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Challenges and Opportunities of Coal Phase-Out in Western Macedonia

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Abstract: As part of the European Green Deal, the EU aims to become climate-neutral and reach net-zero greenhouse gas emissions by 2050. In this context, EU member states are required to develop a national strategy to achieve the required emissions reductions under the Paris Agreement and EU climate goals. Western Macedonia is a region in North-western Greece with its economy largely dominated by lignite mining, lignite-fired power plants and district heating systems. In 2019, the Greek Government set the goal of withdrawing all lignite plants by 2028, with most units being withdrawn already by 2023. This decision has had an immense socio-economic impact on the region of Western Macedonia. This research work reflects the current situation at the socio-economic and socio-political level in Western Macedonia and discusses the policies implemented in the context of the lignite phase-out process to ensure a just transition for households and businesses of the region. Although there is not a ‘one-size-fits-all’ blueprint for successful low-carbon transitions of high-carbon intensive regional economies, the main target of our paper is understanding the impacts, challenges and opportunities of decarbonizing Western Macedonia.

Keywords: delignification; Western Macedonia; lignite phase-out; challenges of decarbonisation

Citation: Ziouzios, D.; Karlopoulos, E.; Fragkos, P.; Vrontisi, Z.

Challenges and Opportunities of Coal Phase-Out in Western Macedonia. *Climate* **2021**, *9*, 115. <https://doi.org/10.3390/cli9070115>

Academic Editors: Dalia Streimikiene and Tomas Baležentis

Received: 2 June 2021

Accepted: 10 July 2021

Published: 12 July 2021

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1. Introduction

The global challenge of reducing greenhouse gas (GHG) emissions, recent technological developments and cost reductions in Renewable Energy Sources (RES), the widespread diversification of gas supply sources and the demand for decentralized power generation, are leading to a complete and irreversible phase-out from solid fossil fuels, i.e., coal and lignite [1,2]. For the European Union (EU) regions with a high dependence of their local economy on the solid fossil fuel industry, the process of decarbonisation will require a significant productive diversification in the medium term and, above all, an immediate solution to the problem of thousands of jobs lost in the coming years [3]. The Paris Agreement, the European Green Deal, the Just Transition Mechanism, and the Coal Regions in Transition Platform support the aim of just transition, where ‘no one is left behind’, which should be the guiding principle of economic transformations in all carbon-intensive regions. In the current paper, we focus on the challenges and opportunities of lignite phase-out in the region of Western Macedonia which is a region in Greece heavily dominated by the lignite industry. The analysis of the specific region can provide very useful guidance for the transition in other carbon-intensive regions in the EU and beyond aiming for decarbonisation in the next decades. It can highlight important lessons that can guide the transition process in carbon-intensive regions and identify ways to overcome the potential adverse effects and develop a sustainable low-emission economy.

Lignite has long dominated the electricity system of Greece, providing cheap and reliable energy, given the abundant and low-cost domestic resources. In line with its national and international commitments to climate action, Greece needs to urgently transform its energy system and overcome its technological lock-ins, paving the way for a net zero emission economy by the mid-century. In 2019, the Greek Government set a goal of withdrawing all lignite plants by 2028, with the majority of units—accounting for more than 80% of current capacity—being withdrawn by 2023 [4]. Considering that the region of Western Macedonia has been hosting 80% of the Greek lignite industry for about 70 years, creating conditions of high dependence of the local economy on the lignite value chain, Western Macedonia is called upon not only to adjust its production model to the new requirements but also to proceed immediately to a comprehensive productive restructuring towards a full phase-out of lignite activities [5]. In this research work, a brief historical analysis of the lignite industry in Western Macedonia is presented, the dependence of the local economy on lignite is quantified, and the national de-lignification strategy is summarized, as well as the magnitude of the socio-economic challenges at the regional level [6,7]. The overall objective of the paper is to present the main impacts, challenges and opportunities created by the lignite phase-out process in the region of Western Macedonia.

The study proceeds as follows. Section 2 presents the short profile of Western Macedonia and the role of the lignite industry. Section 3 summarizes the delignification process in Greece, while Section 4 gives an overview of the local stakeholders and their role in the delignification process. Section 5 describes an analysis of the main strengths, weaknesses, opportunities and threats related to the lignite phase-out in the region. Section 6 discusses the main findings of the analysis, presents some policy recommendations and concludes.

2. The Lignite Industry in Western Macedonia

2.1. Short Profile of the Region

Western Macedonia is a region in North-western Greece with a population of 290,000, with its economy largely dominated by lignite mining and lignite-fired power plants and district heating systems (Figure 1). Since 2010, there has been a constant decrease in lignite-fired power plants—the four oldest units stopped operating—which has accelerated since 2019, triggered by the increased Emissions Trading System (ETS) carbon price which increased the costs to produce lignite-based electricity, combined with policies to promote the use of renewable energy and natural gas [5]. In line with its international commitments to accelerate climate action, Greece has to urgently transform its energy system towards clean energy technologies [4].

In 2019, the Greek Government as part of its National Energy and Climate Plan set the goal of a full lignite phase-out by 2028, with the majority of units being withdrawn by 2023, while only one plant will continue to operate—the Ptolemaida V bloc, which is still under construction and will burn lignite at the latest until 2028 [4]. A recent announcement by the director of the Greek Public Power Corporation indicates an even more rapid transition strategy, aiming to fully phase out lignite by 2025 [8]. Given that about 70% of Greece's lignite production (according to 2019 statistics) takes place in Western Macedonia, this region will face significant challenges but also opportunities to transform the local economy and society [9].



Figure 1. Location of Western Macedonia region in Greece.

2.2. The Delignification Challenges in Western Macedonia

The intensive exploitation of the lignite deposits of Western Macedonia began in 1956 and escalated at a very fast pace, covering for decades most of the electricity consumption in Greece. At the peak of lignite activity, between the years 2001–2004, lignite production in Western Macedonia exceeded 55 million tons per year (Figure 2), followed by a decline to the levels of 30–45 million tons in the decade 2005–2015 [10]. Assuming that lignite activities will be terminated in 2028 (due to the closure of the lignite power plants) and following the national energy planning for lignite production for the period 2020–2028 [4], we estimate that the mined lignite in the period 1956–2028 accounts for 1792 million tn, which is equivalent to 235 million tn of oil, i.e., as much as the country's oil imports in the last 15 years [11].

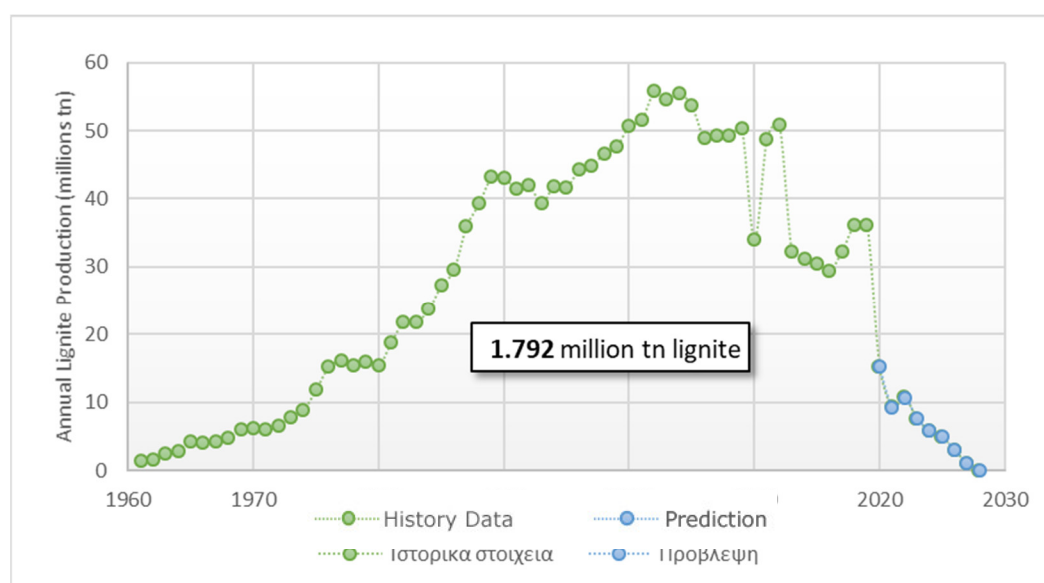


Figure 2. Lignite production in the Mines of Public Power Corporation (PPC) SA in the region of Western Macedonia. Adapted from [11].

At the same time, the Gross Domestic Product (GDP) of the region followed an increasing trend in line with the national and EU economic developments, but also fueled by lignite production activities that created jobs and income in Western Macedonia. Regional GDP reached in 2009 a maximum of € 5.04 billion, which was followed by a large

drop to €3.92 billion in 2016, as a result of the decline in lignite production combined with the onset of the country's economic and financial crisis [10].

The Lignite Center of Western Macedonia in September 2020 employs about 3200 people while about 2000 jobs are maintained by the satellite companies that are active in the region and cover the constant operational needs of Public Power Corporation S.A. (PPC SA). Obviously, after 2023 the above jobs will be in a state of high uncertainty while significant losses are already recorded in satellite companies with high dependence on the lignite value chain [6].

The long-term dependence of Western Macedonia on lignite has created conditions of technological and economic lock in at a regional level (Figure 3), as more than 34% of the Gross Value Added (GVA) in the region comes from lignite activities, while around 10% of local employment is directly or indirectly related to lignite production [10]. For every euro produced in Western Macedonia, 40 cents come from lignite, while every euro produced due to lignite exploitation inductively adds another 3.4 euros to the local economy [11].

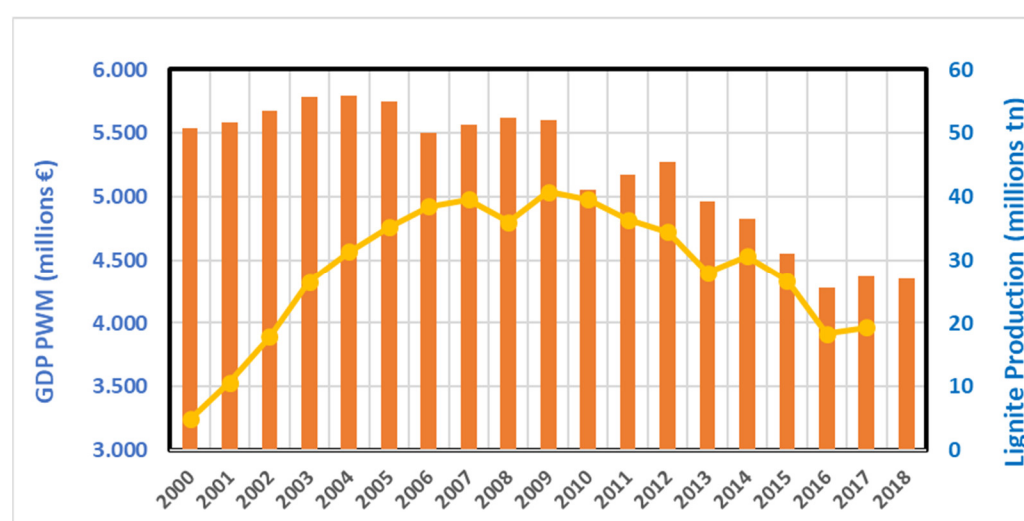


Figure 3. GDP of the region of Western Macedonia in relation to lignite production. Author estimates based on Eurostat and national statistics.

As a result, Western Macedonia faces high threats regarding the national need to move to a low-carbon economy. Western Macedonia will be called upon not only to re-define and adjust its production model, but to immediately create a completely new and productive environment in conditions of zero lignite dependence focusing on the development of new activities [12].

Figure 4 describes the annual changes of regional and national GVA in the period 2000–2017. The analysis shows that:

- Excluding the period 2005–2010, Western Macedonia shows more positive growth trends compared to the Greek economy, both in pre- and post-crisis periods
- The economic recession in Western Macedonia started 2–3 years earlier than the national economic crisis in 2009.
- The effects of the economic crisis were milder in Western Macedonia, compared to other regions of Greece. In practice, the lignite industry acted as a shield for the local industry and economy against the depressing effects of the crisis.

These findings are a consequence of the specificity of Western Macedonia in terms of shaping its production model, with high levels of monoculture focusing on PPC SA and large dependence of the local labor market on the lignite industry and related activities.

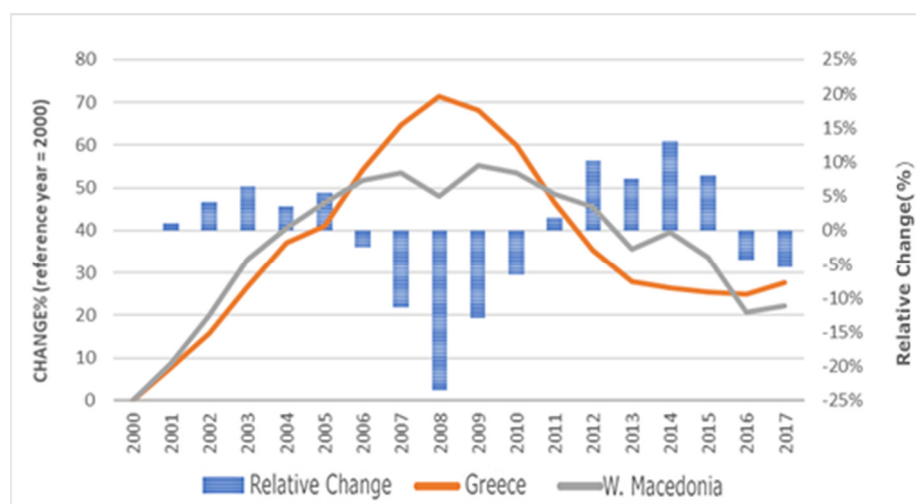


Figure 4. Annual change in Gross Value Added (GVA) in Greece and Western Macedonia (reference year 2000), Figure created by the authors using data from [11].

The Western Macedonian energy industry is facing a rapid lignite phase-out schedule, creating socio-economic challenges, as lignite-related activities account for 34% of regional GDP [10]. The region also faces structural weaknesses as it suffers from high unemployment rates, low diversification of the productive model and limited innovation capabilities [13]. Therefore, in the absence of appropriate mitigation measures, the lignite phase-out in Western Macedonia by 2028 or even by 2025 is expected to lead to a large decline of regional GDP, a loss of 21,000 direct and indirect jobs (as more than 25% of local jobs are directly or indirectly related to the lignite industry) and total income loss in the period 2018–2028 of €9 billion. It is thus clear that the region's long-term dependence on lignite activities has created structural economic problems (Figure 5) reflected in low productivity diversification and low competitiveness [14]. It has also created structural socio-economic conditions [6] that cannot be addressed with only short-term interventions but require restructuring production policies, which should exploit the region's competitive advantages.

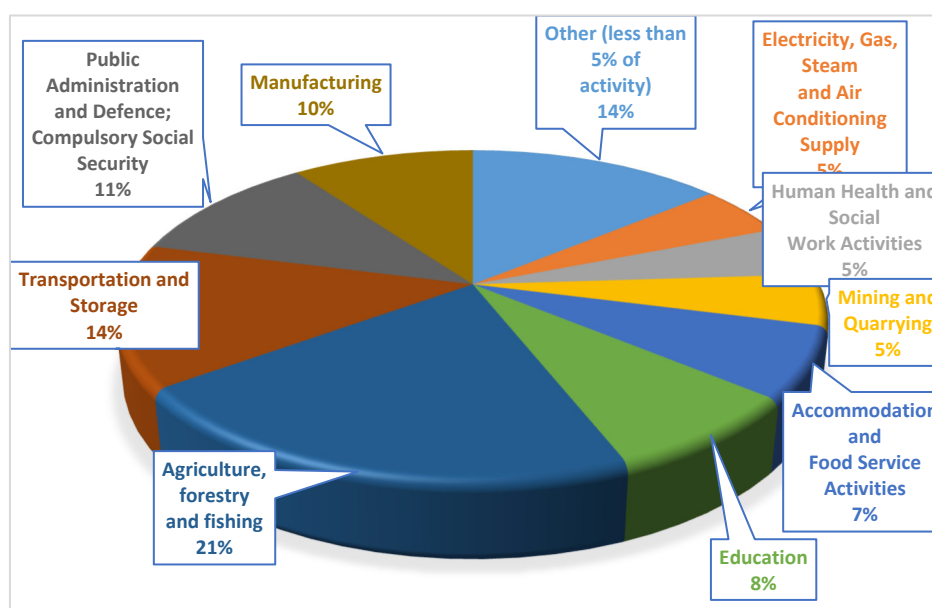


Figure 5. Structure of employment by sector in Western Macedonia, Source: Authors' calculations using EIEAD data, 2018 [15].

3. The Just Transition Plan for Delignification in Greece

In 2019, the Greek government decided to shut down all lignite plants by 2028, and to accelerate the de-lignification by withdrawing 80% of installed capacity by 2023. The road map of the lignite phase-out is reflected in the National Energy and Climate Plan [4], which ensures the stability of the electrical system, while reducing GHG emissions in line with European targets. The goal of a complete delignification serves priorities related to the promotion of low-carbon technologies, environmental protection and diversification of the production model in lignite areas, mainly in West Macedonia.

In December 2019, a Governmental Committee was established to monitor the Just Development Transition to the post-lignite era of Western Macedonia and the Municipality of Megalopolis [16]. The main goal of the Committee is the final approval and supervision of the implementation of the Just Development Transition Plan (JDTP), which handles all issues related to the government policy, to withdraw all lignite power plants by 2028. The main priority of de-lignification is to ensure the fair transition of these areas and which is based on three axes: the protection of labor, to alleviate the socio-economic impacts of lignite areas and to ensure the energy efficiency of the country.

In May 2020 a Technical Committee was established, in order to evaluate the investment proposals and formulate a scientifically substantiated opinion. Since July 2020, an open process of submission of non-binding investment proposals by the public sector has started. The Government Committee has approved a Special Transitional Fair Transition Program which is designed specifically for the lignite areas, and will be financed mainly by the NSRF 2014–2020, the Green Fund and the Recovery Fund [16]. From September 2020, the Public Sector bodies that are active in the lignite areas were invited to submit proposals within the Special Transitional Fair Transition Program (2020–2023), for the financing of projects and actions.

In order to address the socio-economic implications of the rapid lignite phase-out, the Greek Government announced a Master Plan for the Just Development Transition (JDTP) and established a Steering Committee to coordinate the plan. A draft of the Master Plan was presented in September 2020, which then went into public consultation in October 2020 [17]. The revised JDTP was discussed at government level and was presented to the public, on 9 December 2020 (Figure 6). Furthermore, the European Commission and World Bank study entitled “A road map for a managed transition of coal dependent regions” was utilized [18]. According to the Master plan [19], the vision for the “next day” in Western Macedonia is based on five principles:

- Create new employment opportunities in the local community.
- Utilize the comparative advantages of the region, including high technical skill base of workforce, large potential for clean energy investment (solar PV, biomass, green hydrogen), prospects for sustainable tourism and smart agriculture, proximity to large urban centers, availability of district heating infrastructure, etc.
- Ensure a fast transition with a focus on realistic and workable solutions.
- Aim at sustainable development to promote social and environmental sustainability.
- Promote research and innovation and integrate modern technology.

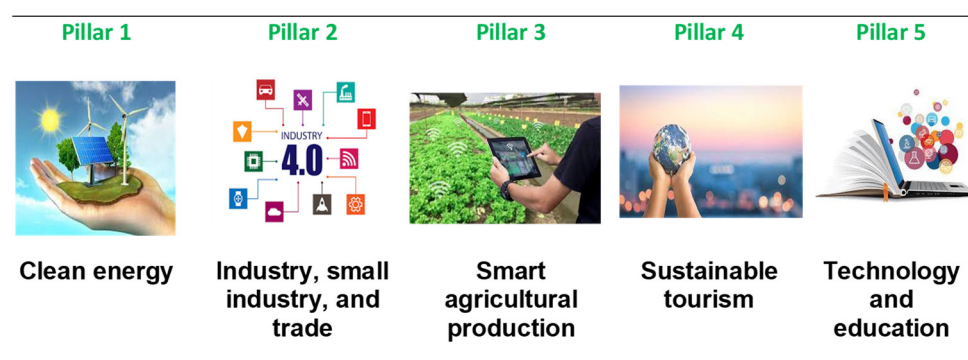
Based on these principles, the Master Plan for the Transition [19] is based on five key development pillars for Western Macedonia:

- Clean energy development (e.g., PV plants of more than 2.5 GW in abandoned lignite mines, battery production, hydrogen production facility)
- Industry manufacturing activities and trade
- Smart agricultural production
- Sustainable tourism
- Research, innovation, technology and education

The indicative measures within the Just Transition Development Plan for Western Macedonia are briefly presented in Table 1.

Table 1. The indicative measures within the Just Transition Development Plan, Source: [19].

Measure	Type of Measure
Construction of at least 2.5 GW of solar PV projects by various companies, including PPC, RWE and Hellenic Petroleum	Investment
Planning a fully self-financed voluntary exit/retirement for the PPC staff	Labor market
Restoration works of PPC mines	Investment/Employment
Develop Alternatives for district heating	Investment
Spatial planning including accelerated permitting processes to enable rapid development	Institutional
Maintaining the Public Power Corporation (PPC) discount invoice for lignite areas	Fiscal/Income
The special levy on electricity consumers will be used to support of lignite regions	Fiscal/Income
Transfer of the auctioning revenues of CO ₂ allowances from Green Fund to the lignite areas	Fiscal
Support the plans of the local Solid Waste Management Bodies	Institutional
Promoting the role of the University of Western Macedonia	Education/human capital
Request to develop special tax incentives	Fiscal

**Figure 6.** Five key pillars for the post-lignite era in Western Macedonia, Source: Authors.

Other major proposals have been made, in addition to those mentioned above, including the construction of: (a) an industrial electromobility park and a battery production facility in the region and (b) a hydrogen production facility with a capacity of 1.5 GW as part of the “White Dragon” project, which is currently considered for funding under the Hydrogen Europe Programme [20]. The total financing required for these projects accumulates to 5 billion euros, with 40% coming from commercial loans, 20% from private investment, 10% from grants (e.g., from EU Just Transition Fund) and 30% from European sources and financial instruments as low-interest loans. With the implementation of the master plan, it is estimated that 6000 new jobs will be created by 2028 [19], which can cover the lost jobs of PPC and contractors and the short-term unemployed of Western Macedonia [19]. This will also result in an inflow of a new high-skilled workforce, e.g., specialized scientists and executives, combined with the absorption of the affected human resources in the affected areas [18]. The professional specialization of the human resources concerns the technical experience and skills related to the production of electricity and lignite mining, earthworks, and machine management, which could be the competitive advantage of the area. [19]. Most of the new jobs will be created for the restoration of the mine lands and the development of clean energy projects (e.g., PV power plants). The construction

phase of these investments will last until at least 2026, and will absorb the lost jobs of the technical staff of Western Macedonia, as it requires similar skills and qualifications. This enables a smooth transition of the regional labor market to the post-lignite era [4,19].

However, the demand for professional skills may change as the operation phase succeeds construction. The operation of new companies will increase the demand for specialized personnel (researchers, managers), while the further diversification of economic activities will create demand for the skills of agronomists, winemakers, farmers, tourism professionals and administrative employees [19]. Given the existing skill set of the region, it is estimated that about half of the PPC workforce and the short-term local unemployed may need reskilling to be absorbed by new economic activities [19,21]. Reskilling programs offer the workforce the opportunity to improve their skills and knowledge and gain practical experience, while also developing wider, necessary skills for the modern economy, such as professional PC operation, new teleworking technologies, etc. [22]. Integrated and coherent policy measures that combine training with work employment subsidy are important to ensure a fair transition with limited negative impacts on the income of local population. The combination of employment programs with reskilling will enable local workers to be absorbed quickly by the labor market and will contribute to attracting new investment.

In order to ensure that the lignite phase-out will not negatively affect the regional economy, Western Macedonia can build on its strengths and competitive advantages, including the high concentration of specialized human resources, its industrial culture, energy infrastructure, an agriculture sector with high potential, existing academic and research structures and a strategic geographic position in South-Eastern Europe [18].

4. The Role of Local Stakeholders towards a Just Transition

In Western Macedonia, several actions and interventions have been undertaken related to the transition process, mainly concerning studies from various stakeholders, but also integrated projects at the municipal or regional level. The interventions of the local stakeholders such as the regional authorities, municipalities, academia and business community, chambers and trade unions, so far show a widespread skepticism towards the accelerated and time-pressing process of delignification [6]. However, following the Greek NECP [4] and the recent increase in ETS prices, there is an increasing understanding in the local community of the necessity for lignite phase-out, while ensuring that the local population and economy will not face hardship from the transition process. Almost all local stakeholders agree on the following:

- There is no alternative economic activity that could unequivocally replace all jobs and income provided for decades by the local lignite industry. This practically means that the new production model of Western Macedonia must be based on a differentiated production paradigm, with multiple, complementary activities that can boost economic growth and create new jobs and incomes in the region.
- There is a need to promote labor-intensive local activities that can create jobs to replace those lost in the lignite industry (e.g., smart agriculture, sustainable tourism, clean energy development)
- Some of these new activities are also knowledge-intensive (e.g., hydrogen production, new manufacturing activities), hence investing in Research and Innovation and building synergies between the local community and the University of W. Macedonia is a critical success factor.
- There must be a strategic balance between external direct investment and the development of an intra-regional production capacity in order to avoid future high dependencies on a single activity or industry
- Reskilling of the local workforce is necessary to enable its efficient transition from the lignite industry to other productive activities [19]

- The rehabilitation of depleted lignite mines, spatial planning, the promotion of licensing simplification, the creation of local energy communities and the launch of big infrastructure projects are recorded as important prerequisites by the stakeholders [23].

It is becoming increasingly clear that the energy transition is not just about choosing the best technical solutions to decarbonize the energy system, but relies heavily on human habits and behaviors and societal transformation and should ensure that no region or worker is left behind (“Just Transition”), especially for Western Macedonia where the transition is accompanied by a generalized reconstruction of the current economic paradigm. Consequently, participatory decision-making of related stakeholders in the transition planning processes, transparency of political commitment and building trust in the local community is crucial for a successful and fair energy transition while achieving sustainable development and environmental protection [18]. The conclusions presented in the section came from the open consultation process related to the Just Transition Development Plan that recently took place in the region of Western Macedonia with the participation of some co-authors in the discussions, as they are affiliated to Western Macedonia stakeholders.

The study of international best practices has shown that coherent regional development strategies should reflect a wide consensus, achieved through transparent processes between the various regional stakeholders, and state in a clear and well-documented way the objectives, barriers, investment projects and pathways for the transition [5]. Important prerequisites towards an effective and sustainable transition are: the development of a clear legal and funding framework, the combination of short- and long-term planning, mine restoration activities, the creation of new jobs and the determination of new land uses. Following the Greek NECP in 2019 and the strategic decision to phase-out lignite by 2028 at the latest, the Just Transition Development Plan provides guidance on how to restructure the economies of the lignite areas by developing new productive activities and creating new jobs. However, it provides only a rough analysis on the funding needs and framework; this aspect should be improved with a clear and detailed quantification of available financial resources that can be directed to Western Macedonia (e.g., using available funds from COVID-19 Recovery packages).

The recent policy developments and the accelerated lignite phase-out have increased the urgency of structural adjustments in the region in order to overcome the transition challenges related to high unemployment, energy poverty, and slow economic diversification. The REACT-EU program and the Just Transition Fund will specialize not only in the restructuring of carbon-intensive regions (through funding new productive activities) but will also define governmental mechanisms with participation of local, regional and national authorities and socio-economic partners, as well as the general framework under which a strong and diversified economy will be developed in the post-lignite era.

5. SWOT Analysis

The section describes the Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis for the low carbon transformation in Western Macedonia. The main findings of the SWOT analysis are presented in Table 2.

Table 2. SWOT analysis of Western Macedonia.

Pillars	Strengths	Weaknesses	Opportunities	Threats
Economy	Comprehensive master plan for post-lignite transition,	High economic dependence on lignite activities, social inequalities	High interest for investment, Policies towards economic restructuring,	Ageing population, growing social inequalities, rising unemployment
Clean energy	Large solar resources, biomass potential, clean energy projects announced (e.g., RES, green hydrogen), availability of district heating systems	Need for improved funding, legal and licensing procedures	Reduce energy poverty, energy communities, active citizen participation in energy markets	Lack of energy efficiency measures, energy poverty, institutional uncertainty
Agriculture	Large workforce in the sector, high potential for smart agriculture	Low training of farmers, low share of young farmers, limited links with innovation	New sustainable agriculture (e.g., precise, organic agriculture, hydroponics), smart agriculture center, create new jobs	Lack of technical knowledge related to sustainable and smart agriculture
Tourism	Explore natural environment and ecosystems and historical and cultural features, easy access and proximity to large urban centers	Bad quality of infrastructure, large distances of communities with urban centers, negative association of the region with polluting activities	Facilitate agritourism, synergies with local agriculture and food industries, Post-mining sites converted to parks and museums, sustainable tourism model	Risk of degradation of the natural and built environment
Other (labor, industry, education)	High technical skill base already available, on-the-job training, work transfer programs	Large job losses from lignite phase-out, lack of digital infrastructure, lack of entrepreneurial attitude, Limited mechanisms to increase public awareness	Reuse lignite industry buildings after mine closure, exploit high technical skill base of local workforce in new industries	Low innovation, limited technical and human capacity and digital infrastructure, lack of synergies and public funds
Environment	Potential benefits from the transition (e.g., reduced pollution)	Repeated exposure to air pollution	Full restoration of lignite mines, Agricultural activities in the lignite center	Negative impacts of climate change

5.1. Strengths

Western Macedonia is an important energy center of Greece, providing lignite-based electricity for decades. Western Macedonia has good solar resources and thus the construction of large photovoltaic plants can offer cheap electricity and create new employment opportunities in the region. This is also acknowledged in the Just Transition Master Plan, which prioritizes the construction of more than 2.5 GW of PV plants, while several solar PV projects are already planned. Engaging citizens through collective actions and the development of energy communities can also reinforce positive behaviors and social norms in the region [24]. Different types of bioenergy can also be explored, e.g., from forestry production and residues, agriculture and bio-waste, to generate electricity and heat. The existing district heating system supplies the region with thermal energy for space heating and domestic hot water [5] and may be exploited in the future but using cleaner energy technologies and not lignite [18].

The high technical skills of the regional labour force is a key strength towards ensuring the fair development transition of Western Macedonia. In addition to human capital development, local infrastructure is of high quality. The constant increases in internet connectivity can improve the quality of life and the living standards through better access to jobs, information and services, opening up new markets and supporting economic growth [25]. Work transfer programs should be developed in the region to allow the re-allocation of lignite-related jobs to other sectors of the economy through supporting the retraining and on-the-job training of workers [26], promoting young well-educated workers to attend retraining programs [27], and supporting those willing to pursue alternative professional plans.

The lignite plants in Western Macedonia produce large amounts of greenhouse gases, due to the high carbon intensity of lignite. The lignite activities are also linked to air pollutants that result in low air quality and repeated exposure of populations to polluted air. The latter has major short- and long-term health impacts on the local population. Lignite is one of the most polluting fuels, causing significant damage to health and the environment [28], as it is estimated that coal combustion results in more than 12,000 premature deaths yearly in the EU [29]. Seventy percent of deaths in Ptolemaida are related to cancer or thromboembolic disease and the incidence of cancer is increasing in the region [30]. Lignite phase-out provides a large opportunity for the region to improve air quality and human health.

Besides lignite activities, the economy of the region is also based on the primary sector, including agriculture, forestry, farming and livestock activity, which employs more than 20% of the local workforce (Figure 4). The region can use these strengths to create incentives to attract young citizens in the rural communities by developing smart agriculture programs, and improving the quality of life. The region can also explore its natural environment, its easy access and proximity to other urban areas (e.g., 1.5 h away from the ports and airports of Thessaloniki and Igoumenitsa) and its historical and cultural characteristics to further enhance the tourism sector and the local economy.

5.2. Weaknesses

As a result of the vast exploitation of its lignite resource, the economy of Western Macedonia depends heavily on the lignite industry and mining activities, and is characterized by very low diversification of productive activities. Thus, the lignite phase-out brings important challenges for the local economy, as local jobs will be lost and incomes will decline, not only for those directly working in the lignite industry, but also for the wider economy, due to the strong interlinkages of lignite activities with other economic sectors. These negative impacts on employment could result in growing social inequalities.

The diversification of the productive structure of regional economy towards low-carbon technologies requires increased funding, legal framework, licensing and administrative procedures. The transition should be based on the most efficient technologies, fully considering the local resource potential for renewable energy and local energy requirements. The currently low training levels of farmers and the overall unattractiveness of agriculture to the young generations poses significant challenges for the development of smart, innovative agriculture activities in Western Macedonia, as the links between agriculture, and research are limited. In addition, the bad quality of transport infrastructure and the large distances of some communities from the urban region centers can hinder the development of sustainable tourism. The negative association of Western Macedonia with polluting activities, as a trademark of the region, can hinder its touristic development.

Currently, most rural regions of Greece suffer from the lack of digital infrastructure and low internet connectivity, which poses significant barriers. The lack of entrepreneurial attitude caused by the large dominance of PPC for decades hinders the potential development of new, innovative businesses, especially in non-traditional sectors. The citizens' awareness of environmental challenges and sustainable development is currently low. Therefore, new approaches for assessing the sustainability of investments is required

[31], together with actions to strengthen the social capital of Western Macedonia and the social acceptance of the delignification process.

5.3. Opportunities

The increased financial resources for the lignite areas (received from ETS allowance auctions through the Green Fund, the Economic Recovery programs and other support schemes) provide a financing support for the transition. Through local, national and EU funds and new financing options for the transition of coal regions (e.g., from the European Investment Bank or the InvestEU financing tool [32]), Western Macedonia can derive the required finance for supporting green, sustainable and reconstruction projects and achieve a well-balanced development of economic activities.

The transition can also support the reduction in energy poverty, especially in low-income households, through incentives for behavioral changes, acceleration of building renovation and supporting measures targeting energy-poor citizens (e.g., subsidies, tax rebates etc.). As part of the Clean Energy Package, the EU supports the active participation of citizens in the energy markets, through the Energy Communities (In the Clean Energy package, Energy communities are legal entities that organize collective and citizen-driven energy actions that will help pave the way for a clean energy transition, while moving citizens to the fore). Greece has developed an enabling legislative framework, aiming to support the development of local energy communities. Therefore, supporting community small-scale energy projects in addition to large-scale PV parks in Western Macedonia is key to increase the social acceptance of lignite phase-out and support local development targets. Community projects can involve the younger generation and provide jobs and incomes to the local population, who would suffer from the delignification process. Integrating the Energy Efficiency First principle in the transition can support the creation of local jobs, increased investment and the development of new business models. Finally, the phase-out of lignite activities will offer important co-benefits in the region as a result of reduced local air pollution and improved human health.

The restoration of lignite mines and the well-trained workforce can support tackling environmental challenges, while new sustainable agriculture models (e.g., precise and organic agriculture, hydroponics), can increase the agricultural productivity and provide environmental and socio-economic benefits [33]. The implementation of new, sustainable activities can drive regional development, as the agriculture and food systems are important sectors of the local economy and can boost agricultural income. Supporting smart agriculture and cultivating entrepreneurial behavior among farmers can be boosted by establishing a smart agriculture center in an (abandoned) lignite complex providing training, linked with research, especially from the University of Western Macedonia. This can engage younger citizens in productive agricultural activities, as they are often more educated, open-minded, and more familiar with new technologies. Modernizing the primary sector to support regional growth through creating new jobs for the processing and standardization of local products and facilitating agritourism is an efficient strategy that combines tourism services, agriculture and food production.

The termination of lignite activities will provide an opportunity to revitalize the area by hosting sustainable agricultural activities or increasing afforestation. The lignite mining assets of Western Macedonia can offer touristic opportunities, attracting (both local and foreign) tourists, given that large urban centers are less than 1.5 h away by road transport means. The local environment can also be revitalized with the creation of a park close to Kozani or Ptolemaida, while the electricity generation installation and related equipment can be transformed into a museum, as already implemented in countries, like Germany, helping some of the people working in the lignite industry to retain their jobs. The buildings of the lignite center can be transformed into research, innovation and entrepreneurship centers, stimulating the development of new, green businesses.

The design and implementation of a sustainable tourism model should be carefully integrated with environmental protection, and energy efficiency. Building on the Global

Sustainable Tourism Council (GSTC) certification criteria [34], local accommodation businesses should optimize their efficiency by actively keeping up with the best international practices and demonstrating their strong environmental action.

The measures described in the Just transition plan offer an opportunity for the diversification of the regional economy [35,36]. There is a high interest in clean energy investment in the region as outlined in the post-lignite Master Plan and the plans for installing PV plants, battery capacities and hydrogen production facilities. In fact, recent analysis using the latest available data and methods [37] has shown the high potential for the large-scale expansion of green hydrogen through electrolysis power by renewable energy resources in the region of Western Macedonia. The transition to carbon-free energy supply and carbon neutrality offers additional co-benefits and opportunities, in particular on reduced climate damages, improved energy security and creating employment opportunities in clean energy without putting any additional burden on energy consumers [38,39].

5.4. Threats

The ageing population combined with the strong dependence of local economy and workforce on lignite activities are the most severe threats for the transition of Western Macedonia. In the case that no measures are implemented to reduce the social hardship, the lignite phase-out will result in increased outward migration due to high unemployment, a decline in region's population and increased social inequalities. The institutional uncertainty is another major threat for the region, as the cost-effective implementation of the transition requires policy certainty and a long-lasting institutional and regulatory framework.

The post-lignite master plan for fair transition does not provide details on how to eliminate energy poverty threats or how to accelerate the implementation of energy efficiency measures, while the continued use of natural gas is a controversial strategy for the region, given that it is an imported fuel that emits GHGs, it creates additional risks for stranded assets and its use will become very costly after 2025, as EU climate policies become increasingly ambitious.

The development of sustainable agriculture is delayed due to the lack of technical knowledge of local farmers about precise, organic and smart agricultural techniques. Overall, the low innovation base and limited technical and human capacity and digital infrastructure of the region results in delayed adoption of innovations, new technologies and business models while increasing the difficulty to re-skill the local workforce. The risk of environmental degradation should be considered, given that the installation of new infrastructure may have negative consequences on the local environment and tourism. The lack of synergies and coherent strategies across sectors poses a threat for the transition, which can be overcome with the active participation of the local population, the promotion of societal synergies and the development of inter-regional networks aiming to mobilize the local human resources. Lastly, a critical risk for the lignite phase-out is related to the lack of public and private financing resources given the recent economic crisis and the effects of the COVID-19 pandemic, which may delay the adoption of new technologies and innovations and inhibit business development in the region.

6. Discussion and Conclusions

The just transition in Western Macedonia is driven by the country's need to reduce GHG emissions, and restructure the local economy phasing-out lignite activities, while implementing investment and creating jobs in productive sectors and industries. The economic restructuring of W. Macedonia is not a matter of a sectoral policy, but needs to be carefully embedded in almost all public policies. The EU actively pursues ambitious emission reduction policies aiming to become climate neutral by mid-century with a rapid phase-out of fossil fuels, especially coal and lignite. In this context, the planning of the transition strategy in Western Macedonia should be organized in a clear and effective way, given that this is a complex, multi-level and multi-annual process.

Although the government has set a goal for lignite phase-out and is committed to further developing renewable energy, there are still many questions that need to be addressed. For example, the large urban centers in Western Macedonia use district heating for the heating needs of households, which is based on the operation of lignite plants. Given that there is no alternative way in the short-term to heat these households in the area, the question arises as to whether the district heating system will continue to operate. One possible solution proposed by the master plan is the conversion of the existing lignite power plants into natural gas or the use of biomass instead of lignite. Although natural gas is a cleaner fuel than lignite, it is still a fossil fuel, which emits GHGs. In addition, such an investment would probably not be accepted after 2025 given the recent EU Sustainable Finance taxonomy (The European Commission defines the EU taxonomy as a classification system, establishing a list of environmentally sustainable economic activities, which acts as a key enabler to scale up sustainable investment and implement the European Green Deal. Notably, by providing appropriate definitions to companies, investors and policymakers on which economic activities can be considered environmentally sustainable, it is expected to create security for investors, protect private investors from greenwashing, help companies to plan the transition, mitigate market fragmentation and eventually help shift investments where they are most needed), and thus could not be financed from European funds. The timeline to shut down existing lignite plants within the next 3 years is ambitious and demanding. Investments in other activities must be made quickly so that their results can be visible by 2023. The challenge is great, as mentioned in the master plan, given that the necessary procedures and mechanisms are still under discussion. Given the situation and in the midst of the COVID-19 pandemic the actual implementation of this timeline is very challenging. However, SDAM is based on good practice for a fair transition to a cleaner future at European and international levels. One of the key points of the just transition process should be the local peculiarities and needs of each region.

Policies should identify the key factors towards promoting the socio-economic development of the region while ensuring just transition where no one is left behind. In this context, here we highlight the strengths, weaknesses, opportunities, and threats related to lignite phase-out in Western Macedonia. The heavy dependence of the local economy on lignite activities has created obstacles and structural weaknesses to the region's socio-economic development. The National Energy & Climate Plan, the PPC's business plan, as well as the ambitious environmental regulations of the EU, all confirm that lignite activities will be phased out in the next years. Therefore, there is an urgent need for effective policy interventions and actions that will support Western Macedonia to create its own path towards just transition, socio-economic development, regional resilience and a prosperous, diversified economy and society.

Western Macedonia is an economically vulnerable region, as a result of its high levels of unemployment and heavy reliance on the lignite sector, its structural weaknesses and the dominance of PPC in the local economy. Our analysis has shown that educational and training programs, along with early retirement schemes, which will support the income of the ex-miners should be designed and tailored to the local needs of Western Macedonia. The regional development process should be based on clean energy investment, industrial development, smart agriculture, and sustainable tourism, while exploiting the technical skill base of the region's workforce, acquired through the operation of lignite-fired power plants and mining. The development of a strong, modern and diversified economy can be achieved through interventions in the region's infrastructure, access to low-cost finance resources, support of entrepreneurship and development of SMEs, institutional arrangements, and creating a culture of public-private partnerships in all sectors of the economy.

The current analysis has provided important lessons that can be used by other carbon-intensive regions in Europe and beyond to guide their transformation towards a low-emission, resilient and sustainable economic paradigm. In particular, the case study demonstrated ways to diversify the local economy towards more productive sectors (e.g.,

clean energy, smart agriculture, innovation, sustainable tourism) while effectively phasing out lignite activities and demonstrated the important role of re-training programs to direct lignite workforce to new, growing sectors and activities. It also shows the high importance of providing the required finance, especially in the first years of the transition in order to minimize the social hardship and lost income and replace lignite-related jobs with new, well-paid jobs in the construction of new infrastructure, clean energy development, sustainable tourism and research and innovation activities. However, local and regional specificities should always be fully considered in the planning of transition in carbon-intensive regions, by exploiting the region's competitive advantages and strengths.

Further research (in CINTRAN project (<https://coaltransitions.org/projects/cintran/> accessed on 25 June 2021) and beyond) can improve and expand the analysis presented here by: (1) developing a quantitative evidence base for the socio-economic and labor market impacts of the transition away from lignite, (2) linking the analysis with the underlying socio-political, socio-economic and socio-demographic factors that may facilitate or hamper the transition to a sustainable low-emission economy, and (3) exploring future development scenarios for the economic restructuring of the region, aiming to illustrate pathways towards a cost-efficient and socially acceptable transformation.

Western Macedonia can have a key role in the transition of Greece's energy system, with investment in low-carbon technologies, including solar PV, electricity storage, green hydrogen etc. The transition away from the lignite-based paradigm can be reinforced with efforts to reduce energy poverty, implement energy efficiency projects and develop energy communities and other collective actions for engaging the local population. A mechanism to support the regional development process can be established to align development priorities with the available human capital and infrastructure. The active promotion of environmental sustainability and inclusive growth can be used to attract new residents by increasing the region's attractiveness (as a place for residence, education—or business activity) and retain the younger citizens in the region through specific incentives.

Policy instruments to promote a strong collaboration between the energy sector, industrial activities, the primary sector and research and innovation activities are required. As technology is already available and scientific human capital is a great asset of Greece, if these are synchronized through a coherent forward-looking strategy, they could promote the sustainable development of Western Macedonia, by creating new high value-added jobs, and protecting the local environment, air quality and human health. The co-operation of local authorities, communities, and organizations could assist with new initiatives, to ensure the effective orientation of the regional economy towards productive, sustainable and green activities. Therefore, a common vision should be carefully designed and shared by the local population and all relevant stakeholders aiming at the post-lignite future of the region. The foundations for transforming Western Macedonia into a strong, diversified economy should be based on the promotion of holistic sustainable development across economic, technological, social, environmental and cultural aspects with a strategic vision integrating clean energy development, innovation, entrepreneurship, sustainable tourism and smart agriculture, and facilitating their synergies.

Author Contributions: Conceptualization, D.Z., P.F.; methodology, D.Z., E.K., P.F., Z.V.; validation, D.Z., E.K., P.F., Z.V.; formal analysis, D.Z., E.K., P.F., Z.V.; data curation, D.Z., E.K., Z.V.; writing—original draft preparation, D.Z., E.K., P.F.; writing—review and editing, E.K., P.F., Z.V.; visualization, D.Z., E.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 884539 "Carbon Intensive Regions in Transition—Unraveling the Challenges of Structural Change (CINTRAN)".

Institutional Review Board Statement: The study does not require any ethical approval.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data of the study are available upon request.

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

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