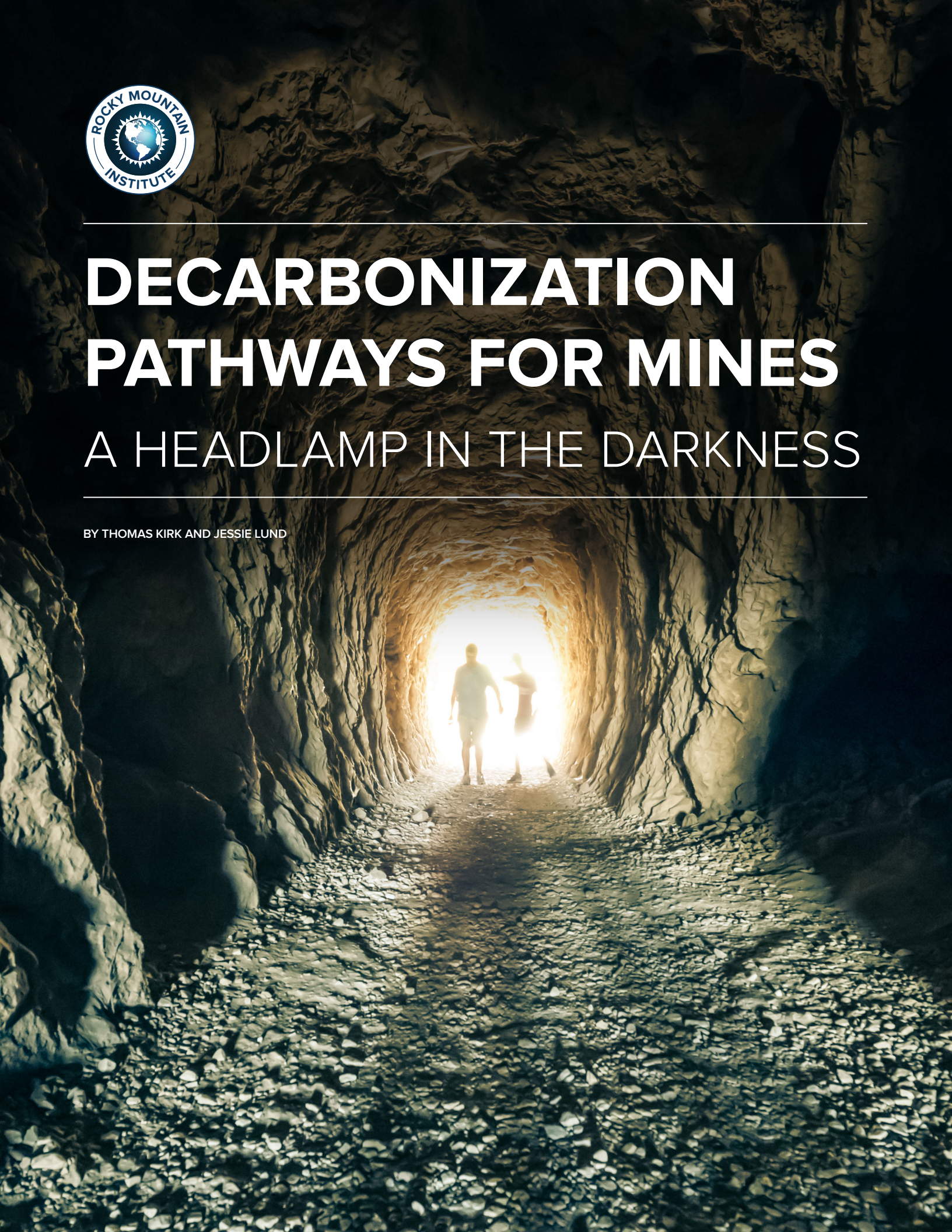


DECARBONIZATION PATHWAYS FOR MINES

A HEADLAMP IN THE DARKNESS

BY THOMAS KIRK AND JESSIE LUND

AUTHORS & ACKNOWLEDGMENTS

AUTHORS

Thomas Kirk and Jessie Lund

** Authors listed alphabetically. All authors from Rocky Mountain Institute unless otherwise noted.*

CONTACTS

Paolo Natali, **pnatali@rmi.org**
Thomas Kirk, **tkirk@rmi.org**

SUGGESTED CITATION

Kirk, Thomas and Jessie Lund. *Decarbonization Pathways for Mines: A Headlamp in the Darkness.* Rocky Mountain Institute, 2018. **https://info.rmi.org/pathways_for_mines/**

EDITORIAL/DESIGN

Editorial Director: Cindie Baker
Editor: David Labrador
Creative Director: Romy Purshouse
Design: Chang Fu
Images courtesy of iStock unless otherwise noted.

ACKNOWLEDGMENTS

The authors wish to thank the following individuals for offering their insights and perspectives on this work:

Nicky Black, International Council on Mining and Metals
Paul Taylor, International Council on Mining and Metals

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.

ABOUT SUNSHINE FOR MINES

Sunshine for Mines, a program at RMI, rapidly accelerates the installation of on-site renewable energy capacity—especially solar photovoltaics (PV)—integrated into the power systems of on- and off-grid mines around the world. Sunshine for Mines works with mining companies to provide assistance with energy strategy, feasibility assessments, and procurement.

INTRODUCTION

Climate change is a real and serious threat that requires substantial effort to address. Global carbon emissions continue to rise. In fact, since 1850, global CO_2 levels have risen over 30%, from 284 ppm to ~408 ppm in 2018.[1] This increased concentration comes from the roughly 35 billion tons of CO_2 that are released into the atmosphere annually, primarily through human activity.[2] Moreover, while annual emissions held roughly stable from 2014 to 2016, they are expected to have risen again in 2017.[3] It is clear that if we are to meet the goal of the Paris Agreement—to limit global warming to 2°C—urgent action is required from all sectors.

The mining sector in particular must engage around solutions. A recent report by CDP (formerly known as the Carbon Disclosure Project) shows that in 2015, half of worldwide industrial greenhouse gas emissions could be traced back to just 50 companies (called carbon majors) working in heavy fossil fuel industries.[4] Mining companies, particularly those involved in coal extraction, ranked high on the list, taking two of the top five spots, and 20 spots overall.[i] Therefore, meeting the goal of the Paris Agreement will require these companies to significantly reduce the amount of CO_2 they release and, in some cases, the types of resources they extract.

Many mining companies are making progress toward decarbonization, but their focus has primarily been on incremental targets instead of planning with the desired end in mind. Mining companies should target the carbon reduction necessary to keep global warming below 2°C. There are many strategies that can advance this goal, including leveraging new technologies and innovations to add renewables to electricity supply, improving mining processes, switching from fossil fuels to renewable fuels, reducing waste, and optimizing transportation. Mining companies need to evaluate these options internally and choose the most beneficial and cost-effective approach for their unique circumstances, but every plan must have an appropriate target as well as public disclosure of progress.

Companies involved in natural resource extraction and refinement are uniquely positioned to both benefit from and suffer from society's response to climate change. On the one hand, global demand for many metals and minerals is increasing as developing nations rapidly modernize and certain industries, such as electric vehicles, batteries, and solar photovoltaics (PV), gain momentum.[ii, 5] Mining companies will play a critical role in the energy transition, providing the raw materials needed to grow these nascent industries. On the other hand, they are vulnerable to both societal pressure and policy changes. In addition, there is a tendency to exploit more remote and inaccessible mineral and ore bodies as the sites with easier-to-reach resources are mined and emptied first. Many remote mining regions will also be among the first to experience the negative impacts of climate change, such as more frequent and more severe extreme weather events. To date, technology has provided the mining industry with incremental efficiency gains, but this confluence of trends means that the industry will need to dramatically reduce its carbon intensity in order to lower its absolute carbon production and meet both regulatory mandates and societal pressures.

The purpose of this report is to discuss the behavioral, policy, technological, and regulatory changes needed to drive the mining industry's carbon reductions. The first section assesses how the mining industry is performing with respect to reducing its carbon

[i] Three International Council on Mining and Metals members made the list as well.

[ii] The metals that will likely be needed for the low-carbon transition include copper, silver, aluminum (bauxite), nickel, zinc, neodymium, and indium, among others.

emissions, and points out problems with current measures and data tracking. The second section identifies areas, processes, and technologies with high carbon-reduction potential for mining companies. The report concludes with a discussion of the corporate governance and strategy needed to lead these changes.

The initial analysis focuses on the 27 members of the International Council on Mining and Metals (ICMM), while the latter sections introduce solutions from the mining industry at large. The ICMM is "an international organisation dedicated to a safe, fair and sustainable mining and metals industry." The goals of the ICMM are to strengthen environmental and social performance and serve as a catalyst for change, enhancing mining's contribution to society.[6] ICMM members were selected for this analysis because they provide a large cross-section of the mining industry in both geography and resources extracted, represent almost half of the global mining industry by value, and are committed to reducing carbon emissions.

CURRENT STATUS

For this paper, the mining companies are evaluated only on their scope 1 (direct) and scope 2 (purchased or acquired electricity, steam, heat, and cooling) emissions. Scope 3 emissions (indirect emissions that occur in company's upstream or downstream value chain) for resource extraction companies are roughly 10 times as large as their scope 1 emissions (the bulk of their scope 3 emissions generally result from downstream use), but are often not as well tracked as scope 1 and 2 emissions by their emitting companies.[iii,7] Scope 3 also raises a difficult policy question, namely, who should pay for the cost imposed by those emissions.

There are inherent challenges to doing this type of analysis that need to be stated up front. The data presented does not account for divestments or mergers (except in the case of BHP), looks only at the most recent years available, and does not attempt to normalize for differences in the resources or activities that companies pursue (e.g., what they are extracting and how much downstream processing they are involved in). The results and relative rankings are not meant to imply any company is ahead or behind on any carbon reduction goal, but instead represent a snapshot of the industry at this time. Specific challenges involving individual metrics are discussed throughout, and an overview of existing target-setting approaches is provided.

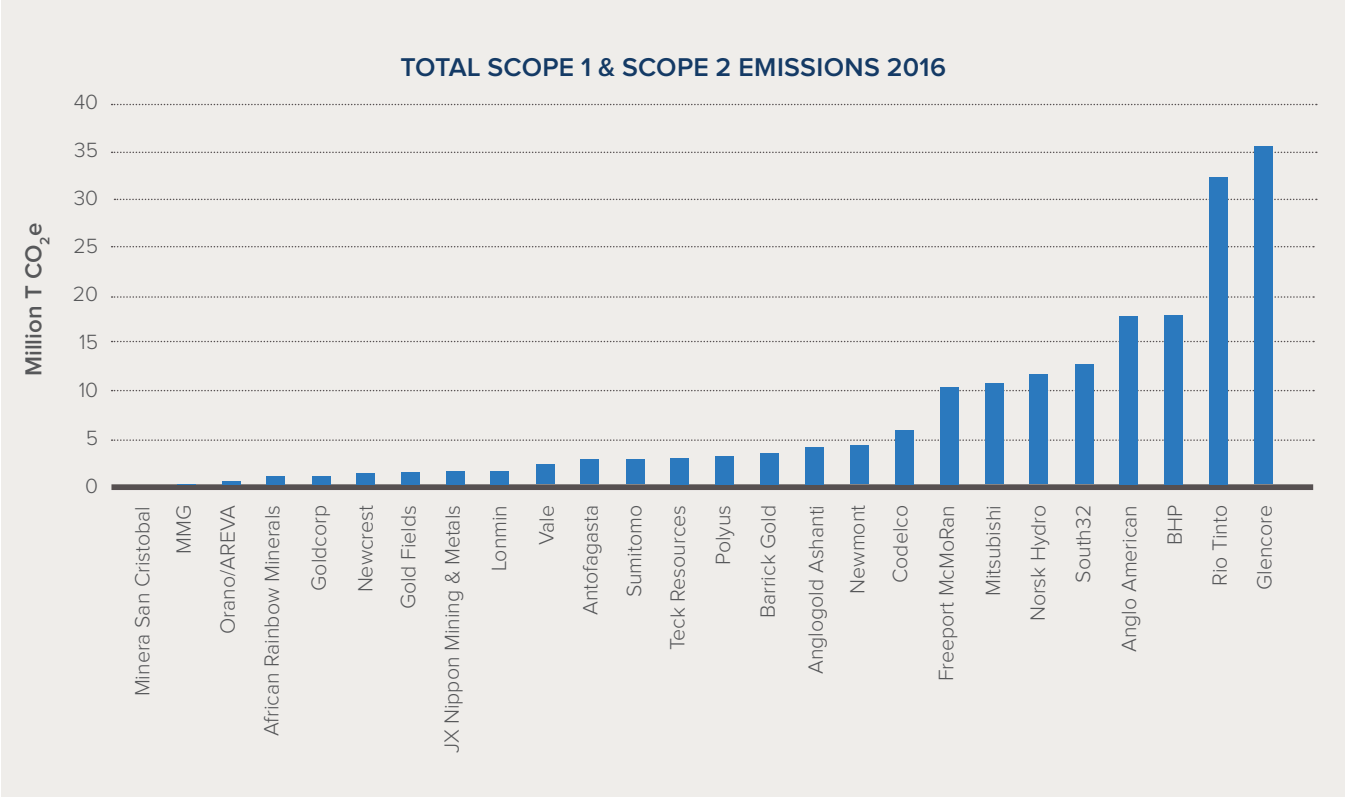
Emissions can be reported in absolute terms (total CO_2-equivalent emissions, or CO_2e) and intensity terms (CO_2e per unit), both of which are important for different reasons. Over time, both metrics will need to come down considerably across the industry to be in line with anticipated required emissions reductions. Absolute emissions metrics are good for comparing mining to other industries and for getting an overall sense of the mining sector's emissions. However, on an individual-company level, absolute metrics can be misleading because a company improving its efficiency but growing rapidly may still increase its overall emissions.

[iii] The size of this ratio varies considerably, with coal companies typically having even higher relative scope 3 emissions than metal and mineral companies.

The absolute emissions for the ICMM members in 2016 were:

FIGURE 1

TOTAL SCOPE 1 AND 2 EMISSIONS OF ICMM MEMBERS IN 2016[iv]



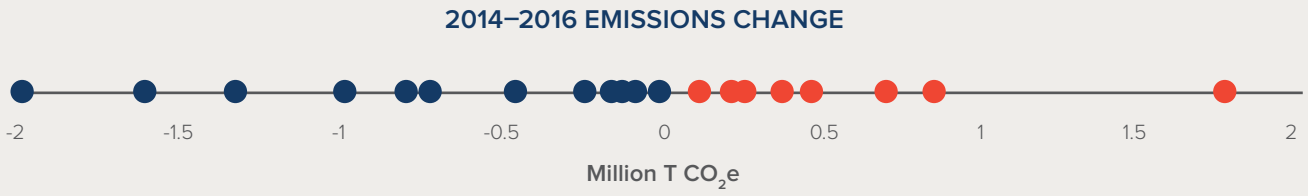
[iv] 2016 is the most recent year for which most members have publicly reported emissions data. 2017 data was not yet widely available at the time of this analysis.

ICMM members have a large amount of variation in their total carbon emissions, from just over 35 million tons of CO_2e to well below 1 million tons, with a standard deviation of 9.2 million tons.[v] The emissions are fairly concentrated, with the top five companies producing ~61% of the total emissions of all members. Until 2016, BHP would have led with the highest total emissions, but following its demerger from South32 in 2015, its total emissions decreased dramatically (down by 27 million tons from 2014 to 2016).

Looking at the change in emissions from 2014 to 2016, we can see that 14 members decreased their total emissions, 10 increased, and three did not have enough data:[vi]

FIGURE 2

TOTAL EMISSIONS CHANGE AMONG ICMM MEMBERS, 2014–2016

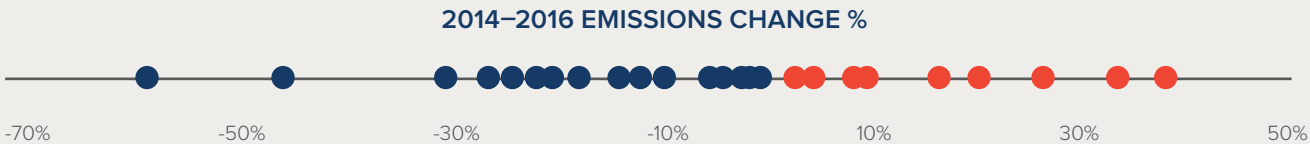


Note: BHP is not shown on this chart to avoid a scaling issue.

Most of these changes appear small; only six were greater than 1 million tons in either direction. However, normalizing for the size of the company and looking at the percentage change shows that some of these shifts are very significant, especially for smaller mining companies:

FIGURE 3

PERCENTAGE EMISSIONS CHANGE AMONG ICMM MEMBERS, 2014–2016



[v] Mean: 7.3 million tons, median: 3.1 million tons.

[vi] The period 2014 to 2016 was selected based on the availability of annual emissions data.

Of the 10 companies that decreased their total emissions by more than 10%, five had total emissions of less than 3 million tons in 2016. Similarly, of the four companies that increased total emissions by more than 20%, all had total 2016 emissions of less than 3 million tons.

A company's absolute emissions metrics will vary when it grows or shrinks or is subject to market forces such as the 2008 economic crisis or commodity price cycles, for reasons that have nothing to do with its environmental performance. Intensity metrics, such as CO_2e per ton of ore mined, are more meaningful because they represent how carbon-efficient a company is, that is, how much it is able to accomplish per unit of CO_2e. Intensity metrics are useful for companies that want to measure their own efficiency performances over time and to make direct comparisons with similar companies extracting the same resource. However, some types of ore or metal are intrinsically easier to mine carbon-efficiently, which means a simple intensity metric—like CO_2e per ton of ore mined—doesn't allow for an apples-to-apples comparison of environmental performance. Because ICMM members mine a variety of minerals and metals, this paper examines total carbon emissions normalized by standard company metrics: OPEX and revenue. The goal is to allow for a meaningful comparison between ICMM members regardless of what resources they extract. As evinced by the different relative rankings produced by using each metric, neither metric is a perfect measure of emissions intensity.

The amount of variation in terms of intensity is similar to that in terms of absolute emissions. Here are two related intensity metrics: tons of emissions per dollar of OPEX, and tons of emissions per dollar of revenue. For each metric, a lower score is better.

The first intensity metric, emissions per OPEX, measures how many thousands of tons of CO_2e were released per million dollars of OPEX. OPEX is a particularly useful intensity metric because it includes fuel costs. However, the limitation of this metric is that a company with a high OPEX will appear better than a more effective company with a lower OPEX but the same level of emissions. Across the ICMM members, the average intensity is 1.55 thousand tons of CO_2e per million dollars of operating expenses, with AngloGold Ashanti as a significant outlier at 11.9 thousand tons per million dollars. Comparing Figure 4 with Figure 1 reveals that many companies are on different places in the two graphs, showing how important it is to use intensity measures along with absolute numbers. Glencore, which had the highest absolute emissions in 2016, ranks third on this scale, showing how large its operations are relative to its emissions.

FIGURE 4

EMISSIONS PER OPEX INTENSITY, 2016

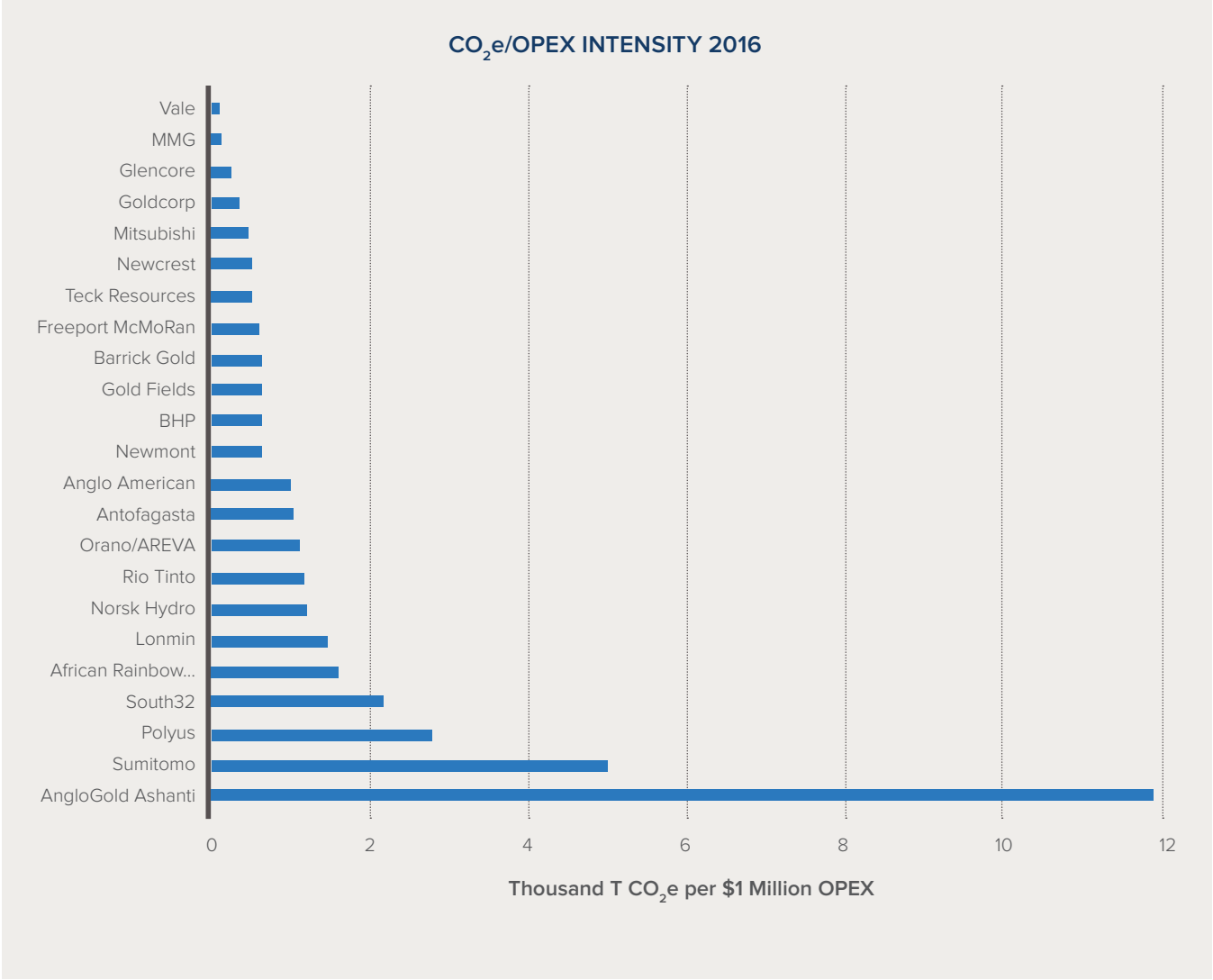
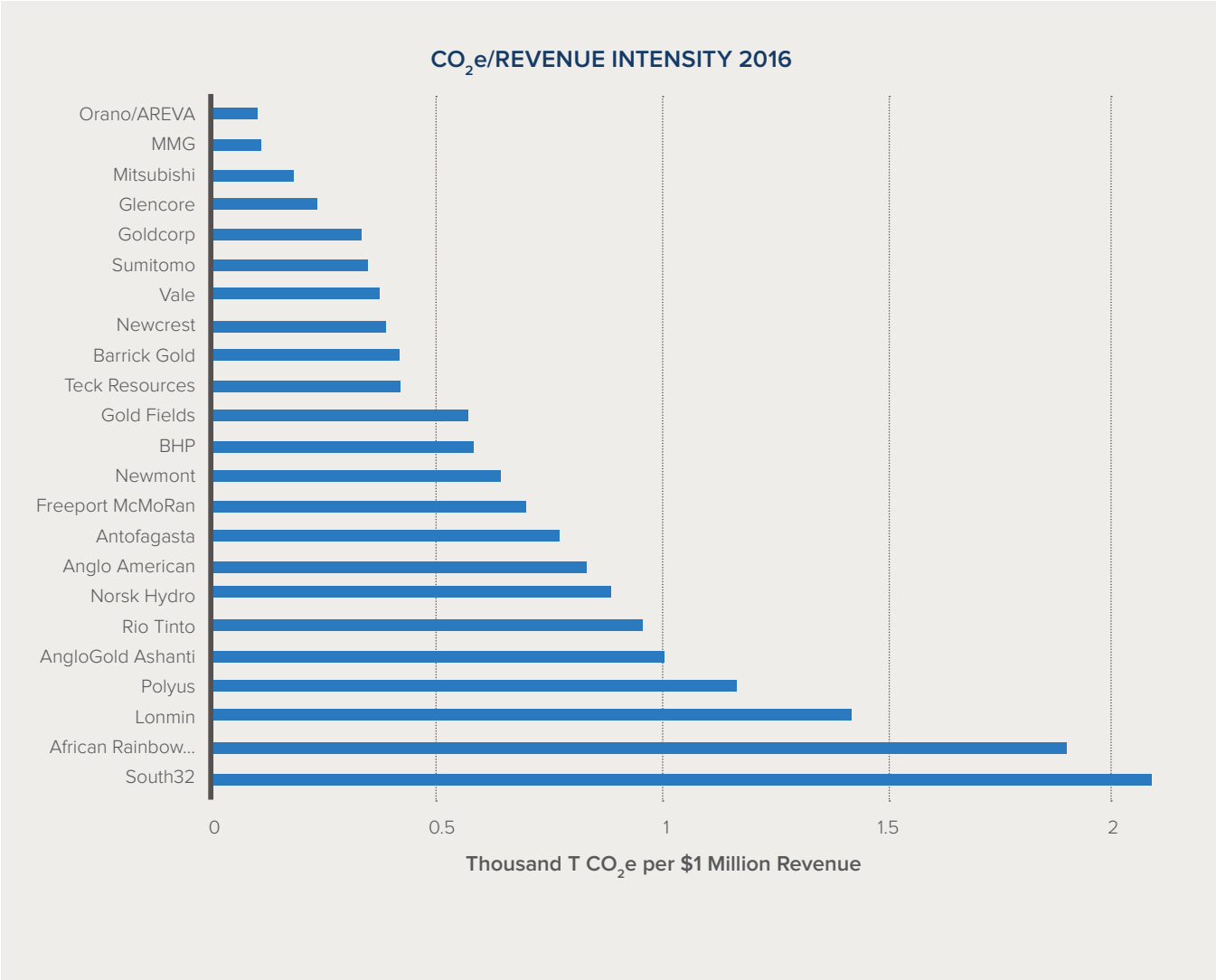


Figure 5 shows ICMM members' emissions intensity in thousands of tons of CO_2e per million dollars of revenue, or tons emitted per unit of value. In other words, this shows how well companies earn money with high emissions efficiency. Companies at the low end of the spectrum show that it's possible to earn money without large emissions relative to a company's size. Orano and MMG were among the smallest absolute emitters in 2016, while Glencore was the highest, yet all three are in the top four companies when ranked by emissions per revenue intensity. Companies that rank high on the revenue intensity spectrum are exposed to higher risk as carbon-pricing systems continue to develop.

FIGURE 5

EMISSIONS PER REVENUE INTENSITY, 2016



On average, ICMM members emit 0.68 tons of CO_2e per $1 million in revenue. Comparing the results derived from using the OPEX and revenue metrics, we see more variation in the results using revenue given its smaller range, and especially if Anglo-American is ignored as an outlier in the ranking by OPEX. While the metrics are related (total revenue is impacted by OPEX), there are several companies that have very different rankings depending on which metric is used. Sumitomo, for example, has high operational expenditures relative to its emissions, but low emissions relative to its revenue. The limitation with this metric is that it cannot account for underlying differences and the challenges each mining company faces. Different ore bodies and metals are more or less expensive to extract, and the market prices for these commodities fluctuate.

Mining companies, both individually and as an industry, should do more to promote transparency and standardization in their emissions reporting. Mining companies are doing well at tracking and reporting their total emissions both in company reports and to the CDP, but there is still work to be done on developing and reporting emissions intensity metrics as well as checking on how these numbers are changing. Companies need to explore and align on standard emissions-intensity metrics, not only to enable fair comparisons, but especially so that companies that grow can show how they're improving even as their absolute emissions might rise. The limitations of both of the intensity metrics used here show that it's important to explore different measures, and to follow the numbers to find trends. Industry groups such as the ICMM are well-positioned to convene mining companies to develop these metrics, and then track and publish the progress of their members over time. Ideally, the development of more sophisticated and consistent metrics will then aid mining companies in continuing to develop and achieve robust emissions targets.

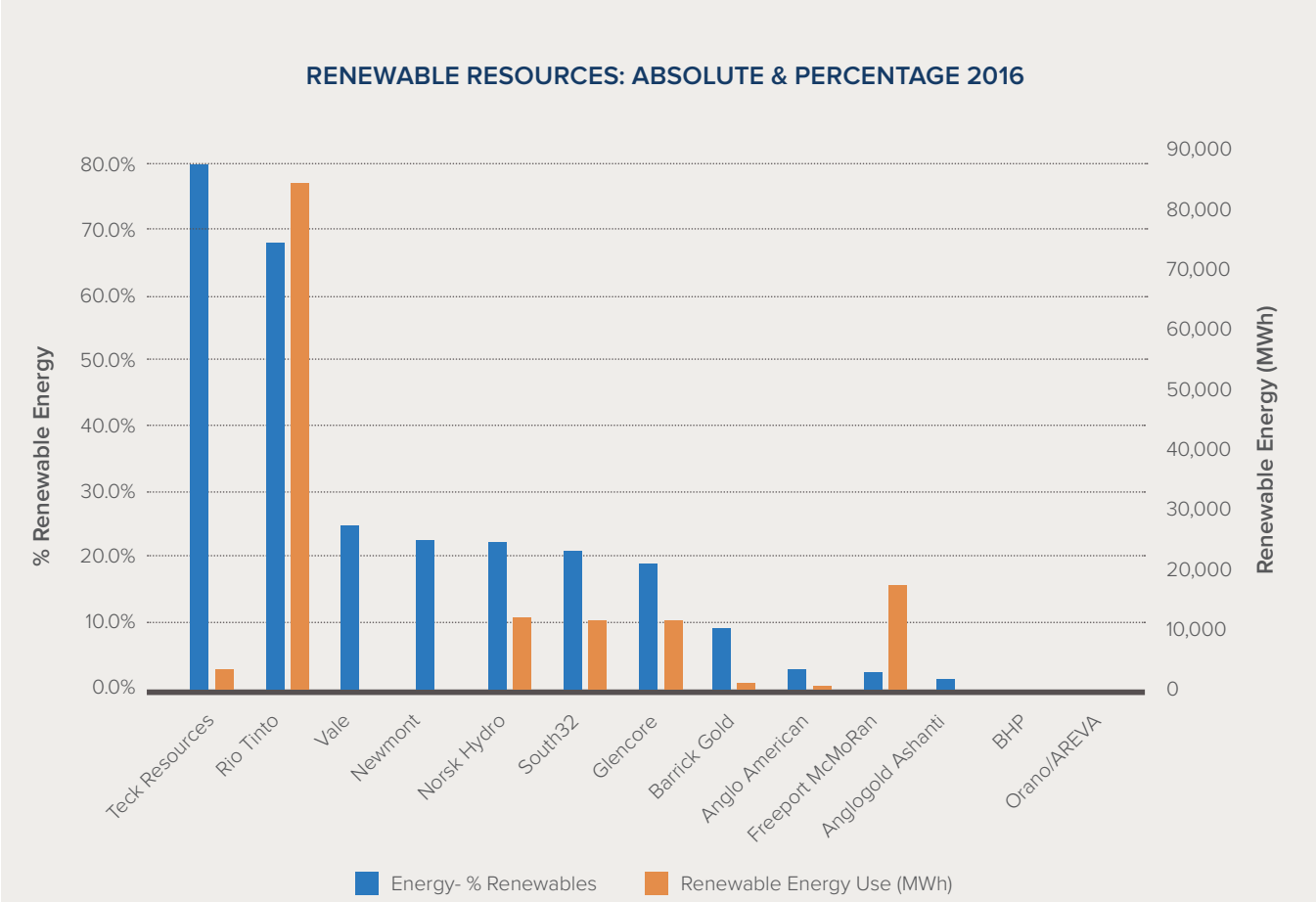
In the meantime, mining companies are adopting goals to help drive their emissions reductions, and to give themselves a public target to hit so that their efforts can be duly recognized by the communities in which they operate, as well as the public at large. Generally, a company's goal is to reduce its emissions by a set amount compared to a baseline year.

The reduction is most often measured as a percentage or absolute amount against a baseline year, but there are intensity targets as well. Of the 27 ICMM members, 13 have set absolute goals, four have set intensity goals, and 10 have not yet set public goals for reducing their CO_2e emissions. The carbon emissions reduction goals of the group vary widely in their ambition. There are several lofty ones, such as Anglo American's target of a 21% emissions reduction by 2020, and a 30% reduction by 2030, from a 2015 baseline. Other targets are for a more conservative 4–5% absolute reduction.[vii]

[vii] The full list of ICMM publicly available emissions targets is in the Appendix.

In addition to their emissions, ICMM members are beginning to report how much of their energy supply is from renewable sources:

FIGURE 6
RENEWABLE ENERGY SUPPLY, 2016



Note: Data primarily drawn from annual sustainability reports and includes hydro as well as RECs. Companies may be inconsistent in reporting renewable energy from RECs.

Of the ICMM members, 10 have not reported the amount of their energy supplied by renewables, while another seven sourced less than 5% of their energy from renewable sources in 2016. Companies using a high percentage of renewable energy are often the beneficiaries of cheap hydropower, a solution not available to all companies. For large companies especially, having a strong renewable resource in one region or business sector can mask supply issues elsewhere. Companies should not only look at their overall renewable supply portfolio, but should also report on an asset-by-asset basis to identify specific risks and opportunities.

SOLUTIONS

How can mining companies continue to produce more while emitting less greenhouse gases? While there's no single silver bullet, there are many actions companies can take depending on their unique circumstances. These include leveraging new technologies and innovations to add renewables to their electricity supply, improving mining processes, fuel-switching to renewable sources, reducing waste, and optimizing transportation.

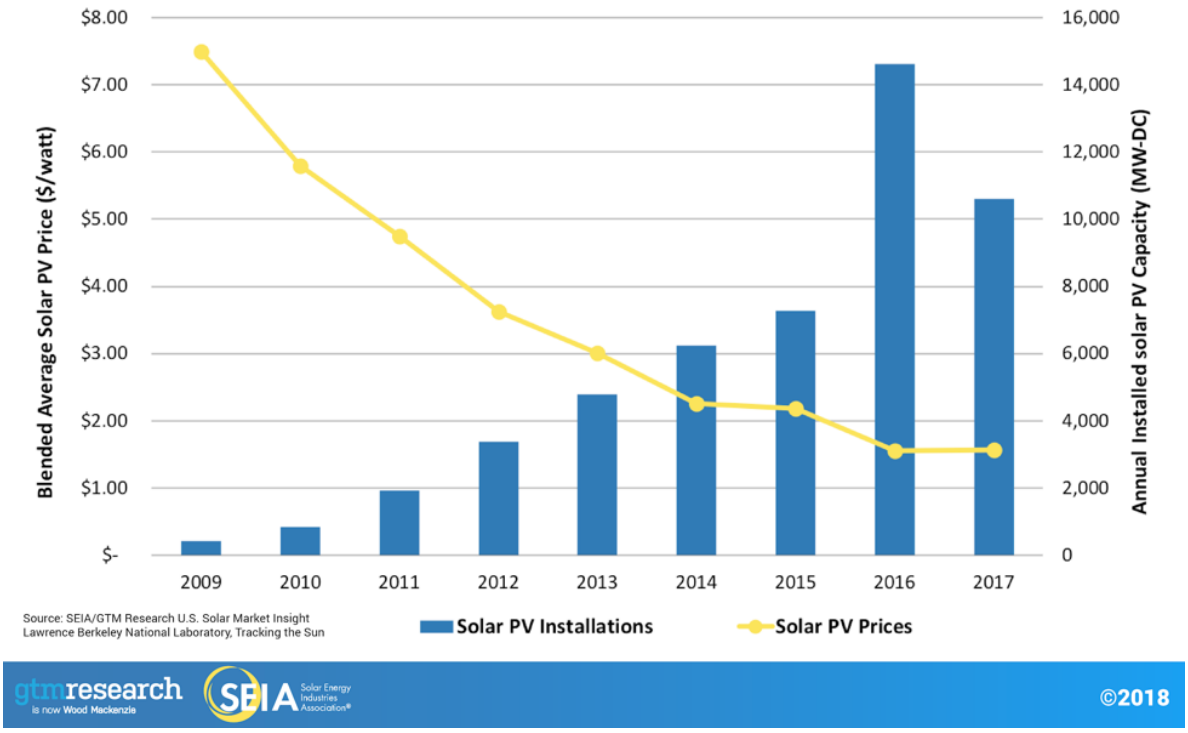
ELECTRICITY SUPPLY

For many mining companies, a good first step for carbon reduction is cleaning up electricity supply. While this may be harder in some regions than others due to regulatory barriers, it is a particularly excellent option for those mines currently powered by on-site diesel generation. It is important for mines to understand their energy security risks and to consider renewables as a possible mitigation. Compared to other heavy industries—such as cement, steel, and chemicals—mining is at an advantage because a large proportion of mining industry emissions are driven by electricity supply.

One renewable resource in particular is getting a lot of media attention: PV. Costs for photovoltaic solar panels have fallen dramatically, averaging a 10–15% reduction each year from 2010 to 2016. As of 2017, National Renewable Energy Laboratory (NREL) estimated the installed cost for a utility-scale, fixed-tilt solar PV array to be $1.34/Wac ($1.03/Wp).[8] The falling price is having a noticeable market effect; in 2017 alone $161 billion was invested in solar projects around the globe. In the United States, data collected by the Solar Energy Industries Association (SEIA) shows how solar capacity has grown as the price has dropped.

FIGURE 7

PRICE AND INSTALLATION OF SOLAR PV



Depending on local utility tariffs, power generation sources, taxes, and other incentives, solar is at or below cost parity with the electric grid as an energy source in many parts of the world.

Along with solar PV, energy storage (ES) is a frequently mentioned technology. While already commercially viable for certain markets and applications, ES is expected to continue decreasing in cost. This will be a game changer for renewables integration, as ES has the potential to offset much of the need for baseload power. Energy storage is often treated as synonymous with batteries, but it also includes pumped-hydro energy storage (PHES),[viii] compressed-air energy storage (CAES), flywheels, and other forms. Energy storage can provide several advantages to mines, including:

- Smoothing renewable intermittency
- Lowering peak demand
- Providing backup power/increasing reliability

The primary driver of PV and ES projects at mine sites is their economic utility, not the green attributes of the power produced. Mines are beginning to recognize this value, and several have already installed or are actively developing PV or PV+ES systems. Examples include:

- Gold Fields is finalizing an on-site 40 MW PV array in South Africa.
- BHP, along with partners, is installing a 13 MW PV array with 1.4MW/5.3MWh of storage.
- Sandfire Resources installed a 10 MW single-axis tracking array with a 4 MW/1.8 MWh lithium-ion battery storage system in Australia.
- Cronimet Chrome Mining SA installed a 1 MW solar array in 2012 that displaces more than 450,000 liters (118.9 thousand gallons) of diesel and 2,000 tons of carbon dioxide per year.
- B2Gold installed a 7 MW solar PV plant in Namibia.
- IAMGOLD installed a solar-diesel hybrid 15 MW PV plant in Burkina Faso.

Renewable energy, especially achieved through large-scale systems, is attractive not just for active mines, but for legacy mines as well. These sites typically have a large amount of unused land that has limited direct economic value, but the mining company must stay engaged with the site during the reclamation process and—assuming the site is grid connected—there is excess transmission capacity to help wheel power away, for which the mine can be compensated. The development of renewable resources offers value in asset conversion by providing a second productive life to a closing mine site. Sites typically have a range of applicable technologies that can be developed, allowing a degree of flexibility in matching the different electricity markets' demands and constraints. However, for the greatest chance of a successful project, renewables on a legacy site need to be considered and planned well before the expected mine closure.

[viii] The vast majority of the ES capacity today is PHES. https://www.energystorageexchange.org/projects/data_visualization

As a baseline comparison, mines can simultaneously explore power purchase agreements (PPA) or virtual PPAs (VPPA) as well. Generally PPAs and VPPAs reduce project risk (because a third party builds, owns, and operates the renewable system, which may be located on- or off-site), but increase project costs to cover the third party's margins. Large companies with concentrated operations may find these to be an attractive option with only a small premium.

Mines are still figuring out how to turn what has traditionally been a liability into an asset. BHP, through its Closed Sites North America initiative, is exploring a portfolio of over a dozen legacy mines across North America to find which sites are the best candidates for low-emissions technologies.[9] Other companies have gone further, such as ASARCO, which installed a 35 MWp solar array at its Pima mine site in Arizona.[10]

PROCESS IMPROVEMENTS

Not all carbon reduction strategies involve electricity. Mining companies are also able to lower their carbon emissions through process changes designed to increase efficiency. One method accessible by every company is finding new ways to obtain and leverage data to make their operations more efficient. Some examples include:

- Advanced asset management strategies bring together operational and inspection data with predictive analytics to show what equipment needs to be serviced or replaced and when. Internet of Things (IoT) devices in particular can help by generating the vast amounts of data needed for these advanced analytics. Properly maintaining equipment prevents failures and lowers overall operational costs.
- Unmanned aerial vehicles (UAVs), commonly referred to as drones, are able to provide several different services to mines, including pit and stockpile assessments, site surveying, and operations planning for blasting and rehabilitation. Compared with conventional tools, drones are able to accomplish these tasks more quickly, cheaply, and safely.[11] Freeport-McMoRan uses UAVs to perform weekly topographic surveys of a copper mine in the Democratic Republic of Congo. Before utilizing UAVs, this work was done by surveyors on the ground, requiring mining operations to temporarily cease, and providing less-accurate outputs.[12]

TECHNOLOGY IMPROVEMENTS

Mines are leveraging new technologies that either are more efficient than older iterations, or represent entirely new ways of accomplishing the same task. Examples include:

- Mines in Nevada upgraded from metal-halide lights to LEDs and installed variable-frequency drives on their crushers and conveyor belts.[13]
- Rio Tinto developed a more efficient aluminum smelter that lowered its costs and emissions while improving productivity by 40%.[14]

- Biomining, the process of using small organisms, such as bacteria, to extract metals from ore, is gaining popularity, especially in remote locations. Biomining generally has a lower environmental impact and requires less energy than traditional mining practices. Codelco, JX Nippon, and others are working to develop and refine biomining techniques.[15]
- Vendors and companies including Anglo American, Rio Tinto, Freeport-McMoRan, Codelco, Komatsu, Caterpillar, and Epiroc are building new machines capable of cutting through harder rock formations to allow continuous mechanical rock excavation at more mining sites. Mechanical rock excavation can be more efficient and predictable than a blast-and-drill workflow because it involves fewer people, can be performed remotely, and will operate on an around-the-clock schedule.[16]
- Anglo American is working on increasing operations efficiency through a combination of advanced fragmentation (reduces the amount of ore sent to high-energy grinding), bulk sorting (takes out less-viable rock earlier) and coarse particle recovery (is able to float larger particles).[17]

ELECTRIFICATION

Environmentally beneficial electrification refers to the "electrification of energy end uses that have been powered by fossil fuels (natural gas, propane, gasoline, diesel, or fuel oil) in order to reduce greenhouse gas emissions."[18] Along with their environmental benefits, electric motors tend to be more emissions-efficient (assuming the electricity source is cleaner as well) and quiet and require less maintenance than similar diesel-powered machines. Lastly, electric motors provide several advantages for underground applications. They don't exhaust noxious fumes or diesel particulate matter, and they produce less heat than diesel equivalents, reducing ventilation needs. Companies such as Sandvik, MacLean Engineering, and others are developing battery- or electric-powered drills, bolters, and other mining machines.

Electric mining technology is mature enough that the dream of an all-electric mine is becoming a reality at Goldcorp's Borden Lake gold mine in Ontario, Canada. The project isn't expected to be complete until 2019, but the goal is to have no diesel equipment underground. By using electric machines instead of diesel, Goldcorp expects to save 7,000 tons of CO_2, 2 million liters of diesel, and 1 million liters of propane annually.[19,20] Not only will this help Goldcorp's bottom line, but it will help its social license as well; operating a cleaner mine makes obtaining the necessary environmental permits easier.

TRUCKING/TRANSPORT INNOVATIONS

The final area ripe for technological change is transport. Transport innovations are based on two different converging trends, electrification and automation. Several vendors are leading the way toward electrification. For example:

- Liebherr is prototyping a diesel-electric truck that will be commercially available by the end of 2018.[21]
- Komatsu is developing a 45-ton all-electric dump truck with regenerative braking to take advantage of moving heavy loads downhill.[22]
- Artisan is a smaller company specializing in electric vehicles for underground use. It recently unveiled a 40-ton underground hauler.[23]

Not only do electric vehicles produce less carbon, but they often have lower O&M costs because their fuel is cheaper and they break down less often because electric motors are mechanically simpler. While EVs today have the downside of long charging times, companies are developing quick-charge methods as well as battery swap stations to allow for near-continuous operation.

Alongside the shift to electric vehicles is a move toward automation. To date, the primary industry leader in this space is Rio Tinto, which operates autonomous haulage trucks at four mines in Australia and has plans to expand to a fifth before the end of the year. In addition to hauling, Rio Tinto is working on an autonomous rail system, AutoHaul, that completed a 100 km journey in October 2017.[24] Other mining companies are developing autonomous capabilities as well, such as Fortescue mining, which has the world's first fully autonomous hauling fleet at an iron ore mine.[25]

Autonomy may not intuitively seem part of a company's carbon reduction plan, but autonomy provides several efficiency benefits. Autonomous vehicles can optimize their acceleration and braking for fuel efficiency and long-term maintenance while adding more operational hours, because there's no human in the cab who needs breaks. Fortescue increased its hauling productivity by 30% after implementing its autonomous hauling system. Due to the heavy electrical needs of an onboard autonomous system, these vehicles are well-suited to be either hybrid or fully electric. Unfortunately, autonomous technologies will likely result in fewer total jobs at mining operations, though they will likely also result in fewer injuries and deaths. Careful consideration will be needed to gauge the impact on the local community, the mine's social license to operate, and potential regulatory interventions.

Electricity supply improvements, and innovations in process, technology, electrification, and transportation all have a role to play in reducing mine site greenhouse gases. Along with these changes, mines will need to consider two more fundamental shifts. First, the mining industry needs to recycle more to reduce the quantity of new resources needed. Second, extraction and production methods need to be designed to optimize on-site resource productivity rather than separating functions.

CORPORATE GOVERNANCE AND STRATEGY

In addition to the technological and operational improvements mentioned above, mining companies that wish to flourish in the new energy transition would do well to research and employ the corporate governance best practices of their peers, both within and outside the mining industry.

First, companies need to plan for the physical risks that come with the new normal of a climate-changed world. For example, they need to plan for stressed water resources and damaged supply chain routes due to more frequent and more extreme natural disasters. They must identify vulnerable areas in their business strategies and then figure out ways to make them as resilient as possible. And they should expect this need to be emphasized by investors who want assurances that their investments are secure and that businesses are prepared.

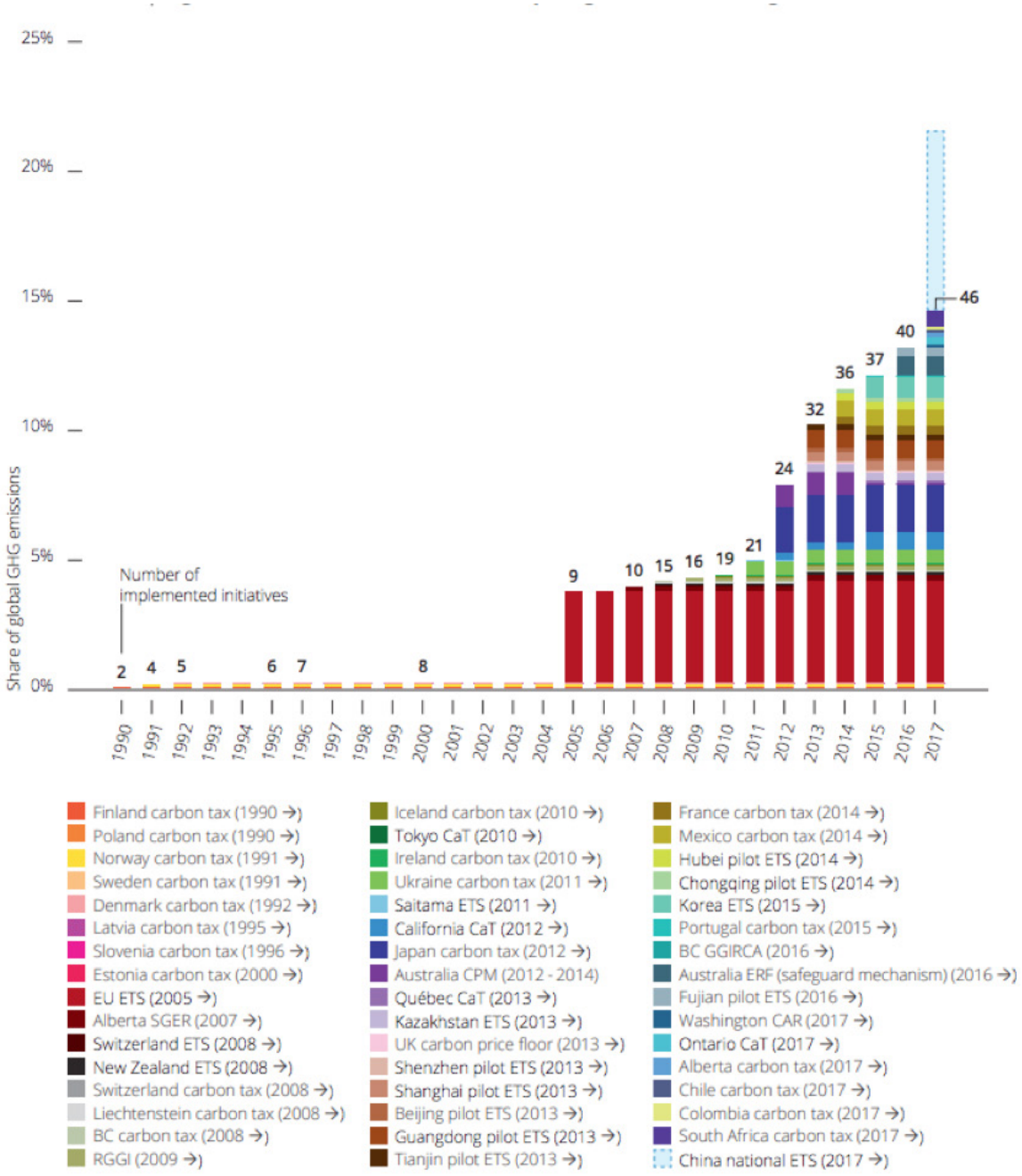
However, companies can't consider just the physical risks; they need to also plan for the financial risks and opportunities that come with a climate-changed world. Per the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD), they should align their governance and remuneration structures with low-carbon objectives and should take action to support policies that help achieve a low-carbon transition.[26]

For example, BHP recently exited the World Coal Association (WCA) over differences on climate change.[27] And while this move was primarily symbolic, another top mining firm, Rio Tinto, recently announced its exit from coal after selling more than $4 billion of Australian mine assets in a week.[28] This major miner's decision to stop extracting the most carbon-intensive fuel tells its customers and its shareholders that it is doing everything in its power to minimize risks due to downstream regulation and changing demand patterns as the world transitions to a low-carbon future.

Conversely, miners are wise to double down on investments critical to the energy transition. Rio Tinto is a prime example of a company that is not only reducing risks but also maximizing opportunities with regard to this transition. As Rio Tinto's chief executive officer, Jean-Sébastien Jacques, said in an interview after the coal announcement, the company's decision is "aimed at prioritizing iron ore, copper, bauxite, and aluminum operations." With solar panels and electric vehicles on the rise, these will be the in-demand commodities of the low-carbon future, and forward-thinking companies like Rio Tinto want to take advantage of that. That is, the mining industry is uniquely positioned to meet the demand for the materials driving carbon abatement—a position that will certainly help it to adapt to the coming energy transition. It is also important to note that although the scope 1 and 2 emissions from forward-thinking miners may increase in the near future, the extraction of these minerals is allowing for a large, long-term reduction in the scope 3 emissions of downstream sectors such as car manufacturing and electricity—industries that are already experiencing increased regulation.

FIGURE 8

REGIONAL, NATIONAL, AND SUBNATIONAL CARBON PRICING INITIATIVES: SHARE OF GLOBAL EMISSIONS COVERED



Source: World Bank, Carbon Pricing Watch 2017[29]

However, the mining industry will need to be cognizant of new regulations as well, with increased regulation in the near future now all but certain. One of the preferred tools thus far—carbon pricing—is rapidly gaining popularity, and according to the World Bank's *Carbon Pricing Watch 2017*, as of 2017, over 40 national and 25 subnational jurisdictions representing almost a quarter of global greenhouse gas emissions are already putting a price on carbon. In fact, over the past decade, the number of jurisdictions with carbon pricing initiatives has doubled, amounting to over $52.21 billion in total value.[30,31] With China launching its emissions trading scheme (ETS) this year, carbon pricing initiatives will now cover over 20% of global emissions.[32,33] It's clear that market-based tools are on the rise, and investors expect companies to be prepared.

Because of increased market measures such as carbon pricing, mining companies must begin to do more than set incremental emissions reductions targets; they must strive for reductions in line with those required by science, international treaties, and, increasingly, investors. In fact, one of the key findings of CDP's recent report on mining was that "investor demands for greater transparency on climate risks will continue to test the sector where scenario planning is in its infancy and requires more standardized reporting against climate constrained pathways."[34] Therefore, another strategy for mining firms that wish to be at the forefront of the energy transition is—plain and simple—to set more aggressive targets.

Whether committing to reduce energy costs, increase renewables penetration, or, ideally, both, the current energy goals of the top ICMM companies can and should go further. It is no longer enough to commit to only the lowest-hanging fruit—that which they are sure they can grasp. The time has come to narrow the gap between their commitments and those necessary to stay within a two-degree warmer world.

SCIENCE-BASED TARGETS

While there is no shame in setting goals one knows one can meet, the urgency of the climate challenge calls for more ambitious goal setting. This is where science-based targets come in. **The Science Based Targets initiative (SBTi)**, a joint initiative of CDP, the World Resources Institute (WRI), the World Wide Fund for Nature (WWF), and the United Nations Global Compact (UNGC), encourages businesses to set ambitious emissions reduction targets based on science in order to help them "future-proof growth" in the transition to a low-carbon economy. Specifically, targets adopted by companies to reduce greenhouse gas emissions are considered "science-based" if they are "in line with the level of decarbonization required to keep global temperature increase below 2 degrees Celsius compared to preindustrial temperatures, as described in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)."[35]

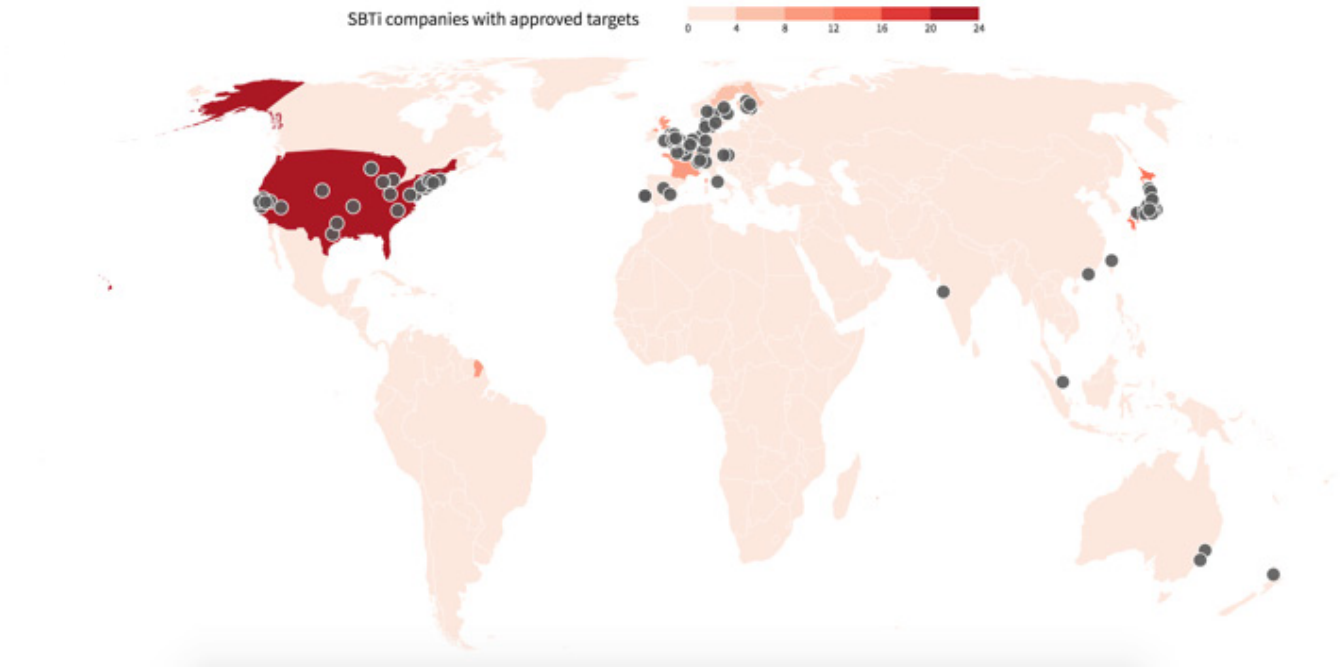
SBTi certainly hopes that science-based target setting will become standard business practice, and there is evidence to suggest this is already happening. In fact, in just the few years since the initiative began, over 120 companies have set SBTi-approved emissions reduction targets in line with climate science and the goals of the Paris Agreement, and an additional 320 companies are committed to following suit.[36]

Furthermore, science-based target setting is already becoming part of the annual reporting practice of companies and the data infrastructure of institutional investors through incorporation into the CDP questionnaire and scoring.

SBTi assures those companies still exploring the idea of setting a science-based target of the benefits, including increased innovation, reduced regulatory uncertainty, strengthened investor confidence

FIGURE 9

COMPANIES WITH SBTI-APPROVED TARGETS



Source: Science Based Targets Initiative[37]

and credibility, and improved profitability and competitiveness.[38] There are also reputational benefits for companies with approved science-based targets—particularly for consumer-facing brands farther down the value chain that are facing increasing pressure from society to do their "fair share" in the fight against climate change.

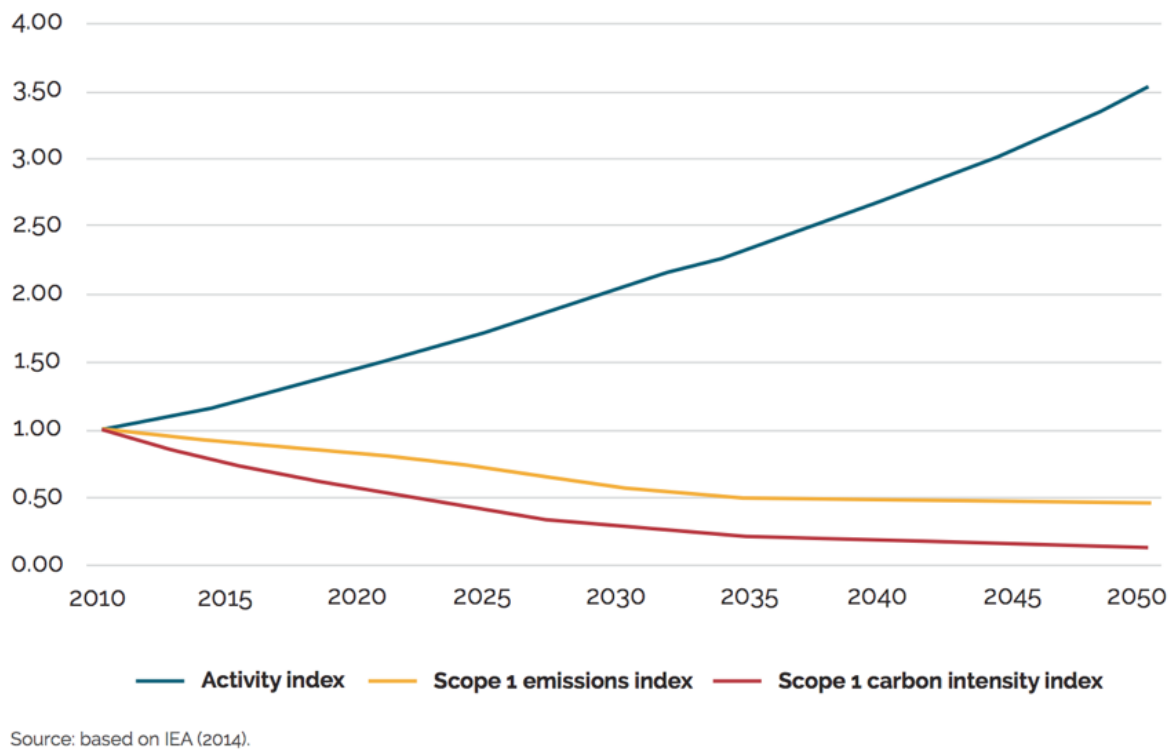
However, it's worth noting that, to date, no mining company has an SBTi-approved target. This is likely due, at least in part, to the fact that mining companies interested in setting a science-based target have two hurdles they need to overcome. The first challenge for mining companies considering setting a science-based target involves their scope 3 (value chain) emissions. In order for a science-based target to be approved, a scope 3 target is required if a company's scope 3 emissions are at least 40% of total scope 1, 2, and 3 emissions. If so, the scope 3 target must include the majority (at least two-thirds) of the company's value-chain emissions.[39] According to a recent report by CDP, "the mining industry has significant potential exposure to carbon emissions regulation in its value chain where scope 3 emissions from downstream customers is estimated at an average of 10x and up to 30x higher than operational emissions."[40] Because scope 3 emissions are notoriously harder to reduce (and even to track) than scope 1 or 2 emissions, setting a science-based target that covers them is sure to be challenging (but not impossible). However, as mentioned earlier, mining operations that supply the minerals necessary for the energy transition may actually significantly reduce their scope 3 emissions. In fact, in this way, whether producing batteries for renewables or steel for lightweighting vehicles, mining is crucial for a low-carbon economy.

The second major challenge mining companies face when trying to set a science-based target involves choosing which approach to use. The most common, the **sectoral decarbonization approach (SDA)**, allocates the 2°C carbon budget to different sectors, taking into account inherent differences such as mitigation potential and how fast each sector can grow relative to economic and population growth. Within each sector, companies can derive their science-based emissions reduction targets based on their relative contribution to the total sector activity and their carbon intensity relative to the sector's intensity in the baseline year.[41] This method is most companies' preferred approach for setting science-based targets, as opposed to the "absolute-based" approach (based on the percentage of absolute emissions reductions necessary) or the "economic-based" approach (based on a company's share of global GDP).

However, unfortunately, there is no specific mining "pathway" under the SDA. Rather, the "manufacturing of nonferrous metals (e.g., copper, lead, nickel, tin, titanium, zinc, gold, silver, platinum)" is considered part of the "other industry" sector, made up of all the industries that could not be grouped into one of the other six industry sectors.[42] Under this "other industry" pathway, according to the methodology, mining companies are expected to have an intensity target that should decline by about 87% by 2050. For context, as a group, the top ICMM mines reduced their total emissions from 2014 to 2016 by 15%, but those reductions primarily came from a few large companies. On a company basis (unweighted) the average reduction was just 4%.

FIGURE 10

MINING COMPANIES WILL GROW, BUT ACCORDING TO THE SECTORAL DECARBONIZATION APPROACH, HAVE A TARGET OF REDUCING CARBON INTENSITY BY 87% BY 2050



Source: Science Based Targets Initiative, *Sectoral Decarbonization Approach Report*

This 87% reduction target does not take into account the heterogeneous nature of the mining sector, but instead treats companies with different resource portfolios (e.g., copper, lead, gold), and even different processing operations (e.g., communition, electrowinning, or none at all) uniformly. This results in the same absolute emissions reductions percentage being applied to all companies within the sector and thus guarantees that, should each company meet this target, the sector would stay within its 2°C carbon budget.

But meeting the target is certainly much easier said than done. For example, although the SDA notes that the steep declines expected from the "other industry" sector are thought to be achievable through "generic efficiency improvements," if it were really that simple, we would expect to have seen much sharper reductions already. The SDA does also note the "potential to reduce scope 2 emissions [through] more-efficient motor systems and decarbonizing electricity," two of the strategies mentioned earlier in this paper. However, it doesn't seem to account for the significant step changes needed in technology throughout the entire mining value chain (smelting, communition, etc.) in order to reduce emissions.

Clearly, there are some significant constraints to this sector-based approach. But not to worry—there are two additional methods for setting SBTs. The simplest, the "absolute-based" approach, assigns a percentage of absolute emissions reductions to individual companies. This percentage equates to a 49–72% reduction in emissions below 2010 levels.[43] However, because it is an absolute reduction, this approach may not be preferred for companies that are expecting to grow.

The final approach, the "economic-based" approach, bases a company's share of emissions on its gross profit, resulting in an intensity target. However, it should be noted that although accepted methodologies exist under this approach, SBT recommends companies use either the sectoral or absolute-based approaches to set their targets. This is because those approaches are the most robust methods to ensure the 2°C carbon budget is conserved, and there is concern that economic-based approaches may not result in absolute global emissions reductions in the long term. In fact, SBT notes that "intensity targets would be considered science-based only if they lead to absolute reductions in line with climate science or are modelled using an approved sector pathway or method approved by the Science Based Targets initiative (e.g., the Sectoral Decarbonization Approach)."[44] However, we feel that this economic-based approach may be the most helpful for the mining industry given the current options.

There are multiple existing methodologies under the economic-based approach, including **greenhouse gas emissions per unit of value added (GEVA)**, which encourages companies to reduce GHG emissions per unit of value added by approximately 5% per year from 1990 to 2050; **carbon stabilization intensity target (CSI)**, which recommends a target of 9.6% reduction in intensity per year over the same time frame; and **the Center for Sustainable Organizations' (CSO's) Context-based Carbon Metric**, which allocates reduction burdens unevenly throughout the world according to where emitters are located and the development status of the economies involved.[45]

We encourage companies to find the method that works best for them and, regardless of approach, to keep in mind the importance of setting targets that are science-based and appropriately ambitious, even if they may not be officially recognized by SBT due to the challenges mentioned above.

TASK FORCE ON CLIMATE-RELATED FINANCIAL DISCLOSURES

Even if mining companies are not yet feeling pressure from downstream customers to measure and reduce their climate impacts in line with climate science, they are feeling this pressure from investors. Investors are concerned about climate risk, in terms of both operational and economic disruptions. Operational disruptions from extreme weather events present a physical risk to their assets and supply chain logistics. Similarly, climate change introduces economic risks through changes in policy (e.g., carbon pricing, as mentioned above), changes to resource prices, or changing demand for products and services (e.g., new energy transition technologies).

However, until recently, there has not been a framework companies could use to disclose climate risk to investors in a consistent and comparable manner. With this in mind, the private sector-led Task Force on Climate-related Financial Disclosures (TCFD) was formed and, in June 2017, it released its final recommendations for "voluntary, consistent climate-related financial risk disclosures for use by companies in providing information to investors, lenders, insurers, and other stakeholders."[46]

These recommendations are structured around four key themes: governance, strategy, risk management, and metrics and targets. Several mining companies, including four ICMM members—Barrick Gold, BHP, Glencore, and Vale—are already signatories to the recommendations.

TCFD is cautious about simply creating a framework that does little to change business as usual, and so it is now focusing on implementation. In partnership with the Climate Disclosure Standards Board (CDSB), TCFD announced the launch of the TCFD Knowledge Hub—a peer-to-peer "platform with relevant insights, tools, and resources to help organizations implement the TCFD recommendations."

CONCLUSION

The mining industry is beginning to recognize the urgency of climate change, but more dramatic action is needed. Companies that wish to develop emissions targets and solutions have access to frameworks, standards, and resources to assist them. But it is up to the companies themselves to use and improve upon these resources if we are to avoid a business-as-usual trajectory, which shows global temperature rise likely reaching 3.4°C by 2100.[47]

Organizations like RMI and those mentioned throughout this report are here to help. However, if a decarbonization pathway for the mining industry (or perhaps even subsectors of the industry) is to succeed, it must be charted alongside the industry itself. Cocreation of this pathway is certainly the next logical step. It should include setting emissions reduction targets in line with climate science; tracking progress rigorously, consistently, and publicly; evaluating long-term climate risks and opportunities; and actively seeking out and developing technologies and strategies to reduce carbon emissions, using the ideas in this paper as a starting point. Winners and losers in the mining industry, as in other industries, will be determined by how well companies prepare now.

APPENDIX: ICMM MEMBER EMISSIONS TARGETS

MINING COMPANY	EMISSIONS TARGET	TYPE
GOLD FIELDS	Set three-year regional carbon emissions and energy efficiency targets to 2016 and revise 2020 targets to include 20% RE on all projects.	Absolute
BHP	Maintain FY2022 GHG emissions at or below FY2017 levels while business continues to grow. Longer-term goal: In line with international commitments, BHP aims to achieve net-zero operational GHG emissions in the second half of this century.	Absolute
BARRICK GOLD	Keep current GHG emissions flat in the short term and achieve a 30% reduction in GHG emissions by 2030, from a 2016 baseline of 3.5 MT CO_2e emitted.	Absolute
ANGLO AMERICAN	Reduce GHG emissions by 22% relative to the business-as-usual projection by 2020 and reduce net GHG emissions by 30% by 2030.	Absolute
TECK RESOURCES	(1) 275 kilotons (kT) reduction by 2020. (2) Implement projects that reduce GHG emissions by 450 kT of CO_2-equivalent by 2030.	Absolute
AFRICAN RAINBOW MINERALS	Scope 1 & 2 5% carbon footprint absolute reduction relative to the FY2014 baseline in FY2018.	Absolute
LONMIN	Reduce scope 1 and 2 GHG emissions by 4% by 2017 from a 2012 baseline year.	Absolute
JX NIPPON	(1) Cumulative allowable CO_2 emissions in Japan of less than 3.06 million tons for FY2016 to FY2018. (2) By FY2030, reduction in CO_2 emissions by 18% from FY1990 levels.	Absolute
NORSK HYDRO	Become carbon-neutral from a life-cycle perspective by 2020.	Absolute
SUMITOMO	Reduce CO_2 emissions by continuing to lower overall CO_2 emissions by 1% each year and by adopting renewable energy.	Absolute
GOLDCORP	Five-year target to reduce annual GHG emissions by 20% from 2011 levels.	Absolute
SOUTH32	Stay below FY2015 scope 1 emission baseline in FY2021. Global goal of achieving net-zero carbon emissions by 2050.	Absolute
VALE	Reduce GHG emissions by 5% by 2020.	Absolute

MINING COMPANY	EMISSIONS TARGET	TYPE
RIO TINTO	Set in 2015: extend GHG emissions intensity target to a 24% reduction, from 2008 baseline, by 2020.	Intensity
NEWMONT	30% reduction in GHG emissions intensity by 2020 compared to 2013 baseline.	Intensity
ANGLOGOLD ASHANTI	30% improvement in carbon intensity by 2022, from 2007 baseline.	Intensity
GLENCORE	Groupwide emissions intensity reduction target of at least 5% from 2016 levels by 2020.	Intensity
FREEPORT MCMORAN	No target specified.	None
MMG	No target specified.	None
CODELCO	No target specified.	None
ORANO/AREVA	No target specified.	None
MITSUBISHI	No target specified.	None
POLYUS	No target specified.	None
NEWCREST	No target specified.	None
ANTOFAGASTA	No target specified.	None
MINERA SAN CRISTOBAL	No target specified.	None
MINSUR	No target specified.	None

ENDNOTES

[1] https://www.co2.earth/

[2] https://theconversation.com/we-need-to-get-rid-of-carbon-in-the-atmosphere-not-just-reduce-emissions-72573

[3] https://www.carbonbrief.org/analysis-global-co2-emissions-set-to-rise-2-percent-in-2017-following-three-year-plateau

[4] https://b8f65cb373b1b7b15feb-c70d8ead6ced550b4d987d7c03fcdd1d.ssl.cf3.rackcdn.com/cms/reports/documents/000/002/327/original/Carbon-Majors-Report-2017.pdf?1499691240 Report examines scope 1 and 3 emissions.

[5] http://documents.worldbank.org/curated/en/207371500386458722/The-Growing-Role-of-Minerals-and-Metals-for-a-Low-Carbon-Future

[6] https://www.icmm.com/en-gb/about-us

[7] https://www.cdp.net/en/investor/sector-research/mining-report

[8] https://www.nrel.gov/docs/fy17osti/68925.pdf

[9] https://www.bhp.com/community/community-news/2018/01/renewable-energy-powering-our-closed-mine-sites RMI is a partner to BHP on this initiative.

[10] http://www.asarco.com/about-us/our-locations/asarco-mineral-discovery-center/avalon-solar-project/

[11] http://www.miningmagazine.com/future-of-mining/future-of-mining-innovation/a-view-from-the-air/

[12] http://www.miningmagazine.com/technology/smart-mining-hub/eye-in-the-sky/

[13] http://www.miningglobal.com/operations/how-save-money-using-less-energy

[14] http://www.riotinto.com/canada/innovation-17285.aspx

[15] http://www.miningmagazine.com/equipment/mineral-processing/embracing-the-benefits-of-bacteria/

[16] http://www.miningmagazine.com/future-of-mining/future-of-mining-innovation/the-cutting-edge-of-hard-rock/

[17] http://www.angloamerican.com/futuresmart/our-industry/technology/picture-this-the-concentrated-mine

[18] https://www.sciencedirect.com/science/article/pii/S1040619016301075

[19] http://www.miningmagazine.com/future-of-mining/future-of-mining-investment/shes-electric/

[20] https://im-mining.com/2018/02/13/sandvik-dd422ie-units-helping-goldcorp-achieve-first-electric-mine-borden/

[21] http://www.mining.com/truck-will-help-liebherr-become-big-name-mining/

[22] https://www.caranddriver.com/news/this-45-ton-all-electric-dump-truck-will-be-the-worlds-biggest-ev

[23] http://www.canadianminingjournal.com/news/truck-artisan-delivers-first-40-tonne-battery-powered-hauler/

[24] https://www.cio.com.au/article/632211/full-steam-ahead-rio-tinto-autonomous-train-project/

[25] http://www.miningmagazine.com/management/fleet/fortescue-boosts-autonomous-fleet-2/

[26] https://www.fsb-tcfd.org/publications/final-recommendations-report/

[27] https://www.reuters.com/article/us-bhp-coal-climatechange/bhp-says-to-quit-global-coal-lobby-group-stick-with-u-s-chamber-of-commerce-idUSKCN1HC075

[28] https://www.bloomberg.com/news/articles/2018-03-27/rio-calls-time-on-coal-with-sale-of-last-mine-for-2-25-billion

[29] https://openknowledge.worldbank.org/handle/10986/26565

[30] http://documents.worldbank.org/curated/en/699641497346643090/pdf/116068-WP-wb-cpw-170609-screen-PUBLIC.pdf

[31] https://carbonpricingdashboard.worldbank.org/

[32] https://carbon-pulse.com/50928/

[33] http://b8f65cb373b1b7b15feb-c70d8ead6ced550b4d987d7c03fcdd1d.r81.cf3.rackcdn.com/cms/reports/documents/000/002/365/original/mining-report-exec-summary-2017.pdf?1500499007

[34] http://b8f65cb373b1b7b15feb-c70d8ead6ced550b4d987d7c03fcdd1d.r81.cf3.rackcdn.com/cms/reports/documents/000/002/365/original/mining-report-exec-summary-2017.pdf?1500499007

[35] http://www.wri.org/our-work/project/science-based-targets-initiative

[36] http://sciencebasedtargets.org/2018/04/17/over-100-global-corporations-using-science-based-targets-to-align-strategies-with-paris-agreement/

[37] http://sciencebasedtargets.org/approved-targets-map/

[38] http://sciencebasedtargets.org/faq/

[39] http://sciencebasedtargets.org/wp-content/uploads/2017/02/SBTi-criteria.pdf

[40] https://www.cdp.net/en/investor/sector-research/mining-report

[41] http://www.wri.org/our-work/project/science-based-targets-initiative

[42] http://sciencebasedtargets.org/wp-content/uploads/2015/05/Sectoral-Decarbonization-Approach-Report.pdf

[43] http://sciencebasedtargets.org/methods/

[44] https://sciencebasedtargets.org/wp-content/uploads/2015/05/Sectoral-Decarbonization-Approach-Report.pdf

[45] https://sciencebasedtargets.org/methods/

[46] https://www.fsb-tcfd.org

[47] https://climateactiontracker.org/publications/improvement-warming-outlook-india-and-china-move-ahead-paris-agreement-gap-still-looms-large/

22830 Two Rivers Road
Basalt, CO | 81621 USA
www.rmi.org