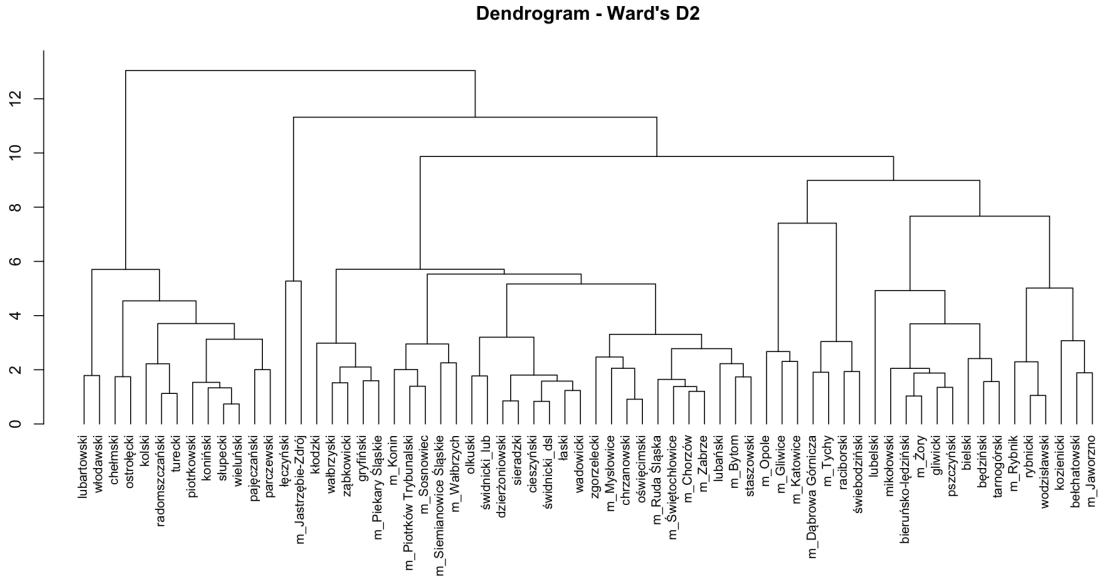

Chart 1 Dendrogram based on Ward's D2.

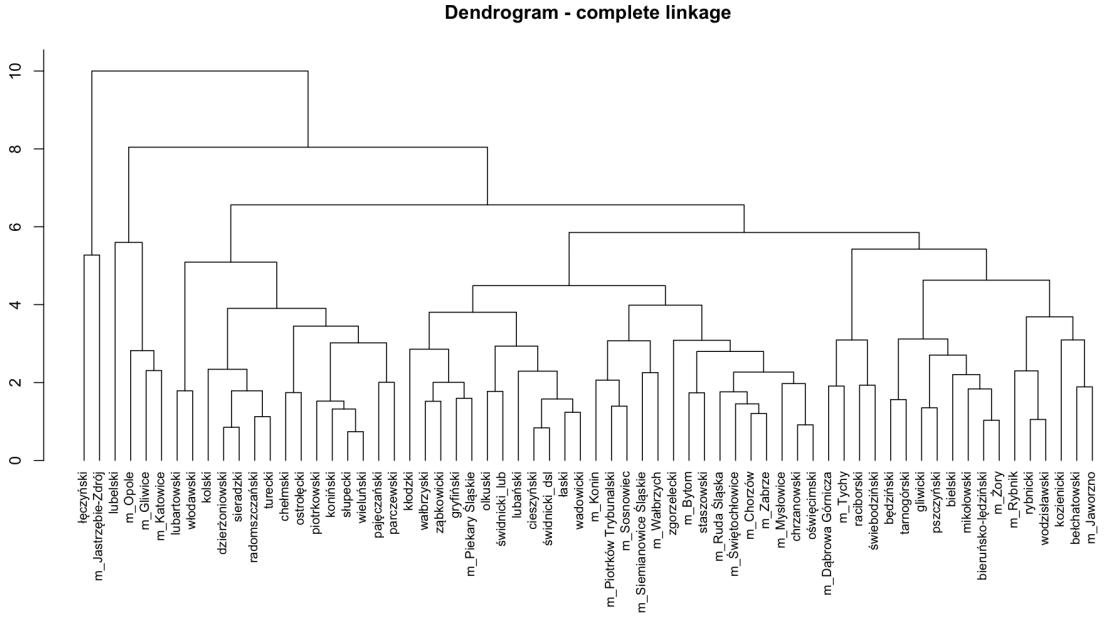

Chart 2 Dendrogram based on complete linkage.

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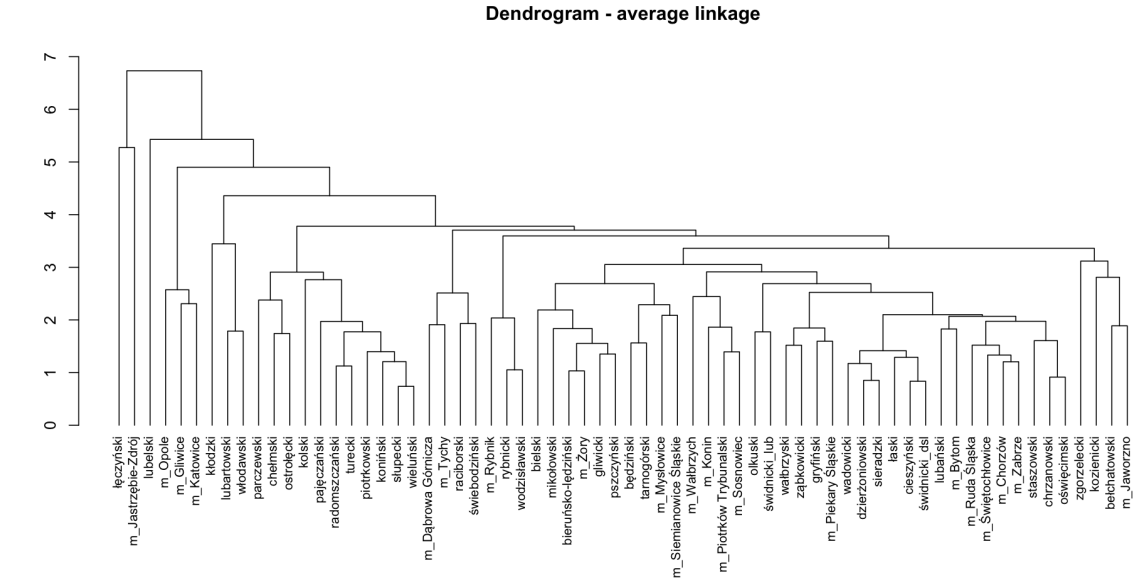

Chart 3 Dendrogram based on average linkage.

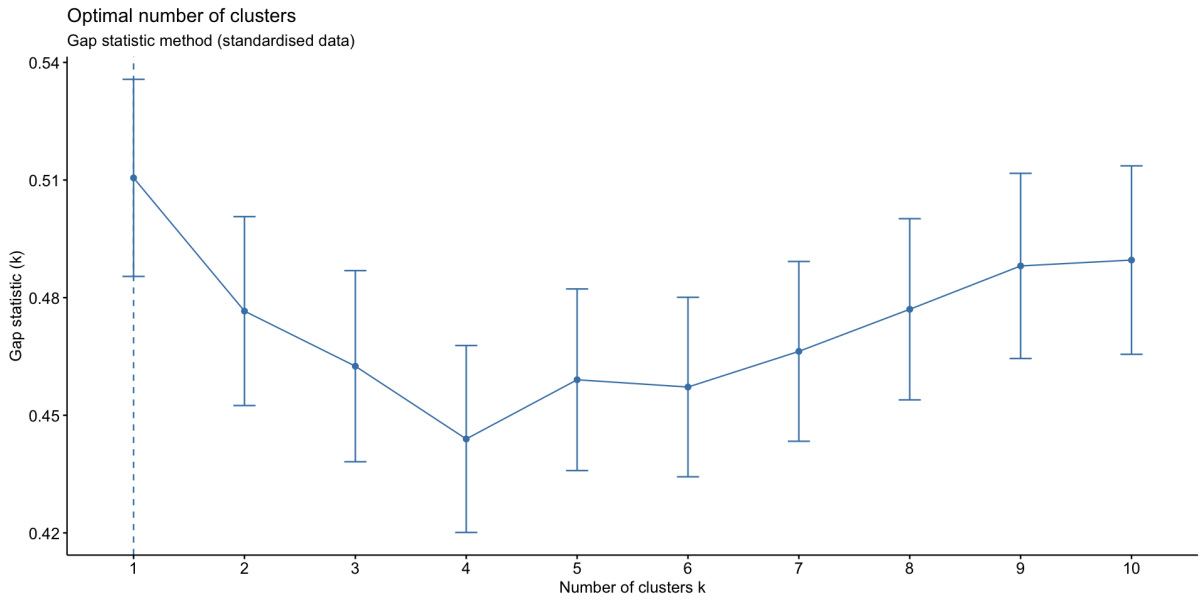

Chart 4 Gap statistic for standardised data.

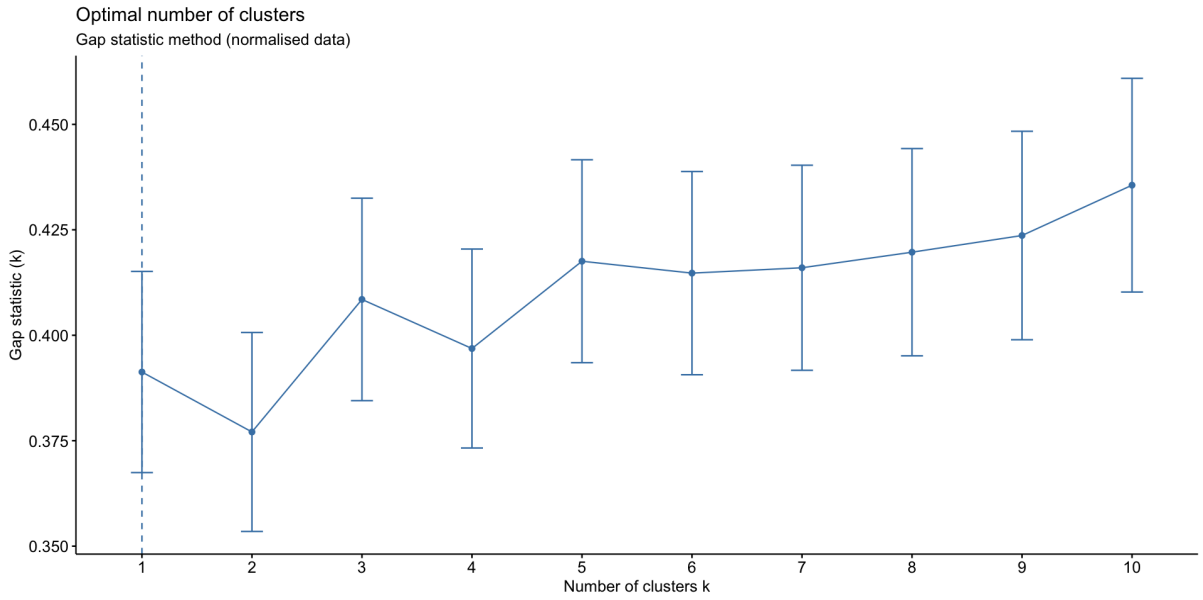

Chart 5 Gap statistic for normalised data.

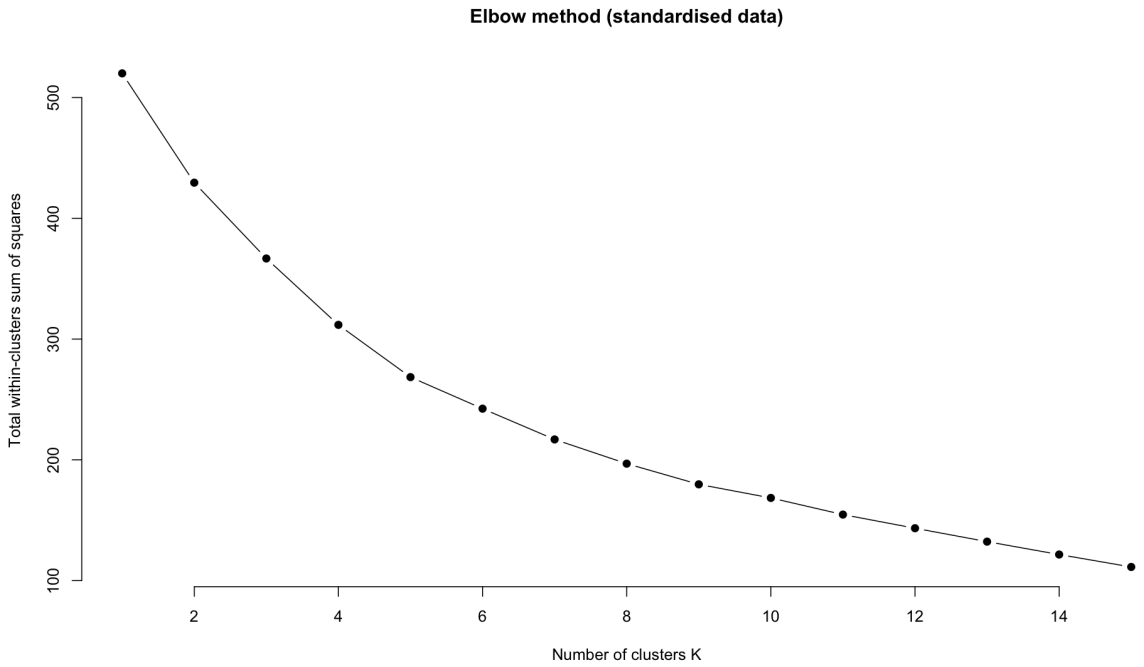

Chart 6 Elbow method for standardised data.

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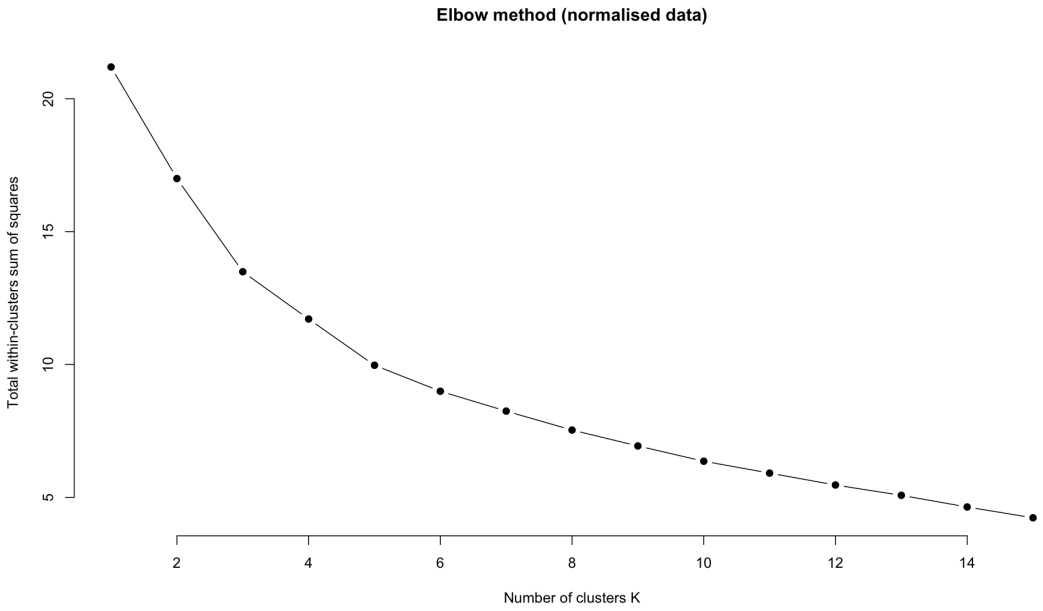

Chart 7 Elbow method for normalised data

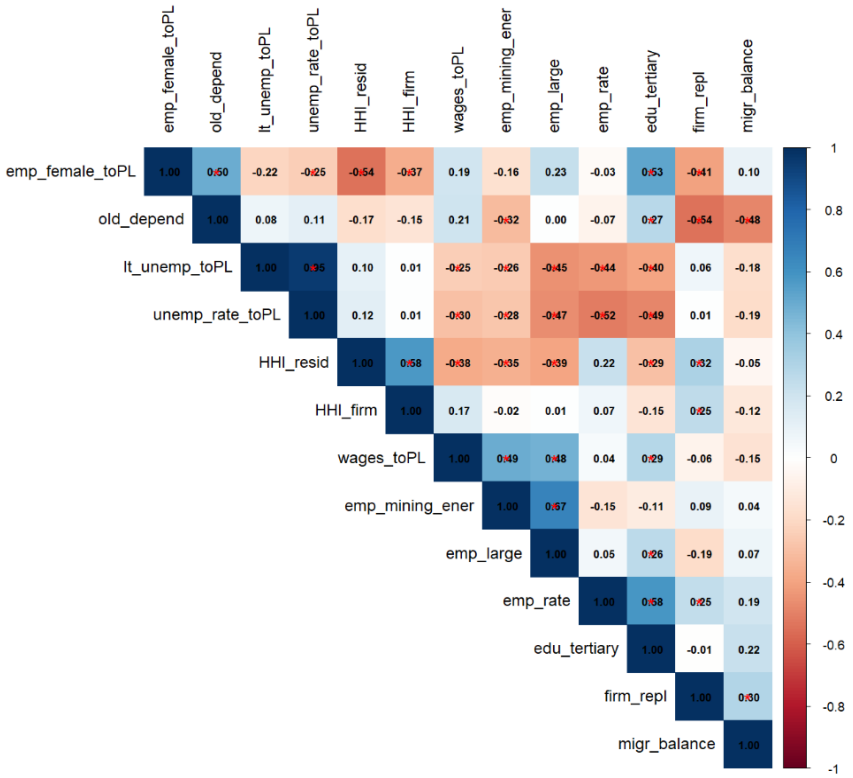

Chart 8 Pearson Correlation Matrix of the full list of indicators. Red dots mark statistically significant correlations (p.<0.05).

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