engineering proceedings

MDPI

Proceeding Paper

Clean Energy Technologies in Western Macedonia: Opportunities for Jobs and Growth within the Coal Phase-Out Era †

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† Presented at the 4th International Electronic Conference on Applied Sciences, 27 October–10 November 2023; Available online: https://asec2023.sciforum.net/.

Abstract: This study presents an overview of the role that clean energy technologies can play in the decarbonisation path of Greece's most carbon-intensive region, namely Western Macedonia. The region has been requested to adjust its production model to the new requirements of the Green Deal Initiative, while simultaneously proceeding to restructure its productive model towards a full phase-out of coal activities. The survey presented below will summarise the main findings and estimates of the clean energy potential from a technical and research point of view, and furthermore present assessments on the potential impact this could have on job creation and regional economic development in terms of potential investments. This study's goals are to identify and promote actions to accelerate innovation performance in the clean energy domain and, simultaneously, serve as a co-working space among key stakeholders from business, government, civil society and innovation who share a vision for a sustainable future. Finally, this study highlights the importance of accelerating innovation in the clean energy domain—spanning energy production, distribution and consumption.

Keywords: coal phase-out; clean energy; technical and research potential; innovation

Citation: Ketikidis, C.; Triantafillidis, A.; Stogiannis, P.; Amarantos, P.; Kontodimos, I.; Grammelis, P. Clean Energy Technologies in Western Macedonia: Opportunities for Jobs and Growth within the Coal Phase-Out Era. *Eng. Proc.* **2023**, *56*, 243. https://doi.org/10.3390/ASEC2023-15404

Academic Editor: Simeone Chianese

Published: 27 October 2023

1. Introduction

The region of Western Macedonia is heavily dominated by a carbon-intensive power generation industry. Considering that it has been hosting 80% of the Greek lignite industry since the 1960s, the region has been requested to adjust its production model to the new requirements of the Green Deal Initiative, proceeding thus to a productive restructuring towards a full coal phase-out. Lignite activities affect the regional economy in a multidimensional way, which can be categorized into direct, indirect and inductive effects. Since the 1960s, the monocultural Public Power Corporation-driven industrial economy has involved more than 16,000 people both directly and indirectly [1].

For a proper transition, funding is required. To this end, the **Just Transition Development Programme (JTDP) 2021–2027** [2] is in place, aiming to revitalise the economies of coal and carbon-intensive regions and therefore securing jobs affected by the shift to renewable energy sources and creating new jobs in sustainable economic activities.

Regional concerns such as structural problems, evidenced by high unemployment rates and the absence of foreign direct investments, are addressed within the **Territorial Just Transition Plan for Western Macedonia**, which places particular emphasis on the impact of the decarbonisation process in several areas, e.g., emissions reduction, increasing energy efficiency or fostering innovation and technological research [3].

The Greek government has set a goal of withdrawing all lignite power plants by 2028, with the majority of plants being withdrawn by 2023. This goal marks the formalization of Greece's transition to a differentiated and carbon-neutral mixture in power generation.

2. Materials and Methods

The present study employs a SWOT analysis to discuss all affected dimensions of the regional coal phase-out plan. Below, some concrete examples of **industries, pilot applications and initiatives** are depicted serving as a base for this analysis [4].

Carbon capture, utilization and storage (CCUS): CCUS is a key technology for reducing emissions from energy-intensive industries. The Centre for Research and Technology Hellas (CERTH) has a research group focused on CCUS.

Circular economy and resource efficiency: The Greek National Circular Economy Action Plan includes measures to support the circular economy in energy-intensive industries, including the lignite mining and processing sector. The Cluster of Bioeconomy & Environment of Western Macedonia (CluBE) includes research on circular economy and resource efficiency, as well as on renewable energy and energy efficiency.

Energy efficiency is an important priority for Western Macedonia. The **Just Development Transition Master plan** is based on five key development pillars and the total financing is estimated at EUR 5 bn [5]. The **Greek National Energy and Climate Plan (NECP)** includes a target to improve energy efficiency by 32.5% by 2030 compared to 2007.

The Eyes Hearts Hands (EHHUR) project steers the transformation of cities while considering local heritage and social context, while REGIO1ST, funded under the LIFE scheme, has the goal of raising awareness about the Energy Efficiency First principle (EE1st) among regional governments and their agencies and supports them to make related decisions in their planning.

Renewable energy is dominant, given the region's abundant resources. The Operational Program "Environment and Sustainable Development" has provided funding for renewable energy projects, including the "Renewable Energy Sources (RES) and Energy Saving" funding program.

The Municipal District Heating Company of Amyndeo (DHCA) has a biomass combustion plant to serve Amyndeon's existing district heating system as well as its future extensions.

Wind generators have been installed in 7 different places in Western Macedonia, with a total power of 180,900 KW. Commercial- or utility-scale solar PV systems installed in the region should amount to 2 GW, while Biogas CHP capacity in the region is low and below 5 MW, which is yielded by three active biogas plants.

H2 Systems. The region has the potential to become an important player in the production and distribution of hydrogen, as it is home to significant renewable energy sources to produce green hydrogen. The latest project envisages an electrolysis unit of 100 MW for the production of hydrogen. The Public Power Corporation (PPC) and Motor Oil are developing it through their joint venture "Hellenic Hydrogen".

The **Green HiPo** project submitted in the framework of the "Projects of Common European Interest" ("IPCEI") aims to support research, innovation and early industrial development in the hydrogen value chain. The project "Western Macedonia Green Valleys of Hydrogen Production (WEMAGH2)" includes the creation of the first Hydrogen Valley in Western Macedonia and Southeast Europe located in an abandoned industrial complex (AEVAL), at Ptolemaida, as part of the **Innovation hub for green hydrogen** and energy storage in Western Macedonia. The H2 Innovation Hub, worth EUR 18 million, is a pilot project which will take place under CERTH's supervision and will be completed in 2024. It will include components such as a PV Park 0.5 MW, electrolyser, fuel cell of 0.2 MW (PEM), H2 station, storage battery array of 250 kWh and special laboratory infrastructure.

Several research and development organizations in the region are focused on hydrogen-related research. For example, CluBE, the Centre for Renewable Energy Sources and Saving (CRES), and the University of Western Macedonia as the Aristotle University of Thessaloniki have research groups focused on hydrogen and fuel cells.

Smart Energy Communities and Cities. The STARDUST project is the first approved project for smart cities and communities in which CluBE and the Municipality of Kozani are cooperating with the regional development Organisation ANKO SA to transform the city of Kozani into a smart energy community. GOAL nZEBs is another project

in which four Partners from Greece and Albania collaborate in order to strengthen the possibilities for cross-border cooperation between Greece and Albania in the nZEB sector and to enhance the potential for energy communities. There are also several pilot projects underway in the region that are focused on smart energy communities, including the smart city of Kozani initiative, to cut greenhouse gas emissions by implementing ambitious measures to reduce the energy consumption of municipal buildings. The Regional Energy Community of Western Macedonia Ltd. is another example where the University of Western Macedonia coordinated the establishment of a Non-profit Regional Energy Community (EC), established in 2021 in the search for energy solutions to mitigate COVID-19 and energy poverty effects. Thirteen municipalities in the region, the Regional Authority and the University of Western Macedonia are members of the EC. Furthermore, it is noteworthy that as of May 2022, 1258 active energy communities were recorded in Greece, 246 of which were located in Western Macedonia.

3. Results

This study has shown that there are enormous clean energy potentials in Western Macedonia, taking into consideration techno- and socio-economic aspects that affect or will be affected by the decarbonization process.

Strengths [6]

Natural Resources, including abundant solar and wind energy potential.

Skilled and well-educated workforce with a strong tradition in engineering, technology, and scientific research.

Strategic Geographical Location serving as a gateway to important regional markets.

Agricultural Potential: soil and climate favourable for high-quality export-oriented agricultural products.

Infrastructure Development with significant investments in transportation, logistics and communication networks.

Entrepreneurial Mindset: a growing entrepreneurial ecosystem and a culture of innovation to foster the development of innovative startups, spin-offs and businesses focused on clean technologies and sustainable solutions.

Opportunities [7]

Funding Opportunities: The European Union has dedicated substantial funding to support just transition initiatives.

Cross-Border Collaboration: opportunity for cross-border collaboration in implementing joint projects and sharing best practices.

Renewable Energy Development will reduce dependence on fossil fuels and accelerate the transition to a more sustainable and low-carbon ecosystem.

Green Infrastructure including sustainable transportation systems, smart cities and eco-friendly buildings.

Digitalization and Innovation: The region can leverage its skilled workforce and invest in research and development (R&D) to foster innovation.

Circular Economy: opportunities for resource efficiency, waste reduction, sustainable production and consumption patterns.

Knowledge and Technology Transfer by collaborating to facilitate the transfer of knowledge, technologies and best practices.

Weaknesses [8]

Economic Disparities within own borders as certain administrative areas may have limited resources and infrastructure to support the necessary transition and investments.

Infrastructure Gaps, particularly in rural and less developed areas, including energy networks, transportation systems and digital connectivity.

Limited Access to Financing: Despite the funding opportunities available, accessing financing can be challenging for small- and medium-sized enterprises (SMEs) and entrepreneurs.

Brain Drain: significant emigration of skilled professionals in recent years, leading to a brain drain phenomenon.

Institutional Capacity: challenges in terms of administrative capacity, regulatory frameworks and coordination mechanisms, e.g., to attract and facilitate investments.

Limited Awareness and Engagement of stakeholders can hinder effective participation and cooperation.

Environmental Challenges, including pollution, habitat degradation and climate change impacts, can affect the viability of certain industries and hinder the transition towards more sustainable practices.

Threats [9]

Political Instability and Policy Uncertainty: Changes in government, inconsistent policies and bureaucratic hurdles can create uncertainty and hinder investment attractiveness.

Social Challenges: the transition to a more sustainable economy should be inclusive and benefit all levels of society.

Limited Technological Capacity can hinder the integration of the clean and innovative technologies needed.

Lack of Public Awareness and engagement can impede the implementation of policies and projects, leading to delays or resistance.

Dependence on Fossil Fuels, particularly on coal, can hamper the transition to a low-carbon economy, since it requires significant investments and structural changes.

Climate Change Impacts pose threats to the region as these impacts can disrupt economic activities, infrastructure and ecosystems.

Global Economic Uncertainties, such as financial crises, trade disputes or global recessions, can affect the investment climate and access to financial resources.

4. Discussion and Conclusions

The transition of Western Macedonia to a carbon-neutral power generation model involves, apart from the energy sector, the wider economic and social sectors. Since lignite mining and electricity generation have dominated economic activities for many decades, clean energy solutions to support the economy and society are imperative, and thus EU funding for a Just Transition is key.

The SWOT analysis presented herein is based on a research analysis in the clean energy domain, which will serve as a tool for policy- and decision makers to implement a successful strategy in the field in question.

The research analysis demonstrated key points for action. Simultaneously, it created the framework for further scientific inquiry to identify concreate research steps. Overall, the shift towards clean energy in Western Macedonia involves diversifying the regions' energy mix, reducing carbon emissions, supporting affected communities and promoting the development of clean and renewable energy infrastructure [10]. The transition requires a comprehensive approach that encompasses policy support, investment, research and collaboration between government, industry and local communities to create a more sustainable and resilient energy future for the region.

Author Contributions: C.K.: methodology, validation, investigation, writing—review and editing; P.S., A.T. and I.K.: writing—review and editing, project administration; P.A. and P.G.: writing—review and editing, supervision. All authors have read and agreed to the published version of the manuscript.

Funding: Partnership and Cooperation Agreement (NSRF) 2014–2020, European Regional Development Fund (ERDF) "Development of New Innovative Energy Technologies of Low Carbon Footprint for the Enhancement of Excellence in the Region of Western Macedonia", MIS code 5047197 of The Operational Program "Competitiveness, Entrepreneurship & Innovation" (EPAnEK), co-financed by Greece and the European Union.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data available in a publicly accessible repository that does not issue DOIs. Publicly available datasets were analysed in this study. These data can be found here: https://excelwmac.gr/en (accessed on 29 August 2023).

Conflicts of Interest: The authors declare no conflicts of interest.

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