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Deliverable 2.3

Report on spatiotemporal evaluation and transition scenarios for the coal mining regions

Public Report

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report represents the second part of the Deliverable 2.3. Report on Spatiotemporal Evaluation and Transition Scenarios for the Coal Mining Regions. The report focuses specifically on transition scenarios and their strategic implications for regions affected by coal mining.

The methodology employed in this report involves a systematic approach, including the selection of transformation directions, scenario development, and an assessment utilizing SWOT analysis. These methodologies have been meticulously applied to provide actionable insights into the transition potential of coal mining regions.

Moreover, the report includes a thorough analysis of the current state of Western Macedonia and Konin Region, along with an examination of the existing transformation plans and strategies in place. This comprehensive evaluation provides a holistic perspective on the regions' transition prospects and ensures alignment with ongoing regional initiatives. Additionally, this document draws upon valuable insights and lessons learned from the Rhur area, offering a rich source of practical knowledge and best practices for the regions under consideration.

This report makes a significant contribution to the overarching goal of facilitating the transition of mining regions towards a sustainable, resilient and prosperous future. It aims to guide policymakers, stakeholders and local communities in their efforts to chart a course towards a more sustainable and vibrant future for these regions.

PROJECT OVERVIEW

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PART II
SCENARIOS FOR THE COAL MINING REGIONS

1. INTRODUCTION

The shift from coal to sustainable energy sources is not just an environmental imperative but a profound transformation for regions like Konin in Poland and Western Macedonia in Greece, where coal mining has been pivotal. This comprehensive report explores these regions' transition, enriched with lessons from Germany's Ruhr area, where a similar shift has been successfully realized. The Ruhr's experience offers valuable insights into effectively managing economic, social, and environmental changes during such transitions.

The report delves deep into the histories of the Konin and Western Macedonia regions, examining how coal mining has shaped their landscapes, economies, and societies. It discusses the multi-faceted impacts of coal dependence and explores strategies for a sustainable transition that encompasses environmental restoration, economic diversification, and community revitalization.

Incorporating lessons from the Ruhr area provides a unique perspective, highlighting successful practices and potential pitfalls in transitioning from a coal-reliant economy. These insights are crucial in shaping strategies that are realistic, inclusive, and forward-thinking. By learning from the Ruhr area, the report aims to provide a roadmap for Konin and Western Macedonia to navigate their transition effectively.

The report emphasizes the need for comprehensive planning and stakeholder engagement in these transitions. It underlines the importance of adapting strategies to local contexts, ensuring that the shift away from coal mining leads to sustainable, resilient, and prosperous communities. The conclusions and recommendations aim to guide policymakers, industry leaders, and community stakeholders towards a collaborative and successful transition to a sustainable future.

2. METHODOLOGY

This chapter outlines a comprehensive methodology adopted for the selection of transition scenarios and their evaluation in the coal mining regions of Konin in Poland and Western Macedonia in Greece, as part of the WINTER project. The methodology is anchored in a three-step approach:

1. **Selection of transition scenarios:**

    a) **Use of Results of Spatiotemporal Evaluation:** The initial phase involves a detailed analysis of spatiotemporal evaluation data. This process is essential in understanding the historical and recent changes in land use and urban planning within these regions, utilizing satellite and aerial imagery. Such an analysis facilitates a nuanced comprehension of the evolving environmental and socio-economic landscapes influenced by coal mining activities.

    b) **Transition Scenario Decision Matrix:** The subsequent phase employs a specifically developed Decision Matrix. This instrument plays a crucial role in systematically evaluating various transition scenarios. It integrates a multitude of factors - encompassing environmental, economic, social, and technological aspects - to ascertain the most suitable and sustainable pathways for the transition away from coal mining in these regions.

2. **Scenario Preparing:** This stage involves the formulation of transition scenarios, integrating findings from the spatiotemporal evaluation and the Decision Matrix. It focuses on crafting scenarios that align with the region's evolving landscape and

energy potential, ensuring they are feasible, sustainable, and responsive to local socio-economic dynamics.

3. **Scenario Evaluation:** The last stage utilizes SWOT analysis to evaluate each transition scenario's strengths, weaknesses, opportunities, and threats. This balanced approach allows stakeholders to identify the internal and external factors that could impact the feasibility and success of a scenario.

The synergy of these phases forms a solid basis for the scenario selection and evaluation process. The following sections of this chapter will detail each phase, elucidating their interplay in creating a comprehensive methodology for transition planning in the coal mining regions. The intent is to provide a transparent and thorough guide to the decision-making framework, grounded in meticulous analysis.

2.1. SELECTION OF TRANSITION SCENARIOS

USE OF THE RESULTS OF SPATIOTEMPORAL EVALUATION

This section outlines the utilization of spatiotemporal evaluation results (as detailed in Part I: Spatiotemporal Evaluation) for selecting transition scenarios in the coal mining regions of Konin in Poland and Western Macedonia in Greece, as part of the WINTER project. The methodology integrates land cover analysis with the assessment of renewable energy sources reutilization options.

Spatiotemporal evaluation serves as a key component in shaping the transition scenarios. The comprehensive analysis of land cover changes and the potential for RES implementation provides a multi-faceted view of the regions' evolution. These analyses are employed in the scenario selection process as per the Figure below.

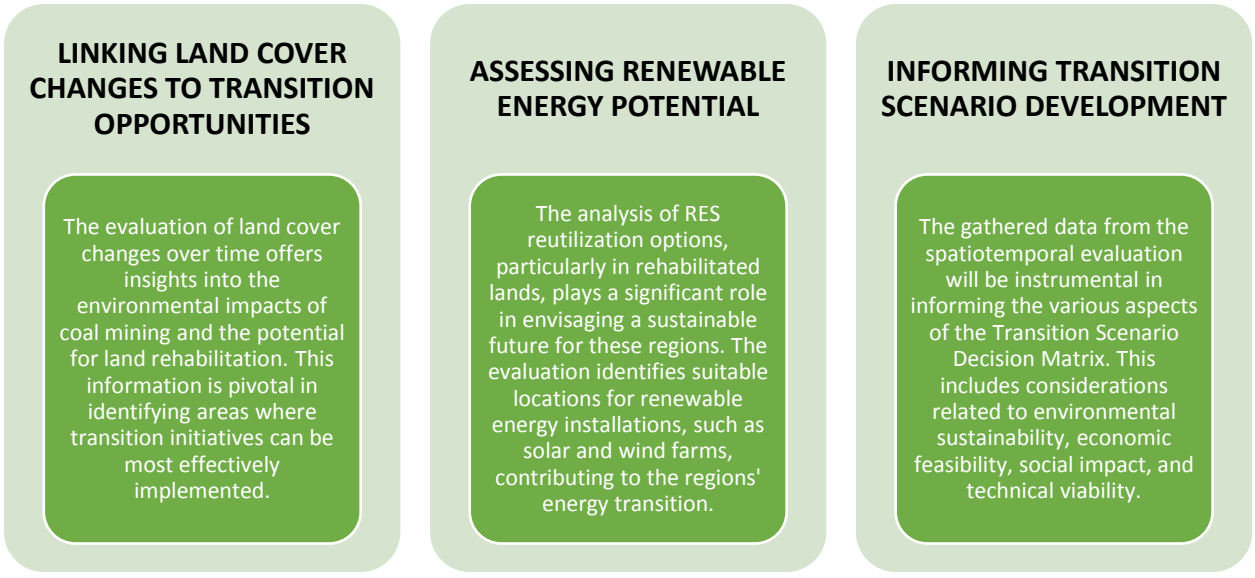

Figure 1. The role of spatiotemporal analysis in transition strategy formulation

The insights gleaned from this spatiotemporal evaluation are crucial in the subsequent phase of developing transition scenarios. The understanding of how land cover has evolved over nearly three decades provides a clear picture of the environmental and socio-economic transformations that have occurred due to coal mining activities. These insights directly inform the criteria and considerations used in the Transition Scenario Decision Matrix, ensuring that the selected scenarios are grounded in the historical and current realities of these regions.

TRANSITION SCENARIO DECISION MATRIX

The Transition Scenario Decision Matrix (Table 1.) is a strategic tool created to systematically evaluate and select the most appropriate transition scenarios for the coal mining regions. This matrix incorporates a variety of criteria that are crucial for assessing the viability and desirability of potential transition pathways. It was designed to comprehensively determine which Transition Scenarios have the greatest potential for realization.

Table 1. Transition Scenario Decision Matrix template

TRANSFORMATION DIRECTION	CRITERIA						OVERALL FEASIBILITY
	ECONOMIC VIABILITY	ENVIRONMENTAL IMPACT	SOCIAL ACCEPTANCE AND STAKEHOLDER SUPPORT	TECHNOLOGICAL FEASIBILITY	SUSTAINABILITY	REGULATORY & LEGAL CONSIDERATIONS	
NATURAL RESTORATION	✓/✗	...	...	...	...	...	Assessment
CULTURAL HERITAGE DEVELOPMENT	✓/✗	...	...	...	...	...	Assessment
COMMERCIAL RECONVERSION	✓/✗	...	...	...	...	...	Assessment
RENEWABLE ENERGY INTEGRATION	✓/✗	...	...	...	...	...	Assessment

The matrix is composed of the following components:

1) **Transformation Directions:**

The matrix rows encapsulate the primary transformation directions, derived from the Classification of post-mining land use outlined in the Deliverable 2.1 BAT guide for land rehabilitation and reclamation, a deliverable of the WINTER project. These directions represent the strategic paths a region can take following mining activities:

- **Natural Restoration:** Focuses on returning the land to its natural state, promoting ecological balance and biodiversity.
- **Cultural Heritage Development:** Aims to preserve and enhance the historical and cultural significance of mining regions, potentially turning them into tourist and educational sites.
- **Commercial Reconversion:** Involves repurposing land for commercial use, driving economic growth and providing new opportunities for the local community.
- **Renewable Energy Integration**: Targets the implementation of renewable energy projects, such as solar or wind farms, contributing to the region's sustainable energy goals and environmental conservation efforts.

2) **Evaluation Criteria:**

The matrix columns feature the criteria considered for each region. Below are examples of aspects that may be considered under the specified criteria. It should be noted that this list is not exhaustive and each region that is experiencing a transition moving away from coal should take into account aspects of each of the criteria that are significant to

it. In this way, it will be possible to universally use the matrix for each unique case of transformation of individual carbon regions.

Table 2. Evaluation criteria description

CRITERIA	DESCRIPTION
Economic Viability	This criterion evaluates the financial aspects, including potential return on investment, job creation, and the ability to attract external investments.
Environmental Impact	Assesses the environmental implications, such as carbon sequestration capabilities, effects on local ecosystems and biodiversity, and the potential for water and soil conservation
Social Acceptance and Stakeholder Support	Measures the level of community support, the potential to address social issues, and the backing from key stakeholders, including government, NGOs, and the business community.
Technological Feasibility	Looks at the availability and readiness of technology, infrastructure requirements, and innovation potential.
Regulatory & Legal Considerations	Reviews compliance with regulations, potential legal challenges, and the availability of incentives or subsidies. Includes consideration of how well the scenario fits within the framework of national/regional/local transition plans.
Sustainability	Considers the long-term viability, resilience to external shocks, and contribution to the UN Sustainable Development Goals.

Methodology for Criteria Weighting

With a comprehensive understanding of the specific region's context, stakeholders can embark on the nuanced task of assessing individual criteria within the Transition Scenario Decision Matrix. This assessment is inherently subjective, reflecting the complex interplay of social, environmental, and economic factors unique to each region.

1) Subjective Assessment:

The evaluation process acknowledges the subjective nature of decision-making. Stakeholders' insights, drawn from their deep knowledge and experience within the region, are instrumental in this assessment. This approach allows for a degree of flexibility and context sensitivity that purely quantitative methods may not capture.

2) Criteria Evaluation Symbols:

To facilitate the evaluation process, a simple yet effective symbolic system is employed:

- ✓ **(Positive Assessment):** This symbol is used when a criterion is assessed to have a favorable impact or high likelihood of success within the context of the region.
- ✗ **(Negative Assessment):** This symbol indicates that a criterion may have an unfavorable impact or challenges that diminish its potential effectiveness or feasibility.
- ✓/✗ **(Neutral Assessment):** A neutral assessment suggests that the impacts of a criterion are mixed, uncertain, or balanced in terms of potential positives and negatives.

3) Overall Feasibility:

After evaluating each criterion individually, an overarching assessment of overall feasibility is conducted. This evaluation synthesizes the findings from the individual criteria assessments to form a holistic view of the scenario's viability.

The overall feasibility assessment is also subjective, relying on the collective judgment of the stakeholders to weigh the various factors and their symbolic evaluations to arrive at a conclusion about the scenario's potential for successful implementation.

2.2. SCENARIO PREPARING

Within the scope of the WINTER project, two distinct scenarios for Western Macedonia and Konin Region will be chosen for further development:

- Renewable Energy Source Utilization Scenario: This scenario will incorporate the results from the WINTER project's spatiotemporal analysis,
- Highest Feasibility Scenario: The second scenario is selected based on its overall highest feasibility assessment from the Transition Scenario Decision Matrix.

Scenario preparation is a critical step in planning for the transition of coal mining regions. This section outlines best practices for scenario preparation, ensuring that each scenario is robust, feasible, and aligned with the region's goals.

1) Data-Driven Foundation:

- **Utilize Spatiotemporal Analysis:** Leverage detailed spatiotemporal data to understand historical and current land use patterns, environmental impacts, and socio-economic factors.
- **Incorporate Quantitative and Qualitative Data:** Use a mix of quantitative data (e.g., land cover changes, economic statistics) and qualitative insights (e.g., stakeholder interviews, community feedback).

2) Stakeholders' Opinion:

- **Gathering Diverse Perspectives:** Actively consider the opinions and insights of various stakeholders, including local residents, businesses, and governmental entities, as their perspectives are vital in shaping realistic and acceptable scenarios.
- **Responsive Scenario Development:** Ensure that the developed scenarios reflect the concerns and aspirations of these stakeholders, balancing economic, social, and environmental interests.

3) Defining a Vision and Objectives:

- **Establish a Long-term Vision:** Develop a qualitative, narrative-driven vision for the region's future, considering that transition and structural change are long-term processes spanning several decades.
- **Set Development Objectives:** Support the general vision with clear, concrete objectives addressing shorter time frames, such as 5 to 10 years, to provide achievable milestones in the transition journey.

4) Scenario Development:

- **Create Multiple Scenarios:** Develop several scenarios to explore different pathways, considering various combinations of industrial, environmental, and social elements.
- **Detail Each Scenario:** Clearly outline the implications, opportunities, and challenges of each scenario, including potential economic, environmental, and social impacts.

5) **Sustainability and Adaptability:**

- **Prioritize Sustainability:** Ensure scenarios align with sustainability goals, focusing on environmental restoration and renewable energy potential.

- **Plan for Adaptability:** Design scenarios that are flexible and can adapt to changing circumstances, such as technological advancements or policy shifts.

6) **Validation and Refinement:**
   - **Assess Feasibility:** Evaluate the technical, economic, and legal feasibility of each scenario.
   - **Refine Scenarios:** Continuously refine scenarios based on feedback, new data, and evolving conditions.
7) **Communication:**
   - **Communicate Clearly:** Use clear, accessible language to communicate scenarios to stakeholders and the public, including potential benefits and risks.

2.3. SCENARIO EVALUATION

The final phase of the methodology is the evaluation of the transition scenarios themselves. This crucial step employs a SWOT analysis – a structured planning method that identifies the Strengths, Weaknesses, Opportunities, and Threats associated with each scenario.

- **Strengths**: This aspect of the SWOT analysis focuses on the internal positive attributes of the scenario that are within the control of the region, such as existing infrastructure, skilled labor force, or natural resources.
- **Weaknesses:** Here, the internal factors that could challenge the success of the transition are examined, including potential economic drawbacks, social resistance, or gaps in technology and infrastructure.
- **Opportunities:** The analysis considers external chances for enhancement or benefit that the scenario could exploit, such as emerging markets for renewable energy, government incentives, or shifts in public policy favoring environmental restoration.
- **Threats:** This final element of the SWOT analysis looks at external factors that could cause trouble for the scenario, like economic downturns, regulatory changes, or environmental risks.

The figure below presents guiding questions for Transitions Scenarios SWOT analysis for better understanding.

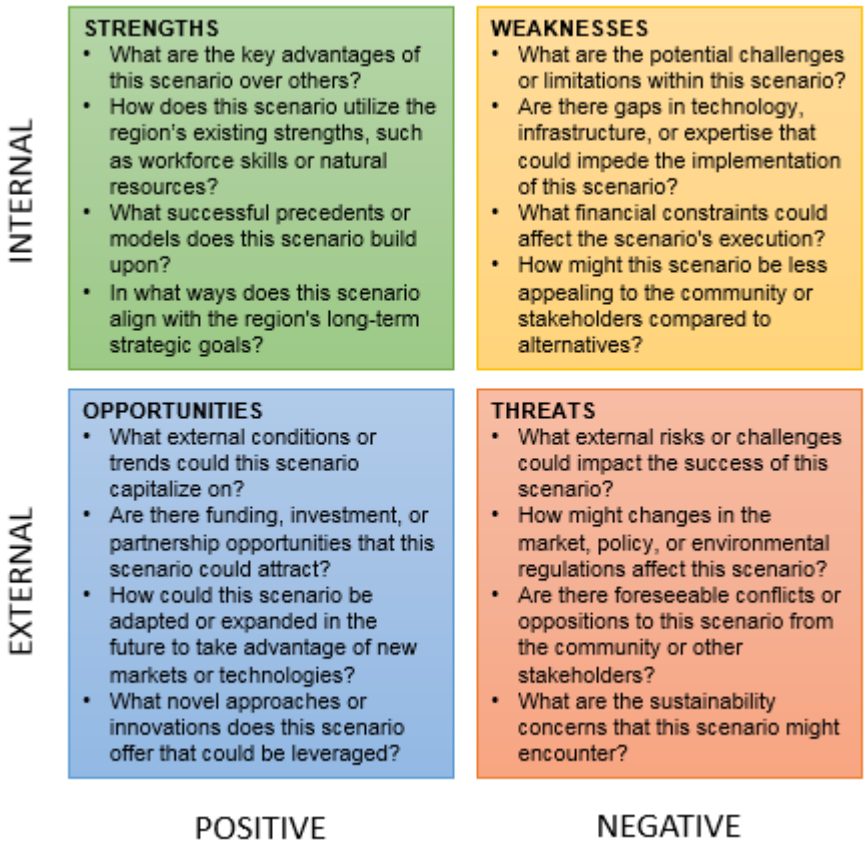

Figure 2. Guiding Questions for SWOT Analysis of Transition Scenarios

3. AREA DESCRIPTION

3.1. WESTERN MACEDONIA

3.1.1. CURRENT STATE

REGIONAL OVERVIEW

Western Macedonia is a region located in northern Greece, bordering North Macedonia and Albania to the north. Its total area is 9,451 square kilometers, which is equivalent to 7.2% of the Greece's total area.

The distribution of the region's land is 82% mountainous and semi-mountainous and 18% plains. There are few flat, highly productive agricultural areas. In each unit, the percentages of land cover and, consequently, land uses vary only slightly, with some exceptions, such as the high percentage of forests in Grevena, reaching about 50%. Also noteworthy is the high percentage of water bodies in Florina due to the presence of numerous lakes. (INSETE Intelligence, 2020)

The climate is characteristic of continental climates, with low temperatures in the winter and mild summers. Snowfall and frost are common, which limits the range of agricultural activities. (INSETE Intelligence, 2020)

Starting from the early 1950s, the lignite industry has played a pivotal role in shaping the progress of Western Macedonia. The choice to intensify the extraction of domestic lignite deposits has been a central political strategy, enjoying support from successive Greek governments throughout the years. As of now, the production of lignite has amounted to 1.7 billion tons, and over 8.5 billion cubic meters of rock have been excavated from four surface

mines (see Figure 3). The remaining exploitable reserves in the active lignite field under the jurisdiction of Public Power Corporation SA are estimated to be around 820 million tons, while private mines hold reserves of 120 million tons. Additionally, Public Power Corporation has rights to extract 460 million tons of lignite in areas where mining operations have not yet been initiated. (Pavloudakis et al., 2020)

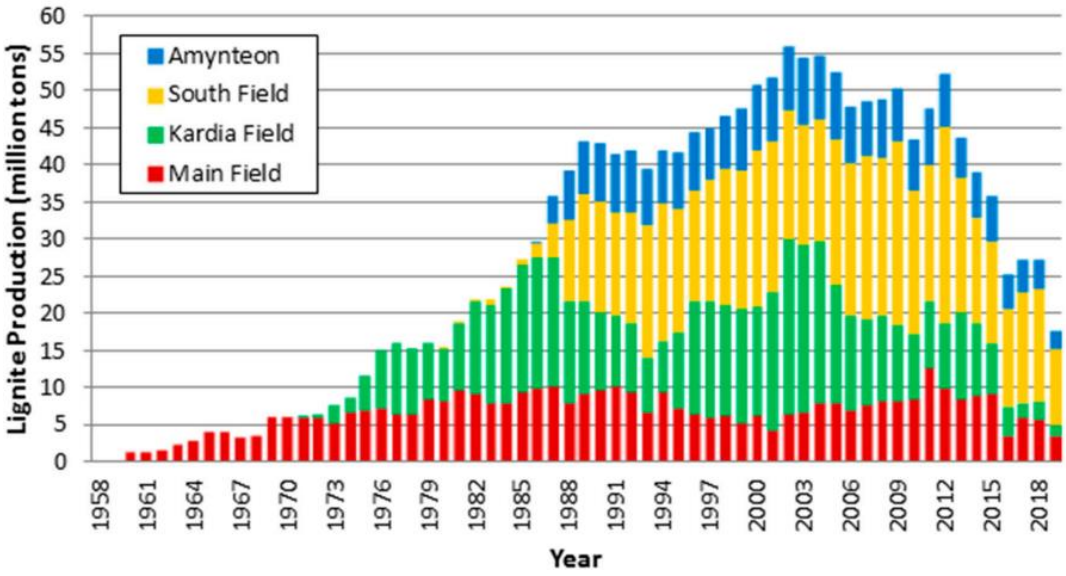

Figure 3. Lignite production of the western Macedonia Lignite Centre (Pavloudakis et al., 2020)

CURRENT LANDSCAPE AND INFRASTRUCTURE

Based on the master plan for Western Macedonia the vision for the "next day" is based on five pillars of development, as follows:

- Clean energy
- Industry, small industry and trade
- Smart agricultural production
- Sustainable tourism
- Technology and education

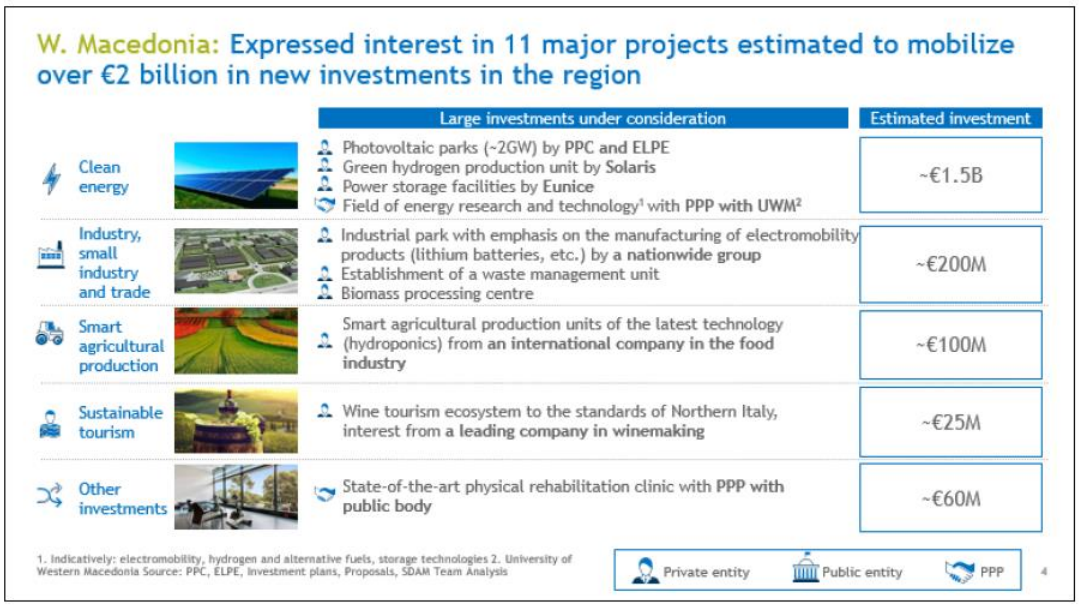

Figure 4. Pillars of development for the energy transition in Western Macedonia according to the Master plan

Table 3. Gross Value Added by Sector (as a % of total GVA by regional unit, base year: 2019) (Government Committee SDAM, 2021)

Region	Agriculture, Forestry, Fishing	Energy, Mining, Water	Manufacturing	Construction	Trade, Hotels, Restaurants, Transportation, Communications	Financial Insurance Activities	Other Services*	Total
Grevena Region	11.37%	2.86%	3.25%	1.70%	21.24%	3.47%	56.11%	100.00%
Kastoria Region	12.67%	1.90%	14.11%	0.43%	21.57%	3.94%	45.37%	100.00%
Kozani Region	7.12%	50.36%	3.32%	0.39%	11.47%	2.39%	24.96%	100.00%
Florina Region	11.48%	39.47%	3.82%	4.91%	10.89%	1.74%	27.69%	100.00%
Total for Western Macedonia Region	9.06%	38.65%	4.71%	1.48%	13.28%	2.52%	30.31%	100.00%

The mining, energy, and water sector accounts for 38.65% of the total Gross Value Added (GVA) in the Western Macedonia region. Moreover, it plays a significant role in the GVA of 50.36% and 39.4% in the regional units of Kozani and Florina, respectively. This underscores the substantial reliance of both the Western Macedonia region and, more prominently, these specific regional units on lignite mining activities.

Approximately 80% of the total Gross Domestic Product (GDP) in Western Macedonia is generated from the regional units of Kozani and Florina, emphasizing their contribution to the regional economy as a whole.

Considering these insights, which highlight the substantial contributions of the Kozani and Florina regional units to both the mining, energy, and water sector and the overall economy, and taking into account the interconnectedness among the individual regional units and intra-

regional transactions, it is clear that the process of phasing out lignite will have a significant impact on the entire economic and business landscape in the Western Macedonia region, with a primary and more pronounced effect on the Kozani and Florina regional units. (Government Committee SDAM, 2021)

In terms of infrastructure and transportation networks, the Egnatia Motorway, as well as the upcoming vertical axis of the Egnatia Motorway «Niki-Florina-Kozani-Boundaries of the Prefecture of Larissa», as well as the International Airport in Kastoria, provide significant competitive advantages for the surrounding area.

District heating networks with low CO2 emissions are operating in various Western Macedonian cities, providing citizens with low-cost heating; there are also a substantial number of pilot power plants utilizing biomass. Finally, one of Western Macedonia's key strengths is its own university, the University of Western Macedonia, which is actively engaged in research, collaborations, and support of local entrepreneurs. The University is a hub of innovation and knowledge transmission, as well as a significant pillar of decarbonization.

Western Macedonia suffers from a lack of infrastructure. A well-organized railway network and multimodal transportation, as well as more efficient freight services and increased incentives for new investments, are critical necessities for the region. Western Macedonia likewise suffers from a lack of economic activity and a lack of business culture, particularly among the youth. Furthermore, it displays a very low level of industrial expertise and a very limited percentage of high-value technology and knowledge-intensive goods. (Tranoulidis et al. 2022)

SOCIO-ECONOMIC CONTEXT

The population of the Western Macedonia region during the period 2015-2020 decreased by -4% (from 276,000 in 2015 to 265,000 in 2020). Specifically, all the regional units within the region saw a decrease in their populations: Kozani (-5%, from 146,000 in 2015 to 139,000 in 2020), Florina (-3%, from 51,000 in 2015 to 49,000 in 2020), Kastoria (-6%, from 49,000 in 2015 to 46,000 in 2020), and Grevena (-1%, from 31,000 in 2015 to 30,600 in 2020). (INSETE Intelligence, 2020)

Western Macedonia presents a strong decrease in the age groups of 0-14 years, 20-24 years, and 25-29 years, while it experiences a more significant increase in the age group of 15-19 years. Additionally, during the period 2015-2020, Western Macedonia showed a decrease in the age group of 65+ years. Specifically, in the individual age categories, the following changes were observed: a decrease in the age groups of 0-14 years (-10%), 20-24 years (-26%), 25-29 years (-19%), 30-44 years (-12%), and 65+ years (-0.1%), while an increase was observed in the age groups of 15-19 years (+22%) and 45-64 years (+3%). As for the distribution of age groups for the year 2020, it is noted that the highest share is held by the age group 45-64 years (30%), followed by the age group 65+ years (24%), 30-44 years (18%), 15-29 years (15%), and 0-14 years (14%)

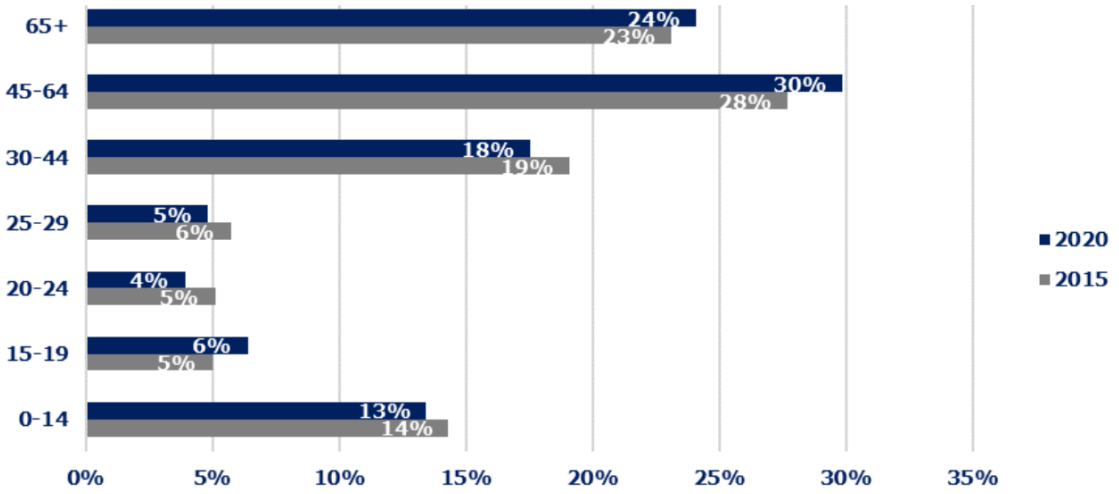

Figure 5. Percentage age distribution of the inhabitants of the Region of Western Macedonia for 2015 and 2020 (INSETE Intelligence, 2020)

The Region of Western Macedonia represents only 2% of the economically active population in the country, while its percentage of economically active population in relation to the population aged 15 and over was 49% in 2015 and 47% in 2020. Compared to the other regions, in 2015, the Region of Western Macedonia had the 3rd lowest percentage of economically active population, and in 2020, it had the 2nd lowest percentage.

The Region of Western Macedonia recorded a decrease in its GDP (Gross Domestic Product) by -19% during the period 2013-2018 (from €5.047 billion in 2013 to €4.107 billion in 2018), in contrast to the overall country, which saw marginal growth. Additionally, during the 2013-2018 period, the Region of Western Macedonia experienced the highest decrease among all the regions in the country. (INSETE Intelligence, 2020)

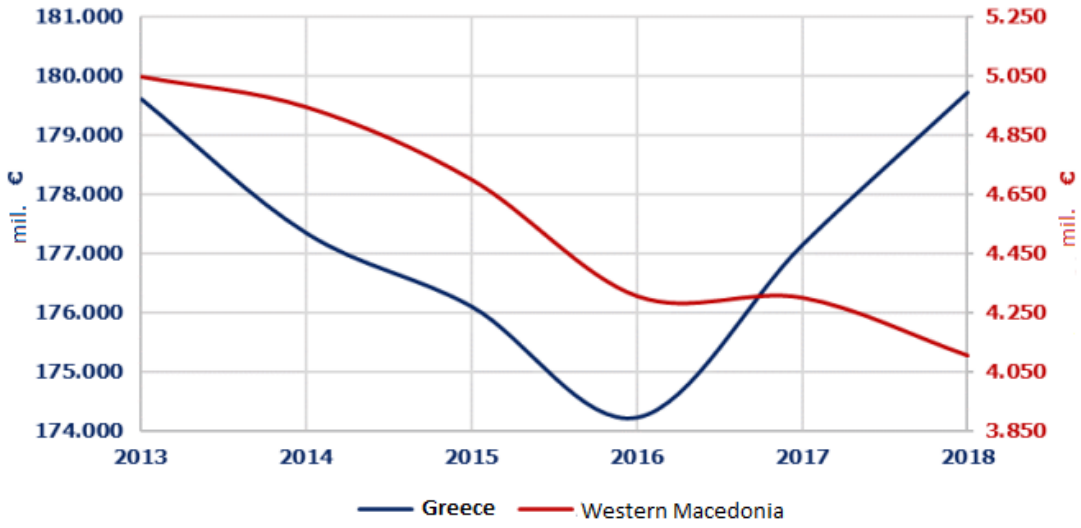

Figure 6. Evolution of the GDP of Greece and the Western Macedonia (in million €), 2013-2018 (INSETE Intelligence, 2020)

Additionally, it should be noted that the energy, mining, and water industry, encompassing activities closely associated with lignite extraction and electricity generation (including lignite mining, electricity production, distribution, trade, as well as the collection, processing, and management of mining waste and land reclamation), accounts for 38.65% of the overall Gross Value Added (GVA) in the Western Macedonia region. This percentage is the highest not only in comparison to the sector's contribution to GVA in other Greek regions but also when

compared to the contributions of other sectors to the GVA in Western Macedonia. (Government Committee SDAM, 2021)

When analyzing the influence of lignite activities at the level of regional units, it becomes evident that the energy, mining, and water sector significantly contributes to the total GVA in the regional units of Kozani and Florina, with percentages of 50.36% and 39.47%, respectively.

A significant portion of Western Macedonia's workforce is closely tied to industries that are either directly or indirectly linked with the region's natural assets, particularly its land and mining resources. The largest employment sector is agriculture, forestry, and fishing, accounting for 21 %of the workforce. Specifically, the cultivation of non-perennial crops within the agricultural sector contributes over 10,000 jobs, equivalent to 12 % of the total regional employment. Transportation and storage follow closely behind, representing 14 % of the total employment, with public administration contributing 11 %. In terms of regional employment, mining and quarrying represents 5% of the available jobs such as the electricity gas steam and air conditioning supply. To provide a comparison, at the national level in Greece, agriculture, forestry, and fishing make up just 12.3 % of total employment, with the largest employment sector being wholesale and retail trade, contributing 18 % to the country's workforce. Manufacturing and the public administration represents each circa the 10 % of total employment. (Christiaensen L. and Ferré, C. ,2020).

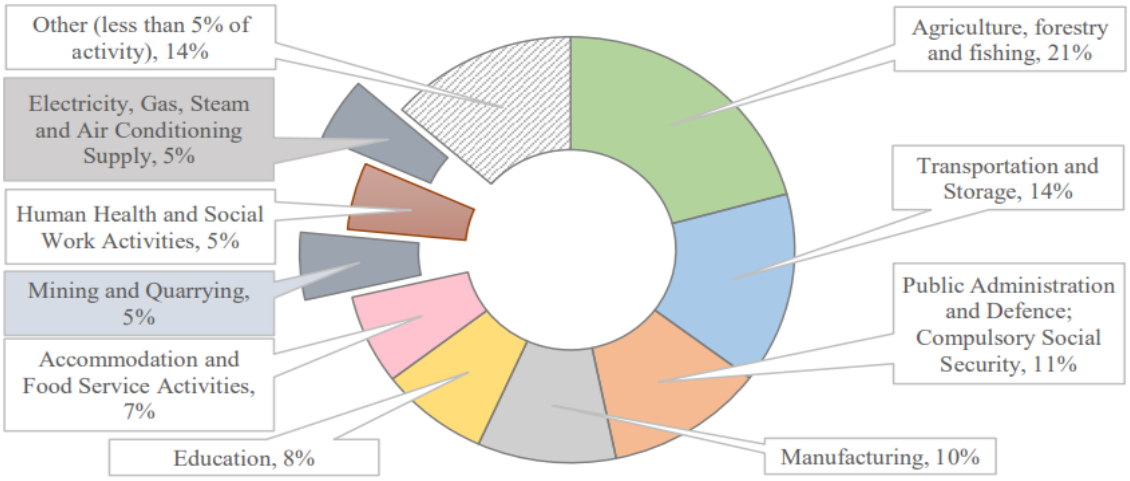

Figure 7. Employment in Western Macedonia Christiaensen L. and Ferré, C. (2020)

However, the majority of Western Macedonia's Gross Value Added (GVA) primarily originates from its industrial sectors, encompassing mining, manufacturing, power generation, and water-related activities. Particularly, the industrial sector holds remarkable importance in Kozani Regional Unit and Florina Regional Unit, where it contributes to 60 percent and 49 percent of the GVA, respectively (Fig. 8).

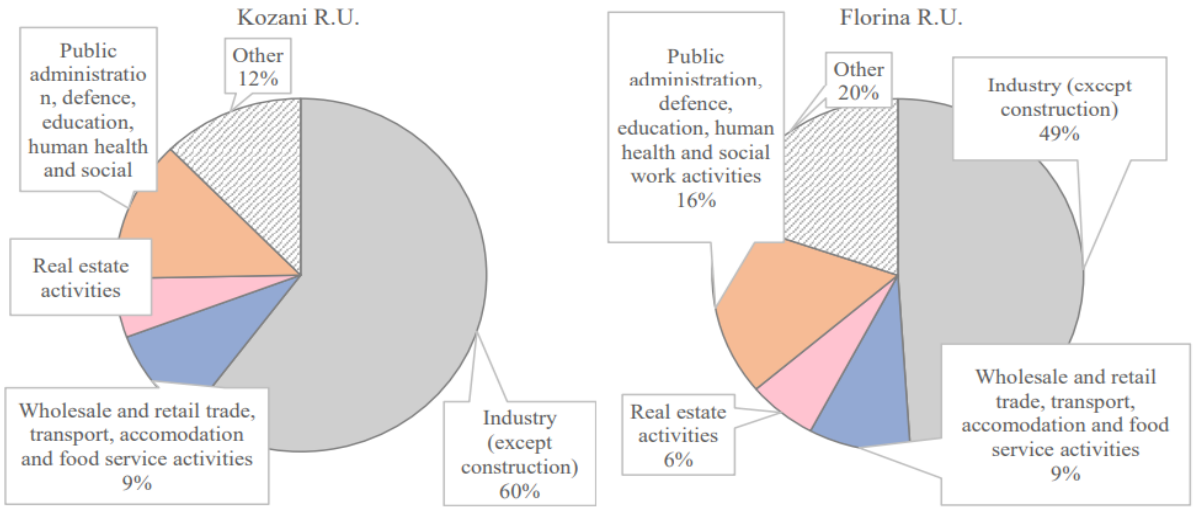

Figure 8. GVA in regional units of Kozani and Florina (Christiaensen L. and Ferré, C. ,2020)

It's worth noting that lignite mining serves as the foundation for power generation, directly employing another 5 % of the Western Macedonia workforce. The generation, transmission, and distribution of electricity represent approximately 5 % of total employment in the region. In contrast to lignite mining, which is largely concentrated in Western Macedonia (accounting for 90.7 percent of all lignite mining jobs in Greece), power generation and transmission are more geographically dispersed, with only about 15 percent of jobs in this sector located within Western Macedonia.

Furthermore, lignite mining and power generation activities significantly dominate employment in the Florina-Kozani region, where they directly contribute to around 30% of the workforce. These activities are primarily concentrated in the eastern part of Western Macedonia, along the Florina-Kozani region, which includes the municipalities of Florina, Amynteo, Eordea, and Kozani. In 2018, both sectors collectively employed between 5,000 and 8,000 people, representing 22 to 33 % of all employment in these municipalities. Direct employment in mining and electricity generation has stayed around 7,500 jobs since 2011, with a peakof 9,567 employees in 2016 associated with the development of Ptolemais V (Figure 9) (Christiaensen L. and Ferré, C. ,2020).

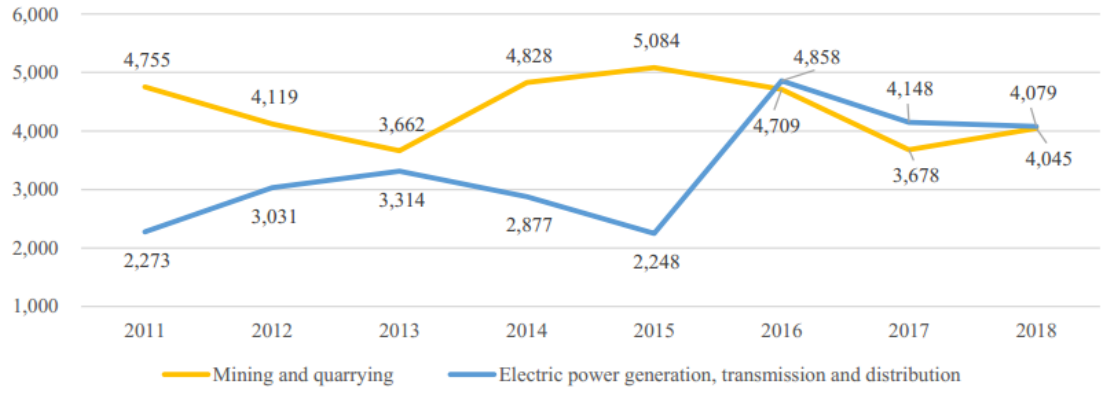

Figure 9. Mining and quarrying jobs and electric power generation jobs during 2011-2018 (Christiaensen L. and Ferré, C. ,2020)

ENVIRONMENTAL CONDITIONS

Key Ecological Features: The region is known for its natural beauty, with forests, rivers, and wildlife habitats. Prespa National Park, located in the north, is ecologically important.

Protected Areas: Prespa National Park is a protected area of ecological significance.

Environmental Challenges:

The energy transition in Western Macedonia, Greece, presents several environmental challenges due to the region's historical reliance on lignite coal for energy production. As the transition to cleaner and more sustainable energy sources takes place, various environmental issues need to be addressed. Some of the main environmental challenges for the energy transition in Western Macedonia include:

1. **Coal Decommissioning and Land Remediation:** The shutdown of coal-fired power plants and lignite mines in the region poses challenges related to decommissioning, land reclamation, and environmental remediation. Abandoned mining areas and ash disposal sites must be rehabilitated to mitigate environmental impacts with main goal the land repurposing for other uses.

2. **Air Quality and Emissions:** The burning of lignite coal has been a significant source of air pollution and greenhouse gas emissions in the region. Reducing emissions and improving air quality are crucial for public health and the environment. Transitioning to cleaner energy sources, such as renewables, can help mitigate this challenge.

3. **Water Resource Management:** Lignite mining and power generation activities have historically affected local water resources, including rivers and groundwater. Proper management of water resources, especially in a region that faces water scarcity, is essential for the sustainability of the energy transition. In particular, planned hydropower facilities such as HPHS have to be implemented taking into account the water demand for the different uses at river basin scale.

4. **Biodiversity and Land Use:** The expansion of lignite mining and associated infrastructure has led to habitat destruction and fragmentation, impacting local biodiversity. Balancing land use for energy projects with conservation and restoration efforts is a key challenge.

5. **Renewable Energy Integration:** Expanding renewable energy capacity, such as wind and solar, and integrating it into the existing energy infrastructure can present technical and environmental challenges, particularly in terms of land use, transmission infrastructure, and grid stability.

6. **Climate Adaptation:** As the impacts of climate change become more pronounced, the region must adapt to changing weather patterns, such as increased temperatures and altered precipitation patterns, which can affect the availability of water and energy resources.

To address these environmental challenges, a comprehensive and coordinated approach is required, involving government agencies, local communities, industry stakeholders, and environmental organizations. Strategies for reducing emissions, transitioning to cleaner energy sources, improving water and land management, and supporting affected communities are essential components of the energy transition in Western Macedonia.

CULTURAL AND HISTORICAL SIGNIFICANCE

Western Macedonia has a rich cultural heritage, with museums, churches, and historical sites. The Region's cultural heritage includes museums that display archaeological findings from the wider area. The most notable museums in the Region are the Byzantine Museum of Kastoria, housing images, sculptures, mosaics, wooden carvings, and religious artifacts spanning from the 12th to the 17th century. Additionally, there are Folklore Museums in Grevena, Kastoria, and Florina, showcasing local attire and objects from the daily lives of the region's residents.

The Archaeological Museum of Aiani exhibits artifacts from excavations carried out in Ancient Aiani, and the Ecclesiastical Museum of Siatista houses religious art such as icons, woodcarvings, small crafts, vestments, and books (INSETE Intelligence, 2020).

Table 4. Museums in Western Macedonia (INSETE Intelligence, 2020)

Grevena	**Kastoria**	**Kozani**	**Florina**
Archaeological Museum of Grevena	Archaeological Museum of Argos Orestiko	Anthropological Folk Museum of Ptolemaida	Archaeological Museum of Florina
Mushroom Museum	Byzantine Museum of Kastoria	Archaeological Collection of Kozani	Folklore Museum of Florina
Natural History Museum	Delinaneio Folklore Museum	Archaeological Museum of Aiani	Museum of Contemporary Art
	Folklore Museum of Kastoria	Archaeological Museum of Kozani	Florina Artists' Gallery
	Costume Museum of Kastoria	Ecclesiastical Museum of Siatista	
	Museum of Wax Figures	Historical, Folklore, and Natural History Museum	
		Kozani Municipal Library	
		Macedonian Struggle Museum of Chromio	
		Museum of Contemporary Local History in Kozani	
		Ptolemaida Art Gallery	

A study conducted by the Public Power Corporation (DEI) in 2019 has revealed plans to relocate the mobile industrial machinery of LIPTOL to the facilities of the former Public Power Corporation of Ptolemaida (DEI Ptolemaida), which had been abandoned after a devastating fire. This relocation aims to house the Industrial Museum of PPC in our area. However, the exact timeline for the transfer of these mobile monuments, the execution of the study, and the exhibition details are not yet known. The implementation of this project is expected to be announced.

In the meantime, some operational installations from PPC 's lignite mines, specifically from the Machinery and Electrical Engineering Departments of PPC Ptolemaida, have already been relocated to the premises. Additionally, the Chemistry Department of the Industrial Complex has been moved to the upper floor of the PPC Ptolemaida administrative building. It's worth noting that a former Minister of Culture, had designated the 21 items of industrial equipment from the LIPTOL and PPC Ptolemaida industrial complexes as mobile monuments. This decision was made due to the historical and technological significance of this industrial equipment, which represents a unique example of the early application of lignite technology in Greece. It serves as a valuable testament to the rapid industrial development of the last fifty years in the country. (Tzeprailidis, G., 2021)

CURRENT ENERGY LANDSCAPE

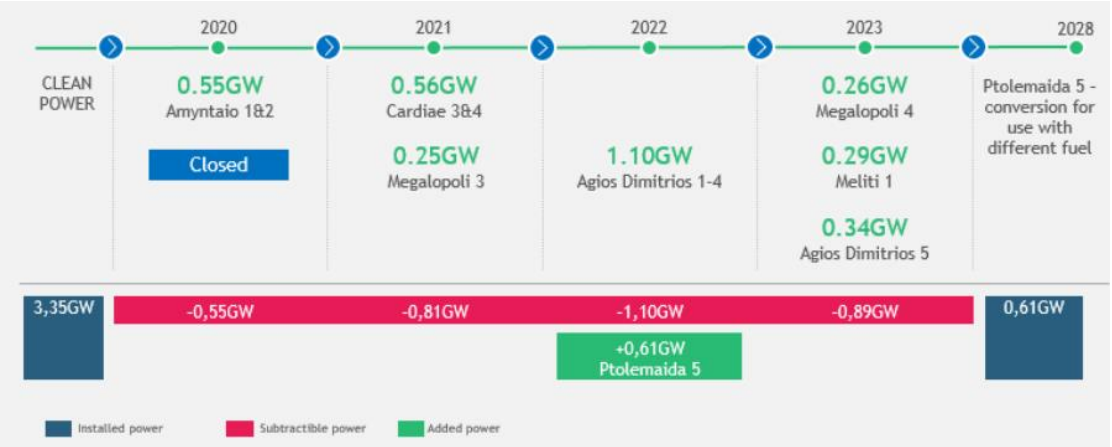

Figure 10. Withdrawal schedule of the installed lignite power by 2028. (Just Transition Development Plan of lignite areas, 2020)

The Greek government decided the closure of all but one of the PPC lignite plants and the shutdown of lignite mines in Western Macedonia and Peloponnese regions by the end of 2028. These closures will affect several power units, including relatively recent ones like Meliti 1 (330 MW, operational since 2002) and Agios Dimitrios 5 (375 MW, operational since 1997). However, one exception is the new Ptolemaida 5 unit (660 MW), expected to operate until 2028 with lignite and/or alternative fuels.

The withdrawal of these lignite power plants will impact district heating in neighboring municipalities, which has been provided at a relatively low cost by PPC SA's thermal power plants. In Western Macedonia, district heating currently supplied by PPC in Amyntaio, Ptolemaida, and Kozani will transition to a common district heating system, including the new Ptolemaida 5 unit and various electric and natural gas boilers. The Municipality of Amyntaio has also constructed a new district heating unit that utilizes lignite and biomass as fuel.

Biomass and other Renewable Energy Sources (RES), including wind energy and photovoltaics, play an important role in meeting the region's district heating and energy needs. Wind energy projects with a total capacity of 2132 MW are in various stages of the procedure, and there are plans for approximately 1.9 GW of installed capacity from photovoltaic parks through partnerships between PPC and RWE, as well as a 204 MW photovoltaic park in Kozani developed by ELPE and Juwi.

The Greek government is also exploring a solar-based hydrogen production initiative, involving large-scale photovoltaic facilities in PPC's lignite fields in Western Macedonia, aligned with Greece's decarbonization plan. Furthermore, the installation of lithium-ion batteries, with a 250 MW project by Eunice in Ptolemaida, and PPC Renewables has received licenses for storage battery projects in Western Macedonia and Arcadia, with a combined capacity of 950 MW.

Western Macedonia, with its strong energy infrastructure and history as Greece's energy hub, is well-positioned for renewable energy investments, fostering power supply and economic growth in the region. (TRACER,2022)

STAKEHOLDER LANDSCAPE

Appendix 1 includes the main stakeholders involved in the post-lignite transition, as well as other interested parties. Their degree of interest, relative influence, and overall position on the post-lignite transition are classified as Very Low, Low, Medium, High, or Very High. These categories are based on interviews, workshops, meetings, and other sources of knowledge. (Olesen 2020)

LEGAL AND REGULATORY FRAMEWORK

In recent years, the Greek government has enacted legislation related to the Just Transition Development in the country. Greek law has defined the transition regions and their management, Spatial Development Plans, and specific zones within mining areas that will undergo transformation, known as the Delignitisation Zones. Concerning the rehabilitation of Delignitisation Zones, Law 4759/2020 details updates to spatial and urban planning regulations and provisions related to these zones and Spatial Development Plans. This law encompasses critical aspects, including the responsibility for conducting technical studies and implementing rehabilitation measures. According to this law, the Hellenic Ministry of Environment and Energy (HMEE) and PPC S.A. have mutually agreed that PPC S.A. bears both technical and financial responsibility for planning, executing, and monitoring all rehabilitation measures within the Delignitisation Zones. They may enlist subcontractors for the preparation of technical studies regarding rehabilitation actions. PPC S.A. is also authorized to introduce new land uses in the rehabilitated areas within these zones and is obliged to establish new forests within the areas of depleted or operational mines. In 2021, following Law 4872/2021 , a new public company named METAVASI S.A. was established for the overall management, reclamation, and repurposing of Delignitisation Zones. This entity is funded by the Recovery and Stability Fund. Law 4956/2022 outlined the collaboration between METAVASI S.A. and PPC S.A. This law also stipulates that, while PPC S.A. is responsible for the rehabilitation works, these efforts will be jointly supervised by both companies, and the rehabilitated areas will be transferred to METAVASI S.A. in stages or as a whole upon completion. The rehabilitation process is expected to conclude by 2025. Law 4872/2021 notes that public areas assigned to a Municipality or the Greek State will be considered common areas post-rehabilitation.

Greek law also specifies the establishment of Renewable Energy Sources (RES) in Delignitisation Zones. Law 4759/2020 specifies the environmental and operational licensing processes for RES installations in Delignitisation Zones' key regions, requiring all licensing bodies to expedite the processing of these permits. This rule also allows for the development of solar power plants in formerly wooded areas within PPC S.A.'s exhausted or under-exploited lignite mines if reforestation is not viable. Following a proposal from the local forestry authority, this activity requires permission from the HMEE's Directorate of Forestry Works and Infrastructure. PPC can produce electricity and create storage facilities in the Delignitisation Zones using RES, green hydrogen, biomass, and waste-to-energy facilities, according to Law 4872/2021. In addition, this law describes the process for revising the environmental license, as well as the rehabilitation works that PPC is required to carry out taking into account the repurposing of certain lands.

The current Master Plan provides some initial suggestions which have been enriched as follows:

1. Simplify present Laws: Begin an assessment of the present legal framework with the purpose of simplifying and justifying current regulations.
2. Create and Implement Land Repurposing Guidelines: Develop a clear and comprehensive legal framework that governs land use repurposing in Transition regions.
3. Complete Land Use Planning: Accelerate the creation of the Master Plan for land use repurposing in the Delignitisation Zones.
4. Strengthen the Green Hydrogen Legal Framework: Implement new laws and regulations aimed specifically at green hydrogen production.
5. Reinforce the Task Force: Enforce the regulatory task force or agency to supervise the transition process.
6. Engage Stakeholders: Involve relevant stakeholders in legislative formulation, such as local communities, industry representatives, environmental groups, and specialists.

7. Periodic Review and Revision of Legislation: Implement a mechanism for regularly reviewing and adjusting the legal framework.
8. Create new Investments: Develop incentives such as tax benefits, grants, and financial support to encourage investments within transition regions.
9. Ensure transparency and permitting procedures: Simplify the permitting process for renewable energy and green hydrogen projects in transition regions

CHALLENGES AND OPPORTUNITIES

Challenges

The Western Macedonian energy sector face an accelerated schedule for lignite termination, which presents socio-economic challenges. Lignite-related activities currently contribute to 34% of the regional GDP. Additionally, the region confronts to structural vulnerabilities, characterized by high unemployment rates, limited diversification in the economic model, and restricted innovative capabilities. Consequently, without effective mitigation measures, the lignite phase-out in Western Macedonia, either by 2028 or even by 2025, is expected to result in a substantial decline in regional GDP, the loss of 21,000 direct and indirect jobs (given that more than 25% of local employment is directly or indirectly linked to the lignite industry), and a total income reduction of 9 billion over the period from 2018 to 2028. (Ziouzios, D. et al. 2021)

Potential Opportunities

Increased financial resources for lignite regions give crucial support for the transition. Western Macedonia can secure the necessary funding to facilitate green, sustainable, and eventually achieve a fair balance of socio-economic activities, through a variety of funding sources in local, national, and EU level.

Furthermore, this transition can play an important role in reducing energy poverty. Greece has created a supportive law framework to ensure the local energy independency. Therefore, promoting small-scale energy projects in parallel with large-scale PV parks in Western Macedonia is essential to achieve the social acceptance of the transition.

New projects can engage the youngers, offering jobs and income opportunities to the local population w Transition goal is the creation of local jobs, increased investment, and new business models. Additionally, it is worth noting that the phase-out of lignite will help improve the public health due to avoidance of emissions.

The reclamation of lignite mines can enhance agricultural production while providing environmental and socio-economic advantages. Building a smart agriculture center, providing training and research capabilities, can help promote smart agriculture among farmers, especially in collaboration with the University of Western Macedonia. This can involve younger people in productive agricultural activities by leveraging their education, openness to new technology and familiarity with new technologies.

Western Macedonia's lignite mining assets can also be repurposed for tourism, attracting both local and international tourists, considering their proximity to urban centers by road. Local environments can be revitalized by establishing parks near Kozani or Ptolemaida, and electricity generation installations and related equipment can be transformed into museums, similar to initiatives in countries like Germany, enabling some lignite industry workers to retain their employment. Lignite center buildings can be repurposed into research, innovation, and entrepreneurship centers.

There is a significant interest in clean energy investments in the region, as evidenced by the post-lignite Master Plan and plans for PV plant installations, battery capacity expansions, and hydrogen production facilities. In fact, recent analysis utilizing the latest data and methodologies has demonstrated the considerable potential for large-scale green hydrogen

expansion through electrolysis powered by renewable energy resources in Western Macedonia. (Ziouzios, D. et al. 2021)

3.1.2. CURRENT TRANSFORMATION PLANS AND STRATEGIES

With the cooperation of the World Bank and the European Commission, Greece has established a plan for the equitable and sustainable development of coal districts to aid in the transition away from lignite. Greece became the first member state of the European Union (EU) to present such a detailed roadmap to the EC for a just transition away from coal that benefits workers and communities. The roadmap is divided into three pillars:

- governance,
- social impact,
- and land use

The governance pillar seeks to build a clear and inclusive institutional framework for transition management, encompassing national, regional, and municipal governments, as well as civil society, the commercial sector, and academic stakeholders. The governance structure will manage the transition activities and projects' design, implementation, monitoring, and evaluation.

The social impact pillar aims to examine existing and future workforce and community requirements and issues, as well as to create and execute solutions to reduce the negative effects of transition, such as job losses, income reduction, and social exclusion. Skills development, employment support, social protection, and community participation will be among the social impact measures.

The land use pillar's goal is to identify and prioritize the greatest alternative uses for former mining areas and assets like power plants, equipment, and infrastructure. The land use alternatives will take into account the transition's environmental, economic, and social aspects, as well as strive to attract new investments and activities in sectors such as renewable energy, tourism, agriculture, and industry.

The roadmap also specifies the transition's funding sources and processes, such as the EU's Just Transition Mechanism, which will contribute up to €5 billion to Greece's coal regions, as well as national and regional grants, private sector contributions, and public-private partnerships.

The roadmap is consistent with the European Union's Just Transition Territorial Plans, which are detailed and participative plans for each coal region that describe the transition's vision, objectives, priorities, and actions. The plans also include a list of projects that are eligible for Just Transition Mechanism funding.

In addition, the roadmap also aligns with the national energy and climate plan, which establishes the targets and policies for Greece's transition to a low-carbon and resilient economy, as well as the national recovery and resilience plan, which outlines the reforms and investments that will aid in the recovery from the COVID-19 pandemic and the green and digital transition.

Furthermore, the roadmap is a live document that will be updated and amended as the transition takes place and new information and opportunities become available. The roadmap is meant to be a guide and tool for the government and stakeholders in planning and implementing a just and sustainable transition for Greece's coal regions, particularly Western Macedonia.

The Greek roadmap for a just transition from coal, supported by the World Bank, calls for the transformation of Western Macedonia into an alternative energy hub. The Greek government has set the goal of withdrawing all lignite plants by 2028, with most units being withdrawn already by 2023. The plan aims to cut down Greece's use of coal, which now makes up only 9% of its total energy supply, down from 25% six years ago. The World Bank has helped develop a roadmap in 2019-2020 to phase out coal in Western Macedonia, where unemployment is the highest in the country, particularly among young people, and where the loss of coal-related jobs could put further strain on the region. The roadmap calls for the creation of new jobs in the renewable energy sector, as well as the development of new infrastructure and the modernization of existing infrastructure. The Greek government has also announced plans to invest billions of dollars in coal-dependent areas to help them build back better and greener.

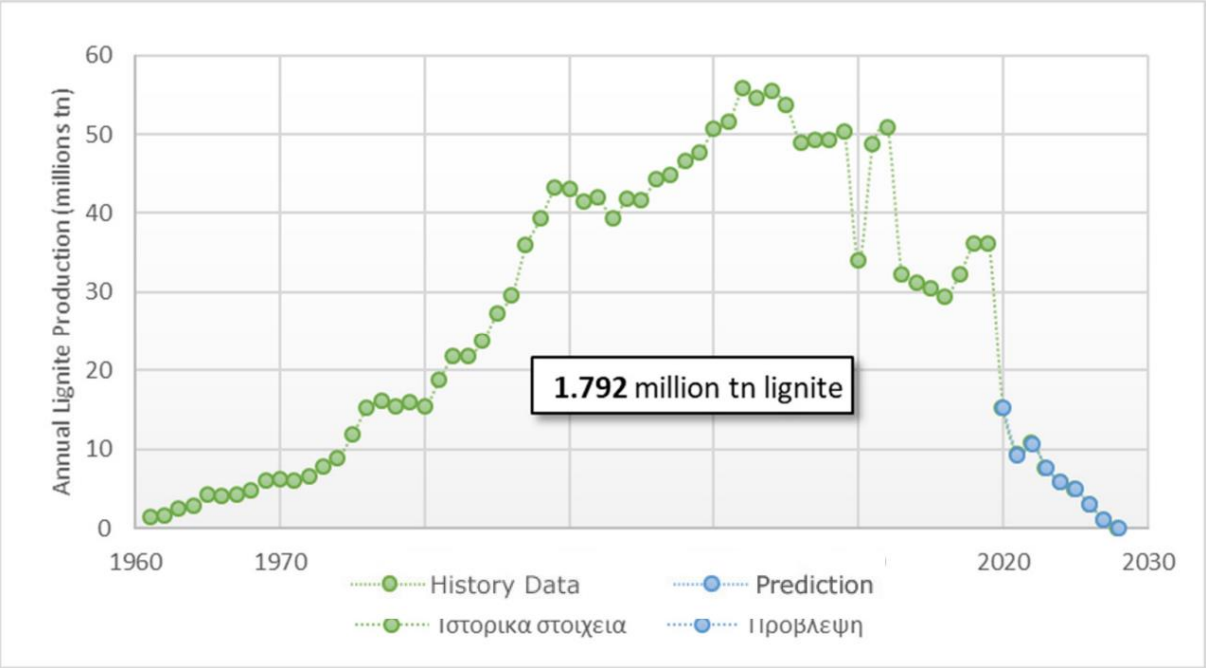

Figure 11. Lignite production in the mines of Public Power Corporation (PPC) in the region of Western Macedonia. (Ziouzios, D., Karlopoulos, E., Fragkos, P., & Vrontisi, Z. (2021). Challenges and Opportunities of Coal Phase-Out in Western Macedonia. Climate, 9(7), 115. MDPI AG. Retrieved from http://dx.doi.org/10.3390/cli9070115)

The following strategies are included in the roadmap:

- Providing a governance framework, a regional transition strategy, a proposal for a public-private partnership, and a stakeholder engagement approach to strengthen government systems.
- Preparing people and communities for a smooth transition away from the coal value chain, with an emphasis on labor market impacts.
- Supporting enterprises by creating a business assistance program, a finance mechanism, and a pipeline of projects.
- Infrastructure development will be accomplished through the creation of a regional infrastructure plan, a pipeline of infrastructure projects, and a finance system.
- Supporting innovation by creating a regional innovation ecosystem, a pipeline of innovative initiatives, and a funding mechanism.

Photovoltaic Projects in Western Macedonia

RWE and PPC: RWE Renewables and PPC Renewables have taken the final investment decision for five photovoltaic projects with a total capacity of around 210 MWp (175 MWac) in the Western Macedonia region in the north of Greece. The solar farms are located within the boundaries of the former Amynteo open pit lignite mine. The total investment of €180 million is planned, with €90 million co-financed by the Recovery and Resilience Fund.

Hydrogen Projects in Western Macedonia

The following projects were planned regarding Hydrogen technology in Western Macedonia:

Hellenic Hydrogen: A joint venture between Public Power Corp. (PPC) and Motor Oil, Hellenic Hydrogen is developing an electrolysis unit of up to 100 MW, with potential for a boost to 200 MW, for the production of hydrogen. The venture is also planning the creation of a hydrogen valley with 27 partners.

White Dragon: The White Dragon project was a proposal for an €8 billion hydrogen production project submitted for IPCEI (important projects of common European Interest) but unfortunately it has not been implemented. The core of the project was based on the gradual replacement of the lignite power plants of Western Macedonia and the transition to clean energy with the ultimate goal of carbonizing the country's energy mix. The project would use large-scale renewable electricity (GW) to produce green hydrogen by electrolysis in Western Macedonia.

Blue Med: Blue Med is a project dedicated to the production of blue and green hydrogen set to start in 2025. The project aims to use large-scale solar capacity to produce green hydrogen by electrolysis in the region of Western Macedonia for use in Greek heating and power, with an overall goal of replacing lignite plants.

Public Gas Distribution Networks (DEDA) has made plans to convert an urban district in Western Macedonia into a hydrogen village to test production, transmission and consumption. Furthermore, two similar projects that got in the IPCEI list is **H2CAT**, launched by B&T Composites, and Advent's **Green HiPo**.

3.2. KONIN REGION

3.2.1. CURRENT STATE

REGIONAL OVERVIEW

The Konin Region occupies an area of approximately 6,398 square kilometers in the eastern part of the Wielkopolskie Voivodeship, Poland. It consists of several counties, including Gniezno, Kolsko, Konin, Słupca, Turek, Września, and the city of Konin itself (GUS, 2019). Wielkopolskie Voivodeship, is one of the rapidly developing regions in Poland and Europe. However, it faces distinctive developmental challenges, highlighting significant internal diversity within the voivodeship in terms of socio-economic development. Over the years, Konin region has experienced numerous unfavorable economic and social trends. Notably, it exhibits one of the lowest levels of economic growth in the voivodship, coupled with a relatively low level of entrepreneurship. Additionally, the subregion is marked by adverse demographic changes, as evidenced by high indicators of an aging population and significant negative migration balances. Despite overall improvements in the national and regional labor markets, the local job market poses a substantial challenge, with the highest unemployment rates in the voivodeship.

In terms of environmental concerns, alongside global climate change threats leading to issues such as atmospheric and soil droughts, the area faces particular risks stemming from the

transformation of land surfaces and disruptions in water systems due to open-pit brown coal mining. In the context of the European Union's new development goals outlined in the European Green Deal (2019), emphasizing the need to build a modern, resource-efficient, and competitive economy, the Konin Region stands out as an area that uniquely concentrates the challenges arising from historical circumstances. These challenges necessitate a transition from over 70 years of an economy based on the extraction and utilization of brown coal deposits to a zero-emission economy aligned with contemporary socio-economic development conditions.

The development of the region emerged in the aftermath of World War II, coinciding with the discovery of brown coal deposits and the commencement of open-pit mining operations for this energy source. Two power plants, Konin (located in the Gosławice district) and Pątnów, were established as a result. Around them, various service enterprises such as briquette factories, the Open-pit Mining Equipment Factory, Aluminum Smelter, and many others flourished. In this context, brown coal extraction historically took place in two mines: Konin and Adamów. Presently, the sole active mining site is Tomisławice (part of the Konin Brown Coal Mine), operated by ZE PAK S.A. The timeline of open-pits Closures is presented in Table 5.

Table 5. Timeline of Open-Pit Closures (based on ZE PAK S.A. materials)

Open-Pit Name	Closure Date
Adamów Brown Coal Mine	
Adamów	2021
Bogdałów	1991
Koźmin South Field	2008
Władysławów	2012
Koźmin Central Field	2016
Konin Brown Coal Mine	
Morzysław	1953
Niesłusz	1691
Gosławice	1974
Pątnów	2001
Kazimierz	2011
Jóźwin	1999
Lubstów	2009
Jóźwin IIB	2023
Drzewce	2023
Tomisławice	2024

CURRENT LANDSCAPE AND INFRASTRUCTURE

From 2011 to 2020, Eastern Wielkopolska experienced stable but modest development in its technical infrastructure. Despite some positive trends, challenges remain, particularly in sewage infrastructure, where the sewage network length significantly lags behind the water supply network. Gasification is another area of concern, with less than 10% of households having access to natural gas, a rate lower than other coal regions. Housing space averages around 26 square meters per person, comparable to other coal regions (Churski, 2022).

In contrast, Eastern Wielkopolska excels in road infrastructure. The region ranks second among coal regions for the length of bicycle paths per 10,000 inhabitants, with approximately 3 kilometers of paths. Additionally, it boasts an impressive 96 kilometers of municipal and county roads with improved hard surfaces per 10,000 inhabitants (Churski, 2022).

Mining activities have significantly altered the landscape. Post-mining areas are being reclaimed and repurposed for agriculture, forestry, water management, recreation, sports, and energy production, including photovoltaic and wind farms. Agricultural reclamation predominates, covering around 6,500 hectares. Successful reclamation projects have led to the integration of these areas into the landscape, serving various natural and social functions such as forests, recreational areas, allotment gardens, and water reservoirs. Water reservoir reclamation is especially valued for addressing climate change adaptation and improving hydrological conditions.

The prolonged industrial and mining activities in the Konin Subregion have created a significant need for land reclamation as part of its economic transformation. This transformation necessitates adapting the transportation infrastructure originally designed to support the industrial and energy sectors. As the region undergoes economic changes, including mine closures and the emergence of new economic centers, infrastructure development needs to reflect these shifts. Emphasis is placed on expanding zero-emission public transport and enhancing road safety. Connecting economic activity areas to major transportation routes and diverting heavy transport from residential areas are key goals.

Eastern Wielkopolska's strategic location within key European transport corridors offers significant advantages. It lies on the Trans-European Transport Corridor II, which includes the railway line No. 3 and the A2 motorway. Additionally, two out of nine TEN-T corridors pass through the subregion, further enhancing its connectivity. The well-developed road network, comprising national and provincial roads, ensures efficient accessibility to major cities within and outside the subregion.

SOCIO-ECONOMIC CONTEXT

The Konin Subregion has seen a declining population trend in recent years, as indicated by Eurostat data (Figure 12). This decline coincides with a decrease in urbanization and shifts in migration patterns. Despite these trends, the subregion has favorable indicators for natural population growth, demographic burden, and mortality rates due to certain diseases. As of 2018, urban areas comprised 46.1% of the subregion's population (GUS, 2019).

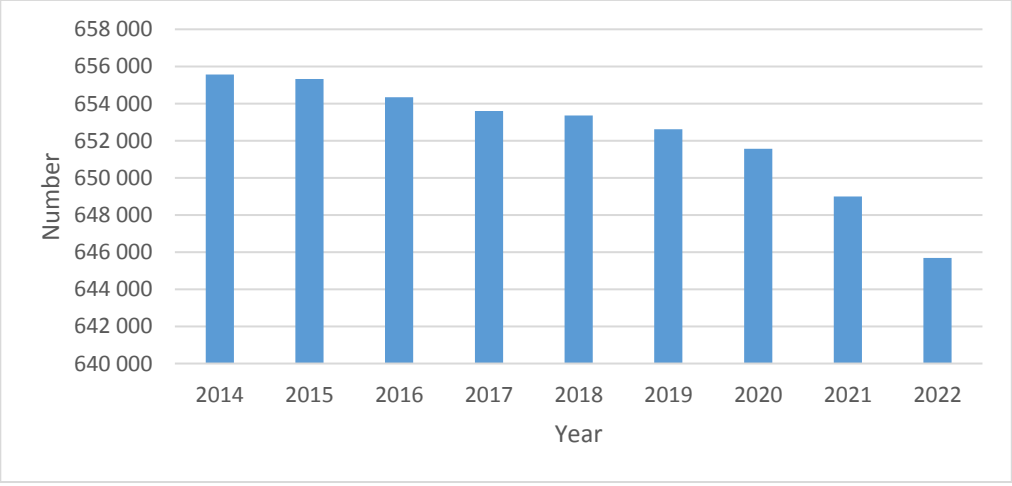

Figure 12. Population in Konin Subregion (Eurostat)

Both natural population growth and migration balances have seen a decline. In 2010, the natural growth rate was 2.44‰, which fell to -0.26‰ by 2018. The migration balance in 2018 stood at -959, equating to -1.46‰ (GUS, 2019). These dynamics influence the demographic burden, and despite relatively favorable conditions, the subregion still faces challenges. Notably, there has been a shift in the age dependency ratio, moving from the highest values among Poland's coal regions in 2011 to the lowest by 2020, indicating an accelerated aging process (Churski, 2022).

Compared to the rest of the province, the Konin Subregion struggle with significant employment challenges. As of late December 2018, registered unemployed individuals in the Wielkopolskie Voivodeship accounted for 4.9% of the working population (GUS, 2019). Since 2010, the unemployment rate in this region has consistently remained at the lowest level in the country, 2.9 percentage points lower than the national average (Szpor and Kiewra, 2018). However, within the Konin Subregion during this period, the unemployment rate stood at 5.6%, surpassing both the rates for Wielkopolskie as a whole and for the entire country. The unemployment rate within the subregion exhibited significant variation among its individual counties. In counties such as Kolski (unemployment rate of 4.4%), Słupecki (unemployment rate of 7.7%), Turecki (unemployment rate of 4.4%), and Wrzesiński (unemployment rate of 3.2%), the number of registered unemployed individuals was below 2,000.

Traditionally, the energy and mining sectors have offered some of the highest-paying jobs in the region. In 2017, the average gross monthly salary in Wielkopolskie's business sector was PLN 4,147.65, a 7.2% increase from the previous year. Sectors such as electricity, gas, steam, and hot water production and supply, information and communication, and mining and quarrying had the highest salaries. However, the Konin Subregion, despite its significant role in mining and energy production, reported lower average salaries (Szpor and Kiewra, 2018).

Economically, the Konin Subregion had the lowest GDP per capita in Wielkopolskie in 2020, at 72% of the provincial level and 78% of the national level. This relative economic position has deteriorated due to the restructuring of the energy and mining sectors and the dynamic development of Poznań and its surrounding areas. The GDP dynamic per capita is illustrated in Figure 13.

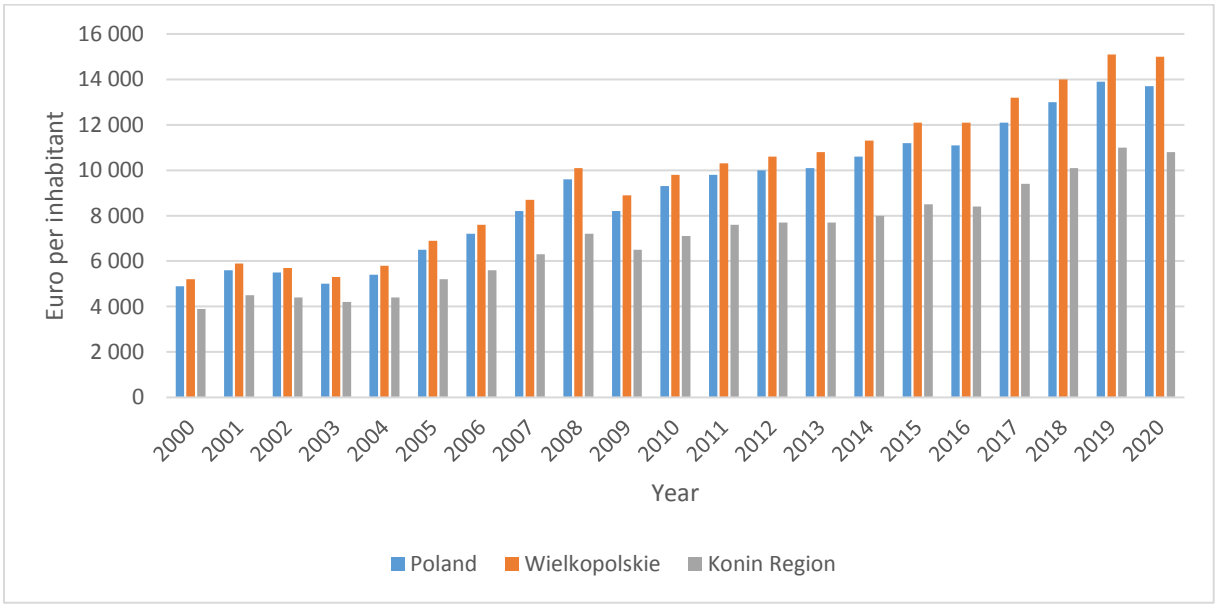

Figure 13. Comparative Analysis of GDP Per Capita Dynamics in Poland, Wielkopolskie Voivodeship, and Konin Region (2000-2020) (Eurostat)

ENVIRONMENTAL CONDITIONS

The landscape of the Wielkopolskie Voivodeship, in which the Konin Subregion is situated, is characterized by vast, flat expanses of fields and large forest complexes. Although the distribution of forests in the eastern part of the voivodeship is uneven, there are substantial and cohesive forested areas that have been preserved.

The Konin Region stands out for its biological diversity and the significance of its landscape features. It is one of the most diverse and scenic regions in Poland. This is evidenced by the fact that approximately 36% of the area is legally protected, making it the second highest in terms of protected area percentage among Polish coal regions. The protected areas encompass a variety of natural elements, underscoring the region's commitment to preserving its rich natural heritage.

Various forms of national and European Union protection have been established and legally sanctioned in the Konin Region, including:

European Nature Protection Areas: Significant for the community, these include:

- Habitat protection areas under Natura 2000, such as Ostoja Nadwarciańska (PLH300009) and Jezioro Gopło (PLH040007).
- Bird protection areas like the Dolina Środkowej Warty (PLB300002).
- Protected Landscape Areas: Notably, the Powidzko-Bieniszewski and Goplańsko-Kujawski regions.
- Nature Reserves: For example, the "Mielno" Reserve.
- Landscape Parks: Including the "Nadgoplański Park Tysiąclecia".

These areas are instrumental in preserving the region's unique ecological characteristics and biodiversity.

In and around Konin, there are several lakes such as Mikorzyńskie, Ślesińskie, Pątnowskie, and Powidzkie. Additionally, there are artificial reservoirs created as a result of mining activities. The Warta River Valley, a significant ecological corridor of national importance, forms the central axis of the natural system in Wielkopolska. Its location along the Warta River brings both ecological significance and the risk of flooding. The region is dotted with numerous natural and artificial water bodies, adding to its ecological diversity.

The region's reliance on brown coal mining presents significant environmental challenges. These include the need to improve air quality, reduce emissions from coal burning and mining operations, protect and maintain groundwater resources, remediate long-term industrially degraded lands, increase the share of renewable energy sources, and adapt to ongoing climate changes.

Long-term industrial activities, especially open-pit brown coal mining, have led to extensive land degradation in the subregion, requiring reclamation of nearly 7,000 hectares as of 2019 (approximately 67% of all devastated lands in the Wielkopolskie Voivodeship). he majority of this degraded land is located in the Konin (around 5,100 hectares) and Turek counties (over 1,800 hectares). The mining operations have not only altered the landscape's morphology but have also disrupted water relationships, leading to large-scale environmental changes, including the formation of extensive depression cones.

Eastern Wielkopolska is characterized by a water deficit, with average annual precipitation of 450-550 mm and potential evaporation exceeding 700 mm. This results in a negative climatic water balance, leading to a general depletion of water resources across the region. Climate projections up to 2030 suggest that the average annual rainfall may reach about 620 mm.

Combined with the impact of open-pit mining, which diminishes water resources in areas affected by expansive depression cones, this is expected to intensify drought conditions.

Mining activities in the Konin Subregion have significantly contributed to an increase in CO2 emissions. In 2019, this area was among those with the highest greenhouse gas emissions in Poland, largely due to energy production and industrial processes. Notably, the ZE PAK Group, operating in the region, was responsible for over 60% of the CO2 emissions in the Wielkopolskie Voivodeship and nearly 90% of emissions within the subregion itself. The primary sources of these emissions are large power plants such as Pątnów I, Pątnów II, and Konin. These facilities significantly contribute to the overall CO2 and particulate matter emissions in the region. Despite some reductions, CO2 levels in the Konin Subregion remain high when compared to other coal regions in Poland. The following figure represents CO2 Emissions from Major Industrial Polluters in Wielkopolskie Voivodeship and Konin Region

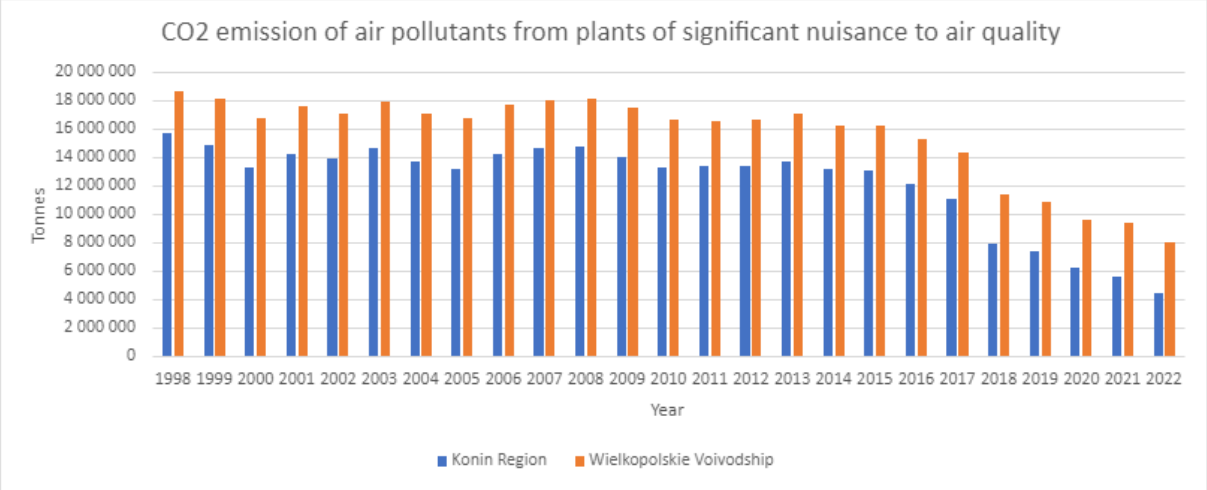

Figure 14. CO2 Emissions from Major Industrial Polluters in Wielkopolskie Voivodeship and Konin Region (GUS-BDL)

Other significant contributors to emissions include the electro-energy and heating sectors, individual heating systems, and transportation. The extensive emissions from these sources highlight the substantial environmental impact of the region's reliance on coal and the need for concerted efforts towards sustainable energy solutions and emission reduction strategies.

In addition to the industrial sector, key areas for reducing greenhouse gas emissions include transport, agriculture, and construction. Households, transportation, and agriculture sectors are significant contributors to the non-ETS emissions in Poland, highlighting the need for comprehensive strategies in these areas to mitigate environmental impact.

CULTURAL AND HISTORICAL SIGNIFICANCE

The Konin Subregion, rich in historical and cultural sites, plays a vital role in preserving and showcasing the heritage of both the region and the country. The city of Konin, beyond being an economic hub, is also a significant cultural center. The cultural assets of Konin could become key factors in enhancing the attractiveness of living in the region and expanding its tourism offerings. Cultural institutions offer opportunities for personal development and "contact with culture," while also elevating the city's prestige.

To illustrate the region's cultural richness, the following table (Table 6) lists some of the notable museums and other cultural sites across the Konin Subregion.

Table 6. Selected Museums and Cultural Sites in the Konin Subregion

Museum/Place	Location
Museum of the Origins of the Polish State	Gniezno
Mikroskala Model Park Education and Entertainment Centre	Konin
Museum of Ceramic Techniques	Koło
Władysław Reymont Memorial Exhibition Chamber	Kołaczkowo
Konin District Museum	Konin
Archdiocesan Museum	Gniezno
Salt Mine “KŁODAWA”	Kłodawa
Children of Września' Regional Museum	Września

CURRENT ENERGY LANDSCAPE

The Konin Subregion has a distinctive energy production landscape, primarily influenced by its historical and ongoing coal mining activities, as well as a growing focus on renewable energy sources.

Historically, Poland's brown coal has been mined in four major mines: Turów, Bełchatów, Konin, and Adamów, with the latter two located in the Konin Subregion. The Bełchatów mine, being the youngest yet largest, is the principal producer, accounting for about 1,170 million Mg (megagrams) of brown coal, which constitutes 40% of Poland's total brown coal extraction since 1945 (Figure 15.). Following this is the PGE GiEK S.A. Turów mine, contributing nearly 32%. These two mines are part of PGE Mining and Conventional Energy S.A. The remaining brown coal extraction in the region is attributed to PAK KWB Konin S.A. and PAK KWB Adamów S.A., which are part of the ZE Pątnów-Adamów-Konin S.A. Group, accounting for 21% and 7% of the market share, respectively (Kasztelewicz, 2018).

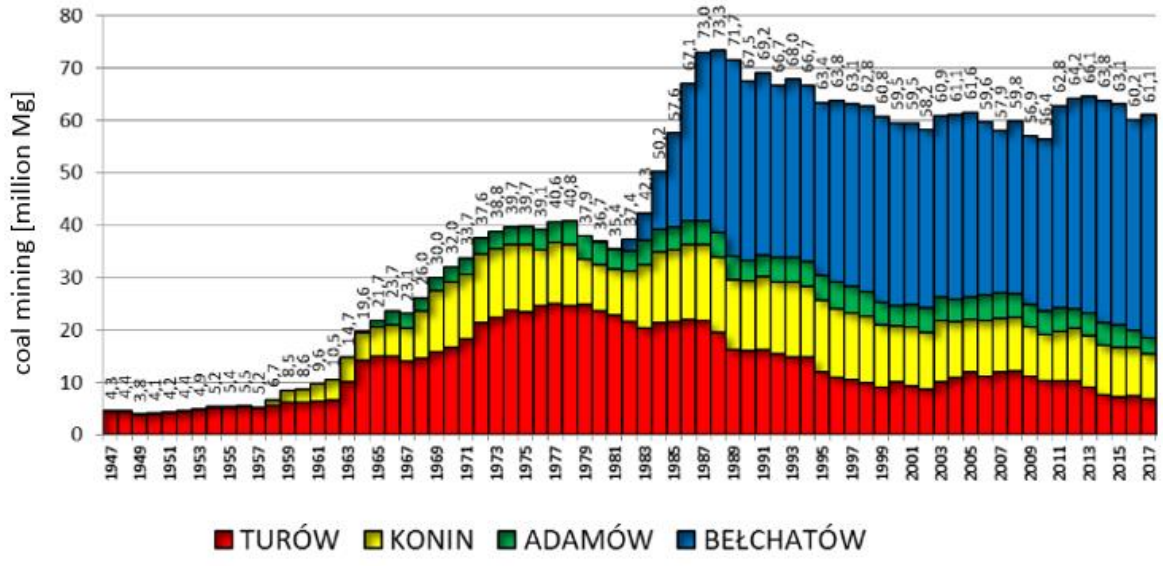

Figure 15. Total Amount of Coal Extracted in Poland from the Beginning of Operations to 2017 Inclusive (Kasztelewicz, 2018)

The Konin Subregion's energy landscape is predominantly shaped by the activities of ZE PAK Group, a key player in the region's energy sector. ZE PAK S.A., operating in the Konin Subregion, is the largest private (non-state controlled) energy group in Poland. The group is a

vertically integrated conglomerate active in brown coal mining, conventional and renewable energy production, and energy trading. It stands as the only producer of brown coal in the Wielkopolska area.

ZE PAK S.A. currently conducts its mining operations at the Tomisławice open pit, initiated on September 20, 2011, to replace the Kazimierz open pit that closed in June of the same year. This mine is expected to be operational until around 2030, with estimated industrial reserves of 41 million tons (http://www.kwbkonin.pl/).

The ZE PAK thermal power plant complex, established in 1970, includes:

- Pątnów Power Plant: The largest in the group, it comprises six energy blocks. Two modernized blocks have a capacity of 222 MW each at 37.5% gross efficiency, and four older blocks operate at 200 MW each with 33.7% gross efficiency. Due to the implemented desulfurization system, only four of these six blocks can operate simultaneously.
- Pątnów II Power Plant: This is the most modern facility within the group, featuring a supercritical block with a gross efficiency of 44% and a nominal capacity of 474 MW. It is expected to be the longest-operating brown coal-based power plant in the ZE PAK group.
- Konin Combined Heat and Power Plant: The oldest and smallest unit in the group, it operates on a collector system with three energy boilers and three turbine sets. Additionally, a newly installed mixed biomass (forest and agricultural) block with an installed capacity of 55 MW produces thermal energy. However, except for the new biomass boiler, this plant is facing imminent closure due to obsolescence (Szpor and Kiewra, 2018).
- ZE PAK S.A. is gradually transitioning towards renewable energy sources. The group operates a photovoltaic farm in Brudzew municipality with an installed capacity of 70 MWp. By 2030, ZE PAK S.A. plans to completely shift from coal, aiming to have 1,282 MW of installed capacity powered solely by green energy sources.

The current RES landscape in the Konin subregion is detailed in Tables 7 and 8.

Table 7. Renewable energy source installations (RES) – installed capacity (MW) in 2021 (Borkowicz K. red., 2023)

Unit	Value
Poland	11 518,72
Wielkopolskie Voievodship	1 354,64
Konin Subregion	350,37
Kolsko County	53,29
Konin County	80,99
Słupca County	36,38
Turek County	119,35
City of Konin	60,36
Konin subregion	
Share of installed renewable energy capacity in the subregion in the installed capacity in the voivodeship (%)	25,86

Table 8.Renewable energy source installations (RES) – installed capacity in the counties of the Konin subregion by type of installation (MW) in 2021 (Borkowicz K. red., 2023)

Type of renewable energy installation	Kolsko County	Konin County	Słupca County	Turek County	City of Konin	**Konin Subregion**
Using biogas	-	-	0,04	2,39	3,01	**5,45**
Using biomass	-	-	-	-	50,00	**50,00**
Using solar energy	6,94	2,00	1,10	78,75	0,05	**88,84**
Using wind energy	46,35	78,90	35,24	38,20	-	**198,69**
Using hydropower	-	0,10	-	-	-	**0,10**
Installation for thermal waste treatment	-	-	-	-	7,30	**7,30**
Konin Subregion	**53,29**	**80,99**	**36,38**	**119,35**	**60,36**	**350,37**

STAKEHOLDER LANDSCAPE

The success of environmental and economic projects in the Konin region depends on the effective involvement of a diverse group of stakeholders. As detailed in Annex 2, there is a wide range of key stakeholders in the region, including social administration bodies, business entities, non-governmental organizations, business environment institutions and trade unions. These groups represent diverse interests, expertise and influence relevant to the regional development process.

Effective stakeholder engagement in the Konin region requires a strategic approach, ensuring all voices are heard and integrated into the development process. This collaborative effort is vital for aligning the region's transformation with the aspirations and needs of its community, thereby fostering a sustainable and inclusive future.

CHALLENGES AND OPPORTUNITIES

The Konin Subregion faces a unique set of challenges and opportunities that are pivotal for its future development. These can be categorized into various dimensions, each with its specific set of issues and prospects (Development Strategy For Eastern Wielkopolska 2040).

Social Dimension

- Resource Allocation: Targeting national and external funds for social policy tasks, including those related to fair transformation.
- Ecological Awareness: The growing environmental consciousness of society facilitates the transformation process of coal regions.
- Social Economy: The increasing importance of the social economy creates opportunities to counteract social exclusion and mitigate negative demographic trends.

Economic Dimension

- Restructuring Funding: Channeling external intervention funds towards the restructuring of the mining and energy industry.
- Energy Policy Focus: Aligning with the European Union and Poland’s energy policies that emphasize the development of Renewable Energy Sources (RES) and leveraging existing energy infrastructure.
- Labor Market Improvements: Addressing unfavorable conditions in the labor market, particularly the relative low wage levels in comparison to the wider Wielkopolska region.
- Work Conditions and Specializations: Enhancing work conditions and focusing on the development of intelligent specializations, which remain the main idea connecting various EU and national policies.

- Global Economic Integration: Developing international economic connections and diversifying international trade directions.
- Technological Advancements: Embracing the development of modern technologies and e-economy.

Environmental-Spatial Dimension

- Post-Industrial Reclamation: Directing external intervention funds towards reclamation and development of post-industrial areas and combating climate change.
- Location Attractiveness: Increasing locational attractiveness due to improved accessibility and strategic positioning in key European and national transport corridors.
- Tourism and Recreation: Developing recreational and tourism activities of national and international scope by utilizing natural areas and reclaimed post-industrial lands.

Through research, analysis, and consultations with Eastern Wielkopolska's residents, several key development challenges for the subregion have been identified (Development Strategy For Eastern Wielkopolska 2040, 2022):

1. **Economic Transformation**: This includes diversifying the economy, increasing the share of intelligent specializations, enhancing innovation and information and communication technology usage, boosting entrepreneurship, attracting new investors, internationalizing local firms, adapting to changing supply chains and market directions, and increasing public support for mining regions transitioning away from coal.
2. **Technological Changes:** Efficient use of the region's potential for energy transition towards low-emission energy, digital transformation, development of a zero-emission and circular economy, including biotechnology, advancement of agriculture innovation, Industry 4.0 and 5.0, and enhancing the role of R&D in local firms and universities.
3. **Social Transformation:** Changing the perception of the subregion, enhancing residents' engagement in improving quality of life, ensuring access to high-quality services, and addressing increasing social crises.
4. **Social Capital Development:** Reducing social exclusion, enhancing community involvement, fostering pro-environmental and civic attitudes, and building a new identity and strong social ties for the region.
5. **Demographic Processes:** Counteracting depopulation, especially retaining young people and integrating immigrants, improving public health, and addressing the effects of the refugee crisis.
6. **Climate Change:** Increasing resilience to climate change and catastrophic weather events, combating water deficits, implementing systemic solutions to natural disasters, protecting biodiversity, and aiming for climate neutrality by 2040.
7. **Environmental Quality:** Improving air and water quality, restoring water relationships, protecting biodiversity, increasing forest cover, managing urban green spaces, conserving ecosystems and valuable landscapes, revitalizing post-industrial areas, enhancing waste utilization, and organizing water and sewage management.
8. **Economic, Social, and Spatial Cohesion:** Reducing developmental disparities, ensuring communication accessibility, effectively utilizing the polycentric settlement structure for balanced development processes.

3.2.2. CURRENT TRANSFORMATION PLANS AND STRATEGIES

The transition of the Konin region from its reliance on brown coal mining is guided by a diverse array of plans and strategies. This chapter presents an overview of these guiding documents, reflecting a multi-level approach encompassing national, regional, and local initiatives.

The landscape of this transition is shaped by several key documents:

- The National Energy and Climate Plan for the years 2021-2030,
- Energy Policy of Poland until 2040,
- Territorial Just Transition Plan for Eastern Wielkopolska,
- Reclamation Plan,
- Entrepreneur's plans.

These documents and plans collectively form a comprehensive strategy, devised and implemented at multiple governance levels. From state policies setting ambitious national goals to regional plans ensuring equitable and just transitions, down to the entrepreneurial level where innovative reclamation and area reuse strategies are being implemented. Each layer, from planning to strategy execution, is critical in shaping the Konin region's future by balancing environmental, economic, and social factors

The chapter explores how these diverse plans interlink and contribute to a cohesive strategy for the transformation of the Konin region, turning challenges into opportunities for sustainable development and growth.

NATIONAL ENERGY AND CLIMATE PLAN FOR THE YEARS 2021-2030

Poland's National Energy and Climate Plan (NECP) for the years 2021-2030 outlines the country's strategic approach to energy and climate policy. It sets specific targets to transition towards a sustainable and environmentally friendly energy system, emphasizing the integration of renewable energy sources, enhancing energy efficiency, and ensuring energy security.

The NECP specifies ambitious goals that serve as benchmarks for regions like Konin:

- **Carbon Dioxide Reduction**: Aiming for a 7% reduction in CO2 emissions in non-ETS sectors by 2030, relative to 2005 levels, the NECP establishes a definitive path for reducing greenhouse gas emissions beyond the Emissions Trading System.
- **Renewable Energy in Gross Final Energy Consumption**: The NECP sets a target of 21-23% renewable energy sources (RES) in gross final energy consumption by 2030, signifying a robust commitment to renewable integration in the national energy mix.
- **Renewable Energy in Heating and Cooling**: The plan includes an incremental increase in the use of RES in heating and cooling, at an average rate of 1.1 percentage points per year, underlining the push for sustainable energy sources in these sectors.
- **Renewable Energy in Transport**: The NECP advocates for a transition to cleaner energy in transportation, aiming for a 14% usage of renewable energy in the sector by 2030
- **Energy Efficiency**: A pivotal target of a 23% increase in energy efficiency by 2030, equivalent to a 23% reduction in primary energy consumption compared to the PRIMES2007 forecasts, reflects the emphasis on reducing energy demand through efficient usage practices.

For the Konin region, aligning with these national-level goals is crucial. The region's transformation strategies must incorporate the NECP's targets into their planning to ensure that local efforts contribute effectively to the nation's energy and climate agenda. By aligning with these goals, Konin region will play a pivotal role in helping Poland achieve its national energy and climate commitments, while fostering regional growth and resilience in a changing energy landscape.

ENERGY POLICY OF POLAND UNTIL 2040

The Energy Policy of Poland until 2040 (PEP2040) articulates a strategic vision for the nation's transition to a low-emission energy system, aligned with the National Energy and Climate Plan

and the broader climate and energy frameworks of the European Union. This policy underscores Poland's dedication to recalibrating its energy sector to meet the EU's climate neutrality aspirations, reflective of commitments under the Paris Agreement and the European Green Deal.

PEP2040 unfolds across three strategic pillars:

- **Just Transition:** Advocating for equitable socio-economic transformations, especially in coal-dependent areas like Konin.
- **Zero-Emission Energy System:** Moving toward decarbonization of the energy sector through the progressive adoption of sustainable technologies and diversification of energy sources.
- **Good Air Quality:** Targeting improved environmental and health outcomes by reducing the negative impacts of energy production and consumption.

Within this framework, PEP2040 advances a sequence of ambitious targets and actions to steer the country towards these objectives, as depicted in Figure 16 (Policy of Poland until 2040, 2021). Some of these key targets include increasing the share of renewable energy in all sectors, enhancing energy efficiency, and expanding the capacity for offshore wind energy.

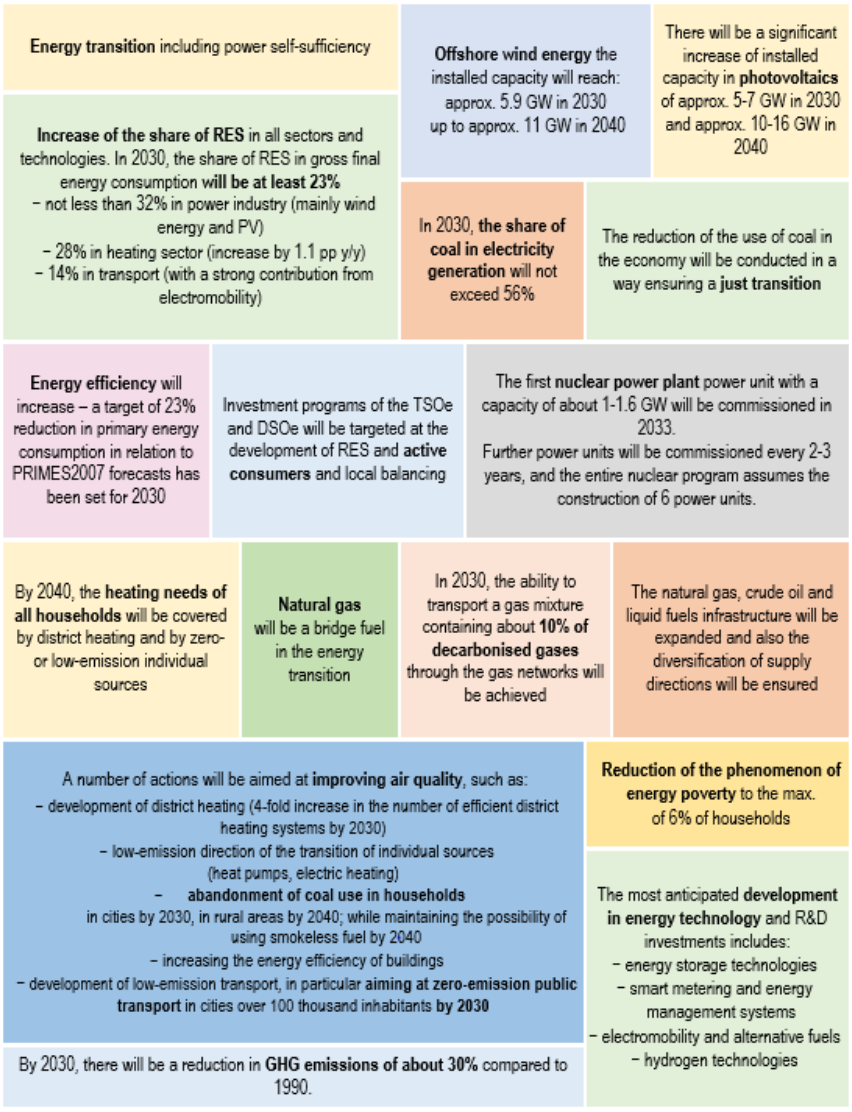

Figure 16. Key elements of Policy of Poland until 2040 (Policy of Poland until 2040, 2021)

For the Konin region, the strategic objectives and projects outlined in PEP2040 carry significant implications, such as:

- The transition of coal regions is addressed directly, with financial instruments such as the EU's Just Transition Mechanism providing support.
- The emphasis on renewable energy sources and nuclear power as part of the zero-emission energy system offers a roadmap for the region's energy diversification.
- The development of smart grids and energy-efficient technologies presents opportunities for modernizing the local energy infrastructure.

In conclusion, PEP2040 lays out a national blueprint for regions like Konin to navigate their energy transitions. The alignment with PEP2040's objectives is essential for realizing the national ambitions for a sustainable and robust energy sector. Therefore, Konin's strategic initiatives must resonate with and actively contribute to the vision set forth by PEP2040, capitalizing on the policy's provision for a just and thriving energy future.

TERRITORIAL JUST TRANSITION PLAN FOR EASTERN WIELKOPOLSKA

The Territorial Just Transition Plan for Eastern Wielkopolska, encompassing the Konin region, represents a commitment to a sustainable future by mitigating the socio-economic impacts of a necessary departure from coal dependency. Aligned with the European Climate Law's ambition for climate neutrality by 2050, the TJTP sets forth a strategic framework for the region's transition, synchronizing with the objectives of Poland's National Energy and Climate Plan and the Energy Policy of Poland until 2040 (PEP2040).

Eastern Wielkopolska's climate policy is anchored in achieving climate neutrality by 2040. Actions are directed towards increasing energy efficiency, including deep thermal modernization, leveraging renewable energy sources and hydrogen — with special emphasis on green hydrogen — as well as fostering circular economy principles and clean mobility.

The plan articulates a clear schedule for phasing out coal mines. For instance, PAK KWB Adamów SA ceased surface mining operations in 2021. Within the KWB Konin SA, the Drzewce and Jóźwin mines have already closed in 2022 and 2023 respectively, with Tomisławice slated for closure by 2030. These closures mark a pivotal change for the region, heralding both the end of an era and the beginning of a new chapter in its economic narrative.

The cessation of mining activities carries significant risks, including economic slowdowns and societal upheaval. Grupa ZE PAK, a major contributor to the region’s GDP and public sector revenue, will cease operations, potentially resulting in a substantial loss of public sector income, exacerbating unemployment, and magnifying the impacts of depopulation.

In this transformative landscape, the TJTP focuses on three critical directions:

1. **Building a Zero-Emission, Dynamic and Circular Economy**: This goal aims to secure Eastern Wielkopolska's future by fostering a competitive and innovative economy that is independent of coal and conventional energy sectors. Through harnessing the region's endogenous potential, new and existing economic sectors will be strengthened, aligning with the objectives of climate-neutral and circular economy development.
2. **Ensuring Integrated High-Quality Spaces**: The plan prioritizes improving the quality and functionality of residential areas, thus guaranteeing a high-quality environment for residents and creating new development opportunities for the economy. Regeneration of areas transformed by industrial activity will be prioritized, with projects that return previous functions or add new ones to previously industrial areas, aiming to reduce the land devastated by mining.
3. **Fostering an Active Society**: The TJTP recognizes the crucial role of an active society as the driving force behind the subregion's transformation. It seeks to address

significant elements that reduce the socio-economic development potential, including negative demographic changes, social inequalities, and the potential adverse effects of the transition. The plan's actions aim to activate the residents of the mining region, combating social exclusion, and improving access to quality, affordable social services.

The TJTP is a comprehensive response to the complex challenges Eastern Wielkopolska faces as it transitions from its coal-based heritage. It represents a proactive and holistic approach to ensuring that the region not only navigates the transition successfully but emerges as a leader in sustainable and equitable development.

RECLAMATION PLANS FOR PAK KWB KONIN S.A.

Reclamation efforts are a cornerstone of PAK KWB Konin S.A.'s operations post-coal extraction, undergoing all transformed lands by the mine. Mandated by law, reclamation occurs within five years after industrial activities cease. Konin Mine executes reclamation in agricultural, forestry, water, recreational, and special categories, in consultation with local municipalities and often in response to residents' requests (http://www.kwbkonin.pl/). Precentage share of particular directions of reclamation in Konin and Adamów mines is presented in the table below.

Table 9. Percentage share of particular directions of reclamation in Konin and Adamów mines (based on Kasztelewicz Z., 2018)

Approach to reclamation	Unit	Mine	
		Konin	Adamów
Agricultural	%	50	59
Forestry	%	31	17
Water	%	8	24
Recreational	%	2	1
Special	%	9	-

Agricultural Reclamation

The Konin and Adamów mines are unique in Poland as the only open-pit brown coal mines engaging in agricultural reclamation (Kasztelewicz, 2018). This reclamation process, primarily driven by the presence of overburden gray clays, involves meticulous technical and agrotechnical treatments, including selective dumping and enhanced fertilization (http://www.kwbkonin.pl/). The result is highly productive agricultural land, surpassing the efficiency of native sandy soils in the Konin region. Notably, this land transformation elevates low-quality soil to higher agricultural classes, enabling the cultivation of various crops and pastures, and exemplifies a successful transition of post-mining landscapes to valuable agricultural resources (Kasztelewicz, 2014).

Forestry Reclamation

Forestry reclamation at the Konin and Adamów mines involves planting on spoil banks to prevent erosion and create fertile soil layers. This reclamation method, adapted to the underlying gray spoil clays, primarily uses deciduous tree species like oak, ash, larch, and beech, along with mixed species like linden, hornbeam, maples, and shrubs like Siberian peashrub and black elderberry. Successful reforestation requires proper site preparation, planting density, and seedling quality, followed by mineral fertilization and maintenance. This effort has led to the creation of several hectares of forests, providing diverse wildlife with new habitats in the Konin region (http://www.kwbkonin.pl/).

Water Reclamation

Water reclamation by PAK KWB Konin S.A. is a pioneering effort in Poland. The Konin Basin, with lignite exploitation dating back to the 1940s, has led to the creation of several post-exploitation lakes. Table 10 presents the characteristics of the Konin region's post-exploitation reservoirs. These lakes have become integral to the region's landscape, significantly enhancing its touristic appeal and providing recreational spaces for the community, complete with beaches, walking paths, and playgrounds. Their crystal-clear waters attract diving enthusiasts, while diverse depths cater to both swimmers and anglers, creating a vibrant ecosystem for waterfowl and fish, showcasing PAK KWB Konin's commitment to combining mining activities with environmental care http://www.kwbkonin.pl/).

Table 10. Table X. Characteristic of Konin region post exploitation reservoirs (based on ZE PAK S.A. materials)

Reservoir	Flooding status	Area at max. filling [ha]	Reservoir depth [m]
Adamów Mine			
Janiszew	Completed	60,0	
Głowy	In progress	91,5	24,5 - 40,5
Koźmin	Completed	121,0	4,0 - 10,0
Koźmin Końcowy	Completed (acceptance by the end of 2023)	131,0	31,8 - 45,8
Władysławów	In progress	109,0	39,0
Adamów Pośredni	In progress	105,0	28,7 - 37,0
Adamów Końcowy	In progress	309,0	24,5 - 37,5
Konin Mine			
Kleczew	In progress	550,0	63,7
Roztoka	In progress	19,0	9,0
Jóźwin	Planned	750,0	40,3 - 68,7
Lubstów	In progress	480,0	63,0 (S) - 55,0 (N)
Bilczew	Completed	41,0	21,5
Drzewce	Planned	160,0	19,0 - 41,0
Tomisławice	Planned	290,0	48,0

Recreational Reclamation

As the newest reclamation direction, recreational reclamation often accompanies water reclamation. Interest in using revitalized areas for recreational and sports purposes has been growing, with many projects realized in response to municipal government suggestions. Examples include the transformation of areas like the Jóźwin IIA pit into Recreation and

Physical Activity Park with water bodies and surrounding facilities, enriching community life and promoting active lifestyles.

ENTREPRENEUR'S PLANS FOR FUTURE LAND USE

ZE PAK S.A., the enterprise responsible for lignite extraction in the Konin region, has set ambitious strategic goals: a transformation from coal to renewable energy sources (RES) — shifting from black to green energy — and establishing the first nationwide, complete value chain for green hydrogen economy, investing in the future, reducing CO_2 emissions, and providing clean air.

Entrepreneur set two main transition goals:

I. **Transitioning to Zero and Low-Emission Energy**
   - Phasing out lignite coal. This includes extinguishing and decommissioning coal-fired blocks and closing open pits, followed by land reclamation and the restoration of water relations.
   - Investing in solar energy production. This involves acquiring ready-to-implement photovoltaic projects and constructing solar farms on reclaimed lands owned by ZE PAK S.A.
   - Wind energy production investments. This includes acquiring ready-to-implement wind projects and constructing wind farms on reclaimed lands, along with collaboration with Ørsted, a leader in offshore wind farms, to explore the potential for building offshore wind farms.
   - Biomass energy production. Adapting coal-fired boilers for biomass combustion at Konin Power Plant.
   - Producing electricity from a low-emission source, such as the gas-steam block being built on the site of the former Adamów coal power plant by PAK CCGT.

II. **Building Green Hydrogen Economy**
   - Green hydrogen production is a significant new area of operation for Konin Power Plant.
   - Hydrogen refueling stations and hydrogen transporters will be developed.
   - Zero-emission bus production, with the concept and implementation of an innovative urban hydrogen bus project.

By 2030, ZE PAK S.A. plans to complete its transition away from coal. Figure below illustrates these ambitious developmental plans, showing a transition in the installed power capacity from coal-based to renewable energy sources. This figure presents the planned structure of installed capacity by fuel type. ZE PAK S.A. aims to have 1,282 MW of installed capacity powered solely by green energy sources by 2030.

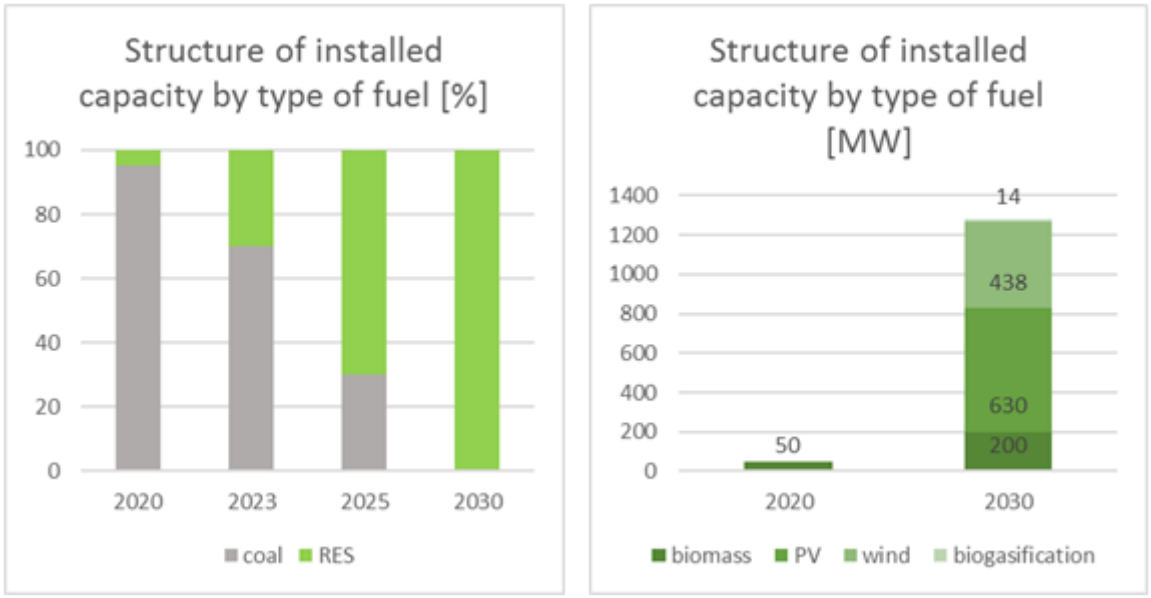

Figure 17. Structure of installed capacity by type of fuel (based on ZE PAK S.A. materials)

4. INSIGHTS FROM RUHR AREA

Start of the transformation process

In 2008, the German government decided to phase out hard coal mining by 2018. This decision enabled the coal mining regions in Germany, the Saar and the Ruhr region to prepare the post coal mining time within this period of 10 years. In the metropolitan Ruhr region, the challenge was and still exists to successful transform the former mining region. So the cities and districts in the Ruhr region concluded jointly to cooperate and to initiate an intercommunal decision matching and dialogue process.

The first step in this transformation process was the development of a strategic perspective for the region for the next decade. Based on the previous urban development policies, the so called "concept Ruhr" took up the future challenges and turned into operation in regional development concepts and master plans. These concepts and plans were also the base for applying and receiving EU regional development funding. One important topic of the "concept Ruhr" was the "site precaution" in the frame of the coal reduction because the effects of mine closures were clarified at an early stage and prevented potential drastic regional disruptions. Besides actual mine closures, long-term future closures were considered. In total, 15 mine sites in the region were included in the "concept Ruhr" and this perspective were the big chance for this 10 years lasting anticipation process.

The second step in this transformation process was the position paper "Change as a chance" in autumn 2008. The aim of this paper was to assess the joint implementation of the medium and long-term concepts because of the coal decision. It tackled more than 40 cities and communities in the Ruhr valley. The position paper described the framework conditions in the region and stated fundamentals for joint actions. In addition, spheres of activity for a coordinated strategy of all actors and precise local and regional projects were determined. Areas should first be safeguarded and subsequently been developed in a sustainable way. The focus was on coordinated research and technology valorisation. New utilisation and development was the base to focus on major mining areas and resulted in the “coal brownfield agreement”. The regional association Ruhr RVR (an association of the eleven cities and four districts of the Ruhr region), the Ministry of Economics NRW and the coal mining company

RAG and its subsidiary RAG Montan Immobilien (the Real Estate company) finally undersigned this document in 2014.

Coal brownfield agreement

This agreement was the start of a new cooperation process. From 2009 to 2014, the parties negotiated the priority development areas. Criteria such as long-lasting reuse, urbanistic priority, industrial location and employment effects, stabilisation of social structures and limitation of land consumption were guiding. The final selection of 20 mine sites and the agreement upon common objectives, which should be achieved in shared responsibility of the partners, was the foundation for the coal brownfield agreement.

For the management of the entire process the parties have established a steering committee and an inter-communal platform. The steering committee consists of representatives of the municipalities, of the director of the regional association Ruhr, of the Ministry of Economics of North Rhine Westphalia, of the respective functional departments of the Ministries and of the District Councils as well as of the board of directors of the coal mining company and is steering the entire process on decision level. In annual meetings, the parties are discussing questions related to funding, project development and financing, but also local characteristics. The steering committee assesses the progress reports and compares the outcomes with the annual land use evaluations.

By establishing the coal brownfield agreement and based on the long-lasting trustful informal collaboration the municipalities in the Ruhr area obtained a formal framework. Within this structure, the cities and districts are working together in close connection with the common objective to realise successful the transition of former mine sites on local level.

The regional association Ruhr (RVR) is coordinating the collaboration and is offering exchange platforms for the town councils. The inter-communal design matching strengthens the position of the councils as a whole towards the other parties. It also allows to transfer knowledge between the local project responsibilities and to increase competences on land development. The inter-communal knowledge transfer helps to identify challenges, which are specific for the transformation of mine sites and require special solutions. Because the municipalities are the numerical largest party in this process, they use the exchange for harmonisation of overarching questions in the sense of a regional consensus. The exchange also allows show promptly obstacles and progress. In that way, the parties can analyse difficulties, align measures and develop solutions.

Effect and benefits of the coal brownfield agreement

The selection of 20 hard coal mine sites for an accelerated development laid the main foundation for this form of cooperation and provided the new frame for the collaboration of the partners. The contents and the structure of the agreements have a direct and indirect impact on the spheres of activities:

- Surface area with the issue of realisation of successful land usages
- Financial dimension with the issue of financing models and access to funding grants
- Time dimension with the issue of coordinated and integrated developments as well as acceleration of the processes
- Organisation with the issue of a reliable and target-oriented collaboration of the partners

All partners state that the coal brownfield agreement provides a frame for short information and decision processes as well as for a quick exchange and knowledge transfer. The aim of an integrated successful land development is supported by interdepartmental coordination and

funding priorities of the State of North Rhine Westphalia. Crucial is bundling of the activities in a leading department (in this case the Ministry of Economics) including the interdepartmental coordination as well as the expansion of utilisation options from pure economic ones to integrated land development.

The specific structures and instruments of the coal brownfield agreement enable an acceleration of the processes and decisions. The annual progress reports demonstrate evolution and obstacles in a transparent manner and are the base for a common evaluation. Action requirements are getting obvious in time and essential decisions can be prepared.

The responsibility for the development actions of each site remains with the proprietary and with the city respectively. On local level, particular structures are created for example cooperation agreement or the establishment of project companies. Local experiences are shared for mutual benefit in two-sided discussions as well as in intercommunal meetings. The project manager and the sites are benefitting from this knowledge transfer.

On each site, collaboration and design-matching processes are initiated, which are not self-evident. One example is the forward-looking design matching process between the mine owner and the respective city regarding the future use of the brownfield in the framework of the mine closure plan.

Compared to other land development projects, the proprietary can be more involved in project financing due to waiving distribution of profits and rolling financing. The intercommunal adoption of usage and development foci as well as market accesses led to common actions rather than concurrent ones. The exchange on topics and problems resulted in a common understanding and benefits for the parties because solutions are presented in time and can be discussed amongst the partners. At the same time, the regular exchange and the evaluation avoids process-inhibited activities. Since the signature of the agreement, the government of North Rhine-Westphalia supports the decision by implementing funding priorities. The local projects benefit from focussing and bundling of the grants for the prioritized projects. The open-minds of the Ministry of Economics for integrated or neutral use approaches of the land development and the inter-departmental coordination allows even integrated financing. The government can tackle upcoming problems and urgent challenges with a high degree of solution.

Lessons learned

In conclusion, it can be said that the coal brownfield agreement is a well-established and reliable form of collaboration between partners with a special focus on financial and human resources for the transformation of mine sites. Regular land evaluation leads to transparent development processes; outcomes and challenges are obvious at an early stage and can be addressed appropriately.

With this site-overarching approach, single areas have received a higher attention. The coal brownfield agreement has raised the importance of the sites in the view of the project participants without losing the overall focus. Coordinated objectives and planning avoids regional concurrence and fosters interdisciplinary acting.

Therefore, the coal brownfield agreement is an interesting model for the transformation of mine and industrial sites. As a regional instrument and considering social, environmental and economic objectives, it can provide valuable advice for the transition in the partner regions.

5. SELECTION OF TRANSITION SCENARIOS

5.1. WESTERN MACEDONIA

Classification of post-mining land use outlined in the Deliverable 2.1 BAT guide for land rehabilitation and reclamation, a deliverable of the WINTER project and the Just Transition Development Plan of lignite areas developed in September 18th, 2020.These directions represent the strategic paths a region can take following mining activities:

- Clean Energy: Focuses on advancing renewable energy sources, particularly the establishment of photovoltaic parks, as a substitute for energy derived from lignite mining, with a goal to build approximately 2 GW of photovoltaic park units, promoting eco-friendly energy and limiting carbon emissions. Notably:

The Public Power Corporation (PPC) has already completed a 230MW photovoltaic park, anticipating an annual production exceeding 350 GWh.

Hellenic Petroleum (ELPE) is in the process of constructing a 204MW photovoltaic park, with an investment of around €130M. PPC expresses interest in an additional 1.7GW of photovoltaic parks currently in development.

The establishment of photovoltaic parks encourages the research and development in hydrogen production units. Clean energy initiatives extend into energy research and technology, fostering collaboration with the University of Western Macedonia. Key areas of focus include electric propulsion, hydrogen, and alternative fuels. This field contributes significantly to the exploration and advancement of new technologies, attracting investment and ensuring comprehensive training for the emerging workforce.

- Smart Agricultural Production: This pillar aims to develop intelligent livestock and animal feed units to increase the livestock capacity of the area. Additionally, smart agricultural units will be developed to produce exportable products, with an emphasis on alternative forms of cultivation such as hydroponics, which are more environmentally friendly and create jobs with increased added value.

- Industry, Technology, and Education: Public investment and the establishment of business parks assist industry, technology, and education in the region. A specific initiative involves the establishment of an Industrial electromobility park, aimed at enhancing Greece's competitiveness in electric mobility development. Presently, there is keen interest from a nationwide group to construct a battery plant, entailing an investment of approximately €200M, potentially creating up to around 600 positions during operational phases.

Simultaneously, the industrial electromobility park could attract units for the manufacturing of raw materials or chargers for highways. Notably, there is already expressed interest for related investments, such as a factory dedicated to producing car parts or spare parts, with an international automotive company considering an investment of €5.3M.

Furthermore this pillar focuses on the development of sustainable tourism, particularly the creation of an original theme park of adventure, entertainment, and education with interest from an international entertainment company. This will promote sustainable tourism and create job opportunities in the region.

Table 11. Transition directions for Western Macedonia

CRITERIA	ASPECTS
SMART AGRICULTURE PRODUCTION	
ECONOMIC VIABILITY	– **Job creation potential.** There is a great potential for job creation taking into account that 21% of the employment rate in Western Macedonia is in the agricultural sector. Thus, this sector has already a large workforce that could increase contributing to the GDP of the region. – **Attractiveness for external investment.** The agricultural production in the region has been improving in the last 5 years, not only in terms of value, but also in terms of productivity per person employed in the sector. Thus, reclaimed land in mining sites can be an opportunity for external investments in the agricultural sector. Organic farming agricultural area rose by 85% in Western Macedonia during the last decade. The indicator can gauge the introduction and adoption of methods for producing higher quality and higher value products of the sector, in coherence with the efforts of the Region to improve the competitiveness and incomes of farmers
ENVIRONMENTAL IMPACT	– **Potential for carbon sequestration or reduction.** Implementing smart agriculture practices like crop rotation and cover cropping can enhance soil health. Healthy soils with increased organic matter contribute to carbon sequestration, helping to mitigate climate change. – **Impact on local ecosystems and biodiversity.** Agroforestry can maintain and enhance local ecosystems within or around agricultural areas. – **Water and soil conservation potential.** Smart agriculture systems often include precision irrigation technologies that optimize water use by delivering the right amount of water to crops based on real-time data. This can lead to significant water conservation.
SOCIAL ACCEPTANCE	– **Community and Workforce Transition:** In a region experiencing demographic challenges, including aging, smart agriculture can provide new opportunities for the workforce transitioning from coal mining. – **Preservation of cultural and historical values**. The adoption of smart agriculture technologies may be influenced by the willingness of farmers and communities to embrace new methods while preserving cultural heritage.
STAKEHOLDER ENGAGEMENT	– **Support from Environmental NGOs:** Likely backing from organizations focused on ecological preservation who support smart agriculture technologies. – **Potential Resistance from Industrial Sectors:** Opposition from stakeholders with interests in other land use investments such as PV parks and wind farms installation.
TECHNOLOGICAL FEASIBILITY	– **Availability of necessary technology and know-how.** Even though the smart agricultural technologies are mature, the local agricultural produces will have to be trained and financially supported to invest at these technologies (Precision Farming Equipment; Sensor Technologies; IoT) – **Infrastructure readiness or requirements.** Reliable and consistent power supply is critical for running sensor devices, precision equipment, and other technological components. The RES installations that are planned in the region of Western Macedonia can be used to support such systems.
SUSTAINABILITY	– **Long-Term Environmental Benefits**: **Reduced Environmental Impact:** Smart agriculture practices are designed to optimize the use of resources such as water, fertilizers, and pesticides. By precisely targeting inputs, farmers can reduce overuse and minimize environmental pollution, contributing to improved water and air quality. **Carbon Sequestration:** Some smart agriculture practices, such as conservation tillage and cover cropping, promote soil health and carbon sequestration. Healthy soils act as carbon sinks, mitigating climate change by removing carbon dioxide from the atmosphere. **Biodiversity Conservation:** Smart agriculture, when implemented with biodiversity-friendly practices, can contribute to the conservation of natural habitats and the protection of diverse ecosystems. This helps maintain biodiversity and supports the overall health of local ecosystems.

	– **Alignment with Sustainable Development Goals**:. Zero Hunger (SDG 2): Smart agriculture contributes to increased agricultural productivity and efficiency, which is aligned with the goal of achieving food security and ending hunger. Clean Water and Sanitation (SDG 6): Precision irrigation and reduced use of agrochemicals in smart agriculture practices can contribute to the conservation of water resources and promote water quality. Climate Action (SDG 13): The adoption of smart agriculture practices supports climate action by reducing greenhouse gas emissions, promoting carbon sequestration, and enhancing climate resilience in agriculture. Life on Land (SDG 15): Biodiversity-friendly smart agriculture practices contribute to the conservation of terrestrial ecosystems, aligning with the goal of protecting and restoring biodiversity.
REGULATORY & LEGAL CONSIDERATIONS	– **Alignment with current transition plans and strategies:** Smart agricultural production is one the main pillars of the national master plan. – **Regulatory Approval Process:** Navigating complex environmental permits and compliance requirements for land use reclamation.
SUSTAINABLE TOURISM & CULTURAL HERITAGE	
ECONOMIC VIABILITY	– **Tourism Attraction:** Western Macedonia has a great potential to attract tourists interested in nature, regional history and culture. In the wider area, there are various Archaeological and folklore museums as well as traditional villages. In addition, ecotourism can be developed due to the occurrence of the National park of Prespa lake. Finally, the closed lignite mines and their infrastructure can be reclaimed towards this direction e.g cultural parks and museums. – **Local Business Boost:** Supporting local businesses, such as small-scale accommodations, local restaurants, and artisanal products, can enhance the economic impact of tourism in a sustainable manner. – **Job Creation:** There is a great potential for job creation as in Greece there is already a pool of employees that have been educated and have the experience to work in tourism. – **Investment Challenges:** Attracting significant investment in cultural infrastructure could be challenging in a region with a different identify which is linked to mining and industry. – **Uncertain Revenue Streams:** Dependency on tourism can be financially unstable, especially in off-peak seasons.
ENVIRONMENTAL IMPACT	– **Environmental Footprint**: Sustainable tourism & cultural heritage practices have a low environment footprint.
SOCIAL ACCEPTANCE AND STAKEHOLDER SUPPORT	– **Cultural Pride and Identity**: Reinforces local identity and cultural pride among residents. – **Community Engagement:** Involving local communities in tourism initiatives can create jobs in community-based tourism organizations, visitor centres, and community-driven projects. – **Stakeholder support:** The direction of sustainable tourism can be supported by local businesses.
TECHNOLOGICAL FEASIBILITY	– **Resource/Infrastructure Constraints:** Western Macedonia suffers from a lack of infrastructure. A well-organized railway network and multimodal transportation, as well as more efficient freight services and increased incentives for new investments, are critical necessities for the region. – **Digitalization and Accessibility:** Employing digital tools to make cultural heritage more accessible and engaging, aligning with the technological advancements in the region.
SUSTAINABILITY	– **Long-term viability.:** The sustainable tourism has a long-term viability if it is well implemented. – **Resilience to external shocks (e.g., economic downturns, climate change).:** Touristic activities are vulnerable to external shocks (e.g. covid pandemic). – **Contribution to UN Sustainable Development Goals.** – Goal 8: Decent Work and Economic Growth: Sustainable tourism has the potential to create decent jobs and promote economic growth, particularly through the development of accommodations, restaurants, tour operators, and related services. – Goal 12: Responsible Consumption and Production: Sustainable tourism encourages responsible consumption by promoting eco-friendly

	accommodations, local and organic food, and sustainable tourism practices that minimize waste and resource use.
REGULATORY & LEGAL CONSIDERATIONS	– **Regulatory Complexity:** Navigating the legal intricacies of preserving nature & cultural heritage while developing sustainable tourism.
CLEAN ENERGY	
ECONOMIC VIABILITY	– Potential return on investment from the construction and operation of photovoltaic parks – Job creation potential in the clean energy sector – Ability to attract external investments for renewable energy project
ENVIRONMENTAL IMPACT	– -Reduction of carbon emissions and environmental impact compared to traditional energy sources – Integration of sustainable practices in the construction and operation of photovoltaic parks.
SOCIAL ACCEPTANCE AND STAKEHOLDER SUPPORT	– Community support for transitioning to clean energy sources – Backing from key stakeholders, including government and environmental organizations
TECHNOLOGICAL FEASIBILITY	– Readiness and availability of photovoltaic technology – Infrastructure requirements for the construction and operation of photovoltaic parks
SUSTAINABILITY	– Long-Term Environmental and Economic Benefits: Contributes to sustainable development through the provision of a clean, limitless energy source – Resilience to External Disruptions: Demonstrates reduced susceptibility to fluctuations in the global energy market. – Technology Maintenance: Need continual updates and maintenance of the renewable energy infrastructure.
REGULATORY & LEGAL CONSIDERATIONS	– Compliance with renewable energy regulations and incentives – Alignment with national/regional energy transition plans
INDUSTRY, TECHNOLOGY & EDUCATION	
ECONOMIC VIABILITY	– Potential return on investment from the industrial electromobility park and business parks – Job creation potential in the technology sectors – Ability to attract external investments for industrial and educational projects
ENVIRONMENTAL IMPACT	– Integration of sustainable and environmentally friendly practices in the technology industries – Conservation of natural resources in the development of industrial and educational facilities
SOCIAL ACCEPTANCE AND STAKEHOLDER SUPPORT	– Community support for the development of new industries and educational initiatives – Social acceptance dependent and stakeholder support very dependent on the type of new technology sectors
TECHNOLOGICAL FEASIBILITY	– Readiness and availability of technology for medical tourism and technological advancements – Infrastructure requirements for industrial and educational developments
SUSTAINABILITY	– Economic Sustainability: initiatives like the Industrial Electromobility Park, which attracts investments and generates jobs – Incorporation of Sustainable Practices: Modern commercial projects in the region increasingly integrates eco-friendly practices into business ventures. – Environmental Sustainability Concerns: Acknowledging the delicate balance between economic development and environmental protection. – Long-Term Viability: The success and longevity of the development initiatives, depend on their adaptability to market dynamics, economic conditions fluctuations
REGULATORY & LEGAL CONSIDERATIONS	– Compliance with industry and educational regulations – Alignment with national/regional industrial technological and educational development plans.

Table 12. Transition scenario decision matrix – Western Macedonia

TRANSFORMATION DIRECTION	CRITERIA						OVERALL FEASIBILITY
	ECONOMIC VIABILITY	ENVIRONMENTAL IMPACT	SOCIAL ACCEPTANCE AND STAKEHOLDER SUPPORT	TECHNOLOGICAL FEASIBILITY	SUSTAINABILITY	REGULATORY & LEGAL CONSIDERATIONS	
SMART AGRICULTURE	✓	✓	✓	✓/✗	✓	✓	**Overall Feasibility:** High **Rationale:**.The overall feasibility of smart agriculture development in Western Macedonia is high. This is due to the fact that there is a great potential for job creation taking into account that 21% of the employment rate in Western Macedonia is in the agricultural sector. Thus, this sector has already a large workforce that could increase contributing to the GDP of the region. The only challenges are related to the availability of necessary technology and know-how.
SUSTAINABLE TOURISM & CULTURAL HERITAGE	✓/✗	✓	✓	✓/✗	✓	✓/✗	**Overall Feasibility:** Moderate **Rationale**: The overall feasibility of sustainable tourism and cultural heritage development in the Western Macedonia region is moderate. On the one hand there is great potential for job creation and local businesses support. However there are challenges related mainly to the lack of infrastructure.
CLEAN ENERGY	✓	✓	✓/✗	✓	✓	✓/✗	**Overall Feasibility:** Moderate to High **Rationale:** The overall feasibility of transitioning to renewable energy, particularly through the establishment of photovoltaic parks, is moderate to high. The positive environmental impact, coupled with technological feasibility and a commitment to sustainability, positions the region well for a successful transition. However, the need for nuanced approaches to social acceptance, especially in the case of other renewable energy forms, and vigilant management of regulatory considerations are crucial for ensuring the long-term success of the initiative.
INDUSTRY, TECHNOLOGY & EDUCATION	✓	✓/✗	✓/✗	✓	✓/✗	✓/✗	**Overall Feasibility**: Moderate **Rationale:** Industry Technology and Education scenario in Western Macedonia presents significant economic growth opportunities, particularly through the development of an Industrial electromobility park and associated projects. However, careful consideration of environmental impact is crucial to ensure sustainable development. The scenario receives biased responses in social acceptance and stakeholder engagement depending on the technological adaptation. Regulatory compliance is attainable but demands diligent effort. Success in this direction depends on the external investments and may face potential infrastructure strain.

5.2. KONIN REGION

The spatiotemporal analysis of the Konin region reveals a significant transformation in its landscape, characterized by an evolving mix of urban and industrialized areas. This change, observed through various time points, highlights a shift in the region's land use and economic orientation. Notably, the analysis uncovers a gradual trend of land reclamation, evident in the increasing presence of green areas and the development of water reservoirs.

In the Jóźwin open-pit mine, ongoing mining activities are evident, yet there is a noticeable increase in vegetation since 2018, indicating active reclamation efforts. The Kazimierz mine, where industrial activities have decreased, shows a clear transition toward ecological restoration. This is highlighted by the transformation from bare soil to vegetation and the expansion of water reservoirs, signaling a move towards a greener, more ecologically balanced state. The Adamów open-pit mine also displays signs of ongoing reclamation, especially in its southern and western parts. Here, a decrease in mining activity is coupled with an increase in vegetation, pointing to a positive shift towards greener land use. Additionally, the stability and slight increase of water bodies in the area further demonstrate the region's commitment to ecological sustainability.

The analysis for renewable energy potential in the Konin region's open pits (Jóźwin, Kazimierz, and Adamów) suggests viable opportunities for the implementation of renewable energy sources (RES), particularly solar and wind energy.

Jóźwin Mine:

- The area is suitable for photovoltaic (PV) installations, mainly in the western and southern parts of the mine, with a coverage of up to 2.4 Km².
- Wind Park (WP) suitable areas largely overlap with PV areas, extending into the central part of the mine and covering up to 2.84 Km².

Adamów Mine:

- PV installation areas are concentrated in the central part of the mine and along the northern boundaries, with a total coverage area of up to 2.13 Km².
- WP installation areas overlap significantly with PV areas, with a slight difference in the southern side of the mine, totaling 2.13 Km².

Kazimierz Mine:

- Both PV and WP installations show similar suitable coverage areas, reaching a total coverage of up to 2.25 Km² for PV and 2.00 Km² for WP.

The analysis indicates that all three mines demonstrate potential for RES installation, with Adamów showing the highest percentage for utilization. Jóźwin has the greatest potential coverage for RES installation, while Kazimierz, despite having lower potential, exhibits a higher percentage of green transition.

The spatiotemporal analysis of the Konin region's mining areas reveals a focused effort to balance industrial activity with environmental restoration. This strategic approach to land use, which prioritizes ecological sustainability alongside economic development, is a critical input for the Transition Scenario Decision Matrix. The analysis provides key insights into how the landscape has evolved and where opportunities for sustainable development lie, which are essential in assessing the viability of various transition scenarios.

In parallel, the assessment of renewable energy potential highlights distinct zones for photovoltaic (PV) and wind power (WP) installations across the Jóźwin, Kazimierz, and Adamów mines. The minimal overlap between these areas suggests the potential for targeted

renewable energy projects. This clear delineation of RES potential areas forms a foundational step for more detailed technical studies and criteria development, crucial for evaluating wind and solar energy opportunities in the region.

It's important to recognize that the identified RES sites are currently potential areas, subject to expansion with the ongoing reclamation process. Such an expansion will further enrich the Transition Scenario Decision Matrix, enhancing the region's prospects for renewable energy projects in alignment with its sustainable development strategy.

This below part presents the Transition Scenario Decision Matrix for the Konin region. The development of this matrix was informed by a detailed analysis of various aspects significant to the Konin region's unique socioeconomic and environmental context, as outlined in Table 13.

Following this comprehensive analysis, the matrix (presented in Table 14) was created to assess the feasibility of different transition scenarios. Notably, the analysis reveals that Natural Restoration emerges as the most promising direction for the region, excelling across in almost all evaluation criteria. Conversely, Cultural Heritage Development is identified as having the least potential, encountering considerable challenges in several key areas.

Table 13. Aspects of the selected transition scenarios

CRITERIA	ASPECTS
NATURAL RESTORATION	
ECONOMIC VIABILITY	– **Diversification Through Green Projects:** Leveraging the increasing green spaces and land reclamation, particularly in areas of Jóźwin, Kazimierz, and Adamów open pits, for eco-friendly initiatives can boost local economies and create jobs, crucial in a region with high youth unemployment and economic underdevelopment. – **Attraction for External Investments:** Opportunities for funding from environmental grants and eco-tourism investments. – **Tourism and Renewable Energy Potential:** The potential for renewable energy in reclaimed areas, alongside ecotourism, aligns with the need for new economic growth areas in the face of declining coal industry. – **Initial High Costs:** Significant investment required for restoration and redevelopment. – **Economic Transition Risks:** Potential short-term economic slowdowns due to the shift from coal-based industries.
ENVIRONMENTAL IMPACT	– **Reversing Ecological Damage:** Transitioning from mining to green spaces, as seen in the expansion of vegetation and water bodies, directly addresses environmental degradation and improves biodiversity. – **Carbon Sequestration:** Natural landscapes can absorb and store carbon, contributing to climate change mitigation. – **Health Benefits:** Mitigating health costs associated with coal mining by transitioning to natural restoration can have significant public health benefits. – **Initial Ecological Disturbance:** Short-term negative impacts during the initial phase of restoration.
SOCIAL ACCEPTANCE AND STAKEHOLDER SUPPORT	– **Community and Workforce Transition:** In a region experiencing demographic challenges, including aging and urban population decline, natural restoration can enhance community well-being and provide new opportunities for the workforce transitioning from coal mining. – **Community Engagement:** Opportunities for local involvement in environmental initiatives. – **Support from Environmental NGOs:** Likely backing from organizations focused on ecological preservation. – **Potential Resistance from Industrial Sectors:** Opposition from stakeholders with interests in traditional industries like mining
TECHNOLOGICAL FEASIBILITY	– **Proven and Ongoing Restoration Practices:** The ongoing reclamation process in the Konin region, as outlined in the spatiotemporal analysis, demonstrates existing expertise and practical application of restoration technologies

	– **Advanced Reclamation Techniques:** Building on the observed progress in vegetation increase and water body stability, the implementation of advanced land reclamation and greening techniques is feasible. – **Existing Infrastructure and Know-How:** The region already possesses the infrastructure and technical know-how for reclamation, making the continuation and expansion of these efforts more feasible. – **Integration with Renewable Energy:** Utilizing areas identified as suitable for photovoltaic and wind energy installations in mines for dual-purpose (energy generation and ecological enhancement). – **Adaptation to Specific Sites:** Each site may require unique approaches or adaptations of existing technologies to address specific ecological and geological conditions.
SUSTAINABILITY	– **Long-Term Environmental Benefits**: Contribution to ecological balance and resilience against climate change. – **Alignment with Sustainable Development Goals**: Supports global objectives such as biodiversity conservation and climate action. – **Ongoing Maintenance and Monitoring:** Requirement for sustained efforts to ensure the restored ecosystems remain healthy and functional.
REGULATORY & LEGAL CONSIDERATIONS	– **Alignment with current transition plans and strategies:** Contributes to fulfilling environmental parts of such plans and strategies. – **Possibility of Incentives:** Potential for government subsidies supporting ecological restoration. – **Regulatory Approval Process:** Navigating complex environmental permits and compliance requirements.
CULTURAL HERITAGE DEVELOPMENT	
ECONOMIC VIABILITY	– **Tourism Attraction:** Potential to attract tourists interested in regional history and culture. – **Local Business Boost:** Can stimulate small businesses like handicrafts, local gastronomy, and lodging. – **Limited Job Creation:** Compared to other sectors, cultural heritage projects might create fewer long-term jobs. – **Investment Challenges:** Attracting significant investment in cultural infrastructure could be challenging in a region with lower GDP per capita and economic underdevelopment. – **Uncertain Revenue Streams:** Dependency on tourism can be financially unstable, especially in off-peak seasons or during economic downturns.
ENVIRONMENTAL IMPACT	– **Low Environmental Footprint**: Generally, cultural heritage projects have a minimal direct impact on the environment.
SOCIAL ACCEPTANCE AND STAKEHOLDER SUPPORT	– **Cultural Pride and Identity**: Reinforces local identity and cultural pride among residents. – **Community Engagement:** Opportunities for community involvement in preserving cultural heritage. – **Potential for Marginalization:** If not inclusive, such initiatives might overlook certain community segments.
TECHNOLOGICAL FEASIBILITY	– **Established Conservation Techniques**: Availability of proven methods for cultural heritage conservation and development. – **Digitalization and Accessibility:** Employing digital tools to make cultural heritage more accessible and engaging, aligning with the technological advancements in the region. – **Resource Constraints for Preservation:** Modern preservation technologies might be constrained by limited financial resources and technological infrastructure in the region.
SUSTAINABILITY	– **Cultural Sustainability:** Helps in preserving cultural practices and knowledge for future generations. – **Maintenance Challenges**: Continuous effort and funding are required to maintain cultural sites. – **Future Viability Concerns:** Long-term viability of cultural projects may be uncertain in the context of the region's changing economic and demographic landscape.
REGULATORY & LEGAL CONSIDERATIONS	– **Support from Cultural Preservation Laws:** Can benefit from laws and policies aimed at preserving cultural heritage. – **Regulatory Complexity:** Navigating the legal intricacies of preserving and developing cultural sites.
COMMERCIAL RECONVERSION	

ECONOMIC VIABILITY	– **Job Creation:** Potential for substantial job creation in new commercial ventures. – **Diverse Revenue Streams:** Opportunities for generating revenue from various business activities. – **Moderate Business Attraction:** The potential to attract new commercial activities may be moderate, given the region's economic challenges, including high unemployment and lower GDP per capita. – **Initial Investment:** Significant capital required to develop commercial infrastructure. – **Market Risks:** Potential for market fluctuations and economic downturns impacting commercial success.
ENVIRONMENTAL IMPACT	– **Regulated Development:** Modern commercial projects often incorporate sustainable practices and technologies. – **Resource Consumption:** Commercial activities can consume significant natural resources. – **Potential Pollution:** Risk of environmental pollution, depending on the nature of commercial activities.
SOCIAL ACCEPTANCE AND STAKEHOLDER SUPPORT	– **Economic Benefits**: Likely to be well-received due to job creation and economic development. – **Community Development:** Potential to enhance local infrastructure and amenities. – Social acceptance dependent and stakeholder support very dependent on the type of new commercial use
TECHNOLOGICAL FEASIBILITY	– **Advanced Technologies:** Commercial projects often leverage modern technologies for efficiency and competitiveness. – **Adaptation of Existing Infrastructure:** Converting existing mining infrastructure for commercial use poses technological challenges and may require substantial investment. – **Infrastructure Development:** Can drive the development of local infrastructure.
SUSTAINABILITY	– **Economic Sustainability:** Potential for long-term economic growth and stability. – **Incorporation of Sustainable Practices**: Modern commercial projects increasingly include sustainable development goals. – **Environmental Sustainability Concerns:** Balancing economic growth with environmental protection can be challenging. – **Long-Term Viability:** Dependence on market forces and economic conditions for sustainability.
REGULATORY & LEGAL CONSIDERATIONS	– **Alignment with Economic Policies:** Often supported by local and regional economic development plans. – **Compliance and Permitting Challenges:** Complex regulatory processes for commercial development, especially in environmentally sensitive areas.
RENEWABLE ENERGY INTEGRATION	
ECONOMIC VIABILITY	– **High Investment Attraction:** Strong potential, particularly in areas like Jóźwin, Kazimierz, and Adamów mines, to attract national and international investments in renewable energy. – **Job Creation in New Energy Sector:** Significant opportunities for employment in solar, wind, and other renewable energy industries. – **Initial High Investment Cost:** Significant upfront capital required for renewable energy infrastructure. – **Market Fluctuations:** Renewable energy markets can be sensitive to policy changes and global energy prices.
ENVIRONMENTAL IMPACT	– **Significant Reduction in Carbon Emissions:** Directly contributes to CO2 reduction targets of the National Energy and Climate Plan – **Resource Use for Infrastructure:** Some environmental impact from the construction of renewable energy facilities.
SOCIAL ACCEPTANCE AND STAKEHOLDER SUPPORT	– **High Public Support:** Renewable energy often enjoys strong public and community backing due to its environmental benefits. – **Need for Public Awareness and Education:** Ensuring the local community is informed and supportive of the new technologies.
TECHNOLOGICAL FEASIBILITY	– **Established and Evolving Technologies:** Availability of proven technologies in solar and wind energy, with ongoing advancements. – **Potential for Innovation and Development:** Opportunities for incorporating cutting-edge renewable technologies.

	– **Integration Challenges:** Need to integrate renewable energy sources into the existing energy grid and infrastructure.
SUSTAINABILITY	– **Long-Term Environmental and Economic Benefits:** Contributes to sustainable development by providing a clean, inexhaustible energy source. – **Resilience to External Shocks:** Less vulnerable to global energy market fluctuations. – **Technology Lifespan and Maintenance**: Ongoing need to update and maintain renewable energy infrastructure.
REGULATORY & LEGAL CONSIDERATIONS	– **Policy Support:** Aligned with Poland's Energy Policy and EU directives advocating for increased use of renewable energy – **Incentives and Subsidies:** Potential for government incentives to support renewable energy projects. – **Regulatory Changes:** Renewable energy sector can be affected by changes in national and international energy policies.

Table 14. Transition Scenario Decision Matrix for Konin Region

TRANSFORMATION DIRECTION	CRITERIA						OVERALL FEASIBILITY
	ECONOMIC VIABILITY	ENVIRONMENTAL IMPACT	SOCIAL ACCEPTANCE AND STAKEHOLDER SUPPORT	TECHNOLOGICAL FEASIBILITY	SUSTAINABILITY	REGULATORY & LEGAL CONSIDERATIONS	
NATURAL RESTORATION	✓/✗	✓	✓	✓	✓	✓	**Overall Feasibility:** High **Rationale:** Natural restoration aligns exceptionally well with the Konin region's current needs and potentials. Given the region's shift away from coal mining and the existing land reclamation efforts, natural restoration offers significant economic, environmental, and social benefits. The presence of expanding green areas and water bodies, coupled with community support for greener and healthier environments, enhances the feasibility of this direction. Technological and regulatory aspects are well-aligned, with available techniques for land reclamation and supportive environmental policies. The sustainability of this approach, both ecologically and economically, is strong, contributing to long-term regional resilience and alignment with broader environmental goals.
CULTURAL HERITAGE DEVELOPMENT	✓/✗	✓/✗	✓/✗	✓/✗	✓/✗	✓/✗	**Overall Feasibility:** Moderate **Rationale**: The feasibility of cultural heritage development in the Konin region is moderate to low due to uniformly mixed evaluations across all criteria. While there is potential for leveraging historical and cultural assets, challenges in economic viability, social acceptance, technological implementation, and regulatory complexities present significant hurdles. The region's economic context and demographic trends further complicate the potential for successful cultural heritage initiatives, making this direction less favorable compared to others..
COMMERCIAL RECONVERSION	✓/✗	✓/✗	✓/✗	✓	✓/✗	✓/✗	**Overall Feasibility**: Moderate **Rationale:** Commercial reconversion offers economic growth opportunities but requires careful consideration of environmental impact. While there is potential to repurpose land for commercial activities, ensuring environmental sustainability will be crucial. The scenario also faces mixed responses in social acceptance and technological adaptation. Regulatory compliance is achievable but requires effort. The success of this direction hinges on balancing economic development with responsible environmental management.
RENEWABLE ENERGY INTEGRATION	✓	✓	✓/✗	✓	✓	✓/✗	**Overall Feasibility:** Moderate to High **Rationale:** The transition to renewable energy, particularly solar, is promising and aligns well with regional sustainable development goals. However, there are notable challenges. While solar energy projects are likely to be well-received, wind energy projects face more complex regulatory hurdles and mixed social acceptance. Community responses to wind farm projects in other areas suggest that social support may not be uniformly positive. This mixed social acceptance, combined with regulatory complexities, particularly for wind energy, makes the feasibility moderate to high.

6. PROPOSED TRANSITION SCENARIOS

6.1. WESTERN MACEDONIA

CLEAN ENERGY

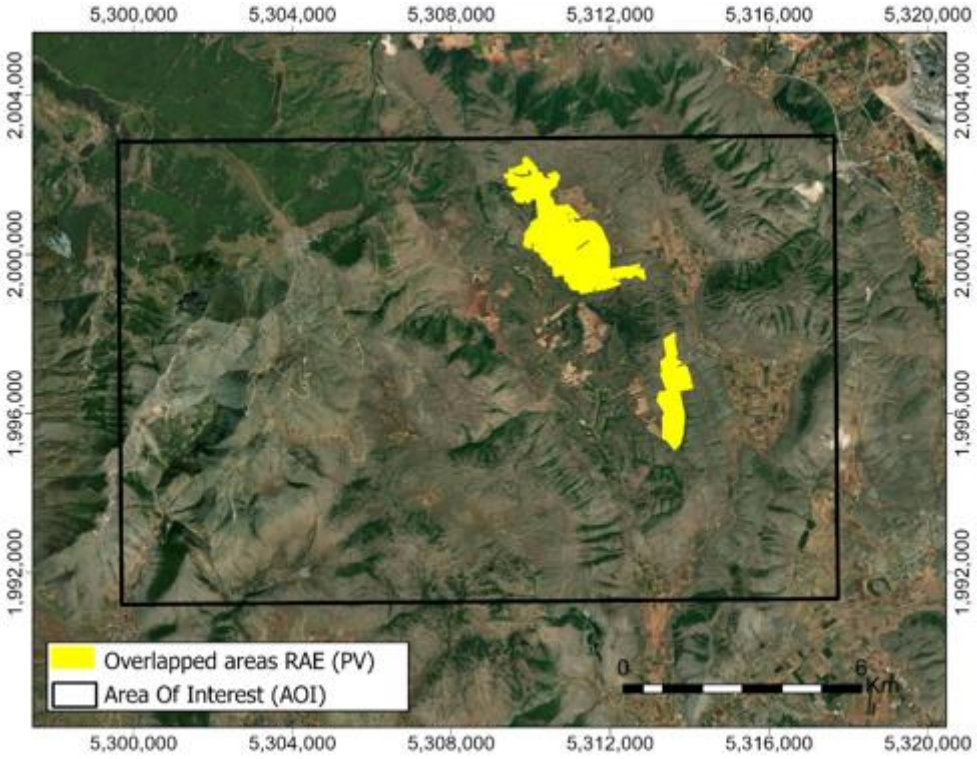

Figure 18. Proposed Site for PV park in Western Macedonia

PV POTENTIAL

According to the spatiotemporal analysis a total available area for PV park has been estimated to 3,463ha.

The Area Available for solar energy scenarios was selected based on polygons defined by the Regulatory Authority for Energy (RAE) to cover the initial study region. This guarantees that the data has undergone verification and complies with the operating and installation licenses outlined by the regulatory authority in Greece. It has been estimated to 600ha.

The annual energy production from solar PV is estimated at 568,440 MWh/year. Considering an average household consumption in Greece: 4,370 kWh/household (URL2), this production capacity can power approximately 130,078 households.

Table 15. Assumptions used for calculations – PV park in Western Macedonia

	Value	Unit
Solar Panel Specifications		
Solar Panel Yield	16	%
Panel Size	1.6	m2
Solar Irradiance		
Annual average irradiation on tilted panels	1, 579	kWh/m2/year (irradiation, RAE, URL1)
Performance Ratio		
Estimated Performance Ratio	75	%
Total Panel Installation		
Total Area Available	600	ha
Total Solar Panel Area*	300	ha

* The designated Total Solar Panel Area for the photovoltaic farm, covering 300 hectares, represents 50% of the total available area. This allocation includes all necessary maintenance routes to ensure efficient operation and upkeep

The economic feasibility of solar PV includes an initial Investment (CAPEX): 384,000 €/ MWp(Vartiainen E et al.2019), having a total investment of 184.32 mln €. With an annual maintenance cost (Maintenance (OPEX): 8,100 €/MWp) of 3,888,000 € and an annual revenue generation of 33,753,967€, the net annual revenue stands at 29,865,967.20 €. The investment's payback period is calculated to be around 6.2 years, as illustrated in Figure 19.

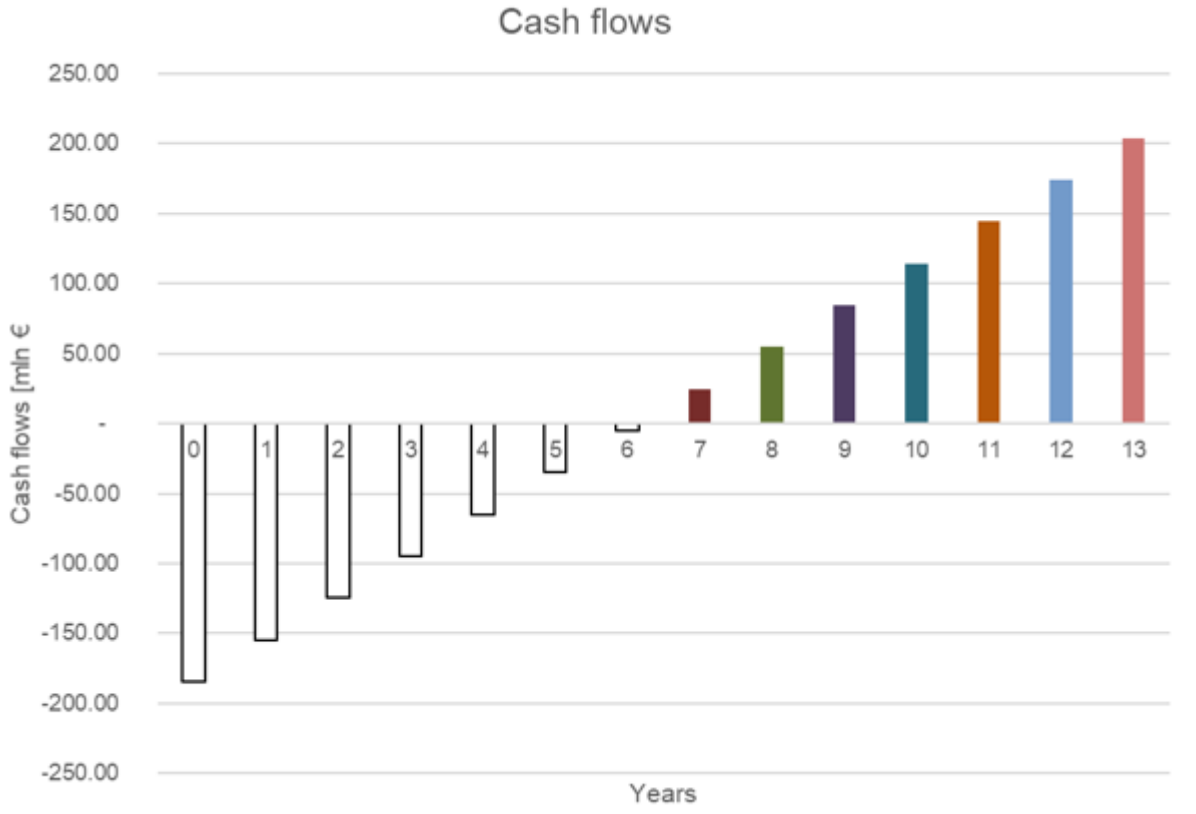

Figure 19. Payback Period Analysis for PV Installation in Western Macedonia Region

The transition to renewable energy not only has an economic dimension but also brings profound environmental benefits. The International Energy Agency (IEA) suggests that PV power has the potential to avoid up to 1.4 million tonnes of CO2 emissions per year per GW of installed capacity. (URL3) It is calculated that PV power has the potential to avoid 0.43 tonnes of CO2 emissions per MWh of electricity generated. It is calculated that PV park avoid 243,576.54 tonnes of CO2 emissions per MWh in the chosen region.

WIND POWER POTENTIAL

According to the spatiotemporal analysis a total available area for wind park has been estimated to 2,816ha.

The Area Available for wind energy scenarios was selected based on polygons defined by the Regulatory Authority for Energy (RAE) to cover the initial study region. This guarantees that the data has undergone verification and complies with the operating and installation licenses outlined by the regulatory authority in Greece. It has been estimated to 1,100ha.

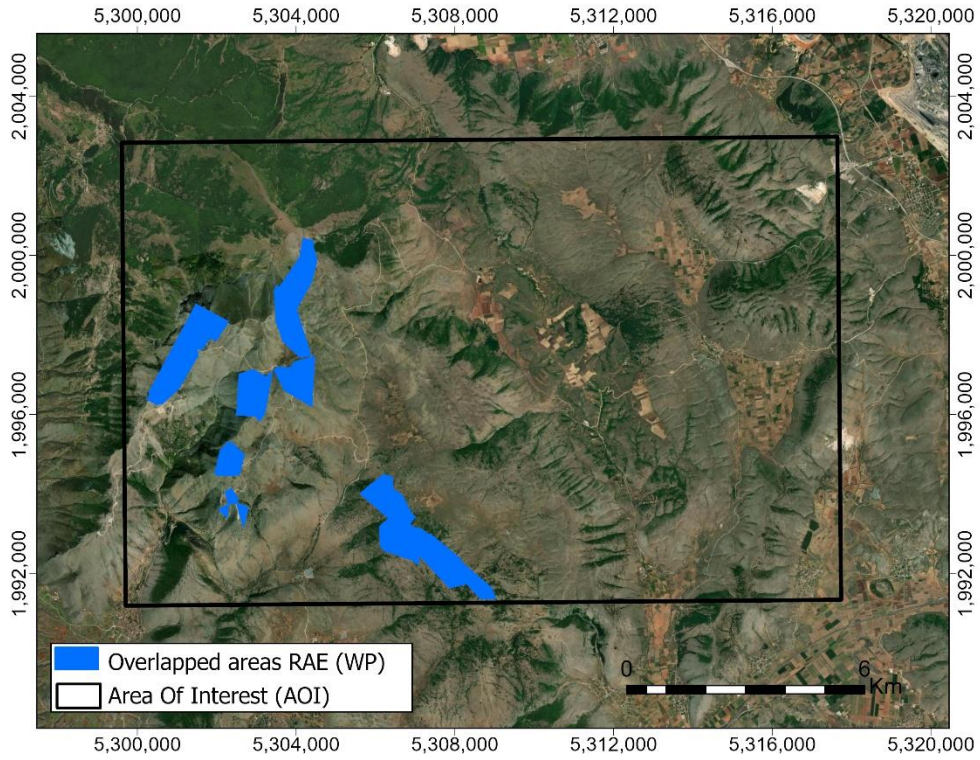

Figure 20. Proposed Site for wind park in Western Macedonia

Table 16. Assumptions used for calculations – Adamów mine – Konin region, photovoltaic farm

	Value	Unit
Wind Turbine Specifications		
Rated Power per Turbine	2.5	MW
Rotor Diameter	120	m
Hub Height	100	m
Wind Conditions		
Wind Speed	6,54	m/s (wind energy potential, RAE, URL1)
Spacing and Layout		
Turbine Spacing	600	m
Area per Turbine	360 000	m2
Capacity Factor		
Estimated Capacity Factor	0.3	
Total Number of Turbines		
Area Available	1100	ha
Total Turbines for Available area	30	

Each turbine is expected to produce 6,570 MWh annually, amounting to a total of 197,100 MWh for all turbines combined. This output can power roughly 45,103 households annually. (Average Household Consumption in Greece: 4,370 kWh/household (URL2)) The wind energy segment requires an initial investment of 1.3 mln € per 1MW (Wind Europe, 2020), culminating in a total of 97,500,000 €. The annual maintenance cost is for Greece 4 %CAPEX calculated to 3,900,000 € annually (Pricetag project 2017), and the annual revenue is calculated at 11,703,798 € (Country

Overview, 2020), 59.38€ /MWh. The net annual revenue is thus 7,803,798€, leading to a payback period of approximately 12.49 years.

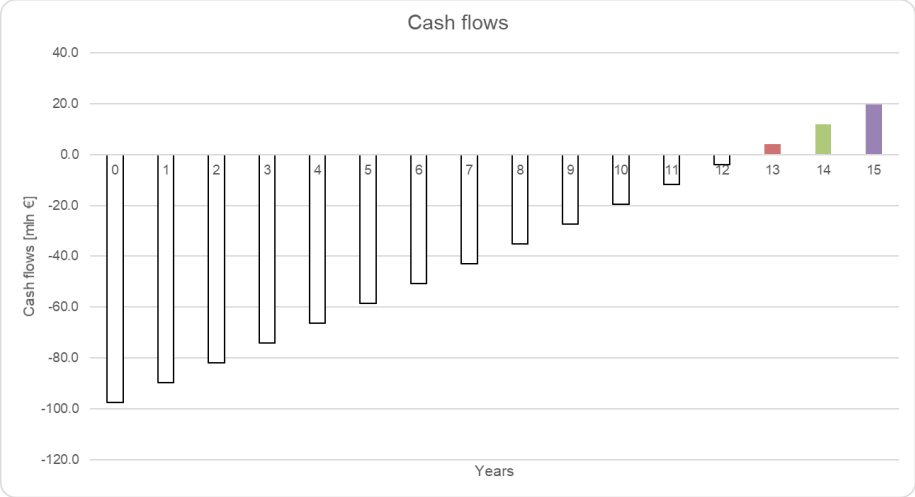

Figure 21. Payback Period Analysis for Wind Installation in the Western Macedonia Region

The wind farm's operation will significantly reduce carbon emissions. The International Energy Agency (IEA) suggests that wind power has the potential to avoid up to 2.8 million tonnes of CO2 emissions per year per GW of installed capacity. (URL3) It is calculated that wind power has the potential to avoid 0.857 tonnes of CO_2 emissions per MWh of electricity generated. It is calculated that wind power avoid 168,914.70 tonnes of CO_2 emissions per MWh in the chosen region.

LEGAL ASPECTS FOR RES INSTALATIONS

The regulatory framework governing renewable energy installations is comprehensively detailed in Deliverable 2.2, which specifically addresses legislation for PV and wind parks. The established legal guidelines ensure strict adherence to regulatory standards, and the area has undergone validation by the Regulatory Authority of Energy.

STAKEHOLDER ENGAGEMENT

A study conurbation explored citizens' investment willingness and views on energy-related topics, revealing a positive inclination towards renewable energy (RES). Most participants expressed a willingness to invest in renewables, emphasizing its potential to mitigate energy poverty, especially among lower-income households. Policymakers are urged to tailor policies and incentives for citizens with lower incomes, fostering a favorable environment for RES installation through low-interest lending and subsidies (Papadopoulou, SD.et al. 2019)

In Macedonia, there exists a favourable attitude towards renewable energy sources (RES), particularly solar photovoltaic (PV) and wind energy, within the local community. This positive perception forms a solid foundation for robust stakeholder engagement, crucial for the successful implementation and enduring sustainability of RES projects in the region.

SMART AGRICULTURE

Reclaimed land in mining sites of Western Macedonia, Ptolemais & Amynteo mines (Fig.22) can be an opportunity for external investments in the agricultural sector. In particular, in the post-mining land a smart agricultural scenario could include greenhouses and hydroponics, producing fresh vegetables through the use of district heating.

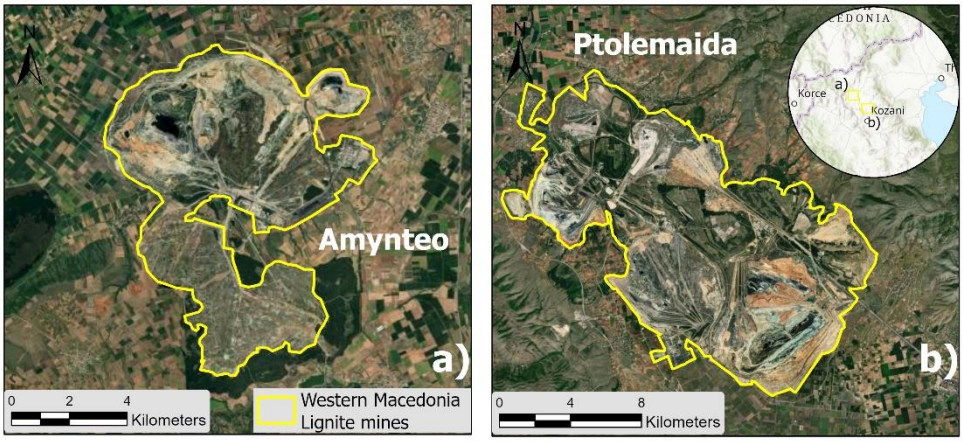

Figure 22. Reclaimed land in mining sites of Western Macedonia

There is a high investment potential as agricultural production in the region has been improving in the last 5 years, not only in terms of value, but also in terms of productivity per person employed in the sector. It is noteworthy that organic farming agricultural area rose by 85% in Western Macedonia during the last decade.

Regarding the scenario, investment incentives tailored for specific purposes could enable the establishment of a greenhouse incubator, particularly in post-mining areas like Kozani and Ptolemaida. The energy needs for such facilities could be met by incorporating solar panels, mild heat pump technology, and district heating. Alternatively, the energy demand might be fulfilled by repurposing waste heat from former lignite power plants, converting it into an alternative thermal process such as biomass or renewable electricity, with the option of using electrical heaters to generate steam. This applies similarly to agro-processing infrastructure.

The Environmental Impact Assessment study developed by the Public Power Corporation (PPC) foresees agriculture as the main option of new land uses. Up to 2018, 4,000 hectares (ha) of the total 16,000 ha of mines in Ptolemaida area have been restored. Around 1,900 ha have been afforested, and 1,500 ha committed agriculture activities. After the completion of the program it was estimated that 5,000 ha of arable land and 5,400 ha of forest would be created, while 1,200 ha would be covered by lakes that would form in the final trenches of the mines. PPC currently has constructed a 230MW PV park and has already developed a district heating system, in line with the National Energy and Climate Plan that aims to phase out coal.

While the potential benefits are substantial, successful implementation requires addressing various factors. This includes providing necessary training and financial support to local producers for adopting smart agricultural technologies. Infrastructure readiness, particularly in terms of a reliable power supply, is crucial for the operation of technology. The planned Renewable Energy Source (RES) installations in Western Macedonia offer an opportunity to support smart agriculture systems. Furthermore, the preservation of cultural and historical values, along with community engagement, will be pivotal to ensure a harmonious transition to smart agriculture, balancing tradition with innovation. Overall, these initiatives align with Sustainable Development Goals, demonstrating a commitment to a sustainable and resilient future for Western Macedonia.

6.2. KONIN REGION

RENEWABLE ENERGY INTEGRATION

In the Konin Region, the integration of renewable energy, specifically solar photovoltaic (PV) and wind energy, presents a significant opportunity for sustainable development. The chosen area for this initiative, part of the Adamów mine (Figure 23), spans approximately 110 hectares, providing sufficient space for renewable energy installations.

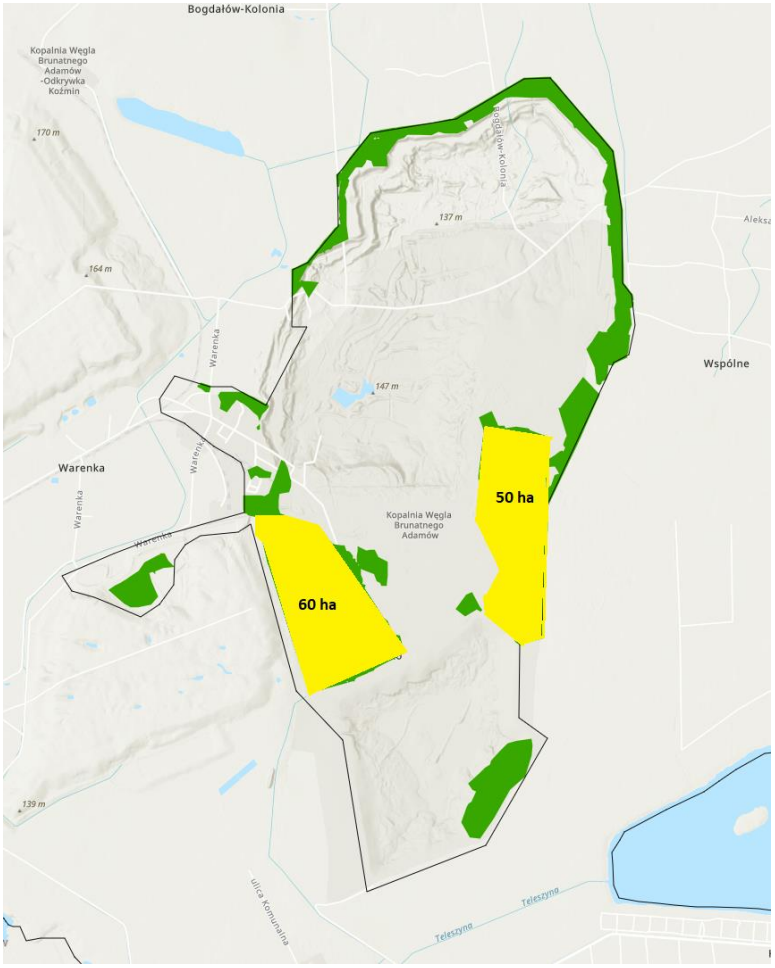

Figure 23. Proposed Site for Renewable Energy Installations at Adamów Open-Pit – Konin Region

PV POTENTIAL

For **solar PV energy**, the scenario is designed around the rehabilitation of land post-lignite coal exploitation, leveraging the region's solar potential. In Table 16., the assumptions used for calculating the photovoltaic potential are presented. The annual energy production from solar PV is estimated at 85,602,000 kWh. T Considering an average household consumption of 2,523 kWh, this production capacity can power approximately 33,928 households

Table 17. Assumptions used for calculations – Adamów mine – Konin region, photovoltaic farm

	Value	Unit
Solar Panel Specifications		
Solar Panel Yield	16	%
Panel Size	1.6	m2
Solar Irradiance		
Annual average irradiation on tilted panels	1 297.0	kWh/m2/year
Performance Ratio		
Estimated Performance Ratio	75	%
Total Panel Installation		
Total Area Available	110	ha
Total Solar Panel Area*	55	ha

* The designated Total Solar Panel Area for the photovoltaic farm, covering 55 hectares, represents 50% of the total available area. This allocation includes all necessary maintenance routes to ensure efficient operation and upkeep

The economic feasibility of solar PV includes an initial investment of 2,500,000 PLN per MW, totalling 220,000,000 PLN. With an annual maintenance cost of 6,160,000 PLN and an annual revenue generation of 26,640,000 PLN, the net annual revenue stands at 18,480,000 PLN. The investment's payback period is calculated to be around 11.90 years, as illustrated in Figure X.

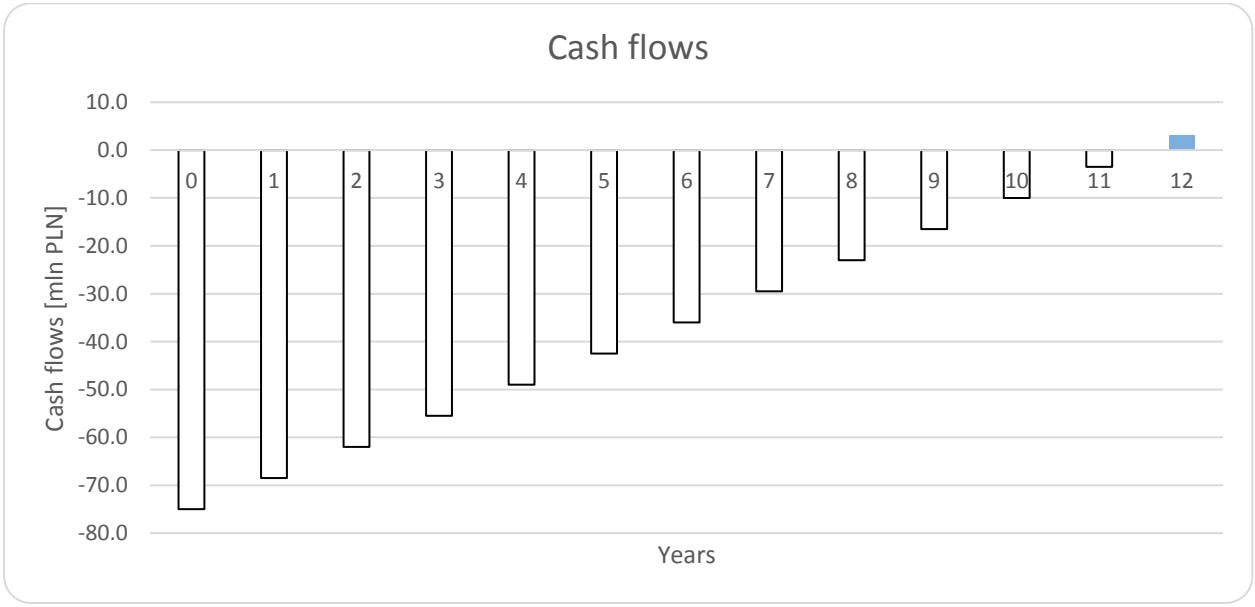

Figure 24. Payback Period Analysis for Photovoltaic Installation in the Adamów mine – Konin Region

The transition to renewable energy not only has an economic dimension but also brings profound environmental benefits. By adopting solar PV energy, the Konin Region can significantly reduce its carbon footprint, contributing to global efforts to combat climate change. Furthermore, the use of post-exploitation lands for solar energy production revitalizes these spaces, turning them into productive areas that generate clean energy. The project's environmental benefits are a testament to the region's commitment to sustainable development and ecological restoration.

In the Konin Region, the ZE PAK Group, a major energy provider, was responsible for over 60% of the CO2 emissions in the Wielkopolskie Voivodeship in 2021. In the subregion itself, this figure rises to nearly 90%. The primary sources of these emissions are large power plants, such as

Pątnów I, Pątnów II, and Konin. Against this backdrop, the introduction of a photovoltaic (PV) farm represents a significant stride toward reducing the region's carbon footprint. ZE PAK's reported annual emissions for 2021 were 4.87 million tonnes. With ZE PAK's emissions estimated at around 1000 kg of CO2 per MWh, the introduction of the PV farm, which has an annual energy production of 85,602,000 kWh, could offset approximately 85,602 tonnes of CO2 each year. This reduction translates to about 1.76% of ZE PAK's total emissions.

Not only does this contribute to the Wielkopolskie Voivodeship's environmental targets, but it also highlights the transformative potential of renewable energy. The PV farm's role in the energy mix could serve as a pivotal factor in reducing the dependency on fossil fuels and in moving towards a more sustainable future, particularly in a region heavily impacted by emissions from traditional power generation facilities.

WIND POWER POTENTIAL

In the Konin Region, the integration of **wind energy** is poised to make a significant contribution to the renewable energy portfolio. The selected site facilitates the installation of five wind turbines, each with a rated power of 2.5 MW. The assumptions for calculating the wind energy potential are detailed in Table 17.

Table 18. Assumptions used for calculations – Adamów mine – Konin region, wind farm

	Value	Unit
Wind Turbine Specifications		
Rated Power per Turbine	2.50	MW
Rotor Diameter	120.00	m
Hub Height	100.00	m
Wind Conditions		
Wind Speed	7.38	m/s
Spacing and Layout		
Turbine Spacing	600.00	m
Area per Turbine	360 000.00	m2
Capacity Factor		
Estimated Capacity Factor	0.30	
Total Number of Turbines		
Area Available	110.00	ha
Total Turbines for Available area	3	

Each turbine is expected to produce 6,570 MWh annually, amounting to a total of 19,710 MWh for all turbines combined. This output can power roughly 7,812 households. The wind energy segment requires an initial investment of 7,500,000 PLN per MW, culminating in a total of 56,250,000 PLN. The annual maintenance cost is set at 3,000,000 PLN, and the annual revenue is projected at 7,125,000 PLN. The net annual revenue is thus 4,125,000 PLN, leading to a payback period of approximately 13.64 years.

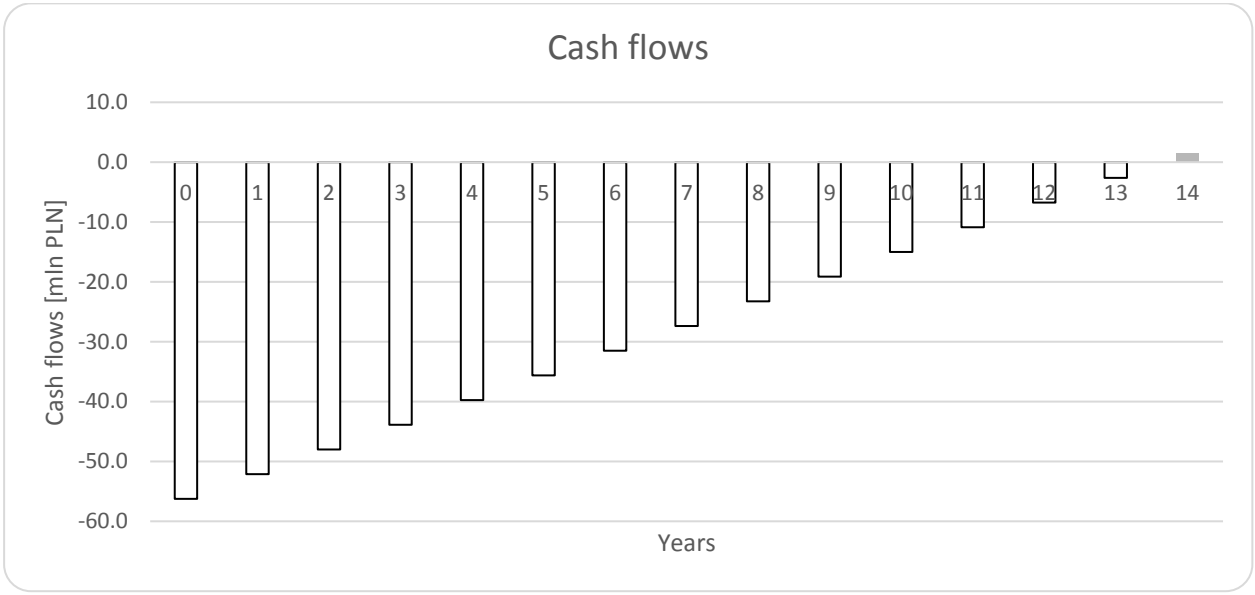

Figure 25. Payback Period Analysis for Wind Installation in the Adamów mine – Konin Region

The wind farm's operation will significantly reduce carbon emissions. Unlike fossil fuel-based power plants, wind turbines generate electricity without CO2 emissions. If we compare this with the regional average emissions for electricity generation, the wind farm could substantially contribute to the reduction of the carbon footprint in the Konin Region.

For the wind farm scenario in the Konin Region, the environmental impact can be quantified in terms of the reduction in CO2 emissions, similar to the photovoltaic (PV) farm analysis. With an annual energy production of 19,710,000 kWh from the wind farm, and considering ZE PAK's emissions rate of around 1000 kg of CO2 per MWh, the introduction of the wind farm could offset approximately 19,710 tonnes of CO2 each year. This reduction represents about 0.4% of ZE PAK's total emissions of 4.87 million tonnes reported in 2021.

LEGAL ASPECTS FOR RES INSTALATIONS

Navigating the legal landscape is a crucial aspect of developing renewable energy projects. In the Konin Region, understanding and complying with the legal requirements for photovoltaic (PV) and wind energy installations is key to the successful implementation of these projects. The following table (Table 18) concisely outlines the selected legal aspects for both PV and wind farms, highlighting the differences and similarities in their regulatory environments.

Table 19. Legal Aspects of Photovoltaic and Wind Farm Installations in the area of Adamów mine

PHOTOVOLTAIC FARM	WIND FARMS
Planning and Land Use: Compliance with the local spatial development plan, as per the Act on Planning and Spatial Development, is mandatory. PV installations must align with designations in the local plan, which could be industrial areas or areas for non-conventional energy production. **Environmental Impact Assessment**: Under the Environmental Information Access Act, PV farms are considered projects that may impact the environment. An environmental impact assessment is required for PV farms that meet certain criteria, as defined by the	**Wind Farm Investment Act**: Regulates special conditions for wind energy generation, including minimum distance requirements from residential buildings and high-voltage power lines, and prohibits wind farm locations in national parks, nature reserves, landscape parks, and Natura 2000 areas. Currently the minimum distance between wind farms andresidential areas is set at 700 meters

Regulation of the Council of Ministers on projects significantly affecting the environment. **Building Permits:** For PV installations exceeding 150 kWp, a building permit is required under the Building Law Act.	**Spatial Planning and Development Act:** Mandates that wind farm locations align with the local spatial development plan. **Environmental Noise Considerations**: Compliance with national noise standards is required, with a maximum of 40 dB noise level during night time. The environmental impact of the noise generated by wind turbines must be assessed and managed. **Environmental Impact Assessmen**t: Construction of wind farms requires an environmental impact assessment and a decision on environmental conditions as per the Act on Providing Information on the Environment and its Protection, Public Participation in Environmental Protection, and Environmental Impact Assessments. This includes public participation in the assessment process. **Regulation on Projects Significantly Affecting the Environmen**t: Wind energy installations are categorized under projects that may potentially have a significant environmental impact, necessitating detailed environmental impact analysis and community consultation.

The process of establishing wind farms is notably more complex and time-consuming compared to photovoltaic farms, primarily due to the extensive environmental and legal-administrative requirements. This complexity underscores the importance of thorough planning and community engagement in the development of wind energy projects.

STAKEHOLDER ENGAGEMENT

In the Konin Region, renewable energy sources (RES) such as solar photovoltaic (PV) and wind energy are viewed positively by the local community. This favorable perception lays a strong foundation for effective stakeholder engagement, which is essential for the successful implementation and long-term sustainability of the RES projects. The following table outlines potential strategies for stakeholder engagement, reflecting the community's supportive attitude toward renewable energy.

Table 20. Engagement strategies for Konin Region

ENGAGEMENT STRATEGIES	OBJECTIVE	METHOD
Public Information Sessions	To inform the community about the benefits of the RES projects, including environmental impact, job creation, and energy security.	Organize town hall meetings and information booths at local events
Collaboration with Local Government	To ensure that the projects align with regional development plans and receive necessary support and approvals.	Regular meetings with local authorities, participation in regional planning sessions
Educational Programs	To raise awareness about renewable energy and its importance for sustainable development.	Conduct workshops in schools and community centers, and create informational materials for distribution.
Community Feedback Channels	To gather input and address concerns from local residents and businesses.	Establish dedicated communication channels like

		hotlines and email addresses, and conduct surveys.
Job Training and Local Employment Opportunities	To enhance the local economy by providing training and job opportunities related to the RES projects.	Partner with local educational institutions and vocational training centers.
Regular Updates and Transparency	To maintain trust and support through transparent communication about project progress and impacts	Regular newsletters, community meetings, and an online project portal.
Collaboration with Environmental Groups	To ensure environmental considerations are thoroughly addressed	Engage with local and regional environmental organizations for input and joint initiatives.
Emergency Response Plan	To ensure community safety and quick response to any incidents	Develop and share a detailed emergency response plan with local authorities and the public.

Future Expansion and Scalability

In the Konin Region, the transformation of the Adamów mine area into a hub for renewable energy installations presents significant potential for future expansion and scalability. As the rehabilitation of the mine progresses, vast tracts of land are gradually becoming available, ideal for subsequent renewable energy installations. This ongoing process of land reclamation provides a unique opportunity to scale up the region's renewable energy capacity in alignment with environmental restoration efforts. The strategy for expansion involves a phased development approach, where renewable energy projects, both solar PV and wind, are implemented in stages. This method allows for a gradual increase in renewable energy production, aligning with the availability of recultivated land and the advancement of technology.

The vision for scaling up renewable energy in the Konin Region is deeply intertwined with the broader goals of sustainable development and ecological restoration. As new areas within the Adamów mine and other open pits are recultivated and assessed for their suitability for renewable energy projects, the region can continuously expand its renewable energy portfolio. This expansion is not just about increasing the number of installations but also about integrating newer and more efficient technologies over time. Collaborating with regional energy providers and authorities to enhance grid infrastructure will ensure that the increased renewable energy output is effectively distributed and utilized. By maintaining an ongoing dialogue with local communities and stakeholders, the region can ensure sustained support for its renewable energy initiatives, adapting to changing needs and technologies while fostering a resilient and sustainable energy future.

NATURAL RESTORATION

For the natural restoration scenario in the Adamów mine area, covering approximately 360 ha of green areas and approximately 400 ha of water reservoirs (Figure 26.), the focus is on harnessing the natural possibilities and remnants of the mining activities to create a unified nature-recreational complex that enhances the attractiveness of the region. Natural restoraion and recreacional developemnt covers:

1) Reclaimed Mining Land
    - **Objective**: Transform the post-mining landscape into a vibrant ecosystem.
    - **Strategies:** Implement extensive greenery through the planting of trees, shrubs, and the creation of gardens, herb patches, and flower beds. This will increase the biologically active area and contribute to biodiversity.

2) Water Bodies and Aquatic Ecosystems
    - **Objective:** Develop water bodies as key features of the recreational landscape.
    - **Strategies:** Conduct water quality assessments in existing ponds and lakes. If contamination is found, apply appropriate remediation techniques. Reshape the banks of these water bodies to make them more accessible and aesthetically pleasing. Consider constructing beaches with imported sand and developing waterfront areas.
3) Recreational Facilities and Infrastructure
    - **Objective:** Establish a nature-centric recreational area within the Adamów mine landscape to promote outdoor activities, leisure, and a deeper connection with the natural environment.
    - **Strategies:** Develop eco-friendly nature trails for exploration and observation, create minimal-impact picnic areas, install educational signage, offer low-impact water activities, and organize environmental workshops, all designed to integrate sustainably with the natural landscape and promote eco-awareness.
4) Environmental Education and Awareness
    - **Objective:** Foster a connection between visitors and the natural world.
    - **Strategies:** Establish educational trails, information boards, and interactive exhibits about local ecology, sustainable practices, and the history of the area's mining and energy production.
5) Community Involvement
    - **Objective:** Engage the local community in the restoration and development process.
    - **Strategies:** Organize community planting days, workshops on environmental stewardship, and involve local businesses in the development of the recreational area.
6) Sustainable Management and Maintenance
    - **Objective:** Ensure the long-term sustainability of the restored area.
    - **Strategies:** Implement eco-friendly management practices, regular maintenance of green spaces and facilities, and monitor the health of the ecosystems.

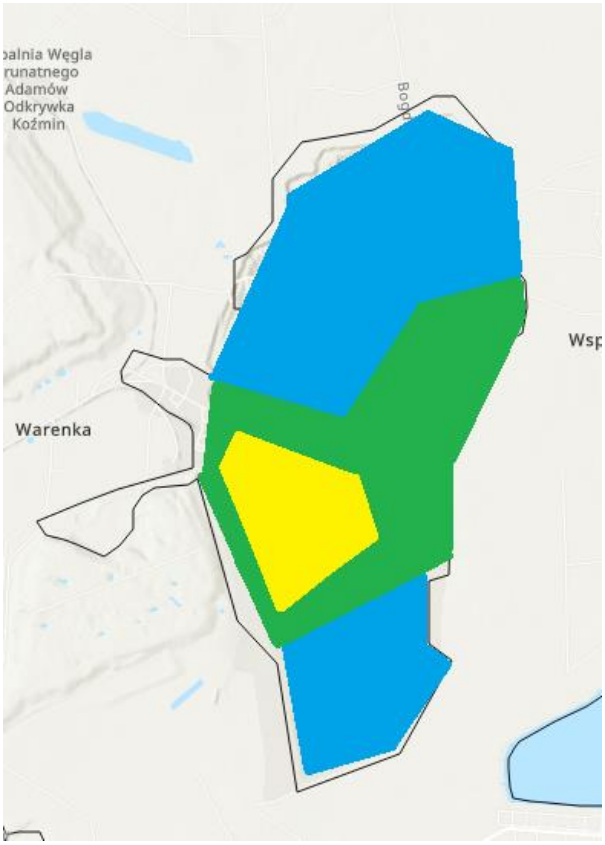

Figure 26. Proposed Site for Renewable Energy Installations at Adamów Open-Pit – Konin Region (blue – reservoir, green – green areas, yellow - forest)

KEY NATURAL RESTORATION INITIATIVES

In the process of converting the Adamów mine area into a region of environmental rejuvenation, a series of key natural restoration initiatives are essential. These initiatives are grounded in ecological restoration principles and aim to address the environmental impacts of previous mining activities. Each initiative is designed to rehabilitate and enhance the natural environment of the area, focusing on practical and effective methods to restore ecological balance and promote sustainable land use. By implementing these initiatives, the Konin Region is taking a methodical approach to environmental restoration, aligning with broader regional goals for sustainable development. The key natural restoration initiatives are included in the table 20.

Table 21. Natural Restoration Initiatives for Adamów mine area

NATURAL RESTORATION INITIATIVE	PURPOSE	ACTIONS
Reforestation and Afforestation	To restore and enhance the forest cover in the area, contributing to biodiversity and carbon sequestration.	Plant native tree species, create mixed forests for habitat diversity, and establish forested corridors to connect fragmented habitats. Implement community-led tree planting initiatives to foster local involvement.
Restoration of Water Bodies and Aquatic Ecosystems	To rehabilitate and enrich aquatic environments, promoting biodiversity and ecological balance.	Develop and restore water bodies, such as reservoirs and lakes, using native aquatic plants and shoreline vegetation to improve water quality and create habitats for wildlife.
Biodiversity Conservation	To protect and promote the area's native flora and fauna, ensuring a balanced ecosystem.	Develop habitats for key species, implement measures to protect endangered species, and create biodiversity hotspots. Collaborate with conservation organizations to develop and implement effective strategies.
Soil and Water Conservation	To prevent soil erosion and enhance water quality and availability in the region.	Implement soil conservation practices such as terracing, cover cropping, and controlled grazing. Establish rainwater harvesting systems and water-efficient irrigation for green spaces. Conduct regular soil health assessments and water conservation workshops.

Along with the progress with the natural restoration of the Adamów mine area, a structured and detailed implementation plan for each key initiative becomes crucial. This next phase of this scenario delves into the specific strategies and actions that will bring the concepts of reforestation, wetlands restoration, biodiversity conservation, and soil and water conservation into reality. This implementation strategy is designed to ensure that the ecological revitalization of the mine area is conducted in a methodical, effective, and sustainable manner. By carefully planning and executing these initiatives, we aim to transform the Adamów mine into a thriving natural landscape, contributing positively to the region's biodiversity and environmental health. The integration of these restoration efforts with recreational and educational components will further enhance the area's value for the local community, making it a model for successful post-industrial land reclamation and ecological stewardship.

Reforestation and Afforestation:

- **Site Preparation:** The designated area for reforestation is marked in Figure 26, encompassing approximately 100 hectares. This area has been strategically chosen based on its suitability for forest regeneration.

- **Species Selection:** Following the successful model used in the Konin mine (located in the Konin Region), the focus will be on leafy, forest-forming species, especially suited to the region's clayey spoil substrates. Primary species will include Pedunculate Oak (Quercus robur), European Ash (Fraxinus excelsior), European Larch (Larix decidua), and Common Beech (Fagus sylvatica). Supplementary species will involve Small-leaved Lime (Tilia cordata), Common Hornbeam (Carpinus betulus), Common Maple (Acer campestre), and Sycamore Maple (Acer pseudoplatanus). Among shrubs, predominant choices will be Siberian Pea Shrub (Caragana arborescens), Hawthorn, Rowan, Sea Buckthorn, Black Locust (Robinia pseudoacacia), and Black Elderberry (Sambucus nigra) (www.kwbkonin.pl).
- **Planting Strategy:** The planting will utilize a mix of seeds and saplings to establish a diversified forest ecosystem. The planting will be scheduled to align with the optimal seasons to ensure the highest survival rate and healthy growth of the trees.
- **Ongoing Care and Monitoring:** A maintenance plan will be established, which includes regular watering, protection from pests, and monitoring of tree health. This plan will be crucial to ensure the survival and healthy growth of the newly planted trees.
- **Community Involvement:** Local communities, schools, and volunteer groups will be involved in the planting process. This approach aims to foster a sense of ownership and environmental awareness among local residents, encouraging their continuous support for the forest's growth and well-being.
- **Progress Evaluation:** The growth and health of the reforested areas will be regularly assessed. These evaluations will help in adapting management practices as necessary and ensuring the success and sustainability of the reforestation efforts.

Restoration of Water Bodies and Aquatic Ecosystems:

- **Site Assessment and Preparation:** within Adamów mine 2 reservoirs are planned to be created: Adamów Pośredni (100 ha) and Adamów Końcowy (300 ha), as part of the ongoing reclamation works at the mine site. The designated areas for this reservoirs is marked on Figure 26, identifying its location within the Adamów mine area.
- **Aquatic Planting and Habitat Creation:** The introduction of native aquatic plants will be prioritized to ensure ecological balance and promote biodiversity. Potential species include Water Lilies (Nymphaea), Reed Mace (Typha), and Water Milfoil (Myriophyllum). These plants are essential for providing habitats for aquatic fauna and maintaining water quality. The creation of various microhabitats, such as shallow marshy areas for amphibians and deeper zones for fish, will help establish a diverse aquatic ecosystem.
- **Water Quality Management:** The reservoir will be monitored for water quality parameters like pH, oxygen levels, and contaminants. Natural filtration methods, such as the use of biofiltration plants along the shoreline, will be employed to maintain water clarity and health. Regular checks for pollutants and remediation efforts, as necessary, will be part of the management plan to ensure the reservoir remains a healthy aquatic habitat.
- **Community Involvement and Education:** The reservoir will be monitored for water quality parameters like pH, oxygen levels, and contaminants. Natural filtration methods, such as the use of biofiltration plants along the shoreline, will be employed to maintain water clarity and health. Regular checks for pollutants and remediation efforts, as necessary, will be part of the management plan to ensure the reservoir remains a healthy aquatic habitat.

Biodiversity Conservation:

- **Habitat Creation and Enhancement:** Develop a variety of habitats within the Adamów mine area to support a wide range of species. This will include woodland areas, meadows, aquatic habitats, and shrublands.Enhance existing habitats by planting native species, creating shelters, and ensuring a supply of food and water to attract and support diverse wildlife.
- **Conservation Programs:** Implement targeted conservation programs for species that are endangered or of particular ecological importance in the region. This might include creating protected areas, breeding programs, or specific habitat enhancements.Monitor and manage critical habitats, employing adaptive management strategies to maintain their ecological integrity and support the species that rely on them.
- **Community Involvement:** Collaborate with local schools and community groups to involve residents in conservation efforts, such as habitat restoration projects and wildlife surveys. Organize awareness programs and workshops to educate the community about local biodiversity, the importance of conservation, and ways to contribute to these efforts.

Soil and Water Conservation:

- **Soil Restoration Techniques:** Implement erosion control measures such as terracing, mulching, and the use of erosion control mats, particularly in areas susceptible to soil loss. Enhance soil fertility and structure by adding organic matter, such as compost and manure. Employ techniques like cover cropping and green manuring to maintain soil health. Promote the use of native vegetation that is well-adapted to local soil conditions, helping to prevent soil erosion and improve water retention in the soil.
- **Water Conservation Measures:** Install rainwater harvesting systems to collect and store rainwater for irrigation and other uses. This not only conserves water but also reduces surface runoff and soil erosion. Implement efficient irrigation systems, such as drip irrigation or soaker hoses, to minimize water wastage. Consider the use of moisture sensors and timers to optimize irrigation scheduling based on actual soil moisture levels. Develop and promote water conservation practices among the local community, including guidelines for water-efficient landscaping and the use of drought-resistant plant species.

INTEGRATION WITH RECREATIONAL AND EDUCATIONAL ASPECTS

In the comprehensive natural restoration scenario for the Adamów mine, a key component involves the seamless integration of ecological restoration with recreational and educational opportunities. This approach is aimed at enhancing the area's value for both the local community and visitors, transforming it into a hub for learning, leisure, and environmental engagement.

The plan includes the creation of recreational spaces within restored natural habitats. These areas will feature walking trails, observation decks near water bodies, and picnic spots in scenic settings, all designed to enable visitors to engage with and appreciate the rejuvenated natural landscapes.

Educational trails will be established throughout various restoration sites, complete with interpretive signage. This signage will provide information about the specific habitats, the species they support, and the significance of the restoration work. Interactive learning stations are also planned to further visitor understanding of ecological processes and conservation importance.

Collaboration with local schools and educational institutions is a crucial aspect of this scenario. Educational programs linked to the restoration project will be developed, offering field trips and experiential learning opportunities. This initiative aims to not only provide educational benefits but also instill a sense of environmental responsibility in younger generations.

Additionally, the plan includes organizing community engagement events such as guided nature walks, conservation workshops, and citizen science projects. These events are designed to involve local residents in the restoration process and deepen their commitment to environmental conservation.

Overall, the integration of natural restoration with recreational and educational elements forms a vital part of the Adamów mine area's restoration scenario. This multifaceted approach aims to establish a space that exemplifies ecological restoration, community involvement, and environmental education.

RECREATIONAL FACILITIES AND INFRASTRUCTURE

As part of the natural restoration project at the Adamów mine, the development of recreational facilities and infrastructure is being planned with a strong emphasis on preserving and highlighting the area's natural beauty and ecological value.

1. **Nature Trails and Viewing Platforms**: The core of the recreational infrastructure will be a network of nature trails that wind through the restored landscapes, offering visitors an immersive experience in the rejuvenated natural environment. Along these trails, strategically placed viewing platforms will provide spots for visitors to observe wildlife and enjoy the scenic beauty of the area without causing disturbance to the habitats.
2. **Eco-friendly Picnic and Rest Areas**: Scattered throughout the area, picnic and rest spots will be established, designed to blend into the surroundings. These areas will be equipped with minimal impact facilities, such as benches and tables made from sustainable materials, allowing visitors to relax and enjoy the natural setting.
3. **Educational Signage and Displays**: To enhance the educational aspect of the visit, informative signage and interactive displays will be installed along the trails. These will focus on the local ecosystem, the restoration efforts, and the importance of preserving natural habitats.
4. **Low-Impact Water Recreation:** Recognizing the significance of the water bodies in the area, water-based recreational activities will be encouraged but managed to ensure minimal impact on the aquatic ecosystems. Activities like birdwatching from the shore, guided nature photography tours, and educational kayaking excursions will be promoted.
5. **Minimalist Infrastructure for Access and Safety**: Essential infrastructure such as pathways, small bridges, and safety signage will be constructed with an eco-conscious approach, using materials and designs that minimize the ecological footprint. These structures will ensure safe and accessible exploration of the area while maintaining the integrity of the natural environment.

In aligning with the natural restoration ethos of the project, these recreational facilities and infrastructure are being designed to provide visitors with opportunities to connect with and learn about nature in a respectful and sustainable manner. The emphasis remains firmly on enhancing the appreciation of the natural world, fostering a sense of stewardship, and ensuring that recreational activities are in harmony with the restoration objectives.

7. ASSESSMENT OF PROPOSED SCENARIOS

7.1. WESTERN MACEDONIA

CLEAN ENERGY

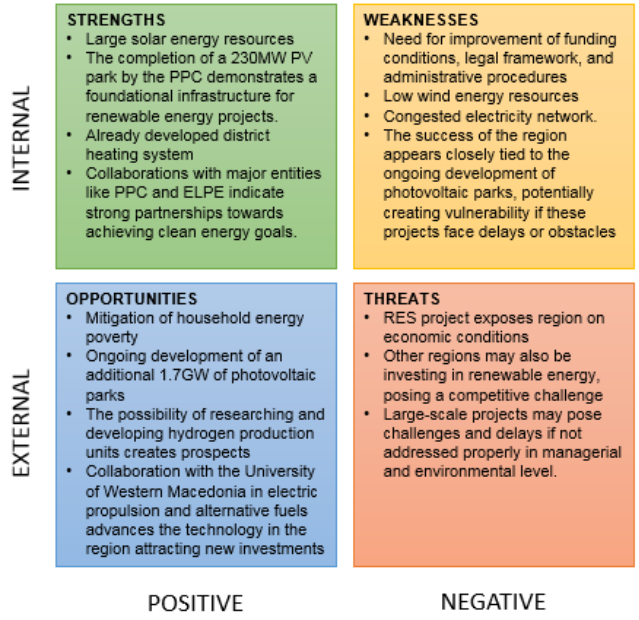

Figure 27. SWOT analysis for the Clean Energy Scenario - Western Macedonia

SMART AGRICULTURE

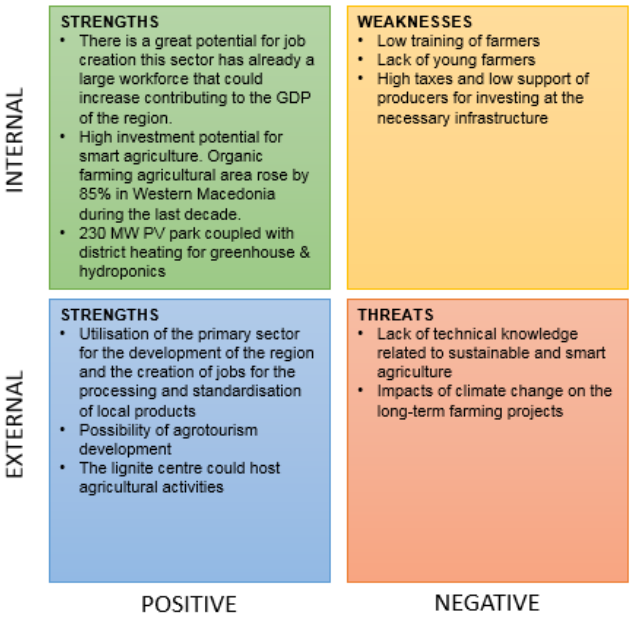

Figure 28. SWOT analysis for the Smart Agriculture Scenario - Western Macedonia

7.2. KONIN REGION

RENEWABLE ENERGY INTEGRATION

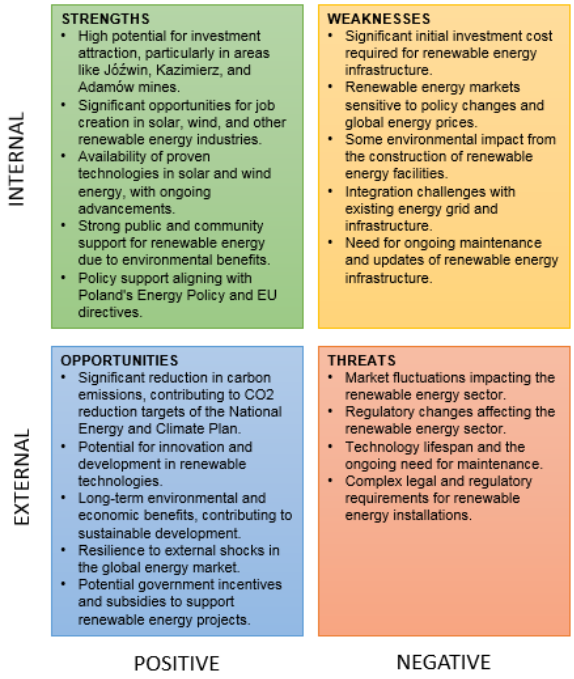

Figure 29. SWOT analysis for the Renewable Energy Integration Scenario - Konin Region

NATURAL RESTORATION

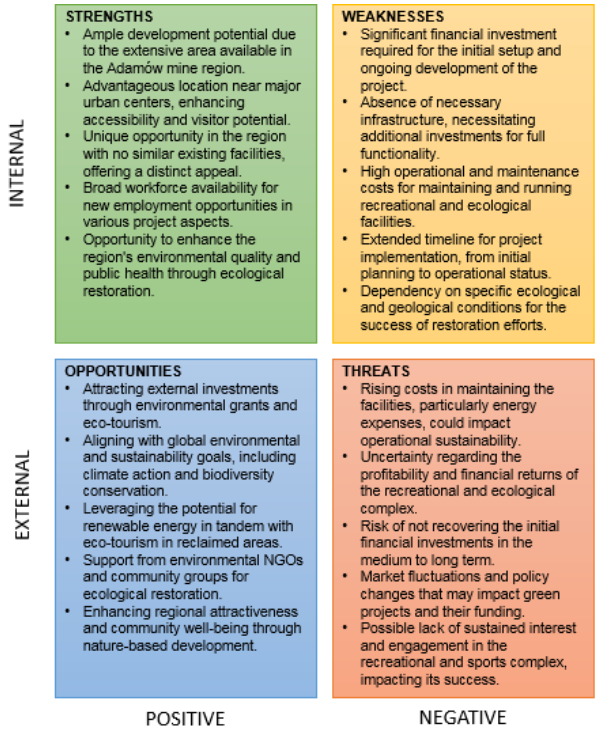

Figure 30. SWOT analysis for the Natural Restoration Scenario - Konin Region

8. CONCLUSION

Transformational scenarios constitute a crucial element in the analysis and planning of socio-economic and environmental transformations. Their significance arises from several key aspects that are worth highlighting:

1) **Understanding Complex Regional Challenges** - Transformational scenarios provide a framework for gaining a comprehensive understanding of the intricate challenges that regions confront. These challenges can encompass economic, social, and environmental dimensions. By envisioning different development pathways, stakeholders can gain insights into the potential outcomes and impacts of their decisions

2) **Guiding Informed Decision-Making** - Transformational scenarios serve as valuable tools for guiding informed decision-making. They enable policymakers and stakeholders to explore diverse scenarios, assess their implications, and identify strategies that lead to sustainable and resilient outcomes. This informed decision-making process is essential for addressing the wide-ranging challenges that regions face.

The scenarios developed for Western Macedonia are a key aspect of our analysis, providing insight into the region's potential transformation trajectories. These scenarios have been carefully designed to take into account the specific challenges and opportunities facing Western Macedonia. Here are the most important conclusions from the scenarios:

Clean Energy Scenario

The Clean Energy Scenario in Western Macedonia envisions a transformative vision centered on the construction of photovoltaic parks and wind turbines, offering economic viability through potential returns on investment and job creation, while also attracting external investments. This scenario prioritizes environmental responsibility by significantly reducing carbon emissions and integrating sustainable practices. It garners strong social acceptance and support from key stakeholders, aided by readily available photovoltaic technology and necessary infrastructure. Sustainability is a core principle, providing long-term environmental and economic benefits and enhancing resilience to market fluctuations. Moreover, the scenario complies with renewable energy regulations and aligns with regional energy transition plans. With an estimated annual energy production of 568,440 MWh/year from solar PV and 197,100 MWh annually from wind turbines, this scenario has the capacity to power approximately 130,078 households and 45,103 households, respectively, contributing to a cleaner and more prosperous energy future for the region.

Smart Agriculture Scenario

The Smart Agriculture Scenario for Western Macedonia envisions a transformation of the agricultural sector characterized by the adoption of advanced technologies, sustainable practices, and community engagement. It has the potential to create jobs, attract external investments, and significantly improve the economic viability of the region, given its 21% employment rate in agriculture. Moreover, the scenario emphasizes environmentally responsible practices, including carbon sequestration and biodiversity conservation, while promoting cultural preservation. Stakeholder engagement, including support from environmental organizations and overcoming potential resistance from other land use interests, will be crucial. The feasibility of technology adoption and infrastructure readiness must also be addressed, with a focus on long-term environmental benefits and alignment with Sustainable Development Goals. Finally, compliance with regulatory and legal considerations is essential for successful implementation.

The scenarios developed for the Konin Region play a pivotal role in our analysis, providing valuable insights into potential transformation trajectories for the region. These scenarios have been thoughtfully designed to consider the specific challenges and opportunities inherent to the Konin Region. The following are the key conclusions drawn from these scenarios:

Renewable energy integration

In the Konin Region, integrating solar photovoltaic (PV) and wind energy across Adamów mine presents a significant opportunity for sustainable development. Solar PV, with an estimated annual energy production of 85,602,000 kWh, can power around 33,928 households while at the same area wind farms can produce 19,710 MWh per year. Legal aspects involve spatial planning, environmental impact assessments, and building permits. Stakeholder engagement includes public sessions, collaboration with local government, education, community feedback, job training, transparency, environmental group collaboration, and emergency response planning. Future expansion aims to scale renewable energy capacity, fostering sustainable development and ecological restoration through ongoing dialogue with regional stakeholders.

Natural restoration

In the natural restoration scenario for the Adamów mine area, the focus is on transforming post-mining landscapes into vibrant ecosystems and creating a unified nature-recreational complex. This involves strategies such as extensive greenery planting, water quality assessments, eco-friendly nature trails, educational signage, community involvement, and sustainable management. Key initiatives include reforestation, aquatic habitat restoration, biodiversity conservation, and soil and water conservation. The integration of ecological restoration with recreational and educational elements aims to enhance the area's value for both the local community and visitors, offering opportunities for nature exploration, wildlife observation, and environmental education while preserving the natural beauty and ecological value of the region.

The lessons learned from the Ruhr region's experience, such as collaborative planning, transparent development processes, and interdisciplinary actions, can be applied effectively in the Konin region and Western Macedonia to navigate the transition of their own mining and industrial sites. These regions can benefit from a focus on coordinated objectives and planning, early problem identification, and knowledge sharing among municipalities and stakeholders. The coal brownfield agreement model offers valuable insights for successfully transforming these areas, promoting sustainable development and regional cooperation.

In conclusion, transformational scenarios play a pivotal role in understanding and addressing the complex regional challenges faced by regions like Western Macedonia and the Konin Region. They provide a comprehensive framework for informed decision-making, enabling stakeholders to navigate the intricacies of economic, social, and environmental transformations. The scenarios presented for both regions offer valuable insights into potential pathways for sustainable development, whether through clean energy adoption or natural restoration efforts. Importantly, the lessons learned from the Ruhr region's experience in collaborative planning and transparent development processes can serve as a guiding light for these regions as they embark on their own journeys of transformation. By embracing these principles and fostering regional cooperation, Western Macedonia and the Konin Region can work towards a more sustainable and resilient future for their communities and environments.

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10. LIST OF FIGURES

11. LIST OF TABLES

APPENDIX 1. STAKEHOLDER ANALYSIS GREECE

Stakeholder	Group	Activities	Level of Interest	Level of Influence	Typology
Full name and abbreviation	*abbre-viations*	*Description of the Activities*	*0 – 5 (Very Low, Low, Medium, High, Very High)*	*0 – 5 (Very Low, Low, Medium, High, Very High)*	*Discursive, Bureaucratic, Technocratic, Financial*
Direct Stakeholders					
Public Power Corporation S.A. (PPC)	**PPC**	Assets in lignite mines, power generation, transmission and distribution.	5	5	Technocratic
Mining-Technical-Trade S.A. (METE)	**MCOMP**	Lignite production in privately owned mines.	5	2	Technocratic
Lignite Mines of Achlada S.A.	**MCOMP**	Lignite production in privately owned mines	5	3	Technocratic
GENOP-DEH 2nd tier union of 27 member unions nationally, of which 6 from Western Macedonia	**LU**	GENOP-DEK is the PPC's main labor union at national level	5	5	Discursive
General Confederation of Greek Workers (GSEE). The highest, tertiary trade union body in Greece made up of 83 worker unions and 74 departmental secondary confederations	**LU**	GSEE is. Its prime purpose is defending the interests of all workers in the private sector. It negotiates the with the employer unions at national level, and can call all workers of the private sector on strike in case the need arises.	4	5	Discursive
Spartakos (a workers union) – member of GENOP	**LU**	Labor union for workers (PPC) at a regional level (Western Macedonia) – 1/3 in power sector and 2/3 in mining	5	3	Discursive

Labor Union Working Solidarity (a workers' union) – member of GENOP	**LU**	Small labor union	5	2	Discursive
Labor Union of Technical Engineers (a sectoral union) – member of GENOP	**LU**	Small labor union	5	2	Discursive
Labor Union Lygkistis (a workers' union) – member of GENOP	**LU**	Small labor union	5	2	Discursive
The Union (a workers' union)– member of GENOP	**LU**	Members in mining, power and adm – but majority miners	5	2	Discursive
Local Committee Number 12/PPC- West Macd (a sectoral union) – member of GENOP	**LU**	Small labor union	5	2	Discursive
SEN Union of Temporary Workers (a workers' union)	**LU**	Small labor union for temp. workers which work on 8 months' contract each year.	4	1	Discursive
Indirect Stakeholders					
TENA S.A., Ptolemais (group of companies)	**SCOMP**	Construction company, excavation and transport in 4 mines	5	2	Technocratic
GAIA Technical S.A., Ptolemaida	**SCOMP**	Mineral extraction works constructions	5	2	Technocratic
KAPA Dynamiki S:A., Florina &Ptolemais	**SCOMP**	Construction company, mineral works, roads, buildings, mechanical works	5	2	Technocratic

ELIKA A.T.E.E.S.A., Kozani	**SCOMP**	Construction of infrastructure	5	2	Technocratic
ERGONSAS S.A., Kozani	**SCOMP**	Mineral extraction works - constructions	5	2	Technocratic
KYBOS S.A., Kozani	**SCOMP**	Industrial services - constructions	5	2	Technocratic
MPETOKAT S.A., Ptolemais	**SCOMP**	Mine exposure - constructions	5	2	Technocratic
SOTTRUCKS, Ptolemais	**SCOMP**	Truck repair, maintenance	5	2	Technocratic
VIER, S:A., Kozani	**SCOMP**	Construction company/industrial services, maintenance	5	2	Technocratic
Polytechniki, S.A., Ptolemais	**SCOMP**	Metal works	5	2	Technocratic
Vita S.A., Ptolemais	**SCOMP**	Electrical and industrial installations	5	2	Technocratic
Mete , Mining-technical- trade S.A S.A., Florina	**SCOMP**	Sub-contracting trucks and excavators	5	2	Technocratic
Greece 2028 Observatory	**SCOMP**	Association of 23 sub-contractors (technical and construction) to PPC.	5	2	Technocratic
Numerous small sub-contractors	**SCOMP**	Provision of different services to PPC SA (e.g. catering, cleaning, waste disposal)	5	2	Technocratic
Numerous suppliers to PPC SA	**SCOMP**	Supply of various material inputs to PPC S.A.	3	1	Technocratic
Ekkentro Ltd	**SCOMP**	Mechanological and Electrological constructions (DEI Blue EV CHARGING POINTS, SUPPORT PROJECTS – MAINTENANCE IN MINES AND PPC SUBSTATIONS etc)	5	2	Technocratic
Advent Technologies (ADVENT) S.A.	**PINV**	Manufacture hydrogen fuel cells, energy storage systems, hydrogen production	5	4	Technocratic

Enel Green Power Hellas	**PINV**	They operate throughout the world with their renewable energy plants. They're facilitating the move towards electrification and sustainable energy by putting people and the environment first, and they're also constantly pushing technological boundaries and increasing stakeholder awareness.	5	3	Technocratic
HELLENIC PETROLEUM (HELPE)	**PINV**	HELLENIC PETROLEUM Group's strategy is focused on creating a balanced portfolio across its core business and growth in New Energy, enabling it to capitalize on opportunities offered by the accelerated Energy Transition.	4	4	Technocratic
		Government			
The European Union	**EU/DG**		3	3	Financial / Bureaucratic
Ministry of Finance	**NGOV**	Overall financial policy.	4	4	Bureaucratic / Financial
Ministry of Environment and Energy	**NGOV**	Protection of the natural environment and resources; Mitigation and adjustment to the implications of climate change	5	5	Bureaucratic
Ministry of Development and Investments	**NGOV**	Responsible, i.a. for the Multi-annual Financial Framework for the years 2021-27, currently under negotiations with EC	5	5	Bureaucratic
Ministry of Labor and Social Affairs	**NGOV**	Labor and social legislation and policy.	3	3	Bureaucratic
Decentralized Administration of Epirus and Western Macedonia	**NGOV**	The Decentralized Administrations are administration units with activities particularly in state audit and executive tasks within the area of their responsibilities.	5	4	Bureaucratic

Region of Western Macedonia	**RGOV**	Administratively a secondary governmental organization. Geographically covers the whole of Western Macedonia	5	4	Bureaucratic / Discursive
Union of Municipalities of Western Macedonia	**LGOV**	Plays a political, coordinating and developmental role for municipalities	5	3	Bureaucratic / Discursive
Regional Operational Program of Western Macedonia Managing Authority	**RGOV**	Responsible for the Regional Operational Program (ROP)	4	3	Bureaucratic
Network of Energy Production Municipalities	**CSO**	Kozani Florina Amyntaio Eordaia	4	3	Discursive
Centre for Renewable Sources and Saving (CRES)	**NBUS**	CRES is the national entity for the promotion of renewable energy sources, rational use of energy and energy conservation. CRES is a public entity supervised by the Ministry of Environment and Energy.	4	3	Technocratic
Hellenic Transmission System Operator (HTSO) & Regulatory Authority for Energy (RAE) The Operator of Electricity Market (OEM)	**SCOMP**	The liberalized electricity market is operated by the Hellenic Transmission System Operator (HTSO) and is supervised by the Regulatory Authority for Energy (RAE), which also supervises the OEM. OEM operates the process of the exchange between electricity producers and electricity consumers	4	3	Bureaucratic / Technocratic

Hellenic Company of Just Developmental Transition S.A. (METAVASI S.A.)	**LGOV**	**The company METAVASI S.A. is established by Law 4872/2021 , operates in the public interest, is supervised by the Minister responsible for Just Development Transition issues, in this case the Deputy Minister of Development & Investments.**	5	5	Bureaucratic / Discursive
National Natural Gas System Operator (DESFA) S.A.	**SCOMP**	The National Natural Gas System Operator (DESFA) S.A. is responsible for the operation, management, exploitation and development of the National Natural Gas System and its interconnections, in a technically sound and economically efficient way, in order to best serve its Users with safety, reliability and adequacy.	5	5	Technocratic
Municipality of Eordaia	**LGOV**	Administratively a local governmental organization	5	4	Bureaucratic / Discursive
Municipality of Amyntaio	**LGOV**	Administratively a local governmental organization	5	4	Bureaucratic / Discursive
Municipality of Kozani	**LGOV**	Administratively a local governmental organization	5	4	Bureaucratic / Discursive
District Heating Company of Ptolemais (DHCP)	**LGOV**	DHCP is intended to Administrate the District Heating System of Ptolemais to construct all the necessary DH infrastructure, to Operate the DH system and to commission DH Heat to consumers.	5	3	Technocratic

District Heating Company of Amyntaio (DHCA)	**LGOV**	The company is municipal enterprise, it constitutes is a Legal Person governed by Private Law, with a social utility character, oowned 100% by mucicipality of Amindeo. DHCA is a non profitable and non governmental entity and is intended to Administrate the District Heating System of Amindeo, to construct all the necessary DH infrastructure, to Operate the DH system and to commission DH Heat to consumers.	5	3	Technocratic
District Heating Company of Kozani (DHCK)	**LGOV**	DHCK is intended to Administrate the District Heating System of Kozani to construct all the necessary DH infrastructure, to Operate the DH system and to commission DH Heat to consumers.	5	3	Technocratic
Other Interest Parties					
West Macedonia Development Company (ANKO) SA	**NBUS**	Established by the local authorities, the State, the agricultural cooperatives and Chambers of Commerce, in order to act as a pioneering scientific organization for the regional development approach	4	4	Bureaucratic / Discursive
Chamber of Commerce and Business, Florina	**NBUS**	Organization of local businesses and companies with a focus on development of the interests of local companies and businesses	4	3	Discursive
Technical Chamber of Greece/ Dept. of WM	**NBUS**	Active members (engineers) employed in industry, construction, consulting, public services. Interest from a	4	3	Discursive

		technological, economic and political perspective.			
Geotechnical Chamber of Greece / Department of West Macedonia	**NBUS**		4	3	Discursive
Hellenic Association of Photovoltaic Companies (HELAPCO) Hellenic Wind Energy Association (ELETAEN)	**SCOMP**	Interested in de-carbonisation and subsequent investment opportunities for RES	5	4	Discursive
DIADIMA / EPADYM Waste Treatment Plant	**PPP**	Interested in establishment of a Circular Economy Park, focusing on waste materials recovery, utilization and management and based on the co-operation of research forces with local businesses to produce innovative products.	4	4	Technocratic
University of Western Macedonia	**ACRES**	Interest based on a research and technological and political/economic perspective	4	4	Bureaucratic / Discursive
Centre for Research and Technology-Hellas (CERTH)	**ACRES**	It is a legal entity governed by private law with non-profit status, supervised by the General Secretariat for Research and Innovation (GSRI) of the Greek Ministry of Development & Investments.	4	4	Technocratic

Cluster of Bioenergy & Environment of Western Macedonia (CluBE)	**NGOs**	Interest from a research and technological and political/economic perspective	4	3	Technocratic
WWF, Western Macedonia Greenpeace Greece Green Tank Kozani Ecological Movement	**NGOs**	Active in campaign to have PPC's environmental permit (2016) annulled for failure to comply with EU laws. Interest in mine closure and promotion of RES solutions.	4	3	Discursive
Active Youth Club of Florina (OENEF)	**CSO**	Is the hosting organization of the Europe Direct Information Centre of Western Macedonia, informs all citizens with a focus on young people, about the European Union, its policies, and its educational programmes, that take place all over Europe and all the advantages and opportunities that people can gain through these programmes	4	3	Discursive
Local and national media (print and electronic media)	**media**	Interested based on the significant socio-economic and political impact of the transition.	4	2	Discursive

APPENDIX 2. STAKEHOLDER ANALYSIS POLAND

Stakeholder	Group	Activities	Level of Interest	Level of Influence	Typology
Full name and abbreviation	*Abbre-viations*	*Description of the Activities*	*0 – 5 (Very Low, Low, Medium, High, Very High)*	*0 – 5 (Very Low, Low, Medium, High, Very High)*	*Discursive, Bureaucratic, Technocratic, Financial*
Direct Stakeholders					
KWB PAK Konin	**MCOMP**	Mine operator	5	5	Technocratic
ZEPAK	**PPC**	Coal, Wind, PV, Biomass power plant facilities	5	5	Technocratic
Inter-Union of PAK Miners of the Adamów Mine	**LU**	Labour Union of miners Adamów Mine	4	2	N/A
KADRA Inter-Union of Adamów Mine	**LU**	Labour Union of Adamów Mine	4	2	N/A
Sub-Union Organisation of the Independent Self-Governing Union "Solidarity" PAK Lignite Mine Adamów	**LU**	Solidarność Labour Union of miners Adamów Mine	4	2	N/A
Inter-Union of Miners of KWB "Konin" S.A.	**LU**	Labour Union of miners Konin Mine	4	2	N/A
Independent Union of Continuous Movement Workers "Ruch" at KWB Konin	**LU**	Labour Union of miners Konin Mine	4	2	N/A
Inter-Union of Engineering and Technical Employees "Kadra" of KWB Konin	**LU**	Labour Union of miners Konin Mine	4	2	N/A

Local community organisations	N/A	N/A	N/A	N/A	N/A
Environmental organisations	N/A	N/A	N/A	N/A	N/A
Industrial and Technology Parks	N/A	N/A	N/A	N/A	N/A
Indirect Stakeholders					
Aluminium Smelter Konin (Aluminium Konin IMPEXMETAL S.A.)	**LBUS**	N/A	4	2	Technocratic
ADM Poland	**SCOMP**	Renewable Energy consulting company	5	2	Technocratic
ARSANIT sp. z o.o	**LBUS**	Insulation / construction company	5	2	Technocratic
Kon-Bet sp. z o.o	**LBUS**	Prefabrication prodution plant	5	2	Technocratic
Neo Energy Sp. z o.o	**SCOMP**	Renewable Energy project development company	5	2	Technocratic
Munda Energy OZE	**SCOMP**	Renewable Energy project development company	5	2	Technocratic
Biomasa Partner Group Sp. z o. o	**SCOMP**	Biomass production	5	2	Technocratic
Biogas Technology	**SCOMP**	Biogas service provider	5	2	Technocratic
DSM	**LBUS**	Metal plate production plant	5	2	Technocratic
Suntherm	**LBUS**	Infrared heating company	5	2	Technocratic
SunErgo Poznań	**SCOMP**	PV company	5	2	Technocratic
Cluster "Green Energy Konin" (Klaster „Zielona Energia Konin")	**NBUS**	Local energy market devevlopment	5	N/A	Bureaucratic
Government					
Discrict Office of Konin (Starostwo Powiatowe w Koninie)	**RGOV**	Regional government office	5	5	Bureaucratic

Discrict Office of Koło (Starostwo Powiatowe w Kole)	**RGOV**	Regional government office	5	5	Bureaucratic
Discrict Office of Słupca (Starostwo Powiatowe w Słupcy)	**RGOV**	Regional government office	5	5	Bureaucratic
Discrict Office of Turek (Starostwo Powiatowe w Turku)	**RGOV**	Regional government office	5	5	Bureaucratic
Ministry of Energy	**NGOV**	N/A	5	5	Bureaucratic
Ministry of Climate and Environment	**NGOV**	N/A	5	5	Bureaucratic
Ministry of Development, Labour and Technology	**NGOV**	N/A	5	5	Bureaucratic
Ministry of National Assets	**NGOV**	N/A	5	5	Bureaucratic
Polish Agency for Enterprise Development, (Polska Agencja Rozwoju Przedsiębiorczości)	**NGOV**	N/A	3	4	Bureaucratic
Higher Mining Authority, District Mining Authority in Poznań	**RGOV**	Mining operations offices	4	3	Bureaucratic
Energy Regulatory Office (Urząd Regulacji Energetyki)	**NGOV**	N/A	4	4	Bureaucratic
Marshal's Office of the Wielkopolska Voivodeship	**RGOV**	Regional government office	5	5	N/A

Steering Committee for Transformation of Eastern Wielkopolska at the Marshal of the Wielkopolska Voivodeship and the Subregional Forum of Eastern Wielkopolska	**RGOV**	N/A	5	5	N/A
The EU	**EU/DG**	N/A	5	5	N/A
Other Interest Parties					
Construction and Vocational School Complex in Konin	**AC**	N/A	4	2	N/A
Central Mining Institute	**AC**	N/A	4	2	N/A
Energy Forum Foundation	**NGOs**	N/A	4	3	N/A
Energy Conversion and Renewable Sources Research Centre of PAN (Polish Academy of Sciences)	**AC**	N/A	5	2	NA
Łukasiewicz Research Network	**AC**	N/A	5	2	N/A
Association of Mining Engineers and Technicians	**NBUS**	N/A	5	2	N/A
Institute of Mineral Raw Materials and Energy of the Polish Academy of Sciences	**AC**	N/A	4	2	N/A

Institute of Mining Technology - KOMAG	**AC**	N/A	3	2	N/A
Council of the Federation of Scientific and Technical Associations in Konin - NOT	**NBUS**	N/A	3	2	N/A
Tauron Polska Energia S.A	**NBUS**	N/A	4	2	N/A
Industrial Development Agency S.A.	**N/A**	N/A	4	2	N/A