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MINING

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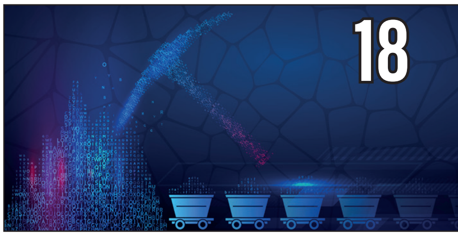

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Dear Valued **watt**now Reader

With the economic engines slowly starting to churn in this new year, and we hopefully see a relief of the lockdown regulations, I thought it apt to produce this issue of **watt**now on Mining.

Statistics South Africa (Stats SA) released data in January 2022 showing that mining production rose 5.2% in November of 2021 compared with the same month in 2020. Platinum group metals (PGMs) lead the way, with production surging 38.1% over that period.

Mineral sales had a more significant spike, increasing by 22.2% year-on-year. This means a significant boost in revenue, which will flow to the bottom line of many companies with spin-offs that include more taxes paid to the Treasury and more hard currency flowing into the economy from exports.

Mining companies need to embrace technologies to optimise operations and profitability better. Since its inception, Mining has helped civilisations and created modern conveniences. Our first feature article on page 18 discusses why digital innovation is vital in Mining.

"Digging beneath the Surface", on page 24, brings you a bumper report on the exploration of the net benefits of Mining in Southern Africa.

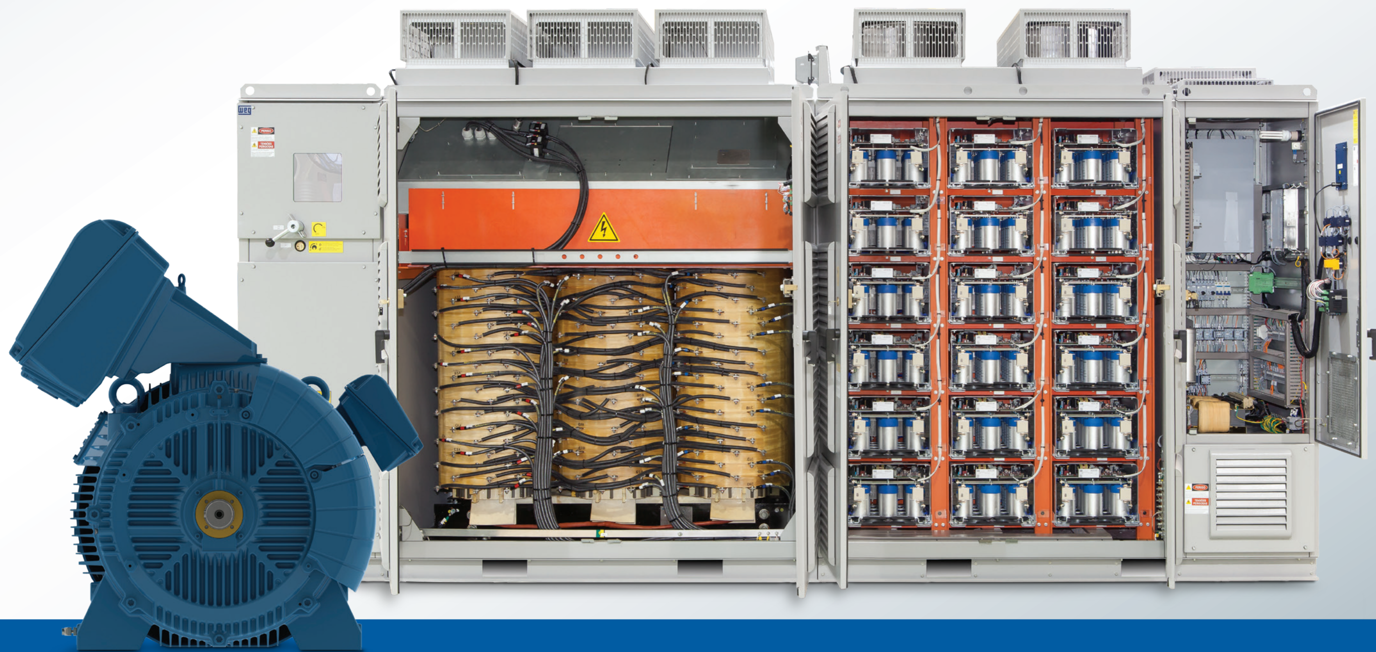
Minerals are in demand worldwide, strengthened by the emerging needs of green energy. Read our article on "How leading mining companies are getting smarter with condition monitoring" on page 114.

The March 2022 issue features Smart Buildings, and the deadline for article submission is 23 February 2022. Please email your articles/white papers to minx@saiee.org.za.

Herewith your February issue, enjoy the read!

PS: The SAIEE is gearing up for its Annual Awards on 11 March in JHB. Due to us maintaining COVID regulations, we have limited space. Find more information here.

Minx



The New First Cut branch in Witbank brings total solutions to the mining and engineering region

The newest branch of First Cut, a leading South African provider of cutting, welding and grinding consumables and equipment, has opened its doors in Witbank. Zelda Vorster, who took on the role of Regional Sales Manager for Mpumalanga some six months ago, is at the helm.

Vorster clarifies: "We did not have a branch here in Witbank previously. After starting with First Cut in mid-2021, working remotely, we realised the potential for the sale and distribution of the full range of First Cut's products in this area. We believed that growing the regional representation and sales of traditional cutting and hand tools offered by First Cut represented a significant opportunity. Additionally, First Cut is now stocking products locally means that we are further enabled to offer our customers a first-class service. I am confident that this new branch is going to be successful."

"First Cut is very service-oriented," explains Vorster, "and so it has been a strategic move to open this new branch in Witbank. We will be complementing the tooling and cutting sides of the business with the addition of welding products and services. The Johannesburg and Nelspruit branches have previously serviced the existing First Cut customers in the region.

We are also planning to promote oxyfuel equipment, a wide variety of hand tools and power tools, general consumables for the workshop, and personal protective equipment (PPE). As a total supply and solutions package, there is nothing that we cannot provide to customers in a workshop or warehouse."

She is excited about the welding opportunities for the Witbank branch, particularly after the recent merger of interests between First Cut and Gas Safety International (GSI), which provides certified training and quality gas equipment to the industrial sector. The new relationship with GSI also became effective from 01 November 2021, the same day the Witbank branch officially opened.

Vorster notes: "I certainly envisage that GSI will be able to add value to our Witbank customers with its gas safety training and its experience in promoting a safe, efficient working environment. For example, GSI's expertise ties in significantly with what First Cut will offer from the oxyfuel side of the business. Emphasising the importance of safety is critical in even the smallest workshops.

Our adopted strategy of 'Safety First' creates the platform to harmoniously blend the gas safety training that GSI offers, together with a world-class range of consumables manufactured in Germany by Messer. Our aim in the Mpumalanga region is to be at the forefront of the First Cut move from 'total cutting solutions' to 'total cutting, welding and grinding solutions'.

I believe this area is hungry for a new, dynamic supplier. We bring in quality products at competitive pricing, with a firm eye on safety aspects. I look forward to entrenching this new channel to the local mining and engineering market and being the solution for the customer," she concludes. wn

Ensuring optimum quality during production underpins the reliability of the Booyco PDS and CPS offering.

Booyco Stays at the Leading Edge of PDS Technology

As one of the earliest pioneers in proximity detection systems (PDS) and collision prevention system (CPS), Booyco Electronics has been pushing out the technology envelope for 15 years in the service of customers' changing needs.

"Understanding market requirements has always been the starting point for our technology journey," says Booyco Electronics CEO Anton Lourens. "We have therefore combined our close customer relationships in the field with an ongoing investment in technical capacity and product innovation."

An important contributor to the technological breakthroughs developed by the company has been its engagement with the Earth Moving Equipment Safety Round Table (EMESRT). This global initiative of major mining companies to improve safety has given Booyco Electronics valuable insight into the future requirements of PDS and CPS.

"Working with the key players in pedestrian and machine safety, we have ensured that we apply the latest technology in precisely the direction that the market demands," says Lourens. "For instance, we were able to develop solutions to meet EMESRT's Level 9 requirements, so that trackless machines could be "instructed" to automatically be brought to a stop in a risk / hazardous situation."

Driving this progress is a top-class engineering team which has been steadily growing to now comprise some 25 specialists. This highlights the need for the company to stay abreast of digital and electronic developments that can be harnessed in the PDS and CPS space.

"Globally, technology is developing at an exponential rate," he says. "To keep up with what is available, and to fully leverage new technologies into our PDS offerings, we employ a team that is young, well qualified and enthusiastic."

To make the most of modern technologies, this new generation of engineers is paving the way to safer and smarter mining, says Lourens. This cohort does not shy away from change and advancement, making them ideal to keep Booyco Electronics at the cutting edge of PDS and CPS innovation.

"This has allowed us to keep upgrading our products for greater functionality and versatility," he says. "The process has included making regular use of the testing services of third party providers, such as. at the Vehicle Dynamics Group at the University of Pretoria – to fully evaluate our innovations before release to the market." wn

A cast resin transformer within an IP54 enclosure with an air-to-air heat exchanger suitable for harsh environmental conditions, such as those in mining applications.

A dry-type transformer within an enclosure with a water-to-air heat exchanger suitable for high temperature confined spaces.

There's more to Transformers than meets the eye

While it might seem at first glance that there is little to distinguish one transformer from another in terms of design and construction (other than size), the differences can in fact be substantial and potential buyers need to be aware that there is certainly far more to a transformer than initially meets the eye.

David Claassen, managing director of Trafo Power Solutions, says that in order to make an informed decision as to which product will best meet the needs of a particular application, the customer will need to look at several factors, including the ambient temperature ranges in which the transformer will operate, the expected core and copper losses, the load conditions and the ability of the manufacturer to test products in accordance with appropriate standards.

"The minimum, maximum and average temperatures in which a transformer can safely operate will affect the design and consequently the price of a transformer," he explains.

In dry-type transformers, two main temperature winding insulation classes exist – namely Class F and Class H. Class F allows the transformer to operate safely at temperatures up to 155°C without damage while Class H allows the transformer to accommodate temperatures up to 180°C.

Claassen says another detail to look out for is that both oil-cooled and dry-type transformers are available in multiple cooling options.

"The most common is natural air (AN), where the surrounding still air is used to keep the transformer operating within the correct temperature range. The second most common option is the forced air (AF) method, which entails moving air over the radiators, or over the core and windings. This allows the temperatures to be kept in check," he explains.

Transformers using forced cooling are able to supply additional load over and above the nominal power rating but it is important to rate the transformer at AN (natural ventilation) and use the fans as a temporary measure.

With regard to transformer losses, these comprise two parts – load or core losses and no-load or copper losses. It is important to note that there are IEC standards set up as to what the maximum allowable load and no-load losses may be. The higher the transformers losses are, the cheaper it is to produce and the operational cost will be higher

Also important is the load that the transformer will supply (or be supplied by). Unfortunately, with today's modern grid there is no such thing as a perfect load. Power electronics, as well as many other switching electronics, have contributed to non-sinusoidal waveforms, and hence harmonics. The Total Harmonic Distortion (THD(i)) that a transformer encounters significantly influences the design of that transformer.

Finally, potential buyers need to look carefully at the quality control programmes manufacturers have in place. These will ensure that at all stages of manufacturing all raw materials and components can be tracked. wn

Neal Froneman, CEO of Sibanye-Stillwater

Sibanye-Stillwater to buy Amplats' interest in Kroondal platinum mine

Sibanye-Stillwater has penned a deal to acquire Anglo American Platinum's share in the Kroondal platinum operation - a move that will double the life of the mine.

The group announced at the end of January 2022 that it had entered into an agreement with Anglo American Platinum which would see Sibanye assume full ownership of the low cost, mechanised Kroondal operation, a Platinum Group Metal (PGM) mine located adjacent to Sibanye-Stillwater's Rustenburg operation. This transaction will see the life of the Kroondal operation extended to 2029 and ensure significant value creation for all stakeholders, Sibanye said.

Sibanye-Stillwater CEO Neal Froneman said the transaction is mutually beneficial and will, through the full consolidation of the operations under a single owner, unlock significant value for all stakeholders by extending the operating life of the Kroondal operation.

As a standalone operation Kroondal was constrained and by the end of 2020 certain of its shafts had already reached the end of the lease area.

"We are unlocking the true potential of these adjacent mines by utilising the mechanised and low cost Kroondal operation to mine cross the boundary with the Rustenburg operation," said Froneman.

"This will accelerate the extraction of more remote parts of the Rustenburg operation orebody, sustain employment for more than 2500 people until 2029 and ensure the creation of significant value for all stakeholders in the region."

Sibanye currently operates Kroondal but the mine is subject to a 50/50 "pool-and-share agreement" between Kroondal Operations Proprietary Limited – a wholly-owned Sibanye subsidiary – and Rustenburg Platinum Mines, an Amplats subsidiary.

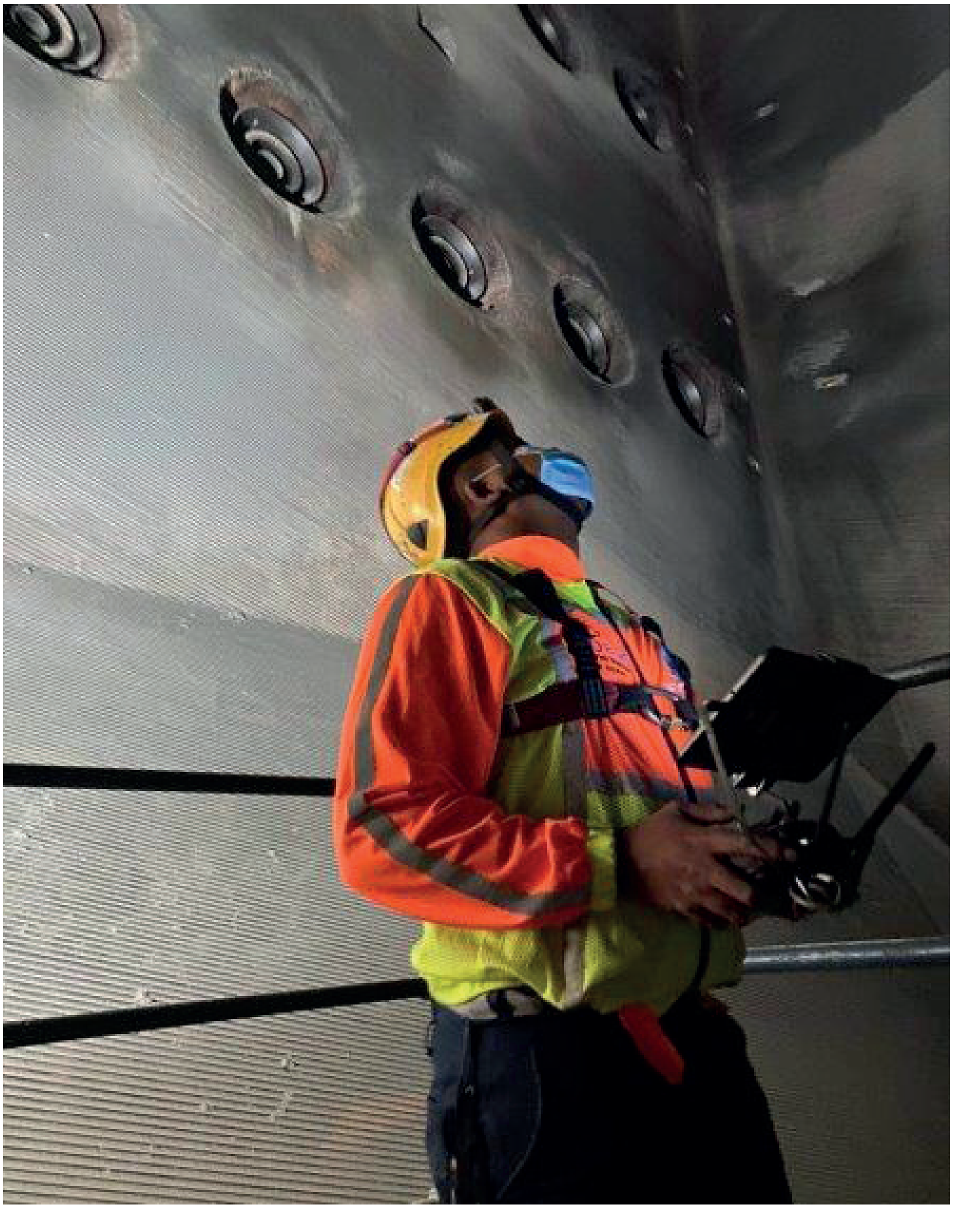
The deal announced on the 31st Jan 2022 will see Amplats dispose of its 50% interest in the Kroondal pool-and-share agreement to Sibanye for the bargain price of just R1. As part of the deal, Anglo will also dispose of the Marikana pool-and-share agreement, where Sibanye is also the other 50% owner. The operation in question has however been under care and maintenance since 2012.

Sibanye will in turn assume all of the associated liabilities, including rehabilitation liabilities of an estimated R415 million.

The deal is conditional to all the regulatory approvals being obtained. Another condition precedent is that Sibanye deliver 1.35 million ounces of 4E PGMs (ore containing platinum, palladium, rhodium and gold) to Amplat's designated smelters. The ore will be obtained from mining Kroondal as well as Sibanye's Rustenburg operation's and its Klipfontein open pit operation. Sibanye said this condition precedent is expected to be fulfilled early in 2024.

Amplats CEO, Natascha Viljoen, said the deal was a win-win. "The Kroondal operation has a short mine life under the current pool-and-share agreement terms. By enabling Kroondal to mine through the boundary at Sibanye-Stillwater's Rustenburg operations, we will extract our attributable share of the Kroondal reserves more quickly and efficiently than under the previous mine plan, unlocking greater value for Anglo American Platinum and Sibanye-Stillwater." wn

Elios SkyEye drone makes light work of boiler inspection at major power station



The benefits of using advanced drone technology for inspecting boiler internals at a power station were on full display when rope access specialist Skyriders Access Specialists (Pty) Ltd. recently undertook a project in the Nkangala district of Mpumalanga.

The Elios SkyEye drone clearly demonstrated not only how accurate and efficient this technology is, but also highlighted its safety aspects, as there is no need to erect expensive and cumbersome scaffolding to gain access to carry out a manual inspection.

"Our drone technology is specifically suited for visual inspection in indoor environments like the large coal-fired boilers and ducting at power stations. Traditional drones cannot use GPS tracking and stability when indoors," explains Skyriders Marketing Manager Mike Zinn. Elios SkyEye, on the other hand, is collision-tolerant for flexible and highly accessible remote visual inspection.

The drone incorporates a full HD camera, a thermal camera, and an onboard LED lighting system with remotely adjustable intensity. This means that an array of onboard tools is available for any lighting conditions. A cutting-edge wireless communications system with a live video feedback means that the drone can be brought into usually inaccessible places up to many hundred metres beyond the line of sight.

The Elios ground station comprises a remote controller, a tablet, and a purpose-designed ground-control application, providing the pilot with live data and an SD live video stream captured by the drone. All the information and controls are on hand for efficient and safe remote operation. In addition, the drone is dust- and splash-resistant and can operate in environments from 0°C up to 50°C.

"Our boiler inspection work has a huge amount of experience behind it. There are other companies that carry out boiler maintenance, but they lack the seasoned piloting capability of our drone team. Our team is really brilliant in ensuring that the deliverable is clean and stable footage, affording them the necessary time as well to carry out a thorough inspection," highlights Zinn.

"Our drone pilots are just so good at what they do. That fantastic imagery we have access to, and which we then use as the basis of our inspection reports, really sets us up for continued success in this important sector." Another key differentiator for Skyriders is that it has been issued with a Remote Operating

SAIEE Africa Research Journal indexed by Directory of Open Access Journals (DOAJ)

The Department of Higher Education and Training (DHET) in South Africa accredits journals in various ways. There are several requirements for accreditation, one of which is that articles must be peer-reviewed. In essence, accreditation means that for papers published in a journal by an author affiliated with a South African public university, the university will receive a subsidy for the publication.

To establish accreditation and associated credibility, DHET recognises journals via its own review processes. Furthermore, DHET also recognises certain national or international databases. The SAIEE Africa Research Journal is listed by SciELO SA, indexed by Scopus and hosted by IEEE Xplore (which also helps for citation tracking).
As of 2022, the journal is listed by the Directory of Open Access Journals (DOAJ) – our latest accolade.

For purposes of DHET accreditation, among others and relevant to the SAIEE Africa Research Journal, the following international databases are applicable: SciELO SA, Scopus and DOAJ. The journal is also listed by the Web of Science (WoS): Emerging Sources

Citation Index. The origin of WoS goes back to the Institute for Scientific Information (ISI) and is currently maintained by Clarivate.

With backfiles of the journal available on IEEE Xplore (since 1909), the international usage of the journal continues to improve.

All articles are accessible as open access. wn

Further information is available here.

Disclaimer: International databases can change at any time and at times without notice – for the latest indexing status, refer to the relevant website: WoS, Scopus and DOAJ.

Certificate (ROC) from the South African Civil Aviation Authority (SACAA). This means it is certified to deploy its drones outdoors within civil airspace, thereby dramatically extending the scope of its inspection services for clients.

Zinn is confident that the project at this large coal-fired power station will secure additional work for the Elios SkyEye drones. The application of the latest inspection technology is a fitting capstone to Skyriders' long involvement with various power stations. wn

Connect with Skyriders on Social Media to receive the company's latest news
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Winners of People.Planet. Product student design challenge

Innovative winning solutions will enhance the design and accessibility of the Divya manual crank washing machine developed by The Washing Machine Project, helping to improve lives

Electrocomponents plc (LSE: ECM), a global omnichannel provider of product and service solutions, has announced the winners of the People.Planet.Product student design challenge launched early last year in collaboration with the company's first global social enterprise partner, The Washing Machine Project, a humanitarian initiative dedicated to alleviating the burden of handwashing in low-income and displaced communities through innovative product design and distribution.

The challenge tasked student members of the DesignSpark engineering community to apply original thinking and practical skills to the ongoing development of The Washing Machine Project's first water-saving off-grid manual crank-handle washing machine, the Divya. Entries were invited in three different focus areas: People (empower people to use the Divya by improving the technology or implementation of the design); Planet (filtering out greywater or microplastics); Product (encourage better posture through changes in weight, portability, for example). The three winning designs selected from six global finalists in first, second, and third place were Kai Goodall, Team Scentury and Joseph Baker.

South African winner Kai Goodall's 'Pedal n Spin' design is a foot-cranked washing machine that rotates easily using a combination of the principle of a treadle system and pedal system. It is a pedal-powered connected rod driven rotating drum washing machine system that is purely mechanical in nature. It improves the user's posture, ease of use, and sustainability of the current Divya washing machine, allowing longer-term adoption, improved hygiene, and increased rotation efficiency with a substantial mechanical advantage.

Kai, currently a master's student in Electrical Engineering at the University of Cape Town (UCT), mentioned that it has been moving to see that his sustainable and user-friendly washing machine design was selected as one of the winners of the global contest.

"My UCT supervisor and chairman of the Institute of Electrical and Electronics Engineers (IEEE) South Africa, Dr David Oyedokun, inspired me to compete in the RS Components Student Design Challenge, and I came out tops with my Pedal n Spin foot-cranked washing machine innovation. Being the sole finalist from Africa in the competition and winning first prize was a special recognition of my invention and motivated me to take my passion to new frontiers, and hopefully inspire more young people to use engineering as a tool for their progression" he said.

South African winner Kai Goodall

All six finalists, including Team Oro (Product), Team Neolithic (Product), and Ketki Dave (Planet), pitched their designs at a live virtual event to a panel of judges from leading industry and humanitarian organisations that share the common goal of helping to improve lives. Mike England, Chief Operating Officer at Electrocomponents, opened the finals with a speech about the company's commitment to 'Making Amazing Happen For a Better World' through social impact partners and education programmes. Yewande Akinola MBE, Ambassador for Clean Growth and Infrastructure, UK, delivered a keynote at the event, emphasising the importance of 'sustainability and innovation for our world.'

Panel judge Navjot Sawhney, Founder of The Washing Machine Project, commented: 'With the Electrocomponents Grassroots team, The Washing Machine Project devised the People.Planet.Product student design challenge to inspire students with STEM backgrounds to get involved in our humanitarian initiative. These are the scientists, engineers, and mathematicians of tomorrow, and the amazing quality of designs we have seen through this challenge is heart-warming and proof that the younger generation is fully engaged in playing their part in a sustainable future."

Fellow judge Mike Bray, VP Innovation and DesignSpark at Electrocomponents, which hosted the challenge, said: "The Washing Machine Project is such a great engineering initiative to help improve people's lives. Combining this with the inspirational ideas of student engineers through our DesignSpark community, we can work together to truly make a massive difference to people around the world."

Providing active support for the People.Planet.Product challenge, and completing the line-up of distinguished judges were: Bjoern Klaas, CEO EMEA region, Protolabs; Clare Larkspur, Head of Product Management, Elvie; Simon Wells, VP Engineering, Shark Ninja; and Eleonora Gatti, Innovation Portfolio Manager (WASH + Climate Change), Unicef.

Each of the three winners receives £1000 in RS products or a cash equivalent to support their prototype development, plus access to a business mentor and a knowledge session with The Washing Machine Project founder, Navjot Sawhney.

Kai has recently joined forces with Forest Creations, a sustainable woodworking company, to create four more improved Pedal n Spin units for donation and field testing in Cape Town townships, looking towards more sustained manufacturing and distribution.

"I welcome collaboration and financial support in my bid to roll out many more of these units, to provide a healthy and sustainable innovation to those in need," he concluded. wn

Kamoa-Kakula Project

ZEST WEG SUPPLIES EXTENSIVE RANGE OF MOTORS AND VARIABLE SPEED DRIVES FOR SECOND PHASE

Zest WEG is supplying an extensive range of motors and variable speed drives (VSDs) for the second phase of the Kamoa-Kakula project, one of the world's most exciting new copper developments, located on the Central African Copperbelt in the DRC.

Phase one produced its first copper concentrate on 25 May 2021, and is expected to produce 200,000 tonnes of copper in concentrate annually. Phase 2, now in the advanced stages of construction, will result in a doubling of production capacity. Future phased expansions will eventually see a mining rate set to process 19 million tonnes per annum.

For the first phase of the project, Zest WEG was also the key supplier for this electrical equipment. According to Joe Martins, mining sector specialist for Zest WEG, the mine's scope of supply for the second phase is a repeat of the first.

The first phase was supplied in 2020 with WEG medium voltage VSDs and WEG high voltage motors to drive the mine's primary and secondary mills in the concentrator plant.

"We began to manufacture these long lead time items in 2019, and delivered two medium voltage VSDs and two 3,3 kV motors for the mine's 7,000 kW primary ball mill and its 7,000 kW secondary mill," says Martins. "Our high voltage motors and medium voltage VSDs were also selected to drive the two 1,200 kW high pressure grinding rolls (HPGRs) in the plant."

WEG high voltage motors and automation solutions drive the underground ventilation fan applications, providing fresh air to the underground mine workings, he says.

All these large items are designed to specification, manufactured and tested in WEG's Brazil facilities. Due to Covid-19 travel restrictions, the factory acceptance tests were conducted virtually, with special processes being developed to allow thorough inspection and comment online. The testing of the equipment for phase two – also conducted in a virtual environment – was completed in the third quarter of 2021.

Significantly, Kamoa-Kakula will be among the world's lowest greenhouse gas emitters per unit of copper produced, and Zest WEG's energy efficient motors and automation solutions will contribute to this.

The first phase order included over 700 WEG low voltage IE3 premium efficiency motors, supplied to various local and international original equipment manufacturers, and installed throughout the concentrator plant. These motors drive equipment such as the rock breakers, conveyor drives, flotation cells, thickeners, slurry pumps, winches and other mechanical OEM packages.

Where processes within the plant required variable speed control, WEG low voltage VSDs were selected to provide the speed and control necessary for this equipment. Martins explains that by selecting WEG low voltage VSDs in combination with WEG low voltage motors, Kamoa-Kakula will benefit from a 36 month warranty period.

"An important part of the energy efficiency strategy was for the plant to standardise on our IE3 premium efficiency motors – rated according to the IEC 60034-30 international standard," he says. "With a class leading energy efficiency rating, this means reduced carbon emissions and greatly reduces operational energy costs."

Additionally, Zest WEG is supplying the Kamoa-Kakula Project with a new 20 MVA, 33kV/11kV mobile substation, which is currently being manufactured in South Africa. The substation will provide stepped down power, and can be moved to supply power to different areas within Kamoa-Kakula's mining footprint.

A large amount of WEG low voltage motors were installed in phase 1 (left) and are also being supplied and installed in phase 2 (right).

"Underpinning the performance of our equipment at the mine will be high levels of service and support from Panaco who is our Value Added Reseller (VAR) in the DRC," says Martins.

A WEG high voltage motor being lifted into position on site at Kamoa-Kakula.

Commenting on VARs, Martins says that those appointed by Zest WEG in this role are far more than simply distributors. "Panaco, as our VAR in the DRC, is a 100% locally owned business specifically chosen to promote and support the wide range of Zest WEG's offering in the region. Its team includes technical specialists and the company's operating methodologies and culture are closely aligned with ours, and will aid in supporting our current installed base, client network and growth expectations in the region." wn

FROM PRE-HISTORY TO MODERN TIMES:

Dutch brewing company continues innovations with Danfoss VLT Drives

Which came first in the history of civilisation: bread-making or beer-brewing? Since the 1950s, scientists and scholars have been arguing about what really caused our early ancestors to start farming and settling down, rather than remaining as nomadic hunter-gatherers.

Ferdie Fortuin, Sales Manager – General Industry at Danfoss Drives South Africa, notes: "Whatever the answer to this 'chicken or egg' question, one thing is certain: human beings have taken the brewing of alcohol very seriously for centuries. For example, the famous German 'Reinheitsgebot', or 'beer purity law', is over 500 years old, and was originally introduced as a trade regulation law. Today it is praised as being an early food safety regulation , possibly even the world's oldest intact law to regulate beer contents . And so, in the spirit and tradition of taking beer brewing and safety regulations seriously, Danfoss offers solutions for different processes throughout the brewing industry, where 'control' is a key word all the way from mash to bottled product.

"Danfoss has experience in breweries application systems worldwide, for example, Danfoss variable speed drives (VSDs) are suitable for all processing control and monitoring, no matter what the specific protocols might be. With our latest condition base monitoring (CBM) technology, we can even provide more information feedback from a single drive that could assist with maintenances schedules within the breweries."

Fortuin clarifies that a brewing company in the Netherlands decided to embrace innovation from Danfoss to secure a more solid and sustainable future. The solution involved using Danfoss VLT® drives with integrated condition-based monitoring (CBM) capabilities to reach its goals.

THE CHALLENGE

With the European beer market expected to grow 15.2 percent by 2025, the company realised that, to meet demand, its production line had to deliver a consistently reliable and excellent performance.

However, prior to Danfoss Drives' input, the brewery faced costly and lengthy disruptions whenever a machine fault occurred, with operations taking place in harsh, wet conditions and all applications containing concealed motors, making them difficult to access when issues arise.

Danfoss was tasked with helping the brewery to:

- Increase up-time;
- Lower overheads;
- Improve management of spare parts and stock;
- Access new levels of machine data; and
- Boost application and system performance.

THE SOLUTION

In August 2019, Danfoss Drives proposed that the brewery install VLT® drives with embedded intelligence, connectivity and sensor capabilities. Condition-based monitoring signals were then integrated into the brewery's maintenance system via edge computing.

The brewery also received 4-20 mA vibration sensors from Hansford Sensors, and Danfoss provided

additional support with project scoping, commissioning, and training, as well as hosting workshops to determine the best solution for the company's needs.

The VLT® drives also support pre-existing communication interfaces and software such as fieldbus, local control panels, and VLT® Motion Control Tool MCT 10, meaning the brewery did not have to invest in a new parallel system as part of the upgrade.

THE OUTCOME

"The VLT® Motion Control Tool MCT 10 plug-in brought a tremendous improvement," says Fortuin, "enabling seamless commissioning with consistent parameter settings. And so, with the power to gather more critical application data in real time than ever before, due to the efforts of Danfoss Drives, the brewery was able to optimise its production line while solving all its challenges and building a total value proposition.

"In addition, Danfoss Drives' digital expertise enabled the company afterwards to retrofit the rest of its drives elsewhere in its facilities with condition-based monitoring functionality."

CONCLUSION

This upgrade shows that condition-based monitoring is no longer a premium product meant for a few critical assets, but an affordable solution available for all, provided by Danfoss Drives' innovative and forward-thinking approach. "Edge computing in the drive ensures smart and simple condition-based monitoring," says Fortuin. "At Danfoss, we have the required experience and specialised application knowledge to act as a competent and trustworthy partner for the global brewing industry.

"It seems that humankind has been brewing beer since the dawn of time, and it is Danfoss' proud intention to continue assisting this process to the highest standards of efficiency and quality control," he concludes. wn

Mining: Why digital innovation is vital

How to capture the skyrocketing demand for minerals with increased operational efficiency via predictive maintenance technology

Mining dates back thousands of years. Since its inception, mining has helped civilisations and created many modern conveniences. Consumer electronics, building materials, and chemical manufacturing rely on mineral components. Coal remains the primary power source for electricity in many developed countries.

Mining is an integral part of the economy for nations worldwide, and our reliance on minerals is profound and widespread. As the world embraces new carbon neutral and green initiatives, the need for minerals is escalating. And, demand is forecasted to skyrocket in the coming years. Mining companies, however, must embrace digital technology and better optimise operations to extract these minerals profitably and meet growing demand.

Since mining is a cyclical industry with capital-intensive operations, successful mining operators must achieve the lowest possible production costs. The critical lever to reducing costs is maintenance, a function full of untapped potential. Areas such as decreasing the steep cost of fleet maintenance and reducing the frequency of unplanned downtime are ripe for mining innovation today to meet demand tomorrow. Novel predictive maintenance approaches answer this need.

In this paper, we've outlined an innovative way forward for mining companies, built on proven and extensive industry experience. Our goal is to inform, enable, and support mining companies, help them meet their goals and collectively build a more robust, greener future for all.

SKYROCKETING DEMAND FOR MINERALS

Mining's rich history has ushered in

tremendous possibilities for humankind. The valuable resources found underneath the earth's surface have enabled profound innovations, bolstered newfound capabilities, and spurred economic growth. Minerals are an essential part of our everyday lives, from salt and toothpaste to electric vehicles and smartphones.

Today, mining is poised to catalyse a new era of innovation in green energy and low-carbon capabilities. As a result, demand for minerals is expected to skyrocket. Per a World Bank Group report, graphite, lithium, and cobalt production could increase almost 500% by 2050 to meet the demands for clean energy.

A significant lever to mineral demand is the requirement to achieve a "below 2 degrees Celsius" future. Estimates project that 3 billion tons of minerals and metals are required to deploy energy storage and wind, solar, and geothermal power to achieve this goal. Nearly 200 countries are committed to limiting global warming to no more than 2 degrees Celsius by the year 2100, the worldwide metric that mitigates significant and damaging changes to the planet. As climate targets and clean energy requirements become more ambitious and accelerate, the demand for minerals escalates. Because of their pivotal role in our economy and future, mining companies have been and will continue to be crucial. Their track record is proof. Mining companies' resilience during volatile times has earned them "the bedrock of economic recovery".

URGENT NEED: IMPROVE MAINTENANCE AND PRODUCTION EFFICIENCIES

In preparation to meet the increasing demand for minerals in the future, mining companies must innovate today. Specifically, proactive versus reactive management of highly cyclical and capital-intensive mining operations is necessary to maintain the lowest possible production costs. Compounding this challenge for miners are rising costs in energy, building materials, and equipment. And, no miner is exempt. According to The Globe and Mail, "Cost issues do not discriminate

70%

Currently, mining operations run at 70% operating efficiency due to breakdowns, stalled production, and other operating issues

30-50%

Maintaining plant, fleet, and equipment comprises 30-50% of mining operating costs

3-5X cost

Breakdowns and unplanned maintenance are 3-5X greater than planned maintenance

5% RAV

The average mining facility spends 5% of RAV (replacement asset value) on maintenance each year. By contrast, top performers spend 60% less, or 2%of RAV, on maintenance

Figure 1

by the metal produced or the size of the miner."

Why the urgent need for innovation? Because as demand grows concurrently, process interruptions carry significantly steeper costs. Additionally, to fully capitalise on the increasing demand, today's mining operations are not at appropriate efficiency levels—primarily due to maintenance issues. Look at the data points in Figure 1.

ENTER: DIGITAL TECHNOLOGIES AND DATA STRATEGIES

To overcome these current operating challenges, the adoption of automation and digital technologies is required. Technological capabilities will foster the creation of "Digital Mines" and help to:

1. Prevent failures/breakdowns/ unplanned downtime
2. Enhance worker's safety
3. Improve efficiency
4. Reduce energy consumption
5. Meet environmental requirements

Maintenance is the first step and a powerful lever to achieve lower production costs in mining.

Consider this mining example, where predictive maintenance technologies enabled the reduction of unplanned downtime. Condition monitoring insights provide the data to alert operators of potential failures before functional failure.

Thus, it allows proactive work scheduling during planned maintenance, partial outage periods, or routine equipment rotations. This optimises production, increases asset availability, and minimises maintenance costs while enabling reliable operations. The result? A 14% reduction in maintenance spending produces an $8 million reduction in operating expenses. See Figure 2.

However, innovation and transformation go beyond just reducing maintenance costs and implementing predictive

Current state—maintenance spend of $56.7M

Planned	45%	$20.0M
Unplanned	55%	$36.7M

Improved ratio—maintenance spend of $51.1M

Planned	70%	$31.1M
Unplanned	30%	$20.0M

Improved ratio—maintenance spend of $48.8M

Planned	80%	$35.5M
Unplanned	20%	$13.3M

14% reduction in maintenance spend equivalent to ~$8M in OPEX

Source: PWC report "Balancing Uptime and Working Capital: Maintenance and Inventory Strategies in Mining"

Figure 2

maintenance technology. For mining companies, it's about working differently and working smarter to achieve more reliable mining operations.

Foundational to this goal is developing a digital data strategy—across functional siloes and technologies.

The potential of data to transform operational effectiveness is irrefutable. However, there is a big jump between collecting data > using and analysing data,> extracting actionable and meaningful insights from that data. A 1% utilisation of data, for example, is the equivalent of squandering 99% of the data-collection investment. Without industry-tailored algorithms and actionable insights to drive measurable business outcomes, the full potential of data-driven innovation cannot be realised.

Similarly, balance is vital. Data helps drive smarter decisions by balancing the reduction of maintenance costs while simultaneously ensuring improvements in operational efficiency via equipment reliability and availability. Enabling operation-wide optimisation mandates to change. This change begins when the shift from reactive, tactical maintenance to predictive, strategic asset management is underway.
In mining operations, employee safety is of paramount importance. Technology is recognised as a critical determinant of enhanced safety. Due to less machine interaction and a decrease in urgent, reactive work, proactive, planned maintenance outcomes can also foster significant safety improvements. In one example, an OEE (Overall Equipment Effectiveness) improvement of 52% delivered a safety improvement of 69% during ten years.

THE POWER OF CONDITION MONITORING SYSTEMS

In mining operations, predictive condition monitoring systems are the gateway to unleashing the latent potential in maintenance and strategically leveraging it. While condition monitoring systems are proven to deliver outcomes, adoption in mining operations is often in siloed applications and not fully integrated as a sustainable business process. However, data-driven, predictive condition monitoring systems are now a must-have competency across mining operations.

The underlying tenet of predictive solutions is this: failure is a process, not an event. This means there is an opportunity to mitigate total failures at the lowest possible cost and with the most negligible operational impact. It also means that time-based systems, although still in use today, are poor predictors of potential failure. Time-based systems can create avoidable and costly unplanned downtime while incurring preventable costs and unnecessary routine maintenance tasks.

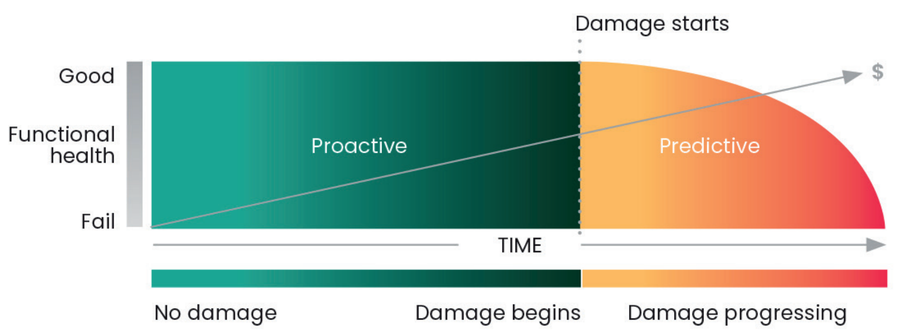

Figure 3

FAILURE IS A PROCESS

Condition monitoring's unique value is built on failure as a process. The P-F curve depicts this concept by delineating potential and functional failure time. Asset health indicators are used to identify potential failure before any damage or degradation. As a result, higher-order situations can be averted, sound decisions made, and repairs scheduled at the most advantageous times and lowest possible costs.

HOW CONDITION MONITORING DETECTS POTENTIAL FAILURES

The way that condition monitoring systems predict impending failures before they occur is by monitoring and assessing an asset's mechanical characteristics such as:

- Vibration
- Temperature
- Efficiency
- Oil chemistry/particulates

By monitoring these variables, customised for each asset, pattern changes or anomalies can be identified. With tailored algorithms and customised configurations and set points, operators are then alerted to developing issues that need to be addressed.

DIFFERENT MINERALS, DIFFERENT ASSETS, DIFFERENT STRATEGIES

Across mineral types, the three primary mining processes, surface mining, underground mining, and mineral processing, are diverse. Further variations exist within the three major mining categories, such as open-pit, quarrying, slope mining, and shaft mining. There are many different assets used (spoiler alert: mining schematic in next section).

While condition monitoring is beneficial across all mining types and processes, different machines require different strategies. As shown below, factors such

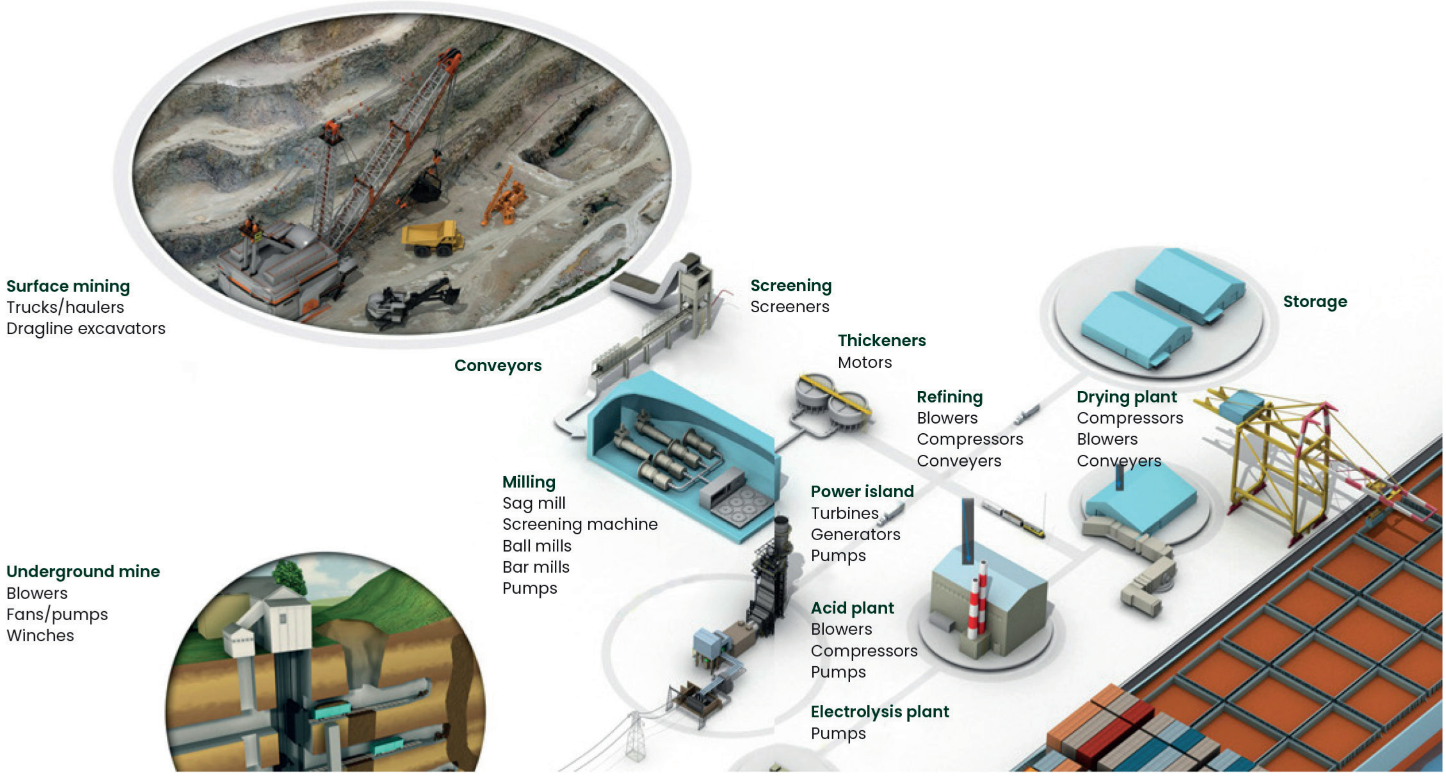

Figure 4

as failure, availability of replacement parts, and criticality/ process all impact condition monitoring specifics.

Upon implementation, additional customisation is done for each asset to collect the proper data. And industry-tailored algorithms diagnose that data into actionable insights and a roadmap.

A clear roadmap helps mining operators to prioritise maintenance activities, establish focus, and incorporate knowledge-based experience "automatically", thereby reducing dependence on the inherent variability in workforce experience while boosting employee safety.

THE DIGITAL MINE: APPLICATION AREAS

Automation and digital technology can be used throughout mining operations, starting with condition monitoring systems. For example, assets such as excavators, conveyors, haul trucks, crushers, blowers, compressors, lifts, slurry pumps, and the power island are well suited for condition monitoring systems.

This schematic shows a sampling of mining assets and application areas apt for condition monitoring technology. See Figure 4.

HAUL TRUCK EXAMPLE

In mining operations, reliance on haul truck health is escalating. Haul trucks move raw materials, so extraction speed must correlate with transportation speed. Miners have invested in larger, automated trucks to ensure better timing alignment. As such, monitoring the health of these assets to bolster availability and reliability is an increasing challenge.

Unique haul truck requirements must be overcome, such as offline monitoring effectiveness, data collection at precise and critical times, and a data link to a monitoring centre.

For one mining company, Bently Nevada engineered a customised solution for the haul truck's control system to monitor its' health in two critical states:

1. Running and loaded. Vibration data is collected while the truck is running, loaded and in reverse mode (braking the truck using the electric motor of the electric wheels).
2. Unloading. Vibration monitoring when the haul truck bucket is rising.

The result? An estimated savings of USD 5 million per year. This is based on an iron mine fleet of 30 trucks operating at 80% capacity. Specific savings categories include USD 40K savings per truck/year, the mitigation of catastrophic failures (using wheel cost of USD 400K), and the increase of uptime and availability of haul trucks, which reduces maintenance time and intervention activities.

GETTING STARTED

Outcomes like the haul truck example above are transformational for mining companies—and this is just one of many applications possible for mining operations.

All condition monitoring systems, however, are not created equal. As digital technologies and automation are used more frequently in mining operations, proven, the comprehensive experience becomes increasingly important. Since technology investments must be scalable and connectable, starting with the proper foundation is essential.

To ensure optimal performance, miners need industry-tailored solutions via a like-minded partner with deep, proven expertise in full-suite condition monitoring technology and mining operations.

ESSENTIAL ATTRIBUTES OF TOP TIER CONDITION MONITORING SYSTEMS

When paired with an experienced solution partner, here are some of the essential attributes of a top tier condition monitoring system:

- Cyber secure architecture
- Data extractions based upon specific domain expertise and reliability engineering competencies
- Interface to corporate data systems
- Enterprise-wide focus (including fleet analysis) with multiple predictive maintenance techniques and analysis methodologies within a single, standard software platform
- Templating for deployment and maintainability efficiencies
- The human-machine interface (HMI) visualises all asset health data across enterprise hierarchies (from fleet level to individual production assets).
- Exception-based monitoring design assigns subject matter expertise to configure and optimise the system only when a pre-configured alarm threshold or automated fault detection triggers the need for analysis. This can drive the more effective deployment of maintenance and reliability resources and reduce analysis workload by 90+%.

SUMMARY

The gateway to a greener future rests mainly on mining companies' solid and time-tested shoulders to supply the minerals for energy storage solutions and make "below 2 degrees Celsius" initiatives possible. To help mining operations meet this increasing mineral demand, technology innovations are needed to optimise production. Monitoring critical asset health to reduce maintenance costs and mitigating unplanned downtime is the first step. Expanding further to connect siloed data and optimise entire operations will bring additional benefits. The key is to start today so that lower operating costs help miners harness the benefits of increased uptime, optimised productivity, enhanced employee safety, and improved profitability. When this happens, mining companies can reap significant benefits. wn

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Digging Beneath the Surface

Mining has been central to the social and economic narrative of Southern Africa, and has been a key provider of investment, employment, government revenue and infrastructure in the region.

In South Africa, the Johannesburg-Pretoria metropolitan area, which serves as the region's economic and financial hub, developed because of the local gold supply. In the early years, mining developed on the back of migrant workers from across Southern Africa who toiled in the mines under poor conditions. Many ex-miners suffer from vocational diseases to this day. While mining has helped build the economies of Southern Africa, it has come at social and environmental costs that cast a long shadow. Inequality is also high in many Southern African countries, suggesting that mining has not translated into inclusive growth. This report attempts to examine and weigh the various benefits and costs that mining has brought to the Southern Africa region.

Data limitations are significant, restricting authoritative conclusions on whether the benefits from mining are positive or negative, on balance, for Southern African societies. The emphasis of this report is thus on taking stock of various benefits and costs associated with mining, while drawing on available information and thought experiments to highlight the potential trade-offs and how they affect stakeholder groups: workers, investors, governments, communities, and the rest of the economy. The countries this report focuses on are Botswana, Lesotho, Eswatini, Namibia, South Africa, Zambia, and Zimbabwe. Sub-soil assets are sources of national wealth.

Extracting them from the ground can unlock their value for societies. This requires that "rents" (i.e. income beyond commercial returns from the mining process) are captured and used for socially desirable ends - which includes investment in other national assets. This is largely the responsibility of the government. Other benefits from mining derive from the production process itself which generates returns to the factors of production (especially capital and labor). Mining is becoming an increasingly capital-intensive process and thus, larger returns tend to accrue to capital. Given the local constraints in many Southern African countries, mining depends on foreign capital and foreign skills, which means that part of the income generated will accrue to foreigners: not all benefits will be captured by the country owning the natural resources.

Mining also creates various costs. Health impacts on mine workers have been significant; pollution can have significant adverse effects on local communities. Carbon-dioxide (CO_2) and other emissions can have localized effects and create global externalities such as the acceleration of climate-change. Mining companies have increasingly been undertaking significant efforts to internalize the costs imposed by mining. They have also become more socially responsible, through investments in health, skills, housing of their workers,

and other significant investments in mining communities. Yet in many cases these efforts have not fully succeeded in strengthening relationships across mining stakeholders.

Finally, mining has created significant

An Exploration of the Net Benefits of Mining in Southern Africa

forward and backward linkages in Southern African economies, providing a stepping stone for the development of value chains. Economic multipliers are significant, meaning that the benefits of mining go beyond the mining sector, creating positive spillovers, such as jobs, revenue that governments use to finance infrastructure in other sectors, (although these sectors also generate negative externalities, such CO_2 emissions associated with, say, energy-generation from the mined coal). At the same time, mining can also cause negative externalities for non-mining sectors, such as an appreciated or volatile exchange rate.

Based on available data, this study finds that the net benefits of mining are positive in Southern Africa, even when taking into account foreign outflows of income. Yet most of these benefits are consumed rather than saved and invested. This means that for countries to maintain their national wealth when depleting their sub-soil assets, they will need to either reduce consumption or mobilize additional savings from other sectors.

Even though this study finds that the net benefits of mining are positive for Southern African societies overall - keeping in mind the data constraints in deriving this conclusion — there is still room for contestation. This contestation can link to the overall amount mining is expected to contribute to an economy, with governments developing requirements designed to foster greater linkages (referred to as "beneficiation"). Or it could be about the overall distribution of income from the proceeds of the production process, with governments trying to capture a higher share of the rent, workers and communities trying to obtain higher wages or benefits or demanding better compensation for the costs they incur. Such contestation can become particularly tense when external pressure increases, say due to falling commodity prices, or due to changes in the production process, such as mechanization, impacting jobs.

Such conflict can be further fueled by incomplete transformation due to opaque reporting or accounting practices, which can undermine trust during negotiations. The study shows that these social dynamics at times result in policies (or actions such as strikes) that can reduce the commercial viability of mining, limiting investment and potentially causing the closure of mines. In other words, where the benefits and costs are considered to be inequitably distributed, the process of unlocking mineral wealth grinds to a halt altogether.

The analysis yields four broad policy implications. 1) Given the substantial risks in the region, relating to contracts, taxation, expropriation, industrial action, corruption, security, and regulatory burdens, creating a stable regulatory climate to de-risk mining investments and increase investor confidence is important. 2) Governments should implement policies that capture the rent, while being mindful of the need for the commercial viability of the sector, ensuring that firms are being compensated for the risks associated with mining. 3) Local beneficiation strategies should be developed around emerging comparative advantages, that can be developed in the medium-term future. 4) Sectoral changes, say from mechanization or transitioning away from fossil-fuel energy, should be managed effectively, by developing skills needed for both the future of mining and for diversified industries.

1. INTRODUCTION

1.1. Problem statement

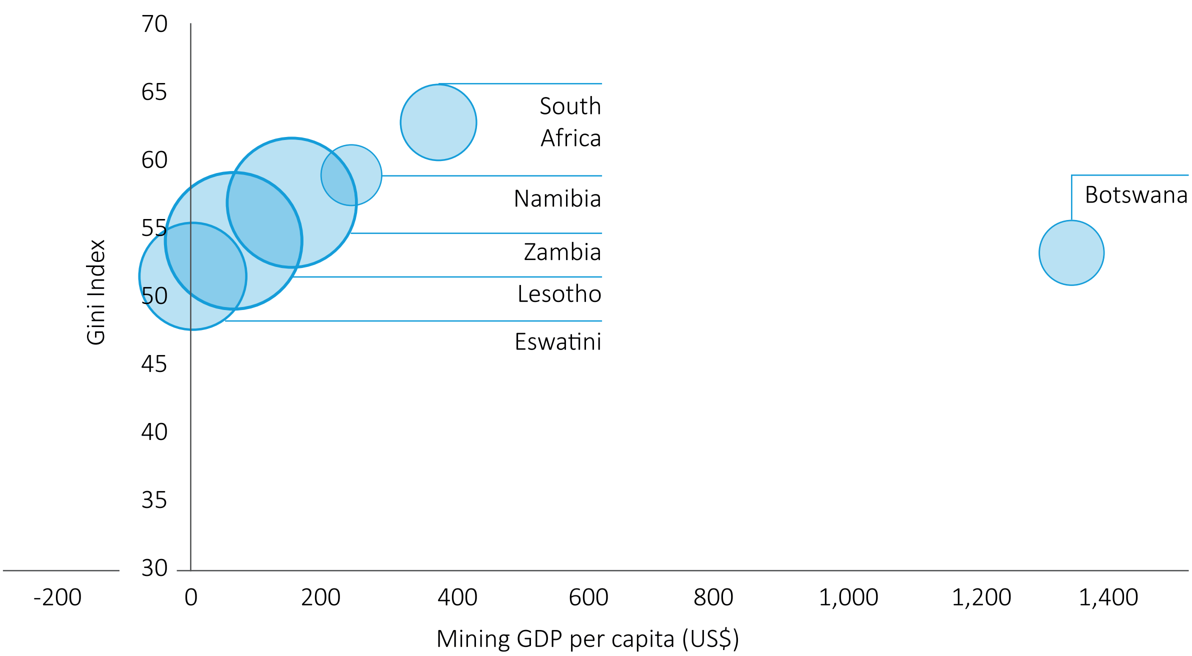
Southern Africa is home to the world's richest mineral deposits. South Africa alone is estimated to have non-energy minerals worth upwards of US$2.4 trillion, making it the wealthiest mining jurisdiction in the world (if petroleum reserves are excluded). However, mining and quarrying as a percentage of total Gross Domestic Product (GDP) has fallen from a fifth in 1970 to 8% in 2018. Lesotho has relatively little mining investment but is home to some of the most valuable diamonds on earth – including a 910 carat gem that was the fifth largest gem-quality diamond ever found. Zimbabwe is home to over 4,000 gold deposits, 90% in greenstone belts, making them some of the richest deposits in the world; the second largest platinum-group metals (PGM) deposits in the world; and is host to significant diamond deposits, among many other minerals. However, the country is still facing significant economic challenges and is shut out of capital markets, making foreign exchange increasingly difficult to acquire.

Yet the region is still among those with high levels of inequality. This report explores the benefits and costs of mining to various stakeholders in selected Southern African countries. Mining in Southern Africa has a mixed history with the sector in many countries associated with their colonial legacies – such as apartheid in South Africa and Namibia – and these perceptions continue to shape these societies (see e.g. World Bank, 2018a). Figure 1.1 shows that mining generates significant income in many countries across the region. Yet at first glance, mining appears to be correlated with high inequality, perhaps with the exception of Botswana, suggesting that the benefits of mining are not equitably shared across society. This report aims to look more closely at the benefits and costs associated with mining, distinguishing between the different stakeholders: workers, investors, governments, and communities. Attempts are also made to estimate the foreign outflows of mining, although various caveats apply to these estimates. It is important to note that the purpose of the report is not to judge whether mining is "good" or "bad" for a country but to take stock of evidence on the distribution of mining-related benefits and costs across a variety of stakeholders. The countries this report mostly focuses on are Botswana, Eswatini, Lesotho, Namibia, South Africa, Zambia, and Zimbabwe. While acknowledging that artisanal mining is an important source of employment in Southern Africa, the emphasis in this report is on industrial mining.

The difficulty in catalyzing mining wealth into more shared prosperity has been a recurrent – and controversial – theme across the region. Countries that are unable to extract resources by themselves are reliant on foreign direct investment (FDI). However, simply being endowed with resources is not enough to attract investment. Mining is a long-term investment – the process of exploration, development, extraction, and closure can range from 15 - 80 years. Thus, mining companies require a stable and predictable business environment to make such long-term investment decisions. At the same time, governments and their citizens want to ensure that they receive an equitable share from mining. Conflict over the distribution of the net benefits between mining companies and other stakeholders results in policy uncertainty that increases risk premia and makes mining companies less likely to invest.

Figure 1.1: The mining sector can be a driver of poverty reduction and inequality expansion

(Inequality and mining GDP per capita in Southern Africa; the size of each bubble indicates poverty rates at US$1.9 per person per day in Purchasing Power Parity terms)



Source: World Bank.
Note: Latest available data.

The distribution of benefits will shift as a result of sectoral dynamics such as mechanization, evolving fiscal regimes, global demand changes and commodity prices. And as each stakeholder seeks to maximize their share of the benefits, conflicts can arise. For example, as mechanization reduces the demand for labor, communities have gone on strike, demanding that more jobs be created, in an effort to maintain their income. Some investors have responded by finding areas for community development, such as vocational training.

The relative distribution of net benefits is changing as extractive operations are experiencing growing pressure to increase productivity in order to remain globally competitive. There are a number of factors contributing to the increasing pressure, including: (i) declining ore grades means that more ore must be processed in order to extract the same quantity of metal; (ii) the need to dig deeper to access reserves is more costly because superficial deposits have already been mined; (iii) the need to secure intermediate inputs, such as electricity and water, at reasonable costs; (iv) the need to have environmentally-friendly procedures, and comply with increasing international standards and safeguards; (v) to have social buy-in from local communities and to obtain a social license to operate, can require increasing expenditures on community development; and (vi) the increasing difficulty of accessing finance for coal projects, given the current climate change policy environment.

Additionally, mining companies have to adapt their strategies for the growing demand for minerals used by new technologies, such as autonomous and electric vehicles, robotics, advanced computing and IT, and renewable energy. Cobalt, nickel and manganese are needed for the future development of batteries; copper is an important conductor of wind power and is also used for wiring and motors; and rare-earth elements (REEs) are important for magnets in wind turbines, computer hard drives, and low-energy lighting. The United States and European Union have identified REEs and cobalt as high priority materials, given their relevance to clean energy and the existence of only limited substitutes.[1] Mining companies are largely focusing their exploration expenditures toward brownfield exploration (expanding existing projects) rather than greenfield explorations (new opportunities) and in jurisdictions that are perceived to have low-risk policy environments.

To remain globally competitive, mining firms have begun to adopt new technologies across the value chain. This has resulted in large job losses. Technological change largely occurs through the application of automation and artificial intelligence for autonomous machinery and equipment, remote and long-distance operation, and control and monitoring systems. The end of the last commodity super cycle accelerated the move to automation, as firms have looked to increase productivity while reducing expenditure on labor, which is the largest cost of a conventional mining operation. Operational jobs such as drilling, blasting and transporting constitute the largest percentage of mine jobs, and can be easily replaced by automated technology. There is an ongoing transition from a demand for low-skilled labor

[1] Carbon Brief, "These Six Metals are Key to a Low Carbon Future." April 12, 2018.

to high-skilled labor,[2] as remotely controlled and automated systems replace blasters and drillers. This will affect firms' ability to secure a social license, which largely depends on the degree to which host communities and countries perceive the benefits they will derive from mining operations, particularly through local procurement (backward linkages) and local employment. Given that no countries in the Southern African region have the necessary capacity to produce all of the automated technology (backward linkages) needed domestically and have turned to importing capital from countries such as the United States, China, Sweden, Canada and Croatia, firms are compelled to advance other benefit streams. This is one reason that mineral processing (forward linkages) has featured prominently on policy agendas in recent years. Another system that has picked up some traction in the region is the infrastructure-resource swap model, in which foreign mining companies develop infrastructure in exchange for access to natural resources.

Mining capital is mobile. Mining companies have finite capital to develop their projects and have many potential investment destinations. As a result, mining is a competitive industry; because there are multiple countries with endowments of any given mineral, investors must be reasonably confident that they can run a profitable operation in the long-run, in a stable fiscal and political environment.

Policy has to carefully balance the objective of maximizing the benefits for the country with the commercial incentives of mining extraction. There is a perception that mining companies, most of which are foreign, are gaining the most benefit from natural resources in Southern Africa while the host countries themselves are not benefiting substantially from their mineral wealth. This has given rise to resource nationalism, or a tendency for governments to exert a higher degree of control over the natural resources located within their borders. A new wave of mining legislation across the region shows that governments are increasing the arsenal of tax and non-tax policy tools at their disposal to increase their benefits from mining. In the instance of Zambia, a new policy for higher mineral royalties and taxes is being used to stabilize the country's debt crisis; one objective of the third Mining Charter in South Africa is improving the social and economic well-being of rural mining communities through the requirement of a 10% investment. This report aims to examine some of the policy trade-offs and draw lessons on how policy can help enhance mining production in an equitable way.

This report is structured as follows: The remainder of this chapter explores the extractive landscape in Southern Africa. It provides an overview of Botswana, Lesotho, Namibia, South Africa, Zambia and Zimbabwe and specific commodities (copper, diamonds, gold and PGMs). The second chapter develops a framework that disaggregates costs and benefits of mining for each of the key stakeholders in the mining sector and offers a quantitative and qualitative discussion. By examining various benefits, including rent, capital, labor and intermediate inputs, and costs, including natural resource depletion, carbon emissions and pollution damage, the

[2] A report by Accenture (2010) evaluated the economics of three types of equipment (trucks, dozers and drills), and found that automation could reduce the number of operators in open-pit mines by up to 75%.

section offers insight into the sustainability of the mining sector. It offers mine-level examples of these costs and benefits across the region. The third chapter offers a macro-level sustainability analysis of mining in the region by looking at the adjusted net savings (ANS) of the mining sector in each country. ANS is a measure of economic sustainability and assesses whether savings and investment in a country compensate for the depletion of physical and natural capital, pollution damage and depreciation. The section also examines how conflicts can arise when the four key stakeholders – workers, investors, government and communities – try to maximize the benefits of mining for themselves.

Policy implications are developed in the final chapter. Chapter four aims to summarize the possible policy choices that can help increase the cost competitiveness of the mining sector and reduce the negative externalities on society. The section is built on four key objectives: developing a regulatory environment that mandates firms to internalize the social, economic and environmental costs of mining; creating an effective system to capture rents; creating policies that promote appropriate backward (inputs) and forward (processing and manufacturing) linkages; and finally, managing the changes affecting the sector as it transitions from being labor to capital-intensive and minimize the negative effects it will have on stakeholders.

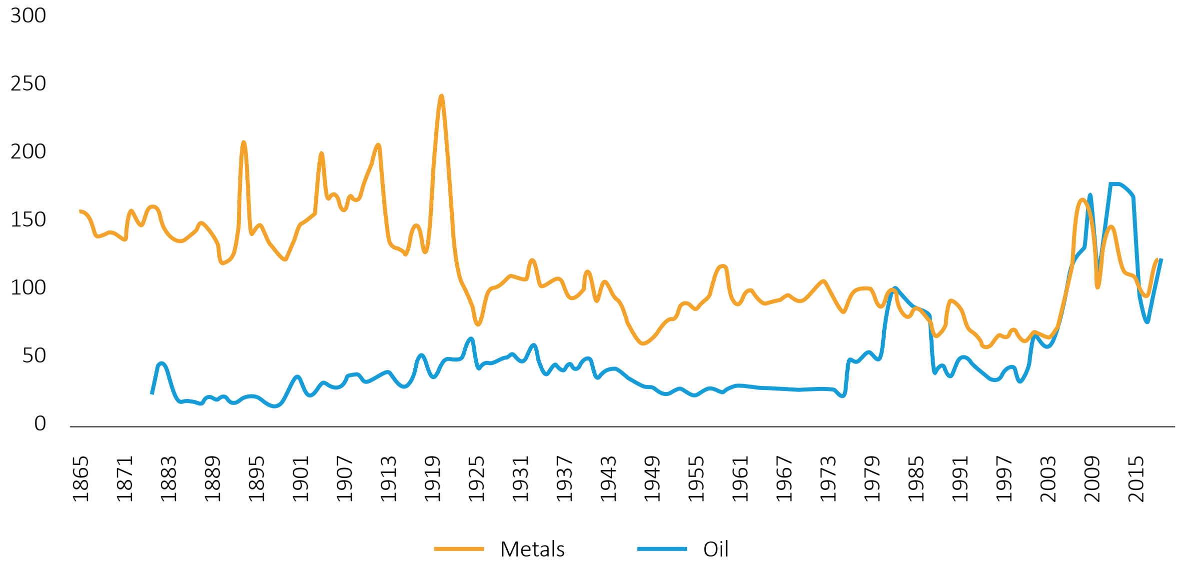
1.2. Overview of mining in selected Southern African countries

Economic developments in the mining sector

Following the end of the latest commodity super cycle, conditions for the mining sector remain difficult. For centuries, demand and supply for commodities have gone through cycles, resulting in major price swings (Erten and Ocampo 2013). Broadly, there have been four commodity super cycles since the 19th century (Figure 1.2): from 1894 to 1932, from 1932 to 1971, from 1971 to 1999, and, most recently, from 2000 to 2015 (see also World Bank, 2015). Following the end of the last super cycle, global commodity markets remain depressed primarily due to lower global demand. For example, gold has witnessed a fall from US$1,569 in 2011 to around US$1,269 per troy ounce in 2018, while the price of commodities such as silver have fallen further from US$35 in 2011 to around US$16 per troy ounce in 2017.

Figure 1.2: Commodity prices have experienced long cycles since at least the 1800s

(Real commodity price index 1865-2018, 1980=100)

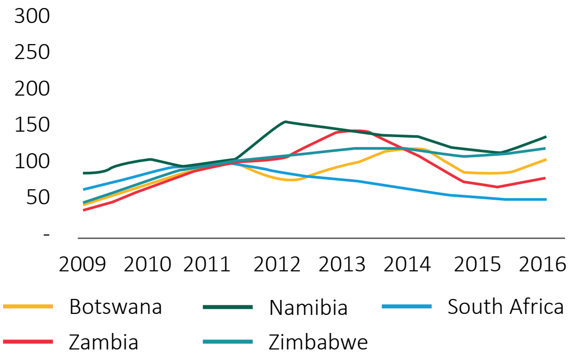


Source: Erten and Ocampo (2013) and World Bank staff imputations using data from the World Bank Commodity Markets Outlook (April 2019) for years 2007-2018.

As the last commodity super cycle ended, mining sector GDP growth slowed down in a number of countries, putting pressure on income, jobs, and the fiscus. Given the reliance on commodity exports, some Southern African countries were hit by both lower production in mining (Figure 1.3) and lower export prices – although the overall impact on the terms of trade (Figure 1.4) was partly offset by weakening oil prices, as most Southern African countries are oil importers. Shocks to aggregate demand undermined economic growth and resulted in job losses. For example, the South African platinum sector dropped 3.5% from 198,000 workers to 191,000 between 2012 and 2013, when demand began declining. In many countries with strong mining exposure, fiscal revenues declined and, coupled with weaker growth, debt sustainability deteriorated (Figure 1.5). In fact, there is evidence from emerging economies that the length of the last commodity super cycle led analysts and policymakers to believe that higher commodity prices were a "new normal", and included high prices in growth projections, thus overestimating potential economic growth (Amra et al. 2019). This may have resulted in under saving during the cycle in countries like South Africa, leaving insufficient fiscal buffers for when the cycle ended. This also helps to explain the decline in sovereign creditworthiness. Some governments have responded by levying higher taxes to increase revenues; Zambia, in the face of fiscal challenges, increased its royalties for the tenth time in 16 years. These taxes added costs to the mining firms; and the sector has responded to the difficult business environment by introducing mechanization, which has increased productivity, and reduced employment, as labor is the largest operating cost.

Figure 1.3: In some countries, the end of the last commodity super cycle resulted in declining growth in mining production

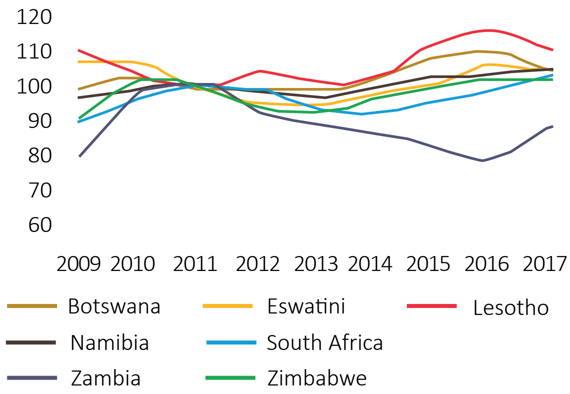
(Mining sector GDP 2009-2016, 2011=100)



Source: African Statistical Yearbook, 2018.

Figure 1.4: ... and in countries like Zambia, the terms of trade deteriorated significantly

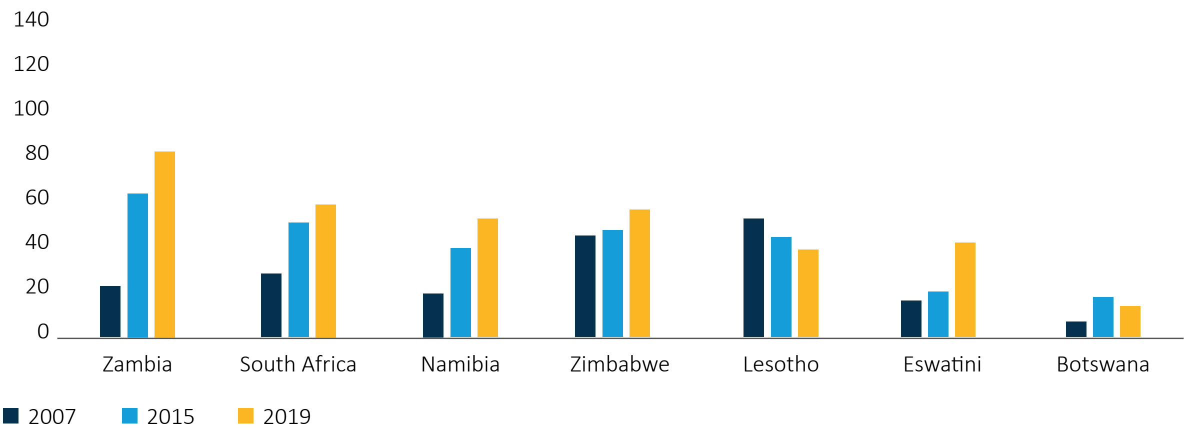
(Net Barter Terms of Trade, 2009-2017, 2011=100)



Source: World Development Indicators and World Bank staff.

Figure 1.5: Several countries have had sharp increases in public debt

(Gross public debt, % of GDP)



Source: International Monetary Fund (IMF) World Economic Outlook, April 2019; for Zimbabwe: World Bank.

There are also important regional spillover effects. While this report does not disentangle such regional effects, it is worth highlighting the various channels that give rise to them. For one, South Africa is the largest economy and mining producer in the region and is a dominant trading partner and source of remittances within the rest of Southern Africa, therefore neighboring countries are sensitive to changes in South Africa's economy, including the mining sector. Migrant labor from the rest of the region used to be an essential part of the South African mining sector, although this has decreased dramatically over the years. Second, South Africa forms a Common Monetary Area (CMA) with Lesotho, Eswatini and Namibia, which constitutes around 43% of sub-Saharan Africa's GDP. Though each CMA country issues its own currency, all are pegged to the South African rand so commodity shocks that drive the South African rand (Maveé et al. 2016) will impact on the other CMA countries, especially if they produce different commodities. Third, South Africa, Botswana, Eswatini, Lesotho, and Namibia form a Southern African Customs Union (SACU). Member countries need to agree on common external tariffs on all imports, including mining, to the union. Beyond this, any impact mining has on economic growth in SACU countries, import values and prices can affect the revenue transfers to the respective member states. The nature of the SACU allocations means that a shock in one country may affect transfers to another country (Honda et al. 2017).

Economic impacts also depend on the mining methods utilized. There are four main types of mining, namely: placer mining, open-pit mining, underground mining and in-situ mining. Placer mining involves sifting metals, usually from sediment in rivers, beach sands or other environments. Open-pit mining is typically used for shallow deposits, where the ratio between the amount of ore and sterile rock is high. Underground mining involves drilling shafts and galleries to reach deeper deposits or deposits where the ratio between the amount of ore and sterile rock is low. In-situ mining involves dissolving the mineral resource in place then processing it at the surface without moving rock from the ground. This is primarily used in mining uranium and salt minerals. The choice of mining method depends on the mineral resource, the geometry of the deposit, as well as the ratio between the amount of ore and sterile rock. These parameters will determine the profitability of its exploitation. Each mining method also has varying degrees of impact on the surrounding landscape and environment. Mechanization is more appealing for shallow deposits given the more attractive risk profile and ease of accessing resources.

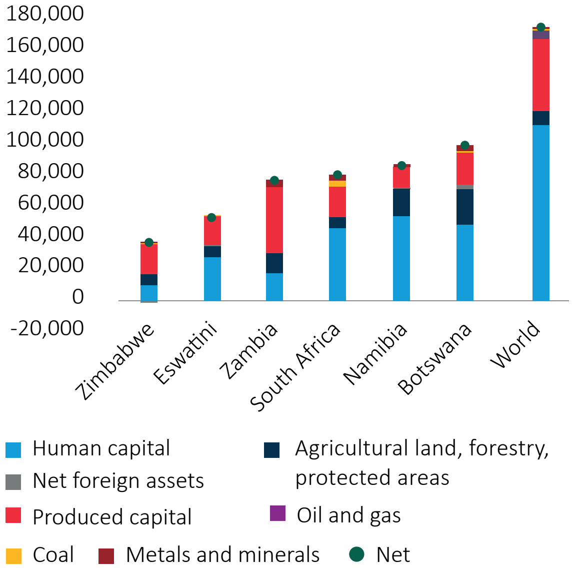
Overview of key commodities in Southern Africa

Southern Africa has considerable wealth in metals and mineral assets. Yet they are not necessarily the most important source of wealth. The World Bank's *The Changing Wealth of Nations* (2018) conducted a wealth accounting exercise to estimate and quantify the sources of wealth for countries across the world. Human capital (measured as the discounted value of earnings over a person's lifetime) and produced capital (such as machinery, buildings, equipment, and residential and nonresidential urban land) are the most important sources of wealth globally and in Southern Africa (Figure 1.6). In Southern Africa, agricultural land, forests, and protected areas are overall more significant assets than subsoil assets, especially in Botswana, Namibia, and Zambia.[3] Natural resources that are mined are relatively small sources of overall national wealth in the grand scheme of things. In Southern Africa, the most important sub-soil assets, by far, are metals and minerals, followed by coal (Figure 1.7). This report will focus on four commodities: copper, gold, diamonds, and PGMs.

3 The data does not account for certain commodities such as diamonds and platinum, meaning that natural resource wealth is underestimated.

Figure 1.6: Human and produced capital are the main forms of national wealth

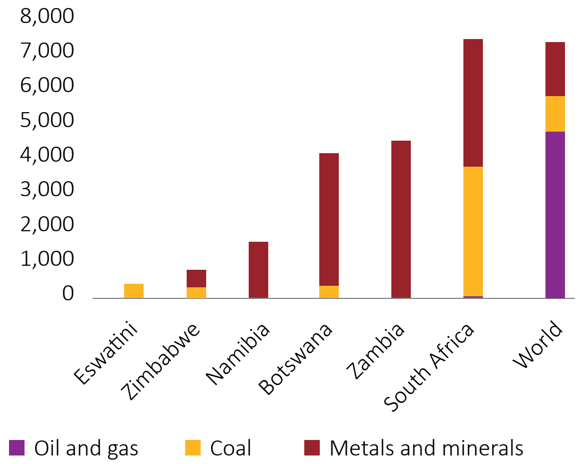
(National wealth per capita, constant 2014 US$, 2014)



Source: World Bank (2018).

Figure 1.7: Metals and minerals are the main mined natural resources in Southern Africa

(Subsoil asset value per capita, constant 2014 US$, 2014)



Source: World Bank (2018).

Disclaimer: These graphs do not include diamonds, PGMs, cobalt, or aluminum. No data for Lesotho.

(i) Copper

Namibia, South Africa, and Zambia are all large producers of copper, with Zambia the largest of the three. Copper faces three major constraints in the Southern African Development Community (SADC): infrastructure deficiencies, inadequate electricity generating capacity, and a lack of institutions to manage policy implementation. Zambia has the added challenge of being landlocked and having very high transport costs.

(ii) Gold

South Africa is the largest producer of gold, although smaller quantities are mined in Zimbabwe and Namibia. Gold mining has been hampered by the cost of extraction; costs have risen as reserves are becoming increasingly difficult to access. Much of the remaining reserves have lower-quality gold. Eight of the world's 10 deepest mines are gold mines in South Africa with depths that require high capital intensity and present substantial risk to workers. Recent power shortfalls in South Africa have also impacted on mining.

(iii) Diamonds

Botswana and Zimbabwe are the largest producers of diamonds, though Namibia and South Africa also produce significant quantities. Lesotho also produces a small quantity of high-grade diamonds. Botswana and Namibia produce for the midstream market, which is the most competitive, least profitable and faces challenges in securing financing. The main activities are cutting and polishing and the trade in the polished products (Linde et al, 2016).

(iv) Platinum-Group Metals (PGMs)

South Africa is the largest producer of platinum in the world, accounting for 80% of global reserves. Its reserves are 52.5 times larger than the next two largest – Russia (second) and Zimbabwe (third). Other metals within the PGM group include palladium, rhodium and iridium. There are also high quantities of chrome in certain PGM mines. The price of platinum has fallen due to lower global demand and an increase in supply due to secondary (recycled) platinum from East Asia. Consequently, platinum prices have dropped from a high of around US$1,719 per ounce in 2011 to under US$820 at present. This has had a significant impact on the profitability of the sector. The co-products mined in PGM mines have been critical in sustaining mine operations while platinum prices have suffered. However, commodity prices for other minerals have also remained low over the past 5 years, affecting the financial profitability of the sector.

The narrative of the mining industry in Southern Africa is unique. Although the region is home to some of the world's richest mineral deposits, these have not been catalyzed into shared prosperity. The following chapters will explore the distribution of the benefits of mining across various stakeholders, which will shed some light on the reasons why mining may not have promoted inclusive growth – and why this creates a difficult policy nexus between encouraging mining investments while ensuring that the benefits and costs are equitably shared.

Country overview

The following provides a brief overview of the mining sector in the main Southern African countries studied in this report.[4]

Botswana

The mining sector constitutes a significant part of Botswana's economy, accounting for 19% of GDP in 2017. Diamonds are the single largest contributor, comprising over 90% of mineral production; while there are smaller quantities of copper, coal and gold. The sector accounts for 92% of exports, and serves as an important generator of foreign exchange. Tax revenues from the mining sector account for 10.1% of GDP. Although the mining sector is capital intensive, it remains a significant employer, with 230,350 workers. Economic prospects for the sector are positive, with diamond production increasing on an annual basis. Although there was a recent cessation in the production of copper and nickel,[5] two new copper mines will start production in 2020. Additionally,

4 In 2017, the ILO estimated that mining's share of employment was 2.7% in South Africa, 2.5% in Botswana, 2.1% in Namibia, 1.7% in Zambia, 1.5% in Zimbabwe, 0.7% in Lesotho and 0.5% in Eswatini.

5 As a result of the closure of BCL, the state-owned nickel mine due to production losses and depletion of reserves.

substantial coal reserves have recently been discovered and are yet to be exploited. Improvements in public infrastructure in railways, electricity and water would support continued improvements in the sector.

Lesotho and Eswatini

Mining remains limited. The mining sector in Eswatini is very small, at less than 1% of GDP. Small amounts of coal, diamonds and gold are extracted. Other minerals such as arsenic, copper, manganese and tin have been found but it is not profitable to extract them. Poor infrastructure, a weak regulatory environment and limited deposits constrain future activity in the sector. In Lesotho, although mining contributes less than 1% of exports, it contributes to 8% of GDP and is home to some of the world's most valuable diamonds. The share of labor in the mining sector declined from 6% in 2003 to 2% in 2010. Other minerals such as dolerite, clay and sandstone are mined though their contribution to GDP is very small. There is no formal mining of the country's coal reserves. Mining contributes an estimated 6% to GDP and to a third of exports.[6] The sector, however, faces major challenges. Though there are opportunities for investment, poor infrastructure, legal and institutional bottlenecks limit prospects for growth in the sector. In particular, the government lacks the capacity to develop the Mining Authority Bill and there are few regulations in place.

Namibia

The country has a vibrant mining sector, accounting for 13% of GDP, and is a major producer of uranium, diamonds, zinc and gold, with diamonds accounting for around 7% of GDP. The sector also accounts for 51% of total exports. With around 130,250 workers, it is a significant employer and tax contributions from mining account for approximately 7% of public revenue (2% of GDP). Prospects for the sector are largely positive. Annual production is expected to rise, due to increased uranium operations with the Husab Mine, the second largest uranium mine in the world recently commencing operations. Gold, zinc and diamond production are also expected to increase.[7] Nevertheless, the sector still faces challenges. Poor public infrastructure (in particular transport and electricity) coupled with a difficult business environment due to volatile taxation policies, have raised the cost of doing business, causing the country's largest gold producer to threaten a production halt and to curb future investments.

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[6] According to data supplied by Lesotho's Bureau of Statistics. However, Central Bank data put it at 4% of GDP.

[7] Onshore diamond reserves are being slowly depleted, but offshore diamond extraction will increase.

South Africa

Although the country is a top producer of a range of commodities, including gold, diamonds, PGMs, coal, and iron ore, the mining sector has fallen to around 7% of GDP. As one of the largest export sectors (28% of total exports), mining generates significant foreign exchange for South Africa. In 2016, exports amounted to R294 billion, or nearly a quarter of total exports. However, the sector has experienced a substantial increase in capital intensity and a commensurate drop in employment to around 400,000 at present. While this represents a mere 3% of formal employment, estimates suggest that due to the high wages earned by workers, every new job created lifts 1.3 people out of poverty. After numerous delays, finalisation of the third Mining Charter in 2018 reduced policy uncertainty, but the industry in March 2019 applied for a judicial review. The sector has attracted three major investments as part of President Ramaphosa's drive to attract US$100 billion in investment by 2023 to stimulate economic growth.

Zambia

The mining sector in Zambia is dominated by copper mining and accounts for 80% of exports. Total GDP of the sector was around US$3.7 billion, 95% of which was copper and cobalt, and 5% gold.[8] Until a few years ago it also produced emeralds. The sector accounted for 15% of total GDP. Moreover, the sector contributed around 26% of public revenues when payroll tax (PAYE) is included and employed 2% of the country's labor force. Growth prospects for the sector are mixed with production expected to increase at key mines such as the Kalumbila Mine. There is potential to attract more investment particularly in the north-west province where newer mines are located, and to scale up production in some existing mines. Nevertheless, policy inconsistency – primarily around tax changes – has been a growing deterrent to investors. In 2018, the Zambia Chamber of Mines released an emergency statement stating that a proposed tax change commencing January 1, 2019 would make Zambia "uninvestable," warning that up to 7,000 direct and 14,000 indirect jobs were at risk. Additionally, an unreliable power supply, high cost of transport, and inadequate infrastructure are constraints to future growth of the sector.

8 Zambia Extractive Industries Transparency Initiative (2016), '9th Zambia EITI Report', December 2018.

Zimbabwe

The mining sector is an important part of the economy, accounting for around 7% of GDP in 2017. Zimbabwe has a long history of mining and is a significant producer of platinum, gold, PGMs, chrome, diamonds and nickel along with other minerals and metals.[9] The sector accounted for around 50% of exports, which has been particularly important given the country's precarious external position. Around 37,000 people are employed in large-scale mining, with approximately another 500,000 people employed in artisanal and small-scale mining. It plays a vital role in livelihoods and the mining sector has potential for significant future growth, given the level of untapped reserves of minerals and metals.[10] However, growth of the sector continues to be constrained by low commodity prices, high taxation and poor infrastructure, including unreliable power supply, and limited access to credit and foreign exchange.

Foreign exchange restrictions have been particularly damaging as hard currency is critical for importing mining inputs and the restrictions amount to an unofficial, yet additional tax on the mining sector. At present, around 80% of foreign exchange generated by the mining sector is exchanged for the government's In 2018, RioZim was forced to close three mines – Cam & Motor, Dalny and Renco – after running out of spare parts and consumables due to a lack of foreign exchange.[11] Prices quoted by local suppliers for some of these products were 300% higher than international counterparts, making operations commercially unviable. As a result, investment in mining has been limited; assets are aging and average capacity utilization stood at only around 71% of the sector's potential. The government has introduced policy reforms to boost investment. In particular, removing the 51% local ownership requirement in the Indigenization and Economic Empowerment Act in 2018, has allowed wholly foreign-owned investors to establish operations for specific minerals.

The narrative of the mining industry in Southern Africa is unique. Although the region is home to some of the world's richest mineral deposits, these have not been used as catalysts for shared prosperity. The following chapters will explore the distribution of the benefits of mining across various stakeholders, which will shed some light on the reasons why mining may not have promoted inclusive growth – and why this creates a difficult policy nexus between encouraging mining investments while ensuring that the benefits and costs are equitably shared.

9 The discovery of diamonds in Marange was one of the largest diamond discoveries this century and there is a good probability of further diamond discoveries.

10 For instance, Zimbabwe has current reserves of 1,200 tons of PGMs and there is estimated to be around 7,800 tons of PGMs in undiscovered resources. Source: USGS 2014; Platinum-Group Elements in Southern Africa—Mineral Inventory and an Assessment of Undiscovered Mineral Resources.

11 These included cyanide, activated carbon, caustic soda, explosives, forged steel balls, and spares for the repair of critical equipment.

Table 1.1: Mining production and reserves in selected Southern African countries

Key commodities	Botswana		Lesotho		Namibia		South Africa		Zambia		Zimbabwe	
	Reserves	Prod.	Reserves	Prod.	Reserves	Prod.	Reserves	Prod.	Reserves	Prod.	Reserves	Prod.
Aluminum							...	890,000				
Bauxite												
Cobalt	...	4,770					29,000	3,000	270,000	4,600	...	358
Copper					...	16,121	...	74,220	20,000,000	740,000	...	8,840
Diamonds (carats)	281,528	6	109,260	0	73,600	0	387,940	1			10,000	4
Gas (millions of tons)					...	7	0	0				
Gold	...	1			300,000	9,272	6,000	140	...	5	...	21
Iron (millions of tons)							1,200	6				
Lead							...	40,000				
Nickel	490,000	17,612					3,700,000	50,000	...	1,756	...	18,802
Oil (barrels)							15,000,000	806,600			...	80,000
Phosphate (millions of tons)							1,500	2		...	1,200,000	13,000
Platinum (kgs)							63,000,000	120,000				
Silver	...	5			...	14	...	32	...	10		
Zinc					...	107,812	...	26,433				

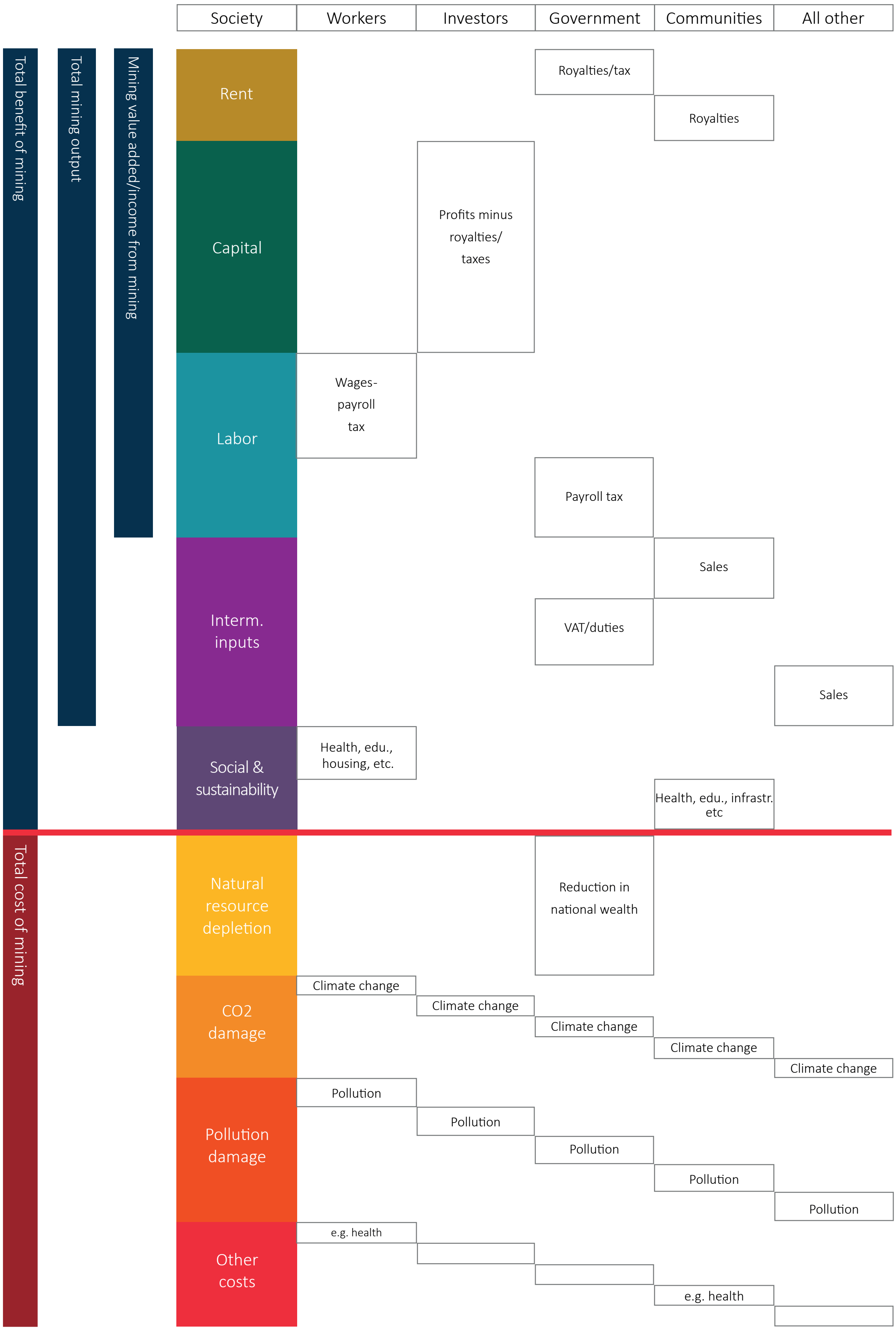
Source: World Bank and SNL.

2. BENEFITS AND COSTS OF MINING IN SOUTHERN AFRICA

2.1. A conceptual framework for the net benefits of mining

Mining impacts a whole range of stakeholders and the sector's inclusivity depends on how the benefits and costs are shared among them. Figure 2.1 presents a simple conceptual framework disentangling the various stakeholders and the types of benefits and costs that are discussed in this report. Broadly, these stakeholders are workers, investors, the government, mining communities, and other parts of the economy (which could be foreign or domestic). It is important to note that any economic actor in the framework could take on multiple stakeholder roles: for example, the benefits and costs of both workers and community members would apply to a worker living near a mine; in countries like Botswana, the government owns a share of mining companies and is thus also an investor; similarly, workers or communities holding shares in mining companies would also be considered investors.

Figure 2.1: A conceptual framework for the net benefits of mining



Source: World Bank staff.

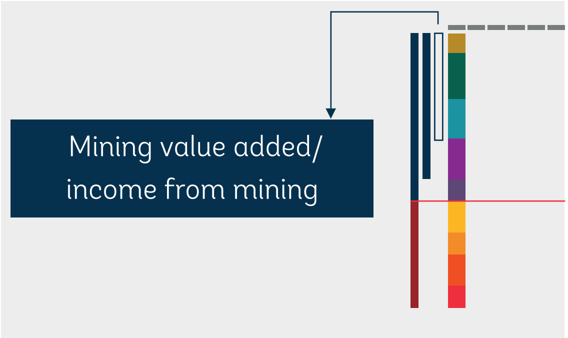
On the benefit side, the focus is on the mining production process, which is the income (or value added) that mining generates. Value added includes the return on the factors on production: wages (the return on labor) to workers, profits (the return on capital) to investors, and revenue to the government. Special focus is given to the "economic rent" in mining, in other words the return on the natural resource itself. These rents are often supernatural profits that arise from mining, or the difference between the value of mining sales, given the costs. As costs are relatively constant, or change slowly, the commodity price determines the size of the rent, with high prices resulting in high rents. In a sense, the purpose of mining is for societies to capture the rent that can be obtained by commercializing natural resource deposits which are a national asset. In addition to value added, the analysis will also focus on the multipliers mining generates through backward and forward linkages with the rest of the economy; this can range from communities supplying mines to highly sophisticated technical inputs sold by local companies or imported from foreign firms. Mining companies internalize many of the externalities the production process generates, including health or pollution costs – this compensation has to also be accounted for under benefits, offsetting costs.

The identification of costs broadly draws on the ANS methodology. They include natural resource depletion, pollution damage and other costs, which are often not measured but will still be discussed in this chapter. These costs can have far-reaching consequences, as mine pollution can adversely affect health and pollute water, air and land for centuries to come. Overall, this framework seeks to provide a lens for analyzing the net benefit of mining (benefits minus costs) for various countries and mines. The individual components of the report will be discussed in more detail below, clearly laying out the extent to which they affect the various stakeholders.

Chapter 3 will extend the framework to look at the overall sustainability of mining. Exploring the concept of ANS specifically for the mining sector, the chapter will examine whether savings generated from the mining sector are likely to offset the reduction in wealth associated with mining a finite national resource. To maintain or increase national wealth through mining, savings (including health and education spending) need to match or exceed the value of the mined asset, depreciation, and the generated externalities.

There are limits to measuring the costs and benefits of mining. This report draws on available macro data, including national accounts, social accounting matrices (SAMs) from the Global Trade Analysis Project (GTAP), balance of payments statistics, and World Bank ANS data. It is important to note that country-level data is not available for all benefits and costs; there are measurement issues that affect the reliability of data, and there is considerable variation around estimates across time and stakeholder groups. These have contributed to the considerable shortcomings of this report. An attempt was made to use micro-level and qualitative data to improve the narrative. Yet caution is warranted when interpreting the magnitude of the results presented. (See Annex 1 for a more detailed explanation of costs and benefits.)

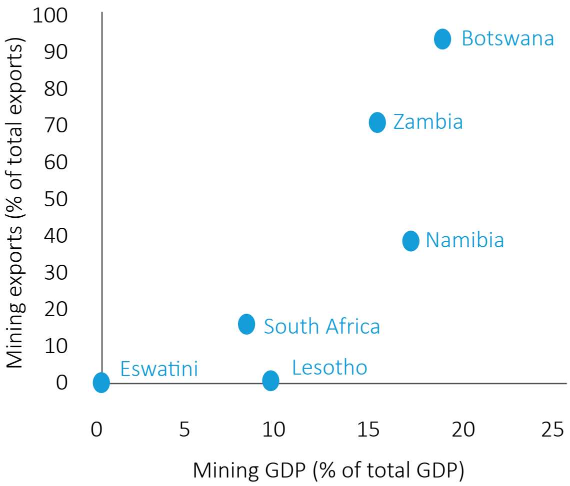
2.2. Mining value added (and exports)



Mining is an important income generator for the region, and a number of countries rely heavily on mineral exports for sales of extracted resources. Figure 2.2. demonstrates the importance of mining to Southern African economies. In Botswana, mining accounts for 19% of GDP and 92% of exports, making it the dominant sector in the country. South Africa is the most diversified economy in Southern Africa and although the country's development relied on mining (and associated sectors like finance and energy), the sector has become relatively less important when compared to other sectors (including those that originally catered primarily to mining, such as finance). The following section discusses the benefits and costs to the identified stakeholders.

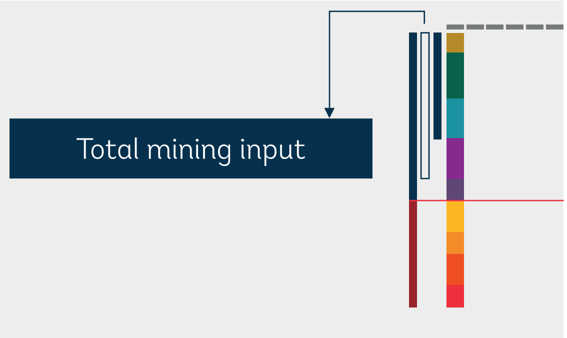
Figure 2.2: Mining is a big contributor to both exports and GDP in Southern Africa

(Mining export share; mining share in GDP)



Source: Comtrade[12] and African Statistical Yearbook.

2.3. Multipliers from mining: production linkages



Mining has significant multipliers in many Southern African countries. The multiplier explains what the impact of spending US$1 in a sector will generate on the overall economy. For instance, a multiplier of 3 for the mining

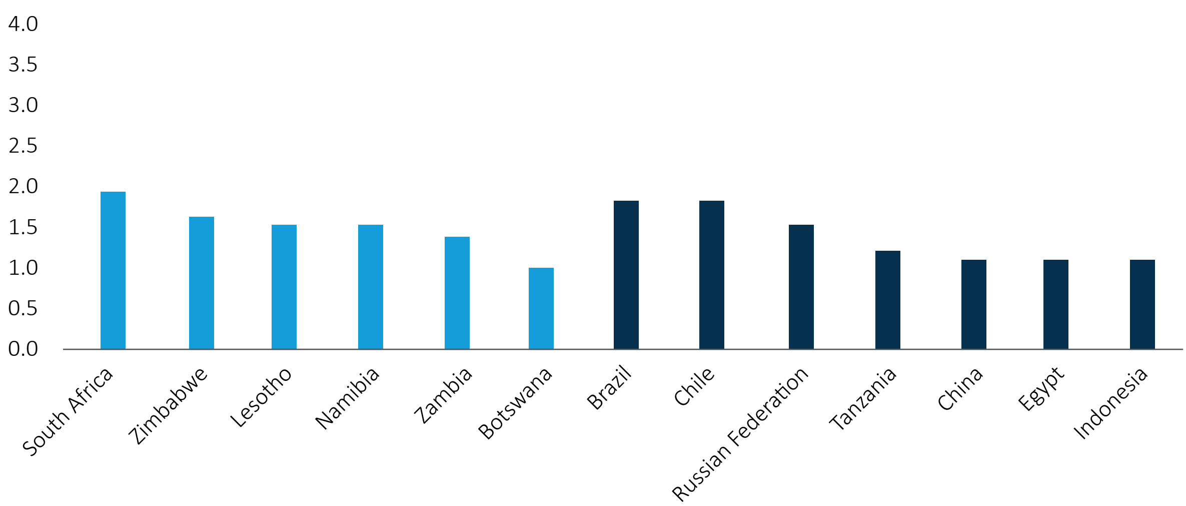
[12] Calculated by using HS codes 71 (natural, cultured pearls; precious, semi-precious stones; precious metals, metals clad with precious metal, and articles thereof; imitation jewelry; coin); 72 (iron and steel); 73 (iron or steel articles); 74 (copper and articles thereof); 75 (nickel and articles thereof); 76 (aluminum and articles thereof); 78 (lead and articles thereof); 79 (zinc and articles thereof); 80 (tin and articles thereof); and 81 (metals; n.e.s. cermets and articles thereof).

sector will ensure that US$1 spent in the sector will generate an overall economy-wide benefit of US$3. All countries included in this study have estimated multipliers equal or greater than 1, and are comparable to other developing countries (Figure 2.3).

Given the impact on living standards, governments often attempt to design policies to increase the multiplier. Value creation policies are intended to develop the mining value chain. Backward linkages, which are reflected in the multipliers in Figure 2.3, include inputs into the mining process, such as machinery. In addition, forward linkages come in the form of the processing of raw minerals and in using them to manufacture other goods. Forward linkages can be a valuable source of national income, as processing and manufacturing can be activities of significant added value.

Figure 2.3: Southern Africa has mining sector multipliers on par with other key mining jurisdictions, such as Brazil and Chile.

(Mining sector multipliers)



Source: World Bank staff based on GTAP SAMs.
Note: Implausible data for Eswatini.

The Southern African Development Community (SADC) "Industrialization Strategy and Roadmap" was designed to identify areas where the region can capitalize on opportunities based on its current and expected economic profile. Given the reliance on mining within the region, developing an industrialization strategy around the sector is highly relevant. For those countries hoping to develop backward and/or forward linkages, creating either a regional or global comparative advantage is important to ensuring sustainability. Value chains can be built across countries in the region if an individual country does not have a comparative advantage in every part of the value chain. World Bank (2019, forthcoming) explores where SADC countries are likely to develop a comparative advantage. Table 2.1 summarized estimated probabilities of progression to other parts of the value chain, based on the concept of Revealed Comparative Advantage (RCA).[13]

There are a number of challenges that must be addressed to develop a comparative advantage, including a policy environment that promotes national interests over regional collaboration. It is difficult for a country to become competitive in every part of the value chain; it is also inefficient for every country to utilize its limited resources to develop the same part of the value chain as its neighbors. Additional challenges to developing an RCA include limited access to and the high cost of infrastructure, as well as skills constraints. It is important to note that the results in Table 2.1 do not factor the political economy of reform into the calculation of progression probabilities.

Table 2.1: There are opportunities to develop mining sector linkages in Southern Africa

(Standardized probabilities of having an RCA>1 within next 5 years)

	Unlikely	Possible	Likely
Prog. probability			

A. Platinum

Country	Entire Regional Value Chain (RVC)	Platinum, unwrought/ in powder from (711011)	Platinum, in semi-manufactured forms (711019)	Palladlum, unwrought/ In powder form (711021)	Palladlum, unwrought/ In powder form (711031)	Rhodium, in semi-manufactured forms (711031)	Rhodium, in semi-manufactured forms (711039)	Iridium osmim & ruthenium unwrought/ In powder form (711041)	Iridium osmim & ruthenium In semi-manufactured forms (711049)
South Africa	2.72	2.51	2.13	3.15	2.69	4.35	1.84	4.30	0.76
Zimbabwe	0.06	1.39	-0.46	0.03	-0.17	0.24	-0.48	-0.11	0.03

B. Diamonds

Country	Entire RVC	Diamonds, unsorted	Industrial diamonds, unworked	Industrial diamonds, worked not mounted/set	Diamonds, non-industrial, unworked	Diamonds non-industrial other than unworked
Botswana	2.36	2.53	2.75	1.44	2.53	2.56
Lesotho	0.71	0.16	1.40	-0.22	2.22	0.00
Namibia	2.29	2.17	2.72	1.36	2.48	2.70
South Africa	2.32	2.54	2.19	1.98	2.22	2.65
Zimbabwe	1.93	2.72	2.53	1.18	1.97	1.27

13 The study employs progression probability analysis at the 6-digit HS level, based on the likelihood of developing a RCA. To put the problem into a more concrete perspective, the study aimed to help answer the question: "What is the probability that, say, Namibia will become a competitive exporter of polished diamonds in 2020, given the set of products in which it is competitive in 2015 and given the capabilities of countries that have in the past developed a comparative advantage in polished diamonds?" The analysis is based on historical data.

C. Mining machinery

Product	South Africa	Zambia
Entire machinery RVC	1.07	-0.19
Self-propelled fork-lift trucks & other works trucks fitted with lifting/handling equipment powered by an electric motor	1.13	0.05
Self-propelled fork-lift trucks & other works trucks fitted with lifting/handling equipment other than those powered by an electric motor	0.76	-0.71
Lifts (i.e. passenger elevators) & skip hoists	1.05	-1
Pneumatic elevators & conveyors	0.82	-0.94
Escalators & moving walkways	0.28	-0.69
Teleferics, chair-lifts, ski-draglines; traction mechanisms for funiculars	0.96	-0.7
Other lifting, handling, loading/unloading machinery, n.e.s in 84.28	2.06	-0.58
Self-propelled bulldozers & angledozers, track laying	0.95	-0.53
Self-propelled bulldozers & angledozers (excl. track laying)	1.4	0.26
Self-propelled graders & levellers	1.78	0.59
Self-propelled scrapers	1.87	0.52
Self-propelled tamping machines & road rollers	0.45	0.95
Self-propelled front-end shovel loaders	0.46	-0.37
Self-propelled mechanical shovels & excavators with a 360 revolving superstructure	0.19	-0.78
Pile-drivers & pile-extractors	0.67	-1.39
Snow-ploughs & snow-blowers	0	-0.8
Coal/rock cutters & tunnelling machinery, self-propelled	0.68	0
Coal/rock cutters & tunnelling machinery other than self-propelled	1.21	1.39
Tamping/compacting machinery, not self-propelled	1.54	-0.27

D. Coal & uranium

Country	Entire RVC	Anth.	Bitu.	Other Coal	Lignite	Peat	Coke/ semi-coke	Coal, water, prod. gas	Naph.	Pitch	Pitch coke	Uranium ore & con	Thorium ore & con
Botswana	-0.67	-0.92	-0.46	-0.98	-0.54	-0.62	-0.76	-0.22	-0.74	-0.92	-1.00	-0.57	-0.69
Namibia	-0.25	-0.2	-0.34	0.61	-0.58	-0.70	0.23	0.98	0.82	-0.63	-0.16	5.13	0.29
South Africa	1.34	3.19	2.78	2.36	0.96	0.73	2.84	1.60	2.91	2.25	2.34	0.79	0.77
Eswatini	-0.20	1.77	1.84	2.22	0.27	-0.45	1.34	0.04	-0.76	-0.21	0.71	-0.46	0.13
Zimbabwe	-0.25	-0.12	0.35	-0.09	-0.52	-0.61	1.17	0.76	-0.27	-0.35	-0.19	-0.46	1.21

E. Oil & gas

Country	Entire RVC	Petroleum (P.) oils/bituminous crude	P.oils & bituminous min.	LNG	Butanes liq.	Micro-crystal P. Wax	P.Coke, uncalcined	P.Bitumen	P.Jelly
Botswana	-0.68	-0.68	-1.66	-0.82	-0.95	-0.62	-0.99	-1.40	0.59
Namibia	-0.43	-0.74	-0.34	-0.79	0.74	-0.92	-1.26	-1.13	-0.35
South Africa	1.23	-0.04	0.16	-0.30	0.24	1.52	2.10	1.48	2.45
Eswatini	-0.36	-0.82	-0.20	-0.76	1.42	-1.12	-0.73	-0.22	-0.69
Zimbabwe	-0.31	-0.49	-1.89	-0.79	-0.86	-0.64	0.58	-0.56	0.20

Source: World Bank, 2019 forthcoming.

Increasing access to and reducing the cost of key infrastructure, such as transportation, is important to becoming competitive. According to the Zambian Chamber of Mines, it is cheaper for South African firms to import goods from South America than Zambia. A UNU-Wider Study (2016) confirmed that prices for overland cross-border freight in Southern Africa are much higher than in other regions. Additionally, border delays add US$20/ton per day to delay costs for a bulk load. For a landlocked country like Zambia, the cost of reaching a port can be sizable and is in addition to high fuel costs and those of replacing transport equipment (mining transport equipment depreciates at 25% per annum, with an average asset lifespan of 4 years). On the one hand, high transportation costs may incentivize firms in Zambia to develop local processing facilities so they can ship a refined rather than a bulk product, but may prevent them from trading with other countries in the region or the world, in a cost-competitive manner.

Increasing cost-competitiveness of linkages requires sufficient skills. Until recently, cutting and polishing diamonds had been highly skilled work requiring many years of development – that was reflected in the tacit knowledge needed to perform these tasks. Thanks to technological advances, diamond cutting is on the verge of transformation, utilizing computer numerical controlled (CNC) cutting and polishing machines, computer-aided design (CAD), and laser equipment. However, the provision of training for these skills is not yet on the government's radar (Morris et al, 2012). The transition to capital-intensive mining has led to a reliance on foreign inputs and reduced backward linkages in the domestic economy. Currently, the majority of new machines being tested are imported from the United States, Sweden, Croatia, and Japan, and include equipment manufactured by Caterpillar, Epiroc, Komatsu, Atlas Copco and Terex. Reliance on foreign technology has been exacerbated by human capital challenges. The new ultra-low-profile (ULP) bolter equipment manufactured by DOK-ING, a Croatian company, has increased safety and efficiency when drilling the ceiling of a mine, helping to prevent rock collapses. It is manufactured abroad by DOK-ING, then exported to South Africa, with the technology managed locally by a team of Croatian expatriates.

Thus, it is important to acknowledge that countries should develop policies that help accelerate the development of a comparative advantage, in a way that is sensible to their current social, political, economic and geological landscape. Policies to develop local production linkages should not be replicated without accounting for the contextual specificities, given that the region is highly heterogeneous in terms of infrastructure, capabilities and geological deposits. Although Botswana had a unique set of circumstances that allowed the government to reach an agreement with De Beers to set aside a specified amount of rough diamonds for local processing, not every country has such an advantage in terms of bargaining power (Box 2.1). In both Tanzania (Box 2.2) and Indonesia (Box 2.3), the ban on exporting raw minerals contributed to a sharp decline in production and led mining firms to take their investments elsewhere.

Box 2.1: Diamonds for development: Botswana's story of developing skills and local production linkages

At the height of its business, De Beers, a London-based mining company, controlled more than 80% of the world's rough diamond supply and oversaw the entire value chain – from mine to consumer. The mining giant had a near-monopoly of the diamond industry in Southern Africa and controlled prices for the entire industry through a single marketing channel.

Botswana has one of the richest diamond deposits in the world – and the stones are both high quality and easy to access due to their surface location. To extract the diamonds, the government of Botswana partnered with De Beers to create a joint venture, Debswana, in 1969, with the government holding a 15% stake. In 1975 the share was increased to 50%.

In the 1980s, the Botswana government sought to increase the value the country gained from diamonds and asked De Beers to facilitate the creation of local production linkages. The company responded by saying that cutting and polishing activities were not commercially viable, but to meet the government's request, it created three cutting and polishing factories – though none were commercially viable. Critics claimed that De Beers had intentionally made these entities unprofitable to avoid further requests from the government.

Two decades later, as its Botswana mining licenses were set to expire, De Beers was also starting to lose its global monopoly due to competition from other regions. Given that 70% of its profits and 60% of its supply of rough diamonds came from Botswana, it would have been impossible for De Beers to stay globally competitive without renewing its licenses in Botswana. As a result, Botswana became vital to the future existence of De Beers and the government was in a strong bargaining position. In 2005 the government successfully negotiated an agreement with De Beers for a specified amount of Debswana's rough diamonds to be cut and polished domestically. The government invited international cutting and polishing companies to set up local operations on the understanding that they would transfer cutting and polishing skills to Botswanians, facilitate local job creation, and develop local manufacturing. Also known as sightholders, 16 operators were chosen and licensed. In exchange for their skills and technology transfer, they were guaranteed a supply of rough diamonds and 13 of the 16 companies received rough diamonds from across the world through De Beers' aggregation business. In general, international good practice shows that if the first exploitation period has been correctly developed, the renewal of a mining right under the mining law provisions should be a smooth process.

Today, Debswana has four diamond mines, including the world's largest, Orapa, and the richest, Jwaneng. It produces 22% of the world's diamond output, contributes to 70% of Botswana's export earnings, and brings in 50% of the government's revenues. There are more than 2,100 firms that are involved in cutting and polishing diamonds and Botswana continues to loosen restrictions to attract investment for beneficiation. Its ability to drive beneficiation hinged on several factors: (i) a stable regulatory climate which enabled De Beers and the government to collaborate through a joint venture; (ii) the high degree of negotiation power the government had due to De Beers' declining position in the global diamond markets because of increasing competition; and (iii) the country's ability to attract international processing firms to facilitate skills and technology transfer.

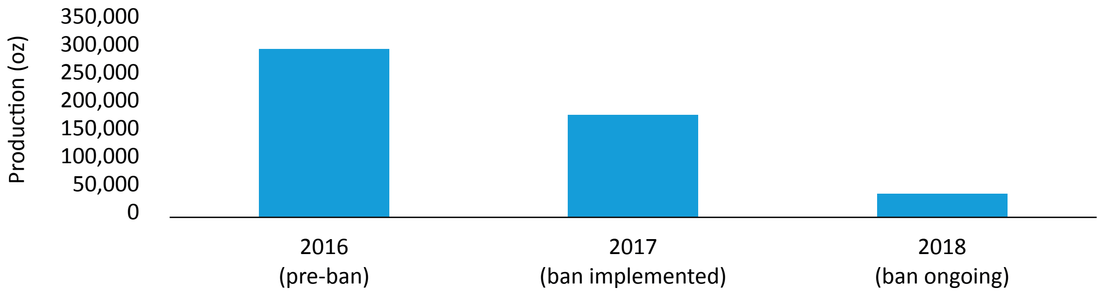
Source: Waves (2016)

Box 2.2: Export bans can limit the production of minerals

In Tanzania, there has been growing tension between the government and mining companies. In an effort to increase the domestic benefits of mining, the government of Tanzania implemented an export ban in 2017 on raw concentrates (including gold, copper and silver) to ensure mineral value-addition activities took place within the country (forward linkages). However, the development of forward linkages was hampered because the country lacks the capacity to process raw mineral output profitably. A 2012 feasibility study showed that based on volume, local processing was not feasible as an insufficient amount of gold was produced. As a result of the ban, mining output and fiscal revenues have been drastically reduced. The Tanzania Chamber of Minerals[14] has recommended that the government temporarily suspend the ban while assessing the viability of in-country refining, smelting and processing operations.

Figure 2.4: The ban on exporting mineral concentrates has been a constraint for many mines.

(Gold production at Acacia's Bulyanhulu Mine in Tanzania)



Source: Acacia Annual Report.

The conflict between firms and the government of Tanzania is exacerbated by distrust. For example, the Tanzanian government has accused Acacia, the country's largest gold mining company, of tax evasion, and handed the London-headquartered firm a US$190 billion tax bill – about four times the country's GDP – for underreporting output.

Acacia has firmly denied the allegations and agreed to pay US$300 million to settle all outstanding tax claims.

14 Mining Weekly, March 3, 2017 "Tanzania bans metals minerals, exports in bid to increase domestic beneficiation".

Box 2.3: Requirements for local production linkages can act as a deterrent to investment

The Indonesian government passed a law in 2009 that compelled mining companies to develop local processing facilities or face a ban on mineral exports within 5 years. The policy was intended to start a minerals processing industry by requiring firms to smelt their ores domestically. But neither domestic nor foreign firms developed refining capabilities for minerals such as bauxite, nickel, or copper, partially because they thought the government would back down. The ban on the export of raw minerals was implemented in January 2014.

Bauxite is a sedimentary rock composed of a mixture of hydrous aluminum oxides. It is the principal ore of aluminum. Indonesia is home to significant bauxite deposits; its state-owned mining company, Aneka Tambang, exports the ore, while the country's sole aluminum manufacturer, Asahan Aluminum, imports the processed alumina – the main constituent of aluminum – from China.

China produces 60% of the world's aluminum and Indonesia has been its largest supplier, providing 70% of the bauxite used. The government's decision to ban the export of unprocessed bauxite was part of a wider plan to force China's alumina refiners to invest in local processing rather than exporting bauxite ore and adding value abroad. Attracting foreign companies to invest in processing facilities became complicated, given the uncertainty as to whether the country had enough high-quality bauxite reserves to remain a competitive supplier in the long term, which was a necessary precondition to justify the construction of costly smelters.

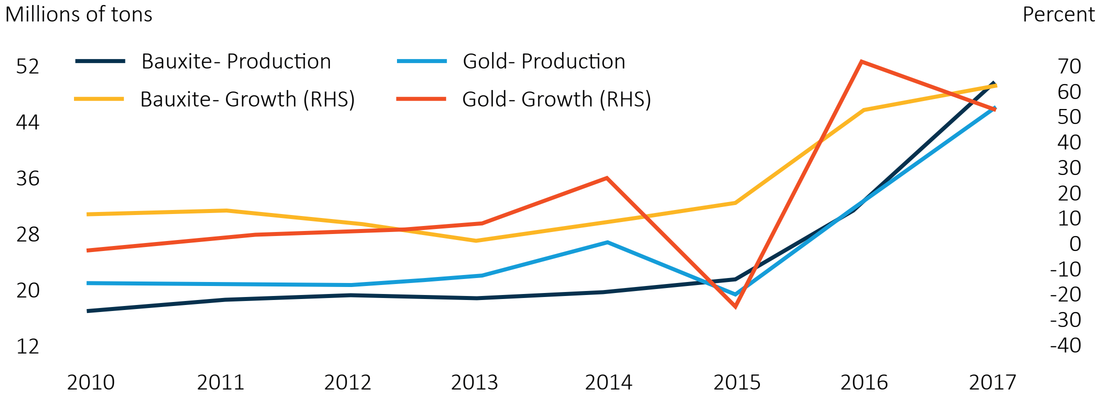
As the ban loomed, China's operators stockpiled bauxite and commenced explorations elsewhere. They also began financing new suppliers of high-quality bauxite reserves in West Africa's Republic of Guinea.[15] [16] Although the Indonesian government began loosening the ban on bauxite exports in January 2017 to alleviate the pressure on local mining firms and workers and to give downstream processing facilities additional time for construction, Indonesia's position in the global bauxite market had permanently changed, leaving the government with limited power.

In Guinea, mining exports increased by 79% year-on-year in 2017, as a result of higher bauxite production. FDI in the mining sector is strong at 13% of GDP and investment-related imports stayed buoyant (Figure 2.5) (IMF, 2018).

[15] Insideindonesia article: "The life and death of Indonesia's mineral export ban", October 19, 2017.
[16] Mining Journal article: Will-indonesia-abandon-its-plan-to-ban-bauxite-exports?, April 12, 2019.

Figure 2.5: Guinea's bauxite production sharply increased in 2015 after the export ban in Indonesia took effect.

(Production and Growth in Guinea's Mining Sector)

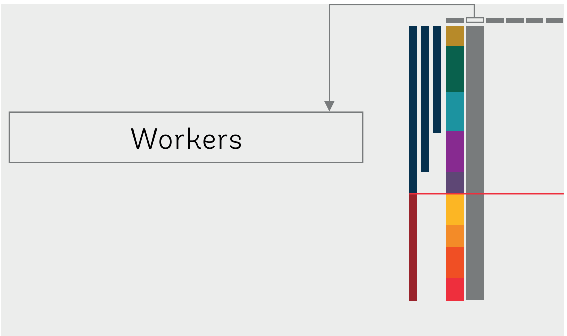


Source: IMF (2018).

While Indonesia has a rich supply of bauxite, the regulatory changes requiring local production linkages backfired as firms opted to take their operations elsewhere. Even with the subsequent loosening of restrictions, the government did not manage to draw investment back to Indonesia. This proved to be very costly – reducing nickel and bauxite exports by approximately US$4 billion annually in 2014 and US$2.5 billion in 2015.

To increase the economy-wide impact of the mining sector, governments are faced with balancing two instruments. They can tax firms and use revenues for social and economic projects and/or require companies to spend on such projects, in addition to paying taxes. In Southern Africa, there has been an increase in regulations that compel firms to pay taxes and spend in other areas such as levies to develop skills and community spending.

2.4. Stakeholder analysis of benefits and costs of mining



Historically, mining has absorbed large amounts of unskilled labor, but that dynamic is changing. There are a number of factors that affect the job creation potential of a mining investment, including: (i) the type of ownership (publicly-owned mines often employ more workers than privately-owned mines); (ii) size of the mine; (iii) the mining life-cycle – employment levels are higher during the construction than the production phase and labor demand can also vary as a project transitions between phases; (iv) type of mining operation – conventional underground mining employs substantially more workers than mechanized open-pit mines; (v) type and grade of the commodity being extracted; and (vi) the construction of infrastructure (Cordes, et al, 2016).

$$B_w = (w(1-\tau) + \forall + H) - HC - \varnothing_1 Y \qquad (1)$$

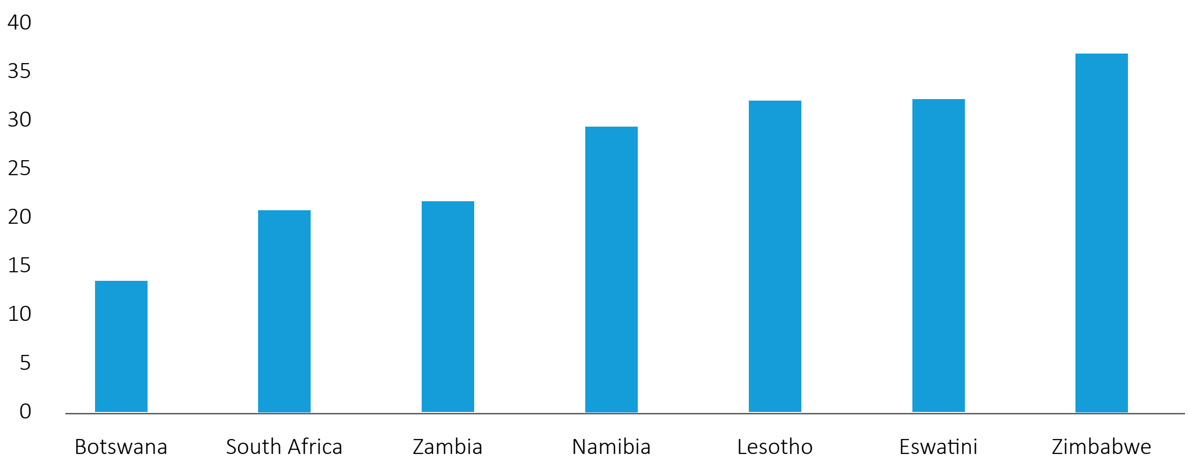
The net benefits for workers (L) in the mining sector (B_w) are that they earn a wage (w) minus payroll taxes (τ). They may also receive additional education ($\forall$) and health spending (H) through a combination of public ($\forall_g + H_g$) and/ or private ($\forall_p + H_p$) provision. Moreover, the worker may save part of his wages to invest in capital in the mining sector which generates a return. Conversely, the activity of mining may introduce specific negative health costs (HC) and carbon emission costs ($\varnothing_1 Y$) on the worker.

Benefits

Wages

Typically, the wages of workers in the mining sector in Southern Africa compare favorably relative to workers in other sectors, but workers' incomes are often more volatile. Historically, the sector has been a significant employer of low-skilled labor. Moreover, workers in the mining sector have earned high wages. For instance, in the South African mining sector, wages more than doubled in real terms from 1994 to 2015. In 2014, the median monthly base wage in mining came to R7,000, or close to twice the median pay in the rest of the formal sector. However, wages have been volatile. During periods of high commodity prices, wages have tripled or base salaries quadrupled, but during periods of low commodity prices production bonuses have diminished or disappeared.[17] Thus, the mining sector has been a notable driver of poverty reduction.[18] The capital-intensity of mining has increased across the region, including in Tanzania, Botswana, South Africa and Zambia. This has led to a reduction in the number and composition of workers, and an increase in labor wages. On the other hand, mining operations in Namibia, Lesotho, Eswatini and Zimbabwe continue to be more labor-intensive, (Figure 2.6). While a wage from mining can be important to reduce poverty, the impact of inequality from mining is less clear. [19]

Figure 2.6: In Southern Africa, mining is most labor-intensive in Zimbabwe
(Labor income in % of GDP)



Source: World Bank staff.

17 Employment, pay and workplace conflict in mining, Trade and Industrial Policy Strategies (TIPS) Briefing Note, October 2015.

18 A recent report estimated that around 13 people were lifted out of poverty for 10 people employed in the mining sector. World Bank (2017) "South Africa Economic Update: Private Investment for Jobs".

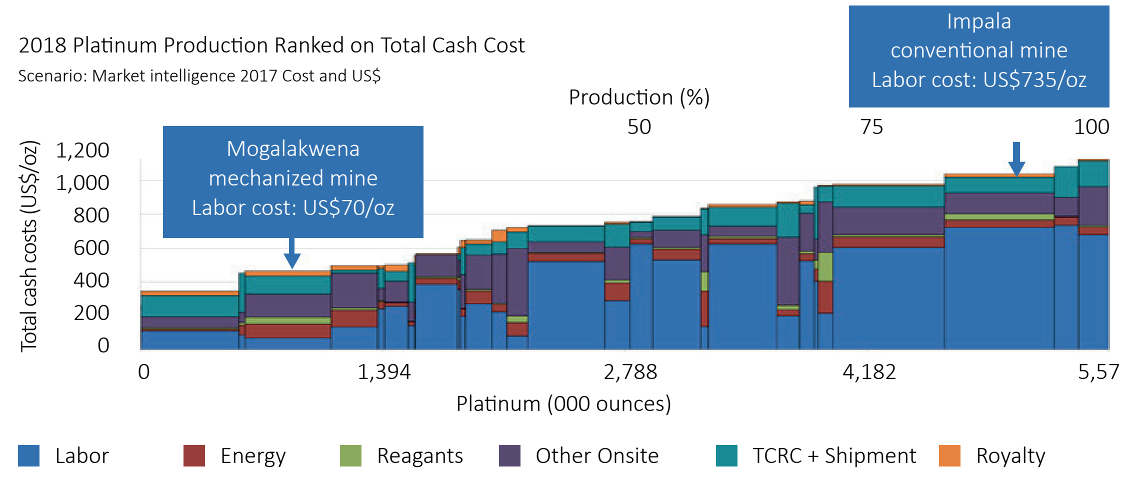
19 World Bank Group (2018c) finds that for South Africa, growth in mining tends to generate more demand for skilled labor, raising the skills premium and thus contributing to wage inequality. This also highlights the importance of investment in skills for inclusive growth.

Box 2.4: Impact of mechanization on the mining sector

Geology plays an important role in determining whether mechanization is appropriate for a particular mineral deposit. For example, in the platinum sector, mines that are thick, flat and less undulating are optimal for mechanization, compared to those that are narrow and potholed. Additionally, shallow deposits have lower risk profiles, and are thus more appealing for mechanization.

Mechanization improves cost-competitiveness but reduces jobs. Levels of automation in the region vary: Botswana and South Africa have a higher degree of mechanization while Zimbabwe and Zambia still largely rely on labor-intensive mines. The reliance on labor as a factor of production is important for the local economy and can make the benefits of mining more broad-based – but it affects cost-competitiveness. Figure 2.7 shows that Mogalakwena falls in the lower half of the first quartile on the cash-cost curve, while Impala, which is a conventional operation, falls in the fourth quartile. Labor costs comprise a majority of the costs in conventional mining. Although Impala employs significantly more people, it announced the closure of five shafts and retrenchments affecting one-third of its workforce (13,000 people) in 2018 due to its sustained unprofitability; while Mogalakwena has continued to scale up operations. Impala's retrenchments were all geographically concentrated in the Rustenburg area, which is primarily home to conventional mining operations and has been heavily affected by retrenchments in recent years.

Figure 2.7: Globally, mechanized mines are significantly more cost-competitive compared to conventional mines.
(Global platinum cost curve)



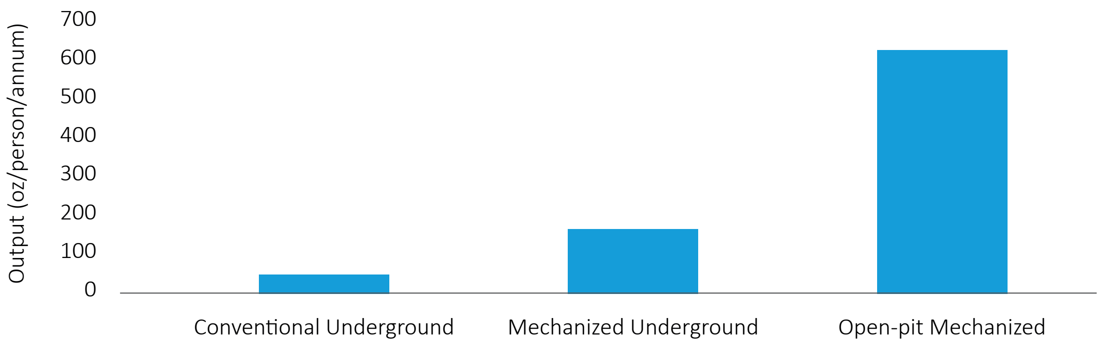
Source: S&P Global Market Intelligence.

In addition to reducing the amount of labor required, mechanization has also shifted the type of labor needed – from low-skilled to high-skilled. For example, rock blasters have been replaced by engineers who can manage the automated equipment used to blast the rock. At Mogalakwena, per worker output was 11 times higher than that at Amandelbult, a conventional underground platinum mine (both wholly owned by Anglo Platinum, a subsidiary of Anglo American) (Figure 2.8).

Moreover, the shift to capital-intensive mining has led to the mines becoming increasingly detached economically from the region in which they are located. Amandelbult employs more than 14,000 people who live proximate to the mine, while Mogalakwena employs just 1,800 but enjoys significantly higher output. Because mechanized mines require high-skilled labor and local mining communities tend to be constrained by skills shortages, it is not uncommon for capital-intensive mines to bring in engineers from other parts of the country.

Figure 2.8: Open-pit mechanized mines are significantly more productive than their conventional underground counterparts.

(Production output, per person, per annum for 3 different types of Anglo American's PGM mines)



Source: Anglo American annual reports.

Additionally, employment in the mining sector has been vulnerable to shocks, which has created cyclical employment patterns. For example, in South Africa, employment in diamond mining fell nearly 40% between 2005 and 2013; while employment in platinum mining was volatile over the period, after peaking at just under 200,000 workers in 2008 (TIPS, 2015).

Social & Sustainability Spending

Mining companies provide significant benefits to workers. In Zambia, the tradition of providing education, health and social benefits as part of workers' benefits package has dated back to colonial times (ICMM, 2014). The real value of these benefits was increased when the mines became nationalized. This gave way to an increased demarcation between living standards on the Copperbelt and elsewhere (Mosley, 2017). When copper prices began to decline in the mid 1970s, it was impossible to maintain the high level of real social benefits, leading to violent strikes in 1977. At the turn of the 21st century, private mines began to scale up benefits again. Konkola Copper Mines and Mopani Copper Mines are two deep underground mines that have struggled with productivity, and by extension, profitability. They continue to operate multiple hospitals, clinics, and schools near the mines. Firms in Southern Africa have utilized social protection expenditures to improve the lives of their workers in several ways, though they have had limited success.

Education

Mining companies finance a variety of skills programs. Workers are provided with three types of training – legally-mandated, firm-mandated, and professional development. Health and safety training is legally mandated across the mining sector and is used to de-risk an inherently dangerous sector. Firm-mandated training is often task-specific (such as operating certain machinery). Professional development is optional training, to improve existing skills or develop a new technical or soft skill.

In South Africa, firms are legally required to provide retrenched workers with portable skills training prior to the conclusion of their employment, under section 189a of the Labour Relations Act No. 66 of 1995. Portable skills training is intended to develop skills that employees can use for self-employment at the end of their careers, after retrenchment, or when losing their jobs due to a mine closure. Training includes gardening, agriculture, construction and sewing, and is useful for workers who have firm-specific skills and have only ever worked in the mining industry. There is consensus within the industry that portable skills training is often merely done for compliance purposes, rather than ensuring competence of the workers by providing training of a sufficient quality and duration. Additionally, most training is done for a single skill rather than a skill set – which can make it difficult to obtain future employment, given that multi-skilling (for example, bricklaying, plastering and tiling as a set of construction skills, rather than just bricklaying) is a growing demand in the labor market. When Petra Diamonds carried out portable skills training prior to retrenchments in 2014, it cost US$345,000 for 183 employees.

Mining communities have been epicenters of communicable diseases, especially tuberculosis (TB) and HIV (Human Immunodeficiency Virus). Mineworkers in Southern Africa have the highest rates of TB of any working population in the world with workers on gold mines at greater risk because of occupational lung disease and the high HIV[20] burden. There are two reasons for this. First, the high incidence of silicosis, pneumoconiosis, and other lung diseases caused by exposure to silica dust makes mineworkers more susceptible. In South Africa the prevalence of TB among miners and ex-miners is estimated at 2,500-3,000 per 100,000 people (compared with 834/100,000 people in the general population), and is more than 10 times the World Health Organization's threshold for a health emergency (World Bank Group, 2018c). Second, nearly 70% of TB cases in the mines are missed or go untreated (World Bank, 2014).

Around 82% of the mining companies analyzed as part of the 2014 World Bank study gave their employees access to a mine clinic or hospital. These were well-equipped, with no shortages of laboratory equipment or pharmaceuticals, including TB medication. However, facilities were sub-standard in the field of diagnosis; only 67% utilized a cough questionnaire (a basic test to identify a nagging cough, which is a hallmark symptom of both silicosis and active TB); and not all companies had access to chest x-ray machines and sputum tests.

There were two major gaps in coverage for TB diagnosis and treatment. First, of the 233,000 mineworkers included in the 2010 review of TB in the mines, 80,000 were contractors; with the study finding that contractors did not have the same access as regular employees to health services. Additionally, 33% of companies had no written policy in terms of providing TB services for contractors and those without written policies did not necessarily allow contractors to utilize their TB services. Second, only regular employees are generally given access to the free care provided by mining companies' health facilities; their family members are required to purchase separate insurance to be treated there. Given the airborne nature of TB, it's common for it to spread to family members but treatment for them could be prohibitively expensive.

Although current and former mineworkers in South Africa are eligible for compensation for occupational lung disease, regardless of their country of origin, many logistical challenges have prevented workers from receiving the care and/or compensation they deserve. South Africa's Occupational Diseases in Mines and Works Act of 1973 required compensation for miners who contracted occupational lung diseases, including TB, silicosis and chronic obstructive pulmonary disease (COPD), to receive biennial benefit mediation examinations (Kistnasamy et al 2018). However, this compensation legislation only covered white miners, excluding black miners even though they comprised the

[20] Higher rates of HIV stem from the fact that historically, mine workers have lived away from their partners/spouses and have been more likely to engage in risky sexual behavior.

majority of exposed workers. Limited diagnosis and treatment avenues made it difficult for black workers to obtain help, as access was difficult in their home areas.

After racial clauses were removed from the legislation after 1994, hundreds of thousands of former miners were found to have been left with occupational lung disease.

Costs

Pollution Damage

Pollution, health and safety

The mining industry has not fully paid for the health challenges workers face stemming from pollution. In addition to the chronic lung conditions such as TB, silicosis and COPD that are best addressed through firm-level expenditures, pollution can impose other long-term health challenges for mine workers, but they are seldom discussed.

Asbestos pollution has been known to cause lung cancer and mesothelioma (a rare cancer of the chest and abdominal lining), among other conditions. In 2011, a court decision[21] in the United States ruled that it is a "fact of common knowledge" that asbestos is a toxic pollutant. Asbestos is common in South African diamond mines due to the nature of kimberlite and their proximity to asbestos deposits, and in Eswatini, where asbestos mines operated for many years.

Though measures are in place to address the consequences of pollution on the health of mineworkers, there is still much room for improvement (Table 2.2). The study by Kistnasamy et al (2018) shows that regional health spillovers are highly prevalent. Although the mine workers in the table below worked in South Africa, negative health effects have spilled over to other countries, as former mineworkers returned home. Just over a quarter of all compensable claims originated from neighboring countries, including Lesotho, Mozambique, Eswatini, Botswana and Malawi. Given that these ex-mineworkers receive limited health care provision when they leave the immediate mining area, the burden of care can fall on the government.

21 Villa Los Alamos Homeowners Association v. State Farm Ins. Co., 198 Cal. App. 4th 522 (2011).

Table 2.2: Occupational lung disease claims stemming from South African mines span the region.

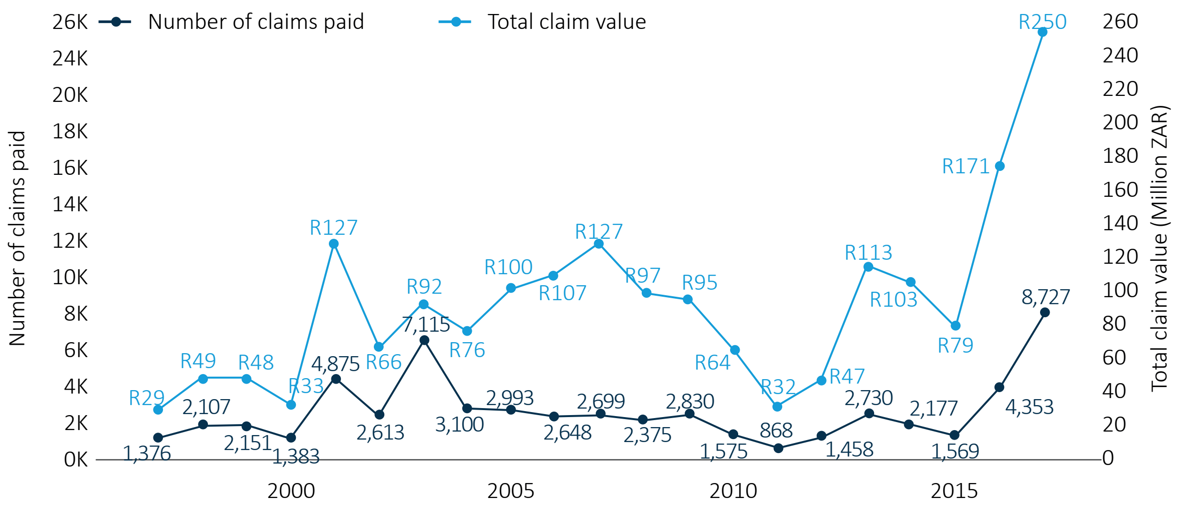
(Number of compensable occupational lung disease-related claims for countries in Southern Africa, 1973–2017)

Country	Miners N (% of total)	Compensable claims (N (% of total)	Rate of claims by country (%)
South Africa	1,189,515 (73.3)	159,858 (73.2)	13.4
Lesotho	191,225 (18.8)	38,192 (17.5)	20.0
Mozambique	152,091 (9.4)	11,496 (5.3)	7.6
Eswatini	31,958 (2.0)	3,402 (1.6)	10.6
Botswana	29,224 (1.8)	4,235 (2.0)	14.8
Malawi	29,741 (1.8)	1,028 (0.5)	3.5
Total	1,623,754	218,301	13.4

Source: Kistnasamy et al (2018).

Figure 2.9: The number of compensation claims paid has steadily increased, by year and amount, from 868 claims paid in 2011, to 8,727 in 2017.

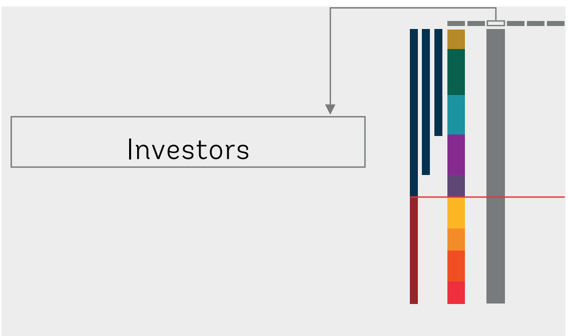
(Frequency and value in ZAR of occupational lung disease claims that have been paid)[22]



Source: Kistnasamy et al (2018).

[22] Displayed by calendar year, from 1997 to 2017. Graph includes 61,722 paid claims over 21 years from 1997 to 2017; it excludes 49,444 paid claims from 1973 to 1996.

Accidents and deaths are not uncommon in the mining industry. Mine workers are at heightened risk due to seismic activity, which can cause the rock to collapse on miners without warning, underground fires, and user error with machinery. Historically, some of the world's worst mining accidents have happened in the Southern African region: in September 1970, 89 miners were killed in the Mufulira mine disaster in Zambia; in June 1972, 476 were killed in the Kamandama mine disaster in Zimbabwe; in January 1960, there were 437 deaths at the Coalbrook North Colliery in South Africa; and in September 1986, 177 were killed in the Kinross gold mine in South Africa. However, there has been a substantial decline in mine-related accidents and deaths, due to increased efforts to make the industry safer. In 2018, the South African mining industry experienced 2,350 injuries and 81 deaths. The gold sector had 40 fatalities, followed by 12 in platinum, 9 in coal, and 20 in the remainder of commodities.



Mining companies are a centerpiece of the mining value chain, as they provide the capital and skills needed to extract the resources. However, many of these companies are foreign (primarily British, American, Canadian, as further discussed in Chapter 3), and are balancing their central role in the value chain with the fact that there are limited benefits for local workers as most of the capital is repatriated to the country of ownership (Mosley, 2017). Furthermore, large-scale mining operations can become a foreign enclave in the host country as the expatriates who run the mines on behalf of the investors don't necessarily integrate. Zambia is particularly vulnerable to this "dual economy," where local, small-scale mines are sparse (Mosley, 2017).

$$B_F = (1 - \tau) PQ - (w + \forall_p + H_p) L - p(IM) - r(K) - dK \qquad (2)$$

An investor in the mining sector's benefits are assumed to consist of total sales revenues net of taxes[23] (τ) minus costs. Total revenue is denoted by (PQ), where (P) are commodity prices, and output (Q) is a function of capital, labor and intermediate (IM) inputs, Q = f(K,L,IM). Costs consist of labor costs (wages plus health and education costs); the price (p) of intermediate inputs; and the return on capital $r(K)$, which also includes rental costs, retained profits, interest on loans, and depreciation costs (dK).[24]

[23] That is taxes minus subsidies provided by the government.

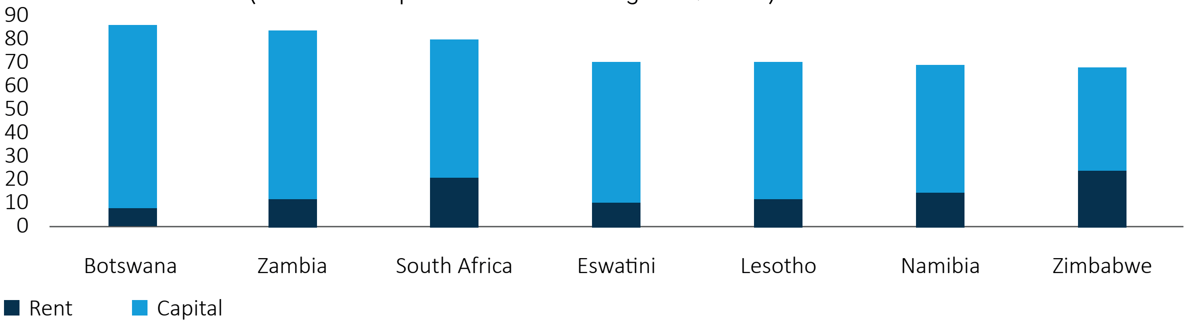
[24] Firms employ inputs on the basis, $L = \frac{w}{P^*MPL}$, $K = \frac{r}{P^*MPK}$, $IM = \frac{p}{P^*MPK}$ that is until the point that the cost of the input, wages (w) or return on capital (r) equal the value of its marginal product. Where marginal product of labor (MPL) = $\frac{\partial f(K,L)}{\partial L}$ and marginal product of capital (MPK) = $\frac{\partial f(K,L)}{\partial K}$

Benefits

Capital and natural resource factor income (rents) account for the majority of mining sector GDP in all countries (Figure 2.10). The distinction between profit (capital income) and rent is a conceptual one. In principle, rents are considered the return on capital that exceed some market-based competitive rates of return. Such a rate is difficult to estimate as it is highly context specific and would need to take into account the risk associated with a mining operation – which may be idiosyncratic and are generally difficult to measure (World Bank 2018c). Essentially, the main reason for mining to take place is for societies to capture the rent: that is monetizing the value of sub-soil assets. In practice, capturing the rent is difficult (as further described below), and investors and governments tend to share parts of the rent through profits and fiscal revenue respectively. Figure 2.10 shows that capital income accounts for the predominant share of GDP, with Botswana being the most capital-intensive country. Zimbabwe, followed by South Africa, has the highest natural resource rents.

Figure 2.10: Capital absorbed the highest share of mining income in Botswana. Zimbabwe had the highest resource rents

(Rent and capital share of mining GDP, 2016)



Source: World Bank staff.

Profits

Commodity prices are an important determinant of profits. As shown in Chapter 1, commodity prices can go through relatively long cycles, which have important implications for national economies. The price is the main determinant of the size of the rent and, to the extent that it is captured by investors, of a firm's profits. Prices have various determinants, including global demand – China has recently been the main source of demand for metals given buoyant investment in the country. Supply is the other factor, and it is affected by new discoveries, the ability to get produce to markets (where the reliability of infrastructure matters, including electricity, rail, and port infrastructure), and work stoppages due to industrial action. Perhaps with the exception of platinum where South Africa is by far the largest global supplier, Southern African countries are too small to affect global prices and are therefore price-takers. Due to the dominance of mining in the Southern African region, exchange rates in many of the countries serve as buffers (or natural hedges) for mining companies – although other sectors may be adversely affected by the impact of mining on exchange rates (Box 2.5).

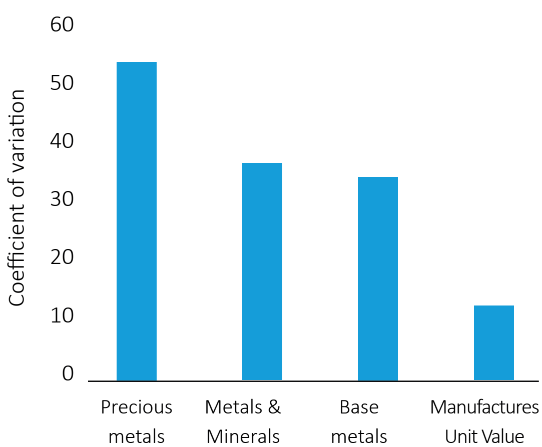
Box 2.5: Commodities, exchange rates, and economic performance

The term "Dutch disease" was coined in the 1960s when the Netherlands discovered large natural gas deposits in the North Sea; causing its currency the guilder to appreciate, making other sectors less competitive globally (Ebrahimzadeh, 2018). The productivity gains in mining exports raise prices in the non-tradable sector, meaning that the prices of non-traded goods increase the levels of non-mining traded goods. The real exchange rate appreciates and unless non-mining exporters step up their productivity, they will lose competitiveness and get crowded out. It is one of the factors that may make it difficult to develop a manufacturing sector in the shadow of mining, a reason South Africa and some other countries in the region have invoked to support manufacturing through industrial policy.

South Africa has a pocket of oil-equivalent and gas condensate resources estimated at 1 billion barrels that was discovered in 2019. Though generally a boon to a country, support from commodities also harbors risks for other sectors. Whether in response to new discoveries or commodity price upswings, currency fluctuations are a consideration. However, policymakers have experimented with mechanisms to limit the appreciation of the real exchange rate. These can include monetary, exchange rate, and fiscal policy interventions, possibly backed by a sovereign wealth fund. Chile and Norway have imposed structural fiscal rules with some success (Caputo and Valdes, 2015). The South African Reserve Bank experimented with a "leaning against the wind" stance through asset purchases to reduce rand appreciation at the beginning of the commodity super cycle. However, the effectiveness or otherwise of this policy is still to be determined. Overall, macro-economic policy responses to avoid commodity-induced exchange rate appreciations require considerable technical capacity – as well as the political clout to explain to voters that the government will run high surpluses for potentially extended periods while apparently ignoring important spending needs.

Figure 2.11: Precious metals have the highest degree of volatility

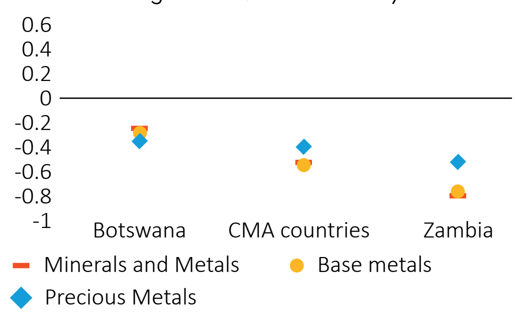
(Volatility of major global commodities)



Source: World Bank staff.

Figure 2.12: Export commodity price shocks have a strong impact on currencies

(Correlation of commodity prices and exchange rates, 2000-2017)



Source: World Bank staff.

Note: Countries of the Common Monetary Area (CMA) are South Africa, Lesotho, Eswatini and Namibia.

Commodity prices also affect economies through their volatility as they fluctuate faster when compared to prices for manufactured goods, for instance (Figure 2.11). This volatility affects exchange rates across the region (Figure 2.12). For commodity exporters, the impact of commodity prices on the exchange rate offers a "natural hedge", where the exchange rate depreciates when commodity prices fall, thus smoothing the income from commodity sales in local currency terms. Yet, for all other companies this creates uncertainty and costs. In countries like South Africa, large companies have access to sophisticated hedging products, but smaller companies may have difficulty accessing such products. In other Southern African countries, hedging options are limited. There is evidence that exchange rate volatility reduces FDI and investments by companies (Algu et al. 2018; Chortareas and Noikokyris, 2018). Macro-policy options to smooth the exchange rates have proven to have limited effect and can be expensive. Company-level financial sector solutions to insulate firms from commodity price volatility may have a higher impact, although more evidence is needed on this.

Mineral grade is another important factor for prices and thus profit margins. Prices for minerals can vary significantly, as illustrated in Figure 2.13 in the case of iron ore; and the difference across grade prices varies over time. This applies to the ores (as the iron mineral) sold directly without previous concentration processes. For the concentrated ores, the selling prices are more uniform. In 2017, high-grade ore was almost twice as valuable as lower-grade ore. This has important implications for calculating the economic rent, taxation and royalties, and for the relative competitiveness of a country as compared to deposits in other parts of the world.

The importance of mineral grade for the commercial viability of a mine – and the relative competitiveness of a resource deposit – can be illustrated with several examples. One is related to copper: although Zambia averages a lower head grade than the Democratic Republic of Congo (DRC) (0.7% for surface operations, compared to 2.7% for the DRC (Figure 2.14)), the country managed to attract considerable mineral exploration until 2017/18, when investment trends diverged in the two countries. This was largely due to a confluence of factors, including increased taxes, levies and the tenth successive royalty increase in 16 years (Figure 2.15).[25] As a result, when compared to the DRC, Zambia earns lower revenue for each ton of copper produced. Given Zambia's fiscal challenges, the country increased taxes in 2018. However, the successive royalty changes have adversely affected the commercial viability of Zambian copper mines, undermining investment in exploration (Figure 2.15). Another example can be drawn from Namibia whose gold mines are struggling to stay open as they balance mining only low-grade gold with the cost of potential tax changes.[26] The Otjikoto Mine, owned by B2Gold, Namibia's largest gold producer, will close earlier than planned and result in the retrenchment of 900 Namibians.[27] In addition

[25] The Zambian Chamber of Mines (ZCM) released an emergency statement stating that the proposed tax change would make Zambia "uninvestable," and warned that up to 7,000 direct and 14,000 indirect jobs were at risk.

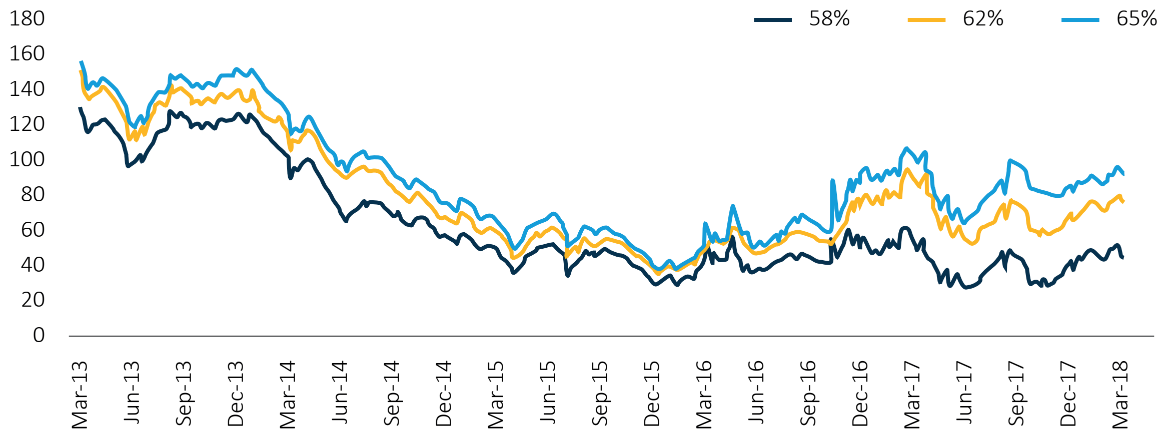
[26] World Gold Council defines a high-quality underground mine as having a gold ore density between 8 and 10 g/t (grams per ton), while a low-quality underground mine has a gold ore density of 1 to 4 g/t. Namibian gold averages 1.4 g/t.

[27] Letter from B2Gold to Namibian Ministry of Finance dated December 13, 2018.

to reducing revenue to the government (including royalties, levies, and taxes paid by employees) by approximately NAD420 million per annum, there will be other negative effects from the closure of an operating mine, especially on local communities.

Figure 2.13: Prices for iron ore can vary widely, based on mineral grade

(Iron ore spot prices for various grades, US$)

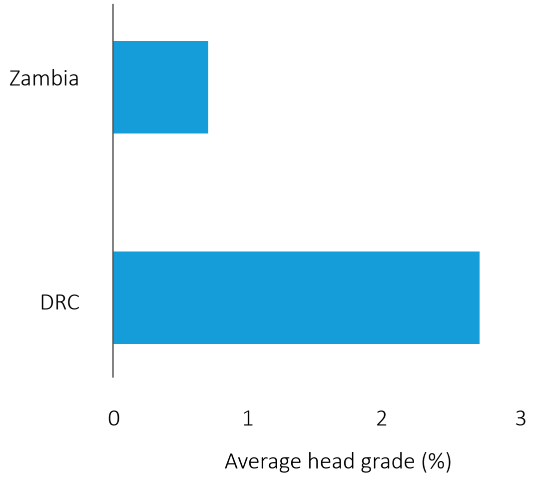


Source: Thomson Reuters and World Bank staff.

On the flip-side, higher mineral grades provide room for firms to incur additional costs, as is the case in Lesotho. As it is a more recent producer of diamonds, Lesotho has less infrastructure than Botswana, an established diamond producer. Poor infrastructure is a concern for development generally and adds to the costs of mining. Given that Lesotho has some of the most valuable diamond deposits in the world (Figure 2.16), as emphasized by the recent recovery of the fifth-largest gem-quality diamond ever found, mining firms are willing to pay a premium in operating costs to access the stones (Figure 2.17). The operating costs per carat in Lesotho are nearly four times higher than Botswana's. To offset the lack of electrical grids, a R195 million infrastructure project to bring electrification to Letseng Mine and surrounding communities, thus reducing the need for diesel generators, which is a substantial cost, has been planned for 2019.

Figure 2.14: Despite being Africa's second biggest copper producer, Zambia has a much lower average copper quality than the DRC

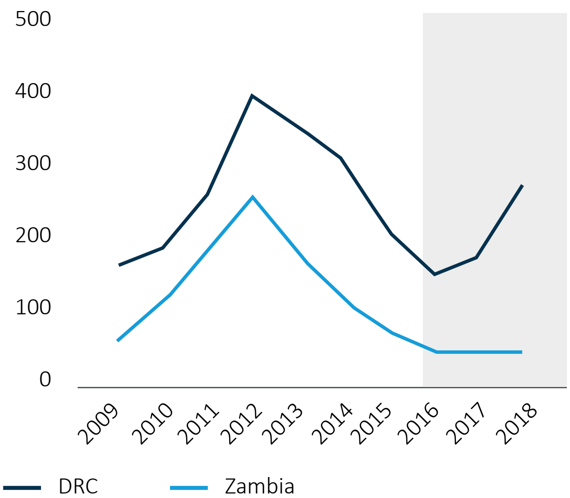
(Average copper head grade for surface operations in Zambia and the DRC)



Source: Deloitte (2015) and World Bank staff.

Figure 2.15: Few exploration investments have been made in Zambia

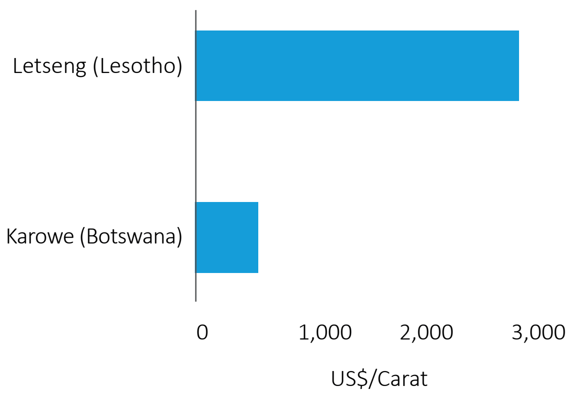
(Exploration investments made in Zambia and the DRC in 2018, US$ millions)



Source: S&P Global Market Intelligence.

Figure 2.16: On average Lesotho's diamonds are five times more valuable than Botswana's

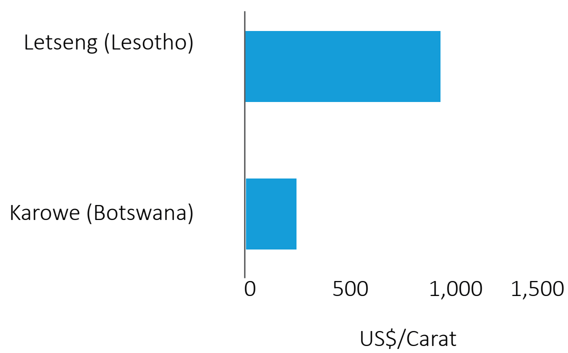
(Average per carat sales price for diamonds)



Source: Lucara & Gem Diamonds Annual Reports.

Figure 2.17: Although the operating cost per carat is nearly four times higher in Lesotho, partially owing to a reliance on diesel generators, mining companies are still making new investments, given the high quality of diamonds

(Operating costs for two mines in Lesotho and Botswana)



Source: Lucara & Gem Diamonds Annual Reports.

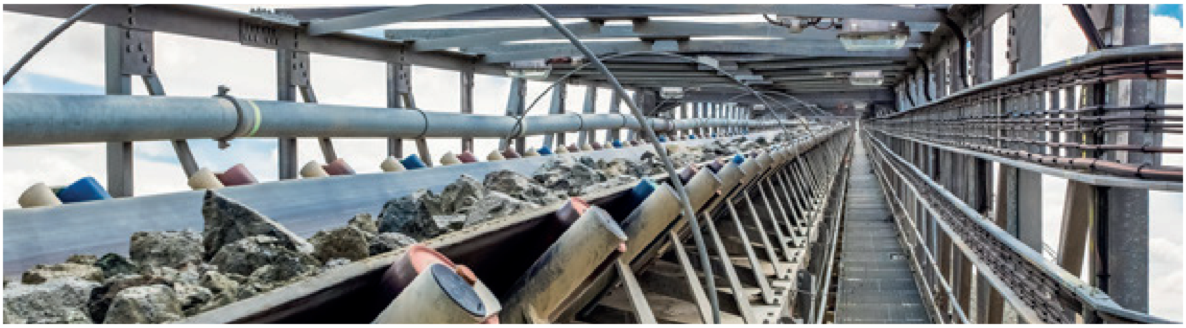
Another important determinant of profits is productivity, a factor over which a firm has the most control. Higher productivity leads to higher rents and revenue streams flowing to the various stakeholders. Beyond the mineral grade, several factors contribute to the level of productivity, including depth, the co-products mined and the level of technology and innovation integrated into the mining process. The transition from labor-intensive to capital-intensive mining has increased productivity substantially while helping to reduce accidents and fatalities. At Anglo Platinum's Mogalakwena open-pit mechanized mine, four shifts are run a day and 85,000 tons are extracted in one shift, whereas at Amandelbult, its conventional counterpart, 85,000 tons are extracted each month.

Despite greater depths, globally there is a shift from open-pit to underground mining. With lower grades of minerals remaining, underground mining is more effective because new technologies can identify the precise location and grades of deposits that can be extracted through fully automated systems. This is more efficient than removing a large ore body just to get a small mineral deposit, as is the case with open-pit mining. However, depth also affects the long-term sustainability of a mine (Box 2.6).

Box 2.6: High depreciation in capital-intensive, deep underground mines results in low long-term sustainability.

Gold Fields South Deep in South Africa is the world's second largest gold mine, and at a depth of 3 kilometers, one of the deepest in the world. It has a life-of-mine of over 70 years. Given its unusual shape – the mine fans out like the pages of a book – it became one of the first South African gold mines to undertake an intensive mechanization process. However, this did not render a profitable operation, as other factors made it difficult to control costs. When expensive machinery fails deep underground, it is both costly and difficult to repair. As a result, South Deep has not been able to come close to the production levels it had hoped for. Gold Fields has also cited a range of operational challenges, including higher operating costs, poor equipment reliability, poor maintenance, low labor productivity, and the need for expensive infrastructure. The mine is experiencing very high depreciation costs after sinking R32 billion into the shaft since 2006, and as of 2019, has yet to yield a sustainable profit. Gold Fields has tried various measures, including changing mining methods, training employees, bringing in expert consultants, reducing management by 25%, and other cost-saving initiatives but is still losing approximately R100 million each month. As a result, 44% of the workforce was retrenched at the end of 2018, negatively affecting workers and the local community.

South Deep's significant depreciation costs contributes to low sustainability. By comparison, shallow underground and open-pit operations in North Mara, Tanzania result in lower depreciation and has a higher degree of sustainability. This illustrates the need for government policies to take into account mines that require significant investment, otherwise production in these types of mines are likely to diminish.

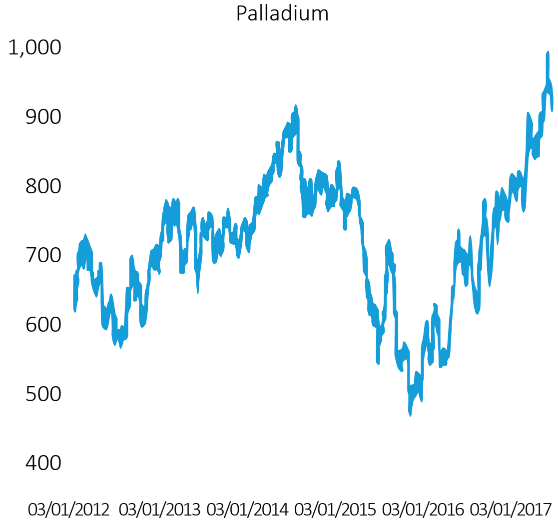


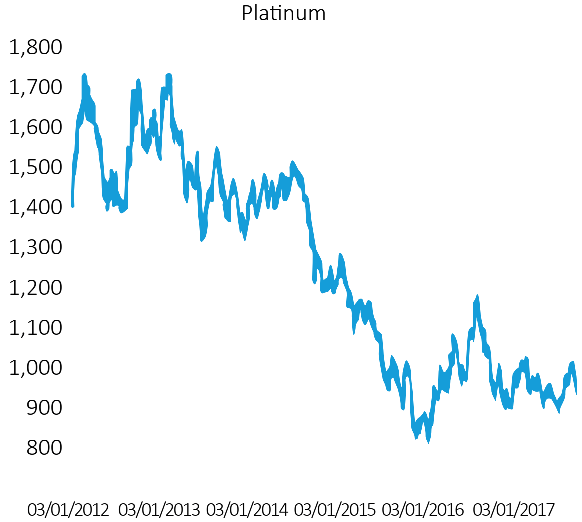
Mines with high value co-products are most likely to generate income and withstand the boom-and-bust nature of commodity cycles. Palladium is a co-product in many platinum mines. A surge in palladium prices amidst a decline in platinum prices, led many PGM firms to re-examine their mining strategy (Figure 2.18). Implats, the world's second biggest platinum producer, in 2018 announced 13,000 retrenchments, amounting to a third of its workforce at its conventional mines in the Rustenburg area of South Africa.

The Rustenburg area has low quantities of palladium in its platinum reefs, so profitability has been minimal, if at all. In the meantime, Implats has raised finance to build a new mechanized palladium mine in the Waterberg, 85 km north of Mokopane in Limpopo. Anglo American Platinum has similarly increased palladium output through the expansion of Mogalakwena, the open-pit mechanized mine also located in Limpopo. Anglo American also sold some of its Rustenburg-area operations between 2012 and 2017, citing low profitability.

Figure 2.18: PGM mines with high palladium concentrates, a co-product of platinum, have been able to stay cash positive and continue operations, while mines with low co-product concentrations have closed due to low platinum prices

(Platinum and palladium prices between 2012 and 2017, US$)

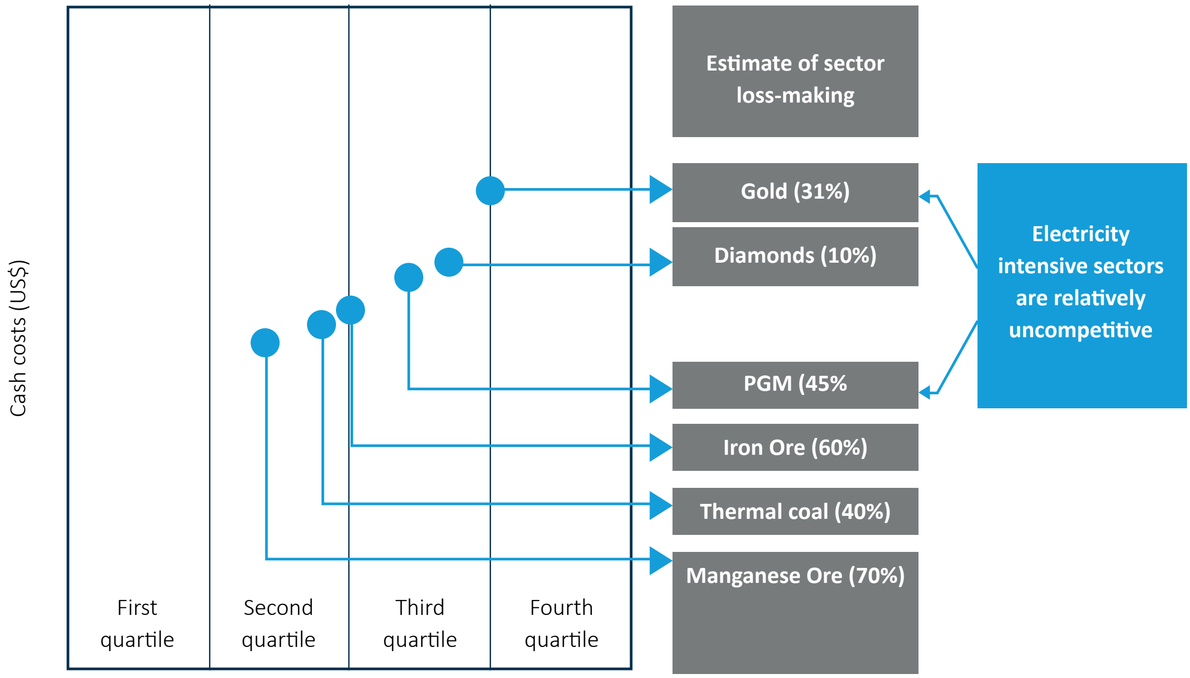




Source: UNCTAD.

Figure 2.19: In South Africa, diamond, gold, and PGM mining are in the third and fourth quartiles of the cost curve, which can be a disincentive for further capital investments for ongoing projects and act as a deterrent to future investments

(Mining cost curves for various minerals in South Africa)



Source: Chamber of Mines (2015).

Innovation in mining is significant. According to World Bank (2017), South Africa has been a leader in innovation, making major advances in mining technology and holding a high number of patents. The country's miners have a reputation for their know-how in deep mining and related services. Spending on research and development is relatively high, although that has been declining in light of recent policy uncertainty in the mining sector. World Bank estimates suggest that stimulating innovation in mining can result in meaningful job creation, especially in low-skilled, labor-intensive sectors like gold (but less so in coal).

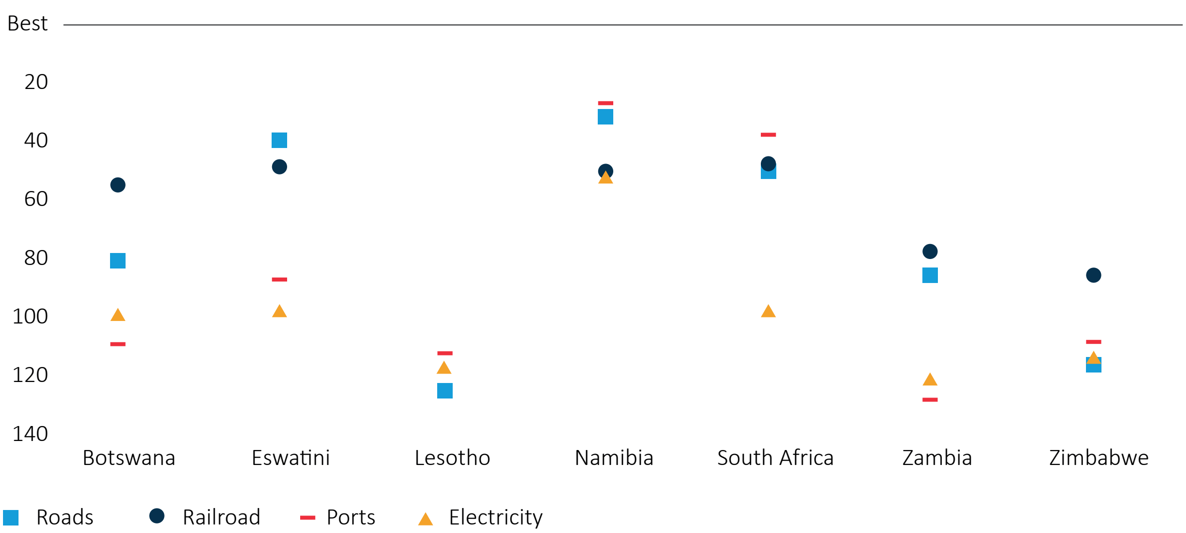
Costs

Costs include fiscal obligations, wages, social and sustainability expenditures, and the cost of capital. Taxes and other fiscal measures accrue to the government and are examined in the next section; wages accrue to workers; and social and sustainability expenditures can accrue to workers and communities – they are discussed in the relevant sections in this report. Generally, mining companies should internalize the externalities that the mining process generates (including social and environmental costs). The cost of capital is another cost. Given the significant need for capital, mining companies often tap into global capital markets – the Johannesburg Stock Exchange, Africa's oldest bourse, was established primarily to obtain capital for mining in South Africa. The cost of capital for mining companies is thus linked to developments in global financial markets, but can also factor in country-specific risk.

The cost of inputs is a critical determinant of mine profitability and commercial viability. As Figure 2.19 demonstrates for South Africa, electricity is an important input into mining production, determining the commercial viability of different commodities. This analysis would suggest that the large increases in electricity prices in South Africa in recent years will have considerable impacts on the ability of gold, diamond, and PGM mines to remain open. Other infrastructure, from roads, rail and ports, and water, to telecommunications – as well as trade-related costs on imports – all affect mining operations and the relative competitiveness of countries as mining destinations. Figure 2.20 provides an overview of the performance of infrastructure in Southern African countries, demonstrating the high quality of infrastructure in Namibia and the varied performance in other countries. Lack of consistently reliable electricity supply is a constraint; in light of regional power markets, the performance of South Africa's Eskom has implications for the competitiveness of neighboring countries.

Figure 2.20: There is considerable variance in the quality of infrastructure in Southern Africa

(Quality of infrastructure, global rank, 1=best out of 140 countries)



Source: World Economic Forum, The Global Competitiveness Report 2017–2018.

Depreciation is another cost. The depreciation of plant, property and equipment can be a large cost to companies (Box 2.7). On average, transport equipment has an asset lifespan of 4 years, machinery 8 years, and buildings and equipment, 21 years. Given that many mines can produce for 25-80 years, there is an ongoing need to replace capital. Depreciation is particularly high for deep underground operations, so tax allowances for these mines are important for their long-term sustainability (Figure 2.21).

Box 2.7: Average annual rates of consumption for different asset types

The average annual rates of depreciation for different asset types are:

Transport Equipment — **25% PER ANNUM** with an average asset lifespan of **4 years.**

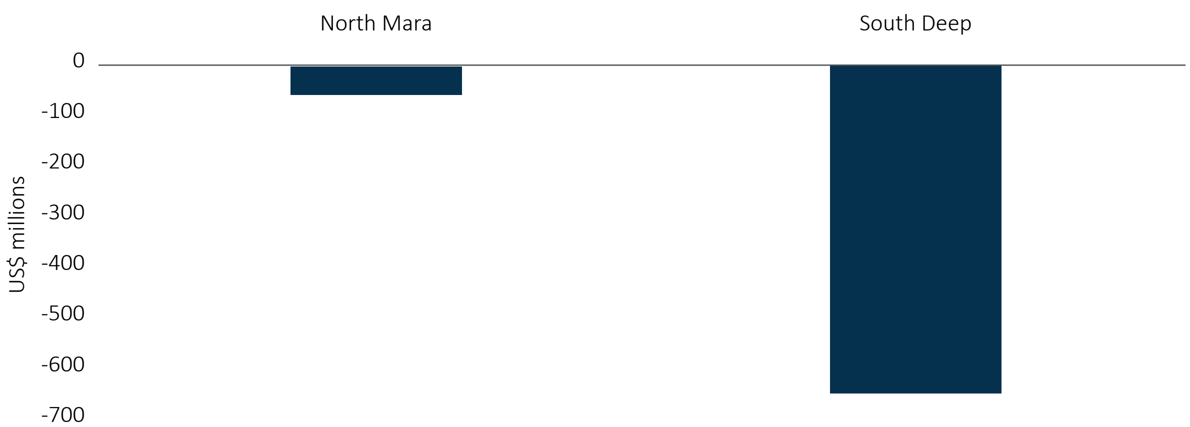
Machinery & Other Equipment — **12% PER ANNUM** with an average asset lifespan of **8 years.**

Buildings & Construction Works — **5% PER ANNUM** with an average asset lifespan of **21 years.**

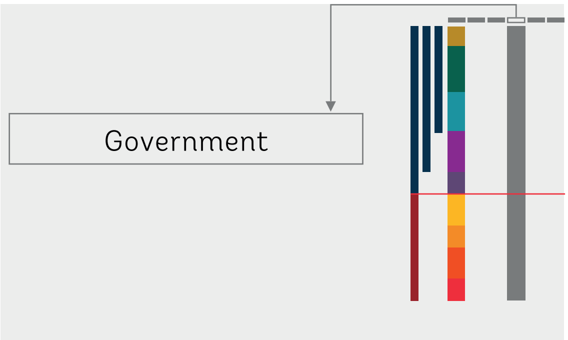
Source: Lockwood (2015).

Figure 2.21: Depreciation is significantly higher for deep underground mines, compared to open-pit or shallow underground mines, which contributes to a higher risk profile

(Depreciation for South Deep, a deep underground gold mine, and North Mara, an open-pit and shallow underground gold mine, US$ millions)



Source: Annual reports and World Bank staff calculations.



When governments confer mineral rights (either prospective or mining rights) to an investor, they confer both rights and obligations, including applicable fiscal measures. Such measures can be tiered based on the various phases of the mining process (exploration, development, production); and include direct and indirect taxes, fees and levies. Sometimes investors ask for a stability clause to be built into the mineral rights, which guarantees the stability of tax and customs regimes for a specified time period. Direct taxes include corporate income tax, or the tax on a company's yearly profits and resource rent tax, which is levied in addition to corporate income tax to capture a higher percentage of mineral rents. Indirect taxes include value-added tax and customs duties. Duties include the fees that are payable upon the granting of mineral rights and each subsequent renewal; ground rent, which is paid annually, proportionate to the surface area granted in the mineral rights; and royalties, which are a tax on the value of extracted minerals. Other levies include withholding tax on dividends, interest and services; capital gains tax, which is generated from the transfer of mining rights and free equity for the state. It is important to note that two mining projects operating at the same time can have different tax and customs policies, because: (i) the dates on which the mining rights were conferred are different, or (ii) the companies utilize stability clauses differently.[28] Some of these fiscal instruments are described further in this section.

Although maximizing various benefits to society is important, taxes and royalties are always the most important. While commodity prices have fluctuated significantly over the last decade, taxes have remained the most important and effective way of capturing mineral rents. Governments have various instruments at their disposal; foremost, they have taxes and royalties; second, they have a host of "regulatory taxes," in the form of social and sustainability costs. It is important to find ways to increase the effectiveness of revenue policies to capture the rent without undermining the commercial viability of mining operations that are needed for extraction.

28 International Centre for Tax and Development Legal Tax Database.

$$B_G = \tau\,(PQ + wL + rK) + (\forall_g + H_g)\,L - RD - \emptyset_1 Y \quad (3)$$

Government benefits consist of revenues from net fiscal measures (τ) on firms' revenues (PQ) (royalties and sales taxes) employment (payroll) and return on capital. It is assumed the government is required to spend on education/training and health care for workers in the mining sector (or education before joining the labor market) and incur resource depletion costs (RD), the costs of carbon emissions, $\emptyset_1 Y$ as well as other environmental externalities,

$$\text{and, } RD = \left(\Sigma^{1}_{i,j,t-n\ldots t}\left(\frac{P_{ijt-n} - C_{ijt-n}}{(1+r)^{t-n}}\right) + \cdots + \left(\frac{P_{ijt} - C_{ijt}}{(1+r)^{t}}\right)\right) \times \frac{Q_{ijt-n}}{t}$$

Resource depletion (RD) in any period is essentially the discounted stream of current and future rent from mineral reserves divided by the remaining life of the mine. Where, P_{ijt-n} is the unit price for a commodity (i) in a particular mine (j), according to the time period (t-n), which is the number of years of reserves at present (t) minus the remaining number of years (n) at a period in the future. C_{ijt-n} is the unit cost for a particular mine and commodity and a point in time. This is discounted by the discount rate (r), which is assumed to be 4%, raised to the power of the time period (t-n). The resulting stream of future unit rents from now until the mine is depleted is multiplied by production in the current period (Q_{ijt-n}), ivided by the years left of operation (t). This provides us with resource depletion.

Where there is public equity participation in a mine, a share of the benefits described in equation (2) above will also apply to the government.

Governments seek to maximize revenues raised from mining and negotiate fiscal terms with firms to achieve this objective. Key taxes include royalties, corporate taxes and value-added taxes. Companies also have to pay prevailing duties on imports. Additionally, taxes may be targeted on mining activity that generates negative externalities on society, such as chronic health problems, and to offset pollution or CO2 emissions. Table 2.3 provides an overview of the main taxes the government of South Africa collected from mining in 2017. Notably, revenue from mining is relatively low in South Africa, at a mere 1.3% of GDP compared to the 7.3% of GDP the sector accounts for. There are multiple reasons for this, from low commodity prices, to provisional payments, and tax incentives. Overall in South Africa, payroll taxes exceeded corporate taxes. Royalties were only 0.6% of total revenue. Value-added Tax (VAT) collections were negative due to high refunds.

Table 2.3: Fiscal revenue from mining in South Africa is relatively small

(ZAR billion and % of total revenue, 2017)

	ZAR bn	% of total revenue
Total Revenue[29]	**1336.2**	**100.0**
Revenue from the Mining and Quarrying Sector	**17.0**	**1.3**
Non-Tax	**7.8**	**0.6**
Mineral Royalties	7.6	**0.6**
Mining Leases and Ownership	0.2	**0.0**
Tax	**9.2**	**0.7**
Personal Income Tax	21.1	**1.6**
PAYE	20.6	**1.5**
Individuals with Business Income	0.5	**0.0**
Corporate Income Tax	13.4	**1.0**
Value-Added Tax	-25.3	**-1.9**
Domestic VAT	10.9	**0.8**
Import VAT	3.6	**0.3**
VAT Refunds	-39.8	**-3.0**

Source: South African Revenue Service Tax Statistics, 2019 Budget Review (National Treasury).
Note: Total Revenue is the consolidated government revenue as reported in the budget, minus the proceeds from transactions in assets and liabilities, which, according to IMF Government Finance Statistics, should be treated as a financing item.

Benefits

Taxes and royalties

Taxes and royalties are the main tools for governments to capture the rent. It is therefore important to ensure that an efficient tax structure exists to provide a revenue stream to the government whenever production is happening (regardless of prices); and that there is a degree of progressivity so that revenue windfalls can be shared between governments and firms. A mix of taxes and royalties can achieve that (Figure 2.22). Table 2.4 demonstrates the importance of mining revenue for a number of governments in

[29] Total revenue is the consolidated government revenue as reported in the Budget Review, minus the proceeds from transactions in assets and liabilities, which, according to IMF Government Finance Statistics, should be treated as a financing item.

Southern Africa. Mining revenue is particularly important in Botswana, accounting for about a third of total revenue, of which the majority comes from taxes. In Lesotho, Namibia, and Zambia, royalties provided a greater share of revenue in 2017/18.

Table 2.4: Taxes and royalties in selected countries

(% of total revenue and % of mining revenue, latest available estimates)

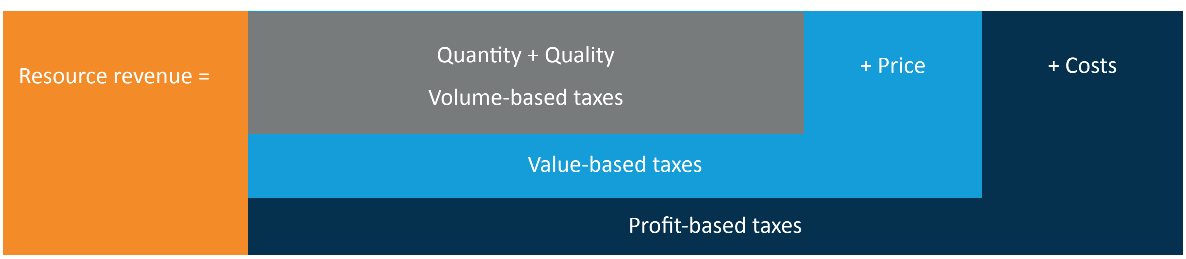
	Botswana	Lesotho	Namibia	Zambia	Zimbabwe
Revenue from mining (% of total revenue)	34.2	4.6	6.8	12.1	3.7
Royalties (% of mining revenue)	29.8	67.4	51.3	61.6	15.8
Tax (% of mining revenue)	70.2	32.6	48.7	38.4	84.3

Source: IMF.
Note: Estimates. Royalties include dividends in Lesotho. For South Africa see Table 2.3.

Most countries use a corporate income tax to collect revenue from mining projects within their standard tax regime. In addition to income tax, firms may also pay a withholding tax on dividends when they are paid to non-residents or on interest payments. When firms operate across multiple tax jurisdictions, there is scope for mining firms to reduce revenues or inflate tax deductions to reduce their tax liability in a specific country. Thus, it is important for governments to close such loopholes. In order to ensure that the government gets revenue from sudden windfalls due to commodity price increases, some countries have utilized a progressive profit tax by creating a stepped tax rate schedule. In essence, this means that as commodity prices increase, tax rates, which are linked to production, volume, sales, or profit-to-sales ratios, also increase. The perverse incentive of progressive taxes is that they may encourage firms to under report income and/or discourage investors.

Figure 2.22: Governments often use a combination of volume-based, value-based, and profit-based taxes to capture mineral wealth

(Volume-based taxes, value-based-taxes and profit-based taxes are three vehicles for rent capture)



Source: World Bank.

Royalties have been one of the most important vehicles for taxing mineral extraction, as the government begins collecting revenue as soon as the mine begins producing. Royalties are a payment to the holder of mineral rights. They can be levied as a per-unit tax (fixed charge levied on a unit of production) or *ad valorem* (fixed charge levied on value of output, which are gross revenues). It is a common usage-based tax which is generally calculated as a percentage of the gross fair market (Halland et al, 2015). A royalty can be categorized as a factor payment for the extraction of minerals to factor payments on capital and labor inputs (Conrad et al, 1990). Some countries apply royalty rates based on the mineral. For example, in Zimbabwe, diamonds attract a royalty rate of 15%, platinum 10%, and coal just 1%. High royalty rates can be a strong deterrent to investment and can make it unprofitable to develop reserves below an economic cut-off grade. As a result, high royalty rates can result in lower-grade mineral deposits going untouched.

Indirect taxes from the mining sector remain an important source of revenue for the authorities. In fact, indirect taxes attributed to the mining sector are significant. However, these revenues vary between Southern African countries, partly reflecting the size of the sector in relation to the economy and the nature of imports and duties. Indirect tax rates, particularly sales taxes, remain fairly similar across this sample of countries, but the use of supplementary taxes may differ.

VAT / import duties

Mining is often treated better than other sectors when it comes to breaks on import duties. Given the substantial demand for capital imports during mine construction and development, import duties can either be a significant stream of revenue for governments while an import tax exemption can be highly attractive to potential investors. Many mines export the majority, if not all of their mineral outputs, and thus get rebates for VAT. This rebate is central to maintaining cost competitiveness. However, Zambia has recently replaced refundable VAT with a non-refundable sales tax, which has increased operating costs.

Payroll tax

Payroll taxes paid by workers and firms are an important source of revenue for the government. There are two types. The first is employer taxes borne by the firm, and include the employers' social contributions and payroll taxes. The second stream of revenue for the government is employment taxes, which are collected through employees' income tax and any income-dependent taxes for social protection measures, such as social security or public health care.

High payroll taxes are reflective of an industry with high wages. In 2008, when commodity prices were high, a global study conducted by PricewaterhouseCoopers analyzed average employment taxes paid across three regional groups. It showed that average employment taxes paid per employee in African countries was US$5,539, compared to an income per capita of US$1,770; in Latin America, employment taxes of US$9,385 compared to income per capita of US$6,766; and employment taxes of US$40,475 compared to income per capita of US$41,971 in OECD countries. This illustrates the fact that during the upswing of the commodity cycle, employees in the mining sector were well-paid and that governments benefited from employment taxes. As commodity prices declined, fewer workers were needed and significantly lower bonuses were paid, which negatively affected the scale of employment taxes collected by governments.

Non-tax instruments

Governments use state equity to ensure revenue streams from profitable projects and to hold decision-making power over the future of mining projects. There are good and bad reasons for governments to utilize state equity. On a positive note, it allows firms and governments to overcome information asymmetry (including on the actual value of the rent) as both stakeholders are represented on the board. On a negative note, conflicts of interest may arise as the government plays the role of the regulator while being an equity stakeholder. One way to prevent a conflict of interest is to separate the regulatory and operational functions of the government, so that there are two distinct state entities. However, for countries with limited state capacity, it is better to keep the functions aggregated. Though there is no panacea, there are various mechanisms through which the government can hold equity in mining operations (Table 2.5).

Table 2.5: Types of state equity participation

Government equity participation	Effects
Paid-up equity on commercial terms	Puts government on equal footing with private investors
Paid-up equity on concessional terms	Government acquires equity share at below-market price
Carried interest	Government pays for equity out of production proceeds, including interest charge
Tax swapped for equity	Government's equity share is acquired through reduced tax liability
Equity in exchange for non-cash contribution	Government provides infrastructure facilities

Source: Daniel, 1995.

Incentives

To offset the risks that mining companies experience during the production life cycle, a package of tax allowances has been a key part of the sector. In South Africa, the incentives provide certain allowances: (i) cater for the large front-end investments made by mining companies; (ii) costs of decommissioning mines (particularly environmental rehabilitation costs); and (iii) commodity-specific allowances – for example, the costs associated with financing capital outlays needed to commission a mine – and relief for firms mining marginal ore bodies.

Governments often forego tax revenue in order to attract investments. Given that minerals exist in multiple countries, governments across Sub-Saharan Africa often create packages of tax incentives to attract mining companies. A 2016 report showed that 4 East African countries – Tanzania, Kenya, Rwanda and Uganda – were losing US$1.5-2 billion a year from tax breaks; Ghana was losing up to US$2.27 billion each year; and Nigeria lost US$3.3 billion in tax revenues to three oil companies – Shell, Total and ENI – through a combination of tax breaks. In South Africa, the mining sector had the lowest marginal effective tax rates among all sectors (World Bank, 2015). Overall, there is a trade-off between imposing costs on mining companies (such as taxes, royalties and "regulatory costs") and offsetting those costs with tax incentives. There is no easy formula for achieving the right balance between obligations and incentives.

The South African government is developing measures to reduce its greenhouse gas (GHG) emissions to meet its Paris Agreement commitments. To reach this goal, the government passed a Carbon Tax in February 2019. The purpose is to direct corporate investments away from high-carbon fuel inputs and production processes toward low-carbon alternatives. The nominal tax rate is R120 per ton of carbon dioxide-equivalent. To facilitate a smooth transition to a low-carbon economy and to mitigate the concerns over competitiveness of the affected industries, the government allows specified tax-free allowances, which can reduce the rate to between R6 and R48 per ton. The tax is based on fossil fuel inputs (such as coal, oil and gas usage), and applicable to entities with a total installed thermal capacity of around 10MW. To address concerns raised by the mining sector, the first phase of the tax (up to 2022) is not designed to affect the price of electricity. After the first three years of implementation, the National Treasury intends to review the impact of the tax, its design features including rates, and the level of the tax-free thresholds.

Costs

Reduction in national wealth

Given that natural resources are finite and exhaustible, it is apparent that minerals are becoming increasingly difficult to reach and deposits tend to be of lower grades. But new technologies for exploration can discover high grade deposits that were previously unknown. In addition, the evolution of technology makes the exploitation of lower grades economically feasible. Although natural wealth is "national", it could also be associated with other stakeholders. For the purposes of this report it will be assigned to the government. As high-quality mineral deposits have already been extracted globally; the remaining known deposits are mainly of a lower quality. This has heightened the need to make mining cost-competitive as profit margins are lower, putting pressure on firms to reduce operating costs. A feature of declining natural wealth is the argument that countries should make sure that they gain maximum value from minerals and that if they cannot ensure meaningful benefits for the country, it may be worth leaving the minerals in the ground until the necessary conditions are in place and the appropriate technology becomes available.

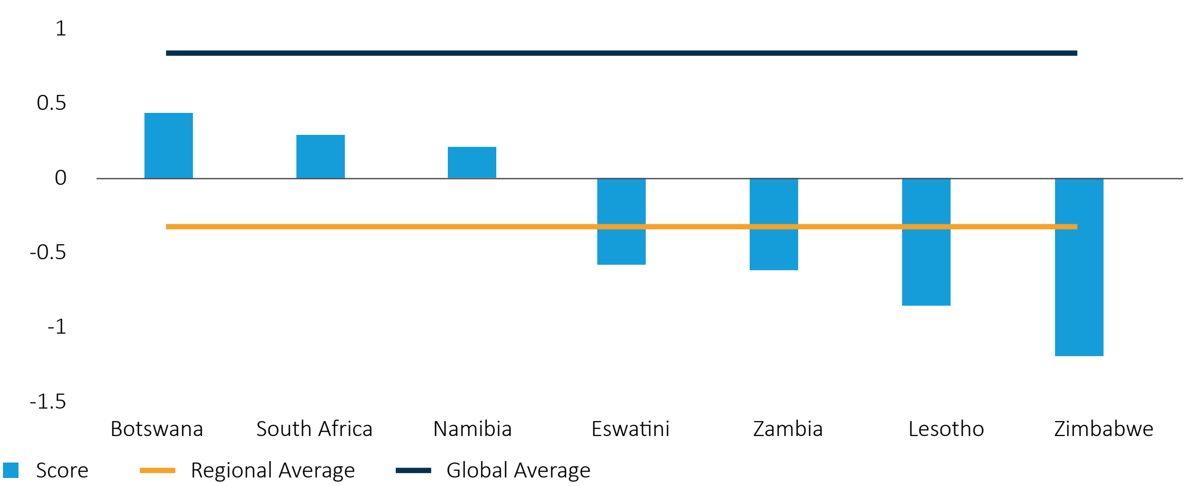
Other

Additionally, governments may need to cover the social and economic costs that are not internalized by mining investors. Other costs explored in Figure 2.1 – such as climate change, pollution, and health – may not always be covered by firms. This can be due to the difficulty of tracing the historical ownership of an abandoned or closed mine, because costs associated with climate change can be difficult to pinpoint to a particular company, or because it is difficult for a company to provide care for migrant workers who have moved back home after the closure of a mine. Regardless, governments may need to cover costs associated with the pollution that stems from mine closure, repairing infrastructure damage, and providing health care to workers and communities affected by mine-related illnesses but who have insufficient health care.

Good governance is critical to catalyzing mineral deposits into shared prosperity. Whether the fiscal revenue enhances inclusive growth depends on the ability of the government to manage the resources and to spend them effectively. Although governance in the region is largely better than the continent as a whole (Figures 2.23 and 2.24), there is significant room for improvement (see Chapter 4).

Figure 2.23: Countries in Southern Africa rank well below the global average for governance effectiveness

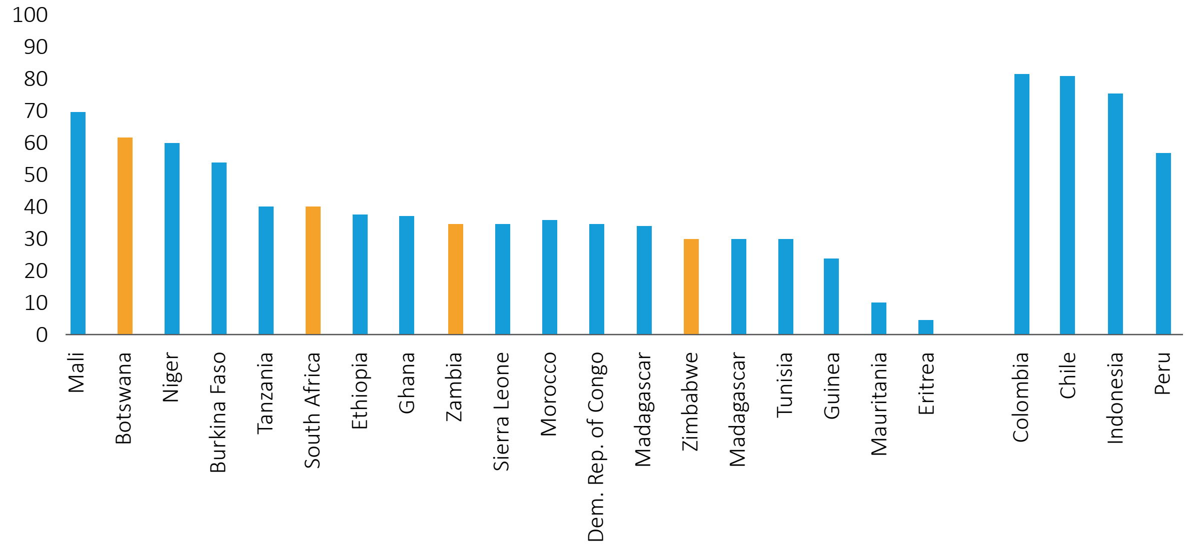
(Governance effectiveness scores)



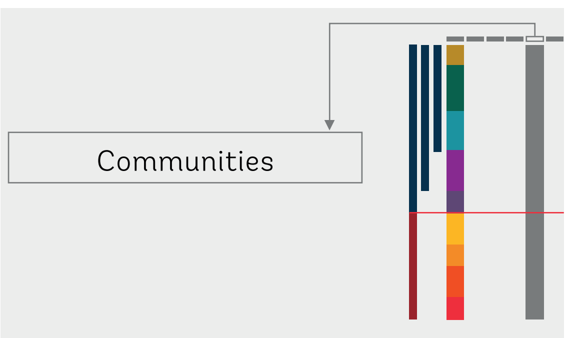
Source: World Bank, World Wide Governance Indicators Project (2017).

Figure 2.24: With the exception of Botswana, countries in the region still lag in terms of effective mining revenue management.

(Natural Resource Revenue Management Index)



Source: Natural Resource Governance Institute (2017),



Communities and workers bear the brunt of mining. Mining communities experience environmental and health consequences – there is significant overlap between workers and communities, as illustrated in Figure 2.1.

Although, in principle, national governments should collect taxes from the mines and then spend on the provision of basic services and infrastructure to local communities, this has not been the case. As most are located in rural areas, these communities often have to contend with an "out of sight, out of mind" attitude and as a result are underdeveloped. Communities then expect mining companies to provide the benefits that the state would ordinarily provide since firms are profiting from the land on which they have lived for many generations.

$$B_C = \propto \left(w\,(1 - \tau - s)L\right) + \vartheta\,(IM) + (RC) + CSR - HC - \varnothing_1 Y - \varnothing_2 Y \qquad (4)$$

Mining communities benefit from the spending of workers, and possibly to a lesser degree investors, in the mining sector, where $\propto$ is the proportion of income spent in mining communities. Local firms sell some intermediate inputs to mines $\vartheta(IM)$. Royalties accruing to communities (RC) and corporate social responsibility initiatives are other benefits. Yet communities are also affected by health impacts, carbon emissions ($\varnothing_1 Y$) and pollution costs ($\varnothing_2 Y$).

Benefits

There are close links between mining companies and neighboring communities. In fact, many communities are located where they are because of mining activities. In the past, this included forced resettlement. Today, communities are home to mine employees and many livelihoods depend on the incomes spent in the community, and on opportunities to sell goods and services to the mines. Increasingly, communities benefit from royalties and social and sustainability spending, such as CSR initiatives.

Royalties

Mining royalties are intended to improve living standards in communities around the mines. Royalties are paid to communities who own the land from which the minerals are extracted and are disbursed in one of two ways: either into a development account (D-account), or by converting the royalties into equity in the mining accounts.[30] However, a 2018 study by Corruption Watch in two South African provinces showed that the royalties rarely reached community members. There were a number of reasons for this: misappropriation and maladministration; severe lack of transparency around the negotiation and conclusion of mining royalty agreements with communities (including a conversion of royalty agreements from a D-account to equity sharing, or vice versa); and the withholding of mining royalties by companies. Tensions can be exacerbated by stakeholders – including mining companies, traditional leaders, provincial governments, and community members – who may try to increase their piece of the royalty pie. These challenges lead to mining communities living in extreme poverty, despite the existence of royalties.

CSR spending

CSR has become a key part of community-mine relations, and has been used to facilitate social and economic development in local communities. An array of education, health, and community development initiatives have been funded in this way. However, mining companies in South Africa had employed some socially destructive practices in the past. Since South Africa's move to democracy in 1994, CSR has been a vehicle for restorative justice to redress the effects of apartheid. To this extent, the mining sector has been a leader, making the largest financial contribution to CSR of any

[30] For local communities who have ownership of the land, mineral extraction is a cost due to the depleting nature of mining. Historically in South Africa, mining companies had to pay two forms of rent – land rent to the surface owner and royalties to the holder of the mineral rights. These could be the same or different people. In many parts of the country, traditional authorities held rights for both surface ownership and the mineral rights ownership. However, in 2002, the Mineral and Petroleum Resources Development Act (MPRDA) was passed, which stated that the state would assume "custodianship" of all mineral resources, thus terminating the existence of mineral rights as a form of property. However, this policy had an exception for black communities who had historically been paid mineral royalties – they could continue receiving that revenue as long as it was used for the development of their communities (Capps, 2016). As a result, people living under tribal authorities were able to continue earning royalties. Therefore, for these communities, a cost of mining is the inevitable reduction of mineral wealth that occurs when resources are extracted.

sector. The shift to democracy led to two big changes in CSR: first, South Africa's capital markets joined the international markets, largely by listing mining companies on international stock exchanges, putting pressure on mining companies to meet international CSR standards, in line with corporate governance structures. This nudged companies into increasing their CSR spending to attract investors mindful of sustainability. Second, the democratically-elected government took ownership of the country's mineral reserves on behalf of its citizens, making private investors apply for mining licenses and concessions. This gave rise to competition between private investors, and a perhaps unintended consequence of that was that companies set out to improve their image and reputation. Competition can have positive effects as firms had the incentive to develop coherent, integrated projects rather than disjointed ones merely for the sake of compliance (Siyobi, 2015).

Local procurement (sales)

Local procurement refers to the purchase by mining companies of goods and services from local businesses. By sustainably and responsibly including local communities in the supply chain, communities can be supported through skills development, job creation, and higher incomes, while firms can source inputs more cost effectively, by lowering the costs of logistics and accessing good services more easily. Local procurement is an increasingly common tool being used by international mining companies for three reasons: (i) to de-risk company operations (communities are less likely to stop operations with protests if they are involved in the value chain); (ii) to comply with government regulations or investment agreements that include local content requirements, making it easier for firms to obtain and keep their licenses to operate; and (iii) provide benefits for local communities by creating business opportunities from which the firm can be an off-taker (IFC, 2011).

Box 2.8: Partnerships to facilitate the development of local suppliers

In July 2007, Lonmin began a three-year partnership with the International Finance Corporation (IFC), a member of the World Bank Group, on local supplier development. The IFC provided expertise, staff and consultants to Lonmin and helped serve as a catalyst for economic development, bringing valuable benefits to local businesses and communities.

IFC and Lonmin helped strengthen local businesses with:

- Business diagnostics
- Training in business management and technical skills
- An incubation center
- ISO and industry quality standards
- Business plan development
- Facilitating access to finance

The Lonmin-IFC Program, through training and mentoring, also focused on capacity building for local small and medium enterprises (SMEs) to meet tender, financial and technical requirements.

Key Achievements

Since the start of the Lonmin Supplier Development Program, 230 SMEs have been selected to participate in business and technical skills capacity building, including through courses on management and technical skills. Additionally, a health and wellness component ensured that SMEs were taught best practices to reduce the risk of HIV/AIDS, tuberculosis, and malaria among their workers and communities.

288

local supplier contracts issued to SMEs

Contracts worth

US$38 million

awarded to local SMEs

19 companies have been assisted with setting up financial and non-financial systems

55

company diagnostics completed

209

individuals provided with small business training.

Source: International Finance Corporation Oil, Gas and Mining SME Linkages Program

Costs

Benefits are intended to offset some of the costs associated with mining. They include royalties, which ensures that communities participate in the resource wealth of their immediate vicinity – which gets depleted through the production process. Externalities of the mines that affect communities include health impacts and pollution. Mining also produces emissions that affect the global climate but which also have localized effects, such as drought or flooding.

Health

Mine dumps have detrimental health consequences for communities. Approximately 1.6 million people live in informal and formal settlements on, or near, mine dumps in South Africa. People in these settings tend to be historically disadvantaged and poor. A study done on air pollution near mine dumps examined the impact of dust particles on the health of children and the elderly living in nearby communities. It found that children in these communities displayed a higher incidence of asthma symptoms such as a wheezing chest and runny nose (21.1%), congested nasal passages and a post-nasal drip (32.9%), than those who lived in Cape Town (20.3 % and 20.7% respectively), or Polokwane (18.0% and 16.9%). Even after taking into consideration lifestyle factors such as smoking habits, exposure to smoke, residential heating and the type of fuel used for cooking, age and sex, the youth and elderly living near mine dumps suffered higher levels of pneumonia, asthma, emphysema, chronic bronchitis, wheezing and a chronic cough.[31]

Pollution

Land and Water

In the past, once land was used for mining, it could not always be used for other purposes such as agriculture, even after the mining stops. In modern mining projects however, the landscape, soil and forest should be restored, enabling the pre-mining activities to continue afterwards. Therefore, granting mine licenses could, in some instances, only temporarily render land unavailable for other uses. This conflict is apparent with coal mining in Mpumalanga, which is also a key agricultural area and home to 45% of all of South Africa's high-potential arable soils. Much of this land is being lost to mining. The Bureau for Food and Agricultural Policy (BFAP, 2012) estimates that 12% of all of South Africa's high-potential arable land will be permanently damaged by current coal mining activity, while an additional 13.6% is being prospected in Mpumalanga. As a result, nearly 25% of all of South Africa's high-value arable soil (100 million hectares), may be irrevocably damaged by coal mining. The Centre for Environmental Rights (CER, 2014) states that "even with the best post-coal mining rehabilitation (a rare occurrence in South Africa), land that has supported coal mining operations cannot ever be used to grow crops." As a result, coal mining in this region can have crippling long-term effects on rural livelihoods and national food security, as rural municipalities cannot recover from industrial-scale mine closures by turning to agriculture, which is the primary economic activity in these areas (Ledger, 2015).

Water has been described as mining's "most common casualty." Although there have been improvements to the mining process, there are still significant environmental risks, particularly relating to water. Most water pollution stems from waste rock and tailings, which can last for hundreds, if not thousands, of years. As mines have become more mechanized, they can extract greater amounts of ore. While this allows them to extract low-quality ore at a profit, it is done at the risk of generating higher amounts of waste. The level of waste is dependent on a host of factors, including composition of the minerals being mined; type of technology utilized; sensitivity of terrain; skill, awareness, and the environmental commitment of the mining company; and the government's ability to implement, monitor, and enforce environmental regulations. It depends also on the monitoring capacity of the local government administration to enforce the environmental management, mine closure and restoration plans.

31 Nkosi, V. (2018, September 05). How mine dumps in South Africa affect the health of communities living nearby.

There are four primary types of water pollution:[32]

1. Acid mine drainage (AMD) and acid rock drainage (ARD)

Acid rock drainage (ARD) is a natural process during which sulphuric acid is created when sulphides found in rocks are exposed to air and water. Acid mine drainage (AMD) is the same process, but magnified exponentially. Both processes are exacerbated by disturbances caused by mining. Once the mine water reaches a certain acidity threshold, a naturally-occurring bacteria called Thiobacillus ferroxidans expedites the oxidation and acidification processes, causing even more trace metals to leach out from the waste. Acid will continue to leach out as long as the rocks are exposed to water and air – and until the sulphides are leached out – a process that can take hundreds, or even thousands of years. The acid is carried from the mine through surface drainage or rainwater and deposited into local streams, lakes, rivers, and ground water. AMD severely damages water quality, can kill aquatic life, and render the water unusable.

2. Heavy metal contamination and leaching

Heavy metal pollution is caused by metals such as copper, cobalt, arsenic, cadmium, lead silver and zinc in rocks that have been excavated from an open-pit mine or exploded from an underground mine. When the rocks come into contact with water the metals leach out and are carried downstream. Metals can be released in neutral pH environments but the leaching is exacerbated by low pH environments, such as those created by AMD.

3. Processing chemical pollution

This kind of pollution occurs when chemical agents (such as cyanide or sulphuric acid used by mining companies to separate the target mineral from the ore) spill, leak, or leach from the mine site into nearby water bodies. These chemicals can be highly toxic to humans and wildlife.

4. Erosion and sedimentation

Mineral development disturbs soil and rock in the course of constructing and maintaining roads, open pits, and waste impoundments. Without adequate prevention and control strategies, erosion of the exposed earth may carry substantial amounts of sediment into streams, rivers and lakes. Excessive sediment can clog riverbeds and smother watershed vegetation, wildlife habitats and aquatic organisms.

Water infrastructure concerns are growing – and areas being mined or prospected tend to need new dams and water infrastructure. Although mining is not particularly water-intensive (it consumes 2.5% of South Africa's water, which is well below its share of GDP), the water damage arising out of it is on a much larger scale. The construction and maintenance of roads, mines and waste impoundments has detrimental effects on soil and rock. Without sufficient prevention and control techniques, erosion of the exposed earth can carry large amounts of sediments into streams, lakes and rivers. Excessive sediment

32 Safe Drinking Water Foundation fact sheet, 2017.

can clog riverbeds and suffocate watershed vegetation, water organisms and wildlife habitats. Rehabilitation can be costly. In 2010, the rehabilitation of the Witwatersrand region cost an estimated R10 billion (over US$1 billion).[33]

The competition between agriculture and mining activity is an issue in many places, including the Northern Cape of South Africa. Mines are given "de-watering" licenses enabling them to pump large amounts of groundwater out of the mines for safety. Farmers near the mines argue that this has a crippling effect on ground water levels and causes their boreholes to run dry. Although some of this water is pumped into a government water scheme, it is not available as groundwater to local farmers. (Ledger, 2015).

Box 2.9: Lead Poisoning at Zambia's Kabwe Mine

With lead levels in Kabwe as much as 100 times higher than recommended safety levels, the town is one of Africa's most polluted places. Far from avoiding contaminated areas, children not only play in the dirt, but community members seek opportunities for income by searching slag heaps for metal and spoil heaps for gravel (Carrington, 2017). The situation in Kabwe is severely detrimental to people and livestock and remains an environmental disaster.

Kabwe started production in 1906, becoming Zambia's largest zinc and lead mine and pre-dated the Copperbelt mines. Operating for 88 years, it is said to have produced 1,800,000 tons zinc, 800,000 tons lead, 7,816 tons vanadium oxide, 80,000kg silver, and 235,000kg cadmium (https://mining-atlas.com/operation/Kabwe-Zinc-Lead-Mine.php; Mufinda, 2015) during its lifetime. The mine was run without pollution controls by Zambia Consolidated Copper Mines (ZCCM) until its closure, at which point such controls were considered financially unviable. The smelters released heavy metals in dust particles, with lead, cadmium, copper and zinc dispersed through the soil over a 20km radius from the mine (IRIN, 2006).

The mine's legacy for the local communities is one where "... on a daily basis we receive cases of severe anemia, vomiting, kidney damage and brain damage, which are all linked to lead poisoning..." (IRIN, 2006). The Blacksmith Institute, since renamed Pure Earth, a New York-based environmental group, in 2007 ranked Kabwe among the world's 10 worst polluted places (Blacksmith Institute, 2007).
The direct and indirect ingestion of heavy metals, not only in the communities surrounding the mine, but also in the livestock and wildlife in the area has been well documented (Nakayama et al. 2011, 2013; Yabe et al., 2011, 2013, 2015; Corley et al., 2014; Mbewe et al., 2016; Bose-O'Reilly et al., 2018).

In 2018 the surface operations of the mine were acquired by the BMR Group which is focused on the recovery of lead and zinc from the tailings deposits. The BMR Group's website makes clear that the company is insulated from any claims or actions arising from the past mining operations. It further states

[33] Trade and Industrial Policy Strategies. 2015b. "Environmental Protection and Mining."

that it is only responsible for ensuring that its own operations are conducted in a manner that avoids any further pollution, in accordance with current regulations. The responsibility for decommissioning and rehabilitation of the sites was retained by ZCCM.

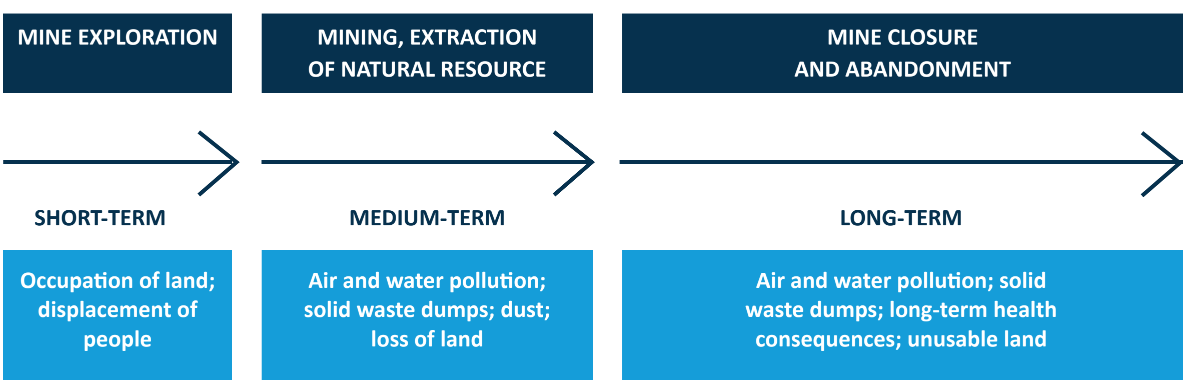
Work on remediation and rehabilitation only started in recent years through initiatives by the Zambian government with support from the World Bank (World Bank, 2012; 2018). The Zambia Mining and Environmental Remediation and Improvement Project will run from 2017 to 2022 and focus on reducing "environmental health risks to the local population in critically polluted mining areas … including lead exposure in Kabwe municipality."

The social and environmental consequences of mining can be endured by communities long after a mine has closed (Figure 2.25). Responsible mine closure requires much more than stopping production and decommissioning a mine. Removing hazardous materials, securing pits and waste disposal facilities and mitigating future groundwater pollution is a starting point. But it also requires reclaiming the land so that it can be repurposed, and ensuring that workers, their families and larger communities, who previously relied on the mine for their income, employment and services, have sustainable livelihoods.

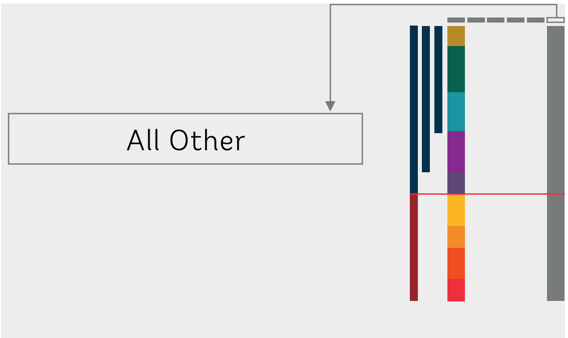
Climate change

Although the environmental impact of a mine affects all of society, mining communities are more vulnerable to certain effects. Mining communities tend to have informal settlements, which are particularly vulnerable to flooding and have insufficient protection from extreme weather, such as floods, heat waves or hail. Because they are also vulnerable to high unemployment rates, these communities may not have the financial ability to respond to these challenges. Mining firms have helped to build more resilient infrastructure in some areas.

Figure 2.25: The impact of a mine on the surrounding community starts during the exploration phase and lasts for many years beyond mine closure.
(Negative externalities across the life of a mine)



Source: World Bank staff.



All other sectors – in the rest of the economy and the world – also benefit from mining activities. This could take the form of capital spending by the mining sector or spending by workers outside the economy. It should be noted that there is an inverse relationship with mining communities. More money spent within communities by the mining sector reduces the impact on the rest of the economy, increasing inequality. Conversely, more spending by the mining sector outside of communities either impacts on the domestic economy or flows out through spending on imports. For this reason, governments try to create incentives for mining firms to source inputs domestically (see discussion on local beneficiation).

$$B_s = (1 - \propto)\big(w\,(1 - \tau - s)L + (K)\big) + (1 - \vartheta)\,(IM) - (\varnothing_1 + \varnothing_2)\,Y \qquad (5)$$

All other sectors benefit from the proportion of labor and capital income spent in the rest of the economy ($1 - \propto$), intermediate inputs not procured from local communities, and global negative environmental and climate externalities.

Benefits

Mining remains an important sector for Southern African economies. As discussed earlier, many industries – beyond local communities – supply to mines, while downstream value chains are also developed to varying degrees. For many countries, mining is a stepping stone into global value chains, and can bring to them innovation in addition to other benefits such as export earnings. Income from mining remains an important source of demand and of national savings. Beyond this there are other less tangible benefits, such as infrastructure spillovers.

Infrastructure spillovers

Infrastructure spillovers have been one of the key benefits of mining operations for communities. In rural mining areas, mining companies have extended infrastructure for energy, transport, mobile and internet connectivity – services that may otherwise not have been provided in the foreseeable future. In Namibia, B2Gold, the country's biggest gold producer, built a 7MW hybrid solar power plant that is the world's first large-scale, three-way (solar, heavy-fuel oil (HFO) and electric) power plant. In addition to substantially reducing the mine's reliance on HFOs, it also contributed to the mine's CSR program as the plant will continue to provide power to local communities after the mine has been shut down.

Costs

While there are positive infrastructure spillovers, mining can also damage existing infrastructure. In South Africa, the Presidential Infrastructure Coordinating Commission (PICC) identified two provinces – Mpumalanga and North West – with serious road safety challenges and damage to infrastructure as a result of heavy-duty trucks transporting bulk commodities out of mines. Additionally, not all infrastructure has been adapted for non-mining uses. For example, even though the mining sector drove the creation of transport corridors, they have not been equipped to allow non-mining firms to access foreign markets. In South Africa, the economic hub of the greater Johannesburg-Pretoria metropolitan area developed as a result of gold mining. In other countries development was facilitated by harbors/ports and motorways, opening up access to international markets. Rail lines were built to get mining outputs from the mines to ports and tax structures were created to reinforce this – tariffs put cargo transporters at a disadvantage when compared to bulk transporters, making non-mining industries rely on road transport. Low-quality port facilities coupled with high port fees (88% higher than the global average) reduced the cost competitiveness of non-mining firms, forcing many out of doing business in international markets and making imports expensive (World Bank Group, 2018).

Mining can lead to multi-dimensional costs for the rest of society. Climate change affects the whole world; exchange rate volatility, stemming from commodity fluctuations, hurts non-mining firms; industrial policy can prioritize mining firms, which affects logistics and incentives for other industries; and while mining can drive infrastructure development, it can also contribute to rapid deterioration of some infrastructure.

3. NET BENEFITS, SUSTAINABILITY, AND IMPACT ON SOCIAL DYNAMICS

This chapter summarizes the net benefits from Chapter 2, drawing on available data. It also examines implications for the sustainability of mining in Southern Africa. Chapter 2 discussed the benefits and costs from mining in detail, laying out some of the complexities in fully taking account of all of them. This chapter will use available data to aim to quantify benefits and costs in order to come up with an estimate of overall net benefits, and their distribution across capital, labor, and the government. As some of these benefits will be saved, the chapter will then deploy the ANS methodology to examine whether countries are likely to save a sufficient amount of net benefits for the mining sector to be sustainable. In other words, it asks whether the mining sector generates sufficient savings that can be used to develop other types of national assets (from infrastructure to human capital) that at least offset the depletion of natural wealth through mining.

An equitable distribution of the benefits of mining is important to mitigate the contestation over resources. As all stakeholders have incentives to maximize benefits from mining for themselves – referred to as resource contestation – conflict can arise over the distribution of benefits. The third section of this chapter will explore this in more detail and also examine how these underlying social dynamics can affect government policies. The chapter will show that conflict over distribution, be it through industrial action or more demanding tax or regulatory policies, can create contradictions with the commercial mandate of mining companies and can, in the first place, undermine investment in mining and the incentives to extract the natural resource. It is in this context that Chapter 4 will discuss policy implications.

The chapter is limited by the availability of data on foreign factor flows. Estimations of foreign factor flows are a critical element in calculating gross national income (GNI) and are important to calculate ANS. However, this is a difficult exercise as data are not readily available. Foreign factor flows are particularly important to the mining sector and consist of interest payments, rental of assets, short-term labor, dividend payments and retained profits that flow into the country, minus flows out of the country. As noted earlier, mining operations in Southern Africa typically require significant foreign investment and, to an extent, labor. Although local mines exist, a sizeable proportion of the mining sector in the selected countries have foreign ownership. As a result, the foreign factor flows are likely to be considerably higher and require careful attention. The chapter will use information from an annual report of a multinational mining company operating across the region to conduct various thought experiments on potential losses to countries from foreign outflows.

More broadly, all analysis in this section is based on macroeconomic data only, which adds to the limitations. Given the nuance and complexity in the benefits and costs discussed in Chapter 2, some of the costs and benefits discussed there cannot be captured in this chapter. All numbers are estimates with considerable measurement error as well as variation around the estimates for different stakeholders. The results should therefore not be seen as exhaustive or authoritative and should be interpreted with utmost caution.

3.1. Net benefits: summary

Estimating net benefits of the mining sector

By adding and rearranging equations 1-5 we can arrive at the overall net benefits of the mining sector (equation 6 below).

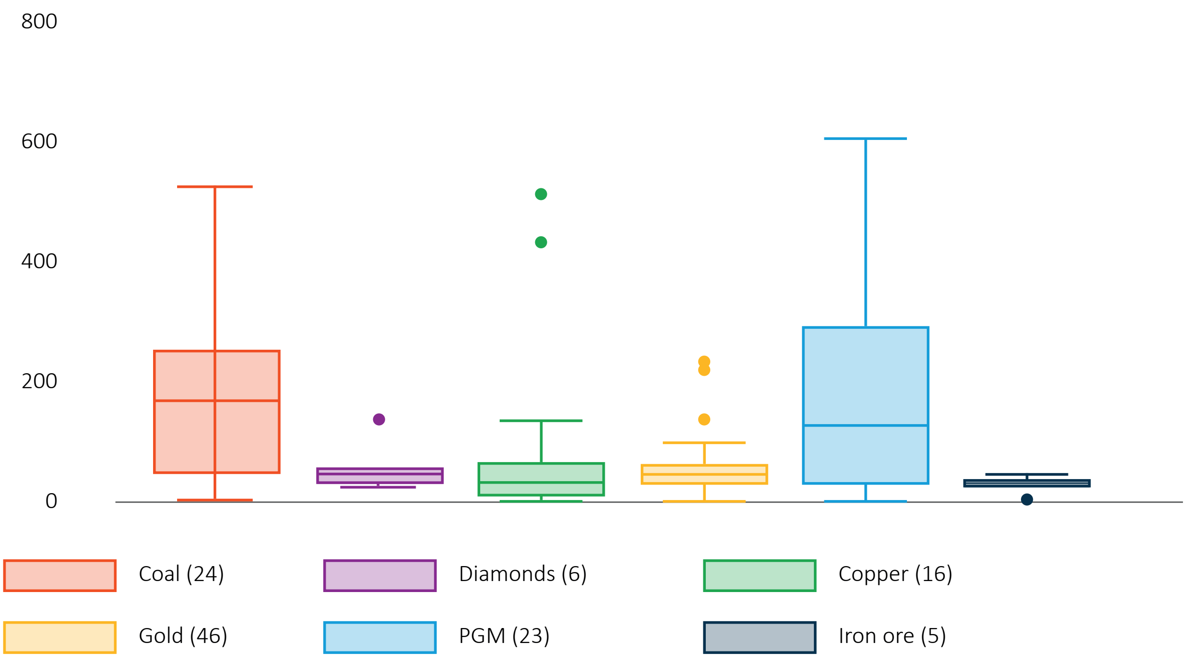
$$B = (1 - \varnothing_1 + \varnothing_2)\, Y - RD \qquad (6)$$

Where Y is GDP of mining sector at market prices. And, $Y = (rK + wL) + \tau_p$, that is capital factor income on mining sector investments (rK) plus wage costs of the mining sector (wL) plus product taxes net of subsidies (τ_p).

Estimating net benefits requires various data sources. To calculate benefits, mining sector GDP was ascertained through national accounts data. The shares of factors of production (capital, labor, factor rent) and indirect taxes in mining income were obtained from national SAMs. Given the limited available data, it is not possible to account for all taxes and to detail the social and sustainability costs that mining companies internalize. With regard to cost, information on CO2 damage and air pollution damage was obtained from the World Development Indicators. CO2 damage was apportioned to the mine sector by drawing on the amount of fossil fuel required for mining production in national SAMs. Air pollution damage is estimated as the total share of mining in production.

Figure 3.1: Coal and PGMs can expect to have the longest life of a mine in Southern Africa

(Life of a mine in years; 10th, 33rd, 50th, 57th, 90th percentile, and outliers; number of included properties in parentheses)



Source: S&P Global Market Intelligence and World Bank staff.

Understanding the expected life of a mine in Southern Africa is critical to estimating resource depletion. In line with established World Bank methodology, resource depletion was estimated using the formula in equation 3 as a stream of foregone future rents.[34] To this end, factor rents were used from the SAMs and assumed to be constant over the life of a mine, discounted at 4% per annum. The life of the mine was estimated based on S&P Market Intelligence data, assuming that latest available annual production volumes will be sustained to extract all available reserves of a mine. The estimated life of each mine was weighted by

[34] Resource depletion has been estimated for Botswana elsewhere (WAVES, 2016). However, due to a different discount rate, data for Botswana is estimated identically to all other countries included in this report.

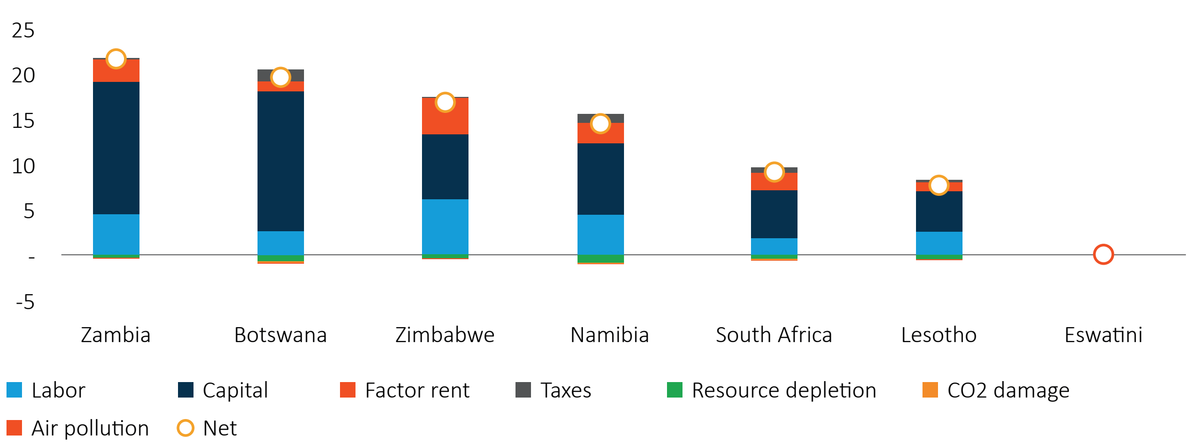
reserves across properties. Only data from active and operational mines were selected from the following commodities: coal, diamonds, copper, gold, PGMs and iron ore. Figure 3.1. provides some descriptive statistics of the estimated life of a mine in Southern Africa. It shows that coal and PGM mines still have the longest estimated life lines in the region. Gold, copper, and diamonds have a larger number of active mines but lower expected lives, with a few notable exceptions in gold (such as Dominion and South Deep in South Africa) and copper (such as Lubambe and Konkola in Zambia). In Zambia, the average life of mine is estimated at 237 years.

The net benefits from the mining sector are substantial across Southern Africa. Benefits primarily centre on increased GDP and additional revenues to the fiscus from mining, as shown in Figure 3.2. Due to the relatively high capital-intensity of mining, it is little surprise that capital tends to claim the largest share of mining income, with wages the second largest. As for fiscal revenue, indirect taxes are relatively small. Factor rents are sizeable in Southern Africa. As Chapter 2 explained, the extent to which these rents are captured by the government or capital-holders depends on the choice of fiscal instruments; quantifying the relative shares goes beyond the scope of this report. The costs are relatively modest, with resource depletion being the largest cost. Looking at the overall effect in Figure 3.2, Zambia, Botswana, and Zimbabwe have the highest net benefits of mining, as estimated in this report.

When including multiplier effects, net benefits could be even larger. Figure 3.3. applies the calculated multipliers from Chapter 2 to the benefits as additional GDP. However, this is incomplete. For the analysis to be balanced, the associated costs would also have to be included. In many Southern African countries, sectors linked to mining companies are likely to be bigger polluters than mining companies themselves. For example, while a mine may produce coal, it is not responsible for the associated CO2 from the burning of the coal for energy – this will be associated with the power plant in the industrial sector. And demand for energy grows with increasing multipliers. CO2 emissions of the mining sector itself are in fact relatively small (Figure 3.4). Nevertheless, although this report cannot tease out these effects in detail, the overall impact of multipliers on net benefits is likely to be significant and positive.

Figure 3.2: The net benefits of mining vary across the region

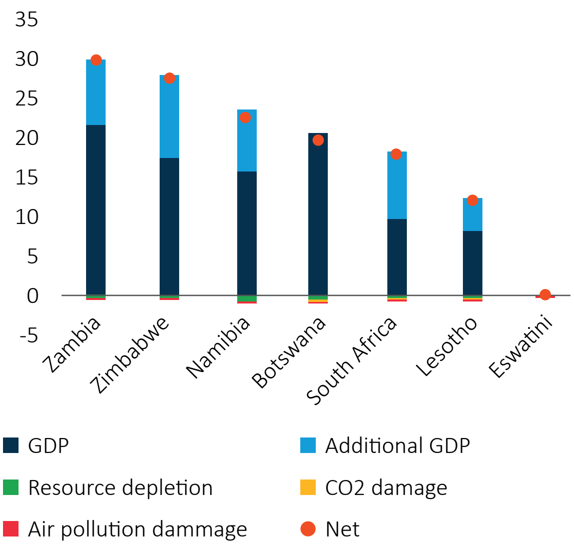
(Net benefits as percent of mining GDP in 2016)



Source: World Bank staff.

Figure 3.3: If externalities in other sectors were zero, including multipliers of mining would significantly increase the net benefit ...

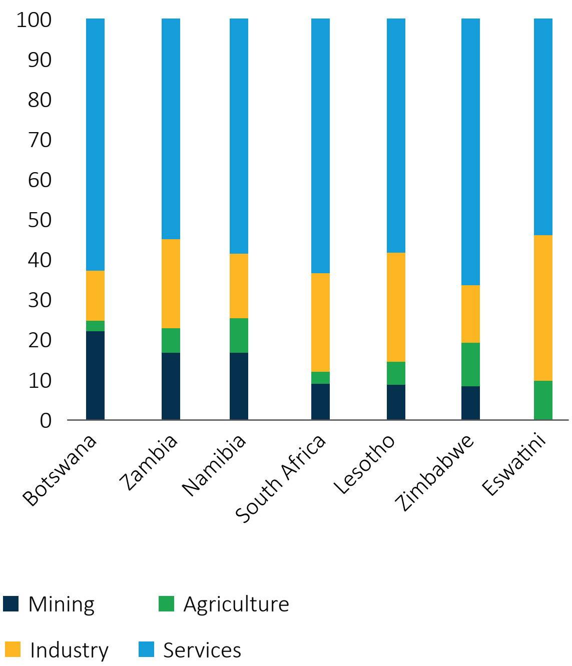
(Mining GDP with multipliers as percent of total GDP)



Source: World Bank staff.

Figure 3.4: ... but industry tends to be associated with high CO2 emissions in many countries

(Mining share of total CO2 emissions)



Source: World Bank staff.

To estimate the share of the net benefits for domestic residents, a thought experiment was developed. Given that many mining companies have foreign shareholders (Table 3.1) and also borrow abroad, a significant share of capital income is likely to leave the country. In addition, foreign skills in the mining sector are not inconsequential, hence remittances are also likely to reduce the overall benefit to the domestic economy. No data are available on the foreign income flows in mining. To get a sense of possible magnitudes of such flows, the annual reports of a large multinational mining company operating in Botswana, Namibia and South Africa were studied for the period 2014-2018, developing estimates of primary income flows in line with UN National Accounts conventions (see Annex 2 for details). Table 3.1 describes that company's calculated value added and the balance of primary incomes. The table shows that primary incomes of foreign factor flows (that is, flows of the mining sector leaving the country) are considerable. In 2016, they accounted for around US$5,695 billion or around 58.8% of gross value added.

Table 3.1: Foreign flows for a selected mining multinational

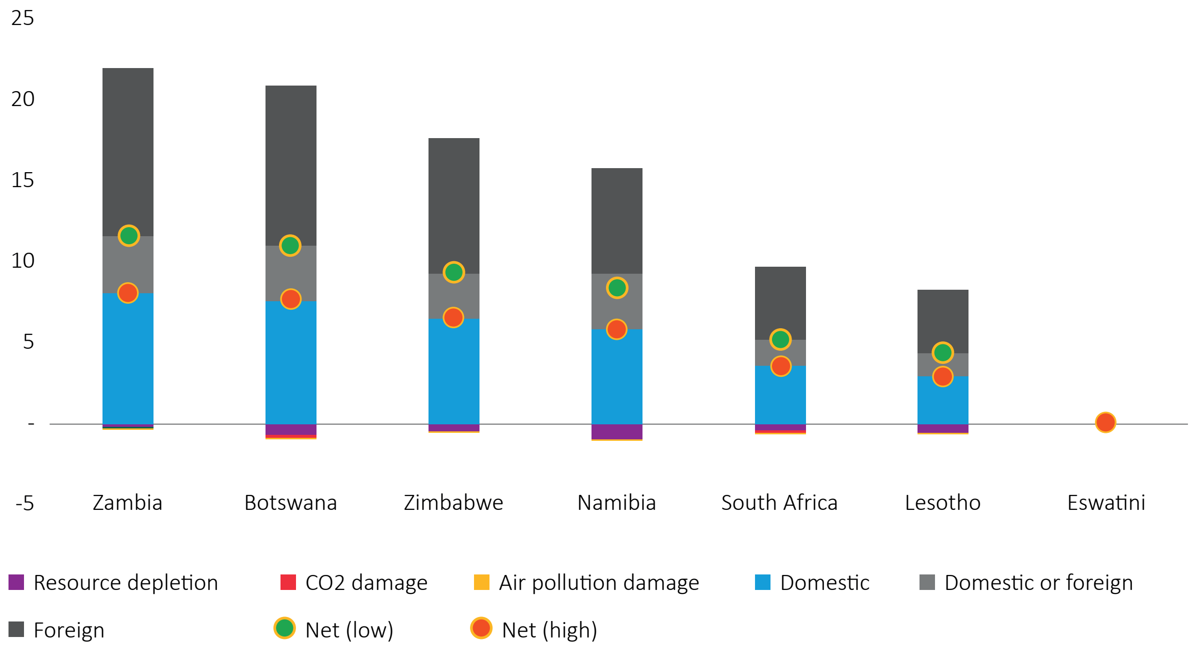
(Foreign flows in millions, US$)

Year	Balance of primary incomes	Value added	BPI / GVA
2014	8,250	14,431	57.2%
2015	4,954	10,519	47.1%
2016	5,695	9,684	58.8%
2017	8,471	13,193	64.2%
2018	8,136	12,894	63.1%

Source: See Annex 1.

Figure 3.5: Including foreign flows, net benefits are much smaller but remain positive

(% of GDP)



Source: World Bank staff.
Note: Applies net foreign flows from Table 3.1.

Table 3.2: Ownership structure of major mines in Southern Africa

	Property	Commodity	Foreign ownership	Government ownership	Domestic ownership	Headquarters
Botswana	Mupane	Gold	100			Canada
	Jwaneng	Diamonds	50	50		Botswana, UK
	Orapa	Diamonds	50	50		Botswana, UK
	Letlhakane	Diamonds	50	50		Botswana, UK
	Karowe	Diamonds	50	50		Botswana, UK
	Ghagoo	Diamonds	100			Australia
	Selebi-Phikwe	Copper, Nickel, Cobalt		100		Botswana
	Phoenix	Copper, Nickel, Cobalt		100		Botswana
	Selkirk	Copper, Nickel, Cobalt		100		Botswana
Lesotho	Liqhobong	Diamonds	75	25		Lesotho, UK
	Kao	Diamonds	62.5	25	12.5	Lesotho, South Africa
	Letseng	Diamonds	70	30		Lesotho, UK
	Mothae	Diamonds	70	30		Lesotho, Australia
Namibia	Skorpion	Zinc				India
	Otjikoto	Zinc				Namibia, Canada
	Rosh Pinah	Zinc, Lead, Gold, Silver	100			Namibia, Canada
	Rossing	Uranium	90		10	Namibia, UK, Iran, South Africa
	Tschudi	Copper, Lead, Silver, Zinc	90		10	Namibia, UK
	Langer Heinrich	Uranium, Vanadium	93.62	3.3	3.38	Australia, Chinese
	Navachab	Gold	97.5		2.5	Namibia, Canada, US
	Husab	Uranium	100			Namibia, UK
South Africa	Secunda Mining Complex	Coal	80	100		South Africa
	Grootegeluk	Coal	97.5	100		South Africa
	Sishen	Iron ore		96.9	3.1	South Africa
	Middelburg	Coal		8		South Africa, Australia
	New Vaal	Coal		100		South Africa
	Mogalakwena	PGM	92	100		South Africa
	Khumani	Iron ore		100		South Africa
	Rustenburg	PGM		100		South Africa
	Kolomela	Iron ore		96.9	3.1	South Africa
		Manganese				
	Impala	PGM		96		South Africa
Zambia	Kansanshi	Copper, Gold	80		20	Zambia, Canada
	Treident-Sentinel	Copper, Cobalt, Nickel, Uranium	100			Canada
	Lumwana	Copper, Gold, Cobalt, Uranium	100			Canada
	Mufulira	Copper, Cobalt	90		10	Zambia, Switzerland, Canada
	Kansanshi SX-EW	Copper	80		20	Zambia, Canada
	Nchanga SX-EW	Copper, Cobalt	79.4		20.6	Zambia, Bahamas
	Muliashi North	Copper, Cobalt	80	20		Zambia, China
	Konkola	Copper, Cobalt	79.4		20.6	Zambia, Bahamas
	Chambishi	Copper, Cobalt	85		15	Zambia, China
	Nkana	Copper, Cobalt	90		10	Zambia, Switzerland, Canada
Zimbabwe	Hwange Coalfield	Coal		100		Zimbabwe
	Zimplats	PGM, Copper, Silver	100			UK
	Mimosa	PGM, Copper, Cobalt	100			South Africa
	Unki	PGM	100			Zimbabwe
	How	Gold, silver	100			UK
	Trojan	Nickel, Cobalt, Copper		100		Zimbabwe
	Freda Rebecca	Gold	85		15	Zimbabwe, UK
	Blanket Mine	Gold	49	15	26	Zimbabwe, Canada
	Shamva	Gold		100		Zimbabwe
	Mazowe	Gold		100		Zimbabwe

Source: S&P Global Market Intelligence and World Bank staff.

Although foreign flows are likely to be large, the net benefits of mining remain positive when including income leaving the country. Assuming cross-border financial flows for mining companies across the region similar to those depicted in Table 3.1, it is possible to illustrate what this means for the benefits of mining that accrue only to domestic residents and governments. This is a very strong assumption and should only be considered a thought experiment – for example, for South Africa, the outflows are likely to be much smaller: most mining companies are domestically owned (although they would have some foreign shareholders to whom dividends will accrue) (Table 3.2). Foreign interest payments of the South African mining sector were only about 0.1% of total foreign interest paid by the entire economy in 2017 (Figure 3.5).[35] It shows that even when assuming considerable outflows of income, based on data from one company, the net benefits of mining remain positive in Southern Africa.

As a highly capital-intensive industry, mining may contribute to inequality in Southern Africa. Figure 3.2 demonstrates that capital tends to capture the largest share of mining income, which is a reflection of the high need for capital, and that is increasing with mechanization. Since richer households have higher savings and are therefore more likely to invest in capital markets, they are likely to capture more of this capital income than poorer households. However, a large share of capital income also leaves countries as many investors are foreign. It goes beyond the scope of this report to estimate the extent to which capital-intensity increases inequality in a country. Wages also tend to be high compared to the median, which can also contribute to inequality. Yet Figure 3.2 also shows that governments do capture a significant part of revenue, although this varies by country (and over time, given commodity price developments). Depending on the progressivity of fiscal policy, this is likely to offset some of the pressures on inequality. Finally, the impact on the distribution of income within a country due to forward and backward linkages is unknown. Overall, the analysis suggests that mining can put pressure on inequality, which may partly help explain levels of inequality documented in Chapter 1. Yet this inequality may have built up over generations and disentangling to what extent this is a function of history and to which extent governments have been able to use public policy to counter the pressures on inequality more recently, is difficult to quantify and requires further research.

3.2. Adjusted net savings

To estimate whether a country uses its natural resources sustainably, ANS are estimated at the sectoral level. This analysis expands on insights gained from Table 3.1 to gauge the magnitude of possible factor flows, which are required to calculate sectoral Gross National Income (GNI).

[35] Only reflects private enterprises resident in South Africa.

ANS, a measure of sustainability, can be calculated not just at the country level but also at the sector level. This is done via the following formula:

$$ANS = GNI - C - dK - RD - (Ø_1 + Ø_2)\, Y + (\forall + H)\, L \qquad (7)$$

ANS is composed of the following components: GNI minus consumption of fixed capital (gross fixed capital formation), investment in human capital and depletion of natural capital.

Where, $GNI = Y - r(K_f - K^*) + w(L_f - L^*)$. GNI is GDP plus net foreign flows (rK_f), which is the difference between short-term flows from foreign workers living in the country and overseas plus the return on foreign capital and the return on the country's capital overseas (K*).

GNI minus consumption (C) of fixed capital, the value of carbon emissions ($Ø_1 Y$) the value of particulate emissions damages ($Ø_2 Y$), depreciation of capital (dK) resource depletion (RD) plus the value of investment in human capital (∀L) and (HL).

Equation 7 can be simplified to examine the likely impact of such externalities on national savings:

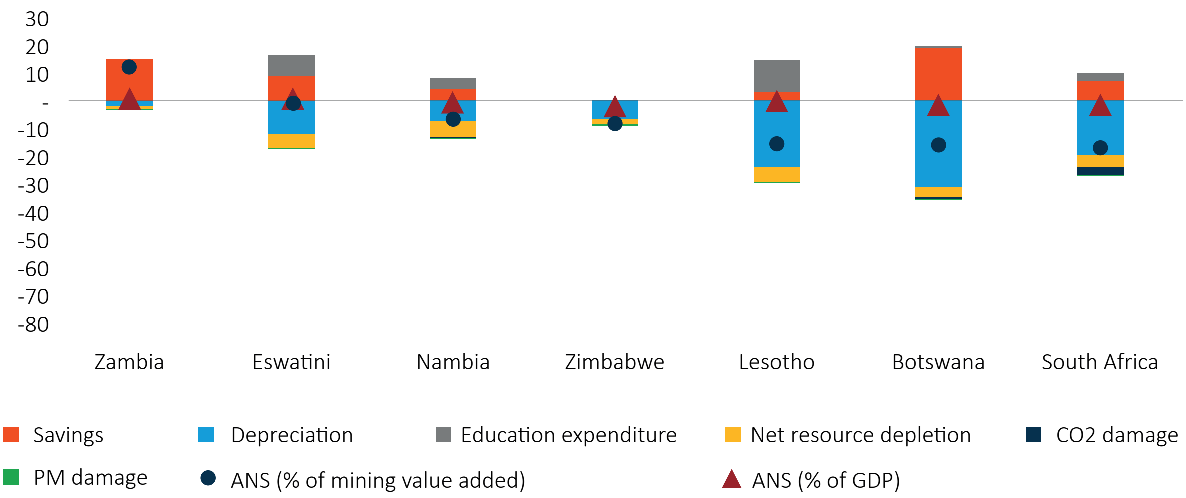
$$ANS = NNS - RD - Ø_1 + Ø_2)\, Y + (\forall + H)\, L \qquad (8)$$

Where, Net national savings (NNS)=GNI – C - *dK*

Given resource depletion and other externalities, it is important to assess the impact of such costs on savings. Here we proxy Gross National Savings (GNS) of the economy for Net National Savings (NNS). Equation 8 is an important test: if countries are to increase or maintain their national wealth derived from their natural resource endowment, savings from the mining sector would need to at least cover these costs. This work requires considerable assumptions. One is on net foreign flows to calculate GNI – here using data from Table 3.1. It is a strong assumption because evidence from one company operating in Southern Africa offers only limited representativeness for other companies. One additional assumption was made on the consumption of income from mining which is assumed by applying the national savings rate. This again is a bold assumption, as mining is a particularly capital-intensive sector and investing households are likely to have higher savings rates than average households. In addition, it is assumed that mining is taxed similarly to other sectors, supporting national health and education spending. This is a strong assumption as mining companies receive significant tax incentives – however, this is somewhat compensated for by the fact that this analysis cannot account for mine-level spending on health and education which can be substantial (see Chapter 2). The costs are identical to those in Figure 3.2 above.

Figure 3.6: Only few countries in Southern Africa are estimated to have had positive ANS

(ANS and components in percent of mining sector value added and in percent of GDP)



Source: World Bank Staff Calculations.

Most Southern African countries require additional savings to maintain national wealth (Figure 3.6). Given the various strong assumptions made, only the South African mining sector is estimated to have positive ANS, i.e. depleting assets to invest in other forms of wealth. Zambia is roughly managing to keep the balance. In other countries, ANS is negative and additional income would need to be saved for the mining sector to sustain itself. One such additional income linked to mining could come through multiplier effects that are again not accounted for in this analysis. Interestingly, the main reason for negative ANS is not the depletion of the resource but depreciation. This is linked to the capital intensity of mining, which absorbs a significant part of national savings for investment to simply offset depreciation. The more capital is invested, the more assets depreciate and the more savings are required for investment to maintain the assets. One implication of this is that mechanization puts additional strain on domestic savings, requiring either higher national savings or higher capital inflows from abroad (which would be reflected in a larger current account deficit).

3.3. Implications for equity and resource contestation

As a capital-intensive industry, mining may contribute to inequality in Southern Africa. Figure 3.2 demonstrates that capital tends to capture the largest share of mining income, reflecting the greater demand for capital, which increases with mechanization. Since richer households have higher savings and are more likely to invest in capital markets, it stands to reason that they would capture more of this capital income than poorer households. However, a large share of capital income also leaves countries as many investors are foreign.[36]

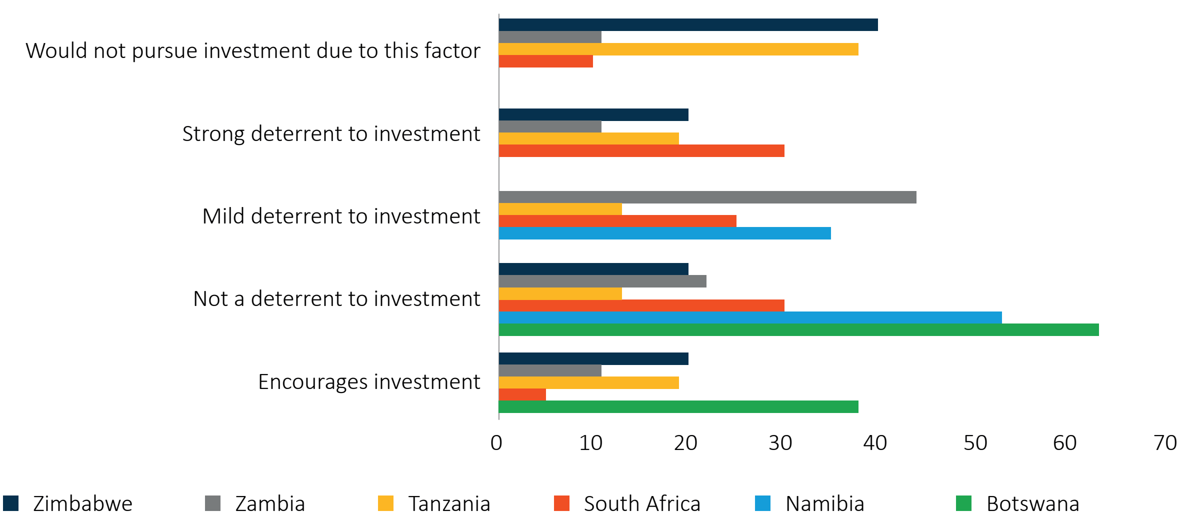
[36] It goes beyond the scope of this report to estimate the extent to which capital-intensity increases inequality in a country.

Wages in mining also tend to be higher than the median, which can contribute to inequality. Yet Figure 3.2 also shows that governments do capture a significant portion of the revenue, although this varies by country (and over time, given commodity price developments). Fiscal policy is likely to offset some of the pressures on inequality, depending on its progressivity. Finally, the impact on the distribution of income within a country due to forward and backward linkages is unknown. Overall, the analysis suggests that mining can put pressure on inequality, which may partly help explain the levels of inequality observed in Chapter 1. Yet this inequality may have built up over generations and disentangling to what extent this is a function of history or if governments have more recently been able to use public policy to counter the pressures on inequality, is difficult to quantify and requires further research.

Disagreement over the equitable distribution of the benefits and costs of mining can fuel conflict. In particular, the economic rent is open to contestation. Investors want a share of the rent to maximize their returns; workers to maximize their wages; communities aim to maximize revenue participation or social spending for themselves; and other players in the value chain try to gain support for the beneficiation of mining products. At the same time, incentives are meant to minimize exposure to the costs of mining. In light of the complexity of measuring and capturing the rent, including in many cases low transparency and a lack of trust among stakeholders, the government may have limited capacity to be an effective arbitrator. At the same time, the ability to deliver benefits from the captured rents may be constrained by a government's capability to deliver services to the people. This can increase the demands on the mines to deliver benefits directly. The competing demands of various stakeholders can give rise to policy uncertainty, which can deter investors (Figure 3.7). This section reviews some of the experiences with resource contestation in Southern African mining.

Figure 3.7: The conflict between various stakeholders can give rise to policy uncertainty, which can act as a strong deterrent to investments

(Uncertainty about the administration, interpretation and enforcement of existing regulations, % of respondents)



Source: Fraser Institute (2018).

Governments seek to capture the rent. The rent is the income a society obtains from turning a resource that is in the ground into a transferrable asset. Governments capture rent[37] to provide public services and infrastructure. However, governments and mining firms have often been in conflict, with each trying to maximize its share of the rent with the disagreements often arising out of a lack of transparency.

Conflict between labor and mining companies has characterized mining in Southern Africa. Because of discrimination and wage suppression, the mining industry in Southern Africa, especially South Africa, has historically had to contend with industrial action that often turned acrimonious. During the apartheid era in South Africa, poor and unsafe working and living conditions and a "color bar" under which there were high minimum wages for whites and low maximum wages for blacks, fueled dissent. Mineworker unions were also a prominent part of the labor movement's contribution to the struggle against apartheid.

In August 2012 a labor conflict on Lonmin's platinum mine in Marikana in the North West province escalated into a brutal confrontation with the police, marking a turning point in labor relations. The strikers, mainly rock drillers, had demanded a salary increase from R4,000 (US$482) a month to R12,500 from Lonmin, the world's third largest platinum producer. On August 16, 2012, the police opened fire on the strikers, killing 34, in what is now referred to as the Marikana Massacre. But in an 8-day period before the massacre, there had been several incidents of violence among different factions of workers, between the strikers and mine security and between the strikers and the police, resulting in 10 deaths. At least 78 people had been injured throughout the period, most at the hands of the police. In 2014, all the major platinum producers in the Rustenburg area – South Africa's key platinum producing region – were again rocked by industrial action when more than 70,000 workers went on strike at Impala Platinum, Anglo American Platinum, and Lonmin. Marikana also opened a new era for labor unions,[38] as it ended the dominance of the once illustrious National Union of Mineworkers (NUM). The NUM was founded in 1982 with Cyril Ramaphosa – South Africa's current state president – serving as its first general secretary. The NUM's proximity to power is illustrated by the fact that from 1991 until 2017, the secretary generals of the governing African National Congress, were all former NUM officials.

But NUM has since ceded ground to the more militant Association of Mineworkers and Construction Union and to the National Union of Metalworkers of South Africa, a former ally that was expelled from labor federation the Congress of South African Trade Unions. Union rivalry is now a factor in workplace conflicts.

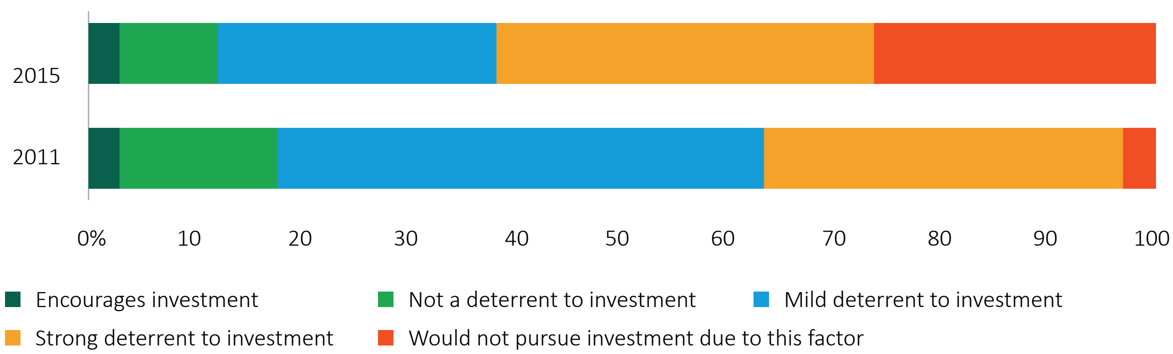
[37] This report does not associate "rent-seeking" with corruption. Rent-seeking and corruption are closely related when these rents are used for private gain and not public benefit. High tax and customs rates; controls on domestic prices and foreign exchange; and ambiguous, opaque and restrictive laws can support corruption (Coolidge and Rose-Ackerman, 1995).

[38] In South Africa, major labor unions have investment companies usually started with seed money from the unions themselves. NUM started the Mineworkers Investment Company (MIC) with R3 million in seed money and by 2015, MIC was managing assets valued at more than R5 billion. Though the MIC does not invest in mining companies, the investment arms of other labor unions are likely to do so.

The platinum sector strikes were costly for both employees and the mining companies (Figure 3.9). Estimates from the South African Reserve Bank suggest that in the aftermath of Marikana between August 2012 and June 2014, the direct loss to striking employees in terms of foregone salaries and wages was an estimated R9.4 billion and lost revenues for firms was estimated at R21.1 billion. In addition, mining companies incurred costs of R68 million per day to keep the shafts accessible for future mining activity, even though the strikes halted production. Suppliers lost R17 million in sales per day while capital investments, estimated at R30 million per day, did not materialize. The loss of income had far-reaching impacts beyond the Northwest Province where the mines are located, as many of the workers were migrants from Gauteng, the Eastern Cape, Mozambique and Lesotho. Labor militancy and heavy regulations are strong deterrents to investments in five Southern African countries (Figure 3.10).

Figure 3.8: The rise in labor strikes from 2012 has become a very strong deterrent to investors in South Africa

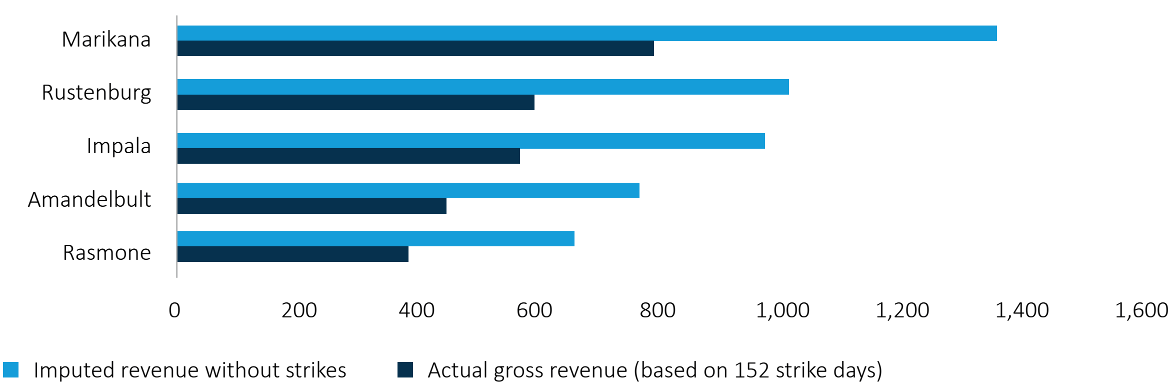
(Perceptions of labor regulations/employment agreements and labor militancy/work disruptions, 2011 & 2015, % of respondents)



Source: Fraser Institute (2011, 2015).

Figure 3.9: The labor strikes have proved very costly for platinum firms in South Africa

(Impact of strikes on platinum mine revenues, US$ millions)

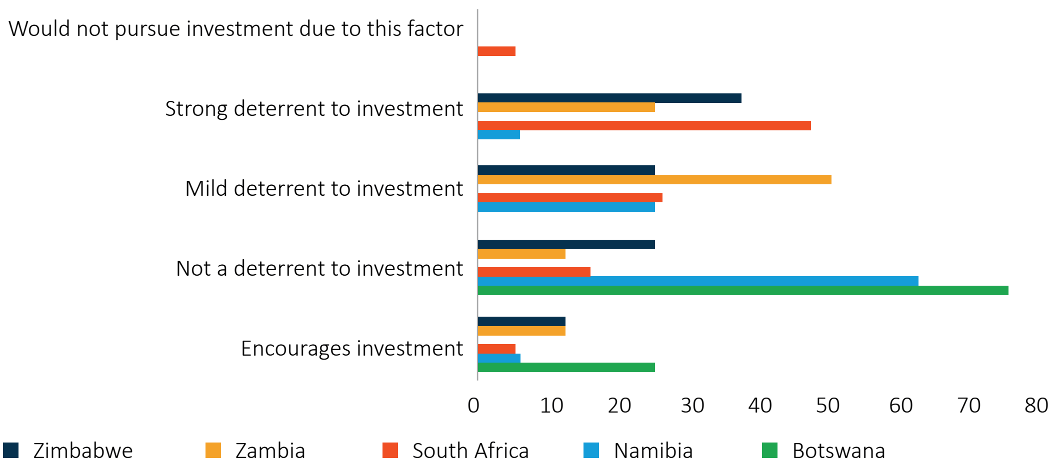


Source: S&P Global Market Intelligence and World Bank staff Calculations.

Hostile labor relations are not unique to South Africa. In 2012, Zambian miners killed a manager by pushing a mine trolley at him during a riot as tensions at foreign-owned mines escalated. A year before, 13 mineworkers were injured after being shot during a pay protest by two foreign mine managers. The Zambian government later dropped charges against the two managers who had been accused of attempted murder. When miners stopped production at three of the four foreign-run copper mining companies in 2011, a company fired at least 1,000 striking workers. However, the government negotiated a reinstatement, though some were disciplined. A 122-page report by Human Rights Watch detailed the pervasive nature of abuse in foreign-run mines, including poor health and safety conditions, having to regularly work 12 and 18-hour shifts and anti-union activities, all of which violate Zambia's national laws and international standards.

Figure 3.10: Tight regulation and labor militancy are a strong deterrent to investment in the region.

(Perceptions of labor regulations/employment agreements and labor militancy/work disruptions, % of respondents)



Source: Fraser Institute (2018).

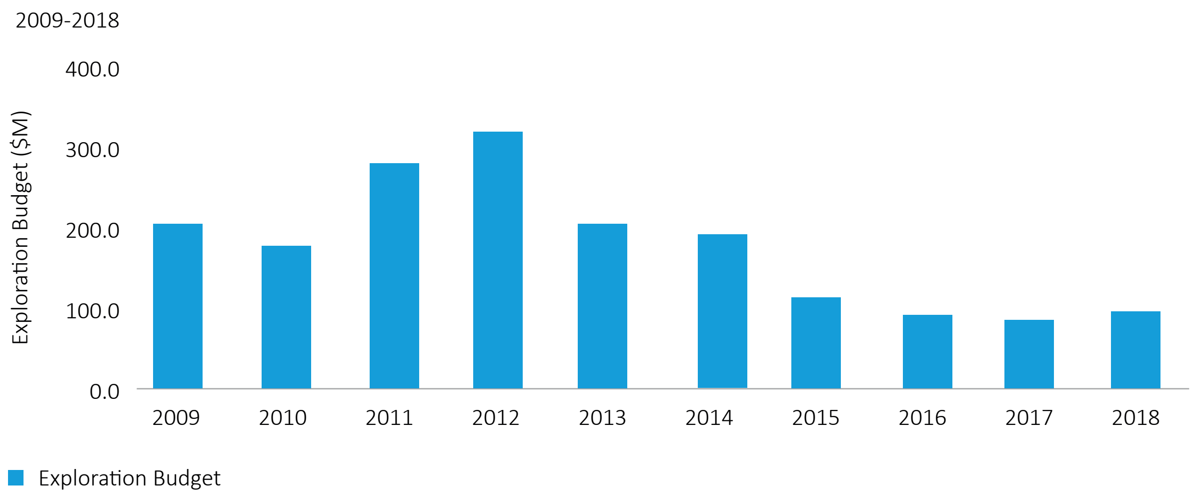
Communities near mines often expect specific benefits from mining companies and conflicts arise when these expectations are not met. The benefits can be schools, hospitals, and infrastructure – but also employment. There has been a sharp decline in the use of migrant labor as communities and unions pressure firms to hire workers from areas neighboring the mine itself. In 2016, after sustained losses due to low prices at Twickenham, its conventional platinum mine in Limpopo, Anglo Platinum put it on care and maintenance, reducing production to the bare minimum needed to prevent the mine's closure. Anglo made nearly all 2,000 workers redundant, retaining only a minimum operations team of 121 full-time staff and turned the shaft into a research and development (R&D) laboratory for new mechanization technology. The surrounding community protested violently against the decision. Burning tires were used to block off the single road that provides access to the mine and protesters tampered with the electricity supply without regard for anyone who may have been underground at the time.

An armed takeover was threatened unless the mine employed 5,000 locals. The demand for 5,000 local workers was a far cry from the 121 staff and 500 R&D contractors from around the world who are on site.

Disagreements over South Africa's Mining Charter are a stark illustration of contestation in mining. The Broad-Based Black Socio-Economic Empowerment Charter for the South African Mining and Minerals Industry, (the Mining Charter), was first developed in 2002, amended in 2010, and revised again in 2017 and 2018. Under the rubric of transformation, the charter aims to undo the legacy of apartheid, making the ownership, labor force (and other aspects of mining) more representative of South African demographics. However, changes to the ownership targets were challenged in court by the industry and added to policy uncertainty amid concerns about higher costs for mining companies. Exploration investment fell (Figure 3.11).

Figure 3.11: There has been a decline in mining investments in South Africa over the past decade, partially due to lower investor confidence

(Exploration budget trends in South Africa, 2009-2018)



Source: S&P Global Market Intelligence.

The 2017 charter raised ownership requirements, creating tensions with mining companies.[39] Black ownership was raised from 26% to 30%, while tightening up compliance requirements.[40] A right holder failing to achieve 100% compliance is automatically identified as non-compliant, regardless of how they score in other areas, affecting mining licenses. Deliberations centered on how to operationalize ownership requirements, testing various models to bring in broad-based black economic empowerment (B-BBEE) shareholders. Figure 3.12 provides an overview of the impact of various possible ownership and funding structures, some of which were considered during the negotiations, modelled for a hypothetical new mining operation:

- **Capital structure.** Percentage of non-B-BBEE ownership and percentage of B-BBEE ownership.

- **Vendor financing.** Ranging from 0 to 100%, vendor financing is defined as the portion of B-BBEE equity that will be funded by the non-B-BBEE shareholder over an agreed term and at a certain interest rate. This rate is usually below the prime rate. Repayments of the funding are capped by the B-BBEE dividends available and shortfalls are carried forward during the 6-year term.

- **Consideration of free carry.** Free carry is defined as the non-B-BBEE shareholder providing vendor financing to the B-BBEE shareholder. However, no repayments of the funding are made to the non-B-BBEE shareholder.

The 2017 Mining Charter would have imposed additional costs on mining companies. Not modelled in Figure 3.12 is the impact of increased B-BBEE ownership which creates costs to existing mining operations by diluting existing shares. The model focuses on a new mine and shows that increasing the required share of B-BBEE shareholding has no impact on the internal rate of return. Vendor financing with free carry for B-BBEE shares, on the other hand, have significant impacts on internal rates of return and thus hurdle rates. The June 2018 version of the Mining Charter requires a 10% free-carry.

Contestation over the Mining Charter continues. In 2019, the Minerals Council filed an application to take the third Mining Charter on judicial review. The council will challenge

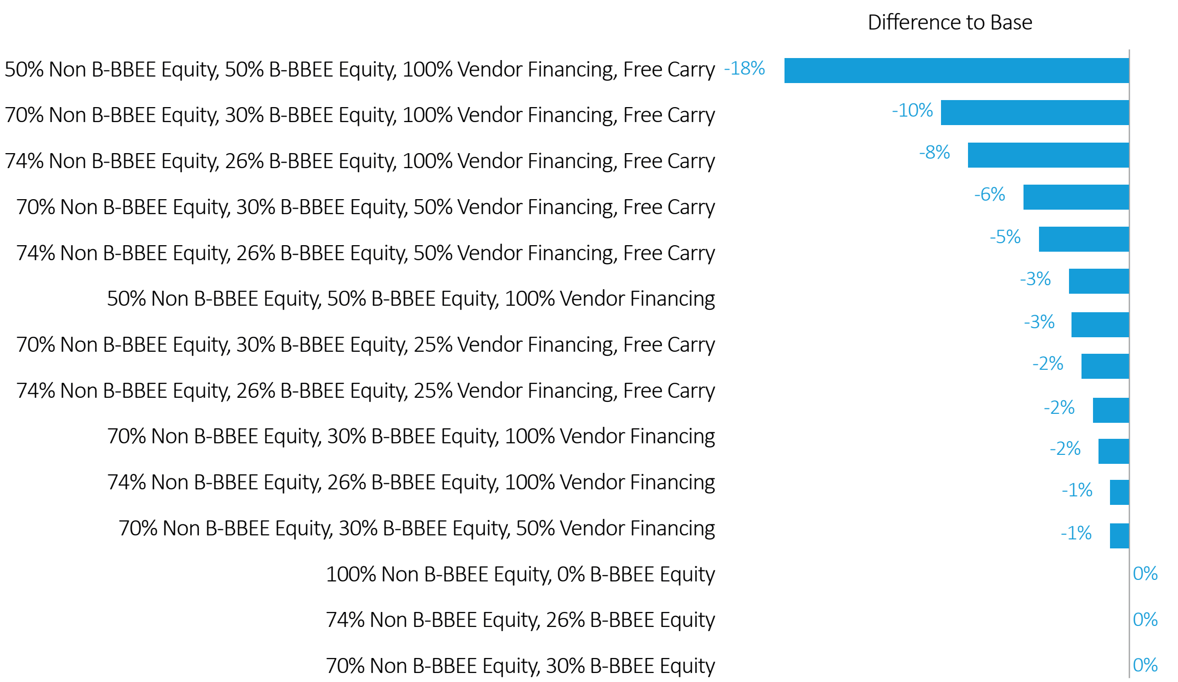
39 After the previous version of the Mining Charter, the Department of Mineral Resources published an outcome of the review of the charter's effectiveness at driving the intended transformation. These were the key outcomes of the review: (i) the industry was not fully transformed – although there have been improvements in compliance, there is still a long way to go; (ii) limited social impact – many people adopted a compliance-driven mode of implementation, designed to protect their social license, rather than create substantial social impact; (iii) insufficient progress in broad-based empowerment ownership – the interest of mine workers and communities are typically held in trusts and there was not always a clear benefit stream from the trusts to the intended beneficiaries; and the flow of benefits which was designed to do more than just service debt, but also provide cash flow to BEE equity owners, was insufficient; and (iv) surrounding communities still live in extreme poverty, which is reflective of the culture surrounding mining operations; despite the MPRDA's transfer of South Africa's mineral wealth ownership to people, it is still under government oversight.

40 The other 3 components of the "scorecard" are employment equity (20%); human resource development (20%); inclusive procurement, supplier and enterprise development (60%). The Charter removed mine community development and housing and living conditions as scoring elements, but rights holders will still be required to submit relevant documents for the housing and living conditions plan and social and labor plan, which will require multi-stakeholder approval.

a number of provisions in the charter, but will focus on the "once empowered, always empowered" principle. Under the revised version of the charter, companies that met the previous 26% ownership target will remain compliant even if their empowerment partners choose to exit the transaction. However, these companies will lose their compliant status when they renew or transfer their mining rights, and would have to top up their B-BBEE shareholding to the new 30% minimum. This went against a High Court ruling in April 2018 which stated that companies that met, but then fell below the 26% target, would not have to top up their B-BBEE shareholding. A second provision that is set to be challenged is that firms must procure a minimum of 70% of goods and 80% of services from South African companies within the next five years. The Minerals Council has said that meeting some of the targets in the specified time frame would be a challenge, given the limited availability of inputs.

Figure 3.12: Combinations of B-BBEE equity, vendor financing, and free carry affect hurdle rates for investment to varying degrees

(Percentage point change in internal rate of return of hypothetical new mine,[41] relative to a case without B-BBEE requirements)



Source: World Bank staff.

Mandatory development of a mining community, stipulated in South Africa's Mineral and Petroleum Resources Development Act (MPRDA) is another area of contestation. The MPRDA states that if there is a mine near a community, it must contribute to the

[41] The model is based on the development of a hypothetical mine comprising a 1-year construction phase and 6-year operational phase, where: (i) revenue is derived from price and volumes of coal, gold, platinum, iron ore and manganese commodities; (ii) costs are derived from the respective direct and indirect high level costs for each commodity type; (iii) on taxes, both royalties and the corporate income tax are factored in, and include the allowance for spend on capex; (iv) major capital expenditure occurs during the construction phase, and "stay in business" capital is considered during operations; and (vi) The construction cost of the mine is funded via a mix of debt (70%, at a cost of 10%, or 1% below prime) and equity (30%).

development of the community. An application for a mining license must include a social and labor plan (SLP), which was designed to promote employment, social and economic welfare, and to ensure that mining firms are contributing to the betterment of the communities in which they operate. SLPs should be done in a consultative process and include the Department of Mineral Resources (DMR), local government, mining companies, communities, traditional leaders, trade unions, and mining contractors (Figure 3.13). A SLP is submitted as part of the application for a mining license and once approved, becomes a legally-binding document. A SLP must contain specific sections, including: (i) a local economic development program; (ii) human resource development program managing downscaling and retrenchments; and (iii) financial provisions. Information on the details in SLPs is scarce, reducing transparency, which undermines trust and makes negotiations more adversarial. For mining companies, in the short-term, SLPs can be a significant expense that contributes to reduced returns.[42] However, in the medium and long term, SLP negotiations and execution also provide an avenue for reducing commercial risk, thus decreasing the likelihood of disruption, and hence, increasing commercial returns. Although earmarking resources for community development is viewed in an increasingly positive manner, efficiency and implementation are areas that could benefit from improvement. Applying a likely range of SLP spend to the hypothetical mining company studied in Figure 3.12, 1% of revenue expenditure on a SLP would reduce the internal rate of return by 2.7 percentage points; 5% expenditure would reduce it by 4.1 percentage points. This can significantly affect hurdle rates, the commercial viability of a mine, and the incentives for mining companies to invest.

Figure 3.13: A SLP is required from mine construction to well beyond the time a mine closes

(Lifecycle of SLP collaboration between firms, communities and the government)

PRIOR TO MINING		PRODUCTION PHASE		MINE CLOSURE
Apply to DMR for a mining license with details of environmental impact. Design and include the SLP which details how the mine will benefit the communities being affected by the mining operations. Consult with communities about the implementation of the SLP.	▷▷	Once the DMR issues a mine license, the company can begin operations. The documents submitted as part of the mine license application become legally binding. The company must show: Fulfillment of all the commitments it made in the SLP and submit annual reports detailing their progress. Submit a new SLP every 5 years.	▷▷	A mining company's responsibilities to its workers and surrounding communities does not end when the mine closes. It must fulfill all SLP commitments. Begin to rehabilitate the land where mining has occured so that it can be utilized for agriculture.

Source: World Bank staff.

[42] Where infrastructure is built for the benefit of employees as part of SLPs, it is allowed as a deduction over 10 years. However, when expended for the benefit of non-employees of the mine, such expenditure is treated as non-deductible capital expenditure unless the expenditure was included as part of the SLP and does not constitute infrastructure (or environmental rehabilitation).

The local economic development and human resource development components of the SLP are designed to improve economic opportunities for workers and mining communities. They are intended to ensure that mining firms contribute to the surrounding communities and to the areas from where their workers are recruited. The section on economic development contains the largest number of programs aimed at broad-based economic development, including poverty eradication and infrastructure development. Both programs must align with the local municipality's Integrated Development Plan targets. The human resource development program must create a plan for developing the skills of both their workers and the larger community. Firms are mandated to provide skills that are relevant for mining and non-mining sectors and programs can include adult basic education, artisan training, apprenticeships and scholarships.

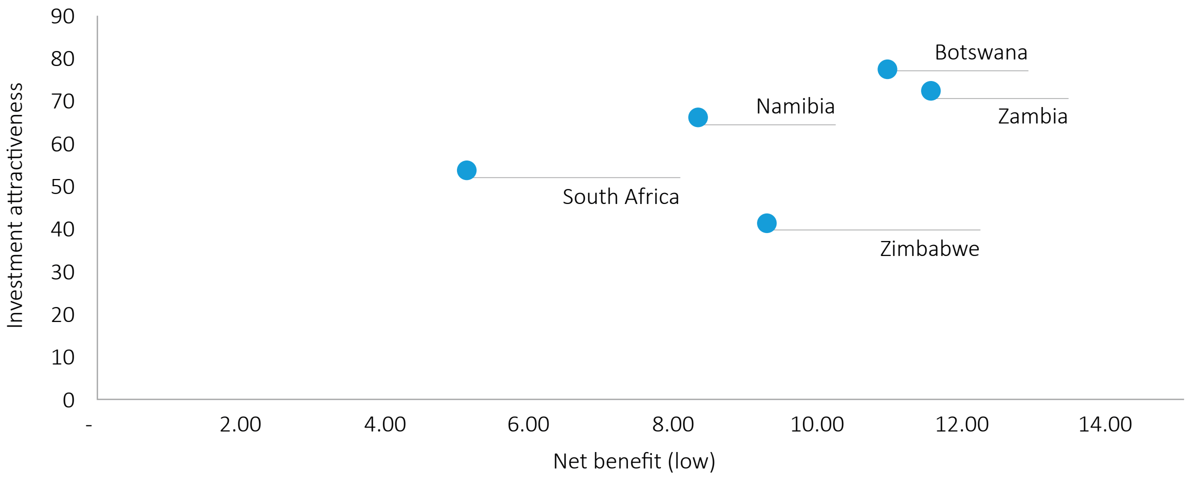
The section on managing downscaling and retrenchment must create a blueprint for how the mine will handle downsizing operations, should that become necessary. This must include: (i) a plan to save jobs and avoid job losses; (ii) plans to provide alternative procedures for creating job security when job losses are unavoidable; and (iii) plans to minimize social and economic consequences on individuals, communities and regions when retrenchments and/or closure of the mine become inevitable. The World Bank, International Council on Mining and Metals (ICMM) and Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development have all recently produced publications highlighting the need for a just transition by taking care of social issues after mine closures.

The financial provision section states that a specified budget must be allocated for each of the three aforementioned sections. Even with this provision, mines can struggle when they lose fiscal capacity due to a downturn in commodity pricing. Although SLPs have been in place since 2002 and were designed with a transformative agenda in mind, most communities are still without meaningful benefits and continue to live in extreme poverty. There are several reasons for this: communities are not always consulted during the development of the SLP, which can make the SLPs irrelevant to local challenges. Although SLP guidelines say that mining companies must consult with the public before completing their SLPs, guidelines do not carry the same legal weight as the MPRDA and regulations, which do offer input on the issue. Furthermore, firms do not always meet their SLP commitments and the DMR does not always hold firms accountable. Ultimately, despite low commodity prices, having provisions to address training, local development and retrenchments improves social cohesion in mining communities and promotes sustainable development.

The Centre for Applied Legal Studies at the University of Witwatersrand carried out research to understand why the SLP system has been ineffective. Key findings included: (i) the SLPs did not address gender inequality. The mining sector can entrench gender inequality because the loss of communal land most commonly affects women, who are usually responsible for providing food; and because women face many obstacles to entering the mining workforce, including high rates of gender-based violence, insensitivity to gender in work allocations and inappropriately designed safety gear; (ii) SLPs were not translated into the languages commonly spoken in mining communities and less than 2% of SLPs were available online; (iii) little due diligence was done to plan local economic development projects – 56% of SLPs did not mention any sort of feasibility analysis prior to undertaking a project; (iii) roles and responsibilities were not clearly demarcated; and (iv) housing is a critical part of SLPs, but there was a lack of clarity as to how firms would facilitate housing for workers and communities.

Figure 3.14: Higher net benefits are associated with more attractive mining regimes

(Fraser attractiveness score (higher is better) and net benefit of mining, 2016)



Source: Figure 3.2, Fraser Institute (2016) and World Bank staff.

The more equitable the distribution of net benefits, the greater the attraction for mining investors. This chapter has illustrated some of the estimated distribution of net benefits to various stakeholders at a macro-level, while providing some nuance to the complexities of establishing a fair and equitable distribution of these benefits. Perceptions about imbalances in the way the resources are shared can result in conflict. Labor tends to respond through strikes, communities through protests and other disruptions, and companies by reducing their investments. Governments, representing the other stakeholders to varying degrees, respond by raising taxes or royalties and through regulations. Figure 3.14, although only a correlation, does suggest that countries that retain higher net benefits *domestically*, tend to have more attractive investment climates. More research is needed to establish causation, but an intuitive understanding suggests that a more equitable distribution of net benefits reduces contestation, and thus, commercial risk, thereby creating environments that are more attractive to investors who would extract the resources for the benefit of all stakeholders.

4. POLICY IMPLICATIONS

The policy recommendation in this section focuses on how governments can create a more equitable distribution of benefits from the mining sector, without reducing incentives to future investments or stopping ongoing exploration or extraction. This section provides four overarching recommendations: (i) develop good governance and create a stable regulatory environment; (ii) capture rent effectively; (iii) strategically develop backward and forward linkages; and (iv) change should be managed efficiently, to minimize negative consequences. Underpinning all of these recommendations is a need to improve the availability of data in the sector, thereby increasing transparency, in order to make good governance easier, develop tax policies with accurate data, understand the commercial feasibility of creating local production linkages and developing policies to benefit all stakeholders.

Recommendation 1 | **Develop good governance and create a stable regulatory environment**

The extent to which a country's natural resource endowments can be used to reduce poverty and inequality, is dependent on the quality of governance. Governance determines the requirements that firms must meet prior to commencing exploration and/or mining (e.g. social licenses), the regulatory costs that firms must cover, the benefits firms are required to provide to workers, communities and the domestic economy, and the amount of revenue that firms must pay to the government. It is also dependent on the institutional capacities to administer and enforce mineral laws, regulations, guides and standards. Without sufficient governance, mining can disproportionately benefit only a few (generally the government or capital holders), and increase inequality.

Creating an environment of stakeholder collaboration is important to facilitating the equitable distribution of benefits from the extractive sector. This report has highlighted the importance of balancing the interests of various stakeholders, including the government, investors, communities and workers, to create an investment-friendly climate, prevent conflicts, and distribute benefits equitably. Although there are certain measures in place, such as the requirement for community consultations, workers' forums and requests for investor inputs into government policies, these are still often done merely for compliance, rather than in the spirit of meaningful collaboration. Creating a forum that brings together all stakeholders for genuine multi-stakeholder discussions, rather than bilateral discussions, could provide a platform that could lead to more meaningful collaboration.

Stable policy is important to reducing risk in mining investments. There are a number of risks that investors face in the region, including contract frustration, rapidly changing taxation policies, expropriation, industrial action, bribery and corruption, security and regulatory burdens. Providing transparency and policy certainty helps firms offset the social, political, and economic risks that have to be endured in addition to the inherent geological risks associated with mining. Additionally, an environment with an equitable distribution of benefits is favored by investors, as it contributes to a stabilized region.

Addressing the distrust between mining companies and governments is important to creating a stable regulatory climate. Historically, distrust has led to abrupt policy changes and operational stoppages in a context where limited mineral sector data prevent objective assessments of the effects of existing policies. The Extractive Industries Transparency Initiative (EITI) was created to reduce information asymmetry and develop a foundation of trust and collaboration between governments and companies. The EITI Standard requires information to be provided for all points of the extractive value chain, including extraction, rent transfer, and how it benefits the public. The EITI aims to reduce rent capture by looking at how licenses and contracts are allocated, who benefits from those operations, the legal and fiscal arrangements in place, how much is paid, how those revenues were allocated, and what extraction contributes to the economy, particularly for employment.

The EITI can also be implemented at the subnational level, which could bring clarity on royalties to local communities. Section 2.4 examined reasons why communities may not receive royalties allocated to them: misappropriation and maladministration, lack of transparency around negotiation and conclusion of mining royalty agreements with communities, and withholding of royalty payments by companies. The EITI would allow local stakeholders access to information on mining operations, how mining revenues are used, how mines operate and what their local impacts are. At the time of publication, Zambia remains the only country in this analysis that has joined the EITI. Reducing the information asymmetry and increasing transparency are key steps to reducing conflict, increasing trust, and bringing stability to the mining sector in the Southern African region. Such steps are also critical to attracting investment and ensuring the future sustainability of the sector.

Honoring the existing fiscal agreements is key to creating a sustainable regulatory climate and giving companies the long-term confidence needed to make mining investments. In response to perceived imbalances in the distribution of benefits, there has been a rise in resource nationalism across the region – including higher taxes and increases in state equity and local beneficiation requirements. When governments unilaterally amend or break existing fiscal agreements they have with mining companies, they signal that future investments or projects are at risk and vulnerable to abrupt changes. Given that mining investments are long-term in nature, generally ranging from 25-80 years, certainty and stability are important.

Creating and consistently enforcing policies that require firms to cover their social and sustainability costs from exploration through to mine closure is central to creating a sustainable policy climate. A reason governments revise existing agreements or create policies that can be perceived as punishing mining companies, is because mining companies generate significant negative externalities, including pollution, health consequences for workers and communities, infrastructure damage and irreversible land damage (section 2.4). The costs of these consequences should fall squarely on the shoulders of those who profit from it – mining companies. However, these costs should be built into the agreements entered into by the firms and governments, so that there are no surprises.

Recommendation 2 | Governments should capture rent effectively

Governments should maximize their revenue collection, while being mindful of the hurdle rate, to ensure firms are being compensated for the risks associated with mining. Developing effective revenue collection policies is a challenge across the region. This is evidenced by the rapid turnover of various resource tax policies. To create a stable regime and attract investors, it is in the best interest of governments to fix their existing tax collection systems, with built-in space for shortfalls and windfalls, rather than continually changing policies based on commodity prices, new mineral deposit discoveries, or other factors. The previous recommendation of joining the EITI to increase transparency and reduce information asymmetry will allow governments to use the most accurate information when creating tax policies. In exchange, governments need to use a fair combination of production taxes, royalties, and regulatory taxes to efficiently capture rents while ensuring firms are profitable.

Additionally, governments would benefit from adequate institutional arrangements for effective and efficient mining revenue collection. Tailored audit manuals, strengthened capacity of revenue authorities, improved administrative procedures and IT systems, enhanced collaboration and coordination between agencies responsible for minerals policies and revenue collection, through comprehensive country-level minerals databases, could reduce misalignments and improve compliance, provided a competitive fiscal regime is in place.

Recommendation 3 — Strategically develop backward and forward linkages

Although the majority of countries in the region are implementing policies to increase the development of local production linkages, more attention should be given to prerequisites such as infrastructure, intermediate inputs such as electricity, and to developing skills. In particular, improving access to, and the cost of, electricity and transportation infrastructure can help make countries in Southern Africa more cost-competitive. For backward linkages, electricity is a necessity for equipment manufacturers and weak infrastructure in this area can cause damage to equipment, slow down the manufacturing and repair processes, and make it difficult to meet deadlines for export customers. For forward linkages, smelting and refining – the first stages in beneficiation – require a substantial amount of electricity, and it is near-impossible to process raw minerals without it.

There are dangers to implementing local beneficiation requirements without developing a strategy for achieving a comparative advantage. Countries should focus on developing a regional or global comparative advantage. Section 2.3 analyzed five value chains – platinum, mining machinery, diamonds, coal, oil and gas, and coal and uranium – to understand which SADC countries are likely to develop a comparative advantage in the short to medium-term. Developing policies without looking at the larger picture or sustainability can compromise commercial viability. For instance, in an effort to meet local processing requirements, Zambia's Konkola Copper Mines, a subsidiary of Vedanta resources, imports small amounts of copper from India and South Africa to meet the minimum requirements needed to be commercially viable. Zambia recently implemented a 5% copper import duty, making the smelting process commercially unviable; Konkola suspended its Nchanga Mine operations as a result of the import duty.

Collaborating between Southern African countries and using a regional approach would help reduce the burden of ongoing constraints, including those relating to infrastructure, skills, technology, and access to markets. This can be difficult given that the current policy climate favors nationalism rather than regional collaboration. However, allowing countries to specialize in various parts of the supply chain increases the likelihood of a sustainable value chain being developed. For example, Fessehaie (2015) notes although there are significant barriers to developing cross-border linkages between South Africa and Zambia, and Zambia and the DRC, there is also potential for improvement. There is scope for linkages between South African-based machinery manufacturers and Zambian suppliers, which could help upgrade the technology in Zambia's Copperbelt. Both South African and Zambian suppliers already use Zambia's Copperbelt to access the DRC mining value chain, since the DRC itself is too volatile to establish operations in. Thus, the Copperbelt offers Zambian suppliers the opportunity to increase operations and achieve economies of scale, while also offering South African manufacturers the incentive to increase the value-added content of their business in Zambia. By joining forces, constraints such as human and technological capabilities, can be overcome, and regional partnerships can yield economic gains.

Recommendation 4 | Manage change effectively

It is important to develop and implement skills development programs aligned with diversified economic activities to absorb the labor displaced by mechanization. Although mechanization leads to significantly higher productivity and revenue, it is having a strong impact on local labor dynamics. The transition to mechanization is creating two changing labor dynamics: in the type of labor demanded, from low-skilled to high-skilled (engineers instead of rock blasters, for example); and a decline in the total amount of labor required. The shift to mechanization has made it necessary to develop a workforce that is suitably qualified for other industries that have the jobs that are able to absorb high amounts of low-skilled labor. The increased tax revenue obtained from higher mining productivity, can be used to finance skills development programs.

Mechanization requires training local suppliers in new skills. Providing them with the necessary training is key to making domestic mining technology and service firms competitive against international counterparts. Given the skills constraints facing many mining communities, capacity building in the areas of technical and business development as well as assistance with access to finance can be catalysts to developing linkages and widening the beneficiaries of the mining sector. Additionally, it is important that there be substantial investment in next-generation mining equipment, which would mostly target the domestic market but could have significant technological spillover that would boost exports. Existing local content policies tend to focus on direct employment targets and less on skills development for the creation of indirect employment around the mining sector. Shifting the focus of local content policies to the latter would help expand mining's multiplier effects and productive linkages. Focus should be put on transferable skills to have versatile workers with flexible skills, who are able to adapt to change or make an industry shift. To leverage mining operations for people beyond their current jobs, incentives and partnerships would probably be more effective instruments, instead of the imposition of stringent requirements. wn

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How leading mining companies are getting smarter with condition monitoring

USING PROACTIVE ASSET RELIABILITY TO IMPROVE OPERATIONS AND PROFITABILITY

Minerals are in demand worldwide, strengthened by the emerging needs of green energy. Mining companies must reduce operating and maintenance costs to capture increasing demand profitably. Future viability requires a transformation in mining operations to improve transparency and proactively manage costs and mitigate risks.

Mining companies are realising their return on investments in condition monitoring due to the reduced maintenance costs, improved asset reliability, better safety and equipment availability, and increased mining yield that these systems offer.

Twenty of the largest global mining companies were surveyed as part of the market analysis for this white paper, revealing critical insights on how these organisations are maximising their profits by adopting condition monitoring systems. This white paper further discusses various approaches to condition monitoring and their application in the mining industry. It establishes the need for site-wide adoption of condition monitoring systems using AI/ML to optimise benefits.

More than 75% of the twenty largest miners are in the advanced stage of implementing a proactive maintenance strategy and are focusing on Mining 4.0 (mining-specific adoption of Industry 4.0) approaches to maximise their yield further. Mining 4.0 approaches include digitalisation, automation, data analysis, operational control and customisation, collaborative working, and artificial intelligence.

Leading players are working on building digital mines and connected mines leveraging emerging technologies such as the Internet of Things (IoT), cloud solutions, and analytics to achieve better performance from mine to market.

Maintenance is a key enabler and a strategic business function that impacts commercial risk, output, production

cost, safety, and performance in mining operations. However, maintenance also comprises a significant portion of OpEx (Operating Expense) primarily because it is reactive and inefficient. The increasing maintenance cost and the continual need to reduce carbon emissions in today's environment make it challenging for mining operations to increase profitability. Over the last ten years, the net profit margin in the mining industry decreased from 25% (in 2010) to 9% (in 2019), emphasising the need for new solutions that focus on proactive maintenance.

New and evolving proactive maintenance solutions can help mines balance operational costs and optimise operations, resulting in higher profits and mining yields while meeting regulatory demands.

UNPLANNED MAINTENANCE: THE ACHILLES' HEEL FOR MINING SAFETY AND PROFITABILITY

Safety, maintenance cost, equipment life, unplanned downtime, production losses, and shortage of skilled labour are vital factors affecting miners' profitability. Declining ore grade, lower commodities prices, decreasing productivity, rising energy cost, and the need to improve safety are significant challenges faced by mining companies. Therefore, leading mining companies focus on achieving a breakthrough in productivity to overcome these challenges.

SAFETY: Safety is the top priority for miners and is directly aligned with management KPIs (Key Performance Indicators) as even a small error at the miners' end can have a cascading effect on operations and productivity. Unreliable mining equipment and the resulting failures can induce undue performance stress on the mining process, aggravating urgent situations and leading to an unsafe and accident-prone operating environment for workers. Many mining companies have adopted proactive maintenance to increase the reliability of equipment and site operations. Proactive maintenance results in fewer man-hours of intrusive maintenance, reduced risk of site accidents and injuries, and improved mining yield. Therefore, equipment reliability in mining plays a crucial role in site safety and productivity.

MAINTENANCE COST: Maintenance, while vital, is a significant cost that can significantly impact the cash flow and profitability of mining companies. An estimated 4–15% of mining revenue is spent on maintenance, making it

Applications of condition monitoring in mining operations

- **Screens:** Due to high vibration and loads, there can be structural damage and spring failures. Proper vibration analysis performed, and vibrations constrained under set limits can reduce this problem.

- **Conveyers:** Due to less lube oil supply and loads on the bearing there can be an occurrence of bearing failure.

- **Ball/SAG Mills:** Thermal stresses result from oil lubrication failure and excessive vibration.

- **Slurry Pumps:** Pumps undergo immense strain due to the transfer of viscous material throughout the pumping process. Sludge and slurry contain high solid content, which causes pitting and cracking.

- **Turbines:** Turbine bearing failures can result from structural misalignments and lubrication oil defects. A malfunction can also occur due to joint dislocation and fatigue while in operation.

- **Fans:** Fans are subjected to excessive thermal and vibration stress, a major reason for fan failures.

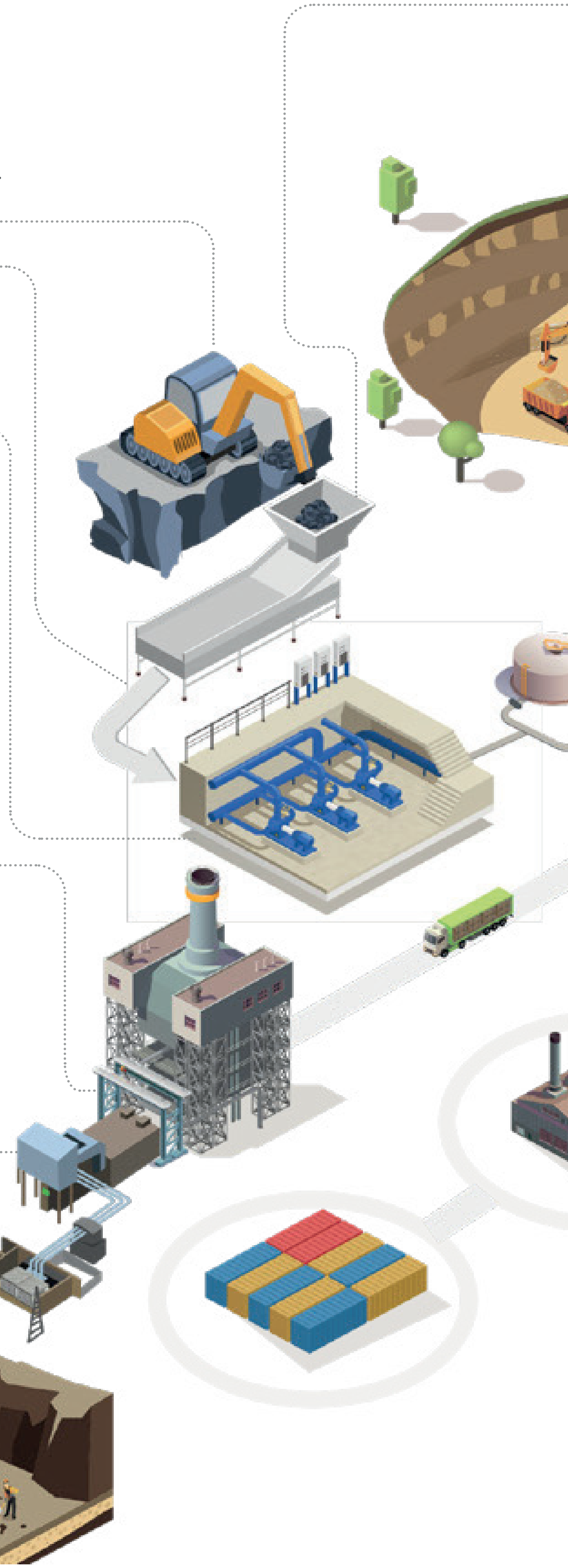


Figure 1

Crushers: Crushers operate at high power to produce materials, putting a lot of strain on internal parts, filters, and bearings.

Electric Motors: Bearing failure is a major issue in electric motors. It is generally analyzed by vibration analysis.

Critical Nodes for Condition Monitoring :

Primary: *Slurry pumps, Fans, Turbines, and Compressors.*

Secondary: *Blowers, Motors and Screeners.*

essential for operators to optimise their maintenance approaches, as higher costs affect other developmental plans and future expansion projects of mining companies. Our survey revealed that adopting condition monitoring systems could save an average of 20% of maintenance expenditure per year.

UNPLANNED DOWNTIME: Unplanned downtime is a severe threat in the mining industry since a failure in one area could have a far-reaching impact in other areas and even cause a site shutdown. Unplanned downtime can last from a few hours to a few days, mainly due to the lack of readiness with equipment, spare parts, or expertise required for the repair. Apart from production losses, unplanned downtime can also lead to supply chain disruptions, further eroding profitability. Unplanned downtime costs much more than planned maintenance and is a controllable cost parameter that remains largely unaddressed today.

PRODUCTION LOSSES: Mining operations are carried out in harsh and corrosive environments that adversely impact and reduce the longevity and performance of equipment, putting additional focus on timely and proper maintenance. Downtime due to inefficient maintenance can result in production losses and secondary process and equipment damage of up to USD 1 million/day. Proactive maintenance strategies can help avoid these unnecessary losses, potentially saving a single operation millions of dollars.

SHORTAGE OF SKILLED LABOUR: The maintenance of operating equipment is crucial and requires skilled operators, which is becoming an increasing challenge. The global retirement rate among skilled workers is rising, with 50% of the workforce expected to retire over 5 to 10 years. This loss of expertise exacerbates the ongoing challenge of optimising productivity in mining operations. To bridge this gap, manufacturers require more callouts to external service companies, elevating costs and facing the probability of longer production delays. Adopting proactive maintenance techniques, such as condition monitoring, can help overcome these challenges and centralise or provide remote access to the necessary information.

DEPLETING EQUIPMENT LIFE: Proactive maintenance programs can identify equipment wear and failure well in advance, significantly reducing downtime and associated financial risk. For example, replacing an impeller in slurry pumps costs about USD 50,000 per pump/per instance, while replacing a pump casing costs about USD 200,000 per instance. These parts that need replacement can be reduced significantly using proactive maintenance and condition monitoring systems.

RESTORING PROFITABILITY BY MITIGATING UNPLANNED MAINTENANCE

To be profitable, mining companies must get ahead of the curve. This requires a strategic approach to monitoring systems that assess equipment health, predict performance curves using industry-based algorithms, and mitigate cost and risk. Condition monitoring is the ideal tool to predict equipment wear and failure. Manual inspections have proven inconsistent and unreliable, emphasising the need for condition monitoring solutions.

A majority of the mining industry uses rule-based SCADA monitoring systems that cannot identify potential failures when manually set thresholds are not crossed. As a result, more than 80% of mines cannot quantify the total cost of downtime due to the various complexities involved. While putting a precise figure to this cost is difficult, unplanned downtime can efficiently run into hundreds of thousands of dollars per year. Our survey results indicate that companies not using a proactive maintenance approach face a significant amount of unplanned downtime that costs 2 to 5 times more than planned maintenance expenditure.

Estimates reveal that 60–80% of equipment problems in mining operations stem from poor, untimely, or incorrect maintenance. Thus, the opportunity cost of leaving maintenance inefficiencies unaddressed—when maintenance is a high percentage of OpEx—is steep and significant.

The good news is that these costs can be mitigated. Major mining operators have already begun optimising processes at their plants to save energy and enhance yield. Solutions include extensive automation packages with machine process controls and quality controls, more intelligent asset performance management solutions through digitalisation, augmented reality, remote monitoring, and even 5G technology. See Figure 1.

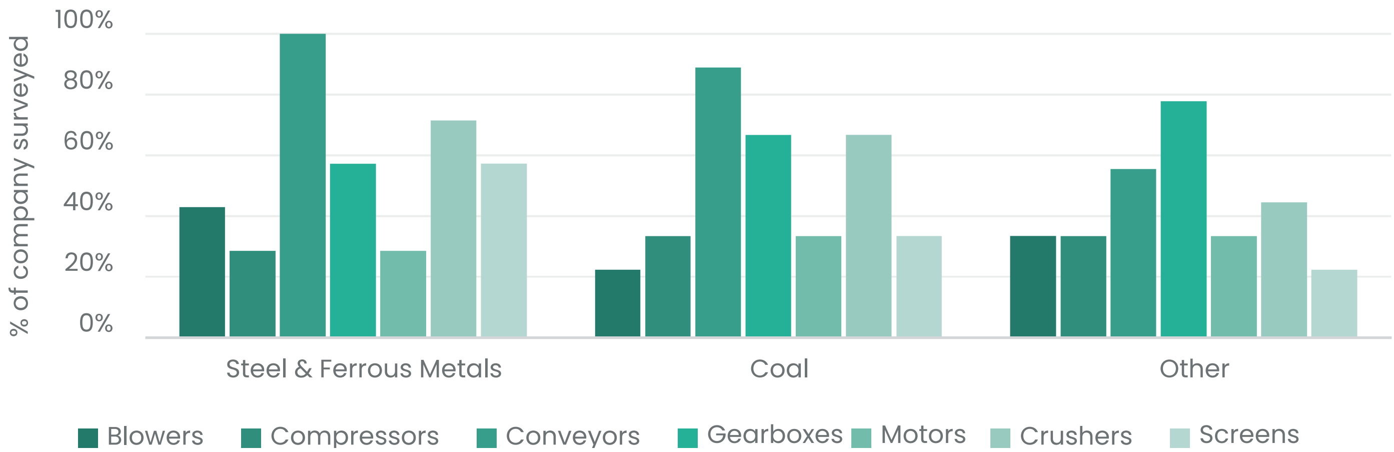
Mining operations are prone to harsh conditions, leading condition monitoring suppliers to tailor hardware and software equipment for practical solutions. The equipment collects data from critical assets at mining sites to identify and prevent damage that may develop into failures. In the mining industry, condition monitoring is implemented on the following critical assets - See Table 1.

Our survey reveals that critical assets for miners differ based on the mineral they are extracting. Coal miners spent more time monitoring the health of their conveyors and crushers' health than gold miners, which are more concerned with gearboxes. The survey results also indicate that bearing failures were the primary reason for the failure of many of these critical equipment types. Ideally,

ASSET TYPE	ASSET	MAINTENANCE ISSUE	FAILURE CRITICALITY
Screening Equipment	Conveyor belts and screeners	Gear and bearing failure, lube oil failure, belt failure, overheating	High
Milling & Crushing Equipment	Ball mills, SAG mills, slurry pumps, screening machines, reclaimers, and crushers	Overheating, vibration, bearing and gear failures	High
Excavating Equipment	Shovels and excavators	Overheating, vibration	High
Ancillary or Auxiliary Equipment	Fans, blowers, conveyors, vacuum pumps, screens, and gearboxes	Bearing failure, lube oil failure, overheating	Medium to High
Electrical Equipment	Electrical motors, turbines, compressors, pumps, and fans	Bearing failure, lube oil failure, overheating	Medium
Logistics and Transportation Equipment	Trucks, small mobile equipment, ship loaders, and rail and cargo transport	Overheating, vibration	Low to Medium

Table 1

Mining equipment with a high frequency of failure



Note: Other metals include gold, silver, nickel, aluminum, zinc, and potash

Figure 2

such critical equipment across the mining industry requires monitoring for vibration, temperature, and oil analysis for smooth, reliable operations. Therefore, it is imperative for miners to adopt proactive maintenance techniques, including condition monitoring systems, to protect and improve the lifespan of their assets.

Proactive asset maintenance can reduce unplanned downtime at mining sites

There are three maintenance approaches: reactive, corrective, and proactive. Of these, proactive asset maintenance is best suited for the mining industry. Reactive asset condition monitoring is generally a last-resort remedy, while corrective asset condition monitoring does not detect a developing fault until collateral damage occurs in the operating equipment. In both reactive and corrective methods, there is a high possibility of severe damage by the time the problem is detected, potentially necessitating the replacement of multiple components. By contrast, proactive asset maintenance can detect potential faults up to 3 weeks in advance, saving the cost of replacing multiple components and allowing for better decision-making involving downtime.

Predictive condition monitoring or proactive asset maintenance is the most beneficial when used on vibrating and rotating machinery. Newer condition monitoring systems can detect a potential fault as soon as it appears, allowing operators to plan maintenance before it affects other machinery or equipment. Condition monitoring systems that incorporate AI (Artificial Intelligence) and ML (Machine Learning) technologies can even identify root cause failure mechanisms in progress before any damage is done. This provides an opportunity for plant operators to carry out maintenance and reliability assessments strategically and proactively—and at the lowest possible cost—rather than in a tactical or reactive, and subsequently, less effective manner.

BENEFITS OF CONDITION MONITORING (CM)

Leading mining companies are leveraging condition monitoring technology to track and address problems proactively and prevent disastrous outcomes. Condition monitoring compares measured physical parameters against known engineering limits to detect, analyse, and correct problems before failure. With condition monitoring systems in place, mining companies can make informed decisions about operations and production, saving them more than 40% compared with reactive maintenance and 15% to 20% compared with corrective maintenance.

Mining companies that use advanced condition monitoring systems can improve their asset health significantly. For instance, the use of a condition monitoring system can extend the useful life of impellers in large slurry pumps from 8 weeks to 16 weeks by early detection of any impending failure and increase the useful life of overall equipment in a mining plant by 2-3x, leading to significant reductions in maintenance costs. Overall, companies can reduce maintenance costs by an average of 20% annually using condition monitoring systems.

Other key benefits of implementing condition monitoring and proactive maintenance systems include:

- Reducing frequent repair cost
- Avoiding expensive maintenance and downtime
- Ensuring equipment health and optimising maintenance planning
- Reducing fuel and energy consumption on-site
- Eliminating false trips of equipment due to improper configuration and installation
- Facilitating Industry 4.0 (4IR) tools with real-time equipment data
- Preventing data loss of events

EXPECTED REDUCTION IN MAINTENANCE COST USING CM SYSTEMS

(Figure 3)

- Our survey reveals that miners achieved average savings of 19-27% in their maintenance expenditure by adopting condition monitoring (CM) systems, primarily because they could save significantly on unplanned equipment failure as well as repair and replacement costs.
- It was also observed that unplanned downtime directly correlated with maintenance expenditure. Reduction in unplanned downtime was highest in steel & ferrous metals (~27%), which led to higher savings. In coal and other minerals, miners achieved around 19-20% reduction in unplanned downtime.

CHOOSING THE RIGHT CONDITION MONITORING SOLUTION

Condition monitoring is a sophisticated process that involves the real-time monitoring and supervision of complete machine conditions throughout operations. Condition monitoring solutions are deployed at mining facilities to monitor machine health, detect potential failures, and improve reliability. Some essential equipment protected by condition monitoring solutions include pumps, conveyors, electric motors, fans,

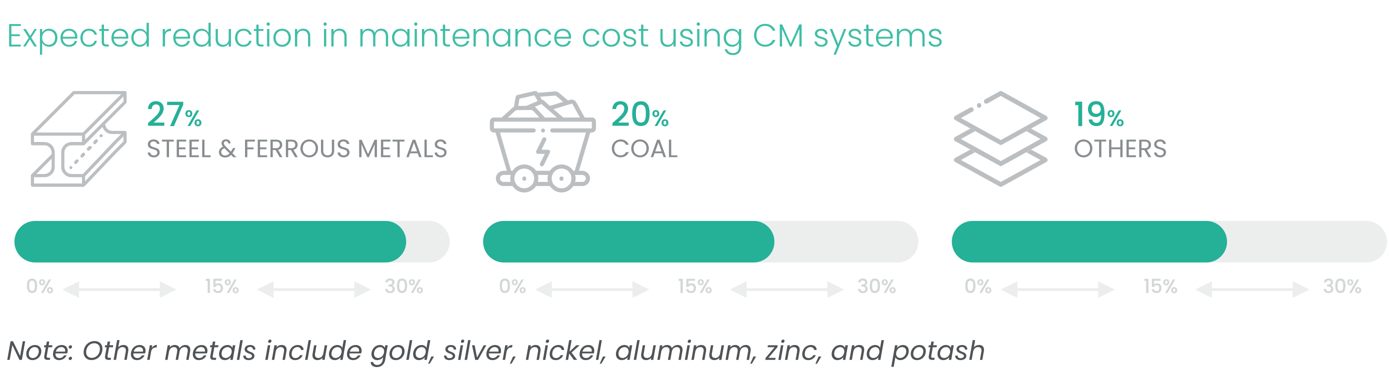


Figure 3

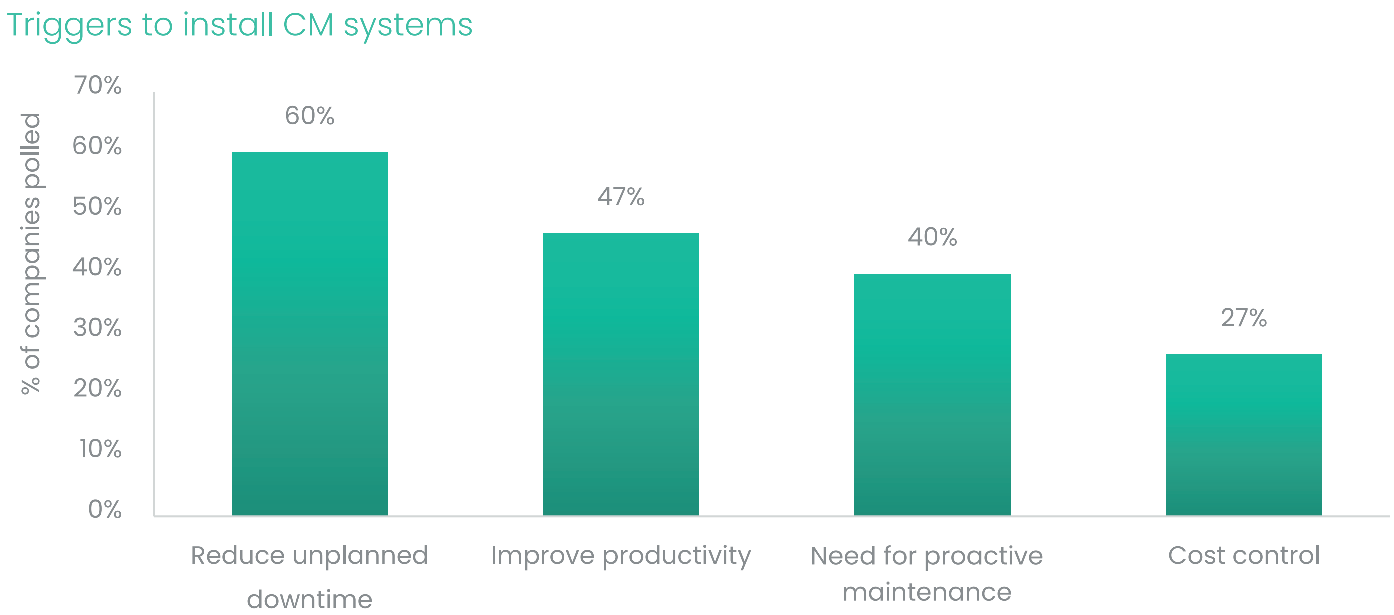


Figure 4: Why reliability professionals are pivoting to condition monitoring systems

and crushers. Nodes most susceptible to failure include screening, crushing, and milling, among others.

DIFFERENT DEPLOYMENT APPROACHES, DIFFERENT BENEFITS

Typically, condition monitoring systems are deployed on-premises or hosted on a cloud server. On-premises deployment is the more conventional method of deploying condition monitoring systems, giving organisations complete control over data.

On the other hand, cloud deployment, carried out with the help of third-party vendors, helps enterprises understand the real-time condition of the machinery in their mines remotely. A key advantage of using cloud deployment is that implementation and maintenance costs are significantly lower since only minimal hardware needs to be installed on-premises. This is the preferred option for mining operators as solution providers offer remote monitoring of critical equipment. Cloud deployment also helps provide faster access to critical data and offers a prompt alarm facility.

CHOOSING A CM SYSTEM BASED ON THE CONSEQUENCE OF THE FAILURE OF ASSETS

The consequences of asset failures in mines are not equal. Gearboxes, crushers, conveyors, and compressors are more critical than motors and fans. Therefore, it is necessary to plan different asset approaches based on their impact on production costs and safety. Online condition monitoring systems are employed to monitor the health of critical assets at mines via a sequence of sensors permanently mounted on critical machines that transmit data to plant operators through a wireless or cabled network. Online condition monitoring systems provide information about process performance and deliver instant alerts of problems that might otherwise go unnoticed.

Online condition monitoring systems are beneficial for machinery operated 24*7 and placed at hazardous and remote locations in the mining industry.

Portable monitoring consists of handheld devices that collect data temporarily for further analysis and provides benefits such as low initial investment, cost savings, and longer equipment life due to flexibility in route-based machine monitoring.

Portable condition monitoring is preferred on less critical equipment. It involves a periodic, manual checkup of asset health and an indication of exceptional performance in the mining process.

THE PERFECT TRIO OF HARDWARE, SOFTWARE, AND SERVICES

Ideally, condition monitoring systems combine hardware, software, and services that provide a broad, connected view of machine operations, allowing operators to mitigate risk, boost safety, and reduce maintenance costs while improving equipment reliability, uptime, and efficiency. Major hardware components include vibration and infrared sensors, spectrometers, ultrasound detectors, spectrum analysers, and corrosion probes. Data collected from these hardware components are processed by software solutions such as data integration, diagnostic reporting, alarm management and notification, order tracking analysis, parameter calculation, and signal processing. Various software solutions based on different technologies and feature functions are available. Service support, such as outsourced expertise for set-up and condition analysis services, is critical for a successful condition monitoring program.

CONDITION MONITORING CAN SAVE HUNDREDS OF THOUSANDS OF US DOLLARS ANNUALLY

The ROI of condition monitoring systems readily justifies the initial Capital Expenditure investment required. The implementation of condition monitoring solutions can help address blind spots by seamlessly sharing performance across the enterprise, strategically leveraging expertise, and digitally transforming operations. Our survey observed that companies could save hundreds of thousands of US dollars by adopting a condition monitoring system for critical assets, making it a starting point of the journey toward site-wide condition monitoring approaches that can deliver exponential benefits over time.

SITE-WIDE CONDITION MONITORING – THE FUTURE OF EFFECTIVE MAINTENANCE

Plant and asset availability are significant priorities for reliability personnel at mines. To achieve this, all assets would be monitored concurrently. That, however, is the desired state and is often not feasible as a starting point. Therefore, mining companies currently focus on monitoring their critical assets frequently and choose less frequent manual checkups for the rest of the equipment/assets. This creates a notable gap in their current maintenance strategy.

Site-wide condition monitoring uses advanced wireless or wired sensors,

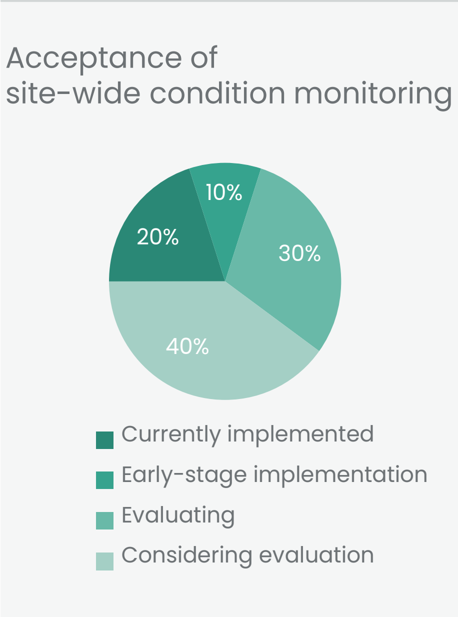


Figure 5

analytics, and visualisation techniques to improve asset diagnostic capabilities. Site-wide solutions enable an eagle's-eye view of operations, facilitating higher-order operational optimisation and real-time decision-making in the proactive maintenance journey of miners. More than 30% of the leading 20 miners have already started their journey with site-wide condition monitoring systems, while more than 40% are interested in exploring this space.

Site-wide condition monitoring provides broader benefits than individual asset protection. Operation-wide optimisation offers a holistic view of the health of equipment and increases the level of sophistication, productivity, and reliability of the plant.

ARTIFICIAL INTELLIGENCE (AI), MACHINE LEARNING (ML), AND THE INTERNET OF THINGS (IOT) TO POSITIVELY IMPACT FUTURE CONDITION MONITORING SYSTEMS

Digitalisation in the mining industry is crucial to improving the productivity of operations. Leading players have already started leveraging digital technologies to enhance their performance. These players have been implementing technologies such as digital mines and connected mines—that take advantage of the large amounts of data generated across sites by applying real-time data analytics and autonomous solutions—across their sites.

Digitalisation has also significantly impacted maintenance approaches. The growing use of cloud-based condition monitoring leads to technologies such as the Industrial Internet of Things (IIoT) and advanced analytics to make mines safer and more efficient. As mining equipment is interconnected through the cloud and other communication technologies, deploying cloud-based proactive maintenance systems becomes more manageable. A recent trend in the mining sector is integrating data from different sites using the concept of connected mines and then processing this data further using analytical and AI tools to enable data-driven maintenance decisions that maximise saving and optimise yield.

Mining companies use machine learning models built with raw data variables to allow inexperienced operators to detect breakdowns. Machine learning, advanced analytics, and applied data science help process large datasets across a significant number of geographically dispersed assets and devices. By understanding data patterns, production processes can be optimised, thereby enhancing efficiency. Assets across facilities can be monitored in real-time using AI to reduce the data processing time by more than 80%.

The adoption of machine learning/data analytics allows mining companies to create IoT systems and models for processes such as detecting and predicting overloads on pump motors and mining production quantity. Nearly 50% of the leading 20 miners are already using AI/ML-based condition monitoring systems, while approximately 20% are interested in exploring this space.

AI-integrated condition monitoring helps diagnose faults by applying machine learning algorithms to machines' vast volumes of data. These algorithms are trained to identify abnormal behaviour patterns and correlations of patterns.

Algorithmic AI- and ML-based condition monitoring systems can classify deteriorations as Time to Failure (TTF) and Root Cause Failure Analysis (RCFA) with supervised machine learning and unsupervised machine learning models. Supervised machine learning models require additional expertise from maintenance and reliability personnel at a facility level. If the machine learning model is not adequately trained, it could generate false positives and negatives, resulting in increased cost and time.

On the other hand, unsupervised machine learning models do not need assistance from maintenance personnel and are less resource-intensive, thereby saving cost and time.

IMPROVING RISK MITIGATION

Besides monitoring asset health and performance, reducing energy consumption and lowering carbon emissions are crucial maintenance and operating trends. Other trends include using advanced technologies, such as smart sensors, the Industrial Internet of Things (IIoT), Big Data, and Augmented Reality (AR), to provide operators with real-time data and 3D animation to support training, operations, and maintenance functions.

Mining companies worldwide are looking for advanced support to standardise maintenance workflows, streamline business processes such as procurement, and closely track

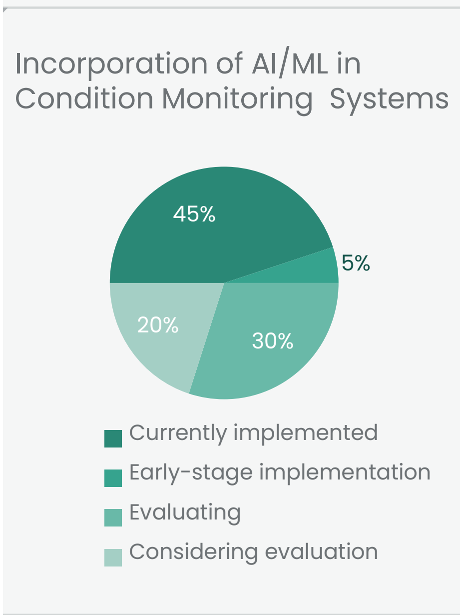


Figure 6

assets. Major manufacturers are also looking for flexible condition monitoring systems that can easily integrate with their existing ERP (Enterprise Resource Planning) systems.

THE ROAD AHEAD

Mines of the future are being built on digitalisation, the Internet of Things (IoT), cloud- solutions, real-time monitoring, seamless communication, data analytics using machine learning, and artificial intelligence (AI). This directional shift is expected to make the mines smarter, reduce unplanned downtime, and drive future growth and profitability.

Our survey reveals that around 45% of the top 20 players in the mining industry are already using condition monitoring systems but are looking to upgrade systems with AI/ML capabilities.

One of the primary drivers for the adoption of AI/ML-based condition monitoring systems is the significant decrease in the cost of data storage and transfer, pervasive connectivity, improved cybersecurity protocols, and a drop in the pricing of computing power. Additionally, major mining companies have begun to recognise the potential impact that AI and Big Data can have on revenue and cost. Regions such as North America and Europe lead in implementing AI/ML-integrated condition monitoring systems today. wn

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The procurement activities of national, state and local governments are directly or indirectly responsible for 15% of global greenhouse gas (GHG) emissions. Abating these emissions will help considerably in reaching the goal of the Paris Agreement to slow global warming to well below 2°C.

Greener public procurement will likely cost more, at least in the short run. And the bureaucratic complexity of public procurement operations will make it difficult to align on decarbonisation strategy. But these barriers can and must be overcome if governments help us reach our climate goals.

This report analyses the benefits and challenges of green public procurement. It provides specific guidance on how procurement officials can ensure that their procurement activities contribute to our net-zero goals.

THE OPPORTUNITY

The vast majority of the emissions for which public procurement is responsible – up to 70% of the total – stem from the activities of just six industries: defence and security, transport, waste management services, construction, industrial products and utilities. The burning of fossil fuels in public transport and defence and security activities is responsible for almost all public procurement's Scope 1 emissions. Its Scope 2 emissions, from the purchase of electricity to run operations, make up 13% of the total. Upstream Scope 3 emissions generated by the companies from which governments procure goods and services make up the rest, as much as 67%.

Abating these emissions will have several benefits. It will lead to an estimated $4 trillion boost to the green economy, create around 3 million net new jobs and considerably reduce the social cost of carbon.

THE CHALLENGES

Greener public procurement will likely increase costs to governments. According to our analysis, approximately 40% of all public procurement-related emissions can be decreased for less than $15 per tonne of CO_2e, although the amount varies by industry. In total, efforts by the world's governments to reach net-zero emissions will increase procurement costs by between 3% and 6%.

A further challenge is the highly decentralised nature of government procurement activities. On average, less than half of 2019 public procurement spending in Organisation for Economic Co-operation and Development (OECD) countries took place at the federally centralised level. In addition, the added costs of green public procurement will have to compete for funding with other government priorities such as health and education. And because transparent data on public sector emissions is lacking, setting emissions baselines, defining decarbonisation targets and tracking progress are difficult.

THE SOLUTION

We offer a ten-step framework for overcoming the challenges of greener public procurement. These include baselining current emissions and future goals, optimising for climate-friendly goods and services, working

GREEN PUBLIC PROCUREMENT:

Catalysing the Net-Zero Economy

with suppliers, engaging with industry ecosystems to promote decarbonisation and enabling the procurement organisation to meet its climate goals.

STEPS 1 AND 2:

- Create transparency in baselines and targets.
- Collect the data, identify heavy-emitting suppliers, prioritise efforts by economic value, determine standard metrics and set targets.

STEPS 3 AND 4:

- Optimise products for greenhouse gas reduction across the life cycle.
- Develop an abatement roadmap outlining the emissions reduction levers to be pulled to reach targets.
- Include factors such as cost, impact and feasibility.

STEPS 5 AND 6:

- Define product and supplier standards and engage suppliers.
- Set procurement standards for internal operations and external suppliers, then assess and prioritise suppliers in terms of progress in setting and reaching emissions targets.

STEPS 7 AND 8:

- Develop the broader ecosystem and create buying groups.
- Work with industry coalitions to promote decarbonisation and certify companies and materials.
- Join buying groups to help create markets for low-carbon products.

STEPS 9 AND 10:

- Transform the procurement organisation and align across agencies.
- Realign the steering model, individual responsibilities and;
- Communications processes, boost capabilities and upgrade data and information systems.

Given its sheer scale and spending power, public procurement can exert considerable influence in the effort to combat global warming. We urge all public procurement officials to take on this crucial task, work in concert with all stakeholders and begin the process now.

1. INTRODUCTION

Through its scale and spending, public procurement can positively impact global efforts to slow climate change.

Governments worldwide are making progress in encouraging the decarbonisation of their countries' economies through regulation, taxation, direct funding, incentive programmes and other means. As of November 2021, 92 countries had pledged to meet net-zero emissions targets, accounting for approximately 85% of global greenhouse gas (GHG) emissions.

Yet governments themselves can have a profound positive effect on efforts to reduce the world's carbon footprint. Public procurement alone is directly responsible for 3% of GHG emissions (Scope 1) and indirectly responsible for another 12% through the emissions released by the companies from which they procure the goods and services they require to maintain their operations (scopes 2 and 3). So abating these emissions – 15% of the total – will make a huge difference in reaching the Paris Agreement goal to slow global warming to well below 2°C.

To do so, governments must pull every lever available to decrease their direct emissions while working with their suppliers to lower their emissions. The $11 trillion that governments worldwide currently spend annually on procurement should give them the power needed to influence the climate-friendly practices of the industries they buy from. And the time is now: unless we can slow global warming, public procurement costs will skyrocket as governments spend to adapt to the effects of climate change.

Admittedly, greener procurement will likely cost more, at least in the short run. And the sheer multi-layered complexity of public procurement operations makes aligning on decarbonisation strategy a challenge. But these barriers can be overcome. Indeed, they must be if governments play their part in reaching global net-zero goals.

While lowering the global public sector's overall operational emissions will be critical to slow global warming, this report focuses specifically on the emissions generated, directly or indirectly, in the production and use of the goods and services purchased through public procurement.

Through their procurement processes, governments can significantly positively impact the climate- friendliness of the goods and services they buy.

In what follows, we analyse the benefits and challenges of green public procurement and provide detailed guidance on how procurement officials can bring about the positive changes needed to ensure that government procurement contributes fully to global net-zero goals.

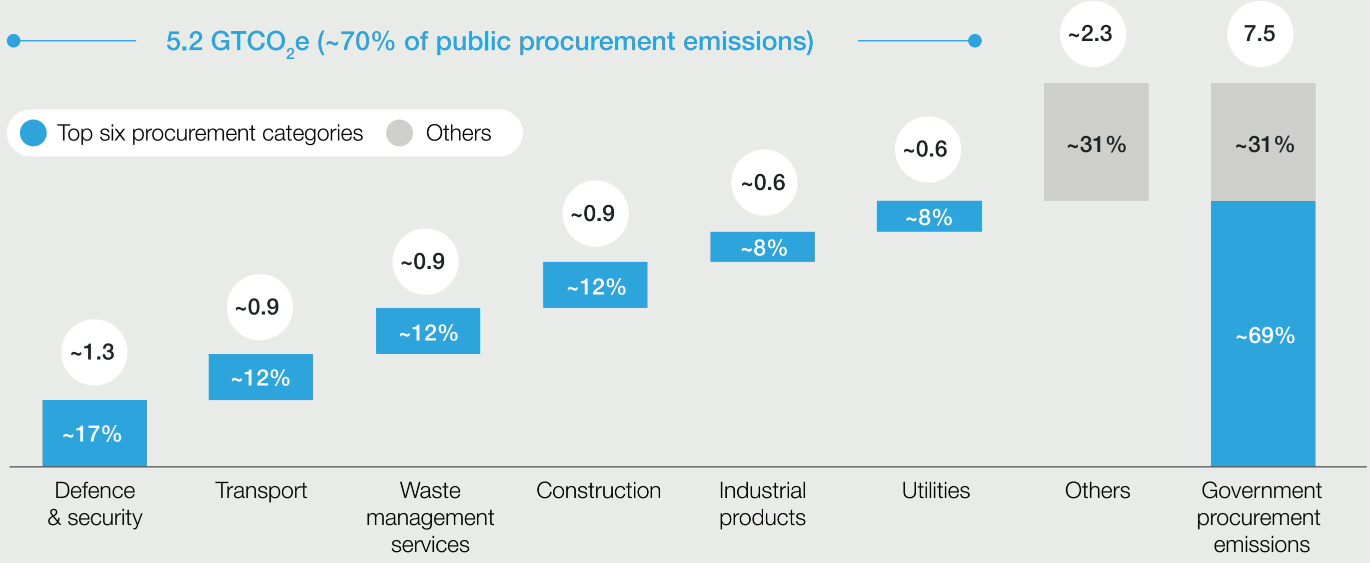
2. THE GREEN OPPORTUNITY

In addition to far lower emissions, climate-sensitive public procurement will stimulate the green economy, reduce carbon's social cost, and lead entire industries towards a net-zero future.

To date, many governments have been lagging in their efforts to set overarching emissions reduction goals covering all of their operations or targets for decreasing the indirect emissions related to the goods and services they procure. There are exceptions: for example, the US, Germany and Canada have each set net-zero targets covering their operations. But none of them has published specific details on how they plan to reach their targets.

That is unfortunate, given that the world's governments have an enormously positive role to play in helping lower GHG emissions, in addition to their current efforts to regulate the private sector companies operating within their borders. Indeed, given its enormous scale and buying power, the potential influence of public procurement is so significant that it can play a leading role in encouraging key industries to reach their own net-zero goals, promoting innovation across the green economy and considerably reducing the social cost of carbon.

Contribution to government procurement emissions (GTCO$_2$*)



* Emissions in gigatonnes of CO_2 equivalent

Source: United Nations Framework Convention on Climate Change (UNFCCC) greenhouse gas (GHG) data (2019); Our World in Data Emissions by Sector (2020); BCG analysis

Figure 1: Six industries alone account for almost three-quarters of the 7.5 billion tonnes of public procurement emissions

The data tells the story:

SCOPING THE CHALLENGE. As noted, public procurement is responsible for releasing 7.5 billion tonnes of CO2e into the atmosphere every year, or 15% of total global GHG emissions. The vast majority of these emissions – up to 70% of the total – stem from the activities of just six industries: defence and security, transport, waste management services, construction, industrial products and utilities (see Figure 1).

The burning of fossil fuels in public transport and defence and security activities is responsible for almost all of public procurement's Scope 1 emissions – as much as 20% of all the emissions for which governments are responsible. Its Scope 2 emissions – the purchase of electricity from the utility industry to run operations – makes up 12% of the total. Upstream Scope 3 emissions – those generated by the companies from which it procures the goods and services it needs – make up the rest, as much as 68%.

Government-funded construction activities, for example, are responsible for up to 17% of total procurement-related emissions, and 4% of that total comes just from making the cement needed for government construction projects. The defence and security industry contributes approximately another 25% of total emissions, mainly through the burning of fossil fuel and the manufacturing of the iron, steel and other materials used to build the defence- and security-related goods that governments buy from radios to submarines (see Figure 2).

These purchased goods and services cost global governments a total of $11 trillion each year, or 13% of global GDP. This amount should give procurement officials considerable influence over the industries they buy from, especially those that are mainly dependent on public procurement. In the defence and security industry sector, 95% of revenues come from public procurement, for example, 60% for waste management services and 25% for the construction industry (see Figure 3). The green demand signals emanating from public procurement activities should significantly impact these sectors.

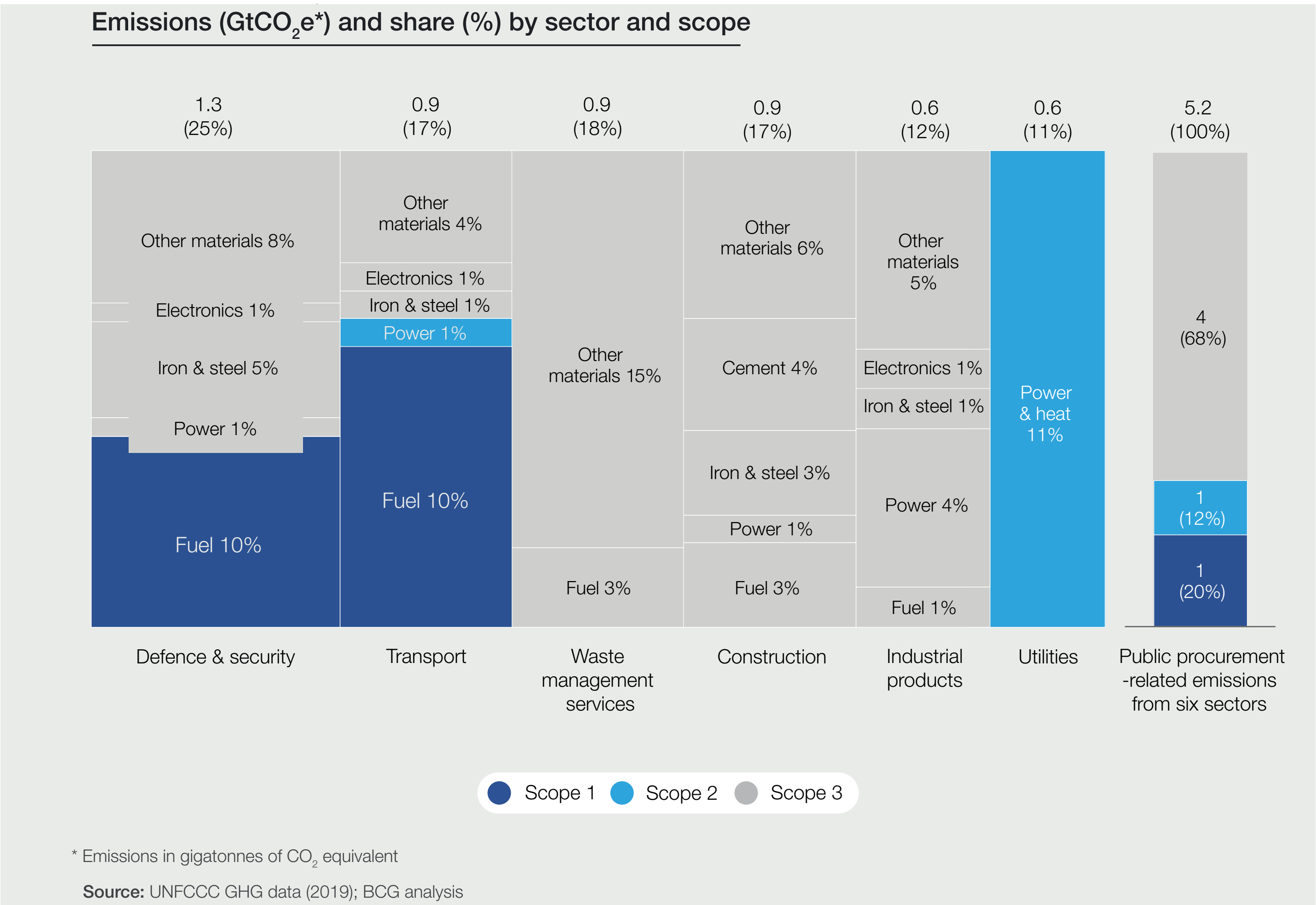
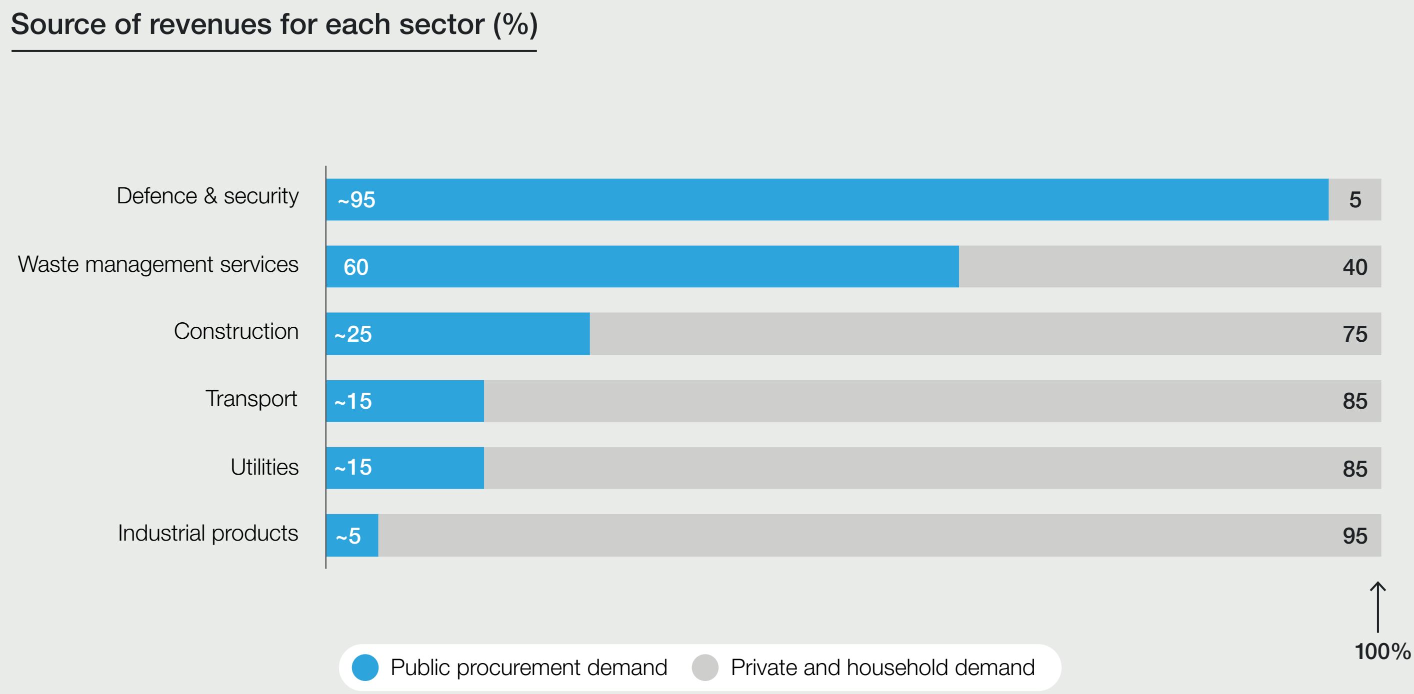


Figure 2: Scope 3 emissions make up two-thirds of the public procurement-related total



Source: US census monthly construction spending (Oct 2021); France public employment (2020); opentender.eu; sector expert interviews; BCG analysis

Figure 3: Public procurement has a great deal of influence, especially over the defence and security, waste management services and construction sectors

THE GREEN ECONOMY. Assuming that public procurement is responsible for 15% of global GHG emissions, its efforts to promote green practices in its operations and through its procurement practices should trigger about $4 trillion of private sector investment needed to reach net-zero emissions by 2050 (see Figure 4).

The majority of these investments will likely be made in the next decade.

This procurement-driven investment activity, in turn, is expected to be responsible for the creation of around 3 million net new jobs by 2050 as the number of jobs in fossil fuel-driven sectors like oil and gas and manufactured goods declines.

That's assuming that total global green investment is sufficient to keep global warming well below the Paris Agreement goal of 2°C.

And the private investment and new jobs triggered by greener public procurement, taken together, will boost global GDP by around $6 trillion by 2050, according to estimates – a significant proportion of the green economy's total GDP of $70 trillion. The additional jobs created through investment in wind farms, for example, will increase both consumption and tax revenues, boosting GDP further.

The social cost of carbon. Carbon emissions and the global warming they are triggering are inflicting huge costs on society across virtually every aspect of life. These include the cost of changes in crop yields, adapting to sea level rise, redesigning water management and heating and cooling systems, and increased medical expenses, among others.
The social cost of carbon increases as the amount of carbon released into the atmosphere increases and is forecast to reach $115 per tonne of CO_2e by 2050.

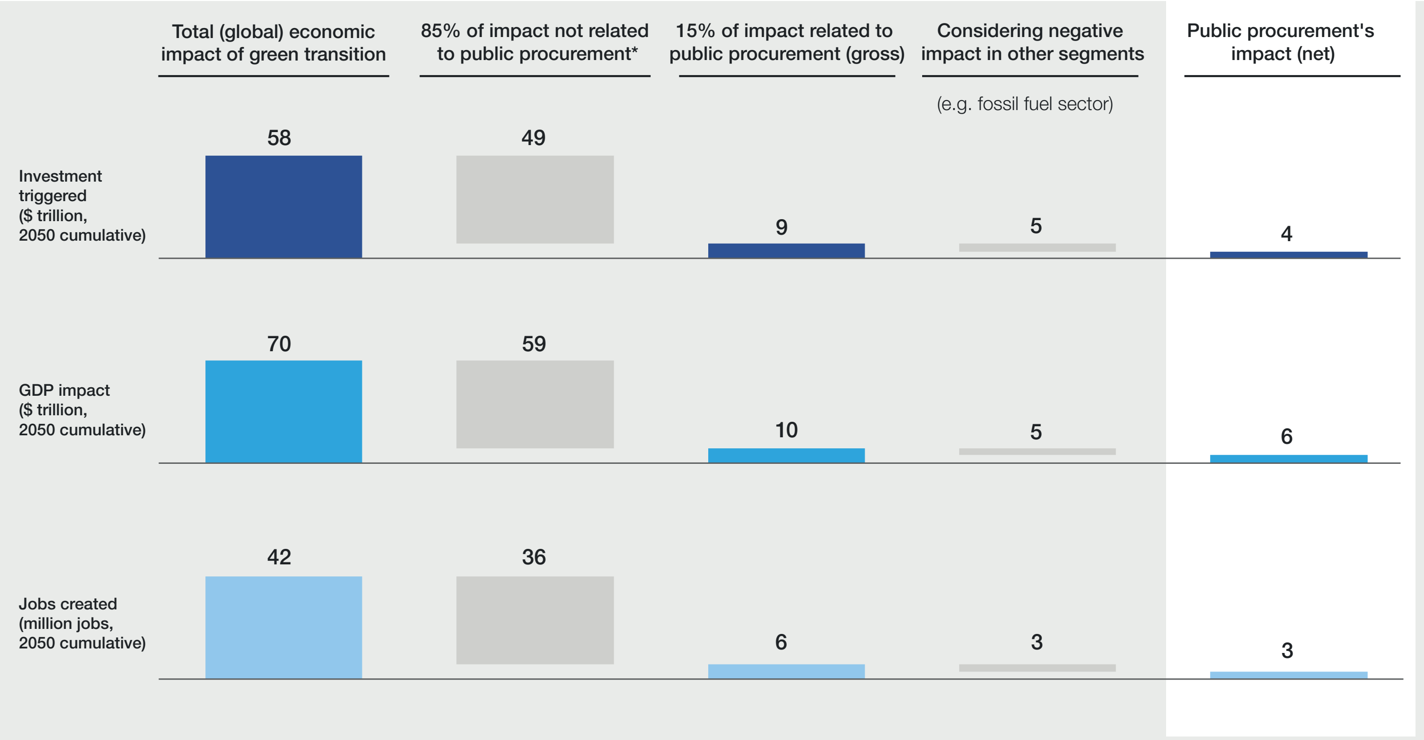
Suppose global public procurement succeeds in decreasing all of the 15% of carbon emissions it is responsible for by 2050. In that case, the cost of GHG emissions to society will be lower by as much as $930 billion annually.

LEADING BY EXAMPLE. The number of private companies pledging to reduce their carbon footprints is rising rapidly; more companies made commitments in just the first ten months of 2021 than in all the previous years combined.

With the influence they wield, government procurement functions can help show many more companies, in every industry, the way forward.

3. FACING THE CHALLENGES

Procurement officials must overcome several challenges in their efforts to reduce their organisation's carbon footprint: cost, complexity, competing priorities and poor data transparency.



* Public procurement's economic impact is determined by applying public procurement's 15% share of global emissions to the total impact

Source: International Renewable Energy Agency, *World Energy Transitions Outlook* (2021); BG analysis

Figure 4: Green public procurement can trigger private sector investment, provide economic stimulus and create new jobs

The rewards of greener public procurement are considerable, but reaping them will take a substantial effort on the part not just of public agencies, policy-makers, regulators and procurement officials, but also the companies in the industries that provide the goods and services governments require.

The cost of greener procurement is just one of the challenges. Others include the bureaucratic complexity and decentralised structure of public procurement organisations and activities, the politics inherent in prioritising green procurement in the light of other governmental obligations and needs, and the lack of data covering procurement emissions baselines and targets. While these challenges are indeed significant, they can be overcome. Doing so will take a strategically astute and carefully organised effort from government officials to keep global warming to less than 1.5°C and to maintain the willingness to pull all the decarbonisation levers available.

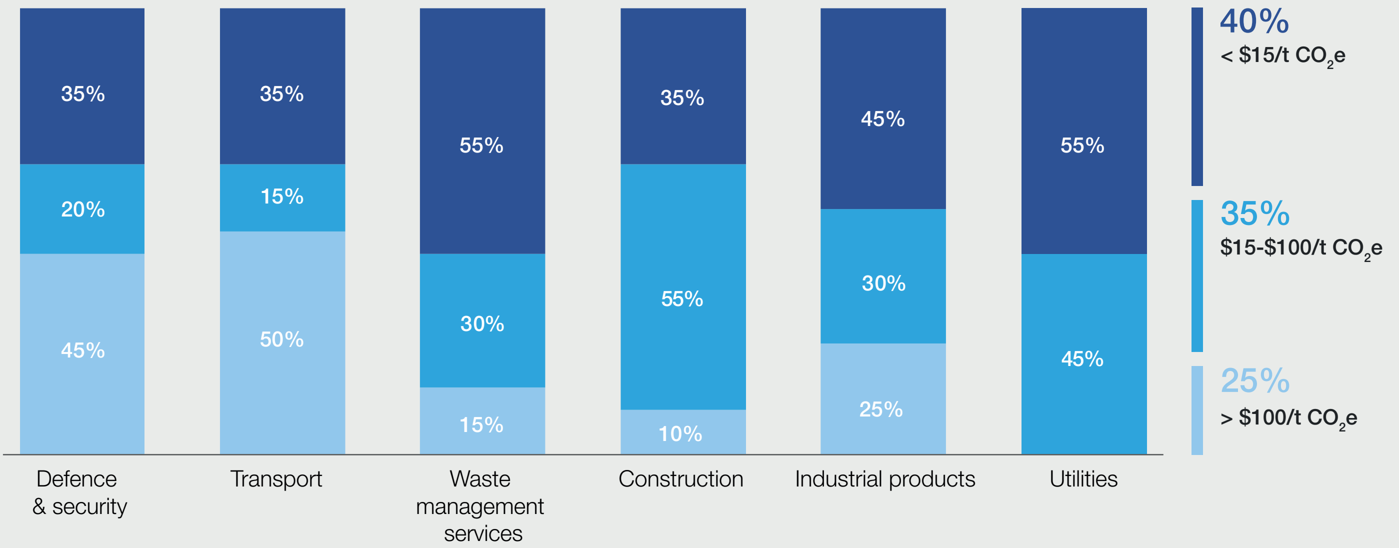
COSTS. The technologies needed to decarbonise the goods and services that governments procure require significant private sector investments, so reducing the GHG emissions for which public procurement is responsible will increase the cost of public procurement. The critical question is, by how much?
That, of course, depends on the various abatement levers available to governments and the industries they deal with. By aggregating the abatement potential of the critical levers for each of the six sectors and then sorting them by cost, we estimate that, while the amount varies depending on the industry, 40% of public procurement-related emissions can be decreased for less than $15 per tonne of CO2e (see Figure 5).

Altogether, we expect that the efforts of the world's governments to reach net-zero emissions will increase procurement costs by between 3% and 6%.

How did we arrive at this figure? We estimated each primary sector's share of public procurement emissions and its share of total public procurement spending. We arrived at the resulting overall price impact in dollars by calculating the price impact of reaching net-zero for each sector (see Figure 6).

By far, the highest cost will involve the decrease of emissions from the fuel used in the defence and security and transport sectors, which will increase fuel prices by up to 70% by 2050. As the industry reaches net-zero, however, the

Cost of abatement by key sectors (%)



* Carbon dioxide equivalent

Source: Sector expert interviews; World Economic Forum and BCG, *Net-Zero Challenge: The supply chain opportunity* (2021)

*Figure 5: 40% of emissions can be decreased at the cost of less than $15 per tonne (t) of C02e**

Global view

	Share in public procurement's emissions	Share in public procurement's spend	2030 product price impact* (%)	Public procurement budget impact ($)
Defence & security	~17%	15-20%	7-9%	$100-140bn
Transport	~12%	5-10%	23-25%	$80-120bn
Waste management	~12%	2-5%	10-12%	$40-60bn
Construction	~12%	20-25%	1-3%	$40-60bn
Industrial products	~8%	5-10%	1-3%	$20-40bn
Utilities	~8%	2-5%	7-9%	$5-15bn
Total	**~69%**	**50-75%**	**3-6%**	**$300-450bn**

* Price impact in % based on US baseline for 2021 – variations to be expected for other countries ; price impact based on average abatement cost by procurement category, adjusted to reflect 2030 costs, assuming similar costs between 2030 and 2050 and applied to projected emissions in 2050. The total 2030 product price impact (%) is the sum of each category's 2030 product price impact weighted by the respective share in public procurement's spend.

Source: BCG analysis

Figure 6: Net-zero goals can be achieved with a 3% to 6% "green premium"

increase in construction costs will raise costs by just 1% to 3% by 2050, adding between $40 billion and $60 billion to global public procurement costs.

The increased cost of green procurement can be seen as a "green premium", providing suppliers with the funds to invest in the technological innovation needed to help them decarbonise. This approach is an alternative to instituting a carbon tax, incentivising suppliers to decarbonise their goods and services to avoid the tax.

DECENTRALISED BUREAUCRACY. As a rule, public procurement in most countries is highly decentralised, making it challenging to devise coherent strategies for decarbonising procurement across all levels of government – an additional challenge for governments in their efforts to lower their carbon footprint. On average, less than half of 2019 public procurement spending in OECD countries occurred at the federally centralised level.

And the range is wide: while New Zealand spends more than 80% at the federal level, Canada spends just 12% (see Figure 7). This is especially true regarding purchases from the construction and waste management services sectors, though less so in defence and security, where procurement is typically more centralised.

Decentralisation also adds significantly to the overall complexity of procurement activities in most countries. Public procurement processes are inherently complicated and frequently inefficient. And while procurement policies are often established at the federal or state level, the actual procuring of goods and services is likely to be carried out by a range of public agencies at different levels of government.

COMPETING PRIORITIES. Government budgets are tight in just about every country worldwide, so the added costs of green public procurement will have to compete with other governmental priorities. This is especially true at the local level, where budgets are exceptionally constrained, and most public funding already goes to such critical priorities as education and health. Therefore, procurement officials at every level of government must engage in discussions about the fiscal trade-offs that may be necessary when increasing purchases of greener goods and services.

POOR TRANSPARENCY. A final challenge lies in the lack of transparent

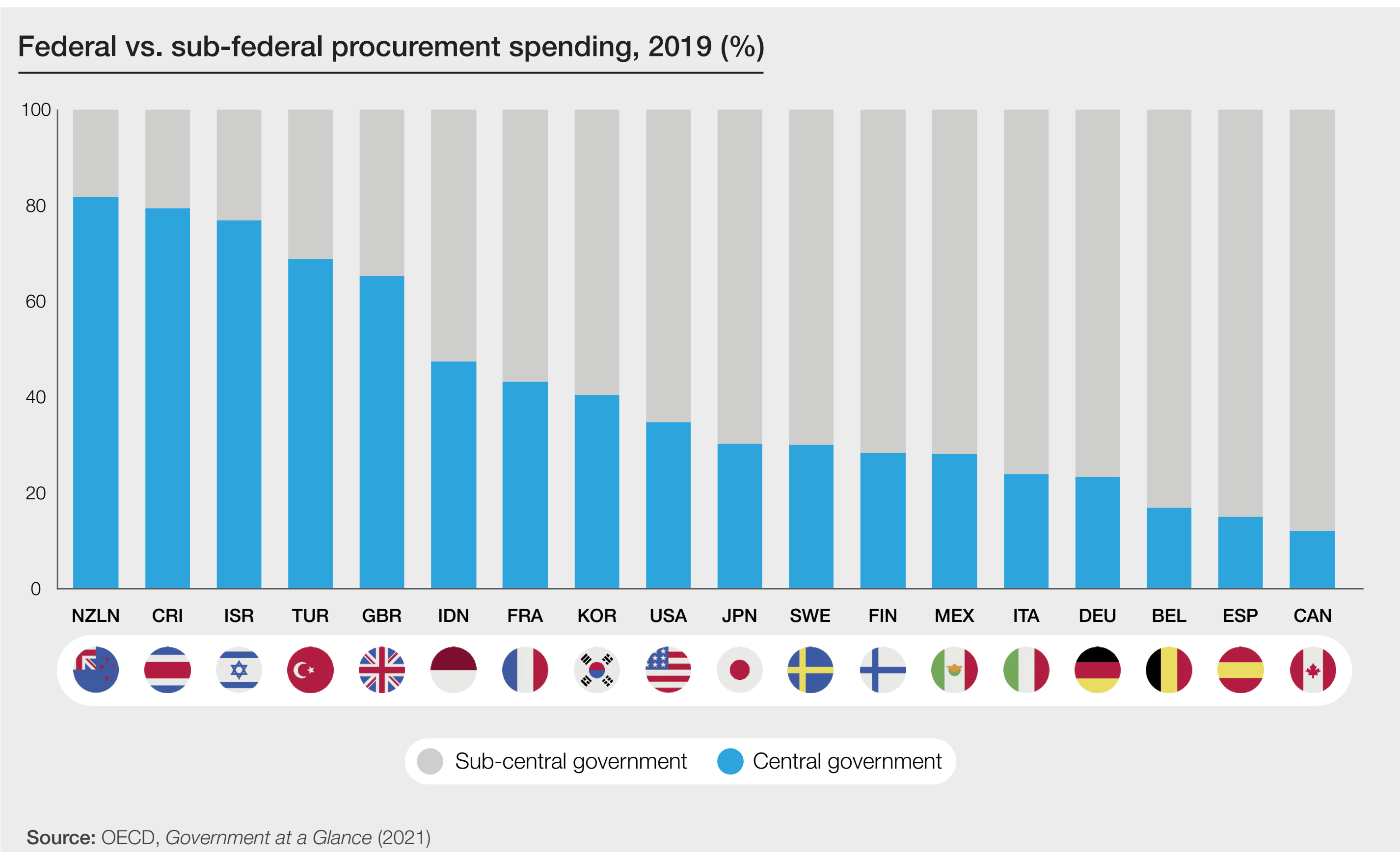


Figure 7: Most government procurement spending takes place below the federal level

data on public sector emissions. While our estimates offer an overview of the opportunity available to governments in reducing their carbon footprint, the devil, as they say, is in the details. Complete and transparent datasets covering emissions resulting from public sector operations and procurement are generally lacking, making it difficult or impossible to set emissions baselines, define realistic, achievable decarbonisation targets, compare data across products, sectors and countries, and track progress. Discrepancies between different official sources of data only add to the difficulty.

4. TEN STEPS TO GREENER PUBLIC PROCUREMENT

Achieving net-zero emissions will require a systematic approach to the task, from determining its scope to working with suppliers to transforming how procurement organisations operate. The key to successful green public procurement lies in facing the inevitable challenges – cost, prioritisation, transparency and complexity – and devising solutions and processes that will help public procurement organisations reduce their carbon footprint methodically and systematically.

Our ten-step framework for reaching and maintaining green procurement goals carries procurement organisations through from baselining current emissions and future goals, optimising for climate-friendly goods and services and working with suppliers, to engaging with industry ecosystems to promote decarbonisation and enabling procurement organisations to meet their climate goals (see Figure 8).

THE KEY IS COLLABORATION: reaping the full benefits of green public procurement will only happen if all stakeholders across the entire public procurement ecosystem work together to set and reach their net-zero goals. The ten steps discussed below can be applied to procurement functions at every level of the public sector, from the federal government to small local procurement offices, and can be adapted to country-specific situations. EU countries, for example, could collaborate regionally, while signatories to the World Trade Organization's agreement on government procurement should ensure continued adherence to the agreement.

4.1 STEPS 1 AND 2: CREATE TRANSPARENCY IN BASELINES AND TARGETS

No effort to decarbonise public procurement can proceed without a clear understanding of the current emissions status for which the procurement function is directly and

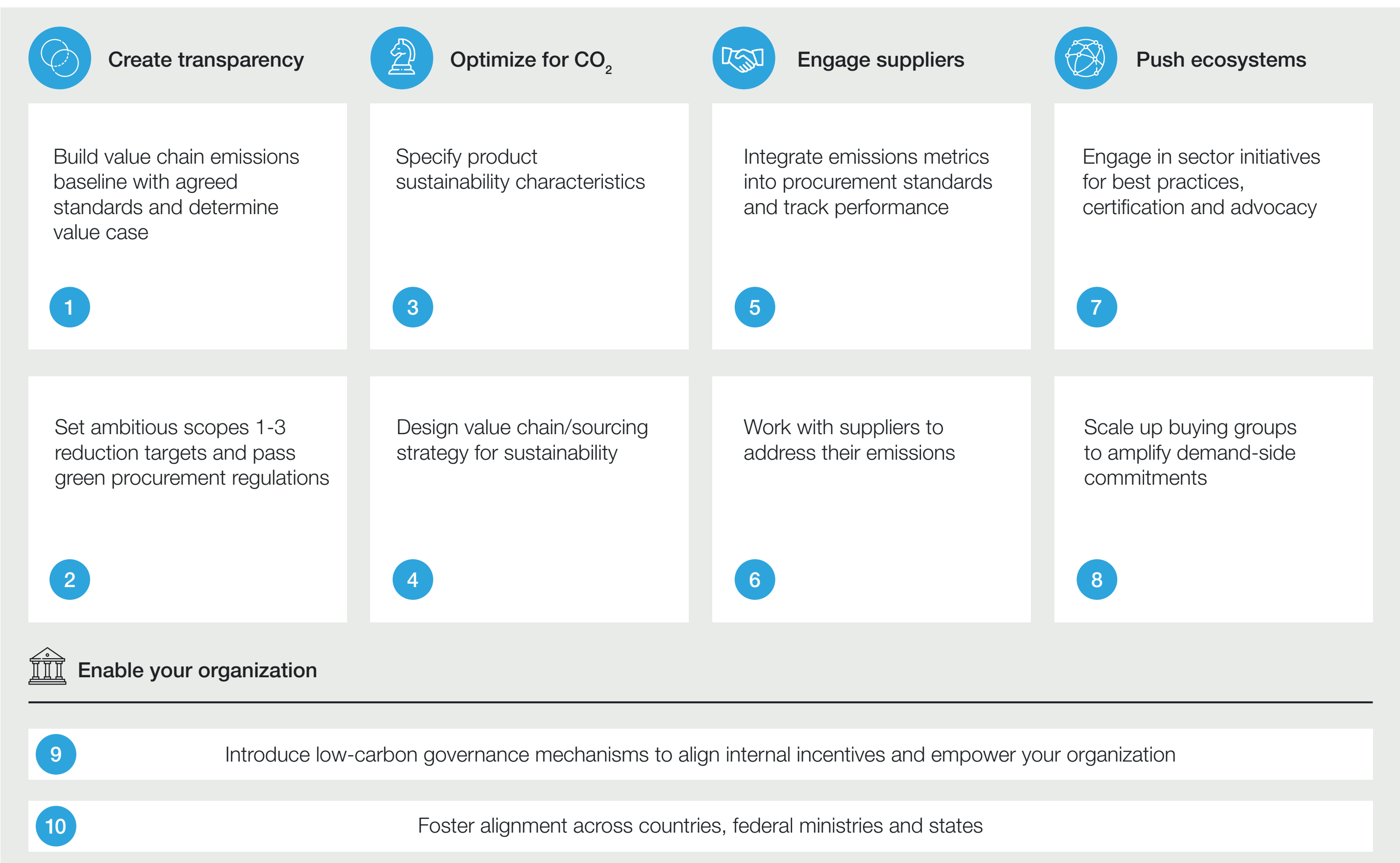


Figure 8: Ten steps to accelerate public procurement decarbonisation

indirectly responsible. This effort will enable procurement officials to gain a complete picture of where they stand and measure the costs and value inherent in their decarbonisation efforts. Once the baseline and decarbonisation value proposition has been determined, procurement functions can move to set their reduction targets for all three emissions scopes. This is also the time to devise and enact regulations promoting public procurement's net-zero goals.

BOX 1 - RAPID DATA COLLECTION

In 2017, the Dutch Ministry of Infrastructure and Water Management decided to create a methodology for computing the sustainability impact of its procurement policies using readily available data. The study focused on eight product categories:

- Transport (including vehicles, transport contracts and services)
- Energy (including gas, electricity and solar panels)
- Occupational clothing

The assessment was carried out in three steps:

1. Tenders for each category published in 2015 and 2016 were identified and collected from TenderNed, the country's statewide electronic tendering platform then reviewed to ensure relevancy. A sample of ten representative tenders was selected for each category. The samples were searched for sustainability criteria to determine each contract's economic value. Interviews were conducted with contract managers to determine the result of each tender: i.e. how much of the product or service was finally acquired and used, whether sustainability criteria were respected and other factors.
2. Products were qualified as "green" for each category using the minimum Dutch green procurement requirements. For example, "green" vehicles included any gas-powered, hybrid or electric vehicle that complied with the Euro 6 standard. The environmental benefits of each product were estimated in terms of CO_2e reduction, with other benefits, such as savings in fossil-based raw materials or avoidance of other pollutants, also assessed where relevant.
3. Results were then extrapolated based on the sampling in economic terms compared with the entire procurement category. This allowed Dutch procurement officials to determine each category's environmental and economic impacts.

COLLECT AVAILABLE DATA. Given the urgency regarding climate and carbon emissions, it is essential to balance the quality of the data gathered to establish the baseline and the speed at which it is collected. As such, countries should strive to create a baseline with readily available data to develop an initial understanding of the challenge at hand (see Box 1).

The baseline can then be refined with the collection of additional data. Procurement officials should begin by mapping the procurement supply chain and identifying suppliers for each focus area. They should then collect data from suppliers covering their emissions related to raw materials, energy and fuel, upstream and downstream transportation and other relevant factors. Finally, they should estimate the total Scope 3 emissions from each supplier, using industry benchmarks and calculating standard emission factors over each product's entire life cycle, from the supply of raw materials to disposal and recycling.

AGREE ON COMMON METRICS. The current lack of harmonisation and granularity in procurement data and non-standardised computation methods often prevent a good understanding of the baseline starting point, a clear definition of the objectives and the ability to track progress accurately. Therefore, governments need to agree internally on common, user-friendly frameworks of metrics that leverage existing standards (such as those established by the International Organization for Standardisation or the European Committee for Standardization), using standard assessment tools, such as Environmental Product Declarations (EPDs) for each sector, in concert with industries and decarbonisation experts.

A workable framework should provide a set of objective and straightforward measures built on existing standards, with the option to add further details once widely adopted (see Box 2). It should be developed in concert with the industry and third-party certification bodies. It should encompass the entire life cycle, from the supply of raw materials to disposal and recycling, and the entire value chain, including subcontractors. And it should complement current certification schemes to provide alignment and integration.

A complete and well-prepared framework will give all stakeholders a better understanding of the current baseline, its principles, and the methods for tracking progress. This, in turn, will encourage alignment across the entire value chain, from the different third-

BOX 2 - A GREEN BUILDING CODE

The EU's Level(s) framework for the construction industry is a comprehensive guide that uses existing standards to provide a common language for ensuring the sustainability of all buildings, enabling certification providers, legislators and companies to align legislation and policies governing construction standards, building practices, materials and environmental sustainability throughout a building's life cycle.

It was created in collaboration with the industry and outside experts and refined and tested through more than 80 projects across 21 countries. Most major European construction certification standards bodies supported its development and planned to align with the Level(s) framework.

The standards on which it is built include Environmental Product Declarations EPDs independently verified and registered documents that communicate transparent and comparable information about the environmental impact of a specific product over its entire life cycle.

Created and registered by EPD programme operators using a framework based on internationally recognised ISO standards, EPDs are emerging as a critical basis for common public procurement metrics in construction, as they allow for comprehensive and verified third-party reporting of environmental impacts. Required indicators of green compliance include measures of the impact of GHG emissions, such as acid rain, ocean acidification, the depletion of fossil fuels and other effects.

party certification bodies to the private suppliers and subcontractors. And it will enable comparisons of baselines, targets and progress nationwide, across geographical areas and for specific parts of the procurement portfolio. Ultimately, the framework will support more vital collaboration and better decision-making among all stakeholders.

IDENTIFY HOT POINTS. Procurement officials should then gather detailed data from suppliers in each industry to assess their specific contributions to the procurement function's Scope 3 emissions.

This data can then be arranged as a matrix, indicating the emissions intensity of the materials used by each supplier within a particular industry, such as construction (see Figure 9).

This will enable the identification of particularly heavy-emitting suppliers. Procurement officials can then plan to work with these suppliers to form an action plan to lower their emissions.

MAKE A CASE FOR VALUE. Once the complete baseline is created for each procurement purchase category – and ultimately for all procurement – countries can build the value case for implementing their net-zero procurement programme. This should include the reduction in total emissions needed to reach net-zero and such value-based benefits as the amount of new private sector investment and net new jobs created, the increase in GDP and the annual social cost of carbon avoided.

SET TARGETS. A standard set of clear, high-level abatement targets at the country level will be needed to develop a workable decarbonisation strategy.

This will involve several steps:

- Generate a view of the forecasted decarbonisation trajectory based on the baseline.
- Set 2050 and interim 2030 targets following the Paris Agreement and align with Nationally Determined Contributions (NDCs), leveraging targets as set by the Science-Based Targets Initiative (SBTs), which are calculated to limit global warming to 1.5°C for each sector.
- Use a flexible approach to achieve the targets, determining the corridor of possible pathways for reaching them by defining the measures required to reach them, their timing and cost, in consultation with suppliers and experts (see Figure 10).
- Over time, refine intermediary milestones and iterate on measures as needed, based on ongoing assessments of current progress and the development of technological improvements potentially affecting decarbonisation levers and goals.

Figure 11 illustrates the target definition process and how governments can leverage SBTs to ensure their high-level targets align with the Paris Agreement's goals.

For example, to determine the construction sector's overall 2030 emissions reduction target, governments first need to identify the materials that generate the sector's emissions and the percentage of the total emissions each material is responsible for.

Then they need to identify the SBT for each material to know what can be realistically abated. Cement, for example, represents 25% of the construction sector's total emissions, 23% of which can be scientifically targeted for

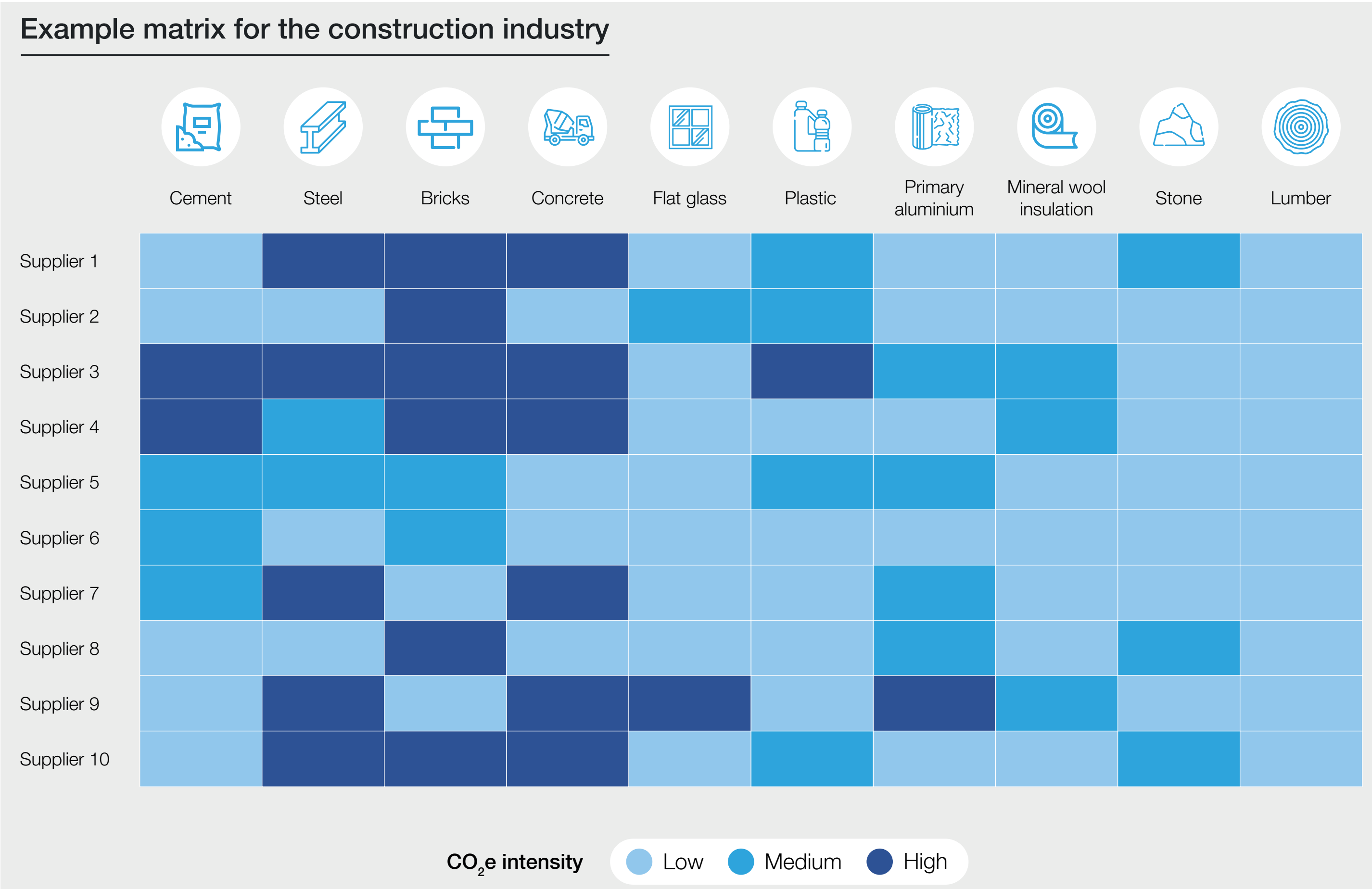
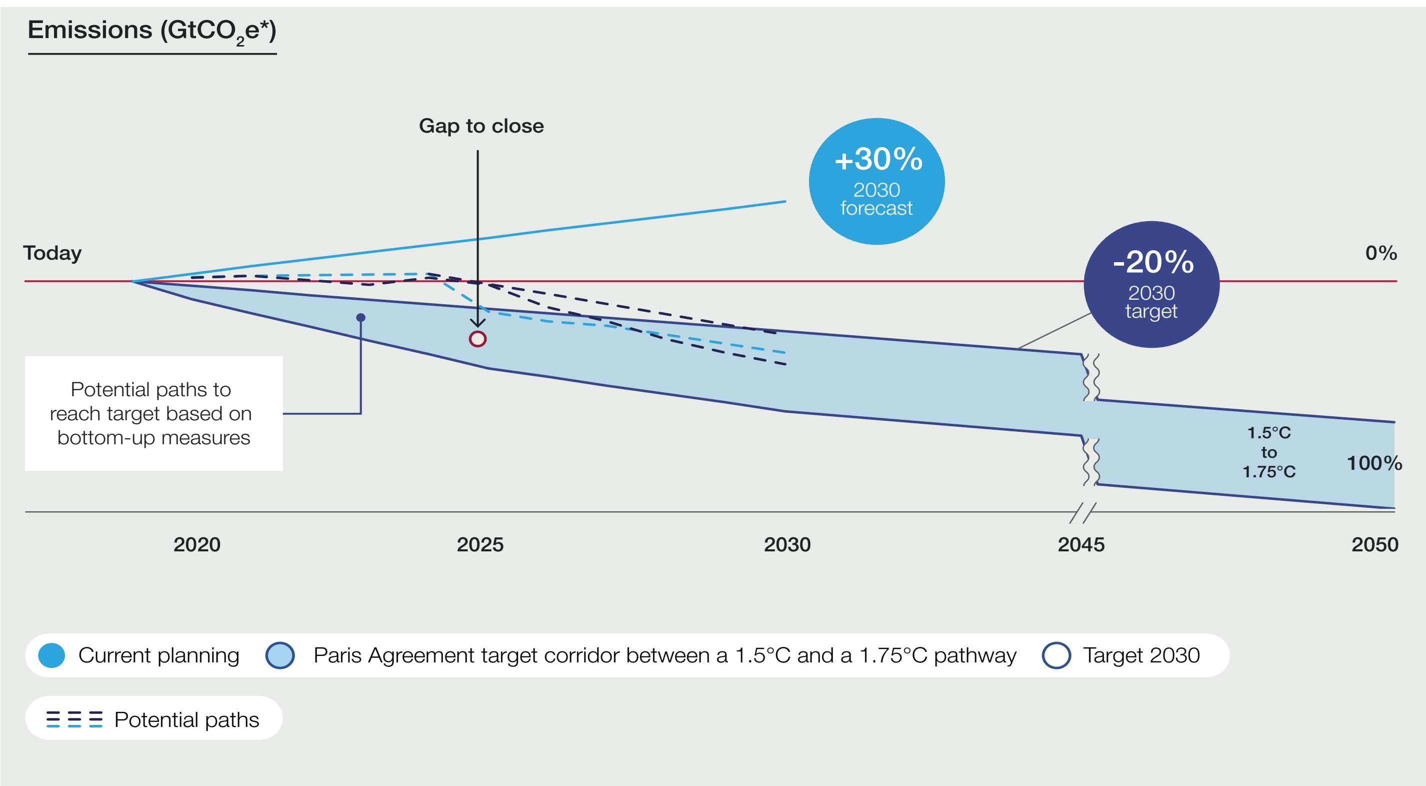


Figure 9 - A supplier and materials matrix helps identify heavy-emitting suppliers



* Emissions in gigatonnes of CO_2 equivalent

Figure 10: Starting from the baseline, set realistic emission targets by leveraging science-based targets and adopting a flexible approach

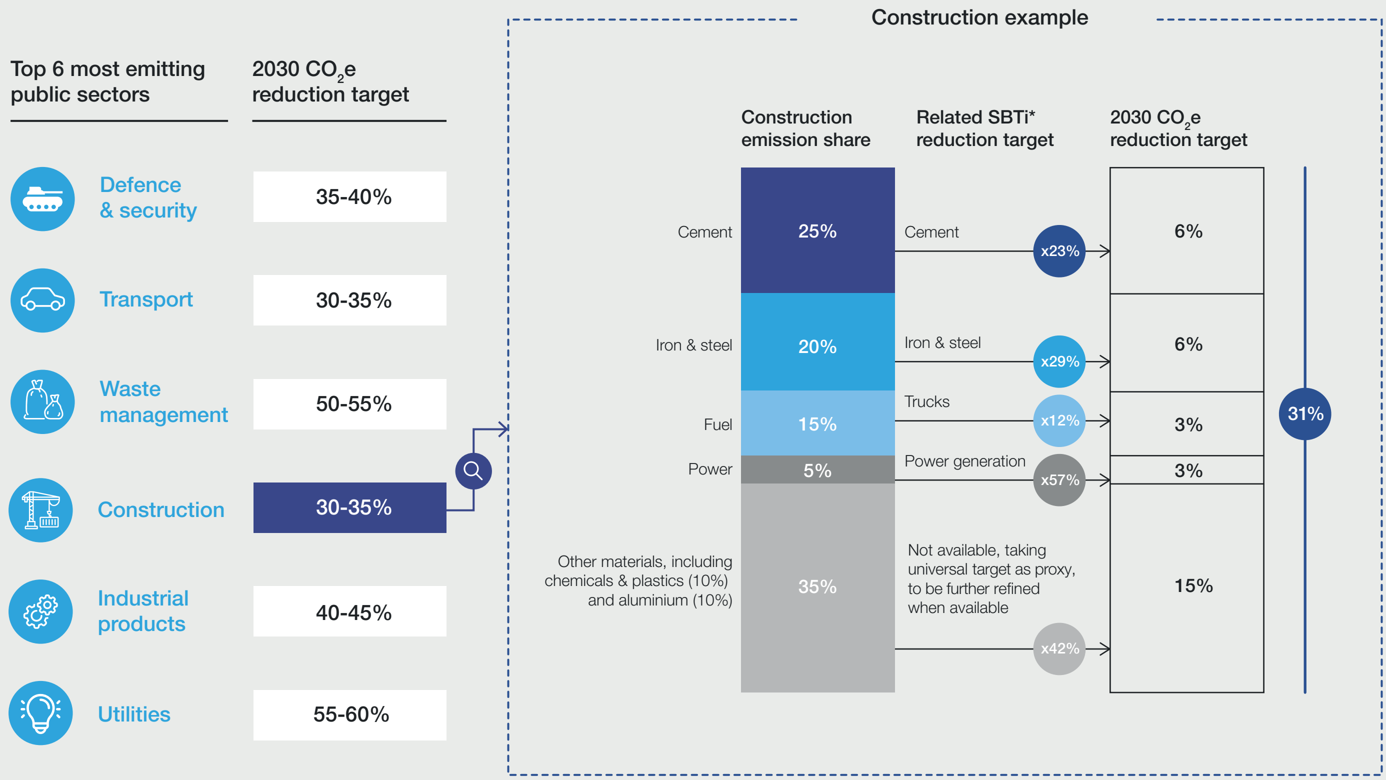


Figure 11: Establish realistic emission reduction targets reflecting the Paris Agreement goals and leveraging science-based targets

decrease. Aggregating the targets for all of the sector's materials results in a single target for the entire sector of 31%.

PASS SUPPORTING REGULATIONS. A workable framework, accurate baseline and clear targets will give governments the evidence needed to set policies and enact regulations promoting green procurement (see Box 3). One such regulatory approach is Buy Clean, which aims to incorporate the requirements for purchasing low-carbon construction materials into government procurement.

To achieve this goal, Buy Clean sets the maximum acceptable global warming potential limit for select construction materials such as cement, steel and glass. The State of California enacted the first Buy Clean policy in the US in 2017. Now policies are also being explored at the federal, state and local levels.

4.2 STEPS 3 AND 4: OPTIMISE PRODUCTS FOR GREENHOUSE GAS REDUCTION ACROSS THEIR LIFE CYCLE

Once the baseline is established and realistic targets are set, procurement officials will need to develop a roadmap with suppliers that clearly outlines the reduction levers to be pulled to reach them. Factors to consider in designing the roadmap for the optimal reduction in CO2e emissions include cost, impact and feasibility.

REDUCTION LEVERS. The first step in building the roadmap is developing a complete list of potential emission reduction levers covering government operations and supplier activities and materials.

For example, the range of potential levers in procurement from the construction industry should begin with the design and development of construction projects, considering the insulation and other materials to be used, energy consumption and the end-of-life re-use of all materials. The list of potential levers should then be extended to include the materials used and how they are manufactured, the transport of materials to the building site, the construction process itself and the operation of the building, once completed (see Figure 12).

COST AND IMPACT. From the long list of potential levers, procurement officials should then determine the balance between the cost of each lever and its impact on emissions levels. Abatement curves can guide for making these critical cost-benefit analyses.

For example, reducing materials waste at construction sites can reduce costs while lowering emissions. Companies can switch to renewable energy at a reasonable cost, where available. In contrast, the use of carbon capture and

BOX 3 - FULL RANGE OF CLIMATE REGULATIONS NEEDED

In addition to promoting greener public procurement, governments will need to enact additional cross-sector and sector-specific emissions reduction regulations to deliver on their net-zero ambitions.

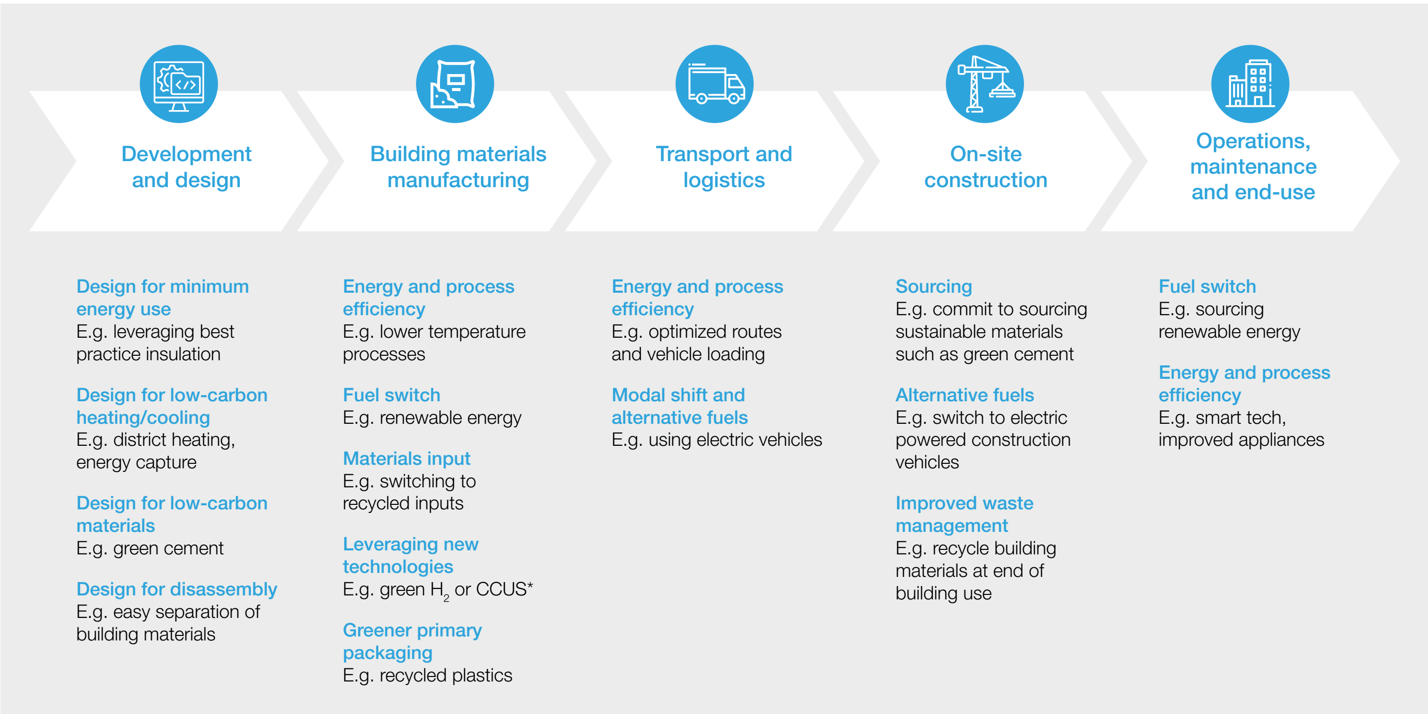
The most effective mechanism is a meaningful price on carbon emissions. Widely recognised as the most impactful and cost-effective way to decarbonise across economies,15 carbon pricing is endorsed by every major multilateral institution, including the International Monetary Fund, the UN and the World Bank.

However, while carbon pricing is regarded as a practical and necessary lever, it is unlikely to be sufficient. Other cross-sector levers include measures to prevent carbon leakages, such as a carbon border adjustment tax and eliminating subsidies on fossil fuels. Sector-specific regulations could include targets for the use of renewable energy, incentives for the purchase and use of electric vehicles and industry-specific efficiency standards.

storage technologies in manufacturing would be far more expensive – at least until the technology is further developed and scaled up (see Figure 13).

LEVER FEASIBILITY. In addition to the cost and emissions reduction impact, procurement officials will need to consider other factors in assessing the viability of their decarbonisation roadmap. Answers to the following questions, to be worked out in concert with suppliers, will help clarify the factors that can affect the implementation of the roadmap:

- Which peers or suppliers have successfully implemented levers?
- Which levers might conflict with other priorities, such as product performance?
- Which levers are already economically viable today, and which ones will require a more extended payback?
- Which levers require more private sector investment to develop further and scale-up?
- What other capabilities will our organisation and suppliers need to build to enhance our ability to reach our emissions reduction goals?



* Carbon capture, use and storage

Source: BCG analysis

Figure 12 : Procurement of construction materials and services offers a range of potential emissions reduction levers

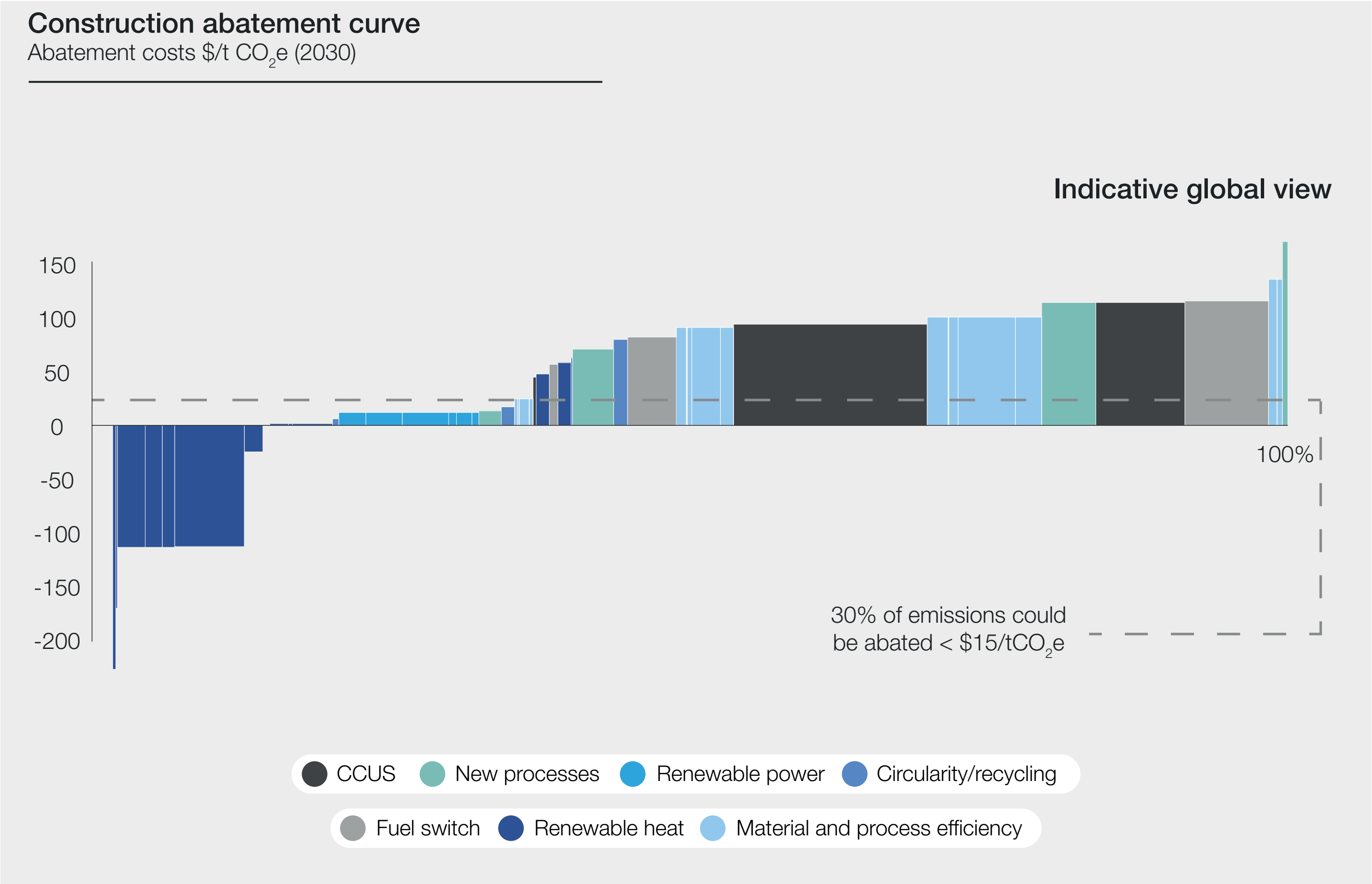


Figure 13: Close to a third of construction supply chain emissions can be decreased for less than $15 per tonne of CO2e.

4.3 STEPS 5 AND 6: DEFINE PRODUCT AND SUPPLIER STANDARDS AND WORK WITH SUPPLIERS

Once procurement officials have identified emissions reduction levers and settled on a roadmap, they must determine the standards with which procurement decisions are to be made and engage directly with suppliers to ensure they meet the new standards and address their own emissions. Working successfully with suppliers will require three critical actions on procurement officials.

DEFINING STANDARDS

Procurement officials must define transparent and sustainable procurement standards covering both their internal operations and the expectations of external suppliers. Standards should cover a full range of products, services and project activities, such as the proportion of power from renewable energy, mandated SBTs for CO2e emissions generated in producing materials such as green steel and green project management goals. And there should be clearly defined consequences for suppliers who fail to meet the standards.

In the US, for example, the Biden administration has proposed a new rule that would require significant suppliers to the federal government to disclose their GHG emissions and climate-related financial risk publicly and set SBTs for reducing them. The rule would also require that the social cost of GHG emissions be considered in procurement decisions. Where appropriate and feasible, it would preference bids and proposals from suppliers with a lower social cost of GHG emissions. The goal is to spend 80% of procurement funds with suppliers that have set SBTs for their Scope 1 and 2 emissions by 2023.

In a similar move, the British government has released new measures as of September 2021 requiring that companies bidding for government contracts worth more than £5 million a year must commit to achieving net-zero emissions by 2050 in their United Kingdom operations. In addition, they must publish carbon reduction plans and provide reporting their Scope 1 and 2 emissions and a sub-set of their Scope 3 emissions.

ASSESSING AND TRACKING SUPPLIERS

Once emissions standards are established, procurement officials need to assess and prioritise their current suppliers concerning their progress in setting and reaching their emissions targets. To do so, they should consider two factors: their capacity to influence specific suppliers and each supplier's ability to meet its targets.

SUPPLIER PRIORITISATION

Officials should rank suppliers across two dimensions: How much is spent with each supplier? And how much does that spending contribute to each supplier's total revenue? The larger the spend and the greater its proportion of the supplier's revenue, the more influence procurement has over that supplier.

SUPPLIER ASSESSMENT

Once the degree of influence over critical suppliers is determined, officials should rank suppliers across several criteria, including standard supplier performance metrics and progress in setting emissions baselines and meeting targets. Standard procurement metrics will likely include product cost and quality, flexibility and others and should be evaluated and compared across the entire supplier portfolio.

Sustainability metrics should include emissions baselines, water and energy use, the amount of waste and a complete analysis of each supplier's commitment to sustainable emissions goals and strategy for meeting emissions targets. For example, suppliers could be ranked regarding the relative ambitiousness and specificity of their sustainability goals and their progress in meeting them. Do they specify SBTs in their net-zero goals? Are those goals aligned with the Paris Agreement's 1.5°C ambitions? And do they report progress to organisations such as the Climate Disclosure Project?

SUPPLIER CRITERIA

Once the priority suppliers are determined and qualified according to their contribution to the procurement organisation's ability to meet its own emissions reduction goals, all contract specifications should be framed according to specific standards and targets.

Assessment criteria and the scoring system should be sufficiently detailed without overly prescriptive. Procurement officials could choose one of two types of assessment criteria:

- **RESULTS-BASED CRITERIA.** Criteria specify expected performance levels such as "30% more efficient buildings" or "10% less CO2- intensive construction activities". Results-based criteria are generally simpler to define and allow more innovation since only the results are stipulated. However, they may be more time-consuming for the reviewer to evaluate, as the proposed solutions will often vary for each bidder.
- **MATERIALS- AND METHOD-BASED CRITERIA.** Criteria specify the types of materials and methods to be used, such as banning fossil fuel vehicles or delivering supplies monthly versus a daily basis. These criteria are easier to assess and compare but must be used carefully to avoid being too prescriptive and preventing innovation. Once the criteria are chosen, procurement officials must decide whether each criterion should be a requirement for supplier qualification or part of the system for awarding contracts.
- **REQUIREMENTS.** This involves passing or failing specific suppliers based on their compliance with specific criteria, such as excluding any bidder using fossil fuel-based vehicles. This method allows procurement officials to easily set minimum requirements and filter out bidders without going over all the criteria. It can be applied to large contracts with a broad set of requirements. However, it risks becoming too restrictive and stifling innovation on suppliers.
- **AWARDS.** This involves actively judging potential suppliers based on their compliance with specific criteria. This system provides bidders with the opportunity to improve their compliance with the criteria and encourages them to adopt new emissions reduction technologies and methods without being overly restrictive. Bidders might get points for using eco-friendly steel, for example, thus increasing their chances of winning the contract. However, the award criteria must be carefully constructed, specific enough and sufficiently comprehensive to reflect all emissions reduction priorities.

Procurement functions frequently use a combination of the two methods. For example, the Maltese government sent out a tender for constructing a school building that would be energy self-sufficient through on-site renewable energy production.

The tender included minimum energy and water efficiency requirements, while additional points were awarded for increased performance. The winning bidder installed solar panels and wind turbines near the school, producing a total of 35,000 kWh over the first ten months. The combination of requirements and awards enabled the agency to set minimum criteria while encouraging bidders to deliver more, and the result-based criteria gave bidders the freedom to innovate.

In another example, the Swedish Transport Administration (STA) requires that contractors use specific materials that comply with predefined performance and climate-related criteria. By requiring specific materials, the agency can quickly assess compliance. The STA also uses a reward/penalty system. The monetary reward/penalty system gives suppliers an added incentive to meet the requirements, even after signing the contract. Each tonne of CO2e avoided beyond the emissions reduction requirement is rewarded financially, and more significant penalties are penalised if the requirement is not met.

WORKING WITH SUPPLIERS

The key to a successful engagement involves establishing clear guidelines on accountability for compliance and incentives and an agreed understanding of the consequences of non-compliance.

Fostering a long-term, mutually beneficial partnership mentality is critical in ensuring that procurement functions and suppliers meet climate-related goals. Therefore, procurement officials should establish a long-term relationship with their suppliers and provide them with the support they need to succeed, including training, technology, financing and innovative products.

Large and long-term engagements can create added incentives for suppliers to meet climate goals. For example, framework agreements can be designed to allow multiple call-off contracts to be awarded without repeating the entire procurement assessment process. Such pooling of demand over time and across different government authorities for goods and services from single suppliers will increase the supplier's incentive to offer environmentally enhanced solutions and enable it to recoup any private sector investments needed to meet contracted emissions reduction requirements (see Box 4).

4.4 STEPS 7 AND 8: DEVELOP THE WIDER ECOSYSTEM AND CREATE BUYING GROUPS

In addition to working with individual suppliers to set and reach emissions abatement goals, procurement organisations could opt to work together and with industry coalitions to encourage the use of best practices in decarbonisation, certification of companies and materials, and the promotion of net-zero activities and goals. They could also work through buying groups to help create markets for low-carbon products. Cross-industry examples include the Industrial Deep Decarbonization Initiative (IDDI), the First Movers Coalition, the Climate Group, Race to Zero and C40 Cities (see Box 5).

For example, the IDDI,22 launched in 2021, is a global coalition of public and private organisations working to increase demand for low-carbon industrial materials. In conjunction with COP26, the IDDI announced its Green Public Procurement programme, intended to align its member governments' procurement activities to further create markets for low-carbon industrial products.

The idea is to use governments' purchasing power to trigger a thriving, greener steel and concrete market.

The IDDI's goal is to have at least ten countries commit to purchasing low-carbon concrete and steel within the next three years. Its current members, including the United Kingdom, Canada, Germany, India and the United Arab Emirates, have also pledged to disclose the amount of CO2e emitted in their major public construction projects by 2025 and reach net-zero emissions in all their construction projects by 2050.

Other examples of organisations developing public-private partnerships include the Mission Possible Partnership, an alliance of business, finance and policy leaders focused on promoting the decarbonisation of the world's highest-emitting industries, and the World Economic Forum itself.

BOX 4 - ENGAGING SUPPLIERS

Long-term engagements can create an ideal environment to provide added support to suppliers, a strategy that companies in the private sector have used successfully.

For example, Grosvenor Britain & Ireland, a large property business, estimated that its supply chain will be responsible for 49% of its business-as-usual emissions between 2019 and 2030. As part of the company's strategy to reach net-zero emissions by 2030, it expects those suppliers producing 40% of its Scope 3 emissions to set SBTs and procure energy from renewable sources by 2030. All vehicles supplying its London operations must be electric by 2025.

In support of its suppliers, Grosvenor has published a list of 12 standards that suppliers must abide by, such as "Tackling climate change together", "Sourcing and using material responsibly", and "Eradicating waste". It also offers free training on sustainability and off-site construction and management techniques. It maintains a dedicated reporting system to monitor and map the environmental impact of its supply chain. And it is working with its suppliers to develop action plans in areas where its emissions abatement standards and goals have not yet been met.

BOX 5 - URBAN RENEWAL

C40-Cities is a network of the mayors of nearly 100 of the world's leading cities who have come together to confront the climate crisis. Its goals include reducing emissions by at least 50% for all new buildings, significant retrofits and infrastructure projects by 2030 while striving for at least 30% by 2025 and the use of zero-emissions construction machinery in all municipal projects starting in 2025. Its Clean Construction Declaration initiative encourages relevant construction industry stakeholders to deliver decarbonisation results quickly.

Among the actions the group plans to take in support of these goals:

- Prioritise the use, repurposing and retrofit of the existing building stock and infrastructure across the cities to ensure optimal use before considering new construction projects.
- Require life-cycle assessments (LCAs) of all new projects, including procuring or requiring zero-emissions construction machinery and circular building designs that efficiently use low-carbon materials and other resources.
- Demand transparency and accountability in all projects, including requiring LCAs in planning, processes and building codes, and the public disclosure of LCA data.
- Approve at least one flagship net-zero emissions project by 2025.
- Advocate for and work with regional, national and supranational governments outside the boundaries of their control to take relevant climate action.
- Publicly report every year on the progress its cities are making towards these goals.

4.5 - STEPS 9 AND 10: TRANSFORM THE PROCUREMENT ORGANISATION AND ALIGN ACROSS AGENCIES

In parallel with the effort to assess, qualify and engage with suppliers, procurement organisations must also transform their internal operations and governance processes to align internal incentives, link to their country's NDCs and ensure their climate goals and targets.

To accomplish this, procurement organisations must realign their steering models, individual responsibilities and communications processes, boost their capabilities and upgrade their data and information systems.

STEERING MODEL. The goal of the green procurement steering model is to ensure clear decision rights and accountability across complex organisations and set comprehensive management-level key performance indicators (KPIs) for achieving carbon targets. While every country is different, most procurement policies covering green procurement are led nationally through the Ministry of Environment and the agency in charge of procurement or their equivalents. It is typically the responsibility of the Ministry of Environment to define the green procurement KPIs and related measures.

The agency or agencies in charge of procurement, often ministries of finance, should oversee the procurement budget and determine any trade-offs to be made in light of any added costs of green procurement. Other ministries, including the ministries of health, agriculture and transport, and individual regional government units and research institutes, should share their expertise on specific topics and issues.

RESPONSIBILITIES AND COMMUNICATION.
Procurement organisations face several challenges in implementing new green procurement initiatives. They include a lack of clearly defined and achievable milestones and objectives for measuring progress, poor commitment from leaders, resistance from employees, insufficient funding and poor communication.

Implementing a central green procurement hub at the ministry level can help overcome these challenges by providing a wide-angle view of a government's green procurement efforts and progress and taking an active role in pursuing its emissions abatement goals.

A central hub can help break down communication siloes and boost oversight and discipline while providing leaders with the level of detail needed to successfully manage multiple initiatives, including developing metrics and reports and conflict resolution.

Its task should include setting priorities and timing to mutually reinforce climate initiatives, creating overall programme target roadmaps and helping agency-level procurement programmes to meet their own goals. It should also coordinate efforts to communicate the green procurement programme and its goals to all stakeholders, why it is needed and how people will be affected.

At its best, the active green procurement hub will monitor an organisation's pulse to ensure ongoing commitment to carbon abatement initiatives and help create and maintain a sense of urgency and mission throughout the organisation.

CAPABILITIES IMPROVEMENT. Traditionally, the criteria for public procurement of goods and services have focused on each project's overall price, quality and related risks, and procurement organisations have long optimised these criteria. With sustainability as a critical procurement criterion, procurement officials must significantly increase their organisation's capabilities. Newly needed capabilities include:

- Understanding sustainability standards and goals. What common standards govern climate baselines and targets? What are Scope 1, 2 and 3 emissions, and how can they be tracked? What do terms such as "life-cycle assessment" and "embodied carbon" mean, and how should they be integrated into supplier assessment?
- Setting targets. How should emissions abatement baselines, targets and priorities be determined, and what goals should be set? How should tenders reflect targets without being too loose or too prescriptive?
- Defining implementation plans. How should suppliers be prioritised, assessed and selected? What is the right balance between the critical price, quality, risk, and sustainability criteria?

The key to successfully improving organisational capabilities lies in embedding learning into all day-to-day operations. This can best be accomplished through outcome-focused learning interventions, such as the "4Es" framework:

- Learning through education. Share best practices through workshops and technology-enabled learning, including online classes, mobile apps and others. Hold retreats in neutral locations to ensure immersion and limit distractions.
- Learning through exposure. Visit outside public and private procurement organisations and suppliers to compare procedures and illuminate concerns. Conduct targeted coaching and check-in sessions and provided dashboards showing real-time performance and progress.
- Learning through experience. Establish playbooks to define all roles, their responsibilities and objectives. Carry out on-the-job training with dashboards showing real-time performance and results. Create on-the-job training programmes with sustainability experts.
- Learning through expertise. Establish a buddy programme among employees to promote learning and talk with sustainability experts to discuss critical topics. Ensure that managers actively mentor employees and promote additional sustainability education.

To ensure that new skills are embedded in the organisation, performance evaluations and remuneration should reflect both an individual's learning progress and overall success in meeting its climate goals.

DATA AND SYSTEMS. Transparency in baselining and targets is key to the successful decarbonisation of public procurement. Achieving this and monitoring supplier compliance and progress towards goals requires proper data management and information systems.

South Korea is one of the few countries to have a central emissions database, which has allowed the country to measure the impact of its green procurement policy since 2005. This database collects data from all public authorities targeted by its sustainable procurement policy, at both the local and national level – a total of more than 30,000 organisations in 900 separate agencies. The system tracks volume and spending data on green and non-green purchases for products with the Korea Eco-label and Green Recycled Mark by public authority and product groups.

Implementing artificial intelligence (AI) as part of systems can deliver deep insights and quick cost-cutting wins and reduce the difficulty and expense of measuring and reducing emissions nationwide while helping officials make a sustainable transition to greener procurement. AI can be leveraged in three key areas:

- Collecting data. AI can be used to automatically track emissions covering the entire carbon footprint and collect data from operations and the entire value chain, including materials and components suppliers, transporters and even downstream users. AI technology can also generate approximations of missing data and estimate the level of certainty of the approximations.
- Finding insights. Predictive AI can forecast future emissions across the procurement organisation's entire carbon footprint, considering current reduction efforts, new carbon reduction methodologies and future demand. As a result, procurement officials can set, adjust and achieve reduction targets more accurately.
- Optimising actions. By providing detailed insights for every aspect of the value chain, prescriptive AI and optimisation analysis can improve efficiency in production, transportation and elsewhere, further reducing carbon emissions and cutting costs.

Germany's government is taking a leadership role in using AI to promote

sustainability. It plans to set up an application lab for AI and big data to develop data-based applications for attaining its Sustainable Development Goals. The programme also plans to maintain cloud-based environmental data, provide transparent access to scientists, businesses, and the public, and further develop sustainable AI applications. Germany has provided around €3 billion to initiate and develop 50 AI applications dedicated to promoting sustainability.

AGENCY ALIGNMENT. As noted above, public procurement activities are highly decentralised, with a highly complex structure, making the alignment of policies, baselines and targets across federal and local procurement agencies essential in promoting the adoption of green procurement and simplifying progress tracking and enforcement.

Governments should, when possible, try to encourage alignment from the top down by implementing centralised federal procurement policies and regulations that can also be applied at the state and local levels. As a rule, this can be more challenging for heavily federalised countries such as Canada and Germany than for centralised countries such as Italy and South Korea. However, numerous examples of both types of countries have successfully developed national green procurement guidelines that also apply to their states and local governments, including Belgium, Italy, France, South Korea, and the US.

Governments can employ different types of incentives to encourage procurement agencies at every level of government to comply with central guidelines and regulations. One option is financial incentives. In South Korea, for example, public institutions that perform well on emissions targets receive a performance bonus, while high-performing local governments are rewarded with a larger budget. In Canada, provinces are supported with transfer payments from the federal government, which often come with specific conditions regarding their green procurement progress, including their progress in reporting and the ambitiousness of their emissions reduction targets.

In contrast, the US Department of Energy's GreenBuy Award Programme recognises Department of Energy agencies for excellence in "green purchasing" extending beyond minimum compliance requirements. Agencies are encouraged to purchase from a Priority Products List of
more than 40 products through the programme to meet their specific sustainability goals.

CONCLUSION

With public procurement responsible for 15% of global greenhouse gas emissions, government procurement organisations must determine their emissions baseline, set targets and define the product and services standards needed to reduce their contribution to global warming.
The costs over time will be reasonable and the benefits real – not just lower emissions, but also a boost to the green economy, more jobs and healthier people.

To succeed, public procurement organisations must work with all stakeholders to combat global warming. Their suppliers and industry coalitions will, of course, be critical to the effort, but policy-makers, legislators and public-private partnerships, too, have crucial roles to play.

The considerable influence that public procurement officials wield makes them instrumental in reaching global climate goals. Now is the time to start using it. wn

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Coega Aquaculture Development Zone

- CREATING AN INVESTMENT-READY PLATFORM FOR INFRASTRUCTURE PROJECTS IN THE EMERGING AQUACULTURE SECTOR

Aquaculture is one of the fastest-growing food sectors globally and is considered a key sector for future food production (Costello et al., 2020). Aquaculture is defined as the farming and husbandry freshwater and marine organisms such as fish, shellfish, and plants (including seaweed). Production can be land-based or off-shore in rivers, dams, or oceans. Land-based aquaculture uses constructed systems with raceways, ponds, or tanks.

By Dr Keith Du Plessis Manager: Business Development

According to Heller (2017), land-based aquaculture is expected to see continued growth to meet the increased market demand as the global demand for seafood grows. It is predicted that by 2050, the production and volumes from aquaculture, particularly around Asia, will double and be the main supply of aquatic dietary protein globally (Stentiford et al., 2020).

Besides having a smaller spatial footprint than land-based agriculture and capture fisheries, aquaculture offers many positive attributes, including poverty alleviation in socio-economically disadvantaged regions, increased production due to technological advances and comparatively lower environmental impacts (Stentiford et al., 2020). Notwithstanding the enormous potential that it holds for the economy of South Africa, the local aquaculture sector is underperforming. It continues to contribute very little to national fishery products and the country's gross domestic product (GDP) (FAO, 2022).

According to Little et al. (2016), aquaculture has expanded faster than any other livestock sector in recent decades, growing at an annual rate of 7.5% between 1990 and 2009, thereby outperforming the global growth achieved by the poultry (<5 %) and pig (<2.5%) sectors. There has, however, been a decline in the global growth rate of aquaculture since the beginning of the century (FAO, 2020), with public opposition, restricted land space for aquaculture farms, licensing backlogs, market issues and diseases being cited as some of the reasons for the declining growth rate of the sector.

To unlock the aquaculture sector in the Nelson Mandela Bay Municipal (NMBM) region, the Coega Development Corporation (CDC), as operator of the leading Special Economic Zone (SEZ) in Africa, decided to develop a 440-hectare (ha) land-based aquaculture development zone (ADZ) in the Coega SEZ to accommodate both freshwater and marine aquaculture.

The overall purpose of the development is to create an investment-ready platform for planned commercial aquaculture operations to establish within the Coega SEZ, thereby facilitating entrance into and boosting the growth of the sector in the region.

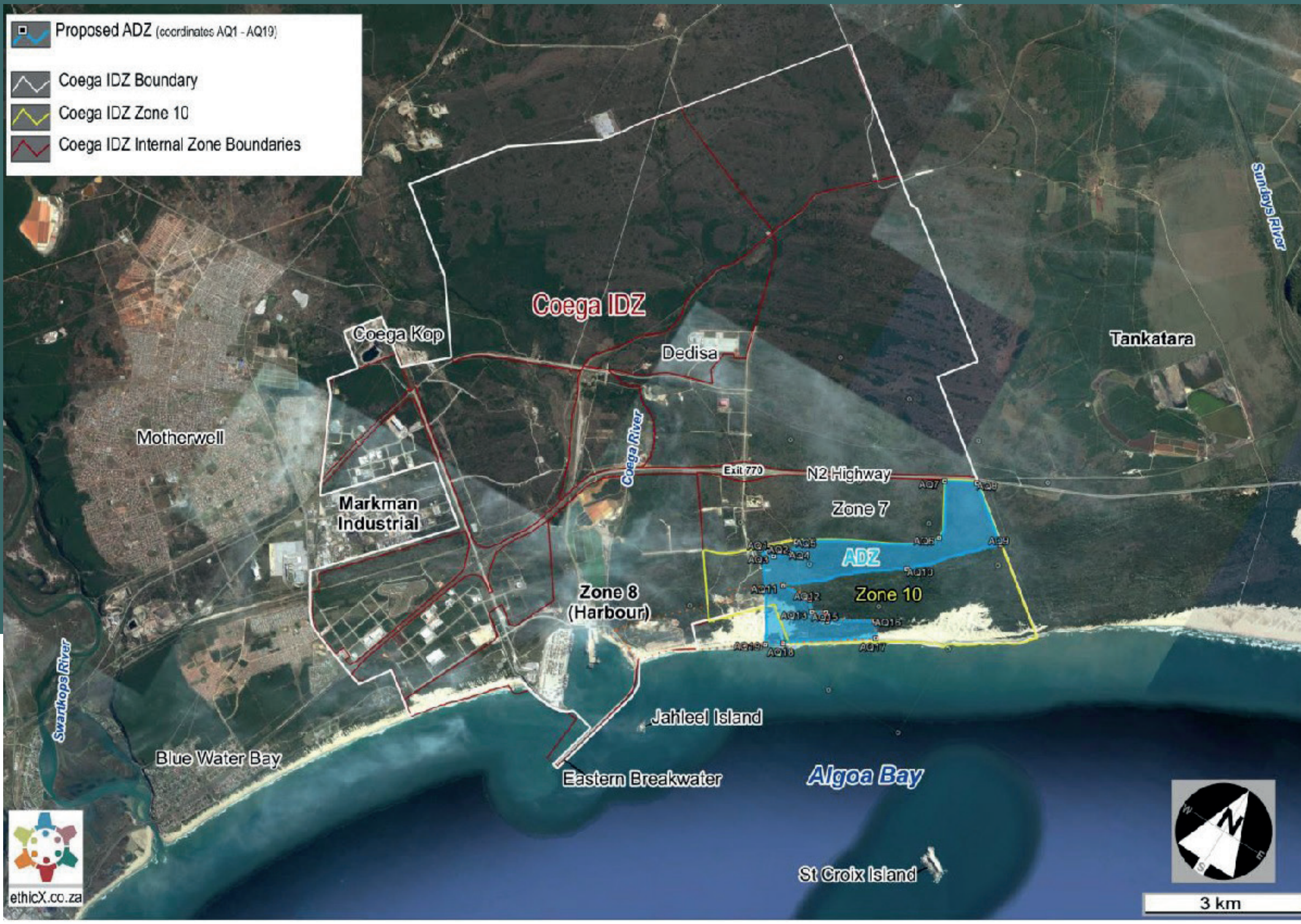

Figure 1: Location of the Coega ADZ inside the Coega SEZ. (Source: Ethical Exchange, 2017

PROBLEM IDENTIFICATION

Through stakeholder engagement and desktop research, the CDC identified some of the significant constraints stifling the sector's growth in the NMBM region and set out to address some of these through public sector interventions. It should be noted that the identified constraints listed below are by no means exhaustive and merely serve to highlight constraints from an infrastructural and environmental perspective that the CDC seeks to address through the development of the Coega ADZ.

THE IDENTIFIED CONSTRAINTS INCLUDE:

Access to land adjacent to the ocean: Land adjacent to the ocean in South Africa is costly to acquire and primarily protected by environmental legislation.

- LOGISTICS LINKAGES TO LOCAL AND INTERNATIONAL MARKETS: It is crucial to have good road networks to transport products to local markets. Being situated close to an airport or seaport for exports is vitally important.
- AVAILABILITY OF BULK INFRASTRUCTURE: Delivering bulk infrastructural services to properties adjacent to the ocean is usually very costly, especially in rural areas. Therefore, the financing of bulk infrastructure as part of the project's development cost would, more often than not, render the project non-viable.
- ENVIRONMENTAL APPROVALS: Cumbersome and costly environmental approvals have been a major stumbling block, especially for SMMEs seeking to enter the aquaculture sector.

COEGA ADZ

Over the past decade, the CDC has set out to develop one of the largest land-based ADZs on a single geographical footprint in South Africa. The 440-ha ADZ is a greenfield development located inside the Coega SEZ adjacent to the deepwater Port of Ngqura (Figure 1).

Being situated adjacent to the Indian Ocean with approximately 12km of coastline forming part of the boundary of the 9003-ha SEZ, it was inevitable that the CDC would pursue aquaculture as one of its targeted sectors for development.

Figure 2: The Coega ADZ indicating the low-lying coastal section earmarked mainly for high seawater users, e.g., abalone farms and higher-lying inland section for marine return aquaculture systems (RAS) and freshwater aquaculture. (Source: Ethical Exchange, 2017)

ADDRESSING IDENTIFIED CONSTRAINTS

ACCESS TO LAND ADJACENT TO THE OCEAN

Following years of planning and assessment, the CDC identified Zone 10 of the Coega SEZ to develop a land-based ADZ. To provide context for the ADZ and the selection of the site within the coastal cluster of development in Zone 10 of the SEZ, various project-specific, SEZ-wide, regional, and strategic environmental and planning processes were undertaken (Ethical Exchange, 2017).

In 2014, an independent concept design and feasibility study designated Zone 10 as a favourable location for aquaculture development, with marine aquaculture being earmarked for the low-lying areas (i.e., closer to the ocean) and freshwater aquaculture for the higher-lying inland area in the zone (Figure 2). In addition, the CDC conducted market research, interacted extensively with the aquaculture specialists and operators, visited various aquaculture operations, and engaged with several potential investors. As a result, in addition to marine aquaculture and following another feasibility assessment, the CDC decided to include intensive freshwater and brackish water aquaculture based on the feedback received and technological development to reduce water exchange and wasteful water use.

LOGISTICS LINKAGES

The Coega SEZ is served by two ports, with a combined capacity of over two million Twenty-Foot Equivalent Units (TEUs) a year. The world's major shipping lines serve both ports. The Coega ADZ is located adjacent to the Port of Ngqura that has 2100 reefer plug points crucial for cold chain maintenance. The ADZ is located approximately 25km from Port Elizabeth, with approximately 1000 reefer plug points. The ADZ is directly linked to the N2 arterial highway, which connects the SEZ to the rest of the region. The SEZ is further connected with the rest of South Africa and neighbouring countries through a rail connection.

The Chief Dawid Stuurman International Airport (DSIA) is approximately 30km from the ADZ and provides connectivity for national and international passengers and freight. This is particularly important

Figure 3: Development of enabling infrastructure to unlock Phase 1 of the Coega ADZ.

for investors seeking to transport cargo to global markets via air freight, e.g., exporting live abalone to China. A flight between DSIA and OR Tambo International Airport is approximately 1 hour and 40 minutes and is serviced by several airlines.

ENABLING INFRASTRUCTURE

In August 2020, the CDC started construction on enabling infrastructure in Zone 10 of the SEZ to unlock approximately 100 ha (Phase 1) of the ADZ (Figure 3). The construction includes the development of road, electrical and stormwater infrastructure unlocking sites for marine and freshwater aquaculture. This means that aquaculture investors can focus on developing their core business rather than raising capital for bulk infrastructure.

ENVIRONMENTAL APPROVALS

In March 2015, the NMBM Bioregional Plan (NMBMBP), which designates ecologically important areas as critical biodiversity areas (CBAs) and existing protected areas (PAs), was adopted by the Department of Economic Development, Environmental Affairs and Tourism (DEDEAT) and officially gazetted.

The NMBMBP informs land-use planning, environmental assessments, and authorisations and highlights how the Coega ADZ development should be accommodated in the environmentally sensitive coastal zone. This paved the way for the CDC to initiate an environmental impact assessment (EIA) for land-based aquaculture on the identified site in Zone 10.

In February 2018, the CDC received environmental authorisation (EA) to develop and operate the Coega land-based ADZ. This allows companies to farm close to 40 marine and freshwater species in the Coega ADZ without additional independent EIA. Investors are, however, required to develop an environmental management plan (EMP) that speaks to the more extensive environmental management programme (EMPr) for the ADZ.

The CDC received EA to abstract and discharge seawater from and into the marine environment in September 2021. This was the final and most challenging hurdle the CDC needed to overcome from an environmental perspective, bearing in mind that the marine environment anterior to the SEZ is a marine protected area (MPA).

The CDC is currently engaging potential aquaculture investors seeking to develop their businesses in the Coega ADZ. We hope to break ground on the first aquaculture investment project in the 2022/23 financial year. This will be a significant milestone in the CDC's journey to create a world-class investment location for aquaculture investors that will contribute significantly to the economy of the NMBM and the larger Eastern Cape. The CDC has laid the foundation for developing the aquaculture sector in the NMBM. It will continue to engage relevant stakeholders to find solutions and ensure that various stumbling blocks hindering the sector's growth are removed. wn

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SAIEE CALENDAR

FEBRUARY 2022

DATE	TITLE
15/02/2022	Design of Economical Earthing Systems for Utility Installations
16/02/2022	Project Management for Engineers
16/02/2022	Road to Registration
16/02/2022	Webinar: Nuclear Medicine & Radiation Biology
16/02/2022	SOLAR POWER AFRICA Conference, CTICC
21/02/2022	Transformer Construction, Operation, Maintenance, Testing and Protection
23/02/2022	Power Systems Protection
24/02/2022	New Engineering Contract (NEC)
23/02/2022	Power Systems Protection
28/02/2022	Fundamentals of Financial Evaluation for Projects

MARCH 2022

DATE	TITLE
04/03/2022	Liability: Occupational Health and Safety Act
08/03/2022	Writing Good Technical Specifications
09/03/2022	SANS 10142-1 Edition 3
09/03/2022	Fibre Optics
11/03/2022	SAIEE Annual Awards
14/03/2022	Finance Essentials for Engineers
15/03/2022	Technical Report Writing
17/03/2022	Earthing and Lightning Protection
17/03/2022	Fundamentals of Practical Lighting Design for Commercial and Industrial Applications
23/03/2022	Fundamentals of Developing Renewable Energy Plants
24/03/2022	Cable Jointing and Selection
24/03/2022	SAIEE Annual General Meeting 2022

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