Blue Mining – Today's Mine Planning for Future Mines

Oliver Langefeld* and Angela Binder

Institute of Mining, Clausthal University of Technology, Clausthal-Zellerfeld, Germany

Abstract: The future of mining will be characterized not only by the application of modern technology, but also by the harmonization of economic, environmental and social issues. These areas set major future challenges which are complex and demand extensive knowledge. As an example, mining of highly complex orebodies for the supply of often critical raw materials, needs to consider technically demanding and cost-intensive extraction issues. The amount of tailings, which need to be stored, increases with the amount of ore mined. Therefore, the negative impact on environment and society increases. Hence mining becomes expensive with regard to all three aspects: economy, environment and society.

In view of a sustainable mining practice this challenge should be used as an opportunity. The positive impact should be maximized for present and future generations. The objective is to create and use the mining openings in an optimum way related to sustainability. The approach of Blue Mining, which focuses on energy and ergonomics in the field of Sustainable Development, enhances the closure planning by recommending subsequent usage of such openings for energy storage. The approach fosters among others the implementation of the 7th Goal for Sustainable Development defined by the United Nations with the assurance of access to affordable, reliable, sustainable and modern energy for all. The usage of underground storage increases the stability of solar and water power usage, which are otherwise unreliable.

Blue Mining embeds these issues in the main planning effort long before groundbreaking. This approach involves experience from past and current projects. This paper introduces the concept of Blue Mining with respect to post-mining utilization of a mine for energy storage. Methods and perspectives are presented with examples covering best-practices and lessons-learned.

Keywords: mining, planning, mine closure, sustainable development goals, energy storage, reliable energy, energy transition

1. Introduction

With increasing awareness and sense of responsibility in today's society, mining faces future problems which cannot only be solved by modern technology. Mining works in a conflicted area of economic, environmental and social matters. As an example, mining of highly complex orebodies for the supply of often critical raw materials, needs to consider technically demanding and cost-intensive extraction issues. With lower grades, the amount of tailings which need to be stored is increased. Thus, the increased demand for space and chemicals conflicts with the sense of responsibility towards the society.

In spite of this, the primary production of raw materials is essential for the economic strength and prosperity of humanity, especially with an ascending demand due to the growth of the total population. Therefore, the implementation of Sustainable Mining Practices is indispensable for the future. Mining must implement Sustainable Development.

According to the Definition by Brundtland (1991), Sustainable Development considers the needs of the present generation while not compromising the ability of future generations to meet their own needs. For developing sustainable mining practices, these principles must be applied to mining itself. Hence a Sustainable Mining Practice ensures the supply of today's generation with mineral commodities,

while the options of the future generations are kept intact. Mining itself cannot be sustainable when considering the definition of sustainability for renewable resources. Minimizing the negative and maximizing the positives impacts leads to sustainable development. Due to lack of data, sustainable development is based on assumptions regarding the needs of future generations. Thus, the objective is to find ways so that Sustainable Mining Practices can maximize the positive impact for all generations.

The development of openings during underground mining, which are used as access to the deposit and for the development of the mining method, constitutes a cost-intensive investment. Therefore the openings should be used as effectively as possible. Shafts and tunnels represent not just the necessary mining preparation, but also a connection from the surface to the underground. These openings can easily be utilized during and post-mining for energy storage and for unlocking new energy sources.

The current suggestion for Sustainable Mining Practices is described in the framework of Blue Mining introduced by Langefeld and Kellner (2013). The core of the approach is an upgraded mine planning process. This paper discusses the approach and the framework and the necessary actions with regard to closure planning and urgency of energy storage and alternative energy usage.

* Corresponding Author: O. Langefeld, oliver.langefeld@tu-clausthal.de, phone: +49 5323 72 2440

2. Current Situation – Framing the need

The Energy Transition (Energiewende) in Germany describes the change to the fostered usage of renewable energy. The aim for 2025 to increase the share of renewable resources in gross electricity consumption (GEC) to more than 40 %, as shown in [Figure 1](#), empowered strong thinking and research on the technology to use, distribute and store energy.

[Figure 1](#). Share of renewables in GEC ([German Federal Ministry for Economic Affairs and Energy 2015](#)).

On the other hand, and following international practice, the spreading of renewable energy is required. Defining Goals for Sustainable Development, the United Nations demands, through Goal 7, insurance of “access to affordable, reliable, sustainable and modern energy for all” ([United Nations General Assembly 2015](#)). To meet this goal with renewable energy, many aspects must be considered and technology must be developed. Due to the unreliability of solar and wind energy, storage is particularly important for reaching this goal. In the field of storage, interdisciplinary research was undertaken to use abandoned mines for storing energy from wind power plants ([Beck and Schmidt 2011](#)).

The study confirmed that the utilization of such mines is possible, but measures need to be taken to prepare the mines to be used as a storage facility. In order to effectively implement such plans, mine planning should account for both ore extraction and other post-mining uses. Considering SDG 7 all possible post-mining uses should be evaluated.

According to [Sassoon \(1996\)](#), closure planning has developed from a no-care attitude to an important element planning, which should be realized at the earliest possible stage. Nowadays, it is one of the most relevant aspects for the public and comprises the main aspects of sustainability.

In defining key components of closure planning, [Jessup Bingham \(2011\)](#) names alternative energy as a closure opportunity. Nevertheless, closure planning focuses more on the minimization of negative impacts than on the development of opportunities.

Opportunities which can be used to foster Sustainable Development can be the connection from surface to the underground, which means not only access to heat and elevation levels, but also areas which are restructured by

means of the mining activity. The primary function of the mine openings should be restricted or inhibited by the foreseen secondary application. It is desirable to design them for both applications where safety will always be the top priority.

Summing up, the concept of mine planning with the objective of minimization of negative impacts must be enriched by the maximization of positive effects. This objective can be achieved with an early implementation of post-mine planning for a subsequent utilization of the underground space, which is not directly mining related. The usage of renewable energy has a favorable perspective in the when considering social, environmental and economic issues. In addition, this post-mining utilization applies to deposits of energy commodities. This rationale and approach makes mining a more sustainable activity.

The approach of Blue Mining is developed to identify these opportunities, evaluate them by the needs of the present and future generations and prevent conflicts by parallel planning at an early stage.

3. Blue Mining

Blue Mining, which was introduced by Langefeld and Kellner during the 2013 SDIMI meeting on Milos Island, Greece, meets the challenges of Sustainable Development in Underground Mining with special focus on energy and ergonomics. The field of energy is represented by the main issues of energy efficiency, energy transformation, energy storage and distribution, as shown in [Figure 2](#).

[Figure 2](#). Aspects of Blue Mining.

The field of ergonomics complements the aspect of energy. The goal is to create safe, healthy and attractive working conditions. By using automation working in unsafe, unhealthy and unattractive conditions such as low seams can be avoided. If avoidance is not possible, the conditions in these areas should be improved.

In the field of energy efficiency the goal is to operate a “low-energy mine”. Therefore, the total energy consumption

should be minimized over the entire lifetime of the mine. Additionally, the use of modern and sustainable energy should be maximized. Processes should be planned, revised and optimized to gain low energy consumption. Gravity usage should always be maximized. Consequently, different alternatives and processes can be evaluated using Life Cycle Assessments.

Mines can also be seen as an energy supplier. On the one hand, they provide geothermal energy, due to a rise in temperature of 3 K/100 m (average in Germany). On the other hand underground coal seams can be used as unconventional methane deposits. Investigations have been conducted on several deposits in western Germany, which are used for energy transformation (Minke and Langefeld 2016).

The third aspect of energy in Blue Mining considers the usage of mines for storing and distributing energy. Active and abandoned mines can be constructed as underground pump storage plants. They can store energy by pumping water to higher elevations during times of lower demand and they can supply energy during times of higher demand. With a low land use compared to other approaches of pump storage, the power grid is stabilized and sustainable energy such as wind and solar power can become more reliable and stable.

The upgraded mine planning in the framework of Blue Mining combines the above-mentioned aspects. The approach is structured in three stages, as shown in Figure 3

Figure 3. Concept stages of the approach.

First of all, opportunities are identified and evaluated, followed by synergies and conflicts of the planned mining activity and the selected opportunities. In the third stage solutions get elaborated, which maximize the synergies and minimize the conflicts.

The first stage focuses on the investigation on opportunities of energy sources or storage. Sources can be:

- Mine water,
- Geothermal energy,
- Mine gas,
- Wind power,
- Solar power,
- Biomass,
- Possible process heat consumption.

The storage of energy can be realized by

- Pump storage,
- Compressed air storage.

For the selection of the possible opportunities it is necessary to determine all the suitable ways of such usage. The characteristics of the project and the spatial environment must be compared with the technological requirements. For example, such requirements include enough sun hours for solar power, restructured areas to grow biomass, suitable coal deposits for methane production, etc. After determining the options which reduce the number of possibilities, the demand for energy must be determined. The determination should be structured into two temporal sections, which are the mining and the post-mining periods.

As noted by Soerensen and Hillig (2016) during the mining period the usage and storage of renewable energy leads to a decreased dependence to diesel or heavy fuel oil, which is typically transported to isolated mines, for electricity generation. A lower dependency leads also to a decrease of dependency on energy prices. Considering the high energy consumption of mining operations, this becomes even more important. Also mines with a connection to the energy grid benefit from the higher stability of the energy supply, which can be just realized if a storage technology is available and installed.

The demand in the post-mining period is more uncertain due to the lack of a forecast. In case the mine is located in populated areas, the existing industry and community can later use the system. In less populated areas, where mining results in settlement of people and perhaps industry, which are both directly linked to the mining, different scenarios can occur: For example, the population can decline and settlement may be abandoned after closure. In this case the planned system can be used only during the period of mining. On the other hand, a post-mining community, which can utilize the conditions and perhaps the advantages stemming from mining activities, can get established. In this case the energy system can support the community and can be an important pillar for a sustainable community. This is also requested in the 11th Sustainable Development Goal by the United Nations (United Nations General Assembly 2015).

The first step in this approach is completed by a selection of suitable components, which complement mining to make energy usage more sustainable. The forecasted energy demand should be studied in conjunction with the spatial parameters of the project and the area.

The second stage brings together the mining project itself and the chosen opportunities by the identification of synergies and conflicts. Synergies describe facilities and openings which can be used for both purposes. Conflicts mark areas where competing interests are present. As a result, the level of detail can be increased in different planning stages. Conflicts and synergies form the basis for the following step.

The third step focuses at first on the development of solutions. In these solutions, identified synergies should be maximized, while conflicts should be minimized. Implementing such solution may require to modify the design of project facilities. An example is to design them for a

longer service life e.g. by a more robust reinforcement. The developed solution is subsequently integrated in the planning process. If there are several options they should be compared by appropriate indicators, for example using a Life Cycle Analysis.

The basis of decision and solutions are engineering skills and techniques as well as experiences in planned, active or completed projects. In the following section four projects are presented to show the influence of a good early planning to the long-term success of projects.

Beck and Schmidt (2011) investigated the storage of energy from wind by the subsequent usage of abandoned mines. The goal of the project was to evaluate the option of using those mines as a decentralized storage facility and to identify suitable regions and mines. The project, conducted by a diverse project team, considered geomechanics, mine surveying, mining aspects as well as the fields of mechanical and energy system engineering and economical, ecological and legal aspects. Concepts for two identified locations were developed and showed that a variety of measures must be undertaken to use the abandoned mines for such projects. In many fields it becomes obvious that design and realization would be easier if the usage was considered at an earlier stage.

To compare different approaches of energetic subsequent usage of hard-coal mines, Minke and Langefeld (2016) collected data for a number of projects which use the energy content of the mine water. A number of projects belong to this category. The energy content of the warm mine water is utilized by a heat exchanger and afterwards used in a local heating network. Due to the “low” temperature differences the energy recovered by this method can be used only for heating. The authors mark three points which must be ensured for an overall system: (a) a system with an economic and ecologic positive impact, (b) acceptance of user and provider based on trust, and (c) a collateralization in the case of an outfall. The important point for the Blue Mining approach is that systems based on opportunity and demand must be established to maximize the positive impact on Sustainable Development on mining operations.

An example for the usage of biomass can be shown at the former hard coal mine Hugo, located in Gelsenkirchen-Buer, Germany. An area of 220,000 m² was restructured in the stage of rehabilitation of the so-called “Biomassepark Hugo”. In this park, which opened in June 2016, wood energy crops such as meadows and poplar are planted, which are harvested after a certain amount of time and processed into woodchips. Alongside with their future use as an energy source, the plants convert carbon dioxide, which has a positive impact on the carbon footprint. Furthermore, the area is used for children and adult outdoor activities in the field of environment education. The project supports the approach of “renaturation as strategy for a sustainable urban development”. An advantage is the flexibility of the project, which allows for another subsequent usage if necessary. The concept with various elements is shown in Figure 4. The hoist frame is still present in area. A main area marked with number 1 is reserved for the plantation. In between a “landscape lab” (marked with number 7) for schools and kindergartens is installed, where children learn how to grow plants and

harvest them. The area is crossed by several ways for walkers and cyclists, which fosters the recreational character of the area (RAG Montan Immobilien 2016, Noll 2010).

Figure 4: Concept of the "Biomassepark Hugo" (RAG Montan Immobilien 2016)

The sun is used as an energy source in different photovoltaics (PV) projects. At different closed hard-coal mines PV-cells were installed on the top of coal blending plants. Examples are the Auguste Victoria Mine in Marl, Germany and the Lohberg Mine in Dinslaken, Germany. The building hosting the plants has a large roof area, which can house a large number of cells. At the Lohberg Mine the roof with an area of 11,500 m² was totally restructured and covered with 6,840 solar modules. The annual output is determined as 1518 MWh (montanSOLAR 2016).

The usage of roofs of processing plants, such as coal blending plants, for solar power adds value to the mining operation. If the planning is aligned in an early stage, buildings which should be covered with PV-cells can be located in a position and orientation to maximize the output. Furthermore, the construction and design of roofs can be adapted to accommodate such a use.

4. Perspectives

The presented concept shows a structured approach to integrate the fostered usage of modern, sustainable, reliable and clean energy into a mining project by upgrading of the planning as well as by different implementations of alternative energy sources. The earlier these opportunities are considered, the better the probability to implement them. The main ground for this is the avoidance of conflicts and the use of synergies at an early stage of planning.

The approach contributes to a sustainable development in mining focusing on the 7th and 11th Goals for Sustainable Development defined by the United Nations.

Forecasts are a way to plan for the future. The technology of the day after tomorrow will be invented tomorrow. The responsibility towards the future generations should be balanced against this uncertainty. For this reason, approaches should always maximize the flexibility of the upcoming generations, which can be realized by choosing more optimistic and less conservative approaches. In planning for Sustainable Mining this should always be a main principle.

5. Summary

The current paper shows the advantage and need to combine mining and the use of renewable or alternative energy sources during mining operations as well during the post mining stage. It represents a possibility to make mining more sustainable by utilizing the opportunities which are presented by mining itself. Blue Mining focuses on the key aspect of energy to foster Sustainable Development. To this end, it provides an approach to integrate modern energy into the task of mine planning. Identified opportunities are investigated on synergies and conflicts with the mining operation, so that solutions which add value to the operation can be developed.

References

- Beck, H.P. and M. Schmidt, 2011. Windenergiespeicherung durch Nachnutzung stillgelegter Bergwerke: Abschlussbericht. Univ.-Bibliothek Clausthal, Technische Informationsbibliothek u. Universitätsbibliothek, Clausthal-Zellerfeld, Hannover.
- Brundtland, G.H., 1991. Our common future (13. impr). Oxford University Press, Oxford.
- Federal Ministry for Economic Affairs and Energy, 2015. Share of renewables in gross electricity consumption until 2014 and target corridor until 2025. Federal Ministry for Economic Affairs and Energy. <https://www.bmwi.de/Redaktion/EN/Infografiken/Alt/geplanter-zubau-erneuerbarer-energien.html>.
- Jessup Bingham, E.L., 2011. Closure planning. In P. Darling (ed.), SME mining engineering handbook, 3rd Ed. pp: 1753 - 1764. Englewood, Col.: SME - Soc. for Mining Metallurgy and Exploration.
- Langefeld, O. and M. Kellner, 2013. "Blue Mining" - The future of mining. In 6th International Conference on Sustainable Development.
- Minke, A. and O. Langefeld, 2016. Möglichkeiten und Perspektiven der energetischen nachfolgenutzung von steinkohlen-bergwerksstandorten: Ein beitrag zur energiewende in nordrhein-westfalen (1. auflage). Wissenschaftliche reihe / TU Clausthal, Institut für Bergbau: vol. 27. Clausthal-Zellerfeld: Papierflieger Verlag GMBH.
- MontanSOLAR, 2016. Photovoltaik-dachanlage auf kohlenmischhalle im kreativ.Quartier lohberg EEG-konform fertiggestellt: Photovoltaik-dachanlage auf kohlenmischhalle im kreativ.Quartier Lohberg EEG-konform fertiggestellt. [http://www.montansolar.de/?id=86&tx_ttnews\[tt_news\]=4908&ajaxSite=1](http://www.montansolar.de/?id=86&tx_ttnews[tt_news]=4908&ajaxSite=1).
- Noll, H.P., 2010. Mit landschaft stadt machen - der biomassepark hugo. Glückauf, 146(10): 466 - 470.
- RAG Montan Immobilien, 2016. Biomassepark hugo - RAG montan immobilien. <http://www.rag-montan-immobilien.de/referenzprojekte/umwelt/biomassepark-hugo/>.
- Sassoon, M., 1996. Closure or abandonment. Mining Magazine, pp: 96 - 100.
- Soerensen, A.M. and T. Hillig, 2016. Requirements related to renewable energy solutions for the mining sector. Mining Report, 152(6): 497 - 503.
- United Nations General Assembly, 2015. Transforming our world: The 2030 agenda for sustainable development. United Nations. <http://undocs.org/A/70/L.1>.