From Mining to Post-Mining: The Sustainable Development Strategy of the German Hard Coal Mining Industry

J Kretschmann[1, a], A B Efremenkov[2, b], A A Khoreshok[2, c]

[1] TH Georg Agricola University, Herner Straße 45, Bochum, Germany
[2] Yurga Technological Institute (branch) of National Research Tomsk Polytechnic University, Leningradskaya 26, Yurga, Russian Federation, 652055

E-mail: [a]Juergen.Kretschmann@thga.de, [b]ytitpu@tpu.ru, [c]haa.omit@kuzstu.ru

Abstract. By the end of the 1950s, the German coal mining industry produced 150 million tons of hard coal per year in 170 collieries with 600,000 employees. At that time, 70% of the primary energy demand of the Federal Republic of Germany was covered by domestic coal. Since the advance of oil, later of natural gas, in the world energy market and with the growth of world coal trade, domestic coal stood under a long-term restructuring pressure. This decision required a new strategy for the coal mining industry. Now German coal mining will be strictly finalized and will be prepared for the post-mining era. Within a sustainability strategy the long-term impacts of mining activities before and after the mine closures concerning the environmental, economic and social dimensions will be analyzed systematically and forward-looking.

1. Introduction

Principally, mining raw materials is a finite business that reaches its limits once the deposits mined are depleted or the resources can no longer be mined in an economically profitable way. However, the impact of winning raw materials by mining is potentially an infinite one – at least if you measure it at a human time scale because mining always means to interfere with geological and ecological structures that cannot be reversed to their original condition. If we look at the entire process of mining end-to-end, we have to consider the period after active mine works have finished as well.

Therefore, the mining cycle can be divided into three stages:

1. The exploration phase, in which 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.

2. What follows is the actual mining period which usually lasts for a long time and ends latest when all deposits are fully depleted. The operational lifespans of German hard coal mines for example reached up to 120 years. This point of time, however, may be brought forward if the economic conditions (production cost or market price) deteriorate. Nevertheless, mining may be resumed even after a longer period of downtime if those conditions become favorable once more (examples are silver mining in Germany or rare earths mining in the USA).

3. The longest stage, however, is the post-mining stage as the human interference into geology and nature is usually intensive and irreversible. Mining can lead to consequences which have a permanently adverse impact on people and the environment; therefore, they have to be managed as best as we can. In Germany, what has to be done at the post-mining stage is called "Ewigkeitslasten" or "Ewigkeitsaufgaben" – which translates as "perpetual obligations" or "perpetual tasks". The literal translation for "Ewigkeit" is "eternity", expressing that we will have to cope with post-mining endlessly [1].

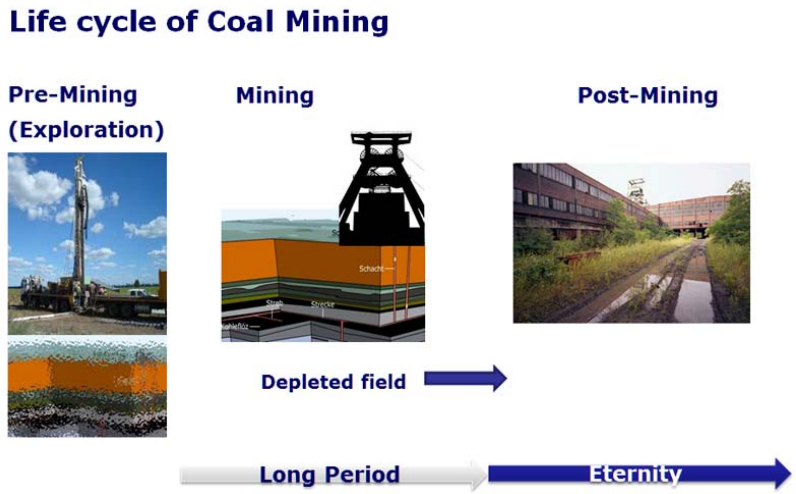

Figure 1 – The mining cycle

In the past, mining companies were mostly busy with the first two stages as those were the ones in which they could act profitably on the market. Moreover, most mining nations had not created a legal framework that would oblige companies to take care of the impact of active mining at the post-mining stage.

As a result, the medium and long term impacts the environment and the people living in the mining regions have to endure were often neglected – and even the economic impact was neglected. Mining damage that occurred years later such as the permanently necessary drainage of mine water and the restoration of land and water bodies are what the entire society has to cover the costs if the funding of such activities is not properly defined. In the end, such impacts can lead to a loss of acceptance that mining often faces in politics and among the population.

2. Material and Method

Thus the aim has to be to strive for mining that is as sustainable as possible. In other words, all three stages of the entire process have to be integrated, and the requirements of post-mining stage have to be included in the strategic planning and the operations. Especially as mining cannot be done without impact, there is the need to minimize the negative consequences as much as possible.

The Brundlandt Report, published by the United Nations in 1987, defines the term sustainable development as follows: "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [2]

The origins of the idea of sustainability or rather, its German expression of *Nachhaltigkeit*, to provide for later, lie in the eighteenth century. The German pioneer of forestry, Hans Carl von Carlowitz,

described in his "Sylvicultura oeconomica", which was the first standard work of this scientific discipline, the "continuous and sustainable use" of wood as essential for economic, social and ecological development. [3] Wood was the major energy source for mining and metallurgy during this period. Because of the intensive use of wood the industry risked depleting this resource, creating an energy crisis that would threaten not only production but the fast growing population as well that also needed wood as fuel for heating. By establishing a sustainable forest economy, Carlowitz claimed, the cultivation and use of wood could be balanced, so that an enduring supply could be ensured as a foundation of general well-being.

Sustainability is sometimes shortened to ecological issues, especially in political debates. But it is by no means limited to ecology. Of equal importance are social and economic aspects. 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). [4]

With particular regard to post-mining, the mining authorities – in close collaboration with the mining companies – have developed a risk management system that facilitates recognition of all risks and definition of suitable mitigation measures.

The risk fields of abandoned mine sites can be divided into the following categories:

- Close-to-surface extractions [5-8];
- Surface openings, shafts [9-12];
- Subsidence, uplifts;
- Discontinuous faults;
- Mine gas emission at the ground surface;
- Surface water, pumping of pit water [13-14];
- Refuse dumps [15-17];
- Operation areas.

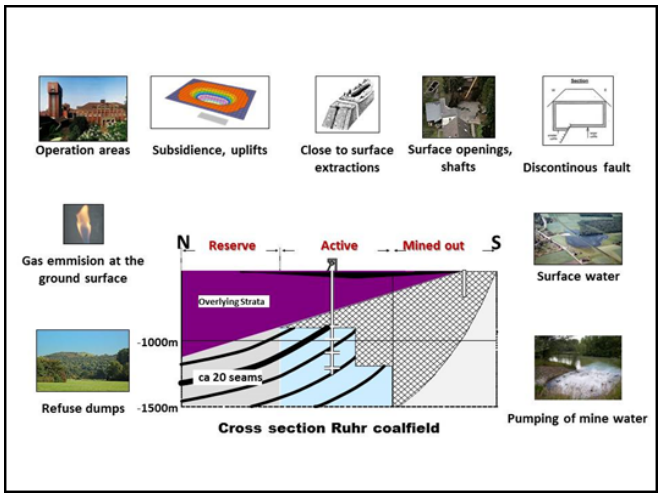

Figure 2 – Risk fields of a mining company

In the risk context, sustainability requires a holistic view of the mining cycle, including the opportunities that arise from abandoned mining sites. Effective post-mining provides numerous opportunities for avoiding, mitigating or even utilizing the risks by reinventing brownfields to create new

jobs. What principally matters is the successful control and management of post-mining risks and the effective use of the opportunities it provides. [1]

3. Results and Discussion

In Germany, industrial underground mining of hard coal began in the early 19th century. In the roughly 200 years since there were times when several hundred mining companies of different sizes existed, mostly located in the Ruhr area and in the Saar region where Germany's largest hard coal deposits can be found.

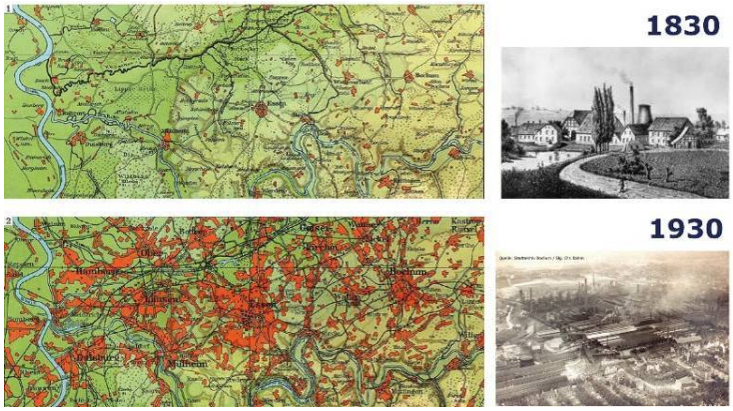

Figure 3 – The Ruhr 1830 and 1930, one of the biggest industrial agglomerations in Europe was built on coal

For more than hundred years, hard coal from domestic production was the basis for industrial success in Germany, even after World War II, when Germany started its "economic miracle", becoming one of the leading economies in the world. But since the 1960s hard-coal mining in Germany has been in the state of continuous decline. Because of relatively high production costs hard-coal mining in Germany seemed not to be capable of competing in the world market any more.

Since the end of mining has been definitely decided at the beginning of the 21st century, 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. The structural change that has been going on in the last decades already aimed at achieving a balance of social and economic sustainability and included certain ecological aspects, too. In today's era of post-mining we need to master the organizational and technical challenges of mine closure in such a manner that any harm to people or damage to the environment can be avoided or offset: we need to strive for environmental and social sustainability. The question of how to master the perpetual tasks is inevitably linked with the question of the running cost, in particular that of permanent mine water drainage. In 2007, the German government passed a bill on funding the termination of hard-coal mining. Based on this act, the "old" RAG was split into three parts: a newly set up foundation, the RAG Stiftung (1), the subsidized coal mining unit plus coal trade, land management, site development, and a few other coal related service companies, still named ("new") RAG (3), and profitable business units mainly the subsidiary Evonik Industries, one of the world´s leading specialty chemicals companies, beside other interests (3). The foundation has to ensure that the proceedings from the profitable business units will be used to provide sustainable funding for the eternity tasks so that German tax payers will not have to pay for them. In addition, the RAG foundation has the responsibility for promotion and support of education, science and culture in the mining regions. This corporate structure mainly aims at economic, ecological and social sustainability. [18]

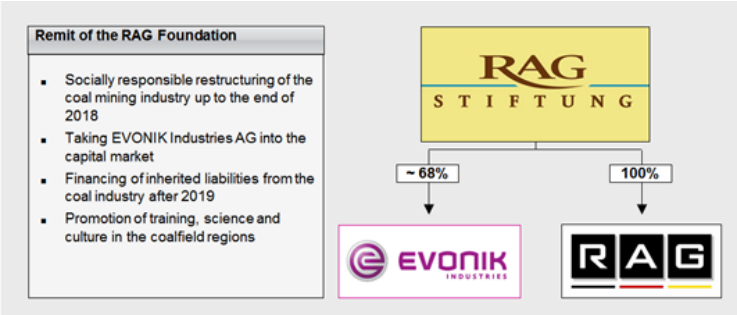

Figure 4 – Company structure of the RAG Stiftung / RAG

The general public only perceives the "tip of the iceberg" when it comes to the impact of underground mining, as the challenges of the development of the entire post-mining underground remain hidden.

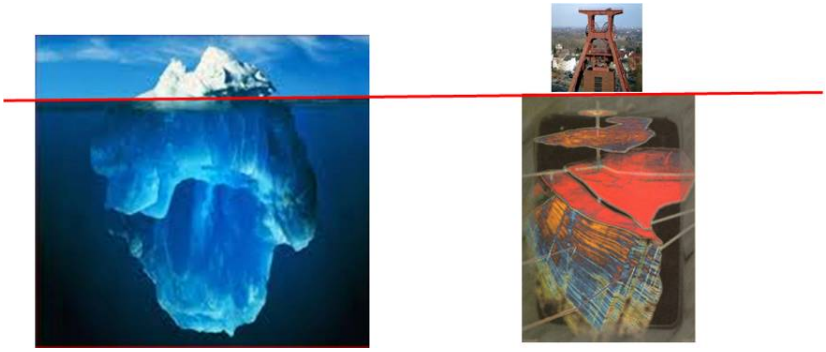

Figure 5 – Challenges in Post-Mining: The Iceberg Model

Regarding the pit water drainage, probably the biggest challenge among the perpetual tasks, the RAG has presented a concept in 2015 that is currently being reviewed by the state authorities. This concept intends to optimize the pumping out of the pit water in the coal fields. As the Chief Executive of the RAG, Bernd Tönjes, has explained: "Our plans on how to optimize the underground water drainage intend to reduce the number of pit water sites successively and to discharge waterbodies from the pit water. Respective measures consider a sustainable protection of drinking water supply and, in addition, also another aim of protection concerned with how to avoid higher emissions of methane, heavy subsidence caused by ground heaving and hazards caused by caving to the surface." [19]

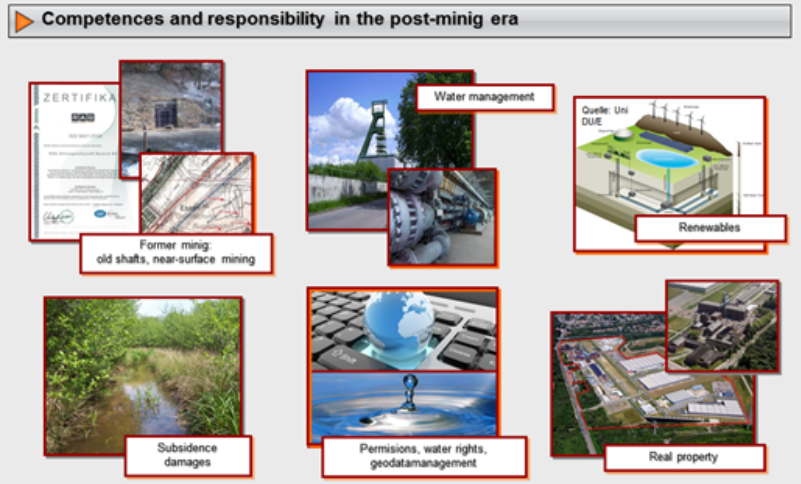

Figure 6 – Burdens and perpetual obligations

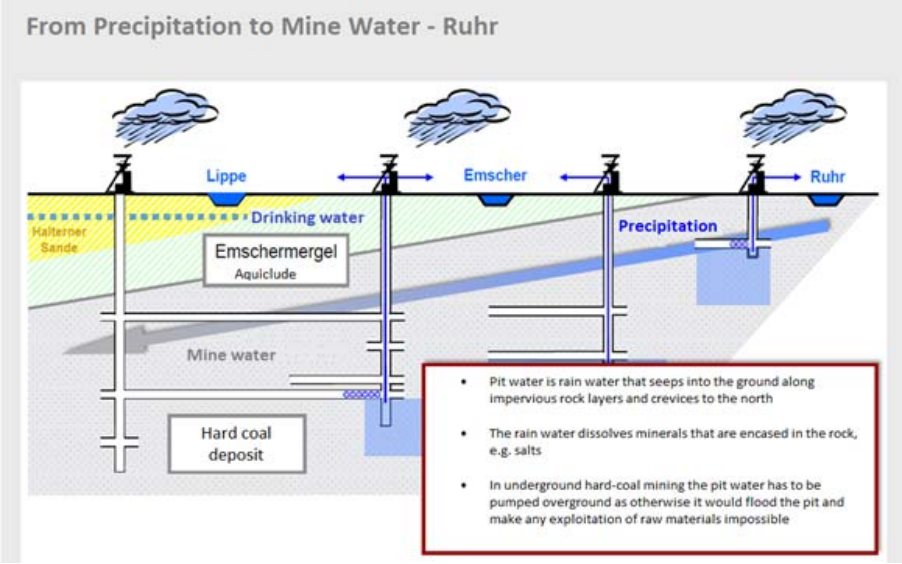

Figure 7 – Pit water handling at the Ruhr

Mine water is rain water that seeps into the ground along impervious rock layers and crevices. The rain water dissolves minerals that are encased in the rock, e.g. salts. In underground hard-coal mining the mine water has to be pumped over the ground as otherwise it would flood the pit and make any exploitation of raw materials impossible. The mine water concept intends to reduce this number to eight water handling systems by connecting adjacent pit works. On the one hand, this project would lead to a reduction in cost, and on the other hand, it would help to discharge some water bodies that still receive strongly mineralized mine water today. Moreover it is planned to raise the pit water level in order to reduce the effort for the pumps. For example, in the Ruhr area the pumping level is to be reduced from 800 m to 600 m whereas a distance of minimum 150 m will be maintained to the drinking water levels above. So far, the drainage is conventionally done in the mine workings which need to be kept open for this purpose; in the future, this system is to be replaced by a well drainage where immersion pumps will be used. These pumps can be

installed in the shaft, lowered from the surface, and can be operated and serviced without the need to guarantee continuous access to the mine workings. [20]

There are a number of applications already in use, research projects, prototypes, ideas and visions included in this:

- Photovoltaic plants on mining areas. Apart from their height, mine dumps have another advantage: there are many free areas and hardly any shading. Therefore, they are ideal locations for photovoltaic systems; like-wise, the large roofs of factory buildings can be used for these, too. (Figure 8.1)
- Heat from mine water or exhaust heat. Every year, approximately 90 m cubic meters of pit water are pumped in the Ruhr area. The temperature of this pit water is 35-40°C (95-105°F) and can be used for supplying heating to buildings by means of heat exchangers or for accelerating the bio mass production when generating energy. (Figure 8.2)
- Wind wheels on refuse dumps. The mine dumps in the Ruhr area are often 80-100m above ground surface; thus, they often feature high wind speeds which allow for an economically reasonable use of wind wheels, and three wind wheels have already been erected. (Figure 8.3)
- Energy-producing utilization of methane that is released from coal beds
- Production of biomass on former mining areas
- Pump-storage power plants either on refuse dumps or underground in existing mine structures
- Geothermal energy. [1]

Figure 8 – 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

Post-mining excellence requires a high motivation as well as a high level of abilities und skills. Without key elements like ideas and visions, research and development, integration of surface and underground, and risk management post-mining will be nothing but inefficient short-term thinking of muddling through, or lip service where no one practices what they preach.

In order to competently implement post-mining management, a sufficient number of experts and executives have to be trained in this field. For example, TH Georg Agricola University offers a unique master program in geoengineering and post-mining to train specialists who will then be able to deal with the challenges provided by legacy and eternity tasks. [21] This focal point in teaching and research also helps to preserve the know-how and intellectual heritage of underground hard-coal mining in Germany: a

knowledge transfer which is also urgently required because, due to the closure of coal mine operations in Germany, many experts in post-mining have either retired or are nearing retirement and the company RAG will not undertake the training of any new specialists. As part of its geoengineering activities the TH Georg Agricola University has opened a research-focused competence center for post-mining where new methods of geoengineering will be developed and tested for a sustainable management of the mining impact. Both the master program and the research center are supported by the RAG foundation which also provides funding for an endowment professorship for geo-engineering and post-mining.

On a global level the perpetual tasks of governments, universities and companies are to interconnect knowledge and experiences from different countries and regions in order to jointly collaborate on finding solutions for post-mining problems that are country-specific, international and global. Excellent post-mining experts and staff members are needed in many countries. That´s why collaborations should aim at long-term continuous improvements step-by-step based on the "plan-do-check-act" circle from Quality Management (Figure 9).

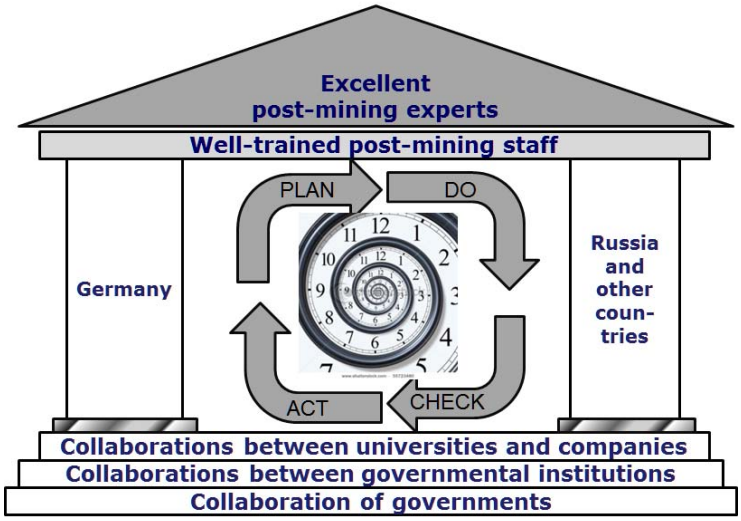

Figure 9 – International Collaboration Strategy

4. Conclusion

Being established in 1968 RAG will stop producing hard coal after a 50 years long period in 2018. To avoid frictions during the transition period from the mining to the post-mining era 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 that have to face similar transition processes in the future. To develop and transfer the knowledge and the experiences in post-mining the TH Georg Agricola University has established a specific master program and a research center.

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