Justus-Liebig-University Gießen

Master's thesis to obtain the academic degree Master of Science (M.Sc.)

"Unfolding the potential of mining activities: Creating shared value by introducing decentralized renewable energy solutions"

By: Nils Robin Kuranel

Study Program: Transition Management

First Examiner: Prof. Dr. Martin Petrick

Second Examiner: Michael Schmidt

Date: January 26, 2022

Acknowledgements

I would like to express my sincere thanks to Prof. Martin Petrick for giving me the opportunity to work on a topic which I am passionate about, even if it may be a bit “off-grid” of the study-programs focus. The provided tips, hints and the valuable feedback were always very helpful to develop this thesis, especially for the methodology and analysis parts. Further, I would like to express my sincere thanks to Michael Schmidt, who always kept the “very long leash”, which provided me a lot of space to conduct this thesis. I am also very thankful for the various meetings we had to further develop this topic, even when time was limited, and the support in finding valuable interview partners and contact persons to gain information about this topic. I am very thankful for the understanding of both supervisors to give me the time I needed to ensure gaining a sufficient amount of valuable data.

As well, I would like to thank Andreas Schäfer and the UNIDO ITPO Germany team for always giving me support, keeping me updated and connecting me with interesting stakeholders.

Not to forget to express my sincere thanks to the interview partners and contact persons, who took their time to answer my questions, provide me with information and to make a great contribution to the empirical data, which made the writing of the thesis possible at all.

Last but not least, I would like to thank my family, girlfriend and my friends for the emotional support when timelines get very critical and for looking at the thesis with an always critical eye – this would not be possible without your contribution.

Statutory declaration

I herewith declare that I have composed the present thesis by myself and without use of any other than the cited sources and aids. Sentences or parts of sentences quoted literally are marked as such; other references with regard to the statement and scope are indicated by full details of the publications concerned. The thesis in the same or similar form has not been submitted to any examination body and has not been published. This thesis was not yet, even in part, used in another examination or as a course performance.

Place, Date: Gießen, 26.01.2022 **Sign** R. Lu

Abstract

The global mining sector, as well as many communities in developing countries are having one challenge in common: access to reliable, affordable and clean energy. While mining companies around the world are seeking to improve reliability and sustainability of their power supply, over 700 million people are without access to electricity (2019). Decentralized Renewable Energies (DRE) provide a solution to solve several issues at once: bringing down the costs of electricity while improving reliability and sustainability. This thesis investigates how DRE solutions can be applied cost efficiently in the mining sector and how these solutions can be shared with communities located nearby the mine. To do so, a qualitative analysis containing 9 expert interviews was conducted. It could be shown that the highest hurdles for executing such projects are resulting from the regulatory framework and geography. Further hurdles which were detected are of economic, educational and technical nature, which however, can be overcome (depending on the circumstances) by taking certain measures. Stakeholder management and financing are further aspects which have to be managed properly. It turned out that DRE deployment is very effective for mining companies, while sharing the infrastructure creates various risks, which hampers the execution of such projects. Sharing DRE in mining is not directly profitable for mining companies in most cases. However, it is still recommended to engage in energy sharing projects, as it can be a very good measure to achieve multiple (indirect) benefits for each party, such as electrification, decarbonization and an improved relationship to communities. The success of sharing projects is however limited by the circumstances of the area and the country. In most cases, it is recommended to develop two separate grids which are powering the mine and the community respectively.

Keywords: Sustainable Mining, Renewable Energy, Creating Shared Value, Rural Electrification

Table of Contents

List of Figures and Tables

Abbreviations

CCSI – Columbia Center on Sustainable Investment

CO_2 – Carbon Dioxide

CSR – Corporate Social Responsibility

CSV – Creating Shared Value

DFI – Development Finance Institution

DRE – Decentralized Renewable Energy

GDP – Gross Domestic Product

GHG – Greenhouse Gas Emissions

GW – Gigawatts

ICT – Information and Communication Technology

IPP – Individual Power Producer

MW – Megawatts

OECD – Organisation for Economic Co-operation and Development

PnG – Papua New-Guinea

PPA – Power Purchase Agreement

PV – Photovoltaic

SDGs – Sustainable Development Goals

UNIDO – United Nations Industrial Development Organization

1. Introduction

In modern times, businesses, households and even whole economies rely on the extraction of minerals as a source for income and the provision of livelihoods. While the extractive industry provides the minerals necessary for the production of even basic goods, the mining sector is situated in a paradox: it suffers from a bad reputation in the public, since it is considered to be a controversial industry, causing heavy environmental damages and social issues in the areas of operation. Further, it is a contributor to climate change due to its massive use of fossil fuels or the need for clearing vegetation to execute its operations (UNDP and UN Environment, 2018, pp. 34-36). On the other hand, modern technologies such as renewable energies or electric vehicles, which play a key role in the decarbonization of economies, are much more mineral-intensive compared to conventional solutions which is why the mining sector is getting more and more important to supply the minerals needed (World Bank, 2017, pp. 26 and 58).

In the past, industrial countries such as Canada, Australia and the US were leading the global mining sector but over the years, the role of developing and emerging economies increased more and more. Nowadays it is the latter group of countries which accounts for more than half of the global mining output (UNIDO, 2016, p. 11). Key-minerals such as copper, cobalt or gold are sourced on a large scale from developing countries, which are highly dependent on the mining sector due to a lack of diversification. Such circumstances expose these countries to special risks because of their reliance on international commodity markets (Statista, 2021a; Statista, 2021b; World Gold Council, 2021a; Pegg, 2006, p. 378).

Power generation in mining regions remains a major challenge for the industry. As a sector consuming huge amounts of energy and requiring consistent and reliable supply 24 hours 7 days per week, mining operations are mainly powered by fossil fuels. Consequently, the sector emits massive amounts of CO_2 and therefore contributes on a large scale to climate change. According to Mckinsey (2020), the mining sector is responsible for 4 – 7 % of global GHG emissions. Depending on the area of operation (remotely situated or close to a city) and whether a reliable power source is available, mining companies are constrained to generate their own power to meet their tremendous demand. Coal, gas or diesel-powered solutions are widespread in this regard, especially diesel is a common solution in off-grid scenarios (CCSI, 2018, pp. 9-12). On the one hand, (off-grid) fossil energy sources are reliable and depending on the life of the mine may even be more cost-efficient than renewables. But on the other hand, they are drivers for climate change and contribute to the bad reputation of the mining sector (ibid. p. 13).

In recent years, a lot of efforts have been made by the mineral-extractive sector to become more sustainable and to implement environmentally friendly technologies, thus contributing to the Sustainable Development Goals (SDGs) (UNDP and UN Environment, 2018, p. 27). To lower its carbon footprint, the implementation of renewable energies in the mining sector is becoming increasingly common. While in 2015 the industry had a capacity of 600 MW of renewable energies installed for its operations, that number increased to 5 GW by the end of 2019 (incl. planned projects) (JISEA, 2020, p. 1). Especially in gold mining, there is a huge potential to decrease the carbon footprint, since 80% of the emissions arising from gold mining are directly related to power generation (World Gold Council, 2021b).

Access to clean and reliable energy remains a crucial problem in developing countries, as there were 759 million people without electricity in 2019 (World Bank, 2021). By applying Decentralized Renewable Energy (DRE) innovations on mining sites, companies are not only having the chance to lower their carbon footprint but to build up a sustainable power-infrastructure from which local communities and developing countries as a whole can benefit (CCSI, 2018, p. 15). This may improve the reputation of mining activities and could even be considered as a competitive advantage, since responsible and low-carbon mined minerals are increasingly demanded (Deloitte, 2017, p. 14). Thus, using DRE solutions for the development of power-infrastructure provide a great opportunity to reach SDGs no. 7 (Affordable and Clean Energy) and no. 9 (Industry, Innovation and Infrastructure).

Though, the execution of energy sharing projects is very complex and has to be evaluated for each case individually. Depending on the mineral, the area and whether sufficient infrastructure already exists, different scenarios have to be considered (CCSI, 2014a, pp. 35-51). This thesis evaluates the potential of DRE innovations and investigates how these solutions can be applied cost efficiently and beneficial for communities living around mining areas. To answer the research question "How can decentralized renewable energy solutions be applied in the mining sector and create shared value?" a literature review about the Concept of Shared Value (CSV); the social, economic and environmental role of mining; and power generation in the sector is conducted. Secondly, case studies are presented to provide examples of successful implementation. The main methodology is a qualitative analysis, which investigates barriers, benefits, risks, financing options and stakeholder management approaches with regards to the installation of renewable energies in mining and community electrification. 9 experts from 4 different groups (energy providers, mining companies, governments and development banks) are interviewed to get a multi-stakeholder view. The results are eventually discussed to provide an answer to the main research question.

2. Theoretical Framework and Literature Review

2.1 The Concept of Creating Shared Value

The concept of Creating Shared Value was first introduced by Porter and Kramer, published in the Harvard Business Review in 2011. According to the authors, modern business is trapped in a vicious cycle: For decades, companies were solely evaluated in financial terms which led to a strong focus on making short-term profits (p. 6). This approach in turn caused several environmental and social issues, such as massive resource exploitation or social inequalities. Policy leaders all around the world tried to mitigate those effects by implementing policies and regulations, aimed at private businesses, which in many cases bring about an undermining of competitiveness (ibid.). As such regulations impact the effectiveness of businesses, the authors describe that there is a more efficient way to solve the problem: Businesses should actively engage and close the gap between society and economy by implementing their own actions (ibid.). The idea is to connect the success of businesses with social progress by taking the opportunity to make profits out of social challenges. As an example, a mining company who is providing clean electricity to a local grid, could not only benefit from an improved reputation but also increase profits through the earnings coming from selling power. In the concept of shared value, tackling social and environmental problems are viewed as opportunities for companies to continue making profits, while neglecting to tackle such issues are considered as risks (FSG, 2022).

Porter and Kramer define the term Shared Value as the following:

"The concept of shared value can be defined as policies and operating practices that enhance the competitiveness of a company while simultaneously advancing the economic and social conditions in the communities in which it operates. Shared value creation focuses on identifying and expanding the connections between societal and economic progress. The concept rests on the premise that both economic and social progress must be addressed using value principles. Value is defined as benefits relative to costs, not just benefits alone. Value creation is an idea that has long been recognized in business, where profit is revenues earned from customers minus the costs incurred…" (Porter and Kramer, 2011, p. 6).

The mining industry is well-positioned to apply this approach, because the sector is already well-known for adopting "Corporate Social Responsibility" (CSR) measures very actively (Smith, 2017, p. 119). There is no definition of the term CSR, which allows industries to interpret the term broadly (ibid.). Porter and Kramer, however, state that CSR is developed mainly due to external pressure and is considered as costs for the company (Porter and Kramer, 2011, p. 6). This is one of the main differences between CSR and CSV, as CSV measures are not considered as costs, but to add profits to a company (ibid., p. 16). Further, CSR measures are widely criticized. Devenin (2018) provides three aspects which are underlining the insufficient nature of CSR projects: Firstly, companies are only open for discussions as long as the fundamental tenets of their business are not endangered. Secondly, the measures are often implemented from a company's point of view without involvement of the community. Thirdly, the contribution to sustainable development seems to be low (p. 1).

According to Porter and Kramer (2011), there are further differences between the approach of CSR and creating shared value. While CSR is mainly focusing on measures which are not at the core of business for many companies and rather improve the company's reputation, CSV aims to improve a company's profitability and competitiveness while empowering society. The following table, based on Porter and Kramer, describes the differences between CSR and CSV.

Table 1: Difference between CSR and CSV (Porter and Kramer, 2011)

CSR	CSV
Value: doing good	Value: economic and societal benefits relative to cost
Citizenship, philanthropy, sustainability	Joint company and community value creation
Discretionary or in response to external pressure	Integral to competing
Separate from profit maximization	Integral to profit maximization
Agenda is determined by eternal reporting and personal preferences	Agenda is company specific and internally generated
Impact limited by corporate footprint and CSR budget	Realigns the entire company budget
Example: Fair trade purchasing	Example: Transforming procurement to increase quality and yield

Another difference stressed by von Liel (2016), is the measurement process. CSR projects are either not measured according to their success, or only in terms of social value. CSV projects in contrast, are measured according to the social and the economic performance, which is why there has to be a change in the evaluation process of companies. This is considered to be one of the greatest hurdles in conducting CSV measures (p. 37).

There are also critical voices with regards to CSV. Smith (2017) provides examples of CSV projects, where the difference to CSR measures is not always clear (p. 129-130). Further, the author describes that there is not always a win-win situation, in which social challenges also represent an opportunity for companies to make profits (ibid., p. 131). De los Reyes (2017) adds that certain situations are left unsolved by the concept of CSV, which pose a threat to companies (p. 4). Thus, CSR indeed has its raison d'être, especially where making profits out of social problems seem to be unlikely. Crane et al. (2014) are supporting these statements and adding that both terms are indeed very similar in their nature, but Porter and Kramer would “caricature the CSR literature to suit their own ends and simply rehash the existing stakeholder and social innovation literatures without due acknowledgement” (p. 6).

Mining activities require developed and reliable infrastructure to operate properly and cost efficiently. Every interruption during the mining process (e.g., coming from power outages) has a negative effect on profits. According to findings in literature, the most crucial infrastructure elements for mining companies are access to water, a reliable energy source, transport facilities such as roads and in many contexts also export infrastructure like ports or railways. Additionally, information and communication technology (ICT) is required e.g., for offices which are built on site, monitoring systems, or for staff living in the area. This is also described by CCSI (2014) in its paper "A Framework to Approach Shared Use of Mining-Related Infrastructure". As infrastructure development is generally well-suited to create social benefits (ibid., pp. 4-5), these four elements (water, energy, transport and ICT) provide huge opportunities for mining companies to apply the concept of shared value. Especially in developing countries with limited infrastructure facilities, the infrastructure often has to be developed. Engaging with the government and affected mining communities to build such infrastructure can potentially create mutual benefits (Collier and Ireland, 2016, p. 65).

2.2 The Economic, Environmental and Social Role of the Mining Sector

2.2.1 Mining and National Economies

The use of natural resources for long-term and sustainable economic development is discussed very broadly in literature. Especially when it comes to the oil and gas sector, many (developing) countries are facing a strong dependency on this sector which leads to a dereliction of other sectors and results in a non-diverse economy. This may expose these countries to special risks since they heavily rely on international commodity markets and are susceptible to fluctuations. This constellation is in general described by the so-called "Resource Curse" or "Dutch Disease", which refers to the fact that many resource-rich countries are still among the poorest due to their reliance on natural resources and the neglect of other industry sectors (IMF, 2020). Poncela et al. (2016) define the term as following: *"Dutch disease is frequently understood as the de-industrialization process of an economy, which is associated with the real exchange rate appreciation, produced as a consequence of an export windfall due to a resource discovery or a raw material export boom"* (p. 778)

Nevertheless, there are voices stating that the mining sector has to be viewed differently (when mentioning the mining sector, extraction of oil and gas is not included). As an instance, Ericsson and Löf (2019) are stating that countries in Africa which are relying on mining were more successful regarding human development and governance (corruption, effectiveness, political stability, regulatory quality, rule of law and voice and accountability), than those relying on the oil and gas sector (measured time period: 1996-2016) (p. 240). Lodhia (2020) states that the mining sector could even be considered as a leader in sustainability practices, as the sector faced severe social and environmental challenges in the past, which led to the emergence of various initiatives towards sustainable development (p. 1). In contrast, Bird (2016) argues that the wealth resulting from mining activities is not distributed equally, especially in developing countries. People who are directly involved in the mining activity (mostly the mining company itself) as well as the government and administration are benefiting the most from the extractive industry. The author adds that in some cases communities nearby also benefit from the mining activity, which depends on the involvement of the community (p. 631).

Chile is a prominent example of setting up a strong mining industry which contributed greatly to the development of the country – even if Chile had to overcome many challenges to let the whole country take advantage of the mining sector (Ghorbani and Kuan, 2016, p. 23). Chile even became a member of the OECD (Organisation for Economic Co-operation and Development), which underlines its economic success. Many countries which are today considered to be among the most developed ones, relied in the past on mining activities for their economic development. The instances of Canada, USA, Australia or Germany are just a few to mention. Those countries (except for Germany which neglected the mining sector more and more and today is focusing on the manufacturing of goods) are still among the most important mining countries. On the other hand, the relative role of emerging markets increased over time and nowadays, most of the global mining output is derived from this group of countries (UNIDO, 2016, p. 12).

The Mining Contribution Index (MCI) by ICMM (International Council on Mining and Metals), which measures the significance of the mining sector in national economies, is published every two years. The MCI uses four indicators: A country's contribution of minerals and metals to total exports; the change of minerals and metals contribution to total exports over a five-year period; total mineral production value as percentage of GDP; and the rents sourced from minerals as percentage of GDP (find detailed calculation in the footnote)[1] (ICMM, 2020, pp. 1-2).

Table 2: Ranking of MCI 2020 (ICMM, 2020)

Rank	Country	MCI Score 5th edition	Metallic mineral, metals and coal export contribution 2018	Change in min. exp. contr. 2013-18 (perc. points)	Change in min. exp. contr. 2013-18 (perc. points)	Mineral rent 2018 (as % of GDP	4th edition rank	Change in rank
1	**Suriname**	**98.1**	80.1%	39.2 pp	45.28%	19.92	1	0
2	**Congo, Dem. Rep.**	**97.6**	91.1%	17.5 pp	32.97%	16.17	2	0
3	**Mongolia**	**95.7**	85.6%	5.7 pp	37.61%	28.88	16	+13
4	**Zambia**	**95.5**	76.1%	8.4 pp	20.64%	14.62	24	+20
5	**Guinea**	**94.6**	82.6%	15.3 pp	14.30%	9.68	3	-2
6	**Burkina Faso**	**94.4**	76.6%	14.5 pp	16.06%	9.64	4	-2
7	**Kyrgyz Republic**	**91.3**	54.4%	8.0 pp	11.89%	11.18	5	-2
8	**Sudan**	**91.3**	40.6%	15.6 pp	12.15%	12.70	22	+14
9	**Mali**	**90.0**	75.6%	2.7 pp	16.03%	8.19	6	-3
10	**Zimbabwe**	**88.2**	44.5%	4.6 pp	17.00%	3.74	19	+9
11	**Peru**	**88.0**	60.5%	2.0 pp	13.04%	8.21	21	+10
12	**Bolivia**	**87.8**	43.3%	19.7 pp	6.66%	4.11	17	+5
13	**Mozambique**	**87.6**	67.2%	20.3 pp	11.13%	0.62	39	+26
14	**Namibia**	**86.7**	50.6%	6.4 pp	6.61%	4.19	11	-3
15	**Ghana**	**85.5**	38.3%	5.7 pp	8.48%	5.65	9	-6

It can be observed that the top 15 countries in the Mining Contribution Index are developing- or emerging economies, whilst no industrial country is named, despite the fact that e.g., the US, Canada and Australia are major mining countries. As all of the

[1] *The countries are ranked according to all indicators and the value for each country is then divided by the maximum value of the respective indicator. This creates a number between 0 and 1. Thereafter, each indicator is weighted equally with 0.25 and multiplied by 100 to generate a number between 0 and 100. According to this number, the countries are finally ranked. The following table shows the top 15 countries of 2020. The effects of the Covid-19 crisis are not represented in this ranking yet (ICMM, 2020, p. 1).*

top 15 countries in the MCI are developing ones, one could also consider this as an indicator that the mining sector does not contribute to or even negatively affect the development of national economies. Literature does not provide a clear answer to the question whether the mining sector provides a good opportunity to prosper or contributes to the opposite. However, especially the Chilean history illustrates that the regulatory framework in which the mining industry operates is crucial for the success and contribution to national development (Ghorbani and Kuan, 2016, p. 23). It is important to create incentives to attract mining companies and investors on the one hand, but on the other, policies and regulatory frameworks should provide a clear guideline for mining companies to operate in the country (ibid., p, 6 &18). Chile, as well as the prior mentioned examples of Canada, USA and Australia are not ranked among the top 15 in the MCI as those countries were able to diversify their economies which results in a lower dependency on the sector (Harvard, 2022).

In contrast, even if dependency on the mining sector brings a lot of risks, it could also be viewed as an opportunity: Actions within the mining industry such as a move to more sustainable practices would have an even greater influence on the country, because of the importance of the mining sector for the whole economy.

2.2.2 Social and Environmental Issues in Mining

Based on the named examples of successful mining countries, it could be shown that mining can, if done properly, contribute to the development of national economies. Nevertheless, there are also several social and environmental issues which can occur as a result of mining activities. This chapter provides a short overview of the issues the mining sector has to deal with. According to findings in literature, the following aspects can be identified as the main ones causing social and environmental issues:

- High water demand: This is especially an issue in arid areas where access to water is limited. Chile is a prominent example and well known for its liberal water code of 1981 which led to a situation where 100% of the groundwater in the Antofagasta region (where, among others, the world’s biggest copper mine is located) belonged to mining companies (Ghorbani and Kuan, 2016: p. 9). This exposed indigenous and local people to serious threats as access to water for agricultural purposes decreased. One example is the Salar de Punta Negra, which was an important pastoral area and a breeding ground for flamingos but got completely dried out due to mining activities nearby. Local farmers were using this natural landscape to harvest eggs and feathers from the flamingos (Babidge, 2015: p. 90).

- High energy demand: Mining activities require huge amounts of reliable energy. In a report from 2015, the World Bank estimated that in Sub-Saharan Africa alone, the mining sector will demand 23,443 MW of power in 2020. With an installed capacity of 80,000 MW on the continent (more than half is generated by South Africa), the problem gets even more visible (World Bank, 2015, pp. xi & 1-4).

- Land requirements and resettlements: Mining requires land for its operations to take place. Even if, especially when comparing it to industries such as agriculture, the share of land requirements is relatively low (0.3 – 0.6 % of global ice-free land), its effects are large (Joint Research Centre, 2021). Mining may lead to resettlements of whole communities and villages, which especially occurs in developing countries but is also an issue in industrial countries such as Germany. According to BUND (2021), about 300 municipalities and more than 120,000 people had to be resettled in Germany since the end of World War II. The resettlements and their attempts usually result in protests against such actions. In contrast, the Fekola Mine in Mali provides an example how communities can also benefit from a resettlement, as the community was provided with solar panels, access to water and local facilities such as schools and a mosque in the new village (B2Gold, 2019, p. 112).

- Deforestation: This is partly connected to the prior point, as mining activities not only require land which might be inhabited but also which has vegetation growing on it. This is especially an issue in tropical regions as rainforest has to be cleared to execute the mining activity (UNDP & UN Environment, 2018, p. 31).

- Air pollution, CO_2 emissions and noise: Blasts and the use of heavy machinery running on fossil fuels, as well as particles arising from the activities itself are causing heavy air pollution, affecting not only the miners but also areas around the mine. Consequently and due to the emissions arising from power generation (e.g., diesel based generators in off-grid scenarios), the mining sector is emitting huge amounts of GHG. Due to the blasts and the machinery, mining sites also emit a lot of noise, affecting the area around (UNDP & UN Environment, 2018, p. 35).

- Mineral and toxic waste: During the mining process, huge quantities of waste rocks, tailings, slag and leached ore are produced. Often, waste resulting from mining activities is also toxic and contaminated, which in some cases is directly disposed of into the environment, causing severe damages to rivers and natural lands. This may also affect the livelihood of farmers nearby, relying on clean water for irrigation (UNDP & UN Environment, 2018, p. 35).

- Gender inequalities: The share of women's employment in the mining sector is very low. As the benefits such as compensations or wages from the mining industry are mainly shared with men, due to their higher status in many traditional societies, there is a missed opportunity to empower women (UNDP and UN Environment, 2018, p. 36). Important to notice is that in many developing countries, women are more likely to spend their income for educational purposes or in favor of the household then men (Mohapatra et al., 2021, p. 19).

- Safety: Mining is one of the most dangerous sectors to work in. Mishandling of machinery, explosions and instability of underground mines are all contributors to a very dangerous working environment. Especially in Artisanal and Small-Scale Mining (ASM), safety remains a major issue as mining sites are built without proper measurements (UNDP & UN Environment, 2018, p.36).

2.3 The Mining Sector and Power Generation

Access to a reliable and cheap source of power is crucial for mining operations. The industry is very energy-intensive, as a mine usually operates 24 hours, 7 days per week. On a global scale, the mining sector accounts for between 1.25 – 11 % of global energy demand depending on the source and scale of downstream activities included in the assessment (CCSI, 2018, p. 17). The remoteness of mine sites, coupled with the need for consistent baseload, often implies limited accessibility to existing power infrastructure, compelling the sector to be highly dependent on fossil fuels to meet its energy requirements (ibid.). 62 % of the electricity used is fossil fuel based and 35 % is sourced from national grids. Depending on the energy mix in the country of operation, the total percentage of fossil fuels is even a lot higher. In 2014, only 0,001 % of the total energy used in the mining sector was sourced from renewables standing on site at the mining activities (ibid.). Considering the portion of renewables in national grids, the mines' energy mix is a bit more sustainable, but the percentage of renewables used in the mining sector has been constantly below 10 % since 1971 (ibid.).

Especially in off-grid scenarios, a backup is needed to ensure constant energy supply, which is mostly provided by diesel generators on site (World Bank, 2015, p. 13). Though, with falling prices for renewable energy and a volatile oil price, DRE solutions are more and more demanded by the mining industry. The installed power by renewable sources in mining increased from 600 MW to almost 5GW in four years (incl. planned projects) (JISEA, 2020, p. 1). Even if the total number is still a very low portion of the whole energy source, there is a clear uptake in demand. Simultaneously, as the energy mix of national grids are getting more and more greener, the mining industry is also improving its energy mix when connected to the grid.

According to McKinsey's latest article, the mining industry is currently responsible for 4 – 7 % of global greenhouse gas (GHG) emissions[2], with 1 % arising from scope 1 and scope 2 emissions directly caused by mining operations or indirectly by electricity consumption used to power mines. The other 3 – 6 % comes from volatile methane emissions. In turn, Scope 3 emissions, i.e., from all other indirect uses of

[2] Scope 1, 2 and 3 emissions: Scope 1 emissions are direct emissions from owned or controlled sources. Scope 2 emissions are indirect emissions from the generation of purchased energy. Scope 3 emissions are all indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions (GHGprotocol, n.d., p. 1).

minerals, such as coal for heat generation, account for up to 28 % of global greenhouse gas emissions (McKinsey, 2020). Among other factors, commitments to the Paris climate target of limiting global warming below 2°C, exposure to energy price volatility and social pressures, new environmental regulatory frameworks and licensing requirements are increasing the pressure to accelerate decarbonizing the energy system of the mining sector (JISEA, 2020, p. v and IEA, 2021, p. 20). The speed at which the energy transition occurs will be a determining factor for the growth in demand of certain minerals, given that zero-carbon technologies in the energy and transport sectors are more mineral intensive. For example, climate mitigation technologies such as solar panels are much more mineral intensive than their non-sustainable counterparts, contributing to the increased demand for key minerals such as copper, cobalt or lithium on a great scale (World Bank, 2020, p. 11). Estimations by the World Bank illustrate that by 2050, production of graphite, lithium and cobalt will increase by 500% (ibid., p. 12). To meet global copper demand, the Warren Centre estimates that the world has to mine the same amount of copper in the next 25 years, which were mined in the last 5,000 years (The Warren Centre, 2020, p. 15).

Energy in mining activities is not only crucial to run operations, it is also associated to be one of the main cost-drivers in the sector. According to JISEA (2020), energy costs can make up 15 – 40% of total operating costs and therefore have a huge impact on the economics of mining operations (p. 2). It is even expected that energy demand for mining activities will increase by 36% by 2035 due to declining ore grades and growing mineral demand (ibid.). Therefore, mining companies should have an interest in reducing energy costs. Due to shrinking costs of renewables in recent years, DRE solutions provide an opportunity to not only decrease the mine's greenhouse gas footprint but also the costs (CCSI, 2018, p. 9). According to CCSI (2018, p. 27), there are five options to source renewable energies for mining companies. These are:

- Self-generation: The mining company itself installs and operates the renewable energies
- Power Purchase Agreement (PPA): An IPP (Independent Power Producer) is instructed to build and operate a renewable energy system and power the mine through a Power Purchase Agreement
- Industrial Pooling: The IPP supplies several mines in the area with renewable energy

- Energy Attribute Credits: A mining company directly purchases credits from a renewable energy plant and can sell the excess energy back to the grid
- Grid Connected Sourcing Green Energy: In case a utility offers renewable energy supply, mining companies can pay a premium to source renewable energies.

The most common one is self-generation, as around 85 % of renewable energy projects in mining are sourced by a direct investment by the mining company (JISEA, 2020, p. 8). The remaining 15 % are sourced through a Power Purchase Agreement (PPA) or other agreements in which the mine is an off taker (ibid.)

Several forms of renewables can be applied on mine sites, with solar and wind being the most common ones (ibid.). If the geographical circumstances allow and a proper water source is available, hydropower can also be a very effective solution, as the source is reliable and not depending on sunshine or blowing wind (given certain geographical circumstances, hydropower can be dependent on dry- and wet season). A fourth solution can be geothermal energy, sourced from beneath the surface (CCSI, 2018, p. 18). Further, there is the option of integrating biomass solutions (charcoal) (JISEA, 2020, p. 20). Hybrid solutions, such as a mix of different renewable energy forms like solar and wind, or a storage system based on batteries provide solutions to increase reliability of renewable energies and help decrease dependence on diesel generators (ibid., p. 8).

The option of sharing energy infrastructure with communities is also strongly dependent on the regulatory framework of the country of operation. Some countries, such as South Africa, do not allow sharing electricity directly with communities. Therefore, mining companies can look for other opportunities to share their DRE infrastructure. According to Mohapatra et al. (2021), there are 4 options to do so (p. 15):

- Sharing DRE from the same grid which is powering the mine
- Build up a separate grid which is powering the community
- Feed into an existing local grid to improve reliability as well as the energy mix
- Use new technologies such as repurposing the mine after closure to transform it into a power plant

The IFC (2019) emphasizes that community sharing in wind and solar projects offer great benefits for the companies themselves, as strong community relations impact project success and increase the likelihood to cooperate in future projects (pp. 1-2). The following boxes present case studies of how mining companies installed renewable energies on their mine sites and also powering communities around. Five different case studies with different renewable energy forms and different contractual forms were chosen to illustrate the possibilities.

Hydropower: Kamoa-Kakula Copper Mine (Ivanhoe Mines), DR Congo

The Kamoa-Kakula Copper Mine, operated by Ivanhoe Mines (39.6%), Zijin Mining Group (39.6%), Crystal River Global Limited (0.8%) and the Government of the Democratic Republic of Congo (20%) is located in the Katanga Copper Belt close to the town of Kolwezi in the DR Congo. The mine is considered to be one of the biggest copper mines in the world (Ivanhoemines, 2021).

In 2021, Ivanhoe Mines Energy DRC, which is a subsidiary of Ivanhoe Mines, announced that it is going to upgrade turbine no. 5 of the Inga II hydropower plant to supply the mine with an additional 162 MW of clean energy. The mine is already connected to the Mwadingusha Hydropower Plant which provides 78 MW of electricity (Afrik21, 2021).

Via a public-private partnership with state-owned power company La Société Nationale d'Electricité (SNEL), the Kamoa-Kakula project is not only powering its operations but also local communities around. With the upgrade of Inga II, Ivanhoe Mines Energy DRC intends to feed excess electricity into the national power grid (Ivanhoemines, 2021).

Geothermal Energy: Lihir Gold Mine (Newcrest Mining), Papua New-Guinea

Lihir Island in Papua New-Guinea has one of the largest known gold deposits. In 2010, Newcrest Mining started its operations on the island. The mine is located within an extinct volcano that is geothermally active (CCSI, 2018, p. 36).

To exploit the geothermal energy potential, a pilot project was conducted in 2003, generating 6 MW. Due to its success, the project was expanded in 2005 and in 2007 (additional generation of 30 MW and 20 MW respectively). Nowadays, the mine is powered 75 % by geothermal power, which complements the previous constructed 70 MW diesel generator. An amount of 3 MW is provided to the local villages around the mine. While built by external contractors, the operations and maintenance is provided by staff of the mining company (ibid.).

"The power plant used carbon credit trading under the clean development mechanism generating US$ 4.5 million in 2008 by selling certified emission reductions on the global market. Furthermore, the investment was supported by the PnG Government through its infrastructure Tax credit Scheme (iTcS). The scheme grants a credit of 0.75 % (of taxable income or tax payable, whichever is less) for spending on approved infrastructure projects contributing to the community. The gold project has a known life of mine of an additional 30 years and geothermal energy will continue to play an important role in the mine's development and support to the local community" (ibid.).

Solar: Fekola Mine (B2Gold), Mali

"The Fekola Mine, operated by B2Gold, is located in Mali, close to the border to Senegal and the Fadougou village. The case study contains two elements:

Commercial aspect: Suntrace, together with its partner BayWa r.e, were commissioned by B2Gold to support implementing one of the world's largest off-grid PV-battery hybrid system in the mining industry. Prior to the implementation of the solar project, the mine's electricity was generated from heavy fuel oil generators. By adding the solar PV system with a total output of 36 MW, 75% of the mines energy demand will be met during peak hours. Further, with the 15 MWh battery storage system as backup, the facility will continue to supply power to the 24-hour operating mine after sunset or during bad weather.

Community aspect: To integrate the community aspect in the project, B2Gold provided electricity to over 700 households in the Fadougou village. Following the relocation of Fadougou due to its proximity to the Fekola mining operations, B2Gold, in consultation with the local community, constructed a new village as a means to address the potential social risks of its operations on the community. Additionally, the Fadougou village provides a complete water distribution system (16 filling points), public lighting, and several community facilities such as schools, a mosque, soccer fields, health and maternity centre, and a community market. The PV-hybrid system by Suntrace and the solar panels in the village are not connected to each other. This is an example of having two separate systems instead of distributing electricity from one source. That provides some advantages as the mine and the community are not dependent on the respective energy demands" (Mohapatra et al, 2021, p. 33).

Wind: Raglan Mine (Glencore), Canada

In 2021, the Government of Canada announced an investment of $7.1 million to TUGLIQ Energy through the Clean Energy for Rural and Remote Communities Program to help fund the third phase of its wind energy project, which will displace diesel generation at Glencore's Raglan Mine in northern Quebec.

The Raglan mine is already powered partially by wind energy, coming from the first and second project phase. Building on the success of these phases, two additional 3 MW wind turbines and 4 MW of energy storage will be installed at the Raglan mine site, which reduces diesel consumption by 4 million liters per year. In total, the Raglan mine will be powered by 12 MW from renewable energies, backed up by 6 MW of storage. This contributes to savings of 6.6 million liters of diesel per year in total. The project will also incorporate the use of Artificial Intelligence to maximize renewable energy integration (Natural Resources Canada, 2021).

"Construction of the project will create about 65 jobs, with another six jobs needed for the operation and maintenance of the wind farm over its lifetime. Renewable energy training and information sessions will also be provided to Indigenous youth in the area to share lessons learned and build local capacity" (ibid.).

Tugliq and the Government of Quebec also contributed to the project, for a total investment of $21.9 million.

Combined technology: Mine in Queensland (Confident), Australia

"This case study is situated close to an aboriginal community in Queensland, Australia. The community is currently connected to the national grid. 247 Solar is going to install a hybrid-renewable energy grid for the project, owned by local mining company (80%) and the local community (20%). The renewable plant will feed 100% of the mine's electricity demand, its campsite, and an export jetty. Additionally, the grid will meet 50% of the community's electricity demand with renewable power. This is an example of satisfying the electricity needs of a mine and a community sourced from the same grid, thus significantly contributing to the achievement of SDG-7, decarbonisation, job creation, climate change mitigation and the expansion of social infrastructure, such as the health centre and school." (Mohapatra et al., 2021, p. 22).

The power grid is going to combine different technologies, consisting of a concentrated solar plant (CSP), wind power, solar photovoltaic, storage (thermal storage) and s control system. The project is going to save about 100 tons of CO_2 annually (ibid.).

3. Research Concept – Methodology and Study-design

3.1 Research Question and Aim of Study

This thesis is based on a qualitative research approach, according to Mayring (2014). He describes in his well-known guideline for qualitative research, that the formulation of a hypothesis in a qualitative study design is very uncommon due to the inductive nature of qualitative research (p. 10). Thus, and in contrast to quantitative research, the main research question is not based on a hypothesis. It should, however, be linked to theory to ensure relevance to praxis (ibid. p. 11). Therefore, a literature review seemed to be a well-suited approach to provide a strong background of the topic.

The literature review revealed current challenges in the mining sector, especially with regards to sustainability and social issues. It was also shown that the mining sector is very well placed to apply the Concept of Shared Value (CSV), as infrastructure has to be built for the mining activity anyway. It turned out that energy is not only a major problem for mining activities, but also for communities living in rural areas in developing countries. In off-grid scenarios, this problem is even more severe, as mines are mainly powered by fossil fuels and communities lack access to electricity due to the non-existence of a local grid. Another finding is that as prices for renewables decrease, mining companies are seeking more and more to deploy DRE solutions at their mine sites.

What has not been studied yet, is how DRE solutions can contribute to electrifying communities living near mining areas. This is supported by CCSI (2018), which states that there is a lack in literature concerning the following area: "*Exploring the possibilities of the electrification of surrounding communities arrangement in off-grid scenarios: This arrangement has the potential to spur rural development around off-grid mine sites, but also suffers from many complexities with various actors being involved.*" (p. 85). The research question was developed based on this recommendation, but does not only focus on general off-grid scenarios: it discusses the potential of *renewable* off-grid solutions and how they can benefit communities nearby. This builds the ground to solve two issues at once, which leads to the main research question of this thesis:

"How can decentralized renewable energy solutions be applied in the mining sector and create shared value?" To give an answer to this question, this thesis evaluates three guiding questions:

- What are the benefits and risks of DRE introduction and energy sharing in mining?
- What are major barriers of DRE introduction and energy sharing projects in mining?
- What are the options / approaches to share DRE power with communities?

3.2 Methodical Review

To answer the main research question, various methods were considered. According to Flick et al. (1995), a qualitative research method should be chosen in cases where topics or research objects are complex, not clearly comprehensible, contradictory, or if there seems to be an obvious answer which could hide unknown phenomena (p. 16). The main research question is indeed very complex as several factors need to be researched, reflected by the three guiding questions. There is also a contradiction, as powering mines *and* communities seems not to be very cost effective for mining companies at a first glance. Therefore, and because a quantitative analysis did not seem to be well-suited to provide an appropriate answer to the research question, the qualitative method was chosen.

Taylor et al. (2015) describe that qualitative analysis usually is inductive, as researchers do not intend to prove an already developed theory but to build a new concept or theory based on the results of the qualitative research (p. 18). This is also reflected in Glaser and Strauss' Grounded Theory (1967) which states that theory is developed from the obtained data and therefore inductive (ibid.). Nevertheless, Taylor et al. (2015) state that "pure induction is impossible" and that a certain basis and assumptions are needed to develop a theory (p. 19). This is supported by DeVault (1995), who states that data missing in the empirical part may be as important as the one which was gained (p. 613). Therefore, a literature review can fill those gaps. This thesis is based on a mixed approach of partly inductive (empirical part) and partly deductive elements (literature review). A well-grounded literature review was necessary to understand the basic principles and current status of sharing infrastructure in mining, as well as to detect gaps in literature. Combining inductive and deductive elements ensures having as few data gaps as possible. Mayring (2014) provides a guideline for the inductive part and the empirical analysis which is described more in detail in chapter 3.4.

The chosen qualitative method is a partially standardized problem-centered expert interview. This method was chosen as it was required to have interviewees with an expertise about the research topic to ensure receiving new findings. The partially standardized concept allows and encourages the interviewees to express their own views and experiences. In total, the empiric analysis comprises 9 expert interviews.

3.3 Description of Literature Research

A literature review builds the ground for this thesis. Detecting gaps in literature provides the basis for developing the research question. The literature research is conducted by screening publications, presentations or reports from the following groups: International organizations, researchers, private companies and scientific institutions. Further, to gain information about specific projects, information on websites were consulted. Scientific books were used to understand challenges and opportunities in the mining sector in general. As the topic discussed in this thesis is emerging recently and therefore relatively new, printed books about electrification in mining are rare.

Through the internet, most literature could be found and accessed. One important tool which was used is the “JUSTfind” application of the digital library of the Justus-Liebig-University. This tool was especially suited to find scientific papers about mining, as well as infrastructure sharing in mining regions and the concept of creating shared value. By searching for specific catchwords such as “Creating shared value” (1,259,298 results) and “Shared-use mining infrastructure” (840 results), important literature could be found. To specify the literature even more, the catchwords “Shared-use mining energy infrastructure” was looked up (615 results). To find more information about the environmental and social role of mining, as well as about the contribution of mining to economic development, several further catchwords were looked up: “Challenges in mineral mining” (182,052 results), “Mining and economic growth” (621,419 results), “Mineral mining and environment” (370,343 results). In addition to JUSTfind, all catchwords were looked up in Google Scholar, as well as on the Google platform. By adding the word “PDF” to the catchwords, helpful articles could be accessed directly via the Google platform. Printed books which were used to understand the basics of the topic were also found via Google and consulted.

To find further relevant literature, the library of the company “Energy and Mines” was screened, as they provide many case studies and publish current developments in the sector. Another source to gain relevant literature resulted from contacting and meeting industry experts. Such experts were found by accessing the UNIDO network or by contacting authors of relevant publications via the social media platform LinkedIn. There were no specific criteria to exclude certain literature, as they were only chosen according to: 1. the relevance for the topic; 2. the helpfulness to understand basics and principles; and 3. to find specific data and findings relevant for the topic. The relevancy of the articles were screened by looking into the table of contents, reading the abstract and certain chapters, if relevant to the thesis.

3.4 Description of the Qualitative Interviews

To conduct and prepare the interviews, it was necessary to have a broad knowledge about the topic, as emphasized by Adams (2015, p. 493), which indicates that there has to be at least some deductive elements. This is supported by Witzel (2000), who states that problem-centered interviews, as used in this thesis, are combining the inductive and the deductive approach (p. 2).

As mentioned, partially standardized, problem-centered expert interviews seemed to be the most appropriate form of interviews for the purpose of this thesis. To gain sufficient data, five expert groups could be identified, from which four were interviewed: Development banks; communities; governments; mining companies; and renewable energy companies. It was chosen not to consider the community group for this thesis, as travels would be necessary to reach remote communities, which was not possible due to current travel restrictions. The interview groups were identified based on conversations with industry experts, as well as by screening case studies and notifying the actors involved. The thesis contains nine expert interviews, coming from eight different countries and four continents. Two interviews were held per expert group, with the exception of the “Renewable Energy Company” group (three interviews) to ensure more variability of the answers. Every respondent received an abbreviation for the analysis part, according to the respective group they belong to. The following table provides an overview of the interviewed persons:

Table 3: Abbreviation of Interviewees

No.	Country	Interview Group	Abbreviation for Analysis
1	Austria	Development Bank	D1
2	South Africa	Development Bank	D2
3	DR Congo	Government	G1
4	Liberia	Government	G2
5	Canada	Mining Company	M1
6	South Africa	Mining Company	M2
7	Bulgaria	Renewable Energy Company	R1
8	Chile	Renewable Energy Company	R2
9	Germany	Renewable Energy Company	R3

According to Flick (1995), one important characteristic of partially standardized interviews is that the respondents are encouraged to answer questions based on their own experiences and views, as there are no parameters set and questions are asked openly (p. 177). This is very important to detect unknown and unobvious data, especially in questions which seem to be answered very easily. In partially standardized interviews, the respondents are allowed to add questions and further notes which they think are relevant for the topic (ibid., p. 178). This is explicitly stated at the beginning of each interview to encourage the respondents to include their own views, experiences and to add notes: "…the questions are formulated in an open way so you can answer them extensively, including your experiences and views … Also, if a question is irrelevant for you, feel always free to point that out" (see interview introduction, Annex IV, line: 61-67)

One variant of partially standardized interviews are problem-centered ones, which are dealing with the experiences, perceptions and reflections of interviewees according to a specific problem or topic. Even if these interviews are held according to a relatively vague guideline, this guideline is not binding and can be adapted by either the interviewer or the respondent (Flick, 1995, p. 178).

The individual experts were identified through screening cases of successful implementation of DRE solutions and community electrification. Further, via the Energy and Mines Africa Virtual Summit 2021, various experts could be identified by attending presentations and conferences. Another source was the UNIDO network, which provided access to industry players, especially in the renewable energy sector. Via the social media platform LinkedIn, direct contact persons could be found by screening through the profiles of employees of certain organizations or companies which were eventually contacted.

There are weaknesses of qualitative interviews, as stressed by Dresing and Pehl (2018). Due to the openness of partially structured problem-centered interviews, the respondents may answer very limited or even too broad which does not provide new data or leads to a deviation from the topic (p. 15). This risk can be mitigated to a certain extent by repeating a question or by reformulating it. If the respondent again answers shortly, this could indicate that he / she is not comfortable with answering the question (ibid.)

All of the interviews were held online at the meeting-platform Zoom and were recorded. The recordings were stored on a separate hard drive until they were transcribed according to the transcription rules by Kuckartz et al. (2014), which were adapted slightly. The method by Kuckartz et al. was chosen and adapted, as non-linguistic data and interpretations are irrelevant for answering the research question. The transcription rules can be found in Annex III. After transcribing, the recordings were deleted. The transcripts are stored on a separate hard disk until the thesis is submitted and finally graded. Thereafter, they will be deleted. At the beginning of each interview, the consent to record and conduct the interview was requested verbally. All interviewees were contacted in advance and if necessary, a pre-meeting was held. In most cases, the interview questions were shared with the respondents in advance, which was helpful to create a relaxed environment and receive well-thought answers.

3.5 Data Analysis

There are also various methods available for data analysis. For this purpose, the qualitative data analysis is based on Mayring (2014). The author describes that after the research question was built and the literature review was conducted, there are two approaches to build categories: inductive, derived from the data; and deductive, based on the literature review (p. 104). There is also the possibility to apply both procedures in a mixed method (ibid.). The code construction is based on the inductive approach (explorative, formulating categories based on empiric results), to cover all aspects mentioned in the interviews as best as possible (ibid. p. 12).

For the inductive part, the thesis follows Marring's 8 steps of inductive category formation: "1. Research question, theoretical background; 2. Establishment of a selection criterion, category definition, level of abstraction; 3. Working through the texts line by line, new category formulation or subsumption; 4. Revision of categories and rules after 10 - 50% of texts; 5. Final working through the material; 6. Building of main categories if useful; 7. Intra-/Inter-coder agreement check; 8. Final results, ev. frequencies, interpretation" (p. 80).

Mayring states that the researcher does not have to consider all material for the analysis and can indeed reject certain passages if they have no relevance for the study. Nevertheless, the researcher has to define the coding unit, the context unit and the recording unit before categorizing and coding (p. 51). For the purpose of this thesis, the coding unit (smallest material which can be considered to be included in a category) is defined as a paragraph, relevant for one of the categories. It can be smaller than one sentence, as long as the keywords relevant for the categories are described and not just standing alone. The context unit (largest material which can be considered to be included in a category) is described as a text section dealing with one specific argument. It can be as long as the section is related to the actual argument. As soon as another argument is stated, the context unit ends. The recording unit is defined as the text portion confronted with the category system (all transcripts, except of the interview introduction) (ibid. p. 51). The coding guideline as well as the inductive code development can be found in the Annex II.

A table containing the specific quotes of the interviewees, based on Mayring (2014, p. 70), can be found in Annex I. This table is based on the four steps Mayring provides for summarizing data: Paraphrasing, generalization according to a pre-set abstraction level, first reduction and a second reduction (p. 68), whereas the reduction part was not conducted in this thesis, as the generalization already provided a very narrow description of the paraphrases. Repetitions, which are according to Mayring (2014) also listed in the generalization column, are expressed in the results chapter. Column R (Respondent) indicates the answers of a specific interviewee based on the given abbreviation of the person. The level of abstraction in this thesis is defined as:

Parts of the paraphrase, which are unnecessary or not directly related to the category can be deleted. However, parts which are not relevant for the category but are important to understand the view and opinion of the interviewee should be kept. In case a paraphrase is written very extensive, but all or most parts are important with regards to the category or the opinion of the interviewee, a sentence can be rewritten and therefore shortened.

4. Empirical Results

4.1 Barriers (C1)

Based on the empirical data, five main barriers for the introduction of DRE in mining and community electrification could be identified. Each barrier was declared as an own category, summarizing the statements of the interviewees.

4.1.1 Economic Barriers (C1.1)

The life of a mine might in some cases not be aligned to the business model of renewable energy providers. This is the case when the life of the mine is shorter than the payback period of renewable energy projects (R1, 1647-1649; M2, 2042-2048; M2, 2034-2037). M1 mentioned that the payback period of their project is expected to be seven years (M1, 1299-1303). This might be a too long time period for certain mining activities and cause an investment in DREs to be cost inefficient.

The size of the mine is a determining factor, as smaller mines cannot afford to build an independent energy plant due to lower electricity demand and because of limited financial capacity. The bigger the mine, the higher is the economic benefit and it becomes more cost effective to install DREs (D1, 1133-1137). This is supported by R2, by stating that the size of the mine is the first point of analysis to determine how feasible such an investment is and what the opportunity costs are (R2, 560-563). Also in terms of social value creation, the size of the mine is a determining factor as smaller mining companies do not have as much financial capacity as larger ones (D2, 238-240). G1 supports those statements by explaining that there are high investment costs of DREs (G1, 3219-3220) which makes it more difficult getting the sources for the deployment (G1, 3328-3329).

DREs regularly require lots of land to be available (especially solar). This might be an economic barrier, as land that has to be rented or purchased cannot be afforded by all mining companies (D1, 1138-1148).

Deployment of DREs is not solely meaningful in off-grid scenarios, it can also be used complementary to a grid. However, this brings its own challenges, especially when the national grid is subsidized, which is stressed by D1 (1164-1173), R1 (1812-1814 and 1831-1837) and R3 (2726-2731). D2 adds that not only the subsidies hampering deployment of DREs, but also the fact that industrial clients have the chance to bilaterally negotiate with the utilities to receive cost efficient electricity prices, which make DREs unprofitable (D2, 421-428). R3 explained that newly developed solar plants are not much more expensive than hydro or thermal plants, but that the competitiveness decreases with subsidized national grids (if they are available). The instance of Zambia provides an example of a very heavy subsidized grid (R3, 2726-2731).

D2 expresses that in the instance of South Africa, many communities already receive a portion of free electricity from the grid, which prevents sharing projects. Further, it is unlikely that communities are going to pay for electricity coming from the mine (D2, 308-313). Thus, mines are left with the only opportunity to electrify communities for free, which according to R2 is not profitable (R2, 609).

Due to the intermittency of DREs, storage solutions are necessary to ensure steady electricity supply. Nevertheless, battery storage can be very expensive compared with biomass or gas (D2, 120-123). R1 mentions that the more reliable a national grid is, the less economically feasible is the deployment of DRE solutions (R1, 1850-1857). Also, D2 refers to the issue of getting favorable tariffs, as this is an important economic barrier which determines if an investment is cost efficient (D2, 356-360).

4.1.2 Technical Barriers (C1.2)

D1 generally thinks that there are only small technical hurdles to power mines and communities by DREs (D1, 924). However, storage is necessary to ensure steady supply (D1, 1005-1007). This is supported by various respondents: R2 states that a combination of technologies can be favorable, especially storage combined with DREs. In the future, green hydrogen will be an important source for leading towards an energy transition (R2, 564-570). M1 mentions that battery storage will be an option to overcome technical barriers and solve the intermittency issue (R2, 1385-1388) (even if the renewable energy project of M1 does not include a battery storage). M2 expresses that 24 hour supply can be achieved by adding a storage element to the system, such as fossil fuel alternatives, which are decreasing costs of the backup system (M1, 2018-2025). This is supported by R1, who states that battery storage is more expensive than a diesel backup, which is necessary to ensure steady supply (R1, 1702-1707). Further, M2 explains that the mine's load profile has to be matched to the generation profile of the DRE and that renewable energies can only displace a certain portion of the energy requirements (M2, 2131-2139). R3 adds that intermittency does not only cause negative effects on the operational side, but as mining equipment is very sensitive to power quality issues, those technologies should be protected (R3, 2586-2588).

As a final point, R1 states that wind power is uncompetitive as large wind turbines and equipment are necessary which require logistics and service (R1, 1696-1698). However, D1 is recommending to combine technologies when deploying DREs. This is not only related to storage (D1, 987-989), but also to combine e.g. solar with wind or hydropower to even more increase the reliability of DREs (D1, 922-924).

4.1.3 Regulatory Framework (C1.3)

Regulatory frameworks determine the possibilities to deploy DREs and to electrify communities. In some instances, they are a major barrier, as the regulatory framework does not allow such practices. This is described by D2, who states that DREs need a certain law in South Africa to be deployed, which is the reason for reluctance of renewable energy (D2, 116-118). D2 expressed that on the day before the interview was conducted, South Africa launched a new regulation with regards to renewable energies. Prior, it was only allowed to deploy renewable energy up to 1 MW without the requirement of a special license. This changed recently to 100 MW, which is why there is an uptake of renewable energies expected (D2, 151-156). Additionally, mining companies are now allowed to sell excess power to the municipalities or to other industrial clients, which was another barrier to be overcome. Nevertheless, it is by law not allowed to share power for residential uses, which hampers the electrification of communities nearby with the use of DREs (D2, 219-224). This is supported by M2, who states that in South Africa, there are regulatory restrictions in place, hampering deployment of private power generation (M2, 2039-2041). Additionally, without a governmental permission, energy cannot be shared to non-mine linked entities (M2, 2173-2175). Thus, D2 explains that there are projects where mining companies have provided solar panels to certain facilities of the community, such as schools or hospitals which then generate clean and free electricity. However, powering communities from the same grid is not allowed (D2, 225-230). R3 adds to the South African instance, that there are very rigid frameworks which prescribe social development measures. In other instances, where there are no strict guidelines, R3 as an IPP, can directly engage with the community and provide various levels of community benefits (R3, 2622-2627).

R3 is also stating that markets for renewable energies are not liberalized in many African countries, as they are limited in size and capacity or not allowed to be installed at all (R3, 2564-2569). R3 is adding that IPPs need a framework which allows and enables them to engage with private entities such as mines, but that there is often a state owned utility which has a monopoly position. This contributes to a high difficulty in implementing DRE projects for IPPs (R3, 2662-2668).

According to M1, project delays can occur due to permitting processes. These delays are unpredictable to a certain extent and represent a risk to the project (M1, 1321-1326).

When it comes to infrastructure sharing, D1 and R2 are stressing that administrative issues are key and have to be overcome. It is important that quantities are defined, expectations are clear and that tariffs are determined. According to D1, this is the role of the government, which should also establish a legal ground for such projects (D1, 1088-1092). R2 supports this statement by referring to the administrative issues. Questions such as: “Where do you draw lines? To what extent? Who is responsible? What happens if people are out of power?” should be cleared in advance (R2, 632-636).

With regards to the regulatory framework, G2 is stating that in Liberia, there is the necessity of a mineral development agreement, before any mining activity can start. Within this agreement, power generation should also be stated (G2, 2893-2899). The interviewee further expands, that there are no limits to private owned power plants in Liberia, however it has to be negotiated with the government in advance (G2, 3077-3079). G1 mentions that there might be issues with the national utility (SNEL) of the DR Congo when it comes to private power generation, but it is not prohibited in general (G1, 3170-3174). G1 adds that taxes have to be paid for the mining activity and additionally for the power plant, which increases national earnings but represent a barrier for implementing DREs (G1, 3279-3282).

D2 recommends that there should be a regulatory framework in which there is a mining plan linked to a government industrial plan, linked with a municipal or provincial plan. Further, the respondent explains: “Any new mine operating in that area has to speak to the mining plan, plus the provincial plan, as well as the national and industrial plan. And you are able to then filter down all the things that you have to do and it should be captured there. And the government should set clear targets and say, if you want this mining license, you will have to build a school, build a training college, you will have to train 1000 local people, you will have to hire from the local area." (D2, 250-261). R2 supports this statement by recommending to establish very clear responsibilities of each party and a governance administration (R2, 744-746). In contrast, R1 recommends having as little governmental interference as possible (R1, 1757-1760).

M2 recommends that governments should actively unlock DRE deployment by private companies in their countries. Besides setting a regulatory framework, they can implement certain risk management measures. They could e.g. decrease the risk of a stranded asset by allowing energy trading which ensures that the asset can be used beyond the life of a mine (M2, 2266-2273).

According to R2, a clear long term vision stating the development plans of a certain region (socially, demographically, geographically, and economically) provides a good basis for future projects (R2, 651-654).

4.1.4 Geography (C1.4)

The location of the mine is a determining factor to several aspects with regards to DRE deployment and community electrification. D1 and M2 explain that the location of the mine is determining whether there is a cheap and reliable grid available which in turn limits competitiveness of the DRE solution (D1, 896-903 and M2, 1990-1992). Moreover, geographical conditions determine which DRE solution is sensible to deploy (availability of sunlight, wind, water etc.) (D1, 937-939 and M2, 2121-2123). M1 adds that due to the favorable conditions at their mine in Mexico, solar was the best-suited solution (M1, 1363-1366). D1 states that geography can even decide about intermittency of DRE solutions, such as hydropower, as water levels may change with the seasons (D1, 1009-1013).

Land availability is also determined by the location of the mine and access to it depends on whom the land belongs to. R1 states that his company needs about 7000 square meters to produce 1 MW of solar power. Further, in some instances an environmental permission is necessary to deploy DREs. (R1, 1651-1655). M2 adds that the topography of the area (hills etc.) and geotechnical conditions can be a barrier to install DRE solutions. Additionally, the vegetation in the area is an important factor, as it might not be sensible to clear a rainforest for the purpose of solar panels (M2, 2152-2160).

When it comes to sharing infrastructure with communities, the distance from the mine to the village is another barrier, which could cause sharing from the same grid to be inefficient. Constructing a transmission line in some cases is even less efficient then building a separate grid for the community (R3, 2634-2637).

Transport of energy as well as transport of equipment and the installation of DREs are further barriers as stressed by G1. In harsh geographical conditions it can be very challenging to deliver certain equipment or to install a transmission line (G1, 3206-3209).

4.1.5 Education and Training (C1.5)

Education about renewable energy can play a huge role in enabling such solutions. According to R2, it is important to educate the mine and the community about the limits of renewable energy. Especially with regards to the fact that energy demand is likely to increase when shared with communities, every party should be able to understand the limits of such a technology (R2, 717-722). Further, the acceptance of projects by communities nearby often depends on the educational status of the community and therefore, requires some degree of education in certain instances (G2, 2880-2886). Moreover, in the event of project implementation, there is an opportunity to create jobs during construction and maintenance for the community. To take this opportunity, the community should be trained in the handling of renewable energies and construction (R3, 2619-2622).

Education and training also play a huge role when it comes to staff of the mining companies or governmental entities. M1 mentions that the mining personnel has to be trained to operate DRE solutions (M1, 1326-1329). This is supported by M2, who states that renewable energy is not core business of mining companies and therefore require specialized training (M2, 2105-2108). Nevertheless, it is not only about education during construction and operation but also to convince mining companies that DRE solutions are beneficial. According to R1, there is a lack of awareness by mining companies with regards to the benefits of renewable energies (R1, 1680-1685). This is supported by R3, who states that concerns of the mining sector often lead to neglecting such solutions and that education is required to convince them (R3, 2531-2535). R1 adds that the mining sector often underestimates the costs of diesel generators, which leads to false cost estimates (R1, 1662-1664).

R3 points out that national energy regulators also need to be educated in some instances, as state owned utilities are sometimes very critical about private renewable energy projects. As the national utilities are in charge of granting such projects, they are a key stakeholder to convince of the project (R3, 2685-2689).

R1 is partially supporting this argument as he states that mines are often convinced that DREs are going to mess up their electrical setup. However, he adds that this is only a perceived and not an actual risk in his opinion (R1, 1645-1647).

4.2 Benefits (C2)

4.2.1 Community Benefits (C2.1)

By electrifying the communities, there are several benefits which improve their livelihood. M1 states that DREs provide green and affordable infrastructure in communities (M1, 1492-1494). Education, security and health improves as well since people are able to study in the dark, to cook with electricity and to benefit from street lighting (D1, 1076-1080). Further, in cases where the electricity is only available for a certain time or limited due to budgetary reasons, people have to prioritize the use of energy. By providing communities with electricity, they do not have to prioritize which gives more autonomy to people in order to fulfill their economic aspirations (R2, 734-743).

There is also the aspect of job creation, not only directly during construction and operation (M1, 1329-1331 and R3, 2616-2619), but indirectly through taking the opportunity of local procurement (M2, 2187-2189). M2 supports the previous by stating that in addition to electricity, local skill development and job creation can benefit communities (M2, 2179-2183). R3 highlights that his company is typically aiming to improve the life of community members by providing them with electricity, skills and jobs and specifies that maintenance and plant security are potential job creators (R3, 2643-2654). There is also the benefit of knowledge and technology transfer to communities and to enable them to build their own infrastructure by themselves (capacity building) (R2, 607-609).

D2 points out that even in instances where electricity cannot be shared with communities due to regulatory frameworks, DRE solutions are likely to benefit the communities, if the mine is selling excess energy to municipalities. This in turn helps to power up the communities and increase the municipality's reliability and sustainability, while enhancing local economic development (D2, 330-333).

M2 highlights that there is the option of handing over the power plant to the community after mine closure, which stimulates economic development (M2, 2205-2210). G2 is adding that a successful implemented project may attract further investors to settle in that area which in turn also fosters local economic development (G2, 3064-3070).

4.2.2 Mining Benefits (C2.2)

Several benefits for mining companies could be identified, caused by implementing DREs and sharing it with communities. For a better visibility, the results are ordered according to DRE deployment in general and sharing DREs.

DRE deployment:

The most crucial ones are cost savings, supply security, improvement of reliability and decarbonization. (D1, 910-912; D2, 96-97; D2, 93-95; R2, 498-501; M1, 1299-1303; M2, 1992-1993; M2, 1999-2001; M2, 2002-2004; R3, 2512; R3, 2516-2518). There is also the dimension of improved control over electricity costs and the independence from a national grid, which might face power outages, such as in South Africa (D1, 903-907 and M2, 2002-2004). R1 adds that the replacement of diesel generators by renewables, reduces the problem of transporting diesel in potentially remote areas. Transport of fuel can be a huge challenge in remote and harsh environments (R1, 1628-1637). The installation of DREs in mining could also be an effective measure in mitigating climate and infrastructure risks (R2, 769-772). Some respondents expect that in the future, sustainably mined minerals will be more demanded and competitive, which contributes positively to the profits of mining companies (R2, 833-835). M2 is stating that especially the carbon footprint is in the focus of stakeholders (M2, 2406-2415). D1 is adding that being an early adapter and gaining knowledge in renewable energies before competitors do, could also be an advantage (D1, 1047-1050). M2 points out that the installation of DREs may protect mining companies from paying international or national carbon taxes, as DREs are contributing heavily to the decarbonization (M2, 2379-2382).

Community sharing:

D2 is stating that in artisanal and small-scale mining, there is often a lack of electricity. By introducing power to such activities, it can extend the life of the mine, as workers can introduce technology and will be able to operate in greater depths (D2, 106-110). Sharing DRE infrastructure is considered to be an effective risk management measure, as it will increase the acceptance of communities to further projects, such as new exploration or mining activities (G1 3239-3244, G2, 2965-2968 and G1, 3282-3290). R2 adds that sharing infrastructure can be a good opportunity to test out new technologies. He provides the example of a project in Ollagüe, a city in Chile, where R2 built a hybrid solar powered plant with a very small wind turbine and accompanied by a fuel generator, which is a backup for it to have 24/7 generation. It was for R2, besides working with local communities, a very good opportunity to explore technologies. (R2, 617-624). There is also the role of an improved reputation and better public image, which applies for the actual deployment of DREs and also for sharing it with communities (D1, 1044 and R2, 614).

4.2.3 Country Level Benefits (C2.3)

As mining activities demand huge quantities of energy, there are also various benefits on the country level when mining companies deploy and share DREs.

One of the most important benefits is the potential to foster economic development in the country (D1, 1219-1221 and G1, 3354-3359). There is even the potential to develop a whole renewable energy industry, which could supply neighboring countries (M2, 2431-2442). M2 adds that this development will also decarbonize a whole country and closes the supply deficit which many national utilities are facing in developing countries (M2, ibid.). This is supported by R3, who states that deployment of private renewable energies will improve the supply of national grids, as energy intensive industries are not so much dependent on the grid anymore (R3, 2550-2553). D2 provides the example of South Africa, which has been facing rolling blackouts for many years. DREs could increase the reliability of the national grid (D2, 90-93). This in turn will foster economic development (D2, 313-314). There is also the possibility to sell excess power into national grids or to other private companies, which then supports the electrification process of residential customers (D2, 338-343).

Besides of tax revenues, which is stated by G1 (3263-3266) and R3 (2668-2671), there would be job creation and lesser necessity by the government to invest in infrastructure, as the private sector would already develop it (R3, 2668-2671). As DREs lead to improved energy supply, this may also attract investors and could lead to a domestic refinery industry of raw materials (R3, 2805-2812). D2 also highlights that due to electrification in artisanal and small-scale mining, miners can work more efficiently, which reduces the need of child labor in certain instances (D2, 103-106).

G2 states that especially developing countries should go into the direction of DRE deployment as it attracts further investment and contributes to a carbon-free economy (G2, 3101-3106 and G2, 3369-3375).

4.3 Risks (C3)

4.3.1 Community Risks (C3.1)

Infrastructure sharing can also pose certain risks to communities. An important one is the dependence on the mine and the issue of mine closure (D2, 285-287 and R1, 1781-1782). In the event of a mine closure, communities will not only lose jobs created by the mine and the DRE plant, but may also run out of energy if there are no plans in place for handing the plant over to the communities (D2, 295-301).

M2 is stressing the issue of job creation during the construction phase, but a lack of opportunities afterwards, which brings some community members at risk of unemployment (M2, 2183-2185). Further, health and safety during the work is another issue which has to be ensured as it should be clear what happens in the event of an accident. Also, there is the risk of power outages, if the mine requires more energy at certain points of time (R2, 704-708).

G2 is explaining that hydropower might compete with the livelihoods of certain communities, as they are dependent on a water source to produce agricultural goods (G2, 2864-2867). Further, there is a risk that mining companies will not engage with the communities and cause damages for which companies will not pay (G2, 2976-2981).

4.3.2 Mining Risks (C3.2)

There are also various risks which mining companies are facing when it comes to DRE deployment and sharing projects. The parts in this section are again split according to the respective risks of: DRE in general and community sharing.

DRE in general:

The due diligence process has to be made very careful. Otherwise it can lead to insufficient power supply and therewith, economic losses (D1, 918-921). This is supported by R2, who stresses that if DRE solutions are not tested accordingly, they can have a huge operational impact, which in turn causes financial losses (R2, 506-512). The transmission line could also represent a potential risk, as problems with the transmission line would affect availability (M1, 1465-1467). Another heavy risk that might occur is the one of a stranded asset in case of a mine closure and when there is no possibility to sell the power to utilities (M2, 2086-2091).

In case the mine is using the national grid as a backup, the costs will naturally increase, as there is a changing role by the utilities from an energy supplier to a provider of a stand-by system (M2, 2350-2354). If a mining company however supplies energy through DREs (e.g. only for reputational or environmental reasons) and neglects to be powered by a national grid which has favorable prices, this will lead eventually to higher commodity prices, paid by the consumer (D2, 404-408). In contrast, M2 is stating that if no sustainability measures which are fostering the decarbonization of mines are implemented, there is a risk for mining companies that it will become more difficult to attract investors and sell products (M2, 2518-2522). On the other hand, power outages by the national grids represent a risk to mining companies, which result in serious economic losses (M2, 2422-2431). This is supported by G1, who states that the national utility SNEL is not able to provide industrial customers with sufficient electricity supply, which is a risk for mining companies (G1, 3157-3161).

In underground mining, intermittency is a huge risk, as it can lead to a situation where workers are stuck underground for hours which has health and safety impacts. Due to the intermittent nature of DRE solutions they are not suited for such instances, except there is a very stable backup (D2, 172-182).

M2 states that mining companies face a risk of conflicting land uses, when it comes to the deployment of DRE systems. The land which could be considered for the installation of DREs might be used for agricultural purposes and this could lead to a conflict (M2, 2237-2243).

Community sharing risks:

There is always the risk of a strike by local communities nearby, in case the mining company does not engage with them and provide social and economic development measures. This may lead to bad press and protests which is why community development measures are so important (D2, 201-209 and D1, 1038-1043). M2 states that even if mining companies have a good relationship with the communities, there is the risk of sabotage or theft as a response to governmental failures because communities cannot necessarily differentiate what belongs to the mine and what to the government (M2, 2225-2231). Also, the acceptance by the community with regards to a certain project is a risk which may endanger the whole investment, also for DRE projects (G2, 2929-2931).

A major issue when it comes to sharing electricity is that the demand is likely to increase dramatically, as the community residents are getting more and more appliances. This leads to a situation where demand is much higher than supply (R2, 691-694 and G2, 2959-2965). This is supported by D1, who states that there is even a risk of migration, caused by providing free electricity to the community which will also cause a skyrocketing electricity demand (D1, 1059-1065). Thus, managing the expectations of energy sharing projects is another risk which determines the satisfaction of the community when powered with electricity (D1, 1055-1058).

R1 mentions various potential risks when sharing infrastructure. Firstly, it should be clear whether the communities have to pay for the electricity or not. If they are going to pay, it has to be declared at which rate and what happens in case of a default on payment. If the power is provided for free, it should be declared how much electricity is provided exactly and what a fair usage policy is. R1 states that he would not engage in a sharing agreement (at least sharing from the same grid), if he would be in charge of a mining company, as there are too many potential risks. The interviewee adds that there is a risk of potential trouble when the mine is closed due to the loss of both an electricity and an employment source (R1, 1719-1720 and R1, 1727-1735). R1 and R3 advise mining companies to build a separate smaller grid or provide the village with solar panels instead of powering from the same grid as there might occur certain problems (R1, 1720-1723 and R3, 2649-2652).

M2 points out that there is a risk of lacking acknowledgement when it comes to sharing, as in some cases the community already receives free electricity to a certain degree (M2, 2199-2205). Further, R3 expresses that providing electricity might only be one part of a puzzle, as working conditions, waste disposal and other issues are as important for stakeholders as the provision of renewable energy (R3, 2769-2774).

4.4 Stakeholder Management (C4)

As many stakeholders are involved in a DRE sharing project, it is very important to manage them the best way possible. This chapter presents all mentioned aspects of the interviewees with regards to stakeholder management.

Firstly, DRE solutions can improve the relationship to certain stakeholders (e.g. investors and communities), as stressed by R2 (610-611). According to R2, the relationship between the stakeholders is one of the determining factors for success or failure of a DRE project (R2, 636-642). R2 adds that it is important to keep in mind that every stakeholder has a responsibility to successfully execute the project (R2, 694-697). It is important to include the government and local communities from the beginning on, as recommended by D2 and M2, to avoid a failure of the project (D2, 272-279 and M2, 2245-2246). In case of a non-involvement of the community, it is likely to experience rejections from the community which will endanger the whole project (D2, 272-279). M1 states that the regulators and governments can play a role in engaging with the communities and also with the national power companies (M1, 1434-1437). M2 adds that the governmental role is to balance the needs of each stakeholder (M2, 2258-2260) and that the government can remove possible bottlenecks when it comes to negotiations between the national utilities, which can speed up the implementation of a DRE project (M2, 2277-2285). G2 also stresses the governmental role as a partner to negotiate with, as they can offer certain incentives like tax breaks (G2, 3039-3044). DFIs can also play a role in educating different stakeholders as stressed by R3 (2681-2683).

M1 provides a positive example of how the mining company overcomes the issue of stakeholder management. The respondent states that frequent meetings, which were priorly negotiated with the community, are held to ensure that their needs and expectations are heard and implemented. Additionally, there is a committee which was established in each of the 11 communities M1 dealt with (M1, 1482-1488). With regards to stakeholder management, R2 recommends to implement proper communication training and to make sure that roles and responsibilities are stated very clearly (R2, 697-700).

D2 describes that there is the option to participate in an industrial development corporation, which helps to bring stakeholders together (D2, 267-270). There is also the opportunity to engage with IPPs through a PPA (R2, 488-493). M1 adds that IPPs can support mining companies in running the plant, even if no PPA is in place. In the instance of M1's project, it was contractually agreed that the IPP is going to support the mining company in that regard (M1, 1333-1336). R2 states that there is an option to access renewable energies directly from the grid in cases where a DRE solution may not be sensible (R2, 788-790).

Also, G2 describes that in the instance of Liberia, a poor and developing country, there is no or limited capacity of the government to support DRE projects (G2, 3021-3025).

4.5 Financing (C5)

Financing is one of the key elements when it comes to DRE projects. This chapter summarizes the results with respect to financing models and opportunities to execute such projects. There is a special focus on DFIs, as they are one of the expert groups.

D1 is considering the role of DFIs in financing feasibility studies or piloting projects and covering certain risks. Nevertheless, big financing is not recommended as DREs are supposed to be commercial operations which do not require much financial support by DFIs (D1, 1103-1112). This is supported by R1, who further adds that the community electrification part may be a project to be considered for DFIs, as those projects are not necessarily commercially feasible (R1, 1767-1775). R3 in contrast points out that DFIs can help out in instances where the local banking sector does not have the capacity to fund DRE projects. Further, as an IPP, R3 always consults with DFIs (R3, 2678-2681). D1 adds that DFIs are very much interested in sustainable projects which is why DRE deployment-projects are attractive to them (D1, 1179-1184). In contrast, D2, who works for a development bank, has not funded a DRE project yet (D2, 124-125). The interviewee also points out that DFIs require various aspects to be cleared when it comes to funding of projects. For instance, whether the local community benefits from the project, what the environmental implications are and if training measures for local people are carried out (D2, 630-638). This can create it difficult to get funding by a DFI, as the conversation is typically very large (D2, 373-377).

According to R2, DFIs indeed play a key role in DRE projects. He provides the example of successfully executed projects in Chile, in cooperation with the international development bank (R2, 674-679). M2 explains the role of DFIs as the following: “DFIs can offer a backup for a corporate lender. So they would offer a backstop to long term debt where a corporate lender could exit after a period of time and the DFI becomes the primary lender. The DFIs could also lend financial resources into the development process, if the mine did not have the capital to develop the projects upfront and take that risk, or they can secure funding from elsewhere. The DFI can potentially fund a portion of the development activities and either convert that into equity later or recover the success fee as project execution” (M2, 2303-2314). D1 adds that DFIs could also support the stakeholder dialogue (D1, 1103-1112).

ESG components are getting more important as millennials will become the next group of investors and they have a stronger interest in sustainable practices (R2, 807-810). M1 is pointing out that there are more and more institutions offering sustainable finance solutions or green loans and funds. Investors’ expectations in terms of sustainability, especially carbon footprint, are increasing (M1, 1443-1446). DREs may not only improve the relationship to investors, but sustainable practices could also be seen as a necessity to continue making business (R3, 2752-2759). M1 supports that view and provides the example of the mining company the respondent is working in, as BlackRock is one of the biggest investors in the company and has made it very clear that expectations with regards to sustainability are very high (M1, 1550-1555). As BlackRock being one of the largest asset management companies in the world, this statement gives an impression about current developments in the financial sector. The way mining companies are going to disclose their sustainability practices is important to attract investors. They have to be very well visible for investors (M1, 1564-1568).

There is also the option of communities participating in the investment and holding a stake in the power plant. In case the community is not able to finance it and the mining company has sufficient capital available, the mine can support it via a so-called vendor financing, to fund the community's portion on their behalf and recoup the original investment through the same way as a loan (M2, 2189-2194).

G2 mentions that the role of governments is very low when it comes to financing DRE projects in developing countries, as governments have limited financial capacities (G2, 3012-3017).

One of the main drivers is the cost of capital, as stressed by R3. There is the issue of lending based on a local country risk, where the cost of capital and the tariff goes up. This has a direct impact on the internal rate of return. He adds that anything which helps to reduce the cost of capital will have a major impact on the price of electricity. There are certain instruments on the market, such as political risk insurance, but they come with a relatively high premium (R3, 2707-2715).

In case a mine is not willing to or cannot spend its own capital, M2 recommends the option of engaging with an IPP and ensuring power supply via a PPA (M2, 2077-2081). Smaller mining companies with limited capital can request advisory services by the IPPs, whereas bigger mining companies have the resources to hire experts for sustainability and energy (M2, 2108-2112).

5. Discussion

The discussion part, similar to the results chapter, is also structured according to the categories. However, as it is meaningful to discuss some of the aspects together, certain categories are merged. The results are discussed by using the results from the literature review, case studies and the data gained in the empirical analysis. Each category which is discussed in this chapter contains arguments coming from another category to compare the statements.

5.1 Barriers

C1.1: Economic Barriers

The first and most mentioned economic barrier which was encountered is the size and life of the mine. This is a determining factor as it may not be cost efficient to invest in an energy plant which has a longer payback period than the actual lifespan of the mine. This fact poses the risk of a stranded asset (R1, 1647-1649; D1, 1133-1137; M2, 2086-2091). While the life of the mine is indeed a limiting factor for long-term investments such as DRE infrastructure, there are several solutions mentioned to overcome this barrier: Governments can reduce the risk of a stranded asset by setting a regulatory framework which allows energy trading. This would enable the mining company to create revenues even after the life of mine (M2, 2086-2091). Via properly negotiated terms in advance of the DRE construction, mining companies can agree to leave the power plant in the community and hand it over to either the national utility or the community itself after the life of the mine comes to an end (M2, 2205-2210). This would create value and job opportunities even beyond the life of the mine and eliminates the risk of a stranded asset (ibid.). A perhaps more risky opportunity is to let the community hold a share in the power plant. The case study in Australia proves that this option can work in practice. However, as Australia is a developed country, it should be at least questioned if such an approach would work in poor, rural areas of developing countries.

DFIs can play a role in risk mitigation, but they are more suited to support community electrification projects than DRE deployment in general (M2, 2303-2314 and R1, 1767-1775). As another option, mining companies can engage with IPPs and obtain DRE power through a PPA, which minimizes the costs of an initial investment and could therefore provide a possibility for smaller mines (R2, 488-493). The literature review has revealed further options such as industrial pooling, energy attribute credits or grid connected sourcing of green energy (CCSI, 2018, p. 27)

Land requirements are another economic barrier, as land has to be purchased or rented. This can indeed represent a huge barrier. Further, there has to be some land available nearby the mine to deploy DREs (D1, 1138-1148). As mining companies should engage with local communities anyway when it comes to DRE sharing, they may also negotiate access to land for the power plant. Alternatively, there is the opportunity to decrease the initial investment of land purchasing by renting land from the community, which in turn receives a share in the power plant.

Subsidized grids represent another barrier (D1, 1164-1173). This is however only applicable to certain instances where the national grid is available to supply electricity to mines and communities. In many off-grid scenarios, this is not a barrier which has to be considered, as there is no grid available. However, in cases where there is a subsidized national grid, it is very difficult to economically justify DRE projects. Nevertheless, it could still be cost efficient in case it improves reliability of power supply. In South Africa for instance, there are rolling blackouts throughout the country which has an impact on the economics of a mine and which is why DREs could still be sensible regardless of the fact that companies can negotiate electricity prices directly with the utility (D2, 421-428).

Renewable energies are naturally intermittent which is why there has to be a storage or backup (D2, 120-123). As put by some of the interviewees, battery storage, which is much more sustainable than diesel or gas based backups, is relatively expensive. Nevertheless, even if a DRE system is backed by fossil fuel generators, it is still an improvement of the sustainability and the economics of a mine, as at least some of the generators are replaced by DREs.

Sharing DRE infrastructure with communities would not be profitable in case the energy is provided for free (R2, 609). Selling the energy to communities has its own challenges, as they might already receive cheap or free energy from the grid, or are not able to pay for it. Only in cases where the community had no access to electricity before, communities might be willing to pay for the electricity, in case they have the financial capacity to do so. Due to the difficulties in selling energy to the community, it may be more meaningful for mining companies to share electricity for free or to engage in a contractual partnership with the local community as a joint-project.

With that said, it very much depends on the location, the condition of the community and the willingness of mining companies to execute a project which is not necessarily profitable in the first run, but will provide indirect benefits. As there is no business case when energy is shared for free, one could argue that it is not a CSV measure due to the missing profits. However, there are indirect benefits for the mining company, which are also creating financial gains, but it is difficult to measure their respective financial performance. In cases where there is an investment by the community themselves, or where the community pays for the energy and benefits also from accessing it, this could be considered as CSV. The case study in Australia provides an example for such an arrangement.

C1.2 Technical Barriers

As stated by various interviewees, there is a necessity to implement a storage solution into DRE systems, due to the intermittency of such power plants (R2, 1385-1388). There are many options to improve the reliability: Battery storage; fossil fuel based backups; national grid (in case it is available); and a combination of different DRE systems, such as solar, wind and hydropower. In the future, there might also be an option for green hydrogen (R2, 564-570).

It could be revealed that the technical barriers can be overcome with combining technologies and storage systems. However, this is dependent on the location, as there might not be sufficient water, wind or sunlight available, which does not allow such combinations. As many off-grid mines are currently running on fossil fuels (CCSI, 2018, p. 17), it should not be a huge barrier to have e.g. diesel generators as a backup, as these generators are on side already. They may not be the most sustainable solutions but in terms of cost efficiency (due to high investment costs of batteries), reliability and feasibility of such projects, they seem to be the best option.

C1.3 Regulatory Framework

There are some locations where the deployment of DREs is strongly regulated and sharing power with communities is not allowed (D2, 116- 118). The instance of South Africa provides a best practice example of how to unlock the deployment of DRE in a country. With the change of its regulation act, there is now an incentive for companies to deploy renewable energies as there is no necessity to obtain a license for power generation up to 100 MW. Further, they can sell excess power to industrial clients. However, the country is still regulated by the national utility ESKOM which has a monopoly status and constitutes a barrier to the economic efficiency of DREs. Further, in the instance of South Africa, it is not allowed to share power with non-commercial entities, such as communities (D2, 219-224). Reducing barriers in form of regulatory frameworks can be very challenging, as changing a law is quite extensive.

The literature review revealed further options which could be considered in case there are barriers in form of a regulatory framework. Mohapatra et al. (2021) demonstrate four approaches to share DRE, from which the first one is powering communities from the same grid. The second one, represented in the case study of the Fekola Mine in Mali, recommends that communities can be provided with a separate grid or mini-grids, not linked to the mine-grid. Thirdly, there is the option to feed into an existing local grid to improve reliability and sustainability. A fourth option would be to make use of emerging technology, such as the transformation of mines into a hydropower plant after closure. By choosing an appropriate option, barriers in form of a regulatory framework can potentially be overcome.

During the conduction of this thesis, it turned out that stakeholder management has also a great impact on the regulatory framework. As stressed by R3, markets for renewables in developing countries are often not liberalized as there is a national utility having a monopoly position (2564-2569). However, by engaging with the government and by negotiating with the utilities, improvements can be achieved which supports the deployment of DRE systems. Further, keeping the dialogue with the governments can remove potential bottlenecks such as delays in the permitting process.

When it comes to infrastructure sharing, it is important to create a framework which includes all aspects that could lead to potential risks, such as defined quantities. Besides, the framework should be developed by consulting all of the involved stakeholders, especially the community to ensure success of the project. Responsibilities of each party should be explicitly stated (R2, 632-636). An educational part is likely to be necessary, as represented in category 1.5, to ensure that all stakeholders are on the same track. As DRE sharing projects are relatively rare, learning from the best practice examples can play a key role in developing them.

The government plays a key role when it comes to DRE projects. The governmental representative of Liberia (G2) stated that an agreement prior to every mining activity has to be signed, which includes, among others, all aspects with regards to energy (G2, 2893-2899). Thus, considering DRE right from the beginning of a mining activity contributes to an easier implementation. D2 recommended linking a mining plan to a governmental and provincial plan, to ensure contribution of the mining activity to local and national development (D2, 250-261). However, there are still voices stating the more "liberal" approach, such as R1, who recommends having as little governmental interference as possible. Even if most of the interviewees agree with this statement, as most governmental regulations lead to neglecting DREs, many interviewees recommend to engage with the government for the implementation of DRE sharing projects. At this point, there is a differentiation necessary between DRE deployment and energy sharing projects, as for the deployment of DREs, the governmental role should be reduced to enable commercial operations. However, when it comes to sharing projects, the governmental role is very important to ensure a well-grounded conversation with other stakeholders. M2 added to the point that governments can eliminate the risk of a stranded asset by allowing energy trading (M2, 2266-2273). South Africa provides a practical example of a country which changed its regulations.

C1.4 Geography

Geographical conditions are very difficult to change or even impossible, which is why a mine has to deal with the environment it operates in. The effectiveness of DREs is limited by the geographical conditions. Before a mine considers to deploy DREs, it should check for land availability and engage with the community in case the land is in their ownership. The literature revealed that land requirements and resettlements are one of the key challenges in mining (see p.15). Through the deployment of DREs, this problem could even increase due to additional land requirements. Additionally, deforestation is another challenge which might occur if vegetation has to be cleared for the purpose of DRE deployment.

Also, the type of DRE is determined by geography. Decision making can be made either through consulting experts or an IPP, or in case the mine has sufficient capital it can hire experts to deal with the deployment of renewable energies (M2, 2108-2112).

Geographical barriers are difficult to overcome, however there are certain options. If, for example, the community is not closely located to the mine, it may be better not to decide for an energy sharing project which is powered from the same grid as the mine. Installing smaller micro grids in the village, like executed the Fekola Mine case study, can be much more efficient as there is no need to install a transmission line.

C1.5 Education and Skills

Including educational aspects into frequent stakeholder meetings to explain and clarify the benefits and risks or renewable energies is an effective measure to overcome educational barriers. As each stakeholder group has its own preconceptions and thoughts about the topic, it is important to educate communities, mining companies, governments and national utilities respectively, to remove their individual concerns.

The community group plays a special role, as there might be educational measures necessary to demonstrate the benefits and risks of DREs, as well as educating the community about the limits of DRE technology to avoid a skyrocketing energy demand.

Technical education and training of either mining staff or communities who are operating the plant is less of a challenge. At this point, an IPP or advisory service can provide the training. This is executed in the example of M1, who states that it is negotiated with the construction company to train mining staff to operate the plant (M1, 1333-1336).

5.2 Benefits and Risks

5.2.1 Communities and National Economies

There is the obvious benefit of access to energy, which subsequently brings a lot of benefits for communities, such as improved education, clean cooking opportunities or security. As access to clean and affordable energy is part of the

Sustainable Development Goals it has a direct impact to achieve no. 7, access to clean and affordable energy. It may also be an option to overcome the mentioned “Resource Curse”, as there is the opportunity to develop a domestic renewable energy industry as pointed out by M2 (2431-2442). Further, reliable and clean energy is very attractive to investors which therefore lead to more investments, economic opportunities, job creation and eventually economic development. Local skill development plays a key role as the construction and operation of DREs create jobs and can provide them to the community. There is even the option of value creating among the mining value chain by developing a refinery industry in the country (R3, 2805-2812 and M2, 2431-2442). Further, DREs increase national income via taxes, which in turn can enable governmental investments.

However, with all the direct and indirect benefits on the country and community level, there are certain risks which should be considered. Firstly, mine closure is one of the most impactful risks (R1, 1781-1782). This can even lead to a shutdown of the energy plant and therefore losing access to electricity. As this is a risk which is taken by both the mining company (stranded asset) and the community (electricity access), there should be even more attention drawn to it. Governments and DFIs can take the risk of a stranded asset to eliminate it.

Job creation during construction can be a challenge, as the jobs are limited in time until the plant is finally built (M2, 2183-2185). However, a mining activity, as well as a DRE plant present several more opportunities for communities nearby. For instance, providing services to the mine and its staff or selling products needed for the mining activity. Thus, even if there are job losses after construction of a DRE plant, the communities can still profit economically from a mining activity.

To eliminate the risk of competitive land-use, communities should negotiate that the mining company is going to compensate for potential losses of agricultural land, which is necessary for food production.

Dependence on the mine is another risk, as the mine can limit energy supply or even not provide it at all in case they need it for the operation. Therefore, quantities and responsibilities should be explicitly defined and written down to eliminate that risk.

5.2.2 Mining Companies

There must be differentiated between the benefits and risks of deploying DREs in general and sharing the infrastructure with communities.

DRE deployment:

It very much depends on the location, country and life of the mine whether an investment in DREs is sensible for mining companies. Generally speaking, DREs can decrease the costs of energy significantly, which has huge impacts on the economics of a mine (R3, 2512). Further is the decarbonization of mining activities not only beneficial in terms of stakeholder relations, but it is also a requirement of certain investors such as BlackRock, as mentioned by M1 (1550-1555). In case the mine priorly faced power outages, the installation of DREs combined with storage or backups improve the reliability of power supply and thus, decreases costs caused by power interruptions. In general, it can be argued that the risks of DRE deployment are relatively low, in case the due diligence process is conducted properly. However, there is the risk of a stranded asset after mine closure, which can be minimized by either selling electricity to the national grid (if available) or by sharing it with the communities (M2, 2266-2273). Important to mention at this point is that all interview groups stressed that the installation of DREs is in most cases sensible for the mining sector. This leads to the assumption that DRE deployment is generally beneficial to mining companies in the absence of a subsidized national grid.

Community sharing:

In contrast to DRE deployment in general, community sharing is associated with certain risks. Besides the benefits for mining companies, such as an improved relation to the community, or investor attraction, the risks seem to outweigh the benefits in certain circumstances. Sharing DREs from the same grid was criticized by many of the interviewees, either because it is not allowed from a law perspective, or because it might lead to potential problems (R1, 1720-1723 and D2, 219-224). To assess whether DRE sharing is beneficial for a mining company, the first question would be whether the mining company is providing the electricity for free. If so, there might occur problems such as migration to the area and a skyrocketing energy demand (D1, 1059-1065). Thus, providing energy for free would not present a business case for mining companies and would only give indirect benefits such as investor attraction. As CSV is associated with doing business while contributing to social development, providing electricity for free would not draw a clear line to a CSR measure as it does not present a business case.

In case the mining company is selling the energy to the community, there might occur the challenge of defaults on payments (R1, 1727-1735). This not only influences the economics of the project but also poses a threat to the mine as there is the question of penalties for not paying it. This could in the worst case scenario lead to unrest by communities, which is an event mining companies want to avoid. Further, the option of selling energy would not be recommended in cases where the community is already electrified and receives energy for free.

Providing the community with separate mini grids, such as solar panels on rooftops, like illustrated in the Fekola Mine case study, are associated with less risks for the mining company. As recommended by some interviewees, powering communities from a separate grid eliminates the risk of competitive energy use (R1, 1720-1723 and R3, 2649-2652). Such an option also provides the opportunity to sell the grid to the community and therefore could be considered as a CSV measure.

With regards to the mentioned approaches of DRE sharing by Mohapatra et al. (2021), the empirical part reveals that the second and third option – powering communities from a separate grid and feeding excess power into a local grid (if available) – are the best suited ones for the mining industry. Powering communities from the same grid as the mine, pose various risks but can also be an option if conducted properly. The fourth option of turning a closed mine into a power grid is in a very early stage and thus, not applicable for every mine.

5.3 Stakeholder Management

Managing stakeholders is key for both DRE deployment and energy sharing projects. The identified stakeholders in both projects are: Mining companies, communities, IPPs, governments, DFIs and national utilities, where applicable.

Engaging with each stakeholder from the beginning on is very important. When it comes to an energy sharing project, each stakeholder should be aware of their respective responsibilities in the project. It is also recommended to conduct a communications training to discuss clearly and sensitive, as the communities represent one of the key stakeholders to engage with (R2, 697-700). This is also stated by M1, who reports that there were community meetings held on a regular basis and a committee was established to make sure that the needs of the community are heard (M1, 1482-1488). This is a very efficient measure which is recommended to be implemented by mining companies and is helpful to eliminate the risk of rejection by the community.

It turned out that DFIs are more suited to finance energy sharing projects than the actual deployment of DREs, as this is supposed to be a commercial operation which should work without the intervention of a DFI (D1, 1103-1112). However, apart from supporting the project financially, DFIs can play a role as an educator for some of the stakeholders (R3, 2681-2683). As education is a key aspect which needs to be managed for each stakeholder, this could be an important support. As described earlier, the conversation with DFIs can be very extensive as there are various aspects needed to be negotiated. This is very important from a stakeholder management perspective, as it can potentially lead to project delays. Nevertheless, DFIs can be a key partner, even apart from financing a DRE project.

5.4 Financing

There are various options to finance DRE projects. A general finding is that investors and DFIs are more and more focusing on sustainability projects, which is why DRE deployment as well as energy sharing projects are well-suited to receive funding (M1, 1443-1446). Further, the empirical results reveal that DRE deployment may also become a requirement for mining companies to ensure future financing.

DFIs can secure funding for DRE projects, however, they should only engage in cases where commercial operations are not considerable or where the local banking sector does not have the capacity to fund such plants. Further, the project requirements of DFIs are relatively high. However, since energy sharing projects are covering various sustainability elements, the requirements are likely to be met. One of the most important possibilities for DFIs to engage in a DRE project is to mitigate certain risks as pointed out by M2 (M2, 2303-2314). It is important to notice that none of the case studies secured financing from a DFI, and none of the interviewees working at a DFI actually funded a DRE project. Thus, it can be concluded, that even if there is a potential, DFI engagement in DRE sharing projects is very low in practice.

Mining companies which are not willing or not able to provide their own capital for DRE deployment have various options such as engaging with an IPP (M2, 2066-2074). To minimize the risks of a DRE project, there is also the option to buy certain insurances on the market, which are covering political risks. Those insurances however, come with high premiums which are in turn increasing costs of a DRE project (R3, 2707-2715).

As mentioned by G2, governments in developing countries have very limited financial capacity to support such projects (G2, 3012-3017). DRE financing by governments might be inappropriate, as governmental funding should not support a commercial operation. The government should only intervene in larger infrastructure projects which have a community or country development aspect. If the government has not the financial capacity to support such a project, it could offer incentives such as tax breaks, which was done in the Lihir Mine case study. In contrast to the above mentioned statement of G2, the Kamoa-Kakula project provides an example where the government of the DR Congo holds a share in the power plant. However, it has to be mentioned that the Inga hydropower plant is the major source of energy in the DRC, which is why it is important from a governmental perspective to engage in that project. This example illustrates the importance of mining in certain countries, as major infrastructure projects are conducted as a response to mining activities.

The option of community participation in the investment is very efficient but difficult to execute as the community needs to have the financial capacity to invest in infrastructure. Thus, it might be a measure more suited for larger communities or cities in developed countries, which is underlined by the case study of 24 Solar in Australia. In poor and rural areas in developing countries, community funding can be very challenging. There is however the option of Vendor Financing, but this pose an additional financial risk to the mining companies.

6. Conclusion and Reflection

By conducting qualitative research, this thesis intended to find out how decentralized renewable energies can be applied in the mining sector and what the possibilities are to share them with communities. To do so, a literature review provided the groundwork and introduction to the issue, whereas best practice case studies illustrate examples from which future projects can learn. The empirical part identified barriers, risks, benefits, funding options as well as recommendations regarding stakeholder management.

Due to the complexity of the topic, there is evidently no general answer of the research question possible. The concept of shared value seemed to be a good option to orientate on when it comes to energy sharing projects, as there can also be some financial benefits for mining companies. However, this is highly dependent on certain circumstances and the definition of what can be considered as shared value. To answer the research question, the following section provides answers to the three guiding questions.

1. **What are the benefits and risks of DRE introduction and energy sharing in mining?**

The following tables illustrate the benefits and risks for mining companies and communities, as well as the benefits for whole economies. For the mining companies, the benefits and risks are split up according to DRE deployment in general and energy sharing.

Table 4: Risks and Benefits DRE Deployment (Mining Companies)

Mining Companies (DRE Deployment)	
Risks	**Benefits**
Failures in the due diligence process lead to insufficient power supply	Cost reduction
Transmission line could pose a potential risk	Decarbonization
Using the national grid as a backup will increase the costs of the grid	Lower logistical requirements (transport of diesel)
DREs may not be suited for underground mining without a very stable backup, as intermittency leads to serious problems	Improved reliability
	Potentially avoidance of carbon taxes
Potentially conflicting land uses can lead to conflicts with community	Control over energy supply
Stranded asset	Improved investor relations
	Mitigating climate risks
	Selling of sustainably mined minerals

Table 5: Risks and Benefits DRE Sharing (Mining Companies)

Mining Companies (DRE Sharing)	
Risks	**Benefits**
Risk of sabotage or theft resulting from governmental failures, despite having good relations	Improvements in ASM mining
The acceptance of the community is important to ensure successful project implementation	Effective risk mitigation measure
Increase of electricity demand by communities	Community acceptance
Risk of migration to the area	Improved reputation, public image
Managing expectations properly to avoid discontent by communities	Good opportunity to test out new technology
If communities pay for the electricity, there is the risk of a default on payment	
Potential trouble after mine closure due to community losses	
Risk of lacking acknowledgement by the community, if already electrified	
Providing electricity to communities may not be sufficient enough to satisfy stakeholders requirements regarding sustainability	

Table 6: Risks and Benefits DRE Sharing (Communities)

Communities (DRE Sharing)	
Risks	**Benefits**
Dependence on the mine	Via electrification, health, security and education can be improved
Mine closure: loss of jobs and even energy supply if mine is shut down	More autonomy of people's life, as they do not have to prioritize their electricity use
Huge job creation during construction but massive job losses afterwards	Job creation
Health and safety during work: Who is responsible in case of an accident?	Skills development
Power outages, if the mine requires more energy	Capacity building
Hydropower might compete with agricultural activities	Local economic development
Companies may not pay for caused damages and leave the community	Local procurement opportunities
	Local investor attraction due to peaceful community relations and sufficient energy supply

Table 7: Country Level Benefits

Country Level Benefits (DRE Deployment and Sharing)
Economic development
Potential to build up a renewable energy industry
Decarbonizing a whole country
Improved supply of national grid
Selling excess power to national grids fosters electrification of residential customers
Tax revenues
Job creation
Investor attraction as the country's energy supply gets more reliable
Electrification in ASM contributes to solve the problem of child labor

2. **What are major barriers of DRE introduction and energy sharing projects in mining?**

The following figure answers the second guiding question and illustrates the major barriers in DRE deployment and sharing, based on the results of the qualitative analysis:

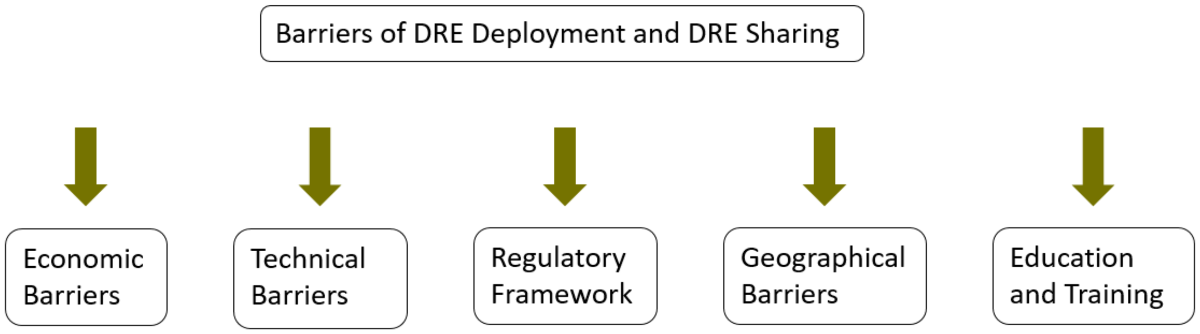

Figure 1: Barriers of DRE Deployment and Sharing

3. **What are the options / approaches to share DRE power with communities?**

The following graph gives an answer to the third guiding question and illustrates the approaches to electrify communities based on Mohapatra et al. (2021). Depending on the regulatory framework in the country of operating and the local circumstances, mining companies can choose the most appropriate option.

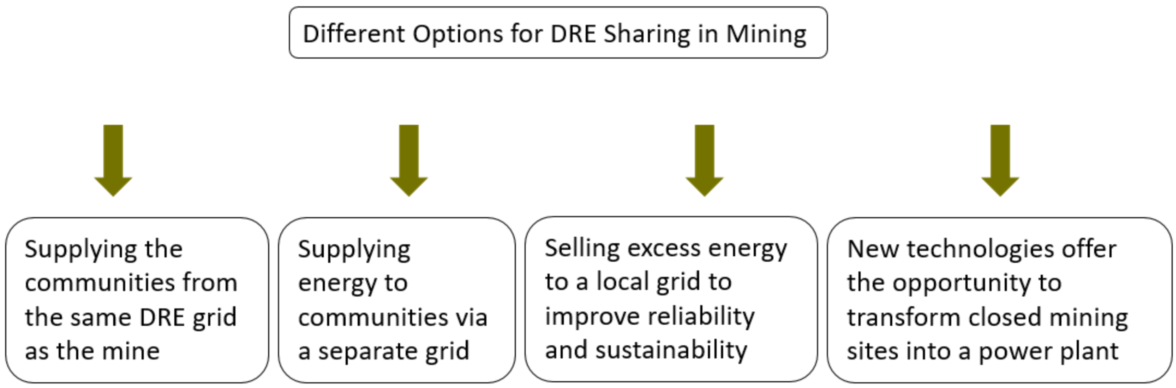

Figure 2: Approaches for DRE Sharing

The above listed graphs provide an answer to the main research question "**How can decentralized renewable energy solutions be applied in the mining sector and create shared value?".** Depending on different scenarios and circumstances, each mining company has to decide individually which approach is best-suited for their project. This thesis can support mines in their decision making process to accelerate and foster the deployment of DREs and community sharing projects. Due to the complexity of the topic, there are further aspects which emerged during the conduction of this thesis and are discussed in the following.

<u>How to finance a DRE sharing project? What is the role of DFIs?</u>

The literature review revealed that most mining companies invest in DREs using their own capital. PPAs provide a good option for mines with a lower financial capacity, whilst industrial pooling and other approaches are relatively rare. When it comes to sharing projects, DFIs can indeed play a role. As described, the deployment of DREs is mainly a commercial operation, which does not require interference of a DFI. As investors are more and more looking in the direction of sustainable projects, DREs provide a good opportunity for them to improve their own sustainability performance. Further, governments (e.g. via PPP) or even the communities themselves can provide capital to execute the project.

<u>Learning from best practice case studies:</u>

It is recommended to learn from the experience of best practice examples. The approaches of the case studies are backed up by the answers of the interviewees, who recommend similar approaches. One instance is the Kamoa-Kakula project in the DRC, which was developed under a PPP project and also recommended by the governmental representative of the DRC. The case study in Australia demonstrates that it is possible for communities to hold a share in the DRE plant, which was also mentioned by one of the interviewees. Further, the case study illustrate that sharing from the same grid is also possible. The Fekola Mine in Mali does not only provide an example of how to power communities from a separate grid, which was recommended by various interviewees, but also how to resettle a village successfully to the benefit of everyone. The Lihir Gold Mine in Papua New-Guinea is a very unique example, as the mine is powered by geothermal energy and provides electricity to the communities. The case study provides an example of how the government can create incentives in form of a tax scheme, which was also mentioned by the governmental representative of Liberia. Further, it proved that selling carbon credits on the international markets works and is profitable. The Raglan mine in Canada is an example using wind power, which is a technology that was criticized by one of the interviewees. Besides powering the mine and the community, the wind power does also provide jobs for the community. This project was also conducted with the support of the government.

<u>Is power sharing with communities a profitable business case for mining companies and can thus considered to be a good CSV measure?</u>

There are some cases, such as the Lihir Mine in Papua New-Guinea, where there is a direct profit for the companies (selling carbon credits). For the most cases however, there is not a direct profit. It generates rather indirect benefits such as attraction of investors or mitigation of protests, than it provides a business opportunity. The risks associated with selling power to communities exceed the potential profits in most cases. Nevertheless, after all that said, it is still recommended for mining companies to go into the direction of sharing projects but without the expectation of making direct profits out of a DRE project. By taking the right decisions, a sharing project can generate multiple indirect benefits, also for mining companies. Whether this is still considered to be a CSV measure depends on the interpretation of the definition. As electrification makes such a huge difference in people's life and as there are many indirect benefits for mining companies, which indeed have a positive effect on the economics, it can be argued that it is a CSV measure, even without selling power directly.

<u>Critical Reflection and future research:</u>

The results in this thesis do not represent the view of local communities when it comes to renewable energy sharing. As mentioned in chapter 3, an interview of communities was not possible due to current travel restrictions and lack of access to the areas. It is important to understand their view and role in the process. An in-depth analysis of the needs and roles of communities, with regards to DRE sharing projects would add more value to the results obtained in this thesis. Such an analysis would even be very helpful for mining companies and future projects to gain an improved understanding of the communities and solve possible lacks in communications.

As there is no specific country in focus in this thesis, the results are very broad. It may be meaningful to conduct an in-depth analysis of certain countries, as the different circumstances require different actions in DRE projects. Further analyses could be conducted e.g. in a country with subsidized grids, in another one where DREs are liberalized, or in another one where the inhabitants already receive sufficient amounts of energy. This would provide specific examples and could support mining countries operating in certain countries.

Good relationships are key:

Having good relations to the community around is still a determining factor which can decide about success or failure, not only of a mining project, but of a mining company in general. As mining activities are influencing the livelihood of communities very heavily, it can be seen as an obligation to compensate for all the changes and risks the communities are facing. With the global mining sector experiencing a push to act more sustainable, powering up communities is a good opportunity to prove that the mining sector can do more than conducting CSR projects: Building the cornerstone of a society to reach prosperity and economic development.

Literature

Adams, W. (2015). *Conducting Semi-Structured Interviews.* In Newcomer, K., Hatry, H., Wholey, J., *Handbook of Practical Program Evaluation (4th Edition, pp. 492-505).* Jossey-Bass.

Afrik21 (2021). *DRC: Inga II hydroelectric plant to power Kamoa-Kakula copper mine.* Retrieved January 15, 2022 from: https://www.afrik21.africa/en/drc-inga-ii-hydroelectric-plant-to-power-kamoa-kakula-copper-mine/

B2Gold (2019). *Responsible Mining Report. Community Owned Process Completion of the New Fadougou Resettlement.* Retrieved January 18, 2022 from: https://www.b2gold.com/_resources/reports/B2Gold-Responsible-Mining-Report-2019.pdf

Babidge, S. (2016). *Contested value and an ethics of resources: Water, mining and indigenous people in the Atacama Desert, Chile*. The Australian Journal of Anthropology (2016) 27, 84–103. https://doi.org/10.1111/taja.12139

Bird, F. (2014). *The Practice of Mining and Inclusive Wealth Development in Developing Countries*. In: J Bus Ethics (2016) 135:631–643. https://doi.org/10.1007/s10551-014-2378-2

BUND (2021). *Verschwindende Dörfer*. Retrieved January 17, 2022 from: https://www.bund-nrw.de/themen/braunkohle/hintergruende-und-publikationen/verheizte-heimat/verschwindende-doerfer/

CCSI (2018). *The Renewable Power of the Mine – Accelerating Renewable Energy Integration.* Columbia Center on Sustainable Investment, Columbia University.

CCSI (2014a). *A Framework to Approach Shared Use of Mining-Related Infrastructure.* Columbia Center on Sustainable Investment, Columbia University.

CCSI (2014b). *A Framework to Approach Shared Use of Mining-Related Infrastructure. Case Study: Mozambique.* Columbia Center on Sustainable Investment, Columbia University.

Collier, P. and Ireland G. (2016). *Shared-use mining infrastructure: Why it matters and how to achieve it.* Development Policy Review (2017) Overseas Development Institute. https://doi.org/10.1111/dpr.12231

Crane, A., Palazzo, G., Spence, L. and Matten, D. (2014). *Contesting the value of 'creating shared value'.* California Management Review, 56(2), 130-153. http://dx.doi.org/10.1525/cmr.2014.56.2.130

De los Reyes, G.; Scholz, M.; Smith, N. C. (2017). *Beyond the 'win-win': creating shared value requires ethical frameworks.* California Management Review, Forthcoming, INSEAD Working Paper No. 2016/67/ATL/Social Innovation Centre. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2848192

Deloitte (2017). *Renewables in Mining: Rethink, Reconsider, Replay – More than just a cost play, renewables offer a distinct competitive advantage*. Thought Leadership Series. Vol. 2. Published by Deloitte Touche Tohmatsu Limited.

DeVault, M. (1995). *Ethnicity and Expertise: Racial-ethic knowledge in sociological research*. Gender and Society, 9, 612 – 631. https://doi.org/10.1177%2F089124395009005007

Devenin, V. (2018). *Collaborative community development in mining regions: The Calama Plus and Creo Antofagasta programs in Chile.* Resources Policy. https://doi.org/10.1016/j.resourpol.2018.10.009

Dresing, T. and Pehl, T. (2018). *Praxisbuch Interview, Transkription and Analyse*. Anleitungen und Regelsysteme für qualitativ Forschende. 8. Auflage. Marburg, 2018.

Ericsson, M. and Löf, O. (2019). *Mining's contribution to national economies between 1996 and 2016.* Miner Econ 32, 223–250 (2019). https://doi.org/10.1007/s13563-019-00191-6

Flick, U.; Kardorff, E. von; Keupp, R.; Rosenstiel, L. von; Wolff, S. (1995). *Handbuch qualitative Sozialforschung : Grundlagen, Konzepte, Methoden und Anwendungen*. Aufl.- Weinheim: Beltz, Psychologie-Veri.-Union, 1995.

FSG (2022). *Shared Value.* Retrieved January 15, 2022 from: https://www.fsg.org/areas-of-focus/shared-value

GHGprotocol (n.d.). *FAQ*. Retrieved January 15, 2022 from: https://ghgprotocol.org/sites/default/files/standards_supporting/FAQ.pdf

Ghorbani, Y. and Kuan, S. H. (2016). *A review of sustainable development in the Chilean mining sector: past, present and future.* International Journal of Mining, Reclamation and Environment. https://doi.org/10.1080/17480930.2015.1128799

Harvard (2022). *The Atlas of Economic Complexity*. Retrieved January 17, 2022 from: https://atlas.cid.harvard.edu/explore

ICMM (2020). *Role of Mining in National Economies. Mining Contribution Index (MCI) 5th Edition*. International Council on Mining & Metals, London.

IEA (2021). *The Role of Critical Minerals in Clean Energy Transitions.* International Energy Agency. World Energy Outlook Special Report. Retrieved January 24, 2022 from: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

IFC (2019). *Local Benefit Sharing in Large-Scale Wind and Solar Projects*. International Finance Corporation, Washington DC. Retrieved January 22, 2022 from: https://www.commdev.org/wp-content/uploads/2019/06/IFC-LargeScaleWindSolar_Web.pdf

IMF (2020). *Dutch Disease: Wealth Managed Unwisely.* Retrieved January 20, 2022 from: https://www.imf.org/external/pubs/ft/fandd/basics/dutch.htm

Ivanhoemines (2021). *2021 News*. Retrieved January 15, 2022 from: https://www.ivanhoemines.com/news/2021/kamoa-kakula-joint-venture-signs-agreement-with-the-drcs-state-owned-power-company-to-upgrade-turbine-5-at-the-inga-ii/

JISEA (2020). *Integrating Clean Energy in Mining Operations: Opportunities, Challenges, and Enabling Approaches*. Joint Institute for Strategic Energy Analysis. Retrieved January 15, 2022 from: www.nrel.gov/publications

Joint Research Centre (2021). *World Atlas of Desertification – Mining*. Retrieved January 18, 2022 from: https://wad.jrc.ec.europa.eu/mining

Kuckartz, U. (2014). *Qualitative Inhaltsanalyse. Methoden, Praxis, Computerunterstützung*. Beltz Juventa, Weinheim, Basel, 2. Auflage

Liel, B. von (2016). *Creating Shared Value as Future Factor of Competition Analysis and Empirical Evidence. Wirtschaftsethik in der globalisierten Welt*. Published by Ch. Lütge, München, Deutschland. https://doi.org/10.1007/978-3-658-12603-2

Lodhia, S. K. (2020). *Mining and Sustainable Development Current Issues.* Routledge Studies of the Extractives Industries and Sustainable Development. Taylor and Francis Group.

Mayring, P. (2014). *Qualitative content analysis: theoretical foundation, basic procedures and software solution*. Klagenfurt. Retrieved January 25, 2022 from: https://nbn-resolving.org/urn:nbn:de:0168-ssoar-395173

McKinsey (2020). *Climate risk and decarbonization: What every mining CEO needs to know.* Article January 28, 2020. Retrieved January 15, 2022 from: https://www.mckinsey.com/business-functions/sustainability/our-insights/climate-risk-and-decarbonization-what-every-mining-ceo-needs-to-know

Mohapatra, D.; Moyo, S.; Kuranel, R. (2021). *Decentralised Renewable Energy Solutions for Inclusive and Sustainable Mining Decarbonising the Mines and Powering up the Communities*. Published by UNIDO (United Nations Industrial Development Organization)

Natural Resources Canada (2021). *Canada Invests in Wind Energy to Reduce Diesel in Northern Quebec.* Government of Canada. Retrieved January 18, 2022 from: https://www.canada.ca/en/natural-resources-canada/news/2021/03/canada-invests-in-wind-energy-to-reduce-diesel-in-northern-quebec.html

Pegg, S. (2006). *Mining and poverty reduction: Transforming rhetoric into reality.* Journal of Cleaner Production 14 (2006) 376-387. https://doi.org/10.1016/j.jclepro.2004.06.006

Poncela, P.; Senra, E.; Sierra, L. P. (2016). *Long-term links between raw materials prices, real exchange rate and relative de-industrialization in a commodity-dependent economy: empirical evidence of "Dutch disease" in Colombia*. https:/doi.org/10.1007/s00181-016-1083-7

Porter, M. E. and Kramer, M. R. (2011). *Creating Shared Value – How to reinvent capitalism – and unleash a wave of innovation and growth*. Harvard Business Review Magazine January-February 2011.

Smith, J. M. (2017). *From Corporate Social Responsibility to Creating Shared Value: Contesting Responsibilization and the Mining Industry.* In Competing Responsibilities, Duke University Press. https://doi.org/10.1515/9780822373056-006

Statista (2021a). *Major countries in copper mine production worldwide from 2010 to 2020.* Retrieved July 21, 2021 from: https://www.statista.com/statistics/264626/copper-production-by-country/

Statista (2021b). *Major countries in worldwide cobalt mine production from 2010 to 2020.* Retrieved November 11, 2021 from: https://www.statista.com/statistics/264928/cobalt-mine-production-by-country/

Taylor, S. J.; Bogdan, R.; DeVault, M. (2015). *Introduction to Qualitative Research Methods: A Guidebook and Resource.* John Wiley & Sons, Incorporated.

The Warren Centre (2020). *Zero Emission Copper Mine of the Future*. Retrieved January 19, 2022 from: https://www.sydney.edu.au/content/dam/corporate/documents/faculty-of-engineering-and-information-technologies/industry-and-government/the-warren-centre/zero-emissions-copper-mine-of-the-future-report-1-the-warren-centre.pdf

UNDP and UN Environment (2018). *Managing mining for sustainable development: A sourcebook.* Bangkok. United Nations Development Programme.

UNIDO (2016). *World Statistics on Mining and Utilities 2016.* United Nations Industrial Development Organization.

Witzel, A. (2000). Das problemzentrierte Interview. Forum Qualitative Sozialforschung / Forum: Qualitative Social Research (ISSN 1438-5627), Volume 1, No. 1, Art. 22. https://doi.org/10.17169/fqs-1.1.1132

World Bank (2021). *Report: Universal Access to Sustainable Energy Will Remain Elusive Without Addressing Inequalities.* Retrieved January 17, 2022 from: https://www.worldbank.org/en/news/press-release/2021/06/07/report-universal-access-to-sustainable-energy-will-remain-elusive-without-addressing-inequalities

World Bank (2020). *Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition.* International Bank for Reconstruction and Development / The World Bank, Washington DC.

World Bank (2017). *The Growing Role of Minerals and Metals for a Low Carbon Future*. International Bank for Reconstruction and Development / The World Bank, Washington DC.

World Bank (2015). *The Power of the Mine – A Transformative Opportunity for Sub-Saharan Africa.* International Bank for Reconstruction and Development / The World Bank, Washington DC. https://doi.org/10.1596/978-1-4648-0292-8

World Gold Council (2021a). *Gold mine production*. Retrieved July 21, 2021 from: https://www.gold.org/goldhub/data/historical-mine-production

World Gold Council (2021b). *Gold and climate change: the energy transition*. Presentation at the Energy and Mines Africa Virtual Summit 2021.

Annex

Annex I: Reference to Data

Category	*No.*	*R*	*Line*	*Paraphrase*	*Generalization*
C1.1	1	D1	1133-1137	If you have a small mining operation I think DRE may be much more difficult to install than when you have a really large scale operation with 10 or 20 year operational horizon that can afford to install DRE on a large scale and over the operational time, it amortizes and becomes cost effective.	Size of the mine is a determining factor for cost effectiveness.
C1.1	2	D1	1138-1148	DRE installations need lots of land. Availability of land is going to be a huge part. So the question is, if mining companies can afford or are prepared to or are supported in purchasing or leasing or using sufficient amounts of land to do these installations. So that could also be a very important factor that makes an operation viable or not.	Purchasing or renting land is a very important economic barrier.
C1.1	3	D1	1164-1173	If you have reliable, cheap power from the grid, and if that actually is not too carbon intensive then why should you make this huge effort and use DRE? So there may be economic and technical situations where DRE does not make sense.	Cheap and clean grids can be more cost effective than DRE solutions.
C1.1	4	D2	120-123	Maybe renewables with some battery, but then they need to weigh up the costs of that and they are saying, no, they would rather do biomass or gas.	Battery storage is expensive compared to biomass or gas.
C1.1	5	D2	238-240	So a mining house that makes profit of three billion euros and one that makes one million euro – they are not going to provide the same amount of a social compact.	Smaller mining companies have limited capacity to provide social compact.

C1.1	6	D2	308-313	I do not see them wanting to pay a mine to provide them with electricity. And I am saying this purely from the South African model that I have seen where people do not even pay the national utility. But perhaps when the electricity is reliable, maybe they might. And if it is reliable and it is steady and it is cheaper than the national utility, they might even protect that investment.	In South Africa, many people do not pay the national utility. Thus, it is unlikely they would pay for shared DRE infrastructure. Maybe they will pay if it is reliable. In cases where DRE is cheaper than the utility, they might be willing to pay and then even protect this investment.
C1.1	7	D2	356-360	It is also the tariffs that they are able to get. Because if the tariff is not favorable, then the mine is not going to go ahead for the most part. They can go ahead simply for novelty reasons or for wanting to reduce the carbon capture, but for the most part, they will not do it.	Tariffs are an important barrier, as mines will not do a DRE project without getting favorable tariffs.
C1.1	8	D2	421-428	This is why there has been such a limited uptake of distributed generation, especially in industrial complexes. If you look at the future electricity price modeling, then, yes, it makes sense to invest now so that in five, six, years' time when the national grid is expensive, your product is not as expensive. But if you are talking about right now as a point in time, perhaps it is not the best option. And this is why so many of these mining houses have been holding back. Because it really does not make sense to us because we are able to negotiate bilaterally with the utility itself.	In South Africa, DREs might be sensible in the future as prices of the national utility are increasing. However, at this point in time, it is not cost efficient. The national utility is often the best option, as industrial clients can negotiate bilaterally with the utility.
C1.1	9	R2	560-563	The volume size is the main, I do not know if Barrier, but probably the first point of analysis and evaluation in terms of how feasible is it? How practical is it? And what is the opportunity cost of adopting this solution versus another? How can we sort of look for hybrids, et cetera?	The size of the mine is a determining factor of how feasible and practical an investment is and what the opportunity costs are.
C1.1	10	R2	609	So I think that it is not necessarily profitable. Probably not.	Sharing DRE infrastructure is not profitable, if provided for free.

C1.1	11	R1	1812-1814	I would say unless you are in the polar latitude, it is virtually universally cost saving. With the exception of countries where there is subsidized electricity prices.	Subsidized electricity prices cause DREs to be uneconomically.
C1.1	12	R1	1831-1837	There is typically a state owned power company. They are running at a deficit when they do this. And then that deficit gets picked up somehow differently through tax or whatnot. But so long as you have that subsidized rate then investing in renewables does not pay off.	State owned utilities with subsidized electricity prices cause DREs to be uneconomically.
C1.1	13	R1	1850-1857	If the grid becomes 90 or 100 percent available, all of a sudden you are paying a premium for the solar power plant. Same from our side. If I would make the investment in the solar plant and only sell electricity to a mine, even with fixed rates, I am not sure I would want to do it because I would know that half the time and possibly in the future that mine would be paying me a premium and at some point they might change their mind. So there is a risk in that.	Availability of the grid determines the effectiveness of solar plants, as accessing power from the utility might be more sensible in that case.
C1.1	14	R1	1647-1649	And a hurdle is on the commercial side, the payback period of making the investment in renewables compared to what the lifespan of the mine might be.	The life of a mine might in some cases not be aligned to the business model of renewable energy providers.
C1.1	15	M2	2042-2048	The timelines to develop these projects are typically quite long. It is largely driven by the scale and your jurisdiction you are operating, where there may be requirements around authorizations if you need in order to put these types of projects in place. But typically, the project development timelines before we even begin construction can be anywhere between 12 to 24 months, and then there is a construction period of a further 12 to 24 months depending on the technology.	Timelines of renewable energy projects are quite long, which is a determining factor as the life of certain mines is not aligned to that.

C1.1	16	R3	2726-2731	Is newly built solar so much more expensive than a newly built hydropower plant or thermal power plant? And I do not think it is. But the benchmark on the off taker side is always the current price of the grid supply power. That is kind of from a business development point of view, from a sales point of view, a difficult benchmark, because we cannot achieve $1 cent in Zambia with a newly built solar plant.	Newly developed solar plants are not much more expensive than hydro or thermal ones. However, competitiveness of solar plants decrease with subsidized grids.
C1.1	17	M2	2034-2037	I think the third challenge is funding them. They typically have quite long payback periods in order of four to seven years. When you have a shorter life of mine that then trades off of capital expenditure on other items that could potentially have a better return versus that becomes an inherent strategic conflict.	An economic barrier is the payback period of DREs as they might be longer than the actual life of the mine.
C1.1	18	G1	3219-3220	A big challenge that I would also like to mention is the cost of beginning the installation of the energy to make it operational. It will be a big puzzle.	Installation of the DRE is a challenge.
C1.1	19	G1	3328-3329	When you get installed, get the source to install the plants, yet the plant can cost too much.	High investment costs.
C1.2	20	D1	924	I think the technical risks are a fairly small hurdles.	Small technical hurdles.
C1.2	21	D1	922-924	It is always good to have your own little energy mix on site. So to combine solar with, hydro and maybe still have a big tank of diesel for emergency power.	Diversification of energy sources.

C1.2	22	D1	987-989	I guess for mining companies, as for many other industries, as for public goods, renewable energy makes sense if you combine it with big storage potential.	Combination with storage solutions is recommended.
C1.2	23	D1	1005-1007	You always have to combine it with some sort of storage because inevitably you have nighttime, some bad weather, you have some cloud cover.	Storage is necessary to ensure steady supply with DREs.
C1.2	24	R2	564-570	And you can definitely combine technologies. Green hydrogen is definitely going to be a very important source for leading an energy transition within the operations and storage technologies as they are advancing and being more competitive and more realistic opportunities to implement. I would say that renewables plus storage are definitely solutions to power mining sites and mine operations for sure.	Combination of storage and DRE is a solution to overcome technical barriers. In the future, green hydrogen is also going to be an important source.
C1.2	25	M1	1385-1388	As we look towards the future to solutions like battery storage, where we can store the energy, given that the sun, to your point, does not shine all the time. I think there will be developments that will come and overcome some of these technical challenges.	Storage is a solution to overcome technical challenges.
C1.2	26	R1	1696-1698	The wind energy, forget it, because for that to work at a cost competitive level, it has to be large wind turbines, which then logistics servicing and whatnot.	Wind is uncompetitive as large wind turbines require logistic and service.
C1.2	27	R1	1702-1707	The only technical complication is there need to be a decent amount of reserve load kept on the generators during the daytime. Then, whenever there is no sunshine, they are 100 percent on generator. Technically, it could be possible to make batteries into this, to increase the solar share, but then you very quickly run into financial trouble as solar plus battery will simply cost more than diesel.	A backup is needed to ensure steady supply. However, battery storage is more expensive than a diesel backup.

C1.2	28	M2	2018-2025	The renewable energy technologies, specifically zooming into solar and wind are intermittent. So you cannot rely on them solely, they need to be in combination with either storage and micro-grid solution or grid backup to supply the balance of your power requirements. So that is really one of the key issues, and there are some technological solutions to that. But as soon as you start combining them, you can potentially increase your costs of supply, like through deployment of storage, etc.	24 hour supply can be ensured with storage or fossil fuel alternative backups, which are in turn increasing your costs.
C1.2	29	M2	2131-2139	I think the third biggest concern after land resource, is electrical interconnectivity. It is to what extent you can technically tie these renewable energy projects into your own operations. And then the fourth one would probably be your own load profile. So matching your load profile with the generation profile. So it can only displace a certain portion of your energy requirements, but you need to have a sort of backup facility or something that will continue to provide a balance of power requirements.	Renewables can only displace a certain portion of the energy requirements and the mines load profile has to be matched to the generation profile.
C1.2	30	R3	2586-2588	Intermittency is one of the challenges of course. Most mines have a very stable load profile, they operate equipment that is probably quite sensitive to intermittency and to power quality issues.	Intermittency is one of the biggest challenges as the equipment of mines is very sensitive to power quality issues.
C1.3	31	D1	1088-1092	The government should provide an enabling framework and allow it, but also regulate in a way that communities are protected. That expectations are clear, that rights are clear, that community obligations are clear, that quantities are defined, the tariffs are defined, if there are any. So the government, I think, has an important role in creating the regulatory framework.	Government should set the regulatory framework and regulate that communities are protected, expectations are clear, quantities are defined and tariffs defined.

C1.3	32	R2	651-654	I would say that at a national level, it is important to definitely have a clear long term vision of where we want to go regionally, understand how in this specific region, geographically, socially, demographically, all of the variables of the particular region, how we can apply and put in practice this long term vision.	A clear long term vision provides a ground for future projects.
C1.3	33	M2	2266-2273	They should actively be looking at how they unlock renewable energy for mines in their countries. So what enabling infrastructure is required: do they need to invest in the local grid local protection and monitoring and control systems to neighborhoods? They should consider the likes of opening up a grid to allow for energy trading wheeling such that the risk of a stranded asset becomes null.	Governments should intend to unlock DRE for mines in their countries. They could e.g. Decrease the risk of a stranded asset by allowing energy trading which ensures that the asset can be used beyond the life of a mine. Further, they should enable required infrastructure.
C1.3	34	R1	1757-1760	My take is that the government should just stay out of it as much as they can, because it will work. If governments were to mandate this like the local community part, I think it just convolutes their investment and so on. My personal preference is less government.	Less governmental interference as possible.
C1.3	35	R2	744-746	The most important part for the success of any solution, whether shared or not shared, is a governance administration and very clear responsibilities of all the involved parties.	Governance administration and clear responsibilities of all parties are key.

C1.3	36	D2	250-261	There should be a mining plan linked to a government industrial plan, linked with a municipal or provincial plan. And any new mine operating in that area has to act according to the mining plan, plus the provincial plan, as well as the national and industrial plan. And you are able to then filter down all the things that you have to do and it should be captured there. And government should set clear targets and say, if you want this mining license, you will have to build a school, build a training college, you will have to train 1000 local people, you will have to hire from the local area.	
C1.3	37	D2	116-118	So the first problem that many mines are going to encounter, and this is why I have not seen a great uptake of renewable energy, is because they need a certain law.	A certain law is necessary to install DREs, which is why in South Africa is not a great uptake.
C1.3	38	D2	151-156	Just yesterday, they launched the 100 megawatt regulations, which is an amendment to the schedule two of the Electricity Regulation Act, where previously any project about one megawatt needed a generation license. Now, any project up to 100 megawatts do not need a generation license anymore. So they are definitely going into that market and they will be aggressive about it.	Less strict regulations to install DRE solutions foster an uptake of such systems. In South Africa the newly established 100 MW regulation is a good example.
C1.3	39	D2	219-224	What is going to become interesting with the publishing of the schedule to electricity Regulation Act, is that these mining houses now can sell to the municipality. If they have excess capacity, they can sell to the municipality, they can also sell to other mines around them. However, it still does not allow them to sell to residential uses. And that has always been the case.	With a change of the regulation act, mining companies now have the option to sell excess power to the municipality or industrial clients. However, it is still not allowed to provide energy for residential uses.

C1.3	40	D2	225-230	The mine will provide solar panels to a nearby school, for instance, or a clinic that operates daytime. So during the day, they will always have electricity. And obviously, after five or six p.m. it is dark, but that is fine because the schools are also empty at that point. So I have seen that. But I have never seen a grid-tied transmission or distribution between a community and a mine. I do not think the regulation allows in many countries.	As regulations in many countries do not allow, mining companies can power facilities of the community from a separate grid (e.g., provide solar panels to a school).
C1.3	41	R2	632-636	I would say maybe sort of governance and administrative issues regarding sharing infrastructure. I mean, where do you draw the lines between? To what extent? Who is responsible? And what if it fails and people are out of power? You are the one responsible? Or is it because their consumption is not proper to the power source we have, et cetera, et cetera?	Administrative issues and governance are key barriers. Where do you draw lines? To what extent? Who is responsible? What happens if people are out of power?
C1.3	42	M1	1321-1326	Right now we are looking to get permitted to construct the plant. And so for us, there is a bit of a challenge in that, not what we expect. We have been working very well with the regulators but certainly that is something that we need to receive before we can construct the plant.	Permitting and delays in projects can present a certain risk.
C1.3	43	M2	2039-2041	In certain jurisdictions like South Africa, there are some policy and regulatory restrictions around deploying private power generation. And that just adds another level of complexity.	In South Africa, there are regulatory restrictions in place, hampering deployment of private power generation.
C1.3	44	M2	2173-2175	In a South African context, the regulations actually prohibit you from distributing energy to non-mine linked entities without getting ministerial permission. By law, we cannot actually share any power for free unless we sought a governmental approval.	Without a governmental permission, energy cannot be shared to non-mine linked entities.

C1.3	45	R3	2564-2569	And this is one of the major hurdles for our business development, that in most countries, especially on the African continent, you do not have liberalized markets. So DREs are often not allowed from a regulatory point of view, or are limited in size up to a certain maximum capacity you can construct and operate on site or off site. But the threshold is usually rather low. So it does not really make sense to pursue that opportunity for the mining companies.	Markets for renewables are not liberalized in many African countries. They are not allowed, limited in size or capacity.
C1.3	46	R3	2622-2627	Some countries have a very, very rigid legal framework, prescribing these measures that are just described. For example, South Africa has that, but in other countries, which do not have those strict guidelines, we try to engage with the community and provide various levels of community benefits to the community in the surrounding area.	Some countries such as South Africa have strict guidelines on how to let communities benefit from the projects, but in other countries mining companies are left on their own decisions.
C1.3	47	R3	2662-2668	We do need a reliable framework in the countries that we are operating that allows private IPPs to supply power to private off takers. In most countries, we still have a very strict monopoly, whereas a government controlled utility basically controls the entire electricity sector. And in that kind of environment, it is often difficult to negotiate such a DRE installation and operation. So we need to have a conducive legal framework that allows these business to business transactions in the power sector.	IPPs need a framework which allows them to engage with private entities and to supply them with energy, as often a state owned utility has a monopoly position.
C1.3	48	G2	2893-2899	So normally, if it is an industrial mining operation, before you are granted the license to mine, we do a mineral development agreement. And so in any mineral development agreement, the terms are still out. So if you were to make use of the government's energy sources, it is stated. If you want to establish alternative energy sources, it is stated and all of those negotiations. So nobody does a thing that is pre-discussed ahead of the mining operations.	In Liberia, a mineral development agreement has to be granted before a mining activity can start, where every action including use of electricity is stated.

C1.3	49	G2	3077-3079	No, for Liberia, we do not have such law. Before you build any plant, you have to negotiate that with the government. We do not have any benchmark. We do not have such a law.	In Liberia there is no limit to private owned power plants, however, it has to be negotiated with the government in advance.
C1.3	50	G1	3170-3174	I think the big challenge accordingly can be the problem of the law. When SNEL or other state companies will see that mining begins to make their own source of energy, it can create more challenges in the process. But it is something which is not refused.	Issue with the national utility SNEL in the DRC and the regulatory framework.
C1.3	51	G1	3279-3282	But when they begin activities, usually you are not going to do it. And when they do it, it must be mentioned in their documents. But when they do it, they must pay taxes according to that act. It will not be involved in the tax of the mining sector. It must be apart.	Taxes have to be paid for the mining activity and separately for the power plant, which is a barrier.
C1.4	52	D1	896-903	It really depends where the mining operation is located. If it is in some isolated area, where public power grids are unreliable or where you have no public power grid, then DRE solutions might be the only thing available. In other situations, you may have a stable grid with fairly cheap electricity access. You may be able to negotiate special tariffs with the utilities. And in those cases, DRE solutions are probably not competitive and therefore not really interesting.	Location of mine and availability of a cheap and reliable grid determines competitiveness of DRE.
C1.4	53	D1	937-939	Well, geography plays a huge role because it influences very much. So the exegetical dynamics that surround the mining operation, meaning, the wind, solar radiation, the availability of running water for hydropower.	Geographical conditions determine if and which DRE solutions are sensible.

C1.4	54	D1	1009-1013	You have countries where you have wonderful flow rates in spring and in summer, fall and winter the river is almost dry. So in that case, mines usually have a big reservoir of storage. But in hydropower, you can also have a storage facility and a generator.	Hydropower can also be unreliable due to changing water levels over seasons, thus needs backup.
C1.4	55	M1	1363-1366	In Mexico, where the sun shines a lot, solar makes good sense for us. I know from a previous company I was working at, we had a mine in Newfoundland on the coast of the Atlantic where the wind blows a lot and so, that company was looking at wind as a possible solution.	Depending on the area, a respective DRE solution is sensible.
C1.4	56	R1	1651-1655	For a megawatt of solar power we need about seven thousand square meters of space on the ground. That space needs to be available and then it needs to be fenced in. Might need some preparation, some deviling and so on depending on what country you are in that requires some environmental permits too.	Space is determined by the location of the mine and access to it is also depending on to whom the land belongs to and if environmental permits are necessary.
C1.4	57	M2	1990-1992	And most mining operations are depend on like you said, the geography where They are located but in some instances there are grid tied and other times they are not.	The geography of a mine also determines whether they are on or off grid.
C1.4	58	M2	2121-2123	I think the biggest one upfront is your natural resources that you have available to you. That would be a key determining factor right up front. And that would depend on where your mind is located in the world.	The available resources necessary for DRE (wind, sunshine, water) are dependent on geography.

C1.4	59	M2	2152-2160	Types of land are also important as well as a suitable topography and geotechnical conditions. So if you are in a particularly hilly area that is heavily vegetated, it is going to be very difficult to deploy the likes of solar. And you also need certain ground conditions to sort of bring down the costs of deploying solar for your operations. If you operate hypothetically in Central Africa in a rainforest, it can be difficult to sort of motivate clearing of rainforests for solar PV.	The topography of the area (hills etc.) and geotechnical conditions can be a barrier to install DRE solutions. Additionally, the vegetation on the area is an important factor, as it might not be sensible to clear a rainforest for the purpose of solar panels.
C1.4	60	R3	2634-2637	Sharing the power infrastructure directly depends a little bit on the distance, of course. If the next village, for example, is 10 kilometers away from the solar park which is providing power to the mine, sharing the infrastructure may not be the most economical way to provide power to the community there.	Sharing DRE infrastructure is dependent on the distance of the community to the power plant, as this impacts costs.
C1.4	61	G1	3206-3209	It is not easy because maybe you are going to look for a river, which can be at a distance to the mine to transport that energy to the site. It is also another challenge, to transport that quantity you are producing. You know, they also must make many technical processes, which cannot be easy to establish.	Transport of energy as well as transport of equipment itself is also very dependent on the location, which is a determining factor here.
C1.5	62	R2	717-722	And you go from four hours of electric energy a day to 24 hours, you start expanding your energy use and get new electric appliances. But businesses start growing so in return the energy demand definitely increases and that is where it is very important to accompany the technology and infrastructure project with the educational part of it.	It is necessary to educate the community, as well as the mine about the limits of renewable energies. As energy demand is going to increase as a consequence of shared power, this can lead to serious issues.

C1.5	63	M1	1326-1329	Any new technology that you bring on, we are going to make sure that our employees are trained to use it properly and know how to use the new equipment. That will be a bit of a change management piece in there.	Training of mining personnel to properly use the new technology.
C1.5	64	R1	1680-1685	The benefits to them are substantially larger than the general market. And then much of the mining sector – the ones that are on site processing, so the precious metals guys – they are also particularly well suited to renewables because they run seven days a week. So despite being very good clients who stand to benefit among the most out of any potential clients, they tend to be slower adopters than many other clients.	Lack of awareness by mining companies with regards to the benefits of renewable energies lead to slow developments of DREs.
C1.5	65	R1	1662-1664	Objectively it does. So from our experience, some mine operators are not very clear on what their diesel generation really costs them per kilowatt hour. Some underestimate that.	Underestimations of the mining sector with regards to calculating costs of diesel generators.
C1.5	66	M2	2105-2108	I think the trick or the difficulty for mines is sort of no size and the specialist skills that you require in order to develop these projects yourself. It is quite a niche sort of field from a mining perspective to develop renewable energy projects, it is not core business.	As renewable energies are not core business of mining companies, skill development is necessary.
C1.5	67	R3	2531-2535	So there is a concern on their end that their machines and their equipment will not be able to operate flawlessly based on a solar generator or solar power provided to them by the mine. So there is a fair amount of education required, you cannot always convince everyone on the operative side of the mines. That is a major, major hurdle there.	Concerns of the mining sectors leading to neglecting DRE solutions. Education is required to convince those companies.

C1.5	68	R1	1645-1647	The risks – there is always a concern from mines if DREs are going to mess up my electrical setup and so on. That is a perceived risk, it is not an actual risk, in my opinion.	Mines are often convinced that DREs are messing up the electrical setup, even if R1 thinks this is not an actual risk.
C1.5	69	R3	2619-2622	That would include a certain degree of education. I mean, most people in the local community, especially in remote areas, did not have a former education when it comes to renewable energy. So there need to be some sort of education and training.	Training and education of community is required if they are going to be employed at the DRE plants.
C1.5	70	G2	2880-2886	Yes, there are some challenges, and most of those challenges come with a community acceptance on the basis of wanting to understand what the impacts of the establishment of those renewable energy facilities are going to be, how those facilities are going to affect their lives both positively and negatively, fitting into government regulations and negotiating terms of projects. Especially in countries like ours, you find it difficult to explain these projects to the people and the benefits.	The acceptance of communities with regards to DRE solutions is determined by their educational status, which sometimes requires education.
C1.5	71	R3	2685-2689	So on the educational side, it is very important because only if you have stakeholders who understand the impact, you can realize such a project. Still, there is a lot of fear on the stakeholder side in the ministries and the utilities on the grid operator side. And these fears have to be reduced.	Education of the national energy regulators is important as in some jurisdictions they play a role in granting DRE projects and are sometimes critical about it.
C2.1	72	D1	1076-1080	In less developed countries, having power can make a huge difference in people's lives. Just being able to read a book at night, to have street lighting, or to be able to cook with electricity changes people's lives.	Education, security and health improves with electrification.

C2.1	73	D2	330-333	This municipality is then able to pass on the savings to local communities. So they are able to pay less, they are able to spend money doing other things which are more economically productive.	Fostering of local economic development, even when power is shared with municipalities, as they can provide the communities with cheaper and clean energy.
C2.1	74	R2	607-609	But there also is an opportunity in terms of understanding how we can transfer technology, knowledge and capabilities for them to sort of develop their own infrastructure, if necessary.	Knowledge and technology transfer to communities can be fostered (capacity building).
C2.1	75	R2	734-743	We have a huge energy poverty issue here in Latin America, and people have to prioritize for which appliances they are using the electricity. Part of their income goes to solving that issue and therefore they cannot invest it in another aspect of their life and therefore limits their economic development. I would say that distributed energy solutions enable and give more autonomy to people in order to fulfill their economic aspirations and therefore being part of the economic machinery that is going on.	Access to energy solves the issue of prioritizing the energy according to the use. People are then able to spend their money on things which enhance their economic development.
C2.1	76	M1	1329-1331	But again, we see that it is a somewhat of an opportunity and that we can train local community members to operate the plant and then use it as another mechanism to create jobs for the local community.	Job creation in the local community in building and operating the plant.
C2.1	77	M1	1417-1420	Building schools and building health centers that will be there long after we are done mining or we see the solar plant as a potential another example of something that we can leave to the community as a positive legacy for them to use after the mine is gone.	After mine closure, infrastructure can remain in the area and handed over to the communities.
C2.1	78	M1	1492-1494	And in doing so, make the local communities greener, but also, I think, from a cost perspective, it help communities as well.	DREs provide green and affordable infrastructure for communities.

C2.1	79	M2	2179-2183	I think there is other benefits that can be present to the community through the deployment of renewable energy projects outside the provision of free electricity. For example, you can ensure that there would be a component of local skills development and employment at those particular projects.	In addition to access to electricity, local skill development and job creation can benefit communities.
C2.1	80	M2	2187-2189	Local procurement could provide benefits: if you can identify suitable components of a renewable energy project that could be procured locally and therewith develop the local supply chains into a renewable energy market.	Local procurement opportunities.
C2.1	81	M2	2205-2210	The opportunity also resides beyond the life of mine. So a locally located renewable energy project could provide some form of economic stimulation beyond the life of an asset. That type of asset can continue to offer employment, as well as social and economic benefits to the local community beyond the life of the asset.	Infrastructure provides benefits even after closure of mine and stipulate economic development.
C2.1	82	R3	2608-2615	We typically try to engage with the local community and if legally permissible, we offer community benefit schemes. And I think it is part of our obligation, not to provide clean and sustainable power to the local communities, but to enable them to develop in a sustainable way and to improve living conditions there. Very often, the people living in the surrounding area do work for the mine, either directly or indirectly.	R3 state that his company is typically aiming to improve the life of community members by providing them with electricity, skills and jobs.
C2.1	83	R3	2616-2619	There are direct employment opportunities when it comes to plant maintenance and security. We always try to engage with the local community to create jobs that are linked to the operation of the solar park.	Maintenance and plant security are potential job creators.

C2.1	84	G2	3064-3070	Other institutions or other companies, when they see that happening, they take interest in that community, also in that vicinity. So they come and explore and look for other opportunities where they can invest also. Because every investor wants a suitable investment climate to where their investment will be sustainable. And so supporting projects to be sustainable are means of attracting more investment because sustainable projects attract investment.	A successful implemented project raises awareness of further investors and companies, which eventually leads to local economic development.
C2.2	85	D1	903-907	DRE solutions are under the company's control. So the mine is not dependent on an external operator, an external utility that may or may not function and not dependent on political interference.	Independence from utilities and national power outages
C2.2	86	D1	910-912	The mine can optimize the costs and operational parameters.	Cost optimization and improvement of operational parameters.
C2.2	87	D1	1044	So I would say a better public image is a very strong benefit.	Better public image.
C2.2	88	D1	1047-1050	And I think mining companies will very much try to be ahead of the curve in terms of technology, development and in application. So being an early adapter and having that knowledge before your competitors have, could also be an advantage.	Pioneering can be a huge advantage to competitors.
C2.2	89	D2	96-97	But the benefit for South African mines, immediate benefit, will be secure electricity supply and that is cheaper also.	Supply security and cost savings are immediate benefits.
C2.2	90	D2	93-95	And also because they have their own climate targets and they are trying to transition away from fossil fuels, it also helps them as well.	Contributes to the decarbonization strategy of mines.

C2.2	91	D2	106-110	You have also got the fact that electricity means now that you can extend the life of mining of that plant. So if you are only going to do open cast coal mining, now, you can go deeper and go into other seams.	Access to and introduction of energy extends the life of a mine in artisanal and small scale mining.
C2.2	92	D2	96-97	So the introduction of embedded generation in one way or the other will definitely improve their economics as a mine and it will obviously give them the electricity that they need.	Cost efficiency and supply of reliable energy.
C2.2	93	R2	498-501	DRE Solutions and their greatest benefits, I would say, are the decarbonization of mining processes and therefore reduction of emissions and also in complement with energy efficient solutions they can be very interesting in terms of cost efficiencies for the mining companies.	Decarbonization and cost savings.
C2.2	94	R2	614	And that in terms of reputational value as well, is very important.	Improved reputation.
C2.2	95	R2	617-624	And the other is, how you can sort of use these shared infrastructures as pilot projects as to test out technology. I think that is sometimes a very good advantage for exploring and venturing into sharing infrastructure. In the example of Ollagüe, a city in Chile, where R2 built a hybrid solar powered plant with a very small wind turbine and accompanied by a fuel generator, which is a backup for it to have 24/7 generation. It was for R2, beside of working with local communities, a very good opportunity to explore technologies.	Sharing infrastructure can be a good opportunity for testing new technology.
C2.2	96	R2	769-772	It is also a great way to manage and mitigate risks, and that is climate risk, infrastructure risk, all that is associated with the different impacts that climate change is having and will continue to have if we do not act now.	Risk mitigation measure in terms of climate risk and infrastructure risk.

C2.2	97	R2	833-835	And when you measure your footprint as a company and you get the direct and indirect emissions, the source of our products is definitely very important. And that is how greener mining is going to be more competitive to more or less sustainable mining.	Greener mining is going to be more competitive than less sustainable mining.
C2.2	98	M1	1299-1303	I think, as with most solutions that benefit the environment, often there is an economic benefit and certainly for us in the solar plant that we are building, there is an economic benefit in that. The payback of the solar plant that we are constructing we expect to happen around year seven.	Environmental and economic benefit. Payback period is seven years.
C2.2	99	R1	1628-1637	It is just a plane cost saving benefit. And then the sort of a fringe benefit for some of them, if they are located far from ports or from wherever the fuel comes from, then including renewable energies means that their fuel stock lasts longer so there is a security aspect or a reduced logistics to that.	Cost saving and logistic benefit, as fuel has to be refilled in larger intervals.
C2.2	100	M2	1992-1993	I think the benefit of renewable energy is obviously bringing down the cost of overall energy supply to a mine.	Cost benefit.
C2.2	101	M2	1999-2001	And so from a cost perspective, it can bring down the cost of supply. It can also then decarbonize the supply through its renewable form.	Cost benefit and decarbonization.
C2.2	102	M2	2002-2004	I think the benefits really are around introducing some degree of control yourself over costs, bringing down your overall costs and being able to decarbonize your supply.	Cost benefit and decarbonization, as well as control over the own costs.

C2.2	103	M2	2379-2382	But with the intent of decarbonizing the operations, there might also be indirect benefits, for example, of avoiding either local or international carbon taxes or carbon costs associated with Carbon intensive electricity provision to mining companies.	Avoidance of local or international carbon taxes due to clean energy generation.
C2.2	104	M2	2406-2415	But I think one of the easiest quantifiable metrics that stakeholders use including customers, to sort of differentiate between commodity producers, is associated carbon footprint. If a mining company is able to demonstrate a reduction in terms of carbon intensity of their product or actually move to the point that it becomes completely carbon free, it might attract a premium from a customer. That has implications in terms of your marketing, your ability to sell the product into different markets.	Improved marketing and ability to sell the products as stakeholders are looking especially at the carbon footprint.
C2.2	105	R3	2512	I think the one obvious benefit is certainly cost reduction.	Cost reduction.
C2.2	106	R3	2516-2518	The other benefit and the other key driver is decarbonization. I think many of those mines or actually all of the mines need to reduce emissions.	Decarbonization.
C2.2	107	G2	2965-2968	And that is one of the reasons why many companies are not too happy with doing that, but they find themselves doing it because they want to get that acceptance from the community.	Community acceptance.
C2.2	108	G1	3239-3244	Finding peace with the local communities, they will only need to share a few quantities with them and when they electrify the communities, I think their relationship with the community will be good. Apart from that, they will be selling the quantity. They will be earning another money apart from the mining activity. That is also another benefit that they will not be spending the money on bringing in fuel as a kind of source of energy.	Peace keeping with community and adding another source of earning money.

C2.3	109	D1	1219-1221	But I also think if it is well regulated and again, if geographic, economic, political factors are in place, you could actually have DRE as a nucleus, an incentive for economic development.	DRE has the potential to spur economic development.
C2.3	110	D2	90-93	And in South Africa, we have been experiencing power outages or what we call load shedding, which is rolling blackouts for the last, 13 years or so. So that has been hampering economic activity. And we have seen a greater push for industries such as mines to use embedded generation.	DRE improves the reliability of the municipalities which in turn leads to improved economic performance.
C2.3	111	D2	103-106	So they do not do deep shaft mining, it is mainly open cast, where they are even using child labor in certain instances. So the introduction of electricity almost immediately gets rid of the child labor element because now they are able to bring in high tech equipment.	In artisanal and small-scale mining access to electricity can solve the child labor issue.
C2.3	112	D2	313-314	And actually, it could have spin-off effects for the municipality itself, and for its growth and development.	Positive spin-off effects for the municipality which leads to economic development.
C2.3	113	D2	338-343	But having embedded generation that will be available, will have positive spinoffs, especially for industry surrounding that mine. I as a mine can sell energy to farms, to other mines. So it is mostly an industrial movement, therefore, leaving the national utility and the municipality to supply the residential customers ultimately.	The ability to sell excess power to municipalities, utilities and other companies enables the national utilities to eventually power residential customers.

C2.3	114	M2	2431-2442	When we deploy renewable energy, we alleviate demand from the national suppliers which then can be used to service other sectors of the economy. And we also then close the national supply deficit. They can also redirect that supply to other portions of our economy. It will also decarbonize an entire country, because then the whole country becomes more competitive and you can then also use the balance of power to sort of continue to develop the economy with electricity being a key national enabler. You could also develop a local renewable energy industry that can then service other heavy industry users, municipalities, et cetera, and even service other countries.	Closing the national supply deficit, which decarbonizes an entire country. This country will be more competitive and electricity generation can be used to develop whole new industries. Even a local renewable energy industry could be developed.
C2.3	115	R3	2550-2553	There is the potential to increase the supply security as well. In areas where you have grid connected mines, and you face load curtailment or load shedding, such as in South Africa or in Zambia, supply security is a major issue.	Improves supply security of national grids.
C2.3	116	R3	2668-2671	And I believe that it is really much to the benefit of the entire country, because it does create jobs, it does generate revenue and taxes and it does bring power onto the grid in an offside PPA situation, without the requirement for the government or the government controlled utility to invest in this infrastructure.	Job creation, tax revenue, no necessity to invest in infrastructure by the government.
C2.3	117	R3	2805-2812	And if that is achieved, then I think DREs can have a transformative impact on the whole economy. If it is not achieved, any energy intensive producer will not choose to open up a production plant in Ethiopia, Kenya or South Africa because very often these plants are very, very energy hungry and the additional costs associated with power procurement in Africa outweigh the cost benefits of lower wages for example. I think that is probably one of the reasons why despite Africa being such mineral rich continent, much of the value added in the value chain is not generated there.	Investment attraction of a country, as power issues keep industries away from the African continent. Improved power supply could also lead to domestic refining of raw materials.

C2.3	118	G1	3263-3266	Because when the company has their source of energy, they will not only be paying taxes for the mining sector, but also they will be paying taxes for the energy sector. It is official benefits.	Tax revenues from energy sector.
C2.3	119	G1	3354-3359	I think that innovation can also impact the local economy. But when the energy is there, I think they will also develop small activities, which will be beneficial for the houses and their families. There is a positive impact when we make it in the mining sector where our population is suffering.	Enhancement of economic activities if power supply is ensured.
C2.3	120	G1	3369-3375	And if I take the specific case of small scale mining in South Kivu, where we have several cooperatives, it could be better to support them with such innovation. Every cooperative or every mining company can have its specific source of energy that will reduce not only impacts of climate change, but it can have advantages to share that energy and to electrify different villages. That is a very important and very, very interesting thing that we can suggest to our government to promote as an initiative in the mining sector.	It is recommended for governments to enable DRE in mining as it decarbonizes and electrifies industries as well as communities.
C2.3	121	G2	2934-2938	So sharing those facilities with the community are incentives to give the project an acceptance by project affected community residents. So in my mind that is the overweighting reasons why project operators should share their facilities with project settler communities.	Energy sharing is recommended as it will improve the relationship to the community and the acceptance of the project.
C2.3	122	G2	3101-3106	What I want to recommend for developing countries is to really look into that direction because it helps to catalyze growth. For development, energy plays a major role in developing any state. So when you have affordable and accessible energy, it does not only attract investment, but it fast tracks development.	Especially developing countries are advised to go into DRE systems as they can catalyze growth. Energy plays a major role in development as it attracts investment.

C3.1	124	D2	285-287	So one of the key risks, obviously, is the safety of the mine itself. You do not want a situation where you have created a dependency on the mine, which is what we saw in South Africa.	Dependence on the mine, which could either close of or stop supplying energy.
C3.1	125	D2	295-301	Eskom is looking at what we call a just energy transition. If we are going to move away from coal to renewable energy, it has to be just and it has to consider these people that will be left unemployed. It must look at reskilling them in what happens to those communities that were built around the coal industry. So it is more of a safety thing and leading to even civil war in some cases.	Communities face serious risks if the mine nearby closes its activities, as employment opportunities decrease drastically.
C3.1	126	R2	704-708	Outages are a risk, but there are also electric safety risks. There are also a series of other risks in terms of the health and safety of the users. And if we have trained someone to do the maintenance of these solutions, what if they have an accident? Do they have all the abilities, capabilities and tools in order to work in the proper way?	Power outages can be an issue. Also, health and safety of the workers is another risk, especially in case of an accident.
C3.1	127	R1	1781-1782	I think the major risk to them is what happens when the mine is gone.	Mine closure.
C3.1	128	M2	2183-2185	In a renewable energy context, such as solar and wind, there is quite a large number of people required during a construction phase, but then sort of tapers off quite quickly during operation. So that can present its own challenges.	Job creation during the construction phase but thereafter, a lack of opportunities.
C3.1	129	G2	2864-2867	So you notice that because of limited basic social services and other things, water bodies are used for livelihood activities also. So the establishment of hydropower on some of those water sources will deny communities along those water bodies some livelihood activities.	Hydropower could potentially compete with the current use of local communities and cause them to stop activities supporting their livelihood.

C3.1	130	G2	2976-2981	But outside of that, there are several reasons why maybe the government should be responsible for those things and not the companies. Because the company is investing to make profits. So those costs that come from the negligence of the locals to the company which is sharing those facilities with them, come back to the company and sometimes the company do not pay for it.	There is a risk for communities that companies do not engage with them are will not pay for damages for which they are responsible in the area.
C3.2	131	M2	2350-2354	And because of that, they become almost sort of a backup generator, if you want to call it that, to supply electricity. So the portion of the fixed costs that they would offer would go up because they need to recover the cost of maintaining a standby system for you, versus the traditional continuous supply of electricity.	In case grid electricity is used as a backup, the costs for the grid power will increase as their service change from a supplier role to having a stand-by system.
C3.2	132	D1	918-921	D1 sees no risks, if the technical due diligence has been done well and the company is convinced that their DRE plant can reliably supply sufficient amounts of energy.	Insufficient technical due diligence / feasibility.
C3.2	133	D1	1038-1043	Shareholder and public opinion, I think, could be a very powerful driver, even if it is not the most profitable solution. Community protests, bad press, are a risk that also has a price tag for mining companies. So they will weigh not only technical solution against each other, but they will weigh the ESG risk attached to technical solutions and factor that into their financial calculation.	Bad press, community protests.

C3.2	134	D1	1055-1058	If your renewable energy supply is not reliable and you have a couple of communities linked to it and they have frequent power, it might also not make them very happy. So I think managing expectations is maybe a bit of a risk here.	Managing expectations.
C3.2	135	D1	1059-1065	So if a community has free electricity, it could grow from a thousand people to 15000 people within two weeks, because people come and settle there because that is the promise of the company. So demand could also skyrocket if something is free. And this is probably a tangible risk, especially in Africa and maybe parts of South America, and Asia as well.	Skyrocketing electricity demand and risk of migration due to free electricity.
C3.2	136	D2	172-182	In some cases, people are going three kilometers underground. They cannot afford to have intermittent technology at all. You need to secure supply and you need backup as well. Sometimes when Eskom implements rolling blackouts, they do not give them enough notice. And you find that miners are now stuck underground for hours and they are not able to get up. And that obviously has health impacts and safety impacts.	In underground mining, intermittency of energy can cause serious threats to the workers as they may get stuck underground. Thus, single DRE solutions without a backup are not suited for such mines.
C3.2	137	D2	201-209	So I think in 2017, there was a massive miners strike in South Africa and not all mines were affected. The mines that were not affected had social plans in place, were mines that had provided housing for their employees, had provided education for the kids and for the miners as well, were paying equitable wages, were investing in their miners and were providing health care.	If mines do not provide social benefits, the risk of a strike increases.

C3.2	138	D2	404-408	However, I must caution that it obviously does have cost implications and the cost implications are felt not just by the local entities, but are also felt by the consumers of those goods ultimately. So I know that if I am buying a BMW, I am going to pay a slightly bigger premium then Mercedes that does not have that requirement because they are just using the national grid ultimately.	Using DREs instead of an available national grid leads to higher commodity prices and eventually this will be paid by the end consumer.
C3.2	139	R2	691-694	The communities and their energy consumption increased significantly, because they were getting more appliances and did not necessarily understand energy efficiency measures or the awareness and so the power demand was much greater than the power that could be supplied by the plant.	Increase of electricity demand if shared with communities.
C3.2	140	M1	1465-1467	I mean availability, I guess, with any power solution could be a potential risk if anything were to go wrong with the transmission lines or with the infrastructure.	Availability is a risk, coming from the transmission line or the infrastructure.
C3.2	141	R2	506-512	The main risk today is the possible and potential operational impacts that these types of solutions can have when not necessarily tested or trialed accordingly as to sufficiently solve the specific aspect they are trying to work on. Because any operational impact is a huge financial impact and risk. So if, for example, we have an off-grid solution that has operational flaws that can directly impact the mine and its operations, it has financial impacts.	If DRE solutions are not tested accordingly, they can have a huge operational impact, which in turn causes financial losses.
C3.2	142	R1	1719-1720	But the potential trouble that will cause you when you shut down the mine or anything else is tremendous.	Troubles due to mine closure when sharing DRE.

C3.2	143	R1	1727-1735	I have no corporate involvement in it because you will run into all sorts of things when you supply power to the village. At what rate? But they always feel like they are being ripped off if they pay at all. What do you do if someone does not pay? Do you cut them off? Then how do you deal with the fallout from you? Cut this guy's electricity consumption, his kid is now sitting in the dark and cannot study. Or if you provide the electricity for free, how much is too much? What is a fair usage policy and so on? So if you have a village with 500 households next door, it has five hundred potential points of trouble so better to dump it on someone else.	Risks associated with the community: if and how much do they pay for accessing power, what happens when they do not pay? There is a potential for trouble in these arrangements.
C3.2	144	M2	2199-2205	I think it depends on the community. Every South African receives a portion of free electricity already. If their free electricity came from the mine, I do not know if the community necessarily attributes the benefit of that free electricity to the mine, so it would not generate a lot of benefits to both parties. I think if you were more remotely located and electrified a community that never had electricity previously, I think that will be recognized as a significant benefit for a local community and they end the upliftment.	Communities in certain areas already receive energy for free from the national utility. In these cases it is not clear if it will be recognized at all, if the mine is powering them. In a scenario where the community never had electricity, it would be a huge benefit.
C3.2	145	M2	2225-2231	We often, unfortunately, have theft of our electrical infrastructure, in depth cables, sabotage of our power lines, etc. by communities. It could be due to the failure of the government to deliver on certain promises, but the communities do not disassociate what is operated by a mine, what is operated by a government and what is operated by a local municipality. If there is community unrest, the mine is normally the first party they go to.	Communities are often not aware of what belongs to the mine and what to the government. So even as a response to governmental failures, mining companies can be at risk of theft or sabotage.

C3.2	146	M2	2237-2243	And I think the land issue is also a key concern, because you potentially using land that could be used for the purposes of agriculture and then it could become a trade off as to what delivers the most benefit to the collective group of stakeholders that would be involved.	There might be a conflict with regards to land use options.
C3.2	147	M2	2518-2522	Mines need to decarbonize in order to ensure that they remain relevant on a global level. If you are not actively setting and achieving decarbonization targets, then you may struggle to attract investors, attract finance, produce relevant commodities in global markets, etc. So you almost need to do that as a prerequisite to operating.	Without decarbonizing industrial processes, it will be difficult to attract investors and finance in the future or to sell the product.
C3.2	148	M2	2422-2431	South Africa at a national level has a generation supply deficit, so when the national utility Eskom has breakdowns in their generation, the whole country's power is stopped in order to ensure supply and demand are met in real time at the national level. And that comes at a huge economic loss, far in excess of the cost of electricity like magnitudes of 10, 20 or 30 times higher. And so in the respect of a mining company.	Power outages by the national grid are a serious threat to mines.
C3.2	149	R1	1720-1723	So if I was in the shoes of a mining executive or if I was to advise them, I would rather donate money for someone to build an off grid system for the village next door but not be connected to it. Not attaching my mine and my power grids to the guys next door.	Build a separate grid for the mining communities instead of powering from one.
C3.2	150	R3	2649-2652	So if you share the same asset there, 99% of the power goes to the mine and 1% for example goes to the community. It is a commercial management related issue more so than a risk. So in some instances, it is easier to really separate those two systems.	It is in some instances more recommended to have two separate systems instead of powering the community and the mine from the same grid.

C3.2	151	R3	2769-2774	If you have decarbonized your power supply significantly I think that helps. On the other side, if you still have working conditions that are not according to international standards, if you employ forced labor, child labor and so forth, if you do not do proper waste disposal. I think you do not meet the mark there. So cleaning up the power supply is just one aspect, among many.	Clean electricity generation could only be one part of the puzzle, as further aspects of international standards have to be considered in the future.
C3.2	152	G2	2929-2931	So normally the acceptance of a project by communities is an issue of concern. Because if the project is not accepted by the project affected communities, the investment is challenged.	Acceptance of communities is an issue as it may lead to denial of accessing further parts of land.
C3.2	153	G2	2959-2965	The power consumption is another issue. Because, for example, what we have noticed is that a family that normally was paying for energy, they had not a lot of energy consuming equipment. And at the end, those same problems come back as cost to the companies.	Power consumption by the community is a risk, as they will get more equipment if the electricity is for free.
C3.2	154	G1	3157-3161	We can find different difficulties according to the distribution and here we are using our sources of energy which are collectively coordinated by SNEL. When you need the energy in your company for your company’s work, you are not going to find it at the moment.	Limited capacity by national utility SNEL.
C3.2	155	M2	2086-2091	There would also be some considerations in terms of risk. What could you do at the asset if the mine fell over prematurely? If you are remotely located, or you are in a jurisdiction that does not allow you to sell electricity back into the grid, that then presents the risk of a stranded asset if the mine had to close.	Operating in remote areas pose the risk of a stranded asset, if the mine will be closed as there is no possibility to sell the power to e.g. national utilities.

C4	156	D2	267-270	So in South Africa and in other countries, you will typically find this what you call an industrial development corporation. They bring, through their development plans, stakeholders together to the table to say if you want funding, this is what you are going to have to do.	Industrial development corporation brings stakeholders together for implementing such projects.
C4	157	D2	272-279	By the time that you are coming for full funding, it means that you have been developing this project for months on end. And this is why now we are even starting to see some pushback from communities, because when some of these mining houses come and engage them, they do not involve governments or anybody else. And they cheat people. And it ends up being a huge mess that by the time government becomes involved in these development institutions, the project is actually ready to fail at that point.	It is important to include all stakeholders, especially the communities and the government already at an early stage to avoid failure of the project.
C4	158	R2	488-493	So due to this previous fact, I would say that mining companies have been primarily seeking energy supplies through renewable PPAs or contracts, and these contracts have allowed our industry to sort of diversify our value proposition by complementing the energy supply contracts with other renewable solutions.	Engagement with IPPs and power supply through a PPA provides a good option.
C4	159	R2	610-611	It is a very good risk management measure, which in terms of the bottom line, definitely impacts when you have good relations with your stakeholders.	DRE solutions can improve the relations with your stakeholders.
C4	160	R2	636-642	I think the main risk and the one to really manage and focus on is the governance administration and the relationship between the parties. I think that is where projects either are successful or fail. Who is going to be responsible? What is the role of each of the actors in the functioning of this solution? Et cetera.	The relationship between the parties is a determining factor for a DRE project.

C4	161	R2	694-697	And so there is sort of a mixed responsibility in all the involved actors when implementing these solutions in terms of the risks related to the success of the solution and all the associated risks, whether it is electric safety or others, it takes huge responsibility from all parts.	Every stakeholder in this project has a responsibility with regards to the risks.
C4	162	R2	697-700	And I would say that it is very important for the success of these solutions that there is a proper communication training and everyone understands what their role and responsibility is in the whole system.	Communication training and clear roles and responsibilities.
C4	163	R2	788-790	There is another aspect, which is the complementary aspect to the national grid. Because you can get renewable energy supply from the national grid through PPAs and other mechanisms.	There is also the option to access renewable energy through a PPA from the grid.
C4	164	M1	1333-1336	We expect there will be some challenges which is the case with any new technology. But we have a great partnership with Scatec, from whom we have procured the equipment from. And part of our agreement with them is to help us along as we get up and running and so we do not see that really as a barrier at all.	Renewable energy companies can support mining companies in running the power plant.
C4	165	M1	1434-1437	So far, our conversations with the regulators have been very positive. They have reached out to communities and to the local municipalities and are being very consultative in their process, which we support fully.	Regulators / governments can play a role in engaging with the communities and local municipalities.
C4	166	M1	1482-1488	I think we have a very positive relationship with our local communities. We meet with them very frequently. We have agreements that are negotiated with each of the 11 communities that are around us, because each of them have different needs and so there are committees for each of these communities established to work with us to establish priorities which could be covered in these agreements. And so it is a very collaborative process.	Frequent meetings, negotiated with the local community, ensuring that their needs and expectations are heard and the establishment of a committee is a good way for stakeholder management.

C4	167	M2	2245-2246	You have to involve a local community. If you do a project in isolation, that project is going to fail from the start.	Community involvement is key, otherwise there is a risk of a failed project.
C4	168	M2	2258-2260	I think the government's role should be around balancing the needs of different stakeholders. For example, they will need to ensure that there is a just transition and moving away from a potential fossil fuel based system.	The governmental role is to balance the needs of different stakeholders.
C4	169	M2	2277-2285	So in most jurisdictions, when you want to develop a renewable energy project, you will interface with a number of government departments and so called government entities like the energy regulators that require you to get another different consent in order to go ahead with the project. If the government was able to streamline that development processes and remove any bottlenecks, you can shorten that development timeframe and bring the benefit of these projects online a lot sooner. So I think that is also a key role the government needs to play.	A government can remove the bottlenecks in the negotiation part with energy regulators, which speeds up the development of DRE projects.
C4	170	R3	2681-2683	Very often it extends beyond and the DFIs start to do a great job in educating local stakeholders.	DFIs can educate the local stakeholders.
C4	171	G2	3039-3044	There are some incentives that are given to these mining companies, like some tax breaks, some waivers and other things. But those things are on the basis of how the project affects the livelihood of other people, how the project supports the development process of our country. So we may not be able to give direct monetary support in the processes, but sometimes we give them other incentives because they are incurring these risks.	Negotiations with the government is sensible as they can offer incentives like tax breaks etc.

C4	172	G2	3021-3025	It is difficult for a country like mine because we are even struggling to be able to provide basic services like rural constructions, electricity and water. We are still far behind in providing those facilities for the people. So that capacity is not there for us to support these type of projects.	In the instance of Liberia, there is no or limited capacity of governments to support DRE projects.
C4	173	G1	3309-3312	And if they can make something like a public private partnership. We are going to make the private sector, public sector and the population together, such kind of contract. I think it can also be very easy to make and it can be beneficial when you complete, if feasible.	A PPP contract could be one option to execute a DRE project.
C5	174	D1	1103-1112	We could help with piloting certain DRE solutions. So this could be a very well suited project for IFC to help to cover the risk of doing a leap of faith and relying on DREs instead of public power. Lastly, we could also work on the community side with the social and environmental aspects, help to finance bankable feasibility studies, help to prepare and conduct community dialogue. There is a wide scope of potential involvement. I do not see us getting involved with big financing because these are supposed to be commercial operations.	DFIs can finance feasibility studies or piloting projects and cover certain risks. They could also support the stakeholder dialogue. As DREs are commercial operations, big financing is not recommended.
C5	175	D1	1179-1184	I think almost all banks are more and more interested in greening their portfolio, so it can only be a positive impact. Of course, banks will look very carefully how it is done on a technological level, and they will look very carefully at the economics. But overall, I think there is a growing openness to finance green investments. And therefore, I would say it can only improve the relationship to your finances and investors.	Interest of DFIs to engage in green projects, thus, DREs are going to improve the relationship to investors.

C5	176	D2	124-125	As a bank, we have not funded any mine that did renewable energy.	DFI has not funded any DRE project in mining.
C5	177	D2	630-638	Because I work for a DFI, the things that I am interested in are how does the local community benefit? And this is part of the whole funding model. Do they get a share of the electricity? Are they going to be employed or upskilled in this new coal power plants that you are coming up with? And do you have a training budget that you included in there for that purpose? I also would look at environmental issues. So if you are looking at this mine and you are looking at this power plant and you are telling me that it is going to be thermal, then the questions become why must it be thermal? Why can it not be renewable?	DFIs require various aspects to be cleared when it comes to project development. For instance, if the local community is benefited from the project, what the environmental implications are and how training measures for local people are included.
C5	178	D2	373-377	So if you are going to be doing solar PV, for instance, where are the inverters going to come from? From a South African company or you going to import? Where the panels are going to buy come from? So it is not just a credit decision, especially when you are dealing with the DFI it becomes a much larger conversation.	It is a larger conversation with DFIs as also local procurement plays a role for funding.
C5	179	R2	674-679	For example, the International Development Bank has co-financed a series of very interesting infrastructure projects in Chile that have been very, very good examples and have been later on replicated by the public and the private sector. So I think They are an important stakeholder in order to make these solutions work.	DFIs can be an important stakeholder, as in e.g. Chile the International Development Bank financed such infrastructure projects which turned out to be done very well.
C5	180	R2	807-810	Millennials are going to be the next biggest group – or if they are not now – of investors in the world and the philosophy is different. They / we are more concerned, more worried about what the money we are putting in is generating in terms of impact, whether environmental, social and others.	As millennials are going to be the next biggest group of investors, there will be a greater focus on ESG components.

C5	181	M1	1443-1446	I think, you are seeing more and more institutions offering things like sustainability loans or green loans or forms of financing that are meant to support and drive sustainable solutions, including renewable energy. I think investors' expectations, are increasing around reducing carbon footprint and making sure companies are operating responsibly. So I think they do play a role for sure.	More and more institutions offering sustainability or green loans to drive sustainable solutions. Investors expectations are increasing with respect to carbon footprint.
C5	182	M1	1550-1555	I think investors are more and more looking to invest in companies that are seen as responsible and in particular seem to be contributing to the fight against climate change. BlackRock, as an example, is one of our biggest investors. The CEO, Larry Fink, has been very, very clear that he expects companies to be thinking about this, to put together strategies to eventually become net zero and to have real plans.	Investors are more looking on the sustainability parts of companies. As an example, the CEO of BlackRock, Larry Fink has made clear statements about the push to become carbon neutral.
C5	183	M1	1564-1568	Perhaps we were not disclosing what we were doing in a way that was easily accessible to investors. We have been really focused on enhancing our disclosure, whether through our annual sustainability report or through enhancements to our website. There are all kinds of ESG questionnaires that are coming in our way that we are participating in, just so that investors know that we are trying to do the right thing.	M1 explains that they were perhaps not disclosing their sustainability practices in a way which is easily accessible for investors. This might be a challenge.
C5	184	M2	2077-2081	If sort of security of supply wasn't such a big issue, or the mine wasn't willing to deploy its own capital to the project and was comfortable signing a long term offtake agreement, then they could go to the power purchase agreement grid, which then requires very little capital from your side, but has to make a substantive commitment in terms of uptake for a given period.	If a mine does not want to spend its own capital for DREs, there is the option to go into a PPA, which requires little capital.

C5	185	M2	2108-2112	A mining company of significant scale can justify sort of resource like myself to look at these projects on a dedicated basis because of the inherent potential that they have for the mining company. When you are a smaller operator, you need to sort of rely more on either advisory services, or directly partnering with the likes of a project developer.	Bigger mining companies can hire experts for sustainability and energy. Smaller companies have the opportunity to consult advisory services due to limited capacity.
C5	186	R1	1767-1775	They should only be working and financing where normal commercial financing is not available so that they add to the pay rather than substitute some other funding solution. So to me, that means as long as the renewable energy thing makes commercial sense by itself and is a transaction between a mine or renewables company and a commercial bank can be structured and works, I think DFIs should rather be spending the money elsewhere. For example, the distributed generation stuff for off grid communities, which is really difficult to make work commercially with commercial loans or whatnot. I think a DFI financing solar plans for major mining companies is a bit beside the point of development finance.	DFIs financing DREs for a mine is not recommended as this is a commercial operation, which should work without DFIs and should not be their focus. The electrification of off grid communities however, is something they might consider as this is not necessarily commercially feasible.
C5	187	M2	2066-2074	The second big consideration is around financing of the project. So there is a range of different financing solutions that a mine could leverage to deploy a renewable energy project. They could be funding it themselves with their own capital balance sheet, to the other extreme end, where you do a full off balance sheet arrangement where you would enter into a power purchase agreement with a project developer who would fund, build, own and operate the asset on your behalf and then sell electricity at a fixed rate over a defined period.	Mines can finance DREs with their own balance sheet or they could enter into a PPA.

C5	188	M2	2189-2194	There is the opportunity of getting the communities to co-invest in the project. So they have an inherent stake in it. And if the community cannot fund it, the mine could do something called like vendor financing, where you effectively fund their portion on their behalf and then you recoup the original investment through the same way as a loan.	There is the option of the community holding a stake in the project. If they are not able to finance it, the mine can help out with a vendor financing to fund their portion on their behalf and then recoup the original investment through the same way as a loan.
C5	189	M2	2303-2314	And where the DFIs can come in is, they can offer a backup for a corporate lender so they could become the first loss facility that said something happened to the project, go take a first loss. They could offer a backstop to long term debt where a corporate lender could exit after a period of time and the DFI becomes the primary lender to the project beyond a typical corporate lending tenure. Also, there is the option to lend finance into the development process, if the mine did not have the capital to deploy the projects upfront and take that risk, or they can secure funding from elsewhere. The DFI can potentially find a portion of the development activities and either convert that into equity later or recovered as success fee as project execution. So in that respect, they could offer initial financing to unlock projects that potentially would not have started until they had funded it.	DFIs can offer a backup for a corporate lender so they could offer a backstop to long term debt where a corporate lender could exit after a period of time and the DFI becomes the primary lender. Also lend finance into the development process, if the mine did not have the capital to deploy to sort of develop the projects upfront and take that risk, or they can secure funding from elsewhere, the DFI can potentially find a portion of the development activities and either convert that into equity later or recovered as success fee as project execution.
C5	190	R3	2678-2681	We always consult with DFIs. We have not gotten to the point where we really have jointly executed a project, but first of all, of course, it is their core obligation to provide accessible and affordable financing solutions to these systems in developing markets, because the local banking sector does not have the capacity.	As the local banking sector in developing countries may have not the capacity, DFIs can jump in at this point.

C5	191	R3	2707-2715	One of the main drivers is the cost of capital. If you have to lend based on the local country risk, and the risk free rate in a particular emerging country, of course, the cost of capital goes up. And thereby the tariff goes up, which has a direct implication on the IRR expectation of the investor. So anything that helps to reduce the cost of capital will have a major impact on the price of the electricity on the SOEs. There are certain instruments on the market, political risk insurance and so forth. But of course, they come with a relatively high premium. So they provide a certain level of risk mitigation or protection rather, but they do not assist in bringing down the SOEs as much as they should probably.	If you have to lend based on the local country risk in a particular emerging country, the cost of capital goes up. And thereby the tariff goes up, that has a direct implication on the IRR expectation. So anything that helps to reduce the cost of capital will have a major impact on the price of the electricity on the SOEs, there are certain instruments on the market, political risk insurance and so forth. But of course, they come with a relatively high premium. So they provide a certain level of risk mitigation or protection rather, but they do not assist in bringing down the SOEs as much as they should probably.
C5	192	R3	2752-2759	When we think about these additional benefits associated with solar parks, we do not in the first place think about the investor relationship. I do not know if it is a requirement. I think there is a number of investors who require that certain SDGs are being met and fulfilled. It is not whether you want or can do it, it is you just have to do it. It is part of a sustainable business development in the context of renewable energy and Africa.	Investor relationship may improve through the deployment of DREs but it could also be a necessity to do so.
C5	193	G2	3012-3017	Unless we are in countries like Liberia, our entire economy is not as strong as other countries. You find that governments are struggling to take care of basic social amenities of the residents, the citizenry, so it makes it difficult for them to get involved with supporting these type of investment initiatives. But in a country where the government's capacity is able to give those supports, I think it is necessary because that would attract more investment.	Governments in developing countries have limited capacity to fund DRE projects, but in countries where it is possible it should be considered.

Annex II: Inductive Code Development and Guidelines

Category	R	Line	Key examples / paraphrases	Coding Definition
C1: Barriers				
C1.1: Economic Barriers	G1	3219-3220	A big challenge that I would also like to mention is the cost of beginning the installation of the energy to make it operational. It will be a big puzzle.	C1.1 includes all statements regarding negative impacts on cost efficiency and any kind of economic barrier associated with the deployment of DRE or energy sharing.
C1.1: Economic Barriers	R2	609	So I think that it is not necessarily profitable. Probably not.	
C1.1: Economic Barriers	M2	2034-2037	I think the third challenge is funding them. They typically have quite long payback periods in order of four to seven years. When you have a shorter life of mine that then trades off of capital expenditure on other items that could potentially have a better return versus that becomes an inherent strategic conflict.	
C1.2: Technical Barriers	D1	1005-1007	You always have to combine it with some sort of storage because inevitably you have nighttime, some bad weather, you have some cloud cover.	C1.2 includes all statements with regards to technical limits and challenges when it comes to powering a mine or communities around with DRE.
C1.2: Technical Barriers	R3	2586-2588	Intermittency is one of the challenges of course. Most mines have a very stable load profile, they operate equipment that is probably quite sensitive to intermittency and to power quality issues.	
C1.2: Technical Barriers	M2	2131-2139	I think the third biggest concern after land resource, is electrical interconnectivity. It is to what extent you can technically tie these renewable energy projects into your own operations. And then the fourth one would probably be your own load profile. So matching your load profile with the generation profile. So it can only displace a certain portion of your energy requirements, but you need to have a sort of backup facility or something that will continue to provide a balance of power requirements.	

C1.3: Regulatory Framework	D2	116-118	So the first problem that many mines are going to encounter, and this is why I have not seen a great uptake of renewable energy, is because they need a certain law.	C1.3 includes all statements with regards to the law, governance and regulatory framework which is hindering the deployment of DREs or community electrification, as well as recommendations how the regulatory framework should be designed.
C1.3: Regulatory Framework	R2	632-636	I would say maybe sort of governance and administrative issues regarding sharing infrastructure. I mean, where do you draw the lines between? To what extent? Who is responsible? And what if it fails and people are out of power? You are the one responsible? Or is it because their consumption is not proper to the power source we have, et cetera, et cetera?	
C1.3: Regulatory Framework	R3	2564-2569	And this is one of the major hurdles for our business development, that in most countries, especially on the African continent, you do not have liberalized markets. So DREs are often not allowed from a regulatory point of view, or are limited in size up to a certain maximum capacity you can construct and operate on site or off site. But the threshold is usually rather low. So it does not really make sense to pursue that opportunity for the mining companies.	
C1.4: Geographical Barriers	D1	937-939	Well, geography plays a huge role because it influences very much. So the exegetical dynamics that surround the mining operation, meaning, the wind, solar radiation, the availability of running water for hydropower.	C1.4 includes all statements regarding geographical barriers when it comes to DRE projects and community sharing.
C1.4: Geographical Barriers	M2	2152-2160	Types of land are also important as well as a suitable topography and geotechnical conditions. So if you are in a particularly hilly area that is heavily vegetated, it is going to be very difficult to deploy the likes of solar. And you also need certain ground conditions to sort of bring down the costs of deploying solar for your operations. If you operate hypothetically in Central Africa in a rainforest, it can be difficult to sort of motivate clearing of rainforests for solar PV.	
C1.4: Geographical Barriers	R3	2634-2637	Sharing the power infrastructure directly depends a little bit on the distance, of course. If the next village, for example, is 10 kilometers away from the solar park which is providing power to the mine, sharing the infrastructure may not be the most economical way to provide power to the community there.	

C1.5: Educational Barriers	R2	717-722	And you go from four hours of electric energy a day to 24 hours, you start expanding your energy use and get new electric appliances. But businesses start growing so in return the energy demand definitely increases and that is where it is very important to accompany the technology and infrastructure project with the educational part of it.	C1.5 includes all statements about education as a key barrier for the deployment and sharing of DRE infrastructure.
C1.5 Educational Barriers	R3	2531-2535	So there is a concern on their end that their machines and their equipment will not be able to operate flawlessly based on a solar generator or solar power provided to them by the mine. So there is a fair amount of education required, you cannot always convince everyone on the operative side of the mines. That is a major, major hurdle there.	
C1.5 Educational Barriers	G2	2880-2886	Yes, there are some challenges, and most of those challenges come with a community acceptance on the basis of wanting to understand what the impacts of the establishment of those renewable energy facilities are going to be, how those facilities are going to affect their lives both positively and negatively, fitting into government regulations and negotiating terms of projects. Especially in countries like ours, you find it difficult to explain these projects to the people and the benefits.	
C2: Benefits				
C2.1: Community Benefits	D1	1076-1080	In less developed countries, having power can make a huge difference in people's lives. Just being able to read a book at night, to have street lighting, or to be able to cook with electricity changes people's lives.	C2.1 contains all statements about benefits for the community as a result of energy sharing projects.
C2.1: Community Benefits	M2	2205-2210	The opportunity also resides beyond the life of mine. So a locally located renewable energy project could provide some form of economic stimulation beyond the life of an asset. That type of asset can continue to offer employment, as well as social and economic benefits to the local community beyond the life of the asset.	
C2.1: Community Benefits	M1	1329-1331	But again, we see that it is a somewhat of an opportunity and that we can train local community members to operate the plant and then use it as another mechanism to create jobs for the local community.	

C2.2: Mining Benefits	D1	903-907	DRE solutions are under the company's control. So the mine is not dependent on an external operator, an external utility that may or may not function and not dependent on political interference.	C2.2 contains all statements about benefits for mining companies as a result of DRE deployment and energy sharing.
C2.2: Mining Benefits	R2	498-501	DRE Solutions and their greatest benefits, I would say, are the decarbonization of mining processes and therefore reduction of emissions and also in complement with energy efficient solutions they can be very interesting in terms of cost efficiencies for the mining companies.	
C2.2: Mining Benefits	G1	3239-3244	Finding peace with the local communities, they will only need to share a few quantities with them and when they electrify the communities, I think their relationship with the community will be good. Apart from that, they will be selling the quantity. They will be earning another money apart from the mining activity. That is also another benefit that they will not be spending the money on bringing in fuel as a kind of source of energy.	
C2.3: Country Level Benefits	M2	2431-2442	When we deploy renewable energy, we alleviate demand from the national suppliers which then can be used to service other sectors of the economy. And we also then close the national supply deficit. They can also redirect that supply to other portions of our economy. It will also decarbonize an entire country, because then the whole country becomes more competitive and you can then also use the balance of power to sort of continue to develop the economy with electricity being a key national enabler. You could also develop a local renewable energy industry that can then service other heavy industry users, municipalities, et cetera, and even service other countries.	C2.3 contains all statements about benefits for the society on the country level as a result of DRE deployment and energy sharing in the mining sector.
C2.3: Country Level Benefits	R3	2668-2671	And I believe that it is really much to the benefit of the entire country, because it does create jobs, it does generate revenue and taxes and it does bring power onto the grid in an offside PPA situation, without the requirement for the government or the government controlled utility to invest in this infrastructure.	

C2.3: Country Level Benefits	G1	3354-3359	I think that innovation can also impact the local economy. But when the energy is there, I think they will also develop small activities, which will be beneficial for the houses and their families. There is a positive impact when we make it in the mining sector where our population is suffering.	
C3: Risks				
C3.1 Community Risks	R2	704-708	Outages are a risk, but there are also electric safety risks. There are also a series of other risks in terms of the health and safety of the users. And if we have trained someone to do the maintenance of these solutions, what if they have an accident? Do they have all the abilities, capabilities and tools in order to work in the proper way?	C3.1 contains all statements regarding potential risks for communities in mining regions, as well as when it comes to energy sharing projects.
C3.1 Community Risks	R1	1781-1782	I think the major risk to them is what happens when the mine is gone.	
C3.1 Community Risks	M2	2183-2185	In a renewable energy context, such as solar and wind, there is quite a large number of people required during a construction phase, but then sort of tapers off quite quickly during operation. So that can present its own challenges.	

C3.2 Mining Risks	D1	1055-1058	If your renewable energy supply is not reliable and you have a couple of communities linked to it and they have frequent power, it might also not make them very happy. So I think managing expectations is maybe a bit of a risk here.	C3.2 contains all statements about potential risks for mining companies when it comes to DRE deployment, energy sharing projects and also risks which can occur if mining companies do not take ESG measures.
3.2 Mining Risks	D1	1059-1065	So if a community has free electricity, it could grow from a thousand people to 15000 people within two weeks, because people come and settle there because that is the promise of the company. So demand could also skyrocket if something is free. And this is probably a tangible risk, especially in Africa and maybe parts of South America, and Asia as well.	
C3.2 Mining Risks	R1	1727-1735	I have no corporate involvement in it because you will run into all sorts of things when you supply power to the village. At what rate? But they always feel like they are being ripped off if they pay at all. What do you do if someone does not pay? Do you cut them off? Then how do you deal with the fallout from you? Cut this guy's electricity consumption, his kid is now sitting in the dark and cannot study. Or if you provide the electricity for free, how much is too much? What is a fair usage policy and so on? So if you have a village with 500 households next door, it has five hundred potential points of trouble so better to dump it on someone else.	
C4: Stakeholder Management	D2	272-279	By the time that you are coming for full funding, it means that you have been developing this project for months on end. And this is why now we are even starting to see some pushback from communities, because when some of these mining houses come and engage them, they do not involve governments or anybody else. And they cheat people. And it ends up being a huge mess that by the time government becomes involved in these development institutions, the project is actually ready to fail at that point.	C4 includes all statements with regards to stakeholder management when it comes to DRE projects or energy sharing projects. Further, statements which are explaining roles of certain stakeholders are also considered.
C4: Stakeholder Management	R2	636-642	I think the main risk and the one to really manage and focus on is the governance administration and the relationship between the parties. I think that is where projects either are successful or fail. Who is going to be responsible? What is the role of each of the actors in the functioning of this solution? Et cetera.	

C4: Stakeholder Management	M2	2277-2285	So in most jurisdictions, when you want to develop a renewable energy project, you will interface with a number of government departments and so called government entities like the energy regulators that require you to get another different consent in order to go ahead with the project. If the government was able to streamline that development processes and remove any bottlenecks, you can shorten that development timeframe and bring the benefit of these projects online a lot sooner. So I think that is also a key role the government needs to play.	
C5: Financing	D1	1103-1112	We could help with piloting certain DRE solutions. So this could be a very well suited project for IFC to help to cover the risk of doing a leap of faith and relying on DREs instead of public power. Lastly, we could also work on the community side with the social and environmental aspects, help to finance bankable feasibility studies, help to prepare and conduct community dialogue. There is a wide scope of potential involvement. I do not see us getting involved with big financing because these are supposed to be commercial operations.	C5 includes all statements with regards to financing options and recommendations for DRE and energy sharing projects.
C5: Financing	D2	124-125	As a bank, we have not funded any mine that did renewable energy.	
C5: Financing	R1	1767-1775	They should only be working and financing where normal commercial financing is not available so that they add to the pay rather than substitute some other funding solution. So to me, that means as long as the renewable energy thing makes commercial sense by itself and is a transaction between a mine or renewables company and a commercial bank can be structured and works, I think DFIs should rather be spending the money elsewhere. For example, the distributed generation stuff for off grid communities, which is really difficult to make work commercially with commercial loans or whatnot. I think a DFI financing solar plans for major mining companies is a bit beside the point of development finance.	

Annex III: Transcription Rules

For this thesis, the transcription rules according to Kuckartz (2014, p. 136) were used and adapted. Non-linguistic data, as well as the style of speaking of the interviewees were not of interest. Thus, and to avoid loss of data due to summarizing, the transcripts were developed as similar as possible to the original audio-files. The transcripts were written with the support of a computer software (Sonix.ai).

1	It is translated literally, not spoken language or summarized. Existing dialects are not transcribed, but translated into standard language as precisely as possible
2	Language is smoothed out slightly, i.e. adapted to written English. The sentence form, definite and indefinite articles etc. are retained even if they contain errors. For instance, I'll will be written as I will.
3	Approving or confirming utterances by the interviewer (mhm, aha, etc.) are not transcribed as long as they do not interrupt the flow of speech of the interviewed person
4	Objections by the other person are put in brackets
5	Paragraphs of the interviewer are marked with interviewer, those of the interviewed person with Respondent.
6	Each contribution is transcribed as a separate paragraph. Change of speaker is made clear by a blank line between the speakers in order to increase readability
7	Faults are noted in brackets, stating the cause, e.g. (mobile phone rings)
8	incomprehensible words are indicated by (inc.)
9	Clear, longer pauses are marked with (...)
10	Sentence breaks are marked with /
11	Repetitive words are deleted. For instance "I was I was" will just be "I was"

Annex IV: Consent of Interviewees

Before the start of each interview, the consent to conduct the interview was questioned. Further, all procedure were explained to the interviewees. The following text is taken from the first interview and is representative for all of the other interviews.

“It is a pleasure to meet you and thanks for the participation in this interview. I will just provide you with the background of the procedure and your rights for data treatments for this interview. So the interview is part of my thesis, which I am writing at the Justus-Liebig University in Gießen, Germany and is part of the study program Transition Management. The topic is about decentralized renewable energies in mining areas and the electrification of communities living around. By doing so, especially developing countries have the opportunity to foster sustainable infrastructure development. My main research question is: How can decentralized renewable energy solutions be applied in the mining sector and create shared value?* To answer this question, I am conducting a literature review, an analysis of case studies and a qualitative analysis by doing these interviews here. The duration is approximately 30 minutes and the questions are formulated in an open way so you can answer them extensively, including your experiences and views. I may exceptionally edit or remove questions depending on the interview flow and the answers. The interview is structured according to three topics, including 16 questions. So in case you cannot or do not want to answer a question, just feel free to skip it. Also, if a question is irrelevant for you, feel always free to point that out. Participation in this interview is voluntarily and you may stop the interview at any time you want. Then the last part is, the interview will be recorded and transcribed, and after transcribing, I will delete the video recordings and the transcripts are stored on a hard drive disk until my thesis is finally graded. Then I will delete them too. You can at any time and stage of the thesis request to delete your transcript, then your answers will not appear in the thesis anymore. Your answers will be treated anonymously by using a coding system and no names will appear in the study, personal data will be treated in a way which does not give any conclusions about the interviewed persons. OK, that is all. And I hope you agree to the mentioned terms?”

**The research question was adapted during the conduction of the thesis and therefore may differ from the introductions in the transcripts.*