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New Tech, New Deal: Mining Policy Options in the Face of New Technology

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INTERGOVERNMENTAL FORUM
on Mining, Minerals, Metals and
Sustainable Development

NEW TECH, NEW DEAL:

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The main authors of the report are Isabelle Ramdoo and Aaron Cosbey. Several authors contributed to specific chapters: Jeff Geipel from Mining Shared Value/Engineers Without Borders and Perrine Toledano from the CCSI on various policy options; Alexandra Readhead, Viola Tarus, and Jaqueline Taquiri from IGF on the future of resource taxation; and Ege Tekinbas from IGF on gender.

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Ultimately, however, this report is the product of its authors. They alone are responsible for any errors or omissions, as well as for the report's findings and recommendations.

EXECUTIVE SUMMARY

THE COMING NEW TECHNOLOGIES

Throughout the history of mining, technological innovation has played a vital role across all cycles of mining projects. The new wave of technological adoption is a combination of evolutionary and revolutionary technologies, with an increasing focus on the latter.

An acceleration in investments in disruptive technologies in recent years has seen the large-scale mining sector finally catching up with a dynamic that has already advanced in many other sectors. The reasons for this shift include more difficult geology, declining ore deposits, the need to reverse a secular decline in productivity, the need to improve safety for mine workers, a need to manage environmental impacts, and—more recently—a reaction to pressures from the COVID-19 crisis.

The technologies in question are a suite of different innovations brought from other fields that work together in concert:

- Enablers of digitization such as radio-frequency identification (RFID) sensors, wearables, drones, and satellites.
- Users of big data such as machine learning and artificial intelligence.
- Integrators of big data such as 5G, the Internet of Things (IoT), systems management software, and blockchain technology.
- Process improvers such as automated machinery, electric vehicles, digital twins, water management and tailings recovery technologies, and renewable energy generation.

IMPACTS OF NEW TECHNOLOGIES

LABOUR IMPACTS

The impacts of new large-scale mining technologies vary according to the type of technology, the type of operation, the level of countries' development, and their social context, among other things. The labour impacts are hard to assess with certainty. But there will probably be fewer jobs in some fields, due to labour-replacing innovations such as automation, drones, and the IoT. This means high risk for low- and semi-skilled occupations, and less risk for unskilled and highly skilled/specialized occupations. At the same time, there will be new higher-paying jobs created in high-skilled occupations such as information technology and engineering. It is worth noting that the large-scale mining sector will also have to face increasing competition from other sectors, such as the technology industry, that already attract more interest among the younger generation of workers. The final effects are more nuanced than a simple loss of jobs; they involve a dynamic restructuring wherein some jobs are lost, some are redefined, and some new jobs are created. A key tension is that the new jobs created may not be based in mining-affected communities or may not be accessible to locals who lack the requisite skills.

WOMEN'S PARTICIPATION IN THE MINING WORKFORCE

Technological change will affect women's participation in the mining workforce. Historically, the mining sector's overall workforce has been dominated by male workers for reasons that include the physical nature of the work, restrictive legal frameworks, cultural barriers, skills barriers, and gender-blind policies and work environments. Some aspects of the new technologies might erode those barriers, including the ability to work in urban remote operation centres. But others may jeopardize the work of semi-skilled women in communities that are mining dependent.

FISCAL IMPACTS

New technologies that reduce the workforce may have important negative fiscal impacts, reducing payroll taxes received by host governments. They may also increase revenues, given the higher pay earned in new jobs created—but only if those employees pay taxes in-country. The impacts on corporate income taxes are also uncertain and will be highly context specific. The shifting locus of value added along the value chain to foreign providers of new technologies and information services lowers taxable activities in host countries and creates a risk of increased opportunities for base erosion and profit shifting.

IMPACTS IN ARTISANAL AND SMALL-SCALE (ASM) OPERATIONS

New technologies will have a very different set of impacts in artisanal and small-scale (ASM) operations. If large-scale mining sheds low-skilled workers, many will flock to the informal sector, with social and environmental impacts that depend on the national policies and capacity for managing ASM. ASM producers may also face price pressures from increasingly efficient large-scale mines. The adoption of basic technologies in the ASM sector holds great promise for efficiency, worker safety, and environmental performance—areas in which ASM has traditionally struggled to perform. But productivity-enhancing technologies in particular also hold great risks for one of the areas in which ASM has traditionally outperformed large-scale mining: employment of large numbers of low-skilled workers, including a large share of women and youth. The potential gendered impacts are noteworthy, given the large presence of women in ASM in many developing countries.

ELEMENTS OF A NEW DEAL

If new technologies do lead to lower employment and other erosion of the value that mining activities bring to local communities and host countries, what policies might governments consider to rebalance the traditional "deal"? The policies assessed here fall into four broad categories:

- Policies aimed at ensuring that whatever employment is available in the mine of the future, and among suppliers, is contestable by locals.
- Policies aimed at leveraging mining activity as a route to ensuring economic diversification, and a reduced dependence on the large-scale mine as a provider of employment-related benefits.
- Policies aimed at rethinking tax revenue mechanisms from large-scale mining operations, and the possibility that such revenues might be used for local development purposes.
- Policies that find solutions to the challenges of new technologies in those technologies themselves.

EMPLOYMENT IN THE MINE OF THE FUTURE

Policies aimed at employment in the mining sector must clearly include a focus on redressing a troubling mismatch between existing locals' skills and the skills needed in the mine of the future. This calls for a partnership approach, with universities and training institutions working closely with the mining industry to design and regularly review the training curricula, and governments consulting mining companies to better understand what skills are needed in light of investment plans. It also calls for good baseline data on the state of skills and the skills needed in future, with special attention paid to challenges and opportunities for women, locals, and marginalized populations. Almost all countries need to increase levels of spending on education, and increase the delivery of foundational skills in sciences, technology, engineering, and math, especially for women. A focus on lifelong learning is needed to equip workers for inevitable change. Governments should consider incentives for mining companies to conduct training, as well as mandatory training policies. Mining companies have a role to play as well, beginning preparation and discussions early in the process of transformation, and participating in training and upskilling. They will increasingly need to compete with other sectors to recruit and retain educated workers, in particular young women, with transferable skills.

Governments might also turn to familiar local content tools such as requirements to employ local workers, or obligations to procure local goods and services. However, while lower employment levels may make such policies more urgent, they also make them more challenging. Setting attainable employment or procurement targets might involve hitting a sinking target when dealing with technologies that lower the total number of workers employed and also the amount of employee-related goods and services needed.

New types of procurement needs will emerge. Governments must therefore work with mining companies to understand those needs, to prepare local suppliers to embrace the opportunities as they arise, including by ensuring that the skills initiatives discussed above also target suppliers. Such policies need to be informed by a baseline knowledge of new technologies in the pipeline and their impacts on job numbers, job descriptions, and skills required.

GOVERNMENT-LED EFFORTS AT TRANSITION SUPPORT

Government might also employ policies aimed at leveraging mining operations to foster diversification and employment outside the mining sector. These policies should ensure that new opportunities secure decent jobs and protect the right of workers. One set of policies supports incentivizes or collaborates with mining companies to engage in social impact investing: investment made with the intention to generate positive, measurable social and environmental impact alongside a financial return. Such investments by mining companies differ from environmental, social, and governance (ESG) or corporate social responsibility (CSR) spending in that they aim to foster self-sustaining profitable entrepreneurial activities in non-mining sectors, such as agriculture or light industry. These efforts amount to regional economic development projects, with the best examples to date being highly collaborative.

In scenarios where new mining technology retrofits displace a significant number of workers, governments should support workers with transition strategies that involve protective policies, such as unemployment benefits, though these depend on fiscal capacity that does not necessarily exist in many developing countries. They can also mandate employer and payroll contributions to schemes such as pension funds, wage insurance, or social insurance funds that can be accessed by workers to support their transition paths. Governments can also pursue proactive policies to create new economic opportunities in mining-dependent communities; there are a few successful examples of such transition efforts, including Germany's transition away from coal dependence.

Local procurement policies can also foster diversification, especially if they are focused on building capacity in suppliers that are not specific to the mining sector. Such policies will be challenged by the reality that new technology may decrease opportunities for local procurement for some types of goods and services, but this just underscores the need for any such policies to be mainstreamed in national industrial policy and diversification efforts that go beyond the mining sector.

RE-EXAMINING TAXATION

If new large-scale mining technology decreases employment-related benefits, one possible line of policy response involves increasing taxes assessed on mining operations and somehow using the revenues to compensate affected workers (and communities) and to facilitate transition. This could be akin to a windfall tax on the profits made from new efficiencies since most new technologies will increase the efficiency of operations. But efficiency is not synonymous with increased profitability, and it is not clear that it will lead to significant and sustained profits over time to serve as a viable basis for such taxes. While some first movers may make additional profit from increased efficiency, eventually, the adoption of new technologies will be industry wide and will be counted as a simple cost of doing business. Even today, operations adopting new technology may simply be trying to maintain existing profits in the face of declining ore grades and more complex deposits; some mines of the future would not be viable at all using conventional technologies.

Regardless of whether technology increases profits, increased taxes could be a way for mining companies to replace the value that was formerly brought through employment, and they may eventually simply become the cost of running the mine of the future. However, if increasing taxes is the only policy pursued, it casts governments as the sole agents in the challenge of translating mining activity into well-being for affected workers and communities. This risks missing the opportunities described in other policy options, for effective collaboration, and for harnessing the capabilities and resources of mining companies.

TECHNOLOGY AS A SOLUTION

Finally, there is a suite of policies and initiatives that seek to find ways in which some technologies might offer new kinds of benefits to workers, local communities, and host countries to offset the disruptive impacts of the new model of mining.

LOCAL INNOVATION TO SUPPORT LARGE-SCALE MINING OPERATIONS

While most of the development of cutting-edge technologies and digital solutions for the large-scale mining sector is led by a handful of global technology companies, there is room for local technology development, which, if properly supported, leads to new avenues of economic development. Local technology providers can deliver tailor-made solutions to locally specific problems by developing new technological solutions or by adapting existing technologies to local conditions and needs, leveraging their local knowledge and connections to provide customized solutions in niche areas. Supporting such firms starts at a broad level with designing national innovation systems and providing an enabling innovation environment, but also includes institutional support and financing for start-ups and small and medium-sized enterprises (SMEs) that are challenged to raise traditional finance. Considering that women entrepreneurs are mostly SME owners, such support can have a positive gendered impact.

LARGE-SCALE MINING TECHNOLOGY IN SUPPORT OF LOCAL ECONOMIC DIVERSIFICATION

As part of social impact investment efforts (or as stand-alone efforts), mining companies should consider sharing some technological solutions with nearby communities to support resilience and create new development opportunities. The cost to mining companies of the "last-mile" investments for the benefit of communities may not be high if they are integrated into the upfront design of the projects. For communities, however, the benefits can be game-changing because technologies are enablers of economic opportunities, social improvements, and environmental management. Local agricultural productivity, for example, might benefit from geographic information system (GIS) mapping of local soil and hydrology conditions, drones, and Internet connectivity. In addition to providing economic benefits, this can have significant impacts on livelihoods and food security for local communities.

TECHNOLOGY AS A BOON FOR ASM

ASM could benefit in multiple ways from technologies that for the most part are not sophisticated or costly and that are appropriate to the scale of the sector: mechanical crushers, grinders, and washers, for example, or the use of blockchain or analytical fingerprinting. These sorts of technologies could improve productivity, worker health and safety, and environmental outcomes, and could help verify responsible supply chains. Governments could support such technology uptake as part of broader programs of ASM support and recognition, including through affordable financing and outreach, support for local manufacturing of machinery, and brokering deals with large-scale mines to transfer machinery that may be obsolete to them. A major caveat, however, is that enhancing the efficiency of ASM also involves displacing unskilled and semi-skilled workers, often including a high percentage of women.

SHARED CONNECTIVITY

Mining companies should consider sharing high-speed connectivity with local communities. To be effective, such efforts would need to be part of a broader initiative and would be most appropriately carried out in concert with local and national governments. As a complement to broader government programs, access to high-speed Internet can be a powerful enabler of development. For example, when coupled with training and access to hardware, it can be a powerful tool for delivering education to remote communities. Similarly, it can be an invaluable aid to the delivery of rural health care through telemedicine. Connectivity is also a foundational enabler of various entrepreneurial activities.

SUPPLYING LOCAL COMMUNITIES WITH DATA OF INTEREST

The data-rich mine of the future will involve real-time flows of information from ubiquitous sensors. Some of that data might be of acute interest to local communities. Examples of this type of data include tailings dam stability readings and outflow water-quality readings. Granting nearby communities access to these flows of data in real time would be enormously valuable to those affected and could help build a robust social licence to operate. Local agricultural producers might also benefit from mining company data such as that gathered in GIS mapping and aerial surveying.

USING MINE-LEVEL DATA TO AID TAX AUTHORITIES

New technologies may bring opportunities to improve government oversight of the mining sector and resource governance overall. The digitalization of operations will mean that mine sites will have access to significant volumes of real-time data. Tools for monitoring the flow and quality of minerals extracted could strengthen government revenue collection by providing detailed information to governments on the grade and quantity of extracted ores. Lack of that information underlies the difficulties many governments face in properly evaluating their mineral resources and in trying to prevent base erosion and profit shifting. That data could also help tax authorities better analyze the tax gap, determine audit priorities, and negotiate fiscal terms. It can also help address corruption.

CONCLUSIONS

The wave of new technology washing over the large-scale mining sector will change the face of the industry, just as technological change has already disrupted sectors like retail, entertainment, and communications. As in those cases, the changes will involve costs and benefits. Our concern is not so much how those costs and benefits balance out, but rather how they are distributed. In those cases where mining-affected communities and resource-rich host countries see costs in terms of lost employment for which they are not compensated in terms of benefits, it is a critical matter of development and of social licence to operate.

Our survey of policies to address this challenge does not discover any silver bullets—there is no single policy solution. High on the list is a focus on education policy, skills training, and educational institutions. This will involve close collaboration between governments, companies, and institutions of learning to help ensure that locals can fill the jobs of the future, will remain adaptable to continued change, and can help drive innovation and entrepreneurship that diversifies away from the mining sector. It is an opportunity to address gender gaps in education and skills for future mining jobs.

Also promising are the many ways in which governments and mining companies might use new technologies as a solution to the problems that some technologies might unleash to bring benefits to local communities and regions. We see great promise—but also daunting challenges—in changing usual practices for collaborations to foster diversification away from the large-scale mining sector, and in a model that looks more like impact investment than like CSR spending, i.e., designed to create sustainable, profitable non-mining-related enterprises in ways that build on existing strengths and resources.

Other policy solutions seem more difficult or fraught with uncertainty. Increasing taxation may be the basis for government support to affected workers and communities, for education systems, and for efforts at transition, but it should probably not be pursued as an exclusive policy solution. Local content policies in procurement and employment are critically important, but they may involve shooting at a sinking target, as opportunities shrink for both employment and procurement. Where new supplier opportunities arise, local content strategies will have to be redesigned, including through more systematic inter-industry collaboration.

All of these policies need to be built on better information—about jobs at risk, skills mismatches, profitability, and future demand for goods and services—than many governments have now. None of it can happen through governments acting alone: the watchword is collaboration.

All of this sees mining policy moving increasingly to intersect with broader industrial policy, including being strategic about the transition to a low-carbon future, of which mineral resources will be key, forced to do so by the changing nature and potential of mining's contributions to national economies. This is a path that probably should have been followed anyway, but the advent of new technology now makes it even more important.

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ACRONYMS

3D	3 dimensional
4D	4 dimensional
5G	5th generation of cellular networks
AI	artificial intelligence
ASM	artisanal and small-scale mining
CAD	Canadian dollars
CCAB	Canadian Council for Aboriginal Business
CDAs	community development agreements
CSI	corporate social investments
CSR	corporate social responsibility
EITI	Extractive Industry Transparency Initiative
ESG	environmental, social, and governance
EY	Ernst and Young
GIS	geographic information system
IBAs	impact benefit agreements
GTK	Geological Survey of Finland
HDSAs	Historically Disadvantaged South Africans
ICT	information and communications technology
ICMM	International Council for Mining and Metals
IGF	Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development
ILO	International Labour Organization
IMF	International Monetary Fund
IoT	Internet of Things
IWiM	International Women in Mining
IP	intellectual property
IPR	intellectual property rights
MOU	memorandum of understanding
OECD	Organisation for Economic Co-operation and Development
PPE	personal protective equipment
R&D	research and development
RFID	radio-frequency identification
RKB	Ruhr Coal Vocational Training Society
RPL	recognition of prior learning
SMEs	small and medium-sized enterprises
SMS	short message service
STEM	science, technology, engineering, and maths
USD	United States dollars
WEF	World Economic Forum

1.0 INTRODUCTION

The large-scale mining sector is on the cusp of a major transition. This is part of the broader Fourth Industrial Revolution in which new technologies transform industrial activities so they are more connected, information-richer, and more efficient in the use of labour and inputs. While relatively late to the game, mining stands to be changed as fundamentally as any other sector.

The results are already evident in terms of more efficient (and therefore usually more climate-friendly) operations and fewer workplace accidents. Our previous work, however, leads us to be concerned that at least in some cases there will also be fewer people employed and fewer local goods and services purchased, even if new jobs are created (Cosbey et al., 2016; Ramdoo, 2019). And we worry that those closest to the mine and with fewer alternative opportunities—i.e., low- and semi-skilled locals—will be at the greatest risk of displacement, with the slimmest chances for re-employment or re-deployment.

In those cases where that is true, the traditional deal between large-scale mining companies, local communities, and host countries is thrown out of balance. Employment and procurement are the most significant and important forms of value a mine can make to its host community/region—much more important locally than taxes and disproportionately important in poorer, less diversified economies. It is more than an expectation. It represents in some sense the "payment" in return for a mine's potential impacts on the local social fabric and the environment and the exploitation of non-renewable resources. If the mine of the future brings much less of that value to a community or a host economy, what could be the elements of a new deal that brings us back to balance?

This report explores that question. It starts by reviewing the nature of the coming technologies and their various impacts in areas such as employment, gender equality, fiscal arrangements, and artisanal and small-scale mining (ASM) (Section 2). It then critically assesses some of the various possible elements of a new deal (Section 3) and considers the impacts and possibilities for marginalized groups before offering some concluding thoughts.

2.0 TECHNOLOGY IMPACTS REVIEW

2.1 INTRODUCTION

Technological innovation is a recurrent feature of modern industrial development. It plays an instrumental role in fostering productivity and in maintaining the efficiency and competitiveness of industries, as new processes are adopted by competitors. In the large-scale mining sector, it is particularly important given the nature of the activities, which are essentially about the extraction of physical and non-renewable resources from the ground. In that regard, constant innovation in processes is necessary to overcome natural factors such as declining reserves, lower ore grades, deeper deposits, and geotechnical difficulties due to harder rocks, amongst others. In short, innovation is critical for the continuity and sustainability of mining activities.

2.2 WHERE DO MINING INDUSTRIES FIT WITHIN THE TECHNOLOGICAL ADOPTION LANDSCAPE?

Throughout the history of mining, technological innovation has played a vital role across all cycles of mining projects. The new wave of technological adoption is a combination of evolutionary and revolutionary technologies, with an increasing focus on the latter. As was highlighted in the 2019 IGF Technological Impact Review, disruptive technologies can make mining processes smarter, leaner, cleaner, more efficient, and arguably more responsible (Ramdoo, 2019). **These technologies have far-reaching implications for employment, expected to be lower for some tasks but definitely more efficient as labour productivity improves, and more flexible**, in terms of work shifts and geographical location of workstations moving away from the mine face.

Despite an acceleration in investments in disruptive technologies in recent years, the large-scale mining sector has been largely surpassed by other economic sectors in the quest to develop and roll out advanced technologies. The information and communications technology (ICT) sector has taken the leap into the digital economy, notably by investing in innovative digital infrastructure, software development, and high-speed connectivity. These are at the heart of the Fourth Industrial Revolution.

Unlike the fast movers in other sectors, many mining companies still struggle to embrace high-tech solutions. Mining companies have spent, on average, a lower share of their operational expenditure in the development of technologies compared to other sectors. Between the 1990s and 2000s, the research and development (R&D) intensity of mining companies, measured as R&D expenditure as a percentage of total revenues, was on average only approximately 0.5% (Filippou & King, 2011), significantly lower than sectors such as ICT or pharmaceuticals, where the level of R&D spending was 24.7% and 25.1% respectively in 2015 (Sanchez & Hartlieb, 2020).

One can attribute this low level of in-house spending to the fact that large-scale innovation in technologies is led by tech companies[1] specialized in developing and providing technological solutions. These tech providers, in turn, supply mines with ready-made equipment and machinery and ensure the accompanying servicing and maintenance services, which include software upgrading and new solutions during the lifetime of the equipment (Sanchez & Hartlieb, 2020).

However, several other systemic reasons explain the slower pace of technological adoption in the mining sector. First, there cannot be a one-size-fits-all solution for the entire mining industry. The sector is heterogenous: almost every commercially viable mineral deposit has its own specific geological characteristics requiring production techniques adapted to its environment.

Second, types of operations (i.e., whether mining operates underground, at depth, or on the surface) affect the feasibility of technological uptake. Surface mining operations have largely invested at grand scale in mechanized processed, unlike underground mining operations, where progress did not happen at the same pace.

Third, industrial mining facilities are complex: the technologies needed are not the same within and across different phases of the mining value chain, and the cost of technologies makes it difficult to select where to invest.

Fourth, market conditions surrounding large-scale mining projects, such as price volatility or the cost of capital, affect the cash flow and the financial capacity of companies and therefore their ability to plan for the long term to invest in expensive technologies.

Finally, economic and infrastructure conditions in host countries affect company's ability to deploy high-tech machinery. When those are not adequate or reliable, mining companies must add the cost of infrastructure development to their technological investment, significantly increasing project costs.

2.3 DRIVERS OF EMERGING DISRUPTIVE TECHNOLOGY TRENDS

Despite intrinsic challenges that slow the pace of technological adoption, the large-scale mining industry seems now to be on an upward trend in investing in cutting-edge innovation and technological adoption to improve its performance. Key factors driving the adoption of new technologies are given below.

1 Global technology suppliers include Sandvik, Komatsu, Epiroc, and Caterpillar, amongst others.

2.3.1 GEOLOGICAL FACTORS

The natural characteristics of mineral deposits produce several challenges that can only be surmounted with the help of technology. For instance, there are geotechnical difficulties linked to the type of the mining activities (underground or surface) and to the geological specificities of ore bodies. Deeper mines with very hard rock, for example, require specialized technological solutions.

Further, faced with declining global mineral reserves, mining companies exploring new frontiers are faced with increasing difficulties accessing potential new deposits found deeper in the sub-soil or in locations not exploited so far, like the seabed or in space. Likewise, as mining activities mature, companies are faced with declining ore grades, rising stripping ratio[2] and increasing hauling distance due to deeper ore locations. New technologies are required to maintain the efficiency of operations.

2.3.2 ECONOMIC FACTORS

Analysis estimates that the mining industry has witnessed a sustained decrease in productivity since the mid-1990s[3] and has struggled to reverse the curve, despite significant cuts in capital spending and operational expenditures and reduction in labour costs (Durrant-Whyte et al., 2015; Flesher, 2018). The lingering productivity and efficiency challenges have been major determinants for mining companies to make the leap toward disruptive technologies, underpinned by an urgency:

- To **reduce overall costs** including (i) existing operating costs as ore grades decline and (ii) new asset development costs as accessibility declines while upfront capital expenditures rise.
- To **improve efficiency** of operations and asset management, in the face of global economic slowdown, thinning margins, and pressure on cash flows.
- To **raise productivity**, for higher production rates. Mining companies estimate productivity improvements between 15% and 30% from autonomous hauling. Full automation at the Resolute Mine in Mali reduced the cost of gold production by USD 135 per ounce and cut mining costs by 30% (Accenture, 2020b).
- **Maintain their competitiveness**, as new actors, such as tech providers, or large buyers of raw materials,[4] enter the sphere of the mining sector.

2.3.3 SAFETY OF MINING OPERATIONS AND MINE WORKERS

Health and safety have long been major causes of concern for the mining industry. Accidents on mine sites—due to issues such as falling of equipment, the handling of explosives, and dangerous working conditions in underground mining—result in a significant number of fatalities and injuries. Estimates reveal that mining accidents are responsible for around 12,000 deaths per year, which represents 8% of fatal accidents globally (Orange Business

2 In surface mining, stripping ratio refers to the amount of waste (or overburden) that must be removed to release a given ore quantity. It refers to how much waste is mined per unit of ore.

3 According to a 2018 McKinsey Report, mining productivity declined between 2004 and 2009 (an annual contraction of 9.6% on average), stagnated between 2010 and 2014 (zero growth on average), modestly started to increase since 2014, when digital-enabled innovations started to be adopted in some operations (McKinsey, 2018).

4 The battery company Tesla has acquired a license in Nevada, Texas, to exploit lithium, which it will then refine, in a bid to secure access to the mineral for its new factory in Texas (Sanderson, 2020).

Services, 2019). This is significant, considering that mining employs approximately 1% of the global workforce.

New technologies can significantly reduce those fatalities by replacing workers with machines, removing people from dangerous sites and protecting them from hazardous activities. Other technologies fitted with sensors allow quick detection and monitoring of hazardous situations for rapid intervention to improve site safety and minimize failures. Similarly, smart connected devices that provide real-time data, analytical capabilities, and virtual visualization of physical environments go a step further and provide multiple advantages: they allow people to work away from dangerous equipment and improve control over mining operations.

2.3.4 MANAGING ENVIRONMENTAL IMPACTS

Some new technologies help mining companies avoid, manage, and mitigate environmental challenges. For example:

1. To reduce their environmental footprint, mining companies are increasingly investing in electric vehicles, renewable energies sources, waste-reducing techniques tailings methods (such as dry stacks or water-saving technologies) and the application of noise-control tools, amongst others.
2. The effects of climate change are accelerating the occurrence of extreme and severe weather conditions, such as warming or polar temperatures, flash floods, or severe droughts. These have complex implications for mining activities, as they affect physical infrastructure and can disrupt activities (BSR, 2017). Waterless technologies, for example,[5] are part of companies' adaptation responses. Anglo American is developing waterless mines to eliminate fresh water from its processing operations.[6]
3. Companies are adopting new technologies to restore mines sites during mining activities and to rehabilitate mines following closure. Technologies such as GIS, remote sensing, and data analytics allow mining companies, public authorities, and communities to capture, track and analyze various environmental information to better manage risks such as acid drainage, flooding, slope instability, tailings systems etc. The tools can then be used to alert and notify observers of any anomalies and review environmental obligations and compliance accordingly.

2.3.5 ADAPTING TO THE COVID-19 PANDEMIC

The COVID-19 pandemic that hit the world in 2020 has been a major inflection point for the mining industry. It has hastened the dynamics of innovation and fast-tracked adoption of digitization and automated solutions. In the short term, the need to respond to the sudden unforeseen shift toward remote working has compelled many mining companies to accelerate the creation, adoption, and execution of digital solutions and the use of the latest mining technologies. At the same time, high-tech solutions are increasingly being sought, not only to avoid future risks for workers but also to optimize mining processes more durably, to reduce

5 To address increasing water scarcity—expected to fall short by 40% by 2030 according to Stinson and Nelson (2020)—as a result of insufficient precipitation, companies are working on waterless technologies.

6 Technologies will provide for a better measurement of evaporation rates to minimize water loss; develop dry tailings disposals; use dry separation techniques during grinding and crushing processes; and use non-aqueous processing techniques to separate rocks from ores (AngloAmerican, n.d.).

costs of operations that had gone up as mining companies had to inject funds to navigate through the crisis.

The EY Global Capital Confidence Barometer[7] revealed that when the COVID-19 pandemic was declared, 66% of mining and metals companies had already invested in some business and technology transformation in some aspects of their operations (EY, 2020). As a result, the first movers in adopting more advanced digital technologies fared better during this crisis. For instance, Resolute's Syama Mining, which operates the world's first fully autonomous gold mine in Mali, reported that its activities at the mine had not been impacted by restriction measures, and its production was forecasted to remain unaffected by the pandemic (Hall, 2020).

The subsequent impact of the pandemic, notably on the labour market, global supply chains, and mining operations, has reinforced the rationale for more investments in innovative technologies, such as automation and digitization (Reuters, 2020).

As mining companies look beyond the crisis, the pace of digital transformation is expected to accelerate further and the rate of investment in technologies—especially those that focus on remote working, improving productivity and workers safety—is likely to grow.

2.4 WHAT TECHNOLOGIES ARE COMING: A TAXONOMY OF DISRUPTIVE TECHNOLOGIES IN THE LARGE-SCALE MINING SECTOR

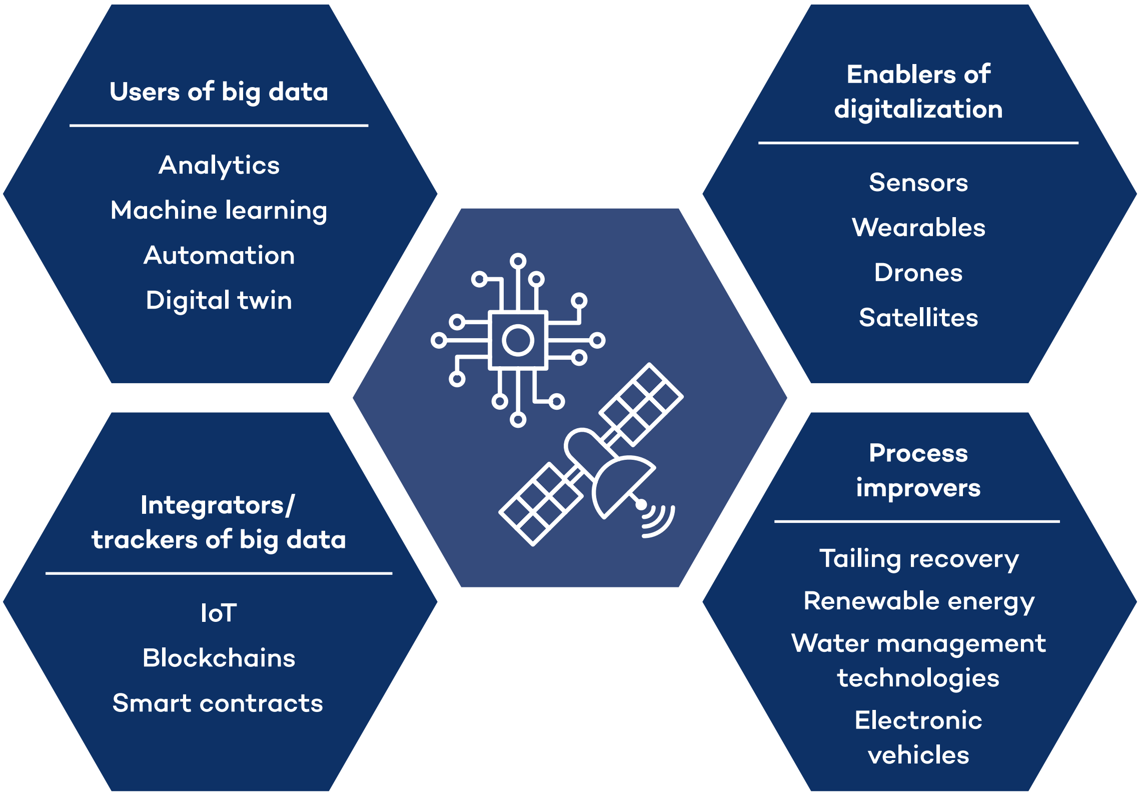
The 2019 IGF Technology Review classifies technologies being developed and adopted in the mining sector, as shown in Figure 1.

Figure 1 highlights technologies that are disruptive because they fundamentally alter the nature of mining operations. The taxonomy classifies new technologies in four baskets:

1. First, sophisticated machines embedded with technologies that use big data meant to boost efficiency of mine operations, such as automated machineries, digital twins, super computers for big data analytics etc.
2. Second, software technologies that collect, analyze, and integrate and track big data, that are then shared through networks and high-speed connectivity. Examples include the Internet of Things (IoT); use of 5G; virtual reality; blockchain technologies etc.
3. Third enablers of digitization, which provide an interface between human intelligence and artificial intelligence. Examples include drones, sensors, connected wearables etc.
4. Finally, process improvers, which are aimed at boosting performance, improving footprints of operations, and responding to environmental, social, and governance (ESG) requirements. Examples include electric vehicles, water management technologies, renewable energy sources etc.

7 Source: https://www.ey.com/en_gl/ccb

FIGURE 1. TAXONOMY OF DISRUPTIVE TECHNOLOGIES IN THE MINING SECTOR



Source: Ramdoo, 2019.[8]

The significance of their impact is not only in their effects as individual technologies, but in the way they operate together as a suite of inter-related innovations. For example, cheap sensors make large amounts of information (big data) available that is routed by 5G and then processed with artificial intelligence and machine learning as part of operational optimization programs. These programs then direct electric autonomous and semi-autonomous vehicles and equipment from remote operation centres. The final impacts are profound structural changes in the organization of the workplace, affecting the nature of tasks, the skills necessary to perform new tasks, the location of workers and, ultimately, employment opportunities at the mine site. They also influence the procurement needs of the mine, away from employee-related procurement to tech-related procurement.

Altogether, disruptive technologies augment the capabilities of mining operations, creating:

1. **Digital mines:** where assets, operations, and the workforce interact with each other through infrastructure such as connected wearables and devices, data platforms, digital tools, and Internet connectivity. These allow mining operations to be more efficient and enable rapid and real-time effective decision making.
2. **Smart mines**, powered by artificial intelligence, the use of big data, and machine learning as well as automated processes and robotics for safer, integrated, and more precise mining operations.

8 See Ramdoo (2019) for a detailed breakdown of disruptive technologies and their uses in the mining sector.

3. **Agile mines**, with leaner organizational structures, able to operate almost continuously and remotely.
4. **Green mines**, fueled by electromobility, renewable energy, and water-saving technologies.

The latest survey conducted by the World Economic Forum's (WEF's) *The Future of Jobs 2020 Report* (WEF, 2020) revealed what technologies are likely to be adopted by mining companies by 2025.

TABLE 1. TECHNOLOGIES LIKELY TO BE ADOPTED BY 2025 (BY SHARE OF COMPANIES SURVEYED)

	TECHNOLOGY ADOPTION IN THE MINING AND METALS INDUSTRY	% SHARE OF COMPANIES LIKELY TO ADOPT THE STATED TECHNOLOGY BY 2025
1	Robots, non-humanoid (e.g., industrial automation, drones etc.)	90%
2	IoT and connected devices	90%
3	Big data analytics	90%
4	Cloud computing	87%
5	Encryption and cybersecurity	83%
6	Text, image, and voice processing	76%
7	Artificial intelligence (e.g., machine learning, neural networks etc.)	76%
8	E-commerce and digital trade	62%
9	Power storage and generation	57%
10	Augmented and virtual reality	57%
11	Distributed ledger technologies (e.g., blockchain)	50%
12	3D and 4D printing and modelling	48%
13	New materials (e.g., nanotubes, graphene)	37%
14	Quantum computing	21%
15	Biotechnologies	16%
16	Robots, humanoid	15%

Source: Adapted from WEF, 2020.

Automation, connected devices, and big data are among the highest priorities for mining companies, reflecting paths toward more sophisticated mining operations. This confirms that the trends already observed in most mining jurisdictions are likely to be fast-tracked.

Data is the common denominator and the central force behind disruptive technologies. In fact, every activity has the potential to generate large volumes of complex information, in raw form, but in real time, that needs to be analyzed very quickly. This is called big data. The pace of technological adoption, therefore, will depend on the mining operation's ability to generate, manage, analyze, connect, protect, and use the wealth of information that is needed for a seamless operation. **Solid, reliant, and secure big data infrastructure**, including strong legal frameworks to ensure data privacy and cybersecurity, is the backbone of the mining ecosystem.

One critical element of that infrastructure is connectivity to fast and reliable Internet. Data needs to be transferred in real time to operating control workstations. The massive amount of information generated on an ongoing basis requires high-speed connectivity.

In a digitized world, every part of the system is connected, and therefore the risk is that breakdowns at the wrong places in the system will paralyze entire operations. Internet downtime at a fully digital site, for example, might shut down most operations. This vulnerability explains the reluctance in some quarters to go fully digital—the risk of costly downtime is too high.

2.5 IMPACTS OF NEW TECHNOLOGIES

The debate around the impacts of disruptive technologies is heavily polarized. One view emphasizes that technologies will lead to lower employment and make mine workers redundant, with dire implications for mine communities and mining-dependent countries.[9] The other view[10] is that technology will create substantial opportunities both for workers and economies and will significantly improve productivity of assets.

The dichotomy, however, is a false one (Acemoglu and Restrepo. 2018). Both arguments are valid, and the final net impacts will be a mix of positive and negative effects that vary by company, by operation, by location, by technology and by job category. The 2019 IGF Tech Review provided a comprehensive outline of impacts that may arise from the adoption of new mining technologies across the mining value chain. The following types of impacts can be expected:

1. New technologies will improve overall labour and asset efficiency and productivity of mining operations.
2. As noted above, technologies that remove workers from the mine face, that automate vehicles, and that monitor worker status (wearables) will improve worker safety.
3. Some technologies will create a substantial loss of low- and medium-skilled jobs. The most impactful of these will be autonomous and semi-autonomous vehicles and machinery, the IoT, and (to a lesser extent) drones (Conference Board of Canada 2018).
4. At the same time, new technologies will create new higher-paying jobs in skilled areas such as engineering (civil, mechanical, electrical, other), and computer and information systems. Semi-autonomous technologies will require some lower-skilled operators, creating new opportunities for different tasks but away from mine sites (Farrant,

9 See for example Brynjolfsson & McAfee, 2014; Frank et al., 2019; Frey & Osborne 2017; Harari, 2014.
10 See for example Autor, 2015; Bessen, 2018; WEF, 2016a.

2018). On balance, in areas with low levels of education, job prospects with the mine of the future will be fewer.

5. Where there are overall job losses, there will also be a reduction of local procurement of employee-related goods and services such as food, housing, uniforms, etc.
6. New technologies will make some new operations viable that could not have gone ahead using conventional technologies and will similarly extend the life of some existing operations.
7. Remote operations and flexible working conditions may offer more employment opportunities for women. However, those jobs may not be available for women will lesser technical and digital skills.
8. Impacts will vary depending on socio-economic conditions and level of development in host countries. More diversified economies tend to be better able to accommodate labour market transitions.

The rollout of new technologies will vary considerably in extent and timing, based on such factors as the following:

1. The type of mining activities. Surface mining, underground mining, and deep mines will necessarily adopt different technologies for different reasons and with different results. Similarly, geological conditions—ore grade, depth of mines, rock hardness—will determine what technologies can be deployed or not. Further, geographical location of deposits—remote areas and/or new frontiers such as seabed or space will determine the use of some technologies over others.
2. The size of mines. The more sophisticated the technologies, the higher the cost of adoption. Large-scale projects backed by large investors have a financial advantage over smaller operations.
3. The age of the mine. Greenfield operations, or mines with a considerable lifetime of exploitation left in them, will be more likely to make technology investments that take many years to pay off.
4. The cost of labour. Where wage rates are high, or costly fly-in-fly-out shifts are the norm, there will be greater incentive for mining companies to roll out labour-saving technologies such as automated machinery.
5. The social context. Where the expectations are high for mining employment and the benefits it brings to local communities, where agreements have been struck on sharing benefits of mining, or where the local communities are highly dependent on mining activity, companies may be reluctant to adopt new technologies out of concern about social tensions and in an effort to preserve their social licence to operate (Cosbey et al., 2016).

Finally, the widespread adoption of new mining technologies is expected to change the sector in fundamental ways.

1. New actors, such as tech providers[11] or automotive manufacturers,[12] may become strategic investors in mining projects. While these new entrants may bring fresh capital and ideas to the mining industry, there is an underlying question about the likely impact this might have on competition (PwC, 2017) and on the way contracts are designed between governments and licence-holders.
2. Universities, R&D centres of excellence, and technological hubs will play a more prominent role in providing innovative ideas, solutions, and high-tech services to the value chain.
3. Technological innovation will come from new fields far outside the core competencies of mining, such as biochemistry, nanotechnologies, bioengineering, and computer science. It will have far-reaching implications for knowledge and expertise needed in large-scale mining and opportunities for local business development, including the increased need to form strategic partnerships with other economic sectors.
4. Following the disruptions caused by travel restrictions during the COVID-19 pandemic, new technologies will further reshuffle mining value chains. This will reshape existing business models and relationships between mining companies and suppliers, locally and globally.

2.5.1 FOCUS ON LABOUR IMPACTS

Quantifying the exact effects of new technologies on employment for developing and advanced economies has proven difficult because there is **a lack of consistent data** about what the jobs of the future will look like and, therefore, what skills will be needed.

However, with leaner mining structures, we expect **a declining employment intensity**. WEF (2020) reports that 51.7% of companies surveyed expect a reduction in the workforce because of automation and augmented technologies by 2025. On average, about 19.9% of employment is expected to be displaced, according to the report.

The final effects are more nuanced than a simple loss of some jobs; they involve a dynamic restructuring wherein some jobs are lost, some are redefined, and some new jobs are created. Importantly, **tasks—more than occupations—are likely to be disrupted** (Pagés, 2019). Not all tasks within an occupation are equally automatable, but some technologies will completely change the nature of certain tasks and the associated skills and competencies requirements needed to perform specific tasks. Table 2 summarizes the reasons for changes in mining jobs, and the implications for specific occupations. As illustrated in the column on future or new occupations created, new employment opportunities will be created in fields that are currently not considered as "mining employment." Other occupational categories will disappear from the list of mining tasks as they are made redundant or restructured.

11 The Australian telecommunications company Telstra launched a new mining services company, saying "the timing of the commodity price downturn means there's a different outlook among mining customers as to how they are going to drive process change in their operations" (PwC, 2017, p. 4).

12 In 2015, automotive and energy storage company, Tesla signed early-stage agreements with junior mining companies, some of them not even in production, to secure supply of lithium, a key metal for batteries, for its new "giga-factory" in Nevada. Those direct procurement deals from source with high-risk companies brought new dynamics to the mining industry (PwC, 2017).

TABLE 2. LABOUR MARKET DYNAMICS AND THE CHANGING NATURE OF WORK IN MINING

CHANGES OCCURRING	REASONS FOR CHANGE	EXAMPLES OF TECHNOLOGIES	CURRENT OCCUPATIONS IMPACTED	FUTURE (OR NEW) OCCUPATIONS CREATED
Obsolescence	Task redundancy	Autonomous vehicles	Vehicle conductors Engine drivers Mining extraction workers	Remote control operators AI and machine-learning specialists
		Blockchains	Data entry clerks Material recording and stock-keeping clerks	Management and organization analysts
		Unmanned vehicles (drones)	Prospectors	Data analysts and scientists Remote sensing scientists and technologists
Restructured occupations	Tasks redesigned	Blockchains	Accountants Procurement officers Financial analysts	Management and organization analysts Big data specialists
		Automation	Machine operators	Remote control operators
Augmented occupations	Tasks enhanced/ modernized	Connected wearables Drones	Geologists Mining engineers Surveyors	Remote control operators Data analysts and scientists Remote sensing scientists and technologists
		Virtual reality	Engineers Data analysts	Remote control operators Big data analysts

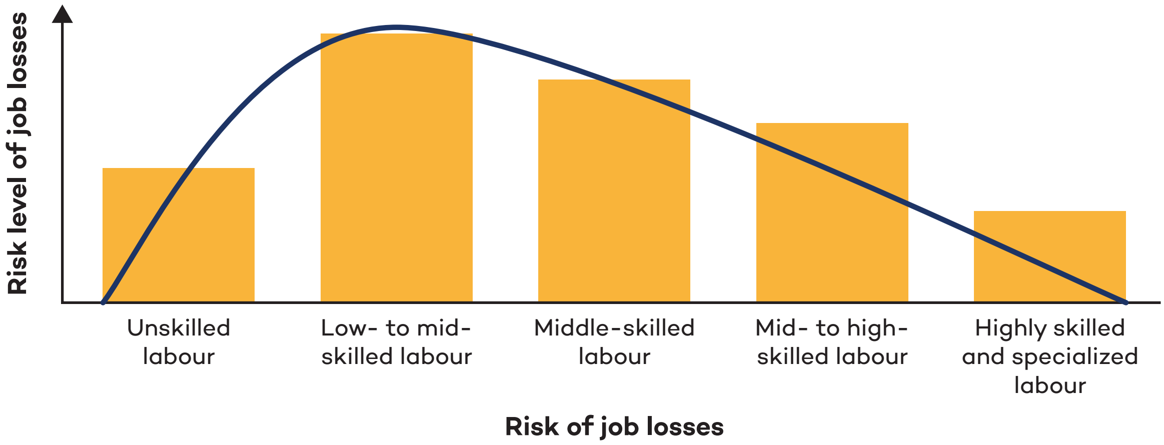
CHANGES OCCURRING	REASONS FOR CHANGE	EXAMPLES OF TECHNOLOGIES	CURRENT OCCUPATIONS IMPACTED	FUTURE (OR NEW) OCCUPATIONS CREATED
Remote working	Tasks outsourced/ made more flexible	Digitized systems	Vehicle conductors Machine operators	Tele-operators
		Software automation	Report analysts Surveyors Machine operators	Remote controllers
Capitalization effects	New tasks entering mining and new organizational structures	Automation		App developers Software developers
		Virtual reality		Big data analysts

Source: Authors.

Changes in welfare distribution will be an important part of the dynamic of change. **New technologies can exacerbate job and salaries polarization for mining workers** (Gibbs, 2017; Manyika, 2017). Certain tasks performed by unskilled labour may be less at risk of becoming redundant due to technologies for two reasons. First, the cost of labour for these types of jobs is very low, and so it may not be cost-effective to replace them with expensive machines. Second, these tasks (often associated with human services) may not be automatable. These include jobs such as labourers, construction workers, and cleaners. Demand for those types of unskilled workers, therefore, is likely to be relatively unchanged (as will their incomes).

Very highly skilled and specialized workers, on the other hand, face lower risk of job displacement from the mines because their skills are critical to performing the new tasks, although they may need some retraining and reskilling. In fact, we expect to see an increase in demand for such types of workers associated with higher wages and increased competition from other sectors, which may require similar competencies. As shown in Figure 3, the largest risks are likely to be borne by low- to mid-skilled and mid-to high-skilled workers.

FIGURE 2. RISK OF JOB LOSS FROM NEW MINING TECHNOLOGY



Source: Authors' diagram.

Welfare distribution effects are critically important for mining-dependent communities. A primary concern is that mining often takes place in rural settings where average levels of education are low relative to urban settings. Remote areas also offer fewer alternative employment opportunities beyond the mine gate. Locals in such settings are traditionally the primary candidates for low-to-mid-skilled occupations, and will have trouble contesting the higher-skilled jobs of the future. Loss of income during job transition may exacerbate poverty and inequality in local communities, with significant consequences for the social fabric. Generally, the adjustment costs are higher for people with lower education levels (International Monetary Fund [IMF], 2018).

As well, the advent of remote-controlled operations will put locals in direct competition with other nationals (also locals, by some definitions) and even global workers, by removing the need for workers to commute to mine sites. This may exacerbate tensions between communities and mining companies but will unlock opportunities for other people in the country. Delocalization of staff will also affect the local economy, leading to closure of businesses dependent on mine workers and hence collateral job losses.

All of these impacts will tend to be more significant in developing countries, where economic activities are less diversified, and countries have a larger workforce in lower-skilled employment with low educational attainment levels compared to advanced economies.

2.5.2 FOCUS ON GENDERED IMPACTS

Technological change will affect women's participation in the mining workforce. Historically, the large-scale mining sector's overall workforce has been dominated by male workers. Although there may be some variations across countries and by types of operations, it is nonetheless estimated that women in large-scale mining represent between 5% and 10% of the mining labour force globally, ranking the mining sector with the worst global gender parity indicators (Eftimi et al., 2009). This situation is prevalent across the entire mining value chain and across all occupations, up to the boardroom (Fernandez-Stark et al., 2019). By contrast, in the artisanal and small-scale mining sector, women are estimated to represent between 30% and 50% of the global ASM workforce (United States Agency for International Development, 2020), where work is often considered informal.

To get a better appreciation of gender representation in the mining sector, it is necessary to look at participation in specific occupations. What follows in this section is, however, limited by the glaring lack of consistent, detailed, and comparable data sets and in-depth analysis on the current state of employment in large-scale mining globally that is disaggregated by gender. Only a handful of countries[13] collect granular gender-disaggregated data on direct employment in mining by type of occupation, skill level, and education required.

The lack of baseline data is even more pronounced when the whole mining supply chain is considered. It is unclear how many women own or work in businesses that supply goods and services to the mining sector. This is a major challenge that hinders efficient and meaningful policy reforms for future employment in the sector. Without evidence, plans for future employment opportunities for both men and women will remain weak and speculative.

Despite consistent data challenges, one can nonetheless observe that there is an over-representation of women in administrative and office-related jobs such as clerical work, accounting, health care, and human resources. Men almost exclusively perform jobs requiring physical strength and endurance such as drill operators. For other tasks requiring mechanical and technical skills or field presence (such as machine operators, engineers or geologists), men occupy a larger number of posts. In Chile, for example, women's representation is the lowest for labour-intensive maintenance activities, accounting for only 2% of workers in the sector (Fernandez-Stark et al., 2019). Similarly, women are largely underrepresented in senior roles globally.

BOX 1. SOME FACTS AND FIGURES: SHARE OF WOMEN IN LARGE-SCALE MINING SECTOR EMPLOYMENT

According to the 2020 Report by the Minerals Council of **South Africa**, women represented 12% of the overall large-scale mining labour force in 2019. Broken down by types of occupation, there were 17% of women in top and senior management positions, 24% in professionally qualified positions and 18% in skilled technical professions (Minerals Council of South Africa, 2020).

In **Australia**, women accounted for a total of 16.3% of the large-scale mining labour force in 2018 (Work Gender Equality Agency, 2019). Broken down by occupation, female participation accounted for only 4.5% of technicians, 11% of machinery operators and drivers, and 13% of labourers. Participation rates improve slightly in higher positions, with 15% and 16% of key management personnel and general management personnel, respectively (Connell & Claughton, 2018).

In **Canada**, while women make up half of the population and 48% of the labour force, they represent only 15% of the mining labour force (Mining Industry Human Resources Council, 2021). The latest Diversity Disclosure Report of 2020 (Osler, 2020) stated that women represented 16% of directors and 14% of executive officers in Canadian mining companies.

There is, however, a lack of consistent baseline data and methodology to assess the real share of female participation in the sector. Each country has its own methodology and occupation categorization, making it difficult to compare the situation across countries.

13 Only a few countries (such as Canada, Chile, South Africa and Australia) collect and publish detailed data on the participation of women in the mining sector.

Several factors explain why women's participation in the large-scale mining sector is lower compared to other economic sectors. For instance:

1. The industry has historically relied on the physical strength of its workers, therefore creating **physical barriers** to female participation.
2. **Legal frameworks** in place in several countries until the end of the 1990s prohibited the participation of women in certain types of operations in the mining sectors. This was the case in countries that ratified the International Labour Organization (ILO) Convention 45 of 1935, which simply proscribed the employment of women in underground mining.[14] Although the Convention has since been denounced by several countries, including Canada, Australia, South Africa, and Chile, it has not been repealed and is therefore still in force in many countries.
3. **Working conditions** at mine sites can be hostile to female participation: for instance, safety risks, long and often inflexible working hours, and rotational shifts requiring workers to stay away from home during the shift, are neither attractive nor conducive for female workers. Remote, isolated, and heavily male-dominated worksites with worker inflow can foster increased gender-based violence mostly associated with sexual harassment and sextortion.[15]
4. Moreover, although this is slowly changing, corporate **gender-blind policies** do not attract and favour the inclusion and retention on women in mining jobs. Examples include the lack of adapted equipment, such as personal protective equipment (PPE) or helmets that are not designed for female morphologies, inadequate sanitary facilities on mine sites, lack of childcare facilities etc.
5. **Cultural barriers** linked to gender stereotypes, ethnicity, and stereotypes about the masculinity of the mining sector, have, for a long time, slowed women's interests in mining jobs and recruitments for onsite positions. While those may be slowly changing, gender-biases remain a barrier.
6. In the past, in some countries, there were other superstitious beliefs that kept women out of mining, like female miners being perceived as "loose women" or bringing a "spirit" of bad luck when in close proximity to minerals or mineral-bearing stones.
7. Importantly, there are significant **skills barriers**. Current education systems do not produce enough skilled female workers, with a science, technology, engineering, and maths (STEM) background required for technical jobs. WEF (2016) estimates that barely 27% of STEM graduates—and only 19% of majors in math, computer science, and engineering—were women. Additionally, of those who complete their training, only a fraction go on to taking up STEM-related jobs.[16] As a result, women hold only 25% of STEM jobs despite representing half of the broader workforce.

Some of those barriers may be eroded by the dynamic changes in mining employment brought about by new technology (Abrahamsson, 2019; Conference Board of Canada, 2018).

14 Several countries, including Canada, Australia, South Africa, and Chile, have since unilaterally withdrawn from (denounced) the treaty, which is still in force.

15 For example, a 2018 Action Aid Social Audit Baseline report (ActionAid, 2018) reflects the results of community-led research conducted in 10 mining-affected communities across South Africa as part of ActionAid South Africa's Social Audit Project. This research is based on interviews with 483 women and 275 men, exploring how they were affected by the presence of mining operations. According to the report, 40% of women who participated in the survey indicated that jobs in the mining sector were only accessible through sexual favours.

16 For more details, see ILO (2020).

More sophisticated operations are expected to be less laborious as machines take over heavy duties. Arguably, this may remove physical and technical barriers in favour of higher female participation. This can further improve access to jobs for women who are banned from working underground in some countries.

Similarly, remote operation control provides a better working environment for women as they normalize the workplace into office-type positions. This will resolve some challenges faced by women in facing the masculine cultural barriers in camp settings, as well as replacing fly-in fly-out model employment with schedules more amenable for those with families.[17]

BOX 2. AN EXAMPLE OF GOOD PRACTICE IN CHILE

In Chile, mining companies such as CODELCO and BHP have introduced flexible and gender-responsive working arrangements such as specific career-development programs offered to pregnant employees in their last trimester and specific career-development opportunities. These have resulted in an increase in women's participation in the mining workforce. While these examples are not necessarily tech driven, one can expect to see a similar trend when and if the potential of new technologies to offer a better work-life balance is fully developed.

Source: Fernandez-Stark et al., 2019

While new mining environments are expected to be more favourable for women, older challenges will not disappear automatically. For one thing, while new technologies will, in theory, provide more opportunities for women in STEM-related occupations, there is still the hurdle of under-representation of women in STEM-related education and skills training. For another thing, mindsets will have to evolve; without specific gender policies in mining industries, the current situation is not likely to change significantly.

Women in local mining-dependent communities may face the biggest challenges. While new technologies may provide better working conditions for highly skilled women, they will also eliminate the jobs of local community women who participate in the mining supply chain. Particular attention will therefore have to be paid to women when addressing transition and alternative livelihoods.

Finally, new challenges essentially linked to the gender digital divide may arise, holding back potential opportunities for women. New jobs and occupations will require new sets of skills that mostly rely on digital literacy and Internet access.

17 To be clear: this shift benefits both men and women with families.

BOX 3. GENDER DIGITAL DIVIDE IS A BARRIER TO WOMEN'S EMPLOYMENT

According to EQUALS Global Partnership, 200 million fewer women than men own a mobile phone, 250 million fewer women than men use the Internet, and only 6% of women develop apps. The gender digital divide is even more significant in developing and less-developed countries. Research by the World Wide Web Foundation (2015b) shows that across urban poor areas in 10 cities, women are 50% less likely than men to be online (World Wide Web Foundation, 2015a) and 30% to 50% less likely than men in the same communities to use the Internet for economic and political empowerment.

This raises the question of whether women are sufficiently equipped to fill new job opportunities arising because of new technologies, or whether we will just be replacing a traditionally masculine mining sector—mostly associated with muscle force and physical strength—with a new kind of masculinity that manifests itself in digital literacy, skills, and resources (Abrahamsson, 2019).

2.5.3 FOCUS ON FISCAL IMPACTS

There are at least three ways in which the advent of new technologies in mining operations might impact fiscal policy for resource-rich countries. **The most direct is the impact on receipt of payroll taxes.**

Salaries and wages constitute 10% to 20% of the economic benefit that countries receive from mining (International Council on Mining and Metals [ICMM], 2016). Fewer jobs also mean lower payroll taxes, which are the second largest source of government revenue from the mining sector (PWC, 2010). In Zambia, for example, payroll taxes represented 15.1% of government revenues from mining in 2019 (EITI, 2020). If new technologies significantly reduce employment levels at existing operations, it is highly uncertain whether these workers will get absorbed into other industries, especially in more remote communities, in which case a significant hole may be left in government budgets and local economies. Similarly, if greenfield mining investment leads to significantly lower employment levels, it will have a much lower value in terms of generating payroll tax revenues.

Cosbey et al. (2016) modelled the fiscal impact of reductions in the workforce in scenarios that saw 30%, 50%, and 70% fewer workers numbers in individual mining operations in a high-income and a lower-middle-income country. In absolute terms, the reduction in government revenues, including direct, indirect, and induced personal income tax revenues, ranged from USD 7.6 million to USD 17.8 million in the lower-middle-income country case and from USD 31.7 million to USD 74.0 million in the high-income country.

These are significant potential fiscal impacts. They arise from worker displacement only in individual operations, so the total impacts across many mining operations could be significantly higher. But while they are indicative of the size of the challenge, they are not necessarily a good prediction of general results. Most importantly, the scenarios do not account for the fact that new technologies will create new employment in higher-skilled occupations that may pay higher salaries, meaning that while total employment may be reduced, those that are employed will be paying higher taxes.

The final effects of this dynamic are highly context specific, and therefore difficult to predict. The final impacts depend on:

- The types of technology adopted and the rate of adoption; as noted above, some technologies are labour neutral, while others are labour displacing, and rates of rollout will vary according to the specific circumstances of each operation.
- The basic job impacts of those technology changes: how many jobs lost, jobs recategorized, jobs created, in what occupations. Jobs recategorized may fetch a higher salary, given the new skills needed.
- The wage levels of those whose jobs are lost or recategorized relative to those whose jobs are newly created. To illustrate, in some developed countries' remote mining operations, even semi-skilled occupations command high wages as compensation for an undesirable fly-in-fly-out model of work. Even if they were replaced one-for-one with higher-skilled remote operations centre controllers, it is not certain that the total wage bill would increase. But this might be the case if they were replaced one-for-one with software engineers. These relative wage level calculations differ for each country.
- Whether the newly created jobs are located in the country of operations or in other countries and when those jobs are created in-country, whether they are performed by nationals or expatriates. That, in turn, is also context dependent, a function among other things of national skill levels, prevailing national wages relative to international alternatives, and national labour retention policies.

Another direct fiscal impact is **corporate income tax revenues**. Investments in new technology will ultimately allow for increases in efficiency and productivity. In some cases, this might mean increased profits, and increased corporate income taxes (and dividends paid to governments). Here again, the final result will be highly context specific, and the possibilities are explored in Section 3.4 as one of a set of candidate policy options for dealing with the impacts of new mining technologies.

Another avenue for fiscal impact is the fundamentally changing nature of mining operations, wherein a greater portion of the rents in the value chain accrue to creators of intellectual property such as patents and algorithms. Intangible assets such as these already represent a major **risk of profit shifting** by multinational companies. Mining companies will be required to pay licensing fees for new technologies. This creates a risk of artificially inflated payment to related companies in low-tax or no-tax jurisdictions, to shift profits and avoid taxes in mining host countries. The redistribution along the value chain to activities in foreign locations presents two problems for host countries of mining activity:

- A legitimate shifting of value, and potentially tax revenue, out of the country of production. More of the mining value chain will sit with foreign suppliers of technology, or potentially with foreign remote operations centres, meaning less taxable economic activity in the country of production.
- The risk that such flows of payment to related companies offer more channels for illegitimate profit shifting, further exacerbating the profit-shifting risks and revenue collection challenges that already exist in relation to corporate income tax, the dominant fiscal instrument in most mining tax regimes.

2.5.4 FOCUS ON ARTISANAL AND SMALL-SCALE MINING

Up to this point, our analysis has mostly been focused on impacts felt in the formal large-scale and medium-scale mining sector. New technologies will have a very different set of impacts on ASM operations.

A first impact we can expect from the adoption of new technology at large-scale mines, and a drop in employment for semi- and low-skilled workers, is an influx of new ASM participants, as some of those workers play on their familiarity with the mining process and turn to ASM as an alternative livelihood. As noted above, this would have highly gendered implications. The final effects of such an emigration to ASM would depend on the various country-level regimes in place to manage ASM, and the characteristics of the labour markets involved. Many countries' regimes are ill-equipped to manage the social and environmental impacts of a significant increase in ASM activity, and such an increase might in some places create heightened conflicts with formal mining operations.

BOX 4. ASM AND NEW TECHNOLOGIES IN BURKINA FASO

ASM in Burkina Faso provides a living for more than 1 million people over an estimated 800 sites. Production, however, is relatively modest in terms of tonnes produced. The government, seeing ASM as an important employer of young and under-educated workers, has taken important steps to both encourage the industry and to regulate it and build capacity in an attempt to improve socio-economic and environmental outcomes.

Mechanization is starting to change the face of small-scale operations in Burkina Faso. Crushing, which was traditionally done by women using hammers, is increasingly being done with mechanical hammer or jaw crushers. The machines are either imported from India or, more often, locally manufactured (a welcome source of industrial employment). Each crusher replaces an estimated 20 women. Grinding was also traditionally the job of women, using mortars and pestles. But increasingly this job is being done with mechanical ball mills.

Washing is done mostly by women in washing sheds. But they are being replaced by centrifugal concentrators. One such machine, costing less than CAD 7,000, needs only five or six operators, and has a processing capacity of 1 to 2 tonnes per hour. Washing sheds by contrast employ two to three people with a maximum treatment of 2 tonnes per day. It's estimated that one machine can replace 20 to 30 employees.

One mine owner who also happened to be the village chief confided to researchers that a centrifuge would be more profitable for him, but asked what would happen to the women for whom this activity is their only livelihood?

Ouedraougo (forthcoming). (An IGF case study on the impacts of new technologies on large-scale mining in Burkina Faso)

A second impact might come in the form of increased competitive pressure from the formal sector. Both modes of production ultimately sell at prices determined by world markets. If formal sector operators are better able to afford the capital to adopt new productivity-increasing technologies, ASM producers might face downward price pressure—a challenge in a sector that already operates on thin margins. There would be gendered impacts. Women account for 30% to 50% of the ASM workforce and are mostly concentrated in lower supply chains. Investments in higher skills and new equipment would be required to remain in business. However, women, who generally have lower skills, would be more severely affected given persistent systemic barriers, such as difficulty accessing finance, for example (IGF, 2018).

One response to that pressure might be the adoption of new technologies in the ASM sector, though the technology in question is very different from that being adopted in large-scale mining. That also would have important impacts. ASM in many countries is evolving, from an activity that was primarily manual to an activity that is semi-mechanized. It is not uncommon to find operations using jackhammers, explosives, bulldozers, crushers, ball grinders, mechanical centrifuges, motorized pulleys, and metal detectors. Some even have ventilation systems for relatively deep or extensive caving excavations. Adoption of these sorts of technologies in small-scale mining will increase productivity and potentially improve health and safety (while reducing environmental impacts), but will also have profound impacts on the numbers employed (see Box 4). This is a concern, since ASM is a major employer of unskilled and semi-skilled workers. Fritz et al. (2017) estimate that ASM directly employs over 40 million people globally, with 150 million dependent on the sector (compared to 7 million direct employees in industrial mining), and they estimate that in Africa that workforce is 40% to 50% women. Lost employment resulting from mechanization will have gendered impacts, with ripple effects on livelihoods, food security, and wellness of families as women tend to invest their income in family nutrition and education.

New technologies in the ASM sector may also lead to increased overall activity. The increasing use of metal detectors, for example, greatly reduces barriers to entry. In those countries where ASM is well managed, this may lead to increased employment opportunities for low- and semi-skilled workers. In other less-well-managed mining jurisdictions, by contrast, it may lead to increased health and safety risks for workers and adverse environmental outcomes. Increases in ASM activity also may lead to increased conflicts between ASM and large-scale mining operations, and, in some cases, may lead to migration from other livelihood activities such as agriculture, which could be a concern from a food security perspective.

3.0 ELEMENTS OF A NEW DEAL

The preceding section describes the advent of new technologies in the mining sector as a mixed bag of potential impacts, some positive and some negative. This section considers policy responses: what should governments do in the face of the coming wave of technological disruption in the mining sector? The policy options considered here include those that aim to address negative impacts and those that aim to exploit positive opportunities. They fall into four broad categories:

- **Policies aimed at ensuring that whatever employment is available in the mine of the future is contestable by local workers.** Those policies include a focus on skills and education, a focus on local procurement, and a focus on employment-related local content policies. Differentiated strategies will need to be adopted to maximize opportunities for men and women.
- **Policies aimed at leveraging the mining activity as a route to ensuring economic diversification and a reduced dependence on the mine as a provider of employment-related benefits.** Those policies include a focus on innovative social impact investment, a focus on government-led diversification and transition policies, and a focus on local content policies that lead to diversification.
- **Policies aimed at rethinking tax revenue mechanisms from mining operations**, and the possibility that such revenues might be used for local development purposes.
- **Policies that find solutions to the challenges of new technologies in those technologies themselves.** These policies include a focus on local innovation to support mining operations, a focus on mining technology in support of economic diversification, and the possibilities of new technology in support of ASM, shared connectivity, mining companies supplying local communities with data of interest, and using mine-level data to aid tax authorities.

3.1 EMPLOYMENT IN THE MINE OF THE FUTURE

One of the most obvious elements of any new deal focuses on employment in the mine. In resource-rich developing countries, direct employment and all the indirect and induced employment associated with it represent the most significant form of value a mine can bring to local communities, and in many cases, the large-scale mining sector is the largest formal employer. Mining activities often take place in remote areas where there are few other sectors that can offer formal employment with regular wages to host communities.

But the previous chapter described the sorts of labour impacts we can expect to see as a result of new technologies: some jobs will be eliminated, some will be altered, and some new jobs will be created. Numbers are hard to predict, but, overall, we can expect to see fewer jobs and perhaps many fewer in communities that host mining operations. The 2020 EY report on top mining risks (Mitchell, 2020) ranked the uncertain future of the mining workforce as the second highest risk for the mining industry. WEF (2020) indicates that an average of 19.9% of mining workers will be at risk of displacement by 2025 if plans to adopt technologies go ahead. A Conference Board of Canada report (2018) predicts that the most impactful technologies will cause mining-related employment to fall by 49% by 2040.

One set of policy options to address these challenges focuses on ensuring that what gender-responsive policies are in place to ensure jobs are available at the mines of the future will, to the extent possible, go to locals. There are three main avenues for achieving this:

- An increased focus on skills and training to help locals compete for the higher-skilled jobs that are created, both at the mine site and in the supply chain.
- Employment-related local content policies.
- Local procurement policies.

It is understood that the policy options are based on collaboration between governments, employers, and workers, such that workers continue to enjoy their rights at work, particularly the enabling rights of freedom of association and collective bargaining.[18]

3.1.1 INCREASED FOCUS ON SKILLS AND TRAINING

New technologies have uncovered a deeper **challenge of skills gap and the skills mismatch**,[19] underlined by the fact that current workers' qualifications are not necessarily the ones needed for the new jobs (Hoteit et al., 2020). Many countries face systemic skills-related challenges and the rapid wave of technological adoption has exacerbated the difficulties of finding suitable workers with the skill sets needed to perform high-tech tasks. The combined effect of skills shortages and mismatches could affect the ability of mining companies to recruit local workers in the short to medium terms, preventing them from benefiting from new technologically intensive job prospects.

A clear way to address this challenge is through skills and training policies and institutions that help locals compete for the mining jobs of the future.

PARTNERSHIP IS KEY

Governments' efforts alone will not be sufficient to embrace the skills challenge. **A collaborative approach is needed** that takes a whole-of-country perspective and includes key stakeholders, each having roles and responsibilities in supporting the skills-building agenda.

18 The Global Commission on the Future of Work outlines a vision for a human-centred agenda that is based on investing in people's capabilities, institutions of work and in decent and sustainable work. You can learn more about the Commission's recommendations at ILO (2019a). This is reaffirmed in the ILO Centenary Declaration (ILO, 2019b).

19 According to the Boston Consulting Group, skills mismatch results in employers hiring workers without the needed qualifications and having to reskill or retrain them. It is inversely correlated to productivity, innovation, and even sustainable development—and denies the world's economies about USD 8 trillion in unrealized GDP each year.

Universities and training institutions need to work closely with the mining industry to design and regularly review the training curricula to ensure that the evolving needs of the industry are reflected in capacity-building programs. Governments need to consult mining companies to better understand what skills are needed in light of new technologies and reflect that in their broader education policies. The initiatives should include workers as well because factors driving the future of work will transcend the boundaries of the mining sector.

In the context of large-scale mining, collaboration between governments and mining companies will be critical and should be formalized in a way that ensures governments are continuously fed with information on private sector plans and labour needs, and mining companies are continuously informed and consulted on evolving government education and skills policies. Mining (and other) companies are best placed to inform governments as well as local training authorities about the skills required for future jobs and those that will be released from the mine site. Most companies are bound by host countries' mining regulatory frameworks (such as local content policies) to submit a labour plan and a training program for local employment. Ensuring that decisions to invest in new technologies are reflected in future labour plans will allow the matching of skills available to future jobs.

When those skills are not yet available locally, coordination initiated at the early project design phase can help identify the gaps and provide training institutions time to (re)design new training programs to equip the labour force with the requisite skills. Here again, there is a role for the mining industry to collaborate with local training institutions to co-design appropriate upskilling programs customized to their needs.

Interministerial coordination will have to be strengthened to ensure the proper alignment of policies within government departments. Ministries of mining and natural resources should coordinate efforts with ministries responsible for education, economic planning, industry, and gender equality.

ASSEMBLE BASELINE KNOWLEDGE ON EXISTING SKILLS AND FUTURE SKILLS

As with employment-related local content policies, the baseline requirement is a good understanding of what skills currently exist and what skills will be needed in the mine of the future. Governments must have a comprehensive understanding of the global trends regarding the Fourth Industrial Revolution and how those are unfolding nationally and in different economic sectors, such as the mining sector. Both are necessary to gauge their likely implications on the domestic economy and at the sub-national level. In the case of mining, sector knowledge will require close collaboration with the industry.

Skills mismatch is not only relevant for the labour force. It can also be a barrier to technological adoption and, therefore, a risk for the productivity of mining activities in an increasingly competitive environment. WEF (2020) revealed that skills gaps in the local labour market were the largest deterring factor preventing mining companies from adopting new technologies, as identified by 73.3% of mining companies surveyed.

To manage transitions and prepare their labour force, governments must ensure they:

1. **Collect and publish granular gender-disaggregated data** on employment, mining-related occupations, skills, and education levels required for jobs relevant for large-

scale mining, on a regular basis.[20] This should also be done for mining supply chains, as far as possible.

2. **Map the types of occupations that are likely to be affected** by the advent of new technologies and identify the gaps in their capacity to adapt. This should take into account how men and women will be affected differently.
3. **Conduct a comprehensive inventory of skills required** for current and future jobs across the economy but with specific needs on a sectoral basis to allow sectors such as mining to clearly feed into the database. The mapping should be based on the economic trajectory the country is set to embark on and take into account existing gender disparity in skills availability.

FOCUS ON EDUCATION

Very few governments have adequate regimes to anticipate the future of work and adapt their education systems accordingly. Moreover, in many less-advanced countries, chronically low levels of public spending on education, especially in higher education and in scientific fields, disadvantage the labour force when it comes to adapting to new working environments.

A whole-of-economy approach is necessary, not least because changes will impact all economic sectors, although the pace of adoption will differ. However, education policy also must be linked to the achievement of other broad social objectives, such as reducing rural–urban inequity and improving opportunities for women.

Key education-related policy options include:

- A general priority for governments as a starting point is to **significantly increase the level of public spending on national education systems and on upgrading and revising the school curricula**. While universal education is meant to target everyone, a primary focus should be on ensuring high-quality formal education.
- **School curricula should provide the foundational skills with emphasis on STEM**, at all levels, from pre-primary to tertiary levels and on digital skills (Woetzel et al., 2021). Particular attention should be given to increasing the enrolment rates of girls in STEM subjects.
- The accelerated pace of technological change means that **conventional approaches to teaching and learning need to change.** Technical knowledge will not be sufficient; rather, education for the jobs of tomorrow must combine technical content with imparting other skills such as the ability to learn, critical thinking, and problem solving (see Table 3). The key to resilient workers will reside in their capacity to be mobile and change careers and sectors many times.

20 The ILO and UNIDO have internationally recognized methodologies to classify occupations and industrial sectors.

TABLE 3. TOP 10 SKILLS IDENTIFIED AS BEING IN HIGH DEMAND FOR FUTURE MINING WORK INCLUDE

1	Technology use monitoring and control
2	Analytical thinking and innovation
3	Critical thinking and analysis
4	Complex problem solving
5	Systems analysis and evaluation
6	Reasoning, problem solving and ideation
7	Troubleshooting and user experience
8	Leadership and social influence
9	Creativity, originality and initiative
10	Active learning and learning strategies

Source: WEF, 2020.

- **Given the rapid pace of technological change, it is critical to systematically encourage lifelong learning**, or the practice of continuing to learn new skills for one's whole life, even outside of the formal school system. WEF (2020) finds that across all sectors, 40% of workers' core skills are likely to change in the next 5 years because of new technologies, and 50% of all workers will require reskilling by 2025. Governments must design lifelong learning incentives programs to motivate workers to continue their learning cycles along their career paths. For example, measures such as credits, unconditional grants, interest-free loans, and tax incentives (including for households) to acquire new skills could be considered.
- Mining companies will increasingly seek workers with specialized as well as cross-disciplinary skills. Therefore, while the level of spending is critical, **education systems should offer multidisciplinary pathways that are transferable across industries**, with programs that include an array of other skills that complement rather than compete with machines. These are portable skills that are critical to building workers' resilience and help them transition across jobs and sectors. They are relatively future proof and can serve as a hedge against redundancy, as they are least automatable.
- **Education policies should narrow the gap between rural and urban areas.** Remote working will exacerbate in-country inequality, providing more opportunities in urban areas as jobs migrate away from the mine face (Woetzel et al., 2021). Unless communities in remote locations are given the opportunities to enhance their capabilities, they will not succeed in creating other alternative livelihoods. Gender-responsive solutions can be provided by sharing digital infrastructure (such as Internet connectivity) and by providing access to education through virtual platforms. Particular attention should be paid to ensure that rural and community women are equal recipients of these services and are able to equally access this infrastructure. Such policies can help remote regions to lower barriers such as shortages of trainers, lack of access to training materials, and costs of travelling to urban areas for in-person trainings.

THE ROLE OF MINING COMPANIES

Mining companies must take a strategic approach to skills development. Decisions to invest in new technologies are known many months (often years) in advance. It is, therefore, possible to start planning for labour adjustments early and hence better anticipate potential tensions while initiating discussions and collaboration with workers' unions, representatives of communities, local authorities, and training institutions, amongst others, to manage transitions and prepare the labour force for new opportunities.

Further, the race for digital skills across economic sectors is likely to be fierce. Mining companies will have to compete with many other sectors to attract and retain the right people in the industry and will thus have to innovate to create a convincing employee value proposition. This will include attractive pay cheques and regular on-the-job training programs in a way that builds unique competencies within the organization.

When there are industry-led initiatives to provide training to employees, governments should work with companies to ensure that those skills are portable and that certifications are recognized (Woetzel et al., 2021). It is the responsibility of governments to guarantee the quality of training dispensed.

To maintain their social licence to operate, mining companies will have to customize skills development programs for communities. If the mines of the future will employ fewer people, providing leadership skills to communities and their leaders is a way to support them in transitioning to other activities.

POLICIES TO ENCOURAGE MINING COMPANIES' ACTIONS ON SKILLS

To encourage as many companies as possible to collaborate and to continue to provide regular information on job training, **governments can provide incentives to mining companies** conditional on jointly agreed learning pathways. Examples of such incentives could include matching grants per trainee, co-funding of training programs, or special tax incentives or credits for specific types of trainings etc. (Woetzel et al., 2021).

As well, **governments designing local content policies should include mandatory training requirements** to ensure benefits from any new direct employment opportunities accrue to local communities to the extent possible. Training should emphasize reskilling and retooling of local workers, and should provide equal opportunities for men and women wherever applicable. This is critical to maximize retention rates and minimize skills mismatches, which are costly both to employees and mining companies. Training should also emphasize portable skills to facilitate mobility and transition across economic sectors.

One of the main challenges will be to manage job transition, for which governments are often ill-prepared. When tasks are being restructured or redesigned, workers are not always trained in advance to recalibrate their competencies to retain enhanced or modernized occupations or fit into new positions. There may also be a time lag between retraining opportunities and (re)employment. For workers furloughed because of redundancy, reskilling and retooling may not provide the solution, as opportunities must be sought in other economic sectors. What would provide a sustainable solution is inter-industry collaboration so that talents can be redeployed in other branches. A key principle of a new deal is that new opportunities should guarantee decent jobs and workers' protection, in line with the ILO's transition guidelines (ILO, 2015).

3.1.2 EMPLOYMENT-RELATED LOCAL CONTENT POLICIES

Despite declining local employment opportunities, employment remains a cornerstone of mining's social licence to operate. It is an expectation and an element of trust building with local communities. Governments, mindful of the importance of direct and indirect mining jobs at the local level, are likely to continue to regulate to require mining companies to give priority to locals to secure what jobs there are.

However, the regulatory frameworks surrounding the mining industry must adapt to the new realities. Among other things, this applies to mandatory requirements made in mining laws and contracts related to local employment. As a starting point, to be effective in the face of a changing reality in mining operations, **regulatory frameworks need to be revised to consider new types of occupations**.

Table 4 highlights the top 10 jobs likely to be negatively affected and the top 10 jobs likely to emerge from new technologies. Some of those jobs will be available to local communities either through local content policies or community-specific agreements.

To design appropriate employment-related local content policies, governments must understand:

- What those new job opportunities will look like and what types of skills they will require, so that any (new) local employment policies are informed by the new taxonomy of occupations and the availability of local workers. If prescriptive measures exist and are to be maintained, they will have to consider the dynamic labour market situation, i.e., what jobs will remain, what new jobs will be created, and whether any positions will be made redundant.
- How many jobs will be needed at mine sites. This allows governments to set realistic objectives. Furthermore, where it is clear that the mining operation will not be providing significant employment, it allows space for central governments, local authorities, and companies to agree on other ways to bring value to local communities.
- To what extent local workers can secure those jobs. For jobs where there is a good match between local skills and job descriptions, employment-related local content policies should continue to require prioritizing local hiring. For those jobs where local skills are lacking, policies should foster training, retraining, and upskilling. This is the subject of the previous section.
- Where the infrastructure allows for it, governments can incentivize mining companies to localize remote operations centres to open up high-skill positions in-country.
- The scope of supply chain jobs. As mines get more capital-intensive, governments should ensure they support local suppliers through supply chain development programs, given their potential to provide alternative employment opportunities, both to local communities and to the national private sector. This should be a whole-of-economy approach and not limited to mining supply chains. This is the subject of Section 3.1.3.

TABLE 4. TOP 10 MINING JOBS LIKELY TO BE MADE REDUNDANT AND TOP 10 MINING JOBS LIKELY TO EMERGE

	TOP 10 MINING JOBS LIKELY TO BE MADE REDUNDANT	IMPACT ON LOCAL COMMUNITIES
1	Data entry clerks	High
2	Assembly/factory workers	High
3	Administrative and executive secretaries	Medium
4	Accounting, bookkeeping, and payroll clerks	Medium
5	Mining extraction workers	High
6	Material recording and stockkeeping clerks	Medium
7	Engine drivers and related workers	High
8	Heavy truck drivers	High
9	Financial analysts	Medium
10	Construction labourers	High

	TOP 10 MINING JOBS LIKELY TO EMERGE	OPPORTUNITIES FOR LOCAL COMMUNITIES
1	AI and machine-learning specialists	Low
2	Data analysts and scientists	High to medium
3	Process automation specialists	High to medium
4	Robotics engineers	High to medium
5	Software and application developers	Low
6	Digital transformation specialists	Medium to low
7	Remote sensor scientists and technologists	High to medium
8	Management and organization analysts	Medium to low
9	IoT specialists	Medium to low
10	Big Data specialists	Medium to low

Source: Adapted from WEF, 2020.

BOX 5. WHY THE ROLE OF THE INDUSTRY IS KEY IN THE SKILLS AND TRAINING

A well trained and equipped workforce is necessary for the resilience of the mining sector. It allows mining companies to make faster investment decisions, knowing that they can tap into the skills of their employees and contractors.

Mining companies are also well placed to customize training programs, based on their specific needs as their organizational structures change. One of the specificities of trends unfolding, is the combination of technologies, that will make each skill almost unique, as roles within organizations will be centred around specific objectives, rather than around particular functions, as was the case until now. Therefore, workers will have to assume multi-skilled roles, which only companies can define acutely (Accenture, 2020a).

The ICMM, a mining companies' association representing a third of global mining companies, has developed a Skills for the Future Initiative (ICMM, 2021) to accelerate efforts among its members to build skills needed to support industries' needs and wider diversification beyond mining. The purpose is to reinforce multistakeholder partnerships, with other industries, governments, and communities, to strengthen capabilities needed for community resilience over the next 15 years.

3.1.3 THE FUTURE OF MINING PROCUREMENT

The advent of new technologies is having profound implications for mining supply chains and is likely to transform the procurement function at the site and corporate levels. Three aspects of procurement will particularly be affected.

First, strategic sourcing—i.e., what mining companies buy, from where, and through the most effective market analysis—is becoming more predictive. This means that mining companies are able to better plan and manage their procurement needs, select their suppliers, and secure the most competitive prices. Centralized decisions are expected to increasingly be made at corporate level, to then be redirected at the country or site level. Unless mandatory local procurement policies require them to do otherwise, this may reduce local sourcing, as local suppliers may not be able to compete with new global suppliers identified by artificial intelligence and thus far unknown. Smaller suppliers may not have sophisticated enough structures to participate in digital platforms to serve mining operations.

Second, with digitized sourcing platforms and payment systems, transactional procurement is being automated, allowing companies to centralize, analyze, and structure their procurement orders more efficiently. Integration of different systems helps reduce risks and costs. Local suppliers may not have the same level of digitization and secured payment systems, which disadvantages them.

Third, leaner systems are redefining mining companies' relationships with their suppliers. Collaborative platforms and suppliers that are able to provide tailor-made solutions or proactive innovative technologies will benefit more from digitized procurement functions than traditional and small local suppliers.

Those changes will have profound implications for local procurement strategies, from both mining companies (as buyers) and local suppliers, who will have to adjust their business models accordingly.

POSSIBLE IMPLICATIONS FOR LOCAL PROCUREMENT STRATEGIES

Most resource-rich developing countries and mining companies have local procurement policies that favour local suppliers. As total direct employment at the mine drops, it is expected that a greater focus will be placed on mining sector supply chains—and therefore on local procurement strategies—as a way to create indirect employment.

But as mentioned, the advent of new technologies, with implications for both the nature and function of mining procurement, may make such policies more challenging. For example, with fewer direct employees, related demand for supplies—such as camp supplies, food, uniforms—will drop. Some of those goods and services are mostly provided by women.

As well, some high-tech capital goods, such as large digital infrastructure and digitized equipment like autonomous machinery, will be supplied by a handful of already-established global tech providers. Those will be more difficult for local suppliers to service and maintain, as they are likely to be subject to original equipment manufacturer exclusive contracts for servicing. This will limit the ability of current local service suppliers to redirect their businesses to new servicing activities linked to technologies.

On the other hand, not all procurement needs will change or drop: some core products[21] to mining operations are not likely to change because of automation or other technology shifts in the short run. Those are often big-ticket items, and many resource-rich countries, including developing countries, have developed production capacity over time.

Importantly, new technologies can be enablers for local businesses. As mining companies adopt a suite of new technologies, this will necessarily lead to new procurement needs, and therefore potential new opportunities for local suppliers. While global technology lead firms will dominate the procurement market for large capital equipment, notably through exclusive contracts with mining companies, new procurement categories will emerge for operational needs. Those could potentially be sourced locally, although local suppliers will have to compete with other global suppliers.

21 Examples include grinding media, reagents, electric cables, HDPE/PVC pipes, sample bags, cement, lime, lubricants etc.

TABLE 5. PROCUREMENT CATEGORIES WITH POTENTIAL FOR LOCAL BUSINESSES

TYPE OF TECHNOLOGY	EXAMPLE OF NEW PROCUREMENT CATEGORIES	EXAMPLE OF LOCAL SUPPLY CHAIN POTENTIAL
Users of Big Data	High-tech machinery Autonomous vehicles Automated drillers	Spare parts (non electronic) 3D/4D printing (and inputs associated with printing facilities) Servicing and maintenance for smaller parts and through franchising
Enablers of digitization	Drones Sensors Connected wearables	Manufacturing capacities including spare parts Metallurgy services and spare parts repairs 3D/4D printing and inputs associated with printing facilities) Hardware servicing and spare parts manufacturing Electronic servicing and spare parts manufacturing Software and app development
Integrators/ trackers of Big Data	Software technologies High-speed connectivity	Internet service provision Mobile service provision Data security service provision Provision of infrastructure (e.g., copper wires, fittings, etc.)
Process improvers	Electric vehicles Renewable energy sources Water management technologies	Repairs and maintenance Servicing Spare parts 3D/4D printing (and inputs associated with printing facilities) Software and app developers

As Table 4 highlights, the increasing use of connected objects means that certain items, such as sensors, communicating actuators, and associated software, will be required more frequently than before. As mines become more digitalized, these connected electronic devices will become the nerve centres of mining operations. However, they are very sensitive and therefore will require regular servicing and maintenance, often at short notice, to prevent breakdown. This implies that repair and maintenance facilities will necessarily have to be close to mine sites.

Similarly, the demand for certain categories of items such as electronics will grow because of the digitization of mining infrastructure, with significant potential to localize workshops and light manufacturing capabilities.

As mining companies invest in renewable energy generation to reduce their carbon footprint, there may be opportunities to work with local construction firms and to source local inputs. Building such domestic capabilities is critical as the demand is set to increase, as more mines adopt more sustainable practices, and as countries step up efforts to meet their commitments to lower their greenhouse gas emissions.

BOX 6. RENEWABLE ENERGY: EMERGING OPPORTUNITIES IN THE DEMOCRATIC REPUBLIC OF CONGO

In 2020, Kibali mine in the DRC invested in a battery grid stabilizer to improve the efficiency of its three hydropower stations. While a large part of the contracts was procured by foreign firms, Azambi HPS, the first hydropower station was awarded exclusively to Congolese construction enterprises, with the main contractors comprising Inter Oriental Builders (IOB), Traminco and Top Engineering Services (TES). None of these contractors had former hydropower construction experience, thus resulting in an opportunity for capacity building in a region notoriously bereft of infrastructure or experienced hydropower contractors. At the peak of construction, over 700 people were working directly on the project, with over 95% being residents (Knight Piesold Consulting, 2019).

TDi Sustainability (forthcoming). (An IGF case study on the impacts of new technologies on large-scale mining in the Democratic Republic of the Congo)

Where there is significant mining activity in a country or a region, there may be potential for governments to collaborate with mining companies and suppliers to build up domestic capacity to supply the technologies and services needed in the mines of the future. If the scale of demand is enough to sustain domestic production capacity, and there is strong capacity in domestic suppliers and innovators, a collaboration of innovators, mining companies, and suppliers, with facilitation from governments, could create new centres of excellence to serve both domestic and foreign demand. Such a prospect was raised in the IGF New Tech, New Deal consultations in the Andean Region with respect to the haul fleet and companies' need to retrofit for productivity and environmental performance (see Box 6).

BOX 7. NEW OPPORTUNITIES FOR INDUSTRIALIZATION

Chile and Peru have among the biggest haul truck fleets in the world, possibly in excess of 3,500 units. Ongoing servicing of such a fleet is a significant sector in and of itself, but new technologies may present new opportunities, as the coming years will see much of the fleet retrofitted with automation and other technologies, and there is a growing movement toward low-carbon fleet solutions such as electrification and vehicles powered by green hydrogen. There is a unique opportunity to build local capacities for the development of regional mining clusters around these two challenges, and it may be that the Andean regional market has the scale to develop production chains to take advantage of technological change and drive changes in production patterns. Properly facilitated by concerted government and private sector efforts, this approach could boost the development of an Andean Mining Cluster that is integrated into global value chains and has partnerships with companies and countries at the forefront of the new technological revolution.

Source: Adapted from Urzúa et al., 2020.

The rolling out of 3D printing can also provide new local procurement opportunities. While many see 3D printing as a threat to traditional local manufacturing, it can also be an opportunity to re-shore printing of those spare parts for which local industries could not compete with global suppliers. It provides the advantage of proximity, reduces lead time for delivery and is cost saving for mining companies. It also provides new business opportunities for other local suppliers: for example, inputs needed for 3D printing factories, such as powdered ceramic, polymers, metals, cement, local transport services etc.

BOX 8. SOUTH AFRICA AND 3D PRINTING

In South Africa, mining company AngloAmerican has initiated a project to manufacture spare parts locally for its mining and processing equipment using 3D printing. The mining company has developed a partnership with a local research institute and a U.S.-based technology company to digitize the procurement of its spare parts to then localize part of its production. This is part of its Impact Catalyst program in the Limpopo region, mentioned in Box 12.

Source: AngloAmerican, 2021.

The disruption of global supply chains because of the COVID-19 pandemic has exposed mining companies to the risk of dependency on external sources for certain critical supplies. As highlighted by Deloitte (2021) as mining companies plan for the future, the thinking around supply chains seems to be evolving from one based on cost and efficiency toward one based on risk mitigation associated with potential disruptions. Localization of critical supply chains, in particular, is emerging as a key strategic option, with significant opportunities for local suppliers.

What is clear is that traditional local procurement policies and frameworks will have to be rethought and redesigned. What is less clear, though, is to what extent and how quickly local suppliers can adjust so there is no disruption in local businesses.

HOW CAN LOCAL PROCUREMENT STRATEGIES ADAPT TO NEW TECHNOLOGIES?

The IGF's *Guidance for Governments: Local Content Policies* (Cosbey & Ramdoo, 2018, p. 23) outlines different policy tools governments can use to increase local procurement from the mining sector. These fall into two broad categories:

- **Demand-side policies** that encourage or mandate mining companies to procure goods and services from local businesses.
- **Supply-side policies** that seek to provide support and incentives to local suppliers, so they can compete with global standards on price, quality, volume and reliability, access mining procurement markets, and seek financing to develop their businesses.

While market conditions will continue to impact policy design, some of those policies need to be adapted to the new reality of mining.

On the demand side, there is an array of traditional approaches that governments have imposed on mining companies to ensure that local businesses have access to mining procurement markets. These include mandated targets (e.g., percentages or quotas) or lists of goods and services to be procured locally; mandatory requirements to submit local procurement plans; and community development agreements (CDAs).

Countries like Ghana[22] or South Africa[23] have managed to increase their levels of local sourcing using mandatory local procurement policies. In the case of Ghana, the local procurement list was jointly agreed with the mining industry, and the result was a very high score in terms of implementation. The 2021 Annual Report of the Ghana Chamber of Mines reported that 87.5% of the total operational expenditures of its producing member companies were paid to manufacturers and suppliers of goods and services based in Ghana in 2020. Non-energy local procurement accounted for 52% of their in-country spending (Ghana Chamber of Mines, 2020, p. 91).

However, the success of targets is not always guaranteed. Blanket targets applicable to the entire mining sector fail to account for major differences across specific mining sites and commodities within the same country. Another challenge with target percentages is that they are sometimes set at levels that cannot be realistically met by mining companies. In the DRC, despite local content targets, less than 10% of the equipment and operational procurement market is captured by Congolese companies with Congolese capital (Federation des Entreprises du Congo, personal communication, 2021). In Mongolia, lack of capital, amongst others, prevents small firms from developing viable businesses (see Box 8).

BOX 9. INSUFFICIENT CAPITAL LIMITS THE ABILITY OF SMALL FIRMS TO SUPPLY MINES IN MONGOLIA

In Mongolia, a large variety of factors limit mining companies from introducing new technologies, including lack of capital and corruption. As such, a local procurement target imposed across the entire industry—affecting both the large Oyu Tolgoi mine site, which is indeed rolling out new technologies in its operation, and the smaller operations that are not yet there—risks imposing unachievable targets on some operations.

Source: Enkhbat et al., 2020 (A New Tech, New Deal background paper on Mongolia)

As mentioned, some core procurement needs will remain unchanged. Governments may, therefore, want to continue to focus on those in the short run. However, to prevent future risks of redundancy, local suppliers need to diversify their client base outside the mining sector, where relevant.

As highlighted in Table 4, the suite of new technologies being adopted will also require an equally new set of procurement needs. These could potentially be sourced locally. If governments adopt mandatory local procurement policies, those will only work if local businesses are able to match the new demands.

22 Ghana revised its Local Content Regulations in 2020 (Minister for Mines, 2020).

23 South Africa has a Mining Charter, revised in 2018, that sets out the conditions for local content (Minister of Mineral Resources, 2018).

BOX 10. GOOD PRACTICE IN DR CONGO THAT CAN SERVE FUTURE DIGITIZATION NEEDS OF THE MINING SECTOR

With a view to promote innovation and entrepreneurship, in 2016 the DRC Ministry of Industry launched the Innovation Award. Among the first recipients was Flech Tech CEO Dieudonné Kayembe, inventor of the Motema Tab, a Congolese-produced mobile tablet equipped with a solar panel. Since then, other innovators have distinguished themselves: they include, Carlo Lekea, mobile app developer and designer and founder of tech firm Idea IT & Conception; and Sam Yongo, a Congolese software developer initially based in the United States, but who relocated to the DRC to build App Corner, a curation platform for apps built by local Kinshasa developers.

A growing number of entrepreneurs and innovators are being established across the country, with some leading ones in Kinshasa, such Congo iHub, Lumumba Lab, and the Mwasi Tech Hub, specific to women entrepreneurs. Although those are not related to the mining sector, such initiatives could provide tailor-made innovative solutions, with proximity, to the mining companies, capitalizing on the latter's changing procurement needs.

TDi Sustainability (forthcoming). (An IGF case study on the impacts of new technologies on large-scale mining in the Democratic Republic of the Congo)

A key challenge with some forms of existing local content policies, such as mandatory lists inscribed into regulatory frameworks, is that they may become redundant as some goods and services may no longer be required by the mines or as technologies change again. In that regard, local procurement policies will have to be reviewed. The main challenge with mandatory targets is that they are difficult to change when inscribed in law. And with technological changes quickly arriving, governments should carefully examine the feasibility and applicability of such policies in the medium to longer term.

WHAT CAN CHANGE?

One area where governments could strengthen their collaboration with the mining industry is in regards to procurement plans. Currently, many mining companies are required to submit annual procurement plans. A different, longer-term approach can be taken by linking procurement plans with planned technology investment plans and with forecast operational expenditures. This can become a powerful tool to inform local suppliers and public authorities about technological change sufficiently ahead of time to allow them to prepare and adjust to new market needs.

Importantly, the ability of host country governments to negotiate and monitor the components of a procurement plan is crucial. Therefore, governments need to ensure they have a comprehensive understanding of procurement changes in the mining sector and adequate internal capacity to design, manage, and implement their policy frameworks so that they work for both the mining sector and their suppliers. If local suppliers are prepared, then governments can adjust their local content frameworks to stimulate local sourcing in sync with new procurement needs.

As the mining market for certain types of procurement shrinks, **local procurement policies should focus on items that have a broader application** beyond the mining sector to provide a larger market to suppliers. For example, PPE is commonly included in listed goods due to the fact it is relatively easy to train local tailors, in particular women, to produce uniforms and other products required by mine site employees. If demand for mining-related PPE demand were to drop, there are other sectors where those suppliers might find markets (such as fire brigades, the army, police officers, or health care workers). This policy requires cross-sectoral collaboration and should not be imposed only on the mining sector.

Another important local content policy tool is to revisit CDAs. These can range from statements of general principles in a memorandum of understanding (MOU) to legally binding agreements. Though they are most often associated with agreements between natural resource companies and Indigenous communities in Canada and Australia,[24] other countries (such as Mongolia and Sierra Leone) are beginning to require them more frequently.

One of the key advantages of CDAs is that they can be much more tailored to the specific conditions for a given mine site and are inclusive of communities' needs and interests. Like local procurement plans, CDAs can lay out targets for goods and services based on the specific demand for goods and services projected by the individual mine site.

With the advent of new technologies, and in particular because there will be a need to support alternative livelihoods for local communities, CDAs can provide a framework to design skill-building programs and support cross-sectoral linkages between local suppliers in mining with non-mining activities. They offer an approach that is more inclusive and closer to the needs of local communities. Women, in particular, should be included in the negotiation and monitoring of IBAs so that they are able to benefit from business opportunities.

Demand-side policies on their own are not likely to succeed in building up suppliers to competitively supply the mining sector. Supply-side policies[25] will need to supplement efforts, in particular by:

1. Building competitive supplier development programs that guarantee supply at high quality and competitive prices
2. Building suppliers networks and facilitating partnerships between local firms and industries
3. Providing access to finance for suppliers
4. Setting up suppliers' portals to help connect suppliers and mining companies

In particular, policy-makers need to think differently about how they develop their supply capacities. There are currently two issues that will impact local procurement policies. First, as mentioned above, digital technologies are redesigning strategic procurement sourcing of companies at the corporate level. Unless local supply chains have sufficiently strong competitive and comparative advantages to trigger decisions to source closer to mine sites—and this can be the case for some items that require short manufacturing and delivery lead times—it will become increasingly difficult to argue for localization.

Second, the COVID19 pandemic has triggered some interesting strategic decisions to reduce the risks of supply chain disruption caused by an overdependence on foreign suppliers. This is not mining specific, but the mining sector has also been affected by sudden disruptions caused by a halt in global production centres and international transport.

24 The names of these agreements differ a great deal, and in Canada are often called Impact Benefit agreements (IBAs), and in Australia, land access agreements.

25 These types of policies are extensively described in the IGF's Guidance for Governments: Local Content Policies.

To give local suppliers a chance to meet the new demands, supportive measures will have to be enhanced and scaled up. Fiscal incentives and access to finance for local suppliers are critical elements. Those policies should have a differentiated approach. One is targeted at businesses that have solid prospects for long-term markets. Here, a collaborative approach between governments and industries should focus on supporting them to gain scale and markets, including internationally. Chile and Australia have adopted this approach based on the higher-technology prospects of their mining sector.

The second set of incentives should be geared toward SMEs and smaller firms, often owned by local communities. Here, the purpose is to support them in sustaining their businesses and improve their business models so they can branch out to non-mining sectors if local procurement markets dry out because of new technologies. Support could include helping them develop their businesses around goods and services that are not specific to mining.

Third is to encourage business-to-business partnerships with global leaders in the sector and national champions as a way to transfer technology and know-how and build local capacity to innovate. Those global leaders could be global tech companies, who may be interested in delocalizing part of their production closer to mine sites through strategic partnerships to serve as regional hubs for high-tech products and related maintenance and repair services.

For both demand- and supply-side local procurement policy options in the New Deal, availability and transparency of data are absolutely crucial. Designing the appropriate local procurement strategies—including guiding local businesses in selecting the right products and targeting supply-side support for businesses—relies on whether the government has accurate information on current procurement needs, as well as how a given mine site is expected to change.

3.2 THE MINE OF THE FUTURE AS A DRIVER OF DIVERSIFICATION

The previous section focused on how to ensure that the jobs that do exist in the mine of the future can benefit locals, mining-dependent communities, and host countries. This section starts from the assumption that new technologies will often—but not always—lead to fewer employment-related benefits for those stakeholders. It asks in what ways large-scale mining operations might nonetheless bring value to people, focusing on the potential for mining activity to support non-mining activities and entrepreneurs.

There are at least three possibilities for that dynamic:

- Social impact investment: Company-led or facilitated economic development
- Government-led efforts at transition and support in moving away from mining dependence
- Traditional focus on backward and forward linkages as a route to diversification.

3.2.1 INNOVATIVE SOCIAL INVESTMENT MECHANISMS

INTRODUCTION

Large-scale mining operations have significant impacts on the lives of host communities, both positive and negative. While they provide employment and business opportunities to local people and pay taxes to governments, they have a wider and longer-term social and environmental footprint in local communities. Direct benefits do not always offset negative impacts, and, when they do, they are rarely a one-for-one trade-off. There is, therefore, an expectation that mining companies need to compensate by taking other initiatives to integrate social, environmental, and other concerns into their business strategies and operations to maintain trust and build peaceful relationships with communities.

Support to local communities comes in different forms of corporate social investments (CSI) and philanthropic programs, such as corporate social responsibility (CSR) initiatives. These programs are social contracts aimed at mitigating risks, contributing to social well-being, and thus obtaining, sustaining, and retaining the social licence to mine.

The importance of these community development supports is well recognized. In many countries, they have filled in the gaps for insufficient public investments in remote locations, providing health care, education services, or access to potable water beyond the mine gate, to the wider local communities. While these types of programs have been necessary to obtain communities' trust and support, they have, however, not been sufficient in themselves to build more resilient communities and help diversify economic livelihoods.

One of the reasons lies in the inherent design of philanthropic programs. They are well meaning and well intended but have in-built limitations in their scope. They are meant to provide social support and are rarely conceived to help develop strategic core business activities in communities, which can then serve as a springboard to create wealth and other economic activities. In parallel, some mining companies have programs to support suppliers' development in an attempt to boost local sourcing, as noted above. But those remain limited in scope—focused only on their own mining supply chains—and often delinked from their traditional philanthropic activities and rarely connected with other economic sectors.

THE NEED FOR NEW APPROACHES

As highlighted already, the advent of new technologies is likely to change the relationship between the mining industry and local communities. While large-scale mining activities are set to become more efficient, greener, and more productive, they will continue to affect communities without the latter necessarily benefiting from technological spillovers.[26] As fewer opportunities become available at the mine site for local communities, new and more sustainable alternative economic activities will have to be sought and supported to provide alternative livelihoods.

Increasingly—and the COVID-19 pandemic has fast-tracked this trend—the urgency of delivering durable outcomes at the local level is driving boardroom decisions regarding mining investments. What that means is that mining companies are being told by their investors and financial partners that "do no harm" is no longer sufficient. They need to embrace a new paradigm and adopt a more innovative approach to "do good and do better." Those who fail to do so will encounter growing skepticism from the market and will end up paying a higher cost for capital.

Investors are already raising the bar with regard to sustainable practices. Climate change and issues such as fairer economic inclusion have become key priorities for the investors'

26 The most important exception to this rule is the case where new technology allows for viability of mining operations that would been unviable using conventional technology. In such cases, while employment and other economic benefits from the mine may be low, they are still more than what would have occurred in the absence of any mining activity.

community and have become an integral part of ESG requirements. The COVID-19 pandemic has accelerated the move in the ESG conversation from being a mere financial requirement to becoming a core sustainability issue, to guarantee stakeholders' trust (Gassmann & Kelly, 2021).

In the mining sector, the traditional CSI and philanthropy approaches have not brought about long-term improvement in the quality of life for most communities, as they have often focused quite narrowly on projects that address immediate needs. In South Africa, in the Northern Cape alone, mining companies collectively reported spending in the region of ZAR 1.6 billion (approximately USD 113.8 million) through their CSI and Social and Labour Plan funds, and yet have been disappointed to observe very little meaningful impact or improvement on the ground.

WHAT KIND OF CHANGES ARE NEEDED?

To achieve a different and better result, there is a need to look for new and innovative mechanisms to complement existing philanthropic support. New mechanisms provide a great opportunity to build in gender-responsive instruments.

The push to align stakeholders' interests with sustainable practices in communities also brings a unique opportunity to rethink and improve the current relationship and engagement mechanisms with local communities.

ESG requirements are a first step in the right direction: they move business decisions from shareholders to stakeholders and attempts to align the business model with the needs of society. While ESG requirements provide companies with an opportunity to transform investment decisions, to be truly inclusive and impactful, they must be implemented through innovative social investment mechanisms. Those mechanisms should then align the needs of society with the business model.

One such mechanism is impact investing. Not a new mechanism but not commonly practised in mining, impact investment offers a fresh perspective by making the business case for other partners—such as non-mining businesses, sustainable investors, and venture capitalists—to collaborate with the mining sector to support longer-term economic development objectives.

BOX 11. WHAT IS IMPACT INVESTING, AND HOW IS IT DIFFERENT FROM ESG?

ESG refers to a company's environmental, social, and governance practices that may have a material impact on the performance of the company. The integration of ESG factors is used to identify potential risks with regards to several topics. It can involve screening investors based on their performance, but the main purpose remains financial performance.

By contrast, an **impact investment** is defined as "one which is made with the intention to generate positive, measurable social and environmental impact, alongside a financial return" (Global Impact Investing Network, n.d.). It goes a step further than ESG, in that it claims that it is not enough to show performance. Impact investments are not philanthropic activities. They are investments with a financial return. However, they are virtuous models compared to traditional investments, and have a deliberate intent to produce visible, measurable, and sustainable results on society. The key element is the intentionality of the impact on society, rather than the financial return.

Through impact investing partnerships, mining companies can use their financial ability to leverage other sustainable investors to work together to find durable solutions for local communities. Together, they can bring financial scale to support wider economic development imperatives in remote areas that otherwise would not have attracted attention and projects, thereby leveraging the power of market to bring durable change

Impact investing is an inclusive mechanism and a people-based approach. It calls for boardroom decisions to first define what impacts they want to leave in the community and then make investment decisions accordingly. It provides an opportunity for mining companies, community representatives, and other stakeholders to jointly decide on a purpose, so that the part the industry agrees to invest in contributes to wider societal benefits.

One of the important potential results of an impact investing approach is that it erodes the enclave economy effect that many mining operations engender (Arias et al., 2013). Most mining operations dwarf the size of the non-mining economy in their local settings and end up creating a dependency on mining activity that leaves communities vulnerable to changes in the fortunes of their local operations, to eventual mine closure, and to the adoption of new technologies that reduce the scale of employment-related benefits that the mine brings. Challenges can have deeper consequences for community women who lose their livelihoods, land, and traditional economic and social power in subsistence economies.

An impact investing approach can address both the need to replace benefits eroded by new technologies and the need to ensure that mining activity helps create social benefits for local communities that outlast the mine itself. Impact investing strategies can provide a tool to analyze and respond to changes in women and girls' economic and social situation in communities.

A case study of this approach from South Africa is profiled in Box 12. In this case, the mining company helped catalyze a collaborative regional development program focused on spatial development. This is an exciting and novel approach, but it has important limitations. The most fundamental is the intractable difficulty of the enterprise of economic development—something an army of development banks, national agencies, and local organizations have struggled to get right for many decades with a mixed record of success. The other is the question of how widely such a model could be replicated to provide equal benefits to all. The mining proponent in this case is one of the world's biggest mining companies, with wherewithal, experience, and resolve that not all companies are fortunate enough to possess.

BOX 12. THE IMPACT CATALYST IN SOUTH AFRICA'S LIMPOPO REGION

Established as a consortium of AngloAmerican, the Council for Scientific and Industrial Research, Exxaro, World Vision South Africa, and Zutari in 2019, the Impact Catalyst is an initiative aimed at supporting large-scale socio-economic development activities and projects in the Limpopo region of South Africa. Activities are conducted through public–private partnerships in collaboration with the Office of the Premier of the Province.

Activities have been conceived around the creation of complementary sustainable economic activities in the region around mines to provide alternative livelihoods—and additional business opportunities—to mine communities and local economic operators in nearby towns.

The Impact Catalyst projects are identified based on their ability to be scaled up to capture larger markets in Limpopo but also nationally and potentially globally. They are meant to become self-sufficient in support and funding over time and hence create territorial spillovers with measurable implications for employment and business development. Examples of projects sponsored by Impact Catalyst program include:

- Laser-based refurbishment and 3D-printing technologies as an alternative to conventional repair techniques, to enhance performance and reduce production loss due to extreme operating conditions. 3D printing is used to repair and replace components with a shorter lead time and at a lower cost. The technology has applications in the energy, oil, mining, pulp and paper, material processing, and chemical processing sectors.
- Manufacturing of personal protective equipment such as hand, hearing, and respiratory protection, surgical masks, protective clothing and footwear. This equipment is used in construction, mining, petroleum and food manufacturing industries, and therefore the project offers wider markets to local industries.
- Integrated game farming that incorporates an industrial approach to develop entire value chains while maintaining sustainable land use. The objective is to create employment and business opportunities for small and medium-sized enterprises (SMEs) in the region of Limpopo.
- An irrigation scheme, to serve fresh produce market and agro-processing, with the aim to contribute to food security in the region.
- A primary health care program for local communities, developed in partnership with the University of Pretoria. This program will provide training to health care workers in the communities so they can deliver primary care for community members in their homes.

The program is in its nascent phase and still needs to overcome some challenges linked to suitable project screening and their potential reach to ensure it creates the dynamics intended and necessary for diversification and territorial development. It is too early to assess its impact, but the holistic approach taken and the partnership model employed provide some interesting ground for mining companies to build upon, as new technologies bring additional possibilities that could be used to scale up regional projects.

3.2.2 GOVERNMENT-LED EFFORTS AT TRANSITION SUPPORT

The transition-support policies discussed here are needed in the case of existing mines retrofitted with technologies that result in major job losses. As discussed above, this is not the general case for the mine of the future; some mines of the future will be greenfield operations, and it is conceivable that retrofitted operations would become so productive that increased volumes mean more overall employment, even if it is less employment per unit of output. However, transition support, where relevant, will have to be based on a common and coherent vision of the future, supported by mutually reinforcing policies that consider gender, diversity and inclusion, decent work, and quality of jobs.

Two types of policies are considered here, both of which are needed:

- Protective policies: those that cushion the impact of disruption for workers and communities.
- Proactive policies: those that seek to build alternatives to the mine as drivers of prosperity for workers and communities.

PROTECTIVE POLICIES

Governments and mining companies have a shared responsibility to protect workers against hardship and economic distress following job losses. Social protection is considered a human right, although a large share of working populations remains unprotected (ILO, 2019a). In the context of mining, the issues presented by significant technology-induced job losses are similar to those faced in the event of mine closure. A major difference is that for the latter there should have been planning for the transition starting many years, even decades, before the eventuality.

Governments must provide universal social protection measures, such as unemployment benefits, minimum social security benefits, free health care, minimum pensions and children allowances and subsidized childcare. They are essential to the most vulnerable workers and are necessary to provide temporary financial security for a “just transition” following jobs losses and pending new opportunities. The main challenge in many developing countries, however, is that national social security funds are poorly funded because of low levels of contribution (due notably to low budgetary allocations to social security and a low tax base due to a large informal sector). This prevents governments from providing decent welfare protection.

An efficient social protection system is dependent on the contribution of employers and employees. **Mining companies, therefore, have a key role to play in contributing to workers’ pension funds and wage insurance** to ensure funds are available in case of job disruptions. Wage insurance provides temporary income supplementing universal unemployment benefits to match the wage lost. As technological change becomes more pervasive and thus augments the risk of being displaced for workers, mining companies will need to increase their social security contributions, including through the creation of special pensions funds for their workers, in particular in countries where universal social protection is insufficient or absent.

Another option for governments is to **create social insurance schemes that workers can use to upgrade their skills**. For example, individual training accounts can be set up, financed by payroll contributions from mining companies (see, for example, Fitzpayne & Pollack, 2018). Amounts collected can then be used to finance the training programs chosen by workers on the condition that they are relevant for the latter's career path. It could be used for training, retraining, reconversion programs.

PROACTIVE POLICIES

To prevent economic hardship and social unrest resulting from rising unemployment in local communities, plans for labour reconversion and transition should ideally be worked out well in advance of the deployment of technologies. These should focus on creating new types of economic activity and ensuring that the conditions for its growth are in place.

These sorts of efforts, however, important as they are, are unlikely to be effective along the timelines needed. As illustrated in the experience of Germany and Finland (see text boxes), they take time—in some cases decades—and any retrofit decisions on new technology are likely to be made without the benefit of years of lead time. This does not mean such efforts, along the lines of those surveyed in the text boxes and in the previous section, should not be pursued. But it underlines the need to pursue them in parallel with efforts aimed at long-term gestation of alternative drivers of growth:

- Drivers that are less long term, building on existing skills, resources, and entrepreneurs.
- Other means by which mining activity can bring more immediate value to communities, including the use of technology as a solution (see Section 3.5).

BOX 13. CASE STUDY: GERMANY'S COAL SECTOR

After destruction and loss during the Second World War, West Germany turned to the hard coal industry to support its reconstruction. Subsequently, hard coal became the centre of West Germany's economy, politics, and society, employing more than 600,000 West German citizens at its peak in 1957. However, in 1956, coal prices, which had previously been regulated, became liberalized, prompting a price drop, leading to the German government's decision to implement a plan to close coal mining operations (Oeia et al., 2020).

This transition process faced several challenges linked mainly to the characteristics of the coal mining industry in Germany: 1) low diversity in the training of workers, 2) a high level of masculinization, 3) high salaries compared to other industries, 4) a lack of employment opportunities in alternative sectors in the coal regions, and 5) a lack of transparency in the execution of public funding for economic diversification as well as lack of agility in public funding's distribution (Sánchez López, 2016).

Despite those challenges, Germany today is a benchmark for how to implement industry transitions at the state, regional, and city levels. To understand the keys to this government program's success, it is useful to analyze the case study from a geographical perspective, understanding which programs were implemented and the procedure used at the state, regional, and city levels.

1. State Level: North Rhine-Westphalia (NRW) (Sánchez López, 2016)

The transition process at the Federal State level of the NRW region focused on the regional development of new industries, mostly linked to "green" technologies, led by the regional government. To boost these industries, the state government focused on the development of business "clusters"[27] with EU support. In 2015, 16 clusters were operating in NRW (Taylor, 2015).

The development of clusters was complemented by the construction of regional and local transport infrastructure and the improvement of coordination and cooperation at the regional level. New technical training centres were created, and existing ones were strengthened; the objective was to close the existing vocational training gap, to create a greater demand for new green technologies, and to promote the emergence of a new "green" sector in the region.

Thanks to these efforts, the region was able to specialize in the environmental industry, which, in turn, served to solve the serious environmental problems created by the mining industry.[28] As a result, the Ruhr area's environmental management and service industries are among the most prominent in central Europe (Taylor, 2015). In addition, the NRW state has become the leading region in business development and green innovation in Germany (Hartmann, 2006).

2. Regional Level: Ruhr Mining Basin

At the regional level, the work carried out in the Ruhr area stands out for demonstrating that developing technical training centres and focusing on retraining are keys to a successful transition (Sánchez López, 2016). In general, this basin went from having a single university in 1965 to more than 22 in 2014, enhancing the attractiveness of the region for companies as well as for citizens (Brauers et al., 2018). In 50 years, it managed to host more than 250,000 students, eight higher education centres, and more than 30 research institutes (Sánchez López, 2016). This involved the hiring of more than 26,000 people in 831 companies in the field of logistics, one of the main fields promoted by the research institutes. This elevated demand for highly skilled workers, research, and innovation was driven by the addition of universities fueled by the shift from a mining economy to an economy of higher-value-adding sectors (Brauers et al., 2018).

Another key feature of the successful transition was the management of job change. To facilitate labour reallocation, employment centres were created. For example, the Ruhr Coal Vocational Training Society (RKB) collaborated with regional governments, companies, and other institutions to assess new training needs based on expected or already existing demand for skills (International Labour Office, 2014; Sánchez López, 2016).

The process of retraining in the region faced several challenges, a major one being that coal miners typically have lower levels of education and fewer translatable skills. In this context, some key strategies that should be considered when implementing a retraining process are (Sheldon et al., 2018):

- A process of skills audit and validation with recognition of prior learning (RPL). RPL is a system for evaluating the skills and knowledge cultivated through life experience and then facilitating their formal recognition by qualifications systems (Miguel et al., 2016). This can have important morale-boosting outcomes and give workers more confidence and direction in their post-retrenchment futures.

27 A cluster is a tailored group of companies, research facilities, political institutions, and non-profit organizations all working together, along a specific project's value chain, to foster a prosperous regional development. For example, the automotive cluster facilitates the exchange of ideas in vehicle technology and connects partners within the automotive value-added chain with related clusters, industry, and academia. The clusters are advised and supported by the state through the NRW Cluster Agency.

28 For instance, air quality has greatly improved and rivers are returning back to their natural states. Dilapidated industrial sites have already been sustainably refurbished, and several more brownfield development projects are underway or planned.

- Retraining needs to occur well before retrenchment to be most effective in the transition to new occupations, without cost, and linked to well-paying regional jobs.
- Training opportunities should come together with pre-training counseling and guidance on how to face change. Older workers in particular tend to feel more pessimistic about their chances.
- A useful process must focus on workers' own needs, interests, existing skills, and aspirations in the context of the transition of their community's economy. Again, RPL methods can help.
- A range of relevant training options, from technical to communication and job-finding, must be available.
- Short-term placements in potential new jobs, ahead of retrenchment, can substantially assist workers in successful transitions. Ideally, those placements should be phased with their training.

Finally, several coordinated initiatives related to social compensation, reinforcement of collective bargaining rights, and contractual reforms were implemented to ensure a successful transition (Galgóczi, 2018). The process took decades. In 1972, state legislation introduced a transitional payment system (APG) for coal industry employees. However, it was not until 1993 that bargaining parties could reach and sign a comprehensive agreement assuring an ethical labour restructuring process. This comprehensive agreement guaranteed a socially responsible workforce restructuring program, including an early retirement system[29] for older workers who cannot be retrained or relocated based on the state legislation introduced in 1972 (Sánchez López, 2016). Layoff payments funded by the federal government are granted to miners who lose their jobs (Galgóczi, 2018).

3. City Level: Inclusive and shared decision making: Bottrop

In 2009, Initiativkreis Ruhr, a regional organization, launched the InnovationCity Ruhr competition to find a pilot city in which to test sustainable structural change in the region. The city of Bottrop proposed an in-depth, participatory plan for the governance of their transition to a low-carbon economy and was selected from the 16 applicant cities (European Commission, 2019).

The main differentiating factors of the proposal were the consultation process carried out with the citizens to gather ideas about improvements to be made in the city, and the use of a network-based approach to developing solutions that emphasized collaboration between industry, businesses, academia, and local and state administrations (Sánchez López, 2016). The Bottrop master plan[30] considered measures related to the housing, energy, transportation, infrastructure, and working environment sectors. The project was a success, having more than 200 measures of the master plan already implemented or in the process of being implemented (European Commission, 2019).

29 This early retirement system takes the form of monthly financial bridging support payments. After a worker's early termination, the worker has a maximum of five years to start claiming these payments and payments can continue until the worker qualifies for pension insurance. Until December 31, 2022, all terminated coal industry workers, upon reaching the specified age threshold and period of service qualifications, are entitled to receive such benefits. For those who are not entitled to APG, an "Agreement on the closure of the Ruhr coal industry" was implemented, providing a specific social compensation plan for these workers.

30 The Bottrop program's commitment to transparency and citizen involvement from the beginning were keys to its success. These commitments were put into practice through the face-to-face and virtual collection of citizens' visions, ideas, and suggestions for the project through workshops, interactions with planners, and an online idea box. Because of this dedication to collaboration with the community, the project has garnered a high level of local support. Additionally, the involvement of a diverse set of stakeholders has been another key element of success. For example, actors from housing construction companies, trades such as craftsmanship, a broad range of industries, and administrations were brought together in the Bottrop project, which demonstrates that sustainable structural change is not just driven by the local governments, but by all stakeholders' involvement.

Takeaways from the German experience include: 1) rely on retraining as a key element in the transition 2) implement inclusive and shared decision-making processes, 3) avoid the need for subsequent transition through the implementation of long-term solutions based on sustainable alternative sectors (e.g., invest in green sectors as alternative sectors to mining), 4) use an integrated planning approach that responds to the different challenges of the transition, and 5) identify those areas that need deep transformations and assign competent leaders to guide these transitions (Sánchez López, 2016).

BOX 14. THE CASE OF NORTH KARELIA IN FINLAND

The region of North Karelia in Finland was an important mining area, known for its copper, until the end of the 1980s, when the mine closed. A strong private–public collaboration initiated by the mining company, with the municipality of Outokumpu and local businesses, successfully managed the transition from mining to manufacturing to develop new economic sectors for the benefit of the community. In particular, the region capitalized on the needs of the mining industry to develop other competencies around metal technologies and mining services, to become a hub for the country (OECD, 2019a).

One of the flagship initiatives was the setting up of the copper refinery's technology division in the municipality, as a way to develop an industrial area with knowledge and innovation capacity of the mining industry. This shift has been effective: today, the municipality is relatively more industrialized than the country average (OECD, 2019a). The mining value chain, with activities such as extraction and processing, has gained prominence in the regional economy, and the municipality has a vibrant industrial park that hosts knowledge-intensive and globally connected companies in the metal technology sector, as well as a Mineral Processing Laboratory of the Geological Survey of Finland (GTK).

The partnership has created jobs and value in the region: today, the manufacturing sector employs 33% of the working age population in Outokumpu, far above the country average (13%). There have been positive social spillovers, with high-quality education and health services for the communities. Future plans include the development of a mining cluster, in coordination with private enterprises, tertiary and research institutions. The cluster will benefit from financial support from the Government of Finland (OECD, 2019a).

Several challenges still need to be overcome, such as declining demographics and workforce and the difficulty retaining highly skilled labour despite employment opportunities in the region. To overcome this, the region is now partnering with other sectors such as tourism to boost the local economy (OECD, 2019a). It is also developing strategies to build the competitiveness of the sector, and to improve its policy frameworks to better incorporate territorial dimensions to the national mining strategy (OECD, 2019b).

3.2.3 LOCAL CONTENT POLICIES AS A ROUTE TO DIVERSIFICATION

Local content policies are considered above (Section 3.1.3) as a route to bolstering local employment. Here we consider the ways in which local procurement policies, in particular, may help the mine of the future act as a driver for diversification, and transition away from the mine as a dominant source of employment and community benefit.

While the overall proportion of in-country payments for a given mine site that goes to procurement of goods and services increases as direct employment decreases, the urgency for avoiding dependency on the mining sector also increases. That said, one of the core reasons it is generally advisable for countries to sequence the focus on backward linkages from large-scale mining before forward linkages—all other things being equal—is that backward linkages have a higher prospect for creating horizontal linkages and diversification (Östensson & Löf, 2017).

As such, a focus on local procurement as discussed in Section 3.1.3. will offer potential ways to leverage existing mining investment toward a diversified local economy that is less mine-dependent. If the aim is horizontal linkages and diversification, some local procurement policies are more appropriate than others. For the most part, the policy options for creating horizontal linkages in mining procurement are more likely to be supply-side policies.

As noted in Section 3.1.3., for some product categories opportunities for local procurement may decrease as a result of new technologies. Labour-related procurement, in particular, will fall in concert with any drops in employment, and original equipment manufacturers may lock up exclusive service contracts for higher-value, more complex capital goods. On the other hand, Table 4 shows that mines will require new sorts of inputs related to new technologies, and these could provide opportunities for local industries.

What does that mean for local procurement policies as a tool for diversification? Ultimately, it makes it that much more critical that **local content policies should be mainstreamed in broader industrial development and diversification strategies**. For example, focus lists of goods and sectors should be defined in part by those non-mining areas that broader industrial policy and planning efforts have determined to be promising. Used in this way, mining-related local procurement policies hold the promise of supporting diversification by acting as a tool of national industrial policy.

3.3 RE-EXAMINING TAXATION

In the event that mining companies contribute less to local communities and host countries by way of direct employment, one suite of policy options for replacing that contribution involves simply raising the corporate income taxes (or royalties, dividends, equity stakes[31]) paid by the mines to the host government.

There are two lines of argument for this policy option:

- The firms, by adopting new technologies, are becoming more efficient and profitable. This is akin to a windfall profit argument. The fact that they might be doing so at the same time as they decrease their positive employment impacts makes this argument even more intuitively appealing.
- Governments are able to take any increased tax revenues and use them to somehow replace the value lost through the use of new technologies, using those funds to bring prosperity to affected communities and workers.

To the excess profits argument: clearly the application of new technologies should make mining operations more efficient. McKinsey suggests that the value of technological

31 In this section we use taxes as a shorthand for all such contributions. In reality they are different instruments with different strengths and weaknesses.

innovation for the mining industry could be as much as USD 370 billion per year, which was 17% of the projected cost base for the industry globally in 2015 (McKinsey, 2015). BHP's automation of blast hole drilling at its Jinglebar mine in Australia has reduced drilling costs by 25%, and reduced the costs of maintaining drills by 40% (Toscano, 2019). Rio Tinto's robotic process operation, predictive maintenance, and other information technologies reportedly save it USD 200 million per year just in equipment maintenance costs (Vella, 2020). The company reported in 2016 that the autonomous hauling fleet at its Pilbara iron ore operation that year ran for 1,000 more hours and at a 15% lower load and haul unit cost than conventional trucks (Gray, 2017). But efficiency is not equivalent to profitability, and most of these figures tell us only the savings realized without also revealing the investment needed to generate those savings. To assess profitability—and therefore re-examine taxation—we would also need to know whether the savings exceeded the investment over time.

As noted above, one of the drivers of this kind of investment is increased efficiency. But in some cases, new technologies are simply managing to overcome cost barriers to accessing difficult resources, with deeper deposits, lower ore grades, harder rock mass or other complexities. Ore grades as a whole tend to be in decline globally in key metals such as copper, gold, lead, and zinc, and growth of energy consumption has outstripped the growth of production (Calvo et al., 2016). New technologies in some cases may be earning normal profits exploiting resources that would not have been viable using conventional technologies.

But most important, any increases in profit that may result from adopting new technologies will be temporary, accruing most to the early adopters. Eventually any broadly available technologies—which most are, being developed not in-house but by original equipment manufacturers and third-party vendors—will be adopted as the new convention, operating costs will decrease across the board, as will prices, until excess profits from new technology disappear. Ultimately, new technology will not be a way to increase profit so much as it would be a necessary investment to remain in operation.

One way or the other, the second line of argument does not depend on any increase in long-term profits. Higher taxes, according to this argument, are a way for mining companies to replace the value that was formerly brought through employment, and they may eventually simply become the cost of running the mine of the future. There are a few challenges worth noting in this context.

One is that any country increasing levies unilaterally would risk becoming less desirable as a destination for mining investment. This is the same challenge resource-rich country governments face in the normal course of events: striving for a fair return on their resources at rates that the investors can bear. In the long run, as new technologies become ubiquitous and all countries face the same challenges, it may be that all operations will simply bear a more onerous fiscal burden, but the near term offers challenges for tax authorities and policy-makers.

Another problem is that, as benefits go, increased transfers to a central government are a poor replacement for direct employment. They put the onus on governments to use those funds effectively to provide opportunities for employment or broader economic development in communities that would otherwise simply have relied directly on the benefits and multiplier benefits that result from mining employment. The funds might also be used to support affected workers and communities; manage their transitions to alternative livelihoods; and invest in human capital, and in particular (re)training and education, to equip workers with portable skills to reduce their dependence on mining altogether. But this can only work if redistribution channels exist, are functional, and are well governed.

A related problem is that if increasing taxes is the only option pursued, it casts governments as the sole agents in the challenge of translating mining activities into well-being for affected workers and communities. While there are many ways that government actions are critical to this task, most of the possibilities surveyed in this chapter involve collaboration beyond government actors, or seek to harness the competencies and resources of mining companies in areas such as skills training, impact investment, or shared infrastructure. In other words, while it is reasonable to expect or require efforts on the part of mining companies to make up for technologies' labour impacts, it is probably not advisable to rely on increased taxes as the sole means by which they might do so.

New technologies may also mean opportunities to improve government oversight of the mining sector, by supplying data to tax authorities that helps them prevent base erosion and profit shifting. This policy option is discussed in Section 3.4.6.

3.4 TECHNOLOGY AS A SOLUTION

This suite of policy options is a departure from the ones considered up to this point. In searching for policies or initiatives that might address the challenges brought by new technologies, it turns to those same technologies as offering solutions. That is, the question becomes: how can new mining technologies be harnessed to bring benefits to communities and host nations to address the challenges that may arise from new technologies in the mining sector?

3.4.1 LOCAL INNOVATION TO SUPPORT MINING OPERATIONS

The development of cutting-edge technologies and digital solutions for the large-scale mining sector is led by a handful of global technological companies. These companies (mostly foreign-owned and/ or foreign-based) offer mining companies turnkey solutions, including software and hardware infrastructure and maintenance services. The resulting changing procurement needs of mining operations and the related new sourcing contracts are challenges to existing local procurement, reducing opportunities for local businesses to supply mines with high-tech goods and services, although, as argued in Section 3.1.3, new opportunities may arise.

BOX 15. THE DIGIMINE LAB: A PIONEERING SOUTH AFRICAN ACADEMIC INNOVATION PROGRAM

In South Africa, mining companies are supporting local universities and research centres to develop customized solutions for their operations. Sibanye Stillwater, a leading mining company producing platinum group metals, gold, and copper globally, entered into a partnership with the Wits Mining Institute at the University of the Witwatersrand, Johannesburg South Africa, to develop a state-of-the-art mining laboratory to improve mine safety. The DigiMine laboratory is a unique facility. The aim is to find digital solutions to put distance between people and risks in underground mining environments to improve safety.

The DigiMine Lab conducts advanced research on digital systems in several themes. A key focus of the lab is to seek ways to transfer surface digital technologies to underground mining environments. As well, it hosts a “mock mine” that reproduces the actual conditions of an underground mine on campus, to allow researchers to test their innovations in a real environment. All data collected in the mock mine are available in a control room on campus for deeper analysis.

The second phase of the project is expected to bring the tested innovation to be applied in Sibanye operations.

Source: Wits Mining Institute, 2020.

At the same time, the mining sector’s drive to adopt new technologies has opened new avenues for collaboration between mining industries and locally based R&D and innovation centres. These centres can supply mines with technology support, delivering tailor-made solutions to locally specific problems, by developing new technological solutions or by adapting existing technologies to local conditions and needs. They have knowledge of the conditions under which mining operates in their jurisdictions, and may engage in regular communication with mining companies to stay current on the challenges that innovation might address. This provides them with an edge to offer customized solutions for mining companies in niche areas, where standardized products supplied by global suppliers cannot.

While the role of the mining industry is key in providing the opportunities to develop and test endogenous innovations, this cannot be done without support from governments at three levels.

1. Legal and Regulatory Frameworks

   Innovation and R&D capacities are the backbone of economic prosperity in the Fourth Industrial Revolution. This is even more important for lower- and middle-income countries who already register important lags when it comes to driving and adopting technologies. The legal and regulatory frameworks should be strengthened, with an emphasis on:

   i. **The design of national innovation systems.** Governments should consider adopting a coherent and comprehensive strategy regarding innovation and R&D. As highlighted by the OECD (2013), these should focus on promoting and empowering the education systems to develop the necessary skills and teaching capabilities; fostering interdisciplinary and transdisciplinary research and solutions to common challenges; changing the paradigm in teaching students to focus on problem solving rather than just learning technical subjects.

ii. **The provision of an enabling environment** and the removal of regulatory barriers to stimulate innovation and entrepreneurship. Many developing countries do not have a strong regulatory architecture to protect ideas and innovations. This includes strong intellectual property rights legislation that adequately protects innovation and ideas. Industrial spaces with an enabling environment should be made available to creative individuals, firms, start-ups, incubators, and accelerators (Lantz & Wu, 2017), so they can work together to collaborate and transform innovative ideas into technologically feasible solutions for mining companies.

iii. **Data protection laws and cybersecurity.** Digitized mining environment generate large volumes of data, some of which are confidential or of strategic important for mining companies. These "big data" are set to become one of the most valuable assets of mining companies. Lack of proper laws and institutions to regulate and protect data and information pose significant risks of cyber attacks and data breaches, and can put at risk entire mining operations.[32]

2. Institutional Support

   In many developing countries, there is a lack of an interface between government agencies and research institutions and mining industries when it comes to promoting innovative local solutions. Public agencies are often weak because their mandates are unclear and they lack oversight, implementation and financial capacity. Strengthening public institutions responsible for innovation and R&D is therefore key to ensure that regulatory frameworks continue to fit the rapidly evolving needs of research institutions and the mining industry.

3. Financial Support

   As noted above, the level of public investment in R&D and innovation is chronically low in most developing countries. Local universities, mining schools and research institutions, therefore, lack financial capacity and logistics to undertake bold R&D programs to fit the needs of high-tech mines.

   Governments must therefore consider dedicating adequate financial resources in the form of grants and funding for R&D and innovation and provide the necessary equipment and logistical support, such as high-speed connectivity, world-class lab equipment etc., to tertiary institutions and research centres.

   Another important role government can play is to help bridge the gap between applied research and business development by supporting innovative local firms through special schemes, including grants, access to finance, intellectual property protection, fiscal benefits etc. Start-ups and SMEs in particular find it difficult to emerge because they are perceived as high risk by traditional financiers and investors. There needs to be particular attention given to such firms, as they can provide very specific customized solutions to the mining sector.

32 In structured interviews and discussions with mining sector representatives from Chile, Colombia, Ecuador, and Peru, cybersecurity was identified as one of the key prerequisites to a successful widespread adoption of mining technologies that could lead to a more sustainable sector (Urzúa et al., 2020).

Finally, governments need to ensure that grants and funding provided to institutions and local firms trickle down to everyone and put in place, where needed, monitoring mechanisms to ensure equal opportunities are granted to groups that traditionally have had restricted access to education and technologies.

3.4.2 MINING TECHNOLOGY IN SUPPORT OF LOCAL ECONOMIC DIVERSIFICATION

As part of social impact investment efforts (see Section 3.3.1), or as stand-alone efforts, mining companies should consider sharing some technological solutions with mining communities to strengthen their resilience and their ability to create new development opportunities beyond the mine gate. The cost of the “last-mile” investments to mining companies for the benefit of communities may not be too high if they are integrated into the upfront design of the projects. For communities, however, the benefits can be game-changing because technologies are enablers of economic opportunities, social improvements, and environmental management.

Moreover, as shown in Table 6, the mining sector shares common challenges with the mining communities, meaning there is tangible potential to adapt existing mining technologies to benefit communities.

TABLE 6. SOME COMMON CHALLENGES FACING THE MINING INDUSTRY AND LOCAL COMMUNITIES

CHALLENGES FACING THE MINING INDUSTRY	CHALLENGES FACING LOCAL COMMUNITIES
Increasing energy consumption costs Technologies being adopted include off-grid investments in renewables.	**Lack of reliable access to energy** Local communities in remote areas do not always have reliable access to the grid. Power outages are frequent. Shared access to renewables can offer a solution.
Connectivity Mining companies are investing substantial amounts of money in digital infrastructure such as Internet of Things, autonomous vehicles, and predictive maintenance systems that depend fundamentally on high-speed Internet (5G).	**Remoteness** Mining communities are not well served by ICT connectivity, in particular when they are in remote regions. Access to the Internet can be a game-changer for communities. If done through a gender lens, this could help close the gender digital divide, which in the longer term will foster girls' education and economic empowerment of women.
Health and safety of workers Often considered as a major risk, new technologies such as connected wearables, seek to minimize incidents and fatalities on mine sites.	**Poor health care services and weak infrastructure** New technologies can help upgrade services at community health care centres. Connected wearables, for example, can help track health patterns for patients and can save lives.
Increasing water scarcity The increased global scarcity of fresh water is a growing concern for mining companies. Technologies are being deployed to minimize water use.	**Lack of access to potable water and for agricultural purposes** Water-saving technologies in mining can free resources for communities and can help them better manage the quality and quantity of water used, with far-reaching implications on health, food security, and well-being. This can also have strong positive spillover effects on the social fabric: for instance, it can increase the time children (in particular girls) spend on education.
Environmental footprint Some technologies are meant to minimize the impact of mining on the environment, along the life cycle of the mine and beyond.	**Environmental degradation** Land, water quality, and biodiversity are of critical importance to the quality of life in remote mining regions. Technologies used in mining can help communities monitor broader environmental issues arising from non-mining activities such as agriculture, fishing etc. This improves food security and help professionalize local farming practices.

Source: Authors.

There is often a clear business case for such initiatives: the sustainability of mining operations is dependent on the prosperity of mining host communities. If mining communities are negatively affected by the adoption of new technologies by the mining companies, tensions and conflicts may arise, which may in turn affect mining operations. On the other hand, if mining communities can benefit from changes emerging from technologies, the acceptance of change—and of risks—is likely to be higher.

BOX 16. DRC: KIBALI'S POSITIVE IMPACT ON THE LOCAL COMMUNITIES

The innovative technologies adopted at Kibali in DRC have brought positive change in the mine's area of influence and potentially beyond. A portion from the mine's power grid capacity is provided free to local communities, reducing their reliance on felling timber from local forests for energy supply. Another positive spillover effect of Kibali's investment in the region is the Kibali-built Durba/Watsa concrete road, with the first section completed in 2020. Kibali also contributed to access to potable water sources for the surrounding villages. Ten community water sources were built in 2020.

TDi Sustainability (forthcoming). (An IGF case study on the impacts of new technologies on large-scale mining in the Democratic Republic of the Congo)

3.4.3 TECHNOLOGIES AS A BOON FOR ASM

ASM could benefit in several ways from even basic technologies that mechanize many of the tasks currently performed manually, such as hauling, crushing, and grinding. Technologies such as metal detectors and drones also promise to vastly increase the efficiency of operations, and technologies for due diligence in the supply chain, such as blockchain and analytical fingerprinting, can be cost-effectively used by buyers to perform the kind of due diligence that would allow the sector's products continued access to major markets. Benefits include:[33]

- Improvements in efficiency of operations
- Improved health and safety performance
- Improved environmental impacts
- The ability to verify responsible supply chains

None of the technologies involved are particularly complex or costly. Most of the basic efficiency-enhancing technologies are widely used and so involve no first-mover risks. There are a few ways in which governments can support their adoption, as part of a broader program of support for and recognition of the ASM sector:

- Operate outreach programs that demonstrate the technologies in the field.
- Low-interest, or at best, commercial-rate financing for the purchase of machinery. Typically, ASM operators are at the mercy of informal financiers that demand punishing interest rates.
- Particular guarantee schemes for those who lack collateral (e.g., including young entrepreneurs; women, very small enterprises etc.).

33 Adapted from Mutemeri, 2019.

- Support for the local manufacturing and servicing of basic machinery appropriate for ASM, such as small-scale grinders, crushers, and centrifuges, as part of a broader industrial policy effort.
- Brokered agreements between the formal and informal sector that see the former transferring "obsolete" equipment to the latter, for whom it may still be valuable.

A major caveat applies, however. As noted in Section 2.4.4, the impacts of new technology in the ASM sector hold great promise for efficiency, worker safety, and environmental performance—areas in which ASM has traditionally struggled to perform. However, the efficiency-enhancing technologies in particular may also hold great risks for one of the areas in which ASM has traditionally outperformed large-scale mining: employment of large numbers of low-skilled workers, including a large share of women and youth. There is no easy answer to this fundamental tension between policy objectives.

3.4.4 SHARED CONNECTIVITY FOR COMMUNITIES' WELL-BEING

Digital infrastructure is the backbone of new technologies in the mining sector. Every technology adopted is conditional on safe, rapid, reliable and uninterrupted access to Internet connectivity. Mining investments in such infrastructure is therefore a big-ticket item and the quality of the infrastructure must be of the highest standard.

Mining companies should consider sharing connectivity with local communities. To be effective, such efforts would need to be part of a broader initiative and would be most appropriately carried out in concert with local and national governments. Access to high-speed Internet can be a powerful enabler of development (World Bank, 2016). Here, we consider just two examples of that dynamic: the delivery of education and health services.

FROM DIGITAL MINES TO DIGITAL SCHOOLS

New mining digital infrastructure can play a significant role in improving the education system in remote mining areas. In fact, this should be a central part of the strategy around skill building for local communities.

Traditionally, mining industries often spend a considerable part of their CSR budget on education, providing schools with buildings, materials, and supplies. Often primarily aimed for their staff, the benefits are generally extended to the host communities at large.

As well as providing connectivity, mining companies should consider providing hardware such as laptops, tablets, and computer labs so that schools become truly empowering knowledge centres. Experience has shown that providing children from an early age with access to the best technologies is one of the best investments that can be made in human development. Adaptive learning software promises to improve the cognitive capabilities of students, thus complementing academic learning. Students can develop their analytical and strategic thinking skills by playing interactive games.

Technologies in schools have the potential to close the gender gap in STEM subjects, a crucial step in giving girls better access to education and the job market (Pathways Commission, 2018).

FROM DIGITAL MINES TO CONNECTED HEALTH CENTRES

Health is another area where mining industries often spend a significant portion of their CSR budget when needs are unmet by the public sector.

Despite those efforts, local communities continue to face several seemingly insurmountable challenges: under-staffed health centres, limited (if any) number of physicians, lack of specialist services, and the need to travel long distances for treatment, lack of infrastructure and poorly equipped health care centres, expertise, lack of confidence in the quality of services, weak administration capacities, amongst others. These are often compounded by low budgets and an absence of coordination with national health systems.

While digital technologies are not a panacea to replace well-functioning public health care systems, they nonetheless offer the possibility of improving the efficiency of health service delivery. Experience elsewhere has shown how progress can be made possible in health care systems in rural areas through digital technologies.

BOX 17. HOW NEW TECHNOLOGIES HAVE IMPROVED HEALTH CARE SYSTEMS

In Uganda, the web-based application Mobile VRS has helped increase birth registration rates in the country from 28% to 70%, thus helping decision-makers track health outcomes and improve access to services (Pathways for Prosperity Commission, 2019).

Drone technologies have been used in Rwanda and Ghana to transport urgent medical supplies to remote regions, thus overcoming land transport infrastructure difficulties and helping to save lives. During the COVID-19 pandemic, they have been used in Ghana to transport testing materials (Baker, 2020). Testing results were sent to patients by SMS.

Access to technologies can improve the quality of health care systems in mining communities and hence help address the challenges mentioned above. For example, technologies can enhance care delivery and improve the efficiency and accuracy of diagnosis. Electronic health records allow health care professionals to view a patient's medical history, anticipate risks, and follow treatments.

Telemedicine can bring a partial solution to a lack of doctors by providing remote consultations. Wearable devices such as fitness bands or blood pressure monitors provide regular checks and alerts. Data transmitted in real time through smartphones allow for regular checkups.

Mining industries can enhance their CSR support by extending connectivity to health care centres and by providing digitally enabled technologies to community centres. This should not be a substitute for governments' responsibilities but should act as a complement to public responsibilities.

3.4.5 SUPPLYING LOCAL COMMUNITIES WITH DATA OF INTEREST

The data-rich mine of the future will involve real-time flows of information from ubiquitous sensors. Big data analysis will provide a wealth of information that can range from mineral resource endowments; ore grades; trade flows; air, soil and water quality; and tailings dam stability readings, among others.

While some data might be sensitive from a corporate perspective, a significant amount of it might be of acute interest to local communities. Granting local communities access to some of those data in real time would be enormously valuable to those affected and might help improve mining governance while unlocking economic opportunities.

To be useful in this way, access to data must be coupled with training in how to use it, and particular attention will need to be given to girls and women, given the existing digital divide. It must be provided in a usable form with understandable context (for example, using a traffic light system for water quality), as opposed to being in "raw" form.

Such an initiative departs from other forms of technology as a solution in that it does not promote economic development as a sort of trade-off for potential job losses from new technology. Rather, it promotes community well-being from an environmental and security perspective. But in so doing, like the other proposed solutions described here, it could help build a robust social licence to operate.

BOX 18. COMMUNITY ACCESS TO TAILINGS DAM DATA IN CHILE

In 2018, as part of its National Tailings Policy the Chilean Ministry of Mining established a pilot project: a standardized monitoring and early warning system for tailings storage facilities. The public–private effort, known as "Programa Tranque," created an online platform that provides real-time information on physical and chemical stability of the El Mauro tailings deposit of the Los Pelambres mine. The system uses innovative mechanisms including Big Data analysis to measure and analyze critical parameters and variables.

The online platform is available to mining companies, communities, and authorities as part of an effort to strengthen operational management, promote a risk culture, improve communication between the parties involved, and respond to possible emergencies.

Source: Consejo Minero, 2021.

USING MINE-LEVEL DATA TO SUPPORT SMART AGRICULTURE

Agriculture is an obvious candidate for local economic diversification in many resource-rich countries. It is often the next most important economic activity in host mining communities. Agriculture generally preceded mining and continues to provide livelihoods to the communities.

In contrast to large-scale mining activities, which are highly productive, farmers in rural areas practice subsistence agriculture with manual and traditional equipment. Yields are low, and therefore income generation remains equally low. Access to and use of better technologies are limited due to costs and limited access to capital and markets. Agriculture practice under those conditions cannot represent a suitable alternative if prospects in mining become limited because of new technologies—and poor livelihood alternatives lead to migration and urbanization.

Mining can help trigger a green revolution in host communities if it supports upgrading of traditional agricultural practices with modern technologies being adopted in the mines. Technologies such as sensors, ICT, IoT, and drones can play a critical role in improving efficiencies of production and yield.

BOX 19. EXAMPLES OF SMART MINING TECHNOLOGIES THAT CAN SUPPORT AGRICULTURE

GIS mapping represents an integral tool used in mining to map and access geospatial information such as geochemical properties of soils, hydrology data, rainfall patterns, soil conditions, etc. Data collected are comprehensive and relevant to other economic sectors such as agriculture and fisheries.

GIS mapping applied to agriculture can considerably improve crop yield estimates and production. A better understanding of soil quality and water levels and quality for instance, allows for better informed decisions about crop varieties to plant, ideal amounts of fertilizer, and water inputs needed, among others.

Drones are used in mining to conduct aerial surveys, ensure surveillance and safety in hazardous areas, and perform inspections and monitoring of infrastructure. Applied to agriculture, drones can support farmers in inspecting plantations, evaluating surface areas, and gathering data to improve production techniques, thus increasing agricultural yields.

In addition to empowering local farmers with new technologies, mining companies can also share data collected for their operations. This can help them to make well-informed decisions, such as on the right timing for sowing periods, what crops varieties may be best suited for better yields, whether or not to invest in irrigation, and when to harvest.

Access to data can incentivize and accelerate modernization of agricultural techniques, if farmers are able to also acquire interconnected devices to monitor their production. This may not be easily accessible to lower-income countries' farmers given the costs involved and the skills required to use sophisticated tools and data analytics.

If real-time data is shared with local authorities as well, they can help manage, anticipate, and mitigate many facets of environmental and water management outside mine sites. For instance, data generated by high-resolution remote sensing techniques, remote satellite imagery, and drones can provide novel insights and detailed information to better plan and improve weather forecasting, disaster management, and smart water and energy management systems that may otherwise have been difficult to capture using conventional methods.

3.4.6 USING MINE-LEVEL DATA TO AID TAX AUTHORITIES

New technologies may bring opportunities to improve government oversight of the mining sector. The digitalization of operations will mean that mine sites will have access to significant volumes of real-time data. Tools for monitoring the flow and quality of minerals extracted could strengthen government revenue collection by providing real-time information to governments on the grade and quantity of extracted ores (EY, 2019). Lack of that information underlies the difficulties many governments face in trying to prevent base erosion and profit shifting. That data could also help tax authorities better analyze the tax gap, determine audit priorities, and negotiate fiscal terms. There are, however, legitimate concerns for the privacy of sensitive commercial information, and governments requiring firms to share data would have to be selective in their demands and institute appropriate protections.

An increased understanding of the resource base may also facilitate the implementation of more nuanced, targeted fiscal terms, provided governments also have access to this data. It could also reduce some of the uncertainty typically associated with mining investments. Artificial intelligence will enable exploration companies to delineate mineral deposits more accurately, potentially reducing geological risk. Less risk could mean cheaper finance and insurance and thus lower hurdle rates.

This policy option does not directly benefit communities that are local to the mine or directly assist those that may have been dislocated by employment shifts, but it does provide a way for new mining technology to deliver wider benefits to the host government at the national level.

4.0 CROSS-CUTTING ISSUES: MARGINALIZED GROUPS

The widespread adoption of new technologies in the mining sector holds both threats and opportunities for marginalized groups.

4.1 THREATS

As with any system, different groups tend to be affected differently by paradigm shifts in industries. The two principal threats to marginalized groups stemming from the adoption of new technologies are reduced direct employment and local procurement.

For employment, the more technologically intense the mine site becomes, the lower the share of lower-skilled positions. In countries where particular groups—be they ethnic, women, or youth—are marginalized, their reduced ability to obtain the education and skills required for such positions may be a major barrier. This means that the employment profile of the mine site, in addition to being smaller, has the potential to become even more dominated by members of the most advantaged social groups.

As an example of this, in 2018 the Centre for Social Responsibility in Mining at the University of Queensland released Indigenous Employment Futures in an Automated Mining Industry: An Issues Paper and a Case for Research (Holcombe & Kemp, 2018). The report's authors point out that without proactive action, the recent gains made by Indigenous employees in the mining sector in countries such as Canada and Australia are likely to be reversed due to increasing automation. In a similar vein, the Conference Board of Canada (2018) predicts that three key technologies (IoT, drones, and automation) will disproportionately affect Indigenous workers in the natural resource sectors, with mining the most adversely affected.

The same study predicted significant negative impacts for women, but they are proportionately less severe than those faced by the total working population in the mining sector. Women are more heavily represented in service occupations in the mining sector, and those jobs are less at risk of obsolescence.

For procurement, as mentioned above, all things being equal, increased adoption of new technologies will generally reduce overall spending on goods and services. Current host country suppliers have the potential to lose opportunities as their products are no longer needed or the volume of them required is lowered. Also mentioned, with lower procurement spending possible, there is the potential for increased competition for the remaining procurement opportunities. This all has the potential to hurt lower-capacity suppliers, especially those in the remote areas where mining typically takes place. This also means there is the potential to disproportionally affect underrepresented supplier groups such as those from marginalized groups.[34]

One common feature of CDAs is the use of "set-aside" provisions. With such provisions, particular goods and services contracts are reserved entirely for suppliers from the community with the agreement. Alternatively, for certain goods and services, the right of first refusal is provided to the community's suppliers. These contracts are often for services that require lower skill levels to perform, such as transportation or janitorial services. If such product needs are reduced due to new technologies—such as due to reduced numbers of employees who need transportation for example—this will lower the ability of a mining company to target benefits for members of the community through such set-aside provisions.

While not focused on mining specifically, the Canadian Council for Aboriginal Business's (CCAB's) recent report Digital Differences: The Impact of Automation on the Indigenous Economy states that 250,000 jobs held by Indigenous workers in Canada are at high risk from automation across 33 industries listed. The five industries most at risk were identified as accommodation and food services; retail trade; construction; transportation and warehousing; and management, administration, and other services (CCAB, 2020). Given the reliance of the mining sector on services such as accommodation, construction, and transportation, this CCAB report raises concerns for suppliers of the mining sector in Canada and beyond.

Not only is this potential local procurement reduction a negative impact in itself, but a community and the wider public's associating technological changes in the mining sector with further marginalization may also serve to raise the potential for opposition to mining activity. As such, there should be alignment between both government and mining companies to mitigate the potential marginalization of underrepresented groups in their ability to take part in the mining value chain.

4.2 OPPORTUNITIES

On the other hand, new models of mining that are less reliant on physical strength and that allow a higher proportion of employees to work remotely—even off the mine site entirely—also may provide new opportunities for participation from people from traditionally underrepresented groups. As noted above, this is especially the case for women. There are many barriers and sources of discomfort for female employees performing certain tasks on a mine site. The lack of PPE tailored to women's bodies is a problem regularly cited by female employees working underground. While some companies are trying to address these challenges, such as the Canadian supplier Covergalls, which makes PPE for women, on the whole there remain many deterrents to women working directly on mine sites.

34 Marginalized groups include "different groups of people within a given culture, context and history at risk of being subjected to multiple discrimination due to the interplay of different personal characteristics or grounds, such as sex, gender, age, ethnicity, religion or belief, health status, disability, sexual orientation, gender identity, education or income, or living in various geographic localities" ("Marginalized groups," n.d.).

As such, the higher the proportion of work on a mine site that can be carried out remotely, even in an office thousands of kilometres away, the higher proportion of jobs for a given mine site that women will be able to perform without existing barriers.

A similar dynamic may also be possible in terms of mining companies seeking to hire more staff from a particular group, such as Indigenous employees. While typically mining companies will prefer to hire as many people as possible from communities close to the site due to the positive impacts on community relations, remote operations make it easier to provide opportunities for marginalized groups that may not be represented in the local community. For mining companies reducing low-skilled jobs on mine sites, this ability to hire from other members of that same particular group in areas with a higher number of those people with the required skills for remote jobs, may be a second-best option.

New opportunities for members of underrepresented groups when it comes to supplier firms—either as owners or employees of supplier firms—are likely to exist mainly in the form of services carried out on the mine site itself. It is common for mining companies to contract out parts of the mining process itself, rather than have these tasks carried out by direct employees or individual subcontractor employees. Where work packages involve tasks that can be carried out remotely by remote control, for example, it is reasonable to expect supplier firms may be able to better target the hiring of members of underrepresented groups than if the tasks need to be carried out on mine sites.

4.3 POLICY IMPLICATIONS

In order for governments to ensure marginalized groups do not become even further disadvantaged by automation and other new technology adoption in mining, a number of policy options are available. Echoing a common theme throughout this guidance, accurate data is crucial to inform such policy responses.

In this light, it is already common practice for multinational mining companies to provide data on what percentage of their employees are female, including some who break down these numbers by seniority. In 2019 a requirement for employment data disaggregated by gender was added to the EITI Standard, helping cement this growing trend. Companies operating in areas with regulatory or societal expectations for prioritized employment from particular ethnic groups, also tend to be able to provide breakdowns of employment by group. For example, in South Africa, mining companies have statistics on employees who are Historically Disadvantaged South Africans (HDSAs), and in Canada it is common for companies to report how many Indigenous employees they have.

For the issue of procurement, it is also common for mining companies to create data on what percentage of procurement spending goes to suppliers from particular groups, often based on societal pressure and regulatory pressure. Like for employment, South Africa is a country where companies are required to report on their procurement from HDSAs.

Less common is the collection of data on procurement spending broken down by whether supplier firms are owned by women or not. While there has been an increasing focus on targeting women entrepreneurs, such as guidance from the International Finance Corporation, there are few, if any, public reporting examples where a breakdown of procurement spending by gender is provided. Most data provided is anecdotal in nature, where mining companies provide case studies of women-owned suppliers they purchase from and/or supplier development initiatives with a focus on women. The Responsible Mining Foundation's 2019 brief, *Research Insight: Women Miners,* provides useful data on which of the world's largest mining companies provide reporting on efforts to target women-owned businesses, but the information shows public reporting remains relatively low.

If, however, governments work with mining companies to create data on what percentage of employment and procurement is going to particular marginalized groups, and then also create data on which of these two opportunities may be negatively impacted by automation and other new technologies, a foundation of knowledge on which to base a response can be created. Without this data, there is a risk that government interventions—as well as those by companies—to try to mitigate the negative economic impacts of new technologies specifically on marginalized groups, will be led astray.

In terms of policy options to respond, like those for prioritizing local employment and procurement in general, potential responses stem from adjusting current demand- and supply-side measures.

For hiring:

- Require public reporting on the proportion of particular employees has the potential to inspire companies to make more proactive efforts to seek and promote those employees. Such public reporting will also help empower government and other actors seeking to support those employees.
- Require CDAs between communities and mine sites that incorporate a focus on training women or members of other underrepresented groups to mitigate job losses in those groups from automation.
- Target specific education and vocational opportunities in the skills required by new mining technologies for members of underrepresented groups, such as through the provision of scholarships.

For procurement:

- For countries using target lists of goods and services, ensure the list includes goods and services that currently tend to be provided by marginalized groups and that will not be significantly reduced as new technologies are adopted.
- Encourage or require mining companies to address particular supplier groups in local procurement plans, including providing training for them to transition to providing other goods and services, and/or to find new markets for their current products.
- Consider the use of CDAs to allow local procurement preferences and supplier capacity efforts tailored to local conditions, that take into account the relative presence of marginalized groups in supply chains. For example, for a mine site where a large number of women are employed at a manufacturing facility that will face reduced demand as automation takes place, the CDA can require specific support for this firm. In this regard, CDAs provide an advantage over a nationwide list of goods and services approach that does not take into account the differences in demographic makeup of suppliers from site to site.
- As with adjusting local procurement policies in general, governments can consider working with industry to determine expected cost savings due to new technologies. All things being equal, so long as these savings remain, the revenue can be utilized for preferential procurement and/or supplier capacity building.

5.0 CONCLUSIONS

The wave of new technologies washing over the mining sector will change the face of mining, just as technological change has already disrupted sectors like retail, entertainment, and communications. As in those cases, the changes will involve costs and benefits. Our concern is not so much how those costs and benefits balance out but rather how they are distributed. Mining-affected communities and resource-rich host countries may see costs in terms of lost employment for which they are not compensated in terms of benefits, even if new better jobs are created and health and safety records improve. This will not happen in all cases; in some cases increased efficiency may mean more jobs than would have been possible with conventional technologies. But in those cases where it does happen, whether in the context of a low-benefits greenfield investment or of a disruptive retrofit, it is a critical matter of development, and of social licence to operate.

Our survey of policies to address this challenge does not discover any silver bullets; there is no single policy solution. At a general level we find that technological change often intensifies the importance of doing what governments, mining companies and communities should have been doing anyway.

High on the list is a focus on education policy, skills training, and educational institutions. As with most of our recommendations, this will involve close collaboration between governments, companies, and institutions of learning to help ensure that locals can fill the jobs of the future, will remain adaptable to continued change, and can help drive innovation and entrepreneurship that diversifies away from the mining sector.

Also promising are the many ways in which governments and mining companies might use new technologies as a solution to the problems of technologies - to bring benefits to local communities and regions. In small but meaningful ways the use of such technologies can help replace the benefits that might be lost by locals in the transition to the mine of the future.

We see great promise—but also daunting challenges—in collaborations to foster diversification away from the mining sector, and in a model that looks more like impact investment than like CSR spending, designed to create sustainable profitable non-mining-related enterprises in ways that build on existing strengths and resources.

Other policy solutions seem more difficult, or fraught with uncertainty. Increasing taxation may be the basis for government support to affected workers and communities, for education systems, and for efforts at transition, but it should probably not be pursued as an exclusive policy solution. Local content policies in procurement and employment are critically important, but they may involve shooting at a sinking target as opportunities shrink for both employment and procurement.

All of these policies need to be built on better information than many governments have now. What jobs are most at risk, given future investment by their mining companies? What jobs will be created, and how many? Is there a mismatch between existing and needed skills, and does the answer change between the mine site and urban centres? What kind of profit levels will accrue to mines adopting new technologies?

None of it can happen through governments acting alone. Throughout this report we note the ways in which mining companies need to act and to collaborate with governments and local communities in order to ensure that the new deal is a good deal.

All of this sees mining policy moving increasingly to intersect with broader industrial policy, forced to do so by the changing nature and potential of mining's contributions to national economies. Again, this is a path that probably should have been followed anyway, but the advent of new technology now makes it even more important.

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