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BAT guide for land rehabilitation and reclamation

Public Report

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1. EXECUTIVE SUMMARY

The best available technologies (BAT) guide for land rehabilitation and reclamation aims to the identification of the main environmental challenges regarding land reclamation in the selected coal regions in transition (Western Macedonia, Ruhr area and Konin region). The results of this deliverable will tackle two main objectives of the Work Package 2, which are: a) to indicate environmental aspects of land reclamation and rehabilitation and b) to present the best practices of post-mining areas reclamation.

The content of this guide is dedicated to the public and the stakeholders of energy transition in coal mine areas, to better understand the nature and the necessity of reclamation process in areas, where mining activity ceases, and new land uses and developments are to be applied. This document highlights rehabilitation sites, that were successful and explain why these methods were beneficial in each particular case.

The three specific regions from Poland, Greece and Germany are described by presenting the mining operations, that took place, or are still taking place and rehabilitation and reclamation work done in the post-mining areas. Best practices from the three areas during transition from mining areas to post-mining areas will be presented in form of fact sheets. Rehabilitation site fact sheets will have the most basic information about each area and rehabilitation work done, innovative approaches will be highlighted. Those examples will serve as an extension to already described good practices from three specific WINTER regions.

Lastly, best rehabilitation practices and case studies will be grouped by the intended land use, which was decided on each area. This should summarize the case studies analysed throughout this document and match them to corresponding planned land uses.

2. PROJECT OVERVIEW

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3. INTRODUCTION

This document is prepared as part of the WP2 of the WINTER project, the work package title is "Environmental challenges of coal regions in transition and land rehabilitation solutions". The specific Task tackled by this Deliverable is "Best available technologies for land rehabilitation and reclamation" within this task analysis of available reclamation and rehabilitation technologies will be conducted. The information of the technological issues will be collected in a form of a guide presenting the most important aspects. Moreover, the guide will be supplemented with the best practice examples of land rehabilitation projects realized in Greece, Poland and Germany as well as in other countries.

4. BACKGROUND

The life cycle of each mining project consists of these main steps: exploration & discovery, feasibility & construction, mining & extraction and closure & site rehabilitation. (Michaux et al., 2020)

Rehabilitation is the process of restoring the usable or natural value of land damaged by mining activities. It is regulated by specific legislation for each country. Reclamation of post-mining areas compensates for the adverse changes caused by mining activity, and, however in many cases, it is considered an opportunity to repurpose post-mining areas to more attractive land uses (*Kasztelewicz, 2010*). Although the process of mine reclamation occurs once mining is completed, the planning of mine reclamation activities begins prior to a mine being permitted or operated. Mine reclamation creates landscapes that meet a variety of goals ranging from the restoration of productive ecosystems to the creation of industrial and municipal resources (Surface Mining Control and Reclamation Act 1977 [US]).

According to the European Commission, "mine rehabilitation is the restoration of the land use on which mining has taken place to the intended post-closure land uses" (Beuermann et al., 2020).

The perception that the coal mining industry harms the environment is changing, and its role as a restorer of landscape qualities and production characteristics of previously mining areas is increasingly recognised. It is not uncommon for such areas to achieve an ecological or land use status, that is better than they were before mining began. Reclamation began to be recognised as an integral part of mining activities in the course of which there is a restoration of those transformed elements of the environment that determine its development and social utility. (Wójcik et al., 2012). Governments and other institutions focus a lot on regional and national approach to reclamation by creating legislation. It is important to highlight, that technologies and examples analysed in this Deliverable are highly influenced by regional environmental legislation. Brief overview of legislation from each region covered by this project will be summarised.

5. ANALYSIS OF REHABILITATION AND RECLAMATION TECHNOLOGIES

As described in the previous chapter rehabilitation and reclamation is the process of restoring an ecosystem with appropriate productive or even extra-productive functions, that is reclaiming the land to pre-mining conditions or with even better conditions. The process can be divided into three main steps (standard PN-G-7800:2002):

- preparation works,
- technical rehabilitation,
- biological rehabilitation.

Preparatory works involve the setting of reclamation requirements during the project design phase of the mining project. This phase requires: determining the directions of future use and performing geological studies (determining water bodies interlinkages, soil properties, the extent of land transformation). During this step, decisions must be made on ways to protect the topsoil, such as whether it is necessary to remove the surface layer of soil and temporarily store it.

Technical reclamation consists of activities such as:

- landscaping;
- regulation of water bodies interlinkages;
- restoration of topsoil by technical methods;
- determination of methods to improve the physical and chemical properties of the land;
- construction of access roads, ramps, bridges, etc., necessary for the use of the land;
- strengthening of slopes.

During technical reclamation, most of the work is earthwork, which involves:

- piling of external and internal dumps;
- separation of toxic or undesirable formations;
- appropriate shaping of end pits;
- controlling groundwater levels;
- elimination of drainage areas, if water reservoirs are not planned; establishment and implementation of such forms of relief in the reclaimed area that allow mechanization of agrotechnical work and at the same time prevent erosion processes. (Kasztelewicz*,* 2010)

Biological reclamation is the third step in the scope of reclamation work, but it can also occur as an independent, fundamental phase of this work. This phase has the task of protecting the area from erosion, biological recovery of the slopes and top soils, as well as initiation and stimulation of soil-forming processes. It involves the introduction of vegetation that has appropriate features, as well as work and treatments to create a soil layer with high biological activity. The extent of biological reclamation may vary, depending on the degree of degradation, the properties of the reclaimed soil, as well as the intended direction of development.

The prerequisite for high biological activity of the soil is to ensure the abundance of nutrients, necessary for the development of microorganisms and plants. Therefore, the most important task is to enrich the reclaimed soil with the right amount of organic matter and fertilise with mineral components

5.1. MINE REHABILITATION TECHNOLOGIES

The initial approach to mine rehabilitation is the decision and planning of the future land use. Since, each mine's productive and operational time is finite, often it is required by law to rehabilitate the land of the mining area to an economically or socially useful state. Such plans need to be at least outlined at the beginning of a mining project, so that any activities will not render future post mining land use repurposing impossible. A good mining planning methodology takes the rehabilitation phase into account during the earlier steps of mine development and exploitation. Between drawing up initial plans of rehabilitation and the actual time when rehabilitation starts or is taking place, many years or decades can pass. New technologies, legislation or social needs can be developed, which could influence and change the directions of reclamation work conducted on a given site. Therefore, a constant monitoring of available technologies and possible land uses needs to be done.

Based on the decisions during mine planning a technical approach of rehabilitating the mined area has to be decided. Depending on the post mining land use very different earthworks are required. During open pit excavation many tonnes of topsoil and overburden material are displaced and stored on heaps and dumps. Dumping should generally be carried out to optimise reshaping to the final land use.

Waste dumps typically consist of a mixture of rock and finer material. The proportion of rock to finer material vary depending on mining methods and geological conditions, but a preliminary analysis can be expected to consider:

- the distribution and size of particles,
- the acid-forming potential of the material,
- specific concerns about the effectiveness of drainage,
- the presence of asbestos or other harmful materials and substances.

If the waste is considered to have the potential to be used in rehabilitation work, then additional analyses could include:

- rock strength,
- particle size distribution (including clay and silt content),
- geochemical analysis,
- susceptibility to erosion,
- water adsorption capacity,
- fertility.

Mine dumps are built from heterogeneous material, which is loosely mounded. It is not uncommon for such dumps to initiate landslides or release harmful substances to the environment. If a decision is to keep the mine dumps as they were dumped during operational stage of the mine, securing such sites is a necessity. Therefore, proper earthwork needs to be carried out like reinforcement of slopes, providing proper drainage or isolation from the environment or even levelling of the heaps.

In the landscaping scope of works the slopes of open pit are taken into consideration as well. Post-mining excavations in the case of open pit mining methods constitute the largest morphological and cubic volume tailings of mining operations, which should be rehabilitated in a manner that depends on the local conditions. The costs of final landform shaping can be minimised if the landform designs are prepared as early in the project life as possible. Proper reshaping of the final pit will greatly influence its later land use.

Another essential activity for mine rehabilitation is managing its hydrogeological conditions. Hydrogeological impacts associated with mining operations are in the groundwater and surface water environment. These impacts are mainly expressed in changes in:

- levels and directions of movement flow of groundwater,
- the location of surface waters in natural and artificial watercourses and water reservoirs,
- conditions and intensity of water flow in natural and artificial watercourses,
- mineralisation and chemical composition of groundwater and surface water.

It is necessary document the geological and engineering conditions of closed mines. Such as changes in the level of groundwater and surface water, resulting in flooding. Areas of uncontrolled flooding are unsuitable for development. Their elimination or territorial reduction requires the construction and maintenance of water drainage systems. An indirect effect of changes in groundwater levels are deformations of the rock mass and land surface. As a result of the depression of the groundwater table, subsidence of the terrain associated with the disappearance of hydrostatic buoyancy in the zone affected by the lowering of the water table and an increase in effective stresses throughout the profile. In open pit lignite mines, the values of land subsidence around the workings are most often 0.1 ÷ 0.4%, but in the initial stage of the process they can exceed 1% of the water table depression. The renewed elevation of the water table after the cessation of mine dewatering, causes uplifts in the area. These are small, however, and in practice amount to about 5 ÷ 10%, maximum 25% of the value of the subsidence that occurred during the phase of lowering the water table. Usually, these uplifts do not exceed the height of a few millimetres, which in the case of wide-spread and long-term development of the process practically should not affect building structures. The indirect effect of depressing of the groundwater level and possible changes in the directions of its flow in the area of the decommissioned mine can cause subsidence deformations on the ground surface. The places and time of their occurrence are difficult to forecast. (Dobak et al., 2009)

In extension, the changes in groundwater levels are changes in hydrological regime, which determines the quality of vegetation in the surrounding area or changes in intake capacity from wells exploited nearby. Depending on intended land use of particular sites, hydrological conditions have to be properly managed. A lot of decommissioned open pit mines are being flooded. This process involves great changes in groundwater table levels, as well as heavily impacts the open pit and its slopes. Incorrectly managed and unmonitored flooding process can lead to slope failures or detrimental changes in geochemistry of flooded water as well as groundwater. However, even if correct management of dewatering wells and hydrological conditions can still lead to some kind of disaster. Therefore, continuous monitoring of the flooding process, which sometimes takes decades, is necessary.

Appropriate water management allows the remaining mining area to be rehabilitated biologically more efficiently. Moreover, in order to restore vegetation on the area, topsoil layer has to be reintroduced. The surface layer in rehabilitated areas must support a self-sustaining vegetative cover. It should:

- have an infiltration capacity,
- have a proper water capacity,
- have adequate aeration,
- provide an adequate rooting depth, without mechanical impediment or by toxic subsoil conditions,
- provide necessary plant nutrients,
- do not exceed dangerous for plants levels of salinity, acidity and alkalinity,
- provide microorganisms necessary for plant growth.

Topsoil is often the most important aspect in determining the effectiveness of reclamation, especially when the goal is to recreate a native ecosystem. A decision on whether soil should be preserved during mining can only be made after a thorough assessment of the and distribution of soil types and overburden prior to mining. In general, soil should be retained and re-used in a reclamation project when the overburden material or other mining waste cannot form the basis for the desired post-mining land use.

Removing the topsoil separately from the subsoil creates the possibility to restore, as close as possible to the original soil profile, with a nutrient- and microorganism-rich layer at the surface where it will be utilized by plants more effectively. Double topsoil removal, where the top 50-100 mm of soil is removed and returned separately and on top of the remaining topsoil, can be justified, especially when the goal is to restore native flora. Most of the seeds are in this topsoil layer, and removing it and returning it as a thin layer on top of the surface maximises the contribution of these seeds to the post-mining flora (Grant et al., 2016). Topsoil can be removed and returned using a variety of machinery, with the most common techniques using a loader and truck, scraper or bulldozer pushing topsoil into a pile.

The selection of plant species used on reclaimed mine site is determined by the goals of the reclamation and the intended land use. In specific cases, certain species of vegetation may be required to accomplish specific ecosystem functions, such as certain levels of nutrient circulation and effects on precipitation infiltration and deep drainage.

Different species may be necessary for different areas of a reclaimed site. Physical, chemical and biological considerations of the growth layer should also be taken into consideration, especially if there has been significant modification of the soil condition due to previous land use, stockpiling or the impact of mining or processing.

In cases of substantial modification, a helpful approach may be to search the local area for analogues of post-mining landscapes and mine soils and use them as models for the suggested post-mining ecosystem.

If natural counterparts cannot be found, selection of species that are tolerant of the growing environment and using the right mix of life forms to fulfil rehabilitation goals is an option. Alternatively, the growth medium may need to be managed, enriched or fertilised to ensure that rehabilitation goals are achieved.

5.2. MINE RECLAMATION DIRECTIONS FOR POST MINING LAND USE

Not all the listed methods of land reclamation can be applied under all conditions. Reclaiming the mining land in the preferred direction is determined by many factors, some of which are decisive, while others are of lesser importance.

The following factors must be taken into account to determine the direction of reclamation (Cymermann, 1988):

- current surrounding land use,
- climatic conditions,
- hydrological conditions,
- soil conditions,
- socio-economic factors,
- technical-economic factors,
- technological feasibility.

Of these, those unchangeable in time - natural factors, such as hydrological conditions, will be decisive in the choice of, for example, the water direction of the post-mining excavation, while such factors as soil conditions, the nature and quality of the surrounding use, will be rather complementary. However, in practice, it turns out that the technical and economic factors are the most crucial.

There are various classifications on proposed post mining land use. Among these are: the classification given by (Maciejewska, 2000), the classification presented in the PN-G-7800:2002 standard and that given by Kaźmierczak U., Malewski J. [2001] . The classification proposed by RAG Montan Immobilien GmbH and English Partnership (Ostręga 2004]) also exist.

Maciejewska [2000] distinguishes six main directions of reclamation:

- agricultural - arable land, pasture or other crops;
- forestry - tree cultivation;
- fishing - fish ponds;
- infrastructural - housing, utilities or other types of construction;
- recreation - water reservoirs for water sports;
- land development - to ensure adequate moisture conditions in the surrounding land, small retention reservoirs.

A new system for designating reclamation directions was proposed by Kaźmierczak U. and Malewski J. [2001] presented in Table 1. The innovation in this classification system is to expand the information on reclamation directions by dividing them into general and specific.

Table 1 Directions of mine rehabilitation

General directions	Specific directions
Agricultural	Farmlands, pastures
Forestry	Management, conservation, recreation
Natural	nature reserve, landscape park, protected landscape area, species protection, nature monument, documentation site of inanimate nature, ecological use, green areas
Aquatic	structures, recreation
Commercial	housing, industry, services

The German company RAG Montan Immobilien GmbH, which specialises in the development of post-industrial sites, distinguishes between current and future development, giving the following division (Ostręga 2004):

- post-industrial;
- open space;
- agricultural;
- forest;
- residential;
- business;
- heavy industry;
- recreation;
- special mining use;
- commercial;
- other - water, drainage, nature, communications.

The Polish standard "Surface mining. Reclamation. General design guideline" lists reclamation directions in a slightly different approach than the classifications presented earlier and is presented in Table 2. It also introduces the concept of "special" direction, which denotes any reclamation and management method other than agricultural, forestry, municipal or water, without specifying what these directions may be (Ostręga, 2004).

Table 2 Area development in reclamation directions

Direction of mine rehabilitation	Land and site preparation
Agricultural	For agricultural development: arable land, grassland, orchards, gardens
Forestry	For forest management: production forests, protective forests
Communal	For municipal purposes, e.g.: for parks, greeneries, sports and leisure facilities
Aquatic	for water reservoirs and the construction of these reservoirs
Special	To be developed for purposes other than reclamation: agricultural, forestry, municipal and water reclamation

Considering the possibility of filling the pit with excavation material only in the case of small, pits, Burnat and Korzeniowski [2003] propose the following directions of reclamation:

- natural (ecological) - this type of reclamation should be carried out after the opinion of ecologists, geologists and naturalists in the areas of large pits. It assumes, among other things, that the excavation is self-filling with water and conditions favourable for the development of vegetation, which, as a result, may contribute to the emergence of small nature reserves;
- recreational - the direction preferred for the reclamation of pits after the extraction of raw material from under water or dry pits, such as after the extraction of rocky materials. As a result of this direction of reclamation, fisherman stands or even sailing centres can be created on the banks of the reservoir, while sports fields, motorcycle tracks, etc. can be created on dry pits;
- agricultural and forestry - this direction is suggested for the reclamation of smaller pits. It consists in filling the excavation with mined, waste material, covering it with a layer of soil (e.g., from the overburden) and planting or planting crops or forest;
- aquatic - involves the installation of fish ponds, retention basins, reservoirs for irrigation and fire-fighting purposes;
- industrial - the adaptation of a reclaimed pit for the storage of municipal and industrial waste, as well as the location in the excavations of warehouses of materials that cannot be stored in municipal areas.

On the basis of the divisions of the directions of reclamation and development compiled so far (mainly by J. Malewski and U. Kaźmierczak) and the review of the methods of development of post-industrial sites, the possible directions for reclamation and development of post-industrial sites are summarised in Table 3 (Kasztelewicz, 2010).

Table 3 General and specific rehabilitation and land use directions.

General directions	Specific directions
Agricultural	farming: animals, poultry, fish
	crops: farm land, orchards, meadows, pastures, gardens for allotments
Forestry	protection
	commercial (e.g., for timber production)
	recreation: hiking trails, parks, hiking and biking paths, health paths, forest promotion complexes
Natural	forms of protection depending on the natural values: sodding, shrubbing, greening
Recreational	sports facilities, including those for winter sports, such as ski slopes, bobsleigh runs, hiking trails, parks, footpaths, health trails, playgrounds, amusement parks, extreme sports centres, skate parks
Aquatic	recreation: bathing sites, water sports
	commercial: retention basin, drinking water reservoirs
Commercial	housing, campuses, garages, tourist and hotel facilities
	industrial parks
	services: business incubators, warehouses, stores, wholesalers, parking lots, sports facilities, etc.
	landfills
Cultural	Educational facilities: thematic paths, laboratories, computer labs, concert and conference halls
	contemplative
	artistic: museums, expositions, exhibition and concert halls, galleries, theatres, stages, cinemas, etc.

6. ANALYSIS OF BEST PRACTICES DURING MINE REHABILITATION AND RECLAMATION BASED ON SPECIFIC REGIONS FROM THE WINTER PROJECT

6.1. CASE STUDY I KONIN REGION, POLAND

The first coal deposits in the Konin area were surveyed in 1926. During World War II the construction of the mine along with a processing plant - a briquetting plant began. After World War II, in 1945, on the basis of the existing infrastructure, the "Morzysaw" open pit movement started, initially to meet the energy needs of the local population and, commencing in 1946, also for the briquetting plant. After the construction of the "Konin" power plant in 1958 and the "Ptnów" power plant in 1967-1969, the other open pits were gradually put into operation. The "Niesusz" open pit began its operations in 1953. (KWB KONIN website, 2022)

The chronological order of open pit excavations is given below:

- "Morzysław" - 1945,
- "Niesłusz" - 1953,
- "Gosławice" - 1958,
- "Pątnów" - 1962,
- "Kazimierz" - 1965,
- "Jóźwin" - 1971,
- "Lubstów" - 1982,
- "Kazimierz Północ" - 1995,
- "Jóźwin IIB " - 1999,
- "Drzewce" - 2005,
- "Tomisławice" - 2010.

Currently, coal mining is carried out from two open pits: "Tomisławice" and "Drzewce".

6.1.1. General description of the rehabilitation area and reclamation work done

Morzysław open pit

The Morzysław open pit was the first lignite open pit in the Konin region, launched in 1945. Excavation was carried out using two single-bucket combustion powered excavators and one single-bucket steam powered excavator. In the following years, after electricity was connected, electric bucket wheel excavators were brought in, increasing the efficiency of mining. After the end of coal mining and reclamation, the areas of the former Morzysław open pit were transferred to the city of Konin. A single-family housing estate "Glinka" was built on the outer heap, and tennis courts and a sports venue were built on the inner heap. The final pit was flooded with water and currently serves as a recreational park seen on Figure 1.

Figure 1. 700th Anniversary Recreational Park (source: http://www.kwbkonin.pl/index.php/odkrywki-2/odkrywka-morzyslaw/)

Niesłusz open pit

When the coal from the Morzysław open pit was being depleted very quickly, efforts were made to open a new open pit located in the village of Niesłusz. Work began in 1949 with the construction of a shaft, and the first tons of coal were extracted only in 1953. As in the Morzysław open pit, the reserves were small and coal mining was terminated in 1961.

Reclamation and development of the site was based on aquatic and forestry direction. Most of the end pit was flooded with water (Fig. 2), restoring the original pre-mining condition, and the rest of the area was reforested and garden allotments were created. In the 1990s, part of the area was developed, with the construction of the "Galeria Nad Jeziorem" mall, as well as tennis courts, grass fields, and walking paths.

Figure 2. Final pit lake of Niesłusz pit (source: http://www.kwbkonin.pl/index.php/odkrywki-2/odkrywka-nieslusz/)

Gosławice open pit

Coal mining in the "Gosławice" open pit was carried out from 1953 to 1974. Reclamation of post-mining areas was carried out in eleven stages: by the end of 1970, about 240 ha of reclaimed land were given over as farmland and allotment gardens, and then 33 ha were transferred to industry "Konińskie Zakłady Naprawcze FUGO Konin".

According to Prof. Skawina, the construction of allotment gardens on the heap was a good idea. Agricultural reclamation, on the other hand, was considered a bad one, since the overburden was dumped in a non-selective manner. By the end of 1975, the rest of the former Gosławice open pit area was completely rehabilitated. Reforestation was adopted as the main direction of reclamation of the dumps. The final pit located in the northern part of the Gosławice open pit was designated as a landfill for industrial waste (ash from the "Pątnów" power plant and alumina from the Aluminium Smelter). The post-mining pit near the Konin Briquetting Plant was earmarked for a water reservoir, which was donated to the Polish Angling Association (Fig. 3).

Figure 3. Final pit lake of Gosłąwice pit (source: http://www.kwbkonin.pl/index.php/odkrywki-2/odkrywka-goslawice/)

<u>Pątnów open pit</u>

Construction of the Pątnów open pit began in 1957, and mining was completed in 2002. The coal deposit of the Pątnów open pit was located near the Gosławskie, Pątnowskie and Mikorzyńskie lakes. In consequence of this, the area's poor water conditions were exacerbated, and the direction of aquatic restoration was modified.

The development of the post-mining areas of the Pątnów open pit was useful for industrial plants, as well as for the community living in the region.

The following facilities were built on the former Pątnów open pit:

- external dump of another open pit - Jóźwin,
- landfill of ash and gypsum from the Pątnów power plant,
- landfill of clay and sand for “Wienerberger” brickworks,
- landfill of communal waste of the municipality of Ślesin,
- farmlands,
- water reservoir.

By raising the height of dumping, the external dump of the Pątnów pit was used as an area for the external dump of the open pit Jóźwin. This decision, allowed to save space and not to occupy additional land, turned out to be partially wrong in the case of the Jóźwin open pit's heap formations (gyttja and water-bearing formations). A number of landslides have occurred in the area of the dump, causing numerous technical problems up to the present time (more than 30 years have passed since then), necessitating additional reclamation work on the slopes of the dump.

The water reservoir in the post-mining pit of the Pątnów open pit has been developed for recreational and sports activities (sailing, motor sports, etc.), as well as for fishing and for agriculture as a source of water for irrigation of agricultural fields. This reservoir is currently the largest post-mining reservoir (Fig. 4) with an area of about 350 ha and a volume of about 85 million m^3 of water.

Figure 4. Final pit lake and its surroundings (source: http://www.kwbkonin.pl/index.php/odkrywki-2/odkrywka-patnow/)

Kazimierz open pit

Work on the Kazimierz open pit began in the early 1960s. Coal began to be extracted from 1965. The open pit was divided into two fields: Kazimierz Południe (south) and Kazimierz Północ (north). In the southern field, mining was completed in 1997, while coal extraction in the northern field began in 1995 and ended in 2011.

During the course of mining, projects were developed for the reclamation and development of the "Kazimierz Południe" open pit area. The projects included various reclamation directions:

- agricultural,

- forestall,
- aquatic - on an area of 110 ha with a final reservoir on area of 65 ha;
- communal waste landfill - on an area of 65 ha;
- construction of Konin Aero Club airport;
- construction of allotment gardens, a sports stadium and a sports shooting range.

The implementation of these projects occurred successively with the progress of the mining operation. Reclamation in the direction of agriculture and forestry has been carried out on the external heap.

The final reservoir (Fig. 5) of the Kazimierz Południe open pit was constructed on the basis of the technical design made by Poltegor-Projekt Sp. z o.o. In 1999, while the dumping procedure was still ongoing, implementation of this project started.

The area of the entire reservoir at the water table ordinate of +97.6 m above sea level is about 65 ha, and together with the surrounding slopes and adjacent areas - about 110 ha. The slopes of the reservoir have been formed with a gradient of 1:8 and 1:5. Selected areas of the slopes with a gradient of 1:8 have been designated for sand and grass beaches. The remaining areas of the slopes above the water table have been wooded and shrubbed. To increase the landscape value, the reservoir is divided by a peninsula, and within the reservoir two islands were formed and developed. The supply of water to the reservoir flows through a transposed segment of Struga Biskupia river flowing out of Lake Koziegłowy. In the deep part of the reservoir at a length of about 1.7 km, geotextile and geogrids were used to strengthen the slopes with a slope of 1:5, which was filled with humus and stone. Filling of the reservoir began in October 2003 and was completed in March 2004, when the target depth was reached. It has a considerable effect on water relations and is a permanent feature of the region's landscape and hydrography. As a result, the area's shallow ponds and marshes will be restored to their pre-mining state. Worth noting that there are around 35 ha of agriculturally reclaimed land and 40 ha of forest area in the local vicinity of the reservoir. The airport, constructed on reclaimed land, serves primarily as a training facility for experienced pilotsCurrently, the Konin Aero Club airfield needs to be modernized to enable landing and take-off of larger aircrafts.

The concept assumes that the Konin Aero Club airport located in Kazimierz Biskupi, after modernization, could receive avionettes and small passenger aircrafts. The airport in Kazimierz Biskupi is the only airport in the Konin subregion, and is located in the centre of Wielkopolska and Poland - which guarantees the success of the undertaking. The project is primarily an upgrade of the airport's infrastructure and the reconstruction and extension of the runway.

Exploitation in the "Kazimierz Północ" lasted until 2011, and the reclamation of post-mining area took up 1045 hectares, including:

- the direction of forest reclamation 75 ha,
- the direction of aquatic reclamation 364 ha,
- the direction of agricultural reclamation 606 ha.

The depth of the reservoir ranges from 20 to 60 m. In the central part in the undumped area of about 36 hectares, the depth will be the greatest, and this area will feed the reservoir with groundwater. The capacity of the reservoir will be about 97 million m^3. The final pit was filled with groundwater, water from precipitation and additionally by the water from the dewatering of the Jóźwin IIB open pit. The recreational elements of this facility are two recreational areas with beaches, facilities with a marina, and green areas with paths agreed with the municipality of Kleczew and Kazimierz Biskupi.

Figure 5. Final pit lake in Kozarzewko (source: http://www.kwbkonin.pl/index.php/odkrywki-2/odkrywka-kazimierz/)

Lubstów open pit

The development of the Lubstów open pit was completed in 1982. During its operation, mining activities caused a significant landscape transformation, characterised mainly by:

- the formation of an external dump with a relative height of up to 30 m, with steep slopes developed in a forest direction;
- the formation of an internal dump shaped slightly above or up to the level of the adjacent land;
- the formation of a pit with a depth of up to 80 m;
- the development of industrial infrastructure, fundamentally affecting the landscape.

The decision of the Head of the City and Municipality of Sompolno dated 1980 established the following directions for reclamation and land use in the post-mining areas of the Lubstów open pit:

- slopes of the external overburden dump - forest direction,
- top of the outer overburden heap - forest direction,
- top of the inner overburden heap - agricultural direction,
- slopes of the inner overburden dump - forest direction,
- final pit - aquatic direction,
- auxiliary areas (coal route, yards and roads, settling tanks, treatment plant, administrative and workshop facilities) - agricultural and forest direction.

The mine excavated peat and peat soils in the area intended for the external dump in the amount of about 2 million m^3, and then, rehabilitated the external dump in the forest and agricultural direction.

After the transfer and partial sale of the outer dump area (early 1990s), reclamation work began on the inner dump. After 1994, the overburden was dumped in the southeastern part of the pit, which allowed the top to be formed at the level of the initial area and enabled the reclamation of this part of the inner dump to begin. In 2009, the placement of the overburden along the eastern slope of the pit in a northerly direction was completed. The water reservoir is built into the south and east sides of the inner dump. Reclamation of the northern part of the inner dump and the final pit began in 2006 and lasted until 2011.

On the area intended for reclamation in terms of special direction, the municipality of Sompolno initially planned to install a municipal landfill. Since the problem of waste management has been solved on an extra-local scale, the municipality has abandoned the above intentions and the prepared nearly 100-hectare area will be developed in other ways (e.g., for further reforestation, construction of sports facilities - shooting ranges or other purposes). The proximity of the reservoir to the projected beaches near the landfill would interfere with a possible recreational and leisure program in the area. In addition, in the future, when the land of the internal dump reaches the standards that allow the foundation of construction facilities (after at least twenty years), it will be possible to use the area for investment purposes.

In addition to designing the infrastructure elements of the developed final pit, a very important point is the possibility of quickly filling the reservoir with water.

According to the 2006 project, the area of the water reservoir is expected to be about 570 ha, of which about:

- 480 ha - the area of the water reservoir at the water table ordinate of approx. +83 m above sea level,
- 90 ha - slopes of the reservoir with different slopes,
- 64 ha - areas adjacent to the reservoir.

Maintaining people and animals out of the reservoir was essential due to its complex topography and relatively deep depth values in many sections (except in specially designated areas).The target shape of the slopes and their anti-erosion protection, as well as aesthetic and economic considerations in relation to adjacent areas and the above-mentioned factors led to the adoption of the following method of biological containment of areas:

- above the water table:
  - slopes of the water reservoir - strip shrubbery with thorny shrubs and wicker,
  - ledges - sodding by sowing with a mixture of grasses and legumes,
  - areas adjacent to the slopes near the water of the reservoir - sodding and afforestation of the remaining area;
- below the water table, the slopes of the reservoir will be sodded with a predominance of legumes and shrubbery with wicker, while the unconverted areas adjacent to the slopes of the reservoir will be sown with grasses and legumes and afforestation.

The reservoir and in its immediate vicinity are to be used for recreation, retention, fishing, water sports, etc.

Hydroseeding consists of covering the soil surface with a product that consists of seeds from various species of grasses, mulch, cellulose fibres of fertilizers, synthetic polymers and hydrogel, mixed with water (Fig. 6). This preparation, during sowing, takes the form of a gel, which adheres to the ground - even very steep - and provides a substrate for the forming grass.

The method is especially recommended for anti-erosion sodding of slopes of water bodies. Reclaimed post-mining areas for further use should be managed by the future owner, whose responsibility is to develop a project for the development of the final pit area of the Lubstów open pit. It is also advisable to use in this project the areas of the internal dump located on the south-east side of the reservoir, currently owned by the City and Municipality of Sompolno. This will allow the creation of a very large recreational and sports complex.

It is currently planned to create in the vicinity of the reservoir:

- a water sports centre,
- play and recreation area for children,
- areas for summer housing,
- reserve areas,
- communication systems.

Figure 6. Final pit lake of Lubstów pit (source: http://www.kwbkonin.pl/index.php/odkrywki-2/odkrywka-lubstow/)

Jóźwin open pit

Construction of the Jóźwin open pit began in 1965 with surface dewatering of the rock mass. Despite the geological issues and problems with the conveyor belts, coal mining began in 1971 and ended in 2020.

Exploitation and, at the same time, reclamation of the post-mining areas of the Jóźwin open pit was divided into three areas:

- Area I - the depleted and embanked southern and eastern parts of the open pit;

- Area IIA - the depleted western part of the open pit, which is located between the protection pillar of the "Przyjaźń" pipeline and the embankment on the border with the Kazimierz Północ open pit;

- Area IIB - the northern part of the Jóźwin open pit, above the pipeline "Przyjaźń".

The reclamation and development of the Jóźwin open pit was developed by Poltegor-Projekt Sp. z o.o.

Area I was reclaimed in the previous period with a dominant agricultural direction with slopes planted with shrubs and tree seedlings and with the location of the Kleczew municipality's municipal waste dump and the Kazimierz Biskupi - Ślesin public road. These areas are an excellent showcase of agricultural reclamation.

In area IIA:

- agricultural direction of reclamation on the area of 274 ha,
- forest direction of reclamation on the area of 51 ha,
- recreational direction of land use on an area of 581 ha.

In area IIB, post-mining land reclamation is envisaged in the following directions:

- agricultural on an area of 543 ha,
- forestry on an area of 438 ha,
- water on an area of 433 ha.

Currently, the mine is completing the implementation of the project of recreational and sports areas in field IIA of the Jóźwin open pit. The recreational and sports elements include: a ski slope, motocross, a golf course, a water reservoir (Fig. 7) and an amphitheatre.

In accordance with the signed agreement with the municipality of Kleczew, the mine is performing technical reclamation of these elements of the recreational complex under the name of "Malta BIS", and the municipality will carry out the detailed development of the entire area. These facilities, once developed, will serve not only the residents of nearby towns, but also others from outside the region [Kasztelewicz, 2010].

Figure 7. Angling station at the pit lake (source: http://www.kwbkonin.pl/index.php/odkrywki-2/odkrywka-jozwin/)

Drzewce open pit

The Drzewce lignite open pit is the ninth mining site of the coal mine in Kleczew that has been put into operation. The removal of overburden, which began in 2005, enabled the first tons of coal to be extracted in early 2006 and lasted until August of 2022.

The Drzewce deposit consists of three erosion washout zones separated from each other - the "Bilczew" area and the "Drzewce A" and "Drzewce B" areas. Mining area Drzewce is located northeast of Konin. According to the project of KWB "Konin", land with a total area of approximately 930 ha will be subject to reclamation.

"Bilczew" area with an area of about 285 hectares, includes:

- the top of the inner dump, with an area of about 110 ha,
- the slopes of the inner dump, with an area of about 80 ha,
- areas adjacent to the heap, with an area of about 95 ha.

Area "A" with an area of about 305 ha, includes:

- the top of the internal dump, with an area of about 150 ha,
- the slopes of the inner dump, with an area of about 90 ha,
- areas adjacent to the heap, with an area of about 65 ha.

Area" B" with an area of about 340 ha, includes:

- top of the inner dump, with an area of about 36 ha,
- slopes of the inner dump, with an area of about 34 ha,
- water reservoir, with an area of about 148 ha,
- slopes and beaches and recreation areas of the water reservoir, with an area of about 74 ha,
- areas adjacent to the heap as well as the reservoir, with an area of about 48 ha.

In accordance with the Decision of the Konin Governor, KWB "Konin" in Kleczew was obliged to recultivate post-mining areas towards forestry and water. In the "Bilczew" and "A" areas, a total of 590 ha will be rehabilitated in the forest direction (Fig. 8), while in the "B" area, in addition to 123 ha rehabilitated in context of the forest direction, a final reservoir will be created on an area of about 148 ha and a grass-sandy beach on an area of about 11 ha. It is also envisaged that the process roads built for communication and transportation at the "Drzewce" open pit can be partially used and serve the local residents. The unforested paths, which will be created during the forest reclamation of the internal dump, will also be used for recreation. To make this possible, it has been assumed that they will be 6-meter-wide roads.

Figure 8. Reforestation at the external dump (source: http://www.kwbkonin.pl/index.php/odkrywki-2/odkrywka-drzewce/)

6.1.2. Best practices used during reclamation

New techniques have been successfully adopted in the "Konin" multi-pit mine. . For instance, the overburden from the Jówin open pit was transferred to the Ptnów open pit; from the Kazimierz Pónoc open pit to the Kazimierz Poudnie open pit; or from the "Jówin IIB" open pit to the "Jówin IIA" open pit. Another method for transferring overburden from one open pit to another is to spread the dump on the foreground of the open pit, and then transfer these dump masses to the inner excavation regions. This technology enables to save space for unnecessary dumping and conserves the energy that is required to move these massive amounts of material (Kasztelewicz & Michalski 2005 and 2006).

Another alternative would be to flood the post-mining pits of the open pit that is being closed by using water that was extracted from the mine during the process of dewatering that occurred when the open pit originally created. The Konin mine was the first company in the industry to implement these technologies. The mine is responsible for carrying out the reclamation in line with the existing directives, which were established as a result of decisions made by the Governor of the Konin and Kolski Districts. Reclamation is carried out mainly in the following directions: agricultural, forestry, water and recreation and sports.

6.2. CASE STUDY II GREEK LIGNITE CENTRES

6.2.1. Lignite Centre of Western Macedonia

Western Macedonia is a region in North-western Greece with a population of 290,000, with its economy largely dominated by lignite mining and lignite-fired power plants and district heating systems. Since 2010, there has been a constant decrease in lignite-fired power plants—the four oldest units stopped operating—which has accelerated since 2019, triggered by the increased Emissions Trading System (ETS) carbon price which increased the costs to produce lignite-based electricity, combined with policies to promote the use of renewable energy and natural gas. In line with its international commitments to accelerate climate action, Greece has to urgently transform its energy system towards clean energy technologies. In 2019, the Greek Government as part of its National Energy and Climate Plan set the goal of a full lignite phase-out by 2028, with the majority of units being withdrawn by 2023, while only one plant will continue to operate—the Ptolemais V bloc, which is still under construction and will burn lignite at the latest until 2028.

The operation of the Lignite Centre of Western Macedonia (LCWM) mines by the PPC started in 1957. As of 2018, the mines extended over an area of 17,000 ha with annual excavations exceeding 170 Mm^3 and lignite production being 27.2 Mt (Pavloudakis et al., 2018). A total of 1.74 Gt had been mined up to the end of 2020, with total excavations of 8.7 billion m^3 and a stripping ratio (waste to lignite) of 4.16 m^3/t. After the closure of the Amynteo - Lakkia and Kardia mines during 2020–2021, Mavropigi and South Field mines will be in operation until the overall phase-out (Antoniadis et al., 2021). Figure 9 shows the two mining areas of Western Macedonia, Ptolemaida and Amynteo.

Figure 9. Satellite view of the Lignite Centre of Western Macedonia, with the yellow lines outlining the two mining areas, Ptolemaida (SE) and Amynteo (NW)

Rehabilitation and reclamation work

PPC has reforested many old mine areas in LCWM mainly with *Robinia pseudacacia L.*, or black locust (Basnou, 2016) seen on Figure 10. 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.

Figure 10. Robinia pseudoacacia L. plantations used for slope stabilisation and erosion control in Amynteon mine (Papadopoulou et al., 2018).

Common reclamation practices for the waste heaps in LCWM, are the plantation of the slopes on their marginal parts and the transformation of their top, horizontal parts in farming areas. The creation of experimental grain cultivation with a view to testing the fertility of the rehabilitated areas started in 1986 and is still in progress (PPC, 2009). The cultivated land is seeded with wheat and rented to local farmers at 100€ per ha per year. The productivities achieved are varying considerably from site to site. In general, the productivity of the reclaimed lands varies from 1,000 kg/ha to 4,000 kg/ha (average value is 2,200 kg/ha) and is comparable to this reported for cultivations developed in the surrounding areas (Pavloudakis et al., 2011; Pavloudakis et al., 2019; Pavloudakis et al., 2020). Also PPC in order to boost the agricultural economy of the greater mining area, will offer 150 ha of reclaimed waste heaps surfaces to young farmers for aromatic herbs cultivation. The productivity of the reclaimed mine land does not differ significantly to this of the land that was not used for lignite mining (Pavloudakis et al., 2018). According to a study by Papadopoulos et al. (2015), the reclaimed soils are of relatively good quality, with low heavy metal concentrations and adequate amount of nutrients.

Apart from the cultivation of crops, a pilot greenhouse for hydroponic cultivations was created, using teleheating run. A model orchard (Figure 11) 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).

Figure 11. The orchard in the area of the Main Field mine (photograph taken on 26 October 2022).

Planned rehabilitation/reclamation work

PPC will continue the above-mentioned reclamation activities in the LCWM, combined with the construction of photovoltaic parks on the waste heaps' large horizontal areas. Additionally, 8% of the total area of the former mines will be transformed into artificial lakes, which is allowed by their topography and the hydrogeological conditions (PPC, 2011; Pavloudakis et al., 2020).

According to the Hellenic Ministry of Environment and Energy (2021), the type of rehabilitation works concerning mines and power plants is defined by the current Approval of Environmental Assessment. In Western Macedonia, additional works regarding post-lignite uses will be specifically defined and will include the development of artificial forest planting, agricultural lands, lakes and general use land, such as business centres, business parks etc. These rehabilitation works will include:

- Surface levelling;
- Ensuring slope stability via slope analysis;
- Analysis for possible surface erosion and landslides;
- Monitoring soil fertility via sampling and laboratory tests;
- Afforestation using specific species, based on the soil and climatic conditions of each area;
- Construction of infrastructure related to water supply, irrigation, drainage, energy, accessibility etc.

Renewable Energy

Between 2018 and 2019, PPC Renewables submitted 19 different applications to the Regulatory Authority for Energy (RAE) for power producer licenses, along with PV panel installation studies. Both former excavations and dumps were considered, some of which are located in active mining areas (Antoniadis et al., 2022).

Funding

In Greece, the mining closure and rehabilitation periods, areas and related costs are defined in the environmental permits that have been approved by the relevant public authorities. Figure 12 refers to the Ptolemaida, Mavropigi and Amynteo mines. The permits include cost of the environmental management activities regarding the operation of the mines and their reclamation but exclude compensation (direct or indirect) to local communities/individuals, as well as financing of projects related to their economic development and welfare (Pavloudakis et al., 2011).

Mine	Total-area occupied (ha)	Environmental cost until permit expiration (€)	Environmental cost until mine closure (€)
Ptolemais	11,089	20,000,000	50,000,000
Mavropigi	1,200	8,000,000	3,200,000
Amynteon	5,294	40,000,000	8,000,000

Figure 12. Cost of implementing the terms and conditions of environmental permits (Pavloudakis et al., 2011).

PPC pays 0.5% of its turnover as a revenue bond to compensate for any negative environmental and economic impacts of open pit mining. As of 2018, PPC has paid a total of 260 M€, which is allocated to the Prefectures, according to lignite production in these areas. The use of the bond for projects is the sole responsibility of the local authorities (Pavloudakis et al., 2018).

6.2.1.1. Ptolemaida mining area

The operation of the Ptolemaida mines (Kozani province of Western Macedonia Prefecture) by the PPC started in 1957. A total of 1.5 Gt of lignite had been mined in the Ptolemaida area until the end of 2020, with total excavations of 6.8 billion m^3 and an overall stripping ratio of 3.7 m^3/t. The corresponding total lignite production from all PPC mines in Greece was 2.2 billion tons and the total excavations 10 billion m^3. The remaining lignite reserves in the area are estimated to about 600 million tons. The currently operating mines, Mavropigi and South Field produced of 8.25 Mt of lignite in 2020 and will continue operating until 2028 (Paraskevis et al., 2021).

Rehabilitation and reclamation work

According to data from the European project CORINE (Coordination of information on the environment land cover), which records land use for 27 member countries of the European Union, 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). Figures 13 and 14 represent reforested parts of the Ptolemaida mining area.

Figure 13 Reforested area in Ptolemaida (photograph taken on 26 October 2022).

Figure 14. Reforested areas on deposited materials of the mines (photograph taken on 26 October 2022).

Approximately 40,000 acres have been reclaimed by the year 2020 from the LCWM, with 20,000 acres of plantations with forest species, 14,000 acres of areas for agricultural cultivation granted to local farmers for exploitation and 6,000 acres allocated for other uses (see bullet points) (PPC, 2009; IENE, 2020). According to the most recent Sustainability Report by PPC (2020), in the context of the COFORMIT program (Contribution of the tree planted land of LCWM in the protection of the environment and the mitigation of climate change), the company created a park in 2019 with pedestrian and bike lanes, as well as seating areas.

Reclamation works are carried out during the mining operation in areas where mining activities are completed. In particular, 18 km^2 have been reforested in the Ptolemaida region and 9 km^2 have been reclaimed for agricultural use (Paraskevis et al., 2021; Antoniadis et al., 2021). The following have been constructed in the area of the Main Field mine, where mining operations have been completed (PPC, 2009; IENE, 2020):

- An exhibition centre, with more than 5,000 visitors/year from Greece and abroad;
- An artificial wetland close to the Kozani-Ptolemaida national road, which will be utilised for environmental education due to its evolvement into a major ecosystem;
- A pilot hydroponic cultivation greenhouse, with coverage of its thermal loads by the district heating system;
- An animal reserve of 8 ha with hares, partridges and pheasants that is used by the Forestry Authority for the enrichment of the area;
- An open-air theatre that was built using old materials from the mines;
- A silviculture park with northern Greek forest species, in the external deposition of the Main Field mine;
- A railway history park;
- An amusement park;
- Industrial waste areas and landfills.

Planned rehabilitation/reclamation work

The is a number of chosen final uses of the mines that have undergone closure and those are shown on Figure 15. Firstly, the slope areas of the final excavations and deposited materials will be reforested for wood production forest lands and also livestock zones will be developed. The horizontal surfaces of the final deposited materials will be developed as agricultural lands, while areas with slope will be transformed into artificial lakes. Other areas will have special uses, such as a motor cross sports centre. An area of 4,000 acres will be allocated for the installation of RES and an Innovation Zone (Zervas et al., 2021).

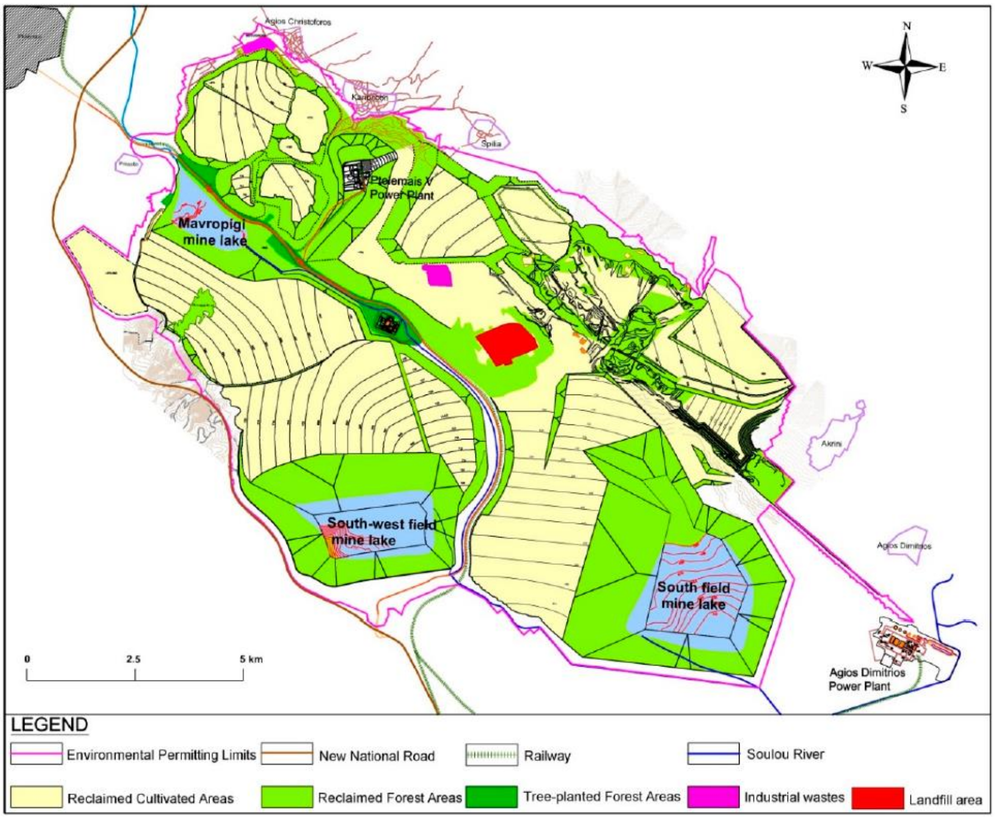


Figure 15. Land uses in the Lignite Centre of Western Macedonia (LCWM) (Ptolemaida) after the mine closure and the completion of the land reclamation programme prescribed in the environmental permits (PPC, 2011; Pavloudakis et al., 2020).

Three PV projects with a total capacity of 230 MW are under construction in Ptolemaida by Public Power Corporation Renewables (Fig. 16), with some parts already completed. Western Macedonia Solar Parks I (Fig. 17) & 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).

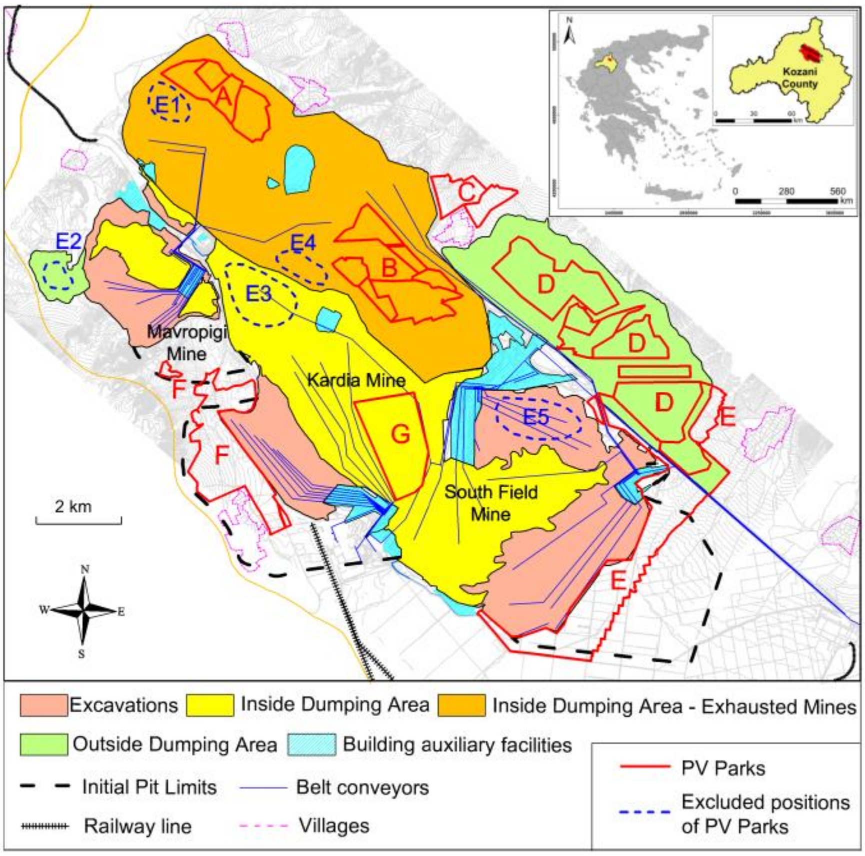


Figure 16. General overview of the Ptolemaida region and locations investigated for PV parks (Antoniadis et al., 2021).

Figure 17. Western Macedonia Solar Park I (under development) (photograph taken on 26 October 2022).

<u>Worst Practices</u>

Numerous inadequacies and ineffective practices have been previously identified during on-site inspections or from complaints by local authorities and citizens. Besides delays in the reforestation program, some of these practices relate to soil management, ground fractures close to the open pits and potential pollutants deriving from the dispersion of dust from the ash disposal site and the improper disposal of used tires, belt-conveyors and waste lubricants. Other practices relate to water management, such as improper discharge of wastewater, lack of elaborate stream mapping, inadequate on-line measurements of wastewater quality and the depression of water table, which leads to the decrease of ground water supply for irrigation purposes (Pavloudakis et al., 2008).

6.2.1.2. Amynteo mining area

In the last 35 years, three open cast mines have operated in the Amynteo mining area. The oldest in the Anargyroi mine (1984-2010), which produced 49 Mt of lignite and 173 million m^3 of total excavations. The Amynteo mine (1989 - 2020) produced 179 Mt of lignite production and 1,595 million m^3 of total excavations. The smaller Lakkia mine (2013-2021) produced 4 Mt of lignite and a 49 million m^3 of total excavations. The Amynteo mining area has produced 232 Mt of lignite in total, with 1,817 million m^3 of total excavations and a stripping ratio of 7 m^3 steriles per ton of lignite. Figure 18 shows a plan of the Amynteo area mines in the Amynteo flood plain (Kavvadas et al., 2022) and Figure 19 illustrates the Amynteo pit lake (Sakellari et al., 2021).

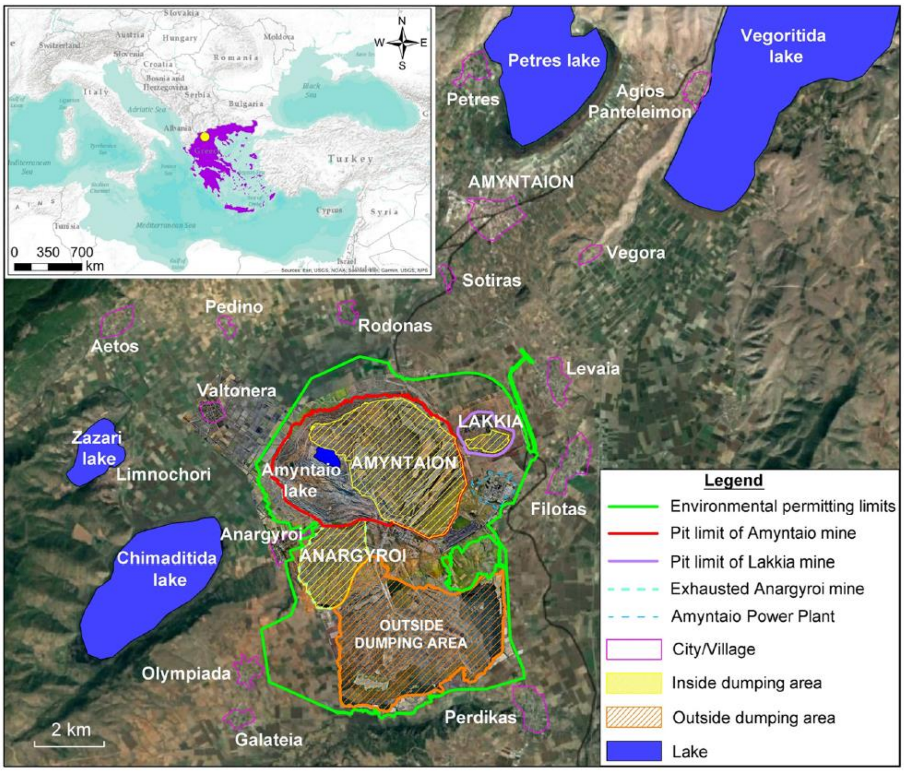


Figure 18 Plan of the Amynteo area mines (Anargyroi, Amynteo, Lakkia). The green boundary shows the limits of the exploitation license (Kavvadas et al., 2022).

The decommissioning of the Amynteo mine was affected by a significant landslide (80 million m^3) which occurred in June 2017 on the southwestern exploitation front, therefore to facilitate the planned rehabilitation activities, the slope was regraded to avoid further drops (Kavvadas, 2017). Following decommissioning, the natural water filling of the mine and the subsequent creation of an aquatic ecosystem has been examined in geotechnical and geochemical studies (Kavvadas et al., 2022).

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 (Fig. 19), 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). 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 (Fig. 20) (Kavvadas et al., 2022).

Figure 19. The Amynteo pit lake (photograph taken on 26 October 2022).

Figure 20. Agricultural lands near Amynteo mine (photograph taken on 26 October 2022).

6.2.2. Lignite Centre of Megalopolis

The Lignite Centre of Megalopolis (LCM) in central Peloponnese includes four open pit mines, Thoknia (1970-1994), Marathousa, Kyparissia (closed) and Choremi , which still in operation by PPC (PPC, 2022). The rivers Elisson and Alfios are located in the areas between the mines (Fig. 21), so the rivers have been and will be subjected in the future to several diversions, in order to ensure the seamless operation of the mines. Overall, the LCM mines produce and average of 9 Mt/year (PPC, 2016; Sokratidou et al., 2018).

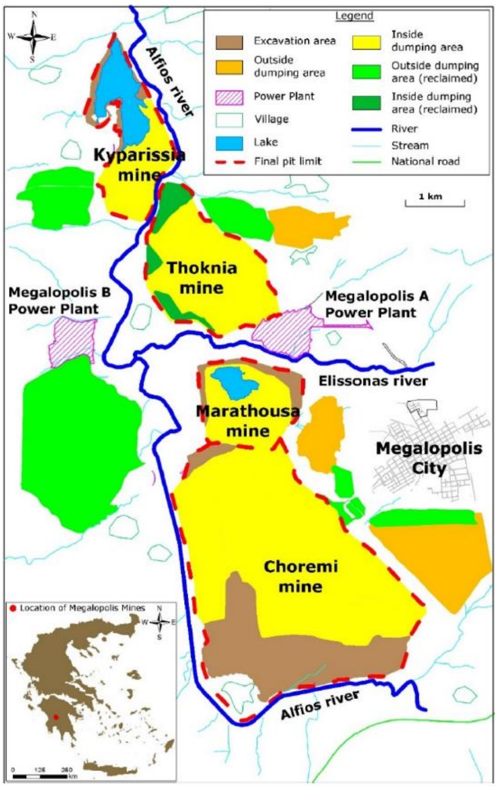


Figure 21. Overview of the Megalopolis mines entering the closing phase (Spanidis et al., 2022).

<u>*Rehabilitation and reclamation work*</u>

Rehabilitation works started with the external deposits of Thoknia and Choremi mines (Fig. 15), where more than 6.5 km^2 were rehabilitated from 2004 to 2012, mainly with the tree species *Robinia pseudoacacia, Cupressus arizonic, Pinus pinea, Eucalyptus sp.* These species were chosen due to their advantageous characteristics, such as their resilience, fast development and limited maintenance, constituting a **best practice** for the area. Other used species are *Pinus halepensis, Spartium junceum, Olea europaea, Castanea sativa, Juglans regia, Ficus carica, Cedrus sp.* and *Catalpa sp*. (Louloudis, 2017; Sokratidou et al., 2018).

Another rehabilitation activity was the filling of the old Thonkia open cast with waste rock material, in order to then deposit by-products of the desulfurization plants of the power stations (Louloudis, 2017; Sokratidou et al., 2018).

There are two pit lakes in LCM. The final, large open cast of Kyparissia lignite field has been transformed into a pit lake (Fig.22), which occupies an area of 0.8 km^2 and can hold 20 * 10^6 m^3

of water, with a depth of 30 m. The lake is hydraulically connected to a karstic aquifer of high quality and capacity; therefore, it is continuously monitored. The second mine that was transformed into a pit lake is Marathoussa, where rainfall runoff was allowed to fill the deepest part of the excavations. This lake, that occupies an area of 0.25 km^2 and a depth of 15 m, has no hydraulic connection with other aquifers and, therefore, its potential development is quite limited (Sakellari et al., 2021).

Figure 22. Kyparissia pit lake (Sakelari et al., 2021).

The LCM, which conducts in reclamation operations, have already reclaimed a total of 7,038 acres until the year 2020. The reforested area occupies more than 4,300 acres, the reclaimed agricultural land 2,300 acres (and it has been leased to local farmers) and 1,700 acres have been allocated to special projects (see below). The remaining 2,000 acres will host a photovoltaic park (IENE, 2020). Experimental cultivations of plants such as tomatoes, potatoes and beans, as well as experimental crops of oats, grains and vetch have delivered very satisfactory results that are generally achieved in the surrounding, unaffected areas (PPC, 2009).

The following special projects have been completed (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 (artificial lakes, some of which have been filled with fish);
- A motor cross track (Fig. 23), declared as model track by international organisations, that hosts international races on a regular basis;
- A runway for ultra-light aircrafts.

Figure 23. The LCM motor cross track (Sokratidou et al., 2018).

Planned rehabilitation/reclamation work

By the completion of the rehabilitation/reclamation works in the LCM, an area of 6.24 km^2 will be used for timber production and a further area of 7.8 km^2 will have been reclaimed as agricultural land. Additionally, another pit lake will be created in the Choremi open cast with a total surface area of 11.5 km^2 shown in Figure 24 (Sokratidou et al., 2018).

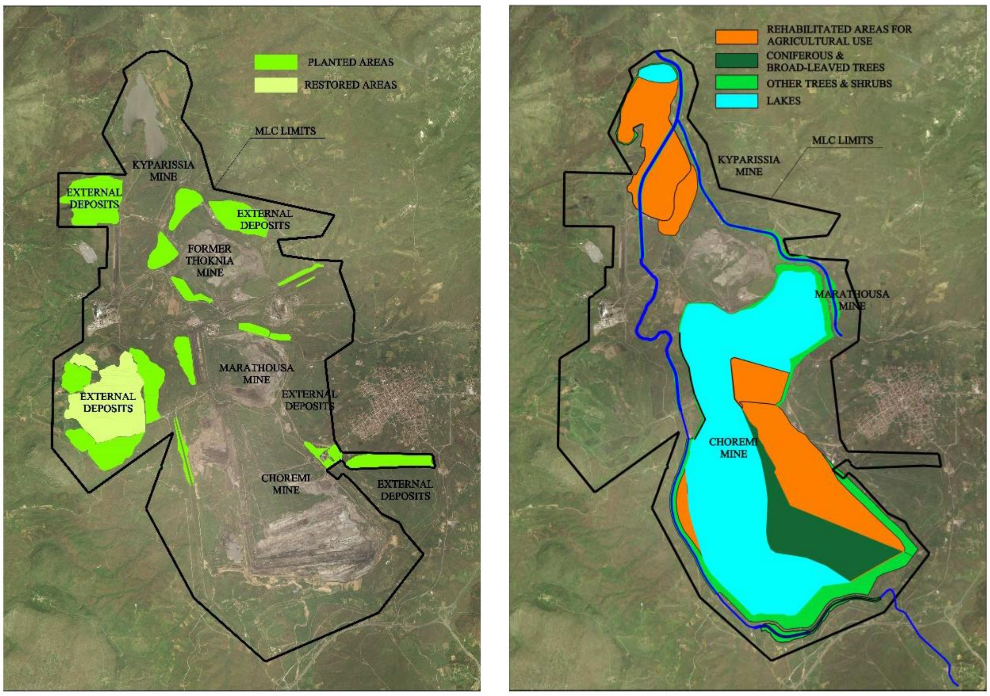


Figure 24. Rehabilitated areas (LCM) in 2018 (left) and 2045 (right) (Sokratidou et al., 2018).

One of the main aims of the reclamation efforts in the area of LCM, is the development of the region in terms of agricultural and livestock production as well as agritourism. PPC has carried out a relevant study in an area of 2.5 km^2 at the external deposits of Choremi mine, where the plan is to create 10 plots of land, along with roads and 6 irrigation reservoirs, which will be combined with water-bearing trees, for recreational purposes. To provide windbreaks, as well as improve the area's biodiversity, the project will also create hedgerows with various specific, resilient species shown in Figure 25 (Sokratidou et al., 2018).

Figure 25. The Choremi mine plantation and maintenance works (external deposits) (Sokratidou et al., 2018).

Other reclamation activities include a section of the former open pit of Thoknia mine that will be utilised as a landfill for hazardous waste, such as asbestos wastes from the thermal plants after their decommission or waste from other public bodies such as hospitals and schools of the Peloponnese region. Another activity is the future construction of an industrial park at the external deposits of the Marathousa mine (Fig. 26). Finally, PPC will collaborate with the

Ministry of Culture in activities for the preservation, protection and development of the archaeological sites of the LCM area, to which end a Memorandum of Cooperation and Understanding has been signed (Sokratidou et al., 2018).

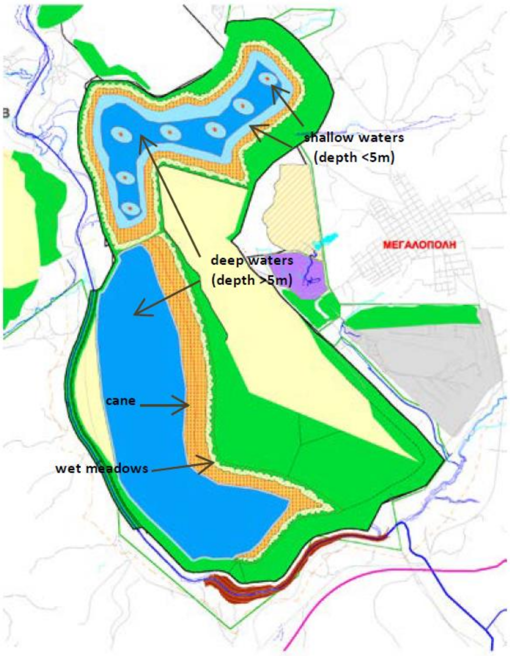


Figure 26. The planned wetlands of the Marathousa and Choremi mining areas (PPC SA, 2016).

<u>Renewable Energy</u>

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 (Fig. 27) and Arkadikos Ilios 2 with power of 39 MW and 11 MW respectively (PPC Renewables, 2022).

Figure 27. Arkadikos Ilios 1 PV project plan (Sokratidou et al., 2018).

6.3. CASE STUDY III RUHR AREA, GERMANY

The Ruhr-area, named after the Ruhr River, covers parts of the Federal State of North-Rhine Westphalia (NRW). According to the Ruhr Regional Association (Regionalverband Ruhr), an administrative association of cities and districts, the Ruhr metropolitan region covers an area of about 4,400 km² and is populated by more than five million people living in 11 cities and four districts. It is the largest urban agglomeration in Germany and the third largest in the European Union after Paris and London. The functional requirements of the former hard coal mining and steel making activities shaped the structure of the cities. The transformation process already started in the late 50’s of the last millennium with first mine closures. In peak time, the coal mining companies in this area employed more than 500,000 people in numerous coal mines. Due to the substitution of coal by other fossil fuels like oil and gas and nuclear power, the number of mines decreased with an accompanying reduction of mine workers (Moellerherm et al. 2022).

In total, about 10 billion tonnes of coal have been exploited from the Ruhr deposit. The exploitable areas influence a zone of more than 3,000 km² at the surface, and the mining-induced subsidence reaches an absolute number of 25 m locally (Harnischmacher, 2010). As a result, 30% of the morphological plane region between the rivers Emscher and Lippe is made up of polder areas — potential flooding areas — with no outlet. These depressions must be artificially drained in perpetuity in order to prevent surface water from accumulating there and causing flooding. As a result, more than a billion cubic meters of water must be pumped off annually throughout the entire Ruhr region. The polder measures belong to the so-called perpetual obligations. These mining induced changes must be permanently managed. They also include the pit water management and groundwater purification.

The beginning of the retreat of the mining industry triggered a crucial structural change in the region. Today, the overall economy is dominated by service industries, high-tech operations, logistics sites and research and educational institutions. In the course of this industrialisation, the population of the Ruhr-area increased very quickly. The infrastructure of the whole region is therefore very well developed.

In 2008, the German government decided to phase out hard coal mining by 2018. This decision enabled the hard coal mining regions in Germany, the Saar and the Ruhr area to prepare the post coal mining time within this period of 10 years. In the Ruhr metropolitan region, the challenge was and still exists to successfully transform the former mining region. The post-mining land use is a complex interplay, both, within the legal framework and within the variety of after-use options. For a successful structural change, the valorisation as well as the sustainable utilisation of former mining sites is a central element. (Melchers, 2016)

6.3.1. Internationale Bauausstellung (IBA) Emscher Park

The Ruhr area or metropolis Ruhr is exceptional when it comes to urban structure and landscape. Due to its unique industrial and montane background the region faced special challenges over a long period of time, making the concept of change its constant (Roters, 2020).

Nevertheless, after a period of post war growth, industrial decline became a negative booster of change and therefore the Ruhr area needed an impulse for the ongoing structural change, guiding it in a conceptual way. That’s why the so called IBA Emscher Park (International

Building Exhibition) was introduced to central and northern parts of the Ruhr area, implementing a sustainable renewal for more than 800 km² and 2.3 million inhabitants. (BBSR, 2022).

The basic idea of executing an IBA dates back to 1901. It was instituted to serve as an impulse for social, cultural, and ecological change in urban spaces and landscapes by concentrating numerous projects in a specific and adequate space. This means the imbedded projects respond to local problems. Even though IBA appears to be an internationally practiced planning instrument, there have been only two outside Germany - Netherlands, Switzerland and Austria.

IBA Emscher Park was the first of its kind to focus on a whole region, instead of a singular city, because of the analogousness of problems within the region. As politics faced and tackled the rising unemployment due to the closure of mines and associated industries such as steel, environmental issues were neglected, being early on a significant limitation of livelihood in the Ruhr area. (Reicher, 2022)

Synonymous for the inhospitality of the regions landscape was the river Emscher, crossing the central parts of the Ruhr area and flowing in the Rhine. During mining and industrialisation times the river got straightened and served as drainage for faeces and industrial waste, making it the most polluted river in Germany and giving it the name “Köttelbecken” (feces basin). Because of mining activities, the underground construction of a large-scale sewage system was not possible. With the guiding idea of removing damages caused by industrialisation, the IBA Emscher Park included the renaturation and restoration of the Emscher delta into its program to help the environment and social justice issues for the local population. (Paetzel, 2020)

Beside renaturing the plus 80 km river a new 51 km sewage canal had to be built underground. The pipes having an inner diameter of 1.4 m up to 2.8 m were mounted in a depth between 8 and 40 m under ground level – at times two parallel pipes and having a continuous slope to guarantee drainage. At the stream mouth – besides three others – the biggest water treatment with biological cleaning stage in Europe got erected in 2001. With 5,5 billion euros invested, the renaturation of the Emscher has been one of the biggest infrastructure investments in Europe as well. In November 2022 the stream mouth got relocated for the last time, which ended the project, outlasting it the IGA Emscher Park for 23 years. (Paetzel, 2020)

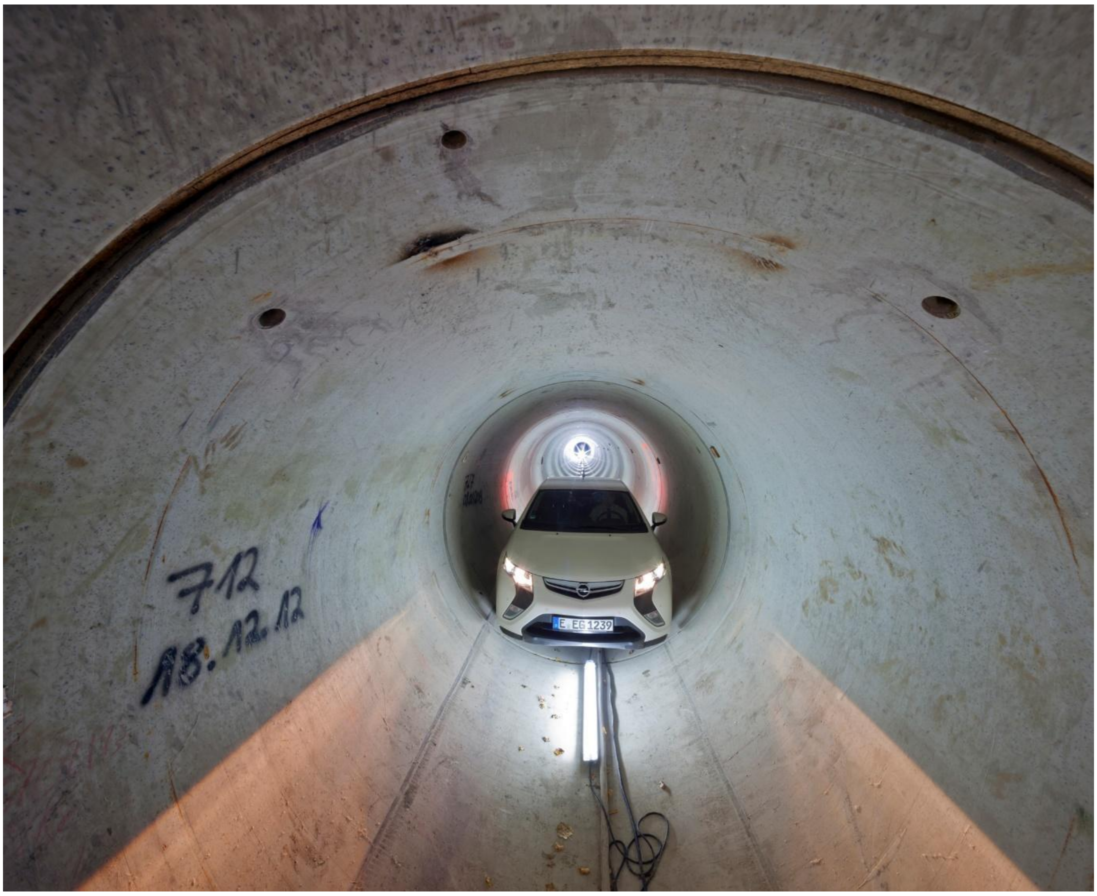


Figure 28.Car in new Emscher Sewage Canal (Source: Klaus Baumers / EGLV)

IBA Emscher Park, with its approximately 120 projects, was not only decisive for the development of the Ruhr area, but also created innovation for planning processes and administration. The 2,5-billion-euro strong exhibition pushed participation to gain trust early on, which among others motivated joint finance from the private sector (Public-Private-Partnership), constituting round about 1 billion euro of the bulk. Besides case-by-case analysis from the local and regional administrations competition procedures became state of the art for broad parts of administrative acting to achieve more quality in planning, as the affected institutions learned from the IBA. (Seltmann, 2020)

IBA as a strategic planning instrument proved itself a viable option towards a holistic approach in regional development. Yet, the IBA Emscher Park set into an experimental setting without scenarios predicted for the aftermath. Implemented by the federal government, the legacy of the IBA is now in the hands of the regional government and its municipalities – or left open. (Jeng, 2018)

6.3.2. Lohberg

The Lohberg mine began mining in 1912 and ceased production on December 31, 2005, after almost 100 years. In 1955 more than 5.400 people were employed and the production of hard coal amounted to about 3.2 million tons. During the operating phase, hard coal was mined from a total of five underground levels. The deepest shaft reaches -1,364 m. A part of the former mine site is used for the mine water drainage, which will be needed for the long term. Here, around 33 million m³ deep mine water must be pumped from the underground mine workings per year. The whole mine site covers an area of around 300 ha, consisting of the operational area and two adjacent dump sites (73 ha, 85 m AGL and 91 ha, 88 m AGL). The reclamation of the dump sites has already been completed.

From 1907 until the 1920s, the Lohberg coal mine colony was built on the opposite side of the mine, the settlement area for the mine workers including necessary infrastructure such as schools and shopping opportunities. Most of the residential buildings have kitchen gardens with the purpose to relieve the budgetary coffers, especially in times of economic crisis. The so-called “Gartenstadt” (garden city) follows the same name concept of Ebenezer Howard from 1898, which tried to integrate benefits of the countryside into urban areas to minimise disadvantages of dense, industrial urban spaces.

6.3.2.1. General description of the Lohberg rehabilitation area

The abandoned hard coal mine site Lohberg Nord is located in Dinslaken, in the western part of the Ruhr area (Figure 21).

The former mine site as well as the district of Lohberg are situated in an urban and scenically distinctive border area at the city limits of Dinslaken to Hünxe. The natural situation of the entire area was characterized by a transition from a higher-lying main terrace plate (Lower Rhine sand plates) to the Lower Rhine plain (Dinslaken Rhine plain). The name Lohberg originates from the resulting elevation change of about 30 m. In this Rhine floodplain lies the miners' settlement of Lohberg, which was built in front of the mine gate. The district of Lohberg, to which the site belongs, is bordered to the west by a green corridor adjoining the settlement area of the Bruch district. To the north and northwest are agricultural areas, areas used for gravel extraction and, to the east, the Kirchheiler Heide recreation area with its extensive wooded areas. In the north lies the city border of Dinslaken to Hünxe (Brüggemann et al. 2017).

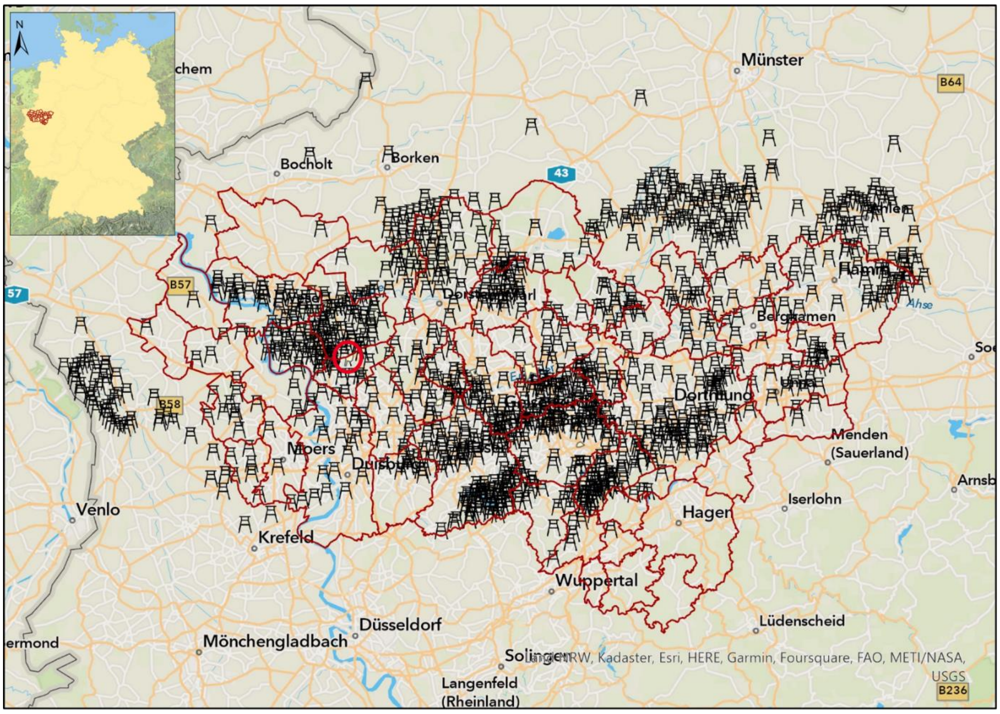


Figure 29. Location of the Lohberg mine site on the community map. The red lines delineate the administrative boundaries of the Ruhr area. The black symbols indicate former mining claims and the red circle marks the location of the Lohberg mine site.

6.3.2.2. Description of reclamation work done

The framework planning was drawn up in 2009. The planning team had convinced a jury of experts and local politicians in 2007 with their structural designs for the Lohberg site in a special workshop procedure. The framework plan is the conceptual basis for the complete future development of the site and is divided into five areas: urban development, landscape, traffic, supply and disposal, and regenerative energy. This framework plan was concretised in 2011 by a local office for spatial planning urban development and architecture.

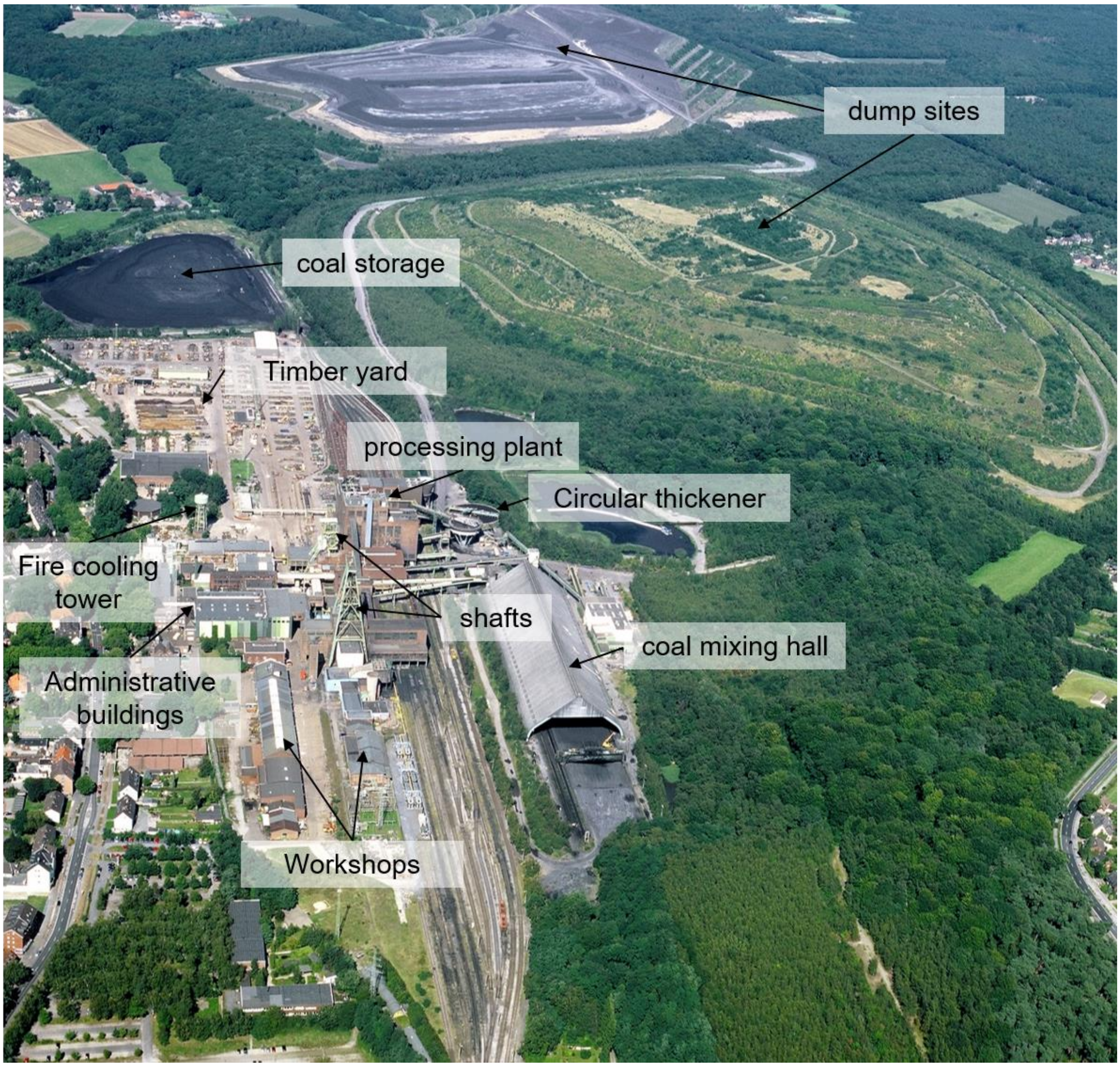


Figure 30. Mining facilities above ground of the Lohberg mine site after the year of closure (2006) (©RVR-Aerial photo)

The reclamation process already started during the active mining phase with the successive backfilling of the deep shafts (2000: Shaft Lohberg 3, 2006 Lohberg 1 and 2). After closure the mining facilities above and below ground (Figure 22) were deconstructed and/or marketed successively. The reclamation of real estates (partly under preservation order) started simultaneously. A project consortium, consisting of the city of Dinslaken and RAG Montan

Immobilien GmbH (the former landowner), was founded in 2008 for the development of the area (Project consortium KQL 2021).

The whole area with a total size of approx. 310 ha was subsequently to be put to a new use, with around 85% of the project area already being green or waste dump areas. The following detailed investigations, in particular those for possible contaminated sites, were the basis for a subsequent public workshop process, which was to formulate guidelines and scenarios for the development of the Lohberg site. A large number of historic buildings and monuments had to be taken into account in the utilization concept.

The perspective for the reclamation of the whole Lohberg site includes the unification of the original mine site and the already renatured adjacent dump sites. A lively, urban quarter with a high quality of residence and life is to be created which meets the targets of modern living and working including the strengthening of identity and valorisation of cultural heritage. The place should be inviting through its architecture, landscape and tourist attractions. The socially, ecologically and economically oriented development will be achieved through the holistic integrated action and creation of new jobs, the construction, design and networking of green and open spaces as well as the broad market access through demand-oriented diversity of use. The project is economically and financially viable in the long term and actively contributes to the structural change of the region. The former operational area is around 52 ha. 40 ha are described as development areas. Approx. 12 ha will be needed in the future for mine water drainage (Regionalverband Ruhr 2022). The future site will be divided into three conclusively separated areas of use (Figure 31): **Residential cluster, Central cluster: Creative Quarter "Kreativ Quartier Lohberg"** and **Commercial cluster.**

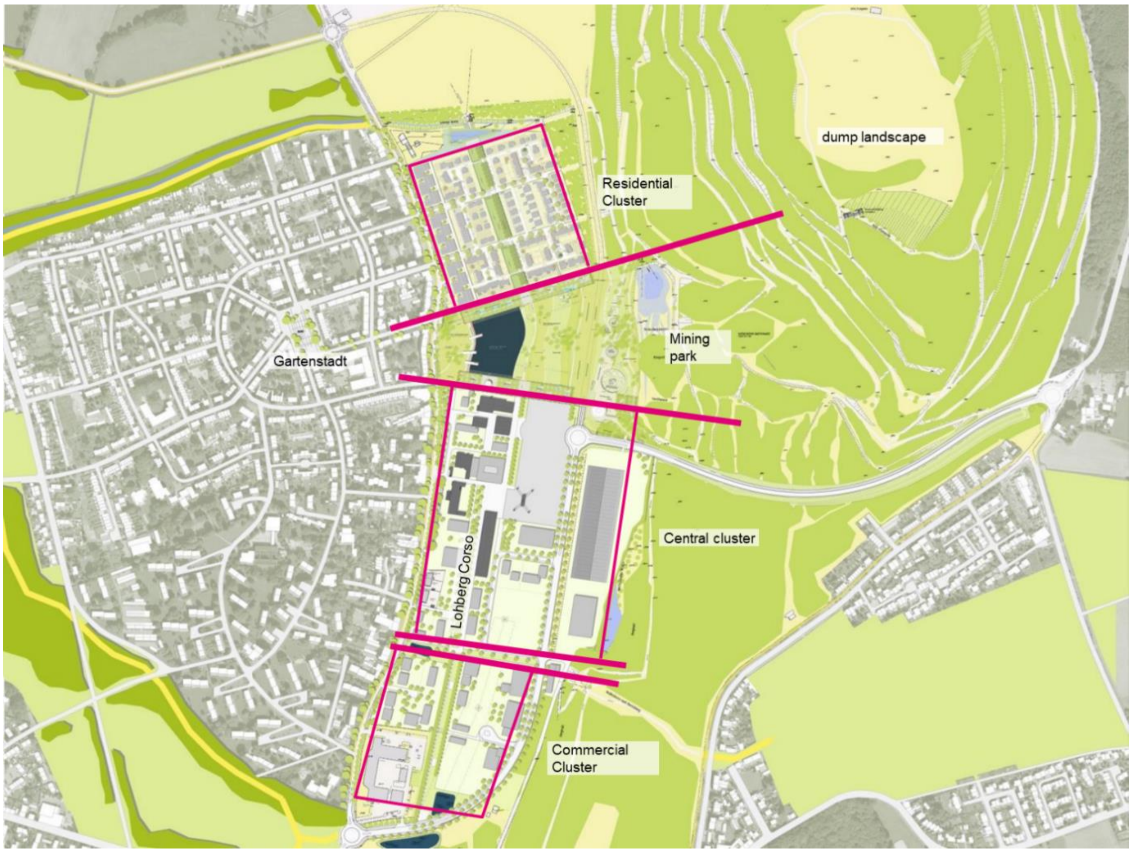


Figure 31. Framework plan for the reclaimed site Lohberg (Lohse 2017)

The three areas of use - residential, creative quarter and commercial - are connected by the Lohberg Corso: a central, car-free pedestrian and cycle path connection designed like a wide avenue. The landscape focal point of the entire site is the new recreation area, called “Bergpark” (mining park): a high-quality park with meadows and play areas, open squares and promenades around the Lohberger Weiher, a newly created lake with a view to the adjacent dump sites.

The creative quarter unifies creativity, landscape and energy. The CO_2 neutral urban quarter is being created for working and living for around 1,000 people. The energy concept is based on the use of renewable energies for electricity and heat generation.

The funding for the site is made up of around 6.2 million euros in urban development funding from the Dinslaken-Lohberg project, which was running until 2016. Further 4.1 million euros came from ÖPEL. ÖPEL is the Ecology Programme in the Emscher-Lippe Region and a funding programme established in 1991 by the state government of North Rhine-Westphalia to improve ecological conditions in the Ruhr area. Further 3.2 million euros stem from the municipal road construction funding guideline. Remaining 0.576 million euros come from other funds. All uses are secured by legally binding land-use plans.

6.3.2.3. Best practices used during reclamation

The main objective of the project consortium is to develop the largest CO_2-neutral quarter in Germany and, beyond that, an energy-plus location. The site of the former Lohberg mine will thus set new standards in the reduction of CO_2 emissions and energy-related urban renewal. A 200-meter-high wind turbine on the Lohberg-Nord dump site sends out a signal for the Lohberg Energy-Plus site. This turbine has a capacity of 3 MW and produces around 9,000 MWh of electricity per year. This amount is sufficient to supply the households in the Lohberg district as well as the creative quarter Lohberg with electricity.

The goal of the energy concept is a decentralised, 100% supply from renewable energies, CO_2-free and efficient. This includes the energetic refurbishment of existing buildings, new buildings in accordance with the Energy Saving Ordinance EnEV 2014 (and 2016) and savings in individual consumption. The electricity and heat supply are to be implemented as a mixture of geothermal energy, solar thermal energy, biomass, photovoltaics, wind power and mine gas or water (Figure 32). For example, the former coal mixing hall is covered with 6,840 PV modules, which supply approx. 1,520 MWh per year, corresponding to the electricity demand of 435 households (Lohse 2017). The energy concept is communicated and aligned through participatory projects and citizen involvement.

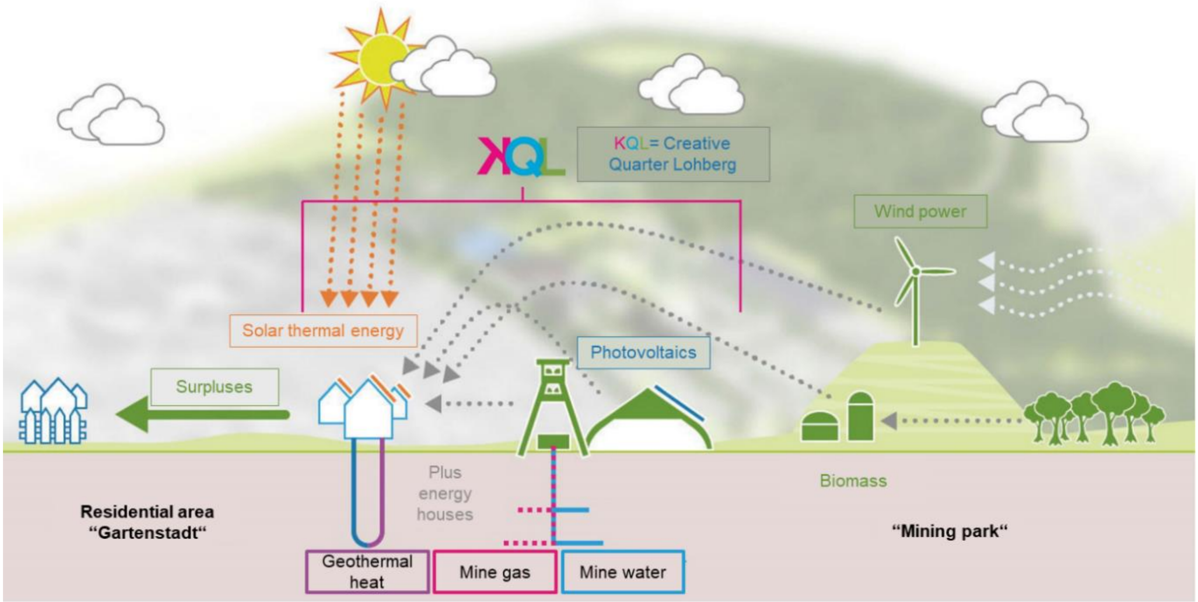


Figure 32. Energy concept of the reclaimed site Lohberg-Nord (Lohse 2017)

Within the creative quarter (residential, central and commercial cluster) the necessary energy is produced by the buildings themselves, primarily via photovoltaics. As they have a low specific energy demand the energy surplus is fed into the grid (Figure 33).

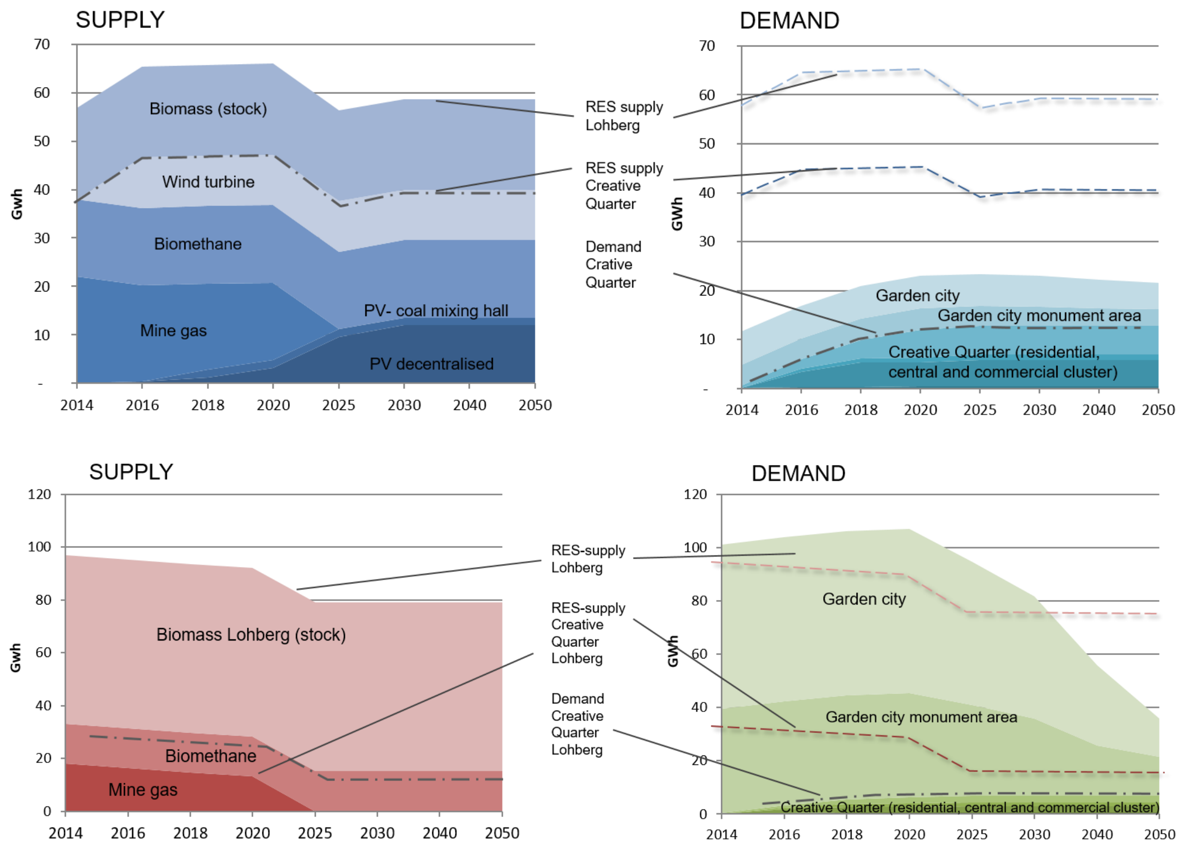


Figure 33. Balance sheet coverage of the Lohberg site for electricity (top) and heat (bottom) (Lohse 2018)

From the very beginning, new approaches were taken in planning the subsequent use of the site. Even before the colliery was closed at the end of 2005, the project consortium had examined the economic, urban development and structural effects, developed scenarios for the subsequent use of the site and analysed feasibility studies. The effects of the mine closure on the city and the region had been worked out parallel to the process of closure. The common goal of the consortium was to initiate a cooperative process involving citizens and companies. Thus, the development of the Lohberg site was formulated in a public workshop process. The energy concept is communicated through participatory projects and citizen involvement. The status of the transformation process was constantly updated via a public website (https://kreativ.quartier-lohberg.de/de/index.php) until completion of the transformation process in 2021.

Cultural activities

Since the mine was closed down at the end of 2005, the site and the buildings on it have been used for cultural purposes several times: Adnan Köse shot his film "Little Murders" there in spring 2011. In 2015, the colliery even became the venue for the Ruhrtriennale. A musical theatre adaptation of Fellini's film "Accatone" was performed in the coal mixing hall. Since 2016, the Freilicht AG has been using the Zechewerkstatt for events.

Measurable effects and long-term benefits

Based on the calculation to the energy concept of the site CO_2 savings are estimated at around 6,000 tons per year (Brüggemann et al. 2017). A living and working area have been established for around 1,000 people.

Current status

In the future, mine water drainage will be operated permanently at the site. In the development area around 260 residential units (residential cluster), approx. 8 ha of commercial space and, including the existing buildings, another 6 ha of service space (including education, events) have been created. In addition, the “Bergpark” (mining park), the Lohberg Corso, a combination of foot and cycle path, as well as other green spaces were created (Figure 34). A traffic bypass for the district and the mine site is planned.

Figure 34. Aerial photo (©RVR-Aerial photo), residential cluster (©RAG Montan Immobilien), Wind turbine and power plant (© Project consortium KQL 2021) and playground in the mining park (© Project consortium KQL 2021)

Almost all the sites in the central and commercial cluster have been sold, reserved or are about to be contracted. The marketing of the colliery monuments in particular is proving difficult. The plots in the residential cluster have been sold. Several building projects in both the residential and commercial clusters have already been realised. The mining park and the Corso have been completed. The infrastructure on the site has also been completed. The cooperative process in which the partners from politics and administration, the citizens, the creative thinkers, the coal producer and the land owner came together required a professional and open project management of the project community. In order to secure the urban development concept in perspective, a high degree of flexibility over a long period of time was necessary without, however, abandoning the common goals. This consensual process was only possible through early, joint goal-setting, in which the partly different interests of the responsible partners, the city and the property owner, were mutually accepted and reconciled.

6.3.3. Ewald

The abandoned hard coal mine site Ewald is located in Herten, in the northern-central part of the Ruhr area (Figure 35). The reclaimed area includes the former operational mine site and the dump site Hoheward.

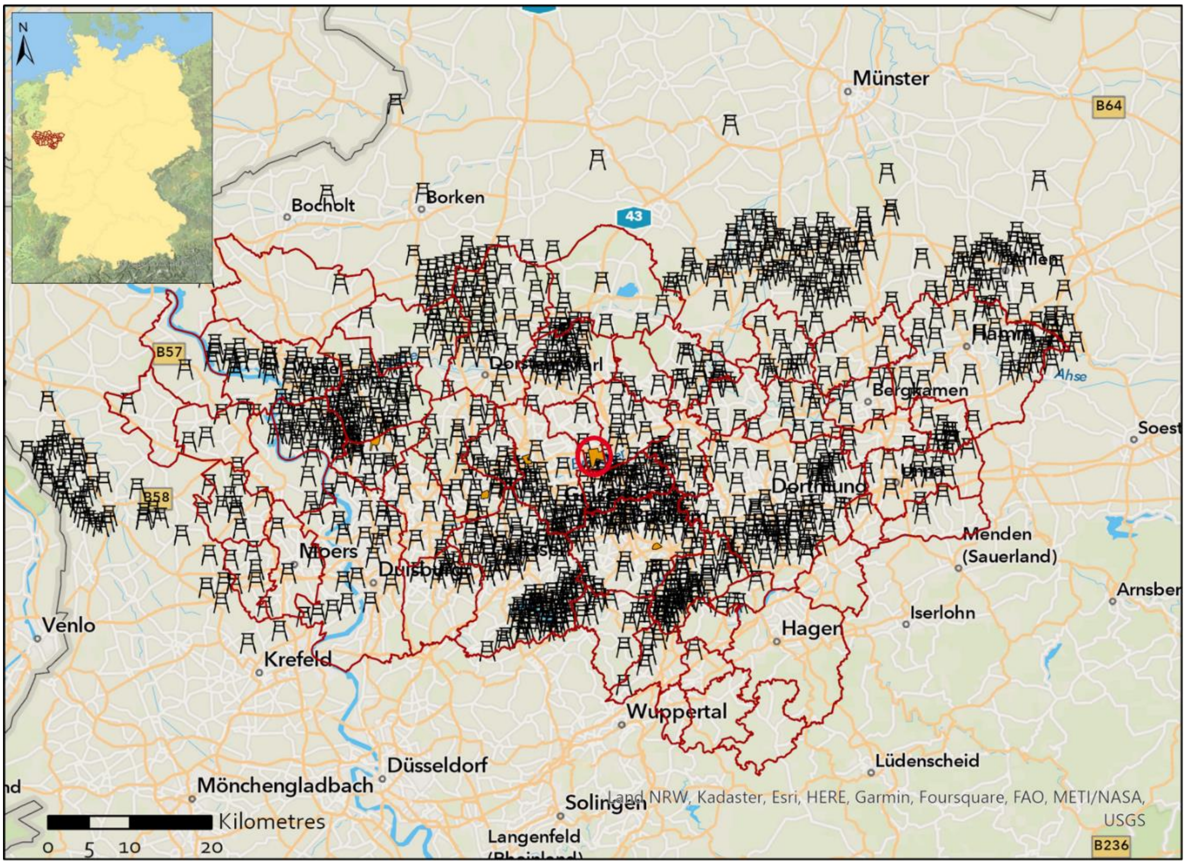


Figure 35. Location of the Ewald mine site on the community map. The red lines delineate the administrative boundaries of the Ruhr area. The black symbols indicate former mining claims and red circle marks the location of the Ewald mine site and adjacent dump sites (Basemap: ©Esri).

The mining operation at the deep hard coal mine Ewald started in 1877. During its active time, Ewald developed into one of the most productive collieries in the Ruhr area and temporarily employed over 4,000 miners. In conjunction with the neighbouring mine, Ewald became the largest production site in the Ruhr area with a production of over 4 tonnes of hard coal in 1998. After 123 years of underground coal production, operations on Ewald were discontinued on April 28, 2000. The operational area includes several shaft towers, workshops, processing plants and other buildings (Figure 36). Due to its mining activities, the city of Herten has been the biggest mining city across Europe (according to the numbers of employees subject to social insurance contributions). After mining has ceased, the city was characterised by a high unemployment rate and a low supply of developed space (Lohse 2021).

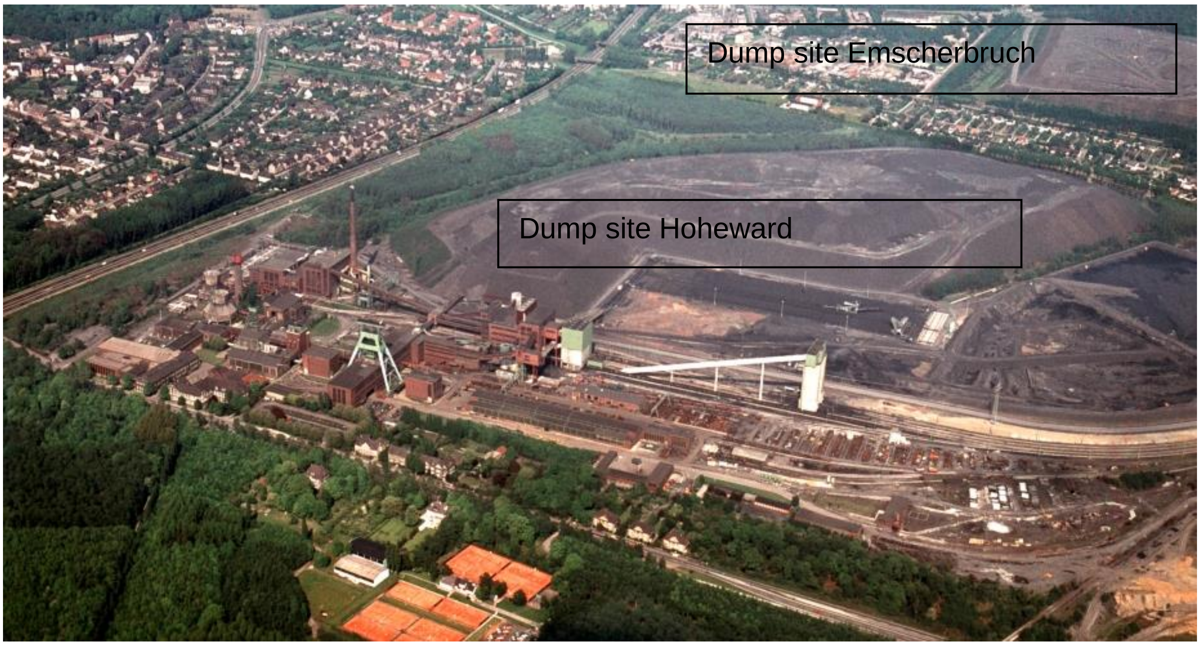


Figure 36. Aerial photo of the active mine site from 1979 (©REGIONALVERBAND RUHR)

The perspective for the reclamation of the whole Ewald site includes a commercial and logistics location on the former operational area and a dump site landscape. The new landscape consists of the two former dump sites (Figure 36) and the “Ewaldsee”, a lake that has developed in a mining induces subsidence area (not visible in Figure 36).

The goal for the post-mining land use of Ewald's mine site was the economic revitalization of the whole area and the creation of at least 1,000 new jobs. The basis for the redevelopment was laid down in the urban development concept called “Landschichten" (land layers), the jointly approved framework plan of the three architects Zucchi, Halfmann and Köster (Figure 37). This combines seven areas of use:

- traffic,
- green & housing,
- history,
- water,
- bureau & services,
- valley,
- industry.

Figure 37. Framework plan for the reclaimed site Ewald (LOHSE 2018)

The framework plan consists of three main development blocks:

- historic buildings in the west of the area that are characteristic of the cityscape,
- large, contiguous commercial and industrial areas to the east of the site,
- Hoheward Landscape Park in the vicinity of the area.

In the beginning, the main reclamation task was to merge two dump sites into one big, which is now the 750 ha Hoheward Landscape Park. The masterplan for the reclamation of the Hoheward dump was called “New Horizons”, inspired by the process that waste material from the deep mined underground forms new horizons. After redesigning, the dump site was developed between 2005 and 2007 for the installation of a sundial, the construction of paths, the horizon observatory and the dragon bridge. Since 1997 neighbouring and already revegetated dump site Hoppenbruch is equipped with a wind turbine (Figure 38). It has a 1.5 MW nominal output, produces 3 million kWh/a and supplies 800 households with electricity (Brüggemann, 2011).

Figure 38. SUNDIAL AND OBSERVATORY FROM ABOVE (©RVR/STAUDINGER), DUMP SITE HOPPENBRUCH WITH WIND TURBINE (©RVR/ADLER) AND DRAGON BRIDGE (©METROPOLE RUHR/NIELINGER)

Characteristic elements of the concept are the historical layer with the winding towers visible from as far as a beacon, as well as attractive squares and path systems, the Ewald promenade, the "blue ribbon" - a greened waterway that runs the length of the entire site and the integration of the site into the Landscape Park. Added to this is the focus on forward-looking technologies. The site has excellent transport links. The immediate proximity to the highways plays a major role in the rapid marketing of the 18 hectares of logistics space to international companies. Also, several high-tech companies, such as Isra Surface Vision, a company specialized in automatization solutions, have chosen Ewald because of the locations' quality and representation (Noll 2015).

As early as 1999, the landowner RAG Montan Immobilien GmbH and the city of Herten founded the Ewald 1/2/7 project consortium, thus setting the course for the reactivation of the coal mine site. In 2008, the transformation process on the former Ewald operational site was completed. As initiated by the project plan the development of the Ewald Future Site project further proceeds. The conversion of the Hoheward dump site started in 2005 and was completed in 2015 (Regionalverband Ruhr 2020)

6.3.3.1. Description of reclamation work done

Figure 39. MINING FACILITIES ABOVE GROUND OF THE EWALD MINE SITE BEFORE CLOSURE (©Regionalverband Ruhr)

The reclamation process already started during the active mining phase with the successive backfilling of the deep shafts. After closure the mining facilities above and below ground (Figure 39) were deconstructed. The reclamation of real estates under preservation order started simultaneously. The challenge was to put 31 buildings and plants, 17 of these under preservation order and 44 ha usable space, to a new use. Among others, the Malakow tower (particular type of winding tower), the steel box girder tower, the double trestle winding tower, several machine buildings, the "Schwarz- and Weiss-Kaue" (the dressing rooms of the miners) as well as the lamp and wage hall had to be preserved. Together, these form a striking landmark and a symbol of mining in the Ruhr region today.

The whole process implemented an extensive deconstruction and remediation work including the demolition of 59 buildings and facilities, 190,000 m^3 demolition volume in converted space and the redevelopment of an area of 460,000 m^2 (Brüggemann, 2011).

The procedure of the project consortium was based on the following guidelines (Lohse 2018):

- The structural change must be spatially compatible and (socially) politically acceptable;
- Subsequent uses can take into account the demand for new jobs;
- The urban planning approach must follow social, environmental and economic sustainability;
- The project development should be economically and commercially viable.

From the outset, the Ewald project consortium pursued an unusual strategy: redevelopment, preparation, development and marketing of the site were carried out in parallel, so that first settlement of commercial estates could be reported just two years after the colliery closed (Figure 40).

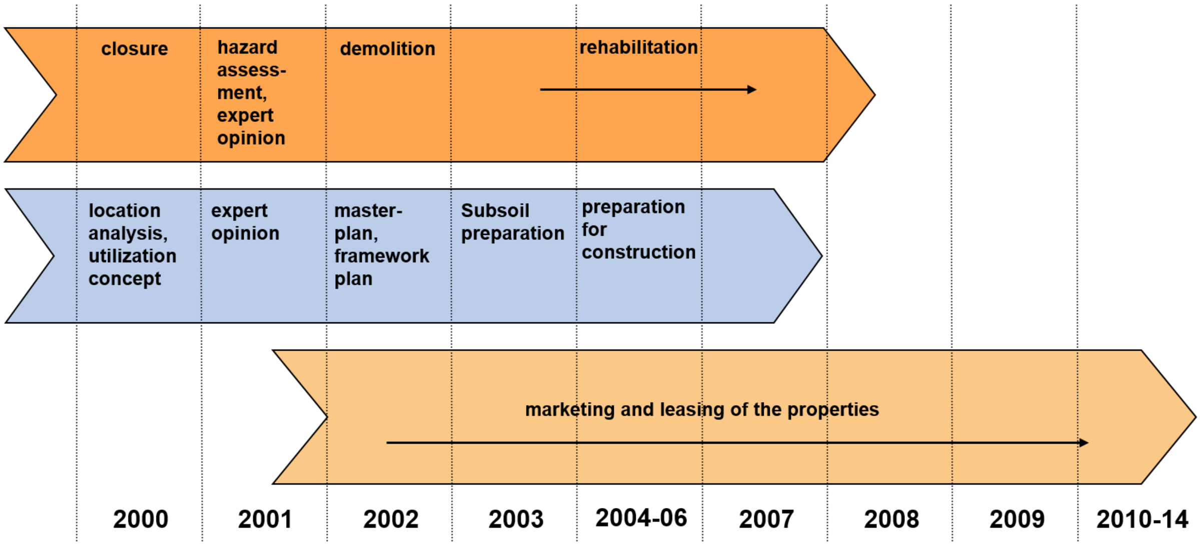


Figure 40. PLANNING PROCESS FOR THE RECLAMATION OF THE FORMER MINE SITE EWALD (AFTER BRÜGGEMANN, 2011)

The consortium was successful on attracting future-oriented companies from the renewable energy and sustainable energy sources sectors to develop the site. For instance, the U.S. company Cummins Inc., a global player in power generation products, established a research and production facility on Ewald.

The key to success at the Ewald site lies in the comprehensive range of space, advice, network and support, as well as the close exchange with business and science. With comprehensive permit management, the city of Herten takes care of planning and permits requirements for commercial construction projects and relocations.

As part of the Hoheward Landscape Park and with the visitor’s centre in the former wage hall, Ewald is integrated into a comprehensive leisure concept of the Ruhr Regional Association (RVR). Both, the dump and mine site have now developed into a popular tourist attraction of the Ruhr area. The former industrial site is an exemplary demonstration of how innovatively the Ruhr region is dealing with its industrial heritage.

The Ewald Future Site project, which has been going on for more than two decades, has in many respects been a pioneer for other projects in the region. In a record time of just seven years, the site in the south of Herten was redeveloped and made ready for construction following the closure of the mine in 2000. Ewald provides the "New Technologies" sector with more than 50,000 square meters of space. In addition to high technology, Ewald is an important site for logistics companies.

A company from southern Germany launches a hydrogen production project, and the state of North-Rhine-Westphalia locates its hydrogen competence centre in the northeastern part of the site.

In fact, the hydrogen competence centre in particular has developed into a project of international renown. The nucleus of the competence centre is the first municipal user centre "h2herten", founded in 2009. Here, the wind power electrolysis project enables, among other things, the production of green hydrogen (Anwenderzentrum h2herten 2022). In the meantime, numerous specialised companies are using the technology as well as the office, conference and technical centre areas of the "h2herten" user centre, whose total area has grown to 8,300 m^2 over the past twelve years (RAG Montan Immobilien GmbH 2021).

The dump site serves as open-air “climatope” in hilltop location with influence on the surrounding area (ventilation, air hygiene, temperature) and large forest and park areas in the west. Therefore, it has a climatic ecological significance and is classified as balancing space with medium to very high importance (Regionalverband Ruhr 2020).

From the very beginning the project consortium was trying to integrate broad public. The project idea for the future location was developed in an international planning workshop open to everyone.

In the area of the historic existing buildings, the Motorworld Zeche Ewald-Ruhr, an ambitious project since 2015, has been pushed ahead, intending to establish Ewald as an event location. Today the “eventlocation Ruhrgebiet”, which manages the various multifunctional rooms and halls, turns the spot to one of the top event locations in the Ruhr area. In addition to the former “Schwarzkaue” (particular type of dressing room) with space for up to 1,000 guests, the two-story machine hall, the neoclassical wage hall and the magazine, the 60,000 m^2 outdoor area also offers a variety of conditions for any kind of events (Figure 41).

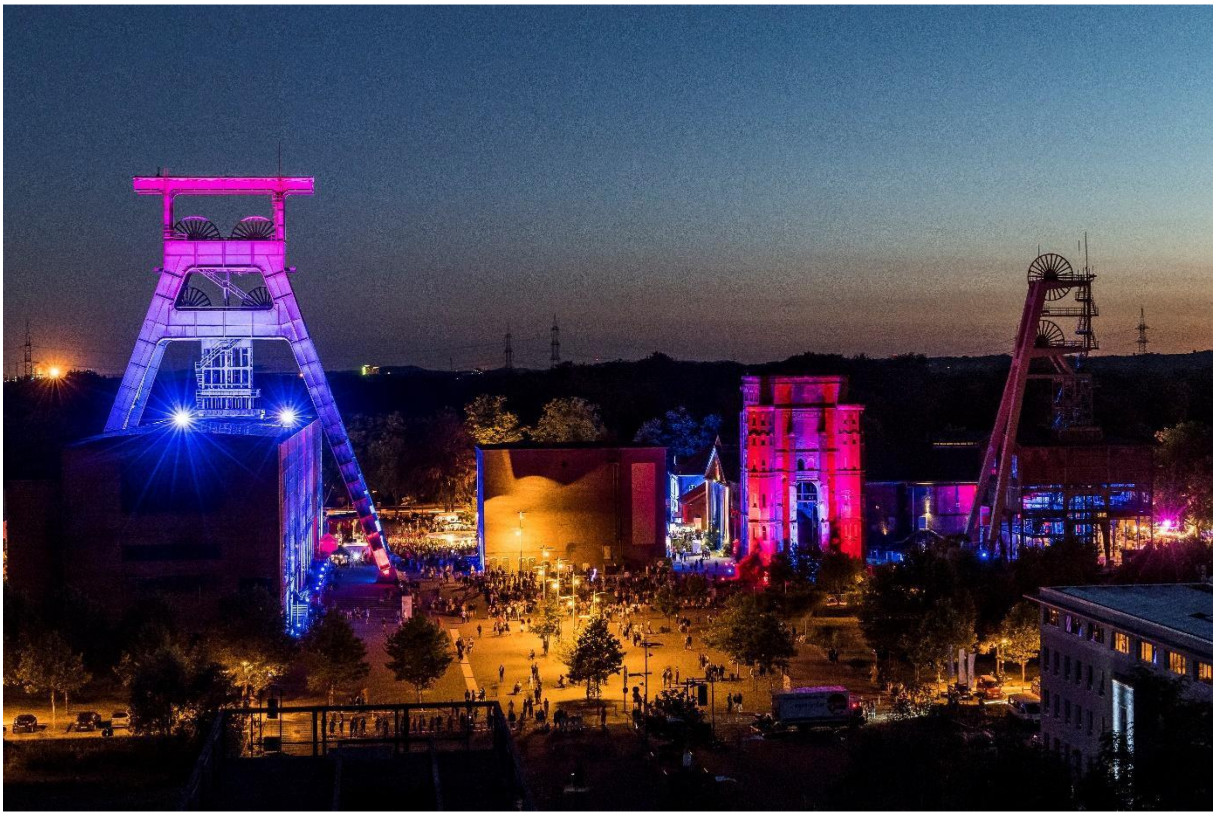


Figure 41. EWALD MINE SITE AS EVENT LOCATION (©NIELINGER)

Measurable effects and long-term benefits

More than 1,500 jobs have now been created on the Ewald site. The dump sites Hoheward and Hoppenbruch in the Hoheward Landscape Park form the second largest dump site landscape in Europe with around 220 ha. Through the revitalisation of this former mining area as a public and freely accessible recreational and adventure area, the Landscape Park has a high social significance for the neighbouring districts of the cities of Herne, Herten and Recklinghausen. The Landscape Park has a high ecological value enhancing the quality of life and tourist attractiveness in the Ruhr metropolitan region. The dump sites and landmarks have become elementary components of the tourist marketing in the region. They stand for the region's transformation and unique experiences.

As a result, the sites with basic tourist facilities are also able to create added tourism value. Since the establishment of the Hoheward Visitor Center in 2013, a stable turnover of tourist services has been generated there with around 15,000 visitors per year. Among other things, the Hoheward Landscape Park fulfils regulatory functions as a climate-ecological compensation area, as an important green space in the biotope network and as a nature or landscape conservation area for the preservation of biodiversity. The socio-cultural services include its high importance for local recreation in the adjacent urban areas. Due to its location in the central densification zone, it is a landscape-related part of the recreational, leisure, and cultural offerings in the region and provides space for active and sporting use (e.g. jogging, hiking, biking, especially mountain biking) as well as quiet, nature-based recreation (e.g. for walking, observing nature). With its unique landscape architectural and artistic design, the Hoheward Landscape Park as a whole ensemble with the Ewald mine site is an important testimony and formative component of the networked industrial cultural landscape, which contributes significantly to the image and attraction of the Ruhr metropolitan region. The approximately 130,000 guests per year are proof of this importance (Regionalverband Ruhr 2020).

Funding

Since 2000, more than 30 million euros have been invested in the reactivation of the Ewald coal mine site (the former operational mine site) by the project consortium. More than half of this - 17.5 million euros - was invested in the development of the site alone, of which more than 13 million euros were subsidies. With measures that were not covered by subsidies, such as the internal development, RAG Montan Immobilien GmbH invested around seven million euros of its own money in developing the site. In addition to this: around 10 million euros from RAG provisions for the dismantling and land reclamation of the mine site. (RAG Montan Immobilien GmbH 2021)

The project received funding from the European Union (European fund for regional development). Beyond that it was financially supported by several funding programs from federal ministry and the state ministry respectively.

The mining landscape has been developed into a landscape park since 2005 with funding from the EU and the state. The "New Horizons" master plan played a key role here. By 2015, more than 30 million euros from the ÖPEL program had been invested in the conversion and design of the dump site landscape. ÖPEL is the Ecology Programme in the Emscher-Lippe Region and a funding programme established in 1991 by the state government of North Rhine-Westphalia to improve ecological conditions in the Ruhr area. A further 10 million euros were investigated in the expansion of the network of cycle paths around the dump site. With Emscherland (OP EFRE, Green Infrastructure NRW) and the IGA 2027 (international gardening exhibition), additional investments are planned for the further development of the park and the implementation of the outstanding sections of the master plan are in preparation (Regionalverband Ruhr 2020).

In the middle of Europe's largest hard coal dump site landscape, a commercial and logistics site of European stature has been created. RAG Montan Immobilien has now marketed all the land at the former Ewald integrated mine. The bottom line: over 1,500 jobs on a showcase site with high recreational value (Figure 41).

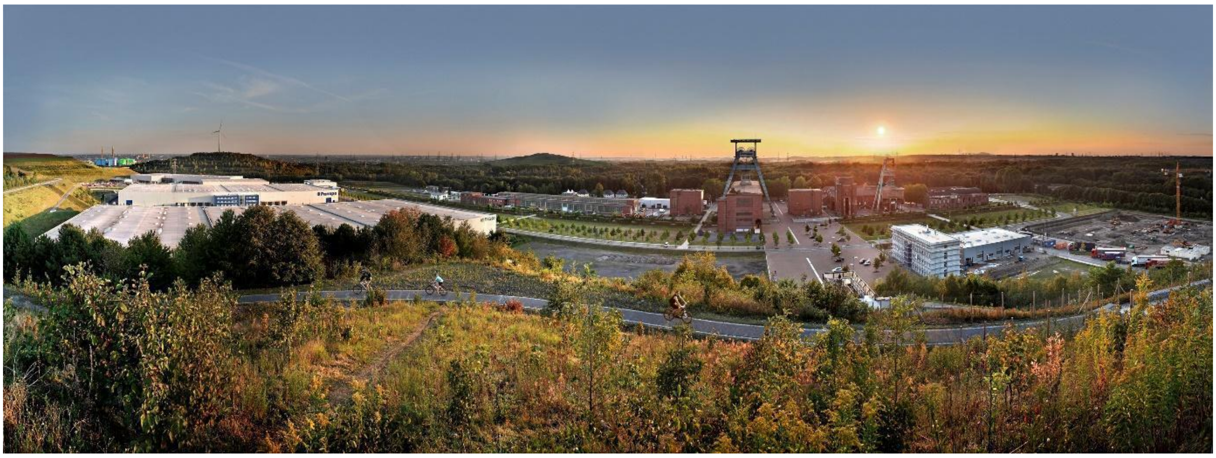


Figure 41. Photo of the Ewald site after reclamation (©RAG MONTAN IMMOBILIEN/THOMAS STACHELHAUS)

6.3.4. MARK 51°7

MARK 51°7 is the name of the new innovative quarter that has been created on the site in the third generation: From 1860 to 1960, the site was a hard coal mine area called Dannenbaum. After the end of mining, a large Opel automotive plant used the site between 1960 and 2014 until the closure of the factory due to lacking economic viability. Only the administrative building of Opel outlasted the demolition process finished in 2015.

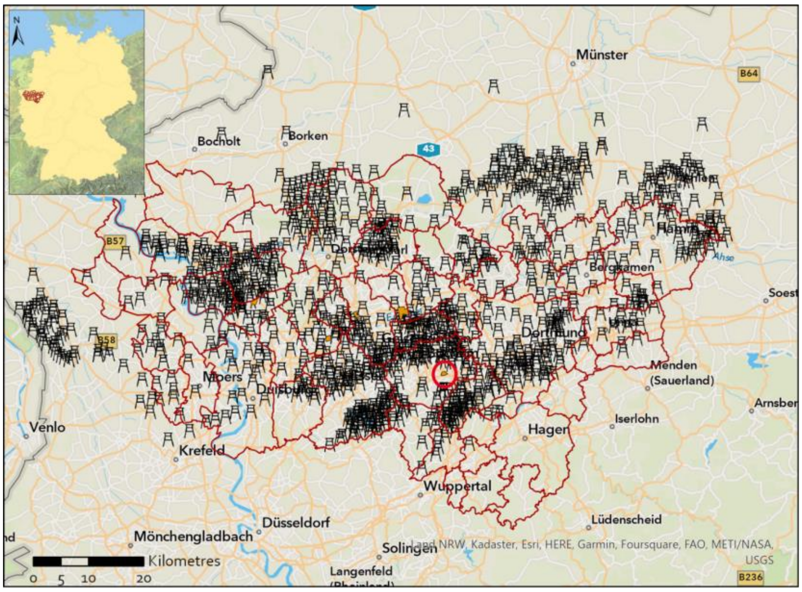


Figure 42. LOCATION OF MARK 51°7 ON THE COMMUNITY MAP. THE RED LINES DELINEATE THE ADMINISTRATIVE BOUNDARIES OF THE RUHR AREA. THE BLACK SYMBOLS INDICATE FORMER MINING CLAIMS AND THE RED CIRCLE MARKS THE LOCATION OF THE MARK 51°7 SITE (Basemap: ©Esri)

In the 14th century first mining activities took place on the described area, yet the colliery "Dannebaum" was established not before 1736. Mining operations took place up to -696 m below sea level. In the early 20th century, it was merged with the nearby collieries "Prinz Regent" and "Friedlicher Nachbar" to optimise administrative expenses and due to the coalition of neighbouring shaft. Therefore, it forms an extensive, interconnected water reservoir to this day. Although the hard coal mine site had already been reclaimed due to the post-mining use of the car manufacturing, the contaminations of the past still had to be taken into account for the new use. Over 50 years of car production left behind 70 ha sealed area with high pollution.

The initial situation consisted of 700,000 m² area heavily built-up and the memorial site of the Opel building. (Bussmann et al., 2019).

The former Opel plant site I in Bochum Laer is currently being developed into an industrial, technology and knowledge campus under the name MARK 51°7. In addition to the development of a total of around 45 hectares of commercial, industrial and technology areas, extensive public green spaces are planned that will generate high quality. An innovation quarter for companies and institutions that invest in knowledge and technology shall be created.

Almost a third of the area will be laid out as green spaces and parks. The work-life balance plays a major role in the concept and will be achieved through:

- Appealing, modern architecture in combination with historical witnesses;
- Attractive and generous green space design over 15 ha;
- High quality of stay for employees and residents through restaurants, cafés and much more (Bochum Perspektive GmbH 2022).

In addition to the planned post-mining land use there are deliberations to implement a utilisation of mine water for heating and cooling of the established or future infrastructure of MARK 51°7 (Bussmann et al., 2019).

The Bochum Perspektive GmbH, a subsidiary of Bochum Economic Development was founded in 2014 to reclaim and develop the site. Their service spectrum covered the implementation of redevelopment, reactivation and development, the completion of properties ready for construction, as well as green and traffic areas, and the laying of utility lines and the sewerage system. Beyond that the company creates a concept and a strategy for the settlement and carries out the marketing (Bochum Perspektive GmbH 2022).

The reclamation work included the solidification of soil and the backfilling of two shafts Hugo (650 m) and Schiller (800 m) with 400 truckloads of concrete (Alfering, 2020).

Important innovations of the future are based on targeted knowledge transfer between business and science. To achieve this, places and platforms for interdisciplinary networking must be created and new working worlds such as FabLabs, co-working spaces and start-up incubators must be integrated. The site is characterised in particular by the integration of the adjacent neighbourhoods and is already considered a reference project for inner-city land development.

Figure 43. Main aspects of the project (©skt umbaukultur)

To achieve this Bochum implemented MARK 51°7 into their municipal strategy. Two of the five pillars of this strategy are "becoming the shooting star of knowledge-based work" and "being a pioneer in modern urban management" (cf. Bochum 2020). The consequent pursuing of this strategy throughout all municipal institutions, and especially by the local business development, is not only efficient but innovative. The capability of Bochum's business development is built-on transparency, less bureaucracy, yet rapid response periods and individual treatment (Schäfer, 2020).

The energy supply of the buildings for heating and cooling will be carried out in a resource-saving way by integrating geothermal energy and district heating (Fig. 44). Geothermal energy is acquired through mine water. Heat and cold can be obtained holistically via a four-wire system on the entire area following a prosumer solution: Investors are not only customers but also members. If they produce heat or cold, they can feed it into the network. The Bochum based Fraunhofer "Research Institution for Energy Infrastructure and Geothermal Systems" (IEG) is including MARK 51°7 into research pursuing a large-scale exploitation of hydrothermal potentials in the Ruhr area. (Fraunhofer, 2022; Bracke, 2020)

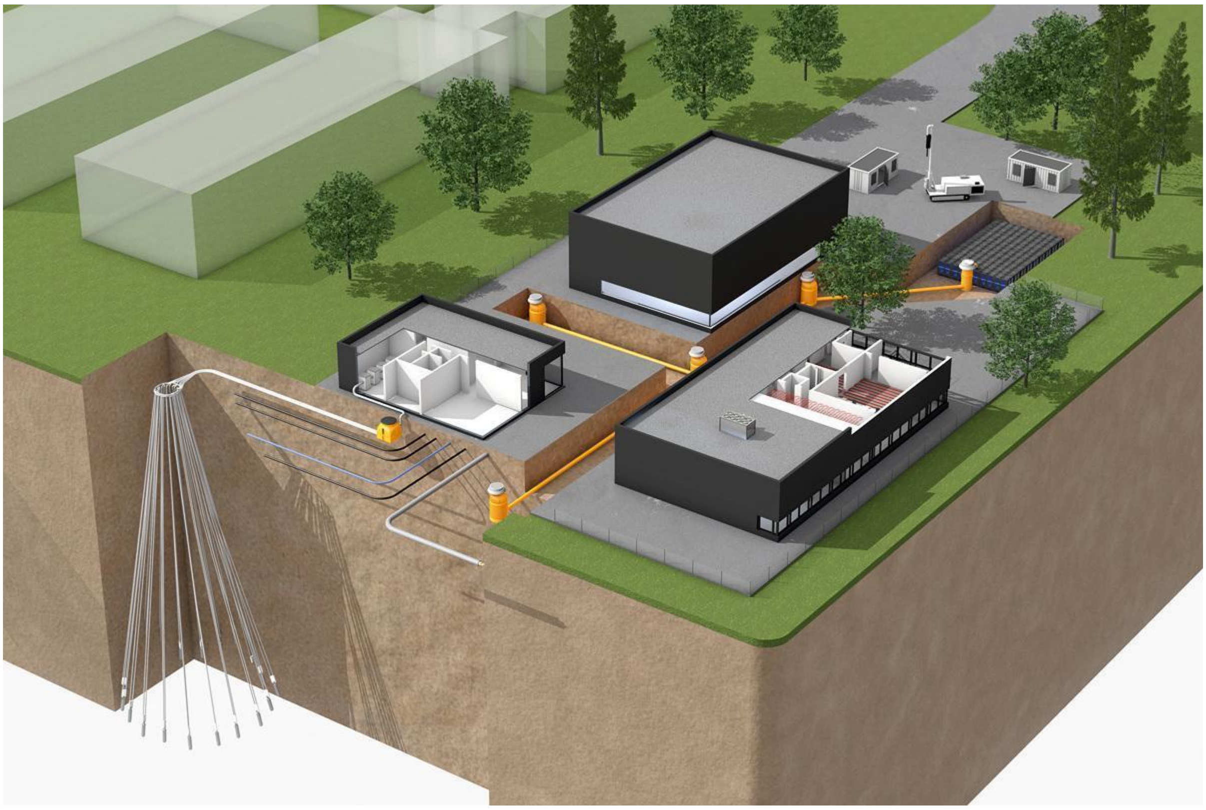


Figure 44. FRAUNHOFER UNDERGROUND LABORATORY TRUDI ("TIEF RUNTER UNTER DIE RUHR" / "DEEP DOWN BENEATH THE RUHR") IN BOCHUM (SOURCE: FRAUNHOFER IEG)

Community involvement

MARK 51°7 site is being developed together with the city of Bochum as part of an integrative concept. The development is open to the broad public and citizens can easily inform themselves via a website. Beyond that the Bochum Perspektive GmbH provides a video-Podcast with different and actual topics concerning the development of the construction site (https://www.mark51-7.de/podcast). Some buildings of MARK 51°7 serve as training centre for immigrants and refugees (Asprogerakas & Mountanea, 2020).

MARK 51°7 is winner of the polis Award 2019 for urban land recycling. The project also won the Brown Field 24 Award 2022 as biggest innovation quarter in North-Rhine-Westphalia.

The companies on MARK 51°7 are globally positioned and technology leaders in their industries. Already today, 96% of the 70 ha commercial and industrial area has been marketed. This alone ensures that more than 10,000 people will work at MARK 51°7 in the coming years.

The reclaimed location is characterised by:

- Excellent infrastructure near city center;
- Knowledge spillover;
- Local and national networks on an international level;
- Qualified workforce and talent pool;
- Universities and institutes;

- Leisure, art, and culture;
- Flexible area cutting.

Surveys predict more than 3,500 jobs to be generated on the area of MARK 51°7, not considering impulses towards associated local and regional economies. Nevertheless, expected impacts regarding long-term unemployment are considered to be marginal (Funke, 2019).

MARK 51°7 is supported by funds from the federal-state joint task "Improvement of the regional economic structure" and urban development funding. This funding structure ensures that both private sector and institutional investors can settle at MARK 51°7.

OPEL Automobile GmbH completed its involvement in the development of the site at the end of 2020.. Bochum Perspektive GmbH continues to develop and market the site.

Figure 45. *AVAILABILITY, RESERVATIONS AND SALES^AT THE MARK 51°7 SITE IN BOCHUM (©BOCHUM PERSPEKTIVE GMBH)*

6.3.5. Rhenish Lignite Mining Area

Though, energy transition is branding the discussion on energy production for almost a decade now and therefore in 2020 Germany had decided to opt out of fossil fuels, lignite will be a reliable energy source for the remaining years until 2038. One of the main lignite mining areas is within the Rhineland located west of Cologne and being close by the Ruhr area, containing 2.5 million inhabitants on an area of 4.800 km². In 2022 lignite power production from this area was responsible for 12% of Germany' s total output. (Zukunfts Agentur Rheinisches Revier 2022)

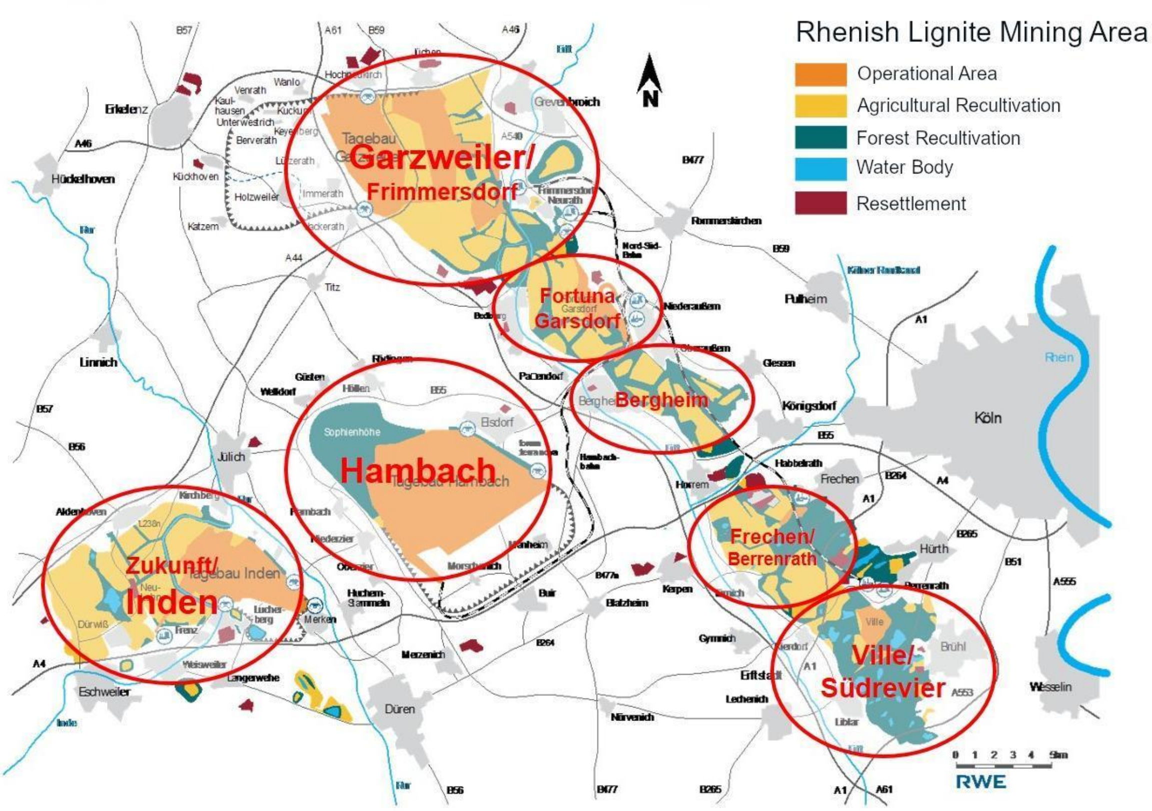


Figure 46. Where Reclamation Takes Place in Rhineland (Source: RWE / Forschungsstelle Rekultivierung)

However, state and federal planning law form a basis for the reutilization of former lignite mining areas towards climate-neutral energy production. In accordance, development goals were implemented in the Regional Development Plan of the State (Landesentwicklungsplan / LEP) and coordinated with targets predetermined by the federal government. An ascertainment of wind or solar parks is performed on municipal level. Having said that, an extensive ascertainment on former surface mining areas necessitates additional and exhaustive environmental assessment being compulsory. Due to the importance of former surface mining for energy transition and a dynamic legal situation, innovative concepts are needed periodically to be adapted into reclamation actions. (Kösling, 2021)

Referring to this, quarrying companies such as RWE Power AG tend to comply with sectoral law when it comes to reclamation and rehabilitation, to achieve required standards – especially in nature conservation. Over the years more than 30,000 ha landscape have been restored in the

Rhenish mining area, always accompanied by funded research with a view to improve rehabilitation processes. Derived from the gained knowledge is an extensive biodiversity strategy developed by RWE in cooperation with environmental and federal institutions, impacting future rehabilitation projects. To this day, about 3,000 species and 1,500 plant types have been recorded on rehabilitated lignite mining areas in the Rhineland, from which a significant number apply to the IUCN Red List of Threatened Species. (Eßer; Janz & Walther 2017)

With funds from the Coal-Phase-out Act the structural change of the Rhenish mining area and other lignite areas were backed up. The package contained a volume of 40 billion euro until 2038, whereof up to 15 billion euro supply the Rhenish area. The so called “Zukunftsagentur Rheinisches Revier” (Future Agency Rhenish Area) was instituted to handle the process of structural change by initiating projects and generating innovative strategies. (Breg 2022; MWIDE 2017).

6.4. REHABILITATION SITE FACT SHEETS

Rehabilitation Site Fact Sheets presented in this subchapter are designed to efficiently recognise and describe best practices during rehabilitation and communicate the most important aspects of rehabilitation done on the listed mining sites. Reclamation of main focus regions of this Deliverable will be summed up in tabular form, as well as some other examples from Europe and around the world.

6.4.1. Ptolemaida mining area

Lignite mining area of Ptolemaida is described in detail in Chapter 6.2.

Table 4 Ptolemaida Site Fact Sheet

1	**Name and location**	Ptolemaida mining area
2	**Operating time**	1957 - today
3	**Area size**	110.80 km^2
4	**Area type**	Two operating mines (Mavropigi, South Field) by PPC SA, two closed mines (Kardia, Main Field), various dump sites (e.g. Kardia)
5	**Type of mining**	Open pit lignite mining
6	**Reclamation start**	-
7	**Completion dates**	Ongoing
8	**Planned post-mining land use**	Wood production forest lands, livestock zones, more agricultural lands, artificial lakes, motor cross sports centre, innovation zone and RES (PV projects)
9	**Reclamation work**	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)
10	**Innovative practices**	pilot hydroponic cultivation greenhouse, model orchard, open-air theatre built using old materials from the mines
11	**Public communication**	Examples: “Adaptation of the Western Macedonia Region to Climate Change” (2022, Information day by Western Macedonia Region), “Regional Authorities and Just Transition” (2022, Information day by Western Macedonia Region)
12	**Measurable effects**	-
13	**Long-term benefits**	Regional upgrade in agricultural sector, recreation and tourism, energy efficiency, environmental protection
14	**Funding**	PPC SA, Recovery and Resilience Facility (NextGenerationEU), National Strategic Reference Framework, InvestEU

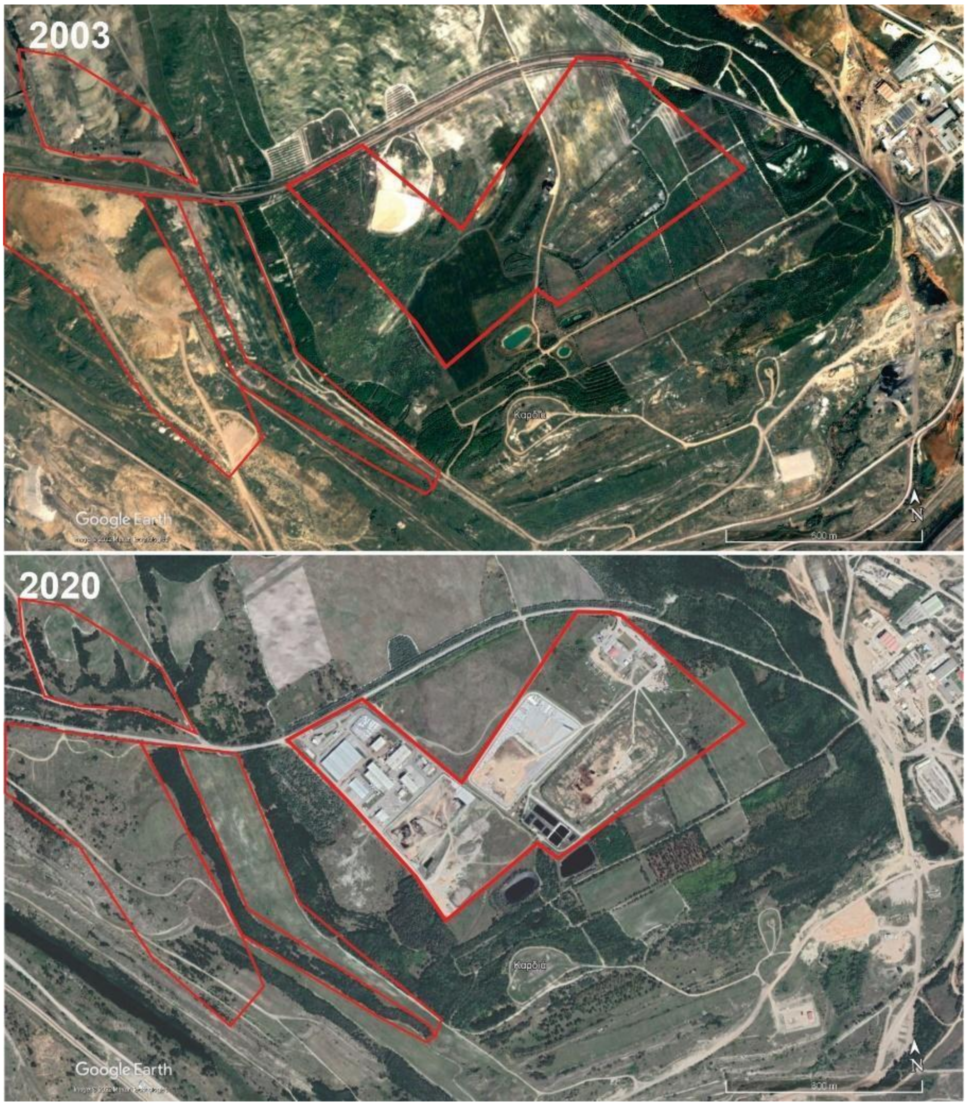


Figure 47. Satellite view of Ptolemaida mine. Top: 2003 image, initial stages of rehabilitation and reclamation observed. Bottom: 2020 image, showing increase of vegetation and change of land use (central portion of image, waste management/recycling facility) (Google Earth).

Figure 48. View of plantations in Ptolemaida mine. Top: 2016 image, during the process of reforestation (Papadelis, CERTH, The Green Link project). Bottom: 2022 image, the development of the same area after 6 years (Batsi, CERTH, WINTER).

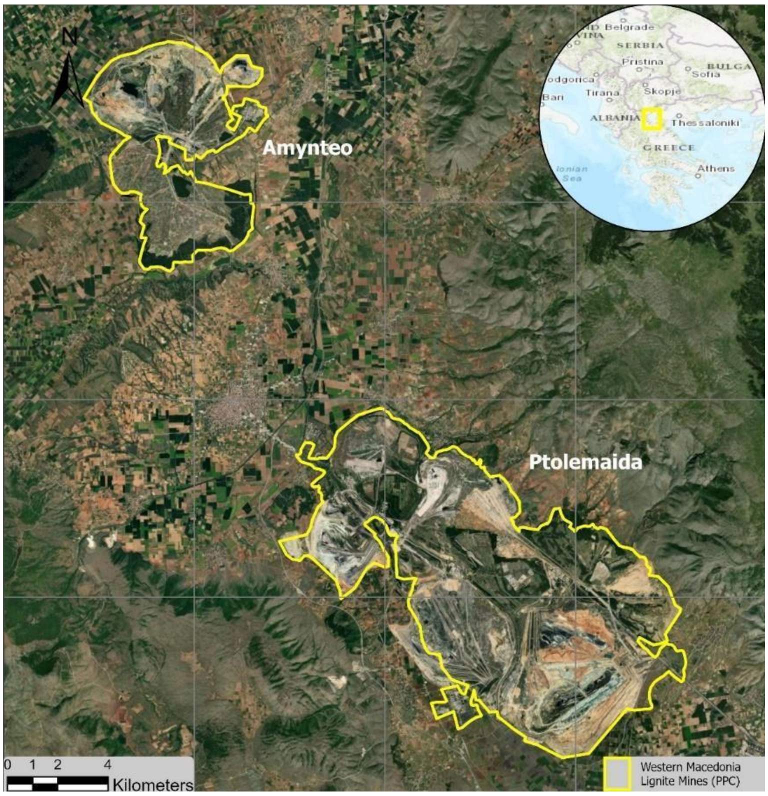


Figure 49. Location of the Ptolemaida mining area in the Lignite Centre of Western Macedonia (ESRI, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community)

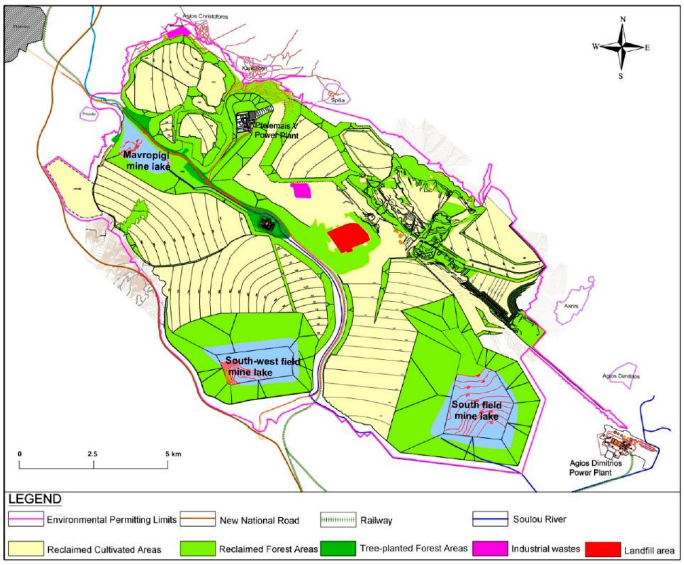


Figure 50. Land uses in the Lignite Centre of Western Macedonia (LCWM) (Ptolemais) after the mine closure and the completion of the land reclamation programme prescribed in the environmental permits (PPC, 2011; Pavloudakis et al., 2020).

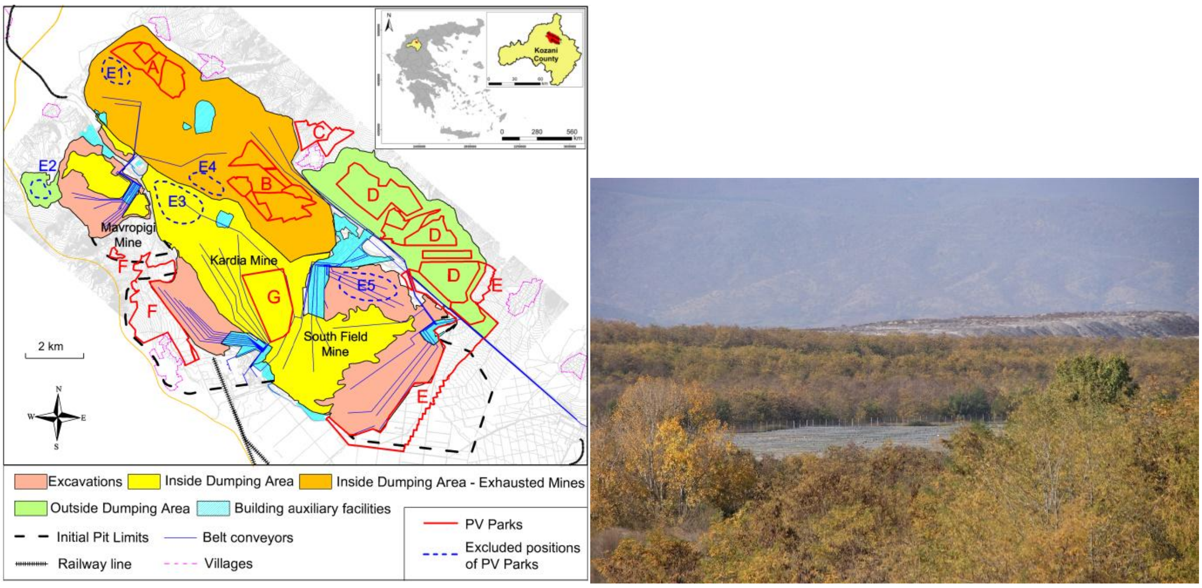


Figure 51. RES projects in Ptolemaida mining area. Leftt General overview of the Ptolemaida region and locations investigated for PV parks (Antoniadis et al., 2021). Right Western Macedonia Solar Park I (under construction) (photograph taken on 26/10/2022).

6.4.2. Amynteo mining area

Lignite mining area of Amynteo is described in detail in Chapter 6.2.

Table 5 Amynteo Site Fact Sheet

1	**Name and location**	Amynteo mining area
2	**Operating time**	1984 - 2021
3	**Area size**	33.56 km^2
4	**Area type**	3 mines (Anargyroi, Amynteo, Lakkia), pit lake in Amynteo mine, several waste dumps
5	**Type of mining**	Open pit lignite mining
6	**Reclamation start**	-
7	**Completion dates**	Ongoing
8	**Planned post-mining land use**	More pit lakes in former mines, RES projects (mainly PV)
9	**Reclamation work**	Pit lake in Amynteo mine, 8 km^2 of reforestations, 1 km^2 for agriculture
10	**Innovative practices**	-
11	**Public communication**	Examples: “Adaptation of the Western Macedonia Region to Climate Change” (2022, Information day by Western Macedonia Region), “Regional Authorities and Just Transition” (2022, Information day by Western Macedonia Region)
12	**Measurable effects**	-
13	**Long-term benefits**	Regional upgrade in agricultural sector, recreation and tourism, energy efficiency, environmental protection
14	**Funding**	PPC SA, Recovery and Resilience Facility (NextGenerationEU), National Strategic Reference Framework, InvestEU

Figure 52. Satellite view of Amynteo mine. Top: 2017 image, showing mine still in operation (right circle). Bottom: 2020 image, after cessation of mining operations. Pit lake (left ellipse) has started to form (Google Earth).

Figure 53. The Amynteo pit lake (photograph taken on 26 October 2022).

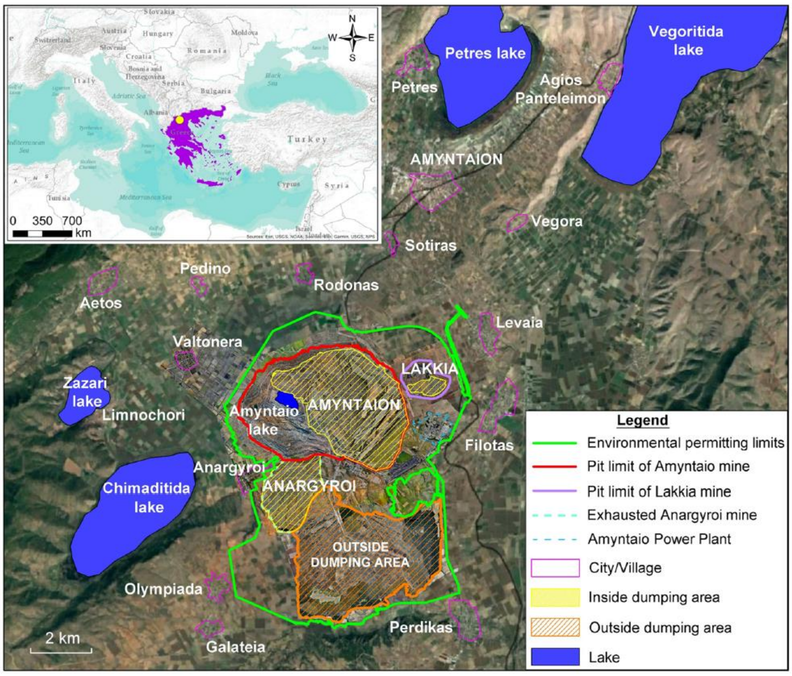


Figure 54. Plan of the Amynteo area mines (Anargyroi, Amynteo, Lakkia). The green boundary shows the limits of the exploitation license (Kavvadas et al., 2022).

6.4.3. Megalopolis

Lignite Centre of Megalopolis is described in detail in Chapter 6.2.

Table 6 Megalopolis Site Fact Sheet

1	**Name and location**	Lignite Centre of Megalopolis
2	**Operating time**	1970 – today
3	**Area size**	
4	**Area type**	4 open pit lignite mines, 3 closed (Thoknia, Marathousa and Kyparissia), 1 still in operation (Choremi)
5	**Type of mining**	Open pit lignite mines
6	**Reclamation start**	2004
7	**Completion dates**	In progress
8	**Planned post-mining land use**	Pit lake at Choremi mine, more agricultural and livestock lands, timber production, industrial park at external deosits of Marathoussa mine, development and protection of archaeological sites, 2 PV projects
9	**Reclamation work**	Reforestations of external deposits of Thoknia and Choremi mines, two pit lakes (Kyparissia and Marathoussa mines). Total reforested areas of 4,300 acres, agricultural lands of 2,300 acres, 1,700 acres to special projects (e.g. visitor centre, recreational park, artificial wetlands, motor cross track)
10	**Innovative practices**	-
11	**Public communication**	-
12	**Measurable effects**	-
13	**Long-term benefits**	Regional upgrade in agricultural sector, recreation and tourism, energy efficiency, environmental protection
14	**Funding**	PPC SA, Recovery and Resilience Facility (NextGenerationEU), National Strategic Reference Framework, InvestEU

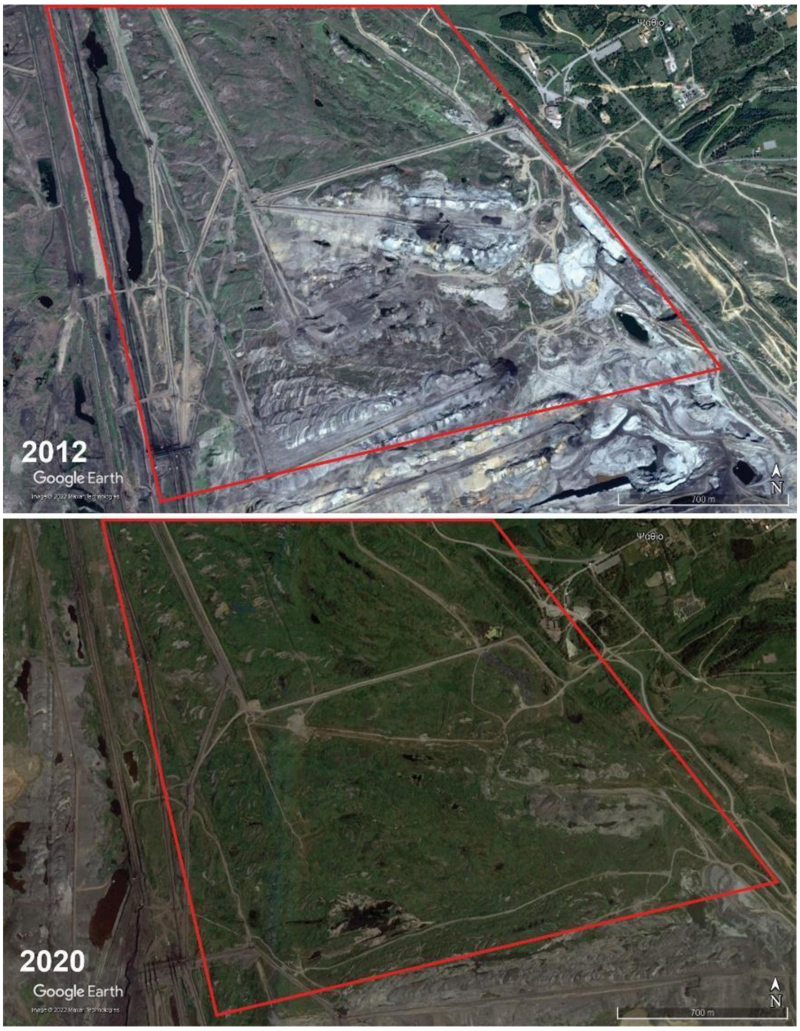


Figure 55. Satellite view of Megalopolis mine. Top: 2012 image, showing recent depositions and initial stage of reforestation (reclamation). Bottom: 2020 image, the vegetation has grown in the mine area (Google Earth).

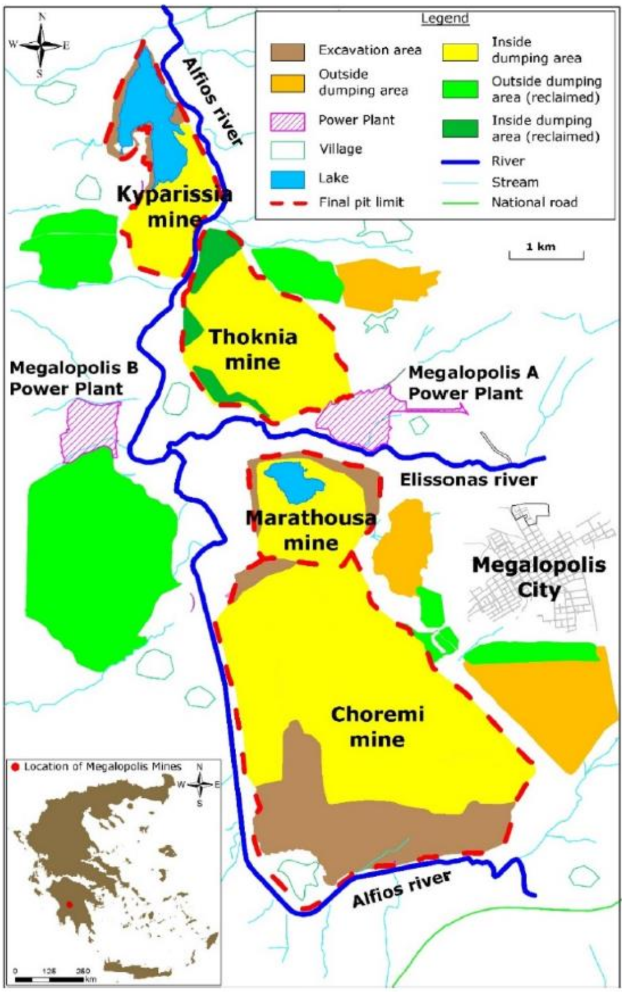


Figure 56. Location of the Lignite centre of Megalopolis, entering the closing phase (Spanidis et al., 2022).

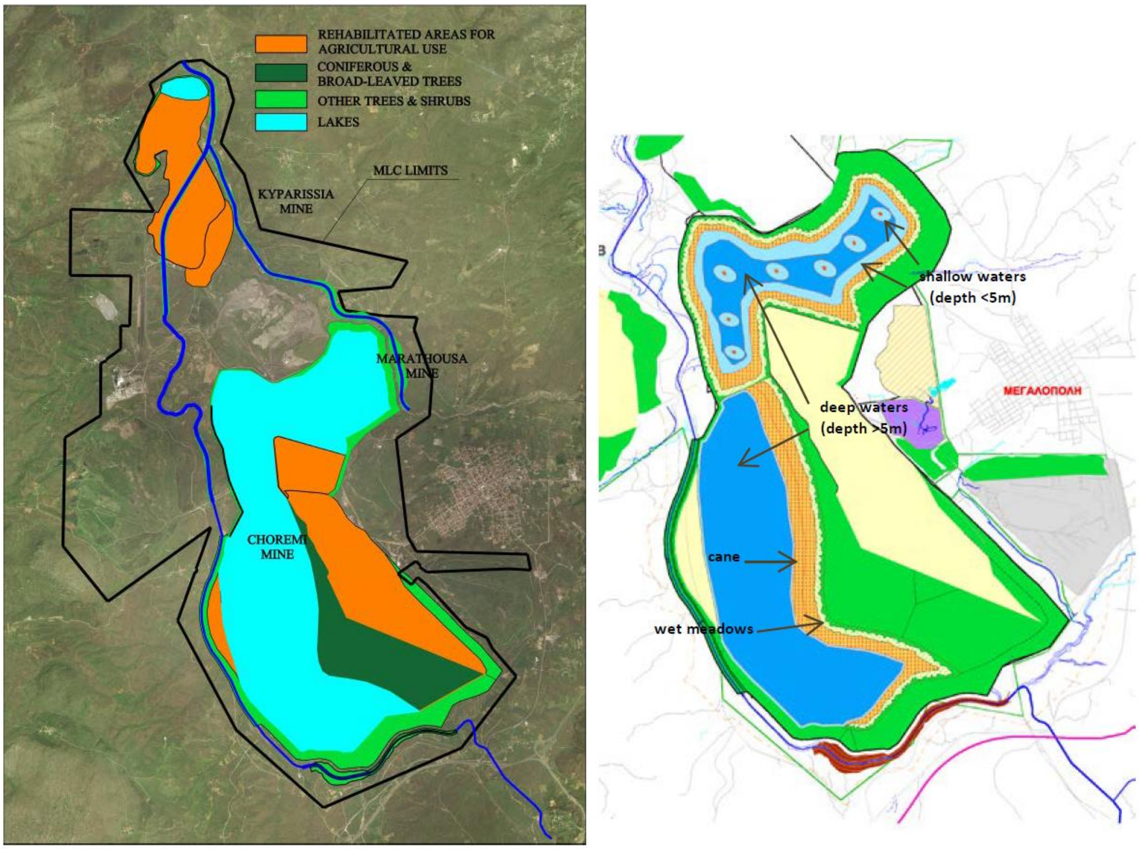


Figure 57. Planned land use in the Lignite Centre of Megalopolis. Left: Planned rehabilitated areas in 2045 (Sokratidou et al., 2018). Right: Planned wetlands of the Marathousa and Choremi mining areas (PPC SA, 2016).

Figure 58. Arkadikos Ilios 1 PV project plan (Sokratidou et al., 2018).

6.4.4. Lohberg

Lohberg mine site is described in detail in Chapter 6.3.

Table 7 Lohberg Site Fact Sheet

1	**Name and location**	Lohberg Nord, Dinslaken, W-Germany
2	**operating time**	1912-2005
3	**area size**	300 ha in total (40 ha development area)
4	**area type**	operational area (including facilities of production and processing); residential area; two dump sites (Lohberg; Lohberg-Nord Erweiterung)
5	**type of mining**	deep hard coal mining (deepest shaft: -1400m below ground)
6	**Reclamation start**	2007
7	**Completion dates**	2021
8	**planned post-mining land use**	Mixed use: Creative quarter (culture and working), mining park (local recreation/landscape), modern housing estate (living), renewable energies
9	**reclamation work**	deconstruction and marketing of mining facilities above and below ground; reclamation of real estates (prtl. under preservation order)
10	**innovative practices**	CO_2 -neutral location, energy-plus location: geothermal energy, solar thermal energy, biomass, photovoltaics, wind power and mine gas or water
11	**Public communication**	workshop procedure for the development of the concept with a jury of experts and local politicians, participatory projects and citizen involvement, website (https://kreativ.quartier-lohberg.de/)
12	**Measurable effects**	CO_2 savings are estimated at around 6,000 tons per year, new buildings in accordance to Energy Saving Ordinance EnEV 2016
13	**Long-term benefits**	Urban quarter, residential and commercial area for around 1.000 people
14	**Funding**	14,076 Mio Euro

6.4.5. Ewald

Ewald is described in detail in Chapter 6.3.

Table 8 Ewald Site Fact Sheet

1	**Name and location**	Future site Ewald and dump site Hoheward, Herten, W-Germany
2	**Operating time**	1877-2000, over 4,000 jobs
3	**Area size**	273 ha in total (53 ha operational area, 220 dump site landscape), 31 buildings (17 of this under preservation order)
4	**Area type**	operational area (including facilities of production and processing); two dump sites: Hoppenbruch (reclamation completed) and Hoheward
5	**Type of mining**	deep hard coal mining
6	**Reclamation start**	1999 (foundation of “project group Ewald”)
7	**Completion dates**	2015 (dump site Hoheward) 2008 (Future site Ewald), further development ongoing
8	**Planned post-mining land use**	Three blocks: townscape-defining, historic buildings; Large, contiguous commercial and industrial areas; Dump site Landscape park
9	**Reclamation work**	Demolition and rehabilitation; reclamation of real estates (prtl. under preservation order)
10	**Innovative practices**	Business park for renewable energy technologies (e.g. Hydrogen Competence Centre Herten, h2herten); Largest European industrial complex on hydrogen and fuel cell technology; Numerous leading projects in the field of renewable energies and nanotechnology; spaces for innovative start-ups
11	**Public communication**	international planning workshop in 2002, visitor centre
12	**Measurable effects**	Wind turbine on Hoppenbruch dump site (1.5 MW output) supplies 800 households, h2herten produces savings of over 110 tons of CO2 each year, 45 established companies, 80 % of the area is marketed
13	**Long-term benefits**	Regional upgrade: over 1,500 jobs, high recreational value, technology, tourism
14	**Funding**	10.4 Mio € (Total costs: 27,4 Mio, revenues: 18.0 Mio €)

6.4.6. Alpincenter Bottrop

Alpincenter Bottrop is a great example of rehabilitation of former mining areas into recreational use and tourist and sport facility.

Table 9 Alpincenter Bottrop Site Fact Sheet

1	**Name and location**	Alpincenter Bottrop on the former dump site Prosperstraße, Bottrop, W-Germany
2	**Operating time**	1983-1991
3	**Area size**	30 ha
4	**Area type**	Hard coal tailing / dump site
5	**Type of mining**	deep hard coal mining
6	**Reclamation start**	1996 (concept development)
7	**Completion dates**	2001 (opening)
8	**Planned post-mining land use**	The centrepiece of the new facility was to be the world's longest covered ski slope, measuring 640 m. Here, visitors should have the opportunity to ski or snowboard all year round, regardless of the season or weather. Catering facilities, conference rooms, the necessary parking spaces and a ski and equipment rental service complete the offer. At a later stage, a hotel and a discotheque were to be built. Additional commercial sports facilities will be created on the outdoor grounds with a high rope climbing course, a summer toboggan run and a wind tunnel.
9	**Reclamation work**	Feasibility study, Spatial impact study; Gaining investor and operator; Implementation of the final operating plan under mining law; Start of construction; In 2001, stabilisation measures were necessary due to detected subsidence and displacements at the foundations
10	**Innovative practices**	world's longest covered ski slope; Due to the given, strong slope, the building does not have to be supported on stilts as is the case with comparable facilities
11	**Public communication**	Broad media echo and high supra-regional profile
12	**Measurable effects**	The Alpincenter is a privately run company and generates its own profit.
13	**Long-term benefits**	Commercial leisure offers with supra-regional alignment

14	**Funding**	Not known

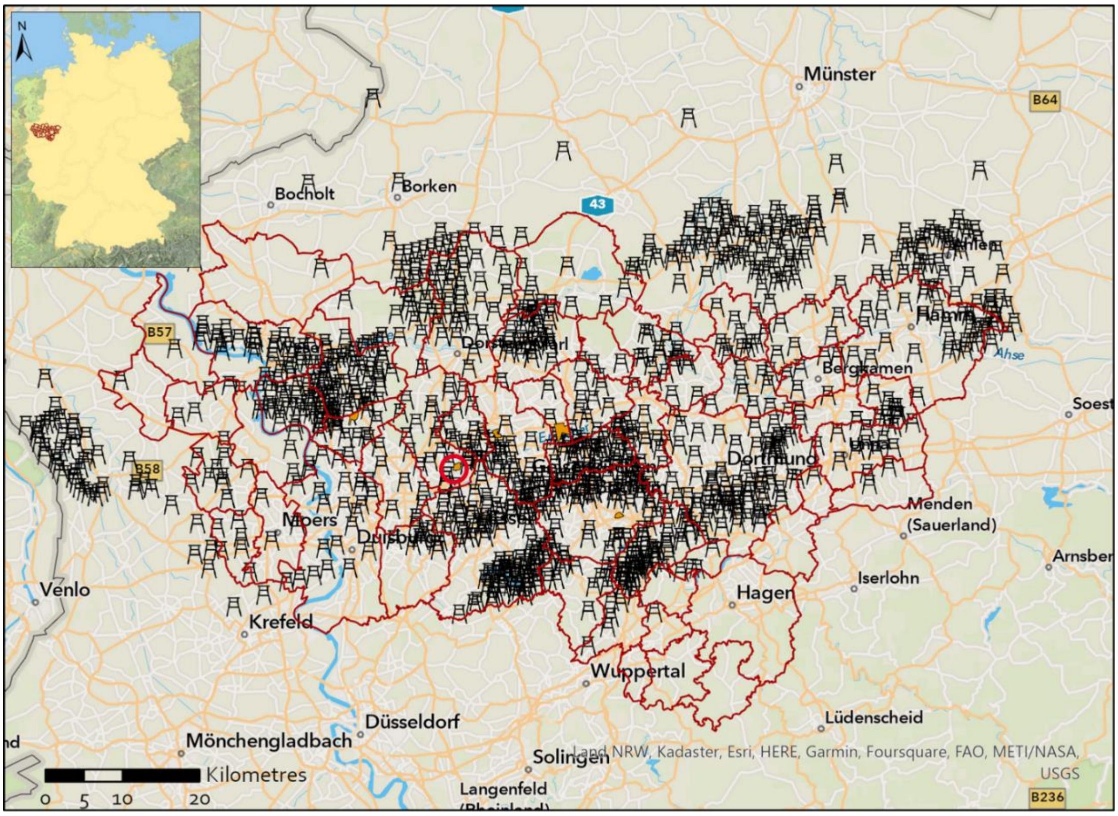


Figure 59. Location of the alpincenter Bottrop on the community map. The red lines delineate the administrative boundaries of the Ruhr area. The black symbols indicate former mining claims and the red circle marks the location of the reclaimed site (basic map: © esri)

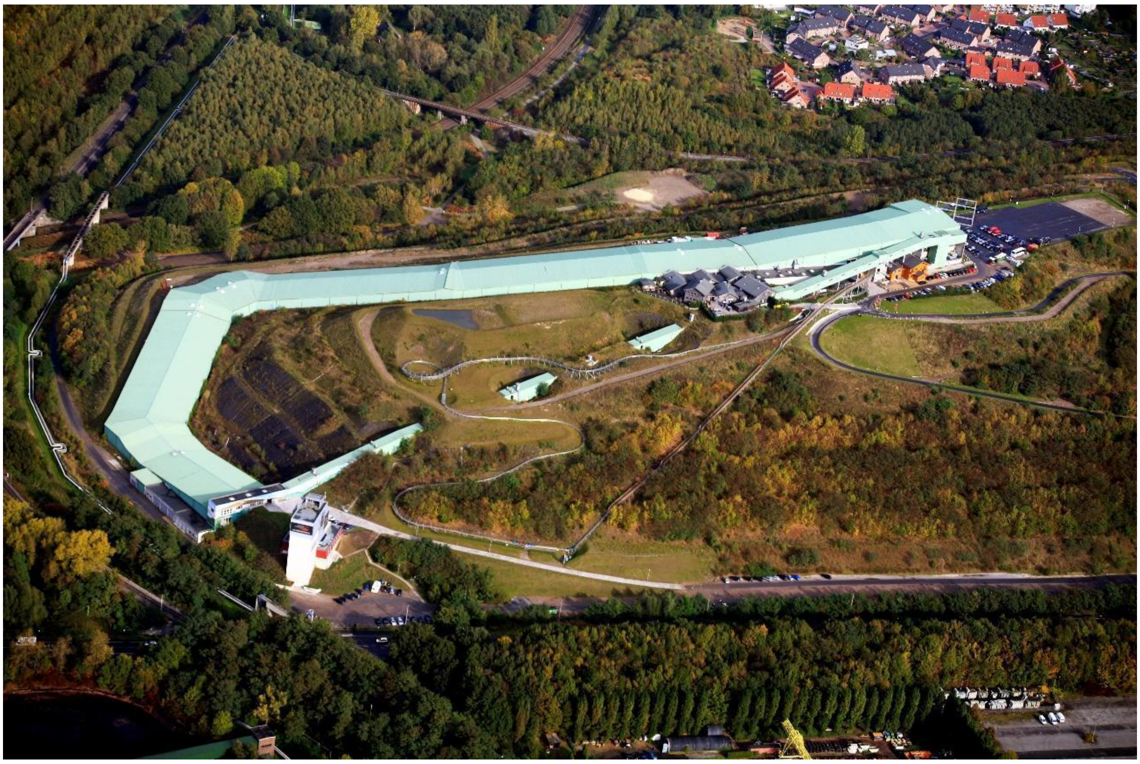


Figure 60. Aerial photo of the Alpincenter Bottrop on the former dump site (©Regionalverband Ruhr)

6.4.7. Hugo

Hugo mining area is a great example of rehabilitation of land and using of its grounds for various goals. Also it represents a good practice in ability to adapt to different environment and successfully change the concept of land use direction.

Table 10 Hugo Site Fact Sheet

1	**Name and location**	Biomasspark Hugo, Gelsenkirchen, W-Germany
2	**Operating time**	1870-2000
3	**Area size**	22 ha
4	**Area type**	Hard coal mine site, coking plant and gasoline factory
5	**Type of mining**	Deep hard coal mining
6	**Reclamation start**	2007
7	**Completion dates**	2016
8	**Planned post-mining land use**	Biomass cultivation and production of renewable raw materials, which were then to be used for energy recovery aiming at minimizing the future maintenance costs; Spatially and socially reintegration of the area into the urban environment of the city as

		a public space that will also be open to environmental education projects and recreational and leisure uses.
9	**Reclamation work**	Demolition and rehabilitation; Application of 550,000 m³ of soils; Development of a species protection concept
10	**Innovative practices**	First large-scale short-rotation plantation on an area formerly used for mining in a European metropolitan area.
11	**Public communication**	Joint project between landowner RAG Montan Immobilien, the city of Gelsenkirchen, Ministry of the Environment NRW and the State Office for Forests and Forestry with scientific support from the Ruhr-University Bochum; Workshops and numerous coordination and on-site meetings with the project stakeholders and with strong participation of citizens
12	**Measurable effects**	Five years after its opening, the area provides a new home for numerous rare animal and plant species; Numerous nature conservation measures; 20.5 ha of eco-account areas, 1.5 ha of community gardens and play areas, 3 ha of forest (forestry compensation)
13	**Long-term benefits**	The objective "biomass production with regular cultivation (agricultural short-rotation plantation)" is not pursued further for various reasons (climate change, extreme drought and thus insufficient growth of the plants, uneconomical harvesting logistics, etc.). Since 2016 the park has become a new type of green space “the green lab”, large parts of which are available for environmental and extracurricular education projects, for leisure and recreational use, as well as for nature and species conservation concerns although the original goal of biomass production was not reached
14	**Funding**	Not known

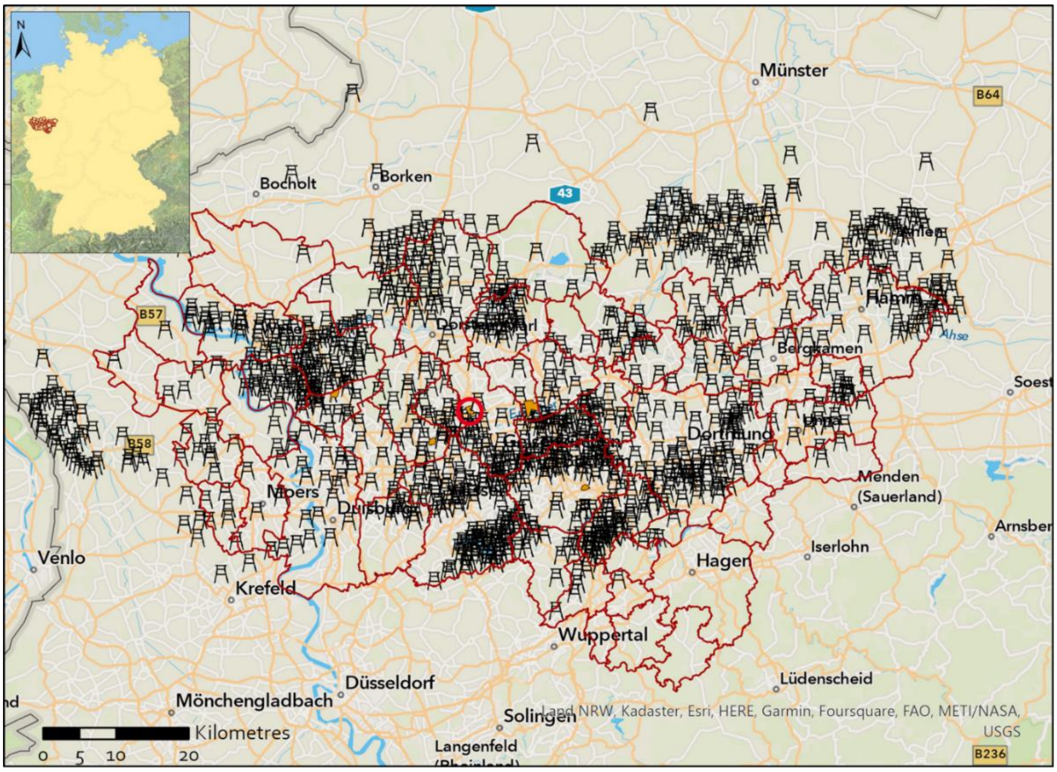


Figure 61. Location of the Biomass park Hugo on the community map. The red lines delineate the administrative boundaries of the Ruhr area. The black symbols indicate former mining claims and the red circle marks the location of the discussed mine site (Basic map: ©esri)

Figure 62. Aerial photos of the Hugo mine site in operation in 1981 and the reclaimed site in 2014 (©Regionalverband Ruhr)

6.4.8. Mont Cenis

Mont Cenis is a great example of rehabilitation of post mining land for public use in metropolitan area with a mix of various land uses. Former mine site is used among others as housing, commercial centre, renewable energy production and heritage site.

Table 11 Mont Cenis Site Fact Sheet

1	**Name and location**	Academy Mont-Cenis, Herne, W-Germany
2	**Operating time**	1872-1978
3	**Area size**	30 ha
4	**Area type**	Mining operational area, colliery wasteland (over 10 years)
5	**Type of mining**	Deep hard coal mining, deepest shaft: -1,300 m
6	**Reclamation start**	1991 (Foundation of „Entwicklungsgesellschaft Mont-Cenis mbH“)
7	**Completion dates**	1999
8	**Planned post-mining land use**	Revitalisation of the economic, functional and urban center; New construction of a training academy of the Ministry of the Interior NRW, expansion of the district centre and creation of housing and green spaces; “Stonefield” as mining relicts, a modern combined residential and commercial building, a senior center, a day care center and the weekly market
9	**Reclamation work**	Demolition of remaining mining facilities above ground; New construction of 10 ha large glasshouse (“micro climate capsule”) with three-story interior houses for public use: seminar rooms, hotel, casino, restaurant, cafeteria, civic hall, municipal service offices and a library (Virtual tour through the glasshouse: http://www2.herne.de/vramc/)
10	**Innovative practices**	Innovative energy concept: A wood-beam supported micro-climate enclosure: 180 m long, 75 m wide and 15 m high, equipped with 10 ha roof integrated photovoltaic solar power plant, a centrally and automatically controlled aeration and deaeration system and a high-performance battery storage system with a capacity of 1.2 MW; Mine gas-fired combined heat and power plant supplies electricity into the grid of the city
11	**Public communication**	International urban planning competition for the new construction of the training academy, presentation at the architecture biennial in 1996 and at the world climate conference in 1997; world

		exposition project at “EXPO 2000”
12	**Measurable effects**	Mine gas-fired combined heat and power plant saves 60,000 t of CO_2 per year and supplies the new residential area and the nearby hospital with power
13	**Long-term benefits**	Creation of a new recreational area and a lively location with many offers for daily life, the new center is at least as lively as it was in the days of active mining
14	**Funding**	Investment volume of all construction measures: 110 M €

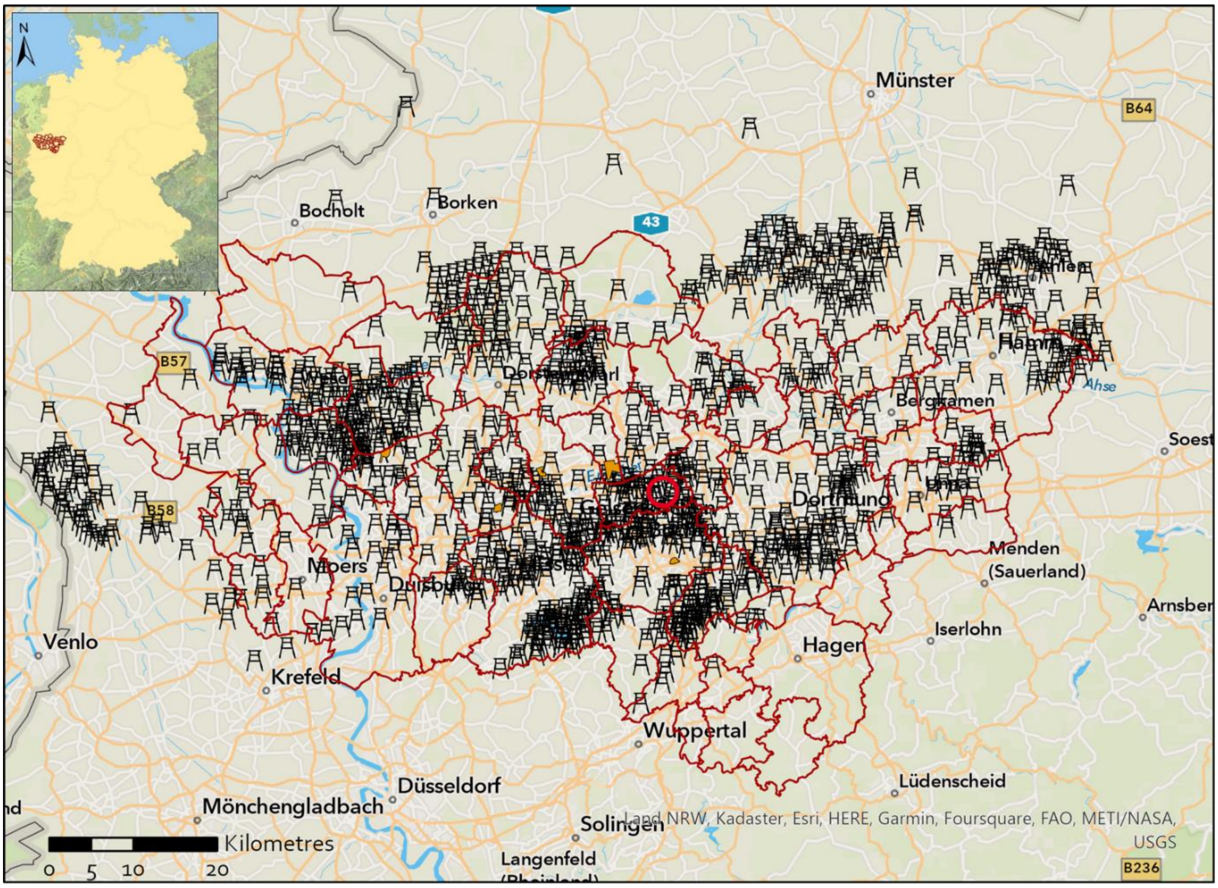


Figure 63. Location of the Academy Mont-Cenis on the topographic map. The red lines delineate the administrative boundaries of the Ruhr area. The black symbols indicate former mining claims and the red circle marks the location of the reclaimed site (Basic map: © esri)

Figure 64. Development of the area from the mine site in 1980 to the academy Mont-Cenis in 2002 (© RVR)

Figure 65. Left: Front view of the academy Mont-Cenis with the protego caps on the backfilled hard coal shafts in the right corner of the picture (©Cebula). Right: Public indoor area with wooden beams and interior houses (©Thomas Schmidt/city of Herne)

6.4.9. Bodelva pit – Eden Project

The Eden Project was established in the area for several reasons. The first reason was to restore the usability of an area damaged by a mine, and the second was to raise the income of Cornwall, which was the poorest county in the UK, with the highest level of unemployment. (Smit, Kendle, 2001)

Noteworthy is the fact that the entire complex is self-sufficient in terms of energy and water circulation. Currently, the botanical garden is powered by energy generated by wind turbines and solar energy obtained through solar panels located on the roof of part of The Core. There are also plans for a geothermal power plant to produce 5-7 MW of which 3-4 MW will be for powering the complex, and the remaining energy produced will be for the region (Eden project website).

Table 12 Bodelva pit Site Fact Sheet

1	**Name and location**	Eden Project, Bodelva pit, Wales
2	**Operating time**	XVIIIth century until XXth century
3	**Area size**	22 ha
4	**Area type**	Biodomes located in former clay pit
5	**Type of mining**	Open pit clay quarry
6	**Reclamation start**	1995
7	**Completion dates**	2001
8	**Planned post-mining land use**	Educational center with tropical and exotic plants located in eco-domes.
9	**Reclamation work**	Stabilisation with rock anchors. Backfilling of the abandoned pit with earth and rock blocks, the total weight of which amounted to about 1.8 million tons. Greenhouses, listed in the Guinness Book of World Records, were built on the already backfilled area, after preparation.
10	**Innovative practices**	As a substitute for glass, hexagonal or triangular plates made of so-called ETFE or tetrafluoroethylene with the industrial name Tefzel, were use. It is a material that shows very strong corrosion resistance, three times the load-bearing capacity of glass. This material can bear a weight equivalent to 400 times its own weight, achieving 1% of the weight compared to glass. The material's innovation also lies in its greater ability to transmit sunlight, its self-cleaning properties, and its lower installation costs (70% of installation costs compared to installing glass panels.
11	**Public communication**	Over those two decades Eden has welcomed more than 22 million people, including more than 50,000 school visitors a year.
12	**Measurable effects**	Since it was fully funded in 2000, the site has been a source of enormous economic revitalisation for Cornwall and the Southwest as a whole – it is believed to have contributed well over £1 billion to the local economy since its launch. Eden employs circa 350 people and gives another 150 people the opportunity to volunteer
13	**Long-term benefits**	The Eden Project is a charitable organisation, although the amount of money it receives from government organisations has sharply decreased. Seen now as more of a social enterprise, the Eden Project is fully capable of funding its operations through gate receipts and other revenue streams. Despite this, the Eden Project still values its charitable ethos,

		placing this at the centre of much of their work. They run many educational programmes at the site, while also using their reputation to push the conversation about our environment
14	**Funding**	The build was funded through a series of government grants and loans from institutions like the Millennium Commission – with funding coming from the National Lottery – and European regeneration funds

Figure 66. Bodelva pit right before Eden Project construction start

Figure 67. Eden Project aerial view

6.4.10. Góra Kamieńsk

Outer waste dump from Bełchatów mine's overburden which was heaped for nearly 20 years. Rehabilitation carried out on this site allowed to create a unique tourist attraction and locally record high hill available for public use.

Table 13 Góra Kamieńsk Site Fact Sheet

1	**Name and location**	Góra Kamieńsk – Bełchatów mine waste dump
2	**Operating time**	1975 – ongoing
3	**Area size**	1480 ha
4	**Area type**	Outer waste heap created the biggest hill in middle Poland, with its relative height of 195 m
5	**Type of mining**	Open pit coal mining
6	**Reclamation start**	1977
7	**Completion dates**	1995
8	**Planned post-mining land use**	Wind power generation, tourism (skiing, biking)
9	**Reclamation work**	1.4 billion m^3 of overburden was heaped, dump shaping, supporting infrastructure, surface dewatering, soil conservation and tree planting
10	**Innovative practices**	Artificially snowed and illuminated ski slope, a four-person chairlift with a length of 760 m and two platter lifts with lengths of 700 and 160 m. During summer used as bike and downhill area. All this in close vicinity of a wind turbines.
11	**Public communication**	-
12	**Measurable effects**	Ca. 8000 daily skiers during winter season, 30 MW renewable energy production
13	**Long-term benefits**	Renewable power generation, tourist attraction, sporting facility,
14	**Funding**	Rehabilitation and ski resort funded by mine operator PGE GiEK

Figure 68. Skiing slope during winter (source: http://gorakamiensk.info/index.php?page=galeria-z)

Figure 69. Wind turbines installed on former waste dump (source:https://pgeeo.pl/Nasze-obiekty/Elektrownie-wiatrowe/Kamiensk)

6.4.11. Guido mine

The Guido mine is a historic deep coal mine and museum in Zabrze. It is a well-recognized landmark (Fig. 70) in mining focused region of Silesia.

Table 14 Guido mine Site Fact Sheet

1	**Name and location**	Guido mine
2	**Operating time**	1855-1922
3	**Area size**	Ca. 100 ha
4	**Area type**	Municipal area of Zabrze city
5	**Type of mining**	Underground hard coal mining
6	**Reclamation start**	1982
7	**Completion dates**	Latest work completed on 2015
8	**Planned post-mining land use**	Experimental mining and testing of mining equipment (until late XXth centrury) , Museum of Hard coal mining, cultural recreational and leisure activities
9	**Reclamation work**	Preparation of underground tunnels and chambers for touristic visits,
10	**Innovative practices**	Deep hard coal mine transformed into experimental mine transformed into underground tourist site with surrounding museum buildings and allowing the attraction of simulated mining work (Fig. 64).
11	**Public communication**	Since 2000 added to registry of historical monuments, well known landmark recognized locally and nationally.
12	**Measurable effects**	The biggest in Silesia centre of mining tourism.
13	**Long-term benefits**	Financial benefit from museum tours, event organisation, educational centre of mining technologies and history
14	**Funding**	Zabrze Municipality and Silesian Voivodeship, in 2010, investment funding from the European Union was obtained of ca 40 mln EUR

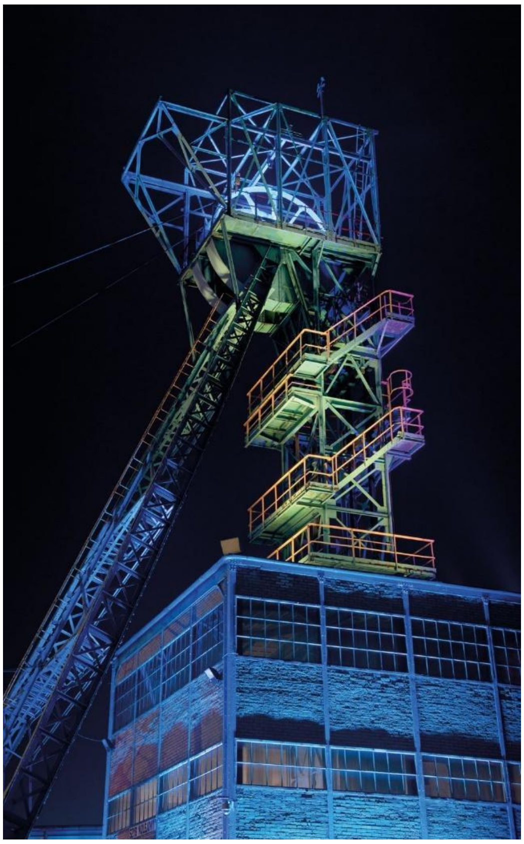


Figure 70. Guido mining tower (source: https://mojbytom.pl/p,s,informacje_turystyka,page,1,item,poznaj-tajniki-gornictwa-z-zabrzanska-kopalnia-guido-1950.html#lg=1&slide=6)

Figure 71. Guido mine tour (source: https://mojbytom.pl/p,s,informacje_turystyka,page,1,item,poznaj-tajniki-gornictwa-z-zabrzanska-kopalnia-guido-1950.html#lg=1&slide=6)

6.4.12. Lake Kepwari

Lake Kepwari is a pit lake in Collie River Valley coal mining area. It is used as recreational pit lake with many activities such as water skiing, boating and camping. A good practice can be considered the way water quality was managed on the site increasing ca. +3 on pH scale over 15 years.

Table 15 Lake Kepwari Site Fact Sheet

1	**Name and location**	Lake Kepwari, Australia
2	**Operating time**	1970s - 1997
3	**Area size**	100 ha lake, 120 ha revegetated land
4	**Area type**	Recreational area, nearby river
5	**Type of mining**	Open pit hard coal mining
6	**Reclamation start**	1980s
7	**Completion dates**	2020
8	**Planned post-mining land use**	Recreational pit lake (water skiing, boating, camping)
9	**Reclamation work**	Flow-through may not work as leading practice for all pit lake closures, particularly those with very high downstream river water quality and end uses and/or restrictions on water availability. The strategy has worked particularly well in the Lake Kepwari pit lake situation because the river channel was able to be maintained in its historical course and was already degraded. This has reduced the risk of AMD on downstream river values. However, like all good mine closure planning, closure of a specific pit lake requires directed technical and supporting studies to provide an evidence-based framework to demonstrate stakeholder-agreed closure objectives are understood and will be sustainably met (McCullough et al, 2020).
10	**Innovative practices**	time frame was reduced considerably by providing additional water by extracting saline first flushes from the seasonal CRSB through a surface water license (Salmon et al, 2017). To accelerate filling of the pit, the lake was rapid-filled by seasonal diversions from the CRSB over the winters between 2002–08 through a valve-regulated offtake in years when river flow was sufficiently high. the pH then fell below 4 once river inflows ceased
11	**Public communication**	A literature review at the beginning of the project, coupled with early and regular engagement, provided confidence to stakeholders that the approach was leading international practice. Following broad stakeholder engagement, including community presentations, and approval by state regulators, a flow-through trial was initiated to assess the benefits of this leading practice management option

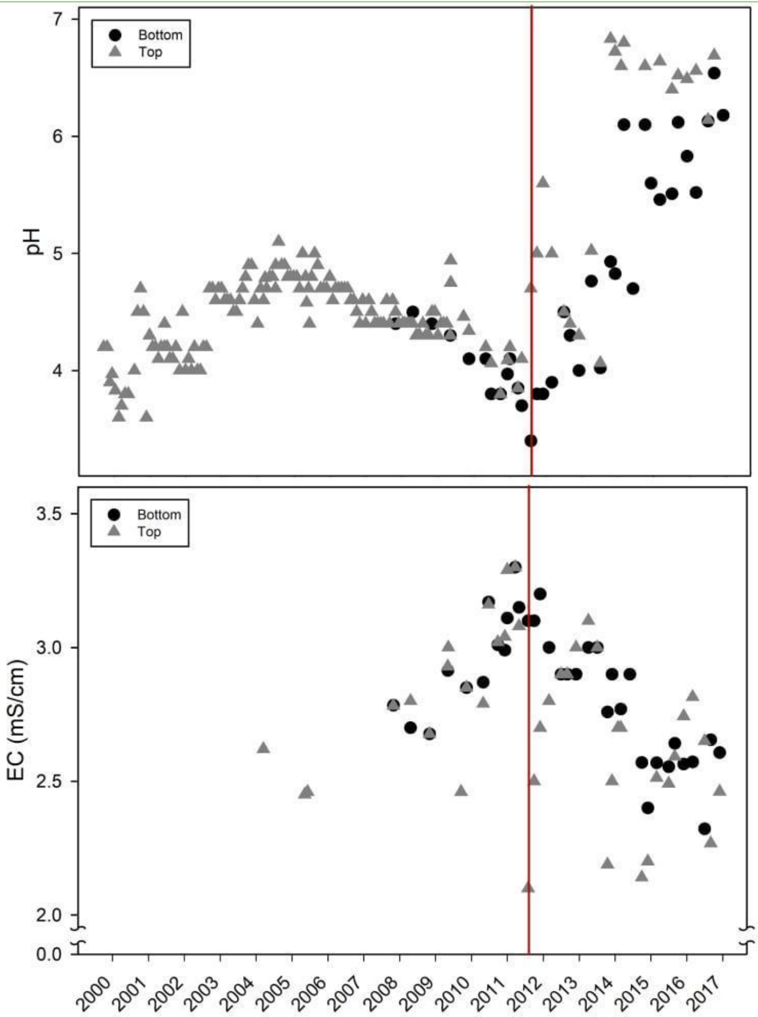
12	**Measurable effects**	 Time-series graph of Lake Kepwari pH historically, during and after flow-through began (McCullough et al, 2010; McCullough et al, 2012).
13	**Long-term benefits**	Early estimates anticipate that after three years, Lake Kepwari should attract up to 22,000 overnight stays and 37,000 day trip visitors per annum, contributing millions to the local economy
14	**Funding**	Premier Coal (Yancoal), The WA State Government identified Lake Kepwari as a key development project in the South West region and committed $5.7 million to realising this vision

Figure 72. Lake Kepwari aerial view (source: https://www.ourwaparks.org.au/lake-kepwari-transformation/)

6.4.13. Pokrovska mine

DTEK, one of Ukraine's biggest energy holder, has developed the former mine site as solar energy production site. The scale of the project is impressive and a good practice can be recognised in quick development and large energy production.

Table 16 Pokrovska mine Site Fact Sheet

1	**Name and location**	Pokrovska Mine, Ukraine (largest solar plant)
2	**Operating time**	1990 - ongoing
3	**Area size**	437 ha
4	**Area type**	Former manganese open pit area
5	**Type of mining**	Open pit mining
6	**Reclamation start**	Beginning of 2019
7	**Completion dates**	October 2019
8	**Planned post-mining land use**	Solar Power Generation
9	**Reclamation**	Earthworks and 840,000 solar panels installed in ca. 8 months

	work	
10	**Innovative practices**	Increased energy independence,
11	**Public communication**	-
12	**Measurable effects**	240 MW power generation
13	**Long-term benefits**	Renewable Energy production, providing independent and sustainable energy source from hydrocarbons market
14	**Funding**	The project is the third large solar facility developed by DTEK, at a total cost of €193 million.

Figure 73. 240 MW solar power plant (source: DTEK)

6.4.14. Wieliczka mine

Wieliczka Mine has 9 levels, the first of which - the Bono level - reaches a depth of 64 m, while the last lies 327 m below the surface. The total length of tunnels connecting about 3,000 excavations (tunnels, ramps, mining chambers, lakes, shafts) exceeds 300 km. The cubic capacity of the pit complex is about 7.5 million m³. The mine is characterized by a unique microclimate, which consists - in addition to high humidity and sodium chloride content - of constant temperature (about 14-16 °C), pressure, ionization and high content of potassium, magnesium and calcium in the air. The Lake Wessel chamber is recommended for people with upper respiratory tract diseases.

Table 17 Wieliczka Site Fact Sheet

1	**Name and location**	Wieliczka Salt Mine
2	**Operating time**	13th century - 1996
3	**Area size**	970 ha
4	**Area type**	Wieliczka metropolitan area and a Polish Historic Monument and a UNESCO World Heritage Site
5	**Type of mining**	Underground salt excavations
6	**Reclamation start**	XVIIIth / XIXth century – first underground touristic route opened
7	**Completion dates**	Since 1978 on UNESCO World Heritage Site list, constantly reworked
8	**Planned post-mining land use**	Historical site - museum, cultural site – event organisation and preservation, tourist facility – tourism routes and attraction
9	**Reclamation work**	Adaptation of mine corridors and chambers for public use
10	**Innovative practices**	Underground event planning (business conferences, sport activities and tournaments, concerts, weddings and other special events)
11	**Public communication**	2017 – 1.7 mln visitors, 2021 – 700,000 visitors, possibility of a Virtual Walk
12	**Measurable effects**	Wieliczka is a very known place among Polish citizens and one of the most popular touristic sites (close vicinity of Krakow), creating a touristic complex of polish culture around Krakow
13	**Long-term benefits**	Preservation of mining culture and Polish history, creating financial profit and ca. 1,500 jobs for local community
14	**Funding**	Mine operators during excavation history and Polish Treasury

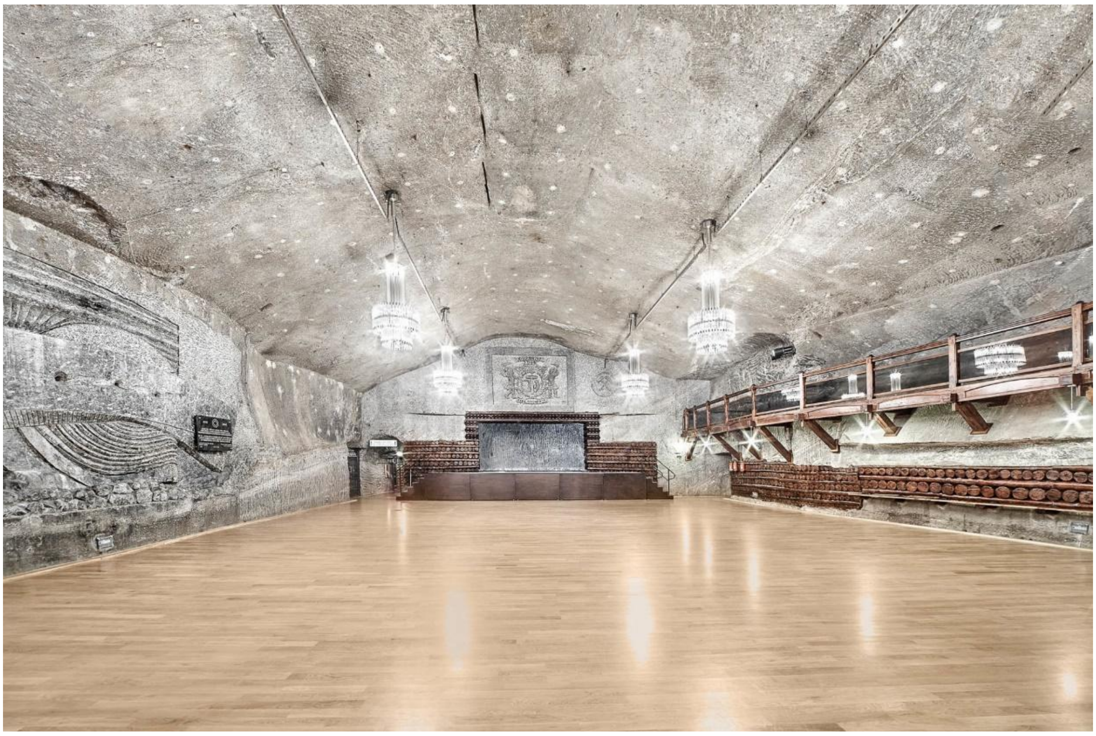


Figure 74. "Warszawa" underground event chamber (source: https://www.kopalnia.pl/imprezy/komory-i-sale-do-dyspozycji/komora-warszawa)

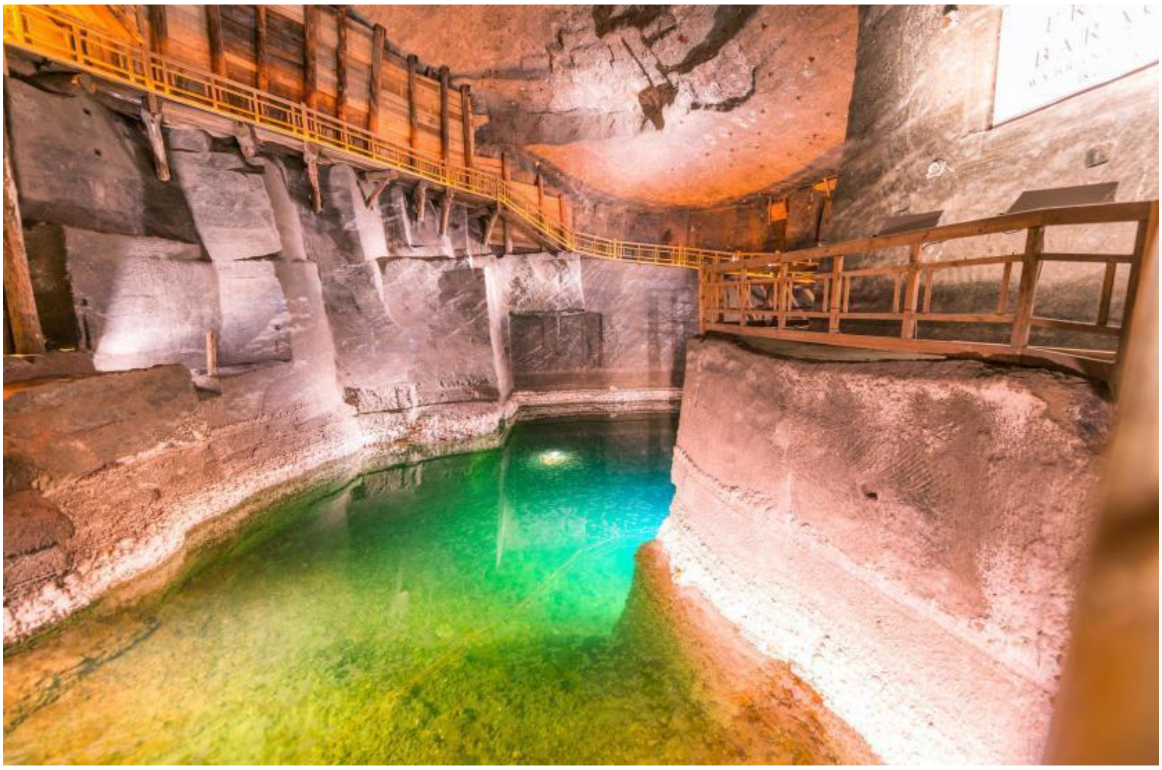


Figure 75. Underground lake in WIeliczka mine (source: https://www.pkt.pl/artykul/a-jesli-juz-jestes-w-krakowie-wybierz-sie-na-wedrowke-po-solnych-podziemiach-kopalni-soli-wieliczka-14243)

6.4.15. PT Newmont Minahasa Raya

Table 18 PT Minahasa Raya Site Fact Sheet

PTNMR established a reclamation forest, developed a tourism area and cooperatives to alleviate the social and economic problems associated with the closure of the mine and ensure sustainable development after closure.

The establishment of a reclamation forest has transformed gold mining into sustainable, high-production timber production that is environmentally and economically viable. The reef ball program and the promotion of underwater tourism in Buyat Bay would create a new tourist facility in the region. (Mamonto et al., 2012)

1	**Name and location**	PT Newmont Minahasa Raya
2	**Operating time**	1996-2005
3	**Area size**	443 ha
4	**Area type**	Tropical mountains and hills
5	**Type of mining**	Open pit mining
6	**Reclamation start**	2004
7	**Completion dates**	2009
8	**Planned post-mining land use**	Forestry, commercial and touristical
9	**Reclamation work**	Construction and monitoring of reef balls artificial reef program, mangrove preservation (50,000 planted), development of local infrastructure, tourism and industry
10	**Innovative practices**	Reforestation will generate income of US$ 20,411,750. The stand could be harvested in rotation to ensure its sustainability
11	**Public communication**	Three community foundations were established: Minahasa Raya Foundation, North Sulawesi Sustainability Foundation, The Ratatotok Buyat Sustainability Foundation
12	**Measurable effects**	Prior to PTNMR operations in 1994, Ratatotok consisted of three villages while Buyat only one village. After the closure period (2011) the area had developed considerably. Ratatotok has grown to become a district which consists of 15 villages, including Basaan in 2003. Ratatotok is presently part of Southeast Minahasa regency. Buyat area had developed to three villages and is presently part of East Bolaang Mongondow regency.

13	**Long-term benefits**	The establishment of reclamation forest had converted gold mining into sustainable high economic timber production (green gold) which ecologically important and economically valuable while the reef balls program and promoting Buyat bay underwater tourism had created a new tourism object in the region and also the cooperatives would financing and facilitating small industry groups of community.
14	**Funding**	Mining operator

7. BAT GUIDE FOR REHABILITATION TOWARDS POST MINING LAND USES

This chapter summarises the findings of this Deliverable and categorises the best available technologies used in the described case studies. As stated in this document, regional legal aspects, environmental conditions and the decisions on future land use have the most significant impact on technologies needed to rehabilitate and reclaim mining areas. Based on the analysed literature and rehabilitation case studies, a proposed classification of post-mining land use is presented below in Figure 76. Numerous examples of successful rehabilitation combine the use of technologies and applications from various suggested post mining land uses. Since mining sites are often large-scale areas, the implementation of many land uses is not only possible, but necessary to reach rehabilitation goals and create the best outcomes. This BAT guide can be used to identify the best technologies available for each post mining land use, with corresponding rehabilitation sites that already implemented and successfully introduced described transformation in real world.

7.1. BAT GUIDE FOR REHABILITATION TOWARDS NATURAL POST MINING LAND USE

Reclaiming mining areas toward natural land use is divided into three specific directions: forestry, aquatic and agricultural. Even though agriculture is a commercial activity and therefore might be classified as a commercial post-mining land use, it is heavily influenced by natural factors and technologies used in biological rehabilitation. Following best practices during reclamation toward natural land use may result to the many benefits listed in this document e.g. saving of operational costs, providing leisure activities to local communities, creating opportunities for land use previously unavailable, providing safe space for the development of natural habitats, providing better hydrological conditions to the area, facilitating topsoil recovery enabling successful agricultural activity, improving landscape aesthetics and many other benefits.

In Figure 77 is a list of practices applied on the previously described rehabilitation sites with natural post mining land use:

- Maintenance of adequate pH levels in pit lakes (Lake Kepwari);
- Storage of stripped soil for later rehabilitation (Konin region);
- Using overburden material to rehabilitate neighbouring pits (from Kazimierz Północ to Południe, from Jóźwin to Pątnów pits, from Jóźwin IIB to Jóźwin IIA pits);

- Hydroseeding (Lubstów);
- Introducing native plants;
- Introducing plants with high resistance to barren soil – black locust (Western Macedonia);
- Creating endangered species habitats (Minahasa Raya, Rheinland mining area);
- Dewatering of one pit fills up another pit (Jóźwin -> Kazimierz, Drzewce->Lubstów).

7.2. BAT GUIDE FOR REHABILITATION TOWARDS COMMERCIAL POST MINING LAND USE

Commercial post mining land use is dependent on socioeconomic factors of the selected regions. Metropolitan area such as Ruhr Valley, can greatly benefit from well-designed commercial land use. Other densely populated areas may take an example of rehabilitation practices carried out there. However, less densely populated areas, such as Konin region, may use a more measured approach and plan appropriate commercial uses for number and type of settlements nearby.

In Figure 78 is a list of the best practices applied on described rehabilitation sites with commercial post mining land use:

- Timber production (Minahasa Raya, Lignite Centre of Megalopolis);
- Touristic attractions (Alpincenter, Lake Kepwari);
- Sport activities (Lake Kepwari, Góra Kamieńsk);
- Industrial parks (Dannenbaum – Opel);
- Business centres / offices (Ewald, Mont Cenis);
- Establishment of communal and industrial landfills (Gosławice and Pątnów open pits, Ptolemaida mining area).

7.3. BAT GUIDE FOR REHABILITATION TOWARDS CULTURAL POST MINING LAND USE

Cultural post mining land use is best applied in areas with high population, where cultural activity is already established. Best practices of this type of rehabilitation direction are best applied in areas with high density of population or increased touristic activity. Dump sites, if rehabilitated correctly, can serve as open-air art galleries like Ruhr Valley’s dump sites. Museums and heritage sites can be established in old mine excavations and post-industrial buildings, as they were described in Chapter 6.4 (Polish underground mines). Cultural activity can also enhance the attractiveness of an area, providing commercial and educational opportunities as described in the rehabilitation case of the Bodelva pit.

In Figure 79 is a list of the best practises applied on described rehabilitation sites with cultural post mining land use:

- Industrial heritage (Ruhr Valley region);
- Mining heritage (Wieliczka and Guido mines);
- Refugee help centres (Dannenbaum - MARK 51°7);
- Educational sites (Bodelva pit);
- Art exhibits (Hoheward, Duisburg).

7.4. BAT GUIDE FOR REHABILITATION TOWARDS RENEWABLE ENERGY PRODUCTION POST MINING LAND USE

Renewable Energy production is a quite popular post-mining land use, and is applied in various types and quantities in all regions specific to the WINTER project. Benefits of this solution were recognised separately in each country and implemented successfully. Wind turbines are an increasingly common solution for rehabilitated mine dumps and beyond. Increased elevation provided by artificial heaps allows for better power yields provided by this technology. The open pit lignite excavation method is carried out on large-scale areas, therefore, if rehabilitated properly, can be utilised to set up large scale photovoltaic farms as the ones being constructed in Ptolemaida region and the planned ones in Megalopolis Lignite Centre. A good practice of large-scale PV farms built in a former mining area is Pokrovska mine, which was constructed very quickly and provides 240 MW of power to the grid. There are other ways of producing renewable energy, for example with biomass plants like at Hugo or Lohberg sites. Former mine sites can support the development of renewable energy production technologies as shown in Ruhr’s area Ewald site and its hydrogen production project (Figure 78).

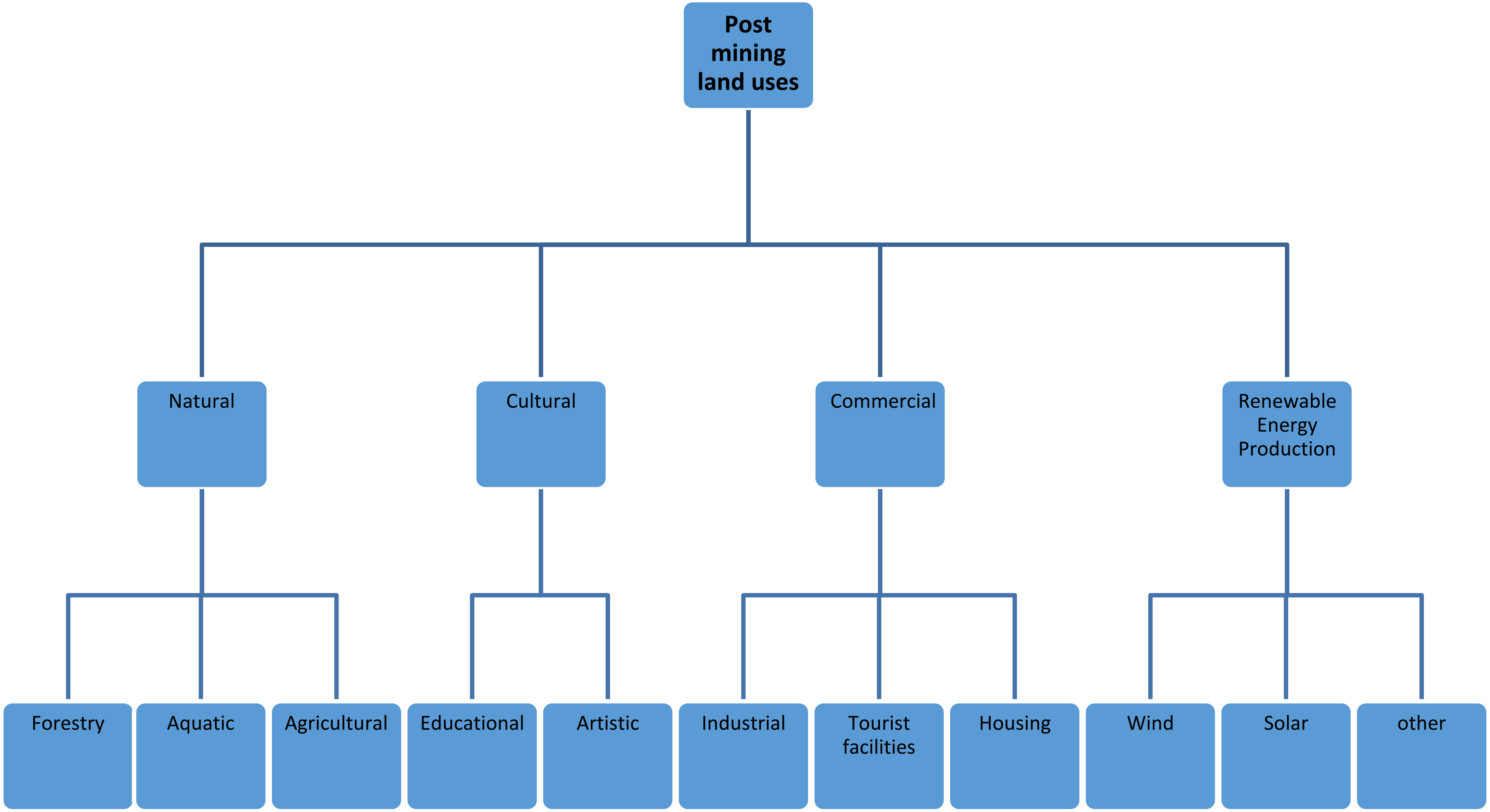


Figure 76. Suggested classification of post-mining land

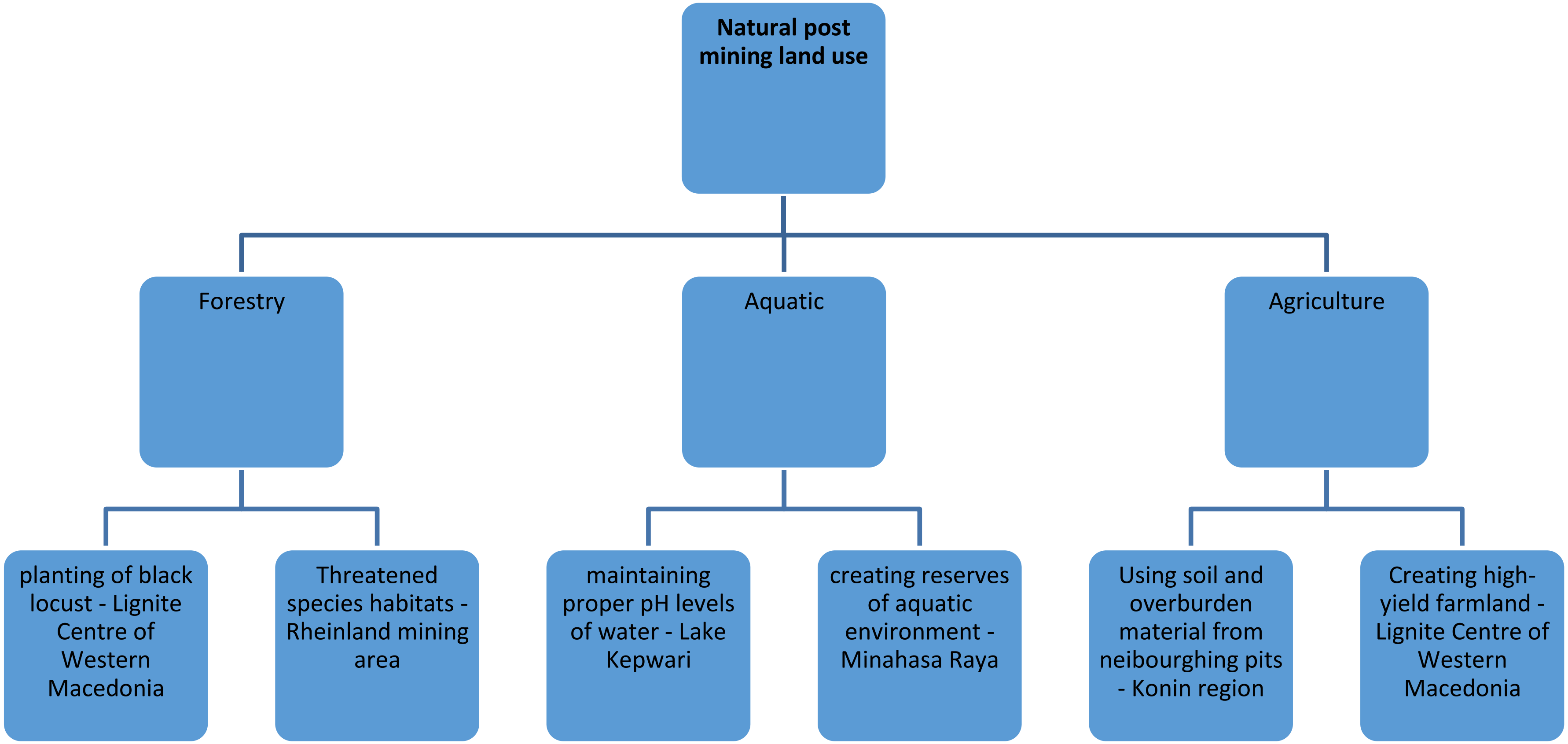


Figure 77 Best practice examples in mine rehabilitation in terms of natural direction

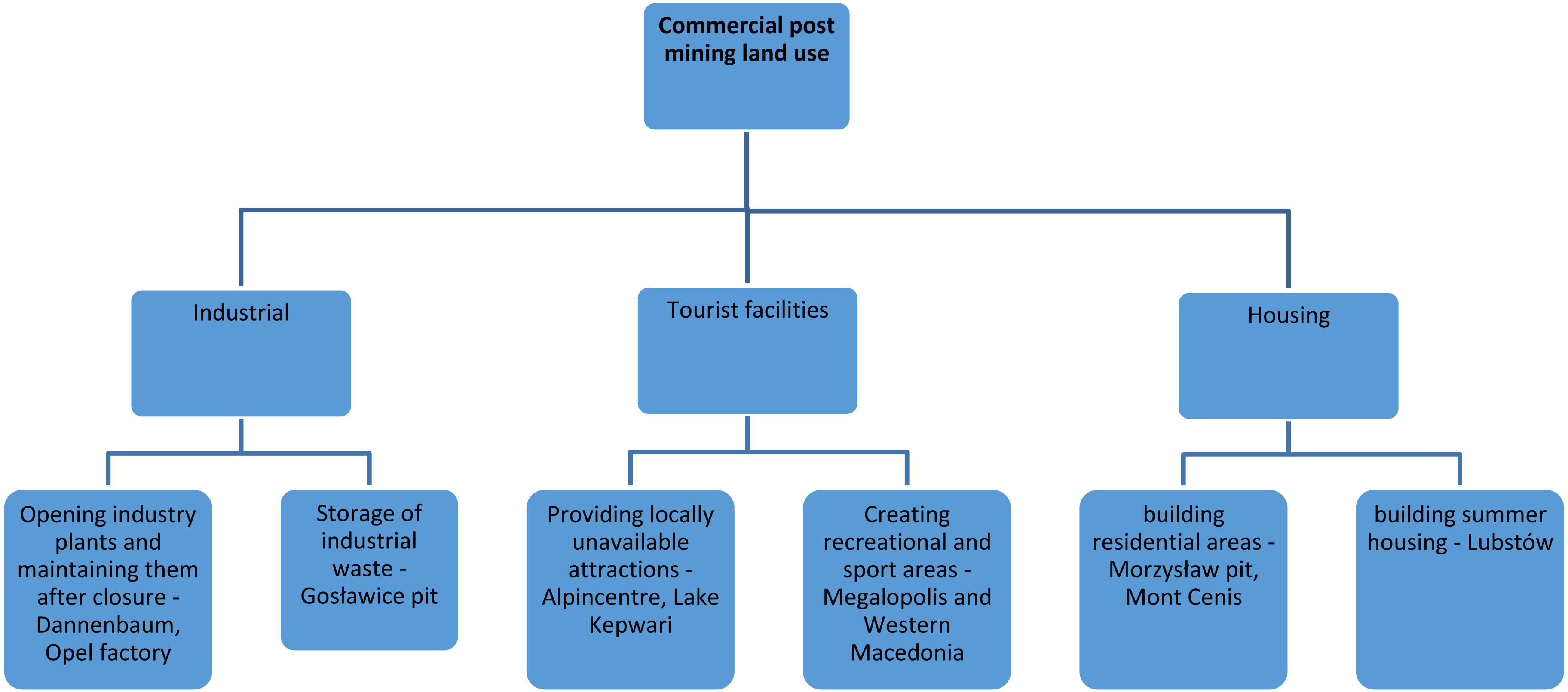


Figure 78. Best practice examples in mine rehabilitation in commercial direction

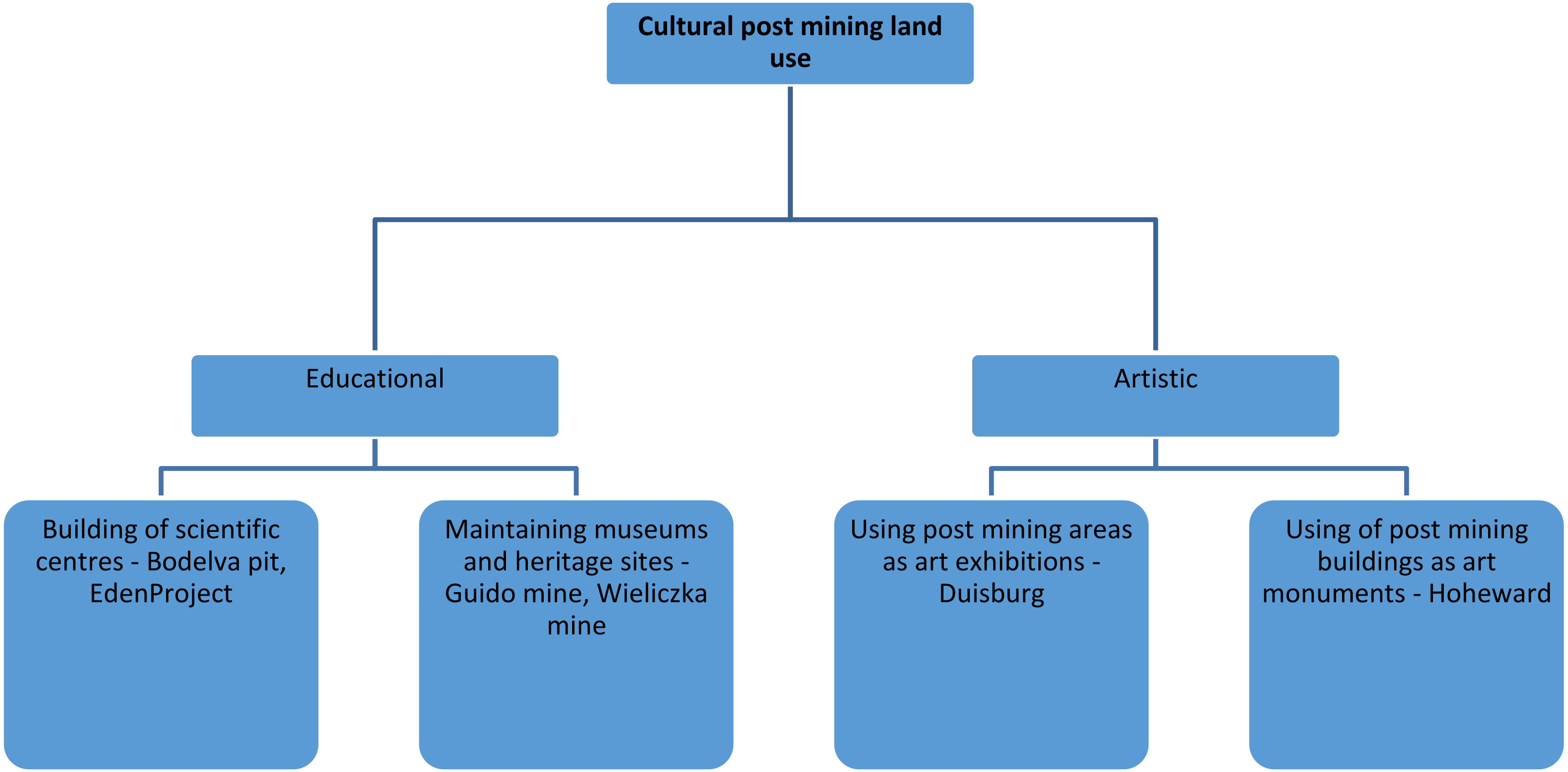


Figure 79. Best practice examples in mine rehabilitation in cultural direction

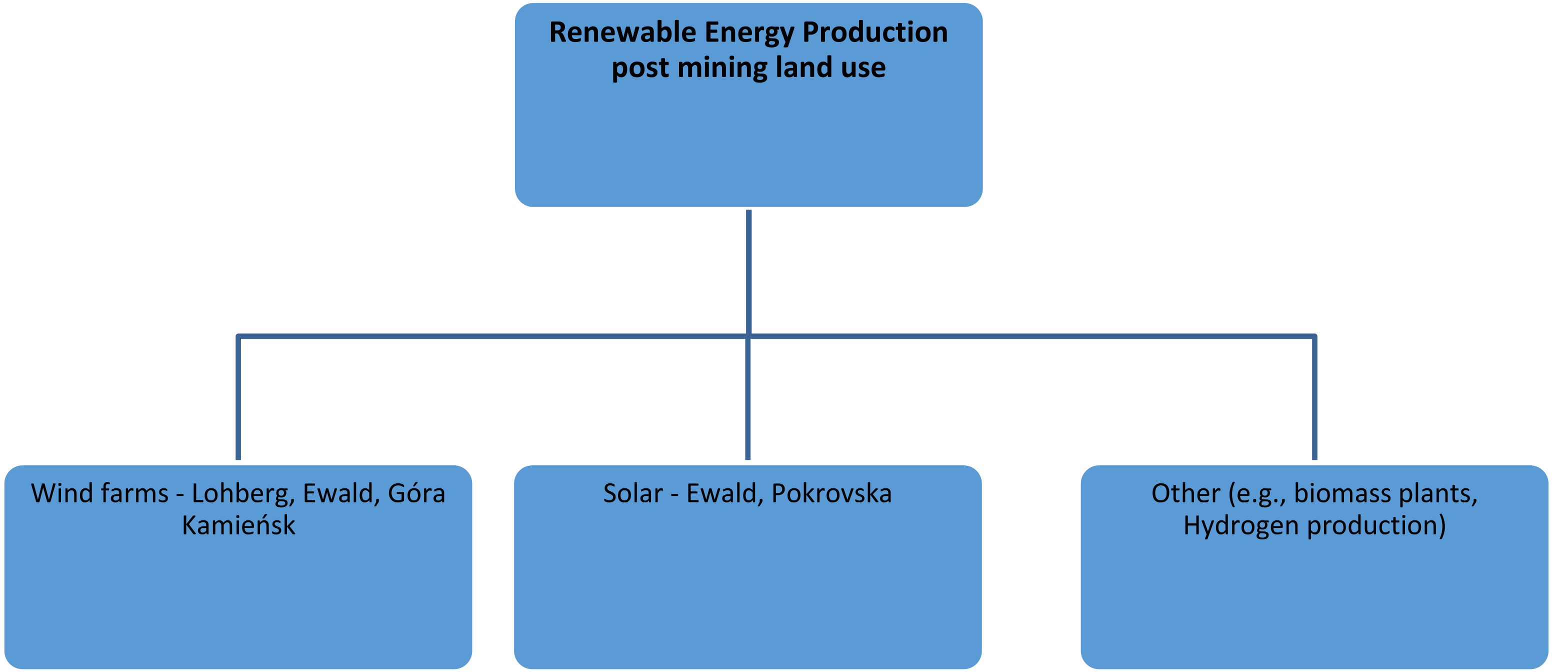


Figure 80. Best practice examples in mine rehabilitation in Renewable Energy Production direction

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