SUNSHINE FOR MINES

TOWARD SUSTAINABLE MINING

INSIGHT BRIEF

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HIGHLIGHTS

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- There is a major untapped opportunity for achieving carbon emissions reductions at the gigaton scale in the mining industry; the energy used by the industry represents anywhere from 1.25 percent up to 11 percent of the world's total energy consumption, depending on source.
- Extracting raw materials is necessary and energy intensive; doing so in a carbon-intensive manner is not.
- Considering current technology costs, every mining function except trucking can be electrified, from shoveling to the on-site movement of raw minerals.
- The hedge against fuel cost volatility may be reason enough alone to consider renewables from an economic perspective.
- By investing in sustainability, mining companies can secure "social license to operate," create new jobs in energy installation and services, and generate additional revenue streams for community improvement or local governments.

THE LARGEST ENERGY CONSUMER YOU'VE NEVER HEARD OF

The story of human civilization began with a human digging in the ground to find a suitable stone to cut into a tool. Since then, the life cycle of every physical product of human intelligence has originated with raw materials: grown via agriculture and livestock; harnessed, in the case of renewable energy; recycled from products no longer in use; or mined.

In contrast with the manual labor required for these primitive activities, up to and including early industrial times, today's mining industry is highly automated. Over the past century, mining has radically and continuously improved productivity and energy efficiency, with vast benefits in terms of both the economics of extraction and labor conditions. Yet mining and mineral processing are still extremely energy-intensive processes, and mining is an industry with many large consumers of energy. But because its activities are often removed from the public eye, and because the industry suffers from a variety of reputational woes, mining does not receive much attention as a great opportunity for decarbonization. Sunshine for Mines, a Rocky Mountain Institute-Carbon War Room program, was founded in 2014 to address the major, untapped opportunity for reducing carbon emissions at the gigaton scale that mining represents.

Today, serving even a fraction of the electricity load of a large mining site via renewable energy can mean adding tens of megawatts (MW) of new renewable capacity in a single project. Over time, this can lead to the displacement of an equivalently large amount of diesel-generated electricity and its associated carbon emissions. But, as is the case with all capital-intensive industries, the extractive industry moves slowly and cautiously. As the life of a mine and its equipment extends over several decades, which means it is poised to face—and must be able to withstand—several commodity and fuel price cycles, the case for new technology needs to be outlined very clearly and, most important, its economic viability and reliability must be proven before industry will adopt it.

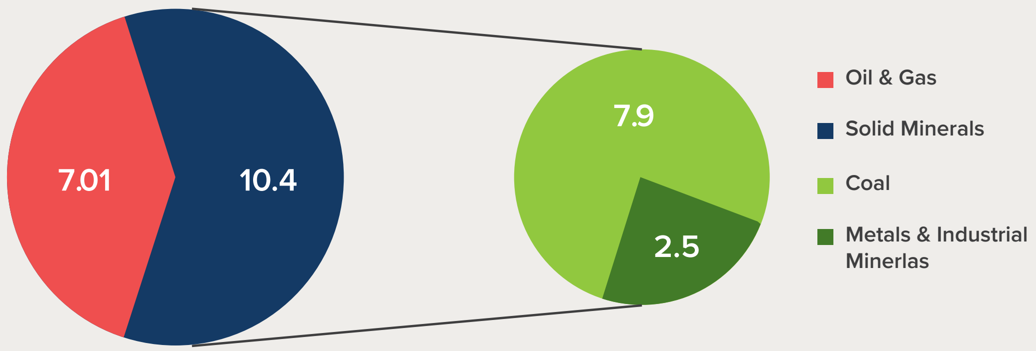
The current state of the industry—including its production methodology and its incumbent technologies—is a function of history. A strategic shift is required to a development path that would enable the industry to successfully meet the sustainability challenges of a world in which demand and population growth require improvements in efficiency and deployment of clean energy, while maintaining or growing the volumes of extracted minerals. These challenges looked like an intractable trade-off until the recent plunge in technology prices for renewable technologies, such as solar PV and wind energy, as well as various types of electricity storage. Thanks to falling costs, new energy solutions are emerging that enable both prosperity and environmental sustainability.

TACKLING NEGATIVE EXTERNALITIES IN THE EXTRACTION INDUSTRY

To approach decarbonization in the context of the extractive industry, it is indeed essential to recognize that without the physical commodities derived from it, we would be confined to a world of minimal economic and demographic growth. Although it is important to cultivate the concept of a circular economy, in which waste products are recycled and put back into value chains, addressing areas of opportunity within the existing realities of the extractive industry while simultaneously working to transform the industry is the most practical path for reducing carbon emissions.

Today, the extractive industry is overwhelmingly dominated by fossil fuel production: of the total 17.4 billion metric tons equivalent of mineral raw materials extracted in 2014,[1] a whopping 7 billion metric tons were oil and gas.[2] The mining industry is the subset of the extractive industry that deals with solid minerals (i.e., excluding oil and gas). The mining industry produced 10.4 billion metric tons of material in 2014, over three-quarters of which was coal, with the remainder being metals and industrial minerals (see Figure 1).

Figure 1: The Mining Industry as a Subset of the Extractive Industry



Note: Figures represent billions of tons equivalent of minerals extracted in 2014
Source: RMI, World Mining Congress

[1] For the purposes of this brief, "mineral raw materials" are defined as the sum of "mine output," (i.e., the portion of the total extracted material that has economic value, and the output of processing at or near the mines).
[2] International Organizing Committee for the World Mining Congresses, *World Mining Data*, Vol. 31, Minerals Production 2016, https://www.en.bmwfw.gv.at/Energy/Documents/WMD2016.pdf

Mining is a transformational activity; however, certain negative externalities can be made sustainable by channeling them in the right direction. A major and yet often unrecognized externality is carbon intensity, a consequence of the energy mix the industry currently uses, the off-grid nature of most mines, and the inherent energy intensity of the extractive process. It takes an enormous amount of energy just to mine minerals out of the ground and decouple them from their native chemical compounds in the ore.

As things stand, most of the required energy is produced by burning fossil fuels. Adding to this, many mining sites are in remote locations for which a capable electricity grid is not available. Consequently, mines tend to rely on the most readily available form of electricity generation, which unfortunately happens to be highly polluting and expensive: diesel fuel. And the mines that are connected to a grid do not escape carbon intensity either, as the electricity mix on the grid is dominated by fossil fuels.

ENERGY INTENSITY NEED NOT IMPLY CARBON INTENSITY

Even though extracting raw materials is necessary, doing so in a carbon-intensive manner is not. Low-carbon and carbon-free energy technologies are scaling quickly across the globe—they are projected to be 60 percent of the global increase in electricity output over the next five years—and are ushering in new opportunities for energy-intensive businesses to replace portions of their load with clean power, and hedge against costly fuel-price volatility.

So how would a large-scale decarbonization transformation affect the mining industry? On a global environmental scale, this is a function of the sheer amount of energy used in mining. In 2014, global energy consumption in the mining industry was almost 1,400 Terawatt hours (TWh).[3] For comparison, the total energy consumption of Spain was just above 1,300 TWh in the same year.[4] The energy used by the mining industry represents 1.25 percent of the world's total energy consumption, which was 110,000 TWh in 2014 (or 375 quadrillion Btu).[5]

To achieve decarbonization, it is necessary to first consider how energy is consumed at a mining site. Mining sites differ from one another in energy intensity as well as in the mode of generation of the energy, depending on the mineral extracted and on whether the operation is open pit or underground. Approximately 32 percent of the energy consumed at a typical mine is in the form of electricity,[6] which can either be generated on site or supplied through a grid connection. The remainder of the energy consumption is fossil fuel based, primarily in mobile equipment with diesel engines (drills, shovels, trucks, etc.). While most mines in the industrialized world are connected to an electricity grid, most of those located in remote sites in developing countries are entirely off grid, due to the distance from, or the absence of, a reliable grid. In all cases, a mine's energy load represents a significant burden on the electricity generation and delivery infrastructure. For example, a large mining operation can easily reach a peak load of 250 MW. This is comparable to the U.S. city of Boulder, Colorado (about 100,000 inhabitants), which is projecting a 257 MW peak demand in 2018.[7] Given this volume of demand, on-site renewable energy solutions for mining installations are becoming increasingly attractive to serve a significant portion of electricity load.

[3] Energy consumption includes energy losses (e.g., conversion into electricity) before final use. Therefore, it is equal to primary energy supply. The figures refer to energy consumption at the mining site and they are exclusive of off-site refining and transport.
[4] Enerdata, Global Energy Statistics Yearbook 2016. https://yearbook.enerdata.net/ Quoted as 113 Mtoe, where 1 Mtoe = 11.63 TWh.
[5] Quoted as 9425 Mtoe. IEA 2016. https://www.iea.org/publications/freepublications/publication/KeyWorld2016.pdf
[6] According to Mining Global. http://www.miningglobal.com/operations/1652/The-framework-for-reducing-energy-consumption-in-mining
[7] https://www.scribd.com/document/262103811/Boulder-wholesale-power-Request-For-Proposal

Another important dynamic that drives energy choices in mining is the degree of dependence on traditional methodologies adopted in underground and open-pit mining. For example, in both cases, material is moved along fixed routes, which do not change entirely, but rather expand in size and complexity with the development of the mine. Material movement accounts for about 40 percent of the total energy consumption of a mine; and it is typically conducted by diesel-fueled trucks. However, material movement along a fixed route can be achieved just as efficiently by a conveyor belt powered by electricity. All or part of such electrification may be supplied by renewable energy.

Even a cursory accounting of the energy demand at mines reveals that they are far from the ideal of an energy efficient, let alone environmentally sustainable, operation. A lot can be done to correct this. The mining industry should be considered a sector with significant and immediate opportunities in the quest for carbon emissions reductions.

HOW MODERN ENERGY ECONOMICS MAKES REDUCTION POSSIBLE

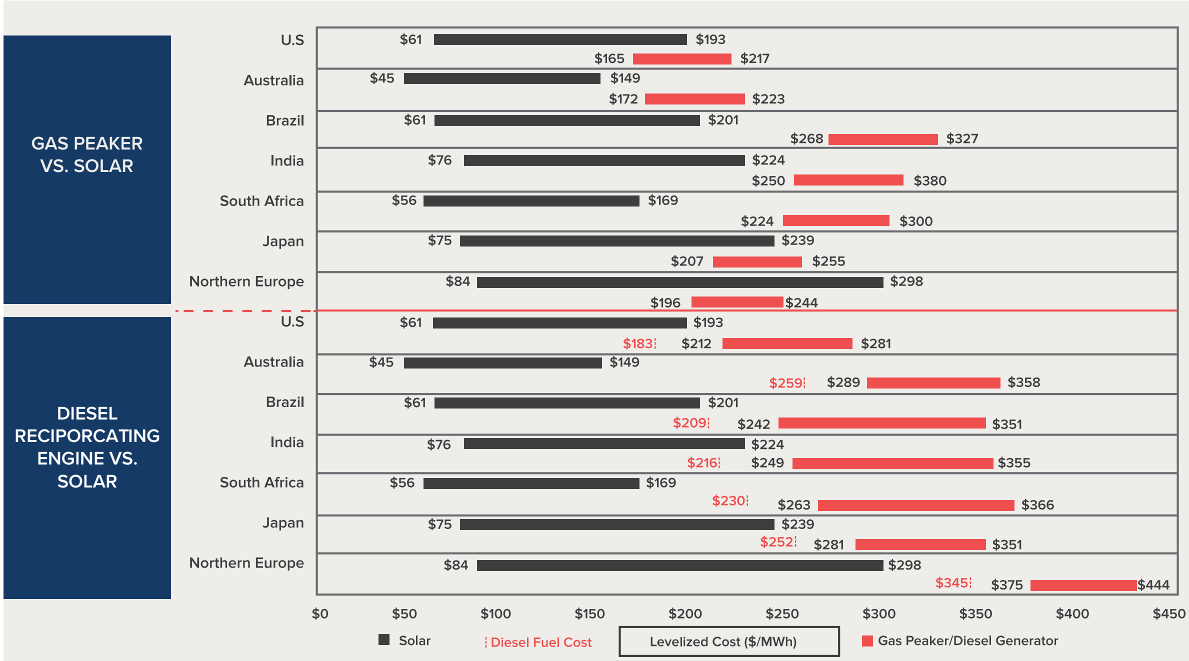
Thanks to advances in technology and finance over the past 5–10 years, the lifetime cost of energy generated by today's solar photovoltaics (PV) is now far lower than the cost of diesel generation. This means that building a new off-grid facility today can be done at lower cost with solar energy than with diesel. Intermittency and nighttime load can be served with a variety of strategies, including battery storage; but even assuming nighttime use of fossil fuels, both carbon intensity and, more importantly, costs will be reduced overall. Additionally, renewables bring benefits in terms of reduced risk exposure to the global oil market and diesel supply chain and increased reliability, albeit in a less dispatchable manner.

The key to unlocking viable low-carbon energy systems for mines has largely been the dramatic reduction in cost for renewable energy technologies and, to a lesser extent, battery and storage systems. Since 2009, the global levelized cost of energy (LCOE) for onshore wind has dropped by 66 percent, and global solar LCOE has dropped by 85 percent.[8] In the context of global power market pricing, these cost reductions have made wind and solar cost-competitive with fossil fuel-generated electricity, and in some cases wind and solar have even beaten low-cost coal and gas on a regional basis. This means that mining operators can lock in prices, either via on-site generation or long-term power purchase agreements (PPAs), at costs competitive with fossil fuel generation for as long as 25 years. The hedge against fuel cost volatility may be reason enough alone to consider renewables from an economic perspective.

A review of the levelized cost of energy for solar versus both centralized natural gas peaking plants and the diesel generation more commonly found at remote, off-grid mining sites reveals significant advantages for renewable generation (see Figure 2).[9]

[8] Lazard Levelized Cost of Energy 10.0 https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf
[9] Ibid.

Figure 2: Levelized Cost of Energy: Fossil Fuels vs. Solar



Source: Lazard Levelized Cost of Energy Study 10.0

REGIONAL SNAPSHOT:

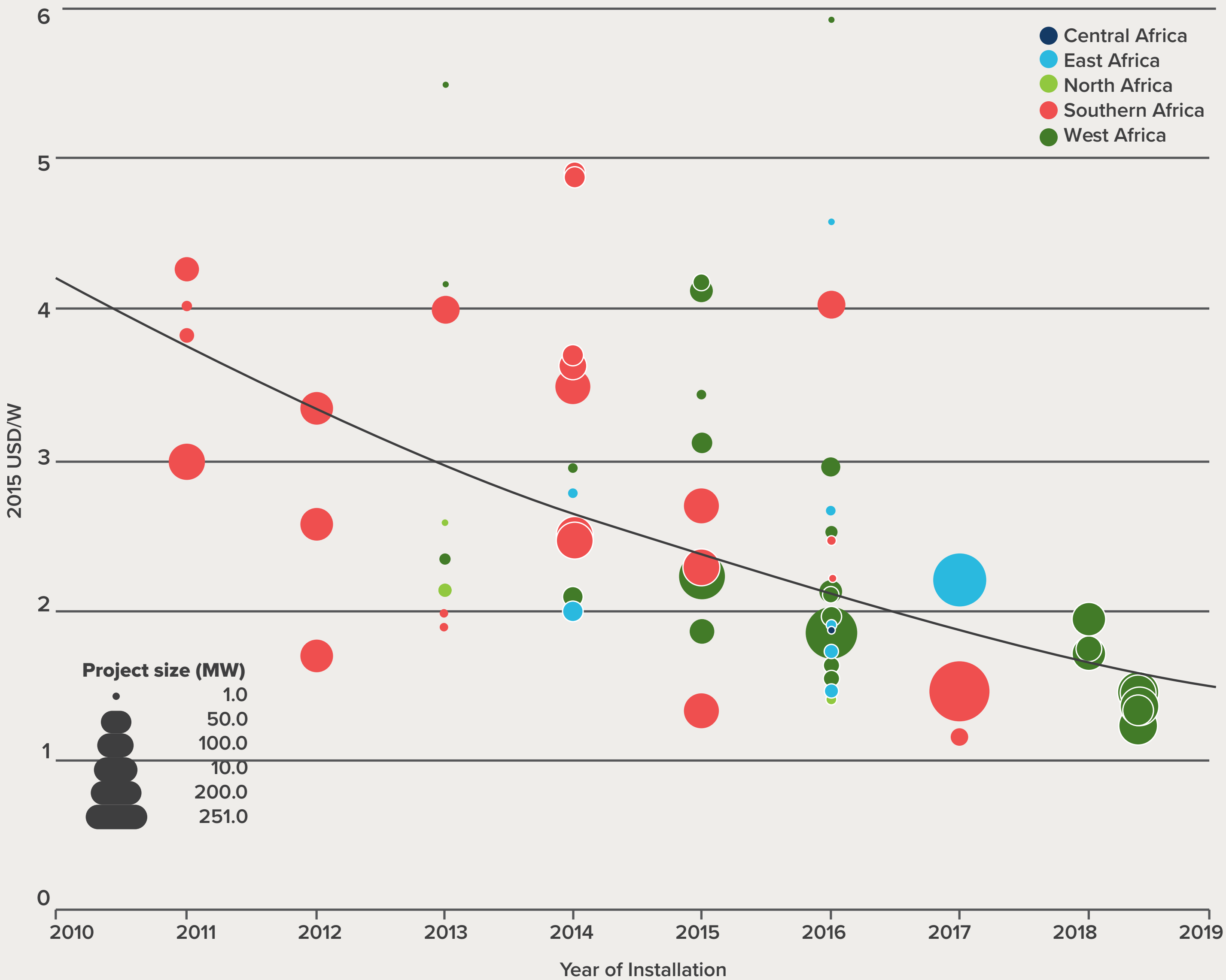
Sub-Saharan Africa—a testbed for on- and off-grid renewables integration

Sub-Saharan Africa is an especially interesting case study for the application of renewable energy, storage technologies, and microgrids in the mining sector. While the African continent is not the largest segment of the global mining industry, it is especially disadvantaged in terms of energy access. A McKinsey study titled *Powering Africa* notes that "[sub-Saharan Africa's] power sector is significantly underdeveloped, whether we look at energy access, installed capacity, or overall consumption....From an electricity-access point of view, sub-Saharan Africa's situation is the world's worst."[10] Seen through this lens, there is an especially strong case for mining firms' investment in low-cost renewables over the higher cost of modular diesel generation or grid infrastructure of varying reliability.

A 2016 study by the International Renewable Energy Agency (IRENA) found that, "New capacity additions of solar PV in Africa in 2014 exceeded 800 MW, more than doubling the continent's cumulative installed PV capacity. This was followed by additions of 750 MW in 2015. By 2030, in IRENA's REmap analysis of a doubling of the share of renewable energy globally, Africa could be home to more than 70 GW of solar PV capacity."[11] The study also estimated that installed solar costs for 2015 to 2016 to range from US$1.30/watt to US$4.10/watt—the lower bound being competitive with today's global average for utility-scale fossil-fuel powered electricity costs.

[10] *Powering Africa*, 2015 McKinsey & Co. http://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/powering-africa
[11] *Solar PV in Africa: Costs and Markets,* IRENA, 2016. https://www .irena.org/DocumentDownloads/Publications/IRENA_Solar_PV_Costs_Africa_2016.pdf

Figure 3: Operating and Proposed Utility-Scale Solar PV Project Installed Costs in Africa, 2011–2018

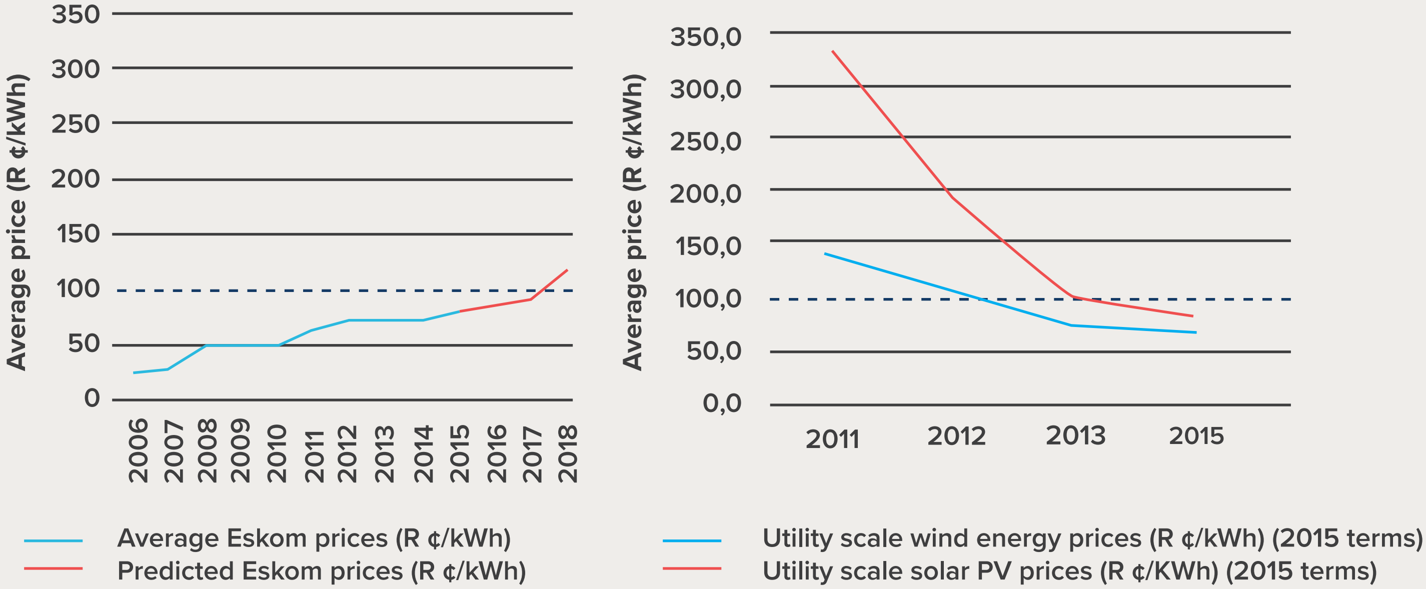


Note: Each circle represents an individual project. The center of the circle represents the value on the Y axis and the diameter of the circle represents the size of the project.

Source: IRENA

And even in regions with greater infrastructure development, renewables can still compete with grid-delivered electricity on cost. For example, in South Africa, a 2016 GreenCape Market Intelligence report demonstrated how falling wind and solar prices are now competitive with average utility-delivered (the utility was Eskom) power (see Figure 4).[12]

Figure 4: Average Eskom Price Trajectories Versus Utility-Scale Wind and Solar PV Tariffs



Source: Adapted from GreenCape (2017)

So, while Africa may not be a leading producing region in terms of total tonnage of raw materials for the extractive industry, it still offers some valuable lessons for mining operators across the world. The McKinsey study on Africa's power potential found that "by 2040, 26 percent of total capacity could come from clean sources (geothermal, hydro, solar, and wind), entirely through market forces."[13] With careful planning and accounting for continued cost reductions for renewables, the African energy markets will likely prove to be a valuable testbed for mining firms making the transition to on- and off-grid renewable energy solutions.

DRIVING SYSTEMIC CHANGE

What needs to be done, then? The dynamics determining how mines make energy decisions can offer important guidance for the most effective actions. First, mines that rely on off-grid solutions almost invariably rely on diesel generators for a significant portion of their electricity generation. However, given the range of generation options available today, this is likely no longer the most cost-effective system. For mines where the cost and the supply security of diesel are important factors, renewable energy has a fundamentally strong business case. As demonstrated in Figure 4, unsubsidized large-scale solar energy is already cost competitive with diesel generation anywhere in the world, and in the regions where solar competes with grid-power prices, solar is usually subsidized to the point of being cost competitive.

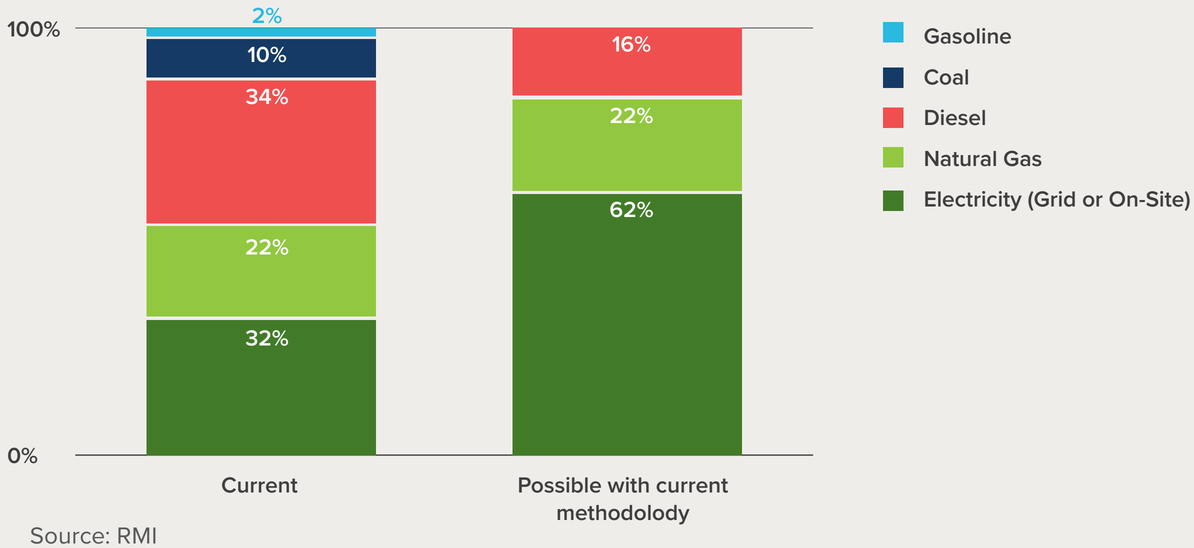
[12] Utility-Scale Renewable Energy Sector—*2016 Market Intelligence Report* GreenCape `http://internationalcleantechnetwork.com/wp-content/uploads/2016/02/Renewable-Energy-MIR-2016.pdf

[13] *A Brighter Africa*, McKinsey & Co., 2015. http://www.mckinsey.com/~/media/mckinsey/industries/retail/our%20insights/east%20africa%20the%20next%20hub%20for%20apparel%20sourcing/brighter_africa_the_growth_potential_of_the_sub%20saharan_electricity_sector.ashx

Moreover, mining sites have an opportunity to end their assumed role as a net user of energy, and instead take advantage of the fact that mines are frequently larger than their local grids. This fact enables not only a strategy to build on-site generation capacity, but also to generate more capacity than needed and connect to the local grid as a supplier, not a consumer. By serving a dual purpose to meet the needs of the mine and surrounding communities, renewable energy at mining sites can generate additional positive benefits in terms of social responsibility and community investment. This is, of course, in addition to the economic and environmental benefits of on-site renewable energy generation: providing the mine cheaper and cleaner forms of generation and using the local grid as a balancing tool that can offtake excess renewable generation and provide backup dispatchable generation at times of high load.

Taking advantage of these benefits will require systemic change across much of the mining sector's current energy applications. Specifically, there is a need to electrify a far greater percentage of the mining industry's existing energy load—to realize both the economic and carbon-reduction advantages of renewable electricity. Of all mining functions, only trucking presents a serious (but not impossible) challenge to electrification, given the menu of technology solutions available today. Every other mining function can be electrified, from shoveling to the on-site movement of raw minerals. By RMI's preliminary estimations, the average mine in the United States can convert an additional 30 percent of its existing energy load to electricity (see Figure 5).

Figure 5: Sources of Energy in U.S. Mines



Source: RMI

And large-scale electrification is just the beginning of a broader move toward the mine of the future. Unlike the science fiction promises of flying cars or other extravagant technology, decarbonization of the power sector is well underway worldwide. For the mining industry to fall behind in this transition will inevitably result in more costs—both economic and social—and a more difficult integration process for new energy technologies in the future. The bottom line for the power sector holds true for mining as well: The future is not fossil fuel-based.

ACCOUNTING FOR THE LESS TANGIBLE BENEFITS

Beyond value creation for mining companies themselves, a transition to renewable energy and sustainability offers benefits and opportunities for local communities. By investing in sustainability, mining companies can, for example, secure “social license to operate,” create new jobs in energy installation and services, and generate additional revenue streams for community improvement or local governments. These less tangible benefits fall into four key areas of opportunity:

- **Creating Shared Value:** By making a public investment in sustainability, companies are often able to create additional jobs for local communities through installation, systems maintenance, and local procurement and skills development. In its 2016 global renewable energy jobs report, IRENA specifically highlighted job creation opportunities in off-grid solar PV, noting “companies that build, install and maintain stand-alone systems are rapidly scaling up operations and creating jobs along the value chain.”[14] With mining companies looking to meet anywhere from 20 percent to 40 percent of their energy demand with renewables, these investments could lead to significant employment growth for local manufacturers, installers, and service providers.
- **Improving Community Relations:** Community integration can have a significant positive or negative impact on a mine’s social license to operate. Investments in site-based sustainability have initial public relations value, demonstrating a company’s commitment to the community’s well-being. But they also open the door to community integration of renewables and other technologies. For example, the global microgrid market is now estimated to top $35 billion by 2020.[15] Investing in microgrids could streamline electricity management for off-grid mining sites, while also bringing stabilized infrastructure to regions that currently lack reliable energy access. Likewise, community solar—co-owned solar installations—is growing rapidly in the United States, with GTM Research predicting community solar will reach 400 MW of installed capacity by the end of 2017.[16] Mining companies can offer a chance for local citizens to literally buy into sustainability efforts, generating clean power and additional revenues for the community. By aligning business interests with community interests for energy development, mining firms have a new and powerful tool for building social license to operate.
- **Mitigation of Climate Risks:** Beyond local communities, renewable energy investments can also offer direct benefits for national governments. Both the United Nations’ Sustainable Development Goals (SDGs) and the Paris Climate Agreement’s Nationally Determined Contributions (NDCs) include focus areas for renewable energy implementation. Governments in mining-heavy nations can demonstrate progress or leadership on SDGs and NDCs by supporting the transition to clean energy in the mining sector. As just one example, Chile has a national target of 20 percent renewable energy by 2025, which is included in its NDC to the Paris Agreement.[17] According to a 2015 study, the Chilean mining industry consumes 38 percent of all electricity produced in the country.[18] The opportunity presented by a transition to renewables in mining alone would be significant for the nation as a whole.

[14] *Renewable Energy and Jobs*, Annual Review 2016, IRENA. http://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Jobs_Annual_Review_2016.pdf
[15] "Global Microgrid Market Will Top $35B by 2020," *Utility Dive*. http://www.utilitydive.com/news/report-global-microgrid-market-will-top-35b-by-2020/412531/
[16] "America’s Community Solar Market Will Surpass 400MW in 2017," *Greentech Media*. https://www.greentechmedia.com/articles/read/us-community-solar-market-to-surpass-400-mw-in-2017
[17] Intended Nationally Determined Contribution of Chile Towards the Climate Agreement of Paris 2015. http://www4.unfccc.int/Submissions/INDC/Published%20Documents/Chile/1/INDC%20Chile%20english%20version.pdf
[18] Energy Use in Premanufacture (Mining), 2015. http://ac.els-cdn.com/S2212827115005107/1-s2.0-S2212827115005107-main.pdf?_tid=0ae033c2-2f75-11e7-ba85-00000aacb35f&acdnat=1493756719_49f2364f1e2ec1c21c2ecd8e8b7cf62a

- **Closure and Post-Closure:** Operating mines creates significant energy demand, but ongoing production is not necessary to produce value via energy production. Renewable energy production on legacy mining sites takes advantage of all three of the preceding areas of opportunity: It sustains local communities, generates revenue for meeting remediation or reclamation costs, and provides ongoing climate mitigation by displacing fossil capacity in either on-grid or off-grid regions.

As we can see, sustainable mining can and should be considered as part of a holistic business strategy that not only considers energy economics or systems flexibility, but also less tangible benefits.

SUSTAINABLE MINING IS NO LONGER SCIENCE FICTION

With the cost of solar and wind energy reaching parity with grid-supplied electricity and diesel generation, the economic incentives to deploy low-carbon electricity technologies are aligning for energy-intensive industries like mining. While a true zero-carbon mine may still be years away, the immediate benefits of renewable energy are available today through on-site and off-site generation and energy storage.

To put this back into numbers: 32 percent of all energy consumed in mining today is already electricity, equal to 434 TWh on an annual basis, corresponding to 58 GW of capacity. In order to substitute this primarily fossil-based capacity with renewable energy, one would need around 180 GW of renewables, given the lower capacity factors of renewable assets.[19] Of these, only about 1 GW is already in the ground, and another 1 GW is in the pipeline of existing mining projects.[20]

The transition to renewables needs to pick up speed, and it will take virtuous and courageous leadership for this to happen. Sunshine for Mines is facilitating an accelerated process for mines to adopt renewables, and catalyzing industry growth to reach a total of 8 GW of renewable capacity in the ground across the mining sector by 2025. We do this by consulting with existing mines to clean their supply through the feasibility and procurement stages, and by exploring innovative concepts such as how electrification and load flexibility can be practiced at mining sites. We are also pushing the idea of the repurposing of closed mining sites into renewable energy facilities, to maximize the useful life of the land with clean energy production. The race is long but, on a plant-lifetime basis, the economics speak loud and clear in favor of renewable energy.

ABOUT ROCKY MOUNTAIN INSTITUTE
Rocky Mountain Institute (RMI)—an independent nonprofit founded in 1982—transforms global energy use to create a clean, prosperous, and secure low-carbon future. It engages businesses, communities, institutions, and entrepreneurs to accelerate the adoption of market-based solutions that cost-effectively shift from fossil fuels to efficiency and renewables. RMI has offices in Basalt and Boulder, Colorado; New York City; Washington, D.C.; and Beijing.

[19] Typical utilization of a conventional fossil-fuel generating asset is ~85 percent, while the capacity factor of renewable assets (wind and solar PV) is closer to ~30 percent.

[20] As a recent study reports, 943 MW of renewable energy capacity are currently installed on mining sites globally. *Energy & Mines Global Rankings 2016*. http://energyandmines.com/2016/10/943-mw-of-renewables-currently-powering-mines-with-more-on-the-way-experts-say/