Western Macedonia region, Greece

Web INTEractive management tool for coal Regions in transition

WINTER

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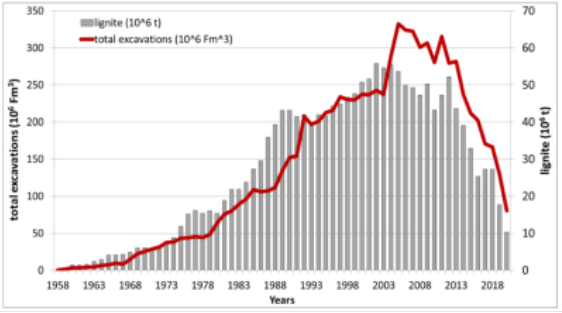
Western Macedonia region

Western Macedonia is a region in North-western Greece with a population of 255,000, with its

economy largely dominated by lignite mining and lignite-fired power plants and district heating systems. Since 2010, there has been a constant decrease in lignite-fired power plants (the four oldest ones have ceased operation). That decrease has accelerated since 2019, triggered by the increased Emissions Trading System (ETS) carbon price which increased the costs to produce lignite-based electricity, combined with policies to promote the use of renewable energy and natural gas.

Western Macedonia region.

The region of West Macedonia covers an area of 9,471km^2 and has a population of approximately 255,000 people. Of those, 88,000 people are employed, and the unemployment rate is currently at 19.8%. The total GDP was reported in 2019 as 4 million € . West Macedonia produces 25.6 million tons of coal per year. The total capacity of installed renewable energy sources is 880MW. Renewable energy sources currently installed include photovoltaics, hydropower, wind energy and biomass. Energy from renewable sources currently makes up less than 38% of the share of power consumed.



Its economy is largely dominated since the 1950's by lignite mining and lignite-fired power plants and district heating systems. Since 2010, there has been a constant decrease in lignite production (the four oldest plants have ceased operation) which has accelerated since 2019. This was triggered by the increase Emissions Trading System (ETS) carbon price which increased the costs to produce lignite-based electricity, combined with policies to promote the use of renewable energy and natural gas.

In 2019, the Greek Government as part of its National Energy and Climate Plan set the goal of a full lignite phase-out by 2028; only one plant will continue to operate until 2028 and is still under construction. Throughout the decarbonisation effort, a central priority is to ensure a fair development transition of the lignite areas of Western Macedonia which is based on three pillars: employment protection, compensation of the socio-economic impact of the transition and energy self-sufficiency of lignite areas and the country at large. To address the socio-economic implications of the rapid lignite phase-out, the Greek Government published, following public consultation, a Master Plan for the Just Development Transition (JDTP) in December 2020.

According to the Master plan, the vision for the “next day” in Western Macedonia is based on five principles:

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

Spatiotemporal evolution of Ptolemaida - Amynteo open pit coal mines, West Macedonia (1984-2022).

Legal Framework

Rehabilitation Legislation

In Greece, the environmental licensing legislation is the basis for all mining, rehabilitation/reclamation works and implementation of future land uses in post mining areas. The main tools for environmental licensing are Environmental Impact Assessment studies and the subsequently issued Environmental Terms Approval Decisions, mainly defined by the Environmental Licensing law. The Mining Code is also instrumental in terms of mine rehabilitation.For mining projects in general, the operator in obliged by the legislation to plan, implement, supervise and fund all reclamation works carried out during and after operation.

Amynteo pit lake.

The same applies to the Delignification Zones in Greece, such as Western Macedonia, where PPC S.A. is the operator. The reclaimed lands are then to be transferred to the State, and the in the case of Western Macedonia they will be transferred to METAVASI S.A., a public company that will then manage their uses (unless they remain to PPC S.A. for future use). All these processes are documented in the relevant recent laws on transition and delignitisation.

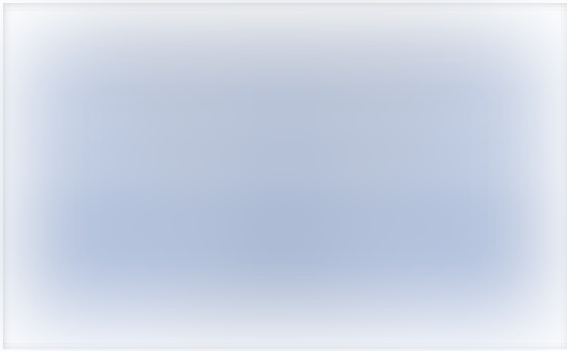
Renewable Energy Sources

In Greece, great effort has been made to apply clean energy technologies as a means of energy production, so as to facilitate the Transition and ensure the country's energy security and efficiency. In this light, many RES projects are being planned and some have already been installed in

regions in Transition (“Delignification Zones”). The Greek legal framework includes a variety of spatial criteria for RES installation, especially for wind farms and solar parks.RES installation in former lignite mining areas is a very important part of the current transition legislation. The approval of environmental terms and the installation and operation licenses are processed with absolute priority by the licensing authorities.

Western Macedonia Solar Park I.

The following flow diagram now includes arrows to effectively illustrate the sequential steps involved in the Rehabilitation Legislation process in Greece. Each step is visually connected, emphasizing thedirectional flow from the initial environmental licensing for mining projects to the final integration of renewable energy sources (RES) in post-mining areas. This graphical representation provides a clear and structured view of the legislation's process.



Flow diagram: Rehabilitation Legislation in Greece.

Mine Rehabilitation and Reclamation Showcase

One of the main objectives of WINTER is the identification of best practices regarding various environmental and social aspects of coal transition, such as rehabilitation, reclamation and repurposing strategies of former coal mining areas. The consortium collected information from various examples from all the study areas of the project, namely Western Macedonia, Konin region and Ruhr area as well as other former mining areas, regarding past, current and planned rehabilitation and reclamation work and its environmental, social and economic benefits for each area. Different categories of post-mining land uses were also identified. Below are presented the most prominent examples of post-mining land uses of former coal mines in Greece, Poland and Germany.

Explore the reclaimed sites in the Western Macedonia region and other reclaimed areas around Greece.

Lignite Centre of Western Macedonia (LCWM)

PPC has reforested many old mine areas in LCWM mainly with Robinia pseudacacia L., or black locust (Basnou, 2016). The plantations started more than 30 years ago covering more than 1,500 ha with average density 2,000 trees/ha. The choice of the black locust, despite the fact that is a non-native, highly criticised species has been characterised as an excellent one for restoring damaged soils and its fast-growing nature makes it popular for former lignite mine reclamation, reforestation and erosion control (Papadopoulou et al., 2018), therefore constitutes **best practice** in terms of land rehabilitation of former lignite mining areas.

Ptolemaida

The reclamation work is ranging up to 20,000 acres of plantations with resilient forest species, 14,000 acres of areas for agricultural cultivation granted to local farmers for exploitation, 6,000 acres for other uses (e.g. exhibition centre, artificial wetland, railway history park).

The planned post-mining land uses will be related with wood production forest lands, livestock zones, more agricultural lands, artificial lakes, motor cross sports centre, innovation zone and RES (PV projects).

Innovative practices

Apart from the cultivation of crops, a pilot greenhouse for hydroponic cultivations was created, using teleheating run. A model orchard was also developed in the internal deposition area of the Main Field mine containing apple trees, pear trees, plum trees, cherry trees and other species, as well as a vineyard for the purpose of demonstrating to the local farmers of the region the possibility of developing agricultural activities with increased added value (PPC, 2009).

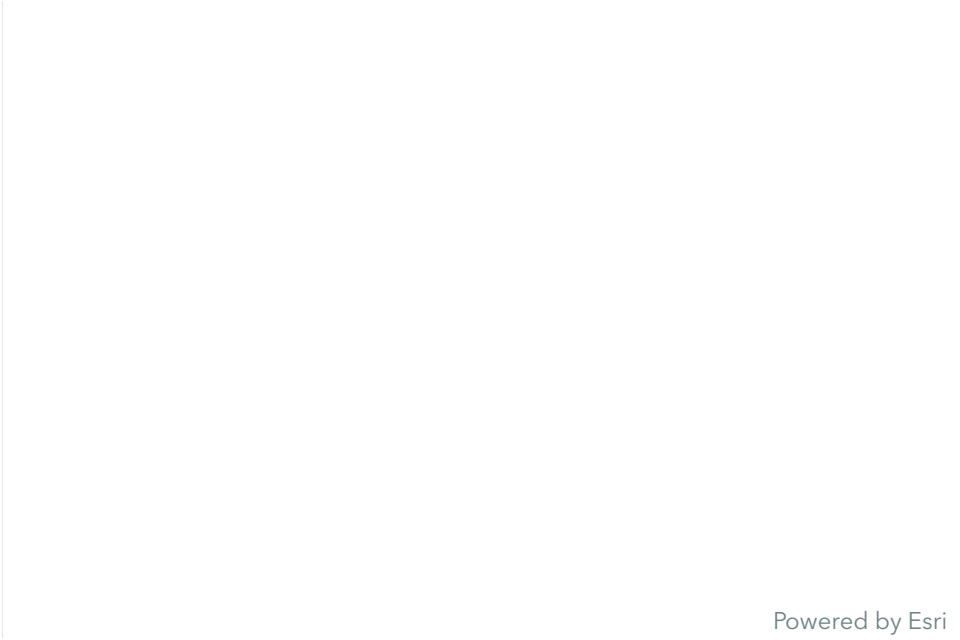
Orchard in the area of the Main Field mine.

Rehabilitation and reclamation works

According to data from the European project CORINE, the

spatial distribution of land use changes in the Ptolemaida mining area suggest that reforestation is the main rehabilitation activity.

In particular, in 1990 the CORINE category “Forests and semi-natural areas” occupied 4.5 km^2 in 1990 and 19.5 km^2 in 2018, indicating an increase in reforested areas of 330% (Torma et al. 2015).

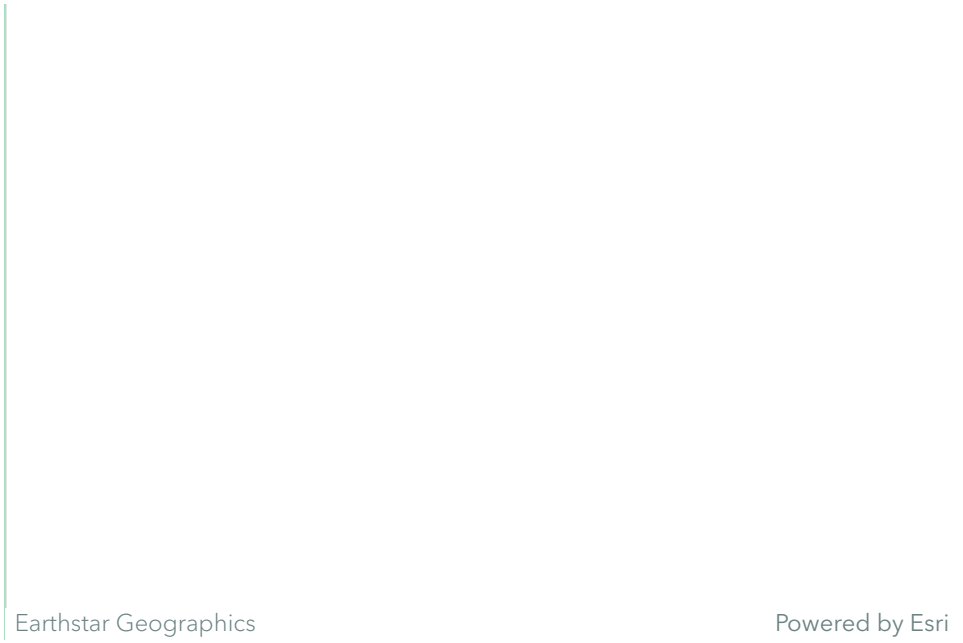


Location of the reforested area in Ptolemaida.

Photovoltaic projects

Three Photovoltaic projects with a total capacity of 230 MW are under construction in Ptolemaida by Public Power Corporation Renewables, with some parts already completed. Western Macedonia Solar Parks I & II will have 14.99 MW power each, with an estimated annual production of 21 GWh each.

Solar Park I will be constructed on a surface of 312,745 km^2 on lignite dumps in the northern part of the Western Macedonia Lignite Centre, on the Paliampela site, while Solar Park II will be constructed on a surface of 300,000 km^2 on the Kardia mine dump, on Ksiropotamos site. The third project, Solar Arrow 1 will have 200 MW power (PPC Renewables,2022).



Location of the photovoltaic parks.

Amynteo

Following the closure and dewatering of the mines of the

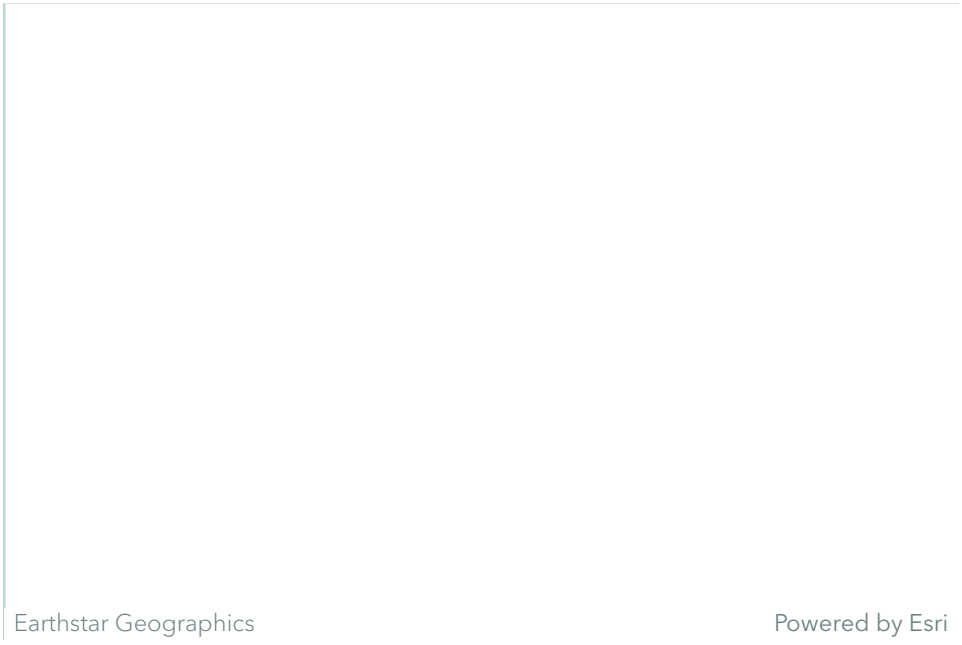
Amynteo mining area, water was allowed to fill the areas between the excavated slopes and the internal waste dumps naturally (Louloudis et al., 2022). Thus, a pit lake has been created in the Amynteo mine, with an area of 0.40 km^2.

Other works include the transportation of spoils form the Lakkia mine for the environmental reclamation of theAmynteo and Anargyroi mines; currently an 8 km^2 area has been reforested and 1 km^2 has been reclaimed for agricultural use (Kavvadas et al., 2022).

Planned post-mining land uses will be related with more pit lakes in former mines and RES projects (mainly photovoltaic parks).

The Amynteo pit lake

Following the closure and dewatering of the mines of the Amynteo mining area, water was allowed to fill the areas between the excavated slopes and the internal waste dumps naturally (Louloudis et al., 2022). Thus, a pit lake has been created in the Amynteo mine, with an area of 0.40 km^2. The lake is recharged by precipitation and the surface runoff of the pit walls. The surface water rising rate has been estimated to at least 10 m/year (Louloudis et al., 2020; Sakellari et al., 2021).



Location of the Amynteo pit lake.

Reclaimed areas for agricultural use

Other works include the transportation of spoils form the Lakkia mine for the environmental reclamation of the Amynteo and Anargyroi mines; currently an 8 km^2 area has been reforested and 1 km^2 has been reclaimed for agricultural use (Kavvadas et al., 2022).

Agricultural land near to Amynteo mine.

Lignite Centre of Megalopolis (LCM)

The reclamation works of the Megalopolis mine are related

with the reforestation of external deposits of Thoknia and Choremi mines, and two pit lakes (Kyparissia and Marathoussa mines). Particularly, total reforested areas of 4,300 acres, agricultural lands of 2,300 acres, and 1,700 acres to special projects (e.g. visitor centre, recreational park, artificial wetlands, motor cross track).

Planned post- mining land use will focus at the creation of a pit lake at Choremi mine, more agricultural and livestock lands, timber production, industrial park at external deposits of Marathoussa mine, development and protection of archaeological sites, and 2 PV projects.

Rehabilitation and reclamation work

The rehabilitation and reclamation work that are already completed in the LCM are (PPC, 2009) an LCM visitor centre, a

recreational park where events in collaboration with the Municipality of Megalopolis are hosted, featuring a grove, a playground and playing fields, artificial wetlands ***(click to zoom in)*** (artificial lakes, some of which have been filled with fish), a motor cross track ***(click to zoom in)*** , declared as model track by international organisations, that hosts international races on a regular basis, and a runway for ultra-light aircrafts ***(click to zoom in)***.

Installation of RES

The PPC Renewables SA has licenced the construction of a 50 MW photovoltaic power station in an area of deposited heaps of the LCM. The project also incorporates tree plantings and the construction of 2 ponds serving as wetlands (Sokratidou et al., 2018). Accordingly, two PV projects are currently under construction in Megalopolis, Arkadikos Ilios 1 ***(click to zoom in)*** and Arkadikos Ilios 2

(click to zoom in) with power of 39 MW and 11 MW respectively (PPC Renewables, 2022).

Spatiotemporal evolution

Western Macedonia region

Based on the quantification of CLC products in the Western Macedonia region, an evaluation of spatiotemporal changes was conducted for all main classes during the period from 1990 to 2018. In particular, in terms of relative change, the percentage of agricultural areas decreased by up to 7.03%, while the urban sub-categories (Industrial, Commercial, and Transport Units; Mines, Dumps, and Construction Sites; Urban Fabric) increased by a total of 101.35%. Additionally, forest and semi-natural areas faced an increase of up to 1.98%, and water bodies by 3.64%, whereas wetlands decreased by 19.31%. Among the three sub-categories of artificial surfaces, the Industrial, Commercial, and Transport Units underwent the most significant expansion, indicating the growth of industrial and mining activities in the Western Macedonia region the particular time period. It is worth to be mentioned that the Mines, Dumps, and Construction Sites category depicted an increase up to 170%.

Relative percentage coverage increase or decrease of LC/LU types in Western Macedonia region, during the time period of 1990 to 2018.

Additionally, by comparing the spatial patterns within the Western Macedonia region boundaries, it is clear that the most significant urban expansion is concentrated around the city of Ptolemaida. This expansion can be attributed to the urbanization of cities and settlements, due to the parallel historical development of the Amynteo and Ptolemaida mines from 1990 and after.

Spatiotemporal evolution of Western Macedonia region based on the Corine Land Cover products (1990-2018).

Amynteo

According to the Machine Learning analysis within the boundaries of the mines, the quantified results were obtained

from the Amynteo open-pit, illustrating a trend toward green transition for the period from 2018 to 2021. Specifically, the relative change in the percentage of active mining areas (depicted in purple) depicted a decrease up to 45%, while the bare soil class has increased by 111.14%. In an effort to better understand the transition of the mining pit, the land cover classes of bare soil, vegetation, and water bodies were merged into a unified class titled as 'Green Transition' and then were compared with the calculated extent of the ML algorithm.

Land Coverage of Amynteo coal mine during the time period 2018 to 2021.

Additionally, a clear increase in water bodies (shown in blue) in the northwestern part of the Amynteo pit, as a results of an ongoing development of an artificial pit lake in the 2021. Bare soil is represented in brown, infrastructures in red, mining active areas in purple, vegetation in green, and water bodies in blue.

Spatiotemporal evolution of Amynteo mine open-pit based on Machine Learning products (2018-2021).

Ptolemaida

Regarding the quantification of the results in the Ptolemaida open-pit, a different pattern was observed in the land cover chnages. Specifically, in terms of relative percentage, a small decrease of the mining active areas up to 7,96% was identified, while the bare soil and vegetation classes remained relatively stable with small increases up to 4.58% and 3.52% respectively. Based on the comparison between the “green transition” classes (bare soil, vegetation, water bodies) and the mining active areas, a slight trend towards the reclamation phase is evident. However, these rates are much lower compared to the Amynteo mine. It should be noted that a significant part of the Ptolemaida mine was active (2021), which justifies the difference between the two Greek study areas.

Land Coverage of Ptolemaida coal mine during the time period 2018 to 2021.

Changes in water bodies are minor representing that water bodies in comparsion with the total coverage are minimum, during the period 2018 to 2021, which can be attributed to the activity of the mine.

Spatiotemporal evolution of Ptolemaida mine open-pit based on Machine Learning products (2018-2021).

Renewable Energy Sources scenarios

The Area Of Interest (AOI) for the implementation of the scenarios for the installation of Renewable Energy Sources (RES) is located close to the southwest side of the Ptolemaida mine. Particularly, the AOI is mountainous area with an

altitude that ranges from 667m to 2102 m, with an average elevation of 1125 m. Specifically, the higher altitudes are located in the western side of the AOI, while on the eastern side are more planar surfaces with lower elevation. According to the Corine Land Cover 2018, the eastern part is characterized by arable lands and agricultural activities, the northwestern side is covered by forests and natural grassland, while the wider region is classified as sparsely vegetated areas.

Southwest region nearby to Ptolemaida mine

The following results based on the above-mentioned criteria, highlighting with yellow color the more suitable areas for the installation of **Photovoltaic parks (PV)**, where the surface is flatter with values less than 10 percent. Specifically, the largest extent of suitable areas is concentrated in planar sites in the

eastern part of the AOI, as well as in the southern site where the elevation has lower values, with a total coverage up to 34.63 Km^2. Regarding the installation of **Wind Parks (WP)**, the suitable areas are illustrated with blue color in the western part of the AOI, where the altitude is higher than 889 m, with a total coverage up to 28.19 Km^2.

Additionally, areas with green color are considered as suitable for both types of **Renewable Energy Sources (RES)** in terms of overlapping. These areas are approximately up to 1.71 Km^2

and are located in planar sites in the eastern and southern part of the AOI.

From the perspective of the **Photovoltaic parks (PV)** scenario, the results identified areas potentially suitable for the installation of Photovoltaic parks on the flatter surfaces located on the eastern and the southern sides of the study area.

In the **Wind Parks (WP),** scenario, the results illustrated that the most potentially suitable areas for the development of WP are on the highest altitudes located on the western of the study area located at the highest elevated regions.

Web GIS Platform

You can access the Web GIS Platform through the following **link**!

or scan the QR code in the image below!

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