2025 Summer School in Greece

With the collaboration of

AI for Next-Generation Agriculture at the Nexus of Energy Security and Rural Transformation

A Policy and Ethical Analysis in Post-Lignite Greece

A Report by the Summer School 2025 Program Participants

Texas A&M Energy Institute
and
Agricultural University of Athens

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Contents

Preface

This report presents the research findings from the 2025 Summer School program, **"Artificial Intelligence for Next-Generation Agriculture at the Nexus of Energy Security and Rural Transformation: A Policy and Ethical Analysis in Post-Lignite Greece."** This intensive 9-week program, a collaboration between the Texas A&M Energy Institute and the Agricultural University of Athens, brought together students from diverse backgrounds to investigate the multifaceted challenges and opportunities arising from Greece's energy transition.

The research focuses specifically on the integration of Artificial Intelligence and smart agriculture in the post-lignite regions of Western Macedonia and Megalopolis, contrasting these with an agriculture-dependent area facing distinct issues, Laconia. Through qualitative analysis techniques, including stakeholder interviews, focus groups, and regional economic assessments, the program aimed to understand the socio-economic impacts of coal phase-out, assess the readiness and barriers to advanced agricultural technology adoption, and propose tailored policy interventions for a new economic model.

The insights gathered within this report are a testament to the dedication of the Summer School participants and the invaluable contributions of numerous individuals and organizations. It is our hope that this analysis will contribute meaningfully to the ongoing dialogue surrounding just and sustainable energy transitions and the future of rural development in Greece and beyond.

Dr. Konstantinos Pappas
Associate Director of the Texas A&M Energy Institute
Principal Investigator of the Summer Program

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AI for Next-Generation Agriculture at the Nexus of Energy Security and Rural Transformation - A Policy and Ethical Analysis in Post-Lignite Greece

Abstract

The study examines the socio-economic impacts on coal phase-out regions, evaluates the readiness and obstacles to adopting advanced agricultural technology, and suggests tailored policy measures for a new economic model. Using Greece as a case study, the research utilizes qualitative analysis to explore the complex challenges and opportunities resulting from the country's energy transition. It specifically investigates the integration of Artificial Intelligence (AI) and smart agriculture in the post-lignite areas of Western Macedonia and Megalopolis, compared to an agriculture-dependent region facing different issues (Laconia). Through a comparative approach, the study gathers insights from stakeholder interviews, focus groups, and regional economic assessments. Results indicate that lignite-dependent regions face "brain drain" driven by high unemployment, causing population decline, and remain economically uncertain despite significant funding from European and national sources. Although not impacted by lignite, Laconia encounters severe water scarcity and an aging agricultural workforce. Common barriers to implementing AI and smart agriculture include high setup costs, a notable "education deficit," digital illiteracy among farmers, fragmented land ownership, and bureaucratic obstacles. The study concludes that effective integration requires both targeted regional solutions and cross-regional coordination, highlighting the necessity of combined funding from EU, national, and local sources for infrastructure (such as broadband and irrigation) and "soft" measures like skills training. A balanced top-down policy approach complemented by bottom-up involvement is crucial to overcoming cultural and informational barriers, encouraging local innovation, and transforming challenges into opportunities for sustainable rural development.

Keywords: Energy Transition, Smart Agriculture, Artificial Intelligence, Post-Lignite Regions, Rural Development

Introduction

The global response to climate change has triggered major shifts in how countries produce energy, manage natural resources, and structure their economies. The European Green Deal is at the forefront of this shift, which aims to make the EU climate-neutral by 2050. Renewable energy, sustainable agriculture, and digital innovation are central to this initiative, all of which are essential for the future of rural areas that have historically relied on fossil fuels (European Commission, 2019). Smart agricultural techniques both contribute to climate change and reduce its effects by becoming more efficient and adopting new technologies. Greece faces the challenge of decreasing its reliance on lignite energy, which has been vital to regional economies, while also working to create an innovative low-carbon rural economy. The updated Greek National Energy and Climate Plan (NECP) confirms the country's plan to phase out coal by 2028, boost renewable sources, and modernize agriculture (Ministry of Environment and Energy, 2024). At the regional level, this transition presents economic, environmental, and social challenges, especially in areas like Western Macedonia and Peloponnese that depend heavily on lignite (European Commission, 2022). The Greek Government, leveraging the Just Transition Fund, aims to implement revitalization initiatives in these regions. In Western Macedonia, which holds 65% of Greece's surface water, the focus is on transitioning to renewable energy, digital innovation, and smart agriculture. However, this shift faces significant hurdles, such as labor shortages and technology gaps (European Commission, 2023). In the Megalopolis area within the Peloponnese, redevelopment of former mining sites is planned to be supported by investments in smart farming and bioeconomy projects, relying on local entrepreneurship and workforce retraining (Just Transition Fund Greece, 2022).

Historically, agriculture has played a key role in the Greek economy and continues to do so in specific regions. Yet, the agricultural sector is in ongoing decline, with climate change and extreme weather events worsening its shrinking importance. For example, Sparti in Laconia, a mostly agricultural area in the Peloponnese known for olives and citrus, is experiencing severe water scarcity that threatens its sustainability. Although pilot projects like water reuse and desalination have begun, sustained investment in smart irrigation systems and digital monitoring technologies is crucial to securing its agricultural future (European Commission, 2023).

This paper examines the complex challenge of sustainable rural transformation in Greece amid climate change and energy transition pressures. In Western Macedonia and Megalopolis, the main challenge lies in restructuring the economy and workforce after moving away from lignite. These regions need to transition to low-carbon models while managing job losses, an aging population, and outdated infrastructure. In Sparti, the crisis is both environmental, focusing on

water scarcity, and economic, as high-value agriculture faces sustainability threats. The lack of integrated water management, funding for smart technologies, and efforts to renew the farming generation endanger the region's resilience.

These issues raise broader questions: How can regions that have transitioned away from lignite develop viable, forward-looking economies incorporating advanced agricultural technologies? What barriers prevent the use of AI and IoT in rural areas? In water-stressed regions like Sparti, can digital innovation help overcome environmental challenges and protect agriculture? How can targeted investments in AI, renewable energy, and education strengthen regional resilience and encourage younger generations to return to rural areas? And what lessons can be learned from the experiences of delignified regions and Sparti regarding policy design and implementation?

Using a scoping literature review, stakeholder interviews, and focus group discussions, the goal is to explore these emerging topics, gather insights, identify gaps, and recommend options for a new economic model for regions phasing out lignite that includes smart agriculture based on AI tools.

1. Energy transition and delignitization policies

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The EU Just Transition Mechanism

The European Union Just Transition Mechanism (JTM) is a key tool to ensure that the transition towards a climate-neutral economy happens in a fair way, leaving no one behind. It provides targeted support totaling around €55 billion over the period 2021-2027 in the most affected regions, to alleviate the socio-economic impact of the transition. A main pillar of the JTM is the Just Transition Fund (JTF) of €19.7 billion in current prices, which is expected to mobilize around €7.3 billion of national co-financing, amounting to a total of €27 billion. Territorial just transition plans define the territories in which the JTF will be used, as well as the development needs and objectives to be met by 2030 (EC, 2022).

Greece and Just Transition

Since 2014, PPC has funded environmental and developmental projects worth around €130 million in the Florina and Kozani regions, as well as the Megalopolis municipality. In 2018, Greece established a Fair Transition Fund to support the diversification of local economies and create new jobs in lignite-dependent regions. The fund collects 6% of revenue from auctioning allowances of the Emissions Trading System of the EU, around €20 million annually. The fund aimed to finance low-carbon and low-environmental footprint projects in the regions mentioned previously. Moreover, the country established in 2021 a Recovery and Resilience Plan to consider the transition-related needs of the areas of Western Macedonia and central Peloponnese. The plan includes measures to improve green skills through training programs covering resource efficiency, low-carbon industry, climate resilience, and managing natural assets. It also includes investment to rehabilitate industrial land, setting the basis for further development of low-carbon investments (EC, 2021).

Greece has also established the goal of ending all coal energy production by 2028 (World Bank Group, 2022) and achieving climate neutrality by 2050 (Greece's Climate Action Strategy, 2025). As of 2022, coal had made up 9% of Greece's total energy supply as opposed to 25% six years prior. The World Bank, partnered with the European Commission, assisted Greece in developing a detailed roadmap for its Just Transition Plan. Their analysis concluded that Western Macedonia is home to generations of skilled coal worker families, millions of dollars' worth of energy infrastructure, and a transmission system to reach all areas of Greece. Months of research and stakeholder engagement by The World Bank built a consensus that clean energy technology could save the region's jobs, while creating new ones. Proposed solutions included concentrating clean energy facilities in the Western Macedonia region and converting thermal power plants into renewable energy plants with energy storage facilities (World Bank

Group, 2022). For the municipality of Megalopolis, the Greek government's vision outlined in the Just Transition Plan includes €460 million in investment for different axes including clean energy, manufacturing, small industries and trade, smart agricultural production, and smart tourism, along with other public investments through the Public Power Company (PPC) (Baker et al., 2022).

The European Commission reported that Greece will mobilize €1.63 billion to alleviate the impact of the energy transition on the local economy, receiving €1.38 billion in grants from the Just Transition Fund (JTF). Greece was the first European Union member state to have its JTF program and plans adopted. Just over half of the funds will support entrepreneurship via financing for new and existing enterprises, business infrastructure, and stronger links between companies and research innovation. The remaining funds will strengthen human resources and workforce development as well as target energy transition, land use adaptation, and the circular economy. In Greece's JTF plan, two operations of strategic importance were highlighted: the "*innovation zone*" of Western Macedonia, promoting development of infrastructure and actions for innovative entrepreneurship, and the "*bioeconomy 360° hub*" in the municipalities of Megalopolis, Gortynia, Oichalia, and Tripoli, aiming to transform business activity in the full range of the bioeconomy value chain (agri-food, circular, and digital economy).

In 2025, the European Investment Bank (EIB) announced an agreement to advise five regions of Greece for investment programs to mitigate socio-economic impacts of delignitization, including Western Macedonia, Megalopolis, Crete, and the North and South Aegean Islands. The EIB's technical assistance is initially valued at €2.75 million, modeled after similar programs that have previously supported Germany, Poland, and the Czech Republic with lignite mine closures. The accord comes under the Invest EU program, part of the European Green Deal and JTM, aiming to support and develop investment in programs for revitalizing and strengthening local economies, enhance institutional frameworks through training, ensure effective project management and compliance with EU standards, and assist regions with preparing grant applications to secure funding.

In the agreement, Western Macedonia is slated for transformation into an alternative clean energy hub to attract investment in new and dynamic sectors of national importance. Megalopolis will be promoted as an entrepreneurship hub with an emphasis on new and innovative productive activities around the bioeconomy value chain. The integration of renewable energy sources and phasing out of autonomous power plants is expected in Crete, as well as greener development and sustainable business models for the island. The North Aegean Islands will also see the phasing out of autonomous power plants, along with

investment in sustainable practices in agriculture and tourism, while the South Aegean Islands are expected to transform their tourism-driven economy and promote green development initiatives and business activities related to clean energy (EIB, 2025).

2. Smart Agriculture and Technological Adoption

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The world population is expected to hit 10 billion by 2050, creating an urgency to improve efficiency and boost output within the agriculture sector. Estimates from food and agriculture organizations state that agricultural output would need to increase by 70% to feed the global population by 2050 (Bhat, 2021). Nutrition and food security are also major priorities, as the population grows (Atalak, 2022). The adoption of technologies such as AI, IoT, and other smart technologies is a possible solution to reach these goals. These technologies are being used for crop monitoring, soil analysis, pesticide application, autonomous vehicles for farming, irrigation, and drainage management, creating a focus on precision agriculture.

The creation of larger controlled greenhouses also provides an environment to adopt many of these technologies, reducing water usage through closed system hydroponics, as well as utilizing space via vertical farming. Through Greece's Rural Development program (Action 4.1.1), several smart farming technologies were funded from 2014 to 2022 (Koutridi, 2023). While these technologies pose as a solution to a growing agricultural need, there are also barriers to their adoption, including a lack of knowledge and education, a lack of funding, age bias against new adoption of technology, and the cost and benefits analysis of small versus larger scale farms (Kalfas, 2024).

Precision Agriculture

Precision agriculture is a term that is often synonymous with smart agriculture. These methods utilize untraditional farming techniques meant to lower costs and boost efficiency. Using technologies, farmers can target issues in their farms and address them directly rather than having to treat the entire crop yield. This could mean using visual analysis to identify pests and treat them with pesticides rather than having to spray down an entire field. If pests or diseases are not identified in time, it can cause serious economic losses for farmers. With visual analysis, these outbreaks could be prevented while also limiting the use of pesticides and fungicides. This reduces costs for farmers while addressing necessary prevention methods (Atalak, 2022).

AI tools, including robotics, visual analysis, machine learning, and natural language processing, are being pilot tested in Greece, integrating with smart technologies to further boost their efficiency (Kalfas, 2024). The combination of data collected from a multitude of sensors and technologies creates a digital map of farm fields that works to improve crop yield, reduce costs, and boost sustainability (Bhat, 2021). Robotics, such as Unmanned Aerial and Ground

Vehicles (UAVs and UGVs), are being steadily implemented into farms as well. These vehicles are able to collect data, as well as perform simple tasks (Bhat, 2021).

Currently, the EU leaders in Smart Agriculture are the Netherlands, Austria, and Denmark, while the least developed in Smart Agriculture is Greece, Portugal, and Cyprus. The technologies have been tested and developed in some EU countries more than others. Greece is further behind because of lower economic development and more severe weather conditions for farming. Greece is known for experiencing large droughts and higher temperatures that can make conditions harsh for agriculture. (Morkunas, 2024)

Internet of Things

The *Internet of Things (IoT)* is a platform used to sync all smart technologies together for an integrated control system. The Internet of Things uses cloud computing to sync sensors and technologies together so they can be monitored and controlled. The IoT has been used widely for years across a multitude of industries. However, it has recently been adopted into agricultural technology. Using the IoT, all sensors and smart technologies can sync their data together and provide easy access to collected data. This makes digital control of farming technology easier, as well as providing a well-rounded digital rendering of everything on the farm (Kalfas, 2024).

Geographical Information Systems (GIS) were implemented in Greece, giving farmers access to technology that manages crop analysis, spatial management, and more via imagery taken by drones. These systems have been very successful thus far in Greece; however, they have not become widespread amongst farmers. GIS systems combine hardware and software and utilize many tools such as IoT and AI (Kalfas, 2024). The massive amounts of data being collected via smart technology and the IoT raise concerns about management and security. The use of blockchain ensures the security of data and helps to solve this issue. Blockchain addresses the transparency, security, and reliability of all data operations collected. Blockchain also works with IoT to address security and reliability challenges (Bhat, 2021).

The implementation of Precision Agriculture into farms requires significant economic incentives and educational understanding. Many farmers must weigh the significant costs of these technologies against the benefits of their improved efficiency and output of crops. Factors such as expected profitability, return on investment, cost savings, increased yield, and producer risk are the main concerns of farmers. Social and political factors are also known to influence farmers (Kroupová, 2024).

While the advent of AI and smart technologies provides many benefits to agriculture, it has mainly been piloted on large-scale farms. While these technologies are still capable of being used on small-scale farms, there are many dilemmas, such as availability, costs, and funding, that need to be addressed. The costs of these technologies outprice many farms from being able to adopt them (Bhat, 2021). This is the case in Greece, where 70% of farms are identified as small-scale (Koutridi, 2023).

Another barrier to the adoption of these technologies is the bias in age. Younger farmers, under the age of 40, are more receptive to implementing new technologies into their farming practices. Whereas older farmers are more traditional and against straying from their practices. Younger farmers are still in need of continued education in the field of AI and Smart Technology in order to be most effective in adopting precision farming on their farms (Tsiouni, 2023).

3. Water Resource Management in Agricultural Contexts

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Declining Precipitation and Diminishing Water Sources

Water scarcity has become a growing concern in recent years in the Southern Mediterranean. This crisis stems from several factors, including the shift to warmer climates, limited availability of freshwater, and the overconsumption of both surface and groundwater sources. Precipitation has decreased significantly over the last decade. One instance of this is Tripolis, in Peloponnese, where the annual average rainfall has declined from 750 millimeters to 617 millimeters (Kokkinidis, 2025). This reduction in rainfall has led to diminishing surface water reservoirs and a decelerating groundwater recharge rate.

Despite Greece's abundance of water sources, many of these sources are unsuitable for direct application in agriculture. A substantial portion of the supply is either seawater or brackish water with salinity levels exceeding the EU safety standard of 2500 µS/cm (Ekstedt, 2013). The inland mountain water typically has the chemical structure of Ca-HCO3, while the coastal water shows signature traces of Na-HCO3 or NaCl, the latter indicating seawater intrusion (Antonakos et al., 2005). Brackish and seawater require treatment before being deemed acceptable for irrigation.

Unsustainable water consumption and inefficient practices

The demand for water has surged immensely in the past 25 years. In 2000, around 800 million cubic meters of water were consumed per year in Greece. This number has increased to 1.8 billion cubic meters per year in 2025 (Tratsa, 2025). According to *figure 1*, the sectors that consume the most amount of water are tourism and agriculture, with agriculture accounting for 85% of the country's consumption.

However, most of this water is lost due to unsustainable irrigation practices, outdated infrastructure, and transportation networks (Tratsa, 2025). According to the Hellenic Survey of Geology and Mineral Exploration (EAGME), Greece's underground aquifers are nearing critical depletion levels (Tratsa, 2025). The increase in groundwater extraction from 1990 to 2022 is shown in Figure 2. Farmers are not allowing enough time for the water table to naturally recharge during dry periods before drawing water for irrigation (Antonakos et al., 2005). By not prioritizing the protection of valuable water sources both above and below ground, the problem continues to grow. Besides the inefficient use of water in agriculture, outdated infrastructure makes the problem worse. Leaks in Greece's water transportation system cause about a 50% loss of supply (Tratsa, 2025).

Intensive agriculture and water over-extraction

A case study in the Evrotas River Basin, located in Laconia, Greece, illustrates the challenges faced in this area. This region is known for its intensive agricultural activity, especially for producing olives and citrus fruits. However, this heavy reliance on agriculture puts great pressure on the region's water resources, resulting in significant shortages that threaten long-term sustainability (Integrated Management Plans, 2009). The Evrotas basin has been designated as a European pilot basin for implementing the Water Framework Directive (WFD) 2000/60/EC, highlighting the seriousness and importance of its water management issues (Integrated Management Plans, 2009).

A main concern in Laconia is the large-scale over-extraction of both surface and groundwater resources, mainly for irrigation. This overuse is worsened by many private pumping stations, especially in areas like Skala, which often operate without proper oversight by local authorities (Integrated Management Plans, 2009). The heavy dependence on groundwater, particularly from karst formations in sub-basins like Northeast Taygetus and Southwest Parnon, further increases the stress on the hydrological system. Consequently, the Evrotas River frequently experiences severe desiccation during the summer months (Integrated Management Plans, 2009). Farmers in the region express deep concern that even the resilient olive tree, a staple crop, will eventually "*dry up and die because of lack of water*" if consistent irrigation is not provided, despite its ability to "*hold water for months and months*" (Focus Group Discussion). Nationally, the agricultural sector in Greece accounts for an estimated 80-84% of total water consumption, contributing to Greece's notably high "water footprint" globally, indicative of substantial inefficiencies in water use (Environmental Friendly Technologies for Rural Development, 2009).

To address these critical challenges, in 2009 the "Integrated Management Plans for the Water Resources of the Evrotas River Basin" outlined a strategic framework aimed at achieving "good status" for all water bodies through integrated, environmentally friendly technologies and socio-economic considerations. Key measures proposed included pollution reduction from agricultural runoff, olive mills, juice factories, and urban wastewater (many settlements lack proper sewerage systems, relying on often poorly constructed septic tanks) (Integrated Management Plans, 2009). The plan was also encompassing coordinated management of floods and droughts, promotion of sustainable agricultural practices (e.g., soil maintenance, appropriate fertilizer use), and significant emphasis on public participation and awareness.

Specific interventions have demonstrated success. For instance, the *LIFE05-EnviFriendly* project successfully implemented riparian forest restoration and

riverbank protection near Sparti, resulting in an average reduction of nitrate-N pollution in groundwater by 70% in the restored area (Riparian Forest Restoration, 2008). Real-time water quality monitoring networks have been operational since July 2004, providing continuous data on critical parameters (Real-time monitoring, 2007). Furthermore, proposals for water storage (e.g., urban floodwaters) and reuse of urban wastewater for agriculture have been put forth (Evrotas Management Plans, 2017). Economic incentives, such as increased pricing for agricultural water use and investments supported by the Agricultural Development Programs (PAA 2014-2020, Measure 4.3.1), aim to foster sustainable water management (Environmental Friendly Technologies for Rural Development, 2009).

Barriers to implementation: Policy, Economics, and Culture

Despite these efforts and demonstrated successes, widespread implementation of the strategic plan has faced significant hurdles and delays. Greece, in general, has experienced considerable delays in implementing the WFD, partly due to a complex governmental structure (Water Framework Directive Implementation, 2010). Policy and legislative complexities, requiring numerous studies and permits from multiple governmental levels (municipal, regional, ministerial), created substantial administrative bottlenecks (Impact of EU Environmental Policy, 2021). Financial constraints are also a major barrier, with restoration projects incurring substantial costs (e.g., €10,000 for 100 meters of restoration, plus €10,000 for floodplain studies and permits), and LIFE projects typically covering only 50% of the funding (Impact of EU Environmental Policy, 2021). Farmers also noted during the Focus Group Discussion that the introduction of innovation and technology into agricultural processes is "still very expensive".

Technological and communication barriers further impede market adoption and effective dissemination of solutions. There is a perceived "lack of interest from young people" in traditional farming, and "elderly people stop the younger ones because they think it is a sort of magic and everything," hindering the adoption of new technologies (Focus Group Discussion). This highlights a generational divide and a general resistance to change among some farmers, who "don't believe" in the benefits of new approaches without prior demonstration of results (Focus Group Discussion). Consequently, the over-exploitation of both surface and groundwater resources remains a persistent issue, leading to the artificial desiccation of large parts of the basin's hydrological network, particularly during summer and autumn months (The Evrotas River Basin, 2017).

The centralized Greek governmental structure has also posed challenges to fully integrating public involvement in water governance, despite the initial emphasis on public participation in the management plan (Demetropoulou, 2010). The lack

of enforceable policy, coupled with governmental fragmentation and the high upfront expense of water-saving technology, hinder effective policy changes. Due to the complicated structure of the regional government and significant cost of essential technology, it is difficult to execute plans. Officials tend to think of short-term solutions that can worsen the problem in the long term (Atay, 2012). There is also a sentiment among some farmers that the government has not delivered on promises regarding support for agricultural development, leading to a desire for projects that can proceed "beyond the government" but with its "blessing" (Focus Group Discussion). According to Atay (2012), an emphasis is placed on the need for policy change and more organized local government.

Some potential solutions to address the severe water crisis in Greece suggested by researchers include the following tactics: restricting tourism, switching to less water intensive crops, managing and storing water in wells, implementing sustainable irrigation practices, investing in water treatment plants and management technologies, such as monitoring sensors and pipelines, and enacting effective policy changes through a bottom-up approach. Vasilis Zorapas, a geologist and scientific manager of the Monitoring Network for the Hellenic Geological and Mining Research Authority (EGMR), a team that tracks the groundwater levels in Greece, and head of the Hydrogeology and Hydrology Department, believes the solution for the water crisis relies on restricting tourism and switching to less water intensive crops (Kokkinidis, 2025). A suggestion made by Savić et al. (2014) was to employ smart technologies such as smart meters to manage water consumption in Greece. Repairing outdated pipelines to mitigate loss of water from leakage is crucial before adding desalination plants and other technology (Tratsa, 2025). Upgraded infrastructure and stricter controls on water extraction are necessary to improve the situation (Gençtürk, 2025).

Socio-economic dimensions of rural development

Demographic trends in Europe are marked by a myriad of shifts, such as an aging population, lack of employment, and low fertility rates (Papadopoulos & Baltas, 2024). Greece, especially areas such as Western Macedonia and Peloponnese, faces an aging population as more of its young workers head to cities such as Athens, Thessaloniki, or internationally for work. This urban-rural divide was intensified during Greece's economic crisis, as employment across the country plummeted. Funding was funneled into cities, creating job opportunities for those willing to relocate, thus draining rural areas of their youth population (Salvati, 2019). Little to no money was given to rural areas, depleting their infrastructure and education. Further, the process of de-lignitization in areas such as Kozani and Megalopolis clearly shows the socio-economic challenges of the energy transition. The closure of coal plants in Kozani and Megalopolis has led to job loss, disproportionately affecting young workers as they undergo a skills mismatch

(Krommyda, Gourzis and Gialis, 2024). Without reskilling initiatives, the energy transition poses a "serious risk of economic decline and mass migration, especially in the case of young scientists (brain drain)" (Tranoulidis et al., 2022).

On top of such difficulties, young people in Greece also face disillusionment. There is a fundamental gap between young people's aspirations and economic opportunities in their hometowns. A survey study done in 2018 found that Greece presented the highest youth unemployment rates in EU member countries from 2014-2018 (Christou & Michail, 2018). Participants at that time expressed, "they are losing the hope that they will be able to fulfill their dreams in Greece" (Christou & Michail, 2018). Similar motivations can still be seen in Greece today, as youth find little hope for employment and quality of life in rural areas. Without a reignited spark of hope, the depopulation of rural areas is set to grow deeper (Salvati, 2019).

4. Methodology

4. Methodology

The research was focused on three different regions: Peloponnese, Western Macedonia, and Athens. In Peloponnese, the main focus was on the transition from lignite mining to renewables, and the consequent economic disruption, workforce displacement, and, also, the limited tech literacy (Megalopolis, Tripoli). Moreover, in one of the main agricultural areas of Peloponnese, Sparti in Laconia, the focus was mainly on agriculture and water scarcity, and the usage of smart water management techniques and precision farming to address droughts and sustain olive and citrus production. In Western Macedonia (Kozani and Ptolemaida), the research was focused on the lignite phase-out and potential opportunities in renewable energy and smart agriculture, while also dealing with labor shortages and infrastructure gaps. Finally, in Athens, there was a focus on analyzing the EU-funded Just Transition Fund in Greece, as well as national policies that have affected different regions.

The research process completed a total of 25 semi-structured interviews, one focus group discussion, and field observations. Representatives of stakeholders who were directly or indirectly involved in the lignite phase-out process, energy transition, and rural transformation were selected. Stakeholders ranged from national and regional governmental officials to local businesses and farmers.. The interviews lasted 30-45 minutes and followed a discussion-guided protocol. (see the appendix for further details on questions). Interviewees received a description of the study prior to their involvement and provided informed consent for recording and data use. Multiple field visits were conducted to coal mines, research labs, power plants, olive farms, and university research facilities. A Scoping Literature Review provided a baseline for data collection and key questions for thematic analysis.

Interview data were coded thematically to identify patterns of recurring themes regarding regional challenges, opportunities, and policy implications. Coding categories used themes such as workforce displacement, technological barriers, environmental concerns, and social dynamics. Themes were grouped by region to reflect the unique contexts: delignitization and economic transition in Peloponnese and Western Macedonia, and water scarcity with agricultural modernization in Sparti.

Triangulation of policy documentation and literature helped confirm the findings and contextualize stakeholder perspectives within broader policy frameworks like the European Green Deal and Just Transition Fund. This process revealed gaps between high-level policy goals and the practical challenges faced by local communities, including issues with infrastructure, education, and access to funding.

5. Thematic Analysis

5. Thematic analysis

The thematic analysis used in the present research focused on systematically interpreting qualitative data collected through interviews, focus groups, and field observations. It sought to identify recurring patterns, underlying dynamics, and critical implications related to energy transition, rural transformation, and the integration of AI and smart agriculture.

The review was guided by the European Green Deal, which lays out a bold plan for the EU to become climate neutral by 2050, and is at the forefront of this global change. Digital innovation, sustainable agriculture, and renewable energy are at the heart of this effort since they are all essential to the long-term survival of rural communities that have traditionally depended on fossil fuels. As a member of the European Union, Greece is actively involved in this shift. It must overcome the difficult task of gradually weaning itself off of lignite energy, which has historically been a major component of its regional economies, while also promoting a creative, low-carbon rural economy.

The updated Greek National Energy and Climate Plan (NECP) confirms the country's commitment to stop using coal by 2028, greatly increase the use of renewable energy sources, and modernize its agriculture sector. This energy transition adds a lot of social, environmental, and economic complexity at the regional level. This is especially noticeable in regions that have relied heavily on lignite for many years, like the Peloponnese and Western Macedonia. The Greek government plans to carry-out revitalization projects in these areas with the help of the Just Transition Fund (JTF). The strategic focus in Western Macedonia is on smart agriculture, digital innovation, and the shift to renewable energy. Significant obstacles, such as ongoing labor shortages and technological gaps, are delaying this ambitious transition. Concurrently, in the Megalopolis area in the Peloponnese, the redevelopment of former mining sites is envisioned to be supported by strategic investments in smart farming and bioeconomy projects, grounded on local entrepreneurship and comprehensive workforce retraining efforts. Distinctly, agriculture-dominant areas like Sparti, in Laconia, face an acute and ongoing challenge of water scarcity that critically threatens their agricultural sustainability, necessitating sustained investment in smart irrigation systems and digital monitoring technologies.

The main set of issues in all regions included workforce displacement and population change, particularly youth outmigration and aging; technology limitations, including digital illiteracy, expensive installation costs, and fragmented land ownership; environmental concerns, including drought, land degradation, and water scarcity; and policy and governance gaps including bureaucratic inefficiencies and disconnection between national policy goals and local capacity to implement.

Thematic coding adopted a region-specific approach to identify localized contexts and allow cross-regional comparison. Policy documents and literature were used to triangulate the findings and contextualize them with broader EU policy frameworks, like the European Green Deal and the Just Transition Mechanism. This served to highlight the gap between high-level policy ambition and the realities on the ground that impact local communities and underline the need for holistic, context-sensitive strategies for rural transformation.

5.1. Economic transformation and employment dynamics

Lignite phase-out: Job losses and economic disruption

The rapid decommissioning of lignite power plants has caused severe economic disruption and extensive unemployment in historically coal-dependent regions. Kozani's economy, for instance, was deeply reliant on lignite, with 70% of the country's electricity production stemming from this sector. The subsequent shutdown of power plants has resulted in massive job losses and a shrinking population, a situation described by stakeholders as the "worst... in 40 years". Similarly, Tripoli and Megalopolis have been "totally affected" by the coal phase-out in Megalopolis, which has led to significant unemployment and a substantial reduction in the Gross Domestic Product of the Peloponnese region.

The rapid, politically driven decision to shut down lignite operations is often described as a "shock" due to the lack of preparedness. It has directly caused a severe economic shock and contributed to a prevalent sense of social depression. The abrupt cessation of high-paying jobs, which had sustained families and enabled educational opportunities (e.g., supporting studies abroad, master's, and PhDs), resulted in a dramatic drop in household income. This sudden economic downturn has led to widespread "social depression" and considerable uncertainty regarding the future economic model of these regions. This establishes a clear cause-and-effect relationship between the speed and top-down nature of policy implementation and profound socio-economic and psychological consequences at the local level.

While large-scale job losses represent a common initial impact across the affected regions, the long-term economic outlook and the pace of proactive diversification efforts exhibit significant regional variations. The interviewees consistently report severe job losses in both Western Macedonia and Megalopolis/Tripoli. However, evidence suggests that Arcadia's transition appears more proactive, reinforced by institutional plans for entrepreneurship and agricultural development. This indicates that although the initial economic shock is shared, the regional capacity and institutional readiness for diversification differ, implying that the pace and planning of alternative economic development can

mitigate the long-term "social depression" and lead to different trajectories for recovery.

Diversification efforts: Shifting towards new economic models

In response to the lignite phase-out, a rigorous effort is underway to diversify regional economies and foster new economic models. In Megalopolis, new businesses are anticipated to emerge, including a large battery manufacturing factory, a waste management factory, a biogas factory, and extensive greenhouses, all projected to generate new employment opportunities. Tripoli's strategic focus centers on developing renewable energy, tourism, and agriculture, with tourism identified as the most promising sector for job creation and overall economic success. Western Macedonia and Kozani are strategically shifting towards agri-food, alternative tourism, and Information Technology, with ambitious plans for large-scale data centers, battery factories, and hydrogen hubs, aiming to transform Kozani into a "digital city". Emblematic projects, such as bioeconomy hubs and hydroponics initiatives, are also integral components of this diversification strategy.

This consistent emphasis on diversifying beyond lignite indicates a fundamental change in economic strategy. The specific sectors being prioritized-for example, Kozani's strong push for IT and digital infrastructure, Megalopolis's focus on bioeconomy and smart agriculture, and Tripoli's emphasis on tourism-reflect a tailored approach rather than generic diversification. This suggests a more sophisticated, though challenging, long-term vision that seeks to leverage unique regional comparative advantages in the post-lignite era. This strategic shift towards a multi-sectoral economy is clearly emerging across the regions, characterized by a degree of regional specialization based on local assets and strategic priorities.

Income disparities and impact on business scale

The economic strain is intensified by a notable income gap between the high salaries previously offered in the lignite sector - where a driver could earn over €35,000 net annually - and the significantly lower potential earnings in sectors like agriculture, which might offer only €10,000-€15,000 with hard work. This substantial income gap acts as a major disincentive for workforce retraining and local retention, creating a significant challenge for job acceptance and contributing to ongoing labor shortages in new industries. The explicit concern about large investors potentially monopolizing the benefits of the transition suggests that the "just transition" might fail to be truly equitable if economic gains are not broadly shared, potentially leading to continued social friction and out-migration among the general population.

The economic impact also varies significantly by business size and type. Small and medium-sized enterprises (SMEs), which constitute the majority of businesses in these regions (e.g., over 95% in Messinia), frequently lack the financial capacity for green investments and struggle to secure refinancing from banks. In stark contrast, new, large businesses with substantial budgets are expected to readily adopt AI systems and other advanced technologies. This dichotomy suggests a widening gap in competitiveness and resilience, potentially leading to the marginalization or failure of smaller, family-owned enterprises unless targeted and accessible support mechanisms are effectively implemented. The energy transition thus risks creating a dual economy where large, well-funded enterprises readily embrace advanced technologies, while numerous small, traditional businesses struggle to innovate due to capital constraints and bureaucratic obstacles.

5.2. Demographic shifts and human capital challenges

Brain drain and youth migration

A pervasive and consistently highlighted issue across all regions is the "brain drain" and significant population decline, particularly among young, skilled individuals. In Kozani, 10% of younger people have already left the municipality for opportunities abroad or in larger Greek cities like Athens or Thessaloniki, contributing to a shrinking population from 74,000 to 67,000 in a decade. Young people in Tripoli are "looking to leave" for universities and jobs elsewhere, a trend directly linked to the lignite plant shutdowns in Megalopolis. The President of the Association of Active Youths of Western Macedonia (OENEF) identifies "brain drain" as the "greatest challenge," exacerbated by the economic crisis and the decline of energy production, leading to youth emigration to other Greek cities and even foreign countries like Germany and Belgium.

The rapid economic disruption resulting from the lignite phase-out is a primary, direct driver of youth out-migration, creating a critical negative feedback loop that severely affects regional revitalization efforts. The consistent and direct causal link between "job losses" and "economic downturn" caused by the lignite phase-out and the subsequent phenomenon of young people "looking to leave" and experiencing "brain drain" is evident. The description of Kozani's population shrinking and the situation being the "worst in 40 years" directly correlates with increased out-migration. This exodus of young talent then exacerbates existing labor shortages and skills gaps, making it harder to attract new investments or successfully implement advanced technologies, thereby creating a detrimental cycle for long-term regional development.

Aging population and labor shortages

The significant exodus of youth leaves behind an increasingly aging population in rural areas, making it challenging to find an adequate workforce. This is particularly severe in the agricultural sector, where many farmers operate in a "primitive way" and there is a "very big demand for skilled workers" like drivers and specialized machine operators, threatening their long-term sustainability and ability to modernize. In Messinia/Arcadia, 70% of businesses are run by individuals aged 50 or older. The Authorized Regional Councilor for European Programs in Peloponnese notes that Greek farmers are predominantly older, lacking modern education, and face difficulty in attracting young people to replace them.

This demographic shift directly translates into a "very big demand for skilled workers" and has led to a heavy reliance on foreign labor for agricultural tasks, with 95% of the harvesting workforce in Arcadia coming from abroad. The "lack of successors" in farming is a critical concern that indicates this is not merely a temporary labor shortage but a fundamental threat to the continuity and viability of agricultural practices. Often, older farmers decide to abandon their land if their children are not interested in continuing the business, making the sector highly vulnerable without significant, systemic interventions.

Challenges in retaining and attracting young talent

Attracting and retaining human capital in post-lignite regions is an effort that faces significant hurdles. It requires a holistic transformation of regional identity and quality of life, extending beyond solely economic incentives to address social, cultural, and lifestyle aspirations. While job opportunities are undeniably crucial, the transcripts reveal that young people are leaving even when good salaries might be available, indicating a deeper underlying issue. Young people often repeated the sentiment of having "no future here". University faculty in Kozani, for example, often do not stay in the region, preferring larger, faster-growing cities.

This points to a broader challenge in attracting and retaining highly skilled professionals. Stakeholders explicitly called for a "new identity" for cities like Kozani, making them attractive to young families. This new identity should go beyond purely economic incentives, suggesting that social, cultural, and lifestyle factors play a significant, often overlooked, role in retention. Investing in and emphasizing quality of life aspects, such as safety for children, low criminality, and strong community ties, implies a necessary shift from a purely industrial / economic development model to a more human-centric one for achieving sustainable population retention and growth.

5.3. AI and Smart Technology adoption: Opportunities and Hindrances

Awareness and understanding of AI/Smart Farming

There is a growing awareness of and general willingness to learn about AI and smart technologies across the regions, although a fundamental knowledge gap and limited practical understanding persist, particularly among traditional farmers and older business owners. In Tripoli, the Deputy Mayor describes their understanding of AI as "like babies, like newborns," yet they are "surprised" by the good answers and believe it "will help". The President of the Arcadia Chamber of Commerce acknowledges, "we need to know more about AI because we know nothing," and is actively holding seminars to prepare businessmen. In Messinia, most businesses are "struggling to find out what is that" beyond basic text generation. Kozani faces a "great gap in the knowledge of the technology matters" among producers, though people are generally "eager to learn" if effective training is provided. This points to a widespread lack of deep, practical understanding of AI's capabilities and applications beyond superficial uses. It also indicates that the primary barrier is not necessarily outright resistance to technology, but rather a lack of prior exposure, comprehensive education, and demonstrable utility, making initial adoption challenging.

Perceived benefits of AI/Smart farming

AI and smart agriculture are widely perceived across various interviews and regions as multi-faceted tools, crucial for addressing numerous interconnected regional challenges, spanning economic stagnation, youth out-migration, environmental degradation, and energy insecurity. Key benefits identified include economic diversification and the creation of new types of jobs, attracting and retaining youth by making farming more scientific and profitable, and significantly increasing agricultural productivity and quality through precision farming (optimized irrigation, fertilization, weather forecasting, disease detection).

AI is also expected to reduce costs and enhance efficiency, for example, by optimizing logistics. Furthermore, it is seen as vital for environmental sustainability and climate adaptation, including wildfire detection and efficient resource management, and for enhancing energy security through smart grids and demand/supply balance. Ultimately, the widespread adoption of AI is anticipated to improve the overall quality of life for residents. This widespread optimism indicates a strong, collective belief in its potential as a panacea for the complex, systemic problems facing post-lignite Greece, despite current low adoption rates, and highlights AI's strategic importance in the long-term vision for regional revitalization.

Barriers to AI/Smart farming adoption

Despite the recognized benefits, several significant, multi-layered, and interconnected cultural, human capital, structural, financial, and policy barriers impede the widespread adoption of AI and smart technologies. The respondents reveal that no single barrier operates in isolation, but are forming a complex web that necessitates holistic, rather than isolated, policy interventions for effective technological integration. There is a pervasive lack of digital literacy and understanding of AI beyond basic applications. This is compounded by a shortage of local AI experts who would impede effective use and trust in new technologies. High upfront costs for new machinery and AI systems are a major deterrent for many small, family-owned businesses.

This is exacerbated by fragmented landownership and bank risk aversion, making it nearly impossible for small farms to invest. Cultural resistance from older generations, who often view new technologies with skepticism or as "magic" and prefer traditional methods, can also prevent younger generations from adopting new practices. Inadequate internet infrastructure in many rural agricultural areas serves as a fundamental barrier. Regulatory hurdles, such as legal issues surrounding agrivoltaics that prohibit plants around solar panels, also hinder implementation. Furthermore, psychological fears about job displacement and time constraints for implementation before the final lignite shutdown in Kozani add to the complexity. The need for a coordinated, multi-pronged strategy targeting several points simultaneously is consistently emphasized to overcome skepticism.

Pilot projects and timeline for adoption

Pilot projects are widely regarded as crucial for building trust and demonstrating the value of AI and smart technologies, but the disparity between their localized impact and the urgent, region-wide transition timelines highlights a significant scalability challenge. Stakeholders consistently emphasize the critical need for "tangible proof" and "showcases" to overcome widespread skepticism and traditional mindsets. The existence of multiple pilot projects across regions confirms that this strategy is being pursued.

Examples include smart agriculture pilots with sensors, drones, and disease detection in Megalopolis, the University of Peloponnese's SodaSense project for precision farming, and an indoor farming pilot in Western Messinia. The Arcadia Chamber of Commerce is actively conducting AI seminars, and the University of Western Macedonia offers workshops on data and AI. Broader initiatives include a bioeconomy hub, living labs, and large-scale hydroponics investment projects. In Kozani, projects like SMARF for forest owners, camera systems for wildfire prevention, and a smart grid pilot in Trepano village are underway. The estimated

timeline for AI education to show effects in Tripoli is "four to five years". However, the "rapid transition" away from lignite and the short remaining timelines (e.g., one year until Kozani lignite shutdown) contrast sharply with the inherently slow, localized, and often experimental nature of pilot project adoption. This implies a critical challenge in rapidly scaling successful pilots and integrating them into broader regional strategies (e.g., a major data center needs "three, four, five years to be installed") to meet the urgent economic and social needs of the transitioning communities.

5.4. Environmental legacies and restoration requirements

Lignite environmental impact and land degradation

Decades of intensive lignite mining have caused severe environmental degradation that spans multiple generations in the affected regions, now posing serious challenges to public health and sustainable land reuse. Air pollution, especially near power plants, has been a persistent and major issue, with Kozani historically known as the "capital of lung cancer in Greece" due to high levels of PM10 particles. This directly connects intensive lignite operations to severe public health impacts, emphasizing a significant human toll. In Western Macedonia and Kozani, large areas of land have been "stripped of vegetation," leading to soil degradation and contamination - a long-term environmental debt that hampers efforts to convert these lands into agriculture, renewable energy, or other productive uses. This creates a complex challenge that goes beyond simple economic restructuring. Additionally, water contamination in both ground and surface waters - caused by aquifer depletion and the use of poorly treated water during mining - remains an ongoing and serious environmental concern.

Environmental restoration efforts and the role of AI

AI and smart technologies are viewed as essential not only for monitoring environmental recovery, including early wildfire detection and disease surveillance by combining satellite data with local systems but also for enabling innovative, sustainable land use solutions that balance economic and ecological objectives. A notable positive effect of the lignite phase-out in Kozani is the rapid and significant improvement in air quality, turning the region from a pollution hotspot into an area with "much cleaner air." Kozani has also committed to an ambitious climate city contract, aiming for zero CO_2 emissions by 2030. This shows that technology is not just a tool for economic transition but a vital facilitator for both reducing past environmental harm and creating a more sustainable and resilient future ecosystem.

Major efforts are currently underway to restore the environment and repurpose land sustainably. A key goal for organizations in Kozani and Megalopolis is to

rehabilitate former mining sites for agricultural and tourism purposes, including planting new forests. Large photovoltaic parks are being installed on former mining lands, and pump storage projects are planned to boost energy storage capacity. The use of AI for environmental monitoring and the strategic integration of renewables with agriculture (agrivoltaics) and urban heating (waste heat from data centers) demonstrate a progressive approach.

Water scarcity and management (Sparti and broader Peloponnese)
Sparti's economy, heavily dependent on agriculture (olives, citrus) and tourism, faces an urgent and existential water crisis worsened by inadequate infrastructure and traditional practices. This challenge is different from the lignite-related issues in other studied regions. Farmers report "significant water scarcity" caused by decreasing rainfall, leading to fears that even resilient olive trees will "dry up and die because of lack of water" without proper irrigation. "I have water, but for how long? And then what?" one farmer asked. There is a critical shortage of water storage infrastructure, such as dams, reservoirs, and wells, along with insufficient piping networks to carry freshwater from mountains. Although seawater is plentiful, its high salinity requires costly desalination before it can be used for irrigation. This complex, multi-layered problem highlights the urgent need for affordable, smart water management solutions. Farmers are interested in desalination plants but face barriers like high costs, small farm sizes, and limited technical expertise and funding.

As a result, water management in Laconia becomes a key case study for understanding and tackling climate adaptation in agriculture. Pilot projects for water reuse and desalination have begun to take shape, showing initial progress. The potential of smart technologies like soil moisture sensors and drip irrigation to improve water efficiency is recognized, but widespread adoption remains difficult due to costs, small farm sizes, and lack of technical knowledge. Local farmers are already practicing circular economy principles by reusing agricultural byproducts, creating a foundation for sustainable practices that can be expanded with technological support. For example, olive oil producers are using liquid byproduct and black mud as natural fertilizers, demonstrating an indigenous, resourceful approach to waste and resource management. This "nothing gets wasted" philosophy is a bottom-up innovation that aligns with broader goals of environmental sustainability and a circular economy. These facts suggest that technological solutions, especially in smart agriculture, should build on and strengthen existing local sustainable practices rather than replacing them, fostering greater acceptance and effectiveness.

5.5. Policy, governance, and funding frameworks

EU and national policies: The Just Transition Fund

The Just Transition Development Plan forecasts substantial investments, such as an expected €3.5 billion and 8,000 new jobs in Western Macedonia. Importantly, it now explicitly includes funding for agri-tech initiatives. Key projects within this framework include establishing an "innovation zone" in Western Macedonia and a "bioeconomy 360° hub" in Megalopolis.

While high-level EU and national policies provide significant financial resources and strategic guidance for the energy transition, the actual impact on the ground varies, with notable differences in implementation timelines and the fair distribution of benefits across regions. The large budget of the JTF and its strategic goals clearly demonstrate strong policy intent at both EU and national levels. However, a comparative analysis shows an "imbalanced timeline," with Megalopolis experiencing limited progress in revitalization efforts despite plant shutdowns, whereas Kozani has made more advanced land rehabilitations. Additionally, concerns about a "monoculture of renewables where only a small percentage of revenue remains in the region" and the idea that most economic benefits go to a few large investors reveal a potential disconnect between the policy's declared "just" aim and its actual equitable distribution of outcomes locally. This suggests challenges in translating high-level policies into widely beneficial regional realities.

Funding accessibility, bureaucracy, and bank risk aversion

Funding remains difficult to access despite substantial EU funds, due to bureaucratic hurdles and bank risk aversion. Businesses and farmers often report being unable to access funds because of "useless bureaucracy," such as lengthy proposal approval processes that can take weeks or months. Small enterprises frequently lack the upfront capital needed for green investments and struggle to obtain refinancing from banks. Financial institutions are often reluctant to assume investment risk, demanding guarantees that exceed the loan amount and offering low loan percentages, which effectively blocks access to vital capital for small businesses and farmers.

The closure of rural bank branches worsens the problem by limiting direct access to financial advice and support. Funding is identified as the "biggest problem," given that the scale of private investments required is enormous for most stakeholders. This indicates that the issue is not a lack of capital—since the JTF is substantial—but rather limited accessibility. This systemic problem directly affects small businesses' ability to invest in green technologies and farmers' capacity to

modernize, creating a frustrating gap between policy goals and practical implementation at the local level.

Centralized vs. Decentralized governance and inter-sectoral collaboration

A significant tension exists between central government control and the need for decentralized, locally driven implementation. Current governance structures often hinder effective inter-sectoral collaboration and community engagement. Greece's system is described as "politically oriented" with a "very top-down approach," where decisions are often "decided in Athens and not on the spot." This centralization causes local frustration and a strong desire for greater autonomy, with stakeholders stressing that the "voice of the people needs to be heard."

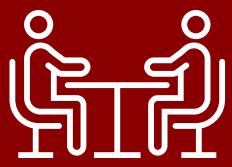
Coordinating among various local actors (government, universities, NGOs) and the "lack of experienced staff" also highlight how a centralized system can create bottlenecks and inefficiencies. While some collaboration exists, such as for training and research, the general sentiment points to a critical need for more empowered local ecosystems to truly drive the transition, ensuring policies are not only tailored but also genuinely accepted and owned by communities.

Despite these challenges, instances of inter-sectoral collaboration are present. For example, cooperation occurs between the EU, national government, city authorities, and private companies for training initiatives. Universities and research institutions work closely with regional authorities to introduce new data and technologies, exemplified by the Bioeconomy Cluster's formation through multi-stakeholder efforts. The Public Power Corporation's large data center project also indicates convergence among energy, IT, and AI sectors. Efforts are underway to establish local committees with multi-stakeholder representation to foster more participatory governance.

Table 1: Stakeholder Roles and Perceptions in the Transition Process

Stakeholder Group	Primary role in transition (as per respondents)	Key perceptions/challenges from respondents
European Union	Primary driver and financier of Just Transition; promotes green growth and training initiatives.	Funds are substantial, but accessibility is hindered by bureaucracy; communication can be complicated.
National Government	Sets national energy/climate plans; provides support and funding.	Centralized, "top-down" approach; decisions are often made in Athens without sufficient local input; bureaucratic procedures are major barriers to funding access.
Local Authorities (Municipalities, Regional governments)	Implement local plans; attract investments; manage local services.	Lack of autonomy and resources to act independently; limited experienced staff; desire for more local decision-making and bottom-up approaches.
Chambers of Commerce	Vital intermediaries; advise businesses/local governments; organize educational seminars on AI.	Actively trying to bridge knowledge gaps; recognize high costs of technology for small businesses; see AI as compulsory for future business.
Universities and Research Centers	Key source of scientific knowledge, research, and training in AI/digital skills; develop tools; offer courses.	Strong academic capacity but struggle to retain faculty/experts; critical for developing practical AI tools and providing training; seen as a source of hope.
Development Organizations and NGOs	Support local entrepreneurs; bridge the gap between businesses and employees; manage EU projects; engage youth.	Actively combat brain drain; facilitate cross-sectoral cooperation; often fill gaps left by traditional governance structures.
Private Sector	Invest in renewable energy projects; land rehabilitation; adopt new technologies.	High upfront costs for SMEs; risk aversion from banks; fear of "monoculture of renewables" where benefits accrue to few large investors.

6. Discussion: Towards a new economic model for post-lignite Greece



6. Discussion: Towards a new economic model for post-lignite Greece

The transition away from lignite in Greece presents a complex challenge that goes beyond energy policy to include fundamental questions of economic restructuring, rural revitalization, and human capital development. Field research highlights both different regional contexts and common underlying issues, pointing to the need for a new, integrated economic model.

Connecting delignitization and economic transformation

The unexpected closing of lignite units triggered significant economic turmoil in regions such as Western Macedonia and Central Peloponnese. Coal-based plants in Megalopolis, which previously employed 2,500 people, now employ only 250; Western Macedonia also reported the highest unemployment rate in the EU in 2021. Job losses have added to economic stress and sped up urban migration. However, this shift is more than just replacing energy sources. It also involves changing the economic profile of rural areas. A major concern among stakeholders is that benefits from large projects like data centers, solar parks, and wind farms may mainly go to a few big investors instead of being shared widely with local communities.

This would oppose the idea of a "just" transition, as the economic gains from the new model might not reach the communities that bore the environmental and social impacts of the lignite era. Therefore, economic diversification success depends on promoting local ownership models, ensuring benefits are shared fairly, and encouraging diverse economic activities that offer a broad range of opportunities beyond just large-scale energy projects. This requires policies that actively support small and medium-sized enterprises, local cooperatives, and community-owned renewable projects to promote more equal wealth and opportunity distribution.

The role of AI and smart technologies in rural revitalization

AI and smart technologies are widely viewed as key drivers for the future economic change in these regions. Stakeholders see them as pathways to boost agricultural productivity and quality, lower operating costs, and improve environmental sustainability. They are vital for professionalizing agriculture and other rural sectors, creating roles that appeal to the digitally native generation. Importantly, these technologies are seen as ways to create "new types of jobs" that need "new skills" in areas like marketing, product promotion, and technical support. Moving from traditional manual labor to more skilled, knowledge-based

roles is seen as a strong motivation to attract and keep younger generations, who often see traditional farming as "primitive." Education and training programs should explicitly link smart technologies to clear career paths and higher earning potential in rural areas to effectively draw in and retain young talent. This shift in rural labor is crucial for fighting brain drain and ensuring the long-term vitality of these communities.

The Sparti case study: A model for resilient agriculture in water-stressed regions

Although Sparti is not a lignite-dependent region, it offers important lessons that can be applied to sustainable agriculture facing environmental challenges, especially water scarcity. Sparti's economy is deeply tied to its agriculture, making water scarcity a critical threat to its economic base and cultural heritage. Its struggles with water scarcity and an aging farming workforce highlight a broader challenge of climate adaptation in traditional rural economies. Farmers have voiced concerns that new energy and land regulations are unclear or unfriendly. Efforts like reusing olive oil byproducts as fertilizer and exploring smart tech such as sensors and drip irrigation show a proactive, though early-stage, approach to sustainability.

Successful adoption of smart tech in Sparti, especially in water management and engaging youth in tech-enabled farming, could serve as a valuable example for other climate-vulnerable agricultural areas, regardless of their energy transition context. Investment in smart farming should be seen not just as regional development but as a pilot project for climate resilience and rural sustainability, attracting wider national and international support. The region's experience shows that practical, locally tailored solutions, even small ones, can build resilience and offer hope amid significant environmental pressures.

Policy and governance dynamics

Greece's energy transition faces ongoing tension between the national government's "top-down" approach and local communities' desire for "bottom-up" involvement. Centralized decision-making, often decided in Athens rather than locally, along with bureaucratic hurdles, causes frustration and delays in effective local implementation.

Although there are commitments to participatory governance and the creation of formal bodies like Regional Just Transition Committees, the spirit of local participation remains incomplete. This creates a disconnect between policies and local needs, leading to mistrust and difficulty in using available funds, especially for small projects. The perception that local voices are ignored fosters disengagement and the view that policies don't truly reflect ground realities. A genuine move toward decentralized decision-making, giving local authorities

and communities more control over funding and project plans, is essential to build trust, gain local support, and speed up the just transition. This also involves encouraging multi-stakeholder cooperation among universities, chambers of commerce, NGOs, and local authorities to bridge gaps and tailor policies to diverse local needs.

Encouragingly, cooperation across sectors is increasing. Chambers of commerce, universities, and municipalities are collaborating on innovation, training, and infrastructure initiatives. Projects like the Bioeconomy Cluster and the Public Power Corporation's data center exemplify the benefits of cross-sector cooperation. Expanding these models will be crucial for developing resilient, inclusive, and future-ready regional economies.

7. Conclusion –

Key takeaways

7. Conclusion

This qualitative work highlights that integrating AI and smart agriculture into a post-lignite economy requires both region-specific solutions and cross-regional coordination. Western Macedonia, Megalopolis, and Sparti each have distinct starting points, yet all would benefit from improved tech literacy, targeted investments, and youth-oriented programs. The phase-out of lignite has certainly caused severe economic disruption, widespread unemployment, and a significant "brain drain" of young, skilled individuals across Kozani, Megalopolis, and Tripoli. Youth migration, combined with an aging population, creates a structural labor crisis that risks threatening the long-term sustainability and modernization of traditional sectors like agriculture.

Despite these tough challenges, stakeholders widely agree on the necessity and transformative potential of AI and smart technologies. These tools are seen as vital for economic diversification, creating new jobs, attracting and keeping young people, increasing agricultural productivity, promoting environmental sustainability, and strengthening energy security. However, the broad adoption of AI faces a complex web of interconnected barriers, including high initial costs for small businesses, widespread lack of digital literacy and local expertise, cultural resistance from older generations, inadequate internet infrastructure, and restrictive regulations like those affecting agrivoltaics.

The gap between urgent transition timelines and the slower pace of technology adoption presents a major challenge. Regional differences further complicate the transition. For example, Sparti faces a critical water crisis that directly threatens its agricultural base, setting its needs apart from lignite-dependent areas. While EU and national policies provide substantial funding, bureaucratic inefficiencies and the risk-averse lending practices of financial institutions act as bottlenecks, hindering the effective flow of funds to local businesses and farmers. Additionally, a significant tension exists between centralized national policy-making and the need for decentralized, locally-driven implementation, often impeding effective inter-sector collaboration and genuine community involvement.

Policies should combine top-down funding with bottom-up engagement strategies, such as community innovation labs, to overcome cultural and informational barriers. Ultimately, the success of the transition hinges on building local capacity for innovation, turning challenges like brain drain, limited capital, and regulatory inertia into opportunities for sustainable development.

Key takeaways

• Tailored, bottom-up approaches are essential
Policies must go beyond centralized directives to truly empower local communities by incorporating their unique needs, knowledge, and existing sustainable practices. This involves fostering greater local autonomy in decision-making and resource management.

• Holistic strategies are needed for AI adoption
Meaningful participation in the workforce and society depends heavily on AI. Addressing the interconnected barriers to its adoption requires comprehensive approaches that simultaneously address financial constraints, improve digital literacy, develop strong internet infrastructure, and actively involve communities to overcome cultural resistance. Isolated efforts are unlikely to produce significant results.

• Investing in human capital must be a top priority
Focus on extensive retraining programs, early digital literacy education, and creating attractive jobs to fight brain drain and ensure a skilled, motivated workforce for emerging sectors. This also means emphasizing quality of life to keep young families.

• Good governance and collaboration are essential
Fostering cooperation among local authorities, universities, development groups, and private companies is crucial. Making bureaucratic processes more efficient and promoting risk-sharing arrangements with lenders are necessary to ensure effective fund use and faster project execution.

• Pilot projects should be strategically expanded
While pilots are useful for demonstrating benefits and building trust, there must be a clear plan for scaling successful initiatives quickly across regions to meet urgent transition deadlines and alleviate socio-economic hardships.

Future research should focus on long-term studies to understand the socio-economic impacts of the transition, detailed cost-benefit analyses of AI in small farms and businesses, and comparative studies of successful bottom-up governance models in other regions undergoing transition. This research can provide valuable, evidence-based guidance for navigating a just and sustainable post-lignite future.

8. Policy recommendations – Identified available funding tools

8. Policy recommendations

Navigating the shift away from lignite, is a big challenge for Greece, but it is also a huge opportunity. The key is to make sure this transition is fair and does not leave anyone behind. These recommendations are formulated to address the multifaceted challenges identified in Greece's post-lignite transition, aiming to foster a just, sustainable, and technologically advanced rural economy. The recommendations integrate insights from stakeholder perspectives, align with existing governmental plans, and consider the differential impact on small versus large investors.

Recommendation #1

Making funding access easier for small-scale enterprises

The current funding landscape, while substantial in volume, is plagued by "excessive bureaucracy, complex application processes, and long delays". Small businesses and local entrepreneurs are often the backbone of a community, but they face a lot of hurdles when trying to get funding. They often get tangled in paperwork and complicated rules, and banks can be hesitant to take a chance on them. These dynamic risks undermine the "just" aspect of the transition by limiting equitable participation and concentrating benefits among a few large players, as funds have been available since 2021, but interventions, according to the respondents, have only recently commenced.

To rectify this, policy interventions must actively de-risk small-scale investments and simplify administrative processes. This includes:

1.1. ***Simplifying application procedures:*** Drastically reduce bureaucratic obstacles and shorten approval times for EU and national funding programs, making them more accessible for small and medium-sized enterprises and individual farmers.

1.2. ***Providing direct assistance:*** Increase capacity through dedicated local support centers to guide small businesses and farmers through the application process, offering practical help with documentation and compliance.

1.3. ***Implementing risk-sharing mechanisms:*** Advocate for policies that incentivize banks to share investment risk with farmers and small businesses, potentially through government guarantees or co-financing schemes, thereby facilitating easier access to loans. This ensures that the "just transition" funds genuinely reach and benefit the local communities and small enterprises most affected by the lignite phase-out, shifting from a purely absorption-driven funding model to one focused on equitable distribution and local impact.

Recommendation #2

Targeted training and digital literacy programs

The new economy is all about technology, and people need the right skills to thrive in it. Providing opportunities for education and training can help keep young people in their communities and boost productivity. Retaining young people demands a multi-dimensional approach: green transition policies, educational systems, smart agriculture, and support for tourism. Moreover, a "great gap in the knowledge of the technology matters" persists among producers, coupled with resistance from older generations to adopt new methods. To make this happen, we should:

2.1. ***Offer comprehensive lifelong learning:*** Implement extensive training programs in AI, IoT, and smart farming, tailored to different age groups and skill levels. These programs should focus on practical applications and hands-on experience, demonstrating how technology can make farming "easier, increase production, and improve revenues".

2.2. ***Connect schools and businesses:*** A coordinated commitment from universities (e.g., University of Western Macedonia, University of Peloponnese, Agricultural University of Athens, Texas A&M University), industry, and policymakers is essential to expanding AI literacy, delivering these programs, and ensuring scientific knowledge and tools are directly transferred to farmers and businesses.

2.3. ***Integrate early AI education:*** Introduce AI education into primary school curricula to cultivate interest and digital literacy from an early age, preparing future generations for a tech-enabled agricultural sector.

Recommendation #3

Strategic investment in high-skilled, diversified industries

To combat brain drain and create attractive job opportunities for youth, particularly given the income disparity between formerly lignite jobs and traditional agriculture:

3.1. ***Prioritize high-tech infrastructure:*** Direct investments in sectors that create high-skilled, appealing jobs, such as IT (e.g., green data centers), renewable energy manufacturing (e.g., battery factories, hydrogen hubs), and advanced agri-food processing.

3.2. ***Utilize rehabilitated lignite lands:*** Strategically plan the rehabilitation of former lignite mining areas for new industrial parks and tech hubs, pilot agriculture uses, ensuring that environmental restoration is coupled with economic regeneration.

3.3. ***Repopulation and integration:*** Alongside preventing youth out-migration, strategies should also focus on refugees and migrants, which can help to

stabilize rural economies as investments in the educational systems are slowly rolled out. Migrant workers could help to revitalize certain areas of Greece in the agricultural sector. Yet, repopulation efforts must align with local needs and incorporate social sensitivities and connectivity.

Recommendation #4

Enhancing local autonomy and participatory governance

When decisions are made far away in a central office, they often do not fit the real needs of local communities. The prevailing "top-down" approach, with decisions often made centrally, creates a "mixture of frustration" and a disconnect between policy design and local needs, hindering effective fund absorption. Giving more power to local governments can ensure that the transition plan truly works for the people it is meant to help. This requires:

4.1. ***Decentralize decision-making:*** Shift towards a more "cooperative approach," empowering local authorities and communities with greater decision-making power over fund allocation and project implementation.

4.2. ***Strengthen regional transition committees:*** Ensure these multi-stakeholder bodies facilitate continuous and meaningful feedback from local communities, businesses, and citizens, bridging the "gap between politics... and the real economy".

4.3. ***Cultivate cross-sectoral cooperation:*** Actively promote collaboration between universities, research centers, local governments, chambers of commerce, NGOs, developmental agencies, and local authorities to bridge existing gaps and ensure policies are tailored to diverse local realities.

Recommendation #5

Tackling Water and Farming Challenges in Sparti, Laconia, and Water-Stressed Agricultural Regions

Sparti's challenges, particularly water scarcity and the aging agricultural workforce, offer a microcosm of broader climate adaptation issues in traditional rural economies. Water scarcity and agricultural issues are serious concerns, and addressing them is a key part of building a resilient economy.

5.1. Integrated water management solutions

5.1.1. Invest in modern infrastructure: Prioritize investment in modern water infrastructure, including repairing outdated pipelines (where 50% of water is lost), constructing new dams, reservoirs, and wells for water storage, and developing connected piping networks to efficiently distribute water to farms.

5.1.2. Promote smart water usage: Support widespread adoption of advanced

irrigation systems (e.g., drip irrigation) and smart technologies like soil moisture sensors for precision irrigation, optimizing water use and reducing waste.

5.1.3. Explore desalination viability: Conduct feasibility studies for small-scale desalination plants, powered by renewable energy, for inland agricultural use, addressing the distance barrier with new piping networks.

5.2. Promoting sustainable agricultural practices and youth engagement

5.2.1. Cultivate drought-resistant crops: Encourage the cultivation of drought-resistant crop varieties and practices that enhance soil water retention, building climate resilience.

5.2.2. Promote circular economy: Support the continued use of agricultural byproducts (e.g., olive oil liquid waste and black mud as fertilizer), demonstrating sustainable waste management and resource efficiency.

5.2.3. Make farming a career: Create attractive, professionalized agricultural roles with decent wages and working hours to appeal to younger generations, moving away from the perception of farming as an "unwanted job".

5.2.4. Support agro-tourism: Develop agro-tourism initiatives and local branding to diversify income streams and attract youth to rural areas by highlighting cultural heritage and high-quality local products.

Identified available funding tools

Each recommendation aligns with an existing funding tool or program:

- the JTF/JTM and ERDF for clean innovation,
- CAP/RDP for sustainable agriculture,
- ESF+ and RRF for training, and
- InvestEU/EIB for mobilizing private finance.

The analysis shows that combining these instruments in a coordinated strategy – tailored to regional strengths and weaknesses – will maximize the impact of investment. For example, EU guidance highlights how CAP modernization and Just Transition funds together can foster precision farming. The recommendations suggested by the stakeholders, combined with these concrete resources, could ensure that the post-lignite transition not only replaces lost jobs but also builds a competitive, tech-savvy rural economy.

JTF/JTM and ERDF for clean innovation

- Leverage the EU Just Transition Fund (JTF/JTM) for Regional "Agri-Tech Hubs".

- Use dedicated JTF allocations in Western Macedonia and Arcadia to establish living-lab centers of smart agriculture (as is already underway with the Megalopolis Bioeconomy Hub living labs).

These centers should demonstrate precision farming (e.g. hydroponics, drones, sensors) and offer hands-on training. They can attract private co-investment (via InvestEU or EIB loans) by showing proof-of-concept. For example, pending EU approval, a large hydroponics project in WM/Megalopolis is expected to be a "game changer". In Sparti, JTF funds could co-finance community irrigation projects and sensor networks, pairing with technical assistance from agricultural universities.

CAP/RDP for sustainable agriculture

Mobilize CAP and National Rural Development Funds for "Green Transition" in Agriculture. Reform the regional CAP Strategic Plan to prioritize Greece's lignite regions. For Sparti and Arcadia, CAP's new "Transition Packages" (as drafted in 2025) can subsidize technologies that improve water and climate resilience. Specifically, grants should cover precision irrigation systems, soil sensors, and drought-resistant crop trials. National rural development programs (e.g. Greece's National Recovery and Resilience Plan, and Rural Development Programme (RDP)) should earmark funds for agri-digitalization trainings. Leveraging CAP in this way aligns with EU reforms that explicitly reward farmers who reduce water use and invest in sustainability.

ESF+ and RRF for training

Expand Training & Reskilling Programs with EU Structural Funds. The European Social Fund Plus (ESF+) and national Just Transition skilling grants should target the cohorts most at risk of unemployment. In Western Macedonia, "dedicated skills development centers" (already planned) can offer curricula in ICT, robotics, and renewable-energy maintenance. In Megalopolis and Sparti, vocational programs should focus on agri-tech: for instance, certificate courses in greenhouse management, automation control, and digital farm accounting. Local universities and technical institutes can be funded to run these programs, drawing on the Just Transition and ERDF (European Regional Development Fund) budgets. Importantly, scholarships and housing support could be offered to attract rural youth back to training.

Support Youth Entrepreneurship through Financial Instruments

Encourage young entrepreneurs to stay by linking innovation grants to startup capital. The JDTP already provides subsidies and low-interest loans for SMEs. Expand these instruments by creating a dedicated "Green Youth Fund" for projects in smart agriculture and clean tech, using hybrid financing (e.g. mezzanine funds from EIB/InvestEU). For example, young agripreneurs could apply

for co-financing to pilot a farm-data SaaS startup or a renewable-powered agri-processor. Greek national grants (from the Development Law or Innovation Programs) should be explicitly made available for high- tech agricultural ventures in these regions.

InvestEU/EIB for mobilizing private finance

Integrate Bottom-Up Participation and Digital Literacy Campaigns. To ensure policies reach all stakeholders, local committees and development agencies should facilitate dialogue (e.g. follow the example of the newly formed Regional Transition Committees). These bodies can run awareness campaigns about funding opportunities (JTF, CAP, national) and organize hackathons or "agri-tech fairs" in rural areas. Digital literacy should be included in school curricula and community workshops. The University of Western Macedonia's "lifelong learning unit" model could be replicated in Arcadia to offer free AI/tech tutorials to farmers and officials. By democratizing knowledge and involving youth voices, such measures will address skepticism and stimulate innovation from the ground up.

Coordinate Infrastructure and Connectivity Upgrades. Recognize that AI and smart farming depend on physical infrastructure. Invest part of EU Cohesion funds and Just Transition resources in broadband internet for rural areas (so that smart devices and AI tools can function) and in upgrading irrigation/drainage where needed. In Sparti, for example, modern water pipelines and small-scale desalination units (with renewable power) were identified as priorities by olive farmers. Public–private partnerships with utility firms could deliver these projects, supported by EU climate adaptation grants.

Table 2: Overview of Fund Allocation and Impact on Small vs. Large Investors

Funding Source	Total Budget	Allocation Criteria (EU Level)	Allocation Criteria (National Level)	Impact on Small Investors	Impact on Large Investors	Proposed Solutions for Equity
EU Just Transition Fund (JTF)	€1.63 billion (Greece)	CO2 emissions, jobs at risk, GDP per capita, population size	Economic dependence on fossil fuels, population loss, diversification potential, environmental conditions	High bureaucratic hurdles, difficulty accessing funds, co-financing challenges, delays in fund absorption, risk of being overlooked for rapid fund absorption	Better equipped to navigate bureaucracy, can absorb initial costs/delays, favored for large-scale projects (e.g., photovoltaics, data centers) for quicker fund absorption	Streamlined application processes, direct assistance, risk-sharing with banks, dedicated "Green Youth Fund," community-owned projects
European Regional Development Fund (ERDF)	Part of JTF framework	Regional development needs	Infrastructure, innovation, SME support	Limited access due to complexity	Favored for larger infrastructure projects	Simplified procedures, targeted support for SMEs
European Social Fund Plus (ESF+)	Part of JTF framework	Human capital development	Skills development, employment support	Benefits from training programs, but job creation may lag	Less direct impact, but benefits from skilled workforce	Scholarships, housing support for trainees, linking training to local job opportunities
Recovery and Resilience Facility (RRF)	Part of national plans	Green transition, digital transformation	Specific national priorities	Indirect benefits from overall economic recovery	Significant beneficiaries of large-scale green/digital investments	Ensure local supply chain integration, promote local entrepreneurship
National Contributions	Variable	National strategic alignment	Complement EU funds	Often insufficient or difficult to access without EU co-funding	Can leverage for strategic national projects	Increase national co-financing for small projects, reduce administrative burden
InvestEU/EIB Loans	Variable	Investment mobilization	Private sector engagement	Limited access due to risk aversion from banks	Primary targets for large-scale, de-risked projects	Develop blended finance instruments, support cooperative models

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Appendix

Appendix A – Figures

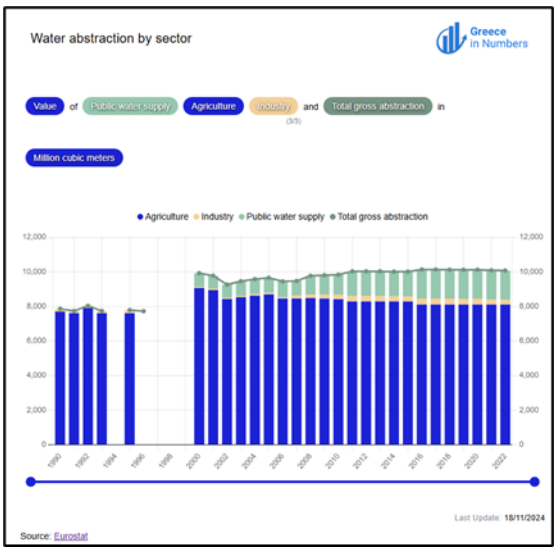


Figure 1: Illustrates that the agriculture sector is the biggest consumer of water during the period from 1990 to 2022.

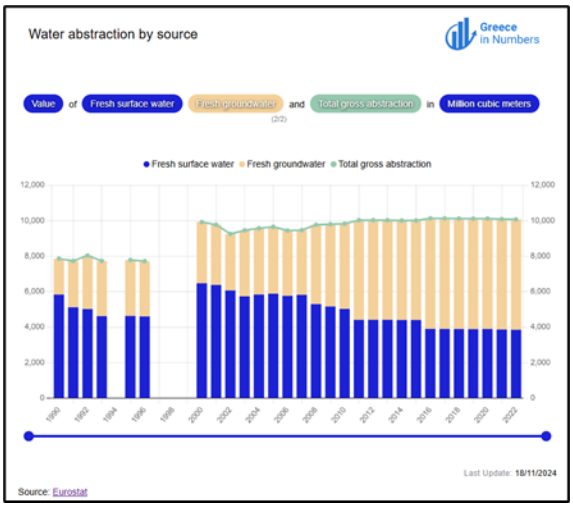
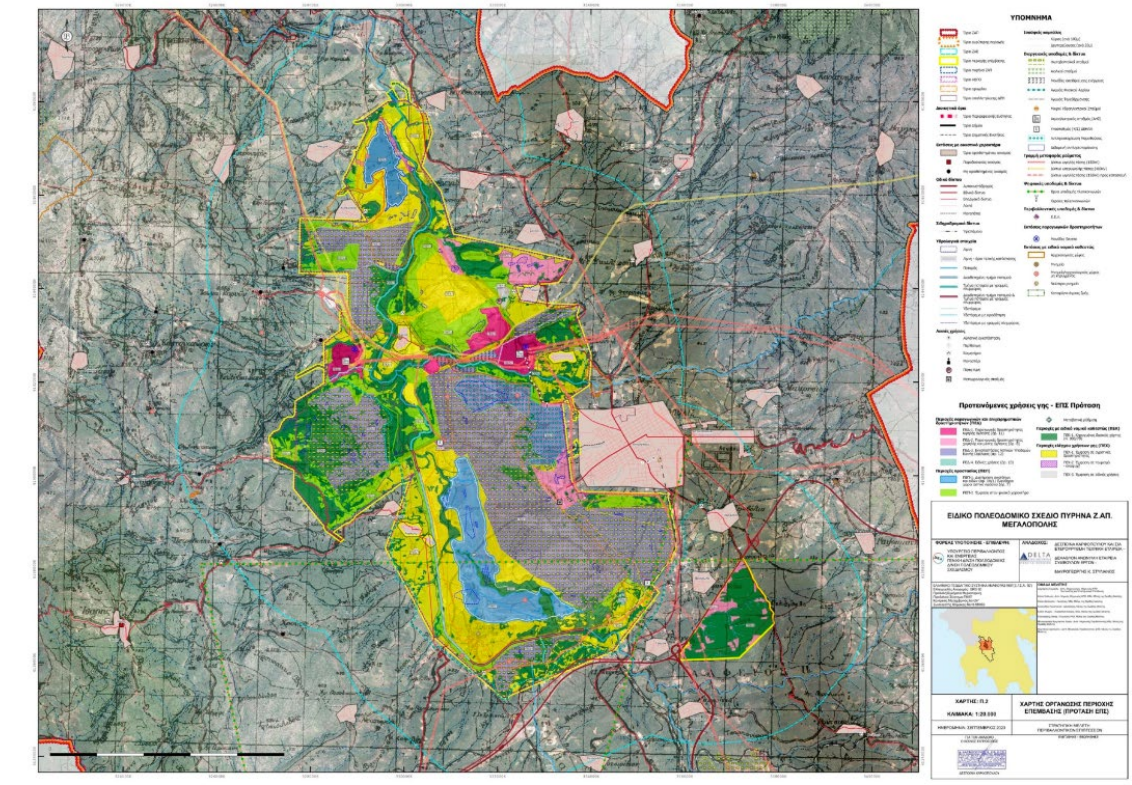


Figure 2: Depicts the increase of groundwater abstraction from 1990 to 2022.



Πηγή: επεξεργασία Ομάδα μελέτης

Figure 3: Illustrates land redistribution plans in the Megalopolis mining area

Social Climate Fund:	€4.7 billion
Just Transition Fund:	€1.63 billion
Modernisation Fund:	€1.6 billion
Island Decarbonisation Fund:	€1.7 billion
Innovation Fund:	€160 million
State Aid for Renewable Projects	€1 billion
Recovery and Resilience Facility	€1.5 billion

Figure 4: Funds for energy transition and their amounts

Appendix B – Interview Questions:

#1.MEDIA

Κύρια Θέματα: Πολιτική, οικονομική διαφοροποίηση, υποδομές, αποδοχή από το κοινό

Ενδεικτικές Ερωτήσεις:

1. Πώς έχει επηρεάσει η ενεργειακή μετάβαση τις αναπτυξιακές προτεραιότητες της περιοχής σας;
2. Με ποιους τρόπους θα μπορούσε η ΤΝ να συμβάλει στη βιώσιμη γεωργία (π.χ. διαχείριση νερού, έξυπνη καλλιέργεια) και στις περιβαλλοντικές δράσεις (π.χ. παρακολούθηση ρύπανσης, αποκατάσταση εδαφών);
3. Πώς μπορεί η ΤΝ να προωθήσει την ενεργειακή ασφάλεια (π.χ. έξυπνα δίκτυα, ενσωμάτωση ΑΠΕ);
4. Ποια είναι τα μεγαλύτερα εμπόδια για την υιοθέτηση της ΤΝ στην περιοχή σας; Τι είδους υποστήριξη ή πόροι θα διευκόλυναν την υιοθέτηση;
5. Πώς μπορεί η ΤΝ να δημιουργήσει νέες θέσεις εργασίας ή να βελτιώσει το βιοτικό επίπεδο στην ύπαιθρο και να διευκολύνει μια δίκαιη μετάβαση;

Questions:

1. How has the energy transition affected the development priorities of your region?
2. In what ways could AI contribute to sustainable agriculture (e.g., water management, smart farming) and environmental operations (e.g., pollution monitoring, land rehabilitation)?
3. In what ways could AI promote energy security (e.g., smart grids, renewable integration)?
4. What are the biggest challenges or barriers to adopting AI in your region? What type of support or resources would facilitate easier adoption?
5. How can AI create new jobs or increase rural living standards and facilitate an equitable transition?

#2. Agricultural Businesses / Farms / Forests' representatives

Ενδεικτικές Ερωτήσεις:

1. Πώς έχει επηρεάσει η ενεργειακή μετάβαση τη γεωργική σας δραστηριότητα; Ποιες είναι
οι μεγαλύτερες καθημερινές σας προκλήσεις;
2. Ποια είναι η άποψή σας για τη χρήση εργαλείων ΤΝ (π.χ. αισθητήρες, drones, ανάλυση
δεδομένων) για την αύξηση της παραγωγικότητας και της βιωσιμότητας;
3. Τι είδους υποστήριξη ή εκπαίδευση θα σας επέτρεπε να εφαρμόσετε τεχνολογίες ΤΝ;
4. Πώς βλέπετε την επίδραση της ΤΝ στην αγροτική εργασία ή στις τοπικές αγορές τροφίμων;
5. Ποιες ανησυχίες έχετε σχετικά με τη χρήση της ΤΝ στο αγρόκτημά σας;
6. Πώς επηρεάζουν η τρέχουσα διαθεσιμότητα νερού και οι πρακτικές διαχείρισής του την
παραγωγικότητα και τη μακροπρόθεσμη βιωσιμότητα της φάρμας σας, ειδικά λαμβάνοντας υπόψη τη συνεχιζόμενη ενεργειακή μετάβαση στην περιοχή σας;
7. Με ποιους συγκεκριμένους τρόπους πιστεύετε ότι τα εργαλεία ή οι τεχνολογίες τεχνητής
νοημοσύνης θα μπορούσαν να σας βοηθήσουν να βελτιστοποιήσετε τη χρήση του νερού,
να παρακολουθείτε πιο αποτελεσματικά τους υδάτινους πόρους ή να αντιμετωπίσετε προκλήσεις που σχετίζονται με το νερό στη φάρμα σας;

Questions:

1. In what ways has the energy transition impacted your agricultural activity? What are your
biggest daily challenges?
2. What do you think about using AI tools (e.g., sensors, drones, data analysis) to boost productivity and sustainability?
3. What kind of support or training would allow you to apply AI technologies?
4. How do you see AI impacting farm labor or local food markets?
5. What concerns do you have regarding the use of AI on your farm?
6. How do current water availability and management practices impact your farm's productivity
and long-term sustainability, especially considering the ongoing energy transition in your region?
7. In what specific ways do you believe AI tools or technologies could help you optimize water
usage, monitor water resources more effectively, or address water-related challenges on your
farm?

#3. Environmental Organizations

Ενδεικτικές Ερωτήσεις:

1. Ποια είναι τα πιο επείγοντα περιβαλλοντικά ζητήματα που σχετίζονται με την ενεργειακή
μετάβαση στις περιοχές αυτές;
2. Πώς μπορεί η ΤΝ να ενισχύσει την περιβαλλοντική παρακολούθηση, την αποκατάσταση
οικοσυστημάτων και τις προσπάθειες προσαρμογής στην κλιματική αλλαγή;
3. Ποιοι είναι οι πιθανοί περιβαλλοντικοί κίνδυνοι ή ηθικές ανησυχίες που σχετίζονται με
την ευρεία χρήση της ΤΝ;
4. Πώς μπορεί η ΤΝ να ενδυναμώσει τις τοπικές κοινότητες στην περιβαλλοντική διαχείριση;
5. Ποιες ερευνητικές ή πολιτικές ενέργειες είναι απαραίτητες για τη μεγιστοποίηση των
οφελών της ΤΝ για την οικολογική βιωσιμότητα;

Questions:

1. What are the most pressing environmental issues related to the energy transition in these
regions?
2. How can AI enhance environmental monitoring, ecosystem restoration, and climate adaptation
efforts?
3. What potential environmental risks or ethical concerns are associated with large-scale AI
deployment?
4. How can AI empower local communities in environmental stewardship?
5. What research or policy actions are necessary to maximize AI's benefits for ecological
sustainability?

#4. Local Government & Regional Development

Ενδεικτικές Ερωτήσεις:

1. Πώς έχει επηρεάσει η ενεργειακή μετάβαση τις αναπτυξιακές προτεραιότητες της περιοχής σας;
2. Με ποιους τρόπους θα μπορούσε η ΤΝ να συμβάλει στη βιώσιμη γεωργία (π.χ. διαχείριση νερού, έξυπνη καλλιέργεια) και στις περιβαλλοντικές δράσεις (π.χ. παρακολούθηση ρύπανσης, αποκατάσταση εδαφών);
3. Πώς μπορεί η ΤΝ να προωθήσει την ενεργειακή ασφάλεια (π.χ. έξυπνα δίκτυα, ενσωμάτωση ΑΠΕ);
4. Ποια είναι τα μεγαλύτερα εμπόδια για την υιοθέτηση της ΤΝ στην περιοχή σας; Τι είδους υποστήριξη ή πόροι θα διευκόλυναν την υιοθέτηση;
5. Πώς μπορεί η ΤΝ να δημιουργήσει νέες θέσεις εργασίας ή να βελτιώσει το βιοτικό επίπεδο στην ύπαιθρο και να διευκολύνει μια δίκαιη μετάβαση;

Questions:

1. How has the energy transition affected the development priorities of your region?
2. In what ways could AI contribute to sustainable agriculture (e.g., water management, smart farming) and environmental operations (e.g., pollution monitoring, land rehabilitation)?
3. In what ways could AI promote energy security (e.g., smart grids, renewable integration)?
4. What are the biggest challenges or barriers to adopting AI in your region? What type of support or resources would facilitate easier adoption?
5. How can AI create new jobs or increase rural living standards and facilitate an equitable transition?

#5. Geotechnical Chamber of Greece

Ερωτήσεις:

1. Πώς εκτιμάτε ότι η ενεργειακή μετάβαση επηρεάζει ή αναμένεται να επηρεάσει τον αγροτικό τομέα στην Κοζάνη; Ποιες είναι οι κύριες προκλήσεις και ευκαιρίες που αναγνωρίζετε από την οπτική γωνία του Γεωτεχνικού Επιμελητηρίου;
2. Ποια είναι η θέση του Γεωτεχνικού Επιμελητηρίου σχετικά με την υιοθέτηση και εφαρμογή εργαλείων Τεχνητής Νοημοσύνης (π.χ. αισθητήρες, drones, ανάλυση γεωχωρικών δεδομένων) για τη βελτίωση της παραγωγικότητας, της αποδοτικότητας των
πόρων και της περιβαλλοντικής βιωσιμότητας στη γεωργία της περιοχής;
3. Τι είδους θεσμικές παρεμβάσεις, πολιτικές υποστήριξης ή προγράμματα εκπαίδευσης/κατάρτισης θεωρείτε απαραίτητα για να διευκολυνθεί η ενσωμάτωση τεχνολογιών Τεχνητής Νοημοσύνης από τους αγρότες και τους επαγγελματίες του αγροτικού τομέα στην Κοζάνη;
4. Πώς προβλέπετε ότι η εκτεταμένη χρήση της Τεχνητής Νοημοσύνης θα επηρεάσει το
επάγγελμα του γεωτεχνικού και τις υπηρεσίες που παρέχονται στον αγροτικό τομέα;
Υπάρχουν νέοι ρόλοι ή εξειδικεύσεις που αναδύονται;
5. Ποιες είναι οι κύριες ανησυχίες ή οι δυνητικοί κίνδυνοι που διαβλέπετε από τη χρήση της
Τεχνητής Νοημοσύνης στον αγροτικό τομέα, όσον αφορά για παράδειγμα την ιδιοκτησία
δεδομένων, την πρόσβαση σε τεχνολογία ή τις κοινωνικοοικονομικές επιπτώσεις στην
αγροτική κοινότητα;

Questions:

1. How do you assess the impact of the energy transition on the agricultural sector in Kozani,
or how do you expect it to impact it? What are the main challenges and opportunities you
identify from the perspective of the Geotechnical Chamber?
2. What is the Geotechnical Chamber's position regarding the adoption and implementation
of Artificial Intelligence tools (e.g., sensors, drones, geospatial data analysis) to improve
productivity, resource efficiency, and environmental sustainability in the region's agriculture?
3. What kind of institutional interventions, support policies, or training/education programs

do you consider necessary to facilitate the integration of Artificial Intelligence technologies
by farmers and agricultural professionals in Kozani?
4. How do you foresee the extensive use of Artificial Intelligence impacting the geotechnical
profession and the services provided to the agricultural sector? Are new roles or specializations emerging?
5. What are the main concerns or potential risks you foresee from the use of Artificial
Intelligence in the agricultural sector, for example, regarding data ownership, access to
technology, or socio-economic impacts on the rural community?

#6. Chamber of Commerce

Ερωτήσεις:

1. Πώς βλέπετε ότι η ενεργειακή μετάβαση επηρεάζει το συνολικό επιχειρηματικό οικοσύστημα και την οικονομική ανάπτυξη στην Κοζάνη, πέρα από τον αγροτικό τομέα;
Ποιες νέες επιχειρηματικές ευκαιρίες ή προκλήσεις αναδύονται;
2. Από την οπτική γωνία του Επιμελητηρίου, ποιες είναι οι πιο υποσχόμενες δυνατότητες με
τις οποίες η Τ.Ν. θα μπορούσε να βοηθήσει τις τοπικές επιχειρήσεις – σε διάφορους τομείς
όπως ο τουρισμός, το ηλεκτρονικό εμπόριο ή οι τοπικές υπηρεσίες – να αναπτυχθούν, να
καινοτομήσουν και να παραμείνουν ανταγωνιστικές κατά τη διάρκεια αυτής της μετάβασης;
3. Ποιος ρόλος μπορεί να διαδραματίσει το Επιμελητήριο στην προετοιμασία του τοπικού
εργατικού δυναμικού και των επιχειρήσεων για να αξιοποιήσουν τις ευκαιρίες της Τ.Ν.;
Ποιες συγκεκριμένες δεξιότητες ή προγράμματα κατάρτισης πιστεύετε ότι είναι πιο κρίσιμα για τα μέλη σας, ώστε να υιοθετήσουν αποτελεσματικά τις τεχνολογίες Τ.Ν.;
4. Ποια είναι τα κύρια συστημικά ή πολιτικά εμπόδια που αποτρέπουν τις επιχειρήσεις στην
Κοζάνη από την υιοθέτηση ή ενσωμάτωση τεχνολογιών Τ.Ν.; Πώς μπορεί το Επιμελητήριο να συνηγορήσει υπέρ πολιτικών που προωθούν ένα πιο φιλικό προς την Τ.Ν.
επιχειρηματικό περιβάλλον;
5. Πέρα από τον άμεσο επιχειρηματικό αντίκτυπο, πώς θα μπορούσε η ευρεία υιοθέτηση της
Τ.Ν. να συμβάλει στη βελτίωση της πρόσβασης σε υπηρεσίες, στην ενίσχυση της καινοτομίας και στη συνολική βελτίωση της ποιότητας ζωής για τους κατοίκους και την
ευρύτερη κοινότητα στην Κοζάνη;

Questions:

1. How do you see the energy transition impacting the overall business ecosystem and
economic development in Kozani, beyond just the agricultural sector? What new business
opportunities or challenges are emerging?
2. From the Chamber's perspective, what are the most promising ways AI could help local

businesses - across various sectors like tourism, e-commerce, or local services - to grow,
innovate, and remain competitive during this transition?
3. What role can the Chamber play in preparing the local workforce and businesses to
leverage AI opportunities? What specific skills or training programs do you believe are
most critical for their members to adopt AI technologies effectively?
4. What are the primary systemic or policy-related barriers that hinder businesses in Kozani
from adopting or integrating AI technologies? How can the Chamber advocate for policies
that foster a more AI-friendly business environment?
5. Beyond direct business impact, how could the widespread adoption of AI contribute to
improving access to services, fostering innovation, and enhancing the overall quality of life
for residents and the broader community in Kozani?

#7. Regional Government

Ερωτήσεις:

1. Πώς έχει ενσωματωθεί η ενεργειακή μετάβαση στις ευρύτερες αναπτυξιακές στρατηγικές
και προτεραιότητες της Περιφέρειας; Ποιες είναι οι βασικές προκλήσεις και ευκαιρίες που
αναγνωρίζετε σε περιφερειακό επίπεδο;
2. Με ποιους συγκεκριμένους τρόπους μπορεί η Περιφέρεια να αξιοποιήσει την Τ.Ν. για την
προώθηση της βιώσιμης γεωργίας (π.χ. διαχείριση υδάτων, έξυπνη καλλιέργεια) και την
ενίσχυση των περιβαλλοντικών δράσεων (π.χ. παρακολούθηση ρύπανσης, αποκατάσταση
εδαφών) εντός της αρμοδιότητάς της;
3. Πώς μπορεί η Τ.Ν. να συμβάλει στην ενίσχυση της ενεργειακής ασφάλειας και στην
αποτελεσματικότερη ενσωμάτωση των Ανανεώσιμων Πηγών Ενέργειας (ΑΠΕ) στα
ενεργειακά δίκτυα της Περιφέρειας; Ποιοι είναι οι σχετικοί τομείς παρέμβασης για την
Περιφερειακή Αρχή;
4. Ποια θεωρείτε ότι είναι τα σημαντικότερα θεσμικά, οικονομικά ή τεχνολογικά εμπόδια για
την ευρεία υιοθέτηση της Τ.Ν. σε όλη την Περιφέρεια; Τι είδους υποστηρικτικές πολιτικές,
χρηματοδοτικά εργαλεία ή συνεργασίες θα μπορούσε να αναπτύξει η Περιφέρεια για τη
διευκόλυνση αυτής της υιοθέτησης;
5. Πώς μπορεί η Περιφερειακή Αρχή, μέσω της αξιοποίησης της Τ.Ν., να διασφαλίσει τη
δημιουργία νέων θέσεων εργασίας, τη βελτίωση του βιοτικού επιπέδου στην ύπαιθρο και
τη διαχείριση μιας δίκαιης μετάβασης για τις τοπικές κοινωνίες που επηρεάζονται από την
ενεργειακή αλλαγή;

Questions:

1. How has the energy transition been integrated into the broader development strategies and
priorities of the Region? What are the key challenges and opportunities you identify at a
regional level?

2. In what specific ways can the Region leverage AI to promote sustainable agriculture (e.g.,
water management, smart farming) and enhance environmental actions (e.g., pollution
monitoring, soil restoration) within its jurisdiction?
3. How can AI contribute to strengthening energy security and more effectively integrating
Renewable Energy Sources (RES) into the Region's energy grids? What are the relevant
areas of intervention for the Regional Authority?
4. What do you consider to be the most significant institutional, economic, or technological
barriers to the widespread adoption of AI across the Region? What kind of supportive
policies, funding instruments, or collaborations could the Region develop to facilitate this
adoption?
5. How can the Regional Authority, through the utilization of AI, ensure the creation of new
jobs, the improvement of living standards in rural areas, and the management of a just
transition for local communities affected by energy changes?

#8. University

Ερωτήσεις:

1. Ποια, κατά την άποψή σας, είναι τα κρίσιμα περιβαλλοντικά και κοινωνικοοικονομικά
ζητήματα που αναδύονται από την ενεργειακή μετάβαση στην περιοχή της Δυτικής Μακεδονίας και πώς μπορεί το Πανεπιστήμιο να συμβάλει στην κατανόηση και αντιμετώπισή τους;
2. Με ποιους τρόπους μπορεί το Πανεπιστήμιο να αξιοποιήσει την Τ.Ν. και τις ερευνητικές
του δυνατότητες για να ενισχύσει την περιβαλλοντική παρακολούθηση, την αποκατάσταση οικοσυστημάτων και τις στρατηγικές προσαρμογής στην κλιματική αλλαγή, ιδίως στον αγροτικό τομέα;
3. Ποιες είναι οι κύριες ηθικές, κοινωνικές ή διακυβερνητικές προκλήσεις που προβλέπετε
από την ευρεία εφαρμογή της Τ.Ν. σε περιβαλλοντικά και αναπτυξιακά πλαίσια, και πώς
μπορεί το Πανεπιστήμιο να συμβάλει στον διάλογο και την ανάπτυξη υπεύθυνων πρακτικών;
4. Πώς μπορεί το Πανεπιστήμιο να διαδραματίσει ενεργό ρόλο στην ενδυνάμωση των
τοπικών κοινοτήτων, των φορέων και των επιχειρήσεων μέσω της εκπαίδευσης, της κατάρτισης και της μεταφοράς τεχνογνωσίας στην εφαρμογή της Τ.Ν. για βιώσιμη ανάπτυξη;
5. Ποιες είναι οι απαραίτητες ερευνητικές κατευθύνσεις, διεπιστημονικές συνεργασίες ή
εκπαιδευτικά προγράμματα που πρέπει να αναπτύξει το Πανεπιστήμιο για να μεγιστοποιήσει τα οφέλη της Τ.Ν. για την οικολογική βιωσιμότητα και τη δίκαιη αγροτική
ανάπτυξη;

Questions:

1. In your opinion, what are the critical environmental and socioeconomic issues emerging
from the energy transition in the Western Macedonia region, and how can the University
contribute to understanding and addressing them?
2. In what ways can the University leverage AI and its research capabilities to enhance
environmental monitoring, ecosystem restoration, and climate change adaptation
strategies, particularly in the agricultural sector?

3. What are the main ethical, social, or governance challenges you foresee from the
widespread application of AI in environmental and developmental contexts, and how can
the University contribute to the dialogue and the development of responsible practices?
4. How can the University play an active role in empowering local communities,
stakeholders, and businesses through education, training, and the transfer of know-how in
applying AI for sustainable development?
5. What are the necessary research directions, interdisciplinary collaborations, or educational
programs that the University should develop to maximize the benefits of AI for ecological
sustainability and equitable rural development?

Questions for the Special Management Authority for Energy Transition

1. What is the Just Transition Development plan?
- Why Greece is needed?
- Main Government structure-components
- Areas that covers

2. Could you please elaborate on incentives and funding plan?

3. We have seen and heard of a population decline and a trend of older workers in the regions we've studied. What specific measures are being implemented to address the population decline in regions like Western Macedonia and Megalopolis?

4. Are funds being allocated to support the transition from traditional to also to smart farming practices?

5. Many people we've talked to consistently have mentioned the top-down approach being taken by the national government and are looking for a bottom-up approach. What mechanisms exist for local communities to provide direct feedback like this on the effectiveness of the fund allocation?

6. A trend in our research has been a brain drain from rural areas in Greece as well as smaller cities such as Tripoli, Megalopolis and Kozani. What funding instruments are dedicated to creating high-skilled jobs that would appeal to younger generations who have left the region?

7. What factors play into the division of funded money how does your department decide where it goes ?(population, GDP, water availability)

8. What are the most common challenges you hear from citizens in areas facing de-ignition

9. What does the timeline for coal phase out to renewable energy's looks like? Is this timeline feasible?