

United Nations University

Institute for Integrated Management of Material Fluxes and of Resources

# RESOURCE NEXUS ANALYSIS OF **TRANSITIONS AFTER COAL MINING** IN SOUTH KOREA AND LUSATIA, GERMANY

January 2026

Weisswasser, Germany



**UNU**  
**FLORES**



**K-eco**  
Korea Environment  
Corporation

Report

# Resource Nexus analysis of **transitions after coal mining** in South Korea and Lusatia, Germany

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## GOOD NEWS!

Both regions manage challenges like acid mine drainage or poor soil quality through proven **reclamation** and **monitoring techniques**.

Unlike many coal provinces globally, regulatory violations or illegal mining are **not the issues** in either region.

## CONTRASTING POST-MINING APPROACHES

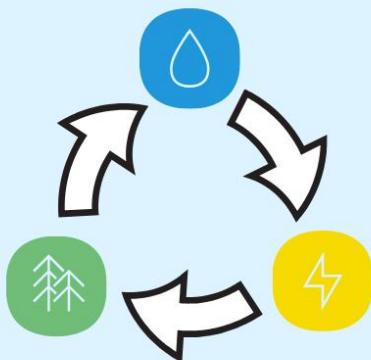


### LUSATIAN COAL MINES

Focuses on **energy, water,** and **biota**

Implements **conservative strategies** for post-mining resource management

Achieves **integrated** transformation through **large-scale** projects (e.g., the Lusatian Lake District, energy parks, and conservation areas)



**INTEGRATED  
CONSERVATIVE**



### SOUTH KOREAN COAL MINES

Utilizes **various** legacy resources, creates new ones

Explores **innovative** post-mining ideas, including smart farming and lunar exploration robotics research

Operates with **fragmented** and **small-scale** efforts, not enough to achieve regional structural transformation



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# Glossary

Table 1 Terminology for the report

Terminology	Meaning
Former mining site	An area of land that was previously used for mining activities but has since been abandoned, decommissioned, or ceased operations.
Post-mining	The phase of a mining project that occurs after the cessation of mining activities. It encompasses the period during which the mine site undergoes closure, reclamation, and rehabilitation efforts to restore the land to a safe and environmentally sustainable condition.
Reclamation	The process of recreating ecosystems targeted at essential ecological processes, such as, e.g., nutrient cycling or habitat provision. The endpoint of reclamation is then a replacement ecosystem, not an original one. Reclamation can also refer to the process of creating new land from oceans, seas, riverbeds, or lake beds.
Recultivation	The term "recultivation" is often used in certain regions or regulatory frameworks, particularly in Europe, to describe land restoration efforts following mining activities or other land disturbances.
Rehabilitation	The process of assessing the costs and benefits of maintaining environmental quality and optimizing land management practices. It encompasses various land-use activities such as agriculture, forestry, or urban development, aiming to utilize the land for human purposes while considering environmental conservation.
Remediation	A targeted process of controlling contamination in specific environmental resources, such as soil, water, biota, and other media.
Resource Nexus	The Resource Nexus approach examines the interconnection between at least two environmental resources to understand interlinkages and interdependencies between their use and availability. This approach identifies trade-offs and establishes synergies between environmental resources (Brouwer et al., 2024).
Restoration	The process of restoring degraded or disturbed land to a more natural, productive, or sustainable state; includes deliberate efforts to revive ecosystems to their pre-existing conditions before undergoing disturbance or degradation. This process aims to re-establish the full functionality and biodiversity of ecosystems, striving to return them to their original state. While restoration endeavors to replicate the exact ecosystem that existed before disruption, achieving this goal may be challenging.
Revitalization	The process of renewing or restoring land that has been previously degraded, contaminated, or underutilized. This term is often used in the context of urban redevelopment, where vacant or abandoned properties, industrial sites, or brownfields are.
Wasteland	A land that has been degraded and rendered barren by human activities. These areas often pose environmental challenges, such as poor soil quality, contamination, and a lack of vegetation.

# I. Introduction

## 1.01 Background and rationale

On October 1st, 2024, Prof. Edeltraud Guenther, a Director of UNU-FLORES, received a call from a Korean non-profit organization, Solution for Our Climate, and appeared on its channel (Fig. 1). Why would a Korean organization reach out to Ms. Guenther, who works in Eastern Germany? The answer lies in her expertise on Germany's coal phase-out. This collaboration illustrates how Germany's experiences and lessons can offer valuable guidance for Korea as it faces its own coal exit.



Figure 1 Edeltraud Guenther, a Director of UNU-FLORES, featured on YouTube by a non-profit organization in Korea.

Note. Source by Solutions for Our Climate (2024).

Global efforts toward a coal phase-out intensified with the Paris Agreement in 2015. To reduce the risks and impacts of climate change, the Paris Agreement was adopted to limit the global average temperature increase to well below 2 °C and pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels (UNFCCC, 2016). The largest share of greenhouse gas (GHG) emissions comes from CO<sub>2</sub> released by fossil fuel combustion (IPCC, 2023). To stay with the Paris Agreement's 1.5 °C limit, global coal-fired power generation without carbon capture and storage should be reduced by 80% compared to 2010 levels by 2030, and completely phased out before 2040 (Climate Analytics, 2019).

Germany and Korea have both historically relied heavily on coal to support their economic development. In Germany, coal production has been concentrated in three districts: the Rhineland in the west, Lusatia in the east, and the Central German district. Among these, Lusatia produced a cumulative 7,150,726,000 t of lignite between 1950 and 2024, peaking at 200,290,000 t in 1988 (Coal Industry Statistics, 2025). It has the largest total area used for mining among the coal districts in Germany (Gerwin et al., 2023). Over the same period, Korea produced 614,926,000 t of anthracite, with a peak of 24,295,000 t in 1988 (Korea Coal Association, n.d.; Statistics Korea, 2025). Despite the lower output compared to Lusatia, Korea's domestic

coal self-sufficiency rate remained high, between 88% and 111% throughout the 1960s-1980s. In both regions, the coal industry played a crucial role in industrialization and economic growth.

Today, however, Germany and Korea aim to phase out coal in alignment with their carbon neutrality commitments. Germany has pledged to close its last coal-fired power station by 2038 at the latest, while Korea plans to exit coal by 2050 (Binz et al., 2024). Lusatia is one of the key examples of post-mining transition in Germany, having actively converted former mining areas into new forests, lakes, agricultural land, and other landscapes (Deshaies, 2020). At the same time, Lusatia faces several challenges for post-mining transition, such as poor soil quality, weak alternative industrial sectors, and limited access to major cities (Gerwin et al., 2023). In this context, Lusatia's experience and ongoing efforts toward transitions after coal mining can offer valuable insights and potential lessons for Korea's coal phase-out.

The transitions after coal mining are deeply interrelated with various environmental resources. Mining activities affect not only the land and soil, but also water systems and biodiversity. Consequently, strategies to transform post-mining areas must take these interconnected resources into account. Post-mining policies and practices must address both the current environmental conditions and the future use of resources. Moreover, the transformation of environmental resources can significantly influence local economies and drive social changes within communities.

To effectively manage such complex transitions, a Resource Nexus approach is essential. The Resource Nexus approach examines the interconnection between at least two environmental resources to understand interlinkages and interdependencies between their use and availability (Brouwer et al., 2024). By applying a Resource Nexus analysis, policymakers and planners can gain a more holistic understanding of post-mining transitions, helping them to design strategies that are environmentally, economically, and socially sustainable.

Therefore, this report aims to analyze transitions after coal mining in Lusatia and South Korea through a Resource Nexus approach. It explores how environmental resources are transformed during the mining and post-mining phases and highlights their role in shaping local economies. Additionally, the report examines the social significance of resources within post-mining communities. Through comparative analysis, Lusatia and Korea can learn from one another's experiences, identifying both successes and challenges to guide a sustainable and just post-mining transition.

## **1.02 Physical geography overview**

Geological and climatic characteristics are important factors influencing disturbances in mining areas. They affect the selection of mining techniques, the types and severity of environmental challenges, and the design of reclamation practices, ultimately shaping post-mining strategies. Before examining the post-mining transitions in Lusatia and Korea, the differing physical geography features of the two regions will be discussed (Table 2).

### **(a) Physical geography of Lusatia**

Lusatia spans parts of Brandenburg and Saxony in Germany and extends into Poland and the Czech Republic. The region covers an area of 11,726 km<sup>2</sup> and has a population of about 1.1 million (Matern et al., 2024). This report focuses on the German part of Lusatia (Fig. 2).

The region comprises two parts, Upper Lusatia and Lower Lusatia. Upper Lusatia, located in the southern part of the region, is characterized by mountainous and hilly terrain, whereas Lower Lusatia in the north is relatively flat (Heer et al., 2021). Lusatia lies within the mid-latitude temperate climate zone. The average annual temperature is 10.38-11.13 °C (Weather & Climate, n.d.). In August, the hottest month, average temperatures range from 23.6°C to 24.3°C, while in January, the coldest month, they range from -2.8 °C to -1.7 °C. The annual precipitation is 171.36–434.4 mm, with summer rainfall accounting for 35.2-37.1% of the total annual precipitation.

Lusatian lignite was formed approximately 15 to 20 million years ago during the early Tertiary from abundant peat deposits that accumulated in subtropical bog forests (Krümmelbein et al., 2012). These peat layers were later compressed under glacial till deposited during the Pleistocene glaciations, developing lignite seams (Gerwin et al., 2023; Krümmelbein et al., 2012). Due to the minimal influence of neotectonic processes in the region, the lignite seams have remained largely undisturbed and maintain their original horizontal stratification, which enables efficient mining operations using overburden conveyor bridges (Gerwin et al., 2023). Meanwhile, the Lusatian landscape itself was significantly shaped by Quaternary glaciations, which created a variety of geomorphological features such as moraines, plateaus, meltwater reservoirs, dunes, sand drifts, and fens (Krümmelbein et al., 2012).



These geological and climatic characteristics have shaped Korea’s mining history and the distribution of coal resources. In particular, the legacy of coal mining remains deeply embedded in certain regions. This report examines the post-mining transitions in seven cities and counties designated as Abandoned Mine Area Promotion Districts: Taebaek, Samcheok, Yeongwol, Jeongseon, Mungyeong, Boryeong, and Hwasun (Fig. 3b). These areas were central to the nation’s coal industry and now face various challenges after mine closures.

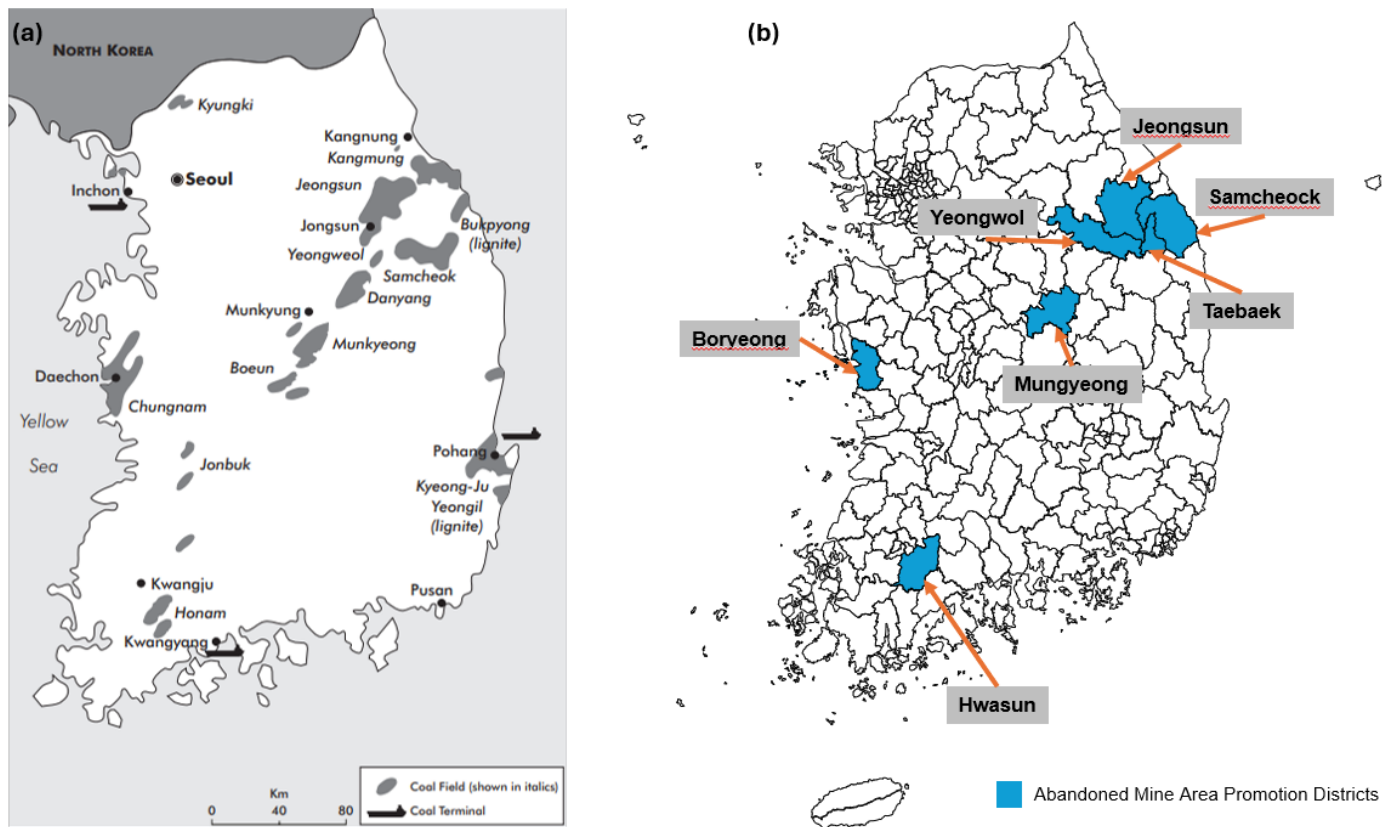


Figure 3 (a) Map of South Korea showing its coal fields and major coal terminals. (b) Seven municipalities designated as Abandoned Mine Area Promotion Districts.

Note. (a) Figure by IEA (2002). (b) Figure by Y. Ok.

## 1.03 Socioeconomic conditions

The mining industry has had a significant impact on local communities throughout its entire life cycle, from initial development to the post-mining period. A historic overview of this section offers valuable insights into how the coal industry has shaped local economies and societies. A just post-mining transition must take socioeconomic characteristics into account to address local needs and preserve community identity (Table 2).

### (a) Socioeconomic conditions in Lusatia

Before the onset of lignite mining, Lusatia was settled by the Slavic ethnic group known as the Sorbs in the 6th and 7th centuries (Prust, 2024). They remained the dominant population until the 18th century. Today, this unique cultural background persists, with fewer than 60,000 Sorbs maintaining their language and traditions in the region.

For centuries, Lusatia's economy was primarily based on agriculture and forestry (Heer et al., 2021). However, the advent of lignite mining profoundly transformed Lusatia's landscape, economy, and society. Large-scale lignite production began in the middle of the nineteenth century (Gerwin et al., 2023). Between 1949 and 1990, 71 villages in Lusatia were demolished for lignite mine development, displacing residents and contributing to the shrinking of the Sorbian minority (German Environment Agency, 2022; Prust, 2024).

As lignite was the primary energy source in the German Democratic Republic (GDR), mining operations expanded rapidly, making the region a key center of energy production for the GDR (Heer et al., 2021; Prust, 2024). In 1989, the lignite production in Lusatia had reached 195.1 Mt, and approximately 79,000 people were employed in the mining industry (Coal Industry Statistics, 2025). In addition to lignite mining and energy production, energy-intensive industries such as glass manufacturing flourished in the region (Heer et al., 2021). Over time, lignite shaped the economy of Lusatia, as well as its regional identity and sense of pride.

However, German reunification in 1990 marked the end of the golden era of lignite, driven by drastic political and economic transformations. Following reunification, many opencast mines in the East German lignite basins were closed (Deshaies, 2020; Heer et al., 2021). This rapid closure of mines profoundly impacted the economy and society of Lusatia. A large number of people lost their jobs, and the local economy experienced a sharp downturn (Coal Industry Statistics, 2025; Heer et al., 2021). These economic challenges persist today. In 2020, Lusatia's average Gross Regional Domestic Product (GRDP) per inhabitant was 30,361 euros, around 66% of Germany's average of 46,264 euros (Statistische Ämter des Bundes und der Länder, 2024). As the economy declined, many residents, especially young people, left the region. The population fell from just under 1.4 million in 1990 to approximately 1.1 million by 2012 (Kluge et al., 2014). By 2022, residents aged over 60 accounted for 37.5% of Lusatia's population, around 130% of Germany's national average of 30% (The Federal Returning Officer, n.d.).

Along with economic and demographic decline, vast areas of former mining land suffered from environmental degradation and required reclamation (Deshaies, 2020; Krümmelbein et al., 2012). To address the remediation of former mining areas in Eastern Germany, the federal government established the Lausitz and Central-German Mining Administration Company (Lausitzer und Mitteldeutsche Bergbauverwaltungsgesellschaft mbH, LMBV) in 1994 (Deshaies, 2020). By 2013, more than 16,000 ha of former mining lands in Lower Lusatia had been converted into forests (8,000 ha), lakes (4,300 ha), agricultural land (about 1,000 ha), and other uses.

More recently, lignite mining has come under growing pressure in the context of climate change. Following German reunification, five mines remained in operation: Jänschwalde, Cottbus-Nord, Welzow-Süd, Nochten, and Reichwalde (Gerwin

et al., 2023). Cottbus-Nord mine closed in 2015, and the Jänschwalde opencast mine was shut down in 2023. Currently, only three lignite mines continue to operate in Lusatia (Lausitz Energie Bergbau AG, n.d.). As the German federal government announced plans to phase out lignite mining by 2038, the Lusatian region faces a new challenge toward a sustainable post-mining transition.

## **(b) Socioeconomic conditions in South Korea**

Modern coal mining in Korea began in 1896, when the Korean royal court formally granted the first mining concession to Nisichensky, a Russian entrepreneur (Korea Coal Corporation, 2001). Until Korea's liberation in 1945, coal mining operations were largely dominated by foreign interests, particularly the Japanese during the colonial period.

After liberation, coal became a crucial energy source for industry and civilian use. It played a significant role in lifting Korea's economy, helping increase the per capita income from under 100 USD in the 1950s to 10,000 USD (D. Kim, 1999). After the Korean War, the Korean government launched a Ten-Year Coal Production Expansion Plan to meet growing domestic demand and achieve self-sufficiency (Korea Development Institute, n.d.). In addition, the national reforestation initiative promoted coal as an alternative to biomass for household energy use. As a result, Korea's coal self-sufficiency rate reached 99.53% in 1967 (Korea Coal Corporation, 2001). During this period, coal-mining regions experienced a remarkable boom. In mining towns, there was even a saying: "Even a passing dog carried a 10,000-won bill in its mouth" (Jeong, n.d.-a). The 10,000-won note was the highest-value note in Korea until 2009, symbolizing the economic prosperity of coal-mining communities at the time.

In the 1980s, the coal industry faced a crisis due to rising production costs, a shift in household fuel use to gas, and a growing preference for cleaner energy sources (Korea Coal Corporation, 2001; National Archives of Korea, 2007). In 1986, the collapse of global oil prices further reduced the demand for anthracite (National Archives of Korea, 2007). To sustain the coal industry, the government implemented the Coal Rationalization Policy in 1987 (Korea Coal Corporation, 2001). This policy included social rationalization measures such as financial support for closing small-scale mines and nationalizing larger operations.

As a result, the number of coal mines dropped from 347 in 1988 to just 11 by 1996, while employment in the mining industry fell from 68,500 to around 10,000 over the same period. Following the rationalization policy, Korea's coal industry declined at 15% annually, faster than the UK (5%), Germany (4.5%), or Japan (11%). The socioeconomic consequences were profound. The combined population of the seven municipalities designated as Abandoned Mine Area Promotion Districts shrank from about 560,000 in 1987 to 460,000 in 2010 (Ko & Cho, 2014). Aging has also become a serious challenge in these post-mining regions. By 2024, residents aged over 60 accounted for 43%, approximately 150% of the national average of 28% (Ministry of the Interior and Safety, n.d.). These socioeconomic difficulties are reflected in the regions' GRDP, with the Abandoned Mine Area Promotion Districts consistently recording below-average per capita GRDP of approximately 21,000 euros, compared to the national average of 25,000 euros (Statistics Korea, n.d.).

The rapid closure of mines created numerous challenges in former mining towns, including unemployment, environmental degradation from past mining activities, and deforestation (Korea Coal Corporation, 2001). These socioeconomic problems triggered population outflows and large-scale public protests (An, 2022b; Jeong, n.d.-b; Kim, 2023). Particularly, residents of Gohan and Sabuk launched a large-scale protest to demand their right to livelihood on February 27, 1995 (Bae, 2023a; Lee, n.d.-b). As a result, the government announced the 'Special Act on the Assistance to the Development of Abandoned Mine Areas' on March 3, 1995, which included the approval of the nation's only domestic casino, Gangwon Land, in former mining areas as part of regional revitalization efforts. In addition, it designated 'Abandoned Mine Area Promotion Districts', selecting towns from seven cities and counties.

Coal mining in Korea is heading to its final phase as the government pursues carbon neutrality by 2050. Driven by the transition to clean energy and low mining efficiency, the last national coal mine, Dogye Mine in Samcheok, was closed on June 30<sup>th</sup>, 2025 (S. Choi, 2025; M. Jeong, 2025). At present, the only coal mine in operation is the privately run Gyeongdong Sangdeok Mine (G. Choi, 2025). Under these circumstances, discussions are underway on just and sustainable post-mining strategies to revitalize former mining areas.

**Table 2 Comparison of the coal industry between the German part of Lusatia and Korea.**

	German part of Lusatia	South Korea
Land area	11,726 km <sup>2*</sup>	100,266 km <sup>2</sup> (South Korea) 1,066 km <sup>2</sup> (Abandoned Mine Area Promotion District)
Population	approximately 684,937*	405,096** (7 cities of Abandoned Mine Area Promotion District, 2022)
GRDP per inhabitant	30,361€ (2020)***	21,025€ (2020)**
Climate conditions	Mid-latitude temperate climate zone  Average annual temperature: 10.4–11.1 °C Precipitation: 171–434 mm/year (summer share: 35–37%)  Relatively moderate climate Lower and more evenly distributed precipitation	Temperate climate zone, but with stronger monsoon influences  Average annual temperature: 7–15 °C Precipitation: 1,306 mm/year (summer share: 54%)  Greater annual temperature range More seasonal extremes in temperature and precipitation
Type of coal	Lignite	Anthracite
Mining method	Open-cast mining	Underground mining
Start of modern mining	Mid-nineteenth century	1896
Coal phase-out period	After German reunification (1990s)	Coal rationalization policy (1989)
Number of mines	33 closed, 3 active (2025.08.14)	442 closed, 1 active (2025.08.14)
Mining area	909 km <sup>2</sup> (2024.12)	No data, but less than Lusatia due to the underground mining method
Environmental impacts of coal mining	Acid mine drainage, water scarcity, soil acidification, poor soil quality	Acid mine drainage, metal contamination of water and soil, land subsidence

\*The Federal Returning Officer (n.d.).

\*\*Statistics Korea (n.d.).

\*\*\* Statistische Ämter des Bundes und der Länder (2024).

# II. Past, present, and future of resources: Environmental transformations and socioeconomic roles

Throughout the mining and post-mining transitions, various environmental resources undergo significant transformations. These transformations affect local communities and can create new socioeconomic opportunities. This research has revealed that in almost all cases, two or more resources are interconnected. Although the following sections are organized around one or two resources, each discussion highlights their interrelations with others. The resources covered include energy, water, land and soil, biota and food, and space.

## 2.01 Energy

Due to climate change, global energy systems are undergoing a significant transition. According to IEA (2024), total energy-related CO<sub>2</sub> emissions reached 37.4 Gt in 2023. Renewable energy sources have been highlighted as key mitigation options for climate change, and many countries are aiming to phase out coal and shift toward clean energy resources (IPCC, 2023). As Germany has committed to phasing out coal by 2038, 57.4% of Germany's electricity was generated from renewable energies in 2024. In contrast, Korea has set a coal phase-out target by 2050, with renewable energy accounting for only 9.6% of its electricity generation in 2024 (Binz et al., 2024; Our World in Data, 2025). Despite Korea's slow transition to renewable energy, both Germany and Korea are progressing in phasing out coal, which further underscores the need to expand renewable energy as a replacement. One notable environmental transformation of post-mining is repurposing former coal mining sites for renewable energy production, offering valuable examples of a green and sustainable energy transition.

### (a) Environmental transformations and socioeconomic roles of energy in Lusatia

Although Lusatia has long been an energy region, the economic role of the energy sector is no longer prominent. Since German reunification, employment in the lignite industry has declined by 89% (Coal Industry Statistics, 2025). Today, the lignite sector accounts for 4.3% of the gross value added and 3.3% of employees subject to social security contributions (Berger et al., 2019; Gerwin et al., 2023). This structural decline in the lignite sector has contributed to the region's broader economic weakness. Lusatia's gross value added per employed person remains well below the national average (Hirschl et al., 2022). Nevertheless, the ongoing energy transition presents opportunities for Lusatia to re-establish itself as a new energy region.

Lusatia has demonstrated notable examples of transforming former lignite mining areas into renewable energy landscapes. Wind energy marked the beginning of this transition. Between 1999 and 2006, 50 wind turbines were installed on mining wastelands of a former Klettwitz opencast mine in the municipality of Schipkau in Brandenburg (Deshaies, 2017, 2020). This began with the first wind turbine placed at the top of a mine spoil heap. In addition to large wind potential on these elevated spoil heaps, mining wastelands offered advantages in installing wind turbines due to their distance from residential areas and protected natural sites (Deshaies, 2017).

In recent years, Lusatia has continued to expand its wind energy capacity. In the Forst Briesnig I wind farm, five turbines were installed on the reclaimed post-mining landscape of the Jänschwalde opencast mine, with additional turbines planned within the same site as part of the Forst Briesnig II wind farm (ABO Energy, n.d.; Gerstner, 2025). By 2018, Lusatia hosted a total of 1,075 wind turbines across 143.7 km<sup>2</sup>, generating 3,804 GWh of electricity annually (Hirschl et al., 2022). However, wind power generation is unevenly distributed within the region. The Brandenburg part of Lusatia produced 3,268 GWh in 2018, whereas the Saxony part generated only 536 GWh (Hirschl et al., 2022). This disparity is linked to Saxony's installed wind capacity being five times lower than that of Brandenburg (Deshaies, 2017).

In addition to wind energy, mining wastelands hold significant potential for photovoltaic (PV) energy. According to Richwien et al. (2018), a total of 48,264 hectares across both active and inactive mining sites were determined as suitable areas for PV deployment. Potential installation sites include woodland, spoil heaps, heathland, agricultural land, standing water, mining pits, and wasteland (Richwien et al., 2018).

On the former Meuro opencast mine, several large PV parks were established in 2011 (Deshaies, 2017). In recent years, additional solar parks have been constructed and commissioned. The Lusatia Energy Park was built on the former dump of the Klettwitz opencast mine (GPJOLE, n.d.; Fig. 4). It integrated solar power plants into an existing wind park that has operated since 1999, making it one of the largest solar and wind energy parks in Germany (GPJOLE, 2023). In 2024, the Haidemühl Solar Park and the Boxberg Solar Park began operation, located on the former Welzow-Süd and Nochten opencast mines, respectively (LEAG, n.d.-a; Fig. 5). Furthermore, additional PV projects are planned or under construction, such as the Bohrau Energy Park, located on an agricultural reclaimed area of the Jänschwalde opencast (LEAG, n.d.-c).

Producing bioenergy crops on post-mining landscapes is one of Lusatia's energy transition strategies. In particular, short rotation coppice systems are getting attention for their high potential on marginal mining wastelands with poor soil quality (Grünewald et al., 2009; Quinkenstein & Jochheim, 2016). Short rotation coppice is an agricultural method in which woody biomass is harvested above the stump and roots after a rotation cycle of 2–6 years. In 1995, a 2.5-hectare short-rotation plantation was established on the former Welzow-Süd mining area (Bungart et al., 2000). In the following years, additional experimental sites for short rotation coppice were set up in the Jänschwalde, Welzow, and Selditz mining districts (Grünewald et al., 2009). Beyond producing energy crops, short-rotation coppice systems also enhance carbon sequestration within the trees and soils (Quinkenstein & Jochheim, 2016).

Lusatia holds substantial potential for further renewable energy development. By 2040, electricity generation from wind and solar PV could increase approximately fourfold and eightfold, respectively, compared with 2018 (Bode et al., 2024). However, the potential of bioenergy remains limited due to land-use competition. Taken together, under an ambitious climate neutrality scenario, these transitions could add around 450 million euros to the regional economy and create 3,560 full-time jobs by 2040. Furthermore, Lusatia has the opportunity to transform itself from a lignite-based region into a green energy region.



**Figure 4** The Energy Park Lusatia.

*Note.* Photo by LEAG (n.d.).



**Figure 5** Haidemühl solar park on mining wasteland of the former Welzow-Süd mine.

*Note.* Photo by LEAG (n.d.).

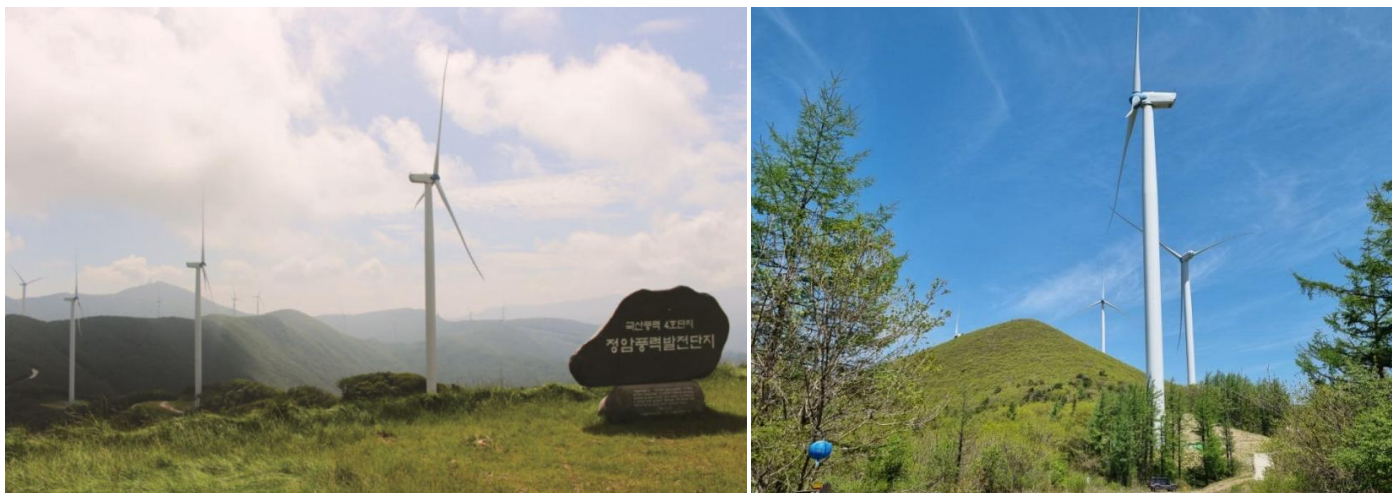
## **(a) Environmental transformations and socioeconomic roles of energy in South Korea**

Although Korea's transition to renewable energy in post-mining areas began later than in Lusatia, there are notable examples of energy transformation. In 2018, the Jeongam wind farm was constructed in the post-mining region of Jeongseon, Gangwon province (J. Kim, 2018; Fig. 6). The facility was not built directly on former mine sites, as wind farms cannot be installed on underground mines. However, this project was still influenced by past mining activities, particularly due to the risk of potential subsidence. Despite this challenge, the wind farm's 14 turbines generate enough electricity for about 2,200 households each year, helping to revitalize the local economy. In addition, a trekking course, called 'Celestial Wind Trail', was developed as a new tourist attraction (Cho, 2023). More recently, in 2023, Korea East-West Power signed a business agreement with Gangwon Land and Youngjin E&R to develop a wind farm in post-mining areas in Jeongsun. They planned to construct a 100 MW wind farm to further revitalize the community (J. Kwon, 2023).

In the case of solar energy, the Ministry of Trade, Industry and Energy (MOTIE) announced the 'Solar Mine' project in 2017, aiming to generate revenue through solar power generation on mining wasteland and return the profits to local revitalization (Ministry of Trade, Industry, and Energy, 2017). A waste rock pile from Hambaek mine in Jeongsun was selected as a pilot site (Fig. 7). However, the project ultimately resulted in only one PV development at Hambaek, as its economic viability proved lower than expected (J. Kim, 2020). This was largely due to MOTIE's 2018 decision to reduce the Renewable Energy Certificate weight for forest-land PV projects from 0.7–1.2 to 0.7, which directly undermined the financial feasibility of further developments (Ham, 2018; J. Kim, 2020). Moreover, unlike Lusatia's vast opencast post-mining lands, Korea's small underground mining wastelands offer little potential for large-scale profits.

Beyond solar and wind energy, Taebaek City has launched 'ECO JOB CITY Taebaek', an integrated renewable energy and cultural development project to rebuild the post-mining region (Korea Coal Corporation, 2018; Taebaek Mayor, 2024). As part of this urban regeneration new deal, the project includes a Forest Resource Renewable Energy Town. Current construction works include an unused forest biomass collection center, a small-scale district heating grid, and a wood pellet power plant.

In the scenario of replacing coal with renewable energy in Korea, 92,000 additional jobs are projected annually during 2026–2030 compared to current policy plans (Climate Analytics & Solutions for Our Climate, 2021). Job creation by renewable energy transition is expected to more than offset coal-related job losses in all provinces, providing net employment benefits even in coal regions. In addition, the value-added effect is estimated at approximately 65 billion euros during 2020–2034 based on the government's renewable energy targets (C.-Y. Lee, 2021). However, most existing studies focus on the economics of coal-fired power plants, while coal mining regions are often overlooked in discussions of Korea's renewable energy transitions. Fig. 8b illustrates the difference in job creation between the current policy scenario and the coal phase-out scenario (Climate Analytics & Solutions for Our Climate, 2021). Yet, these projections are not aligned with coal mining regions (Fig. 8a). For instance, although nearly half of the coal mines are located in Gangwon Province (KOMIR, n.d.), the projected job creation is the lowest in Gangwon among all regions.



**Figure 6 Left: Jeongam wind farm in Jeongsun, Gangwon province; Right: Hiking view of Jeongam wind farm.**

*Note.* Left photo by Jeongi Seolbi (전기설비) (2019). Right photo by Yunzz (윤쯔) (2024).



**Figure 7 Solar Mine project on the waste rock pile from Hambaek mine.**

*Note.* Photo by J. Kim (2020).

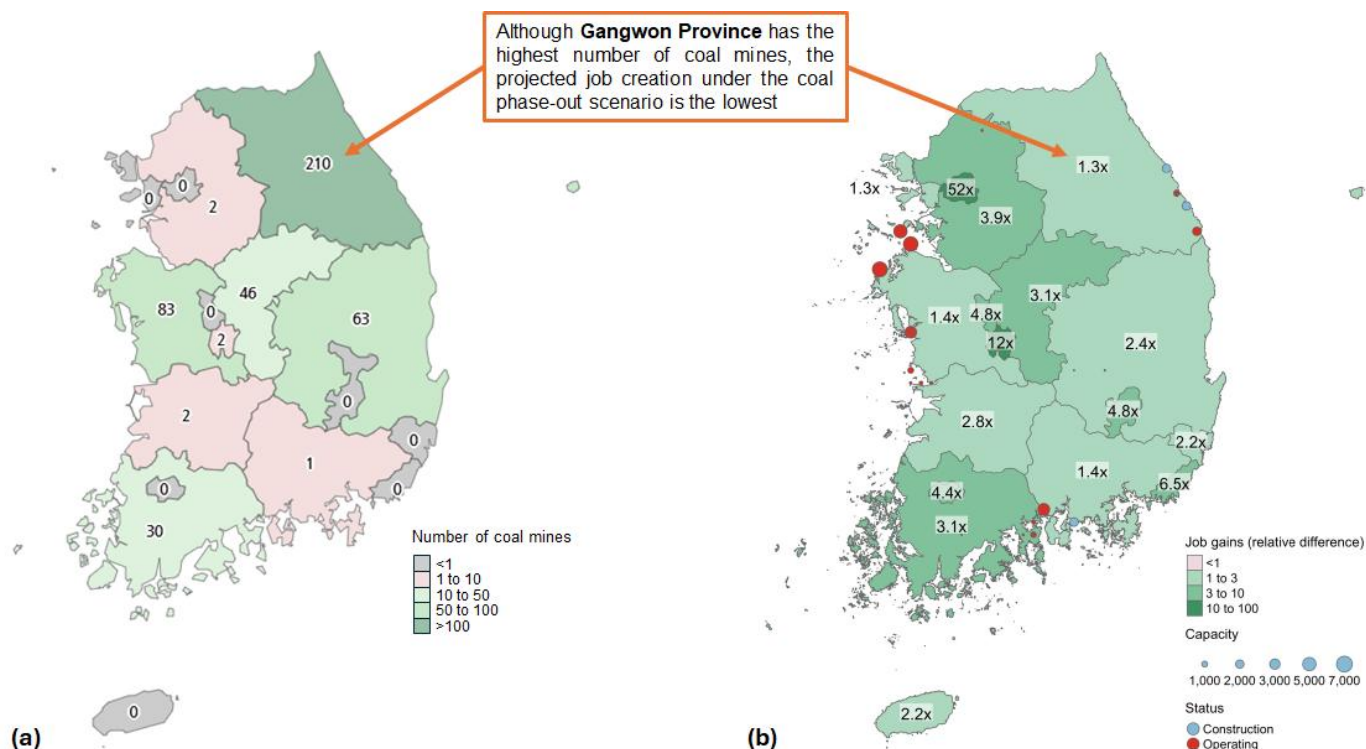


Figure 8 (a) Number of coal mines, both active and inactive, by province. (b) Difference in job creation between the Current Policy and the Coal Phase-out scenarios. “2x” indicates that the Coal Phase-out scenario generates twice as many job-years as the Current Policy scenario. Circles represent the capacity and location of coal power plants. Note. (a) Data source by KOMIR (n.d.) and illustrated by Y. Ok. (b) Climate Analytics & Solutions for Our Climate (2021).

## (b) Comparison of Lusatia and South Korea

Lusatia has been transforming from a traditional lignite-mining region into a developed renewable energy hub. Large-scale installation of renewable energy facilities has been ongoing, and post-mining areas offer significant potential for further development. The combined potential of wind, PV, and bioenergy in Lusatia exceeds projected future electricity demand, underscoring opportunities to export power to neighboring metropolitan areas such as Berlin and Dresden (Hirschl et al., 2022).

On the contrary, Korea has only a few cases of renewable energy projects in former mining areas. This difference is closely related to the mining methods used in each region. Most mines in Korea are underground mines, whereas Lusatia’s lignite mines are open-cast. Consequently, post-mining areas in Korea are generally smaller than those in Lusatia, making it more difficult to deploy large-scale renewable energy installations. J. Kim (2020) noted that the lack of government attention to renewable energy projects in such areas could be linked to the difficulty of constructing large-scale PV plants. Furthermore, Korea’s post-mining lands are often susceptible to subsidence due to underground mining (D.-K. Lee et al., 2013b). The Jeongam wind farm project, for example, also struggled with subsidence concerns in the post-mining area (J. Kim, 2018).

Despite these challenges, discussions and initiatives for developing renewable energy facilities on mining wasteland in Korea are underway. To facilitate these efforts, supportive policy measures are needed. For example, differentiated Renewable Energy Certificate weights could be applied to PV projects on mining wastelands, instead of assigning them the same weights as projects on ordinary forest-land. More broadly, the utilization of wastelands and abandoned facilities for renewable energy production should be actively promoted.

## 2.02 Water

Mining activities are closely linked to water. During the excavation of coal, groundwater is pumped out and discharged on the surface. This discharged water can contaminate the surface and groundwater due to a high load of total suspended solids, total dissolved solids, hardness, or metals (Tiwary, 2000). Even after a mine closes, the cessation of pumping can lead to acute contamination of hydrogeological environments (Banks et al., 1997). As groundwater rebounds to its original level, it can inundate low-lying areas, mobilize and transport contaminants, cause subsidence in shallow workings, increase mine gas emissions, and cause acid mine drainage (Banks et al., 1997). At the same time, however, water can also play a positive role in reshaping post-mining areas. This section discusses how water has influenced the transformation of post-mining landscapes and communities.

### (a) Environmental transformations and socioeconomic roles of water in Lusatia

In Lusatia, water resources have been central to reshaping the post-mining landscape. By the late 1990s, former mining pits were flooded to create artificial lakes, aiming to transform the region into a growing tourist destination (Deshaies, 2020). These developments feature beaches, boating, water activities, marinas, cycling routes, and heritage sites. The first large-scale lake created in the lignite mines in Lusatia was Lake Senftenberg (Irimie, 2019). It was formed by flooding the former Niemtsch lignite mine after its closure in 1972 (Lausitzer Seenland, n.d.-c). It features 7 km of sandy beaches with water sports facilities. Until recently, this lake was the largest in the region at 1,300 hectares. Lake Sedlitz now holds the record, covering 1,418 hectares. This lake has been flooded since 2005 and is expected to be full by 2025.

Since 2015, several mining lakes around Senftenberg have been connected by canals, allowing visitors to sail from one lake to another (Deshaies, 2020). Currently, 4 lakes – Lake Senftenberg, Lake Geierswalde, Lake Partwitz, and Lake Großbräschen – are connected by navigable waterways, with further expansions planned (Lausitzer Seenland, n.d.-c). As of 2025, 8,978 hectares of reclaimed mining areas have been converted into water areas or designated for future water areas (Coal Industry Statistics, 2025). Today, the Lusatian lake districts consist of 32 lakes and 3 additional water areas, making it Europe's largest artificial lake land (Elliott, 2025; Lausitzer Seenland, n.d.-c; Figs. 9-10).

This lake district is becoming an increasingly recognized tourist destination, crucial to Lusatia's economy (Fig. 11). In 2019, the Lusatian lake district generated 265 million euros in gross tourism revenue, contributing 122 million euros to regional income (Sporer et al., 2021). This amount corresponds to the average primary income of approximately 6,370 people. And it attracted 311,347 tourists in 2024, a 5.7% increase compared to 2019 (Lausitzer Seenland, n.d.-d). Furthermore, as four additional large lakes are planned to be opened to the public, it will further boost tourism revenue (Tiedt, 2024). Nevertheless, the long-term economic impact of tourism remains uncertain. To maximize the benefits from the lakes, continuous maintenance and creation of tourist values that encourage repeat visits are essential.

Although the creation of these lakes marks a significant achievement, some water-related challenges remain in Lusatia's post-mining transition. According to Nixdorf et al. (2016), half of the mining lakes in Lusatia showed very high acidity, with pH values between 2 and 4. This acidity results from acid mine drainage caused by pyrite oxidation (Banks et al., 1997; Gerwin et al., 2023). Acid mine drainage creates extreme lake environments with limited biological activity (Hüttl, 1998) and also poses serious risks to both groundwater and surface waters (Gerwin et al., 2023). To address these problems, remediation measures such as liming have been implemented to improve water quality for aquatic life and human recreation (Elliott, 2025; Gerwin et al., 2023).

In addition to water quality concerns, water scarcity has emerged as a major issue following mine closures. For more than a century, groundwater pumped from lignite mines has increased runoff in the Spree River, supporting water supply in Lusatia and even contributing to Berlin's drinking water system (Uhlmann et al., 2023). Pumped groundwater accounts for half of the water carried in the Spree by Cottbus and up to 75 percent during the summer months. After 2070, with post-mining measures, the annual water deficit of the Spree is projected to be 95 million m<sup>3</sup> in Saxony and 126 million m<sup>3</sup> in Brandenburg. This projected shortage reflects the cessation of groundwater pumping, compounded by artificial lake filling and climate change.

Recent climate changes have already affected Lusatia's water resources in multiple ways. For instance, Brandenburg experienced severe water shortages due to an increase in the number of summer days (Gerwin et al., 2023). Looking ahead, projections under the RCP 8.5 scenario suggest that annual precipitation in Lusatia will rise by 11.1%, along with more frequent heavy rainfall events. At the same time, higher air temperatures are expected, which will intensify evaporation and reduce surface and soil water availability. These climatic pressures are further compounded by the environmental legacy of opencast mining, which has reduced vegetation cover and limited the region's capacity to retain water. Taken together, these challenges highlight the urgent need for integrated water management that considers altered hydrological conditions after mine closures and the projected impacts of climate change.



Figure 9 Map of the Lusatian lake districts (German: Lausitzer Seenland). The inset in the upper left shows its location within Germany, while the main map depicts the artificial lakes and water bodies in the region. Note. Figure by Lausitzer Seenland (n.d.).



Figure 10 Aerial view of the Lusatian Lake district.

Note. Photo by Lausitzer Seenland (n.d.-a).

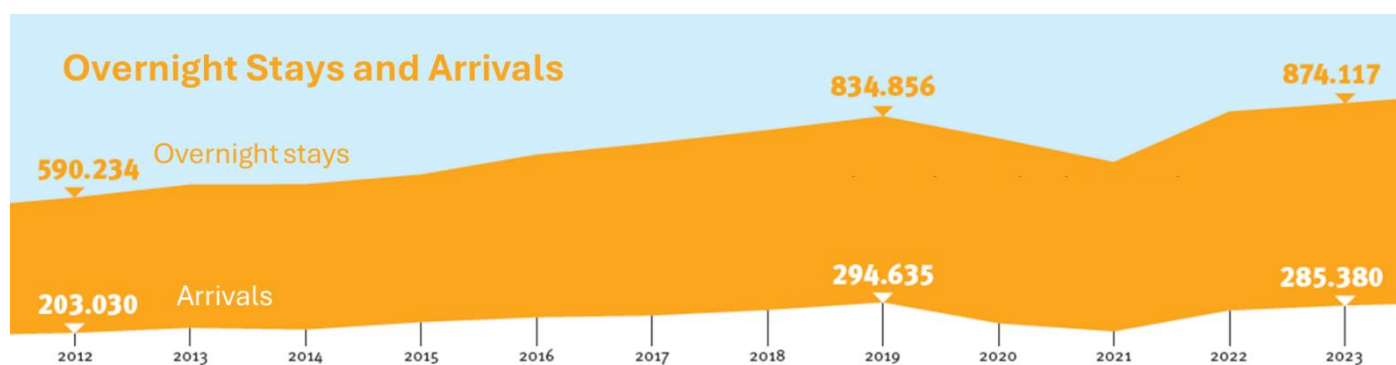


Figure 11 Overnight stays and arrivals in the Lusatian Lake District.

Note. Adapted from Lausitzer Seenland (n.d.-d).

## **(b) Environmental transformations and socioeconomic roles of water in South Korea**

In Korea, flooding former mines often poses more problems than opportunities. Flooding underground shafts after closure is a common measure, as pumping out groundwater is costly. However, in several cases, flooding plans have sparked conflicts with locals and mine reclamation agencies.

One notable example is the Hwasun Coal Mine, Korea's first coal mine. Following its closure in 2023, the Korea Mine Rehabilitation and Mineral Resources Corporation (KOMIR) announced plans to flood the shafts with groundwater to prevent subsidence and collapse (Cheon, 2023; H. Lee, 2024). KOMIR stated that it would remove only movable materials, such as remaining oil and mine carts, while leaving other underground facilities due to safety, cost, and time constraints. This plan has drawn opposition from Hwasun County, the Association of City and County Council Chairpersons of Jeollanam-do, and locals. They raised concerns about potential contamination of groundwater and surrounding waters if most coal mine structures remain before flooding. In addition, residents emphasized the cultural and historical value of the mine and called for alternative development strategies. The Hwasun County Mine Closure Countermeasures Committee continues to demand the complete demolition of shaft facilities before flooding to prevent environmental pollution and ensure a safe post-mining transition (M. Park, 2025).

A similar conflict arose over the closure of Jangseong Coal Mine in Taebaek City. Residents protested against KOMIR's flooding plan, stressing that underground mines represent a valuable industrial and cultural asset (H. Kim, 2023b; S. Park, 2024). They argued that abandoned mines hold limitless potential, including storage facilities, tourism sites, and for military training. Additionally, they emphasized that flooding the shafts without proper review would cause substantial losses at both the local and national levels.

Water pollution from mine drainage has also been a persistent issue (Fig. 12). In Taebaek City, only 26% of mine drainage sites are equipped with purification facilities, while water from the other 23 drainage sites flows directly into upstream rivers (Bae, 2023b). In addition, acid mine drainage is a serious problem in Korea, similar to Lusatia. According to W. Choi (1997), the pH of the mine drainage from 10 abandoned coal mines was between 2.6 and 6.5; in five of these mines, the drainage was highly acidic with a pH below 4. Therefore, proactive measures are required both to prevent pollution and to harness water from mines as a resource.

In Korea, there have been a few cases of mine water utilization. At the former Hambaek mine, drainage water is treated through a purification system and repurposed to produce artificial snow at a nearby ski resort and to supply swimming pools, while the filtered sludge is reused as a cement additive. (S. Park, 2023). In another case, Boryeong City sought to use water from three closed mines for domestic supply during a severe drought (E. Lee, 2015a; Seo, 2015). Approximately 1,000 tons of water flowed daily from these mines, enough to cover 4-5% of the city's tap water demand. Initial tests by the city suggested that natural purification in a nearby stream, followed by treatment at a purification plant, would make the water safe for drinking. However, after several weeks, excessive levels of metals, bacteria, *E. coli*, color, and turbidity were detected in the water from two of the mines (M. Kim, 2015; E. Lee, 2015b). As a result, the city abandoned plans to use water from the two problematic mines and decided to utilize only water from the Myeongcheon-dong mine, which was deemed suitable for drinking, as an alternative water source during future shortages.

Although the economic value of these applications has not yet been reported, this approach could potentially be extended to various other industries. Korea is a manufacturing-centered country, ranking second in the world in the share of manufacturing in GDP (Hong, 2025). Consequently, water shortages for industries, such as semiconductor clusters and petrochemical complexes, have become a growing concern (KBS News, 2023; SBS News, 2025). In this context, properly treated mine water could serve as an alternative water source for industrial use.



Figure 12 Left: red water phenomenon caused by mine drainage in Gangneung. Right: Jijirigol in Taebaek, polluted by mine drainage.

Note. Left photo by K. Choi (2025). Right photo by Bae (2023b).

## (a) Comparison of Lusatia and South Korea

While both Lusatia and Korea have adopted flooding as a post-mining strategy, their outcomes have been markedly different. In Lusatia, former open-cast mines were transformed into mining lakes, reshaping the regional landscape. The Lusatian lake districts have become Europe's largest artificial lake areas, contributing to the local economy through tourism. This economic potential is expected to grow further as additional lakes are opened to the public. In contrast, the flooding of underground mines in Korea has raised community concerns about pollution and the loss of cultural assets. Moreover, problems related to mine drainage remain unresolved, and the economic potential of mine water has yet to be realized.

Although Korea's underground mine cannot replicate Lusatia's approach of creating mining lakes, they both face the same challenge of water quality, particularly acid mine drainage. They can therefore benefit from sharing experiences and research on mine water treatment and management. Furthermore, Korea can draw lessons from Lusatia's experience in implementing projects that benefit local communities. In Korea, mine reclamation agencies' plans often do not align with the expectations of local governments and residents. Local communities advocate for alternative uses of underground facilities, whereas KOMIR insists on flooding closed mines due to the high costs of drainage. For a just post-mining transition, however, community perspectives must be taken into account. The potential utilization of underground mines should be carefully assessed in terms of long-term economic benefits and cultural value, and the industrial utilization of mine water should be actively explored. Achieving this requires the active participation of diverse stakeholders, including local communities.

## 2.03 Land and soil

When determining the future land use of post-mining areas, soil characteristics are among the first factors to be considered. Mining alters the physical, chemical, and biological properties of soils (Alekseenko et al., 2025; Krümmelbein et al., 2012). In addition, underground structural changes and groundwater withdrawal can cause subsidence (Lee et al., 2013b). Because mining leads to soil pollution and land degradation, reclamation must precede any new use of mining wasteland.

### (a) Transformation of land and soil in Lusatia

Lusatian soils are predominantly sandy, with low water and nutrient retention due to the nature of their parent rock (Gerwin et al., 2023). As a result, their agricultural use is limited, and large parts of the region are covered by forests adapted to poor soil quality and water stress.

Reclamation of Lusatia soils presents various challenges. Soil development at post-mining sites begins with the translocation of overburden materials into former mine casts (Fig. 13). A major challenge in this process is soil acidification caused by Tertiary substrates. During excavation, the high pyrite content in these substrates oxidizes, releasing iron ions and sulfuric acid (Krümmelbein et al., 2012). This pyrite oxidation leads to severe acidification, creating hostile conditions for plant growth, generating acid mine drainage, and contributing to the acidification of groundwater and nearby lakes. To address these problems, such soils require heavy amelioration through applying large amounts of calcareous materials (Gerwin et al., 2023). In contrast, Quaternary substrates do not contain lignite or pyrite and generally do not cause acid drainage (Krümmelbein et al., 2012). For this reason, they are often used to cover Tertiary substrates or mixtures of Tertiary and Quaternary materials deposited at the base of reclamation sites. However, both Quaternary and Tertiary substrates are sandy and poor in nutrients. Moreover, all substrates lack structure due to repeated mechanical disturbance during mining and site preparation.

Therefore, soil amelioration is necessary to recultivate this post-mining land. For the amelioration of sulfuric substrates and buffering acid production, lime and brown coal ash are commonly applied (Krümmelbein et al., 2012). In addition to pH correction, establishing a closed nutrient cycling system is vital for creating a sustainable ecosystem. Various fertilizers can be used to supply nitrogen, phosphorus, and potassium. The application of soil organic matter and topsoil helps compensate for the lack of recent organic carbon in most substrates of Lusatia. Furthermore, inoculating rhizosphere bacteria and mycorrhizae can further improve soil quality.

After basic soil amelioration, further treatments can be applied depending on the purpose of the recultivation. Based on characteristics of reclaimed soils, suitable tree or crop species are selected, and further measures such as tillage, deep loosening, or additional fertilization may be implemented (Krümmelbein et al., 2012). Despite these efforts, the soil quality of post-mining areas in Lusatia generally remains limited (Gerwin et al., 2023). As a result, most post-mining land is used for forestry, while only areas with more favorable properties, such as sites with glacial till, can be restored for agricultural use.

Land and soil serve as critical foundations for generating economic value in post-mining regions. Consequently, substantial investments are directed toward land and soil reclamation. Each year, about 500 hectares of land are claimed for mining, and an equivalent area is simultaneously recultivated (Vattenfall, 2012). These recultivated lands often take on new land uses that differ from their previous functions (Fig. 14). Notably, the share of agricultural land in reclaimed areas tends to decline, water areas increase, and forest areas remain relatively constant (Krümmelbein et al., 2012; see Fig. 14). Although such land-use changes are closely linked to the Lusatian economy, research on the economic role of land use and soil remains limited.



Figure 13 At the Nochten II opencast mine, soil is being spread over the mining wasteland for recultivation.

Note. Photo by Y. Ok.

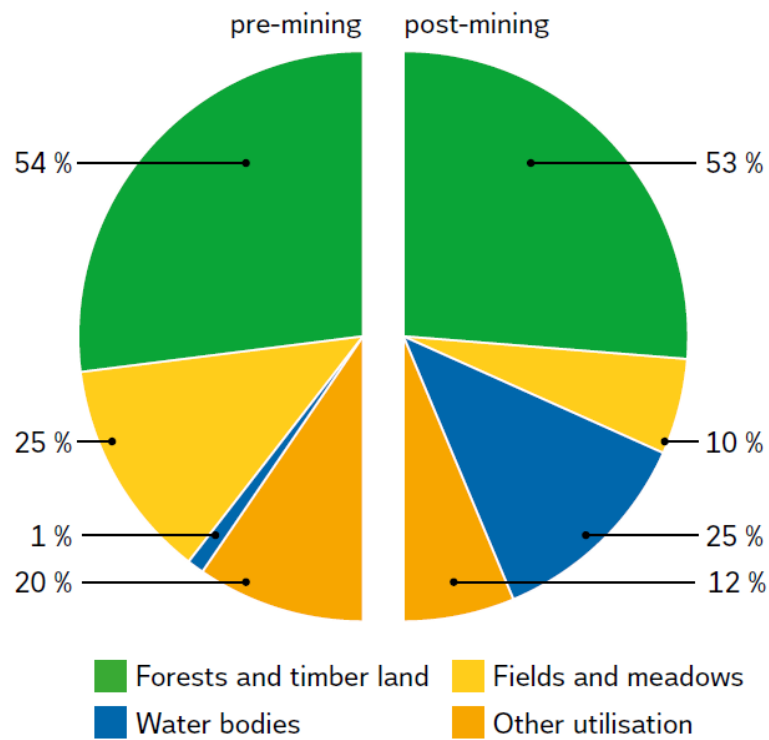


Figure 14 Land-use of the pre-mining and post-mining areas.

Note. Figure by Vattenfall (2012b).

## **(b) Transformation of land and soil in South Korea**

Korea faces several challenges related to post-mining land and soil. According to a survey on soil contamination around abandoned coal mines, metal pollutants were detected in several areas surrounding closed coal mines in Gangwon Province (Ministry of Environment & Korea Environment Corporation, 2010). Among 151 closed coal mines in Gangwon Province, 38 exceeded the soil contamination concern level for six metals, including arsenic and cadmium. Among these, nine sites exceeded the more serious countermeasure threshold. The contaminated sites were distributed across various land use types: 29 forest lands, 21 arable lands, 2 paddy fields, and 5 classified as other areas.

Beyond contamination, soil quality in reclaimed post-mining forests also presents limitations. Jung et al. (2010) reported that reclaimed forests in post-mining areas generally exhibited lower levels of total organic carbon and nitrogen than natural forest soils. Unlike the typically acidic soils of Lusatia, the pH value in these reclaimed sites in Korea ranged from 4.2 to 8.1, with an average of 5.5, which is similar to natural forest soils. Despite this, the overall soil conditions in post-mining forests remained unfavorable for vegetation growth, underscoring the need for continuous management and restoration efforts.

In addition to soil degradation, ground subsidence poses a major issue in Korea. Because the caving method was widely used in underground mining, post-mining areas remain highly vulnerable to ground subsidence (D.-K. Lee et al., 2013b). 349 subsidence incidents have been recorded, including 9 cases at operating mines and 340 at closed mines. Such subsidence can extend beyond the mine sites, posing risks to nearby areas and hindering revitalization projects in post-mining regions.

To address these challenges, the KOMIR has taken a leading role in mine reclamation in Korea. Between 2023 and 2025, KOMIR conducted subsidence prevention projects in closed coal mine areas with a budget of 1.3 million euros (KOMIR, n.d.). During the same period, 2.5 million euros were allocated to forest soil reclamation and 3.2 million euros to soil improvement and restoration projects. These investments are essential for ensuring the safety of residents and for the recultivation of agricultural and forest lands.

Transformations of land and soil in Korea are closely tied to mine waste, as soil amelioration is typically applied to mine spoils to prepare them for other uses. Reclamation measures include leveling the slopes of mine waste dumps, covering them with soil, and then sowing seeds or planting trees (National Institute of Forest Science, 2013; Fig. 15). To prevent waste rock erosion, tree planting is often combined with microbial inoculation to enhance root establishment (E. Lee, 2014; Y. Lee, 2016). In reforestation projects on coal mine spoils, organic fertilizers are applied to address the low organic matter content and low pH of the soils (B.-S. Lim et al., 2022). For agricultural land use, soil covering techniques are particularly important to prevent the transfer of metals from contaminated soils to crops (Koh et al., 2023; J. Lee, 2017).

Meanwhile, climate change adds further complexities to post-mining rehabilitation, particularly in land and soil reclamation. Over the past 30 years, the average temperature in Korea has risen by 1.4 °C compared to the early 20th century, while annual precipitation has increased by 124 mm (National Institute of Meteorological Sciences, 2018). Future projections indicate a temperature rise of 2.6-7.0 °C and a 3-14% increase in precipitation by 2081-2100, along with more frequent extreme rainfall events (National Institute of Meteorological Sciences, 2020). These changes are likely to influence post-mining rehabilitation, as increases in annual precipitation and extreme rainfall may enhance rainfall erosivity (Bulovic et al., 2024). To mitigate these risks, measures such as reducing slope gradients, planting various vegetation, and improving soil stability can be applied. Given these climate-related pressures, it is essential to integrate climate resilience into reclamation and recultivation plans.



Figure 15 Left: slope grading of mine waste dump. Right: planting pine seedlings inoculated with *Pisolithus* for mine waste dump restoration.

Note. Left photo by National Institute of Forest Science (2013). Right photo by Y. Lee (2016).

### (c) Comparison of Lusatia and South Korea

Both Lusatia and Korea face challenges with soil and land in post-mining areas. In Lusatia, soils of mining wastelands are characterized by acidification from pyrite oxidation, low nutrient levels, and limited organic carbon. In Korea, soils of post-mining land vary more widely in pH but often have risks of high metal content and low organic matter. Although Korea has its own soil-related challenges, unlike in Lusatia, soil quality is not usually emphasized in research as a major barrier to reclamation. Instead, subsidence receives greater attention in Korea's reclamation plans than in Lusatia, reflecting the widespread use of underground mining techniques.

Despite vast reclamation efforts, neither Lusatia nor Korea reports the economic benefits derived from post-mining land and soil. Land and soil are generally regarded as targets of investment for reclamation, primarily to prevent potential environmental or safety hazards. However, such reclamation efforts form the foundation for creating economic value from other resources.

Regarding land-use change, Korea lacks precise data on the extent of mining areas, likely due to the dispersed and small-scale features of mines. In contrast, land-use changes in Lusatia reveal distinct differences between historical and current land-use practices, reflecting the region's evolving post-mining economy. Nevertheless, research on the relationship between land use and economic transformation remains limited.

## 2.04 Biota and food

Biota comprises living plants, animals, and microorganisms within a region (Brouwer et al., 2024). And food is inherently part of biota, as it is derived from living organisms. Since agriculture, forestry, and fishing are typically grouped as a single sector in statistical reporting, this report addresses biota and food together within the same section.

Mining activities disrupt biota through diverse paths. Mineral extraction can destroy or degrade habitats, while toxic chemicals and acids released during mining further threaten biodiversity (Sonter et al., 2018). Coal mining, particularly, caused the loss of 335,700 hectares of global forest between 2000 and 2019, accounting for 34% of the total mining-induced direct deforestation area (Kramer et al., 2023). In response to these impacts, increasing attention is being directed toward ecological restoration and nature conservation in post-mining landscapes.

Mining also poses significant risks to regional food security. Mining and agriculture compete for land and water resources (Simpson et al., 2019). In addition, mining-related water pollution, land degradation, and trace element contamination further compromise the safety and productivity of food systems (Blanco et al., 2023; Krümmelbein et al., 2012; Simpson et al., 2019). Nevertheless, with appropriate management, post-mining lands can provide opportunities for agricultural use and contribute to regional food resilience.

### (a) Transformation of biota and food in Lusatia

Before mining changed Lusatia's landscape, the region was characterized by extensive bogs and fens (Krümmelbein et al., 2012). However, most of these wetlands have been severely degraded by groundwater lowering, and today, only a small remnant of the marshlands and floodplain remains. As of 2024, a total of 90,900 hectares of land have been used for lignite mining (Coal Industry Statistics, 2025). Mining operations destroyed and degraded large parts of the excavation areas, causing severe impacts on biota. Yet, since mine closure, signs of recovery have been observed in Lusatia's degraded ecosystems.

Forest cultivation has played a crucial role in reclaiming these post-mining landscapes (Fig. 16). Of the 60,373 hectares of reclaimed land, forestry recultivation accounts for 54% (32,843 hectares) (Coal Industry Statistics, 2025). For forest recultivation, the available geotopes are classified according to texture, brown coal and lime content, and plant-available water (Krümmelbein et al., 2012). Suitable tree species are selected based on the dumped substrate, trophic level, humidity, and growing-stock objective (Houbold-Rosar & Knoche, 2007). Over time, the main tree species planted for recultivation have changed, from pioneer species like birch to other species, including red oak, fast-growing pine, and eventually broadleaf trees selected to reduce the risks of forest fires and insect outbreaks (Hüttl, 1998). Today, pine (*Pinus*) remains the dominant tree in Lusatia's recultivated forests (Krümmelbein et al., 2012). However, multi-species stands play an important role in soil development by enhancing bioactivity and improving water and nutrient balance. Looking ahead, the selection of tree and crop species should prioritize adaptability to local environmental conditions and resilience to future climate change, ensuring long-term sustainability of post-mining landscapes.

Although Lusatian soils have limited agricultural use due to poor water and nutrient retention, 10,741 hectares of Lusatian former mining areas have been converted into agricultural land, accounting for 18% of all reclaimed areas (Coal Industry Statistics, 2025; Gerwin et al., 2023). For agricultural recultivation, substrates are classified into seven classes, and revegetation treatments are applied accordingly (Krümmelbein et al., 2012). To ensure soil fertility, at least one meter of coverage is necessary for agricultural use (LMBV, 2020). Depending on site conditions, additional measures may be necessary, such as liming to adjust pH, as well as leveling and surface preparation to reduce soil compaction. Based on these treatments, suitable crop rotations are developed. Selected crops should not place high demands on substrate structure or nutrient cycling

and should use water efficiently (Krümmelbein et al., 2012). Successful examples of crop rotations on reclaimed land include sweet clover, winter rye, alfalfa, winter barley, and rapeseed.

Viticulture offers another compelling example of transforming post-mining land into productive agricultural use. The Wolkenberg Vineyard, established on the former Welzow-Süd open-cast mine, cultivates around 26,000 vines and produces around 30,000 bottles of wine annually (Richter, 2022; Thread, n.d.; Vattenfall, 2012; Fig. 17). Similarly, Winery Dr. Wobar operates on the former Meuro open-cast mine (Lausitzer Seenland, n.d.-e). These post-mining vineyards not only contribute to local wine production but also support the regional economy and new images by attracting visitors through wine tours, festivals, and harvest events.

Recently, vertical farming has gained increasing attention as a promising solution for food production in Lusatia, where soil conditions pose challenges for conventional agriculture (Gerwin et al., 2023; Krümmelbein et al., 2012). Vertical farming is a method of growing crops in vertically stacked, soilless systems and requires fewer resources than traditional agriculture (Van Delden et al., 2021). Recognizing its potential, UNU-FLORES has launched a vertical farming project in Lusatia's post-mining landscape to enhance local food production and support the regional economy (UNU-FLORES, 2025). As a part of the initiative, partnerships were established with a local kindergarten, a company, and the Nochten Boulder Park to gather data on resource efficiency and assess social acceptance of vertical farming systems (Fig. 18).



**Figure 16** Afforestation on the former opencast mine Berzdorf in 2008.

*Note.* Photo by LMBV (2020).



Figure 17 Wolkenberg Vineyard in the former mining overburden.

Note. Photo by Thread (n.d.).



Figure 18 Vertical farming at the local kindergarten in Lusatia.

Note. Photo by MDR (2025).

Aside from planned recultivation, unique biotopes have emerged in Lusatia's barren mining wastelands. Opencast mining influences the regional-level climate by creating vast areas without vegetation. With relatively low wind speeds, these areas experience lower temperatures during the night and higher temperatures during the day (Krümmelbein et al., 2012). Under such conditions, abandoned opencast mines have developed unique ecosystems of high conservation value. In addition, the absence of human intervention in the post-mining areas has allowed natural succession and the return of wildlife. Harsh site conditions create low competitive pressure, meaning that only specialist species capable of tolerating such environments can survive. Recognizing this, conservationists have advocated for protecting these nutrient-poor post-mining lands (NABU-Stiftung Nationales Naturerbe, n.d.). Large-scale restoration in these areas has therefore focused on minimizing human intervention and associated costs while ensuring long-term conservation value (Heinz Sielmann Stiftung, n.d.).

One conservation example is Sielmann's Nature Landscape Wanninchen, a protected area established on former open-cast mining sites in Lower Lusatia (Heinz Sielmann Stiftung, n.d.; Fig. 19). Covering 3,300 hectares of lakes and extensive open areas, it provides vital habitats for a wide range of rare species (Heinz Sielmann Stiftung, n.d.). Another example is the Grünhaus nature reserve, created on former mining sites in Klettwitz and Kleinleipisch. More than 3,000 plant and animal species have returned to Grünhaus, including wolves, hoopoes, rare insects and amphibians, and orchids (NABU, n.d.). Much of the area has been incorporated into the Niederlausitz Heath Landscape Nature Park (NABU-Stiftung Nationales Naturerbe, n.d.). Both Wanninchen and Grünhaus are also recognized destinations for birdwatching and nature tourism.



**Figure 19** Thousands of cranes use the shallow waters as a resting and roosting area in Sielmann's Nature Landscape Wanninchen.

*Note.* Photo by Heinz Sielmann Stiftung (n.d.).

Gross value added from agriculture, forestry, and fishing in Lusatia has shown a slight overall increase despite periodic fluctuations, reaching 688 million euros in 2022 (Fig. 20a). However, employment in this sector accounts for only 2.1 percent of the workforce, the smallest share among all sectors (Fig. 20b). While its economic contribution is relatively small, recultivation and conservation efforts play a vital role in shaping Lusatia's regional identity. Moreover, innovative approaches to biota and food, such as vertical farming and energy crop cultivation, can offer promising opportunities to increase economic value in post-mining landscapes.

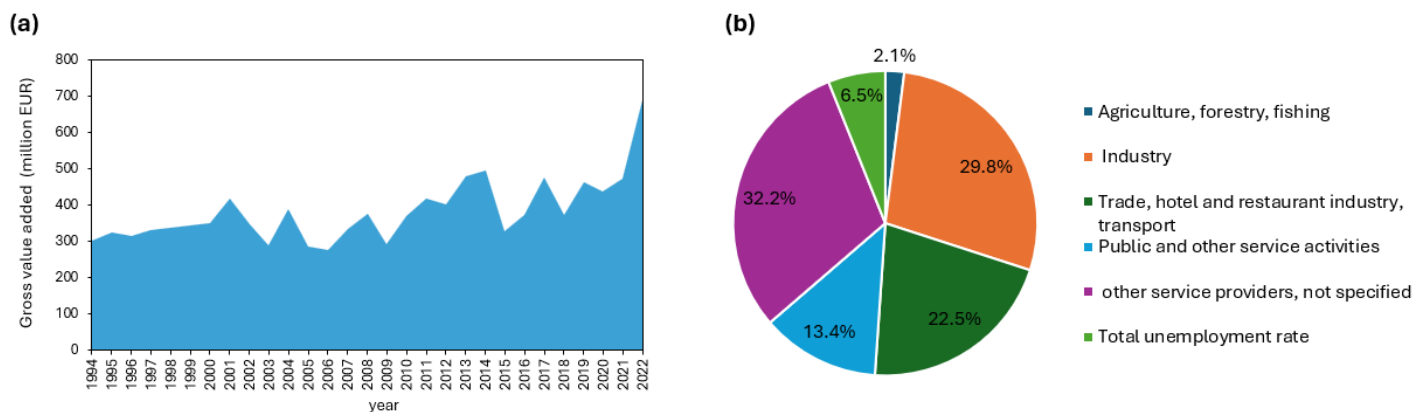


Figure 20 (a) Gross value added at current prices from agriculture, forestry, and fishing. (b) Share of total employment by sector in Lusatia.

Note. (a) Data by Statistische Ämter des Bundes und der Länder (2024). (b) Data by The Federal Returning Officer (n.d.).

## (b) Transformation of biota in South Korea

Mining activity has also affected Korea's biota. According to MOTIE (2022), deforestation was the most common type of mine damage in Korea, accounting for 32% of all reported cases. To restore degraded mining wastelands, Korea has actively pursued afforestation since 1990. The Coal Industry Rationalization Project Group designated 582 forest restoration sites and restored 421 of them (1,152 m<sup>2</sup>) between 1990 and 2003 (Hong, 2003). However, the outcomes of these efforts have been questioned despite significant investment. Early restoration efforts were carried out without sufficient understanding of site conditions or long-term planning. In the early years, full soil recovery was not applied, resulting in repeated damage to the restoration sites (C.-M. Park et al., 2018). Although various techniques to stabilize soils and slopes have been adopted since 1995, early efforts that relied on hastily planted thorny shrubs and limited tree planting fell short of achieving ecological restoration (Hong, 2003; C.-M. Park et al., 2018). One notable example of early forest recultivation is the Jijirigol Birch Forest, established between 1998 and 2000 on the site of the former Hamtae coal mine, which closed in the 1980s (An, 2022a; Fig. 21). Through this project, 20 hectares of mining wasteland were transformed into a birch forest. Today, the site attracts tourists and is also used by locals for trails.

More recently, afforestation has expanded. Between 2007 and 2025, 133 afforestation projects were implemented on former coal mining lands (KOMIR, n.d.). Building on these efforts, MOTIE announced a basic plan for mine reclamation for 2022-2026, presenting a vision of contributing to carbon neutrality through the prevention of mine damage in both coal and metal mining areas (MOTIE, 2022). Beginning in 2026, the plan aims to offset 1,400 t of CO<sub>2</sub> annually by restoring forests on mining wasteland. It also seeks to expand afforestation projects, increase the share of specialized carbon-absorbing forests, and promote the registration and management of forest carbon offset projects.

Although Korea has restored many forests on former mining lands, their utilization remains limited. Restored forests like the Jijirigol Birch Forest in Taebaek attract some visitors, but alone they are not sufficient to serve as major tourism resources. Instead, some post-mining regions have begun leveraging broader biotic resources, such as surrounding natural forests, in combination with mining heritage to create new economic opportunities. A representative example is the 'Untangodo 1330' trail, which includes the Jijirigol Birch Forest as part of a long-distance trekking trail that follows the historic coal transportation route through Yeongwol, Jeongseon, Taebaek, and Samcheok. Over 80% of the Untangodo area is forested, offering rich natural landscapes. By linking mining heritage with surrounding forests, the trail has become a valuable tourism asset, drawing around 6,000 participants during its annual trekking event and many more visitors throughout the year (O. Kim, 2024).



**Figure 21** Jijirigol recultivated forest in Taebaek.

Note. Photo by An (2022a).

In parallel with afforestation, Korea is also working to restore habitats for endangered species to enhance biodiversity and recover ecosystems. The Wonju Regional Environmental Office carried out a habitat restoration project in the Mulhan-ri Valley of Mt. Baegun, a former coal mining stream, by releasing 500 lenoks and 30 pairs of the endangered red-spotted apollo butterfly (I. Lee, 2017; Wonju Regional Environmental Office, 2017). Within two years of the restoration project, evidence of successful adaptation and habitat recovery was observed.

Beyond ecological restoration, Korea has explored innovative uses of post-mining infrastructure for food production. In Boryeong city, button mushrooms are cultivated using cold air and groundwater from abandoned mine tunnels (Baek, 2012; I. Jeon, n.d.; Fig. 22). Even during hot summers, when outdoor temperatures rise above 30°C, the cultivation sites remain at 16–18°C without any cooling systems. This natural cool airflow reduces energy use and improves product quality. In 2022, Boryeong accounted for 20–25% of the national button mushroom production, contributing to the local economy (Baek, 2012; I. Jeon, n.d.). In 2016, 180 farms produced about 2,000 tonnes of mushrooms, generating approximately 10 million euros in revenue (E. Lee, 2016). Furthermore, Boryeong has been designated as a ‘Mushroom Industry Special Zone’ and aims to establish an efficient cultivation environment and strengthen its regional brand identity. It plans to develop industries beyond agriculture, such as mushroom- and mining-themed experiential tourism, as well as research and education ecosystems for sustainable mushroom production. More recently, Boryeong has expanded the use of underground mines to other types of food production, such as bean sprouts and fermented *Jeotgal* (Korean salted seafood).

In addition to indirect use of mine air and groundwater, the direct use of underground shafts for farming has also been tested. At Hamtae mine, which closed in 1993, wasabi cultivation was attempted (S. Park, 2019; Fig. 22). Wasabi stems are mostly imported because of their demanding growing requirements, including average daily temperatures below 20 °C and abundant water. Abandoned mine shafts offer favorable conditions for wasabi cultivation, with consistently high humidity and stable temperatures between 10–15 °C. Since mine shafts are naturally shielded from outside light and heat, the installation of simple partitions, lighting, and irrigation systems can provide suitable facilities for cultivation.

Further expanding agricultural innovation, KOMIR is promoting a smart farm valley project in former mining areas (A. Kwon, 2024). A representative example is Nexton, the world’s largest indoor strawberry farm, established on the former Jangseong mine site. By repurposing abandoned land, the farm has reduced cultivation costs and produces about 130 tons of strawberries annually. Unlike conventional farms that typically produce strawberries only in winter and spring, Nexton cultivates them year-round. As a result, its strawberries are sold at roughly three times the usual market price during summer. However, despite substantial financial support from Taebaek City, concerns have been raised about the company’s limited contribution to the local economy (H. Kim, 2023a). Because its corporate headquarters is registered outside the mining region, Taebaek City does not benefit from local tax revenues.

Employment in agriculture, forestry, and fishing accounts for approximately 1.3 percent of the workforce in the post-mining regions (Statistics Korea, n.d.). While this figure may appear modest, it is notably higher than the national average of 0.3%. This suggests that post-mining areas hold significant potential to enhance regional food security and contribute to the nation’s overall food resilience.



**Figure 22 Left: Button mushroom cultivation using cold air from underground mines. Right: Wasabi farming in an abandoned underground mine shaft.**

Note. Right photo by B. Kim (2025). Left photo by S. Park (2019).

## **(c) Comparison of Lusatia and South Korea**

Both Lusatia and Korea have actively implemented forest recultivation in post-mining areas. In both regions, it took time and trial-and-error to achieve satisfactory ecological restoration (Hong, 2003; Hüttl, 1998; C.-M. Park et al., 2018). Today, forest recultivation plans are examined more carefully, taking site-specific characteristics into account. Moreover, forest recultivation often pursues objectives beyond ecosystem restoration, including nature recreation and carbon credits (Hüttl, 1998; MOTIE, 2022). In both regions, soil reclamation has been identified as the key to successful afforestation (Hüttl, 1998; S.-J. Kim et al., 2023).

In terms of nature conservation, Korea has a few cases of endangered species reintroduction to former mining lands, but such efforts remain limited compared to those in Lusatia. Since many mining areas in Korea are located in forested regions, reclaimed sites could provide potential habitats for wildlife. B.-H. Kim et al. (2000) discovered that forests established on former mining lands contained plant species different from those in nearby natural forests, owing to the distinct environmental conditions of post-mining areas. Further research on wildlife in these reclaimed sites could offer valuable insights into the ecological restoration of post-mining areas in Korea. Furthermore, such areas could be designated as nature reserves, taking the Lusatian cases of natural conservation as a reference.

Based on restorations of biota, nature-based tourism has emerged as a promising economic sector in both regions. In Lusatia, conservation areas established on former mining sites attract visitors, whereas in Korea, natural forests surrounding mining heritage sites are utilized to draw tourists. Moreover, although recultivated forests can provide timber and renewable energy sources, the extent of biomass utilization from restored forests has not been reported in either region. To ensure the sustainable value of restored ecosystems, their use should be carefully planned with due consideration for ecosystem conservation.

Regarding agriculture, while Lusatia has mainly focused on recultivating opencast mining sites to agricultural land, Korea has explored direct and indirect uses of underground mines for food production. In Korea, cold mine air and groundwater are utilized to grow mushrooms and other crops, and smart farming has been tested both in mine shafts and on former mining areas. As soil quality remains the primary challenge for agriculture in Lusatia, smart farming approaches could offer valuable applications there as well. With the recent launch of a vertical farming project, Lusatia has the chance to build on Korea's longer experience in smart farming. In both Lusatia and Korea, abandoned old buildings in former mining communities could be repurposed for vertical farming by making use of remaining infrastructure, such as water and electricity. Drawing on such initiatives, Lusatia and Korea could exchange knowledge and create synergies in regional food production and new economic opportunities in post-mining areas.

## **2.05 Space**

Space is an environmental resource closely linked to the planning and management of land and seas (Brouwer et al., 2024). Space is a valuable resource for human livelihoods, industrial development, wildlife habitats, and many other uses. Mining leaves behind distinctive spaces after closure, including vast mining landscapes, underground shafts, spoil heaps, and associated facilities. These spaces can be repurposed for various functions, including renewable energy production, forestry, agriculture, lakes, and nature reserves, as discussed in previous sections. This section, therefore, focuses on the uses of former mining spaces beyond these functions, emphasizing space itself as a resource.

### **(a) Transformation of space in Lusatia**

Lusatia's open-cast lignite mining created vast disturbed areas and waste heaps, covering a total of 90,900 hectares of land used for extraction (Coal Industry Statistics, 2025). Lusatia has transformed these mining wastelands into diverse new functions, notably as tourist destinations and cultural heritage sites. One prominent example is the Eurospeedway Lausitz, a racetrack built on the site of the former Meuro mine and opened in 2000 (RacingCircuits.info, n.d.). Utilizing around 550 hectares of the former mine, it has hosted numerous international racing events on various tracks. In 2017, the vehicle testing firm DEKRA acquired the entire facility, renaming it DEKRA Lausitzring. Today, it serves Europe's largest automotive testing facility while still accommodating a variety of events.

Another notable example is the Nochten Boulder Park, a botanical garden established on 20 hectares of reclaimed land from the former Nochten opencast mine (Lausitzer Findlingspark Nochten, 2023; Fig. 23). The park showcases around 7,000 erratic boulders transported from Scandinavia during the last Ice Age and later unearthed during lignite mining. These boulders, combined with both native and exotic flora, create a distinctive landscape that reflects the region's geological and cultural history. In 2023, the botanical garden welcomed approximately 61,000 visitors (Weiß, 2024), demonstrating a successful case of creating new value by integrating post-mining spaces with mining waste resources.

In addition to the vast mining sites, industrial facilities also provide valuable space resources. The Werminghoff briquette factory in Knappenrode has been converted into a museum, now known as the 'Knappenrode Energy Factory' (Energiefabrik Knappenrode, n.d.; Fig. 24). It presents an exhibition on the development of the Lusatian mining region, spanning from the beginning of extraction to the post-mining era. By utilizing an actual factory, the museum provides visitors with vivid insights into briquette production and the broader history of lignite mining in Lusatia. In the outdoor area, numerous equipment from the former opencast mines, such as electric mine locomotives and coal wagons, are displayed.

Although Lusatia has begun repurposing its post-mining spaces, the resulting revenue and contributions to the local economy have yet to be fully assessed. In addition, considerable potential remains for utilizing abandoned land and facilities. Following the decline of lignite mining and the outmigration of residents, many residential and industrial buildings were left vacant (Prust, 2024; Verlassenes.de, 2025). Despite their disuse, these structures often remain well-equipped with essential infrastructure such as electricity, sewerage, and road access. With minimal renovation, they hold strong potential for repurposing into a variety of new uses.



Figure 23 Nochten Boulder Park.

Note. Photo by Y. Ok.

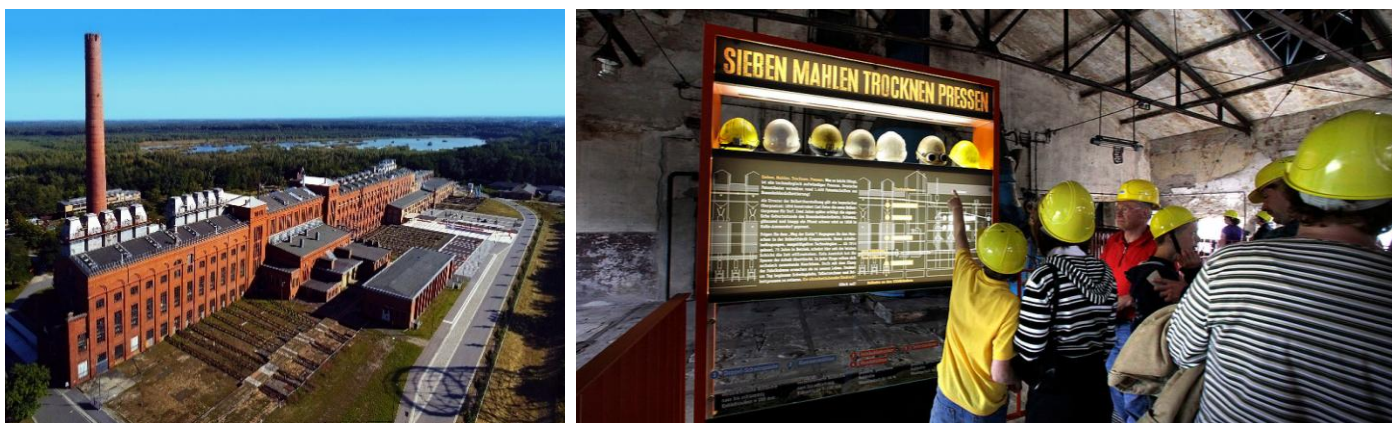


Figure 24 Left: Exterior view of Knappenrode Energy Factory. Right: Factory tour at the Knappenrode Energy Factory.

Note. Photos by Energiefabrik Knappenrode (n.d.).

## (b) Transformation of space in South Korea

Korea has 442 closed mines, all of which are underground except for a single open-cast mine in Yeoncheon (H. Jo, 2016). Underground mining has left behind abandoned shafts, land, and associated facilities that represent valuable space resources.

One of the most prominent transformations of these spaces has been tourism and recreation (Fig. 25). Tongri Tantan Park is a theme park created by repurposing two abandoned shafts of the former Hanbo Coal Mine in Taebaek City. It features interactive digital art exhibitions that depict the past of Taebaek and its coal industry, as well as the future of former mining villages, within two tunnels of 613m and 363m in length. Another recent example is the Boryeong Cool Air Spa, established on the site of the former Yeongbo Coal Mine and opened in June 2025 (Song, 2025). The facility utilizes the mine's naturally low temperatures as a summer retreat. In the first ten days after opening, it attracted more than 10,000 visitors. Visitors can also see exhibits on the

former mine shafts and coal extraction scenes at the entrance. Likewise, several mine shafts have been repurposed as cultural and educational spaces, including the Sabuk Coal Museum, the Taebaek Experience Park Field Study Center, and the Boryeong Coal Museum.

In addition to the reuse of mine shafts, the entire mining town of Cheoram has been transformed into the Cheoram Coal Mine History Town (Y. Lee, n.d.-c). This site preserves the appearance of a mining town in the 1980s. Each building hosts exhibitions on coal mining history, while the exteriors of pubs, restaurants, and grocery stores once frequented by miners have been retained. Similarly, the Mungyeong Coal Museum utilizes the former buildings of the Korea Coal Corporation's Eunsung Mine branch to present the history of coal mining (Y. Lee, n.d.-a).

Despite these efforts, some sites have not attracted as many visitors as expected. Tongri Tantan Park was built with an investment of approximately 7.7 million euros (B. Kim, 2024). Yet it attracted only 40,000 visitors in 2022 and 27,000 in 2023, far below the city's initial target of 125,000 visitors per year. The low turnout has been attributed to the impacts of COVID-19 during the park's early operation period and insufficient promotional efforts. Other tourist attractions in post-mining regions face similar challenges. According to K. Jeon (2014), various coal museums and cultural experiential facilities attract fewer than 30,000 visitors annually. This is largely because similar museums and experiential facilities have been redundantly constructed across different municipalities, diminishing their overall competitiveness. Therefore, qualitative improvements are needed for these facilities to make a meaningful contribution to the regional economy.

Beyond tourism, underground mining shafts offer unique environments that can be repurposed for various uses. In March 2025, the Korea Institute of Geoscience and Mineral Resources (KIGAM) tested lunar resource development equipment in the abandoned shafts of the former Hamtae Coal Mine in Taebaek (N. Lim, 2025; Fig. 26). With limited air circulation, low oxygen, darkness, and low temperatures, these shafts closely resemble conditions on the Moon or Mars, eliminating the need to build costly simulation facilities. KIGAM plans to establish the Taebaek Space Resource Convergence Demonstration Complex, using abandoned mining spaces to test space resource technologies and, eventually, to develop methods for extracting rare resources from the Moon.

Another project utilizing the unique characteristics of underground shafts is planned at the former Jangseong Coal Mine. Taking advantage of its naturally low temperatures, a national artificial intelligence data center is planned to be built at the shaft (Shin, 2025). Situated 200 meters below ground, the facility maintains a constant temperature of 10–15 °C, which can significantly reduce cooling expenses that account for up to 70% of a data center's operating costs. A feasibility study evaluated the site as offering the most suitable conditions for an underground data center, with plans for an investment of approximately 188.5 million euros and the creation of 500 jobs.

Despite these transformations of post-mining spaces, many houses and buildings in post-mining regions remain vacant. To address this, Gangwon Province launched a program to renovate empty buildings and support start-ups by residents and entrepreneurs in former mining areas (Gangwon Province, n.d.). The initiative provides financial assistance for renovation and consulting services for business development. Fig. 27 illustrates renovation projects carried out for vacant buildings.

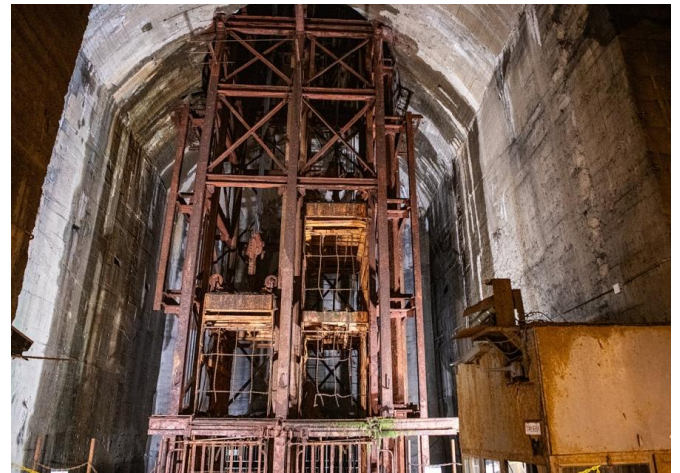
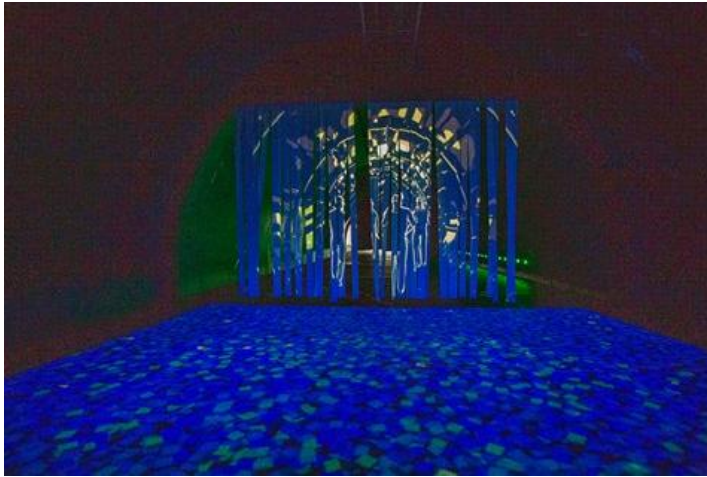


Figure 25 Top: Digital art exhibitions in Tongri Tantan Park, created in the shafts of the former Hanbo Coal Mine. Bottom: Hamtae Coal Mine Tunnel in the Taebaek Experience Park Field Study Center.

Note. Top photo by Ttakkttaguri (딱따구리) (2021). Bottom photo by Captain (캡틴) (2025).



Figure 26 Demonstration of lunar resource development equipment at the former Hamtae underground shaft.

Note. Photo by S. Jo (2025).

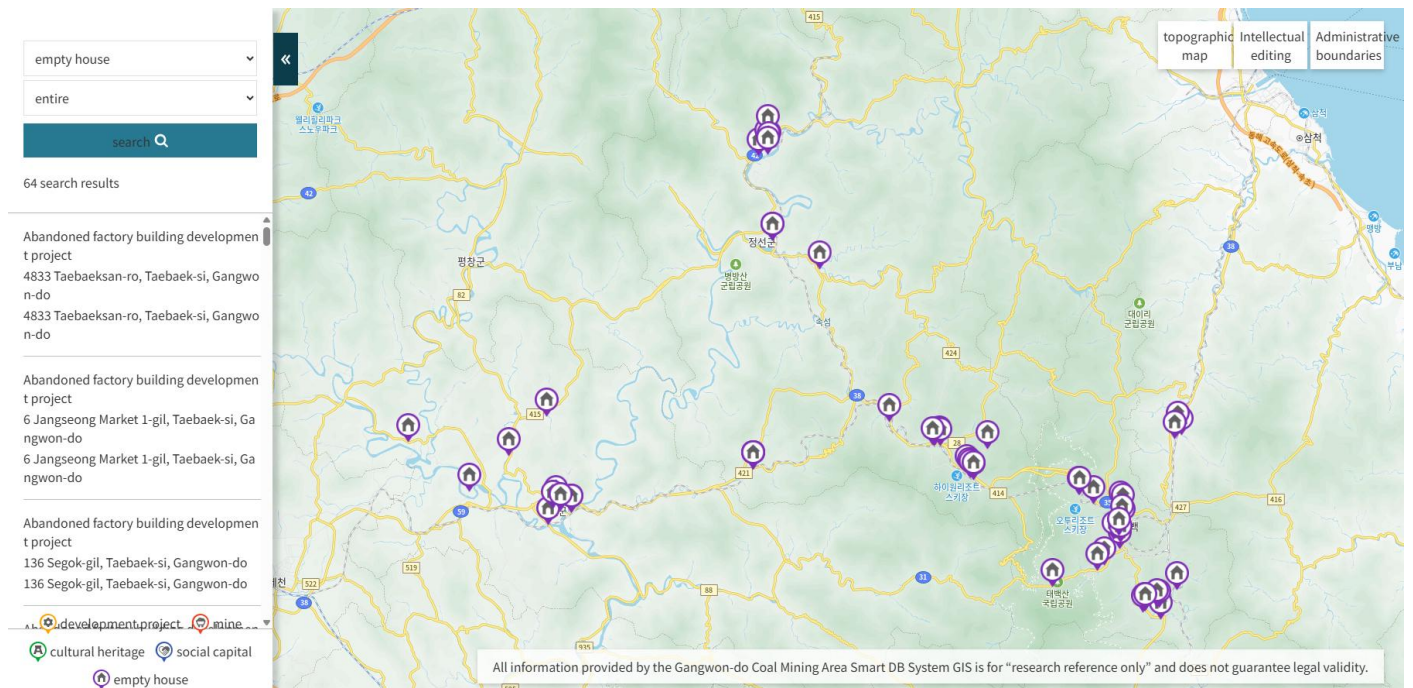


Figure 27 Map of renovation projects for vacant buildings in Gangwon province.

Note. Source by Gangwon Province (n.d.).

## **(c) Comparison between Lusatia and South Korea**

Both Lusatia and Korea possess unique post-mining space resources, such as vast wastelands, spoil heaps, underground shafts, and abandoned facilities, that can be repurposed into new opportunities. In both regions, former mining sites have been developed for tourism and recreation. Lusatia has successfully developed attractions that reflect the unique characteristics of its former open-cast mine areas, helping to reshape the region's image. On the contrary, several coal museums and theme parks in Korea have struggled to attract visitors due to a lack of uniqueness, as similar facilities have been redundantly constructed across municipalities.

More recently, Korea has begun exploring industrial and research-oriented applications that leverage the unique characteristics of underground shafts. These innovative repurpose strategies can offer valuable inspiration for Lusatia, especially in diversifying the use of post-mining spaces beyond tourism. Both regions also share opportunities to repurpose vacant houses and buildings. Gangwon Province's program to renovate empty buildings and support local start-ups presents a promising model that could be adapted to Lusatia. By combining infrastructure reuse with entrepreneurial support, such initiatives have the potential to generate employment, attract new residents, and stimulate regional economic revitalization.

Although wastelands and abandoned facilities in post-mining regions hold clear potential, their economic value has not yet been systematically assessed in either region. Viewing space itself as a resource may open new pathways for socioeconomic recovery in post-mining areas.

### III. Conclusions

Unlike many coal mining provinces globally, regulatory violations or illegal mining are not the issues in either Lusatia or Korea. In addition, both regions have established effective reclamation and monitoring practices to address open environmental questions such as acid mine drainage and poor soil quality. However, mine closures in both regions have resulted in similar socioeconomic difficulties, including population decline and economic downturn. Despite these shared challenges, Lusatia and Korea have pursued distinct strategies for transitions after coal mining.

Lusatia has focused on repurposing its vast former open-cast mines by leveraging conservative approaches centered around energy, water, and biota. These include the development of renewable energy facilities, the creation of artificial lakes, and large-scale reforestation efforts. On the contrary, Korea has adopted innovative post-mining ideas by utilizing various legacy resources and creating new ones. It has transformed underground shafts into venues for smart farming and lunar resource development research, with a plan underway to establish an artificial intelligence data center in the former mine. These initiatives showcase creative ways to utilize the unique characteristics of underground mining infrastructure.

While these approaches differ significantly, both regions offer valuable lessons in post-mining revitalization. Lusatia's success lies in its integrated planning and large-scale transformation efforts. The Lusatian lake districts, where canals connect multiple lakes surrounded by other tourist attractions, exemplify effective inter-municipality cooperation. Additionally, the development of a large-scale energy park highlights successful collaboration among various stakeholders. In contrast, Korea's post-mining efforts are often fragmented and led by individual municipalities, making it difficult to address the root causes. As a result, similar projects are frequently replicated across different areas, leading to redundant tourist attractions and a lack of distinctive local identity. To overcome these challenges, Korea would benefit from adopting integrated, regionally tailored strategies, drawing on Lusatia's experience. Enhanced cooperation among municipalities, government departments, and local communities could enable the development of large-scale projects that support both the local economy and demographic resilience.

At the same time, Korea's innovative use of resources offers insights for Lusatia. While Lusatia has excelled in tourism and energy redevelopment, industrial uses of mining wastelands and abandoned facilities remain underexplored. Agora Energiewende (2018) mentioned that Lusatia could not yet be considered an innovative region as of 2017. Although efforts to revitalize the area have been underway over the past eight years, global challenges such as the COVID-19 pandemic and the Russia-Ukraine war have constrained opportunities for innovative transformation. As a result, Lusatia's level of innovation has remained relatively stagnant, leaving considerable room for further development. Given these circumstances, Korea's initiatives to repurpose buildings for start-ups and utilize underground spaces for research demonstrate new possibilities. By adopting similar strategies, Lusatia could attract businesses and diversify its economy.

While both regions have implemented various revitalization strategies, they have conducted limited assessments of how post-mining transformations have impacted local economies and communities. Evaluating socioeconomic impacts of environmental resource transformations is crucial for guiding future planning and ensuring long-term success. By exchanging experiences, lessons learned, and forward-looking plans, Lusatia and Korea can foster more sustainable and just transitions beyond coal mining. Such collaboration will not only benefit Lusatia and Korea but also enrich global knowledge on post-mining revitalization.

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