RENEWABLE ENERGY (RE) FOR THE MINING INDUSTRY: CASE STUDIES, TRENDS AND DEVELOPMENTS, AND BUSINESS MODELS

Kateryna Zharan

TU Bergakademie Freiberg, Schlossplatz 1, 09599 Freiberg, Germany, +49 15902 428125., eszharan@gmail.com

Abstract: Taking into account statistic of development of RE in the European Union, it is clear that RE has strong priority for government and society. The European Union concentrates on increasing the capacity of RE generation and consumption. It is reflected in the Directive on the promotion of the use of energy from Renewable Energy Sources. The specific objective of this paper is to explore contributions to the implementation of RE sources to the mining industry.

The analysis is conducted across two main categories: On the one hand, the case studies for implementation of RE into the mining industry of some of the major mining countries such as Australia, Canada, and South Africa are considered. The main criteria for a business model for the European mines are given. On the other hand, the authors emphasize the technological and economic possibilities and constrains for elaboration of hybrid energy system and the way how RE could be implemented for mining.

The focus is based on the comparative analysis of mining hybrid energy operation systems in Australia, Canada, and South Africa. The analyses proves that there are technological and economic perspectives for development of hybrid energy systems for penetration RE into the mining operational process. Consequently, the main findings concern the peculiarities of RE implementation for European mining companies. Moreover, the benefits for penetration of RE into mining are defined.

Keywords: Renewable Energy Sources, Fossil Energy, Hybrid Energy System, Implementation of RE

1 Introduction

The main issue of this paper on the penetration of RE into the mining industry has been raised in different studies. This issue attracts attention from both scientific experts and industrial decision-makers. Mining and metal processing are very energy-intensive processes. Moreover, costs for traditional energy sources increase year by year, European mining companies are looking for new solutions for the substitution of fossil energy sources for renewables. The key point is that the costs of RE generation, grid connection and RE integration system and software for implementation to the mining sector deployment are equivalent to those fossil energy sources. However, the implementation of RE for mining needs still has a lot of constraints in European countries.

The European Union has increasing tendencies for development of RE. It confirms by RE development data and the National Action Plan until 2020 by 20%, 2040 by 40%, and 2050 by 80%. Taking in consideration Germany sample, the share of renewables in final energy consumption has risen steadily in the past decade to a current 12%. In the production of electricity of regenerative share of over 20% is already relatively high. Nevertheless, the electricity is still responsible for more than 40% of Germany's total CO2 emissions today. Therefore decarbonizing the electricity sector for climate protection reasons has important significance.

On the one hand, the mining industry is going to be less attractive in the modern society, who changes of the industrial priorities in favor of sustainable companies. Therefore, mining companies is searching of more sustainable way of production, and fulfill reorientation for RE. On the other hand, the RE becomes economically attractive year by year, thus motivating miners penetrate of RE instead of fossil one.

1.1 Objectives and research questions

Energy is the main component in the mining industry. On the accounting for 20 to 40 percent of energy expenses in mine’s operational process the reliability, secure, and costs of energy is the major indicators for a mining company. RE can help economically to meet the mining power needs by means of reducing the consumption of fossil fuels and carbon emissions. In this paper the following research questions have been formulated:

(1) What are the case studies for penetration of RE into the mining industry in the some of the major mining countries as Australia, Canada, and South Africa?

(2) What are the technological possibilities for implementation of RE into the mining industry in the European Union?

The overall goal for the European Union is to intensify the development of renewable energy and bring it into the main energy consuming industry.

The main goals for mining companies are:

- to get an economically attractive resource of energy for high daily level of energy consumption,
- to avoid resource intermittency in energy consumption,
- to evaluate technological possibilities for RE implementation by means of comparative analyses of the case studies from some of the major mining countries.

The objective of this paper is to assess the economic and technical feasibility of deploying renewable energy sources at the mining companies. The case studies from the major mining countries are considered in an attempt to identify potential further development of the business model for Germany mines by means of world experience usage.

There are potential benefits of implementation of RE in mining:

- Reduction in fuel and electricity costs, including transportation costs;
- A secure and reliable energy system for the private sector;
- Reduced risk of power loss from supply disruptions;
- Enhanced economic competitiveness for the sector;
- Predictable energy costs, and therefore reduced risk from volatile and rising diesel prices;
- Reduction in carbon emissions and overall a less-polluting source of energy for the region;
- Opportunities to repurpose land used by the mining community;
- Growth in domestic renewable energy market;
- Opportunities for cooperation with neighboring industries.

2 Case studies

As we can see in Table. 2, the share of energy from renewable sources in ten most important mining countries increases by 2013 and tends to grow according to Target 2020. Thus, we can make an assumption that a RE growing capacity could be redistribute to mining energy needs.

Next step we consider the major mining countries around the world.

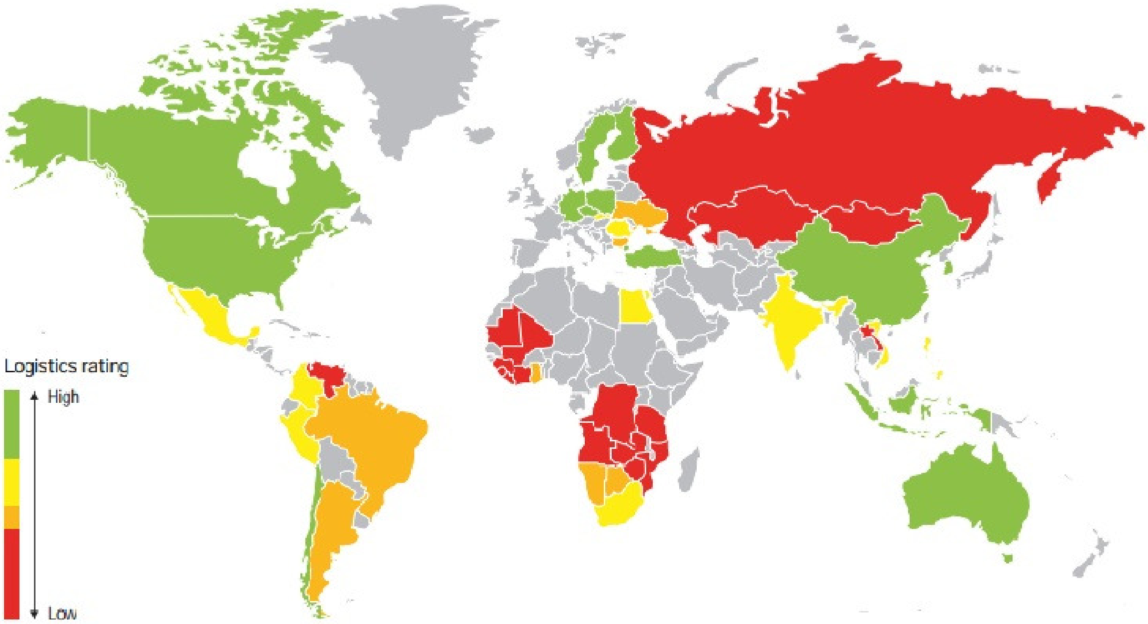

Fig. 1. BMI logistics ratings: Major mining countries [5]

According to Fig. 1 the major mining countries are Australia, Canada, and South Africa. In this paper we will concentrate on the case studies of these countries. The data about the technology of the RE-diesel hybrid system, peak output capacity, energy storage system, costs and energy saving after implementation, payback period, and pollution avoided will be used for the analysis.

Before developing the business model for implementation RE In the mining in Germany, we will consider the existing world experience in the major mining countries. First, the technological part of RE integration shows the main questions that the mining company should concentrate on. Second, the production value from RE will demonstrate the optimal level of conversional energy substitution. Finally, the main benefits from implementation RE into the mining will be reduction of CO2 emission during the mine operation activity, and decrease of energy costs in future.

2.1 Australian case studies

Rio Tinto and the Australian Renewable Energy Agency (ARENA) have announced the Weipa Solar Plant will generate electricity for the mining conglomerate's bauxite mine, facilities, processing and the township. At peak output, the 1.7 MW plant can generate sufficient electricity to support up to 20 % of the town's daytime electricity demand. ARENA invested an initial $ 3.5 mill. for the project and up to $ 7.8 mill. is provided for the second phase. The RE was expected to help reduce diesel usage at the mine's power station by up to 600,000 L a year. This will dicrease mine's greenhouse emission by around 1600 t/a, equivalent to removing around 700 cars [1].

The ARENA reported that module installation had started at Australia's largest renewables mining project. By the end, Sandfire Resources DeGrussa Copper-Gold Mine in Western Australia will be equipped with a 10.6 MW PV power plant to supply the mine's daily operations.

Single axis tracking will be deployed on the project that will use 34,080 solar PV modules. The Juiwi Group is working on the project that will offset approximately 5 million liters of diesel fuel annually. ARENA is providing AU$20.9 million (US$15.25 million) investments for the AU$40 million (US$29.2 million) project [6].

2.2 Canadian case studies

In Canada from 1999 to 2011, the annual costs for energy for mining processes more than doubled, costing Canadian miners $2.4 billion in 2012. This cost increase can mostly be explained by the lack of regional energy infrastructure, the remote location of many Canadian mines, and the dependence on diesel. From 1999 to 2013, the average price of oil increased tenfold, from about US$10 to more than US$100 per barrel. Increased transportation costs have also raised the price per unit of delivered fuel, pushing the generation cost for some remote mines up to $0.30 per kWh [2].

In the environment of heightened cost of power for mining operations, miners are started to pay more attention for renewable technologies. The levelized cost of electricity (LCOE) for solar photovoltaic, wind, solar power and some biomass technologies has steadily decreased, enhancing their competitiveness, particularly for off-grid generation. The International Renewable Energy Agency report [2] announced that the average LCOE for wind, solar, and biomass technologies in North America was $0.08, $0.16 and $0.08 per kWh, correspondingly.

Glencore had a test 3-MWt wind turbine installed at its Raglan Mine. The 3-MWt turbine is expected to offset diesel consumption by 5 %, or approximately 2.4 million liters per year. The goal of the project has significant savings of cost and emissions reduction. At Raglan Mine, energy normally accounts for about 20 % of total operating costs. If the wind turbine test proves successful, Glencore will supposed to install additional turbines that could generate a total of 9 to 12 MWh of energy, reducing the mine's overall diesel consumption by up to 40 %.

There is another example of implementation RE into the mining. The Powering a Remote Remediation Camp with Diesel and Renewables and Energy Storage projects [7] have been developed to maximize the fuel savings. All components, including battery chemistry, inverter technology, generator type and hybrid construction were considered. The customized hybrid system has been integrated into a single modular container, which accommodates a generator, a photovoltaic array, a battery, and an inverter system equipped with remote control and monitoring systems. Such design makes the hybrid system portable and rough, while allowing multiple systems to be stacked to achieve higher generation and storage capacities, as well as to increase reliability through redundancy.

Hybrid Microgrid Power System Features [7]: Peak output capacity: 69 kW; 60 kW diesel generator with 42 kW/259 kWh energy storage system; 20-foot modular container, climate controlled, remotely operated; Easily integrated into existing site infrastructure; A payback period of less than 12 months of operation; Providing approximately CAD$93,000 in savings during its first four months of operation.

The Diavik Diamond Mine is considered as another example of RE implementation in the mining industry. The company installed a wind farm consisting of four Enercon E70 wind turbines, with a total capacity of 9.2 MW, and an annual production of 17 GWh. This represents 8.5 % of the mine's power needs (Diavik Diamond Mines Inc., 2014 [3]).

The result of the case study of the Diavik Diamond Mine [8] indicates that, a PV installation is economically feasible if the primary load is in the range of about 3000–6000 kWh per day. The implementation of this technology can bring yearly savings of almost 50,000 L of diesel and supply approximately 9 % of total energy consumption. The installation of wind turbines for the extraction phase can essure even larger savings due to the high energy demands of the processing plant. A wind farm deployment of 5–10 wind turbines can generate from 30 % to 40 % of the total plant's power demand, saving from 25 to 35 million liters of diesel annually.

2.3 South African case studies

South Africa has abundant sources of minerals. The mining industry is highly developed in that part of Africa together with renewable energy. Therefore, we can consider the case study for implementation RE into the mining. There are two types of hybrid integration technology such as solar-diesel integration and wind-diesel.

1.4.1 Solar–Diesel Integration

Table 2. Business model for implementation RE into the mining [4]

Business Model	**Project Development Options**

Self-generation	A mining firm develops, finances, and operates a PV plant on their own land, or potentially through a subcontracts with an external PV constructors
	Alternatively, a mining firm leases their land to an independent company, how will oversee one or more aspects of development, financing, and operation of the plant.
Industrial Pooling	A consortium of industrial firms enters into a long-term Power Purchase Agreement (PPA) with a shared distributed generation plant
Net Metering	A grid-connected mine develops, finances, and operates a PV plant on their industry's own land. The utility running the grid purchases the excess capacity generated by renewable plant.
Self-generation + Power Townships	A mining firm develops, finances, and operates a PV plant on their own land, or potentially through a subcontracts with an external PV constructors. A nearby community, close enough to be connected with the PV plant, applies for government support to run a transition line.

The business models, presented in the Table 2, demonstrate different types of operational models for implementation RE into the mining. In accordance with a project development, a mining company chooses an appropriate model corresponding to their location, geological conditions, and infrastructure availability.

The Fig. 2 shows the business model of implementation RE into the mining for the Eskom company in South Africa. The Fig.2 consists of five operational cycles – electricity generation, transmission, trading and wholesale, distribution to final users as well as supply to final users.

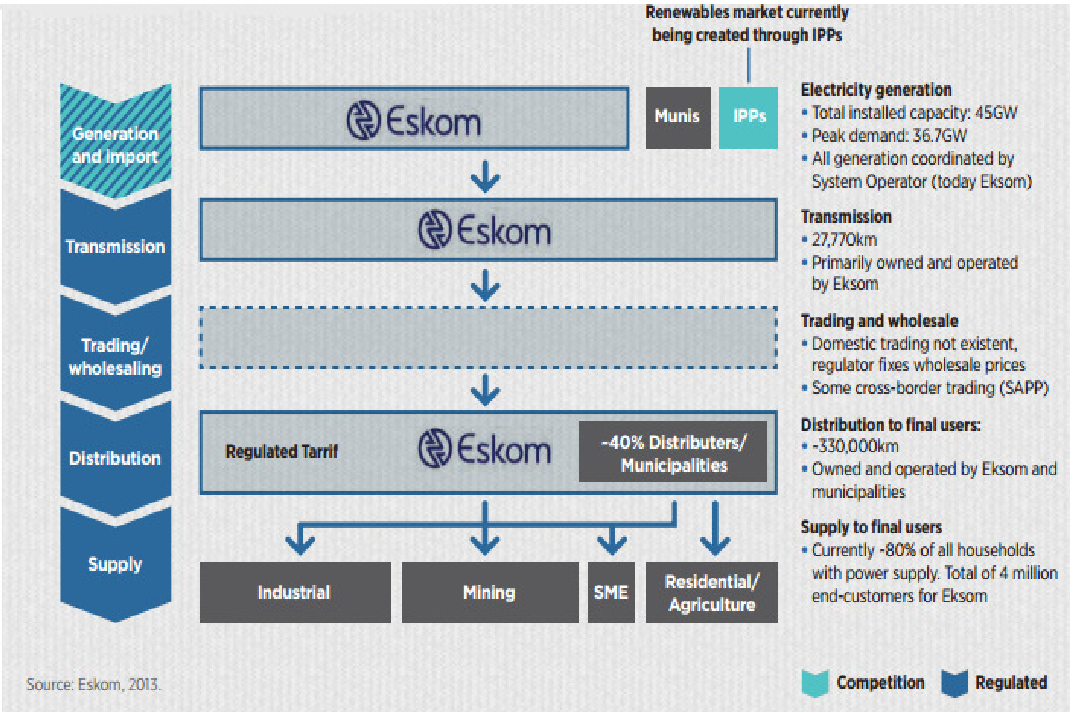

Fig. 2. Business model for implementation RE into the mining [4]

There are technical options for using distributed renewables to power off-grid mines as following:

• Renewables + Storage: Energy generation only from renewable sources, with sufficient storage capacity to provide of reliable power 24 hours a day.

• Hybrid Systems: Advanced “fuel-save” modules connect solar or wind assets with diesel generators, preventing load loss and optimizing use of renewable resources.

• Hybrid Systems + Storage: The addition of various forms of storage capacity to hybrid micro-grids, further maximizing use of the renewable resources in the system.

In South Africa today, solar-diesel hybrid systems are the most cost-effective means of generating electricity for off-grid mines. However, Cronimet is currently examining adding energy storage components to their system in order to further maximize their use of solar resources.

1.4.2 Wind–Diesel Integration

There is another case study for RE penetration into the mining. The SNIM Company (Société Nationale Industrielle et Minieres) [4] operates iron ore mines in Zouerate, region of Tiris in Mauritania. More than 12 Mt of ore per year is transported by train from the mines to Nouadhibou harbour to be loaded and exported by boat. SNIM is the 2nd largest producer of iron-ore in Africa employing about 10,000 people .In order to reduce the carbon footprint and energy production costs, SNIM issued an EPC tender in 2010 for the construction of a 5 MW state-of-the-art wind farm in Nouadhibou. The existing grid was powered by a 16 MW diesel plant equipped with 4 diesel gensets, feeding a 5.5 kV grid. The energy is used to power motors for the ore conveyors and crushers (with more than 20 loads ranging from 200KW-600KW)].

The figures: Wind farm output: 19 GW h/year; Fuel savings: 4800 t/year; Pollution avoided (C O2, N Ox, SO2): 11 500 t/year.

This case study is real example of wind-diesel hybrid energy system. The data of practical implementation of equipment by Vergnet Group shows the successful operation of the system and leading to large fuel saving with maximum wind penetration.

3 Technological possibilities of RE implementation into the mining

The infrastructure requirements of miners, and thus the focus of this plan, include: transport and logistics links comprising ports and associated land transport such as road, rail and slurry pipelines; installations to collect, treat and, if necessary, transport water to mine sites; installations to produce energy and connect it to mine sites. The Table 1 demonstrates the infrastructure needs for mining.

The subsidiary company of MIBRAG, Neue Energie Inc., operates the wind farm "Am Geyersberg" near the mine layers Weitramsdorf / Hohendorf (district of Leipzig). Since 2010, the green electricity fed into the grid. The total output of the 3 wind turbines is 6.9 MWt.

Table 3. Description of the two open-pit mine in the district of Leipzig

	Name of mine, location	Description
1	PROFEN,	Crude ash 7 to 11 percent

	Saxony-Anhalt (Burgenlandkreis) Saxony (district of Leipzig) White Elster basin	Coal production up to 9 million tons per year Overburden power 35 to 40 million cubic meters per year Water elevation 45 to 50 million cubic meters per year
2	VEREINIGTES SCHLEENHAIN, Free State of Saxony (district of Leipzig) White Elster basin	Coal production approximately 11 million tons per year Overburden 30 to 38 million cubic meters per year Water elevation 35 to 40 million cubic meters per year

For the future research, we will evaluate possibility for integration of wind and solar energy into the German mining companies. The Table 3 shows the two open-pit mines, which will be considered for creation of business model.

There is the question, how much electricity can be substituted from fossil for wind and solar in a German mine?

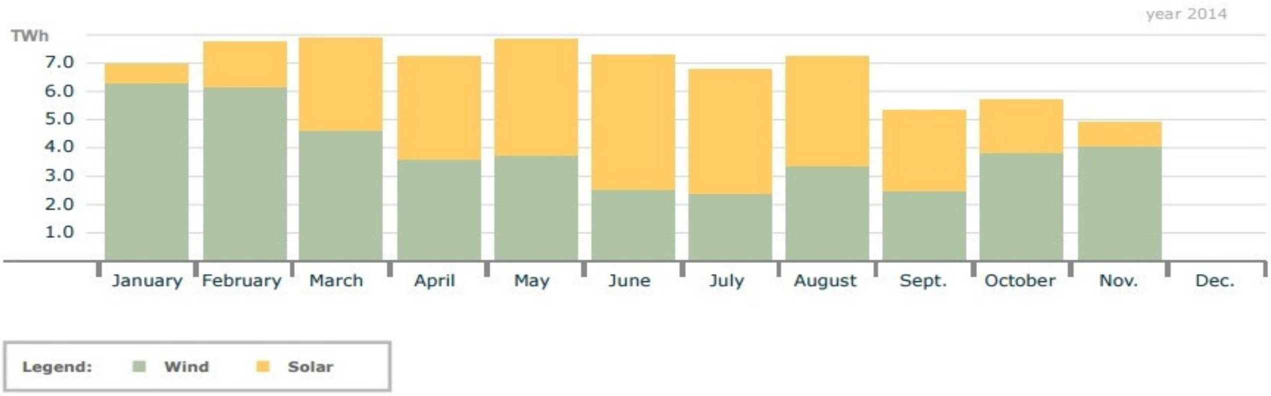

Fig 3. Monthly production solar and wind [9]

The subsidiary MIBRAG Neue Energie GmbH operates the wind farm "Am Geyersberg" near the mine layers Weitramsdorf / Hohendorf (district Leipzig). Since 2010, this green electricity fed into the grid. The total output of the wind turbines is 6.9 megawatts. With the establishment of the first three wind turbines MIBRAG provides a further proof that future-oriented, sustainable economy is a fundamental maxim of the company.

There is the technological possibilities for implementation of wind and solar hybrid system into the mining industry. For instance, the truck conveyors can work by means of usage of usage of wind or solar energy.

One of the primary barriers to renewable energy development, especially wind and solar power, is justifying the significant capital costs associated with their construction. Although renewable energy economics are largely constrained by fixed geographic factors (i.e. wind conditions, in the case of wind energy), additional siting factors may significantly ameliorate the financial feasibility of individual projects.

4 Conclusions

The implementation of RE into the European mining industry has several challenges. On the one hand, the mining industry operates very energy-intensive processes which require a reliable energy source. On the other hand, new RE technologies are intensively spreading though Europe and make RE economically competitive and attractive for the mining industry.

The main results of this study can be summarized as follows:

(1) According to comparative analysis of the case studies from Canada, Australia, and South Africa the main benefits of implementation RE in the mining are:

For Australia

- output capacity the 1.7 MW/day, plant can generate sufficient electricity to support up to 20% of the town's daytime electricity demand,
- diesel saving by up to 600,000 L/year,
- greenhouse emission by around 1600 t/a, equivalent to removing around 700 cars

For Canada

- output capacity 3 MW h/day,
- diesel saving by 5%, or approximately 2.4 million L/year,
- saving approximately 20% of total operating costs,

For South Africa

- output capacity 19 GW h/year,
- diesel saving 4800 t/year and costs saving 207011,6 USD/ year,
- payback period of project can be 12-24 months,
- pollution avoided (C O2, N Ox, SO2): 11 500 t/year.

(2) There is a necessity to make a comparative analysis of technological opportunity before developing business model for penetration RE into the mining. The economic efficiency from wind-diesel and solar-diesel hybrid system is demonstrated.

The future research will be consistent with the following issues:

- development of a questionnaire for mining and renewable experts in order to find a key point about possibilities, economic efficiency, perspectives, model of implementation of RE in the mining industry;
- usage of dynamic linear and non-linear panel data analysis for evaluation the data from experts to find out correlation and to calculate of prognoses for future;
- find out the government incentives for the deployment of RE technologies in Germany

5 References

1. Rio Tinto-ARENA's new Solar Plant for Weipa mine starts operation (2015). World of Mining – Surface & Underground 67 (2015) No. 5. – p. 295.
2. Marshall B., (2014). Facts & Figures of the Canadian mining industry. The Mining Association of Canada. p. 61.
3. Diavik Diamond Mines Inc. (2014). Diavik Diamond Mine: 2013 Socio Economic Monitoring Agreement Report.
4. Crespo P. (2015). Wind hybrid project for SNIM iron ore mine in Mauritania. Energy and mines. http://energyandmines.com/2015/11/wind-hybrid-project-for-snim-iron-ore-mine-in-mauritania/
5. Business risks facing mining and metals 2014–2015. http://www.ey.com/Publication/vwLUAssets/EY-Business-risks-facing-mining-and-metals-2014%E2%80%932015/$FILE/EY-Business-risks-facing-mining-and-metals-2014%E2%80%932015.pdf
6. Gifford J. (2015). Investors moving on offgrid PV, mining leading the way. PV magazine. http://www.pv-magazine.com/news/details/beitrag/investors-moving-on-offgrid-pv--mining-leading-the-way_100022295/#ixzz3tQvQESdE
7. Jansen R., Rohraff D. (2015). Case Study: Powering a Remote Remediation Camp with Diesel, Renewables and Energy Storage. Energy and Mines. http://energyandmines.com/2015/10/case-study-powering-a-remote-remediation-camp-with-diesel-renewables-and-energy-storage/
8. M.A. Escalante Soberanis, A. Alnaggar, W. Merʹrida., (2015). The economic feasibility of renewable energy for off-grid mining deployment. The Extractive Industries and Society. 509–518
9. Burger B., (2014). Electricity production from solar and wind in Germany in 2014. Fraunhofer ISE; data: EEX Transparency Platform