Reuse of underground coal mines at the end of their lifetime through emerging renewable energy technologies and circular economy principles

Green JOBS
RFCS RESEARCH PROJECT
Research Fund for Coal & Steel
Co-funded by the European Union

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I N T E R N A T I O N A L W O R K S H O P
"MINING AND POST-MINING ISSUES DURING THE ENERGY TRANSITION"
5th December Gliwice 2024

Silesian University of Technology
EXCELLENCE INITIATIVE RESEARCH UNIVERSITY

GreenJOBS

Leveraging the competitive advantages of end-of-life underground coal mines to maximise the creation of green and quality jobs

Call: RFCS-2021
Instrument: RFCS-RPJ
Start date: 01/07/2022
End date: 31/12/2025
Budget: 2,202,647 €

Universidad de Oviedo

grupohunosa

FAEN Fundación Asturiana de la Energía

Magellan & Barents

Technische Hochschule Georg Agricola

WĘGLOKOKS KRAJ

GIG Research Institute

PREMOGOVNIK VELENJE Skupina hse

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Problems tackled by GreenJOBS –

Before GreenJOBS, there was no guidance focused on operating underground coal mining companies to understand, evaluate, design, and implement alternative economic activities within their future closing period, i.e., to have a holistic and long-term approach:

1. Leaving behind short-term patchwork.
2. Promoting sustainable local economic growth.
3. Maximising the number of green and quality jobs.

Problems tackled by GreenJOBS –

There were no studies on repurposing end-of-life underground coal mines, leveraging their competitive advantages:

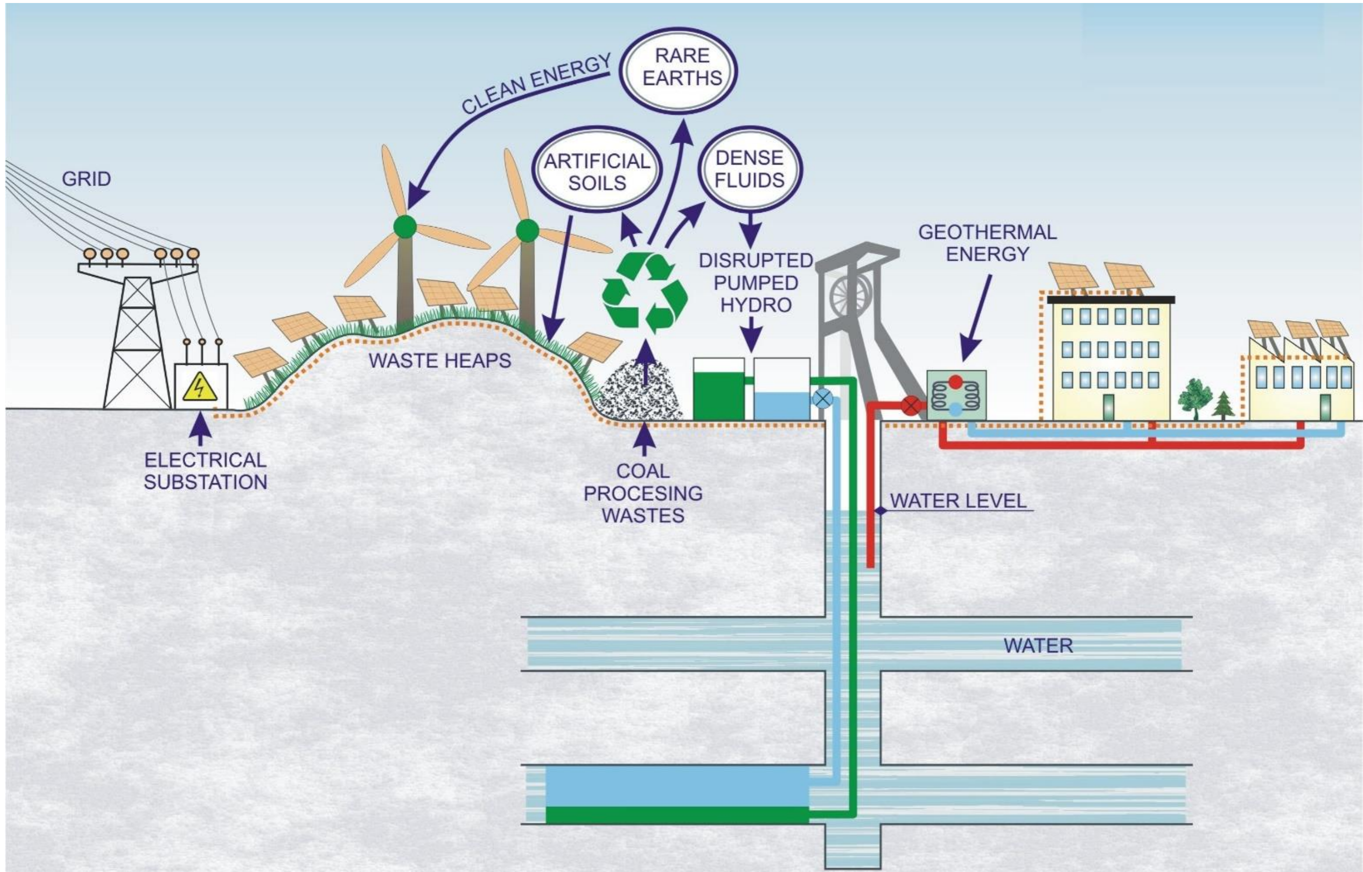
- Mine water.
- Connections to the grid.
- Large waste heap areas.
- Very deep shafts and galleries.
- Fine coal waste.

Main objectives

- To develop for coal mining companies innovative business plans for deploying emerging renewable energy and circular economy technologies to facilitate their exploitation.
- To plan and disseminate among mining companies and regional authorities in the coal regions in transition, training and re-skilling programmes addressing former coal mining.

Main objectives

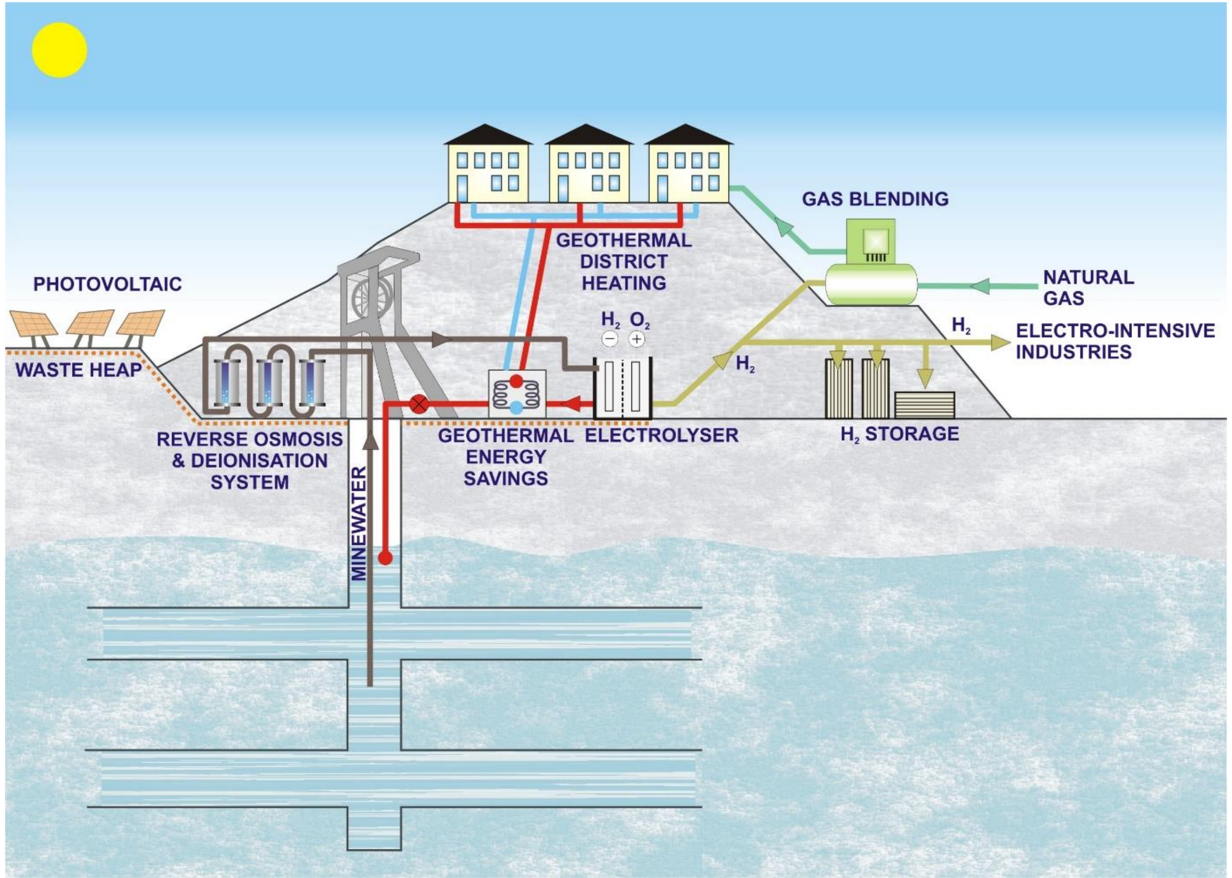
- Two innovative business plans:
  1. A **Virtual Power Plant** where the energy locally produced will be sold to the grid or used to power electro-intensive industries or companies with constant energy consumption close to mines, such as aluminium factories or green data centres.



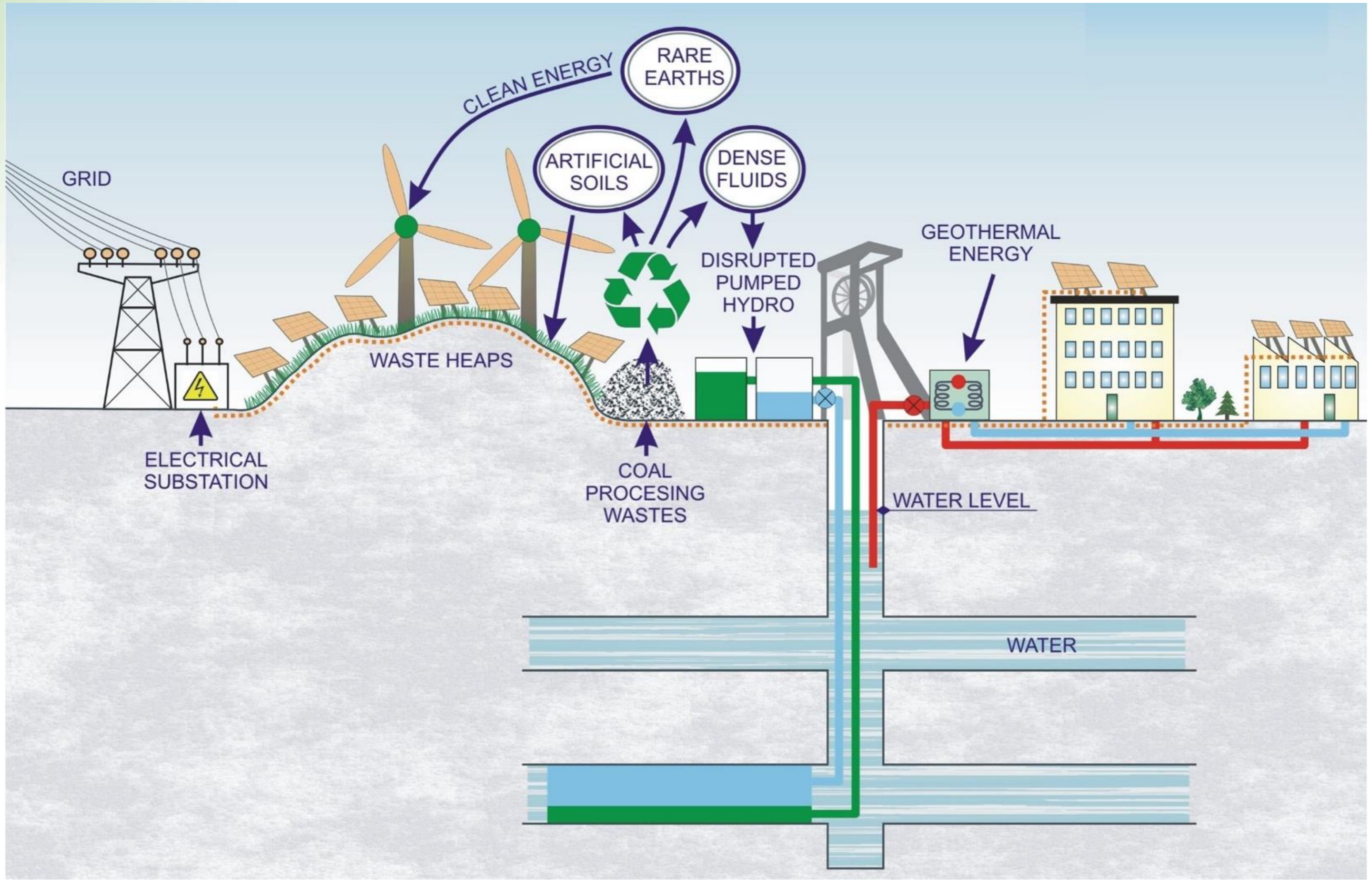
Main objectives

- Two innovative business plans:

  2. A **Green Hydrogen Plant** where renewable hydrogen will be produced by electrolysis of mine water and green electricity.



Business model 1
Virtual Power Plant where energy is sold to the grid.



Photovoltaic deployment parameters

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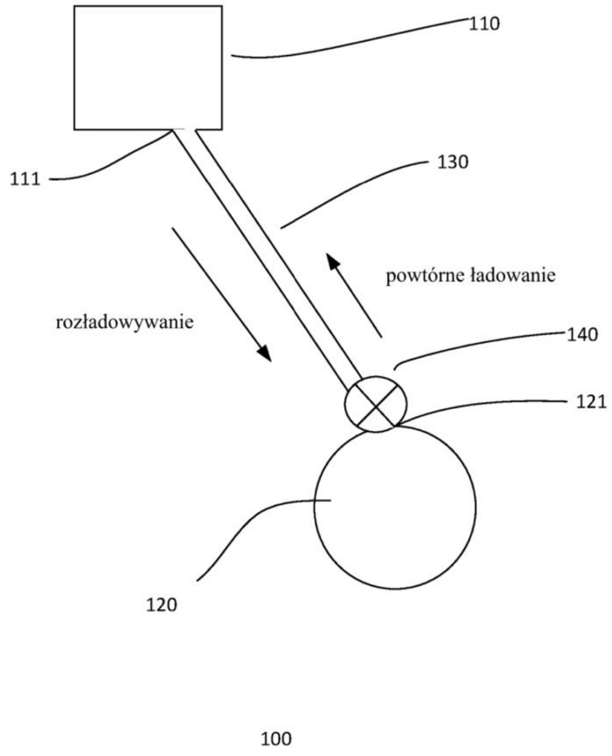
Photovoltaic parameters for a 50 ha waste heap area with an installed capacity of 1 MW/ha, a capacity factor of 30% and 50% of energy to be stored.

Parameter	Value
Installed capacity	50 MW
Estimated investment (plant life: 25 years)	20 M€
Capacity factor (% time of use of the installation per year)	30%
Daily production (50 MW x 30% x 24 hours)	360 MWh
Fraction of energy to be sold, the rest to be stored	50%
Daytime energy sold (360 MWh x 50%)	180 MWh
Daytime energy price	40 €/MWh
Daytime revenue (180 MWh x 40 €/MWh)	7,200 €
Photovoltaic annual revenues (7,200 € x 365)	2.63 M€
Annual expenditure (staff, maintenance and overheads)	0.50 M€

Disrupted pumped hydro storage deployment parameters

Parameters of the disrupted pumped hydro storage calculated to cover daytime energy storage plus a 10% safety margin, with around half of the daytime hourly energy production in twice the time (around 16 hours), resulting in an installed capacity of 200 MWh-10 MW.

Parameter	Value
Installed capacity	200 MWh-10 MW
Estimated investment (plant life: 50 years)	5 M€
Roundtrip efficiency	80%
Daytime energy storage (360 MWh x 50%)	180 MWh
Night-time energy production (180 MWh x 80%)	144 MWh
Night-time energy price	70 €/MWh
Night-time revenues (144 MWh x 70 €/MWh)	10,080 €
Annual revenue for Disrupted pumped hydro (10,080 € x 365)	3.68 M€
Annual expenditure (staff, maintenance and overheads)	0.15 M€



Cash flow calculations (k€)

Using high-power batteries for very short periods, with an estimated investment of 1.5 M€ for an installed capacity of 200 MWh-2 MW and an annual expenditure of about 0.05 M€, cash flows for the three first years, using constant 2021 euros, annual depreciation of 5% and working capital of about 9% of operating revenues, are presented.

Item	2021	2022	2023
Capital expenditure	(26,500)		
Working capital	(565)		
Operating revenues		6,310	6,310
Operating expenses		(700)	(700)
Depreciation (20 years)		(1,325)	(1,325)
EARNINGS BEFORE INTEREST AND TAXES		4,285	4,285
Taxes (25%)		(1,072)	(1,072)
NET INCOME		3,213	3,213
CASH FLOW (Net income + Depreciation)	(27,065)	4,538	4,538

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Expected financial outcomes

Considering an 8% capital cost, the expected financial outcomes for 25 years will be:

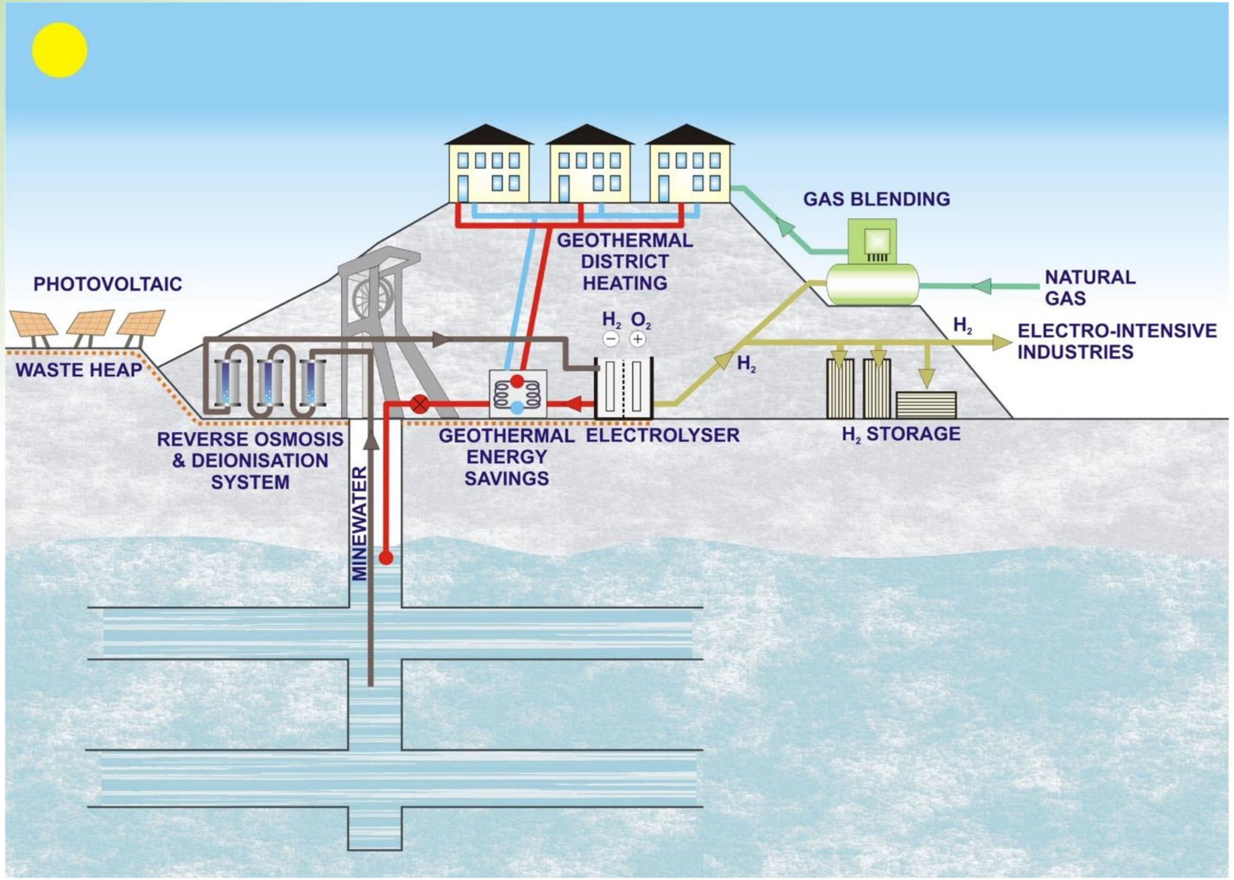
$$NPV = -27{,}065 + \frac{4{,}538}{(1+0{,}08)} + \frac{4{,}538}{(1+0{,}08)^2} + \ldots + \frac{4{,}538}{(1+0{,}08)^{25}} = 21{,}991\ k€$$

$$Internal\ rate\ of\ return\ (IRR) = 16\%$$

$$Payback\ Period\ (PP) = 9\ years$$

These figures confirm the project's commercial viability, showing an economic added value of almost 22 M€, for an investment of 27 M€.

Business model 2
Green hydrogen plant.



Capital expense (CAPEX)

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Capital expense for a 3MWp photovoltaic plant, a 2.5 MW Green Hydrogen Plant, a hydrogen refuelling station at 350 bar built for intercity buses, and a blending installation into the existing natural grid (5%).

Description	Estimated cost (€)
3MWp Photovoltaic plant	4,040,000
Electrolyser system	3,200,000
Mine water feeding and treatment systems	220,000
Blending installation	901,202
Hydrogen storage and refuelling systems	3,559,675
Electrical system connections	324,000
Mechanical balance of plants (BOP)	390,000
Electrical balance of plants (BOP)	190,000
TOTAL	**12,824,877**

Technical and economic parameters

Parameters for a 69% of green hydrogen plant functioning and a 14% of photovoltaic plant functioning.

Description	Value
Functioning hours of the installation for one year	6,000 h
Annual hydrogen production (45 kg/h)	270,000 kg/year
Photovoltaic energy production (1,200 h/year)	3,600 MWh/year
Tolls and charges for electricity supply	15 €/MWh
Operating expenses (personnel, maintenance, repairs)	250,000 €
Electrical consumption of the plant	3 MWh
Hydrogen sale price	8 €/kg
Power purchasing agreement (PPA) price	55 €/MWh
Green hydrogen plant depreciation period	15 years
Photovoltaic installation depreciation period	25 years

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Cash flow calculations (€)

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Cash flows for the first three years, using constant 2021 euros and working capital of about 9% of operating revenues, are presented. To simplify calculations, no inflation was considered.

Item	2021	2022	2023
Capital investment	(12,824,877)		
Working capital	(170,100)		
Operating revenues		2,160,000	2,160,000
Operating expenses		(846,000)	(846,000)
Depreciation of green hydrogen plant		(543,212)	(543,212)
Depreciation of photovoltaic installation		(48,480)	(48,480)
EARNINGS BEFORE INTEREST AND TAXES		722,308	722,308
Taxes (25%)		(180,577)	(180,577)
NET INCOME		541,731	541,731
CASH FLOW (Net income + Depreciation)	(12,994,977)	1,133,423	1,133,423

Expected financial outcomes

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Considering an 8% capital cost and a residual value of the photovoltaic plant of 1,616 k€ (10/25 of the initial investment), the expected financial outcomes for 15 years, will be:

$$NPV = -12{,}995 + \frac{1{,}133}{(1+0{,}08)} + \frac{1{,}133}{(1+0{,}08)^2} + \ldots + \frac{2{,}749}{(1+0{,}08)^{25}} = -2{,}784\ k€$$

$$Internal\ rate\ of\ return\ (IRR) = 4.511\%$$

$$Payback\ Period\ (PP) = N.A.$$

These figures confirm that even with a hydrogen sale price of 8 €/kg (currently is about 6 €/kg), the project's commercial viability is not achieved.

GreenJOBS Project case studies

Bobrek-Piekary Coal Mine, POLAND

Aller-Barredo-Figaredo, SPAIN

Premogovnik Velenje, SLOVENIA

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Case studies

Bobrek-Piekary Mining Complex (Poland)

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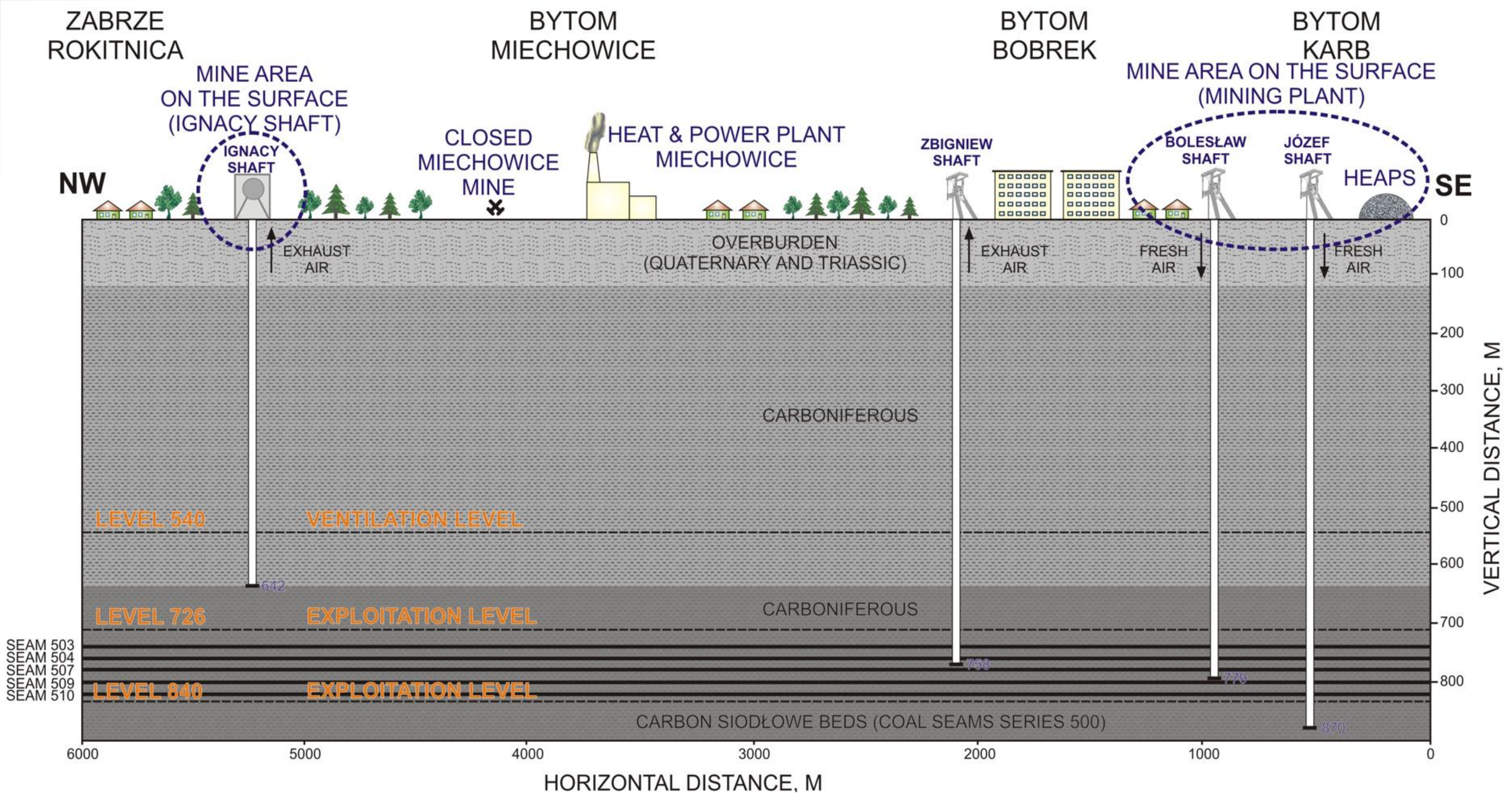
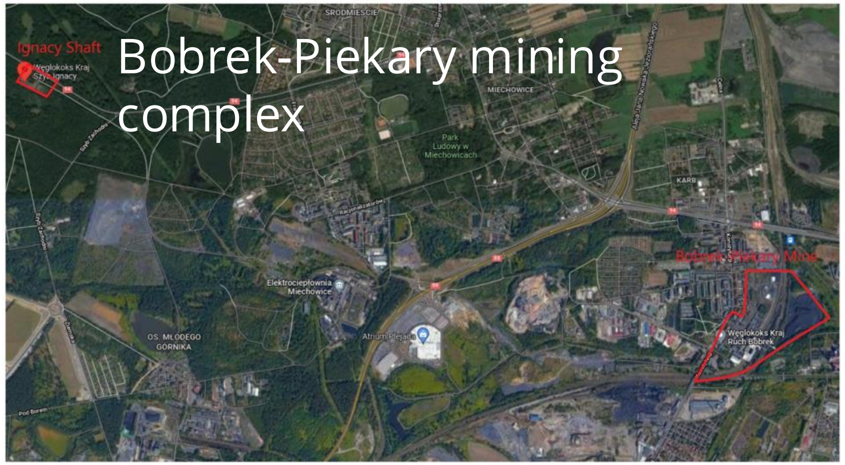


Case studies

Bobrek-Piekary Mining Complex (Poland)

1. The depth of extraction is >900 m.
2. The complex is close to a densely populated area
3. The decommissioning of the mine is foreseen for 2040.
4. Pumping capacity: >5000 m3/day. Water temperature: >25ºC.
5. When the mine will stop operating there will be 8 ha of available place for installing photovoltaics.
6. The mine area has >2 ha of forest, with the possibility of installing wind power.
7. An electrical substation and three switching stations.
8. The number of employees are 2000.



Case studies
Velenje mine in Slovenia

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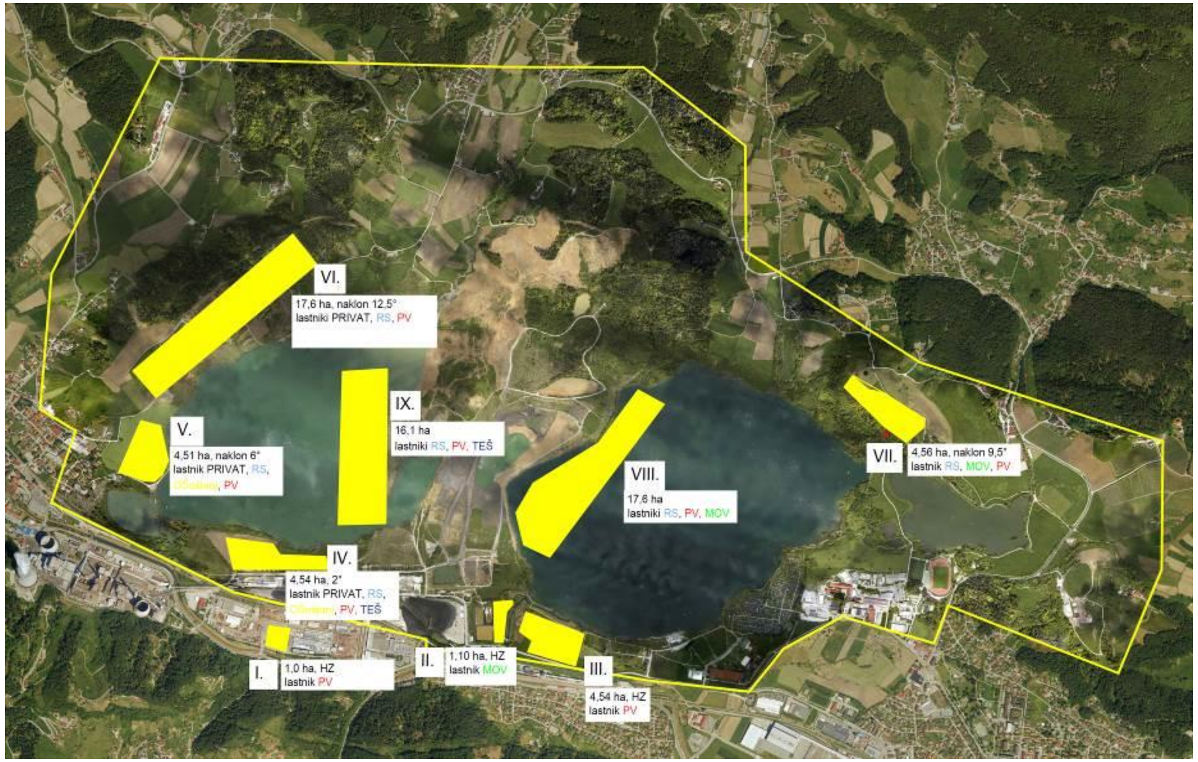
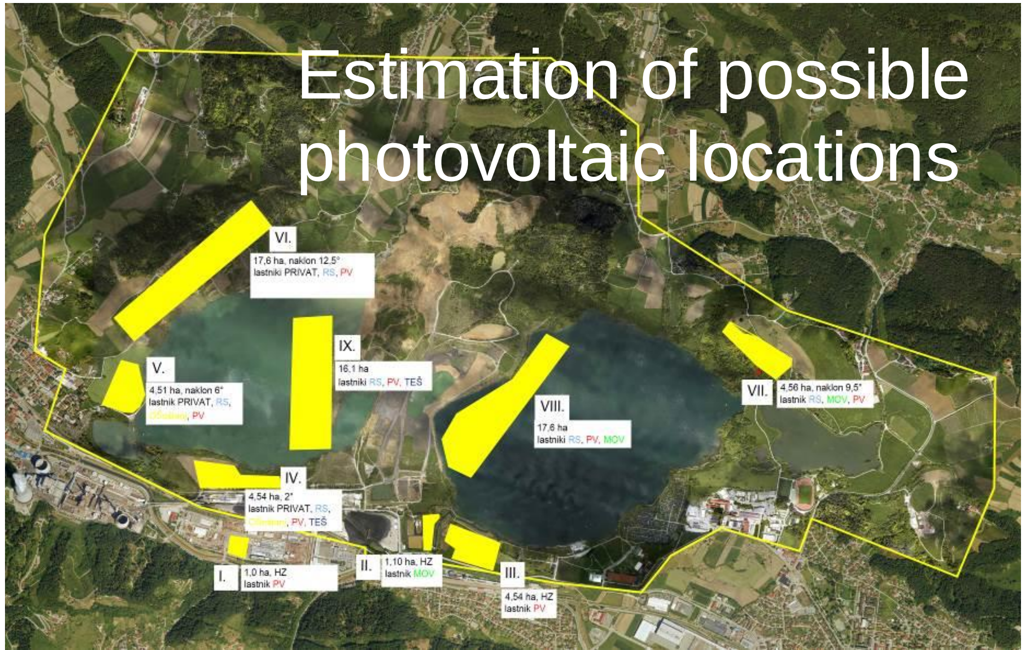


Case studies
Velenje mine in Slovenia

1. Lignite mine with a depth of extraction of >500 m.
2. Pumping capacity: >1 Mm3/year. Water temperature: >18ºC.
3. Possible photovoltaic locations on the land of about >30 ha and on water (lakes with floating photovoltaic) >30 ha.
4. The most significant potential for wind turbines is in the hills of the nearby valley, at an altitude >600 m.
5. Nearby there is a power plant and the Velenje electrical distribution transformer station.
6. The number of employees are 2000.

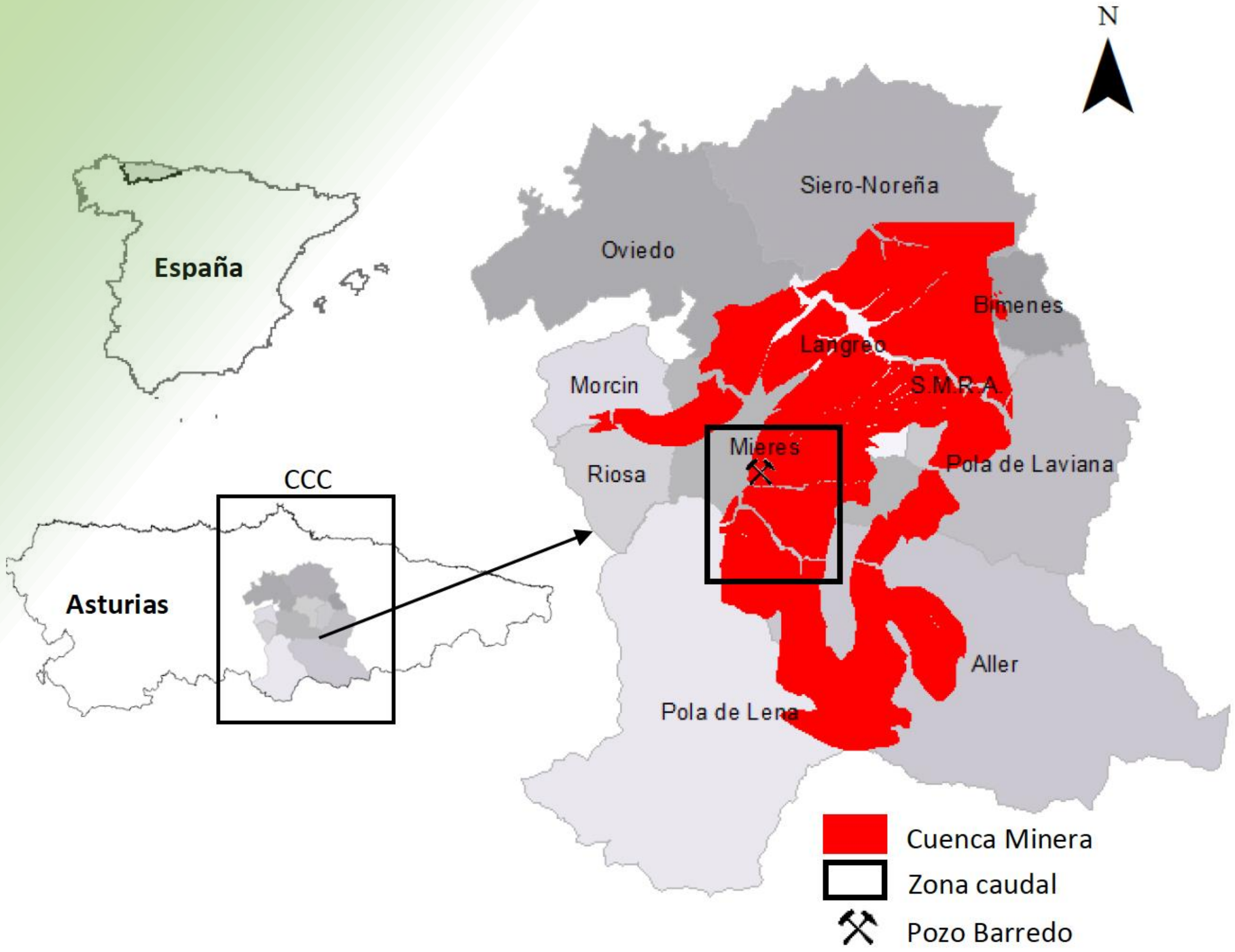


Estimation of possible photovoltaic locations

Case studies
The Aller-Barredo-Figaredo Mining Complex

1. The depth of extraction is 355 m.
2. The complex is close to a densely populated area
3. The colliery ended its activity in 1995 (**In operation from 1937 to 1995**).
4. Pumping capacity: 4 Mm^3/year. **(Total HUNOSA ≈35 Hm^3 per year)**
5. Water temperature: 23ºC.
6. There is a geothermal installation with an installed capacity of 6 MWt by means of heat exchangers and heat pumps.
7. In the vicinity there are old open-pit mines with potential to be used for photovoltaics.
8. Medium voltage supply.

Case studies
The Aller-Barredo-Figaredo Mining Complex



Case studies
The Aller-Barredo-Figaredo Mining Complex

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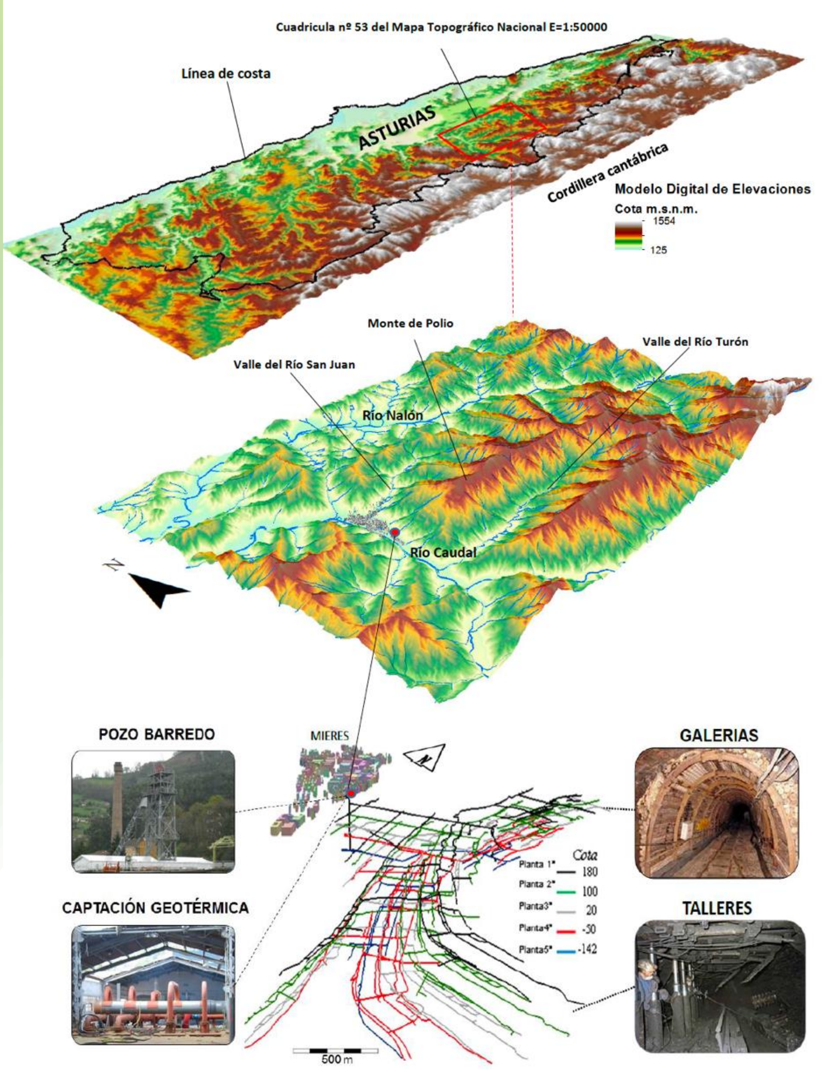

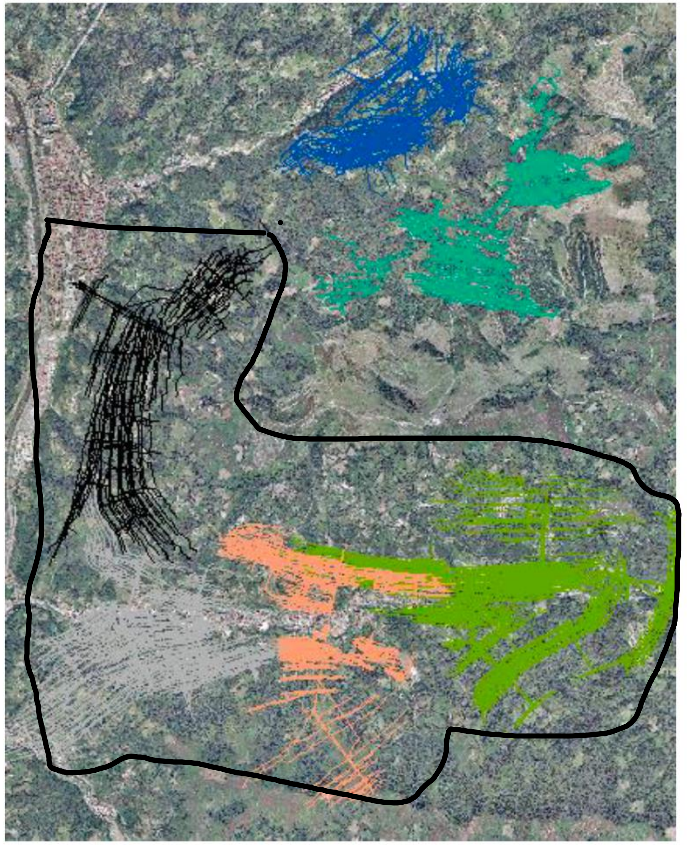

Case studies
The Aller-Barredo-Figaredo Mining Complex

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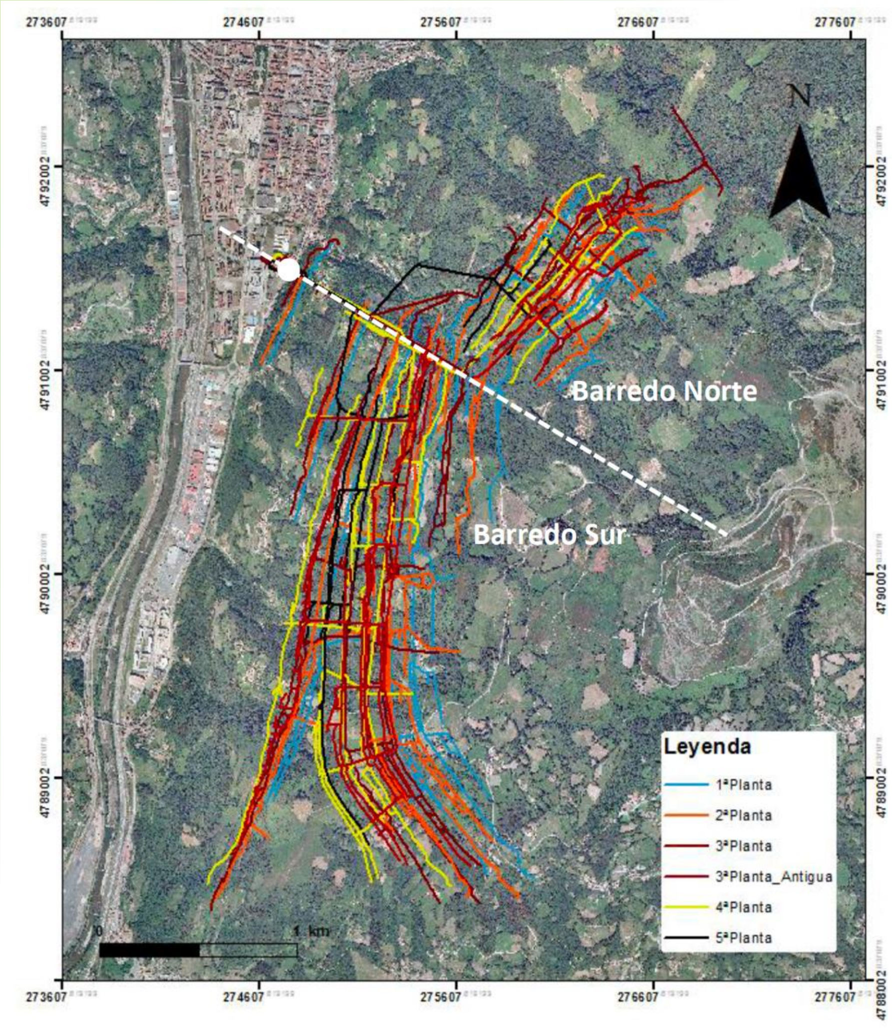
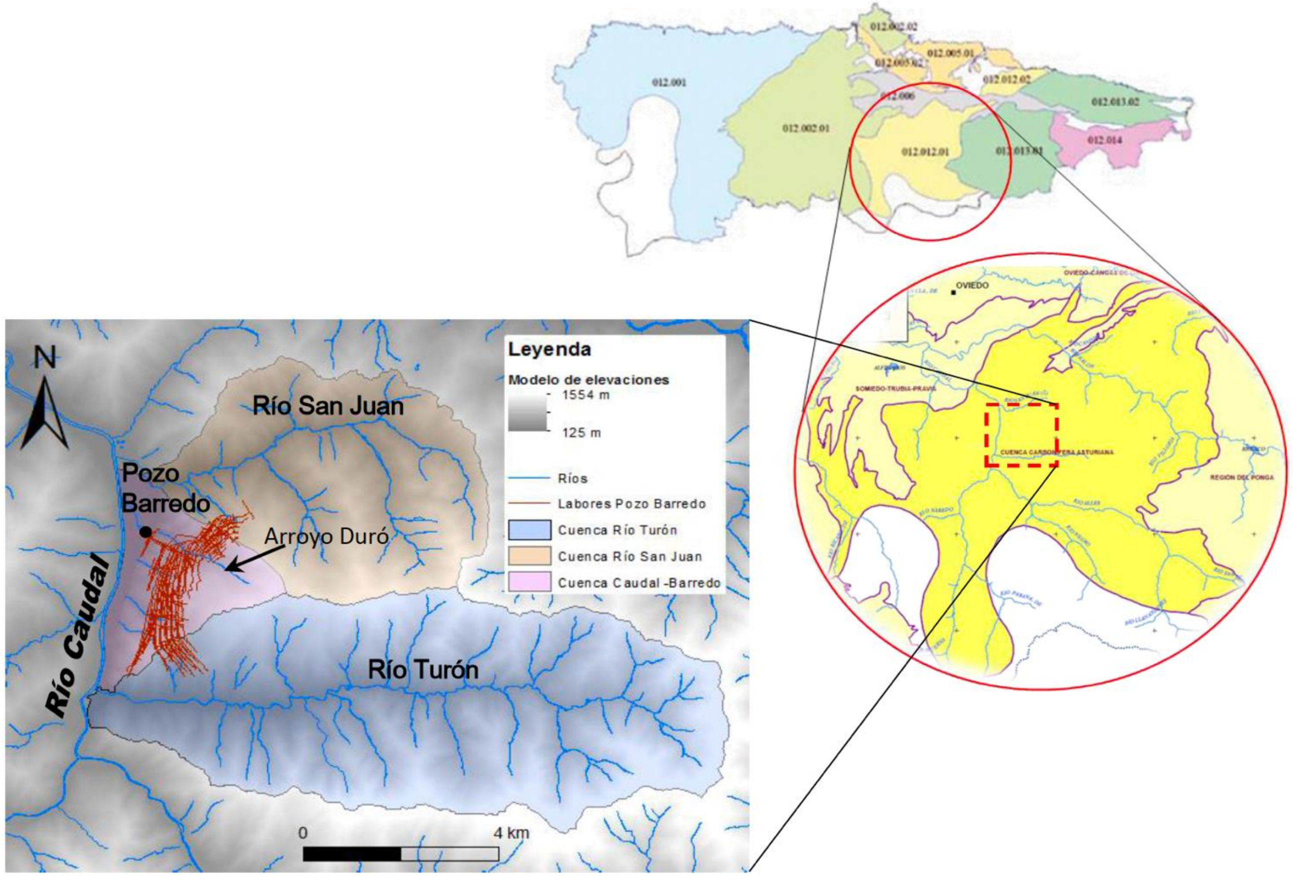
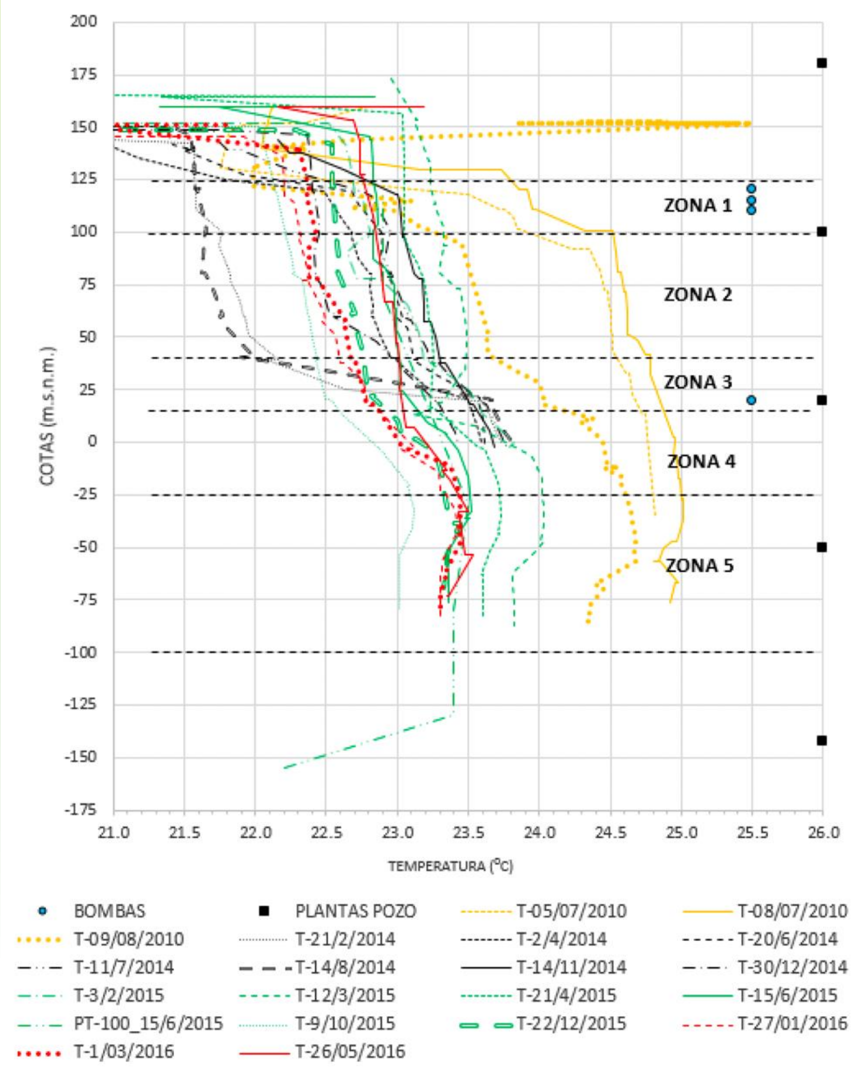
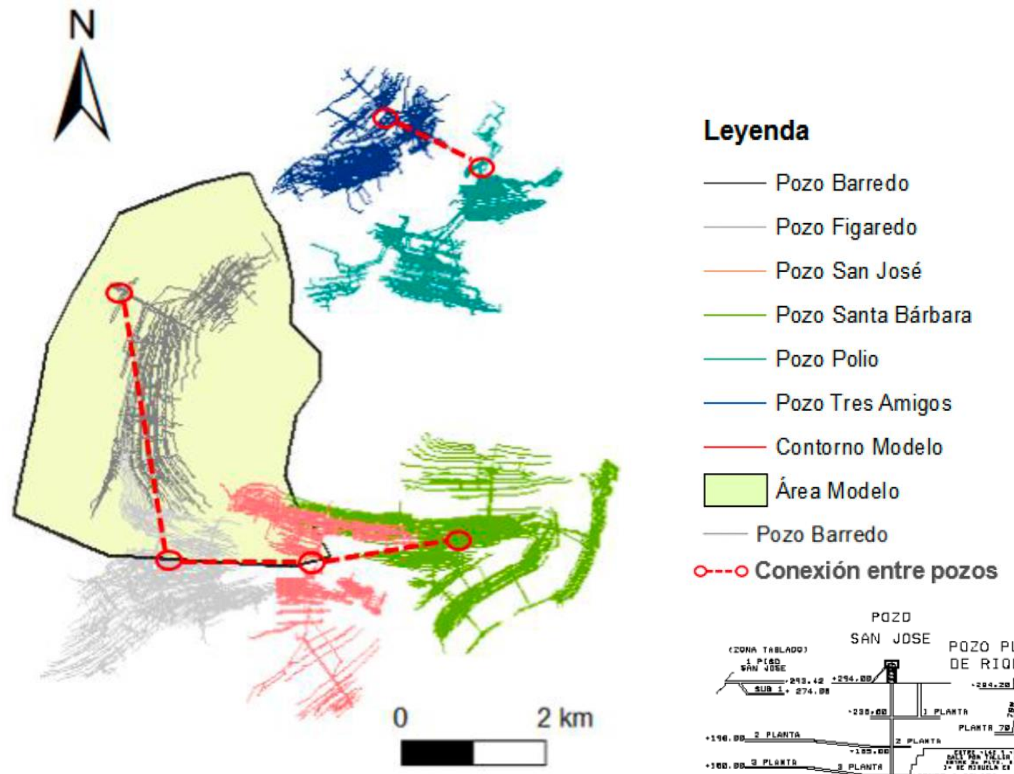
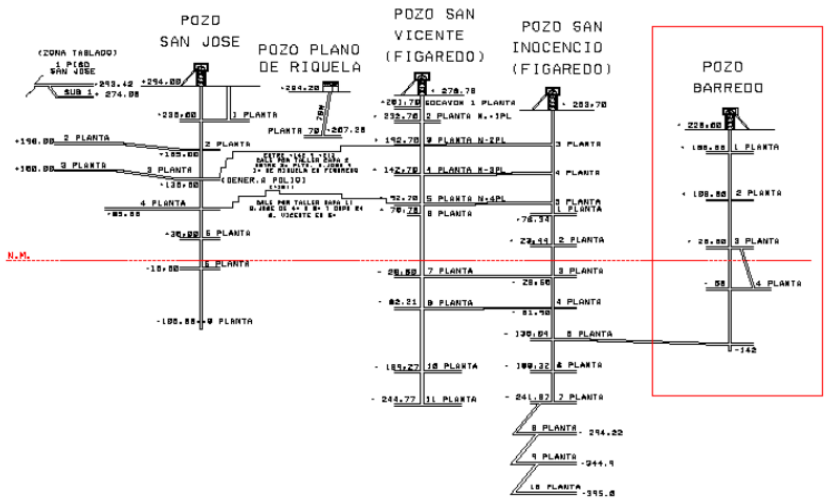




Case studies
The Aller-Barredo-Figaredo Mining Complex







Case studies
The Aller-Barredo-Figaredo Mining Complex

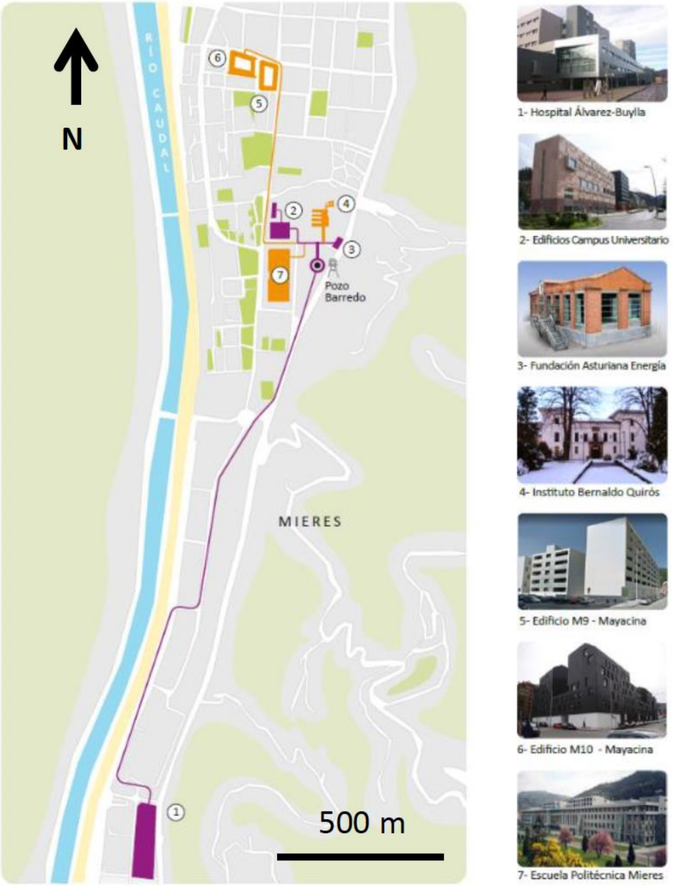
BarredoFirst facilities, in Mieres(1st phase). Heating and cooling (in operation since 2014 -2016):

1. Hospital of Mieres
2. Research Building of the University of Oviedo -Campus of Mieres
3. Headquarters of Asturian Energy Foundation

First and second phase.
Barredo Colliery (Mieres)

BarredoDistrict Heating, in Mieres(2nd phase). Heating and domestic hot water (in operation since 2020):

1. Dwellings: Blocks of apartments
2. Secondary School
3. Main building of the University of Oviedo –Campus Mieres.



Reduction of CO_2 emissions: 1.600 t

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GreenJOBS RFCS RESEARCH PROJECT Video

Green JOBS
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https://www.youtube.com/watch?v=o2sngsLmjwY

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