RESEARCH REPORT
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SUNSHINE FOR MINES: IMPLEMENTING RENEWABLE ENERGY FOR OFF-GRID OPERATIONS

THE CARBON WAR ROOM | JOHNS HOPKINS SAIS

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Contents

FIGURES

Sunshine for Mines: Implementing Renewable Energy for Off-Grid Operations

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Executive Summary

ABOUT THIS REPORT

The Carbon War Room's goal is to bring attention to what it believes is an extremely promising pathway for increasing deployment of renewable energy in South Africa, and to provide guidance on how the mining industry, often criticized for its record on environmental protection and labor relation practices, can lead the way in bringing modern energy services to the region of the world that suffers the greatest lack of access to this basic resource.

Access to modern energy services continues to be a key developmental and environmental challenge in Sub-Saharan Africa. Lack of access to clean, affordable, and reliable energy hinders economic growth and results in a reliance on energy sources that are not only expensive but also unsustainable and particularly damaging to the environment, such as wood, kerosene and diesel fuels. In recent years, decreases in the cost of renewable energy and the development of innovative delivery channels have made at least some forms of distributed renewable energy available to even the poorest. Despite these advances, access continues to remain stubbornly low or insufficient across much of the region.

This lack of access to modern energy services primarily affects individuals and rural communities, but it also takes a toll on businesses that operate in remote areas and must therefore rely on costly diesel generators to power their operations. This is particularly true for the mining industry, which in recent years (and for the foreseeable future) has needed to operate in increasingly remote areas as proven mineral reserves close to grid-connected power are exhausted. For the mining industry, and others operating off-grid, the opportunity to move towards distributed renewable energy systems is economically compelling today.

Mining is a major industry in South Africa and neighboring countries, and one that uses large amounts of energy to power its operations. In 2011, the South African mining industry used 14.3% of the energy generated by the national utility Eskom (Greenpeace 2012). But many mines are located in remote areas, far from transmission lines, and therefore are currently reliant on diesel generators, though the precise amount of diesel fuel consumed by these mines is undisclosed. Were these off-grid mines and other remote industries to invest in renewables, they would considerably reduce the CO_2 emissions of their operations while increasing their long-term economic competitiveness. This also presents a major opportunity to improve supply chain efficiency, as reduction in diesel demand greatly reduces the number of tanker trucks required to travel long distances to remote sites, and thus further reduces emissions and costs. Incorporating distributed renewable energy into energy systems provides mine operators with an opportunity to stabilize energy costs and hedge against rising diesel prices.

Mines operating off-grid in South Africa, and likely throughout Sub-Saharan Africa, can greatly reduce their energy costs by introducing renewables into their energy-supply mix.

Potential Benefits of Distributed Renewable Energy for Mining and Large Industrials in South Africa

- Reduction in fuel and electricity costs, including transportation costs
- Predictable energy costs, and therefore reduced risk from volatile and rising diesel prices
- Reduction in carbon emissions and overall a less-polluting source of energy for the region
- A secure and reliable energy system for the private sector
- Reduced risk of power loss from supply disruptions
- PV plants are a high-value, long-term asset
- Enhanced economic competitiveness for the sector
- Opportunities to repurpose land used by the mining community
- Opportunities to power local communities and improve the local economy
- Job creation for the region and the community
- Opportunities for cooperation with neighboring industries
- Growth in domestic renewable energy market

As an added benefit, the development of renewable energy capacity could help to expedite the development and permitting process for new mines. Mining firms are required to demonstrate they have sufficient capital and energy supply to remediate the land after the mine closes. A solar plant will, in all likelihood, outlive the productivity of a mine, which ensures that the mine has the assets needed to conduct remediation. Following mine closure, the solar plant can also be used to power local communities, which also helps with the permitting process.

One mine, operated by Cronimet Mining SA, is leading the way. By developing a 1 MW solar photovoltaic (PV) plant as part of a solar-diesel hybrid system, Cronimet has been able to reduce its annual diesel fuel consumption by 24%, resulting in an approximate 1,200-ton annual abatement in CO_2—equivalent to taking 235 passenger cars off the road per year (EPA 2011; Cronimet Mining-Power Solutions 2013). Better still, the initial investment for the solar plant had a payback period of only 3.6 years, with a net present value of US$ 2.3 million over the lifespan of the plant, making this a remarkably compelling opportunity for investment in solar energy.

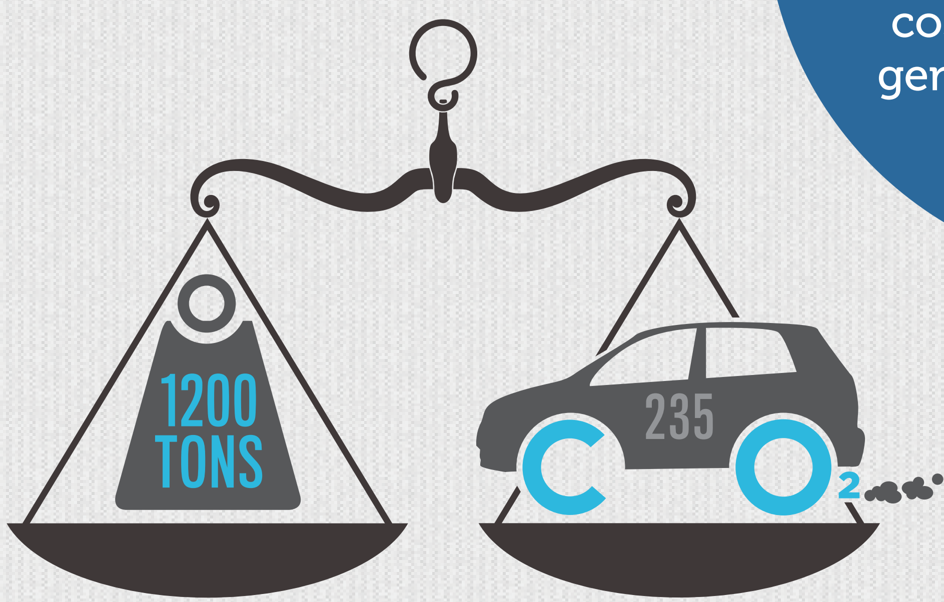
The Cronimet case study also demonstrates that the adoption of renewables by private companies to power their off-grid operations could potentially yield other benefits, such as access to energy for local communities, and general development of the solar market in the region. In fact, the adoption of distributed renewable energy systems by private sector entities could represent one of the greatest opportunities for the development of the renewable energy industry in areas where people have the lowest levels of access to this basic resource.

Additionally, recent studies suggest that the mining industry, by driving demand, could foster an additional and significant new economic opportunity in the form of local production of PV systems and local labor for their installation and maintenance. All of these benefits could be significant drivers of economic development in one of the world's poorest regions.

Although distributed renewable energy cannot currently compete with grid power on a cost-per-kilowatt-hour (kWh) basis in South Africa,[1] distributed renewables may still be attractive for on-grid mines, given: a) the ever-increasing unreliability of the national grid in South Africa as a result of rising demand outstripping supply; and b) the rapidly rising price of electricity, which increased by 26% between 2007 and 2012 alone (E&Y 2013).

While renewables cannot currently compete with grid power on a cost-per-KWh basis in South Africa, solar-diesel hybrid systems represent the most cost-effective means of generating electricity for off-grid mines.

By developing a 1 MW solar photovoltaic plant as part of a solar-diesel hybrid system, Cronimet has been able to reduce its annual diesel fuel consumption by 24%, resulting in an approximate 1,200-ton annual abatement in CO_2—equivalent to taking 235 passenger cars off the road per year (EPA 2011).



[1] In areas where entire utility grids operate in isolation, relying predominantly on imported fuel for electricity generation, distributed renewable energy systems can be highly cost competitive.

KEY FINDINGS

The South African mining industry and renewable energy project developers have explored several different models through which distributed renewable energy could be used to profitably reduce diesel consumption by off-grid mines. This report presents an analysis of four business models, shown in Figure 1, for developing distributed renewable energy systems to power off-grid mining operations in South Africa. The report then presents a case study of a company that has successfully implemented the one business model that is currently the most attractive and feasible for the region, from technical, regulatory, and economic perspectives.

Based on user interviews and an analysis of the South African regulatory regime, the Self-Generation model—specifically one based on solar-diesel hybrid systems—represents the most viable option of these four approaches.

The experience of Cronimet Mining SA and Cronimet Mining-Power Solutions, presented as a case study in this report, demonstrates not only how the Self-Generation model could be a viable option for other off-grid mines in South Africa, but also potentially for mines in other countries in Sub-Saharan Africa and other for industries with off-grid operations.

While the other business models evaluated in this study are not currently as attractive as Self-Generation, they also show great promise. At present, however, Net-Metering would require policy changes, while Industrial Pooling and Powering Communities will become more feasible as storage technologies and technical capacities evolve locally. In any case, all of these models could be incentivized with regulations, the introduction of third-party "energy services" companies besides the utilities, and greater cooperation between industrial sectors.

Technical Options for Using Distributed Renewables to Power Off-Grid Mines

- **Renewables + Storage:** Energy generation solely from renewable sources, with sufficient storage capacity to reliably provide power 24 hours a day.
- **Hybrid Systems:** Advanced "fuel-save" modules connect solar or wind assets with diesel generators, preventing load loss and optimizing use of renewable resources.
- **Hybrid Systems + Storage:** The addition of various forms of storage capacity to hybrid micro-grids, further maximizing use of the renewable resources in the system.

This report finds that, in South Africa today, solar-diesel hybrid systems are the most cost-effective means of generating electricity for off-grid mines. However, Cronimet is currently exploring adding energy storage components to their system in order to further maximize their use of solar resources, with initial assessments suggesting such an approach is now also economically feasible.

Figure 1: Business Models for Distributed Renewable Energy to Power Off-Grid Industrial Processes

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

Additional Trends Reinforcing the Case for Distributed Renewable Energy

A variety of other market forces and government-based incentives have arisen in South Africa in recent years that favor renewable energy:

- **An ongoing and steady decrease in the cost of PV** (and other renewable energy technologies) is expected to continue, further emphasizing the economic benefits of transitioning from reliance solely on diesel fuel to the use of hybrid systems. However, the cost of certain ancillary components of renewable systems and other soft costs have not declined as rapidly as the cost of the PV panels themselves.

- **A South African carbon tax, to be introduced in 2015,** will be an important step towards further incentivizing the adoption of renewables, especially among the operators of large mining installations. This tax will also increase transparency with regard to the actual costs (such as the long-term environmental costs) associated with fossil fuel-based electricity, and will help the market to compare "apples with apples" when it comes to investing in either renewable or conventional generation projects.

- **An increased commitment from the South African government to provide markets with more stringent and reliable policy directions,** just one example of which The Renewable Energy Independent Power Producers Program (REIPPP). REIPPP is a positive development towards more transparency and more stringent regulations, as it offers a predictable set of regulations to Independent Power Producers (IPPs), as do the other policy developments shown in Figure 1.

Challenges to the Uptake of Distributed Renewable Systems in South Africa

While there is a strong business case for solar-diesel hybrids to power off-grid mines via the Self-Generation model, the adoption of distributed renewables faces several market-based challenges:

- Securing debt financing for the initial investment in infrastructure is persistently difficult. As in other renewable energy applications, the shift from operating expense to capital expense can be challenging without external capital. This shift makes financiers and mining firms alike uneasy, especially as mines have a finite life span and therefore represent a far-from-guaranteed long-term revenue stream.

- A lack of technical capacity in the region is proving to be a major constraint on the ability of South African mining firms to develop renewable energy systems, particularly since solar-diesel hybrid systems are more complex than simple home solar systems or other common grid-connected rooftop systems.

- Many large project developers also lack the needed expertise, as their experience is often constrained to utility-scale projects. Meanwhile, the electrical engineers already employed by mining firms in the region have a specialized understanding around how to build and operate diesel gen-sets, but their knowledge does not usually extend to solar-diesel hybrid systems.

The provision of technical training and additional human resources, as well as the development of consulting businesses, will be essential to scaling-up the deployment of distributed renewable energy systems in South Africa and beyond. Consulting firms and project developers are already actively addressing additional risks such as local currency fluctuations, but their approaches will require ground-proofing before becoming more widely accepted. More generally, the new financial models and the development of technical capacity resulting from early experiences such as those described in this paper are already helping to overcome the aforementioned impediments.

Energy stability is essential for the mining industry. Brownouts in South Africa cost the country an estimated $2.2 billion in Gross Domestic Product losses in 2008, which forced the permanent closure of several mines

(Calldo 2008; Myburgh 2008).

Introduction

South Africa is Africa's largest economy and by far the largest energy consumer on the continent.

South Africa is Africa's largest economy and by far the largest energy consumer on the continent. Its US$408 billion gross domestic product (GDP) is almost double the size of Africa's next largest economy, Nigeria, while its annual electricity consumption amounts to 234.2 billion kWh—which represents approximately 45% of Africa's total electricity consumption (World Bank 2013; CIA 2013).

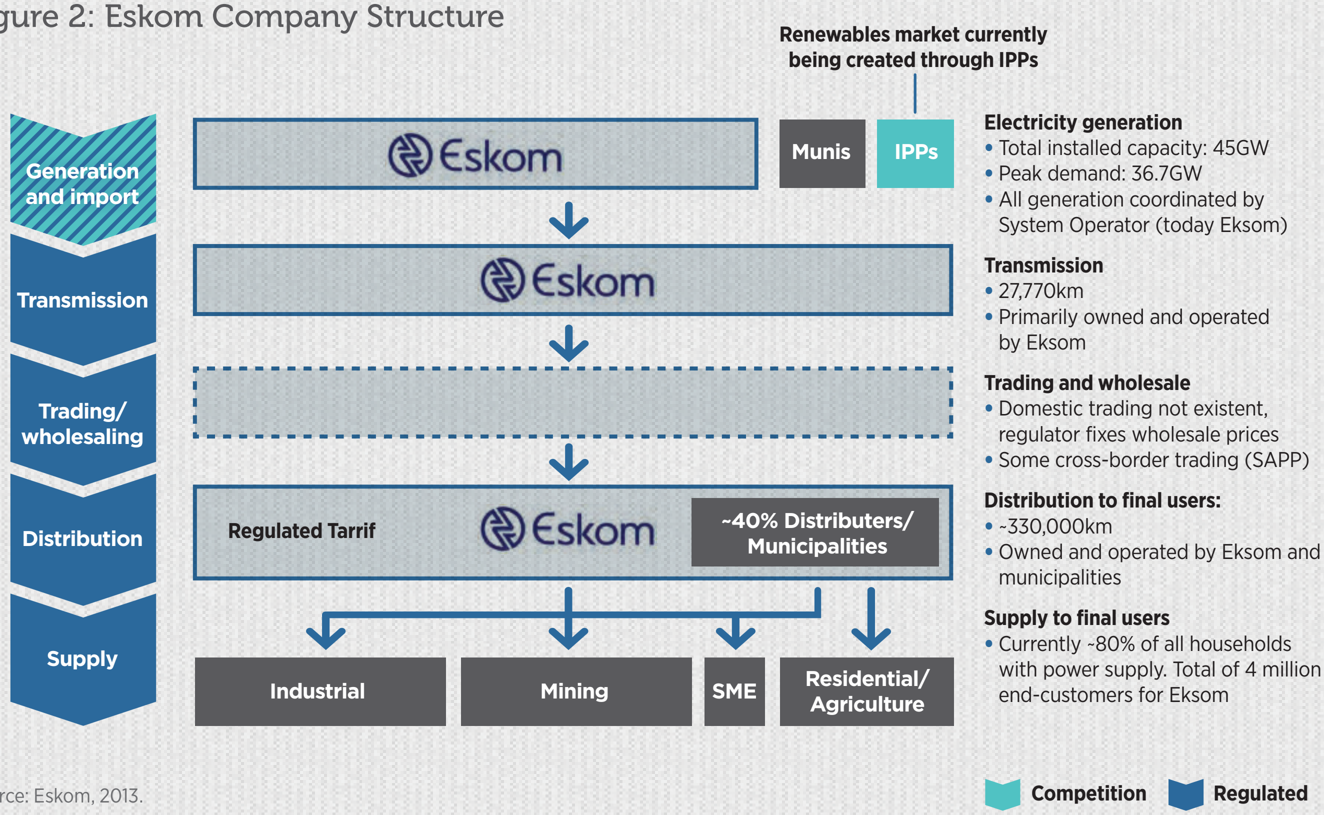
The state-owned utility, Eskom, produces 96.7 percent of the power used in the country, 92.6% of which is generated in coal-fired power plants, as shown in Figure 2 below (South Africa Department of Energy). Eskom is a vertically integrated monopoly whose per-kWh prices are among the cheapest in the world (Parliamentary Monitoring Group 2012). However, as a result of underinvestment, aging infrastructure, and financial mismanagement, Eskom is today struggling to provide a reliable energy supply (Reuters 2013).

South Africa's electricity reserve margin is extremely low, making its power supply highly unstable and vulnerable to demand disruptions (Mail & Guardian 2013). Such paper-thin margins increase the chance of load shedding (an intentional cut in power to certain areas engineered to prevent a complete loss of power), which has been a pressing issue in recent years and is continuing to be so (Du Plessis 2013). Notably, in 2007 and 2008, South Africa experienced blackouts that brought cities and industrial activities to a standstill. Some studies found that the blackouts caused the country's GDP to shrink by around US$2.2 billion in 2008 alone, and it is certain that the load-shedding regime imposed by Eskom to manage those blackouts forced the permanent closure of several key mines (Calldo 2008; Myburgh 2008).

In spite of making substantial progress (20 years ago the nation's electrification rate was only 36%), on a broader level Eskom and the South African government have failed to achieve their goal of universal access to electricity by 2012 (IRENA 2013). Figures vary, but South Africa still has between a 15% and a 36% shortfall in electrification (GNESD 2013).[2] The current energy deficits are only compounded by the fact that South Africa's energy demand grew by more than 20% over the past decade, and is expected to double from today's levels by 2030 (Roula 2010). The big picture illustrated by these statistics is that, in today's South Africa, a large swath of the country's industries and communities are either wholly reliant on diesel generators or biomass as their sole power sources, or are forced to maintain such options for backup generation on an unreliable grid.

[2] The varied figures are due in part to the imprecise definition of "electrification," as some studies count any degree of grid-connectedness, while others only consider connection to a modern, reliable, and affordable grid.

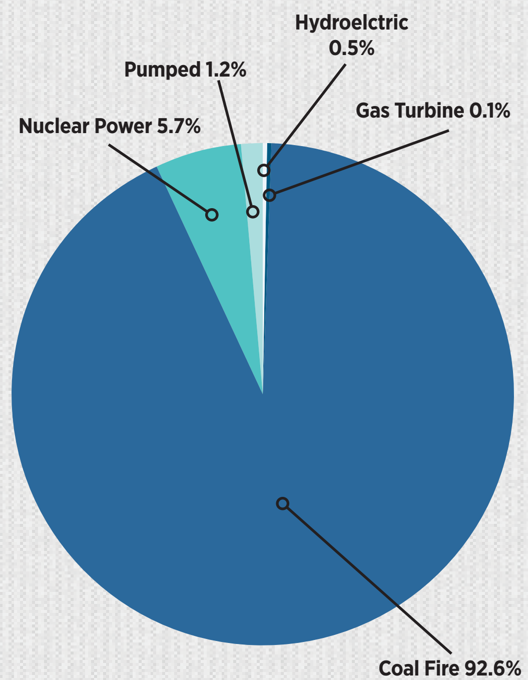
Figure 2: Eskom Company Structure



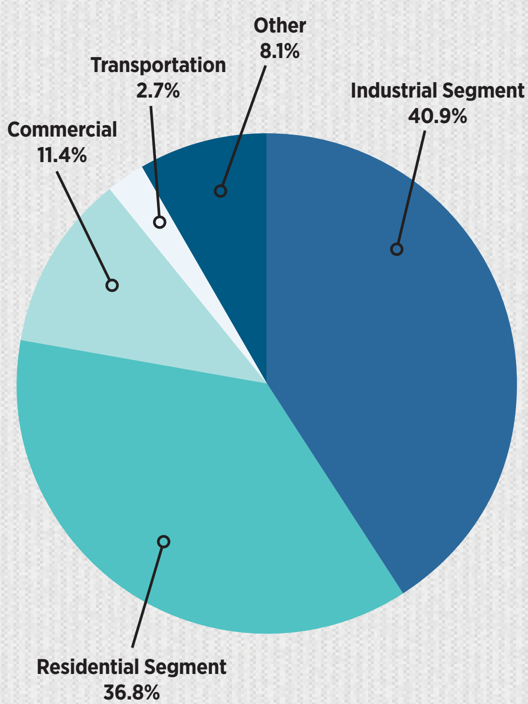
Source: Eskom, 2013.

Figure 3: Electricity Production Sources and Consumption by Sector

Electricity Production



Electricity Consumption



Source: South Africa Department of Energy.

The blackouts suffered by grid-connected customers, and the total lack of supply that persists for other customers, both serve to highlight the fact that substantial investment into generation capacity is needed in South Africa. To truly meet growing national demand with a centralized grid system, Eskom will need to invest an estimated US$171 billion into additional capacity, and an estimated US$14 billion into additional grid extensions, all in the next 12 years (Kimani 2008). This may prove difficult, as Eskom possesses neither sufficient capital nor credit to make these investments.

In light of these challenges, the South African government and the National Energy Regulator of South Africa (NERSA) have recently pushed for the opening of the electricity market, with the goal of extending the grid and securing a reliable electricity supply (IMF 2008). Although this would require ending Eskom's monopoly over energy production, and perhaps also over transmission and distribution, no clear measures have been agreed upon. For example, the establishment of an Independent System and Market Operator (ISMO) has been repeatedly discussed in parliament, but little progress has been made.

How Eskom and the government handle these energy supply challenges will have serious implications for South Africa's future economic growth, particularly if they are unable to provide inexpensive and reliable energy to the mining and manufacturing sectors, which account for the majority of the 41% share of energy consumed by South African industrial users, as shown in Figure 3.

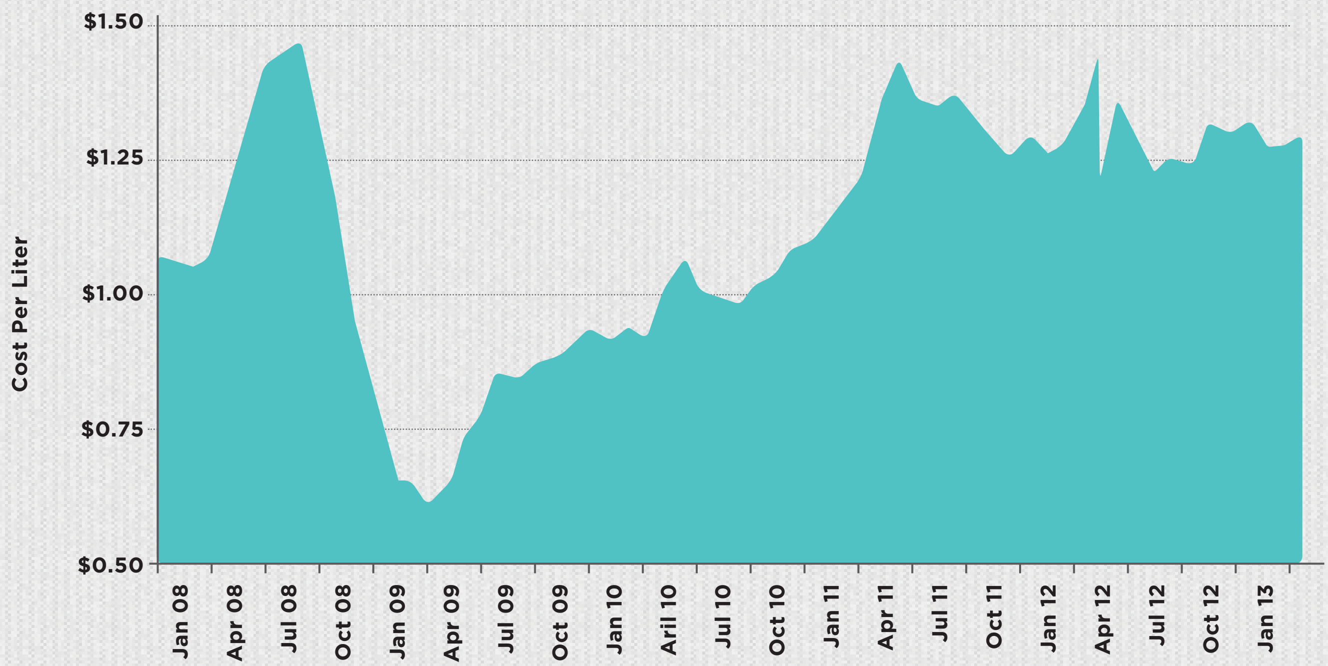
Companies with off-grid industrial operations may therefore assess this current situation and determine that they do not in fact have the option of receiving reliable and affordable power from the grid in the next decade. The rising price of diesel and the slim likelihood of grid expansion, combined with the continued risk of blackouts and cost uncertainties faced by on-grid customers, should motivate those off-grid companies to take control of this critical input into their businesses, and to seek out options that will allow them to generate their own electricity – such as distributed renewable energy.

The Energy Profile of the Mining Sector

South Africa has the highest level of industrialization in Sub-Saharan Africa, and mining is its most significant industrial sub-sector, accounting for 18% (US$ 73.4 billion) of GDP and 60% of exports each year (PwC 2011). With mineral reserves worth over US$ 2.5 trillion, South Africa boasts the world's largest reserves of chrome, gold, vanadium, diamonds, manganese, and platinum, and therefore one of the world's largest mining industries (CMSA 2012; Cohen 2011). The country's mining sector employs nearly 1 million people (490,000 directly and 500,000 indirectly), and absorbs 20% of Foreign Direct Investment (SA Info 2013).

The mining sector is a compelling starting point for exploring the potential impacts of renewable-based distributed generation systems on electricity costs and greenhouse gas emissions in Sub-Saharan Africa, as mines are large electricity consumers. In fact, the sector is responsible for 15% of the South Africa's total electricity demand, a significant fraction of the over 40% of consumption claimed by industry overall (Eskom 2008). One of the larger industries in the region, the mining industry pays a particularly high price for its power, due to both its high energy usage and the often remote geographical location of its operational activity, which forces many mines to rely on expensive and high-emissions diesel fuel that is transported over long distances to their sites.

Figure 4: Nominal Diesel Prices in South Africa (2008 – 2013)



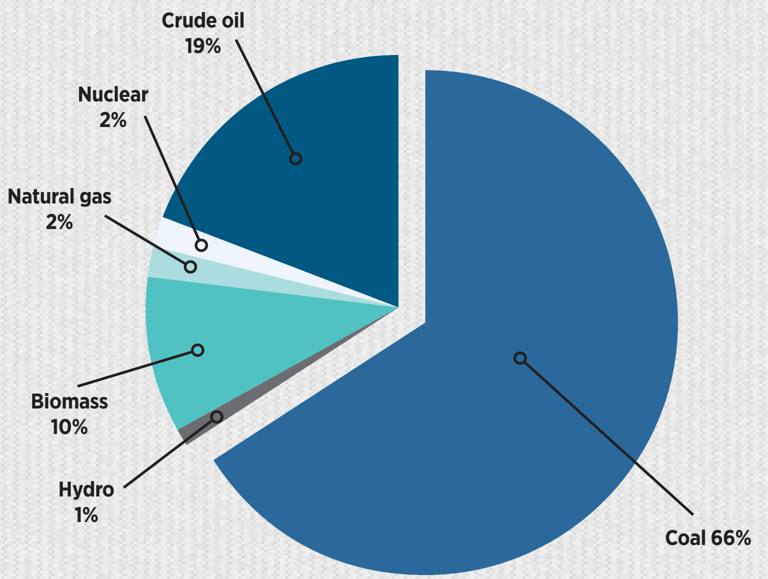
Source: AA, 2013.

But the energy consumption of mines that are not on the grid is not well-tracked by the government or industry groups, and comprehensive statistics are scarce. What is known is that many mines are located in remote areas, and that the national grid of South Africa has limited reach in such regions – only 55% of rural regions enjoy grid-based electricity (EIA 2013). Moreover, even many grid-connected mines must maintain diesel generators for redundancy to protect against the risk of load loss or blackouts. While renewables cannot currently compete with grid power on a cost per KWh basis, solar-diesel hybrid systems represent the most cost effective means of generating electricity for those mines operating off-grid.

Mining companies and mine operators are beginning to take notice of the economic risks associated with dependence on fossil fuels, whether on- or off-grid. For example, the price of coal rose from US$ 65 to US$ 100 per tonne in just one year between 2006 and 2007, and the price of coal-powered grid-connected electricity jumped accordingly (GNESD 2009). Reliance on diesel generators for off-grid operations has become equally risky, in light of the volatility of day-to-day diesel prices over recent years, which has occurred within a larger trend of consistent and persistent diesel price increases (See Figure XX). Overall, South African mines faced annual cost increases of 26% for electricity and 15.7% for diesel fuel from 2007 to 2012 (E&Y 2013).

Finally, the depth of South Africa's mineral reserves means that mining will be a growth industry for the country for decades to come. That growth is currently strong enough that an estimated 6900 GWh of new annual energy demand is predicted from the mining industry alone by 2019 – equivalent to a full 3% of South Africa's total generation capacity in 2008 (Toledano 2012). Combined with trends of growing energy demand overall in South Africa – analysts project a need for 40,000 MW of new generation capacity by 2025 – these predictions raise serious concerns of whether or not Eskom alone will be able to meet this demand (South Africa Department of Energy).

Figure 5: Total Primary Energy Supply in South Africa



Source: U.S. EIA, 2013.

Climate, Environment, and Renewables

Coal-fired electricity used by grid-connected customers is only one part of South Africa's total energy mix. Although 92.6% of on-grid power is supplied by coal-fired power plants, as shown on page 12 in Figure 4, primary energy supply figures (the sources of all energy used in total – transportation, electricity, heat, etc. – when compared equally in terms of BTUs), tell a different story. As shown in Figure 5 above, crude oil provides about 19% of primary energy for South Africa, most of which is used for transportation, but a significant amount is consumed by the mining industry, for transport, diesel generators, and other purposes.

As mentioned, it is unclear what percentage of these primary energy sources are used for powering off-grid mines. But it is known that significant air pollution and greenhouse gas emissions result from the burning of diesel or simple biomass (generally wood, dung, or charcoal) to meet the energy needs of the high numbers of South African communities and industries that lack access to electricity (IEA 2011).

Some in South Africa suggest that renewable energy already supplies a full 10% of South Africa's energy needs, but this fact should not be taken at face value, since the majority of that 10% is simply the unsustainable burning of wood, dung, and charcoal. Advanced and sustainable renewables, such as hydro, solar, or wind, currently represent only 1-2% of South Africa's primary energy supply (EIA 2013).

Fortunately, South Africa has substantial renewable energy resources, offering the potential for the country to dramatically increase its renewable generation capacity. In particular, South Africa has some of the best solar potential of any country on Earth, with solar irradiation levels that average more than twice those of Europe (South Africa Department of Energy 2013).

The South African Regulatory Regime

Recognizing their domestic renewable potential, and driven by commitments to reduce their reliance on carbon-intensive fossil fuels, the National Energy Regulator of South Africa (NERSA) has set a target for renewable resources to provide 16% of the nation's power generation by 2014 (Parliamentary Monitoring Group 2012). The state-owned utility Eskom is aiming to cover 13% of this, while the remaining 3% will be provided via the Renewable Energy Independent Power Producers Program (REIPPP), through which Independent Power Producers (IPPs) will compete for market access over the next few years (ibid).

To date, renewable energy project developers looking to operate in South Africa have focused their efforts on the costly bidding process for these REIPPP licenses, with which they will develop large-scale, grid-connected generation capacity. However, little progress has been made on such projects to date, with the REIPPP expected to have allocated only about 1500 MW of capacity by the 2014 close of the third of its five rounds of bidding (Kane & Shio 2013). Moreover, the REIPPP is capped, such that only 9% of the grid-connected energy market will be opened to independent renewables providers by 2030 (Greenpeace 2013).

The mining industry pays a particularly high price for its power, due to both its high energy usage and the often remote geographical location of its operational activity.

Figure 6: Renewable Energy Policy in South Africa

Policy	Goal	Launch
White Paper on Energy Policy	General energy policy. Set goal of developing renewable energy by reforming fiscal, legislative and regulatory regimes.	1998, renewed 2009
White Paper on Renewable Energy	Laid the foundation for the widespread implementation of renewable energy, and set target of 10,000 GWh by 2013.	2003
National Cleaner Production Strategy	Framework (non-binding) to promote sustainable energy production and consumption across South African industries.	2004
Energy Act	Contained strategy for increased generation and consumption planning (renewable and conventional energy sources).	2009
Renewable Energy Feed in Tariff program (REFIT)	Set tariffs for wind, small hydro, concentrated solar, and landfill gas technologies. The tariffs were aligned with falling technology costs in 2011.	2009
Integrated Resource Plan (IRP)	A national, long-term plan on electricity supply, based on nuclear power, coal and renewables. Total PV capacity goal is 8,400 MW. The REIPPP falls under this plan.	2010–2030
Renewable Energy Bids (REBID)	Independent power producers bid for on-grid production capacity. In the first round (2012), 1,415 MW was allocated across concentrated Solar PV, Concentrated Solar PV, and biogas.	2011

Source: REEGLE, 2013; South Africa Department of Energy, 2010; Fritz, 2012.

Though imperfect, the REIPPP is one example of a positive development towards more transparency and more stringent regulations, as it offers a predictable set of regulations to Independent Power Producers (IPPs), as are the other policy developments shown above in Figure 6.

In sum, independent renewable energy companies face high barriers-to-entry for developing grid-connected projects in South Africa, despite the recent policy reform efforts of the South African government. Industrial operations such as mines provide a clear alternative point of market entry for these actors, though the project size will be much smaller. Distributed renewable energy projects allow project developers to work directly with private sector actors to install renewables on private land – skiting many aspects of the REIPPP process and its associated costs.

Moreover, a recent study found that South Africa's manufacturing sector has the potential to supply 38 GW of solar power by 2030 using PV components that boast a 90% local-content ratio across the entire supply chain for such projects, boosting the domestic economy by creating jobs in a new clean-tech industry, (WWF 2013). Finally, on the demand side, for remote mines that currently lack grid connection, these technologies remove the cost and lag-time of developing centralized energy infrastructure.

The country's mining sector employs nearly 1 million people (490,000 directly and 500,000 indirectly), and absorbs 20% of Foreign Direct Investment

(SA Info 2013).

Business Models For Distributed Renewable Energy

As stated above, many of South Africa's remote communities and industries, including its off-grid mining sector, have a substantial energy need that is not currently being met by the centralized energy grid, nor likely to be met in a reliable and affordable manner in the near future by the utility Eskom. Moreover, mines operating off-grid in remote areas are currently paying much higher prices for their electricity (supplied by diesel generators) than their grid-connected counterparts. Finally, the current South African policy regime is favorable to the adoption of distributed renewable energy systems by private-sector actors, in that there is a lack of regulation on the use of such systems and, as will be elaborated on later in this paper, solar-diesel hybrid systems are economically competitive with diesel-only systems today.

In light of these current market and regulatory forces, there is a clear economic case for distributed renewable energy to replace a significant percentage of diesel generation capacity for off-grid mining operations in South Africa. To facilitate the adoption of these technologies, mining companies and renewable energy firms have explored several business models, as described in Figure 7.

Figure 7: Business Models for Distributed Renewable Energy to Power Off-Grid Industrial Processes

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

Business Models In-Depth

SELF-GENERATION MODEL

Actors:
A single industrial enterprise, which is unconnected from the grid and currently relies entirely on diesel generation for electricity and also, potentially, an independent power producer.

Goals:
Develop a renewable generation plant to reduce the industrial enterprise's energy costs and secure its energy source.

Potential Adoption Processes:
The industrial enterprise may choose to adopt renewable energy via this model in one of two ways:

- Develop, finance, and operate the plant on their own land, potentially through a subcontract with an external renewable energy developer;

OR

- Lease or otherwise provide land to an independent power producer, who will in turn handle the development and, potentially, even the financing and operation of the plant.

Benefits:
Out of the four models considered, this model has the fewest actors involved, making it the most straightforward to implement and therefore the preferred model of the experts surveyed.

Downsides:
The downsides to this model are the same as for any renewable energy system—the initial required investment for adoption is high, representing a shift from operating expense (diesel fuel) to capital expense (PV panels and related infrastructure). Also, mining companies typically have limited knowledge of renewable technologies. These downsides can be mitigated through third-party financing (which also has challenges) and partnerships with independent power producers who have the required expertise in renewable-diesel hybrid systems.

NET METERING MODEL (GRID-CONNECTED MINES ONLY)

Actors:
A single industrial enterprise, which is currently connected to the grid, from which it buys electricity; the utility company running the grid.

Goals:
Develop a renewable generation plant to reduce the enterprise's energy costs and avoid any potential supply disruptions or price uncertainties associated with the existing grid.

Potential Adoption Processes:
The industrial enterprise may choose to adopt renewable energy via this model in one of two ways:

- Develop, finance, and operate the plant on their own land, potentially through a subcontract with an external PV constructor;

OR

- Lease their land to an independent company, who will in turn handle the development, financing, and operation of the plant.

THEN

- The utility running the grid purchases the excess capacity generated by the renewable plant.

Benefits:
It creates an additional revenue stream for the operator and could reduce waste by utilizing all of the energy created by the PV installation.

Downsides:
Net Metering is not currently feasible under South Africa's regulatory regime.

SELF-GENERATION + POWERING TOWNSHIPS MODEL

Actors:
A single industrial enterprise, which is unconnected to the grid and currently relies entirely on diesel generation for electricity; a nearby community, which is close enough to be connected with the industrial enterprise by means of a mini-grid; potentially an independent power producer.

Goals:
Develop a renewable generation plant to reduce the enterprise's energy costs and achieve electrification for a local community.

Potential Adoption Processes:
The industrial enterprise may choose to adopt renewable energy via this model in one of two ways:

- Develop, finance, and operate the plant on the industry's own land, potentially through a subcontract with an external PV constructor;

OR

- Lease their land to an independent company, who will in turn handle the development, financing, and operation of the plant.

THEN

- A nearby community, close enough to be connected with the PV plant, applies for government support to run a transmission line.

Benefits:
This model, in particular, creates an additional revenue stream for the industrial operation—in the form of the energy they sell to the township. Such an approach would also advance national goals of rural electrification.

Downsides:
This model is not viewed as feasible for active mines, as it would represent a deviation from the core business of a mining company. Moreover, the industrial enterprise would have to undergo the time-consuming process of getting permits from Eskom, NERSA, and land management offices in order to construct the power

INDUSTRIAL POOLING MODEL

Actors:
Several industrial enterprises, all unconnected to the grid and currently entirely reliant on diesel generation for electricity, who decide to form a partnership to reduce their generation costs, potentially with a third-party project developer and systems operator.

Goals:
Develop a renewable generation plant to reduce their energy costs.

Potential Adoption Processes:
- This consortium of enterprises will together enter into a long-term Power Purchase Agreement (PPA) with shared distributed renewable energy assets.
- The industrial enterprises may choose, as a consortium, to adopt renewable energy via this model in one of two ways:

EITHER

- Develop, finance, and operate distributed renewable energy assets on one or more of the industries' own lands, potentially through a subcontract with an external PV constructor;

OR

- Lease their lands to an independent company, who will in turn handle the development, financing, and operation of the system.

Benefits:
This model would achieve greater economies of scale than the Self-Generation model, would create opportunities for increased renewable penetration through the development of a micro-grid, and would allow for the greater stabilization of a micro-grid by having multiple energy generation sources and a diversity of uses.

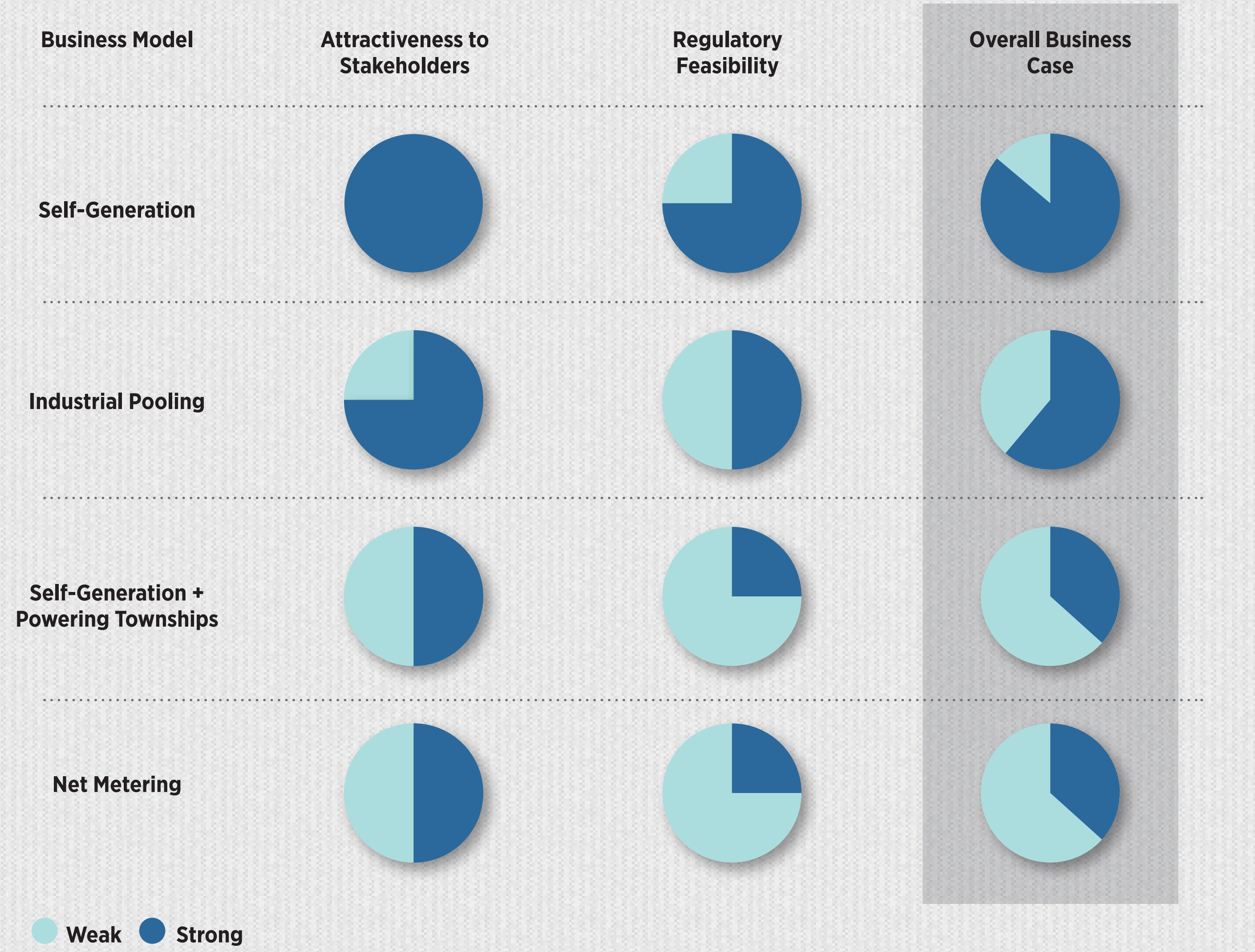
Downsides:
Although the sharing of capital costs and the creation of economies of scale are attractive, in practice this model faces several difficulties. In particular, mining firms have proven wary of undertaking joint capital projects with their competitors. Given their possibly divergent interests, and the uncertain lifespan of neighboring mines, negotiating such a deal would be challenging, and currently there is a lack of interest in devoting resources to such collaboration. No streamlined mechanism for structuring such agreements exists in South Africa today.

COMPARATIVE ASSESSMENT

Based on expert consultations, as well as a review of existing literature on distributed renewable generation, the mining sector, and the South African energy regulatory regime, the four models can be ranked according to their attractiveness to the relevant stakeholders (mining companies, mine operators, and renewable energy firms), as well as their regulatory feasibility, providing an overall assessment of the strength of the business case for each model. This assessment is shown in Figure 8.

According to the analysis of this report, Self-Generation—whereby a mining firm develops a solar-diesel hybrid plant independently or in partnership with an independent power producer—is the strongest, most feasible model from both a regulatory and economic perspective.

Figure 8: Assessment of Proposed Business Models



CASE STUDY: Cronimet Mining & Cronimet Mining-Power Solutions

About Cronimet

Cronimet Chrome SA (Cronimet), a subsidiary of Cronimet Mining AG, based in Switzerland, entered the South African chrome mining industry in 2008 through its acquisition of Platinum Mill Investment. In this transaction, the company acquired the rights to develop the Zwartkop Chrome Mine near Thabazimbi, Limpopo, and the firm began mine development shortly after the acquisition.

Under a business-as-usual approach, and because its remote location made it inaccessible to the power grid, the Cronimet "Zimbi" mine would have been reliant on 1.6 MW of diesel generation capacity to meet its annual power needs.

At an average cost of US$0.41 per KWh for diesel generation, this is far more expensive than purchasing energy from Eskom, which in any case is not an option for remote mines. Moreover, diesel prices are increasing on average by 12% to 20% a year (See Figure 9), with the potential for major shocks—for example, diesel prices more than doubled between April 2009 and March 2011, from US$0.61 per liter to US$1.36 per liter (AA 2013). As a result, diesel fuel is the single largest operating expense for off-grid mines, and unpredictable price spikes can erase profits.

Cronimet's Renewable Project

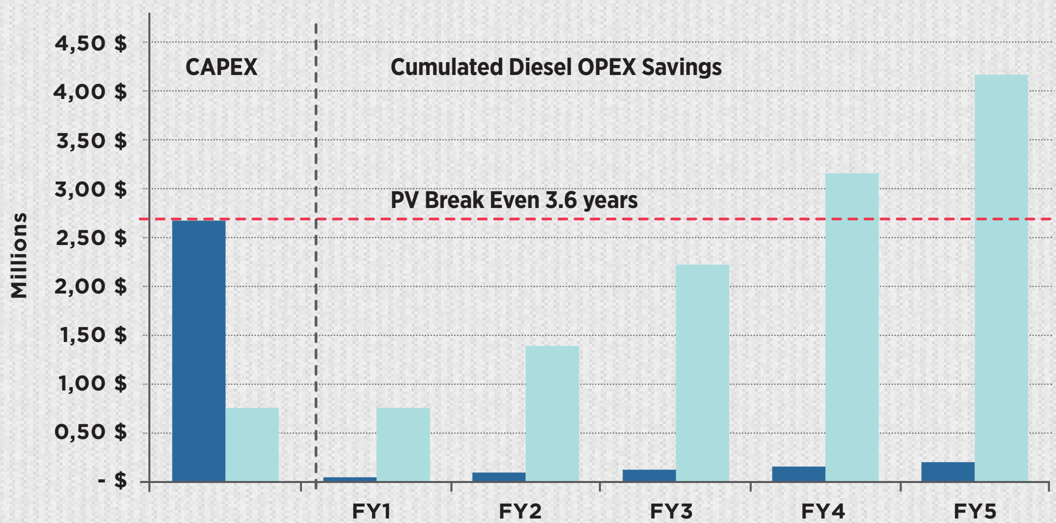
This volatility in the price of diesel, along with sustained decreases in the price of solar panels, motivated Cronimet to explore the feasibility of developing an on-site PV facility for the Zimbi mine, particularly in light of the high solar irradiation enjoyed by the mine's location. Following the Self-Generation model outlined earlier, the mine elected to develop, finance, and operate a solar-diesel hybrid system on their own land, in partnership with Solea Renewables Ltd., a South Africa-registered engineering, procurement and construction (EPC) firm.

Through its German parent company, Cronimet secured a 4.5%, US-dollar-denominated loan from Deutsche Bank and the German Reconstruction Credit Institute (KfW) to cover the US$2.66 million in CAPEX required for the construction of the plant, which used 4,158 PV panels and 63 decentralized three-phase inverters produced by SMA.

In November 2012, Cronimet completed their 1 MW PV facility, which will produce about 1.8 GWh of electricity annually, or about 60% of the mine's annual daytime power needs. The mine will continue to run one back-up diesel generator to stabilize the captive hybrid mini-grid during the day, and will depend fully on diesel for its energy needs at night. Over the year, the PV plant will replace approximately 24% of the mine's annual diesel consumption, significantly lowering the mine's total operating expenditure.

At the time of this project's development it was not deemed cost-effective or technologically feasible to invest in any storage capacity, which capped the PV power penetration ratio to 60% of the installed diesel-generation capacity. However, Cronimet Mining-Power Solutions is currently simulating the economic feasibility of adding both battery packs and additional solar generation capacity to this plant in order to further offset diesel consumption. Recent assessments indicate that such developments would also be economically attractive today.

Figure 9: Simple Breakeven for Cronimet's Solar-Diesel Hybrid System

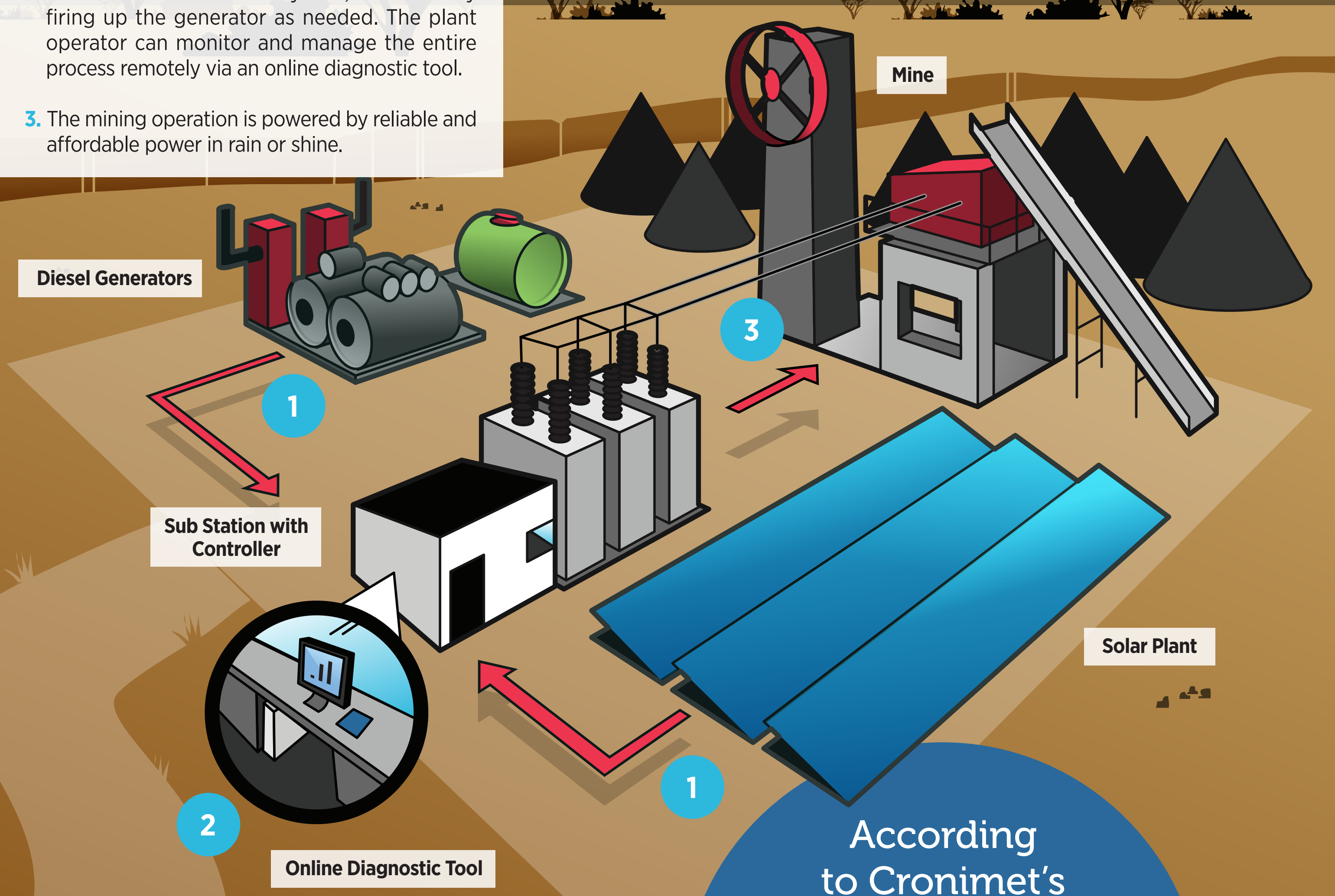


Diesel gensets	2 x 800 kVA
PV Plant	1000 kWp
CAPEX	$2.66 million
O&M	1% of CAPEX
Diesel Price 2012	**$1.15/liter**
Diesel Inflation p.a.	12%

Source: Cronimet Mining-Power Solutions, 2013.

Solar-diesel hybrid systems have several key components: a solar plant, a backup diesel generator, and a substation with advanced and automatic ICT controls. These components are integrated in a three-step process.

1. The solar plant generates the bulk of the mine's electricity, while the diesel generator is kept on standby for moments when either sunlight is low or the mine's demand exceeds the solar plant's generating capacity. Both the solar plant and diesel generator contain sensors that are wirelessly interfaced with the control device.
2. The sub station with controller monitors the mine's energy supply and demand to optimize the function of the whole system, automatically firing up the generator as needed. The plant operator can monitor and manage the entire process remotely via an online diagnostic tool.
3. The mining operation is powered by reliable and affordable power in rain or shine.



According to Cronimet's analysis, the project will yield a NPV of $2.3 million over 20 years, assuming an 18% discount rate.

Cronimet's Results

From concept to commissioning, this project took just six months to complete, with three months for technical planning and development and two months for financing the project (which ran parallel to the technical planning), and just three more months for construction.

As result of the addition of a 1 MW solar plant, which was synchronized to the existing diesel gen-set mini-grid with the assistance of SMA's Fuel Save dynamic control system, Cronimet is achieving an annual reduction of 450,000 liters in diesel consumption. Taking into consideration annual diesel fuel price inflation, Cronimet will realize a simple payback on their system in only 3.6 years—an exceptionally short amount of time for a solar project, as shown in Figure 9 on page 23. The attractive financials for this project can be attributed to three main factors: 1) optimization of solar penetration by using a programmable logic control (PLC) technology, which was supplied by SMA; 2) having Solea Renewables, now Cronimet Mining-Power Solutions, as an experienced EPC contractor able to expedite the entire solar-diesel hybrid system planning, engineering, procurement, construction and commissioning phase, and, moreover, to serve as a single risk-wrapped and turnkey point of contact for the mine; 3) the relatively low cost of capital for the loan secured by Cronimet.

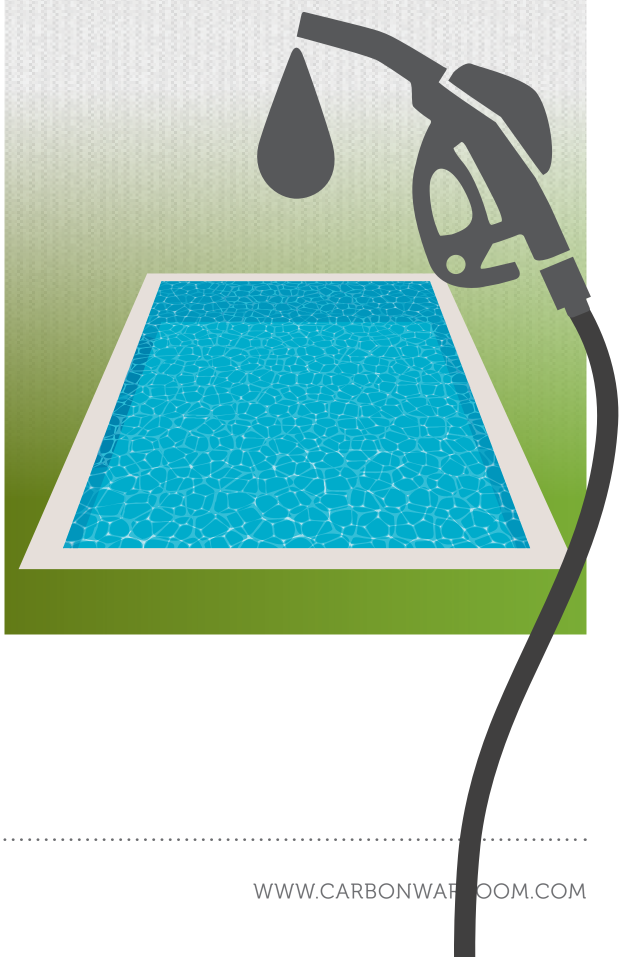
A deeper look at the financials of this project reveals that beyond the projected simple payback period, Cronimet stands to save millions by reducing its diesel consumption over a 20-year period. At an average price of $1.15 per liter of diesel, the mining operations will save up to US$500,000 in the first year alone. Even if the mine ceases output due to either shifting economics (the price of chromite may decline, making further extraction and transport to Durban for shipping unfeasible) or the mine becoming unproductive (many mines do not last 20 years), electricity will still be needed on the site for years to come in order to fulfill South Africa's requirements for land remediation.

The development of the PV facility also confers significant GHG emissions savings to the mining operation. The use of solar energy will allow Cronimet to save 450,000 liters of diesel annually, resulting in an approximate 1,200-ton annual abatement in CO_2—an amount equivalent to taking 235 passenger cars off the road per year (EPA 2011; Cronimet Mining-Power Solutions 2013).

Cronimet Mining AG deemed this project to be so successful that they have since acquired Solea Renewables, the firm that oversaw the construction of the solar PV plant at Cronimet's mine in Thabazimbi. The firm is now called Cronimet Mining-Power Solutions GmbH, and has its headquarters outside Munich, Germany.

Cronimet Mining-Power Solutions GmbH offers turnkey EPC and financing services to other mines and industrial companies worldwide that seek to replicate this successful model and develop solar-diesel hybrid systems of their own. In particular, the firm assists its clients with arranging financing for their hybrid power plants or even for the electricity itself. The most innovative and contemporary of these financing solutions that they offer today is a "swap agreement," in which electricity is distributed to the client in exchange for the delivery of metal ore. This type of approach is known by Cronimet as a Power Purchase Metal Swap Agreement (PPMSA), and it has the advantage of taking local currencies out of the equation entirely, thereby further helping clients hedge against risk.

As result of the addition of a 1 MW solar plant, Cronimet is achieving an annual reduction of 450,000 liters in diesel consumption - enough diesel to fill 8½ average swimming pools a year.



Challenges & Opportunities

While technical capacity remains a challenge, successes like Cronimet's will help to increase familiarity with such approaches among the mining industry as a whole, and will develop greater technical capacity for such projects in South Africa and the surrounding region.

In spite of the potential demonstrated by Cronimet and Cronimet Mining-Power Solutions, globally, only a few other mining companies with off-grid operations have considered investing in renewable energy to power their operations, and fewer still have moved forward into project development. Most of these developments have used the Net Metering approach, in areas where such a model works under the regulatory regime, such as northern Chile. Rio Tinto has also developed a wind-diesel hybrid system in Lac de Gras, Canada at their Diavik diamond mine, 140 miles south of the Arctic Circle.

The lack of more widespread use of such systems for powering off-grid mines is partially due to the fact that they are relatively new and more complex than utility-scale renewables or rooftop solar. While renewable energy technologies are decades old and well proven, the advanced controllers that allow for reliable integration with diesel gen-sets at high penetration levels are a more recent technological development.

In any case, there are still other challenges that must be addressed in order to increase the deployment of distributed renewable energy systems for off-grid mining, particularly securing financing and lack of technical capacity.

Finance

Financing distributed renewable energy projects continues to prove challenging due to the small size of the projects, the risky nature of the investment—which is caused by both volatility in commodities prices and the uncertain lifespan of mines—and the risk profile of investing in many of the regions where off-grid mines operate.

In the case of Cronimet, the Thabazimbi Chrome Mine was able to rely on the considerable assets of its parent company to raise funds, thereby overcoming this challenge and making the development of its project feasible. Companies that lack such an option may find it more challenging or otherwise more expensive to raise the needed capital for covering the initial expense if they are also unwilling or unable to finance such a development on their own balance sheet. Innovative firms like Cronimet Mining-Power Solutions are responding to this challenge by offering mining clientele the option to either purchase the power plant or the electricity with the metal ore they extract, rather than other forms of capital.

The Self-Generation model, in particular, will face challenges in areas where diesel fuel is subsidized. The authorities who oversee programs supporting rural electrification could be brought to bear in a greater push to end such fossil fuel subsidies, or otherwise in shifting towards a model whereby subsidies support initial investment and not ongoing fuel costs.

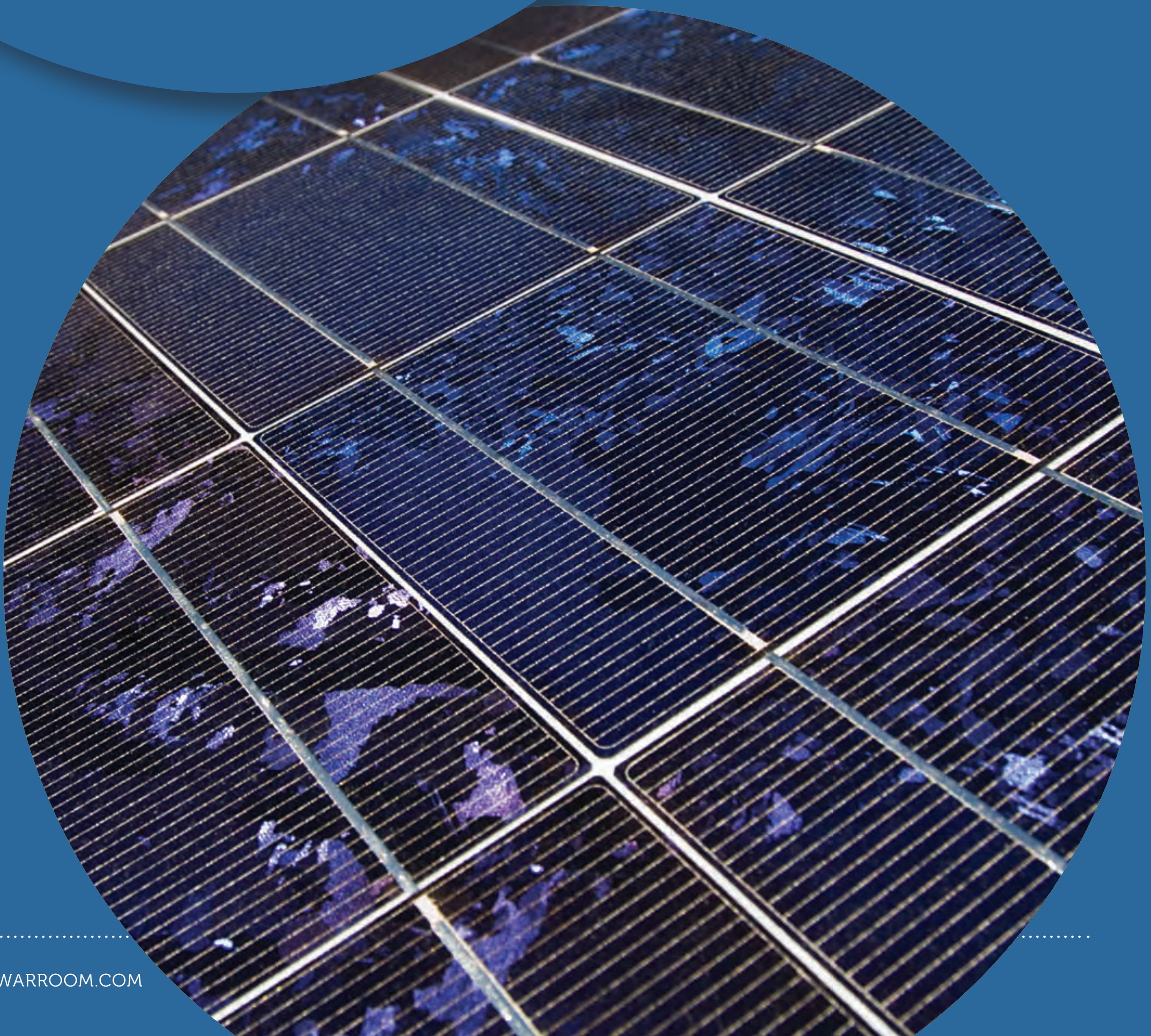
Technical Capacity

Historically, diesel generators have been the most cost-effective method for powering off-grid operations. Until recently, most South African mines did not even consider the option of generating their own renewable electricity, given that large mining operators had abundant access to cheap power, whether from the grid or from cheap diesel fuel. Eskom has long been able to lobby for policies that discouraged independent power production, while mining firms and local contractors in South Africa lacked the technical capacity to develop and implement distributed renewable energy projects.

There is an additional risk associated with the development of solar-diesel hybrid systems in rural areas, as often the technical capacity to fix them is not available on site, and components can be costly to procure, with long delivery times. A big part of the challenge with scaling up the use of such systems will be to familiarize plant managers and their electrical engineering teams with these systems.

While technical capacity remains a challenge, successes like Cronimet's will help to increase familiarity with such approaches among the mining industry as a whole, and will develop greater technical capacity for such projects in South Africa and the surrounding region. As additional early adopters of distributed renewable energy are able to demonstrate their results, knowledge of and interest in renewables projects should grow rapidly. The promise of these technologies and business models is such that some in the mining industry have even begun to develop new businesses around sharing their knowledge of project development, as in the case of Cronimet and Cronimet Mining-Power Solutions

Conclusions



The Self-Generation model illustrated in this report represents a promising opportunity for mining operators in South Africa and beyond, as well as for other heavy industries. Considering the importance of the mining industry in this region, targeting mines as early adopters of renewable energy sources could have a "ripple effect" across the economy and open the door for the greater adoption of renewable energy. Overall demand for electricity in Sub-Saharan Africa is expected to increase steadily in coming years. The mining industry in particular, and its associated energy needs, is likewise predicted to grow in coming years, despite decreased profitability.

As a result, industry focus has shifted from "maximizing value by increasing production volumes, to maximizing returns from existing operations from improved productivity and efficiencies" (PwC 2014). Implementation of renewable energy into the energy portfolio of off-grid operations can help reign in energy costs and should therefore be a key approach for mining firms in coming years.

While Self-Generation is currently a very promising option, the other models analyzed in this report have potential as well. The Net Metering or Self-Generation + Powering Townships models would only require regulatory changes, at least in South Africa, in order to be feasible. Meanwhile, skyrocketing energy prices alone could motivate the private sector to explore the sort of collaboration among competitors required by the Industrial Pooling model.

Many of South Africa's neighboring states suffer from unreliable energy supplies, high rates of energy poverty, underdeveloped infrastructure, and weak or nonexistent renewable energy policy frameworks. As a result, they could benefit substantially from distributed renewable energy systems. While regional characteristics differ, solar-based renewable energy pursued via the Self-Generation model profiled in this research has strong potential across Africa, reducing carbon emissions and strengthening the growth of a market for distributed renewable energy in the region. The mining sector offers a key entry point for the adoption of such systems, given its prominence in the region of Southern Africa, its relatively high energy needs, and the often remote or off-grid nature of its operations.

Although this analysis has focused on mining operations, the business model presented in this report could be applied to a range of other industries. Potential applications are found in forestry, agriculture, and the service industry (e.g. remote hotel resorts). For example, a 1.1 MW solar plant that will be integrated with existing diesel generation capacity to form a hybrid system is planned for a brewery in Namibia, following on the testing of smaller systems throughout Africa (Lena 2013; Donauer 2013). While these systems show tremendous promise, more will need to be done to overcome the financial and technical capacity challenges that prevent greater deployment.

In coming years, the use of solar-diesel hybrid systems should be a key focus for the international aid community, the various industries where such systems can be used, and the solar industry itself, as these systems show the greatest potential for developing the market for solar energy technologies in areas of the world with little or poor access to modern energy services, and for generally increasing solar's economic competitiveness in a global market.

Implementation of renewable energy into the energy portfolio of off-grid operations can help reign in energy costs and should therefore be a key approach for mining firms in coming years.

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ACRONYMS USED

ANC	African National Congress
CSP	Concentrated Solar Power
DOE	South Africa's Department of Energy
EPC	Engineering Procurement and Construction
Eskom	The Electricity Supply Commission is South Africa's public utility
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GWh	Gigawatt hour
INEP	Integrated National Electrification Program
IPP	Independent Power Producer
IRP	Integrated Resource Plan
kWh	Kilowatt hour
MWh	Megawatt hour
NERSA	National Energy Regulator of South Africa
NPV	Net Present Value
PPA	Power Purchase Agreement
PV	Photovoltaic
REBID	Renewable Energy Bid
REFIT	Renewable Energy Feed In Tariff
REIPPP	Renewable Energy Independent Power Producer Procurement Program
SAPP	Southern African Power Pool

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The Carbon War Room identifies and works in sectors where emissions can be reduced profitably, and where there are barriers preventing greater adoption of low-carbon solutions. Within these sectors, we launch Operations and collaborate with the sectors' stakeholders. The War Room's current Operations include Maritime Shipping Efficiency, Green Capital for Energy Efficiency in the Built Environment, Renewable Jet Fuels, Smart Island Economies, and Trucking Efficiency.

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