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Sustainable Development

IMPACT OF NEW MINING TECHNOLOGIES ON LARGE-SCALE AND ARTISANAL MINING IN BURKINA FASO

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Impact of New Mining Technologies on Large-Scale and Artisanal Mining in Burkina Faso

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ACRONYMS

ANEEMAS	National Agency for the Supervision of Artisanal and Semi-Mechanized Mines
BUMIGEB	Burkina Faso Bureau of Mines and Geology
CNM	National Mining Commission
DGESS	General Director of Sectoral Studies and Statistics
FMDL	Mining Fund for Local Development
GPS	Global Positioning System
MMC	Ministry of Mines and Quarries

1.0 INTRODUCTION

Technological change is inevitable and requires continual adaptation. Throughout history, nations have succeeded by swiftly developing and adopting new technologies. The mining sector, perhaps more than others, thrives on technological progress. Burkina Faso, a landlocked country over 1,000 km from the coast that has no oil resources, is now a significant gold producer in West Africa. This is not only due to the increase in the price of gold, reforms, and the other incentives adopted, but also—and above all—due to new operating techniques that have made it possible to derive more value from limited deposits.

The introduction of increasingly effective and efficient technologies is an integral part of mining operations; it is a matter of adapt or die. However, any change also brings disadvantages: these need to be anticipated and their negative consequences curbed. Among them, the consequences for employment are a particular concern. Indeed, in the current context—that is, post-uprising—Burkina Faso must, like other West African countries, consider all sources of conflict and find long-term solutions for them for the sake of its economy.

With a poverty rate of over 40%, population growth of 3.1% annually, and a high level of youth unemployment and under-employment (World Bank, 2016), it is essential to protect any jobs created in the country or, at the very least, take steps to create more than are destroyed. Moreover, it is important to ensure that technological change does not disrupt what has already been achieved in terms of local economic development, in particular, maintaining the balance between communities. This study of Burkina Faso aims to examine the situation in detail, identify the changes taking place, and anticipate the next steps based on a series of recommendations.

The goal is to present practical policy proposals and recommendations that aim to (i) encourage investment; (ii) ensure that both Burkina Faso, as a host country, and neighbouring communities can manage and adapt to change; and (iii) ensure that the country continues to derive long-term socio-economic advantages from mining operations.

2.0 REVIEW OF THE MINING SECTOR

Investments in mining in Burkina Faso have increased by 800% over the last 10 years because of the rise in prices of the main metals. As a result, the number of industrial mines increased from one to 17 between 2007 and 2019, with 16 gold mines and one zinc mine[1] (totalling 26 valid large-scale mining permits). There are also 26 valid operating permits for semi-mechanized gold mines, 28 artisanal gold mining authorizations, and 26 industrial quarries. A study mapping the main artisanal gold mining sites, produced in 2018 by the National Agency for the Supervision of Artisanal and Semi-Mechanized Mines (ANEEMAS), identified roughly 800 sites across the country.

TABLE 1. VALID MINING PERMITS AND AUTHORIZATIONS BY TYPE OF OPERATION

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Artisanal	171	146	149	313	336	362	63	61	30	28
Semi-mechanized	13	18	23	23	22	36	32	33	32	26
Industrial	10	11	11	13	15	18	20	26	25	26
Total	**194**	**175**	**183**	**349**	**373**	**416**	**115**	**120**	**87**	**80**

Source: Ministry of Mines and Quarries Statistical Yearbook.

Until 2008, mining tended to be dominated by the use of artisanal, traditional methods or gold panning. Large-scale industrial mining has grown significantly since 2009, particularly as a result of the increase in the price of gold and the successive reforms made to the 2003 Mining Code.

Unlike the Mining Code adopted in 1997 (Act no. 023/97 of 22 October 1997), the 2003 Code (Act no. 2003-31 of 08 May 2003) is marked by the extent of the tax incentives it offers. Before the Mining Code came into effect, a number of alarming facts had emerged, including a fall of over 60% in direct revenue paid into the state budget, the departure of numerous mining companies (with a fall in the number of active permits from 224 in 1998 to 58 in 2002), and several projects that had already been launched being called to a halt (Directorate of Communication and Ministerial Press, 2003). This situation was attributable in part to the fall in the price of gold (from an average of USD 400 in 1998 to USD 270 in 2002) but, above all, to Burkina Faso's fiscal regime for mining. The main aim of the 2003 Code was therefore to reduce mining sector taxation.

The Mining Code draws a distinction between the construction phase and the operating phase of a mine. Several tax and customs incentives apply during the preparatory stages and construction of a mine, including a value-added tax exemption for 3 years on purchases of goods and services and an exemption on customs duties (but not community taxes). During the operating phase, tax on industrial and commercial profits is reduced by 10 percentage

1 These are the gold mines in Taparko-Bouroum (Namentenga), Youga (Boulgou), Inata (Soum), Mana (Balé and Le Mouhoun), Essakane (Oudalan), Bissa (Bam), Yaramoko (Balé), Karma (Yatenga), Netiana (Ziro), Hounde (Tuy), Boungou (Tapoa), Wahgnion (Leraba), Bouere-Dohoun (Tuy), Samtenga (Oubritenga), Sanbrado (Ganzourgou), the small industrial mine in Guiro (Namentenga), and the zinc mine in Perkoa (Sanguié).

points to 25%, tax on income from marketable securities is cut by half to 12.5%, and an exemption from stamp duty applies to companies that decide to increase their share capital. Apart from the fact that they contribute to the country's reputation for socio-political stability, these incentives have helped revive activities in the sector. Another study carried out by the World Bank showed that in 2018, more than 20% of all investment in gold exploration in Africa was made in Burkina Faso (World Bank Group, 2019). In terms of industrial production, over 50 tonnes of gold and 211,243 dry metric tonnes of zinc concentrate were produced in industrial mines in 2019. However, the level of gold production from artisanal mining reported remains low, mainly because of fraud. Quarrying has also increased, with industrial ore production increasing from 400,626 m^3 in 2017 to 788,726 m^3 in 2019.

TABLE 2. PRODUCTION BY TYPE OF OPERATION (IN TONNES)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Artisanal	0.6	0.5	1	0.4	0.2	0.312	0.2	0.1	0.3	0.259
Semi-mechanized	0.1	0	0.1	0.4	0.2	0.001	0.035	0.005	0	0
Industrial	22.5	32.1	29.2	32.5	36.3	36.237	38.285	46.397	52.4	50.3
Total	**23.2**	**32.6**	**30.3**	**33.3**	**36.7**	**36.6**	**38.5**	**46.5**	**52.7**	**50.6**

Source: Ministry of Mines and Quarries, 2019.

The change in the mining sector's trade surplus has made a significant contribution to improving the overall balance of trade in Burkina Faso, which had achieved equilibrium since 2016, before falling to -1.9% of GDP in 2019. The share of export revenue from the gold sector increased from 42.3% in 2009 to 70.3% in 2019. As a result, thanks to the increase in the price of gold, the extractive industries' share of GDP improved considerably, from 3% in 2009 to 12.4% in 2018 and 12.2% in 2019.

The direct contribution from mining to the state budget increased from around XOF 8 billion in 2008 to XOF 276 billion in 2019. Local authorities benefit directly from surface taxes, business rates, and the Mining Fund for Local Development (FMDL). As of June 30, 2020, over XOF 51 billion had been transferred to local authorities under the FMDL. In addition to contributing to the fund, some mining companies also invest in communities as part of their corporate social responsibility programs. In terms of energy, almost all mining companies use thermal power stations and therefore benefit from the facilities offered by the Mining Code in relation to imports of hydrocarbons. The only company that has invested in renewable energy sources is Essakane SA, with the creation of a solar farm whose entire production is injected into the power grid run by the Burkina Faso national electricity company to the benefit of the community, which helps mitigate its environmental impact.

TABLE 3. MACROECONOMIC INDICATORS FOR BURKINA FASO'S EXTRACTIVE INDUSTRIES

Indicator description	2016	2017	2018	2019
Contribution to GDP	8.3%	11.4%	10.6%	12.2%
Number of mines in operation	10.0	12.0	13.0	16.0
Industrial production of gold (in tonnes)	38.3	46.4	52.4	50.3
Production of zinc (in thousands of tonnes)	155.7	164.3	183.4	190.8
Export revenue (in XOF billion)*	974.0	1,181.0	1,294.0	1,420.0
As % of total export revenue	0.7	0.7	0.7	0.7
State budget revenue (in XOF billion)	190.0	226.0	252.0	276.0
Growth of direct revenue	12.8%	19.0%	11.5%	9.4%
As % of total revenue	15.4%	16.4%	15.4%	14.0%
Initial investments (in XOF billion)	197.3	187.7	131.6	83.4

** XOF = West African CFA franc*

Source: Ministry of Mines and Quarries, 2019.

In terms of employment and professional skills, the total number of employees in mining companies in Burkina Faso at the end of 2019, all categories combined, was 15,342, of whom 13,874 were citizens of the country, representing 90.43% of the total mining workforce. Senior and middle-ranking executives from Burkina Faso represented around 27.13% of employees. Quarrying accounted for around 8,900 jobs, mainly occupied by people from Burkina Faso. A study of artisanal gold mining carried out by the United Nations Development Programme in 2017 estimated the number of gold panners at 1.3 million (cited in Bohbot, 2017).

Data on socio-professional categories show that 61% of employees in the formal sector are unskilled workers, 9% are senior executives, 7% are senior technicians and middle-ranking executives, and 23% are technicians, supervisors, and skilled workers (Zerbo & Ouadraogo, 2014). Women make up the majority of the workforce in certain areas of artisanal mining, such as washing, but the proportion of women in the formal mining sector (large-scale industrial mines) is only around 6%.

2.1 LARGE-SCALE MINING

Unemployment and under-employment are widespread in Burkina Faso and West Africa more generally, driven in part by a high rate of population growth (3.1% annually). This lays the foundations for significant conflicts between the mining companies and local communities related to the jobs the companies create. These companies are practically the only employers, and therefore precipitate the migration into the local labour market of workers drawn from an ever-younger population—workers with few prospects outside mining (industrial or gold panning), who flock to mining areas in the hope of being hired. The fact that communities are nearby, combined with the lack of other opportunities, dictates a cautious approach that the

companies must take, to avoid any sudden change in technology or production processes that could compromise the ability of local populations to access jobs in the mines.

In practice, however, mining companies generally have little appetite for communicating about the technological changes they are adopting. They argue that the production process is defined by the feasibility study approved by the National Mining Commission (CNM), which determines the lifespan of the mining project and the level of production throughout the period of operation. Any change in technology would therefore not be on the agenda, and thus the technology described in the study remains unchanged throughout the life of the mine. In any case, a change in progress would have to be documented and accepted by the administration. They also state that the agreements reached in relation to the Environmental and Social Management Plan (in which a commitment is made to communities in relation to local employment) aim to guarantee peaceful operation without conflict. As a consequence, any change can produce conflict, and information about any technological change is carefully withheld and divulged only within a very small circle.

Another argument put forward by the mining companies is the high cost of investing in highly sophisticated technologies. While in the West these types of investments help reduce operating costs by lowering labour costs, this is not the case in Burkina Faso. The relatively low cost of labour means that the companies prefer to use less-advanced operating technology to safeguard jobs and allow higher profits. So for them, using the older methods is a "win–win" strategy. However, it does not exclude the possibility that they may eventually adopt new technologies to improve their efficiency and yield.

That said, it is important to note that the COVID-19 pandemic has forced the mining companies to implement health and physical distancing measures and, like other sectors, to adopt new working methods, inevitably including remote working and, therefore, more technology. This increased flexibility around work could last or be repeated over time, depending on how the health situation evolves. Even if these new arrangements are a temporary response to the pandemic, however, the mining sector has still shown that it is not necessarily dependent on the local labour force.

At the same time, the health crisis has highlighted the lack of flexibility in mining jobs. In fact, all the mining companies have adjusted their working hours to avoid layoffs. As a result, employees have been paid without being forced to go to work, while executives have continued to work remotely and by videoconference, creating additional costs that have been entirely borne by the companies. It is important to emphasize that this adaptation was possible thanks to the increase in the price of gold seen throughout this period. Nevertheless, the pandemic has proved that the mining industry could function with a smaller workforce.

Even so, there have been discussions with the administration on the need to mitigate the impacts of introducing new ways of working or new technological processes. In fact, Article 39 of the Mining Code requires that the Technical Committee have the opportunity to issue an opinion when there is a change to a mine's development plan. This opinion must be based primarily on the mine's production capacity and lifespan to avoid "high grading."

In an application for an extension or revision of the mine development plan using the same technology, there would be a proportional recruitment of employees. However, with a change in technology, there is a risk of less-than-proportional recruitment, resulting in a potential loss

of employment for the communities. For example, if the mine decides to use larger dumpers or other automated equipment, it will de facto recruit fewer employees than if it were to use the same type of equipment.

When new permits are granted, the operator's preliminary feasibility study must mention the most recent and most appropriate technology it will use for the site's specific characteristics to secure a return on its investment. The Technical Committee will not assess the loss of opportunity in terms of jobs if a particular older technology is used. For example, when the company Wahgnion Gold Operation was sold to Teranga Gold, the leaching process was changed from heap leaching to column leaching because, according to the company, the yield from column leaching would be higher. This new technology helped increase the mine's production capacity, disrupting its development plan and therefore justifying a review of the plan by the CNM. With this more efficient technique, the company was able to substantially increase its production and profitability. But in order to do so, it had to increase the speed of excavation, which, all other things being equal, assumes the use of new physical (e.g., excavation machinery) as well as human resources. This should translate into either an increase in the workforce and/or adjustments to each employee's working hours, for example, by paying overtime. In all cases, it would have an impact on employment, and an analysis of this kind would have to be carried out by the CNM to assess all the consequences.

In any case, we note the usefulness of an analysis of a negative impact from technological change on mining jobs in Burkina Faso, even if the mining companies do not explicitly confirm it. The essential criteria governing mining activities are safety and profitability. In general, mining companies accommodate community concerns and manage conflicts most effectively by using fixed-term contracts more frequently and making extensive use of temporary employment agencies to avoid having to manage disputes related to staffing cuts. The only currently unknown factor is how long it will take for Burkina Faso to develop an appropriate new technology or when it will arrive, if it is imported.

At the moment, most parent companies in Canada, Australia, and South Africa run tests to ensure that a technology works efficiently before any transfer to their subsidiaries in Burkina Faso. Accordingly, we know, for example, that Caterpillar is allegedly finalizing tests on autonomous machinery. The parent companies concerned are already using very advanced technologies that require very little labour, in light of the high cost of domestic labour, the unpredictable geology of resources, and the exhaustion of open-cast quarries (forcing them to move to underground operation).

2.1.1 JOB LOSSES

In general terms, there are three kinds of jobs in the mining sector:

- Mining-specific jobs: People who work in these types of jobs can only work for a mining or specialist geology organization, and they represent around 30% of a mine's total workforce. These jobs are found at every stage of mining activity, such as exploration, feasibility studies, construction, operation, processing, rehabilitation, etc.
- So-called "transverse" or cross-functional jobs: These are found throughout the process and include work in civil engineering, electrical installations, machinery driving, industrial maintenance, general safety, etc. They represent around 40% of the workforce.

- Administrative or support jobs, which represent around 30% of staff: These are necessary for the business to operate, particularly in terms of management, general services (secretarial, accountancy, finance, and human resources), legal affairs, communications, stock management, etc.

Technological change makes mining-specific jobs more precarious than cross-functional and administrative roles, since these employees are ill-equipped for working in other sectors. Furthermore, in addition to the risk of a fall in the gold price, the lifespan of a mine in Burkina Faso is relatively short (10 years on average), which influences the precarious nature of these jobs.

TABLE 4. NOMENCLATURE OF POSTS IN THE MINING SECTOR IN BURKINA FASO

Occupational groups	Occupational sub-groups	Jobs
Mining-specific jobs		
Mining research/ exploration (upstream or integrated)	Geology	Exploration geologist (senior, junior)
		Geological technician
	Geophysics	Geophysicist
		Geophysical technician
	Hydrogeology	Hydrogeologist
	Geochemistry	Geochemist
		Geochemical technician
	Geomatics	Geomatics specialist
	Chemistry	Chemist
		Laboratory technician
	Drilling	Driller
Feasibility	Mine engineering	Mining engineer
		Chemist
		Minerallurgist
		Geologist
		Metallurgist
		Processing engineer
	Mining economics	Economist
		Geo-statistician

Occupational groups	Occupational sub-groups	Jobs
Mine construction	Engineering	Mining engineer (quarries and mines)
		Geotechnical engineer
		Technician (props, ventilation, etc.)
		Ventilation engineer
		Geologist
		Dynamiter
		Hydrogeologist
Mine operation	Preparation and extraction	Mining engineer (quarries and mines)
		Geologist
		Hydrogeologist
		Technician (geological or mining)
		Driller
		Dynamiter/blasting specialist
		Vehicle operator
		Instrumentation engineer
		Foreperson
Mineral processing	Chemical treatment	Minerallurgist
		Chemist
		Laboratory technician
	Design	Metallurgist engineer/Hydro-metallurgist
	Processing operations	Plant operators
		Foundry technician /Foreperson
		Foundry worker

Occupational groups	Occupational sub-groups	Jobs
Rehabilitation/closure	Environment	Mining environmental specialist
		Hydrogeologist
		Environmental technician
		Biologist
		Chemist
		Mining engineer
		Geotechnician
Cross-functional roles		
Industrial technology and maintenance	Topography	Surveyor
		Topographer
		Designer
	Masonry	Mason
	Joinery	Timber/metal joiner
		Carpenter
		Technician
	Welding	Welder
	Mechanics	Mechanic
	Boilermaking	Boilermaker
	Pipework/plumbing	Plumber
		Industrial pipefitter
	Industrial pumping	Pumping operator

Occupational groups	Occupational sub-groups	Jobs
Industrial electricity, electricity production and distribution	Electrical engineering	Electrician
		Electrical engineer
		Electrical engineer
		Automation specialist
	Electricity production and distribution	Industrial wiring specialist
		Overhead and underground network installers
		Power station or electrical generator foreperson
		Automation specialist
Telecommunications network	Telecommunications engineer	Engineer
		Technician
Heavy machinery driving	Driving	Heavy machinery driver (civil engineering/mines)
		Crane operator
		Operator
Mobile equipment maintenance	Maintenance	Maintenance engineer (mining machinery)
		Maintenance technician
		Maintenance electrician
		Safety controller
		Fire safety officer
		Security guard
		Flag attendant
Workplace health and safety	Health	Nurse
		Doctor
	Mine safety	Safety officer/specialist
Environmental protection	Environment	Environmental specialist
		Technicians

Occupational groups	Occupational sub-groups	Jobs
Support roles		
Support roles	General services	Camp manager (accommodation)
		Vehicle manager (vehicle fleet)
		Cook
		Surface technician
		Laundry worker
	Stock	Warehouse keeper
		(Stock) manager
		Logistics specialist
	Buying	Buyer
	Accounting/finance	Financial administrator
		Financial controller/management
		Accountant
		Accounts assistant/cashier
	Human Resources Management	Human resources manager
		Human resources assistant
		Human resources officer
	Training	Training officer
		Trainer
	Administration	General administrator
		Administrative officer
		Deputy administration officer
		Administrative assistant
		Management secretary
		Secretary/receptionist
		Translator/interpreter
		Liaison officer/courier
		Driver

Occupational groups	Occupational sub-groups	Jobs
	Legal affairs	Lawyer
	Communication	Communications officer
		Communications specialist
	Community relations	Community relations officer
	IT department	IT maintenance and equipment officer
		Engineer
		Technician

Source: Extract from draft decree no. 2020-_/PRES/PM/MMC/MFPTPS/MJPEJ/MINEFID establishing a nomenclature for posts and quotas for local jobs based on a mine's lifecycle.

Jobs occupied by local people in Burkina Faso are generally low-skilled (manual workers, unskilled labour, etc.). These roles fall into major groups 8 and 9 of the International Labour Organization's International Standard Classification of Occupations, which covers "Plant and Machine Operators and Assemblers" and "Elementary Occupations." For example, the cross-functional role of machinery driver, which falls under "Plant and Machine Operators and Assemblers" alone represents almost 10% of the workforce at the Nantou Mining mine. A job of this kind is threatened in the medium term. Trials of autonomous machinery are alleged to be underway, and autonomous dumpers could soon replace the vehicles operating today.

Drone trials for topographical surveys are also thought to be taking place. On average, a topographical team consists of 13 people, including a topographical engineer, two assistants, and 10 operators. Depending on the size of the mine, there may need to be several "topo" teams working. Nonetheless, a drone can produce the surveys carried out by all the teams and record more reliable data. In general terms, these types of jobs and skills are more likely to be impacted by technological change. For example, Bissa Gold employs a total of 1,267 people, 1,192 of whom are from Burkina Faso. Among the latter, 128 are executives, 118 are technicians, and 947 are manual workers. The technicians (geologists, senior geological technicians, supervisors, etc.) and manual workers are the most likely to be threatened by technological change.

Jobs that are likely to disappear as a result of technological progress will involve routine, repetitive tasks that are mainly done by manual workers and other technical staff. Since there are more of them, especially compared with executives, the social impact will be all the greater.

As a result, whether we are talking about excavation (extraction), processing, or transport activities, technological change will have repercussions on a large number of jobs. For example, a larger, more autonomous dumper now needs one driver rather than two. In terms of dynamiting, the use of mixer wagons and automatic drilling machinery is reducing the average number of dynamiters from seven to two.

According to a study based on a sample of three large-scale mining companies (Houndé Gold, Riverstone Karma, and IAMGOLD Essakane), the number of staff employed directly by them who are likely to be impacted by technological change represents 78.4% of their total combined workforce, or 3,487 employees. These are mainly geologists, topographers, drillers, machinery mechanics, heavy goods vehicle drivers, supervisors, manual and unskilled workers, etc. We should note at this point that all job categories are affected, from mining-specific to cross-functional and administrative roles. However, only a portion of these jobs are likely to disappear, depending on the type of technology used. With technology that only affected 10% of jobs (such as machinery drivers), the number of workers concerned would be around 350; across the 17 mines in production in the country in 2020, a total of 840 jobs would be affected.

2.1.2 UNDERGROUND MINES

The strenuous and dangerous nature of underground mining activities has been an important driver of increased automation for certain activities. At least three mining projects in Burkina Faso are planning to switch from open-cast to full or partial underground extraction. In many cases, however, underground operations are contracted out, and the subcontractor arrives with a full complement of staff, often made up of expatriates. A number of employees may nonetheless be kept on, having been trained to work in an underground environment. It is important to note that the switch from open-cast to underground mining undoubtedly results in the loss of at least half the jobs previously available.

2.1.3 NEW SKILLS

The new skills required will depend on the technology used. In general terms, there is a trend toward more automation; the qualifications required will therefore relate to IT, application development, robotization, etc., and these skills are rare, if not non-existent, in Burkina Faso. Moreover, there is as yet no map of the new skills the mining companies will be looking for.

2.1.4 OPPORTUNITIES FOR ARTISANAL MINING

Artisanal and/or semi-mechanized mining in Burkina Faso could benefit from skills transfers from large-scale mining companies. We are already seeing artisanal mining develop around large-scale mining projects, often benefiting from their expertise by “squatting” in the areas adjacent to those covered by industrial permits.

These artisanal operators thus benefit from the results of the studies already carried out by the mining companies in relation to their application for a large-scale mining permit. Moreover, employees who are forced to leave their jobs or who are made redundant as a result of technological progress in the large mines may opt to put their skills to good use and apply them to semi-mechanized mining. The “galleries” dug at certain points, often strengthened with props to consolidate the pit, provide evidence of informal skills transfers from industrial to artisanal mining. Knowledge transfer of this kind can only produce better organization, improved safety, a better yield, and—often—fewer negative impacts on the environment.

2.2 ARTISANAL MINING

The intrinsically informal nature of artisanal mining makes collecting information about it challenging. The survey carried out by ANEEMAS (Effigis, 2018) calculated that there are 800 artisanal mining sites in the country. While some of these are properly registered, known, or recognized, others are classified as "unlawful" or clandestine and are located in areas where mining is prohibited, such as protected forests, cultural areas, and/or places of spiritual significance. It is common to see squatters on mining sites taking advantage of lawfully granted permits, which sometimes causes conflicts.

Burkina Faso's Mining Code defines artisanal mining as "all operations consisting of extracting and concentrating mineral substances such as gold, diamonds and other gemstones, from primary and secondary deposits on or below the surface, and producing saleable goods from them using manual and traditional methods and processes. It does not use mechanical equipment or energy and is not based on the discovery of a deposit."

According to those involved, this definition does not reflect (or no longer reflects) the reality on the ground. Indeed, only a few sites are still involved in rudimentary ore extraction. At least one mechanical grinder, commonly known as a "wanbyaaré," is used at all artisanal mining sites. Machinery and tools are found at almost all sites, and it would be more appropriate to describe all mining operations in Burkina Faso as semi-mechanized.

Semi-mechanized mining: All operations that consist of extracting and concentrating mineral substances and producing saleable goods to dispose of them, using some mechanical resources in the process. Semi-mechanized mining as practised in Burkina Faso is a somewhat improved version of artisanal mining using certain processes and tools. It represents a transitional step to small-scale mining.

Small-scale mining: Small-scale mining is based on the existence of a deposit, using industrial or semi-industrial processes in line with standard practices in the sector, whose annual production once it is up and running does not exceed a certain tonnage of saleable product such as ore, concentrate, or metal. There is only one so-called small-scale mine in Burkina Faso, in Guiro.

Artisanal mining currently supports over 1 million people, although production volumes remain relatively modest. According to a study by the National Institute of Statistics and Demographics carried out in 2017 (Institut National de la Statistique et de la Demographie, 2017) national production is around 9.5 tonnes a year. In 2018, ANEEMAS estimated that there were over 800 active artisanal and semi-mechanized mining sites. As a result, over XOF 300 billion (EUR 456 million) circulates every year through the countryside where these sites are located, thus contributing to the development of the local economy. Given this situation, any change in the processes used will have a significant socio-economic impact on all parts of the artisanal production sector. Technological progress will help improve yields and reduce harmful environmental impacts. At the same time, however, it will inevitably destroy jobs.

The importance of artisanal and small-scale mining as a source of employment for an ever-younger and under-educated population is seen by the public authorities as a strategic niche to be protected. As a result, unlike some neighbouring countries that have decided to prohibit it, the government of Burkina Faso has opted to create a framework for it. ANEEMAS was created in 2015 for this purpose. Its role is to establish and raise awareness among stakeholders about good practices, particularly around safety, as well as the spacing of shafts and techniques for installing props, etc. It also has the power to decide on buying prices in order to guarantee profits. Buying prices are therefore set at between -13% and -15% for operators, -10% and -13% for collectors, and -10% and -7% for buying offices. In reality, however, there is currently a hidden intermediary in the sector that captures over 80% of revenues because they also provide funding. The official financial system is disinclined to fund this type of activity, which further increases the precariousness of artisanal mining.

2.2.1 RESEARCH OR EXPLORATION

Artisanal mining research is instinctive and intuitive, and the knowledge of how to "follow the seam" is surrounded by mysticism. However, times are changing. Once the sole preserve of masters, metal detecting can now be carried out using "vin-vin" metal detectors imported from India or China. Young people have also specialized in using these devices, creating a new kind of work in artisanal and small-scale mining as decently remunerated "prospecting expert" service providers. We are also witnessing the increasing use of high-performance detectors, creating conflicts with holders of industrial permits, since they can detect the tiniest particles of gold, leaving no opportunities for the permit holder of the site being explored.

2.2.2 OPERATION

Until recently, artisanal mining was characterized by the use of rudimentary tools such as chisels and hammers. Now, it is not unusual to see sites using pneumatic drills, explosives, compressors, Poclain excavators, bulldozers, skip lorries, motorized pulleys, etc. Compressors are also used for ventilation. These techniques have allowed artisanal mining to reach an unexpected level of performance, sometimes descending to significant depths, with some galleries reaching 180 metres.

This shift toward gradual mechanization can only help to transfer obsolete or depreciated machine tools from industrial to artisanal mining sites. This is an opportunity for both artisanal and industrial operators, allowing the former to acquire equipment at competitive prices and the latter to dispose of it. New jobs could also be created in artisanal mining that could be taken up by some "victims of technological change" who are willing to take advantage of retraining opportunities in this sector.

As well as second-hand or obsolete equipment, forward-looking, large-scale mining operators are managing to dispose of stocks of bulky machinery and/or unused spare parts that could be made available to artisanal miners and industrial quarry operators.

2.2.3 PROCESSING OPERATIONS

Processing begins with crushing, which is mainly done using rudimentary tools such as hammers. This is a strenuous, demanding task that is mainly done by women. Once it has been crushed, the ore is transported to the processing area by motorcycle taxi.

Increasingly, however, we are seeing the introduction of equipment such as hammers or jaw crushers, often imported from India or produced by domestic equipment manufacturers. Domestic production is calculated to represent around 60% of the equipment used (M. Yves Zongo, personal communication, July 28, 2020). The use of crushing equipment has a direct impact on the number of people employed since a machine would replace 20 people. And, despite the strenuous nature of the work, women take a dim view of the introduction of the machines, since crushing guarantees them a daily wage of XOF 3,000 to 4,000 (EUR 4 to EUR 6) (M. Salofou Traore, Director-General of ANEEMAS, personal communication, Sept 3, 2020). This allows them to cover day-to-day needs, particularly their children's schooling.

Crushing is followed by grinding. Traditionally carried out by women using pestles and mortars, this task is increasingly being done by men with the appearance of machinery made in India (ball grinders).

The next task is washing: 100% of washing in Mossi areas and 50% in the southwest is done by women (M. Romba Abdoul Gafard, Director of ANEEMAS, personal communication, Sept 3, 2020). Washing is carried out in "wash hangars" owned by women. However, with the gradual introduction of GoldKacha-type centrifuges, women have become concerned, since a single machine (which costs between XOF 2.5 million and 3 million) can replace 20 to 30 employees. In practice, a centrifuge can run with five or six operators and has a processing capacity of around 1 to 2 tonnes per hour, while a wash hangar employs two or three people and processes a maximum of six to ten 200-kg sacks of ore a day. A shaft owner who is also a village chief commented that the use of the centrifuge is more profitable for him; nevertheless, he wonders what will become of the women for whom this activity is their only means of earning a living. The use of chemical products such as cyanide and mercury is prohibited in artisanal mining. In this respect, the ANEEMAS plans to organize operators into cooperatives, which will make it easier to introduce new processing procedures with less toxic products, thanks to targeted training.

2.3 MINE GOVERNANCE

Mine governance is also affected by technological change. Global Positioning System (GPS) and drones are not yet properly covered by the regulations. As a result, technological progress causes constant upheavals that force people to adapt in terms of research, permit management or monitoring, and controlling mining infrastructure and activities.

In terms of research, the Burkina Faso Bureau of Mines and Geology (BUMIGEB) is making mapping easier, faster, more reliable, and more economical by using aerial photos and remote detection. The introduction of GPS technology has limited the number of people required for mapping assignments, reducing the number of staff such as geologists, geological technicians, senior geological technicians, forepeople, manual workers, etc. to a third at best. Work that used to be done by 50 people can now be done by five. A drone, for example, requires a single operator.

In terms of drilling, thanks to dedicated research funding, the BUMIGEB has just acquired new, more autonomous drilling equipment that requires a maximum of three people (a driller, a mechanic, and an unskilled worker), compared with six or seven people with the previous machines.

In terms of laboratory tasks, since 2003, the BUMIGEB has had a chemical measuring device (using inductively coupled plasma mass spectrometry) that is capable of carrying out automatic analyses to identify all the chemical components in samples. The whole manual analysis process has disappeared with this device. In fact, it has reduced processing time from 10 days to one, and the number of employees by the same amount.

In terms of controlling and monitoring quarrying, the plan in the short term is to operate drones, as is the case in certain neighbouring countries. A survey to measure indicators used to assess quarrying operations will be carried out by a drone operated by a person in an office, instead of a team of three people for an assignment lasting two or three days. This technology not only reduces working time and the cost of the activity, but also provides more reliable results in real time. The use of drones is also envisaged for certain monitoring, control, and inspection of mining infrastructure and activities missions. The introduction of these devices will enable more effective and efficient administration since they require fewer staff.

In terms of managing mining permits, computerizing the issuing system will soon allow companies to apply online for them and, among other things, check the availability of the area concerned electronically and facilitate the processing of the application. It will also enable orders to be printed and make it possible to produce demands for the payment of surface tax and fixed fees, and ultimately allow for the automatic allocating of surface tax and the FMDL. According to the Director General of the Mining Registry, this kind of modernization would cut her department's staff by half, from 26 to 15 people (Georgette Kientega, Director-General of the Mining Cadaster [Mining Registry Office], July 29, 2020).

3.0 PROSPECTS AND RECOMMENDATIONS

TRANSPARENCY AROUND THE FUTURE ADOPTION OF TECHNOLOGY

- Encourage mining companies to indicate the types of jobs they will be looking for in their pre-feasibility studies based on their planned use of technologies.
- Ask mining companies to add their technology adoption plan to the file submitted to the CNM that examines the project for the purpose of granting a permit.

TRAINING AND SKILLS DEVELOPMENT

- Encourage mining companies to anticipate change and adapt their training/retraining plans so that employees can be redeployed to newly created jobs.
- Create a training organization for mining occupations and emphasize the jobs that will be created in the future, particularly those linked to connectivity, automation, information technology, etc.
- Manage, train, and raise awareness among professional executives in the mining sector to encourage them to retrain in artisanal mining; they can act as a springboard to help artisanal mining evolve and gradually become semi-mechanized. Medium-sized mines can thus develop and increase in number.
- Train young people in quarrying and the use of quarried materials and encourage local authorities to use materials processed locally by these young people, such as for road works (resurfacing), construction projects, etc.

REDEPLOYMENT OR REUSE OF SKILLS

- Redeploy people with certain skills (BUMIGEB, General Directorate of the Mining Registry) to employ them in other administrative bodies, particularly in monitoring and controlling mining infrastructure and activities in general.

MEASURES TO SUPPORT WOMEN

- Encourage women to organize themselves into cooperatives, which could provide services such as purchasing centrifuges and modernizing wash hangars.
- Use pit water for fruit and vegetable cultivation so that women who lose their job can find productive new outlets.
- Offer women training in different occupations, such as the restoration of mining sites using local products, particularly those derived from fruit and vegetable cultivation using pit water, fattening cattle and sheep, and breeding poultry. Industrial and artisanal and small-scale mining sites are major consumption centres.

LOCAL CONTENT POLICY TO DEVELOP EMPLOYMENT

- Conduct a large-scale study on local, regional, and national opportunities for mining procurement to be satisfied at the local level; local content policies, particularly based on program frameworks, are useful monitoring and action tools.

- Build capacity among local equipment manufacturers so that they can participate in the modernization of artisanal mines.
- Promote the use of locally manufactured equipment.
- Implement a mechanism to allow artisanal miners to source their equipment locally and thus avoid getting into debt as a result of prohibitive interest rates.

FINANCIAL SUPPORT

- Raise people's awareness on preparing for life after mining in the municipal committees responsible for monitoring the implementation of the FMDL; allocate mining resources to investments that will survive once the mine has closed. This involves reviewing local municipal development plans and ensuring that no segment of the population (women, young people, etc.) is left behind.
- The FMDL offers a development opportunity for regional comparative advantages that will allow them to specialize for beneficial future trade. Job creation in the context of implementing municipal development plans will help to absorb "victims" of technological change.
- Mining companies must refocus their corporate social responsibility activities to mitigate the effects of incorporating technologies that destroy jobs. Some legislation encourages mining companies to produce training plans and schemes to transfer skills from foreign workers to local people. This is, therefore, a path that should be pursued to redeploy skills and allow local workers to acquire the qualifications required by the new technologies.

INFRASTRUCTURE AND TECHNOLOGY SHARING

- Mining investments involve the construction of numerous types of infrastructure that could benefit the population. It is possible to envisage agreements between the state (on behalf of communities) and mining companies so that the latter direct their investments in infrastructure to respond more effectively to local needs (for example, building reservoirs to support fruit and vegetable crops, fish farming, power stations, the use of renewable energy sources, etc.). Infrastructure construction could be co-funded in conjunction with the Financial Contribution to Water, which is payable to the state.
- Given its scale, energy infrastructure could provide a source of employment, particularly in the area of ongoing maintenance. This type of infrastructure can also benefit the mining company by helping it reduce its carbon footprint. Furthermore, good community organization and setting up relevant initiatives and projects might allow them to access the Green Climate Fund set up by the United Nations.
- Finally, mining companies could be encouraged to invest in 5G beyond their own needs, which would allow communities living alongside mining projects to access it, as part of the collaborative relationship that must exist between the two parties.

4.0 CONCLUSION

Although the mining companies operating in Burkina Faso are not yet in the era of modern mining, which relies on robotic machinery, this study shows that technological change is taking place to some extent in the industrial sector and more extensively in artisanal and small-scale mining. Most of our recommendations encourage the development of a mining economy based on local input. It is a question of genuinely encouraging the integration of the mine into the economy at all levels, not simply in terms of jobs.

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APPENDIX

TABLE A1. LIST OF MINING COMPANY REPRESENTATIVES MET

Last name and first name	Mining company
BADO Sirinatou	ESSAKANE IAMGOLD SA
BARRY Adama	TERANGA GOLD
DABIRE Auguste	OREZONE
DABIRE Marcel Winbale	Nantou Mining BF SA
FAUCHER Patrick	TERANGA GOLD
KAGAMBEGA Ernest	SOMISA
KAMBOU Sié Jonas	ROXGOLD SANU SA
KERE Abraham	OREZONE
KOMBOOGO Daouda	BMC
MONE Bourahima	D-HRTI
NEBIE Lydie	Nantou Mining BF SA
NIKIEMA Amadou	OREZONE
OUEDRAOGO Boukary	KARMA
OUEDRAOGO Christian	SOMISA
OUEDRAOGO Issouf	BMC
OUEDRAOGO Raphael	SEMAFO BOUNGOU SA
OUEDRAOGO Touendé	HOUNDÉ GOLD Houndé SA
OUEDRAOGO William	ESSAKANE IAMGOLD SA
OUEDRAOGO/KERE Alima	BISSA GOLD
SAWADOGO Rasmané	BISSA GOLD
SORO Adama	EDV
TOUBGA Hamadé	ROXGOLD SANU SA

TABLE A2. LIST OF REPRESENTATIVES OF MINE ADMINISTRATION MET

Last name and first name	Organization
BAGRE Mathias	Director of Sectoral Statistics/ DGESS
ILBOUDO Ousmane	Permanent Secretary, SAMAO
KAGAMBEGA Nicolas	Director General of Mines and Geology
KIENTEGA Georgette	Director General of the Mining Registry
NIKIEMA Désiré	NGO “Mine responsable”
ROMBA	Director at ANEEMAS
SAGNON Mamadou	Mining Registry Director
SAMA Martial	Mining Director
SAMBARE Abdoulaye	Director General of Quarries
SOMDA Bonaventure	Director of Regulation at ANEEMAS
TRAHORE Salifou	Director General of ANEEMAS
WOBGO Boukary	Permanent Secretary, CNM
YONLI Banseli	Director of Policy Formulation/ DGESS
ZOUNGRANA Djibril	General Inspector of Mines

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