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SUSTAINABILITY-ORIENTATED POST-MINING IN GERMANY

Mining has deeply influenced the social, economic and ecological development of many regions by changing the landscapes, cities and population structures. Beside of this mining has always created all kinds of cultural artefacts from jewelry to miner's songs, that can be called mining heritage. Especially, built heritage is one of the most identity-performing cultural artefacts of a modern society. In our fast-moving globalized world, there is a need to preserve, develop and present these artefacts, especially mine sites, as a distinct and important contribution to a sustainable development of each mining region. The idea of preservation of decommissioned industrial sites to keep the regional identity started parallel to the decline of the heavy industry in the Ruhr region. In 2007, a political understanding was arranged to phase out German hard coal mining in a socially acceptable manner by the end of 2018.

This decision required a new strategy for the coal mining industry. Being strictly finalized, the German hard coal mining industry has to be prepared for the post-mining era. To create a sustainable development strategy, the long-term impacts of coal mining activities in Germany concerning the environmental, economic and social dimensions will be analyzed systematically and forward-looking. The regional and social responsibility during the closing process and for the post-mining era will be emphasized. High technical standards in environmental protection and post-mining technologies, as well as long-term experiences in the development of former mine sites to create new jobs are significant from an international point of view. The traditionally constructive social partnership between employers, union, and employees has enabled long-term stable adaption processes and avoided social friction. The sustainability strategy of the German hard coal mining industry can be regarded as a role model for other mining countries and regions facing similar transition challenges.

***Key words:** hard coal mining, mine closure, mining heritage, post-mining, post-mining management, RAG, sustainability*

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Introduction

In general, the mining cycle can be divided into three phases: In the exploration phase the deposit is investigated to determine its technical and economic profitability. The period of these undertakings is relatively short and can lead to the launch of mining operations. The actual mining phase usually lasts for a long time and ends latest when all deposits are fully depleted. This lifespan may be shortened if the economic conditions (production cost or market price) deteriorate. Nevertheless, mining may be resumed if those conditions become favorable once again. The post-mining phase finally is the longest phase as the human interference into geology and nature is usually intensive and irreversible and may have a permanently adverse impact on people and the environment [1].

In the past, mining companies were mostly busy with the first two phases as those were the ones in which they could act profitably on the market. Moreover, many mining countries have not created a legal framework that would oblige companies to handle the impacts of active mining on the post-mining phase.

As a result, the medium- and long-term impacts on the environment and the people living in the mining regions were often neglected — and even the economic impact was neglected. Mining damages that occurred years later such as subsidence damages or the restoration of land and water bodies represent costs the entire society has to cover if the responsibilities and the funding by the mining companies are not properly defined. In the end, such impacts can lead to a loss of acceptance in politics and among the population [2]. As mining cannot be done without impacts, it is necessary that negative consequences are minimized. Beside of this, effective post-mining provides numerous opportunities by reinventing mine sites to create new jobs. What principally matters is the successful control and management of post-mining risks and the effective use of these opportunities.

Sustainability and post-mining

The Brundtland Report, published by the United Nations in 1987, defined the term sustainable development as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs [3]. Sustainability is about three basic aims: the share of wealth for as many people as possible (social sustainability), a durable positive economic development (economic sustainability), and the preservation of nature (environmental sustainability).

This three-dimensional approach to sustainability can be transferred to post-mining activities. Sustainable management of mining impacts means that environmental damages caused by emissions, subsidence and such should be limited (environmental dimension); the costs of managing both mining damage and permanent obligations should be kept as low as possible (economic dimension), and the population living in the mining regions should be offered future prospects to ensure their standard of living and their well-being after mining has come to an end (social dimension).

To reach these aims the requirements of the post-mining phase have to be included in the strategic planning and the operations of every mining project from the beginning of the mining cycle.

Hard coal mining in Germany: from industrialization to post-mining

In Germany, industrial underground mining of hard coal began in the early 19th century. In the roughly 200 years since then, there were times when several hundred mines of different sizes existed, mostly located in the Ruhr area in the state of North-Rhine Westphalia and in the Saar region.

For more than hundred years, hard coal from domestic production had been the basis for industrial success in Ger-

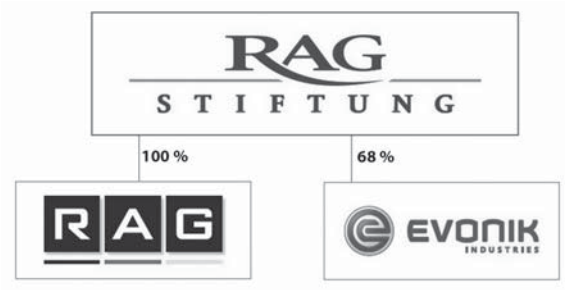

Fig. 1. Company structure of the RAG-Stiftung/RAG

many, even after World War II, when Germany started its "economic miracle", becoming one of the leading economies in the world. However, since the 1960s, hard-coal mining in Germany has been in the state of continuous decline. Because of relatively high production costs, German hard-coal mining could not compete on the world market.

At that time, the German government decided an adjustment process that would reduce the social consequences. To do so, the mining companies worked in a close collaboration with political institutions and trade unions. The objective has been, until today, to achieve the economically necessary downsizing without creating a large number of unemployment in the mining regions. This objective could be achieved by a number of measures like agreements of early retirement or retraining of young miners for new jobs, by attracting new employers of the manufacturing industry, and by establishing universities in the mining region. This so-called structural change of the regional economy was accompanied by the assignment of new land use functions to closed mining areas. Many of these areas were opened to the public, and mine sites were restored for recreational and environmental purposes or commercial uses.

In 1968, the remaining mining companies in the Ruhr area merged their coal activities under the supervision of the so-called Ruhrkohle AG. The hard-coal production received state subsidies to ensure the domestic power supply and the supply of coking coal. In 1997, Ruhrkohle AG was restructured and received a new name, RAG. The operation of the mines was separated from the other business units in order to separate profitable and subsidized business activities [4].

In 2007, the German government decided to end the financial support of the coal mining industry in 2018 because the European Union no longer allows such subsidies. This has led to a final mining closure program. To realize and organize this program the German government has passed a law. Based on this law, the «old» RAG was split into three parts: a newly set up foundation, the RAG-Stiftung (RAG-foundation); the subsidized coal mining unit plus coal trade, land management, site development, and a few other coal related service companies, still named («new») RAG; and profitable business units mainly the subsidiary Evonik Industries, one of the world´s leading specialty chemicals companies, beside other interests. The foundation has to ensure that the proceedings from the profitable business units will be used to provide sustainable funding for post-mining tasks so that German taxpayers will not have to pay for them. In addition, the RAG-Stiftung has the responsibility for promotion and support of education, sciences and culture in the mining regions [5] (**Fig. 1**).

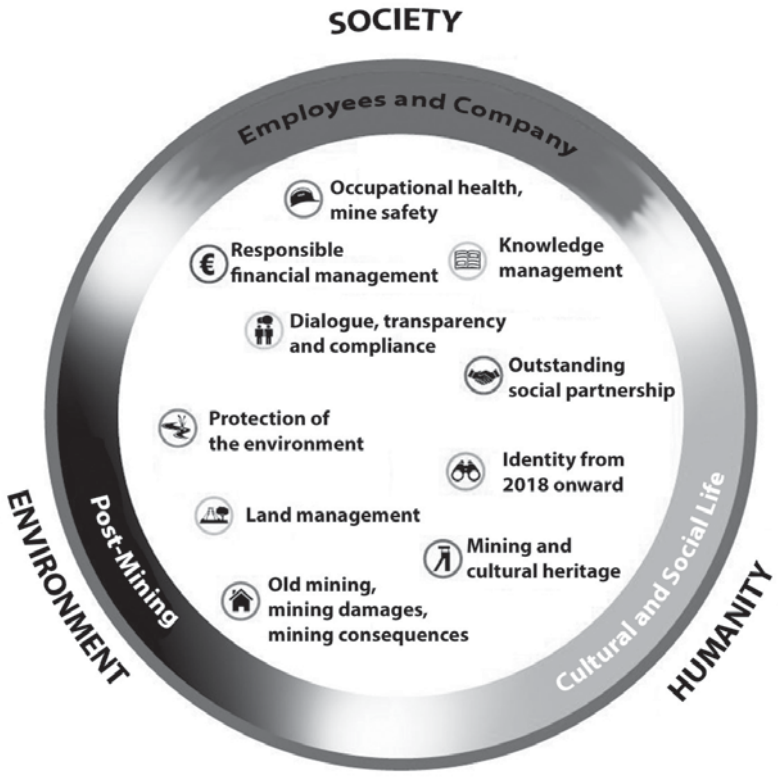

Fig. 2. 10 Spheres of activity of the sustainable development strategy of the RAG

Sustainable development in post-mining at the Ruhr

Industrial development had a formative regional importance on society and architecture in Germany, especially in the Ruhr region. Driven by the availability of hard coal an agglomeration of industrial influenced cities arose since the early 19th century. Today these cities are forming a metropolitan area with more than five million inhabitants.

In this setting numerous objects of coal mining concerning extraction, production, transport and infrastructure have been built and are imprinting signs of the «coal age» in Germany now (e.g. colliery and coking plant Zollverein in Essen), which is a World Heritage site on the UNESCO list).

The idea of preservation of decommissioned industrial sites to keep the regional identity started parallel to the decline of the heavy industry in the Ruhr region. First some workers' settlements were kept. Later a group of interested citizens together with monument curators and politicians recognized the historical significance of entire industrial sites, including pit frame heads or production halls with dimensions to speak of "industrial cathedrals".

A big challenge in the beginning was the necessity to convince the «man in the street» and many politicians that these «awkward» objects of heavy industry do have a comparable status for the history and the cultural development of North Rhine Westphalia as e.g. impressive and beautiful churches like the Cologne Cathedral. More than a decade was needed to change the negative image of these objects in the mind of the inhabitants in the Ruhr region (places of donkeywork, rage because of job losses caused by closures ...). A positive feeling was created expressed in the word «industrial culture». People became proud of their cathedrals of industrial culture and started to look at them from a different perspective [6].

RAG is turning from an active hard-coal producer to a post-mining group. Its business activities today can be defined according to the three dimensions of sustainability. In the era of post-mining, RAG has to master the organizational and technical challenges of mine closures in such a manner that any harm to people or damage to the environment is avoided or offset [7].

Fig. 3. Creating renewable energy, an opportunity of post-mining: *1* — Photovoltaic plant on a mud pond; *2* — Heat from mine water; *3* — Windmill on a dump hill

Just recently, RAG has published the first sustainability reporting that emphasizes its three columns of the sustainable development strategy: environment (post-mining), society and finances (employees and company) and humanity (cultural and social life). A very important aspect to develop a sustainability strategy is a continuously open and transparent dialogue with the stakeholders and the general public. In the course of this dialogue, the challenges of post-mining should be intensively discussed. In order to summarize the outcome of this dialogue as the basis of its sustainable development strategy RAG has defined spheres of activity (**Fig. 2**).

The CEO of RAG Bernd Tönjes has summarized the motivation of RAG to develop its sustainable development strategy as follows: «At the end of the year 2018 the German hard coal mining will end. More than 200 years it has transformed villages into cities and industrial centers. For many decades, coal provided economic power for the mining regions and the whole federal republic. Mining has shaped visibly the landscapes, even after the end of the production. Its impacts are noticeable. But the unavoidable impacts can be regulated and mitigated in a responsible way. We are meeting the challenge to take responsibility for the impacts of coal mining — even when the time of an active mining is over» [8].

Transforming mine sites — an opportunity for sustainable mining

In the past, post-mining management in Germany has been focused on the issue of reducing and preventing risks. In the last years, however, the situation in the energy industry has undergone fundamental changes. Some keywords in this context are: the finite nature of fossil fuels, global warming, CO_2-emissions, and the risks of nuclear power. Therefore, German politics achieved a change towards renewable energies. This change brought about a boost of creativity and innovation that also enclosed post-mining areas. Because historical mining encompasses many opportunities of generating renewable energies as well as other new, future-orientated uses for former operating areas.

In the future, post-mining management has to incorporate these opportunities, as the sustainable management of the mining areas will have huge impact on the acceptance of the mining industry as such. If the mining companies fail to seize the opportunities post-mining offers, mining will not be truly sustainable.

At the Ruhr a number of applications are already in use or exist as research projects, prototypes, ideas and visions like:

— Photovoltaic plants on mining areas: Apart from their height, dump hills have another advantage: there are many free areas and hardly any shading. Therefore, they are ideal locations for photovoltaic systems; likewise, the large roofs of factory buildings can be used for these, too. (**Fig. 3.1**)

— Heat from mine water: Every year, approximately 70 million cubic meters of mine water are pumped in the Ruhr area. The temperature of this mine water is 35-40°C and can be used for supplying heating to buildings by means of heat exchangers or for accelerating the biomass production when generating energy. (**Fig. 3.2**)

— Wind turbines on dump hills: The dump hills in the Ruhr area are often 80-100 meters above ground surface. Thus, they often feature high wind speeds that allow for economically reasonable use of wind turbines. (**Fig. 3.3**)

— Energy production from methane that is released from coal beds

— Production of biomass on former mining areas, especially dump hills.

— Pump-storage power plants using dump hills and underground mine structures

— Production of geothermal energy [9]

Fig. 4. Kreativ Quartier Lohberg. Overview (RAG/Klingenburg)

Examples of a sustainable development of former mine sites

The biggest opportunity for former mine sites liens in a development that integrates surface and underground uses. The project of Ewald Colliery serves as an excellent example to il lustrate this. Until 2000, the colliery produced an output of approximately 2.5 m metric tons per year. Its premises included around 0.44 km^2 (109 acres) of surface area, 2 shafts and more than 90 buildings.

After the mine closure, a team consisting of architects, urban planners, technical authorities, municipalities and individual citizens developed a concept of how to utilize the surface areas. The area was redeveloped, i.e. some buildings were demolished, others restored and marketed. By now, a number of companies have found a new home there, including industries such as logistics, technology, services, crafts, commerce, tourism and real estate, as well as catering and even a theater.

At the same time, mine gas is extracted from the old shafts and sold. At the mine dump nearby, a wind turbine has been built to generate energy; in the medium term, a hydrogen competence center is to be established to promote energy generation from hydrogen. All of these developments show that the former colliery is being revamped as a location that fulfills all aims of a sustainable development: new economical values, new jobs, and ecological recovery [10].

Another example where all three aims of sustainability have been reached by reshaping a mine site is the Kreativ Quartier Lohberg. This development project illustrates the transformation of a former mine site into the first CO_2 neutral suburb of Germany. An important feature of this site is the combination of modern and listed architecture that is completely supplied by renewable energy resources like photovoltaic plants, heat from mine water, biomass, wind turbines and geo-thermal energy [11] (**Fig. 4**).

In the former mining town, Kamp-Lintfort the Rhein-Waal University of Applied Sciences has transformed an area of the closed Friedrich-Heinrich mine into a campus. This campus «built on coal» is another example how mine sites can be transferred successfully for new purposes [12].

Two lessons learned

Considering the above-mentioned facts and figures, there are two lessons learned to create suitable post-mining strategies and measures successfully.

Sustainability and originality

A positive result in the preservation and development of a mine site for new purposes will be achieved only in a consensus between the stakeholders concerned. Many discussions will arise if there is an enforcement of singular interests to the disadvantage of others. It may result in short-term success of one stakeholder, but a missing long-term acceptance will generate sticking points on the way to a successful realization.

Thus, a very puristic preservation of a mine site just keeping most of the object in an original condition may be a success for the preservation authorities but may also cause the disinterest of owners and investors regarding the future use of the object. A resulting lack of funding is of great disadvantage because it will prevent necessary maintenance and repairs. A surviving of a mine site without a new compatible use is possible only under very rare circumstances. However, a reuse of the site just with the consideration of user interests might result in a reconstruction that has nothing to do with the former monument. In this case, if the uniqueness, the image and the

charisma of the object are gone and the value of the object for the region is reduced.

Sustainability has to be considered within the technical measures of the individual sites, too. The given substance should be regarded as a non-renewable resource. Any work at the object should consider its originality at any time. For example, an additional supporting structure, which allows the continuation of a weak original beam or pillar at the place, has to be seen long-termed as a more valuable measure than an apparently easier or cheaper replacement of the original. A copy is never the original although it looks in the same or even better. Lost originality cannot be regained. Originality and sustainability are two sides of the same coin when it comes to preserve and develop a mine site.

Creating a better image for an entire region

Actual attempts and successes at the Ruhr demonstrate that former ugly mine sites have been transferred into appreciated and accepted objects of mining culture. An important factor of success is the explanation of measures to the public. People were invited to join the long way of conversion from the state of industrial functional buildings (with sweat and tears) to the identity forming objects of mining culture (with joy and pleasure). The aim of the people in charge was to explain the social significance of these objects to the public. Potential problematic objects were turned into places with a positive image, because measure that are just enacted by certain experts and not discussed in public will fail to be accepted as social valuable [13].

The attempts in the last 30 years in the Ruhr region have created a new atmosphere in the entire region. The declaration of the town of Essen together with the Ruhr region as the cultural capital of Europe in 2010 was an important milestone on this way to a bright post-mining future. Enthusiasm of the inhabitants and the increase of foreign tourists, indicated by enormous visitor numbers in 2010 [14], illustrate that industrial, especially mining culture has become an important brand of this region.

In the year 2017, the former mining town Essen, the biggest city in the Ruhr region, has won the European Green Capital Award by the EU. The responsible EU commissioner Karmenu Vella pointed out that Essen has used the lessons from its industrial past to build an environmentally sound future [15].

Post-mining education — the basis for post-mining excellence

Post-mining excellence requires high motivation as well as a high level of abilities and skills. Without key elements like ideas and visions, research and development, integration of surface and underground challenges, and risk management — post-mining will be inefficient, based on short-term thinking, muddling through or in the worst case on lip services.

High motivation needs a change of mind: post-mining no longer means simply avoiding certain hazards but has to be seen as an evolutionary sustainable process that is based on the management of risks and the utilization of opportunities. This process should be encouraged by suitable governmental regulations and incentives to promote ideas, to support research and development, and to run widely visible lighthouse projects profitably. The implementation of such innovative lighthouse projects at old mine sites is often a milestone for mining communities on their long road to a brighter future. To improve abilities and skills, the existing network of companies, universities, government institutions, mining authorities and research centers can be used. Its members can promote a transfer of both knowledge and technologies.

In order to competently develop post-mining technologies and management skills, a sufficient number of experts and executives have to be qualified in this field. For example, the TH Georg Agricola University offers a unique master program in geoengineering and post-mining to qualify specialists who will be able to deal with the challenges [16]. As part of its activities, the TH Georg Agricola University has established a research center for post-mining where new methods of geoengineering will be developed and tested for a sustainable management of mining impacts. Both, master program and research center are supported by the RAG-Stiftung [17].

Conclusion

Germany will stop producing hard coal at the end of 2018. To find sustainable solutions for the post-mining era, especially to create good perspectives for the generations to come, RAG has realized a sustainable development strategy that includes numerous measures. The experiences RAG has made and the knowledge the company has gained can be used in many mining regions all around the world, which tend to face similar transition processes in the future. To develop and transfer knowledge and experiences in post-mining, the TH Georg Agricola University has established a specific master program and a research center. Post-mining is sustainable, it can create values and jobs, and it revives old mine sites environmentally friendly. There are enormous opportunities of which we only start to see the beginning!

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REMOTE MONITORING OF ECOLOGICAL STATE OF DISTURBED LANDS IN THE AREA OF TROJANOVO OPEN PIT COAL MINE IN BULGARIA

Trojanovo Open Pit Mine, Bulgaria is a known coal producer being among the top largest open pit coal mines in Europe. Started its history in the early 1960s, the open pit coal mine is now the only Bulgarian open pit mine that meets its own needs for power-generating coal. For the whole period of operation of the mine, the area of disturbed lands has made 15 thousand hectares. Mining has inflicted a large-scale damage to the natural landscape. In this connection, it has become of the theoretical and practical concern to carry out long-term monitoring of the disturbed land reclamation in the area of the open pit mine.

In recent years, the issues of the mining ecology become in spotlight for researchers on every continent. At the same time, as the review of the scientific literature shows, the open pit mining ecology issues have never been studied using resources of the remote sensing of different duration.

The article presents the results of the analysis of the disturbed land reclamation dynamics in the area of Trojanovo open pit mine using the freely accessible information resources of the remote sensing of the Earth.

Key words: *open pit coal mine, mining ecology, disturbed land reclamation, overburden dumps, recovered ecosystems*
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Introduction

Currently open pit coal mining has reached high levels in the Central and Eastern European countries. In Germany, Poland, Greece, Czech Republic, Serbia, Bulgaria, Romania, Bosnia and Herzegovina, there are 53 operating open pit coal mines. Among the ten largest coal companies in Europe, Trojanovo open pit coal mine has been producing coal since the 1960s in Bulgaria. Mining activities have brought an immense damage to natural landscape: total area of disturbed lands makes 15 thousand hectares. In this