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**ENERGYANDMINES**

# THE RENEWABLE POWER OF THE MINE

**ACCELERATING RENEWABLE ENERGY INTEGRATION**

**REPORT** DECEMBER 2018



## The Renewable Power of the Mine

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### Columbia Center on Sustainable Investment

The Columbia Center on Sustainable Investment (CCSI), a joint center of Columbia Law School and the Earth Institute at Columbia University, is the only university-based applied research center and forum dedicated to the study, practice and discussion of sustainable international investment. Our mission is to develop practical approaches for governments, investors, communities and other stakeholders to maximize the benefits of international investment for sustainable development.

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### BMZ & GIZ

On behalf of Germany's Federal Ministry for Economic Cooperation and Development (BMZ), GIZ implements the sector program "Extractives for Development" jointly with BGR (Federal Institute for Geosciences and Natural Resources). In addition to providing advisory services for the Ministry on a variety of resource governance issues, the program actively promotes sector-specific dialogues, engages in multi-stakeholder initiatives and enables research and piloting of upcoming topics.

Currently GIZ also partners with the World Bank in developing a Climate Smart Mining (CSM) strategy, which features increased renewable energies uptake in mining as one of its key building blocks.

<http://www.bmz.de/rue/en/index.html>

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Over the last six years, Energy and Mines has built a reputation amongst the mining and renewables sectors as the first point of contact for connection and information on renewables in mining. The company has built a strong network of relationships with senior mining, renewables, finance and government connections to drive technology and project success in this growing space.

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# FOREWORD

In 2015, when the Sustainable Development Goals (SDGs) were adopted, it was immediately clear to us that the Mining Sector could be a critical and influential partner in achieving the SDGs. With support from the German Cooperation, the Columbia Center on Sustainable Investment (CCSI), United Nations Development Programme, World Economic Forum, and the Sustainable Development Solutions Network mapped out the potential contributions of the mining sector to each of the 17 SDGs, highlighting ways in which the mining industry could contribute through its own operations, and through collaborations and partnerships with other companies, governments, development partners and other actors.

Considering the drivers of both the mining sector and the SDGs, it is indisputable that energy lies at the center of both. In terms of development, SDGs 7 (ensure access to affordable, reliable, sustainable and modern energy for all) and 13 (take urgent action to combat climate change and its impacts) underpin the achievement of all of the other SDGs. We cannot achieve the goals on health, work, education, and eradicating poverty, for instance, without addressing the massive and growing electrification deficit. And similarly, the alarmingly rapid pace of climate change has proven to be one of the greatest threats to our and future generations; a failure to end global warming and move rapidly to a net-zero emissions global energy system would undermine all of the other goals, and indeed, the safety of all species on this planet.

Just as it is central to the development challenge, energy is central to the growth and success of the mining sector. As this report highlights, the global transition toward net-zero emission energy systems will increase mineral demand, as certain minerals are key inputs for renewable energy technologies and electrified transport systems. This will drive increased electricity demand by the mining sector, further accelerated by automation and electrification of mines.

As the World Bank's Climate Smart Mining Initiative has noted, this shift and increase in mineral demand will set forth "a series of challenges in the extraction and processing of these materials from a sustainable perspective. This includes managing greenhouse gas emissions, energy and water use and local environmental impacts to ensure that social pressures are adequately addressed."

While the challenge is substantial, the opportunity is equally as great. Indeed, the importance of energy to both the mining sector and the achievement of the sustainable development goals uniquely positions the sector for transformative impact. As we indicated in the Atlas, "The mining industry can improve energy sustainability by accelerating the incorporation of energy efficiency measures and renewable energy into mine power supplies and partnering with utilities to increase the use of renewables...mining can also leverage its energy demand to extend power to undersupplied areas through partnerships that enable the shared use of energy infrastructure."

Three years later, we're delighted to have the opportunity to expand and elaborate on those ideas, unpacking the financial, operational, logistical and political challenges, and proposing both solutions and examples of the dozens of pioneering companies that have taken steps to integrate renewables in their mining operations.

Three messages from this report stand out. First, there is a tremendous and urgent opportunity for the industry to assume its responsibilities under the SDG framework, to mitigate its contributions to climate change, particularly in light of the various pressures that will lead to higher energy demand by the sector. Second, the sector has a great opportunity to contribute to the accessibility of clean, modern energy through various energy sourcing and sale arrangements. And third, the transformation needed will require the collaboration of a range of actors, including governments, independent power producers, DFIs, and utilities.

Renewable technologies have developed so rapidly over the last few years, so the technology is no longer the main hurdle. Now, with leadership within the industry and the right incentives in place, the industry can and should aim for far more ambitious targets in terms of reduced emissions and renewable power integration.

Many eyes are on the mining sector, and expectations for leadership and innovation within the sector are growing. We hope that the report sparks discussion and dialogue, among the industry and its partners and constituencies, about the role the sector can play in helping to achieve the global goals on climate and clean energy.



**Lisa Sachs**  
Director of CCSI

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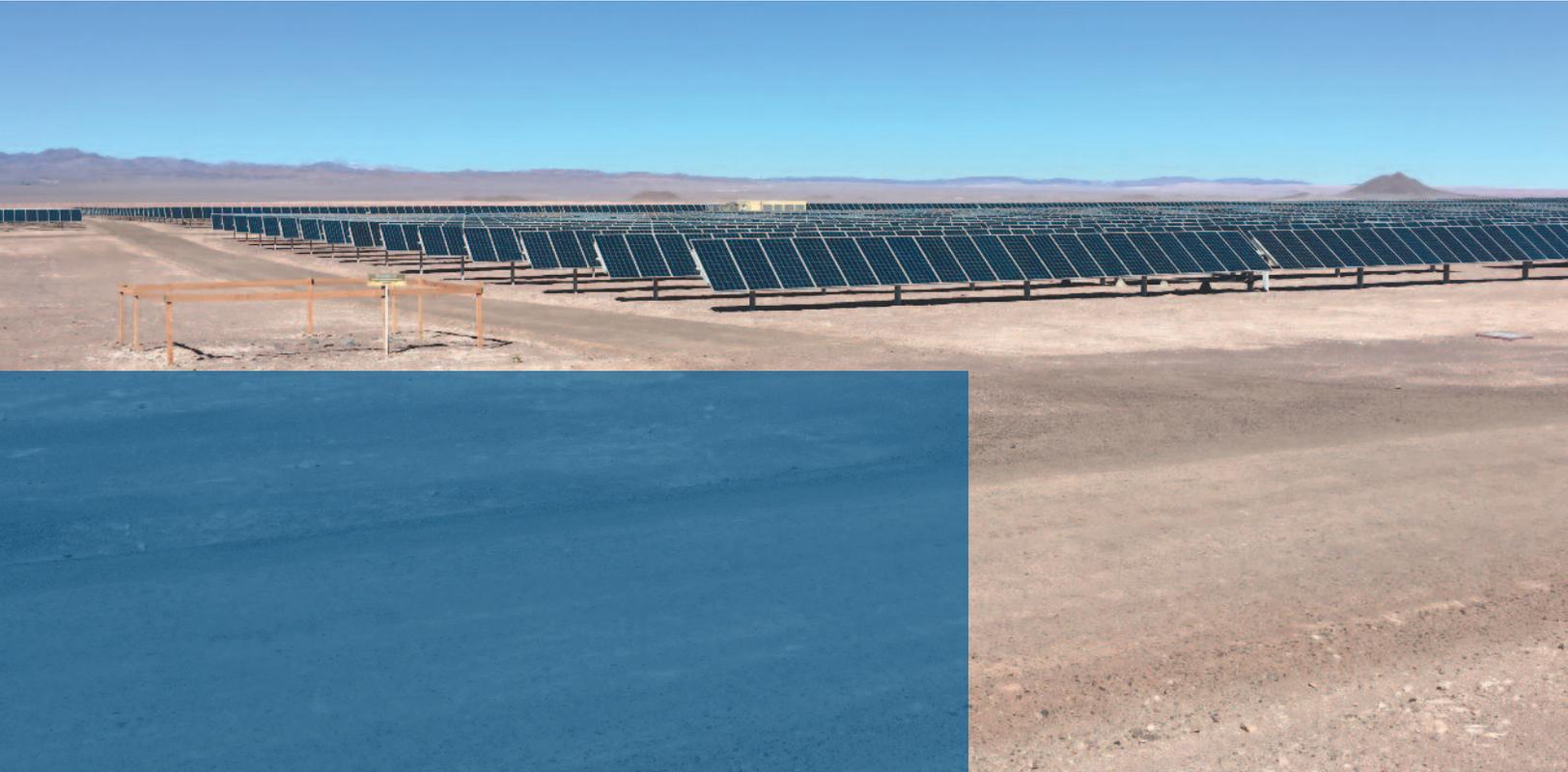
<b>ABB</b>	Swedish-Swiss company operating mainly in robotics, power, heavy electrical equipment and automation technology areas	<b>IADB</b>	Inter-American Development Bank
<b>AEMP</b>	Africa Energy Management Platform (Africa based Renewable and Hybrid Independent Power Producer and Equity Investor in Renewable Energy)	<b>ICMM</b>	International Council on Mining and Metals
<b>ARENA</b>	Australian Renewable Energy Agency	<b>ICT</b>	Information and Communication Technology
<b>ASI</b>	Aluminum Stewardship Initiative	<b>IFC</b>	International Finance Corporation
<b>Banco BCI</b>	Chilean bank	<b>IPP</b>	Independent Power Producer
<b>BBVA</b>	Banco Bilbao Vizcaya Argentaria (Spanish Banking Group)	<b>JV</b>	Joint Venture
<b>BHP</b>	Australian – British diversified mining company	<b>KFW</b>	German Development Bank
<b>BNP Paribas</b>	French Banking Group	<b>KWh</b>	KiloWatt hour
<b>BOS</b>	Balance of System	<b>LCOE</b>	Levelized Cost of Energy
<b>CAP</b>	Chilean holding company of the mining and steel sectors	<b>LGC</b>	Large-scale Generation Certificate
<b>CDSB</b>	Climate Disclosure Standards Board	<b>MW</b>	Megawatts
<b>CEFC</b>	Clean Energy Finance Corporation	<b>NEOEN</b>	French Independent Power Producer of renewable energy
<b>CFD</b>	Contract for Differences	<b>OPIC</b>	Overseas Private Investment Corporation
<b>CNE</b>	Chilean National Energy Commission	<b>PDAC</b>	Prospectors and Developers Association of Canada
<b>CO<sub>2</sub></b>	Carbon dioxide	<b>PNG</b>	Papua New Guinea
<b>CODELCO</b>	National Copper Corporation of Chile	<b>PPA</b>	Power Purchase Agreement
<b>CORFO</b>	Corporación de Fomento de la Producción de Chile, the Chilean Economic Development Agency	<b>PV</b>	Photovoltaics
<b>CRONIMET</b>	German Mining and Power Solutions Company	<b>R&amp;D</b>	Research and Development
<b>CSN</b>	Brazilian steel-making company	<b>RAF</b>	Road Accident Fund
<b>CSP</b>	Concentrated Solar Power	<b>RE</b>	Renewable Energy
<b>DCS</b>	Distributed Control Systems	<b>REFIT</b>	Renewable Energy Feed-In Tariff
<b>DFI</b>	Development Finance Institution	<b>REIPPPP</b>	Renewable Energy Independent Power Producer Procurement Program in South Africa
<b>DOE</b>	Department of Energy	<b>RET</b>	Renewable Energy Target
<b>DSM</b>	Dutch multinational active in the fields of health, nutrition and materials	<b>RMI</b>	Rocky Mountain Institute
<b>EAC</b>	Energy Attribute Certificates	<b>SARS</b>	South African Revenue Service
<b>ENERCON</b>	German wind-turbine manufacturer	<b>SCADA</b>	Supervisory Control and Data Acquisition
<b>EPA</b>	US Environmental Protection Agency	<b>SDG</b>	Sustainable Development Goals
<b>EPC</b>	Engineering Procurement Construction firm	<b>SING</b>	Sistema Interconnected del Norte Grande
<b>EREN RE</b>	French Independent Power Developer and Producer	<b>SSI</b>	Scaling Solar Initiative
<b>ESKOM</b>	South African national electricity public utility company	<b>TCFD</b>	Task Force on Climate-related Financial Disclosures
<b>GHG</b>	Greenhouse Gases	<b>TSM</b>	Towards Sustainable Mining Initiative
		<b>TUGLIQ</b>	French Independent Power Producing Group
		<b>UK</b>	United Kingdom

## TERMS AND DEFINITIONS

<b>Anchor off-taker</b>	Is the primary purchaser of electricity that will guarantee project viability.
<b>Balance of system</b>	Encompasses all components of a photovoltaic system other than the photovoltaic panels.
<b>Base load</b>	The amount of power required to meet minimum demands based on reasonable expectations of customer requirements.
<b>Blackouts</b>	A failure of electrical power supply.
<b>Bundled EAC</b>	EAC where electricity and certificates are sold and delivered together.
<b>Capital lease</b>	The lessor finances the leased asset but the ownership of the asset remains with the lessee. This is like a loan obtained by the lessee from the lessor.
<b>Care and maintenance</b>	When production is stopped and the mine is temporarily closed, but managed in a way that ensures the possibility of recommencing production at a later stage.
<b>Curtailement</b>	One among many tools to maintain system energy balance which consists of reducing the output of a generator from what it could otherwise produce to adjust to demand.
<b>Duck curve</b>	A graph of power production over the course of a day that shows the timing imbalance between peak demand and renewable energy production. In many energy markets the peak demand occurs after sunset, when solar power is no longer available.
<b>Economies of Scale</b>	The cost advantages that enterprises obtain due to their scale of operation (typically measured by amount of output produced), with cost per unit of output decreasing with increasing scale.
<b>Electrowinning</b>	Also called electroextraction, is the electrodeposition of metals from their ores that have been put in solution via a process commonly referred to as leaching. Electrorefining uses a similar process to remove impurities from a metal.
<b>Feed-in Tariff</b>	Is a payment for electricity fed into the supply grid from a renewable energy source, such as wind or solar panels. Feed-in Tariffs can be mandated by the government or offered voluntarily by an electricity retailer.
<b>Feeder tariff</b>	Payments to ordinary energy users for the renewable electricity they generate.
<b>Frequency control and spinning control</b>	A process to maintain stability in the power system when there is deviation between power supply and demand.
<b>Hybrid energy system</b>	A power system which consists of two or more energy sources used together to provide increased system efficiency as well as greater balance in energy supply.
<b>Independent power producer</b>	An entity, which is not a public utility, but which owns facilities to generate electric power for sale to utilities and end users.
<b>Intermittency (of RE)</b>	The extent to which a power source starts and stops at irregular intervals.
<b>Levelized cost of energy</b>	The net present value of the unit-cost of electricity over the lifetime of a generating asset. It is often taken as a proxy for the average price that the generating asset must receive in a market to break even over its lifetime.
<b>Life of mine</b>	The time in which, through the employment of the available capital, the ore reserves—or such reasonable extension of the ore reserves as conservative geological analysis may justify—will be extracted.
<b>Load curve</b>	A chart illustrating the variation in demand/electrical load over a specific time. Generation companies use this information to plan how much power they will need to generate at any given time.
<b>Load shedding</b>	Action to reduce the load on something, especially the interruption of an electricity supply to avoid excessive load on the generating plant.
<b>Minigrid</b>	It involves small-scale electricity generation (10 kW to 10MW) serving a limited number of consumers with a distribution grid generally operating in isolation from national electricity transmission networks.

TERMS AND DEFINITIONS *CONTINUED*

<b>Mothball</b>	To take a mine out of operation but maintain it so that it can be used in the future.
<b>Net-metering</b>	A system in which solar panels or other renewable energy generators are connected to a public-utility power grid and surplus power is transferred onto the grid, allowing customers to offset the cost of power drawn from the utility.
<b>Off-site</b>	A power plant that is not on the concession of the mine.
<b>Off-balance sheet</b>	Assets or debts that are not considered in the balance sheet of a company
<b>Off-grid</b>	Not being connected to the grid.
<b>On-grid</b>	Being connected to the grid.
<b>On-site</b>	A power plant that is on the concession of the mine .
<b>Off-taker</b>	The party that is buying the electricity.
<b>Operating lease</b>	A rent agreement where the lessee pays fees to the lessor and does not own the asset.
<b>Oracles</b>	An agent that finds and verifies real-world occurrences and submits this information to a blockchain to be used by smart contracts.
<b>Purchasing power agreement</b>	A contract between two parties, one which generates electricity (the seller) and one which purchases the electricity (the buyer).
<b>RE100</b>	Initiative of companies that are committed to 100% renewable electricity.
<b>Renewable Energy Buyers Alliance</b>	Initiative to identify barriers to buying renewable energy and develop solutions that meet rapidly growing voluntary demand.
<b>Shared Value Paradigm</b>	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.
<b>Sleeved PPA/back-to-back PPA/off-site physical PPA/direct PPA</b>	An agreement by which the IPP sells the electricity directly to the off-taker for an agreed price.
<b>Spinning Reserves</b>	The extra generating capacity that is available by increasing the power output of generators that are already connected to the power system.
<b>Strike Price</b>	Bilateral agreement in which one party gets a fixed price for electricity.
<b>Synthetic PPA/Virtual PPA/Financial PPA/Contract for difference</b>	Unlike a physical PPA, a synthetic PPA is a financial contract and can only exist if there is a spot market. In such arrangement the IPP sells the electricity at the spot market price and then settles the difference between that price and the agreed price in the PPA with the off-taker.
<b>Turnkey</b>	Project that is constructed so that it can be sold to any buyer as a completed product.
<b>Unbundled EACs</b>	EACs where the electricity and certificates are sold and delivered separately.
<b>Variability (of RE)</b>	The extent to which a power source exhibits changes in output.
<b>Wheeling</b>	The transportation of electric energy (megawatt-hours) from within an electrical grid to an electrical load outside the grid boundaries.



**Solar farm** in Atacama Desert, northern Chile.  
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## EXECUTIVE SUMMARY

Mining is an energy intensive industry that requires access to a stable electricity source. With rising mineral demand and falling ore grades, energy demand is estimated to increase by 36% by 2035. Electricity demand is expected to grow at an even faster rate, given that automation and electrification of mine sites are going to rebalance the energy demand from liquid fuels towards electricity. Energy produced and procured by mining companies today is mostly fossil fuel

based. This will have to change if the sector is to contribute to the decarbonization of the world economy, needed for countries to meet the target they adopted in the Paris Agreement of keeping global temperatures from rising more than 1.5-2 degrees Celsius. At the same time, the costs of solar, wind and battery storage systems have been falling at an unprecedented scale, which has encouraged an increasing number of mining companies to test these technologies at their mine sites.

This report provides an overview of how the mining sector has been integrating renewables in their mining operations, the bottlenecks that still exist, and the future trends that are likely to further drive the roll-out of renewables to supply electricity to mine sites. The primary focus is on wind and solar sources due to the rapid uptake in recent years and continued expected falling costs, making them more attractive from a business perspective, and given that these technologies can be integrated at more mine sites than other renewable energy sources.

After an extensive review of existing literature, 53 people were interviewed from the various stakeholder groups to capture the latest developments and discuss issues that are not covered in the literature. 38 case studies have been included to highlight practical examples and lessons learned.

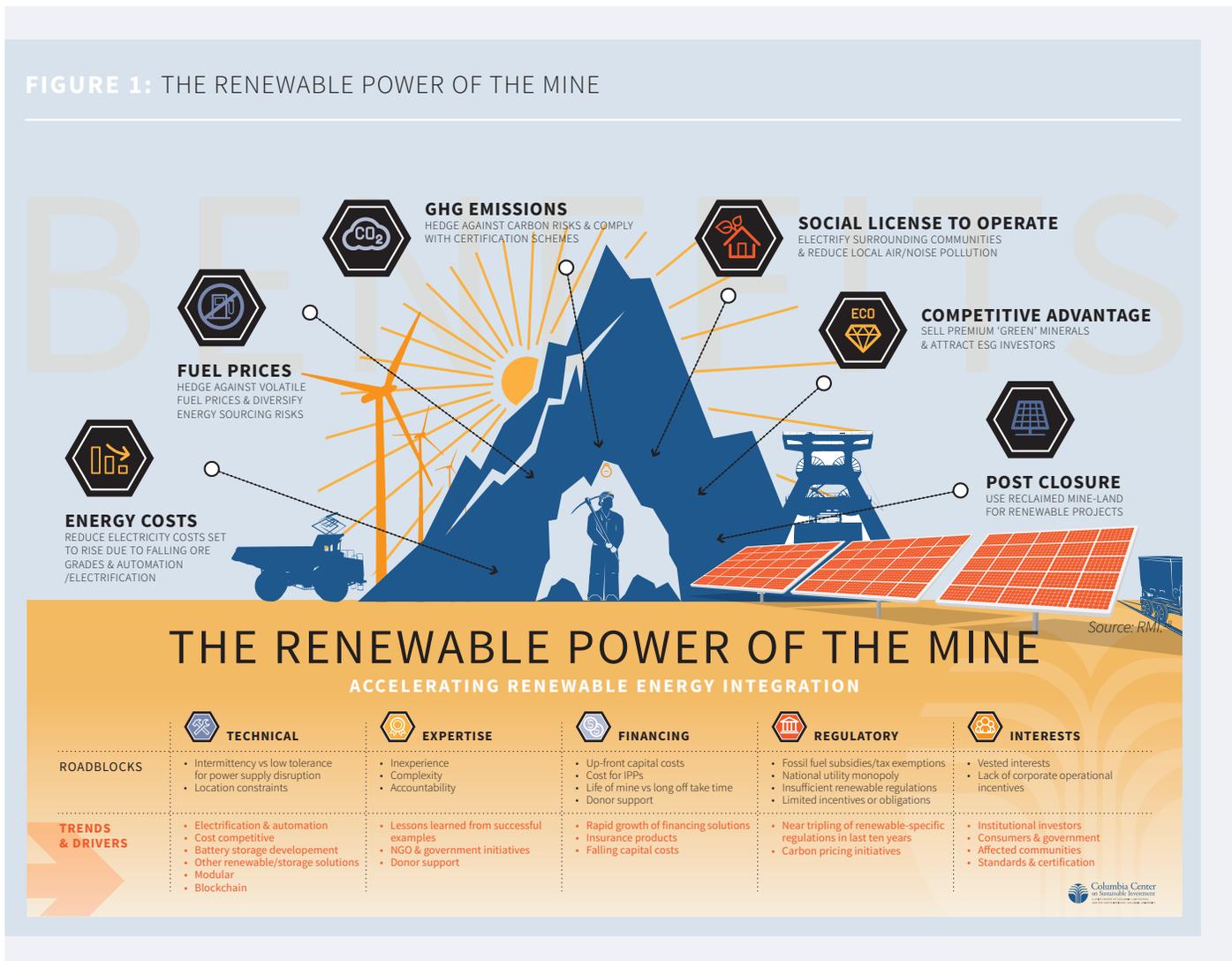
The figure below summarizes the findings from the report. Apart from reducing operating costs, renewable energy solutions have the potential to help mining companies to hedge against volatile commodity prices when the energy source is fossil fuel based and diversify energy sourcing risk; reduce greenhouse gas emissions thereby

mitigating carbon tax risks, and complying with industry certification schemes; secure the social license to operate by reducing local noise and air pollution, as well as improving energy access in remote regions when the mining project is off-grid and can be leveraged to electrify surrounding communities; build a competitive advantage with ESG investors and clients by selling premium low-carbon products, and install renewable energy projects on reclaimed mine sites to earn land leasing fees and support the region post mine closure.

The recommendations have been divided up by the most important stakeholders that have a role to play in implementing the scale up of renewable power integration at mine sites – these include governments, mining companies, independent power producers (IPP) and donors.

### FRAMEWORK

There are several factors that will determine how and to what extent mining companies can integrate renewable energies in their operations. These include:



- 1. The potential for renewables:** Including the location, mine design and other power sourcing options. The location is related to the weather conditions in the area or grid system, land site characteristics and whether these are suitable for the construction of wind or solar systems. The mine design relevant for renewable energy integration includes the load-profile and lifetime of the project. The latter, in particular, will be fundamental in determining whether the renewable power project is bankable and can be outsourced to an IPP.
- 2. Access and stability of grid:** Mines that are off-grid or cannot rely on the grid will require separate power plants or backup generators.
- 3. Stage of the project:** Most of the energy will be consumed during operations. However, there are also opportunities to integrate renewables during exploration and post-closure.
- 4. Regulatory framework:** Including renewable energy policies, taxes and incentive mechanisms;
- 5. Beneficiaries:** Recipients of the electricity from the renewable energy project could be the mine, the grid and/or communities in close proximity to the mine site.

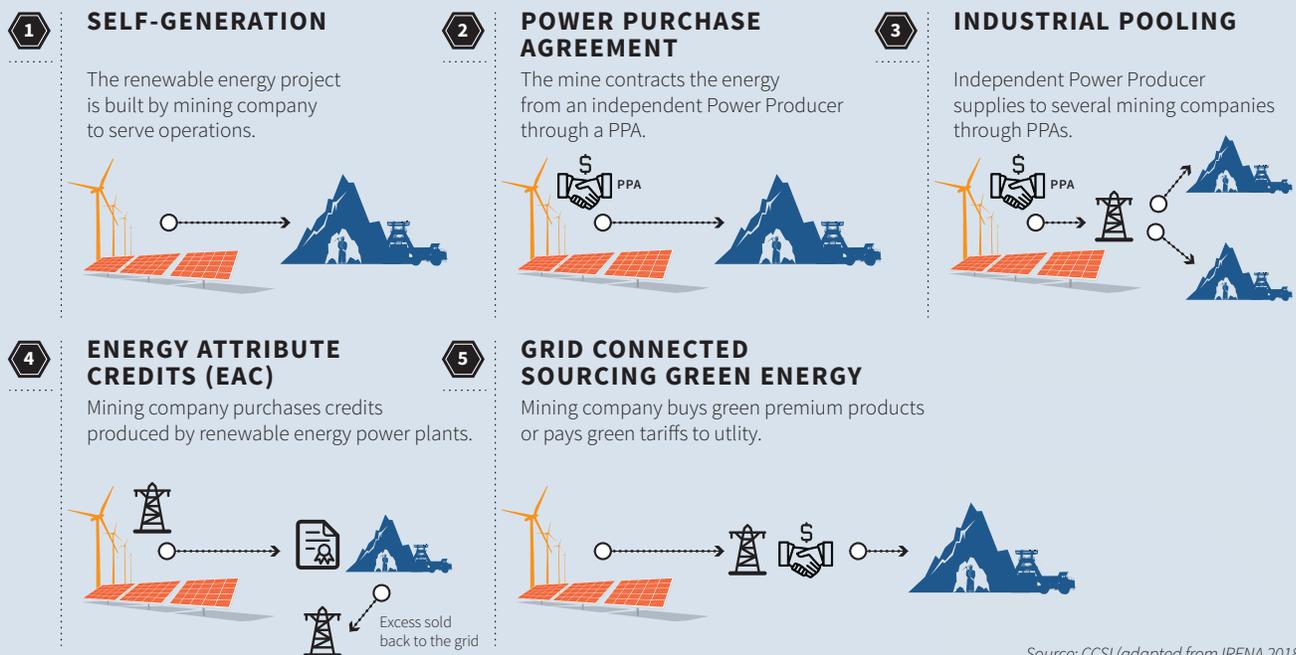
These factors are often interlinked. For example, the existence of additional beneficiaries will be closely related to whether the project is off-grid or on-grid, and whether the regulatory framework allows

for third party sales. Furthermore, these factors will determine the penetration rate of renewables. In a location where wind and solar profiles complement each other, for example, higher renewable penetration rates can be achieved as demonstrated by the Zaldivar Copper Mine (Box 5) in Chile for an on-grid project and the Coober Pedy (Box 14) hybrid power system in Australia for an off-grid project. For renewable penetration rates above 20% in off-grid scenarios there is a need to integrate storage and power controllers that conduct real time monitoring of the power balance, energy quality and stability.

There are five renewable power sourcing arrangements available for mining companies as illustrated in the figure below:

- 1. Self-generation:** The renewable power project is built and owned by the mining company.
- 2. Power Purchase Agreement (PPA):** The mine contracts the energy from an IPP and commits itself to buying the electricity at pre-agreed terms that are laid out in the PPA.
- 3. Industrial Pooling:** Several companies commit to buying electricity from an IPP making a renewable project viable.
- 4. Energy Attribute Credits:** The mining company purchases credits produced by renewable energy power plants.
- 5. Grid-connected sourcing green energy:** The mining company buys green premium products or pays green tariffs to a utility.

FIGURE 2: RENEWABLE ENERGY SOURCING ARRANGEMENTS



Source: CCSI (adapted from IRENA 2018).

The self-generation and PPA arrangements are most commonly used in the mining sector. The former is particularly well suited for off-grid mining projects in jurisdictions that do not have a regulatory framework in place allowing for third party electricity sales. While this arrangement can help reduce electricity prices for operations, it increases the capital expenditure and risks borne by the mining company. When PPA arrangements are allowed, they transfer the capital expenditures to the IPP. There has been a proliferation of corporate and mining related PPA agreements that have been adapted to specific contexts and needs.

There are three renewable power sale arrangements that are linked to mining projects that are illustrated in the figure below:

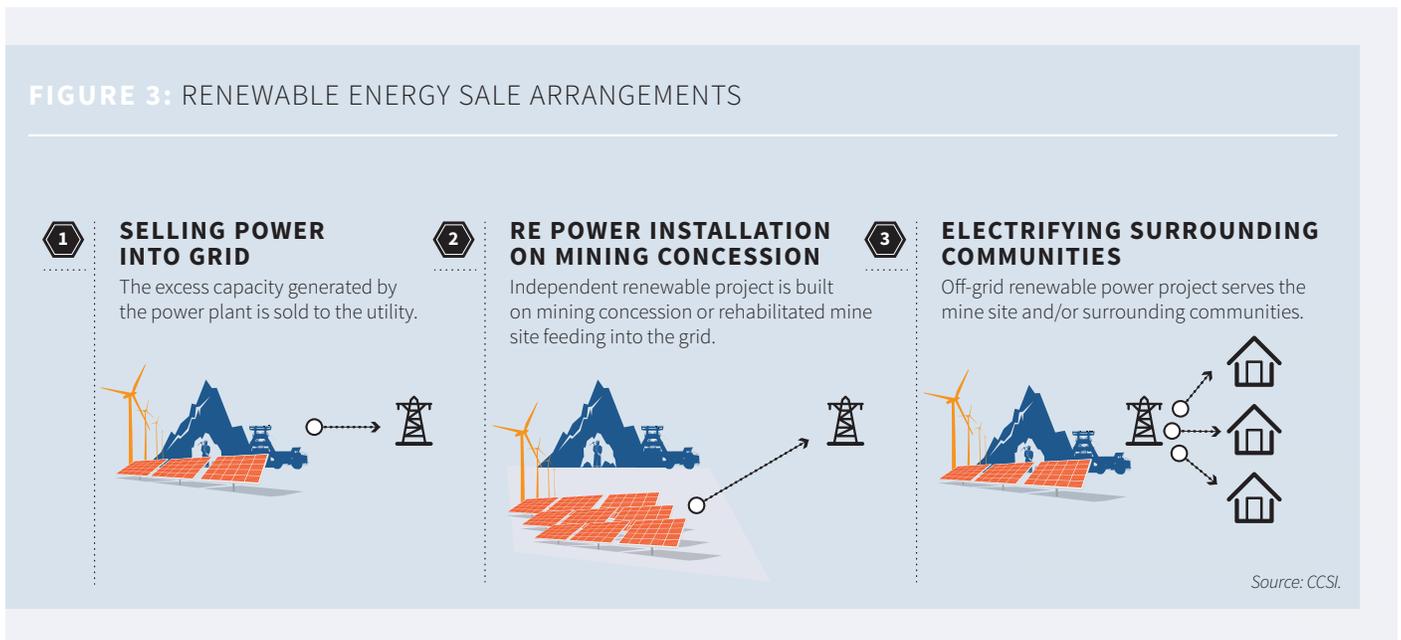
1. **Selling power into the grid:** Excess capacity generated by the renewable power plant is sold to the utility.
2. **Installing renewable power project on mining concession:** The mining company provides or leases the land to an IPP without necessarily using the power for the mining operation itself.
5. **Electrifying surrounding communities:** In an off-grid scenario the renewable power project serves the mine site and/or surrounding communities.

While the first sale arrangement is uncommon in mining, there are several examples of the second and third. The mining company Asarco in Arizona (Box 12), for example, has signed a long-term lease with an IPP for building and operating a renewable power project on its concession. This is particularly attractive for the post-closure phase

where the previously mined land is a liability for a company. At the same time, access to suitable land is one of the biggest obstacles for renewable energy projects to go ahead. Rehabilitated mines with existing infrastructure access can lower renewable project costs and present the opportunity for an alternative use of the mine site, as well as a potential revenue source to the mining company. Furthermore, the flat terrain of rehabilitated tailings facilities is well suited for solar installations and does not require clearing of land. There are several examples of renewable energy projects operating on rehabilitated lignite mines in Germany, while BHP Billiton (Box 13) is currently reviewing its legacy mines for renewable generation and storage potential.

In remote regions, mining companies have traditionally built infrastructure and provided services for mining towns necessary to house the workforce. This has included the provision of electricity. By extending this infrastructure to surrounding communities, mining companies can increase electrification. Particularly in Africa where energy poverty affects around 600 million people, this is a huge development opportunity. The Weipa bauxite mine (Box 15) in Australia and Lihir gold mine (Box 16) in Papua New Guinea are examples where solar and geothermal power projects have been integrated to serve the mine site and feed into the mini-grid of surrounding communities. While this sale arrangement tends to be more complex, it has the potential to significantly contribute to the ‘shared value paradigm’ of the sector, reduce the possibility of community opposition, and contribute to the continued development of the region in the post-mining period as the average renewable power project exceeds the lifetime of mining projects.

FIGURE 3: RENEWABLE ENERGY SALE ARRANGEMENTS



## ROADBLOCKS

The roadblocks to increased renewable power integration can be grouped into five categories: technical, expertise, financing, regulatory and interests/incentives.

### Technical

The technical roadblocks are associated with intermittency and variability of renewable power generation sources. Mining projects are designed to operate 24 hours a day and 365 days a year, and consequently require stable electricity access without interruptions. Solar and wind power can only be generated when the sun is shining and the wind is blowing. Particularly for off-grid mine sites this means that a backup energy source is needed that is dispatchable (in most cases diesel is used). The design of a hybrid energy system not only needs to consider the 24-hour cycle, but also seasonality and multi-year cycles such as El Niño to ensure power is guaranteed in the worst-case scenario. As such, capital expenditures associated with a backup dispatchable energy system cannot be eliminated, which makes financial investment in higher rates of renewable power penetration less appealing. Another technical roadblock is associated with the location and installation. There will be areas where the weather conditions may be less suitable for solar and wind energies. Furthermore, the mine site may be located in terrain where it is difficult to build a solar or wind power plant given that the land-use intensity of solar photovoltaic is 25 times, and wind 2.5 times, higher than diesel-based generation systems.

### Expertise

Given the relatively recent trend of mining companies seeking to integrate renewable energies into their mining operations, the experience and in-house knowledge on wind, solar and hybrid electricity generation systems are still nascent as compared to those of traditional power plants such as diesel gensets, which mining engineers are used to operating and repairing. To address this shortcoming, mining companies may seek to outsource the renewable or hybrid plant to an IPP. However, procurement systems also need to be adapted in order for the projects to be palatable for IPPs and financiers. Moreover, if the energy solution is not fully integrated between the different elements of the hybrid systems, it might create logistic and accountability issues.

### Financing

Financing constraints relate back to the cost structure of renewable power plants. While diesel fired power plants have higher operating costs, the renewable up-front capital costs are and will remain higher for the foreseeable future. This is problematic from a cash-flow perspective in the self-generation sourcing arrangement, as investors want to recoup initial capital expenditures as quickly as possible. As

mentioned above, outsourcing to an IPP addresses this problem, but it will come at a higher price paid for the electricity as the IPP will need to make a margin and may suffer from higher financing costs than large mining companies. Furthermore, the IPP will require a commitment by the mining company in case it is the anchor off-taker (or sole off-taker in the off-grid scenario) that is long enough in order to recoup the investment. This commitment is tied to the life of mine, which in turn is determined by the mineral reserves that are economically feasible to extract. If the life of mine is in line with the life of the solar/wind power plant, which are designed for around 20-25 years, the renewable project is likely to offer significant cost saving opportunities as compared to less capital-intensive energy solutions such as diesel. Mining companies, however, are incentivized to limit up-front exploration costs to the point where the mining project becomes bankable (i.e. to have sufficient reserves that will attract financing) and then continue exploration while operations are ongoing. While the mining project is therefore likely to run longer than the initial life of mine would suggest, IPPs and financiers are unwilling to take the risk of a shorter initial commitment. With a shorter life of mine, the attractiveness of renewable energy solutions falls.

Even with sufficient reserves to warrant a long mine life, mining companies are reluctant to sign long-term PPAs or provide parent guarantees, as this reduces the flexibility of putting a mining project into care and maintenance in case there is a significant market downturn. Long-term PPAs lock mining companies into price commitments in an era where electricity prices offered by IPPs are falling rapidly. Furthermore, the solar and wind sector has seen market consolidation with many IPPs being acquired or going bankrupt in recent years. The most prominent is SunEdison, once reported the world's largest renewable energy company, which filed for bankruptcy in 2016. This adds to risk of entering into a long-term commitment with renewable IPPs.

Financing is also a bottleneck to operationalize the sale arrangement whereby surrounding communities are electrified. This model should be particularly appealing for donors given the development potential. However, development finance institutions (DFIs) are more focused on financing large-scale renewable utility projects rather than smaller hybrid systems relevant for off-grid mines and surrounding communities. Administrative costs are higher on these smaller systems and most DFIs do not finance fossil fuel projects, which at least for now, would have to be part of a hybrid system in an off-grid scenario. Furthermore, long processes to approve finances are an obstacle in a fast-paced renewables market.

### Regulatory

Fossil fuel subsidies are slowing the integration of renewables at mine sites. Globally, fossil fuel subsidies in 2015 were about double the subsidies for renewable energies. Furthermore, mining companies are often exempt from paying taxes on fuels used for off-road operations

and for energy generation. In mining rich jurisdictions such as Australia and South Africa, the mining sector is among the biggest recipient of fuel credits or refund claims. These subsidies and incentives make renewable energy sources less attractive. Many resource rich jurisdictions also lack renewable energy specific regulations. For off-grid mining operations in developing countries, the PPA between the IPP and the mining company can dictate the rules of the game and compensate for a deficient legal framework. However, as soon as the renewable energy project is connected to the grid and/or is designed to sell to third parties such as communities around the mine site, a renewable power legislation is necessary. While there are some mining projects that have committed themselves to electrifying communities surrounding their operations, there is a lack of incentives, commitments or legal requirements to advance this arrangement.

### Interests

While from a technical perspective the regulatory changes necessary to encourage renewable energy projects seem relatively straightforward, in practice energy reforms are difficult to implement. This is because there are powerful private and public interests that are set to lose out from policy changes. Reforms aiming to unbundle the energy sector to allow for third party producers to compete in the generation and distribution often face opposition from the public utility that would lose its monopoly power. There are also powerful interests in the fossil fuel sector, which are set to lose from an increasing uptake of renewables. This ranges from politicians wanting to appeal to electoral votes that benefit or have benefitted from the fossil fuel value chain, to private sector groups lobbying governments and funding disinformation campaigns. Furthermore, the diesel fuel import and sale sector in developing countries is often controlled by influential and well-connected business elites.

At sector and company level there are also competing interests. The mining sector is less geared towards innovative thinking and more reluctant to change than other industries like for example the ICT sector that is leading in renewable power integration. The “first to be second” attitude of wanting to integrate new technologies once proven successful by others is hampering the testing of new renewable energy solutions at mine sites. At the company level, while management and the sustainability department of a mining company may be interested in renewable power integration for reputational reasons, a mine manager that is paid according to meeting production targets may not. Furthermore, contractors are incentivized to design conservative systems with low renewable power penetration rates to ensure that they can meet the guaranteed energy requirements.

## TRENDS AND DRIVERS

The trends and drivers have also been grouped into the five categories set out above.

### Technical

Growing demand of minerals and falling ore grades will require more energy per tonne of output. Electricity demand is going to make up an increasing proportion of total energy as mines electrify. Goldcorp’s Chapleau gold mine (Box 26) exemplifies this trend. At the same time, solar and wind generation costs are expected to fall further in coming years making these sources the lowest cost electricity options (on a levelized cost and non-subsidized basis). Today, renewables such as wind and utility scale solar are already cost-competitive on an unsubsidized basis. The Thabazimbi mine (Box 27) in South Africa provides an example where already in 2013 solar integration provided a cost saving, with the plant breaking even after 3.6 years. Since then the levelized cost of solar PV has dropped by a further 44%.

It is also forecast that battery prices will fall rapidly with costs cut by half between 2017 and 2025. This will make battery storage increasingly attractive to help address solar and wind intermittency, thereby allowing for higher renewable penetration rates in off-grid scenarios. The Degussa (Box 28) copper/gold mine in Western Australia provides a good example of a project that has already integrated batteries in its hybrid power system.

Other promising storage solutions for the mining sector that may help address renewable intermittency include the development of solar thermal, pump storage and hydrogen technologies. At the Gabriela Mistral (Box 29) mine in Chile a solar thermal plant supplies 80% of electricity of Codelco’s electrowinning facility. Furthermore, there are several concentrated solar power (CSP) plants being built to serve the mining sector’s needs in Northern Chile such as the Cerro Dominador (Box 30) project. Pump storage systems could be integrated at abandoned mine sites. The most advanced pump storage energy project using two open pit mines comes from Kidston (Box 31) in Australia. Hydrogen is particularly attractive to the mining sector, because it presents the opportunity to not only provide a storage solution for renewable energy-based electricity generation, but also has the potential to substitute liquid fuels in mining machinery – a solution that the Raglan Mine (Box 32) is piloting in Canada.

To address the commitment constraint outlined above whereby mining companies are unable or unwilling to sign long-term PPAs, modular renewable technologies may provide a solution. The length of the PPA can be shortened and the systems can be re-deployed if the PPA is not renewed. This technology could also help to integrate renewables during the exploration phase. Modular solar technologies are being integrated at the Century mine (Box 33) and Cannington mine (Box 33) in Queensland, Australia.

## Expertise

An increasing number of mining companies are integrating renewable energies in their mining operations and are gaining experience and expertise. IPPs are also improving their knowledge on the mining sector specificities that they need to consider when offering commercial renewable power solutions. Furthermore, government institutions and NGOs that are working on projects related to renewable power integration at mine sites – for example ARENA (Box 34) by the Government of Australia and the Sunshine for Mines project by the Rocky Mountain Institute – are disseminating their findings and lessons learned. Donors too have accumulated experience helping governments to design enabling policies and procure renewable energies. Lessons learned from other sectors can help address several of the sourcing arrangements outlined above. For example, GIZ’s Anchor-Business-Community project (Box 35) has the potential to help stakeholders implement the community electrification sales arrangement. These experiences, particularly as they begin to show evidence how mining companies can commercially benefit, will further drive renewable energy integration.

## Financing

Financing for renewable IPPs is still the largest constraint – particularly in developing countries where the regulatory regime is not yet adapted to renewables and where perceived risks are higher. However, there are positive trends when looking at corporate PPA developments. The volume of corporate PPAs has increased immensely from about 2 GW in 2012 to 29 GW in 2018. A wide range of PPA forms, financing and insurance products have been developed to accommodate different project specificities and risks. As a result, equity rates are now in the range of 5-10% in Australia where they used to be in the range of 10-15% for on-grid renewable projects. A similar trend is being observed for off-grid mines.

DFIs play a particularly important role in de-risking renewable energy financing as seen in the Amanecer Solar CAP project in Chile (Box 37). Furthermore, institutional investors such as pension funds, sovereign wealth funds and international private asset managers may increasingly be attracted to investments in renewables as the field divests from fossil fuel projects freeing up long-term capital.

## Regulatory

Governments around the world are increasingly putting in place financial and fiscal incentives that make renewables more attractive, as well as regulations to support renewable energy roll-out. While in 2007 only 50 countries had renewable power regulations and incentives in place, this has increased to 128 countries in 2017. More than 150 countries had renewable power-related targets in place at the national level. Furthermore, the number of jurisdictions that have put in place carbon pricing initiatives has increased rapidly, reaching 40 national and 25 sub-national jurisdictions in 2017. Consequently,

the quantity of emissions covered by carbon pricing has increased fourfold over the past decade. Such initiatives will internalize the costs created by emissions of fossil fuels and further strengthen the economic case for renewables. This trend is set to continue as countries are seeking to address commitments made in the National Determined Contributions under the Paris Agreement.

## Interests

Shareholders and institutional investors are increasingly concerned about the climate change risks in their portfolio. In the US, climate change has topped the list of shareholder resolutions in recent years with investors asking companies to put in place management systems to reduce carbon risks, and set energy efficiency and renewable integration targets. Similar trends can be observed in other jurisdictions where mining companies are listed. Initiatives such as the Task Force on Climate-related Financial Disclosures and the Sustainability Accounting Standards Board are setting new climate-related disclosure requirement standards. The Science Based Targets initiative is helping companies and investors assess what targets are in line with the Paris Climate Agreement.

Similarly, consumers are increasingly putting pressure on suppliers to guarantee a responsible value chain. The responsible sourcing of cobalt from the Democratic Republic of Congo is a recent example where the mining sector has been directly impacted. Reporting of carbon emissions in the value chain has been requested by companies such as Apple, which are putting pressure on suppliers to reduce emissions. Being one of the biggest emitters in the value chain of consumer products, the mining sector will be affected by these trends. Particularly in the car manufacturing sector, where about two thirds of the total carbon content of the car during its lifecycle will shift from use-of-car with an internal combustion engine to the production of a car with an electric engine. Another potential driver for increased demand of low carbon minerals is public procurement. EU and OECD country policies are seeking to reward greener supply chains in the construction and transportation sectors.

While less concerned about carbon emissions, affected communities care about local air and noise pollution from mining projects, which renewable energy integration can mitigate. The mining sector has increasingly struggled to obtain and retain the social license to operate in many mining jurisdictions in recent years. This pressure is likely to intensify as mining companies seek to automate their sites leading to fewer employment and procurement opportunities at the local level. To benefit local communities in off-grid scenarios, mining companies could seek to electrify surrounding communities as a way to rebalance the ‘shared value’ paradigm.

As an answer to growing stakeholders’ pressure, the mining sector has seen an increasing number of standards over the last years that foresee mining companies to do more in order to address climate change. To various degrees, international and national mining

associations have adapted climate change standards. Certification schemes, such as the Aluminum Stewardship Initiative and the Initiative for Responsible Mining Assurance, are also requiring companies and mine sites to set more ambitious greenhouse gas emission targets. Complying with these will require mining companies to adopt renewable energies more widely.

## CONCLUSIONS AND RECOMMENDATIONS

The momentum and long-term trends all point towards renewable energies playing a bigger role in the mining sector. As the impacts of climate change worsen, climate adaptation expenses increase, and prices for renewable and storage technologies continue to fall, this momentum is likely to grow with pressure from the various stakeholders intensifying. This development presents an opportunity for forward looking mining companies to build up expertise in renewable power integration. As integration advances, investments can be leveraged to increase electrification in rural off-grid scenarios with the help of donors. Post-closure, there is also great potential for mining land to be used for renewable energy projects.

To facilitate the integration of renewable energies in the mining sector, governments, mining companies, independent power producers and donors have a role to play.

**Governments** looking to attract renewable power investments could allow IPPs to enter the market. Alternatively, corporate procurement programs could be offered by utilities. Governments could also mandate the inclusion of renewable energy assessments in feasibility studies for greenfield projects and negotiate community electrification requirements where suitable. Regulations should be adapted to allow for the continuation of renewable energy project post-closure. Furthermore, setting carbon emission targets for the sector where it is a large contributor to national emissions could be considered. To further incentivize renewables, governments could adopt carbon pricing initiatives, remove fossil fuel subsidies and track renewable attributes. Research and Development (R&D) in this area and first-movers should be rewarded. On the demand side, governments could seek to adopt green public procurement practices to incentivize the decarbonization of the construction and transport supply chains.

**Mining companies** and associations should seek a race to the top with greater renewable power leadership and more ambitious targets. Developing low-emission premium products can provide a signal to consumers of leadership and may lead to a competitive advantage in the future. Training staff on renewable energy opportunities and aligning incentives can help to internalize this leadership throughout the company. Mining processes and renewable power options need to be reviewed regularly given the rapid development of renewable technologies and fall in prices. Adapting procurement practices to better cater for renewable energy solutions is key. In off-grid scenarios mining companies should more strategically consider the role that they can play in designing energy solutions to spur rural economic development through increased electrification.

**Independent power producers** could seek to better address the mining companies' needs by developing hybrid power solutions that cater for various circumstances. Following stringent environmental, social and governance standards would help to ensure that the renewable power projects retain the social license to operate in the future. As more renewable projects come on stream, resistance by affected communities may increase if best practices are not followed. Seeking financing from DFIs can support in this undertaking.

**Donors** should seek to increase climate finance given that developed countries are lagging behind in their commitments. Particularly financing for medium-sized renewable energy projects suitable for mine sites, is currently lacking. A one-stop shop for renewable power integration in corporate (mining) projects could be designed to streamline support. Donors can play a particularly important role in developing and implementing off-grid community electrification schemes and to coordinate power demand pooling. Streamlining support programs from inception to conclusion would help keep up with the fast-paced renewable energies sector. Increased collaboration between the mining and renewable energy departments within donor organizations, as well as between the technical advice and financing units can help identify opportunities and implement them. Finally, donors should work politically to help advance energy reforms that support the integration of renewable energies in resource rich developing countries.

We hope that this report will contribute to the understanding of renewable power integration in the mining sector. During the research and in conversations for this study, several interesting follow-up ideas came up which deserve additional attention. These include: (1) Reviewing other renewable energy technologies and assess, which technologies are particularly promising along the mining value chain; (2) assessing the extent to which developing mining countries with hydro-potential could both facilitate and benefit from the penetration of solar and wind energy; (3) designing a mining operation around renewable power generation profiles and comparing the resulting economics of the project with the traditional approach of designing energy solutions around a mine that operates at a set capacity; (4) in-depth analysis and piloting of the electrification of surrounding communities arrangement in off-grid scenarios; (5) developing guidelines and training materials to help mainstream renewable power integration; and (6) assessing whether there is potential for renewables in artisanal and small scale mining operations.



Concentrated solar power plant. © shutterstock.

## INTRODUCTION

The mining sector is an energy intensive industry requiring constant and reliable access to energy for its operations. Depending on the source and the level of downstream activities included in the assessment, the mining industry makes up between 1.25-11% of global energy demand.<sup>1</sup> On average, the sector's final energy consumption is highly dependent on fossil fuels with 62% of final energy consumption being made up of oil, gas and

coal. 35% is made up of electricity consumption and depending on the country of operations, the grid is also fossil fuel based.\* In 2014 only 0.001% of the final energy consumption mix in the mining and quarrying sector was solar, wind or other types or renewables installed on site.<sup>3</sup> By including the average electricity generation mix from the grid, renewable energy contribution to mining has been relatively constant at below 10% since 1971.<sup>4</sup>

### NOTE

\* Ferrous and non-metallic minerals tend to have a higher fossil fuel to electricity consumption ratio (around 87-88%) as compared to non-ferrous metals (around 60%).<sup>2</sup>

Looking forward, energy consumption by the mining sector is expected to increase by 36% by 2035<sup>5</sup> due to declining ore grades and growing mineral demand. At the same time, the world has committed itself to the Agenda 2030<sup>6</sup> and keeping global temperature from rising beyond 1.5 degrees Celsius. This will require a rapid decarbonization of the global energy system by the middle of the century.<sup>7</sup> These two trends present the mining sector with an unprecedented opportunity and challenge. On one hand, the speed at which the energy transition occurs will be a determining factor for the growth in demand of certain minerals, given that carbon-zero technologies in the energy and transport sectors, are more mineral intensive.<sup>8</sup> On the other hand, the mining sector will have to drastically reduce its dependence on fossil fuels in its operations to lower its carbon emissions. Solar and wind generation projects have the potential to decarbonize the electricity component of energy consumption.

Against this backdrop, and considering the advances in solar and wind technology, as well as the drastic fall of solar and wind energy prices over recent years, renewable energy solutions have become increasingly attractive for mining companies. On average, energy expenses make up around 15% of total costs and can rise to 40% in the metals mining industry when processing is involved.<sup>9</sup> Therefore savings in this cost component, which is likely going to increase in the future, is an attractive proposition to mining companies. Currently, there are a number of solar and wind power projects that are coming on stream, and Ernst and Young anticipates that by 2022 the mining sector's investment in renewable energies will be more than double today's investment.<sup>10</sup>

Despite increased interest for renewable uptake in the mining sector, the penetration rate of wind and solar is still small. It has not increased significantly as a proportion of total energy consumed by the sector. Reservations about renewable energy integration continue to exist. This can be traced back to several reasons, including; (a) the intermittent nature of solar and wind power supply; (b) the inadequate quantification of proven mineral reserves in place to justify a long term investment in renewable power infrastructure; (c) the lack of know-how by the mining industry about renewables; (d) the incentive structures in mining companies that are not conducive to change; and (e) a lack of understanding by renewable energy developers of how to structure commercial energy deals fine-tuned to the specificities of the mining industry.<sup>12</sup>

The goal of this report is to provide recommendations to mining companies, independent power producers, governments and development partners on how to accelerate the integration of renewable energies in the mining sector. It does so by identifying the

existing bottlenecks and future drivers that are going to influence the speed of integration. After an extensive review of the literature, 53 people were interviewed from the various stakeholder groups to capture the latest developments and discuss issues that are not covered in the literature. Relevant quotes from these interviews have been included throughout the report. Furthermore, case studies were reviewed to highlight practical examples and lessons learned. These are presented in boxes throughout the report. Particular focus has been placed on reviewing the regulatory framework and case studies in Australia, Canada, Chile and South Africa. These regionally diverse resource rich countries are at the forefront of renewable power integration at mine sites, and have developed advanced regulatory frameworks to support such systems. As such, they present valuable lessons learned that other resource-rich countries can learn from.

The primary focus of this report is on solar and wind energy sources that supply large-scale mining operations. These technologies have been chosen due to their rapid uptake in recent years,\* the continued expected falling costs in the years to come making them more attractive from a business perspective, and given that these technologies can be integrated at more mine sites than other renewable energy sources.\*\* Hydropower is a more mature technology where costs are unlikely to fall significantly in the coming years. Furthermore, hydropower-mining synergies and case studies have already been highlighted in the "The Power of the Mine" report that is co-authored by CCSI.<sup>14</sup> This does not mean that hydropower and other renewable technologies should not be considered by mining companies when assessing potential power sources and the report provides case studies of hydropower integration (Box 5 and 7) and geothermal integration (Box 16). Particularly hydropower has a large potential to address the intermittency problems associated with wind and solar, and can more adequately serve the very high energy needs of smelting operations.

The report is structured as follows: Part 1 provides the framework of how mining companies can source wind and solar power for their operations. It highlights the factors that need to be considered when choosing the energy sourcing arrangement and the renewable penetration rate that can be achieved with various technologies. Various renewable sale arrangements are also outlined. Part 2 highlights the roadblocks that have hampered increased renewable energy uptake in the mining sector, and Part 3 outlines the future trends and drivers that are going to lead to a faster uptake of renewable energies in mining. Part 4 concludes the report and provides recommendations for stakeholders (governments, mining companies, independent power producers, and donors).

#### NOTES

\* See Annex 1 for latest global snapshot of renewable energy uptake.

\*\* Many of the remote mining operations are located around the equator between the 35° latitude North and South parallels where the sun is intense and reliable (ex. in the sub-Saharan Africa, Australia or Northern Chile) and therefore ideal for solar power electricity generation.<sup>13</sup>



**Copper mine** in the Atacama region, northern Chile.  
© shutterstock.

# PART 1

## FRAMEWORK FOR RENEWABLE ENERGY INTEGRATION AT MINE SITES

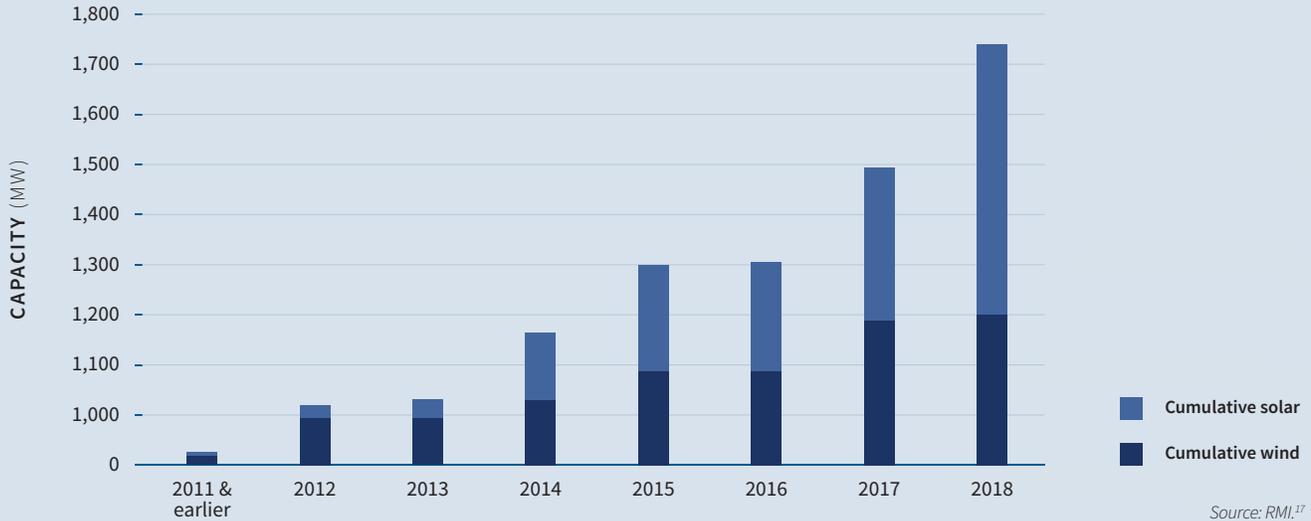
The interest in renewable power integration by mining companies has grown in recent years and more projects have come on stream and have been commissioned.\*

Figure 4 highlights the recent trend. Of the installed capacity, 59% are wind, 37% solar PV and 4% solar thermal projects.<sup>16</sup>

### NOTE

\* The Rocky Mountain Institute keeps an updated list of renewable power projects that are announced and commissioned at mine sites or are owned by mining companies.<sup>15</sup>

**FIGURE 4: CUMULATIVE COMMISSIONED AND ANNOUNCED RENEWABLE ENERGY CAPACITY**



This section highlights the considerations that determine the potential for renewable power integration in a mining project. The factors to consider are discussed prior to describing the determinants and requirements for different levels of renewable power penetration rates in a mining project. The third sub-section highlights the different sourcing options available to mining companies. The fourth sub-section focuses on sale arrangements when the renewable project is not solely powering the mine site.

**1.1. FACTORS TO CONSIDER**

Figure 5 outlines the factors that mining companies need to consider when determining the power sourcing/sale arrangements. These are often interlinked. For example, the beneficiaries will be closely related to whether the project is off-grid or on-grid, and whether the regulatory framework allows for third party sales.

**FIGURE 5: FACTORS DETERMINING THE POWER SOURCING ARRANGEMENT**

Potential for renewables	Access and stability of grid	Stage of project	Regulatory framework	Beneficiaries
Location	Off-grid	Exploration	Taxes and subsidies	Mine
Mine design	Unstable on-grid	Operation	National utility	Grid
Power source options	Stable on-grid	Post closure	IPP opportunities	Community

Source: CCSI.

### Potential for renewables

To decide whether solar or wind power should be part of the mine's energy mix, the location, mine design and other power options need to be reviewed. The location includes the weather conditions in the area of the grid system (e.g. sun radiance or wind profile) and land site characteristics (e.g. large flat terrain suitable for a solar power plant). The mine characteristics relevant for a renewable energy project include lifetime of the project and the load-profile of operations. The renewable power sources need to be compared with other energy sources. This includes understanding the costs and

reliability of the various power options. If, for example, the mine can source all energy from a stable hydro-power based electricity grid, it is less likely that a solar or wind project will be able to compete with the prices offered by the grid given that sourcing from a hydro-based grid systems is commonly less expensive.\* The opposite is the case with diesel powered alternatives, where apart from the price, the risks of supply and price volatility risks need to be taken into account.

A 2016 study has taken this assessment a step further by taking into account more considerations when comparing various energy solutions for four South African mines (Box 2).

#### BOX 1: RENEWABLE POWER INTEGRATION ASSESSMENT FOR COLLAHUASI<sup>19</sup>

The following four simulations were performed to assess the potential financial impacts resulting from the integration of a 150 MW solar project at the Collahuasi copper mine in Chile:

1. Solar PV model highlighting the price point and margin to developers;
2. Mining power energy model that explores potential fluctuation in power prices and changes in mining power needs over the lifetime of the project due to for example ore degradation or increase in mineral hardness;
3. Levelized cost savings of energy per tonne for various mining processes including the concentrating plant, desalination plant, services, electro-wiring and leaching;
4. The levelized value of energy, which considers the increase in the company shares' value due to the savings. In this specific example it demonstrates that the increased value due to savings resulting from solar electricity, exceeds the upfront capital investment of the 150 MW solar facility.

#### BOX 2: COMPARING DIESEL AND HYBRID SOLUTIONS OF FOUR SOUTH AFRICAN MINES<sup>20</sup>

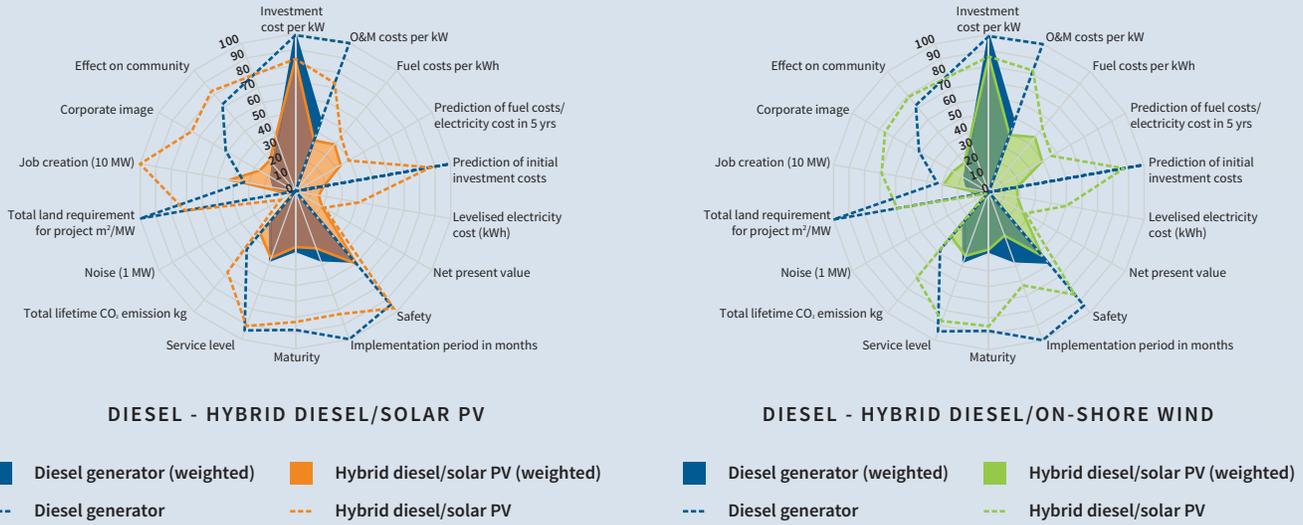
As illustrated in Figure 6, the diesel-based power plant outperformed the hybrid solutions in terms of installation costs, space requirements and implementation timelines. Hybrid solar and wind solutions performed better in terms of fuel consumption, lowering the levelized cost of electricity, lowering CO<sub>2</sub> emissions, promoting a better corporate image and improving community relations. Over a period of 20 years, €44 million (US\$ 50 million) could be saved by introducing solar energy and €55 million (US\$ 62 million)\*\* by introducing wind as compared to the diesel only solutions. The hybrid wind solution required 3 months longer to be implemented as compared to the hybrid solar solution. It also presented a lower potential to create additional jobs.

#### NOTES

\* The Power of the mine report estimates at \$5cts/kwh.<sup>18</sup> There may be opportunities for using renewables for pump-storage systems (see Section 3.1.4.).

\*\* Using exchange rate from October 1, 2018.

FIGURE 6: COMPARING DIESEL AND HYBRID SOLUTIONS



**Access and stability of grid**

The power sourcing arrangement possibilities will be fundamentally different depending on whether the mining project is connected to the grid or not. For grid-connected projects the power sourcing arrangement will also depend on the capacity of the grid as compared to demand by the mine. Mining projects with higher power demand than grid capacity will require on-site generation. Also projects connected to unreliable power grids will require back-up generation capacity.

The 2016 study mentioned above includes a survey of 22 solar and wind power projects supplying mine sites that are grouped according to their characteristics. The main determinant for power sourcing arrangements was whether the project was on-grid or off-grid. In off-grid situations, mining companies have often invested in the projects themselves, rather than sourcing from Independent Power Producers (IPP) (Table 1). This highlights the IPPs’ aversion to be solely reliant on a mining project as an off-taker.

TABLE 1: GROUPINGS OF RENEWABLE PROJECTS POWERING MINE SITES

	Off-grid projects	On-grid projects
Countries	Various countries	8 out of 10 on-grid reviewed projects were in Chile
Financing	7 out of 12 self-financed	90% financed through PPAs
Size	Up to 9.2MW	Up to 115MW

Source: Votteler (2016).<sup>22</sup>

### Stage of Project

Renewable energies have been integrated in mining projects during exploration, production and post-closure. Most of the examples in this report are focused on renewable power integration during operations given that this stage makes up the bulk of the energy demand of a mining project. However, as showcased in Boxes 3 and 4, renewables have also been deployed during exploration and post-closure.

Exploration often occurs in remote areas that are not connected to the grid. Power is needed for drilling purposes and for the exploration camp.<sup>23</sup> These operations are generally powered by diesel generators, resulting in high operating costs and transport requirements of fuel to the exploration sites. Given the shorter-term nature of the exploration stage, modular renewable technologies (see Box 3) are key to unlocking the full potential of renewable energy.

At the end of the life of mine, mining companies are subject to closure and reclamation regulations which require them to decommission, restore the land and waterways, and manage the long-term maintenance and monitoring of the closed site to avoid contamination and degradation post-closure. The mine and its associated land therefore become a liability for the company. In this context, renewable energy projects present the opportunity for an alternative use of the site, as well as a potential revenue source. The mine can lease the land to the IPP and earn revenues from the lease (as showcased in Box 12 and Box 13). In other circumstances, the renewable energy projects can serve to reclaim the site. Under the Superfund Redevelopment Initiative, the American Environmental Protection Agency (EPA) has identified and implemented several renewable projects at old mine sites.<sup>24</sup> The United Kingdom (UK) has started a similar initiative (Box 4).

### Regulatory framework

The energy sector is highly regulated in most countries. The legal framework will determine whether it is possible to source from third party actors (e.g. if an energy wheeling framework is in place) or if the company can only contract with the national utility (see Section 2.4.). The framework will also define whether electricity can be fed back into the grid, and the existence of feed-in tariffs and net metering will determine at what price it is possible for the renewable energy project to sell back into the grid any electricity that is not used by the mining project (see Sections 1.4 and 2.4).

National policies, taxes and incentives in the energy sector will also determine the economics of the power source. Renewable projects will be less appealing in countries that subsidize fossil fuel (see Section 2.4.1).

### Beneficiaries

The design of the energy system will need to be adapted to who the end users are. Selling into the grid or distributing power to surrounding communities of an off-grid mine site will require different infrastructure investments and load management compared to an on-site power system that only serves the mining project.

#### BOX 3: VALE POWERING EXPLORATION CAMP<sup>25</sup>

To power its exploration camp in the Atacama region of Chile, Vale installed modular solar panels. The panels provided heating for around 70 staff members and replaced 66% of diesel demand of the camp (5,100 liters) during four months of exploration.

#### BOX 4: POWERING THE RECLAMATION OF MINE SITES WITH RENEWABLES<sup>26</sup>

In the UK, 75 legacy mine sites require continued water treatment to avoid contamination of waterways and aquifers. In 2016 the Coal Authority trialed the installation of 192 solar panels on the roof of one of the main treatment plants. Having found this energy source to be efficient and cost-effective, solar panels will now be deployed at all legacy mines requiring continued water treatment.

### 1.2. RENEWABLE ENERGY PENETRATION RATE

Apart from deciding whether or not a mining company is to integrate renewables in the energy mix, it will also have to make a choice about the percentage renewables will make up of the total electricity demand of a project. Based on the assessment of the above factors, the mine will decide what kind of renewable energy penetration it can accommodate.

Large-scale mining operations require energy 24 hours a day and 365 days a year and are designed to operate at constant capacity. Mines have low tolerance for power supply disruption given the impact on production and revenues. For a renewable energy solution to work, it needs to seamlessly integrate with existing power supply conditions in order not to disrupt the mining business model. While for on-grid mining operations it may be feasible to run operations at a high rate of renewable energy penetration, it is not viable for off-grid mining operations to rely exclusively on solar and/or wind without storage. A hybrid system of solar and wind combined with fossil fuel

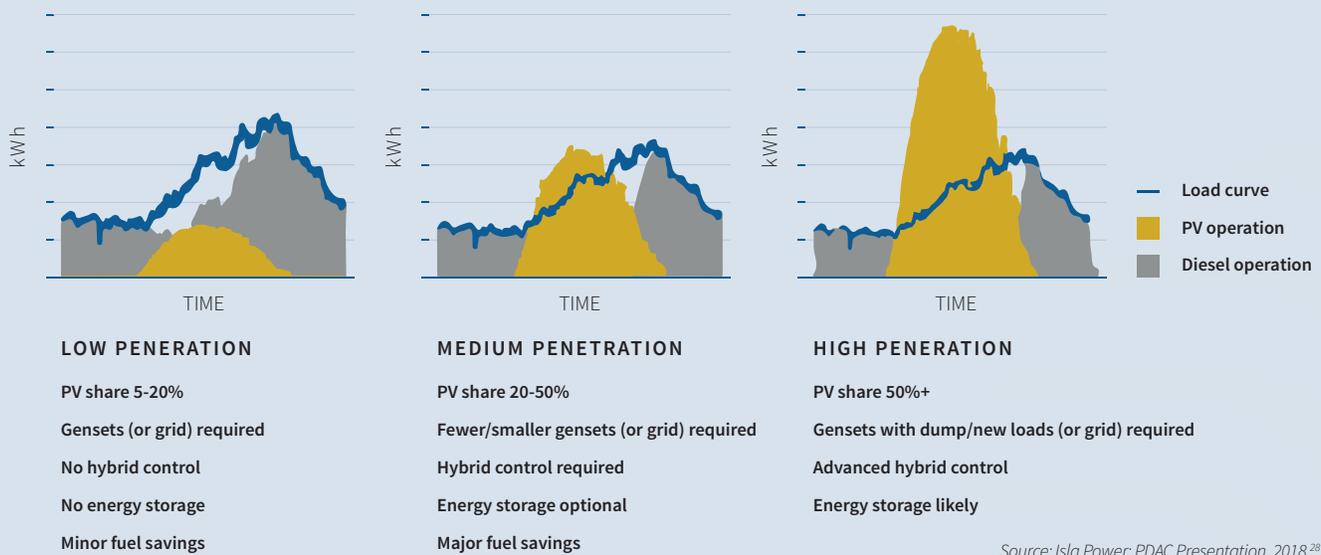
generation is necessary to compensate for those hours where the sun is not shining and the wind is not blowing.

As can be seen from Figure 7, the extent of the renewable energy penetration will determine the extent to which there is also a need for a control system, storage capacity, load control and management.

Below a penetration of 20%, there is no need for storage and control systems, which reduces capital requirements but also lowers diesel savings. The renewable energy will be used during peak load. As renewables are intermittent and diesel generators need a certain time to start-up, this rate of penetration will entail that generators run as base load, but not at full capacity thereby lowering diesel costs.

Above a penetration rate of 20% (other studies estimate this threshold at 30%)<sup>27</sup>, the diesel savings become substantive but at the same time the mine needs to invest in a control system. Above a penetration of 50% a storage component will be needed.

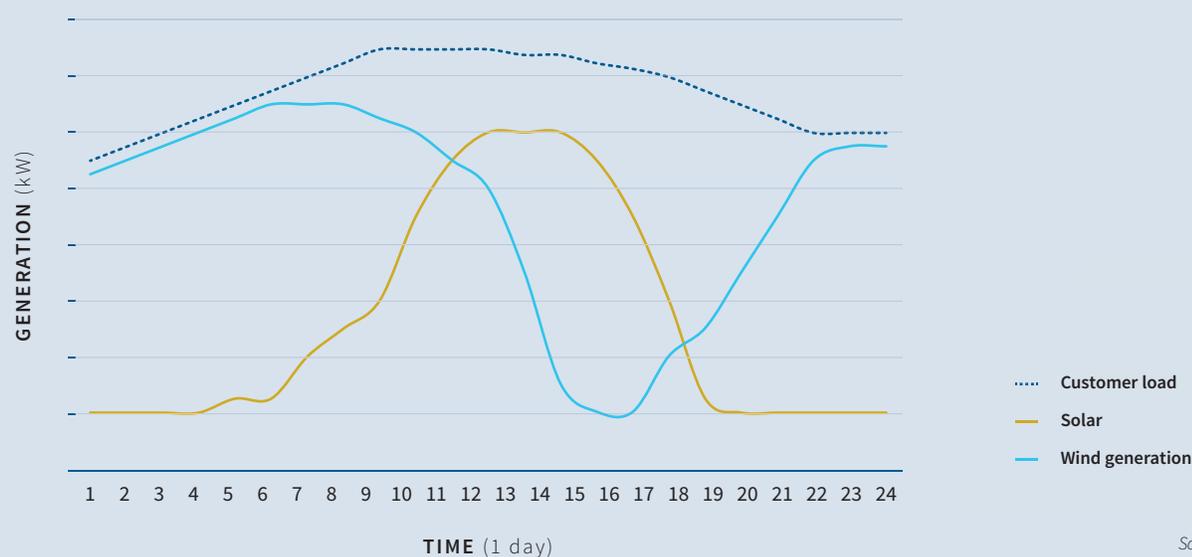
FIGURE 7: RANGES OF SOLAR PV PENETRATION



In places where there are complementary generation profiles between wind and solar sources, higher renewable penetration rates can be achieved (see Figure 8 and Box 5). When merged with storage, penetration rates can be increased further (see Box 14).

In Box 5, the Zaldivar mine reaches 100% of renewable of power by hybridizing both types of renewable energy and by being connected to the grid, which eliminates the needs for storage completely.

**FIGURE 8:** PRODUCTION PROFILE OF WIND, SOLAR AS COMPARED TO A LOAD PROFILE



Source: Arena 2017.<sup>29</sup>

### BOX 5: SOURCING 100% RENEWABLE POWER FROM THE GRID

<b>Location:</b>	Chile
<b>Mining Company:</b>	Antofagasta and Barrick Gold
<b>Mine:</b>	Zaldivar Copper Mine
<b>Project Owner:</b>	Colbun
<b>Project Capacity:</b>	550 GWh/year using a combination of solar, wind and hydro
<b>Savings:</b>	350,000 t/year of CO <sub>2</sub> e

**Background:** Zaldivar Copper Mine located in Northern Chile is a joint venture between Barrick Gold and Antofagasta Mining Company. It started its operations in 1995 and in 2017 produced 103,000 tonnes of copper cathodes. Its remaining mining life is estimated at 13 years.

**The Project:** The project signed a 10-year power purchase agreement with Chile's electricity company Colbun to be the world's first copper mine to source 100% renewable energy from hydropower, solar and wind energy sources. The project will consume 550 GWh/year starting in July 2020. This PPA will help cut the mine's greenhouse gas emissions by around 350,000 tonnes per year. The electricity source will be certified by an external body.<sup>30</sup> The combination of renewable energy sources is enabled by the interconnection of the Northern (SING) and Southern (SIC) grids in Chile. The Southern grid will provide the wind and hydro component, while the Northern grid will provide solar and wind component. This hybridization of renewables addresses the intermittency problems outlined in Section 2.1.1 and allows for 100% renewable penetration.<sup>31</sup>

As stated above, at penetration rates above 20-30%, hybrid power controllers will be needed to conduct real time monitoring of the power balance, energy quality and stability.<sup>32</sup> The most efficient controllers are automated systems called supervisory control and data acquisition (SCADA) or distributed control systems (DCS). These are composed of software and hardware on both demand side (load) and supply side (generation) that ensure communication between load and generation. For the impact of these systems to be optimized, the schedules of production, processing and other operations need to be put into the system.<sup>33</sup> The hybrid power generation performance and its impact on fuel savings is maximized through a holistic design that considers both the load and generation.<sup>34</sup> Energy storage is also likely to be needed to reach this level of penetration rate (See Box 28 for a mine site with a SCADA and storage component).

On the load side, energy intensive activities are scheduled at the time of high renewable energy intensity (e.g. daytime for solar). However, load shifting is only economic for certain activities. Figure 9 shows the electricity demand profile of a South African underground gold mine.

The lower energy demand around 9am and 7pm is associated with optimizing scheduling of systems like pumping and refrigeration to reduce the electricity bill and benefit from Eskom’s Megaflex tariff structure that charges large consumers more during peak demand times in the mornings and evenings. However, this load shifting only decreases electricity demand by around 20% for four hours during the 24-hour cycle.

Load shedding or the scheduled disconnection of a load to reduce overall demand to avoid potential blackouts, also needs to be considered and catered for by the mines.

On the generation side, the management of “Unit Commitment” is crucial, which is the schedule of the operation level and time of various generation units within the power system. This includes the use of power curtailment whereby the amount of power generated or transmitted is reduced when the load profile is lower than the generation, as well as determining spinning reserves which refer to the extra on-line generation capacity of the fossil fuel generator/thermal plant in case of contingency events.<sup>35</sup>

FIGURE 9: ELECTRICITY DEMAND PROFILE OF AN UNDERGROUND GOLD MINE



Source: Votteler 2016.<sup>36</sup>

### 1.3. RENEWABLE ENERGY SOURCING ARRANGEMENTS

Figure 10 shows the most common renewable energy sourcing arrangements. The mining sector has primarily used the self-generation (sourcing arrangement 1) and power purchase agreement (sourcing arrangement 2) arrangements.

#### 1.3.1. Self-generation

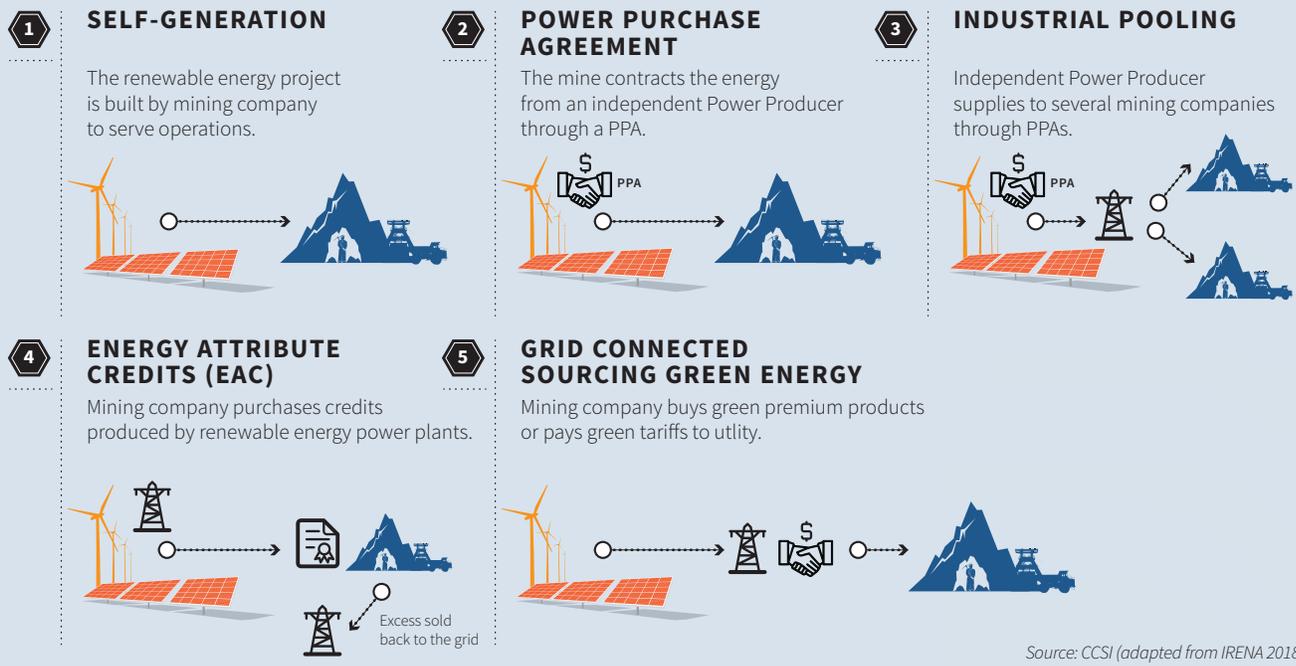
The self-generation arrangement implies that the mine is involved in the financing and ownership of the renewable power project. Commonly such projects are on-site, whereby the renewable power plant is built on the mining lease and connected directly to the operation. This power arrangement is well suited to the mining sector as it can accommodate off-grid projects. Furthermore, the regulatory requirements are less onerous than other types of arrangements. Off-site projects also exist, in which case transmission fees or wheeling charges may have to be paid to the grid owner. These projects are more common in liberalized electricity markets.<sup>37</sup>

The following self-generation structures exist:

- A. The mining company owns and finances the project and procures the plant through a turn-key agreement with an external renewable energy developer. This arrangement is most frequent with projects under 5 MW.
- B. The mining company invests equity in a joint-venture with a third-party. The mine is a joint owner and user of the plant, buying the energy on favorable pre-agreed terms.
- C. The mine shares the risks and benefits with the IPP, by entering into a capital lease. The IPP is the lessor and finances the power plant while the mine is the lessee that pays capital leasing fees and keep the rights of ownership.

In all three cases, the plant stays on the mine's balance sheet. The trade-off between the different self-generation structures lies between higher capital expenditures vs. operating expenditures. In the first structure, the mining company will have larger capital outlays and lower operating expenditure so the risk is higher. In the last arrangement, capital costs are passed to an IPP, but operating costs under the form of lease costs are considerably higher. Table 2 summarizes the risk/return of different ownership and financing scenarios. The third case in the table is explained further in Section 1.3.2.

FIGURE 10: RENEWABLE ENERGY SOURCING ARRANGEMENTS



**TABLE 2: VARIOUS OWNERSHIP AND FINANCING MODELS**

Ownership and Financing models	Characteristics of the financing arrangement	Risk/ Return
Mine owns and finances	Equity and debt with turnkey arrangement with a project constructor	High/High
Mine owns (eventually) and third-party finances	Capital lease	Medium/Medium
Third party finances and owns	Power Purchase Agreement with an IPP	Low/Low

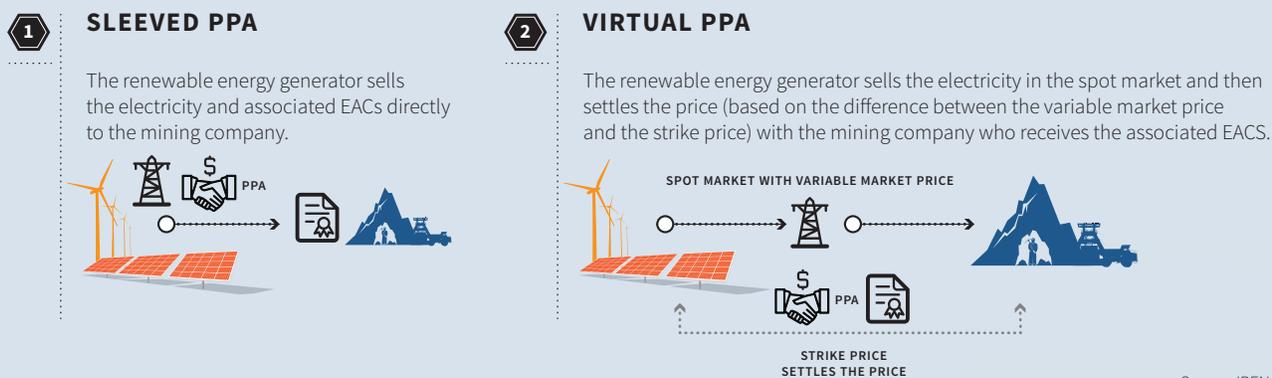
Source: Adapted from Isla Power – PDAC 2018 presentation.<sup>38</sup>

**1.3.2. Power Purchase Agreement**

The mine does not own or finance the renewable project. Instead it contracts the energy from a renewable project that is financed, built and operated by an IPP or utility. This is done through a Power Purchase Agreement (PPA). The PPA defines the commercial terms affecting the sale of electricity between the two parties including the starting date of the commercial operation, the schedule for delivery of electricity, the tariff, the volume of energy expected to be delivered, payment terms, penalties for underperformance on either side, and provisions for termination.<sup>39</sup>

As of the end of 2017, 35 countries have seen corporate PPA deals, with many mining-rich jurisdictions among them.<sup>40</sup> While there is a range of PPA adaptations and opportunities,\* the two principal PPAs used by mining companies are “sleeved” PPAs (also called back-to-back or off-site physical PPAs) and “virtual” PPAs (also called synthetic PPA, financial PPA or Contract for Differences). A sleeved PPA is when the developer sells the electricity directly to the mining company for an agreed price. If there is a spot market and the IPP can sell to the grid, the IPP may sign a virtual PPA. In such arrangement the IPP sells the electricity at the spot market price and then settles the difference between that price and the agreed price in the PPA with the mine off-taker (Box 6).<sup>41</sup> These two forms of PPAs are illustrated in the diagram below (Figure 11).

**FIGURE 11: SLEEVED VS. VIRTUAL PPAS**



Source: IRENA.<sup>42</sup>

**NOTE**

\* For more information on corporate PPAs, risks and benefits/drawbacks of the various options, please refer to <https://www.wbcsd.org/Programs/Energy-Circular-Economy/Climate-Energy/REscale/Resources/Innovation-in-Power-Purchase-Agreement-Structures> and [https://www.ifc.org/wps/wcm/connect/f05d3e00498e0841bb6fbb54d141794/IFC+Solar+Report\\_Web+\\_08+05.pdf?MOD=AJPERES](https://www.ifc.org/wps/wcm/connect/f05d3e00498e0841bb6fbb54d141794/IFC+Solar+Report_Web+_08+05.pdf?MOD=AJPERES).

**BOX 6: VIRTUAL PPAS IN CHILE**

A significant portion of Chile's mining operations occur in the Northern Region which has the best solar radiation in the world.

In 2016 Chile became the largest producer of solar energy in Latin America with more than 160 solar developers, including the largest solar plants under construction in the world. With this success, Chile is on track to beat its mandatory target of 20% penetration of renewable energies by 2025 and reach its 70% target by 2050.<sup>43</sup>

In 2015, an amendment to Law 20,018 (passed in 2005), mandated distribution companies to conduct tender processes for securing energy supply to their regulated customers, contributed to this success. It introduced different sized hourly blocks of energy supply (day, peak, night, 24 hrs.), and a longer supply period of 20 years. This amendment promoted renewable energies considerably and decreased the average price of energy awarded from US\$ 77.6/MWh in 2013 to US\$ 47.6/MWh in 2016.<sup>44</sup> Renewable energy providers undercut traditional energy projects by more than 70 percent in some cases.<sup>45</sup>

This tendering law provided the right enabling environment to the renewable IPPs in Chile at a time when the marginal cost-based spot market could not guarantee the viability of renewable IPPs. Power in Chile is dispatched onto the grid in order of the lowest marginal cost (based on variable costs) and this system theoretically favors renewables, especially in an environment of high gas and oil prices, because the variable costs of renewable energies are negligible.<sup>46</sup> Amidst the commodities boom of the first decade of the 21<sup>st</sup> century, high oil and gas prices and severe droughts (reducing hydro-generation and increasing its costs), IPPs benefitted from high spot prices. However, during 2015-2016, the onset of declining copper, oil and gas prices, in conjunction with particularly strong El Nino rains (replenishing hydro-dams), marked a massive increase in power supply and wiped out the financial viability of hundreds of megawatts of IPP solar projects (a third of the installed solar capacity in Chile).<sup>47</sup>

Many of these projects are expected to be bought up and consolidated by larger developers, while at the same time they are seeking to sign long term contracts – being either PPAs or Contract For Differences (CFDs) to hedge exposure to the spot market.<sup>48</sup> CFDs are particularly favored as hedging instruments since the generator and the buyer agree on a strike price. The buyer agrees to pay the difference to the generator when the marginal cost of power is lower than strike price and vice versa if the marginal cost of power is higher than the strike price.

With the increase in energy costs incurred by the mines due to their energy intensive desalination plants and declining ore grades, the demand for solar projects is on the rise again, and with them more opportunities to sign PPAs and CFDs. Mines have even been trying to rescind their long-term agreement with conventional energy providers.<sup>49</sup>

**1.3.3. Industrial energy pooling**

Industrial energy pooling involves a shared distributed generation plant supplying power to a pool of mines to decrease their generation costs. The plant is developed and operated by a third party. The plant could also be financed by the third party that would lease the land from the mines or be co-owned and financed by the mines. The mines will collectively enter a PPA with the operator. The advantage of this

arrangement is to benefit from economies of scale and to spread the risk for the developer.

As mentioned in the Power of the Mine report,<sup>50</sup> this arrangement is not that frequent due to the competitive nature in the mining sector and mining projects being designed and developed at different speeds. Box 7 nevertheless describes such an arrangement in the context of hydropower.

**BOX 7: JOINT POWER INVESTMENTS IN THE FACE OF THE ENERGY CRISIS IN BRAZIL**

The US\$ 240 million Igarapava hydroelectric power plant in Brazil has a capacity of 210MW and began operations in 1999. The project is owned by a consortium of private sector companies, including the energy company Aliança Geração (52.65%), the mining company AngloGold Ashanti (5.5%), the steel company CSN (17.92%), and the industrial conglomerate Votorantim (23.93%). At the time, this project gave the consortium companies a competitive advantage in Brazil, as the electricity prices if sourced from the Brazilian state-owned utility company Eletrobras were US\$ 38/MW – almost 8 times higher than the electricity price from the hydroelectric project.<sup>51</sup> By pooling their energy demand and resources the consortium companies gained access to significantly cheaper electricity prices.

## BOX 8: THE DUTCH WIND CONSORTIUM

Four companies AkzoNobel, DSM, Google, and Philips jointly negotiated PPAs with wind projects in the Netherlands. This led to the construction of the 102 MW Krammer Wind Park project in 2016 and a second project of 34 MW has been agreed.

The consortium negotiated the PPAs as a group, but each partner signed a separate contract with the project developer. The four PPAs are identical in terms of quantity of power purchased and power price. Thanks to this standardization, negotiation costs and timelines could be reduced. To ensure seamless communications with the wind farm owner/operator, the consortium appointed a single point of contact for operational questions.<sup>52</sup>

To our knowledge this arrangement does not exist in the context of solar or wind projects and mining. However, inspiration could be drawn from other sectors where companies from various industrial sectors pool together their energy needs (Box 8).

### 1.3.4. Energy Attribute Certificates (EACs)

An EAC is an instrument that tracks the source of the energy. Given that power from the grid comes from a range of sources, it is not possible for the consumer to physically only source renewable energy. By purchasing a renewable EAC, the purchaser can claim and “retire”<sup>\*</sup> the power produced by a renewable power project (generally 1MWh) thereby creating a supply and demand market for renewables. EACs can be “bundled” whereby the electricity and certificates are sold and

delivered together (a mining project that signs a sleeved PPA with an IPP also receives the certificates) or “unbundled” whereby the certificates are bought independently.

For this system to work, a tracking and oversight mechanism needs to be in place. Box 9 outlines some of the information that is tracked in such mechanisms.

As of the end of 2017 EACs could be purchased in 57 countries<sup>\*\*</sup> and a total of 130 TWh of corporate renewable electricity sourcing was done through EACs.<sup>53</sup>

As highlighted in Box 10, Australia has developed an EAC system that the Degussa (see Box 34) and Cannington mines benefit from due to the integration of solar power in mining operations.

## BOX 9: EAC ATTRIBUTES

- Certificate Date
- Certificate type
- Tracking system ID
- Renewable fuel type
- Renewable facility location
- Nameplate capacity of project
- Project name
- Project vintage (build date)
- Certificate (generation) vintage
- Certificate unique identification number
- Utility to which project is interconnected
- Eligibility for certification or RPS
- Emissions rate of the renewable resource

### NOTES

\* A certificate is retired when it is used by the owner and cannot be sold or transferred to another party.

\*\* The EAC system is expanding in Latin America and Asia-Pacific. In Africa, South Africa and Uganda have EAC systems in place (IRENA 2018).

## BOX 10: AUSTRALIA ENVIRONMENTAL CREDIT SYSTEM

The legislation that created the Australian Renewable Energy Agency (ARENA) (See Box 34) was passed by Australian parliament in November 2011 as part of the Clean Energy Future package, which also included the foundation for Australia's emissions trading scheme and the country's green bank, known as the Clean Energy Finance Corporation (CEFC).<sup>54</sup> The CEFC package was passed following an increase in 2009 of the country's Renewable Energy Target (RET) to 41,000 GWh or 20% by 2020, from the 9,500 GWh original target that was set in 2001. The RET was subsequently reduced in 2015 to 33,000 GWh by 2020, following the coalition government's assertion that increased surplus generation capacity and decreased power demand warrants a decrease in the RET.<sup>55</sup>

Under the RET, accredited renewable energy generators receive Large-scale Generation Certificates (LGCs) based on the amount of eligible renewable electricity they produce above their baseline. One LGC is equal to 1 MWh of renewable generation. Entities, such as electricity retailers, and energy intensive industries including mining, are legally required to buy a certain number of LGCs.<sup>56</sup> For instance, South32 will purchase LGCs at a pre-determined price from SunSHIFT (Box 33) for its Cannington mine in order to meet its obligations under Australia's RET.

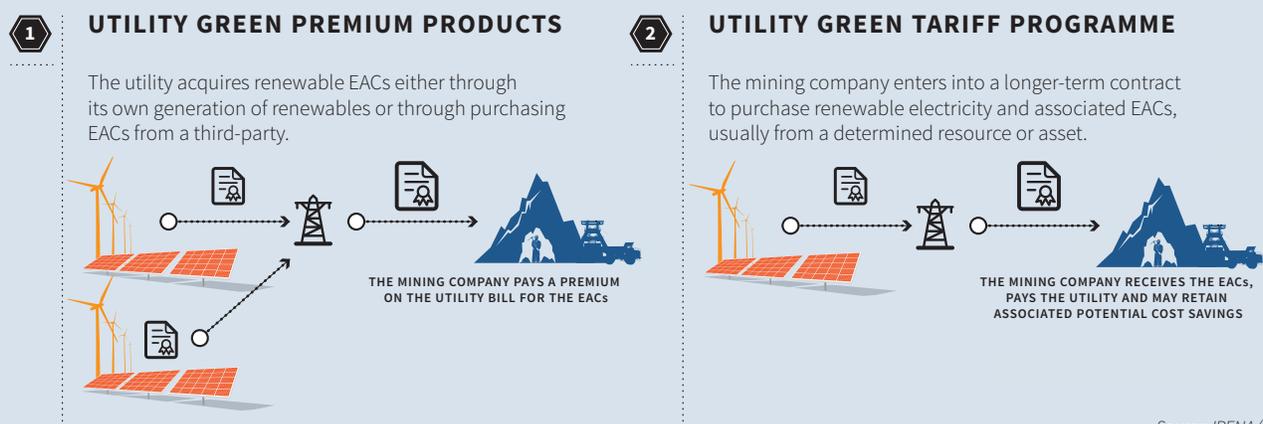
If these electricity retailers and energy intensive industries are not able to source enough renewable energy required for an LGC, they can buy the certificates. The users have three years to pay for the LGCs prior having to pay a shortfall charge.<sup>57</sup> An LGC was priced at AU\$ 84.25 on the spot market in early May 2018<sup>58</sup> and prices are expected to fall since the RET has been met, thereby incentivizing users to delay purchases.<sup>59</sup>

### 1.3.5. Renewable energy offerings from utilities

To meet rising demand, utilities are increasingly offering renewable electricity options. These can be divided into two broad categories, namely green premium products and green tariff programs. The former is a flexible purchase option and is primarily targeted at smaller consumers, who pay a premium on the utility bill. The latter

requires a longer-term commitment and is often linked to a specific renewable power project. For both models the renewable energy projects do not necessarily have to be owned by the utility. In the case where the utility does not own the renewable energy production sites, it acts as an intermediary buying and selling the renewable power and associated EACs. Figure 12 illustrates the two categories.

FIGURE 12: CATEGORIES FOR UTILITY PURCHASE



Source: IRENA (2018).<sup>60</sup>

As of the end of 2017, 39 countries offered utility green products, which accounted for around 7% of total corporate green sourcing from all sectors.<sup>61</sup> It is less common for mining companies to source utility green products even though they are on offer in many mining-rich jurisdictions such as Australia, Canada, South Africa and the United States. However, as more utilities around the world offer such schemes this option may become increasingly attractive particularly in non-liberalized energy markets where the utility has monopoly control.

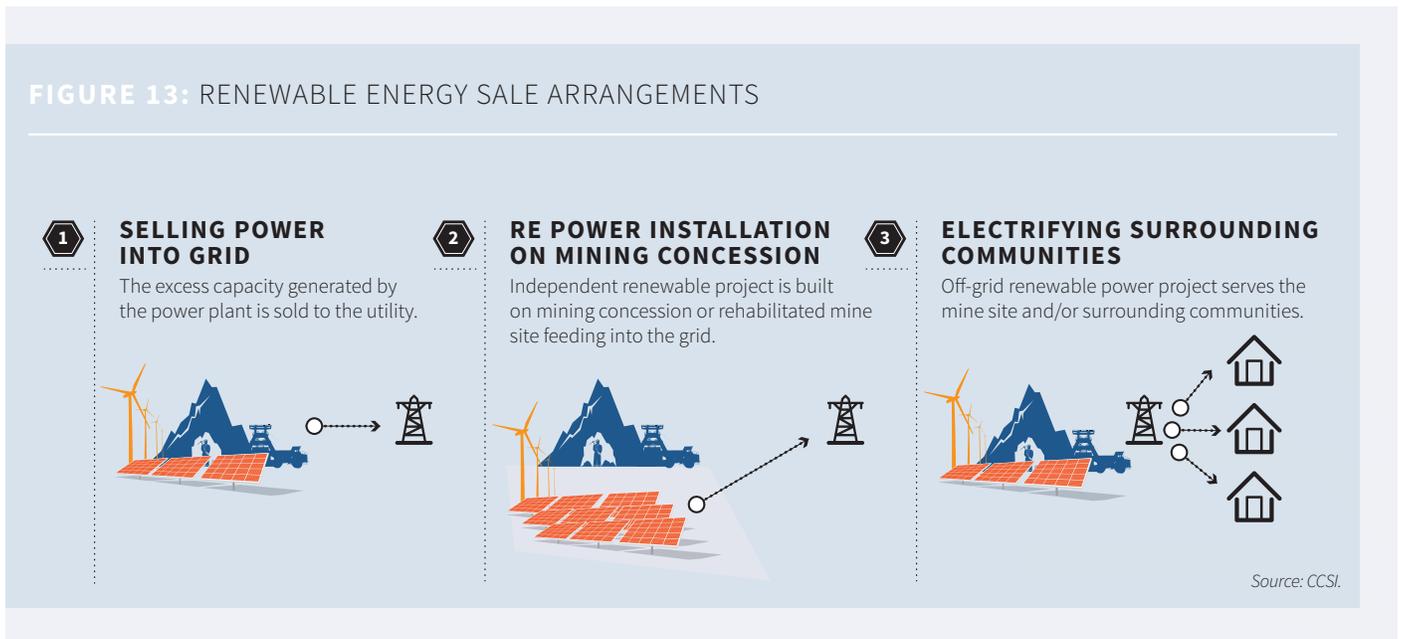
**1.4.1. Selling power into grid**

This sales arrangement involves a grid-connected mine. The excess capacity generated by the power plant is sold to the utility through a net metering arrangement. Net metering is a billing arrangement on the part of the utility that credits on-site renewable generation owners for the electricity they produce.<sup>62</sup> To our knowledge there is no example of a mine involved in a net metering arrangement given that existing on-site projects are still very small.

**1.4. RENEWABLE ENERGY SALE ARRANGEMENTS**

When the renewable power project does not solely serve the mine, sale arrangements also need to be considered. Three options are outlined in Figure 13 below. The first two are grid-connected, whereby the renewable power project sells into the grid. This can be the sale of excess electricity into the grid during times where power generation exceeds the mining project’s demand (1.4.1), or, allowing an IPP to either use its unused mining lease area or reclaimed land to build and operate a renewable power plant (1.4.2). The last arrangement is related to an off-grid mining scenario that powers surrounding communities through a mini-grid (1.4.3).

**FIGURE 13: RENEWABLE ENERGY SALE ARRANGEMENTS**



Box 11 below presents the case of a solar project that is connected to the grid but where the mine has priority use of the power. This example is not a pure net metering arrangement but presents some similarities given that the mine's utility bill is reduced as a result receiving low-cost electricity from the solar generation plant.

#### 1.4.2. Installation of renewable power project on mining concession

Access to land is one of the main considerations for renewable power projects and the mining concession areas are often significantly larger than the area that will be mined. Furthermore, mining operations can carry out progressive reclamation, whereby portions of the site are not required while mining continues in other parts of the concession. This reclaimed land can be leased to a renewable power operator without necessarily using the power for the mining operation itself. An example of such arrangement is highlighted in Box 12.

Post-closure, once the mining activities have ceased, there is also the opportunity of using reclaimed land for the installation of renewable power projects. For instance, in Germany several wind farm projects are being developed on former lignite mine sites.<sup>63</sup> The Rocky Mountain Institute (RMI) has reviewed BHP's legacy mines and has found significant renewable generation and storage potential (Box 13).

#### 1.4.3. Electrifying surrounding communities

In remote regions, mining companies have traditionally built infrastructure and provided services for mining towns necessary to house the workforce, including the provision of electricity. By extending this infrastructure to surrounding communities mining companies can increase electrification. Particularly in Africa where energy poverty affects around 600 million people this is a huge development opportunity.

### BOX 11: IAMGOLD'S ROSEBEL SOLAR POWER PROJECT IN SURINAME<sup>64</sup>

<b>Location:</b>	Suriname
<b>Mining Ownership:</b>	Iamgold and its subsidiary, Rosebel Gold Mines N.V
<b>Grid Status:</b>	On-grid
<b>Solar Project Size:</b>	5 MW
<b>Solar Project Commissioning:</b>	2013
<b>Solar Project Cost:</b>	US\$ 11 million
<b>Solar Project Developer:</b>	Rosebel Gold Mines

**Background:** The open pit gold mine is located in North Eastern Suriname and is owned 70% by Iamgold and 30% by the Government of Suriname. Commercial production began in 2004.

**The Project:** Iamgold financed and developed a 5 MW solar project when additional power was needed by the operation to mine harder rock.<sup>65</sup> The plant was commissioned in October 2014<sup>66</sup> and resulted from an agreement between the mining company and the Government of Suriname. In exchange for increasing the amount of power supplied to the mine at a lower cost, the mining company committed to commissioning the solar plant, which is intended to offset the increased power supply under the amended power agreement during peak demand hours.<sup>67</sup> On average about 750 kWh is generated at an operating cost of US\$ 0.01 per kWh. This compares to US\$ 0.12 per kWh paid to the government for their power supply in 2017.<sup>68</sup>

The electricity generated by the solar project prioritizes on-site use.<sup>69</sup> The power plant is however connected to Suriname's electric-power grid. Thus, excess power could be fed into the grid during high radiation hours.

### BOX 12: ASARCO LEASES LAND ON MINING CONCESSION TO IPP

Copper mining company Asarco in Arizona entered into a long-term lease with the IPP Clenera to rent a 500-acre site on the mining lease.<sup>70</sup> Asarco is grid connected so does not need to buy directly from the IPP. The collaboration between IPP Clenera and Asarco was born out of the American Environmental Protection Agency (EPA)'s program seeking to develop renewable energy projects on disturbed lands, including mine sites.<sup>71,72</sup>

In addition to gaining leasing fees and complying with regulations, the mine is also gaining access to a business partner that can share the purchase of inputs such as sand and gravel, aggregate, limestone for cement, steel, silicon for solar panels as well as buying the mines products as the solar project needs considerable amounts of copper.

### BOX 13: BHP TURNS ITS US LEGACY SITES INTO IDEAL LANDS FOR RENEWABLE ENERGY PROJECTS

In 2016, BHP engaged the Rocky Mountain Institute to evaluate the potential of renewable energy development at 22 BHP legacy mine sites in North America. RMI identified a promising subset of sites with a collective potential of over 0.5 GW. For most of the sites, because of their location, solar PV emerged as best opportunity, but a few were also well suited for wind development. Various storage technologies were also analyzed.<sup>73</sup> BHP has acted upon these recommendations and now has a site in Arizona and New Mexico in the design and/or permitting phases, while a site in New Mexico has signed both a lease with a solar and storage developer.<sup>74</sup>

The program has gained traction and interest from mining companies, while from a technological perspective a number of the proposed projects are viable, yet there are still challenges on the commercialization of these projects. Sites that are located near to grids with existing renewable power penetration face the constraint of exacerbating the duck curve and destabilizing the grid. Furthermore, third party distribution operators may not be incentivized to wheeling the generated electricity if it does not serve its own customer base. RMI has therefore increasingly reviewed storage options and attracting industrial users close to the site, to help address these issues. For remote sites, the lack of grid connection can be the major bottleneck.

Mines' power demand and financial capacity can be leveraged to build a power plant at excess capacity, beyond what is needed by the mine, in order to extend power access to surrounding communities at a low marginal cost by taking advantage of economies of scale.

This sale arrangement foresees an off-grid renewable power project that serves the mine site and surrounding communities through a mini-grid. This could be a newly constructed mini-grid where the renewable energy project is designed to not only serve the mine site, but also the surrounding community. Or it could feed into an existing mini-grid to

complement existing power sources. For example, a diesel-powered mini-grid for a mining community could benefit from renewable power integration to lower diesel costs and/or improve the reliability of the grid.

Box 14 highlights a case from Australia where the integration of renewables has lowered the cost of electricity for a mining town that previously relied on a diesel-based mini-grid. Box 15 highlights an example where a mining company in Australia is the off-take signatory for a renewable power project that also services the township mini-grid.

### BOX 14: COOBER PEDY RENEWABLE HYBRID POWER STATION

<b>Location:</b>	Coober Pedy, Southern Australia
<b>Project Owner:</b>	Energy Development Limited (EDL)
<b>Project Developer:</b>	Hydro Tasmania
<b>Project Capacity:</b>	4 MW wind, 1MW solar, 1 MW/500 KWh battery storage.
<b>Financing:</b>	AUS\$ 18.4 million Arena grant for EDL

**Background:** Coober Pedy is known as the opal capital of the world. It is estimated that 70% of the world's precious opal has been mined in the fields around this town. It is located in the Australian Outback far off the nation's electricity grid. Following the discovery of opal in 1915, settlement began and the population peaked at over 3,000 in the 1980s at which point the settlement elected a local government. Today, the Coober Pedy has around 1,750 inhabitants relying on the opal and tourism industry.

**The Project:** Like many remote Australian mining towns Coober Pedy relied on a 3.9 MW diesel power station owned by EDL. In 2014 ARENA and EDL signed off the investment of a wind, solar and battery power project that would be integrated in the existing energy system with a 20-year PPA with the District Council of Coober Pedy. The project started operations in March 2017 with the aim of displacing on average 70% of diesel requirements. In September that year the town was powered 100% by renewables for an uninterrupted 35 hours – an important milestone to demonstrate that it is possible to operate with 100% renewables without an engine running.<sup>75</sup>

Figure 14 shows the real-time dashboard that Coober Pedy's community and wider public can visit online to check the sources of energy currently powering the town.

FIGURE 14: LIVE DATA FOR COOBER PEDY RENEWABLE HYBRID POWER STATION

Source: Energy Developments.<sup>76</sup>

## BOX 15: WEIPA CASE STUDY

<b>Location:</b>	Bauxite mine in Queensland, Australia
<b>Grid Status:</b>	Off-grid
<b>Solar Project Size:</b>	6.7 MW total, to be developed in 2 phases
<b>Solar Project Operation:</b>	2015
<b>Solar Project Cost:</b>	US\$ 23.2 million
<b>Solar Project Owner:</b>	First Solar
<b>PPA:</b>	15 years
<b>Diesel Savings:</b>	600,000 – 2.3 million liters annually
<b>Carbon Savings:</b>	1,600 tonnes of CO <sub>2</sub> annually

**Background:** After discovery in 1955, bauxite production began at Weipa in 1963. Today, Weipa is Rio Tinto's largest bauxite mine, producing 31 million tonnes per annum from its two sites at East Weipa and Andoom.<sup>77</sup> The nearby Weipa township was built for the mining operations in the 1960s and has grown to become a regional hub for business and government.<sup>78</sup> A 36 MW diesel power plant has serviced the mine sites, the Weipa township and the nearby Napranum community through a mini-grid.<sup>79</sup>

**Solar Project:** In 2015 the Weipa Solar Plant was inaugurated providing renewable power to the mine site and township. Rio Tinto signed a 15-year PPA with the IPP First Solar.<sup>80</sup> Pending the success of the first phase, a second phase will include a battery storage component in addition to more photovoltaic panels. At peak time, the solar plant covers 20% of the township's daytime demand.<sup>81</sup> The Australian Renewable Energy Agency (ARENA) has provided AUS\$ 3.5 million grant to the first phase and has earmarked an additional AUS\$ 7.8 million for the second phase of the project.<sup>82</sup>

An example from a developing country comes from Papua New Guinea (PNG) where the geothermal\* potential has been used to supply the mine site and the local community’s power system (Box 16). This investment is incentivized by the PNG government granting a tax credit for infrastructure in the community.

**BOX 16: GEOTHERMAL POWERING NEWCREST’S GOLD MINE AND SURROUNDING COMMUNITIES**

<b>Location:</b>	Lihir Island, Papua New Guinea
<b>Grid Status:</b>	Off-grid
<b>Geothermal Power Plant:</b>	56 MW
<b>Start of operation:</b>	2003
<b>Project Owner:</b>	Lihir Gold Limited (100% owned by NewCrest Mining)
<b>Revenue Savings:</b>	US\$ 40 million from offsetting diesel consumption + US\$ 4.5 million from sales of carbon credits on the global market.
<b>Carbon Savings:</b>	280,000 tonnes of CO <sub>2</sub> annually

**Background:** Lihir island sits on one of the largest known gold deposits. The first gold was poured in 1997. In 2010 Newcrest acquired the operations. The mine is located within an extinct volcano that is geothermally active.

**The Project:** To make use of the geothermal potential, Lihir Gold Limited piloted a 6 MW project in 2003. Given the success of the pilot project a 30 MW expansion was commissioned in 2005 and a further expansion of 20 MW in 2007. The plant complements the previously built 70 MW diesel-based power plant. The geothermal power plant covers around 75% of the mine’s power needs with 3 MW serving the local villages on the island.<sup>83</sup> While built by external contractors, the operations and maintenance is provided by staff of the mining company. The power plant used carbon credit trading under the Clean Development Mechanism<sup>84</sup> 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.<sup>85</sup>

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.<sup>86</sup>

**NOTE**

\* Geothermal energy refers to the energy stored in the earth. Its potential is in areas with volcanic activity, hot springs and steam vents. Steam is pumped to the surface and converted to electricity. The potential is estimated at 12,000 TWh per year. Nevertheless, this potential is unevenly distributed and is usually located very deep below the surface making accessibility difficult.

When the community pays for the electricity, this arrangement requires clarity regarding compensation mechanisms for the electricity sold to third parties and additional redistribution infrastructure investments in the case that the mini-grid does not exist. As such, this model is more complex and involves more players. For example, payment and currency risks will have to be addressed and allocated if local communities pay for the electricity in local currency.

However, this sale arrangement also has many potential benefits. From a development perspective, access to electricity is a key ingredient and could help mining companies to re-balance the “shared value paradigm”<sup>\*</sup> that is increasingly under threat due to automation, which will reduce local employment and procurement

opportunities.<sup>88</sup> It could also help companies to attain and retain the social license to operate in rural areas where communities are opposed to mining. Furthermore, the renewable projects can support the local community post mining.<sup>89</sup> Iamgold foresees the solar plant at its Essakane mine in Burkina Faso to benefit local communities once the mine site closes (Box 17). While the mine life is 10 years, the useful life of the solar plant is 20-25 years. Given the low operating expenditures of the renewable energy plant after the initial capital expenditure, such a legacy project is affordable for the government and the community to maintain and operate. To allow for such arrangement, the closure and reclamation regulations need to be adapted to ensure that the power plant is excluded from the requirements to dismantle the mine’s infrastructure.

### BOX 17: ESSAKANE MINE

<b>Location:</b>	Northeastern Burkina Faso
<b>Mine Ownership:</b>	IamGold (90% Stake) Government of Burkina Faso (10%)
<b>Grid Status:</b>	Off-grid
<b>Solar Project Size:</b>	15 MW
<b>Solar Project Commissioning:</b>	2018
<b>Solar Project Cost:</b>	US\$ 20 million
<b>Solar Project Developer:</b>	EREN RE and the Africa Energy Management Platform (AEMP)
<b>PPA:</b>	IamGold has a 15-year PPA with the project <sup>90</sup>
<b>Diesel Savings:</b>	6 million liters annually
<b>Carbon Savings:</b>	18,500 tonnes of CO <sub>2</sub> annually <sup>91</sup>
<b>Other Component:</b>	57 MW diesel

**Background:** Mining activities at Essakane began in 2009, after Iamgold acquired the project from Orezone in 2008. The mine sits within the Essakane Main Zone, the largest known gold deposit in the country.<sup>92</sup> It has 2.65 million ounces of recoverable gold reserves and an expected 8.6-year mine life. Reserves could increase by 39% and extend the mine’s life past 2030.<sup>93</sup> Higher fuel prices, hard-rock content and a fall in production have contributed to a 16% increase in production costs.

**Solar Project:** In March 2018, a 15 MW solar project was commissioned at the Essakane mine after developers Eren RE and AEMP secured a US\$ 16.5 million loan from BNP Paribas subsidiary Banque Internationale pour le Commerce, l’Industrie et l’Artisanat du Burkina.<sup>94, 95</sup> The year-long construction period was overseen by engineering, procurement and construction contractor Wärsilä. Generation from the solar component, which will connect with the mine’s existing 57 MW diesel generators,<sup>96</sup> will cover up to 8% of the mine’s energy needs.<sup>97</sup> The miner pursued the project in order to improve the economics of the mining operation, hedge energy supply and provide some protection against oil price volatility.<sup>98</sup>

#### NOTE

\* 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.<sup>87</sup>



Open cast mine  
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## PART 2

### ROADBLOCKS TO INCREASED RENEWABLE ENERGY INTEGRATION

This section lists the major roadblocks hindering the increased integration of solar and wind energy in the mining sector. The bottlenecks have been grouped into five categories: (1) technical, which include the intermittent and variable nature of solar and wind energy sources, as well as the location specificities that may hinder the construction of renewable power plants near the mine site; (2) expertise, which includes limited experience of the mining sector with the construction, operation and procurement of renewable energies;

(3) financing, given that mining companies prefer not to take on additional capital expenditures on the balance sheet, but also do not like to commit to long-term PPAs, particularly when the life of mine is short or uncertain. Additional complexities are incurred when communities are to benefit from renewable power solutions; (4) regulatory, which are primarily composed of fossil fuel subsidies and the lack of laws that encourage the investment in renewables; and (5) interest, which may not be aligned in the government or the private sector to support renewable power roll out. Some of the roadblocks apply to all sourcing and sale arrangements outlined in the previous section. Others are specific to specific circumstances (such as off-grid mine sites) and sourcing/sale arrangements.

## 2.1. TECHNICAL

### 2.1.1. Intermittency and variability

Intermittency and variability are the biggest technical drawbacks of solar and wind energy sources. While mining needs an uninterrupted power supply, power from renewable energies is only generated when the sun is shining and the wind is blowing, and the amount of power produced depends on the cloud coverage and wind speed.

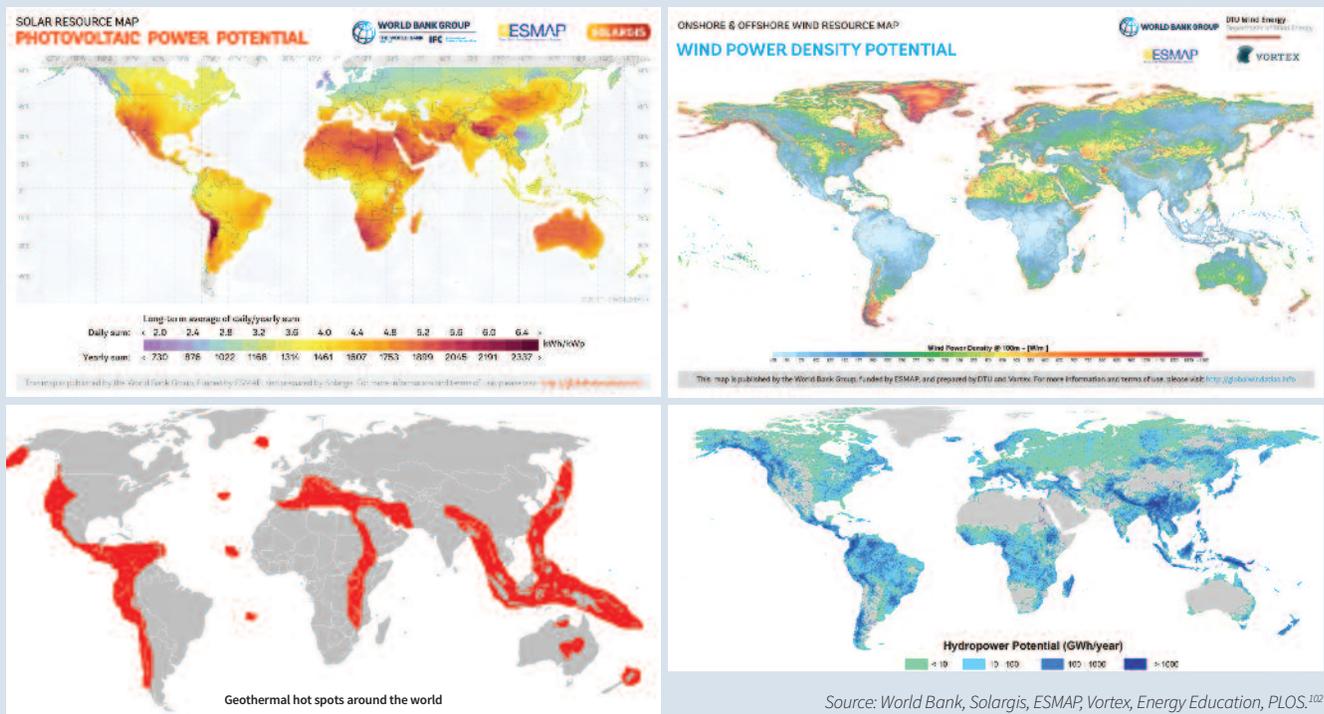
When designing the amount of solar or wind that can make up the energy generation mix, not only does one have to consider alterations over a 24-hour cycle, but also seasonal and multi-year cycles: for instance, the system needs to be optimized so that there are no power interruptions during the monsoon season or El Niño years. For wind, which tends to be less reliable than sun, the worst-case scenario needs to be considered in designing the back-up system. As such, off-grid mines will continue to have to rely on a fossil fuel-based power plant, even when increasing the battery storage component. Thus, the capital expenditure in the backup system cannot be eliminated and cost savings are less than if one would compare a renewable plant vs. a diesel plant. Cost savings are only associated with the number of diesel generators that can safely be replaced by the hybrid system, and the diesel costs saved during operations. Furthermore, capital expenditure can be amortized over a longer period of time given that wear and tear of the generators is lower.

A game changer to the intermittency and variability problem is the falling cost of battery storage (see Section 3.1.3). However, battery storage will not eliminate the presence of diesel completely in off-grid scenarios in the near future. Furthermore, it is still unclear what battery technology will ultimately prevail. Lead-acid batteries have been widely used as storage given their lower costs, but with falling prices of lithium-ion batteries, more IPPs are swapping to the lithium-ion technology. This technology is superior in terms of higher density, improved resiliency and a longer life.<sup>99</sup> Despite a longer useful life as compared to lead-acid batteries, lithium-ion batteries still need to be replaced during the life of the renewable energy project, which is costly. Flow batteries have a longer life than lithium-ion batteries, but are less efficient and reliable increasing the potential of disruptions.<sup>100</sup> Battery technologies still need to develop further to become more attractive for mining projects (see other promising storage technologies in Section 3.1.4).

### 2.1.2. Location and installation

Renewable energy potential is highly dependent on location. Figure 15 shows the potential for solar, wind, hydro and geothermal.<sup>101</sup> While the maps show that pretty much all parts of the world have at least potential for one type of renewable (if not more), there will be specific spots where the renewable potential is less appealing.

FIGURE 15: RENEWABLE POTENTIAL BY SOURCE



Source: World Bank, Solargis, ESMAP, Vortex, Energy Education, PLOS.<sup>102</sup>

Apart from the regional potential for renewables, there are site-specific considerations that need to be taken into account. At remote sites without weather stations close by, it may be necessary to collect additional wind measurements and solar yield rates over one to two years to establish an average production estimate taking seasons into account.<sup>103</sup>

Moreover, the installation of renewable energies requires significantly more land than other power plants. This is shown in Table 3 that provides estimates for land use intensity by energy source. Access to

land is one of the main bottlenecks for the increased roll-out of renewables more generally. However, this is also one of the biggest potential synergies with the mining sector given that mining companies tend to have concession areas that are larger than what they are going to mine. Remediated mining land and particularly remediated tailing dams have the added benefit of being flat and not requiring clearing costs, making them ideal for renewable power installations (see Section 1.4.2).

**TABLE 3: LAND USE BY ELECTRICITY SOURCES\***

Product	Primary energy source		Land use intensity [m <sup>2</sup> /MWh]				
			U.S. data <sup>a</sup>	U.S. data <sup>b</sup>	EU data <sup>c</sup>	UNEP <sup>d</sup>	Typical <sup>e</sup>
Electricity	Nuclear		0.1	0.1	1.0		0.1
	Natural gas		1.0	0.3	0.1	0.2	0.2
	Coal	Underground	0.6	0.2	0.2		0.2
		Surface ("open-cast")	8.2	0.2	0.4	15.0	5.0
	Renewables	Wind	1.3	1.0	0.7	0.3	1.0
		Geothermal	5.1		2.5	0.3	2.5
		Hydropower (large dams)	16.9	4.1	3.5	3.3	10
		Solar photovoltaic	15.0	0.3	8.7	13.0	10
		Solar – concentrated solar power	19.3		7.8	14.0	15
	Biomass (from crops)	810	13	450		500	
Liquid Fuel	Fossil oil		0.6		0.1		0.4
	Biofuels	Corn (maize)	237		220		230
		Sugarcane (from juice)	274		239		250
		Sugarcane (residue)					0.1
		Soybean	296		479		400
		Cellulose, short rotation coppice	565		410		500
		Cellulose, residue			0.1		0.1

Source: UNCCD, IRENA.<sup>104</sup>

**NOTE**

\* Note that data include land use for spacing and from upstream life cycles (e.g., mining). a) Trainor et al. (2016); b) Fthenakis and Kim (2009); c) IINAS (2017); d) UNEP (2016); e) own estimate for unspecified region (i.e., generic).

## 2.2. EXPERTISE

### 2.2.1. Energy systems and procurement

Health and safety are deeply engrained in the mining industry's attitude and every mining company will have full-time employees purely focusing on training and improving health and safety standards. This is not the case for power solutions and energy saving efforts. As a mining company representative highlighted:

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“At our company there is not one full-time employee whose sole task is reviewing the energy solutions at our mine sites and assessing energy efficiency potentials. Typically, energy sourcing is the responsibility of someone at the mine site who also has other responsibilities. He/she may therefore not have the time to develop their understanding on renewable or hybrid energy solutions. From a business perspective that seems like a missed opportunity given that about a quarter of operating expenses of our many mine sites are related to power.”

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As a result, there is a lack of technical know-how in mining companies regarding renewables and hybrid systems. Mining engineers and traditional suppliers know how to build, operate, repair and maintain diesel powered systems at off-grid mines, which acts as a constraint to renewable power integration. As outlined by another interviewee from a mining company:

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“Mining companies need power, but are not interested in the power generation business. Our core competency is to dig stuff out of the ground. Where possible we will therefore connect to the grid and buy power from an IPP or utility. When off-grid, it becomes trickier and it is a trade-off between keeping it simple by outsourcing the power plant and the cost of doing so. But the expertise required to manage a diesel plant, if the mine decides to retain ownership and operations, is relatively straightforward and not too dissimilar from other operations at a mine site. Renewables, on the other hand is a completely different ball game. Integrating a hybrid system is complex and requires a different skill set currently not available in companies.”

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Only recently have power suppliers to the industry begun providing hybrid system solutions. In South Africa the lack of expertise to repair renewable power systems has been a major hurdle for mining companies to integrate renewables.<sup>105</sup>

There is also lack of know-how in the sector when it comes to procuring renewable energy. Mining companies have been slow at adapting their contracting methodologies due to the lack of understanding of what renewable IPPs require. For example, a one-sided termination clause will scare off IPPs.\* As noted by one interviewee:

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“Mining companies tender renewable or hybrid IPP contracts as they have done procurement in the past. But this does not work, as the procurement procedure needs to be adapted to the specificities of renewables. Properly structuring the tender procedure to solicit bids from IPPs would go a long way in streamlining renewable power integration, but this is not as straightforward as people think. It has taken utilities a long time to get it right and the weakest link in the procurement chain will break a deal. Rather than reinventing the wheel and going through the same painful learning process that utilities have gone through, mining companies should consult those involved in structuring successful IPP bids.”

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### 2.2.2. Logistics

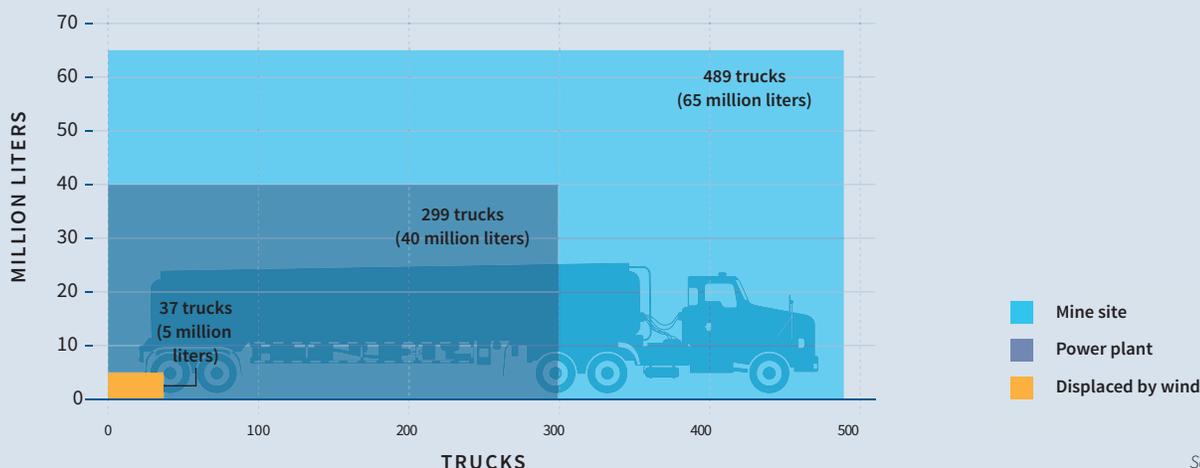
The logistics of procuring heavy fuel or diesel to off-grid mine sites is a big undertaking and mining companies have become good at this. This is particularly the case in frontier areas like in the Arctic. At the Diavik mine (Box 18), for example, heavy machinery and trucks can only reach the site via ice roads during a few weeks during the winter months. One of the benefits associated with integrating renewables at such locations is to reduce the logistics and costs associated with transporting the fuel. As outlined in Diavik's sustainability report its 9.2 MW wind farm in 2014 produced 11% of the mine's power and displaced 5 million liters of diesel. This is equivalent to 37 fuel trucks on the ice roads and seems to be quite an achievement. However, when this number is put into perspective to total fuel consumption at the mine site (not only looking at the power component, but also including other fuel consuming activities such as the truck fleet) this is minimal. Diavik consumed 64.7 million liters of diesel in 2014, which is equivalent to 489 fully loaded fuel trucks (Figure 16). This may be altered significantly once mine sites get electrified (see Box 18).

From the Diavik example it becomes clear that from a logistics perspective it is likely that renewable power integration will not reduce the complexity. On the contrary, the fuel procurement logistics will have to continue for the foreseeable future and the energy system will become more complex.\*\* Furthermore, the logistics of constructing the renewables plant will require additional planning and more people on site. Glencore for instance, has had to carefully assess how to bring in all the components of a windfarm to its Raglan mine site situated in the permafrost and how to address the control and maintenance of the windfarm under very harsh conditions where access to roads and telecommunications is limited.<sup>106</sup> While the Raglan mine and Diavik mine are extreme examples given their harsh climatic conditions, they do highlight some of the complexities related to renewable power integration that go beyond the cost argument.

#### NOTE

\* The Business Renewable Center produces primers and guides to help companies navigate the specificities of renewable energy deals: available at: [http://businessrenewables.org/primers-and-guides/#learn\\_more](http://businessrenewables.org/primers-and-guides/#learn_more)

\*\* Once mine sites get electrified, this may change significantly the logistics constraint – see Box 26.

**FIGURE 16: FUEL TRUCKS AT DIAVIK MINE IN PERSPECTIVE (2014)**

Source: CSSI.

**BOX 18: DIAVIK DIAMOND MINE**

<b>Location:</b>	North Slave Region, Northwest Territories, Canada
<b>Mine Ownership:</b>	Joint venture (JV) between Rio Tinto and Harry Winston Diamond Corp
<b>Grid Status:</b>	Off-grid
<b>Wind Project Size:</b>	9.2 MW (supplying about 11% of Diavik's annual power needs)
<b>Wind Project Operation:</b>	2012
<b>Wind Project Cost:</b>	US\$ 33 million
<b>Wind Project Owner:</b>	Rio Tinto and Harry Winston Diamond Corp
<b>PPA:</b>	N/A
<b>Cost Savings:</b>	US\$ 5-6 million annually
<b>Diesel Savings:</b>	5 million liters annually
<b>Carbon Savings:</b>	12,000-14,000 tonnes of CO <sub>2</sub> annually (about 6% reduction in the mine's carbon footprint)

**Background:** Diamond deposits at Diavik were discovered in 1994 and production at the mine began in 2003.<sup>107</sup> The site, which is 220 kilometers south of the Arctic Circle is notable for its remoteness, harsh weather conditions and sensitive ecosystem.<sup>108</sup> The mine is accessible via ice roads during an eight-week period, when major pieces of equipment and machinery are delivered to the site. Workers and supplies access the mine year-round via an airstrip on a nearby island.

**Wind Project:** Diavik commenced a three-year renewable energy feasibility study by installing a meteorological tower at the site in 2007.<sup>109</sup> After positive results, wind turbines were installed and the project began operating in September 2012. The ENERCON turbines were designed to operate in -40 degrees Celsius, which is below the industry standard.

**Impact:** In addition to cost savings and the reduction of carbon emissions, Diavik has become a testing ground for wind power in the area. Dominion, which owns a minority stake in the Diavik mine, is considering installing wind turbines at its nearby Ekati diamond mine, which is set to undergo an expansion that would extend its mine life to 2033. A study reviewing wind and solar potential also came from a review board representing First Nations residents in the area.<sup>110</sup> The study published in February 2017, pointed to Diavik's success and recommended further economic and technical studies and even interconnection with Diavik wind project.<sup>111</sup>

**Community components:** While the power from the wind project is not shared with the local community, Diavik has donated the meteorological tower and enacted a local partnership to share R&D results. The US\$ 450,000 R&D initiative could support efforts to use wind energy in the cleanup and remediation of the Giant Mine site near Yellowknife to contain arsenic related compounds from contaminating the surrounding environment.<sup>112</sup> Moreover, it has been proposed that the wind turbines are donated to close-by Northwest Territories once the Diavik mine closes around 2023.

## Community involvement

In cases where the renewable or hybrid system not only serves the mine, but is also used to electrify surrounding communities, additional complexities arise. While the marginal cost of the additional power for a small community is relatively low, the logistics become more complex. Questions that arise include the creditworthiness of the local population if they are to pay for the power. One renewable power provider concluded:

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“The marginal cost of building a slightly larger wind or solar power plant to also provide power to the community surrounding the mine site is not so high. But aligning a PPA with a mine and a local population is very difficult. Furthermore, when providing power to the population in most cases require additional government approval processes that may be waived if only providing power to a mine. These are two completely different businesses in terms of the regulations, financing and technical requirements such as load profiles. Right now, we would therefore propose two different power solutions. While this may come at a slightly higher cost, the logistics of a single higher capacity renewable project to service both the mine and the community are currently too difficult to handle.”

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With an increasing number of projects and experience about how to best streamline renewable power integration during the construction and operation, as well as more case studies of renewable energy projects electrifying surrounding communities of mining projects, it can be expected that this constraint will become less problematic in the future.

### 2.2.3. Accountability

When there are separate actors responsible for the diesel and the renewable components of a hybrid power system at a mine site, this could result in problems related to accountability. For example, at the Raglan mine (Box 32), diesel is managed by Glencore and the wind energy project by a third-party provider.<sup>113</sup> At the Degrussa mine (Box 28) the renewable and diesel generator system are outsourced to different parties. Apart from increasing the coordination costs among the various actors, such arrangements may lead to finger pointing when there are problems. To avoid such outcomes miners may seek a single point of accountability whereby the service provider for one power solution sub-contracts the provider of the other power solution. Certain IPPs are also building up their expertise to provide the full hybrid solution which should help avoid these coordination and accountability problems.

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“There are several companies such as Wartsila, Siemens and ABB that are offering advanced integrated systems, and project developers are also increasingly gaining expertise with building and operating these. However, there is still a higher technological risk associated with hybrid systems as they are being rolled out and the question arises of whom will carry this risk and compensate the mining company when something goes wrong.”

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## 2.3. FINANCING

### 2.3.1. Cost structure

The up-front capital cost of a renewable plant is, and will remain higher for the foreseeable future, than for additional generators of a diesel plant. When considering a self-generation sourcing arrangement (Arrangement 1 in Section 1.3.1), this is problematic from a cash flow perspective as it will delay the recuperation of the initial investment. Particularly for investors with higher discount rates, such up-front capital expenditures are problematic. As highlighted by one of the interviewees:

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“There is a gross aversion to capital expenditure by the mining industry. While renewable projects may make sense when considering a longer-term perspective given the negligible operating cost as compared to diesel plants, shareholders do not want to see the return to their investments delayed.”

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The aversion to capital expenditure is also problematic when considering the options of higher renewable penetration or provision of electricity to surrounding communities. While there are economies of scale associated with building solar<sup>114</sup> and wind<sup>115</sup> projects at a larger capacity (Figure 17), this is still associated with higher up-front capital costs, which will delay the recoupment of the investment. Capital costs will increase further if the distribution costs associated with the electrification of the community are carried by the mining company.

### 2.3.2. Outsourcing

A solution to reducing capital cost is to outsource the renewable project to an IPP (sourcing arrangement 2 in Section 1.3.2).<sup>\*</sup> However, when outsourcing the ownership of a renewable project to an IPP the main constraint becomes one of financing. Most renewable IPPs do not have the equity to finance the up-front capital expenditure associated with a renewable project. With insufficient capital, banks will either not provide the loan for the renewable project or charge high interest rates to compensate for the risk of the investment. The cost of capital for smaller IPPs is therefore often higher than the cost of capital for a mining company with a large balance sheet. As explained by one of the interviewees:

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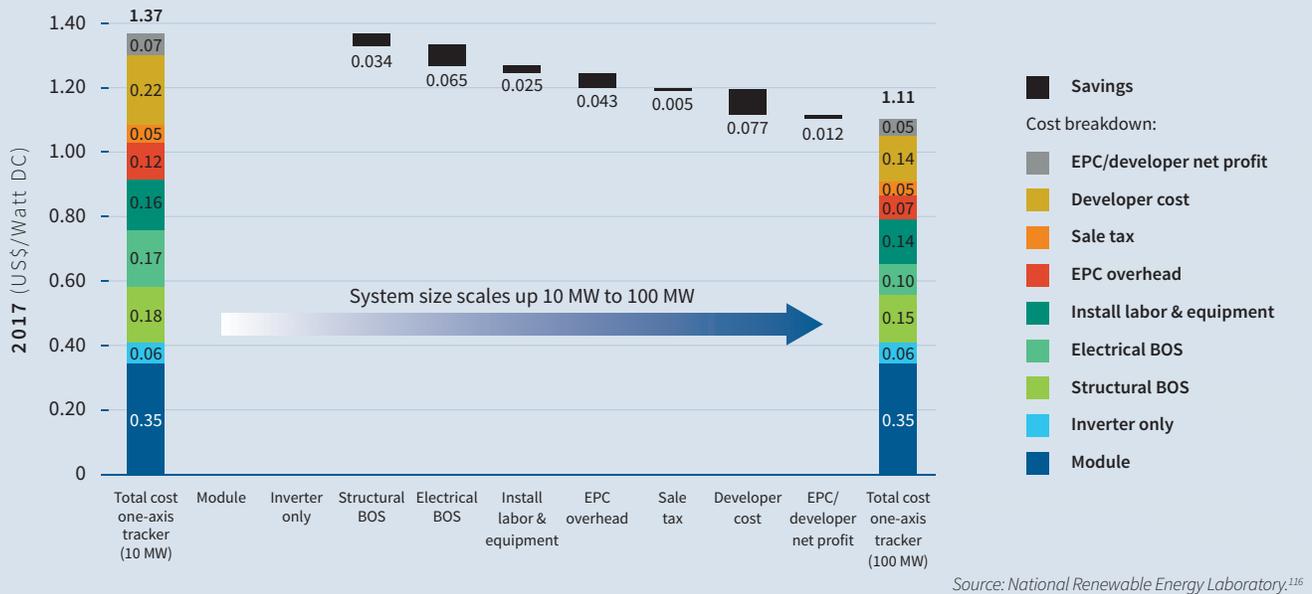
“While mining companies prefer to outsource renewable power projects and not own these assets, this strategy comes at a higher cost. At one of our mine sites the cost of capital for the IPP was 7%, whereas we could borrow at 4%. This makes a big difference to the economics of the project and the electricity rates that need to be charged.”

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#### NOTE

\* However, as noted in section 1, outsourcing to an IPP has not been very common in the past for off-grid mines.

**FIGURE 17: ECONOMIES OF SCALE FOR SOLAR PLANTS IN THE UNITED STATES**



**2.3.3. Commitment**

When the miner is the off-taker, lenders will analyze the risk profile of the mining company and the length of the PPA. The PPA should be long enough to guarantee a financial return on the renewable project. A short PPA means that the electricity price that the IPP will have to charge the mining company in order to make the project viable, will in most cases not be competitive when compared with a diesel-based

power plant. Bank loans with a short maturity will make the economics of the renewable project even more uncompetitive given the nature of the up-front capital cost.

The expected remaining life of mine becomes a key determinant on whether renewable projects are competitive given that this will determine the length that the mining company can commit to. Table 4 gives an indication of the years required for different power solutions.

**TABLE 4: LIFE OF MINE: MAKING VARIOUS TECHNOLOGIES VIABLE**

	Life of mine 3-7 years	Life of mine >10 years
Diesel generators	✓	✓
Gas turbines	✓	✓
Photovoltaics (PV)	✓	✓
Wind turbines	Unlikely	✓
Concentrated solar power (CSP)	Unlikely	✓

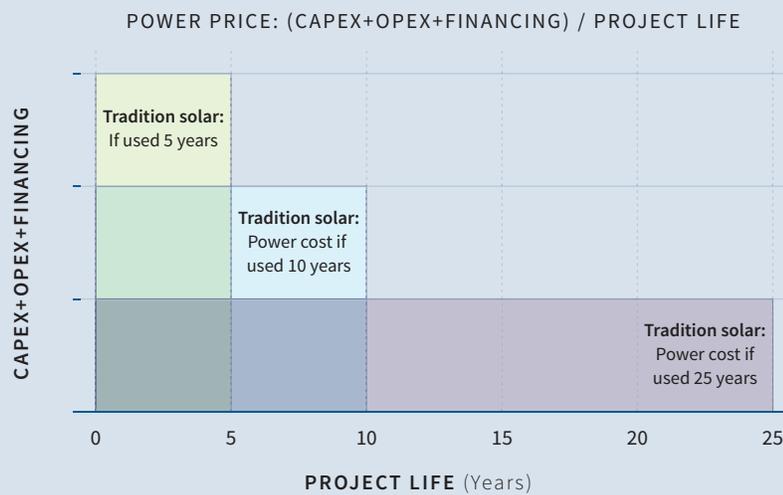
Source: Arena handbook.<sup>117</sup>

If the mine-life is in line with the life-time of a solar/wind plant, which are designed for around 20-25 years,<sup>118</sup> the renewable project is likely to offer cost saving opportunities compared to less capital-intensive energy solutions such as diesel. With a shorter mine life, the attractiveness of renewable energy solutions for off-grid mines falls.

“In contrast to a utility-scale investment, where there is a 20- to 25-year horizon, a mine’s potential contract period reduces yearly, which can increase the power price by up to 25%. In other words, if only one year could be added to the PPA period, the renewable electricity could be 25% cheaper.”<sup>119</sup>

One of the problems identified by the interviewees in existing off-grid mines in Australia is that the remaining life of operating mines are not long enough to make IPPs and financiers comfortable to invest in renewable projects. This is supported by a recent analysis by Goldman Sachs, which found that the average mine life of Australian mining companies has fallen by 5.5 years between 2012 and 2017. Reserves\* are mined without being replenished. Figure 19 on the following page shows the variation of mine-life according to commodity, and Figure 20 shows the mines that were included in the assessment illustrating that 40% of the mines have a mine life below 10 years.

**FIGURE 18: POWER PRICE SIMULATIONS BASED ON PROJECT LIFE**

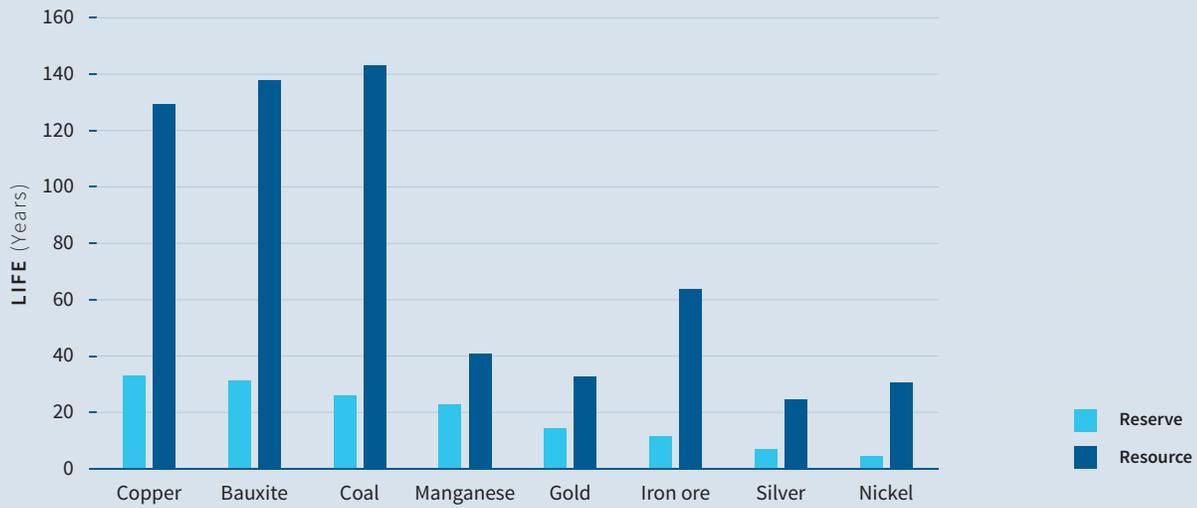


Source: Isla Power: PDAC Presentation, 2018.<sup>120</sup>

**NOTE**

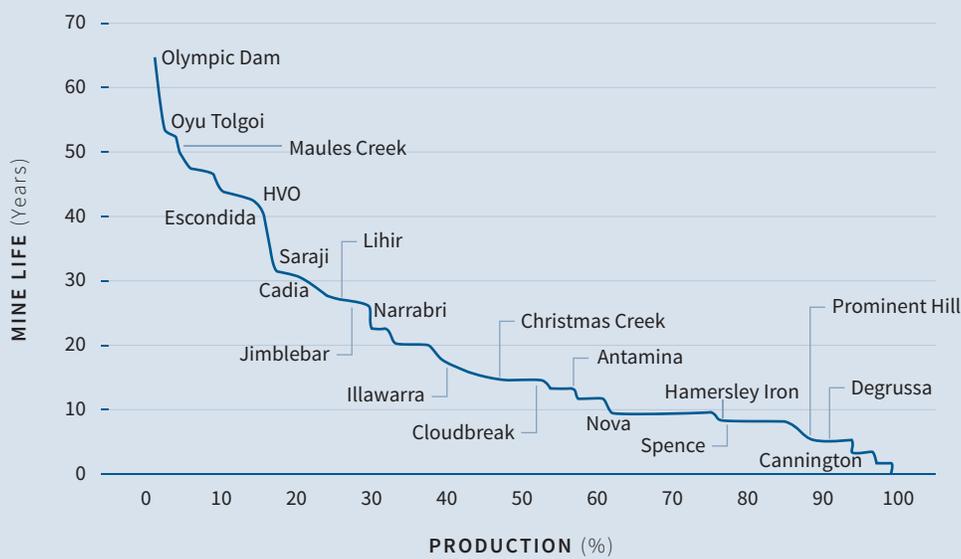
\* Mineral reserves are resources that are economically feasible to be extracted. Certain assessments and conditions have to be fulfilled according to pre-defined standards for companies to be able to re-classify resources as reserves.

**FIGURE 19: AVERAGE RESERVES AND RESOURCES BY COMMODITY**



Source: Goldman Sachs.<sup>121</sup>

**FIGURE 20: MINE-LIFE OF SELECTED MINING PROJECTS**



Source: Goldman Sachs.<sup>122</sup>

It is important to note that these mine life estimates do not necessarily materialize. Timeline shifts constantly on the basis of market developments and further geological assessments. To minimize up-front costs, mining companies will do sufficient exploration and economic analyses to show sufficient reserves to make a project viable and get bank financing, and then continue geological assessments to extend the mine-life thereafter. This reserve uncertainty is a significant risk to IPPs and financiers backing renewable projects. While this is a bottleneck that is consistently highlighted in the literature and has been mentioned by several interviewees, it should be noted that both the Degrussa (Box 28) and Cannington (Box 33) mines have a relatively short mine-life (see Figure 20) yet have integrated renewables in their operations. Modular and movable solar technologies may also help to address the problems related to the length of PPAs (see Section 3.1.5).

Even with sufficient reserves to warrant a long mine life, mining companies are reluctant to sign long-term PPAs. This reduces the flexibility and increases the cost of putting a project on care and maintenance in case there is a significant market downturn like the one experienced after the commodity super cycle came to an end in 2014. As highlighted by one of the interviewees:

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“While mothballing a mine is a measure of last resort and mining companies will only take this step after all other cost-cutting measures have been exhausted, it is a strategic consideration that mining company executives need to take into account. To address this, a clause could be included in a PPA that exempts the mining project from paying for power in the case of a mothballing event. However, this will be unacceptable to the IPP and financiers given that they are not willing to take on the risk of the commodity market.”

---

Long-term PPAs also lock in electricity price commitments at a time where power markets are being disrupted by renewable technologies. Chile is a good example where long term PPAs have harmed profits of the mining industry (Box 19). As a result of this experience in Chile, the PPA length that mining companies are willing to commit to is falling. While in Chile there is the spot market that the renewable energy project can continue to sell into, shorter PPA commitments are particularly problematic for off-grid mining projects where there are no alternative off-takers.

Apart from securing a PPA with an acceptable length for the lenders/investors, parent guarantees may also be required. However, both parent companies of IPPs and mining companies are often unwilling to take on this risk. As highlighted by one interviewee:

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“We have also seen commercial and industrial customers being unwilling to offer their parent support behind the credit for the contract. That has led to some interesting discussions about what is the appropriate level of credit required for the off-taker. Those are tough conversations because there is no science to it.”

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One of the reasons that mining companies may not be willing to sign long-term PPAs and provide parent guarantees is the risk of the energy supplier going bankrupt. This was rated as the second highest risk in a recent corporate survey.<sup>123</sup> Rapidly falling prices over the last years has meant that both solar and wind IPPs have gone out of business and there has been market consolidation. SunEdison from the United States, once reported the world’s largest renewable energy company, filed for bankruptcy in 2016. In Japan alone, 50 solar companies went bankrupt in the first half of 2017.<sup>124</sup> In the wind sector many leading manufacturers closed factories and restructured their businesses. At the same time, there are new entrants into this already crowded space. For example, the oil and gas companies with deep pockets are increasingly investing in renewables, putting further pressure on prices.<sup>125</sup>

## BOX 19: CHILE’S MINING SECTOR IN A CHANGING ENERGY MARKET

With little fossil fuel resources of its own, Chile has relied on imports for electricity generation. Prior to 2004, gas made up around 37% of Chile’s energy mix and Argentina was its main supplier. Argentina cut exports due to an energy crisis of its own, leading to power cuts and massive price increases in Chile. At its peak in 2011 the price paid was almost double the global average.<sup>126</sup> The high electricity cost and uncertainty of future electricity supply led to mining companies searching for power solutions to satisfy their needs. Codelco invested in their own solar and wind projects, and other companies signed long-term PPAs to see new power projects coming on stream. BHP Billiton, for example, tendered a long-term power contract for the construction of the 517 MW Kelar gas power plant to satisfy the energy needs of its Escondida mine and other operations in Chile.<sup>127</sup>

Since its peak, power prices have come down significantly. Renewable firms have undercut bids by traditional producers by more than 70% in auctions. With some mining companies locked in PPAs signed during high energy prices paying over US\$ 100/Mwh, they have sought to renegotiate these agreements given that new renewable projects have offered 24-hour power for prices as low as US\$ 38/MWh on Chile’s public grid.<sup>128</sup> This experience of rapidly changing prices in the Chilean power market has led mining companies to be increasingly careful in signing long-term agreements. “Before, mining companies would be prepared to make a 15-20-year commitment. Today, PPAs are often half that time and are tied to the spot market or include renegotiation clauses depending on how the market develops.”<sup>129</sup>

### 2.3.4. Off-grid solutions for communities

From a development perspective, a model whereby renewable energy solutions not only supplies the mining project, but also electrifies a nearby community in an off-grid scenario, is particularly appealing. Several interviewed representatives of IPPs agreed that while in theory DFIs are well placed to help with the financing of such a project, several problems stand in the way. One interviewee highlighted:

“DFIs are focused on financing large-scale utility type renewable projects. Medium-sized projects like those required for remote mine sites are less appealing, because administration costs as a percentage of the loan are higher. Furthermore, DFIs don’t have lending solutions for hybrid power projects as they have a mandate to finance clean energies. So would a hybrid system require two different loans at different rates? Or would a diesel plant have to be financed by a commercial bank given that DFIs are increasingly moving away from fossil fuels? Not having a simple financing solution for hybrid systems makes it more complex to get financing from DFIs.”

Another interviewed IPP representative working in Africa explained:

“The financing terms offered by DFIs are more appealing than those of commercial banks. But in my experience the studies and standards that DFIs require to be involved are too cumbersome and the process takes too long. Particularly in the renewable space where technologies are changing rapidly I cannot afford to take two years in order to get a loan agreement with a DFI. I therefore prefer to finance projects with commercial banks at a slightly higher cost. DFIs need to move quicker if they are to help electrify Africa.”

While the DFI approval process might appear cumbersome and costly to IPPs, this process has value to reduce the social and environmental risk of a project. It is therefore a trade-off between getting the project approved and built quickly, against the risk of losing the social license to operate due to insufficient consultations and due diligence.\*

Some interviewees also mentioned that if the renewable project is linked to the mine, DFIs will perform due diligence and require compliance of social and environmental standards of both the mine and the IPP, which will delay the negotiation process between the IPP and the mining company.

Without regulations explicitly requiring electrification of communities living in the vicinity of mining projects (see Section 2.4.3) or DFIs’ stronger involvement in financing higher capacity renewable projects and mini-grids to serve communities, it is hard to see this model evolving.

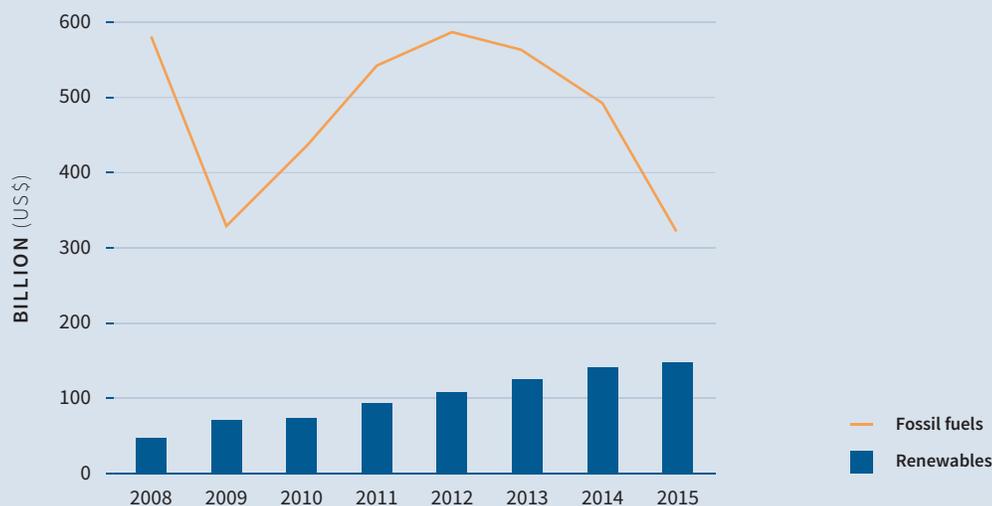
## 2.4. REGULATORY

### 2.4.1. Fossil fuel subsidies

The two largest regulatory obstacles to integrating renewables in mining operations are fossil fuel incentives and the lack of energy laws that have been adapted to support the characteristics of renewable energy projects.

Figure 21 shows that at a global level, subsidy for renewables have been on the rise and subsidies for fossil fuels have been decreasing. However, renewable energy subsidies are still about half of the subsidies that fossil fuels receive and the fossil fuel subsidy downward trend may be reversed when prices of coal, oil and gas increase again. Around 40% of fossil fuel subsidies are targeted to keep electricity prices artificially low<sup>130</sup> thereby hindering the competitiveness of renewable power sources.

FIGURE 21: GLOBAL LEVELS OF SUBSIDIES FOR RENEWABLES



Source: FT<sup>131</sup>

**NOTE \*** For a review of the human rights impact of 59 renewable energy projects see: <https://www.business-humanrights.org/en/renewable-energy-solar-bioenergy-geothermal-sectors/renewable-energy-briefing-2018>; For a review of the environmental impacts of renewable energy projects see: <https://www.ucsusa.org/clean-energy/renewable-energy/environmental-impacts#.W479hn4nbBI>

Furthermore, in developed and developing countries alike, mining companies are often exempt from paying taxes on fuels used for off-road operations and for energy generation (Box 20). In South Africa, for example, diesel refund claims were highest for the electricity generation sector with the mining sector coming in second.<sup>132</sup> In Australia, the mining sector is the biggest recipient of fuel tax credits.<sup>133</sup> Lower fuel costs for energy generation makes renewable integration less attractive.

#### 2.4.2. Lack of Renewable Energy specific regulations

Laws and regulations particularly in low-income countries,<sup>134</sup> have yet to be developed in order to support the characteristics of renewable energy systems. “Regulations and governance in the sector consistently lag behind technological innovations”.<sup>135</sup> The lack of relevant regulations has acted as a barrier for mining companies to integrate renewable energies – particularly in cases where the projects are connected to the grid. Given that the regulation requirements differ, it is worth distinguishing between the development of on-site renewable energy projects and the procurement of renewable energy from off-site projects.

The following regulations are conducive for renewable energy projects installed on the mining lease (on-site):<sup>136</sup>

- **Ability to source from third parties:** In numerous cases, mining companies will prefer outsourcing power generation services. It is therefore conducive to have regulations in place that allow for companies to contract directly with non-utility electricity providers.
- **Compensation for selling excess energy into the grid:** Having the opportunity to sell into the grid, when there is one, will reduce the risk for the energy provider to solely rely on the mining project. Such arrangement requires regulations that allow for a third party to feed into the grid and to get remunerated through compensation mechanisms such as a net metering or a feed-in tariff system.
- **Interconnection policies:** In cases where the utility is responsible for the grid connection, clear rules and transparent processes on timing and access conditions are required. This will reduce uncertainty for developers when providing power to other customers apart from the mining project.
- **Ability to sell to third parties:** Where the renewable power project is off-grid and there are opportunities to provide energy to surrounding communities, regulations are required to be able to do so at a determined price.
- **Ownership of renewable attributes:** When excess electricity is sold into the grid, clarity should exist regarding who owns and can claim the benefits associated with renewable power certificates.
- **Streamlining the permitting phase:** The approval for renewable power projects and mining projects requires permits from different authorities. The zoning of the mining and renewable projects, as well as the inspections can be streamlined and simplified to support this process.

#### BOX 20: FUEL TAX EXEMPTIONS

**Australia:** Australia introduced an excise on fuel as means for financing road development and improvement in the 1920s, with a separate tax for diesel introduced in 1957.<sup>137</sup> Excise rates, which are indexed twice per year to the Consumer Price Index, for diesel were AU\$ 0.409 per liter in May 2018.<sup>138</sup> Several industries, including mining, agriculture, fishing, forestry, construction and commercial, stationary and portable power generators are eligible to take advantage of fuel tax credits that reduce the cost of fuels used for machinery, equipment and heavy vehicles.<sup>139</sup> These industries are generally exempted from the tax because of their limited use of roads in remote locations. The Australian government is expected to award miners AU\$ 2.5 billion in fuel tax credits in 2018.<sup>140</sup>

**South Africa:** The South African Revenue Service (SARS) administers and collects a fuel levy that is used to fund the Road Accident Fund (RAF), a state-backed insurer that was created in 1996 and covers all motor vehicle drivers in the country for liability or damage incurred from a traffic collision.<sup>141</sup> The fuel levy, which is set annually by the National Treasury, was 163 cents per liter in 2017.

The diesel refund system was established in 2000 and provides the agriculture, forestry, fishing and mining sectors with up to 100% relief from the fuel levy. The system is designed to alleviate the road-related tax burden of the RAF for sectors that have low road usage and to protect the competitiveness of local industries. Miners have received a refund rate of roughly 40% of the fuel levy since 2005, receiving more than R 2 billion in refunds for diesel between 2015 and 2016.<sup>142</sup>

For off-site procurement from independent renewable energy providers the following aspects need to be considered to create a conducive business environment for renewable energy companies in addition to all the ones above (besides streamlining the permitting process):<sup>143</sup>

- **Electricity price subsidies for corporate customers:** Subsidized electricity prices for corporate customers may make new renewable energy projects by third parties less compelling unless the renewable energy projects also benefit from the same subsidies.
- **Green tariffs:** In countries where the electricity market is vertically integrated and not liberalized, utility green-tariffs can allow mining companies to contract long-term renewable energy at an agreed price.
- **Price transparency:** Increasing price transparency will help mining companies understand the price difference between renewable PPAs and the traditional electricity market.
- **Open access transmission policies with prescribed legal and technical rules:** Will allow renewable energy providers to wheel power on the utility transmission lines without suffering from discriminatory access fees
- **Curtailement risk:** By putting in place transparent guidelines and regulations regarding dispatch order and priority, curtailment risks can be reduced. Some countries have granted priority to renewable energy sources, thereby increasing the attractiveness to investors and developers.

While mining rich countries such as Australia, Canada and Chile already have a more advanced regulatory framework and policies in place to support the roll-out of renewables, other countries do not yet have these systems. For off-grid mining operations in developing countries the PPA between the IPP and the mining company can dictate the rules of the game and compensate for a deficient legal framework. However, as soon as the renewable energy project is connected to the grid and/or is designed to sell to third parties such as communities around the mine site, a renewable power legislation needs to be in place. Including renewable energy specific regulations is part of greater energy market reforms, which may face opposition by political and private actors that stand to lose out from such reforms (see Section 2.5).

### 2.4.3. Lack of incentives or obligations to electrify nearby communities

As mentioned above, sharing the renewable energy power with the communities remains challenging from a technical and financing point of view. It may be difficult to resolve this without incentives, commitments or a legal requirement to do so. Only one contract on ResourceContracts.org, a publicly available database of 1613 contractual documents from the extractive sector, includes an explicit legal requirement to electrify surrounding communities (see Box 21). Other Liberian mining contracts<sup>144</sup> and the PNG model contract<sup>145</sup> foresee the production of excess energy to be sold to the government or a third party.

## BOX 21: LIBERIA: CONTRACTUAL REQUIREMENT TO DESIGNING EXCESS CAPACITY FOR THE COMMUNITY

The Putu mining contract includes the following clause:

“the Power Plant shall be designed to generate a quantity of electric energy in excess of the electric energy required by the Company for Operations to supply third party users located within a 10 km radius thereof on a 7-days per week, 24 hours per day basis in accordance with third party user demand from time to time. The Company may charge residential users reasonable rates for their power usage based upon their ability to pay. The Company may charge businesses commercially reasonable rates for their power usage. The Company shall provide electric power free of charge to non-profit organizations and Government agencies.”<sup>146</sup>

Moreover, section 19.3(d) requires the Power Plant to be designed and constructed in a way that allows expansion “on a commercially feasible basis to have twice the electricity generating capacity required to service Operations.”

## 2.5. INTERESTS

### 2.5.1. Government

From a technical perspective the regulatory changes necessary to encourage renewable energy projects seem relatively straightforward.

There is plenty of experience from jurisdictions that have implemented bidding rounds and regulatory changes—to support renewables—that can be learned from (for example from the well-designed Renewable Energy IPP Procurement Program in South Africa (Box 22)).

#### BOX 22: SOUTH AFRICA'S RENEWABLE ENERGY BIDDING ROUNDS

**Background:** The Renewable Energy IPP Procurement Program in South Africa (REIPPPP) was unveiled by the South African government in 2012, after President Zuma pledged to reduce CO<sub>2</sub> emissions (Meier, 2015). The pledge, which was conditional upon international financial and technological support, catalyzed the Department of Energy to include renewable energy options for the first time in its Integrated Resource Plan for 2010-2030.<sup>147</sup>

**REIPPPP Design & Implementation:** The REIPPPP was meant to address the weaknesses of the Renewable Energy Feed-In Tariff (REFIT) program that was proposed in 2009 but was never implemented. REIPPPP was designed to foster competition that would put pressure on pricing, a result that is precluded in a feed-in tariff scenario where prices are fixed and do not necessarily reflect the most current and cost-efficient options for off-takers.

The Request For Proposals documents were devised in August 2011 after an initial prospective bidder conference. A two-step evaluation process was designed, with bidders required to meet minimum environmental, land, commercial/legal, economic development, financial and technical standards. Seventy percent of the second-step evaluation was based on bid pricing with the remaining 30% focusing on scores concerning job creation, local content, preferential procurement, enterprise and socio-economic development.

At that time, minimum project size was set at 1 MW with the maximum size varying by technology. Bidders were allowed to bid for multiple projects and different technologies, with each having a unique price cap. The winning bidder would receive a 20-year local currency denominated power purchase agreement (PPAs) with Eskom.

**REIPPPP Results:** In the first bidding round (November 2011- 2012) 3,625 MW of capacity was offered with 2,128 MW of capacity spread across 53 bids. Twenty-eight bids representing 1,416 MW of new capacity and US\$ 6 billion in total investment were accepted. South African commercial banks provided most of the debt financing. The second bidding round (March 2012-May 2013) saw oversubscription; with 1,284 MW of capacity being offered and seventy-nine bids representing 3,255 MW being received. Fifty-one bids qualified, with lower pricing across technologies. The ensuing bidding rounds further decreased in price as shown in Figure 22.

The following lessons can be learned from South Africa's experience:

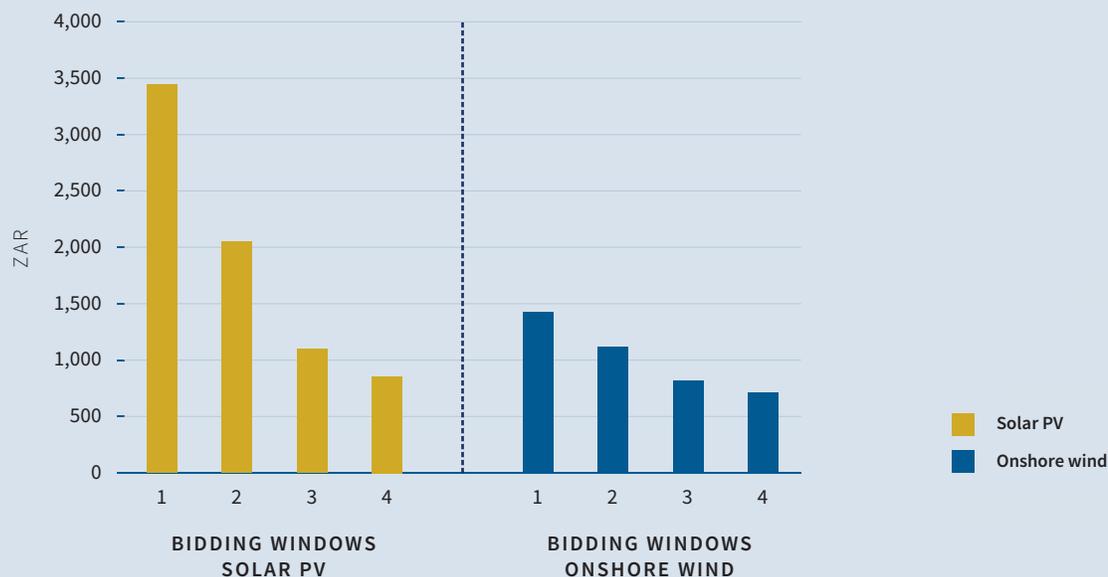
#### Benefits

- The competitive structure of the REIPPPP resulted in lower pricing of renewable energy capacity.
- There was a robust response from a diverse pool of bidders, including several international companies.
- The Government and utility increased accountability, adhering to schedules, bidder requirements and tender design. External advisors were contracted to evaluate bids.
- Flexibility of REIPPPP design allowed for continued improvement based on engagement between bidders and authorities.
- Local content targets have resulted in spurred local job creation and inclusion, with 30% of shareholding represented by black participants.<sup>148</sup>

#### Challenges

- High transaction costs for bidders and authorities due to need of external advisors and lack of institutional capacity on both sides.
- Competitive nature of the process may have resulted in unrealistic pricing that is so low that projects become financially unfeasible.
- The success and implementation of the REIPPPP has highlighted the constraints of adequate transmission and grid infrastructure.
- The lack of cooperation from Eskom, which refused to sign more PPAs under the REIPPPP from 2016 to 2018, citing costs and overcapacity (see political motivations for this response in Box 23).
- Small IPPs were particularly constrained by relatively high costs associated with grid connection estimates.

FIGURE 22: AVERAGE PRICE PER BIDDING

Source: Mangondo, 2017.<sup>149</sup>

While relatively straightforward in principle, in practice renewable energy reforms are difficult to implement. This is because there are powerful private and public interests that are set to lose out from policy changes. This is not new. Energy reforms aiming to unbundle the energy sector to allow for third party producers (regardless of energy source) to compete in the generation and distribution of power have faced opposition from the public utility that would lose monopoly power. While a vertically integrated public utility made sense in the past due to high barriers of entry and economies of scale resulting in big centralized power generation and distribution systems that have helped to advance industrialization, new technologies and competitive smaller scale power generation means that such vertically integrated systems are outdated. They tend to lead to higher electricity prices for consumers due to monopoly power or subsidies that ultimately also have to be paid for by the consumer.

Another factor, which complicates energy reforms that favor renewables, is the powerful interests in the fossil fuel sector, which are set to lose from an increasing uptake of renewables. This ranges

from politicians wanting to appeal to electoral votes that benefit or have benefitted from the fossil fuel value chain,<sup>150</sup> to powerful private sector groups lobbying governments and funding disinformation campaigns.<sup>151</sup> Furthermore, the diesel fuel import & sales supply chain in developing countries is often controlled by powerful and well-connected business elites. The case of South Africa illustrates that even though the REIPPPP program has been well designed and received a lot of interest, the implementation has been difficult due to opposition from powerful actors (Box 23). As one of the IPP interviewees that has worked extensively in South Africa highlighted:

“South Africa is a fantastic case study of ‘what to do’ and ‘what not to do’. The regulations and bidding rounds have been well designed and have attracted a lot of renewable company interest. The market is very attractive. However, there is no political will to then move these renewable projects forward with obstacles at every step of the way. Many IPPs have become very frustrated.”

**BOX 23: POLITICAL ECONOMY IN SOUTH AFRICA'S RENEWABLE ENERGY POLICY**

South Africa's electricity utility Eskom is vertically integrated; holding power over generation, transmission and some distribution. In 1998 a policy framework was submitted that foresaw the restructuring of Eskom and entry of IPPs. However, these reforms were driven by private sector actors and international consultants without having sufficient political backing. As a result, no regulatory framework was developed to implement the policy.

With a looming energy crisis caused by increasing demand and insufficient power generation investments due to a lack of financial resources by Eskom, the government raised electricity tariffs and Eskom started its generation expansion program by investing in large-scale coal fired power plants. But these investments came too late leading to blackouts throughout the country in 2007-2008. The energy crisis was used by Eskom to highlight the importance of the government keeping control over the sector to ensure energy security. During the mid-2000's the Renewable Energy Feed-in Tariff (REFIT) program was started to cater for increasing international interest by renewable energy providers to enter the South African electricity market. However, the program "was plagued with policy incoherency, uncertainty, and confusion – the result of continued resistance from an incumbent regime battling to maintain control over energy generation."<sup>152</sup>

With increasing frustration about rising electricity prices, power outages and a lack of confidence in ESKOM, a new unit was created independent of ESKOM and the Department of Energy to produce a competitive bidding implementation platform. The Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) was established to bring in renewable IPPs and drive down prices. There was large interest in the REIPPPP bidding rounds which resulted in competitive price offers. However, delays in the sign off by ESKOM on the PPAs with the renewable IPPs has led to investor concerns and project delays.<sup>153</sup>

Further complicating the energy policy dynamics of South Africa has been President Zuma's Government strong commitment to nuclear energy. Cost estimates suggest that nuclear energy solutions are not economic when compared to coal and renewable energy solutions. There have been allegations that agreements have been negotiated and signed with kick-backs to individuals in the Government.<sup>154</sup>

Despite entrenched interests and political opposition to change, energy reforms have been implemented in the past. Particularly, they have occurred as a response to energy crises, being part of broader economic reforms, or resulting from a change in power from "left-wing" to "right-wing" governments or vice versa.<sup>155</sup>

**2.5.2. Private sector**

Within the renewable power and mining sectors, it should be highlighted that there are many different incentives and interests at stake. As one interviewee that used to work for an IPP noted:

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"Maybe the most important question to ask is who has been driving the debate about integration of renewables in mining. It has been the developers and providers trying to sell their solutions to mining companies rather than the mining companies asking for these. This is why we have been discussing renewables in mining for some time now, but the uptake has been a lot slower than expected. For the past five years I have been to conferences on this topic where people speak about the falling costs of renewables and that we are at the cusp of an inflection point where renewables in mining will become mainstream. But the reality is that we are still talking about some case studies we discussed 5 years ago, which suggests that it has not yet been mainstreamed. As long as it is the IPPs pushing this agenda and not driven by mining companies demanding renewables, I don't see an inflection point."

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Interviewees traced back the seeming lack of commitment to renewables to the conservative nature of the mining sector as a whole. Unlike the ICT sector, for example, where several companies have made more ambitious commitments to source from renewables (see Box 24), management within the mining sector tend to be from an earlier generation – a generation that did not grow up with the pressing concerns about climate change and more wary about new technologies. As highlighted by one interviewee that used to work at a mine site to test and integrate new technologies:

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"The way that the previous and today's generation was taught engineering could not be more different. The past generation can hear if a diesel generator is running smoothly or not. The older generation does not trust a computer system to the same extent that the younger generations do, because they did not grow up with these technologies. This may also lead to an aversion to technologically more advanced hybrid power systems that integrate renewables at off-grid mine sites. I always went to two of the younger mine-site managers to test new technologies, as I knew that they would be more receptive than their older counterparts."

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## BOX 24: GOOGLE AND APPLE AIMING TO REACH 100% RENEWABLE ENERGY PURCHASING

The ICT sector currently produces 2% of global CO<sub>2</sub> emissions and consumes 7% of the total electricity, a percentage expected to grow up to 13% by 2030. The primary driver of the rapid growth in energy consumption has been mainly due to the accelerated expansion of data centers, which require constant and reliable power. This characteristic provides an interesting comparison to mining, which also needs 24-hour uninterrupted power access.\*

ICT companies have an average of 60% renewables in their energy mix, which is the largest percentage across all industries. The sector is leading corporate investments in new energy technologies.<sup>156</sup> The push for renewables in the sector can be traced back to economic motives and environmental concerns. ICT companies have made use of all the sourcing models outlined in Section 1.3 including investing in renewable power plants themselves, signing PPAs, industrial pooling, purchasing renewable energy credits and contracting green utility products. Furthermore, ICT companies have been a leading force in the Renewable Energy Buyers Alliance and RE100 that aim to share renewable power purchasing experiences and create user-driven market pressure.

For example, in 2017 Google met its target to consume 100% renewable energy for its offices and 15 data centers located across the world. To achieve this, Google committed to purchasing the entire production of a 72 MW wind farm in Northern Sweden through a 10-year PPA. This allowed OX2, the developer, to secure financing backed by the insurance company Allianz.<sup>157</sup> Google directly and indirectly supports nine further wind energy projects, four located in the US and the remaining five in Sweden, and that provide a total of 1.1 GW in wind energy to the company (the equivalent of 35% of its operations).<sup>158</sup>

In April 2018 Apple also announced that it had achieved 100% renewable electricity powering its facilities across 43 countries.<sup>159</sup> In China, Apple built an on-site solar energy power plant that has been supplying 100% of the 40 MW that their facility needs, since 2016. Additionally, the company invested in three mega solar-projects across China that produce 200 MW of clean energy.<sup>160</sup>

Reasons that may explain why the ICT sector is more ambitious than the mining sector in sourcing renewable energies in their operations include:

1. The ICT sector will always invest in a grid-connected area, which provides more renewable power sourcing options than off-grid mine sites.
2. The ICT sector is closer to the consumer than the mining sector and therefore more conscious of being seen as a progressive company combating climate change.
3. Due to its characteristics, it is easier to reach 100% renewables for an ICT company than for a mining company and therefore the incentive for getting there is larger.
4. The largest ICT companies have accumulated significant resources<sup>161</sup> over recent years and are searching for investment opportunities that provide them stable returns.
5. The people working in the ICT industry and its leaders tend to be of a younger generation that is more conscious about climate change.

The mining industry is also less geared towards innovative thinking and is more reluctant to change. Many companies do not want to pioneer new technologies and rather follow once something is proven to be successful. This “first to be second” attitude does not only relate to renewable power solutions, but also other types of technologies.<sup>162</sup>

Investment in innovation in the mining sector amounts to around 0.5% of revenues as compared to 2-3% in manufacturing and 3-5% in the oil and gas industry.<sup>163</sup> Box 25 highlights how the Chilean Government has proposed to address this “first-mover problem” with technologies to reduce the carbon footprint of copper mining in the country.

### NOTE

- \* One of the most significant differences of the two sectors is that datacenters are not geographically bound, and therefore can be built close to low-cost energy sources.

## BOX 25: CENTER FOR THE ENERGY TRANSITION

To encourage the adoption of new technologies by the mining industry in Chile, the Government has proposed to setup the Center for the Energy Transition (previously named the Solar Mining Institute). This public private partnership proposes to develop labs and test technologies to make use of Chile's competitive advantages and reduce the carbon footprint of the mining industry. Proposed research streams include solar PV and concentrated solar technologies, storage technologies, and hydrogen and liquid fuel technologies that can serve the transport and processing activities of the mining sector.

The institute is designed to work with the collaboration of government, private sector and academia, to foster a high-level and applied innovation environment. The project will be tendered by CORFO and located in the Antofagasta region. Royalties received from the lithium mining company Soquimich, which was acquired by Albemarle in 2015, will contribute to the initiative with a minimum of US\$ 12 million per year. This financial support was part of the agreement reached between Rockwood and the Chilean Government in 2017.<sup>164</sup> Other companies are encouraged to also invest in this new initiative.

The reluctance of mining companies to be seen to fail may also explain why most existing renewable projects that have been integrated at off-grid mine sites are relatively small and have low penetration rates. Most interviewees suggested that higher renewable penetration would have been viable from a technological and economic perspective. However, mining companies have approached renewables by starting off with a small-scale testing prior to increasing reliance. This may not be an efficient way of testing renewables given that the problems and technological solutions for higher penetration rates are different. Contractors have also an incentive to design very conservative systems to ensure that they can meet the guaranteed energy system.

Within a mining company there are also different interests and drivers. While management and the sustainability department may be interested in renewable power integration for reputational reasons and to reduce the carbon footprint of the company, a mine manager that is paid if he meets his production target, may not.

“The role of the mine manager should not be underestimated, because he has more influence on decisions than company executives would like to admit. A mine manager does not have a long-term perspective. Particularly if it is a remote mine site, he will do the job for no more than 5 years before moving on. His primary concern will be to operate the mine without interruptions. The prospect of having a technology that he is probably not familiar with, be integrated in a key component of the mine that determines whether he can guarantee production 24 hours a day and 7 times a week, is not particularly appealing. In brownfield projects there is the additional concern about the disruption caused during construction. From his perspective it makes more sense to use traditional energy sources that he knows he can rely on based on past experience, even if this is at a higher cost... And for off-grid mines everyone is paying the price for diesel, so his power expenses will not necessarily be an outlier when compared to his fellow colleagues or competitors.”



Iron ore © shutterstock.

## PART 3

### TRENDS AND DRIVERS

Growing demand of minerals and falling ore grades will require more energy per tonne of output. Furthermore, the automatization and electrification of trucks and other mining processes will rebalance the demand for energy from liquid fuels towards electricity as exemplified by the Borden mine (Box 26). This section outlines the foreseeable trends and drivers that will determine whether wind and solar energy sources will play a bigger role in powering the

increasing demand of the sector. The same categories as in the roadblock section have been reviewed. Namely; (1) technical, reviewing the price projections for wind, solar and storage technologies, as well as prospects for modular solutions and blockchain; (2) expertise, to assess whether and how the stakeholders involved are learning from existing initiatives and projects; (3) financing, where new banking products are being developed that make it easier for large consumers to source renewables; (4) regulatory, showing the increasing trend of governments supporting renewables in respective legislations; and (5) interests, to assess what driving factors are likely to encourage further integration of renewables in mining.

### 3.1. TECHNICAL

#### 3.1.1 Electrification of mines

As highlighted in the introduction, solar and wind generation projects have the potential to decarbonize the electricity component of energy consumption. Electricity is already used for ventilation systems, water pumping, crushing, grinding and other processing operations. With increased automation and electrification of mine sites, there is further potential for wind and solar projects to decarbonize the final energy consumption mix of the sector.<sup>165</sup> GoldCorp is developing Canada's first all-electric "mine of the future" (Box 26).

#### 3.1.2. Falling costs of renewables

Solar and wind energy costs have fallen dramatically in recent years. Particularly solar PV installation costs have plummeted 70-80% in the last 8 years.<sup>166</sup> This is the result of improvement in manufacturing processes, their shift from high-cost countries (e.g., Germany, Japan) to lower-cost countries (e.g., China), efficiency gains in the supply chain and more widespread integration of wind and solar energy due to policies in Europe, China and California creating a bigger market for it.<sup>167</sup> On a least cost of electricity basis,\* solar and wind energy sources are now largely competitive with fossil fuel-based sources as shown in the two figures on the following page.\*\*

#### BOX 26: BORDEN MINE TO BE THE FIRST ALL-ELECTRIC UNDERGROUND MINE IN CANADA

<b>Location:</b>	Chapleau, Ontario, Canada
<b>Mine Ownership:</b>	GoldCorp
<b>Grid Status:</b>	On-grid
<b>Electric fleet providers:</b>	MacLean, Sandvik and Medatech
<b>Cost Savings:</b>	C\$ 9 million per year
<b>Fuel Savings:</b>	2,000,000 liters diesel & 1,000,000 liters of propane per year
<b>Energy savings from reduced ventilation needs:</b>	33,000 MWh
<b>Carbon Savings:</b>	7,000 tonnes of CO <sub>2</sub> e/year (70% reduction to baseline) <sup>170</sup>

**Project:** The Borden mine is expected to begin commercial production in the second half of 2019 and is set to become Canada's first all-electric underground mine. The aim is to replace diesel equipment for drilling, blasting, bolting and transportation with battery alternatives. For this purpose, GoldCorp has contracted MacLean and Sandvik to supply the battery powered fleet including a 40 metric tonne battery powered haul truck. Currently, the exploration ramp-up is already using electric vehicles from these two suppliers, including a Caterpillar service vehicle that has been retrofitted by Medatech.

While capital expenditure is expected to be higher than a conventional mine given that electric carriers are 25%-30% more expensive than conventional machinery, it is expected to halve the cost of energy intensive ventilation due to using battery powered systems.<sup>171</sup> Furthermore, cost savings are expected from lower diesel costs and fleet maintenance as diesel trucks typically have 1,000 more parts than their electric counterparts.

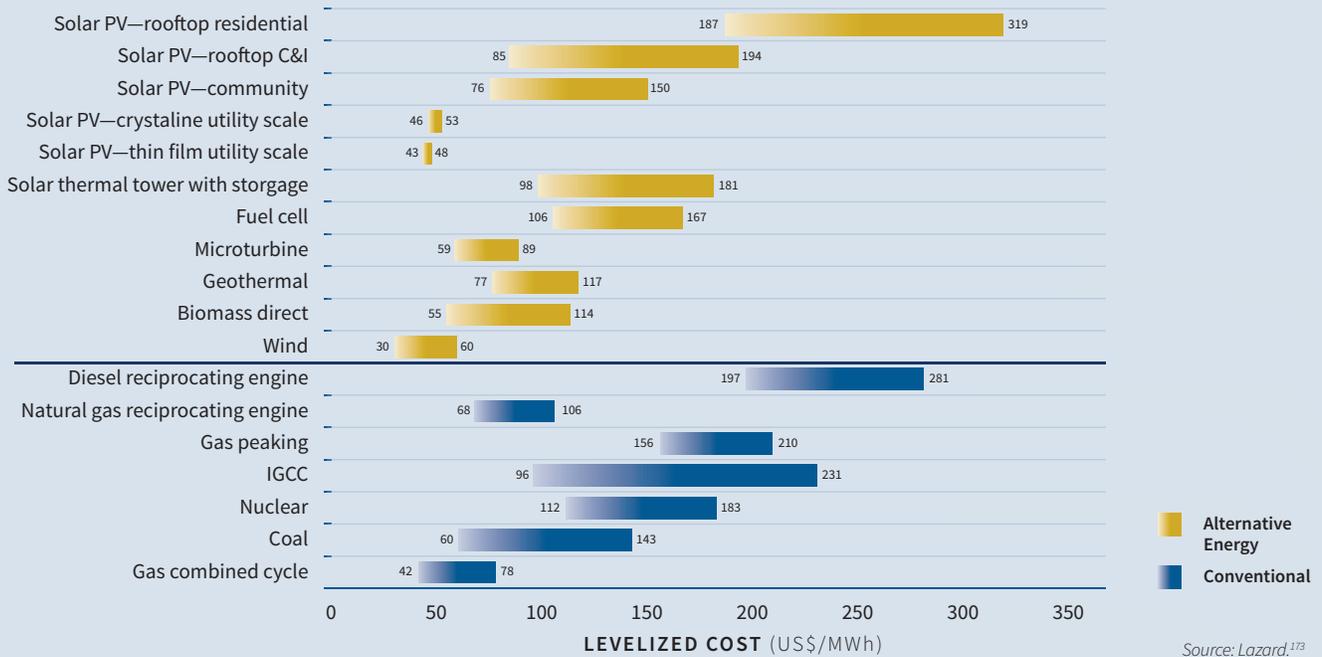
To support GoldCorp as a first-mover investing in these new cleaner and more sustainable mining technologies, the Government of Canada has provided the company with a US\$ 3.8 million grant. The grant comes from its US\$ 155-million investment fund for clean technology research, development and demonstration projects in energy mining and forest sector, called the Natural Resources Canada's Clean Growth Program.<sup>172</sup>

#### NOTE

\* The Least Cost Of Energy (LCOE) of a given technology is the ratio of lifetime costs (including installation costs, financing costs and operating costs) to lifetime electricity generation; both are discounted using a discount rate that reflects the average cost of capital.<sup>168</sup>

\*\* The rapidly falling costs of renewables have meant that renewable projects that were not attractive a few years back now are. For example, the Zenith Energy's Nova solar plant project in Australia "transitioned from cost prohibitive, even with governmental support, to being funded on a purely commercial basis".<sup>169</sup>

**FIGURE 23: COMPARISON OF UNSUBSIDIZED LEVELIZED COST OF ENERGY (LCOE) (2017)**



Source: Lazard.<sup>173</sup>

**FIGURE 24: LCOE OF SOLAR VERSUS GAS AND DIESEL ACROSS GEOGRAPHIES (2017)**

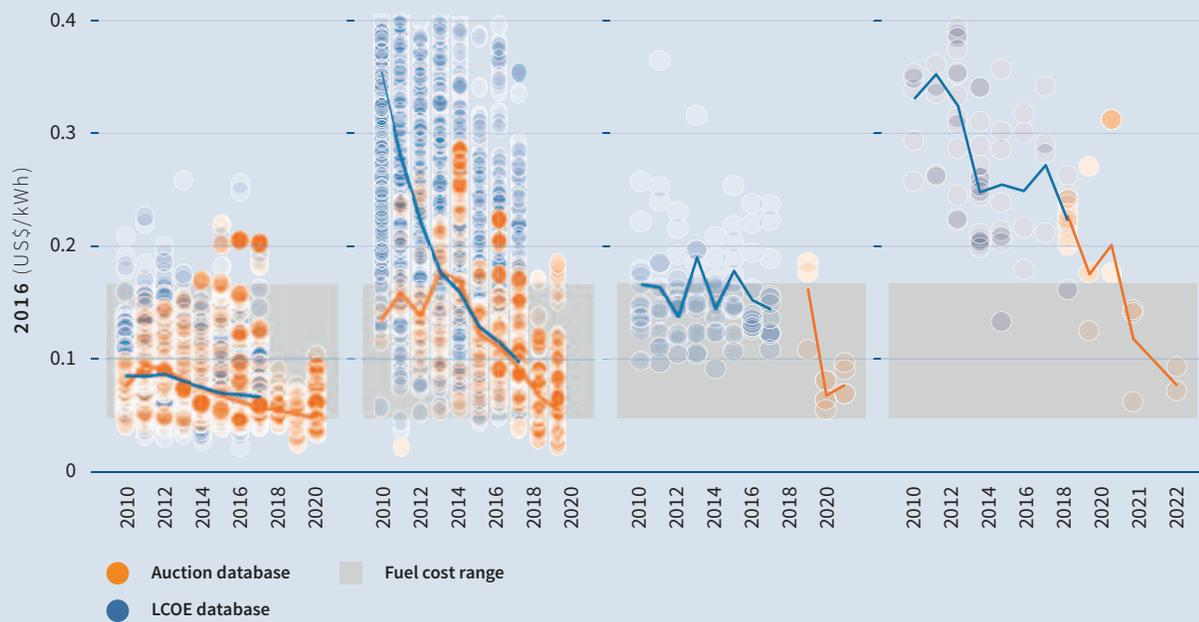


Source: Lazard.<sup>174</sup>

This price trend is expected to continue. Onshore wind and solar PV projects that feed into the grid will be more competitive than fossil-based energy sources without incentives or subsidies. “The best onshore wind and solar PV projects will be delivering electricity for an LCOE equivalent of US\$ 0.03/kWh, or less, with CSP and offshore wind capable of providing electricity very competitively, in the range of US\$ 0.06 to US\$ 0.10/kWh from 2020.”<sup>175</sup> Figure 25 shows levelized cost estimates based on recent auction results.

The above trend shows cost comparisons for grid connected projects. For mining projects that rely on diesel generators to power their operations, the price differential is even larger. Box 27 provides a cost-comparison at the time when one of the first mine sites integrated renewables in its power generation mix. Already in 2013 when renewable energies were not as cost competitive, Cronimet managed to prove the business case for integrating a 1 MW solar PV plant in their operations.

**FIGURE 25: LCOE FOR CSP, SOLAR PV, ONSHORE AND OFFSHORE WIND PROJECTS, 2010-2020**



Source: Irena, 2018.<sup>176</sup>

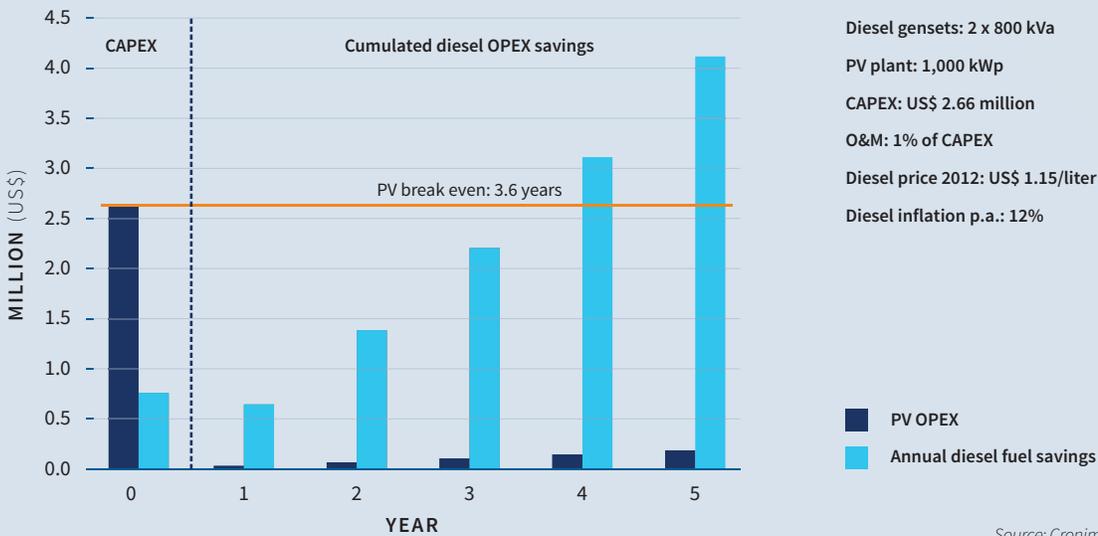
**BOX 27: CRONIMET'S THABAZIMBI MINE<sup>177</sup>**

<b>Location:</b>	Thabazimbi, South Africa
<b>Mine Ownership:</b>	Cronimet
<b>Grid Status:</b>	Off-grid
<b>Solar Project Size:</b>	1 MW
<b>Solar Project Generation:</b>	1,800,000 kWh (30% of operations)
<b>Solar Project Commissioning:</b>	2012
<b>Solar Project Cost:</b>	US\$ 2.66 million
<b>Solar Project Developer:</b>	CRONIMET Power Solutions (joint venture between Cronimet and Solea Renewables)
<b>Cost Savings:</b>	US\$ 500,000 annually
<b>Diesel Savings:</b>	450,000 liters annually
<b>Carbon Savings:</b>	2,000 tonnes annually
<b>Other Component:</b>	1.6 MW diesel (1.9 million liters/yr, US\$ 2.18 million/yr)

**Background:** Cronimet's chrome mine in Thabazimbi, South Africa holds a 30-year lease on a site with proven reserves amounting to over 17 million tonnes of chromium ore. The site however had no access to the South African electricity grid and would have to run diesel powered generators to supply the 1.6 MW of energy needed 24 hrs a day.

**Solar project:** By working with a solar developer Solea Renewables (now CRONIMET Power Solutions), Cronimet was able to build a solar-diesel hybrid system that reduces diesel consumption by 450,000 liters a year through a power purchase agreement (PPA) signed with the mine. Solea Renewables was able to offer the Engineering Procurement Construction (EPC), operations and maintenance services required to maintain the project for the full life time of the PPA. Overall, the project had a 3.6-year payback, and in the long-term a net-present value of US\$ 2.3 million (Figure 26). The project financing came from CRONIMET Energy, a separate business unit to the mine, meaning that the costs were not on the mine's balance sheet.

**FIGURE 26: SYSTEM COST BREAKDOWN: THABAZIMI MINE SOUTH AFRICA**



Source: Cronimet Mining-Power Solutions.<sup>178</sup>

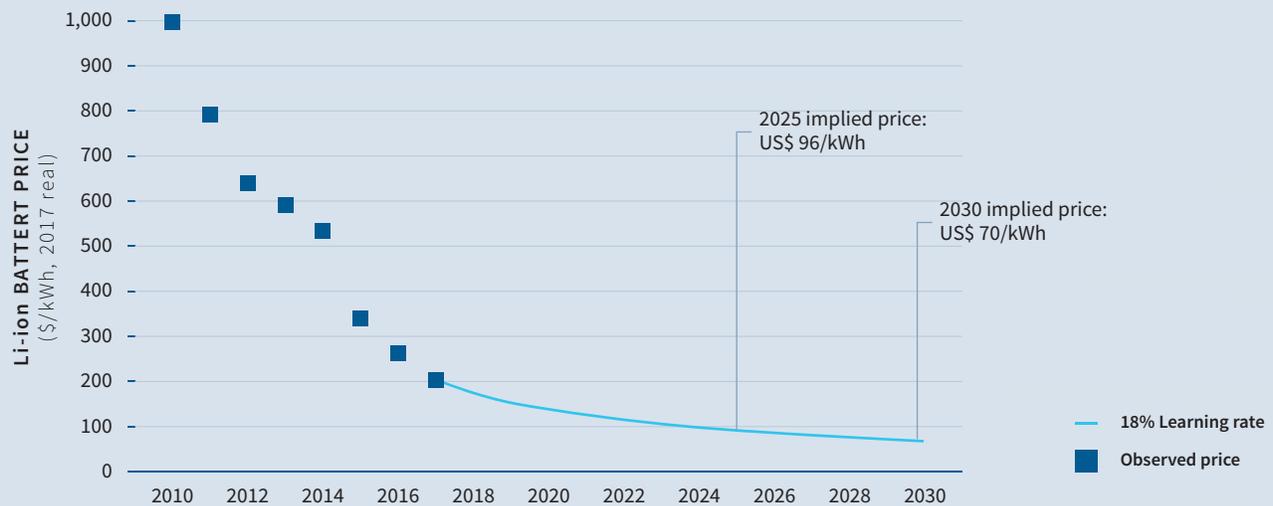
### 3.1.3. Falling costs of battery storage

Lithium-ion battery costs are also anticipated to continue to fall rapidly as production is ramped up. As shown in the Figure 27, prices are estimated to fall from above US\$ 200/kwh in 2017 to below US\$ 100/kwh by 2025. This development may address some of the intermittency problems of solar and wind power and allow for higher renewable penetration rates at off-grid mine sites as mentioned above.

Sandfire Resources’ Degruussa mine in Australia is an interesting case, because it has already integrated battery storage in its hybrid power project (Box 28). The 6 MW battery system addresses solar variability by

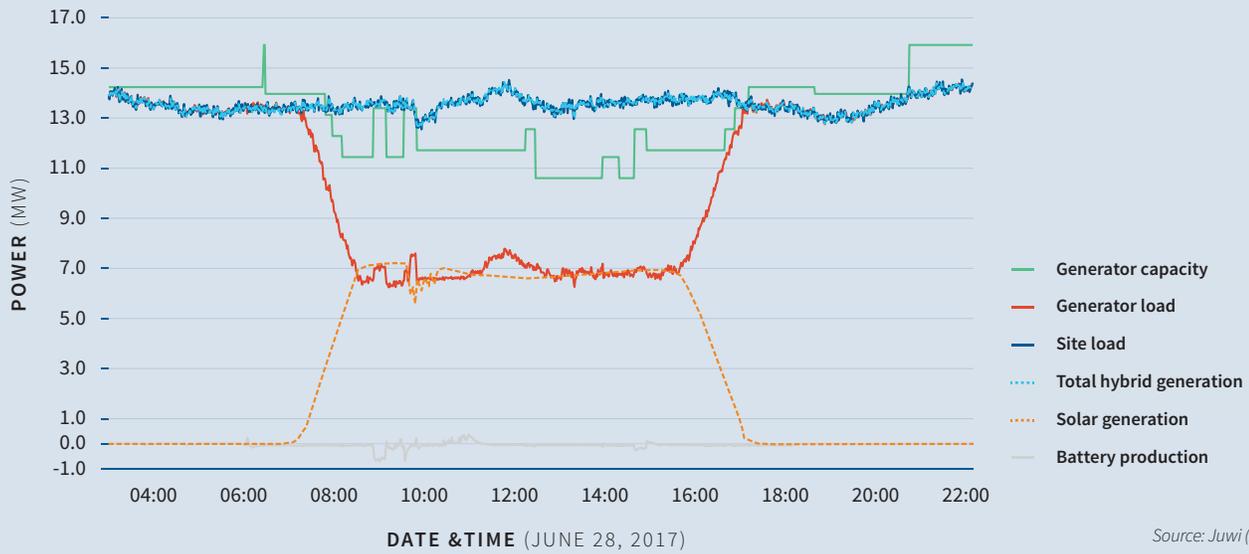
providing frequency control and spinning control. Figure 28 shows the interaction between the diesel generators (red and green lines), solar (dotted orange line) and battery system (grey line). The benefit of the battery system is that it allows for the diesel generators to be switched off rather than running them at below-load, which reduces efficiency. In case of a cloud passing by as shown around 9am, the battery reacts quickly to provide power until an additional diesel generator is turned on again (green line shows capacity). With increased storage capacity at lower costs, the developer has modeled different scenarios showing that the penetration rate of solar could be increased to 82.9% with a simulated power profile as shown in Figure 29.

FIGURE 27: LITHIUM-ION BATTERY PACK PRICE

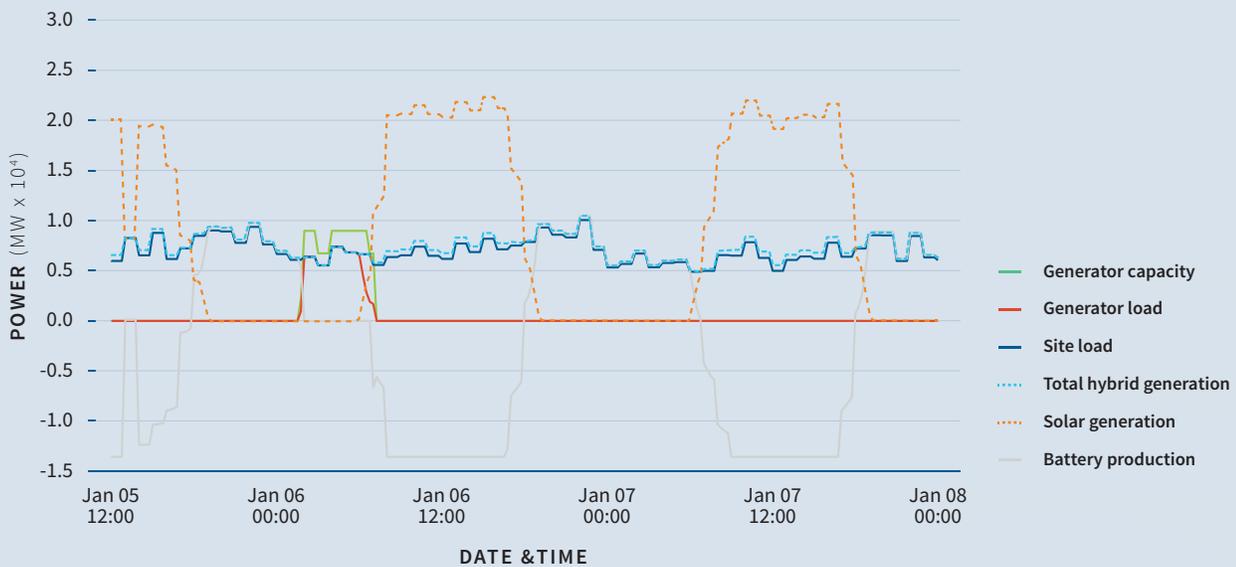


Source: Bloomberg NEF.<sup>179</sup>

**FIGURE 28:** POWER PROFILE OF DEGRUSSA MINE ON A HIGH RADIANCE DAY (10.6MW SOLAR PV, 6MW STORAGE)



**FIGURE 29:** POWER PROFILE OF OFF-GRID MINE ON HIGH RADIANCE DAY (40MW SOLAR PV, 17MW STORAGE)



**BOX 28: DEGRUSSA SOLAR**

<b>Location:</b>	Remote Western Australia
<b>Mine Ownership:</b>	Sandfire Resources
<b>Mine:</b>	DeGrussa Copper/Gold Mine
<b>Project Owner:</b>	NEOEN, long-term owner-manager of the project
<b>Project Developer:</b>	EPC contractor
<b>Project Capacity:</b>	10.6 MW solar integrated with existing 19 MW diesel generator and advanced lithium-ion batteries that can store up to 6 MW
<b>Total Cost:</b>	AU\$ 40 million

**Financing:** The Australian Renewable Energy Agency (ARENA) provided a AU\$ \$20.9 million recoupable grant, the Clean Energy Finance Corporation (CEFC) provided AU\$ \$15 million in debt financing, NEOEN has invested equity in the project.<sup>182</sup>

The DeGrussa copper mine went into operation in 2012 and is set to produce up to 300,000 tonnes of high-grade copper and gold annually. Sandfire cites its strong commitment to sustainability behind its consideration of solar power options for DeGrussa, which the company began pursuing in 2014. ARENA agreed to support the project in order to demonstrate the affordability, reliability and security of renewables to the domestic mining industry.

The renewable power project went into operation in 2016 after less than a year of construction making it the largest off-grid solar and storage facility on a mine site in the world. Prior to startup and commissioning, the EPC company for the project - Juwi, reviewed and planned all possible scenarios with the mine management team and the power plant owners in order to reduce the risk of potential problems. This allowed them to react quickly and efficiently in case unforeseen circumstances would arise to minimize mining interruptions.<sup>183</sup>

French company NEOEN bought the project from Juwi for an undisclosed fee in 2015 and entered a five and a half year PPA with Origin Energy to sell the Large-scale Generation Certificates from the project. The installation is expected to generate more than 20,000 LGCs per year and the tenure of the PPA between Origin and NEOEN reflects the expected life of the mine.<sup>184</sup>

**Benefits:** The installation has the potential to meet 90% of the mine's daytime demand and saves roughly five million liters of diesel each year, resulting in an annual decrease of 12,000 tonnes of CO<sub>2</sub>.<sup>185</sup> The project is a natural hedge against volatility in exchange rates, CO<sub>2</sub> costs and diesel prices.<sup>186</sup> ARENA and Juwi have both hosted tour groups of mining industry leaders on visits to the DeGrussa project over the past two years. The project garnered Project of the Year award from the Toronto Energy and Mines World Congress 2016.

**3.1.4. Other storage solutions**

Apart from battery storage, there have been other important recent developments in alternative storage mechanisms. Mining companies are particularly investing in research and development in solar thermal, pump storage and hydrogen. This report therefore highlights the potential of these three technologies below.

**Solar Thermal**

Solar thermal technologies can be divided up into non-concentrated and concentrated technologies, both of which are of interest to the mining sector. The former has been integrated at the Gabriela Mistral mine in Chile (Box 29) and serves to replace conventional heaters at its electrowinning plant, thereby reducing diesel consumption. The heat obtained from the solar system is transferred to a water storage tank, which is then pumped to the process heat exchanger. The storage tank allows for the system to also operate during all hours of the day. Back-up generators are in place in case of cloud coverage (see Figure 30 for an illustration of the process).

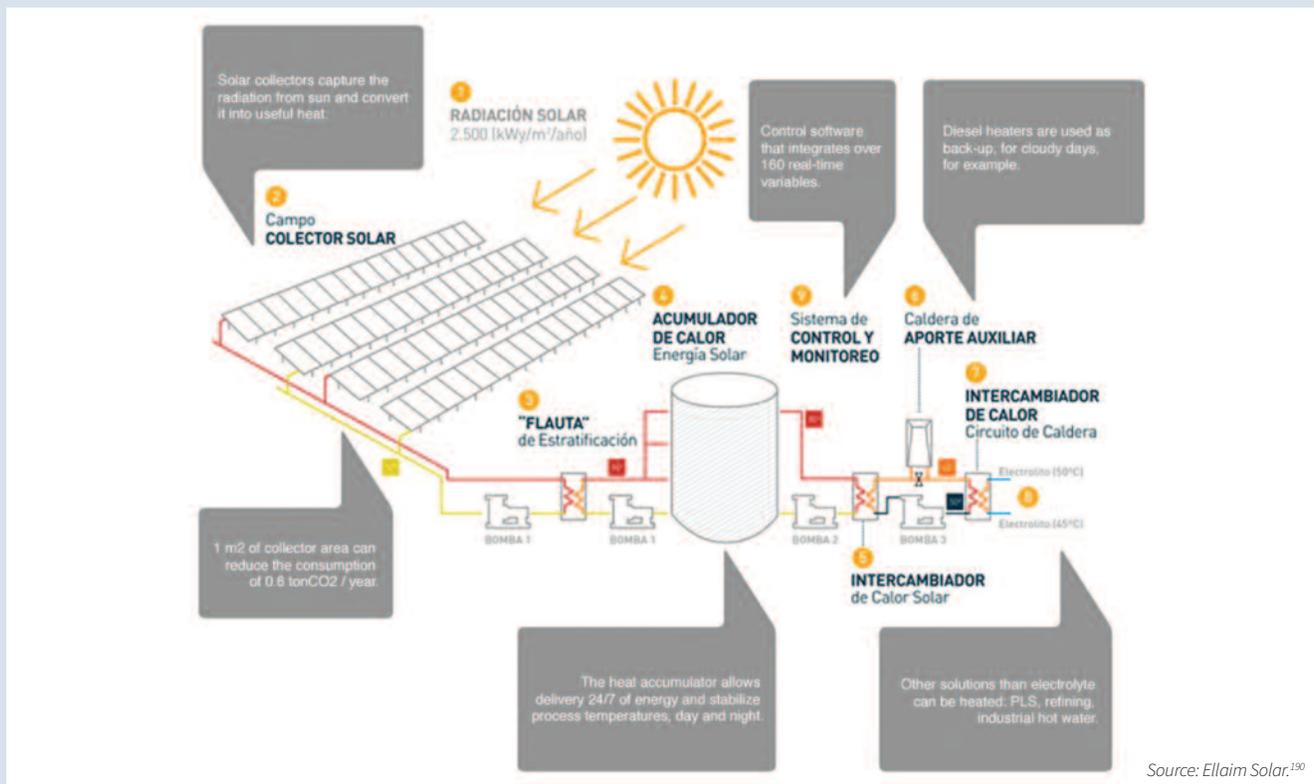
**BOX 29: GABRIELA MISTRAL – CHILE**<sup>187</sup>

<b>Location:</b>	Atacama, Chile
<b>Mine Ownership:</b>	Codelco
<b>Grid Status:</b>	On-grid
<b>Thermal Project Size:</b>	34 MW
<b>Thermal Project Production:</b>	80,000 MWh (covers 80% of energy demand)
<b>Solar Project Commissioning:</b>	2012
<b>Solar Project Cost:</b>	US\$ 26 million
<b>Solar Project Developer:</b>	Energía Llaima - Sunmark
<b>PPA:</b>	10 years
<b>Diesel Savings:</b>	6.5 million liters annually
<b>Carbon Savings:</b>	15,000 tonnes annually

Codelco’s Gabriela Mistral mine is located in the Antofagasta region. For its energy intensive copper electrowinning (EW) facility, it awarded a tender to the Chilean-Danish consortium Energía Llaima and Sunmark, who were given the responsibility to build, manage and maintain the plant. A 10-year PPA agreement was signed and the land area for the installation of the solar project was provided by CODELCO. Project financing was structured through Banco BCI.<sup>188</sup>

The Pampa Elvira solar project is composed of close to 300 solar panels covering 44,000m<sup>2</sup> and generating 80,000 MWh per annum. It covers 80% of Gabriela Mistral’s electricity needs, which equates to 250,000 barrels of diesel that previously had to be transported to supply the electrowinning facility.<sup>189</sup>

**FIGURE 30: SOLAR THERMAL SYSTEM SUPPLYING GABRIELA MISTA MINE**



While temperatures of up to 150°C can be achieved with non-concentrated solar, higher temperatures require concentrated solar power technologies (CSP).<sup>191</sup> Electricity generation using concentrated solar technologies are well developed and commercialized. In essence, the sun's rays are reflected by mirrors onto a receiver, which creates heat that can be stored or turned into electricity. For storage, molten salts or fuels are used that are well suited to retain the heat.<sup>192</sup>

In Chile and Australia several CSP plants are currently being constructed in mining intensive regions to supply increasing energy demand by the sector (Box 30). There is also potential for this technology to be used for metallurgical processing purposes such as solar thermal decomposition of alumina, calcination of limestone, and magnesia, and solar syngas production for direct reduction of metal oxides.<sup>193</sup>

### BOX 30: CERRO DOMINADOR<sup>194</sup>

<b>Solar Project Developer:</b>	EIG and Abengoa
<b>Grid Status:</b>	On-grid
<b>Solar Project Capacity:</b>	100 MW
<b>Thermal Project Capacity:</b>	110 MW
<b>Project Generation:</b>	950 GWh per year
<b>Solar Project Operation:</b>	expected 2019
<b>Solar Project Cost:</b>	US\$ 2.3 billion
<b>PPA:</b>	15 years
<b>Carbon Savings:</b>	873,000 tonnes of CO <sub>2</sub> annually
<b>Additional operations:</b>	17.5-hour thermal storage in molten salt

The Cerro Dominador power plant is one of the largest thermo-solar power plants currently being constructed in Latin America. With a total installed capacity of 210 MW at a cost of US\$ 2.3 billion, it produces energy through two main sources of power: Photovoltaic (PV) and concentrated solar power (CSP); an innovative technological system unique in the region and the world in general due to its high installation costs. The facility features a 17.5-hour thermal storage in molten salt that will allow the plant to operate 24 hours per day.

For its construction, the Chilean Government - through the National Energy Commission (CNE) - launched in 2015 a US\$ 1 billion procurement process based on a 15 year PPA requiring a total installed capacity of 110 MW and a minimum production of 950 GWh per year. The concession was initially granted to the Spanish contractor Abengoa. For its financing, the Chilean government - through the Energy Ministry and the Chilean Economic Development Agency (CORFO) - provided a US\$ 20 million grant and a free land concession for the plant, in addition to a loan package of approximately US\$ 500 million from various development banks, namely the IADB (Inter-American Development Bank), the Clean Technology Fund, the German development bank KfW, European Union and the Canadian Fund.

Due to the success of the initial bid, as well as the positive energy outlooks of the region, Abengoa requested permission to expand the power plant's capacity for an additional 100 MW through a photovoltaic energy project of 392,000 solar panels distributed across 300 hectares. The US\$ 1.3 billion expansion was approved by the government in late 2015.

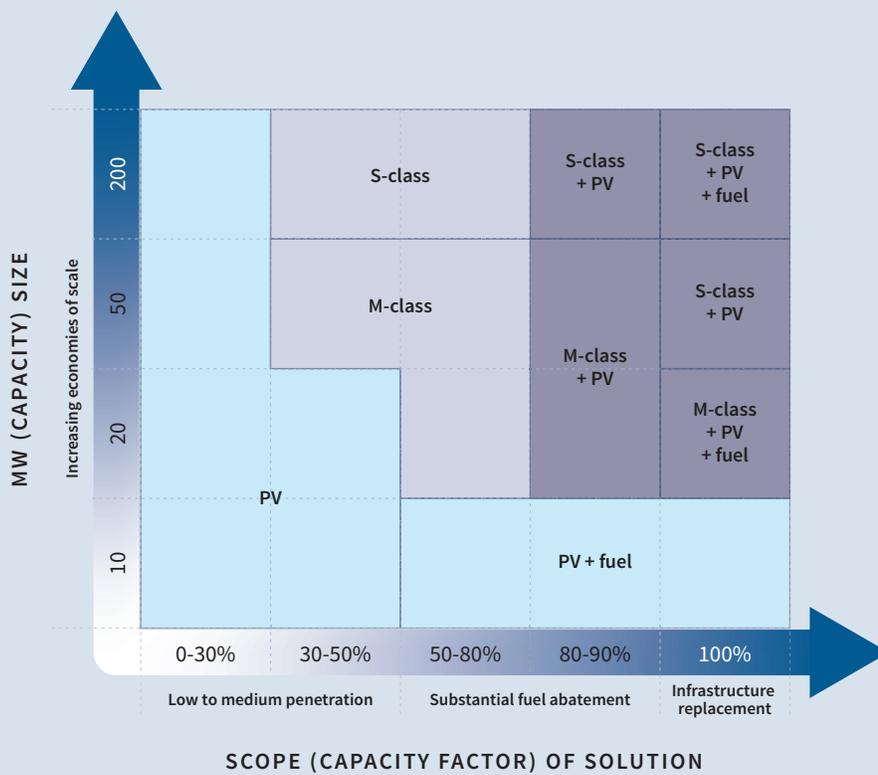
In 2016 EIG bought 55% of the shares of the project at a cost of US\$ 1.3 billion. Thanks to this acquisition, it was possible to attract additional funding from the private sector, adding up to US\$ 638 million from BBVA, Deutsche Bank, Intesa, Natixis, Santander and Société Générale.

The CSP is expected to start operating in 2019, while the PV plant has been operating since 2017 at a 62 MW capacity. Once the plant is in full operation, it will help reduce Chile's emission by 873,000 tonnes of CO<sub>2</sub> and supply clean energy to 492,000 households.

One of the largest drivers of this project was the increasing energy demand of the mining sector, which was the biggest consumer in the Sistema Interconnected del Norte Grande (SING) in 2015.

Figure 31 shows the potential for CSP with integrated molten salt energy storage to increase the renewable power penetration rate at mine sites, with S-class and M-class standing for different sized CSP plants. To achieve 100% penetration rate in an off-grid scenario, the mine would still require fuel-based backup generators.

**FIGURE 31: POWER SOLUTIONS FOR MINING COMPANIES OFFERED BY SOLAR RESERVE**



Source: Solar Reserve.<sup>195</sup>

## Pump Storage

While pump storage technology is not new, it is being revisited to address the intermittency issue of renewable power generation. For pump storage to work, two water reservoirs at different levels of height are needed that are connected by a pipeline. When power is being produced by intermittent sources, a generator pumps water to the higher reservoir. When there is no sun or wind, the water is released from the higher reservoir and energy is generated like in a normal hydropower dam. The US has more than 20 GW of pumped storage capacity,<sup>196</sup> making it the largest energy storage component in the country.<sup>197</sup> Currently discussions are ongoing whether the Hoover Dam in Nevada could become the largest “battery” in the world to help address instability resulting from increased renewable power integration in the grid.<sup>198</sup>

There is also research underway on how to integrate renewable energies into hydro-based grids to help address the vulnerability of electricity generation to changing hydrological conditions driven by climate change impacts.<sup>199</sup> This can present an opportunity for resource-rich countries boasting a hydro-based energy grid\* to which mines are connected to. There are several examples where mining companies have invested to expand hydropower capacity and transmission infrastructure when the cost of doing so is lower than the self-generation arrangement.<sup>201</sup> Where relevant and viable, mining companies could contribute to renewable power integration in such systems to reduce hydrological risks and guarantee their power demand.

Abandoned mine sites are also well suited for pump storage systems. Studies are ongoing to fill underground mines with water and pumping the water to reservoirs at the surface.<sup>202</sup> The most advanced pump storage energy project using two open pit mines comes from Australia (Box 31).

## Hydrogen

Hydrogen technology has the potential to substitute liquid fuels in mining machinery and to be used as energy storage. In combination with renewable power sources, the first step involves converting electricity into hydrogen through electrolysis. The hydrogen can then be used to supply trucks and power generation systems or be stored in tanks for later use. The advantage of hydrogen over battery-powered truck systems is that it does not require long loading cycles, existing fleets could be adapted more easily to dual hydrogen/diesel systems, and that hydrogen is better suited for large-scale and heavy trucks. In Chile, CORFO joined forces with a range of private sector actors in the mining sector to develop hydrogen-solar energy systems and to hybridize the mining truck fleet.<sup>203</sup> The Raglan mine provides an example of how hydrogen can be used for storage purposes (Box 32). Impala Platinum Holdings Limited has also invested in hydrogen and fuel cell technologies to power its operations in South Africa.<sup>204</sup>

### BOX 31: KIDSTON PUMPED STORAGE HYDRO PROJECT<sup>205</sup>

<b>Location:</b>	Far-North Queensland
<b>Nameplate capacity:</b>	250 MW, 2000 MWh
<b>Generation duration:</b>	8 hours
<b>Start-up time:</b>	<30seconds

The Kidston project is being proposed by Genex Power and consists of two phases. The first phase is a 50 MW solar farm, which has been completed and is feeding renewable power into the grid. The second phase foresees a 270 MW solar plant with a 250 MW pump-storage system – the first of its kind in Australia. The feasibility study has been successfully completed and Genex Power expects to secure off-take agreements and reach financial closure by the end of 2018. ARENA has provided a AUS\$ 4 million grant for the technical feasibility study and will also provide a grant to the second stage of the project, which is estimated to cost around AUS\$ 740 million.<sup>206</sup>

The pump-storage system will use two pits of an old gold mine that was one of the biggest in Australia for more than 100 years. Barrick closed the mine and placed it under care and maintenance in 2001. The two pits have filled up with water and a lot of the infrastructure of the mine is still in place including the transmission connection to the grid. Furthermore, the flat terrain of the tailings facility that had been rehabilitated is well suited for the solar installation and does not require clearing of land.<sup>207</sup> These site characteristics contributed to the success of the feasibility study.

#### NOTE

\* In Africa for instance the highest hydroelectric generating capacities installed are in: Ethiopia (2,552 MW), Democratic Republic of the Congo (2,495 MW), Zambia (2,272 MW), South Africa (2,251 MW, pumped storage 1,580 MW), Sudan (2,250 MW), Mozambique (2,187 MW), Nigeria (2,040 MW) and Ghana (1,584 MW).<sup>200</sup>

### BOX 32: GLENCORE'S RAGLAN MINE

<b>Location:</b>	Cape Smith Belt, Nunavik, Quebec
<b>Mine Ownership:</b>	Glencore
<b>Grid Status:</b>	On-grid
<b>Wind Project Size:</b>	3 MW
<b>Wind Project Commissioning:</b>	2014
<b>Wind Project Cost:</b>	C\$ 22 million
<b>Wind Project Developer:</b>	TUGLIQ
<b>Diesel Savings:</b>	2.4 million liters

**Background:** The Raglan mine is a large underground nickel-copper mining complex located in the Arctic region of Canada. It started production in 1997 and still has reserves for at least another quarter century.

**Energy project:** In 2014 Tugliq, a provider of turnkey energy solutions, partnered with Raglan Mine to install and operate a C\$ 22 million wind/hydrogen system. The project is groundbreaking as it is piloting storage technologies and an advanced controlling system under Arctic conditions. This off-grid region has been powered by diesel generation with industry paying between C\$ 0.25 and C\$ 0.60 / kWh. At the Raglan mine energy makes up 13-18% of the mine's operating costs.<sup>208</sup>

The project first installed a 3 MW wind turbine with a three-tiered storage system. Over the 20-year life of the wind turbine, the project aims to achieve savings of about C\$ 41 million in fuel and operation and maintenance as compared to the diesel only solution.<sup>209</sup>

The three-tiered storage architecture is composed of a fast-transient storage flywheel to filter out large wind power variations in short durations, a short-term lithium battery storage to start up diesel generators or fuel cells for transition back-up, and a hydrogen fuel cell storage to minimize the loss of wind energy over longer time periods and capture energy that would otherwise be wasted.<sup>210</sup>

This architecture minimizes the wear and tear of backup diesel generators and the diesel spinning reserves. It also captures the waste from wind curtailment occurring during excess wind conditions, when wind is greater than the load.<sup>211</sup> In the future, the hydrogen storage solution may enable the use of hydrogen for the truck fleet, saving additional diesel.<sup>212</sup>

A second 3 MW wind turbine is being installed with the ultimate objective to build a 9 MW-12 MW windfarm.<sup>213</sup> Its storage system will only be based on lithium battery. The aim is to reach 15-20% renewable energy penetration.

The project is a benefactor of grants from the Federal and Provincial government of Canada, including grants encouraging research and development efforts for renewable energies at mine sites.<sup>214</sup> It aims to transfer the knowledge from this research, to local communities and governments to ensure faster deployment of wind energy in the Arctic.<sup>215</sup>

#### 3.1.5. Modular solar

As highlighted in the roadblocks Section 2, one of the main bottlenecks to renewable power integration in mining is the limited time commitment that mining companies are prepared to sign up for in PPAs. Furthermore, powering the needs of the exploration phase requires a mobile power solution given that the phase is relatively short and there is no guarantee of finding a sufficient quantity of valuable mineral deposits to justify setting up expensive power

solutions.<sup>216</sup> In this context, the growing development of semi-portable, flexible solar and wind energy solutions are attractive for the mining sector. The length of the PPA can be shortened and the systems can be re-deployed if the PPA is not renewed. Modular renewable energies also display environmental benefits that make them cost-effective because "less resources are needed, less material must be transported to the remote sites, and when dismantling the systems, the impact is also minimized."<sup>217</sup> SunSHIFT has been leading the modular solar market (Box 33).\*

#### NOTE

\* One obstacle that remains as solar technologies continue to develop quickly is that companies may prefer to invest in new technologies rather than in a redeployed solar system that is older and less efficient.

### BOX 33: SUNSHIFT'S MODULAR SOLAR SOLUTION

SunSHIFT is a pre-fabricated, modular and mobile solar power generation technology designed to address off-grid mining challenges. The concept was originally conceived in 2013 by UK-based global engineering, procurement and construction firm Laing O'Rourke. The concept was presented to the Australian Renewable Energy Agency (ARENA) in March 2014, which provided an AUS\$ 410,000 grant to fund the initial feasibility study of a hybrid solar-diesel plant.<sup>218</sup> Additional funding was provided by ARENA throughout piloting and testing stages.<sup>219</sup>

After a successful pilot, ARENA committed AUS\$ 2.1 million, backing a test deployment of a 1 MW block of SunSHIFT in the Hunter region of New South Wales in April 2017. To develop the modular hybrid solutions several partners worked together, including US-based photovoltaic manufacturer SunPower Corp., the Swedish-Swiss industrial technology company ABB, and Laing O'Rourke subsidiary Select Plant, which manages more than 200 diesel generators across Australia.

**Mining integration:** SunSHIFT is working with New Century Resources to deploy a 120 kW solar project for the company's open pit Century mine and processing site in Northwest Queensland. The power price agreement has been kept under AUS\$ 120/MWh with a flexible PPA.<sup>220</sup> This cost represents a significant cost saving in comparison with around AUS\$ 400/MWh the mine pays for diesel generated power.<sup>221</sup>

In partnership with South32, SunSHIFT is planning to develop a 3 MW installation at the Cannington zinc, lead and silver mine in Queensland. Excess power from the solar project, which will primarily provide energy to the village and airport, will supply mine processing and operations.<sup>222</sup> The installation at Cannington marks the first off-grid mining solar power project to be integrated with a gas-fired power station and will be the largest re-deployable solar project in the world. It will abate 4,000 to 6,000 tonnes of greenhouse gas emissions per year.<sup>223</sup>

#### Benefits:

1. SunSHIFT has reduced the 'stranded' asset risk associated with permanent solar installations by owning the panels and being able to relocate them in case that a mining operation ceases to operate.
2. By being able to redeploy the solar panels, SunSHIFT can reduce the PPA duration, making solar competitive with diesel generators for mining operations that cannot or do not want to commit to longer PPAs. PPAs have a minimum four-year tenure to help secure project financing, but contracts contain a termination clause allowing miners to end the PPA in special circumstances (for example if reserves are exhausted).<sup>224</sup>
3. SunSHIFT's pre-fabricated and electrically pre-engineered panels offer significant reductions in development time and costs. Particularly in high labor cost environments like Australia this offers a lower cost and more efficient system compared to permanent installations.
4. Offered in 2 kW modules that build into 1 MW blocks, SunSHIFT solutions can be easily integrated with diesel generators and energy storage. This provides mining companies flexibility and incremental renewable power integration options.<sup>225</sup>

#### 3.1.6. Blockchain

Blockchain technology helps track information by providing transactions with a unique code that is traceable. This has the potential to increase transparency and make trading easier and more secure. Within the energy sector, blockchain allows users to track who produces and who consumes electricity, provided that smart meters are used, the so-called "oracles". This may be particularly helpful in accelerating decentralized energy systems, as it will make it easier to track payments to producers and from consumers or administer digital assets.

While this technology has limited benefits in the off-grid self-generation model, it could play a role in proliferating on-grid virtual

PPAs, as it will be easier and more transparent to track sources and payments. In the case where energy is also sold to nearby communities through a micro-grid, community members with small scale generation and storage components (for example electric vehicles) could potentially also sell energy back to the mining project during low consumption times, thus creating new markets and allowing for new ways of electricity supply.

Another potential use of blockchain related to mining companies is its application to trace 'green' minerals (see Section 3.1.6).

As the blockchain technology matures, more research is needed to understand the potential of blockchain for the issues at stake in this report.

## 3.2. EXPERTISE

### 3.2.1 Private sector

An increasing number of mining companies are integrating renewable energies in their mining operations and are gaining experience and expertise. IPPs are also improving their knowledge on the mining sector specificities that they need to consider when offering renewable power solutions. These experiences, particularly as they start generating commercial benefits to the mining companies, will further drive renewable integration at mine sites and will play a key role in increasing renewable penetration rates.

### 3.2.2. Governments and NGOs

Government agencies and non-profit organizations are working towards increasing investor and mining company confidence in renewable energies. These organizations share experiences across companies and provide financial contributions for R&D and pilot projects. On the government side particularly ARENA in Australia has pushed renewable power integration in the mining sector (Box 34).

The Rocky Mountain Institute (RMI) has been supporting renewable integration at mine sites through its Sunshine for Mines program. It is responsible for supporting and publishing the findings of one of the earlier renewable integration projects at Cronimet's Thabazimbi mine (Box 27). RMI continues to develop tools and information to support the adoption of renewables by the mining industry, working directly with mining companies and IPPs, assisting with renewables screening studies, optimizing feasibility studies and market engagement.<sup>226</sup>

#### BOX 34: ARENA

ARENA was established by the Australian federal government in July 2012 with the goal of supporting commercialization of innovative renewable energy solutions and increasing their competitive position and deployment throughout the country. ARENA seeks to support projects that require a mix of financing from commercial and non-commercial sources.<sup>227</sup> The agency aims to help overcome barriers from early stage development to commercial deployment. Through support of research, development and pilot projects, ARENA provides assistance that helps de-risk emerging and innovative technologies.<sup>228</sup> To achieve these objectives, the agency provides:

- Financing, in the form of grants, to innovative and trial-stage projects, technologies and early-stage companies that have challenges accessing capital.
- Research and development support.
- Knowledge and information sharing on technologies and best practices.
- Advice to the government and raising public awareness of renewables.

The agency was initially allocated AUS\$ 2.5 billion through 2022. It also inherited around AUS\$ 1 billion when it assumed responsibility for the Australian Centre for Renewable Energy. Despite its exposure to changing political regimes,<sup>229</sup> ARENA has overseen 320 projects with more than AUS\$ 3.5 billion in investment over the past six years.<sup>230</sup>

ARENA's support for renewable energy projects powering mines include:

- Providing AUS\$ 11.3 million in funding for First Solar's 6.7 MW PV installation at Rio Tinto's Weipa bauxite mine in Queensland in 2014.<sup>231, 232</sup>
- Providing an AUS\$ 2.1 million recoupable grant in 2017 to showcase a 1 MW installation of technology from SunSHIFT, the company that is pioneering eponymous portable solar modules (see SunSHIFT case study).
- Providing AUS\$ 20.9 million in recoupable grants to a 10.6 MW solar project and 6 MW of energy storage at Sandfire Resources' DeGrussa copper mine (see DeGrussa Case Study).<sup>233, 234</sup>
- Creating a guide, set for publication in 2018, that explores best practices for developing renewable projects at mine sites, from site assessment and data collection to negotiating the power purchase agreement and achieving financial closure.

### 3.2.3. Donors

Donors too have accumulated experience helping governments to design enabling policies and procure renewable energies. Figure 32 highlights some of the mechanisms that donors can help put in place to further unlock renewable energies.<sup>235</sup>

Donor projects to support renewable energy projects are plentiful. GIZ, for example, has been a long-time partner of the Chilean Government to support their renewable energy policies with the German Development Bank (KfW) financing projects that today supply mining projects (see Box 37). Furthermore, GIZ has been

supporting rural electrification projects in developing countries that aim to leverage anchor consumers to electrify surrounding businesses and communities (see Box 35).

Another example, is the Scaling Solar project by the World Bank Group (Box 36), which has been setup to support governments in de-risking procurement programs for solar IPPs. It has been successful in attracting top developers at competitive prices in jurisdictions that are considered risky. Apart from supporting legal reform that will spur renewable investments, cross-learning from these programs can also help mining companies to de-risk renewable energy projects.

**FIGURE 32: POLICIES, TOOLS AND INSTRUMENTS THAT REDUCE BARRIERS AND MITIGATE RISKS**



Source: IRENA.<sup>236</sup>

### BOX 35: THE A-B-C MODEL<sup>237</sup>

The A(nchor)-B(usiness)-C(ommunity) model foresees that a large, reliable and credit-worthy customer guarantees the electricity purchase to make a power project viable for an IPP. These can include projects in the mining, tourism, agriculture and telecommunications sectors. For example, there are an estimated 150,000 mobile towers in Africa which are often located in off-grid areas that require power access. Through this anchor customer it becomes viable for the IPP to build the power plant at a larger capacity and also supply surrounding businesses and communities thereby improving productivity and local development. The IPP benefits from opening up new market segments and reducing the risk through a sector anchor load. The anchor customer benefits from lower energy costs and the potential to support their social license to operate in the region. GIZ has piloted projects of this nature in Eastern Africa and has helped structuring financial partnerships. The German Investment Corporation (DEG) can support such projects through financing particularly if they use renewable energy sources.

## BOX 36: SCALING SOLAR

Scaling Solar is a program developed in 2015 by the World Bank Group and managed by the International Finance Corporation (IFC). The primary objective of the program is to create utility-scale and bankable solar projects in emerging markets, particularly in Africa.

Despite the many opportunities that exist in emerging markets for the development of solar energy projects – estimates at 1.2 GW only in the countries of Zambia, Senegal, Ethiopia and Madagascar - the Scaling Solar Initiative (SSI) has identified a series of challenges that need to be overcome in order to successfully harness renewable energy opportunities in developing economies. Among the most prominent challenges identified by the program include (1) the limited institutional capacity to manage a renewable energy concession; (2) lack of financing for large-scale projects; (3) lack of competition in the energy market; (4) high transaction costs; and (5) perception of high-risk.<sup>238</sup>

To overcome these challenges, the Scaling Solar Initiative is a “one-stop shop” where governments can get advice on negotiations with renewable companies; help with managing tendering processes to ensure active and broad participation that guarantee the best possible outcome; and, which serves as an intermediary to de-risk projects.<sup>239</sup>

The program is designed to be operational within two years after a country asks for assistance and is granted support. For this purpose, the process is divided into three phases with five critical steps. During the first phase (eight months), the IFC will support the host government manage the procurement process, including the technical and legal preparations as well as with the feasibility studies; work on preparing and launching the bid; and help assign the winner. During the second phase (six months), the program will support the winning bidder and government with the financial management of the project, such as helping with the finalization of the contract, insurance issues and transferring the loan. During the final phase (10 months), the winning bidder is in charge of carrying out the construction and operations of the solar plant.<sup>240</sup>

One of the most positive experiences of the program has been in Zambia, which was the first country where a Scaling Solar project was executed. Following the energy crisis in 2015, the program attracted 48 companies. Of these, 11 companies pre-qualified to develop the initial 2x50 MW utility-scale solar photovoltaic project under the first round of the total 600 MW target.<sup>241</sup>

Neoen/First Solar was the winning bidder. To develop the US\$ 40 million project, three senior loans were agreed to by the IFC, IFC-Canada and the Overseas Private Investment Corporation.<sup>242</sup> Thanks to this partnership, it was possible to build a 47.5 MW facility that will provide stable, clean energy at a fixed price for the next 25 years of US\$ 0.015/kWh, the lowest price registered in sub-Saharan Africa at the time.<sup>243</sup> Furthermore, due to the success of this project, a second bidding process was launched in Zambia for an additional 180 MW plant.

Since the first plant in Zambia had a completion date in September 2018, the impact of the project is still to be seen and has also been a subject of scrutiny. Various investors have noted that the low selling price of the energy can be a significant disincentive for future investments in other projects.

## 3.3. FINANCING

### 3.3.1. Corporate PPAs

Financing for renewable IPPs is still the largest constraint – particularly in developing countries where the regulatory regime is not yet adapted to renewables and where perceived risks are higher.<sup>244</sup> However, there are positive trends when looking at corporate PPA developments. The banking sector is learning to put together financing solutions to support renewable PPAs. A wide range of PPA forms have been developed to accommodate different project specificities and risks. This has led to the growth in the volume of corporate PPAs in recent years (Figure 33).

Furthermore, “matching platforms” have been developed to make it easier for renewable power sellers to find buyers (Table 5). These platforms could also drive the standardization of PPAs and therefore the speed of transactions.<sup>245</sup>

### 3.3.2. Insurance

Insurance products have sprung up to help protect corporate purchasers against unforeseen events. Over 80 risks have been identified that insurance companies have developed to support renewable energy projects.<sup>246</sup>

Access to capital is perceived as the highest risk in renewable projects and insurances are the most common tool used to transfer this risk to third parties.<sup>247</sup> For example, the 105 MW wind farm at Maevara, Sweden was covered by Allianz, which provided the loans for the construction of the wind farm by OX2 and took ownership of the project upon completion. A 10-year PPA was signed between Allianz and Google, which was the corporate off-taker (see Box 24).<sup>248</sup>

Munich Re has developed insurance products for the second highest risk associated with renewable energy projects, namely for protection against technical failure for on-land renewable energy projects, as well as specific insurances on solar operational performance and energy efficiency. These

FIGURE 33: CORPORATE PPAS

Source: Bloomberg NEF.<sup>249</sup>

TABLE 5: MATCHING PLATFORMS

	On-grid projects
RE-Source platform	Launched in 2017 by SolarPower Europe, WindEurope, RE100 and WBCSD, the RE-Source Platform is a European alliance of stakeholders representing clean energy buyers and suppliers for corporate renewable energy sourcing. This platform pools resources and coordinates activities to promote a better framework for corporate renewable energy sourcing at EU and national level.
Renewable Energy Buyers Alliance (REBA)	Run by the World Wildlife Fund, the World Resources Institute, the Rocky Mountain Institute and Business for Social Responsibility, that works across customers, suppliers, and policymakers to identify barriers to buying clean and renewable energy and then develop solutions that meet rapidly growing voluntary demand.
Energy Web Foundation	Founded by the Rocky Mountain Institute and Grid Singularity, this group is not directly focused on corporate PPAs but represents the way in which blockchain technology can create innovations in energy trading that will support new models to bring generators and users together.
Green Electricity Consumption Cooperative Organization (GECCO)	Launched in June 2017, this collaboration between developers and corporate buyers in China provides an exchange platform to facilitate the trading of new Green Electricity Certificates (GECs) and to encourage investment in new renewable energy projects.
New Energy Opportunities (NEO) Network	Created by Schneider Electric, this collaborative online platform connects corporate buyers to viable projects, developers and technology providers, as well as affiliates such as investors and law firms.
Powerbloks	Edison Energy offers its corporate customers Powerbloks, a shorter term (10-year) PPA executed in 10 MW increments, as an alternative. They are intended to provide accessibility to medium to large corporates with smaller load requirements.
PowerX	This is an aggregator in South Africa that buys renewable energy from independent power producers and sells it directly to corporate buyers. It acts as a conduit between buyer and seller, assuming and actively managing the risks that they cannot assume or mitigate themselves and thus facilitating corporate PPA arrangements that might not otherwise be viable.

Source: WBCSD.<sup>250</sup>

products provide 5 years compensation in case of underperformance or shortfalls, technology breakdown and failures, and third-party liabilities.<sup>251</sup> FM Global Insurance has specialized in mitigating negative externalities, which is perceived as the third highest risk associated with renewable energy projects.<sup>252</sup>

### 3.3.3. Development Finance Institutions

DFIs can play a role in de-risking renewable energy financing by offering “longer tenors, affordable debt, government access, different risk profiles and increasingly flexible financing structures including mezzanine-type

debt.”<sup>253</sup> This makes them key actors in supporting renewable power roll out, particularly in developing countries where the perceived risk is higher. For on-grid renewable projects, DFIs have financed several large-scale power plants linked to mining projects. For example, in Northern Chile where the mining industry is the largest energy off-taker accounting for 33% of total energy consumption,<sup>254</sup> DFIs have financed several projects: The 100 MW Amanecer Solar CAP Power Plant was co-financed by the IFC (Box 37). The Inter-American Development Bank, German KfW Development Bank and European Union helped finance the 110 MW Cerro Dominador concentrated solar power plant (CSP) that is owned by Antofagasta Minerals (Box 30).

#### BOX 37: AMANECEER SOLAR CAP

<b>Location:</b>	Comuna de Copiapó, Atacama, Chile
<b>Mining Company:</b>	Grupo CAP S.A.
<b>Solar Project Developer:</b>	SunEdison Chile*
<b>Main sources of funding:</b>	In 2013 SunEdison secured US\$ 212.5 million non-recourse debt financing agreement with the IFC and the Overseas Private Investment Corporation (OPIC). The Dutch bank Rabobank was also involved.
<b>Grid Status:</b>	On-grid
<b>Solar Project Capacity:</b>	94 MW (supplying 15% of the group’s energy demand)
<b>Solar Project Generation:</b>	270 GWh per year
<b>Solar Project Operation:</b>	2014 (completion date)
<b>Solar Project Cost:</b>	US\$ 241 million
<b>Solar Project lifespan:</b>	25 years
<b>Diesel Savings:</b>	71 million liters of diesel annually
<b>Carbon Savings:</b>	135,000 tonnes of CO <sub>2</sub> annually

**Background:** Compañía de Acero del Pacifico (CAP) S.A. is the largest steel mining group of Chile. It is comprised of three main subsidiaries: CAP Minería (mineral mining), CAP Acero, and Novacero (steel production); through which they produce 99% of the steel that is exported and supply 97% of the local demand.<sup>256</sup> Furthermore, they are also one of the largest holders of port infrastructure in the country with a total six of ports distributed along the coast of Chile.<sup>257</sup>

**Solar Project:** CAP’s energy demand is 1,800 GW/h per year.<sup>258</sup> Based on this and given that its original power purchase agreements in the region of Atacama was set to expire in 2015, the company started in 2012 looking for new sources of energy to supply their operations. CAP hired the services of ASSET Chile to locate new sources of energy within the central region grid (SIC) - characterized by a lack of overall energy projects and limited transmission infrastructure. With the support of ASSET, CAP established a partnership with Guacolda thermoelectric energy plant located in the Huasco Province, as well as with SunEdison, to build a 100 MW photovoltaic power plant. These two projects would guarantee 218 MW of power supply at a stable price. A 9 km transition line was constructed to connect the 220 kV Cardones-Cerro Negro Norte grid to the SIC main transmission grid.<sup>259</sup>

Through the partnership with SunEdison Chile, which was secured through a 20-year PPA to build and operate the plant, the project was able to access a financing agreement of US\$ 212.5 million with the IFC and the Overseas Private Investment Corporation (OPIC),<sup>260</sup> providing US\$ 65 million and US\$ 147.5 million respectively. The support of OPIC and IFC was instrumental since it provided security to the investors in the projects; and the low-interest rates of the loans allowed the price of energy to be competitive.<sup>261</sup>

The plant will help cover 90% of the energy need of CAP’s Cerro Negro Norte mine - a US\$ 1.2 billion project that will increase iron production by 4 million tonnes. Additionally, the production will be managed with 100% ocean water through an on-site desalination plant.<sup>262</sup>

In words of the IFC Vice President for Sub-Saharan Africa, Latin America and the Caribbean, “This project proves that with the right sponsors, domestic environment and financiers, debt financing has become a viable option for merchant solar plants. The IFC’s support is a continuation of our strategy to promote commercially competitive renewable solutions in Chile and the wider region.”<sup>263</sup>

#### NOTE

\* While the American company SunEdison has filed bankruptcy in the US and has sold many of the Chilean assets to the electricity company, Colbun, it is for now still operating this project. There is however an arbitration going on between CAP and SunEdison following an accusation by CAP that the panels are of low quality.<sup>255</sup>

As a result of public and private investors becoming more familiar with renewable projects and the increasing number of risk-mitigation mechanisms available, the cost of capital for renewable projects has been decreasing for on-grid mines: Equity rates are now in the range of 5-10% where they used to be in the range of 10-15%.<sup>264</sup> According to ARENA, the same evolution is happening for off-grid mines but at a slower rate.<sup>265</sup>

This development could further attract institutional investors such as pension funds, sovereign wealth funds, international private asset managers to the field of renewable energies. While their contribution to the total investment in renewables is limited (less than 1% as of 2016)\* there is an expectation that this contribution will grow as an increasing number of them divest from fossil fuels freeing up long term capital.<sup>267</sup> BNP Paribas, for example, announces that it will no longer do business with companies whose principal business activity is related to fossil fuels and will increase its total financing for renewable energy projects to € 15 billion by 2020.<sup>268</sup>

### 3.4. REGULATORY

#### 3.4.1. Renewable energy policies

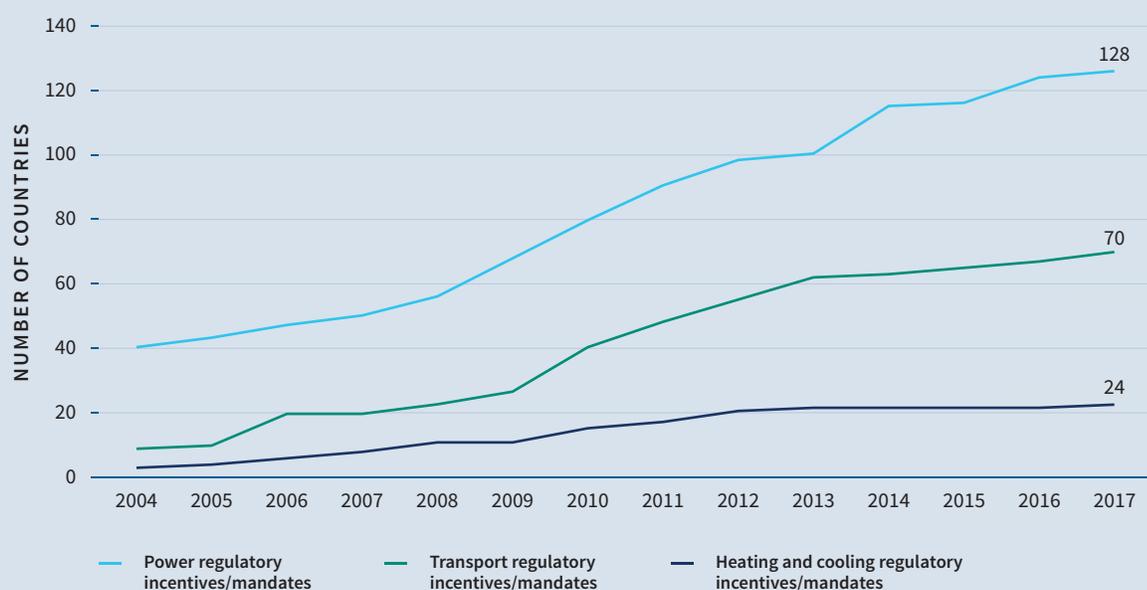
Figure 34 highlights that governments around the world are increasingly putting regulations in place to support renewable energy roll-out. While in 2007 only 50 countries had renewable power regulations and incentives in place, this has increased to 128 countries in 2017. Furthermore, more than 150 countries had renewable power-related targets in place at the national level.<sup>269</sup>

Apart from targets and regulations, Governments have also put in place financial and fiscal incentives that make renewables more attractive. Figure 35 shows investment credits, tax exemptions and public investments have been used by an increasing number of countries.

#### 3.4.2. Carbon pricing initiatives

In the last 10 years, the number of jurisdictions that have put in place carbon pricing initiatives has increased rapidly reaching 40 national and 25 sub-national jurisdictions in 2017. Consequently, the quantity of emissions covered by carbon pricing has increased fourfold over the past decade.<sup>270</sup> Such initiatives will internalize the negative emission externalities of fossil fuels and further strengthen the economic case for renewables.

**FIGURE 34: NUMBER OF COUNTRIES WITH RENEWABLE ENERGY REGULATORY POLICIES**

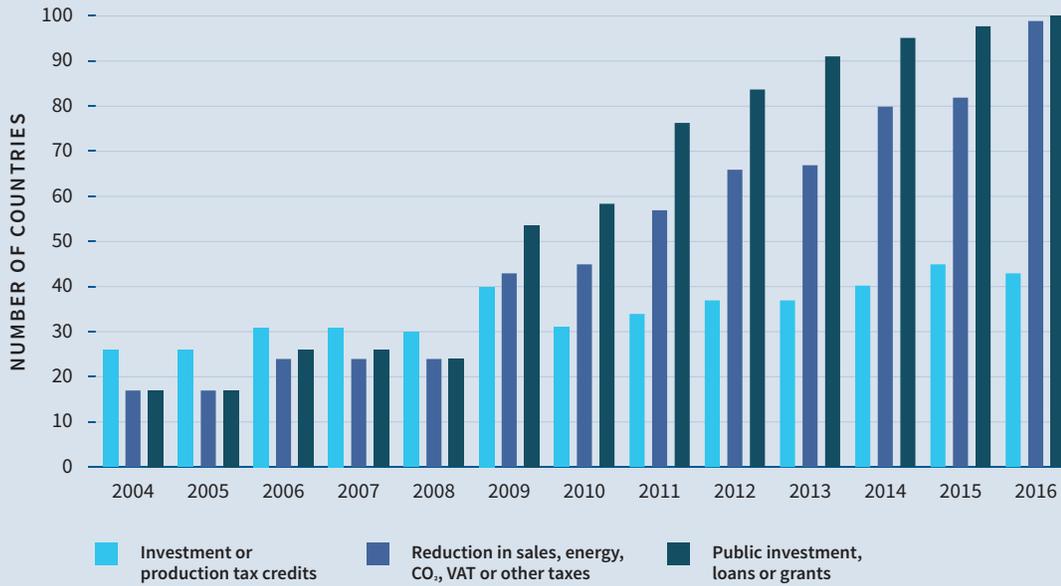


Source: REN21.<sup>271</sup>

#### NOTE

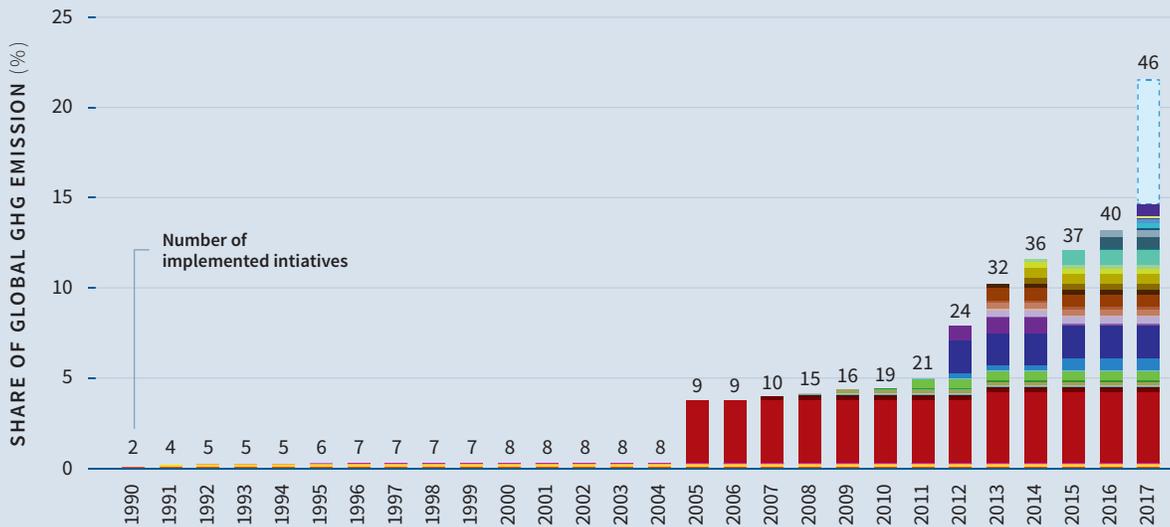
\* See Annex 1 for the IRENA's global landscape for renewable energy finance in 2015-2016.<sup>266</sup>

**FIGURE 35: TRENDS IN THE ADOPTION OF FINANCIAL AND FISCAL INCENTIVES**



Source: IRENA 2018.<sup>272</sup>

**FIGURE 36: NUMBER AND SHARE OF EMISSIONS COVERED BY CARBON PRICING INITIATIVES**



Source: World Bank.<sup>273</sup>

### 3.5. INTERESTS

#### 3.5.1. Shareholders

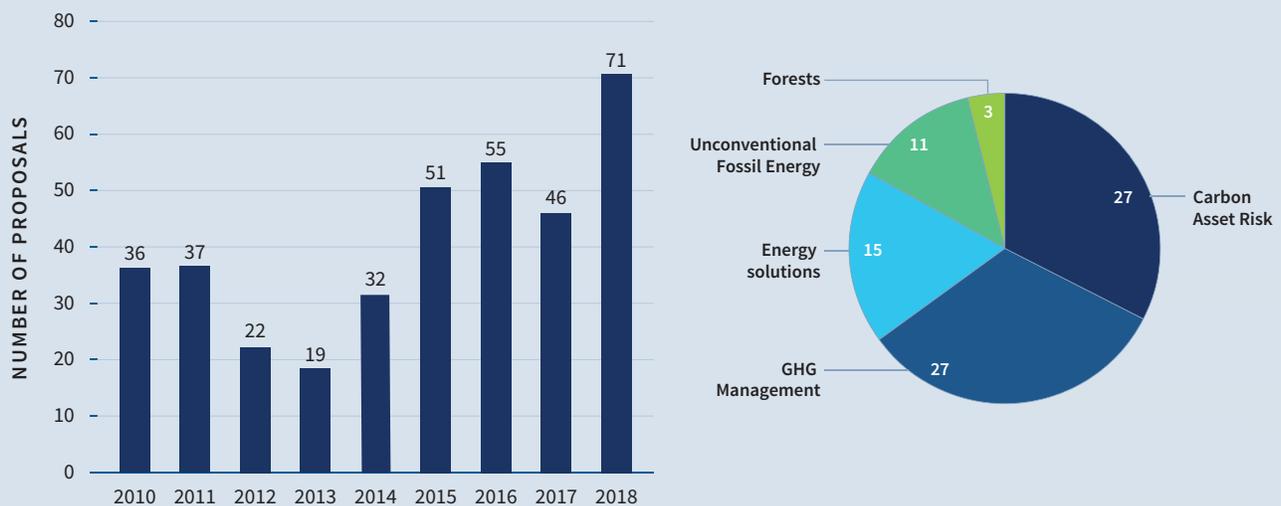
Shareholders and institutional investors are increasingly concerned about the climate change risks in their portfolio. In the US, climate change topped the list of shareholder resolutions again in 2018 making up 20% of the environmental, social and sustainability resolutions. Among them, 15 resolutions were aimed at increasing renewable energy integration and setting energy efficiency targets (see Figure 37). Similar trends can be observed in other countries where mining companies are listed. In the UK, the “Aiming for A” coalition proposed climate change resolutions at the annual meetings of Anglo American, Rio Tinto and Glencore, which all passed with more than 96% of the votes.<sup>274</sup> In Australia too there is increased interest by investors in climate related issues.<sup>275</sup>

The formation and recommendations of the Financial Stability Board’s Task Force on Climate-related Financial Disclosures (TCFD) and the efforts of the Sustainability Accounting Standards Board (SASB) have put climate-related disclosures by public companies under the spotlight.

In partnership with the Climate Disclosure Standards Board, TCFD launched a Knowledge Hub - a peer-to-peer “platform with relevant insights, tools, and resources to help organizations implement the TCFD recommendations.” Several mining companies, including Barrick Gold, BHP, Glencore, and Vale are signatories to the recommendations.<sup>276</sup> Compared to other heavy industry sectors, such as cement, steel, and chemicals—most of the emissions of the mining industry are driven by electricity supply. Integrating renewables is an opportunity to meaningfully address shareholders’ requests.<sup>277</sup> Setting long-term carbon intensity and overall greenhouse gas emission targets as well as integrating low carbon technologies are questions explicitly stated in the “Investor expectations of mining companies” guideline drafted by institutional investors concerned about climate change.<sup>278</sup>

To help investors understand what company targets are compliant with the Paris Agreement, the Science Based Targets initiative<sup>279</sup> has been launched. It encourages businesses to set ambitious emission reduction targets that would keep global temperature increase below 2 degrees. On the date of writing 498 companies were taking part in the initiative with 151 having their science-based targets approved. In the mining and metals sector only Hindustan Zinc Limited and Mahindra Sanyo Special Steel have had their targets approved.<sup>280</sup>

FIGURE 37: CLIMATE CHANGE RESOLUTIONS IN THE USA



Source: ProxyPreview (2018).<sup>281</sup>

### 3.5.2. Consumers and future recruits

Consumers are increasingly putting pressure on suppliers to guarantee a responsible value chain. Such requests are also increasingly affecting the mining sector. The most notable recent example comes from the cobalt value chain, which has been straddled with child labor and human rights violations in the Democratic Republic of Congo. There is also increasing interest and reporting of carbon emissions in the value chain (scope 2 emissions, which capture the indirect emissions from the generation of purchased energy, and scope 3 emissions, which capture all other upstream and downstream emissions) and companies are putting pressure on suppliers to reduce emissions. Apple, for example, is helping suppliers to switch to renewable energy and has 23 suppliers that have committed to 100% renewable energy sourcing for Apple supplies.<sup>282</sup> Apple is also partnering with Rio Tinto and Alcoa to develop carbon free aluminum.<sup>283</sup> In the car industry BMW has set a goal for its supply chain to reduce its resource consumption per vehicle produced by 45% by 2020.<sup>284</sup>

Being one of the biggest emitters in the value chain of these consumer products, the mining sector is going to be affected by these trends. Particularly in the car manufacturing sector, where about two thirds of the total carbon content of the car during its lifecycle will shift from use-of-car with an internal combustion engine, to the production of a car with an electric engine. Foreseeing this trend, Codelco and BMW have announced the Responsible Copper Initiative, whose objective is to achieve a higher ecological and social standard in the copper industry<sup>285</sup> – similar to the standard established in the aluminum sector (see Box 38).

Another driver for increased demand of low carbon minerals is the public procurement sector. The European parliament approved a revision to the public procurement directive in 2014.<sup>286</sup> It foresees the integration of life-cycle costs like energy use and greenhouse gas emissions. This means that despite higher up-front capital costs, ‘greener’ construction inputs and public transport solutions could enjoy a competitive advantage. A number of OECD countries have followed this approach and adopted similar initiatives. With public procurement making up around 12% of GDP in OECD countries<sup>287</sup> this development could create a significant market for low-emission minerals to feed into the construction and transport sector.

The integration of renewables in mining projects will be a primary driver to reduce carbon emissions in the supply chain. It is yet to be seen whether such distinguishable products can attain a price premium, but the public procurement developments of OECD countries and recent experience from the aluminum sector (see Box 38) suggest that consumers are willing to pay more for social and environmental issues they care about.

Apart from consumers, younger recruits may also be attracted by mining companies that are future oriented. This is the view of a vice-president from ABB: “Mining needs a revolution to avoid retention or employment issues. Working with stone-age technologies is not sexy for technicians or engineers coming out of school.”<sup>288</sup> Furthermore, younger generations are more aware of and concerned about the consequences of climate change. To continue to attract top talent, mining companies should take this trend into account.

#### BOX 38: PRICE PREMIUM FOR “GREEN” ALUMINUM<sup>289</sup>

Converting bauxite into aluminum is a very energy intensive process. Smelters sourcing electricity from hydropower are promoting their environmental footprint with emissions that are six times lower than the aluminum produced using coal-fired power. Rio Tinto and Alcoa are selling ‘RenewAl’ and ‘Ecoloum’ aluminum which guarantee a maximum of 4 and 2.5 tonnes of CO<sub>2</sub> respectively in its production process. This is far below the industry average of 11 tonnes. Apart from also offering a low-carbon aluminum product, Hydro\* has also launched a product with a guaranteed post-consumer recycled content of minimum 75 percent.<sup>290</sup> The companies are marketing these products at a price premium for their clients.

#### NOTE

\* Hydro has also committed itself to have a neutral carbon footprint by 2020.

### 3.5.3. Affected communities

The social license to operate has been increasingly at risk in many mining-rich jurisdictions during and after the commodities boom in the 2000's. Particularly in Latin American countries that have a long mining history, there have been numerous conflicts around mining projects that have halted projects and have had significant costs to the sector.<sup>291</sup> This can be traced back to a number of issues including more and larger mining projects due to higher demand and falling ore grades, increased competition for water resources, more awareness of environmental externalities, and social media empowering communities that are opposed to mining. Compounding this trend is the growing automation aspirations of the sector, which will lead to a fall in local employment and procurement, thereby intensifying the questions by affected communities on what they are set to gain from mining projects in their local area.<sup>292</sup>

To re-balance the 'shared-value' proposition of mining projects and help address community expectations, renewable power integration can help in two ways. First, renewable power plants are less polluting than fossil-fuel based power plants and therefore reduce the negative externalities on those living around the mine site. Apart from reduced air and noise pollution from the power plant itself, adverse impacts from fuel trucking such as increased road traffic and accidents can be reduced. Secondly, the arrangement whereby an off-grid mine electrifies surrounding communities through a local mini-grid powered by a renewable project (Sale arrangement 3 in Section 1.4.3) would significantly contribute to the development of the region.

In fact, decentralized renewable energy systems have been shown to be a cost-effective solution to tackle energy poverty in rural areas. In some remote rural areas of Africa, it has been estimated that the average energy cost can amount as much as US\$ 6/kWh. With solar/battery mini-grid systems this could be reduced to US\$ 1.30/kWh.<sup>293</sup> In Nigeria, which has subsidized diesel, the LCOE of solar PV is significantly lower than for decentralized diesel generators. In the Democratic Republic of Congo, it was assessed that between 45-85% of the population would be better served by renewable-energy based mini-grids than building out the central grid.<sup>294</sup> And in Myanmar the energy costs of households that are grid connected are almost double as those that are connected to solar mini-grid pilot projects (US\$ 819 vs. US\$ 357 per household).

### 3.5.4. Standards and certification schemes

As an answer to growing stakeholders' pressure, the mining sector has seen an increasing number of standards over the last years that foresee mining companies doing more in order to address climate change. The members of the International Council of Mining and Metals (ICMM), for example, have committed themselves to being part of the solution to address climate change.<sup>295</sup> To be part of ICMM, mining companies need to comply with its 10 sustainability principles – one of which is on environmental performance (principle 6).<sup>296</sup> This principle could be strengthened by explicitly highlighting the role of renewable power integration to manage emissions. The Towards Sustainable Mining Initiative (TSM) of the Mining Association of Canada has done so, by developing the Energy Use and Greenhouse Gas Emissions Management Protocol, which aims to provide guidance to its members about how to evaluate their energy use and greenhouse gas emissions management against TSM indicators. Three performance indicators are included, namely management systems, reporting systems and performance targets, and it states that the purchase of or investment in renewable energy is core to the achievement of the targets.

Certification schemes are also increasingly playing a role. For example, the Aluminum Stewardship Initiative (ASI) seeks to "enable the aluminum industry [at all stages from bauxite mining to semi-fabrication and refining] to demonstrate responsibility and provide independent and credible assurance of performance" and by doing so it helps the industry "reinforce and promote consumer and stakeholder confidence in aluminum products." The ASI launched its standards in 2017. ASI's standard number 5 promotes the reduction of CO<sub>2</sub> emissions and the purchase of renewable energy in the smelter management system to achieve this. Similarly, the Initiative for Responsible Mining Assurance (IRMA) – a multi-stakeholder member initiative that seeks to certify individual mine sites based on whether they achieve high social and environmental standards, has included a chapter on greenhouse gas emissions. In order to receive the certification, the operating company will require to have a greenhouse gas policy in place with corporate and mine specific targets and plans for implementation, quantify emissions according to set standards, and publicly disclose mine and corporate emission results. The standard is also considering requiring the inclusion of science-based targets as part of the requirement when it starts certifying mines in 2019.<sup>297</sup> Complying with more ambitious GHG reduction targets will require mining companies to adopt renewable energies more widely.



Wind farm in the Atacama desert, Chile. © shutterstock.

## PART 4

### CONCLUSION AND RECOMMENDATIONS

The momentum and long-term trends all point towards renewable energies playing a bigger role in the mining sector going forward. There are many different sourcing arrangements through which mining companies can increase renewables in their energy mix. While technical and commercial bottlenecks still exist, these are actively being addressed.

Technological progress is rapid with prices for renewable energy and storage solutions falling making them more competitive than traditional energy sources. Financing and insurance products are being adapted to meet the specificities of the mining sector. Furthermore, increasing experience by mining companies, IPPs, financiers, governments and donors should help the sector taking on a more ambitious approach to renewable power integration in mining operations with higher penetration rates.

The question then becomes about the speed at which mining-rich jurisdictions and mining companies will embrace renewable energy technologies. The Agenda 2030 and the Paris Agreement have created momentum to increase the speed of the energy transition from a fossil fuel based world economy to a renewable based one. While the adverse impacts of climate change intensify and climate adaptation expenses rise, the prices for renewable technologies continue to fall; this momentum is likely to grow with pressure from various stakeholders increasing. This development presents an opportunity for forward looking mining companies to build up expertise in renewable power integration and develop a competitive advantage to source ESG financing and sell premium low-carbon minerals.

As renewable power integration in the mining sector advances there is the opportunity to leverage investments to increase electrification in rural off-grid scenarios. Lack of access to electricity is one, if not the biggest barrier to rural economic development. Governments, mining companies and donor agencies all have an interest in developing financing, operating and commercial mechanisms that can make such arrangement viable. For mining companies this arrangement can help to rebalance the shared-value paradigm and provide community benefits post-closure.

Apart from powering mining projects, there is also great potential for mining land to be used for renewable energy projects to install themselves post-closure. Access to land is one of the biggest obstacles to renewable projects. When rehabilitated mines are located close to the grid and have existing infrastructure in place, this can lower project costs. Furthermore, mining pits can potentially play an important role in addressing intermittency and variability issues when energy grids are increasingly fed by wind and solar energy sources by providing pump storage solutions.

To increase the speed of renewable power integration in mining the following recommendations are proposed by stakeholder:

#### 4.1. GOVERNMENTS

**Allow for IPPs to enter the energy market:** Traditional vertically integrated utilities are not best placed to develop and offer disruptive renewable energy solutions. Energy reforms should seek to allow IPPs to enter the market and sign corporate PPAs with private entities such as mines. To further support renewables, countries could seek to develop IPP regulations and setup an independent regulatory mechanism that can regulate tariffs and access charges to transmission networks at non-discriminatory prices. Where feasible, unbundling the generation, transmission and distribution components would further help IPPs enter the market.

**Offer green corporate procurement programs:** Apart from allowing IPPs enter the renewable market, utilities could consider developing green products and green tariff options that reflect the source of energy.

**Require renewable power sourcing feasibility studies:** Resource rich countries could require greenfield mining projects to include renewable sourcing options as part of their feasibility studies. The integration of renewables could also be a factor to include in competitive bidding processes for awarding mining leases.

**Negotiate contractual requirements for electrification:** The government could consider leveraging renewable power investments in off-grid mining areas to also serve surrounding communities. Donors, mining companies and IPPs can support the government with developing mechanisms that outline who is responsible for operations, maintenance, payments for electricity, and succession plans post-mine closure. Such arrangements could be supported through tax incentives, preferential loans and/or capital grants.

**Design closure regulations that allow for the continuation of renewable energy projects post-mine closure:** Post-mine closure requirements often stipulate the dismantlement of all infrastructure related to the mine. Governments should adapt these regulations to allow for the continuation of the renewables power plant where feasible. Ownership and/or operations could be transferred to the government or the community once the capital expenditure has been amortized and the mining project ceases operations.

**Set carbon emission targets:** In resource-rich countries where the mining sector is a large contributor to greenhouse gas emissions, the Government could include sector specific targets and develop plans on how to reduce emissions. Targets should be in line with the Government commitments under the Nationally Determined Contributions.

**Adopt carbon pricing initiatives:** Greenhouse gas emissions are a negative externality that in many countries is not priced appropriately. By putting in place a carbon tax or a carbon trading system, Governments can help internalize these costs on fossil-fuel based energy systems thereby increasing the appeal for renewable energies.

**Remove fossil fuel subsidies:** Fossil fuel subsidies and tax exemptions/credits for electricity generation projects makes renewable power integration less appealing and will delay roll-out.

**Incentivize R&D and reward first-movers:** Many of the innovative renewable integration case studies throughout this report have occurred in Australia, Canada and Chile. This is no coincidence, as these three countries have put in place government incentive mechanisms to reward first-movers.

**Track renewable attributes:** Independent and transparent EACs incentivize mining companies to integrate renewables both to fulfil quotas where such mechanism is in place, and to be able to prove renewable sourcing on voluntary markets.

**Adopt green public procurement practices:** Governments can play an important role in incentivizing the decarbonization of the construction and transport supply chain through their public procurement programs.

## 4.2. MINING COMPANIES

**Leadership and ambitious targets:** Leadership is required to be the first-mover and test new technologies. The IT sector has shown strong leadership in renewable power integration making commitments with ambitious targets. While there are example of projects integrating renewable energy solutions, the mining sector as a whole is lagging behind. Mining companies should not shy away from setting ambitious renewable energy and carbon emission reduction targets that are in line with the SDGs and the Paris Agreement. There are multiple initiatives, best practices and standards that have been developed to support mining companies down this path.

**Encourage mining associations to integrate renewable energy ambitions in their standards:** Reviewing and prioritizing renewable energy solutions could, for example, be integrated in Principle 6 of ICMM – “Promoting continual improvement in environmental performance”.

**Train staff on renewables:** Up-to-date knowledge about renewable energy solutions of management and staff is necessary to consider renewable power options. The sector is fast paced with technologies changing and costs falling rapidly. Therefore, offering continuous courses containing the newest information is important.

**Align incentives:** While the leadership of a mining company may be interested in increasing renewables in the overall energy mix of a company, this is unlikely to materialize without aligning the incentives at the operational level. For operations to value energy efficiency and greenhouse gas emission reductions, key performance indicators need to be designed and integrated in contracts of operational staff. Furthermore, a sufficiently senior manager should be in charge and responsible for the coordination of energy supply and emissions management.

**Review mining processes to optimize the use of renewables:** The current mine design is optimized to operate traditional fossil fuel-based truck fleets and energy systems. In greenfield mining projects there is an opportunity to re-design sites to better cater for the characteristics of renewable energies. Brownfield projects can review their processes to assess where energy efficiency can be improved and load shifting be implemented.

**Check competitiveness of renewables:** Prices for renewable energy and storage solutions continue to fall at a rapid rate. Projects that were uncompetitive a few years back may today be profitable solutions. It is therefore worth to frequently reassess renewable power integration options.

**Adapt procurement practices to better cater for renewable energy solutions:** Mining companies have experience in procuring fossil fuel based energy sources. Practices need to be adapted to take renewable IPP requirements into account.

**Take a long-term holistic approach when designing energy solutions:** One of the largest potential benefits that off-grid mining projects can bring to spur rural development is access to electricity. Renewable based mini-grids have the potential to electrify rural regions. Mining companies should consider how to work with governments and donors to leverage renewable energy investments to provide power to surrounding communities.

**Develop low-emission premium products:** Companies selling consumer products are increasingly interested in reducing the carbon footprint of their supply chain. By developing product lines that emit less greenhouse gas emissions, mining companies can cater for such demand and may be able to charge a premium.

## 4.3. INDEPENDENT POWER PRODUCERS

**Better address the mining company’s needs:** While mining companies need to adapt their procurement practices to better cater for the needs of IPPs, IPPs should also seek to better address the requirements of mining companies. For example, construction logistics should seek to minimize potential mining interruptions and delays.

**Address coordination and accountability problems:** In a hybrid power plant solution where there are separate operators for the diesel and the renewable power components, clear coordination and accountability mechanisms need to be put in place to ensure efficiency and avoid finger-pointing in case of power interruptions.

**Develop hybrid solutions:** To maximize efficiency and avoid accountability problems, IPPs could further develop and offer fully integrated diesel/renewable hybrid power solutions.

**Embrace DFI support and superior environmental, social and governance standards:** While securing DFI financing may be more cumbersome due to high standard requirements, their financial and technical support can be critical to develop projects. This is particularly the case in developing countries with a higher perceived risk. Furthermore, high standards for renewable energy projects are key to ensure project sustainability and the retainment of the social license to operate.

## 4.4. DONORS

**Increase climate finance:** Developed countries are lagging behind the climate finance commitments made in the Paris Agreement. With their patient capital and risk mitigation products, DFIs are important first-movers that can catalyze additional funding from other actors such as institutional investors.

**One-stop shop for renewable power integration in mining projects:** Similar to the Scaling Solar project for governments, it may be worthwhile to create a program that provides technical and financial support to corporate players seeking to integrate renewable power in their operations.

**Increase finance for medium sized renewable energy solutions:** DFIs prioritize large utility scale renewable energy investments. Medium sized renewable energy projects are often not supported due to relatively high administration costs. However, this is the scale of project that off-grid mine sites require to integrate renewables in their energy mix.

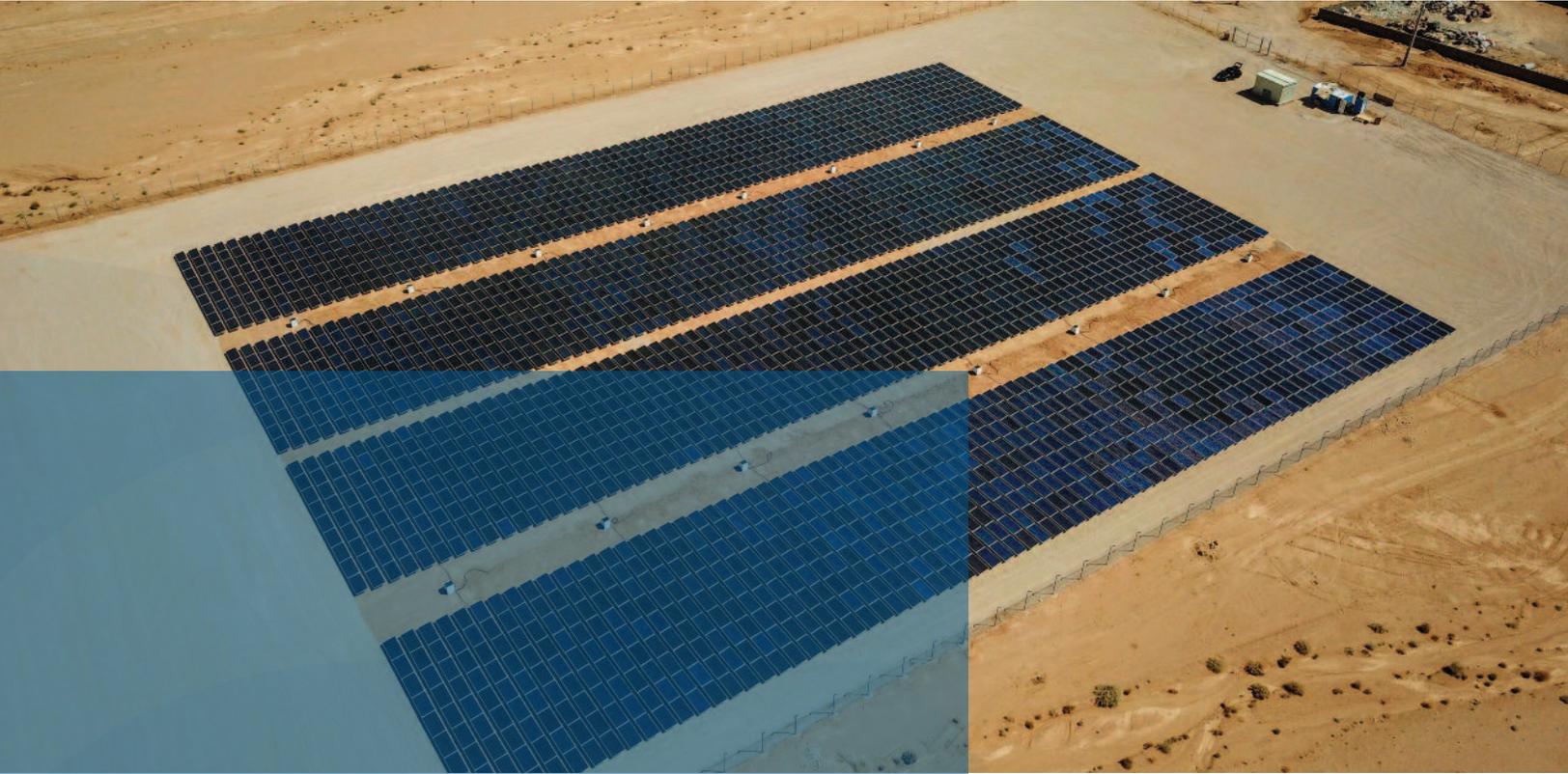
**Focus on financing and implementing the off-grid community electrification arrangement:** Particular focus should be placed by donors on how to leverage renewable power investments by off-grid mining projects to also electrify surrounding communities. While there is a commercial incentive to integrate renewables to power the mining operations, the additional costs and complexities associated with also powering surrounding communities makes mining companies wary of this power sale arrangement. This is a where donors could make an important contribution.

**Build the case for power demand pooling:** While mining companies are wary of pooling their power demand because of the competitive nature of the industry and the different timelines that projects operate on, in some circumstance there might be opportunities to do so with other industries in the area. This could create economies of scale making large-scale renewable projects viable, which in turn could attract financing.

**Streamline activities:** While due diligence is important—and holding companies accountable for higher standards is a key role of donor agencies—the renewable power sector is fast paced with technologies rapidly changing and costs falling. Donors should seek to adapt their processes to make sure that they can play an important role in this fast-paced environment.

**Collaboration within and among stakeholders:** In order to identify synergies between the mining and renewable energy sectors which traditionally have not necessarily worked together, it is important for the respective departments within donor institutions to coordinate and cooperate. The technical assistance and financing institutions of bilateral and multilateral donor agencies should also coordinate closely to take projects from conception to implementation. Donors can also play a key role in helping to coordinate public and private stakeholders in countries where these opportunities arise.

**Work politically to help drive energy reforms that support the integration of renewable energies in resource-rich developing countries:** Energy reforms are politically charged. It is therefore important for donors to understand the political dynamics and interests at play, and adapt policy advice accordingly.



Solar power plant,  
South Africa. © shutterstock.

## PART 5

### FUTURE RESEARCH

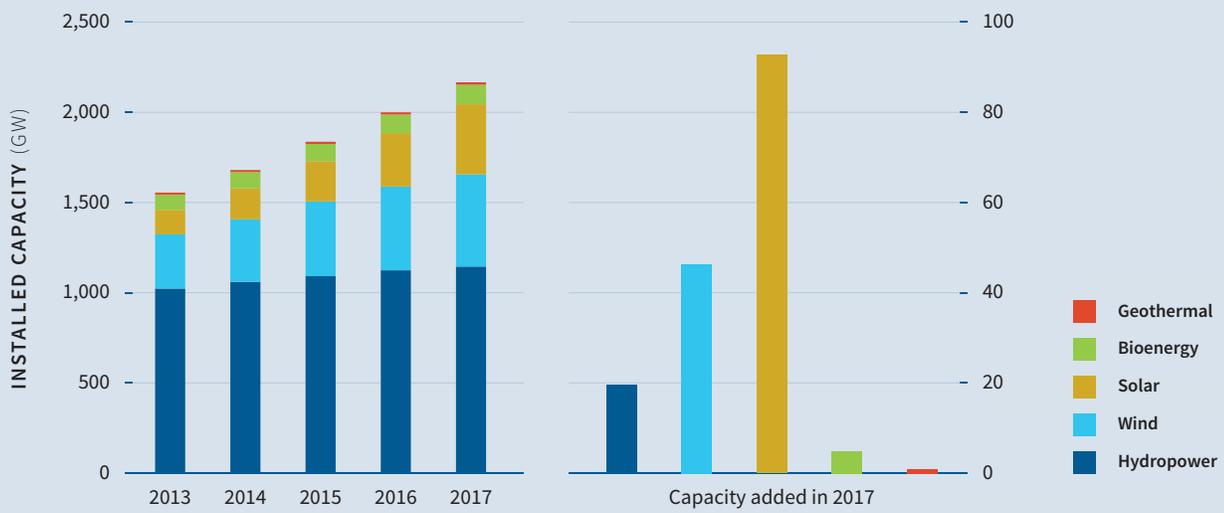
This report provides an overview of existing efforts and case studies of wind and solar power integration at mine sites.

During the literature review and consultations, many interesting follow-up research ideas came up that would deserve additional attention. These include:

- 1) **Reviewing other renewable energy technologies and assess, which technologies are particularly promising along the mining value chain:** This report primarily focuses on wind and solar technologies with examples focusing on the mining component of the value chain. A valuable extension of the report could review additional technologies such as hydropower, geothermal and biomass, and focus on the hybridization of various renewable energy options to achieve higher penetration rates. Furthermore, it would be worthwhile to assess which renewable energy technologies are better suited for downstream activities, such as processing and smelting.
- 2) **Assessing the extent to which developing mining countries, rich in hydro-power potential could facilitate and benefit from increased solar and wind penetration:** This report focuses on the business case of wind and solar integration for mining projects that are off-grid relying on diesel based generation systems, or connected to expensive and unreliable electricity grids. While the report touches on the fact that solar and wind power projects can help solve the instability of hydro-based grids with existing hydro-dams serving as batteries, further research could focus on the extent to which resource-rich developing countries with a relatively inexpensive hydro-based grid could benefit from the integration of wind and solar projects that are linked to the mining sector.
- 3) **Assessing the design of a mining operation based on generation profiles of renewable energy supply:** Large-scale mining projects are designed to operate at a set capacity 24 hours a day and 365 days a year. The energy system then needs to be designed considering this feature. It would be interesting to compare the design and associated costs/benefits of this traditional approach with one where the mine is designed around the generation profiles of various renewable energy sources and hybrid systems that rely 100% on renewable sources.
- 4) **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. Doing a review of existing case studies where this arrangement has been tried would help to better understand the bottlenecks and how these can be resolved. Finding a project where this arrangement is piloted and documented could further provide guidance to leverage power demand by mining investments to increase rural electrification.
- 5) **Developing guidelines and training materials to help mainstream renewable power integration:** It is noticeable that the reviewed case studies of renewable power integration at mine sites are very different and context specific. Guidelines and training modules that outline the decision-making process regarding renewable energy integration could help with the roll-out of renewable energies linked to mining projects. Such guideline/training should include specific components targeted at the different stakeholders.
- 6) **Assessing the potential of renewables for artisanal and small-scale mines:** The focus of this report was on large-scale mining operations. While artisanal and small-scale mines require significantly less energy, they often make use of diesel-based pumping systems and processing machinery; power is needed particularly for the minerals that are sold for their physical characteristics and not for their metal content. This includes for instance, sandstone, granite, slate, marble and semi-precious stones.<sup>298</sup> Their low and dispatchable consumption of power may be compatible with small scale renewable energy systems. However, mining permits are often too short to make renewable energy investments viable.<sup>299</sup> Renewable power solutions would therefore have to go hand-in-hand with government and donor initiatives that create a leasing system or provide financing solutions. This could be part of projects that seek to formalize artisanal and small-scale miners, and improve their sustainability practices.

ANNEX 1: SNAPSHOT OF GLOBAL RENEWABLE ENERGY LANDSCAPE

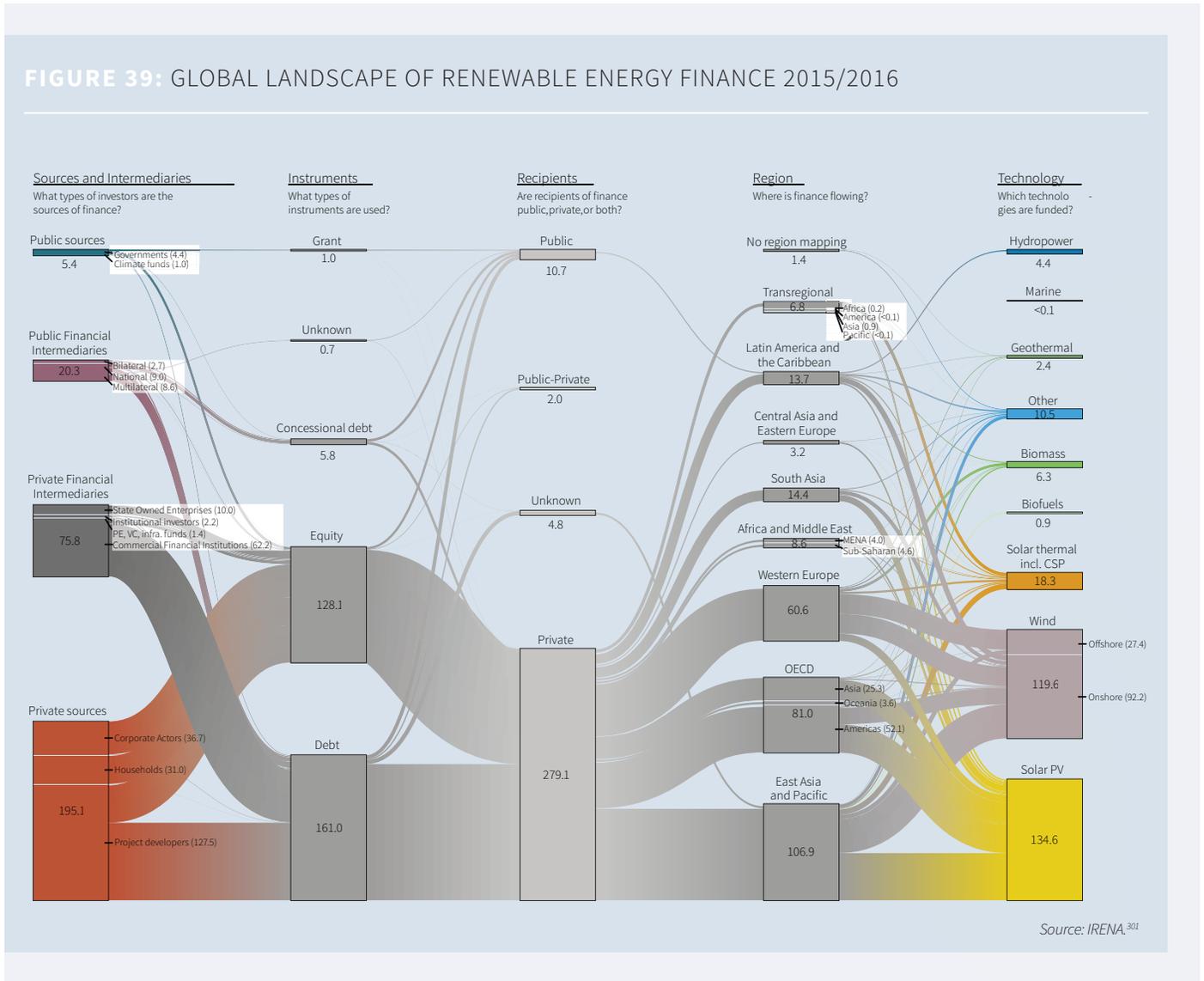
FIGURE 38: INSTALLED CAPACITY AND GROWTH



Source: IRENA<sup>300</sup>

ANNEX 1: SNAPSHOT OF GLOBAL RENEWABLE ENERGY LANDSCAPE

FIGURE 39: GLOBAL LANDSCAPE OF RENEWABLE ENERGY FINANCE 2015/2016



The diagram shows global renewable energy finance flows along the investment life cycle in 2015 and 2016, taking into consideration the full range of sources, instruments, regions and technologies, as well as distinctions between public and private finance sources. Values are averages of the data from the two years, in US\$ billion.

ANNEX 2: EVALUATION CRITERIA TO INTEGRATE RENEWABLES INTO MINING PROJECTS

TABLE 6: EVALUATION CRITERIA TO INTEGRATE RENEWABLES INTO MINING PROJECTS

	Off-grid projects	On-grid projects
Economy	Investment cost	Investment cost includes all costs regarding the planning, purchase and installation of the electricity source.
	Operating and maintenance costs	Operation costs entail employees' salaries and the products and services for the system's operation. Maintenance costs ensure that the system is in operating condition, in order to prolong the system's life and avoid failures that result in downtime.
	Fuel / electricity cost	This criterion represents the money spent to produce one kWh. In the case of diesel generators, it is the cost of diesel. In regards to grid-connection it is the average kWh tariff.
	Prediction of fuel costs	This criterion provides a prediction of the fuel price in 5 years, consumed by the electricity source to produce electricity.
	Prediction of initial investment costs	This criterion provides an estimation of how the initial investment cost will develop in 1 year. If the technology is relatively new, possible price drops can be expected.
	Levelised electricity cost	This criterion measures the cost per kWh including all costs incurred by the initial investment till the end of the predicted lifetime – which is placed in relation with the projected output of kWh in the same time span. Included: Depreciation; Interests; Loan; Initial investment; Operating and maintenance costs; O&M escalation; Rest value. Discount rate; Initial kWh; System degradation; Tax rate; Change of fuel costs; Number of years.
	Net present value	This is a financial method to define the total present value of a series of annual cash inflows and outflows during the lifespan of the asset. The cash flows are discounted back to their present and added up. The final present amount is compared to the initial investment cost.
Technology	Safety	Safety relates to the degree of safety for employees working on site.
	Implementation period	The implementation period is the amount of time needed to realise the project.
	Reliability	Reliability is defined as the capacity of a system to perform as designed and planned.
	Supply 24/7	Most mining operations need a day and night (24-hour) electricity supply.
	Maturity	Maturity refers to the development stage of the technology. The stages range from 'only tested in laboratories' to 'close to reaching the theoretical limits of efficiency'.
	Service level	Service level measures the availability of experts and spare parts to repair damaged equipment.
Environment	GHG emissions	This represents the measurement of the emission of a colourless, odourless and tasteless gas, which is mainly emitted through the combustion of coal, oil and gas.
	Local air pollution	Refers to the release of hazardous substances and particles in the air that harm the surrounding environment and exposed humans.
	Noise	Noise is the machine-created sound that disrupts human and animal daily life.
	Land requirement	This criterion represents the amount of land that the electricity source requires to produce a certain capacity.
Social	Job creation	Job creation means the number of people employed during the life cycle of an energy system.
	Corporate image	Corporate image represents the possible impact of the electricity source on the corporate identity in the minds of diverse publics, such as customers, investors and employees.
	Effect on community	This criterion refers to the possible impact on the surrounding residents, after the decision to close the mine. The community could further utilise the electricity source.

Source: Votteler (2016).<sup>302</sup>

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