UNIVERSITY OF WESTERN MACEDONIA

COLUMBIA CLIMATE SCHOOL
Climate, Earth, and Society

REPURPOSING COAL MINES FOR FLEXIBLE RENEWABLE ENERGY

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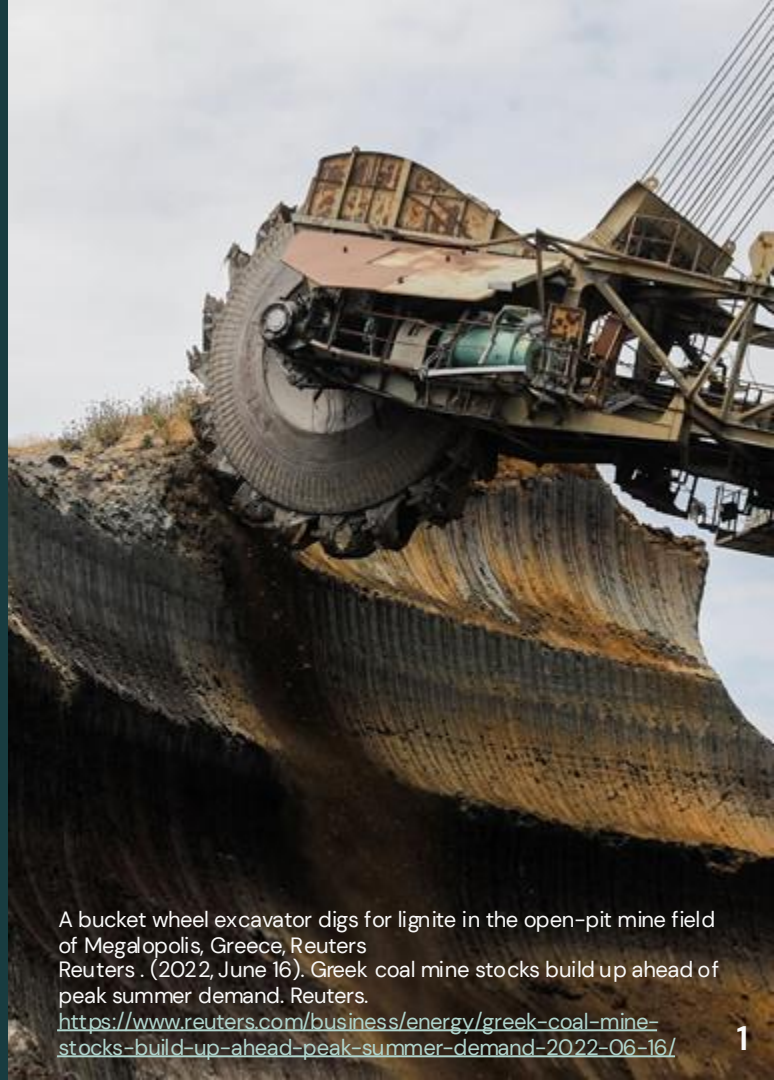


A bucket wheel excavator digs for lignite in the open-pit mine field of Megalopolis, Greece, Reuters
Reuters . (2022, June 16). Greek coal mine stocks build up ahead of peak summer demand. Reuters. https://www.reuters.com/business/energy/greek-coal-mine-stocks-build-up-ahead-peak-summer-demand-2022-06-16/

The European Green Deal: A Framework for Diversifying Energy Resources

Just Transition Mechanism

The EU just transition mechanism is funded to the order of 55 billion euros to provide funding guarantees and loans.

2050 Climate Neutrality Target

Strategic objective of achieving net-zero emissions by 2050 drives private investment in innovative technologies.

Social Cohesion

Transitioning fossil fuel workers and creating sustainable jobs in emerging industries is essential for social cohesion.

European Commission. European Green Deal. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en;
European Commission. Just Transition Fund. https://commission.europa.eu/funding-and-tenders/find-funding/eu-funding-programmes/just-transition-fund_en

Economic and Environmental Advantages of Repurposing Coal Mines for Renewable Energy

Solving the renewable energy problem during periods of excess energy:

Pumped-storage systems help balance the electricity grid by storing energy when there is excess generation and releasing it when demand is high.

Avoiding high costs and achieving land savings:

Repurposing coal or lignite mines significantly reduces costs. The elevation differences between deep pits and the surrounding higher ground already exist.

A giant lignite excavator at the South Field coal mine near the village of Agios Dimitrios, in the regional unit of Kozani, *ekathimerini.com*

U.S. Department of Energy. Pumped storage hydropower. https://www.energy.gov/cmei/water/pumped-storage-hydropower
https://www.ekathimerini.com/in-depth/1304348/navigating-life-after-lignite-in-kozani/

Global Case Studies for Repurposing Mines

- **Kidston Pumped Storage Hydro, Queensland , Australia**
  Large-scale project reusing two former gold mines as water reservoirs
  Power: 250 MW
  Scheduled to become operational in 2027.

- **Prosper-Haniel Mine, North Rhine, Germany**
  Former coal mine, planned to be repurposed for PHS
  Estimated power: 200 MW
  No construction has begun; in planning stage since 2017.

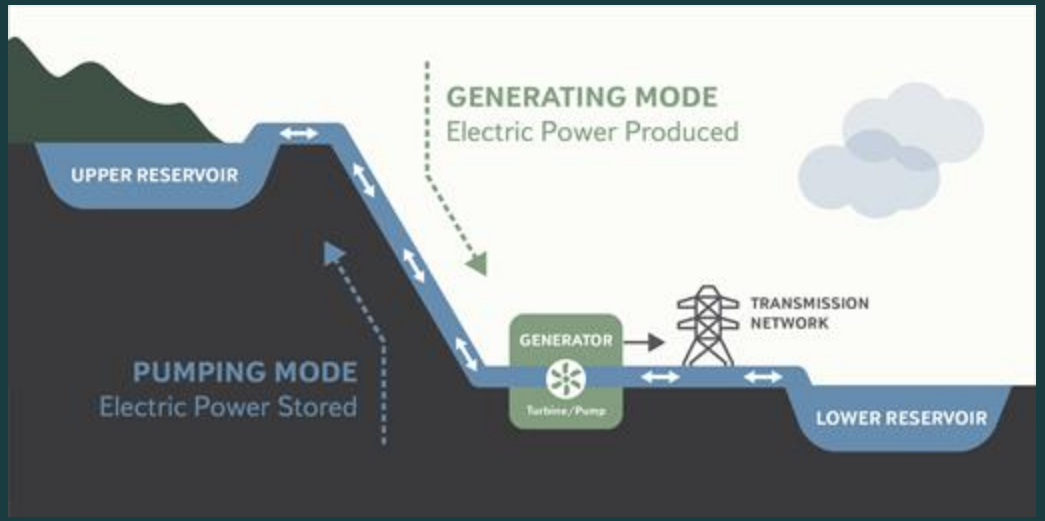
- **Kardia, Kozani, Western Macedonia, Greece**
  A new path to a sustainable energy future for Kozani
  Former lignite mining area operated by PPC, planned to be repurposed for PHS
  Maximum production power: 148 MW
  Preliminary study done in 2022; no construction has begun

Kidston Pumped Storage Hydro, Queensland, Australia

Sofios Consulting Engineers. (2022, May). Pump storage in the Kardia mine, Prefecture of Kozani, Greece. https://www.sofios.gr/en/projects/ergo-antlisotamiefsis-sto-orycheio-kardias-n-kozanis/

Basic Principles of Pumped Hydropower Storage (PHS)

- PHS requires two water reservoirs with different elevations.
- Electricity is generated through water drop due to gravity.
- Key mechanism involves the ability to pump water back to upper reservoir for future use.
- Natural energy storage mechanism is a unique advantage.



Pumped storage hydropower, *U.S. Department of Energy*

U.S. Department of Energy. *Pumped storage hydropower* **[Infographic].** https://www.energy.gov/cmei/water/pumped-storage-hydropower

Integration of Battery Storage (BESS) with PHS

Fluctuations in energy demand are common

Unpredictable situations can lead to grid instability.

Hydro Plants can alleviate the situation with backup energy storage.

Hydro plant turbines cannot compensate sufficiently

Sudden changes in grid frequency that last milliseconds cannot be accounted for by the hydro plant without causing mechanical damage.

Abrupt fine-tuning of turbines for grid stability is not a sustainable practice.

Battery energy storage systems, *enel group*

International Hydropower Association. (2021). *Improving grid services by coupling hydropower and batteries*. https://www.hydropower.org/case-study/turbine-and-battery-hybrid ; Enel Group. BESS: Battery energy storage systems. https://www.enel.com/learning-hub/storage/bess

Kozani: The Perfect Testing Ground for Repurposing Mines for the Future

First steps taken

Hydro Pump Storage is already planned and state confirmed in Kardia, Kozani.

Expansion of idea

The repurposing of abandoned lignite mines as reservoirs for storing water has several existing case studies around the world.

Opportunities for local blue collar positions

Highly experienced workforce and machinery from the lignite mines are transferable to hydropower operation, stimulating the area's economy.

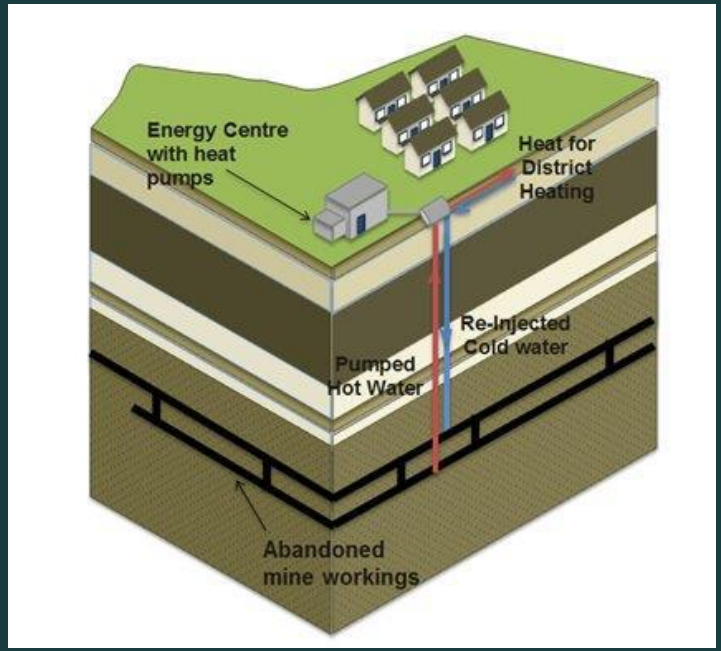
Promoting the region as new economic hub

PHS provides enticing career opportunities for both foreign experts and local graduates who are familiar with the area. It enables Kozani's rebranding from lignite economy to a hub of innovation. Declining population and brain drain are addressed.

Schnepper, T., et al. (2025). Potential hydrochemical impacts of pumped hydropower storage operation in two European coal regions in transition: the Szczerców–Bełchatów mining complex, Poland, and the Kardia Mine, Greece. Environmental Earth Sciences, 84(9).

Geothermal Energy Recovery from Abandoned Mines

- Deep underground abandoned coal mines offer potential for direct heating via geothermal energy.
- Flooded underground tunnels naturally heat groundwater.
- Next-generation geothermal technologies provides a pathway for energy access and affordability.
- Applicable skills between the geothermal energy and fossil fuel energy sectors enables ease of deployment.



Schematic of direct heating via geothermal applications in abandoned mine shafts, *Durham University*.

Huang, Y., Kong, Y., Cheng, Y., Zhu, C., Zhang, J., & Wang, J. (2023). Evaluating the long-term sustainability of geothermal energy utilization from deep coal mines. Geothermics, 107, Article 102584. https://doi.org/10.1016/j.geothermics.2022.102584

Costs of Repurposing Coal Mines for Renewable Energy

Pumped Hydro Storage

54–61 €/MWh · LCOS

Mine depth and existing pits are used for long-duration storage.

Geothermal

50–102 €/MWh · LCOE

Mine water and boreholes reduce exploration risk and support local heating.

Battery Storage (BESS)

113–210 €/MWh · LCOS, 4-hour Li-ion

Fast-response storage is realized. BESS is useful when paired with pumped hydro and renewables.

Colthorpe, A. (2025, April 9). Greek utility PPC plans 860 MW energy storage in mining region. ESS News. https://www.ess-news.com; NREL. (2024). 2024 Annual Technology Baseline: Utility-scale battery storage. National Renewable Energy Laboratory.
Otto, C., Louloudis, G., Roumpos, C., Mertiri, E., Ernst, P., & Kempka, T. (2025). Economic feasibility of Pumped Hydropower Storage in a European open-pit lignite mine. Energy Conversion and Management. ; PPC Group. (2026, April 6). PPC Group completes construction of 2.13 GW photovoltaic projects in Northern Greece [Press release].

Funding Mechanisms to Repurpose Mines

Just Transition Mechanisms

€150 B mobilised
€40 B in JTF grants

Modernisation Fund

€20 B+ disbursed (2021–2025)

EU Innovation Fund

Largest dedicated innovation programme

EIB Public Sector Loan Facility & CEF

EIB: €325 M for Greek just transition

Innovative Financing →

Community / local bonds

PPC €5 M · 8% yield · Kozani + Florina residents

Public-private blending

PPC CAPEX €5.8 B + EU grants + EIB loans

Diversified revenue streams

- Tourism
- Data centres
- Green hydrogen

European Commission. The Innovation Fund. https://climate.ec.europa.eu/eu-action/eu-funding-climate-action/innovation-fund_en ; European Commission. (2024). EU funding possibilities in the energy sector. https://energy.ec.europa.eu; European Investment Bank. (2021, July 12). Greece: EIB to support EUR 325 million Just Transition investment in lignite mining regions [Press release]. ; OECD. (2021). Towards a just transition in Greece's lignite-dependent regions. OECD Publishing; Pappas, K. (2024, December 19). Supporting sustainable energy solutions in Greece. Texas A&M Energy Institute. ; Spasić, V. (2026, March 18). Just transition in Greece — residents of coal regions can invest in economic makeover. Balkan Green Energy News.

Opportunities and Challenges for Repurposing Mines

Opportunities:

- Rebranding from a fossil-fuel-based economy to a modern city is based on renewable energy.
- Leader for other cities in the EU.
- Retrofitting fossil fuel industries enables continued energy access and affordability.
- Skilled brain drain is prevented.

Challenges:

- Funding and financing
- Workforce development: enable transferable skills and technological adaptation.
- Societal reaction to change.
- Lignite mines are not preferred for direct heating in W. Macedonia.

Conclusion

- Pumped Hydro Storage (PHS) provides opportunities for around-the-clock renewable energy storage.
- Financing via EU public funds and innovative public-private blending can be harnessed.
- Local workforce stimulation and training for transferable skills are needed.
- Diversified and affordable energy access is achieved with the integration of Pumped Hydro Storage and Battery Storage.

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Thank you

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