Mining and Green Growth in the EECCA region

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Foreword

For most countries in the Eastern Europe, Caucasus, and Central Asia (EECCA) region, mining is an important economic sector that contributes to employment and public revenue. It is also a major historic source of environmental damage, and continues to have the potential for immediate and long-term negative environmental effects. As governments in the region work to support the transition to greener economic growth in their region, they have a vital role in supporting better environmental performance in the mining sector and ensuring that the industry can be a progressive part of greening the economy.

By examining the environmental impacts of the mining sector in the EECCA, assessing what has worked and not worked in OECD member countries to improve environmental performance, and studying specific examples of successful sustainable mining operations, this report provides a foundation on which to develop country specific strategies for reconciling green growth and the mining sector.

This report reviews environmental impacts and trends in the mining sector. It complements existing international knowledge and efforts in providing new evidences and best practices from leading mining jurisdictions, and provides policy makers with guidance to reconcile environmental and competitiveness objectives in the mining sector.

This report:

- Reviews principal examples of the environmental damage caused by different forms of mining;
- Presents emerging technology trends that are either directly or indirectly impacting environmental performance in mining;
- Identifies linkage opportunities between the mining sector and the green economy; and
- Suggests key recommendations on areas of policy response that governments can undertake to improve environmental performance in the mining sector.

Executive Summary

In most countries in the Eastern Europe, Caucasus, and Central Asia (EECCA) region the extraction of mineral resources is an important contributor to export earnings, employment and public revenue at the national and sub-national level.[1] Globally, green economy and digitalisation trends are reinforcing demand projections for raw materials such as copper, lithium, and cobalt that are central for many green economy applications, including renewable energy and electric vehicles. However, the mining sector remains a major potential source of immediate and long-term environmental damage. With many EECCA countries eager for the influx of both revenue and technology that new mining developments may bring, governments should ensure that industry can be a progressive partner in implementing strategies that promote green economic growth. Making this transition in the mining industry is vitally important, and contributes to numerous Sustainable Development Goals (SDGs).

The world's largest multinational mining companies have increased their focus on sustainability. Beyond reducing the impact of mining on the environment and local communities, sustainability is increasingly an asset for competitiveness. Good environmental performance lowers costs by improving efficiency and helping ensure that mining companies gain social license from stakeholders. In addition, future access to resources and as well finance is increasingly impacted by responsible business practices.

The mining sector has substantial backward and forward linkages to other parts of the economy, and shifting mining to a more sustainable path can potentially improve environmental performance in existing linkages as well as develop new ones. This includes acting as a conduit for new technologies, such as automation and digitalisation, as well as a driver for environmental service providers, renewable energy, and green infrastructure.

Environmental impacts across mine types, time, and distance

The most common mining techniques, surface mining and underground mining, have the potential for significant adverse environmental impacts in the immediate operational area, across broader watersheds and country borders, and in contributing to climate change. Environmental impacts in the immediate area potentially include ecosystem destruction, negative effects on biodiversity, release of heavy metals, toxic substances and particulate matter through both mining and the beneficiation processes, and significant use of water resources. Mines can potentially damage watersheds through acid mine drainage, lowering pH value and causing the leaching of heavy metals and other toxic contaminates into the water table, making water unusable for drinking and agriculture and killing wildlife.

Because the mine closure/post-operation phase tends to be less monitored than the operational phase, environmental impacts can be particularly damaging, whether over the long term or the more acute timescale of an accident at a tailings management facility (Vijgen and Nikolaieva, 2016[1]). The failure of a tailings dam in any part of the world has the potential to impact the social acceptance for all other operations of the company concerned and also for the mining industry in general (UNECE, 2014[2]).

Although OECD mining jurisdictions generally have legal requirements for site rehabilitation, waste rock and tailings management facilities can remain potentially dangerous sites of environmental contamination for decades and even centuries after mining operation ceases. This is particularly pertinent in the EECCA region, where the legacy of Soviet-era mining has left significant numbers of poorly maintained non-operational mine sites and heritage pollution issues.

Mining also contributes to climate change through the release of greenhouse gases (GHG) in the beneficiation and smelting processes[2], as well as fossil fuels for transportation, operation and power generation. As climate change increases the frequency and intensity of extreme weather events and exacerbates water scarcity in some parts of the world, mining companies will also need to consider it in planning.

Technology trends on sustainability in the mining sector

Improving production efficiency through the deployment of new technologies such as automation, energy and resource efficiency and electrification lowers the environmental footprint of mining operations and provides cost savings.

Automation: The use of automation and remote control in mining is driven by productivity, health, and safety concerns but also has positive effects on environmental performance. For instance, automated mining trucks and rigs can reduce emissions, more efficiently use inputs, and prolong machine life.

Electrification: The mining sector has not escaped the global shift towards electric vehicles and renewable energy deployment, with potential benefits for input efficiency, reliability, and emission reduction. For example, for off-grid mines, renewable energy or hybrid systems reduce emissions and operating costs while improving reliability. For underground mines, the shift to electric vehicles means a safer and more efficient operation.

Digitalisation and remote sensing: Advances in data digitalisation and remote sensing have drastically changed the quality and quantity of data that mining companies have access to. For instance, exploration companies can now rely on a range of different geophysical and remote sensing technologies to show them what is underneath the surface, to sample, and to make the decision on whether to develop a mine or not.

Developing the connections between the green economy and the mining sector

Improving the environmental performance of the mining sector has tangible economic and social benefits to mining companies and positive spill over effects into other parts of the economy through. However, in EECCA, few of these benefits evident. Public policy can play an important role in facilitating transferability of skills and technology by supporting its deployment through incentive structures, by mandating technology transfer and training as components of mining licenses, by encouraging mining companies to maximise local procurement and supporting local companies to meet internationally recognized standards, and by developing human capacity through education and vocational training programs.

Deployment of new technology: The mining sector can act as a conduit for the deployment of new green technology, including automation, which can be transferable to other sectors of the economy. More energy efficient operations, increased electrification, and increased use of renewable energy are also applicable to other economic sectors.

Environmental services: This shift can also generate new markets for environmental services companies who support mining companies in going green. Environmental services companies are relevant at every stage of the mining process, including the environmental assessment phase, operational phase, and mine closure and site reclamation.

Green shared infrastructure: Mining operations require significant amounts of infrastructure, including transportation, water, and power. That infrastructure can be harnessed to benefit communities in the area, as well as to support the growth of other industries while mitigating environmental impact.

The circular economy: The circular economy, a conceptual re-envisioning of economies from linear patterns of material use (raw materials, production, use, and disposal) to one without waste (materials reused, repurposed or recycled at every economic stage) has the potential to impact the mining sector across a number of areas:

- The “urban mine” of industrial appliances and electronics that can be recycled and processed is a potentially rich source of metals.
- Tailings and waste rock sites from older mining facilities may contain metals due to inefficient or uneconomic extraction techniques during their initial processing.
- The increased ability to track metal and mineral commodities from their point of origin enables the potential for new business models, where mining companies stay responsible for the processing and recycling of the metals they sell.
- Vertically integrated business models, drawing on both secondary metals from recycling facilities as well as primary metals directly from mines.

Key recommendations

Successful OECD jurisdictions demonstrate a confluence of policies that together incentivise, support and regulate mining companies to reduce their environmental impact. Key recommendations to governments in the EECCA region include:

- Develop a whole of government, coordinated approach to improving environmental performance in the mining sector, drawing on international conventions and agreements as valuable conduits for standards, coordination and information.
- Implement clear, stable and consistently enforced environmental regulation that stimulate operators to implement efficient and green techniques and technology.
- Facilitate broader stakeholder participation in support of good environmental performance from mining operations, including the inclusion of local communities in the monitoring environmental impacts during operations and after mine closure.
- Support innovation in the mining sector through promoting sustainable and innovative infrastructure and the funding of sector-specific and applied research.
- Build human capacity in technical and environmental skills and knowledge through education, training and work experience.
- Develop policies to address abandoned and orphaned mine sites, including holding responsible parties liable and incentivising investment in reprocessing waste.
- Support the development of a market for third-party green service providers in the mining sector, including accreditation processes.

1. Mining, sustainability and the EECCA region

This chapter discusses the environmental impacts of mining operations at different stages of the mine lifecycle, including impacts on water, soil, biodiversity, and climate change. It also provides context on current sustainability trends and drivers in the mining sector. Mining across the countries of Eastern Europe, the Caucasus, and Central Asia (EECCA) is explored, with a focus on its economic importance and the need to improve environmental performance. Finally, this project is put in context with ongoing OECD work related to the region and to the mining sector, as well as projects and conventions at the international level that can help shape sustainability and the mining sector in the EECCA region.

1.1. Introduction

Mining remains an important economic sector for many countries in the Eastern Europe, Caucasus and Central Asia (EECCA) region. At the same time, EECCA countries are adopting strategies to promote green growth, aiming to improve livelihoods while decoupling economic growth from destructive environmental practices. Determining the role of government policies in rationalising green growth strategies with the extractive sector, and improving the environmental performance of mining operations, is a critical challenge.

The immediate impact of mining on ecosystems and human health, as well as long-run concerns about climate change and global ecosystem sustainability, are sharpening focus on the environmental footprint of the mining sector. Whether underground or open pit, mines have the potential to affect their environment, both locally and over broader geographic areas, including across borders.

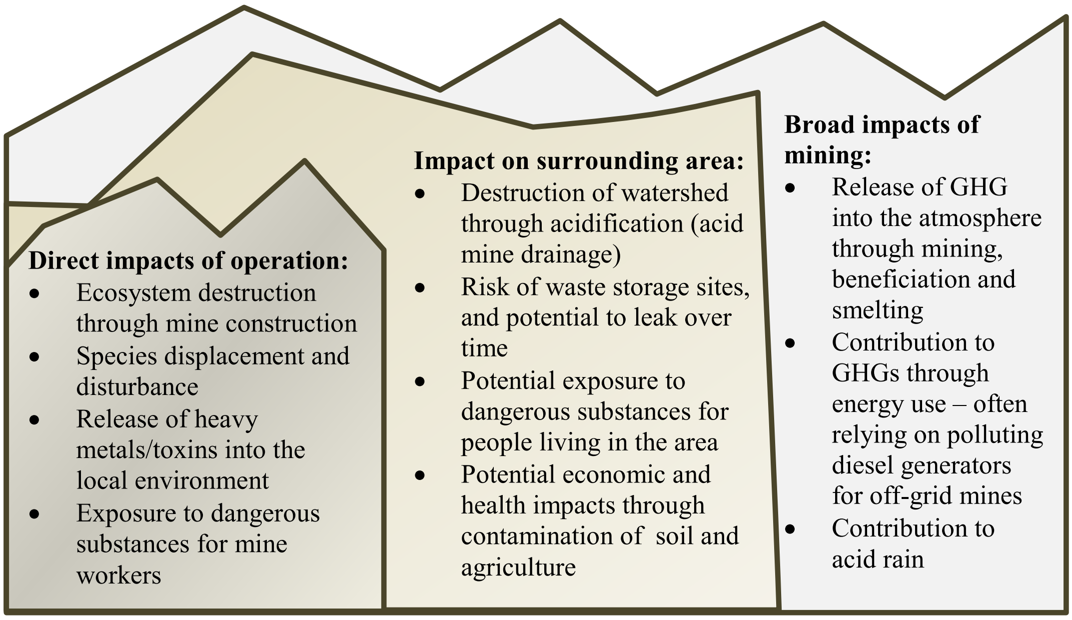
Despite that, transitioning to a greener economy will continue to require new sources of minerals and metals - some of which have not been heavily exploited in the past. Even the most optimistic circular economy projections anticipate that we will continue to need new primary sources of metals and minerals. Governments have a vital role in ensuring better environmental performance in the mining sector and ensuring that the industry can be a progressive part of greening the economy. Although there is an inherent contradiction in the term "green mining", the mining sector can improve its environmental performance and reduce impacts.

1.2. Environmental impacts of the mining sector

The extractive sector involves, as the name suggests, permanently removing natural resources from the ground. This takes a variety of forms, including surface mining (most commonly open-pit), underground, in-situ and heap leaching, as well as small scale and artisanal mining. Each of these carries its own environmental challenges. Beyond that, the characteristics of where the mine is situated form the underlying environmental risks and challenges, including both ecosystem issues as well as those that affect communities in the area.

The potential environmental impacts of mining can be seen as a series of nested circles, beginning with the immediate impact of the mine – the hole that is dug, the tunnels that are built, the soil and water that are displaced. Then there are the impacts on the wider ecosystem – how water is used or contaminated, how habitats are disturbed or destroyed, and how biodiversity suffers. This is not just limited to the mine site itself, but also encapsulates the transportation and energy infrastructure that needs to be built for most projects. Going larger still, there is the impact that mining has through airborne emissions, contributing to both air pollution and greenhouse gases.

Figure 1. Environmental impacts of mining



Source: Author's graphic; MIT 2012. "Environmental risks of mining." Massachusetts Institute of Technology.

Related to this, but potentially distinct in terms of the policy responses, is the impact that it has on people. Most immediately, the people working at the mine operation, the nearby communities who are impacted by noise and air pollution and habitat destruction, as well as those who make their livelihood directly from the land, including food production and agriculture. Contaminated water, air and soil can also have major health impacts. These issues can also be considered in terms of time scale, related to the stage of project development – exploration, to construction, to operation, to closure and site remediation.

1.2.1. Impacts on water, air and soil

The degree and type of environmental impact is dependent on the mining method used, on the existing geography and ecology, and on the geology and the specific metals and minerals mined. Beyond this extractive process itself most mined materials need to be processed to separate the economically valuable metals and minerals from the waste rock. This process normally occurs on site to reduce transportation costs, and is itself a major component of both energy and water use, as well as potential emissions.

The mining of a wide number of base metals, including gold, copper, and nickel, can result in mine waste that acidifies water and causes significant ecological damage, negatively impacting biodiversity in both land and water. In addition to being highly acidic, the water then also dissolves heavy metals and other toxic elements into it. Damage can occur from tailings and mining waste, as well as from the active mining site itself. The process of acidification can occur through a variety of chemical processes, but most often occurs with iron sulphide associated rocks (Akcil and Koldas, 2006[3]).

Although acid mine drainage can form during any stage of the mining process, including both surface and underground mining, during the operational phase the danger is normally not as significant. In a properly regulated mine, water is pumped and treated, and prevented from mixing into the groundwater. However, after a mine has closed, monitoring is generally reduced, if it occurs at all. In both underground and open pit mines, mining often occurs below the water table. With the pumps shut, returning water dissolves minerals and rock and becomes acidic. This process also occurs in waste dumps and tailings storage areas, where it can lead to results that are more devastating as the base material is more concentrated. Even where tailings are being managed, unexpectedly high rainfall or other weather conditions can cause dams and earthworks to fail, leading to destructive discharges of highly acidic water into the water table (Johnson and Hallberg, 2005[4]).

The effects of such accidents can go far beyond country borders, especially if transboundary rivers are polluted, and affect neighbouring countries. The 2000 Baia Mare accident in Romania, for example, triggered by heavy rainfall, released 100,000 m^3 of cyanide into the Somes River and had sever effects on Hungary. It threatened the drinking water supply of more than 2.5 million Hungarians, killed 1,200 tonnes of fish and causing 15,000 people in the fishing industry to lose their livelihoods. Other than high rainfalls, severe weather events such as earthquakes, floods and extreme heat can also cause tailings failures. Natural hazard triggered technological accidents (NATECH) accidents can trigger domino/cascade events (OECD, 2015[5]).

Box 1. Environmental impact by mine type

Surface mining, including open pit, strip, and mountain top removal, are the most common form of mining. Material is excavated and processed, with different techniques depending on the metals or minerals being sought. Because the economically viable minerals or metals are generally not at the surface, the removal and relocation of substantial quantities of overburden and “waste rock” is required. This has direct environmental impacts – habitats for flora and fauna are destroyed, and ore that can contain radioactive elements and asbestos is exposed.

The pits often go below the level of the water table. In order to facilitate deeper mining, water is progressively pumped out. In addition to the risks of water contamination during the mining process, this also leads to issues when the mine is shut down and the water table rises again; left behind mining by-products can contaminate the water and drastically change its pH level, leading to broader damage to surface and underground water.

Underground mining also involves the removal of substantial amounts of waste rock and the disturbance of flora and fauna. It can also contribute to changes in the landscape when tunnels collapse, land subsides and sinkholes develop. Water contamination is a common issue, as water is pumped out of mines that are below the water table – just as with open pit mining, if not properly monitored and controlled that water can contaminate surface and groundwater. The same issues exist as well with tailings ponds.

In-situ leaching (ISL) is a mining process which causes minimal surface disturbance. Holes are drilled from the surface; once the mineral deposit is reached, a leaching solution is pumped into the whole to dissolve the minerals. The solution containing the minerals is then pumped to the surface, where the desired minerals are filtered out.

While ISL does not cause dust or airborne radiation pollution and does not disturb flora and fauna on the surface, it does require the treatment of substantial quantities of wastewater. Because the dissolving solution is highly acidic, it can also dissolve toxic and radioactive elements. The solution needs to be thoroughly treated before being released again in order to avoid contamination of the water table, or must be stored in tailings ponds.

Similar to ISL, **heap leaching** involves dissolving (leaching) valuable minerals from waste rock. However, the ore is first mined and piled on to a large area with a sealant underneath, to prevent leakage. While it avoids the dust release of the pulverising the rock, and potentially the risk of leaking directly into the water table that ISL has, the solution still needs to be properly treated and disposed of, and the heap leaching area itself must be properly sealed, with waste stored in tailings ponds or treated.

Different mineral concentrating and beneficiation processes, including smelting, electrowinning and floatation usually take place at or nearby the mine site and have significant environmental impacts. In order to separate the targeted material from the waste rock, ore is pulverized and mixed with water into a thick solution. Separating minerals and metals can involve introducing other environmentally harmful substances, such as arsenic. Once separated, the mixture of mixed waste rock and water is left in tailings ponds, which can be toxic and radioactive. If not properly stored, tailings can leak into the water table and surrounding environment.

A tailings failure may also result in uncontrolled spills of tailings, dangerous flow-slides and the release of hazardous substances, leading to major environmental catastrophes within and across borders. Pulverizing the ore creates dust, which leads to air pollution and can further release the aforementioned elements. In addition, tailings can dry out and the dust can be spread over tens of square kilometres due to strong winds, affecting human health and the environment in the surrounding areas.

Source: MIT (2012). “Environmental risks of mining.” Mission 2016: The future of strategic minerals.

Across the EECCA region, the mining sector’s impact on air, water and soil is evident. In Armenia, there are at least 15 active tailings ponds covering 700 hectares. There is little oversight of these ponds, and they are vulnerable to weather events and have significant potential to impact human health (World Bank, 2014[6]). Pure Earth, an NGO, organised a Toxic Site Identification Program in conjunction with the World Bank and other development partners that found that these sites were contaminating soil, groundwater and surface water with toxic metals such as cadmium, lead and arsenic. Toxins were found to be entering into ecosystems and affecting human health when contaminated water was used for irrigation or the tailings were used for local building materials (World Bank, 2014[6]).

Bioaccumulation, with toxins concentrating as they move up the food chain from water, to soil, to the plants that grow in it, to the people that eat them or use them for livestock feed, is a major issue with many heavy metals. A study of data from Armenia found that mercury from mining operations was detected in the hair of children living in impacted areas, as mercury polluted soil and water fed into crops and cows’ milk (Sahakyan, 2011[7]).

In Ukraine, one of the leading sources of wastewater discharges is the metallurgy industry, while mining and quarrying was responsible for 37% of industrial air pollution in 2004. Waste rock and mining tailings from ferrous metal mining operations have contributed significantly to acidification of local water and the leaching of heavy metals such as cadmium, arsenic, and lead. About 120 million tons of waste are generated annually from the mining sector (UNECE, 2007[8]). The past tailings accidents in Kalush (2005) and Nikolaiev (2011) demonstrate the urgent need for action to deactivate some of these “ticking time bombs”.

In Kazakhstan, the mining and metallurgical sector (excluding hydrocarbons) is one of the biggest polluters in the country, with different impacts depending on the metals mined and the associated geography. For example, one study estimated that by 2006, 21 billion tons of solid waste had accumulated from the mining sector, with an additional 1 billion tons added every year. Tailings ponds from polymetallic mining operations continue to leak into groundwater, while gold mining operations often still use cyanide in their processing (UNECE, 2008[9]). The negative environmental impact that an uncontrolled spill of hazardous substances from tailings facilities could create, have been demonstrated, not least, by the mining waste spill in Ridder in 2016 (The Siberian Times, 2016[10]).

1.2.2. Impacts on biodiversity and ecosystem integrity

Mining impacts biodiversity by destroying habitats in the immediate area of mining activity, by breaking up wildlife corridors through the construction of transportation infrastructure, by contaminating air, water and soil with toxins, and by changing the pH balance of water and soil, thus affecting flora and fauna that live in those habitats. Depending on the size and type of mine, as well as the controls taken to reduce impact, the loss of biodiversity may be local without broader impact.

The type of mining undertaken can affect how biodiversity is affected. Open-pit mining tends to have a greater impact on biodiversity, as the habitat in the immediate impact of the mine is destroyed or significantly disturbed. While underground mining, heap and in-situ leach mining do not necessarily cause as much surface damage, they can still have major negative effects on biodiversity through water, soil and air quality damage. That impact can also be difficult to predict; some studies have found that the pools created specifically by closed underground mines can create valuable habitats for certain species (Dolný and Harabiš, 2012[11]). This is in contrast to pools created at flooded open pit mines, which tend to be acidic and not supportive of life.

It is worth noting that compared to agriculture, mining can actually have a relatively controlled effect on biodiversity. Even with open pit mines, the area of land use tends to be smaller than agriculture. However, this does not account for the range of other indirect and direct means through which mining can impact ecosystem integrity and biodiversity (Rolfe, 2001[12]). The local effect on biodiversity in the immediate area around a mine can become more significant and widespread if there are numerous mine sites operating in the same area. Releases of mining waste into water, unplanned or planned, can massively expand the geographic impact on biodiversity. This is relevant for the countries in EECCA, as there are numerous mines that were developed under older mining regimes with more lax regulatory setups, as well as mines that continue to operate for socioeconomic reasons despite violating environmental regulation.

Box 1.2. Industry solutions to biodiversity concerns in mining

Major mining companies have shown a strong interest in trying to address threats to biodiversity from mining, both due to regulatory pressures and in order to ensure that they continue to have the social license to operate. The International Council of Mining and Metals (ICMM) collaborated with the International Union for Conservation of Nature (IUCN) to develop the *Good Practice Guidance for Mining and Biodiversity* (ICMM, 2006[7]) Approaches to addressing risks to biodiversity from mining projects emphasize:

- having a deep understanding of the ecosystem and the biodiversity that exists through baseline studies;

- the importance of addressing the situation before the mining process starts, and including specific considerations for biodiversity at the exploration, operations, and closure and rehabilitation stages;
- avoiding decisions that would damage the ecosystem and if the ecosystem will necessarily be impacted than minimizing the damage as much as possible;
- taking steps to repair damage to specific ecosystem features; and
- offsetting damage by investing in improving or protecting other areas if damage around a mine site cannot be avoided or restored.

Source: ICMM 2017, "Good Practice Guidance for Mining and Biodiversity", International Council of Mining and Metals (ICMM)

1.2.3. Mining, climate change and GHG emissions

Mining operations contribute to climate change through energy use in day-to-day operations, through the release of GHGs in smelting and other beneficiation processes, and through the destruction of carbon sinks, mainly in the form of forests. Although many mining companies are reducing their carbon footprint through more efficient use of fuel and other energy inputs, electrification of vehicles, and use of renewable energy, climate change adaption will also be a major issue (Odell, Bebbington and Frey, 2018[13]). With their remote locations, reliance on water sources, and exposure to severe weather phenomena, the mining sector has the potential to be significantly impacted by climate change.

In filings with the Carbon Disclosure Project from 2009, more than three quarters of responding mining companies noted climate change was a concern. Areas of concern included disturbance to mine infrastructure and projects, changing access to supply chains and distribution routes, worker health and safety conditions, environmental management and mitigation, community relations, and exploration and future growth (Nelson and Schuchard, 2010[14]).

While attribution of particular climatic events or weather shifts to climate change is difficult, major weather events, warmer or colder than normal temperatures, and droughts or floods are becoming more common. Weather events can have a major impact on mining operations. Despite the fact that these risks are acknowledged by mining companies, many are loath to take action because there are other more immediate costs (David Suzuki Foundation, 2009[15]). Asking a company to comply with a 1 in 500 years storm makes good policy, considering the disastrous environmental impacts that occur when a tailings dam is breached. However, climate change is a long-run threat for many operators, and their priority is complying with their regular environmental operating restrictions.

Box 3. Impact of climate conditions on mining operations

Climate change presents risks to the mining sector, both for those operating in remote areas and for mines that are grid connected and closer to population centres.

- **Increased frequency of extreme weather events:** Mines generally need to be prepared for a certain frequency extreme weather event – a once in fifty years storm, or a once in one hundred year storm. The risk of these events is manifold – high water levels can cause tailing dams to breach with catastrophic results. However, the storms that were considered 1 in 100 year storms now occur with much more regularity.
- **Transportation challenges related to extreme weather:** mines in remote areas in cold climates often rely on ice roads – a warming climate is already making those roads less reliable, and shortening the season of their operation. Other remote mines rely on air resupply, which faces a different set of difficulties: increased frequency of extreme weather makes flying that much more difficult.
- **Impact of rising temperatures on air quality:** rising temperatures and humidity levels contribute to reduced air quality through the retention of particulate matter. This is of particular issue in areas where mines are operating close to population centres. This can force mines to shut operations on a daily basis, to avoid exceeding pollution limits.

Source: (David Suzuki Foundation, 2009[15])

1.3. Sustainability trends in the mining sector

One of the oldest industries known to humans, mining has constantly evolved with new developments in technology. Its adaptation to environmental concerns has come more slowly. With operations most often occurring in remote or sparsely inhabited areas, access to information on environmental impact has historically been low unless an environmental catastrophe occurred. This is no longer the case. Today sustainability reports are *de rigueur* for the leading mining companies, and environmental concerns are increasingly at the forefront of discussions (Jenkins and Yakovleva, 2006[16]).

While environmental impact is intrinsic to mining, new driving factors including technology development, economic trends, and societal expectations have begun to shift the industry towards better environmental performance:

- Better awareness and understanding among the public about the environmental issues related to mining, including the danger from tailings dam disasters, and better information dissemination concerning environmentally impacts when they occur (Jenkins and Yakovleva, 2006[16]).
- Global concern about climate change and greenhouse gas emissions, influencing both mining operations as well as mineral fuels being mined (coal and bitumen) (Odell, Bebbington and Frey, 2018[13]).

- Increasingly stringent environmental regulation in jurisdictions like Canada, Australia and the UK that are home to globally active mining giants.
- International initiatives that force better standards across entire value chains, thereby providing a strong incentive for large publically listed multinational mining companies to ensure that down the line their suppliers and sub-contractors abide by the same environmental performance standards as the parent company espouses to its shareholders.
- Technology advancements that ensure better environmental performance, both through pollution management and control as well as optimizing operations to use less inputs and the shift to renewable energy.
- Increasing interest in circular economy considerations and waste reduction (OECD, 2019[17]).

Responding to these drivers, governments from resource producing companies are attempting to improve the environmental performance of the mining sector through a range of different policy and regulatory approaches.

This is a vitally important topic for the EECCA region, a vast geographic region with a diverse range of countries within it. Though mining varies in importance in the different countries from central to secondary in economic importance, it has a role in almost all the countries in the region. While exports are one measure, this does not reflect associated employment, taxes, and related industries, such as equipment production. For instance, Belarus, while not having a resource-oriented economy compared to Kazakhstan, is a key manufacturer of mining equipment. How the region addresses sustainability in the mining sector will be for both supporting economic development and improving environmental performance.

1.4. Mining in the EECCA region: centrality, challenges and opportunities

The mining sector currently plays an important role in most EECCA countries, contributing to export earnings, employment and economic growth. This is evident across a range of indicators. In the International Council of Mines and Metals' (ICMM)[3] 2016 Mining Contribution Index (MCI)[4], which measures the significance of the mining sector's contribution to national economies, three EECCA countries (Uzbekistan, Kyrgyzstan and Tajikistan) rank among the top ten globally, together with two others (Ukraine and Armenia) in the top twenty. In 2015, in the Kyrgyz Republic, Uzbekistan, and Armenia mineral rents constituted 7.5, 4.6 and 3.2% of GDP respectively. In the same year, ores and metal exports contributed 44.4, 15.6 and 12% of total merchandise exports in Armenia, Georgia and Kazakhstan.

Kazakhstan is the largest producer of uranium, the second largest producer of chromium, and a significant producer of many other metals. Belarus is the third largest exporter of potash. Armenia was the sixth largest world exporter of molybdenum in 2015. Tajikistan is the second largest producer of antimony and the third largest producer of mercury. Uzbekistan is a globally significant producer in many mining products, including gold, rhenium, titanium, kaolin, and others. Ukraine is a top producer of gallium, rutile, titanium, iron ore, among other things. Even Azerbaijan, whose exports are dominated by crude oil and natural gas, produces a range of minerals and metals including aluminium, iron ore, steel, bromine and iodine, while Turkmenistan is a leading producer of bromine and iodine (United States Geological Survey 2016).

Many EECCA countries also produce coal, both from open pit and underground mines. Kazakhstan is a coal exporter, while other countries such as Georgia produce it for domestic consumption. All EECCA countries also quarry building materials, which have some environmental impacts, though relatively smaller than most metals extraction.

Countries in the EECCA region are often divided into two groupings – the resource-rich ones (Azerbaijan, Kazakhstan, Turkmenistan, Ukraine and Uzbekistan) and those with lesser natural endowments (Armenia, Belarus, Georgia, Kyrgyz Republic, Moldova and Tajikistan). However, as Table 1 below illustrates, even in the countries that are not traditionally considered resource rich, mineral and metals still have an important role in their economies.

Table 1. Key export minerals and metals in EECCA countries

Country	Selected minerals and metals (as percentage of national exports)
Armenia	Copper ore (20), copper (4), ferroalloys (3.9), molybdenum (0.4),
Azerbaijan	Gold (0.6), aluminium (0.5)
Belarus	Potassic fertilizer (10), iron and steel (2.9)
Georgia	Copper ore (9.3), ferroalloys (7.3), gold (4.4)
Kazakhstan	Copper (6.2), uranium (5.1) , ferroalloys (3.4), zinc (1.5), chromium ore (0.35)
Kyrgyz Republic	Gold (42)
Moldova	Gypsum and aggregates (0.3)
Tajikistan	Aluminium (30), gold (17), lead ore (6.7), zinc ore (6.6)
Turkmenistan	Sulphur (1)
Ukraine	Iron and steel (21.2), iron ore (5.5)
Uzbekistan	Gold (32), copper (9)

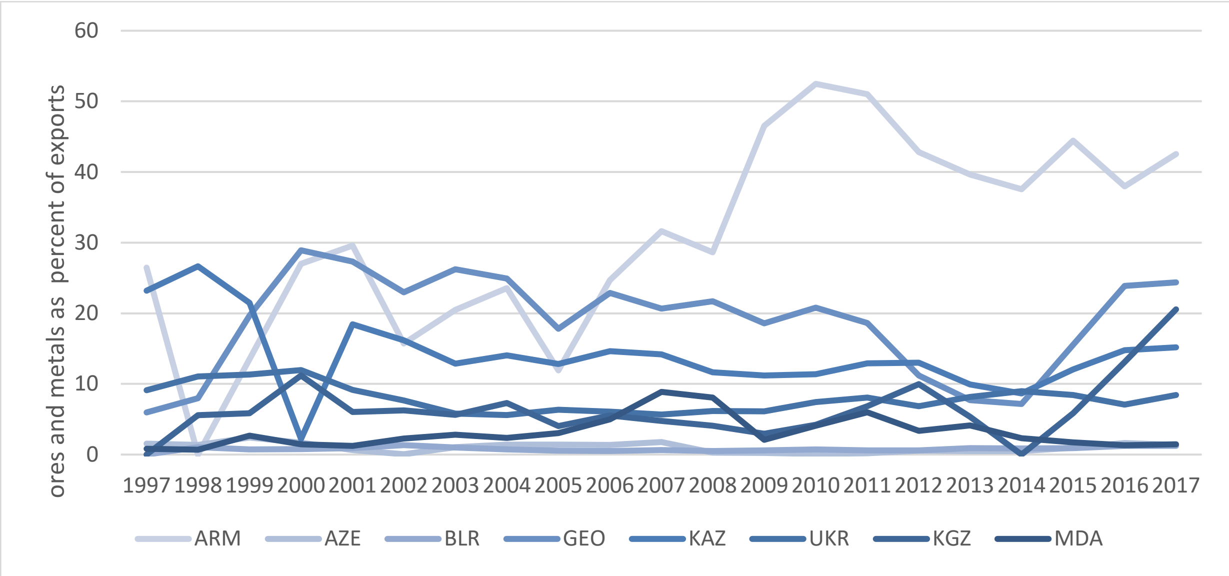
Source: UN Comtrade, Observatory of Economic Complexity, author's own calculations

As shown in Figures 2 and 3 below, mining accounts for an important share of GDP and products from the mining sector still make up substantial portions of most EECCA country exports. Strong growth in China and other emerging economies from 2000-2012 drove increased demand for almost all minerals and metals. Even while minerals and metals as a share of exports have remained relatively steady (Figure 1), increased commodity prices ensured that its importance to government revenue grew (Figure 2).

Beyond its contributions to export earnings and government revenue, the mining sector is also an important source of employment in many EECCA countries. In Kazakhstan, the mining and quarrying sector employees 277 000 people, amounting to approximately 3% of total employment (KAZ Stat 2017). In the Kyrgyz Republic, the Kumtor Mine is the largest private employer in the country, as well as the largest private sector purchaser of goods and services (Kumtor 2017). In 2014, employment in Armenia's mining sector accounted for 10% of total industrial employment (World Bank 2016). Even when the mining sector it not a significant employer on the national scale, mines are often located in rural and remote areas in which they are regionally important employers.

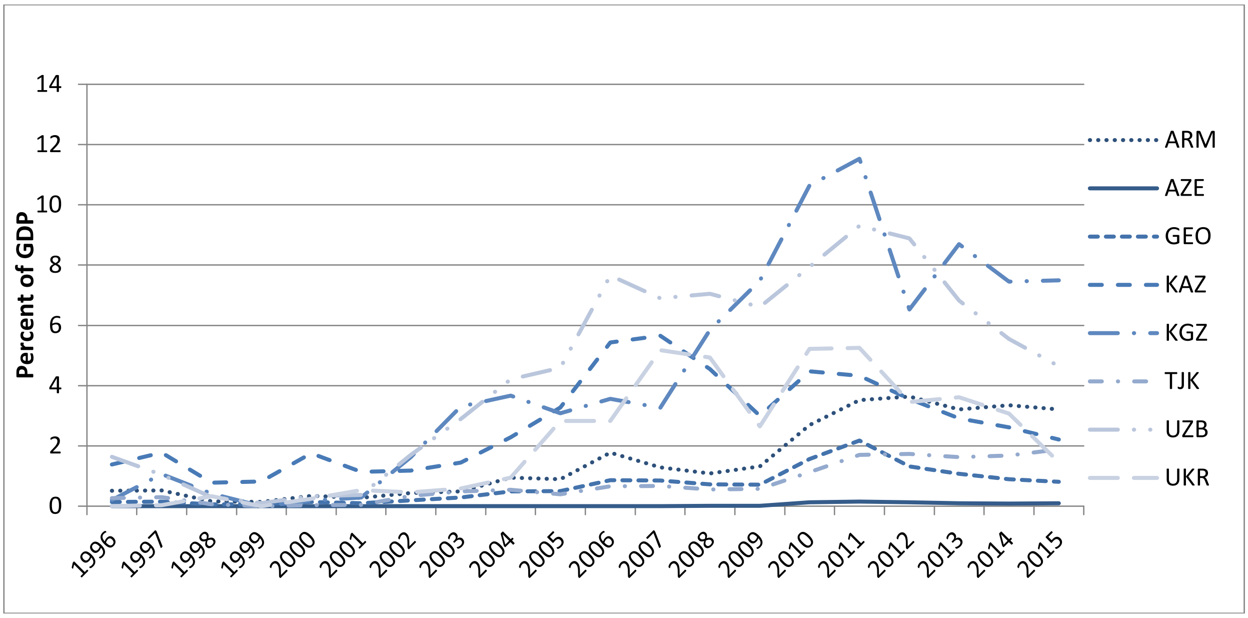
Direct employment from mines only captures one dimension of the overall impact, which in addition to royalty and tax revenue include goods and services purchased locally, the development of related industries, and horizontal linkages such as power and transportation infrastructure. In some cases, mines also support forward linkages to downstream industries as well.

Figure 2. Ores and metals as share merchandise exports for EECCA countries (1997-2017)



Note: (1) Uzbekistan and Tajikistan were not included due to insufficient data. (2) Merchandise exports refers to exports of goods only (excludes services) (3) Ores and metals comprise the commodities in Standard International Trade Classification (SITC) sections 27 (crude fertilizer, minerals); 28 (metalliferous ores, scrap); and 68 (non-ferrous metals).
Source: World Bank Development Indicators database

Figure 3. Mineral rents as percentage of GDP for selected EECCA countries (1996-2015)



Note: (1) Belarus, Moldova and Turkmenistan were not included due to insufficient data. (2) Mineral rents are the difference between the value of production for a stock of minerals at world prices and their total costs of production. Minerals included in the calculation are tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite, and phosphate.
Source: World Bank Development Indicators database

Almost all EECCA countries have unexploited resources which have not been tapped for various reasons, including unfavourable investment environments, insufficient exploration data, and poor electricity and transportation infrastructure. Governments in the region have expressed interest in supporting new mining development. For example, in Kazakhstan, the government has developed a new mining code drawing on the experiences of Australia and other OECD countries (Deloitte, 2018[18]), and has been working at attracting new investment (supported by the OECD, through the OECD-Kazakhstan Working Group on the Mining Competitiveness). Tajikistan's government has pledged to support the development of its minerals sector through a better permitting process, and the establishment of a Geological Information Centre (US International Trade Administration 2015). Armenia has seen strong growth in its mining sector in recent years, and became an Extractive Industries Transparency Initiative (EITI) member in 2017.

At the same time, the legacy of Soviet-era mining continues to pose a challenge, with aging mining facilities and equipment that is inefficient and environmentally polluting. Mining waste and tailings facilities are not constructed to modern standards, and many sites are abandoned and unmonitored, posing an ongoing environmental risk. One challenge of moving forward with the environmental performance of the mining sector in EECCA will be addressing this legacy.

1.5. Building on the foundations of ongoing OECD and GREEN Action Taskforce work

Against this backdrop of diverse drivers, countries in the EECCA region are attempting to shift towards greener economic growth, while also maintaining the extractive sector as an engine for jobs and revenue. This is true both in resource giants like Kazakhstan, in smaller countries like Armenia where mineral exports are a key source of revenue, and in countries like Tajikistan that have substantial resource potential but have not yet created the necessary conditions or frameworks to encourage significant new mine development.

Countries in the EECCA region are faced with both the ongoing legacy of environmentally damaging mining practices from the Soviet-era as well as the challenges of developing a modern approach to the mining sector that can minimise environmental and health impacts while maximising social and economic benefits. At the same time, many countries are eager for investment, and for the potential influx of both revenue and technology that new mining developments may bring.

The avenues to improve environmental performance in the mining sector are well known and documented by the literature, but considerably more complex to implement. Mining companies need to use processes that monitor and control pollution effectively, invest in processes and equipment that improve input efficiency and reduce emissions, and ensure the rehabilitation of environmental damage incurred during the mining process. The question is less about the what to do, than how companies can get there, and what governments can do to encourage this.

By examining the environmental impacts of the mining sector in the EECCA region, assessing what has worked and not worked in OECD member countries to improve environmental performance, and studying specific examples of successful sustainable mining operations, this report provides a foundation on which to develop country specific strategies for reconciling green growth and the mining sector.

This report, as part of a broader project on green growth and the mining sector, aims to both motivate and inform governments in the EECCA region as well as companies operating there. Today, looking at trends and new directions in the sector surfaces a strong push for going green. This is not only motivated by the need to reduce the negative impact of mining on the environment and local communities, but it increasingly becomes an asset of companies aiming to remain competitive in a fast changing sector. The report aims to provide policy makers in EECCA with guidance to reconcile environmental and competitiveness objectives in the mining sector. Through an in-depth review of environmental impacts and trends in the mining sector, the report complements the existing international knowledge and efforts in providing new evidences and best practices from leading mining jurisdictions.

This project has been developed in the context of the OECD's ongoing work on the mining sector, including the intersections of mining, economic growth and diversification, and the environment.

- The OECD's Mining competitiveness project in Kazakhstan, with a first phase that ran from 2014-2018, included specific work on how environmental payments in the mineral sector could improve environmental performance.[5]
- The OECD through the GREEN Action Taskforce is currently building on that start with a project on reforming environmental payments in Kazakhstan generally, supporting the development of a new environmental code.
- The OECD Policy Dialogue on Natural Resource-based Development, which brings together governments from resource-producing economies, major extractive enterprises, and civil society organisations, to discuss solutions to issues around extractive-driven economic development. Environmental issues are increasingly a component of that, including recent work on the role of renewable energy in the extractive sector.[6]
- The OECD's work on mining regions, which held its first meeting in Chile in 2017 and second meeting in Australia in 2018, focuses on economic diversification and improved regional development outcomes in mining intensive regions. It involves sub-national and national governments, as well as the private sector and civil society.[7]

1.6. Ongoing work at the international level is driving forward the discussion

At the international level, a number of the Agenda 2030 Sustainable Development Goals (SDG) are relevant. More specifically, there are a number of increasingly widely adopted international conventions that positively shape the mining sector towards better environmental performance. These conventions, of which many EECCA member countries are members of, provide tools, norms, and approaches that can already be adopted by countries. They also help establish international standards, and provide frameworks to work through transboundary environmental issues arising from mining.

The Sustainable Development Goals (SDGs) and Agenda 2030

The SDGs, adopted at the UN as part of the 2030 Agenda for Sustainable Development in 2015, are relevant to mining across a number of different areas. This provides an overarching framework for contextualising the need to improve the mining sector's overall environmental performance.

- SDG 6 relates to water pollution and the release of hazardous chemicals, the treatment of wastewater, and efficiency of water use.
- SDG 8 promotes inclusive and sustainable economic growth and employment.
- SDG 9 promotes the safe management of industrial installations to make them sustainable.
- SDG 12 aims to shift to more sustainable consumption and production patterns, structured over eight targets. This includes the use of natural resources and the integration of sustainable practices into the production processes.
- SDG 13 requires that countries and the international community take urgent action to strengthen resilience and combat climate change and its impact.
- SDG 14 (Life below water) and 15 (Life on land) are connected to mining's impact on biodiversity.
- SDG 16 ensures participatory decision-making by involving the public into discussions related to the siting, prevention and preparedness of hazardous activities.

This is against the backdrop of international agreements, conventions and frameworks that can support countries in undertaking better environmental performance in the mining sector while also standardizing approaches, helping to avoid competition among mining jurisdictions to increase their attractiveness for investment by lowering standards.

United Nations Framework Classification

The UNFC provides a unified way to sustainably manage mineral resources, as well as oil, gas, uranium, different forms of renewable energy, and anthropogenic resources (recycling). Vitally, anthropogenic resources focus on secondary resource use and recovery from mining wastes, tailings, and other already processed materials. Using visual representation, the UNFC provides a triple axel accounting system of socio-economic viability (including environmental impact), project feasibility, and geological knowledge level. Though not focussed exclusively on environmental impacts of mining, it provides governments with a holistic means to track projects and reserves through an internationally comparable system (UNECE, 2018[19]).

The Aarhus Convention

The UNECE Aarhus Convention on Access to Information, Public Participation in Decision Making and Access to Justice in Environmental Matters entered into force on 30 October 2001. National Parties to the Convention are required to ensure that they make the necessary provisions at the federal, sub-national, and local levels to ensure the public (both individuals and organisations) has:

- **access to environmental information** held by public authorities, both through specific requests for information with a maximum of one month following a request, as well as through the active dissemination on the part of public authorities;
- **the right to participate in environmental decision-making** on projects that are relevant to them, including plans, proposals, and projects that are likely to directly or indirectly impact the environment; and

- **access to justice** so that environmentally damaging actions can be challenged in court, and so that the justice system can be used as a means to enforce the first two rights listed.

Currently, most countries in the EECCA region are either full signatories or are party to the convention, with the exception of Uzbekistan (United Nations, 2018[20]), (UNECE, 1998[21]).

The Minamata Convention

The Minimata Convention on Mercury, which entered force in 2017 after being signed in 2013, aims to improve environmental protection from mercury. Although naturally occurring, various industrial processes including small-scale mining and mineral processing can release significant concentrations into the environment, with major ecosystem and human health impacts. The convention bans new mercury mines, and also addresses site remediation for areas contaminated with mercury. The Convention has 128 signatories, but does not include any of the five Central Asian countries from EECCA (UNEP, 2018[22]).

The Espoo Convention

The Espoo Convention on Environmental Impact Assessment in a Transboundary Context, entering force in 1991, obliges its signatories to conduct joint EIAs for projects that have the potential for transboundary environmental impacts. It counts Ukraine, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan and Armenia among its signatories, and has already been used as a framework for action in the region. In 2013-2014, the UNECE Secretariat to the Espoo Convention supported Ukraine and Belarus in doing a post-project analysis of an EIA for the Hotislavskoe project in Belarus. The chalk deposits are located 250 meters from the border with Ukraine, and resulted in the establishment of a bilateral working group to implement a joint monitoring programme. In another example, in 2007 a pilot EIA process was conducted between Kazakhstan and Kyrgyzstan, supported by the Organization for Security and Co-operation in Europe (OSCE) under the auspices of the Espoo Convention and in cooperation with NGOs, industry and the appropriate national government bodies in Kazakhstan and Kyrgyzstan (OSCE, 2009[23]).

Convention on the Transboundary Effects of Industrial Accidents

The Convention, originally adopted in 1992, came into force for 26 UNECE members and the European Union in 2000. It has now risen to encompass 41 Parties, including Armenia, Azerbaijan, Belarus, the Republic of Moldova and Kazakhstan. The Convention aims to reduce the frequency of industrial accidents, including those at tailings management facilities, and if they do happen, lower their severity and mitigate their effects, protecting both human health and environment (UNECE, 2016[24]). It includes both mining and mining waste. UNECE is currently undertaking two pilot projects to strengthen the safety of mining operations, in particular tailings management facilities (TMFs), in Kazakhstan (running from 2018-2019) as well as in Tajikistan and the broader Central Asia region (running from 2019-2020). Sponsored by the Swiss Federal Office for the Environment, the projects draw on UNECE's experience in improving tailing and mine waste facilities, including two previous projects focussed on Ukraine, as well as UNECE's Joint Expert Group on Water and Industrial Accidents (UNECE, 2017[25]). This group brings together industrial safety and water experts, and it is activated on an ad-hoc basis to support development and implementation of new guidelines that bridge disciplinary silos, in particular in EECCA and SEE countries.

UNECE's Environmental Policy Reviews

Within the region, the UNECE's series of Environmental Policy Reviews (EPRs) have regularly featured chapters on the mineral sector, with recommendations on how to improve environmental performance, at every stage of the development process (from exploration to site reclamation and mine waste management). Lessons from UNECE EPRs are incorporated into this report. This includes recent EPRs on Belarus, which looks at mining waste and extractive sector taxation (UNECE, 2016[26]), and Georgia, which includes pollution flows from mining, damage to soil in mining regions, water contamination, and mine waste amongst other topics (UNECE, 2016[27]).

2. The impact of technology on sustainability in the mining sector

This chapter explores how different technology trends are impacting the mining sector, providing the potential to improve efficiency and competitiveness while lowering the economic impact of mining activities. Topics addressed include automation, remote control, electrification, renewable energy, digitalisation and remote sensing. The impact of economic shifts towards electric vehicles, renewable energy and continuing economic digitalisation on metal demand is also discussed.

2.1. Introduction

Over thousands of years of history, the fundamental purpose of mining has remained the same: removing metals and minerals from the ground, and separating those that are desirable. However, while a miner from 3000 years ago would recognise the basic fact of digging into the ground to find the earth's riches, both the scale of mine sites and the technology used has changed dramatically. At the same time, new technological and economic developments also determine what metals are in the most demand, helping to shape the industry. Understanding the potential impact of new technologies is vital in moving to a more sustainable paradigm of mining.

For most of humanity's history, mining technology focused on maximising outputs of mined material and minimising the cost for doing so. This single-minded approach helped fuel economic growth and provide the raw materials needed to build new things. It also resulted in significant environmental contamination, with ecosystems often severely damaged, as well as largescale remaking of the environment, with massive open pit mines and enormous dams that reconfigured hydrological systems and not infrequently failed, sending toxic water back into the ecosystem. Considering that environmental impacts from mining operations from two millennia ago are still detectable today (Pyatt et al., 2000[28]), it is important that environmental issues continue to be part of the industry's focus.

Globally, over the past two decades increased scrutiny of environmental and social issues has led major mining companies to adopt sustainability plans (Jenkins and Yakovleva, 2006[29]). At the same time, new technology trends and economic developments are shaping the future of mining. The prolonged rise in prices for minerals and metals during the commodities super cycle fuelled mining company expansion; when prices crashed in 2014, companies were forced to adopt a greater focus on increasing efficiency and bringing down cost margins.

In the EECCA region, this pressure is acute. Countries in the region were particularly exposed to negative environmental impacts of mining, as the centrally planned economy of the Soviet era focused on production and had little in the way of functional environmental oversight. Once closed, mines were often simply abandoned with no efforts to remediate the environmental damage, leaving a hazard for people living in the area as well as the larger environment. Countries in the EECCA region are faced with both the ongoing legacy of environmentally damaging mining practices from the Soviet era as well as the challenges of developing a modern approach to the mining sector that can minimise environmental and health impacts while maximising social and economic benefits.

Greening the mining sector in the region is an opportunity to introduce innovative, environmentally sensitive practices that can positively affect other related areas of the economy. For countries with large mining sectors, this is vital, and even for countries where the mining sector is less dominant, it provides a channel to introduce clean technology.

2.2. How technology is impacting mining operations

Mines have long lives, and depend on reliability and predictability, both for production and for ensuring the health and safety of those working there. Because of this, mines have traditionally been conservative in deploying new technology. However, after a rapid expansion in operating and planned mines driven by sustained high prices in the commodities super cycle and ongoing strong demand from China, the sudden decline caused a renewed focus on efficient and lean operations. This is compounded by a general trend across the mining sector – as the richest and most easily accessible deposits have been mined, industry is increasingly going after lower ore concentration deposits and/or lower depth deposits.

At the same time, mining companies have faced demands for better environmental performance and transparency to achieve social license to operate. Resource companies have also begun to look at ways that they can improve efficiency and position the mining sector as a modern and forward-looking part of the transition to a more sustainable economy. The technologies discussed in this section are an exploration of that.

2.2.1. Automation

One of the most important trends in the mining sector is automation. The drivers for this are not primarily environmental – they are about productivity, health, and safety. Mining is a dirty and often dangerous business – the deployment of automated mining trucks and rigs means that fewer workers need to be directly exposed. At the same time, it also allows mines to function around the clock and maximise their use of inputs (Natural Resources Canada, 2016[30]). It also has the advantage of being able to be retrofitted in some cases onto existing equipment, rather than requiring investment in entirely new equipment. To date, major multinational mining companies like Rio Tinto have used particular mines as test cases for "mines of the future", but as more manufacturers get on board the technology is becoming more accessible.

Automated machinery follows stricter protocols than human operation, reducing unnecessary use – theoretically prolonging machine life and reducing operational emissions, and more efficiently using inputs. Automation takes a number of forms, with potential benefits that go beyond productivity to reduce environmental impact:

- Autonomous trucks: trucks with this technology rely on GPS, lidar, and sensor systems embedded in the mine structure to help navigate. They are able to operate almost continuously, aside from breaks for refuelling and maintenance. They benefit from longer vehicle lifespan, reduced fuel use, and reduce maintenance costs (Nebot, n.d.[31]). At Vale's Brucutu mine in Brazil, the company estimates that vehicle lifespan will increase by 15% and fuel consumption and maintenance costs will decrease by 10%, resulting in a lower carbon footprint (Vale, 2018[32]).
- Automated drilling and tunnel-boring systems: automating drilling and tunnel boring has safety benefits, by removing humans from a potentially dangerous position due to hazards such as rockfall, gas outbursts, and high temperatures underground. It also has environmental benefits; linked with advanced sensing technology, automated drilling and boring systems are able to more precisely target ore deposits underground, reducing wasted drilling time and maximizing outputs (Ranjith et al., 2017[33]).
- Automated site monitoring: Automation and remote sensing can potentially benefit environmental performance by ensuring that issues are caught before they become significant, or before they occur at all. This includes weakening of separation barriers for tailings areas as well as levels of emissions from mining and beneficiation itself (Wang, Yang and He, 2018[34]).
- Automated ventilation systems at underground mining sites: a major cost of underground mines is ventilation systems to the surface. This is vital to ensure that diesel fumes, gases, and smoke from blasting are cleared, temperatures are controlled, and mine operations are safe. Automated ventilation systems do not

operate continuously, and instead rely on a network of sensors to move air to where it is needed at any given time, saving significant amounts of energy – up to 40% (Natural Resources Canada, 2016[35])

- Autonomous long distance trains: mines are often located far from ports, population centres and industry. Transporting ore can be expensive, carbon intensive, and potentially hazardous. To alleviate costs and increase efficiency, Rio Tinto is in the process of automating its train systems in Australia's Pilbara region. The inaugural fully automated trip took place in July 2018. Automation provides more consistent speeds with less breaking and accelerating, better coordination between trains on the tracks, and eliminates the potential for driver fatigue (Rio Tinto, 2018[36]). However, it is worth noting that most mines do not have dedicated rail systems, and the reason this makes sense for Rio Tinto have to do with the scale of their Pilbara mining operations and the distance to port.

Automation has impacts beyond productivity gains and reduced environmental footprint. In many cases, it will change the employment structure, reducing local and low-skilled employment opportunities. While some new jobs will be created in terms of remote monitoring, there will be higher skill requirements. Even maintenance on automated vehicles will require new training and qualification (International Institute for Sustainable Development, 2016[37]). At the same time, mines are being built in increasingly remote locations, often with low or non-existent local populations. Increasing use of automation and remote control, requiring less direct employment, will reduce the need for large numbers of individuals to live around a mine. This will also reduce its environmental footprint (Nebot, n.d.[38]).

2.2.2. Electrification

Fossil fuel use at mining sites is a significant operational cost and source of both local particulate matter and air pollution as well the release of GHGs. At off-grid mining sites, diesel generators are normally used to power equipment. Shipping in fuel is expensive and carbon intensive. At mining operations that are connected to electricity grids, large trucks and mining rigs release substantial emissions, generally running on diesel.

Box 4. Goldcorp's all electric underground mine

In Ontario, Canada, Goldcorp's Borden mine is completely electrified. Operating deep underground, everything from the loading and hauling vehicles to personnel transportation to ventilation, drills and ore transportation is electrified. Although this carries a 25-30% premium on the cost of equipment, the savings over the long term are significant. Goldcorp expects savings of CAD 9 million annually in operational costs from lower diesel use. There will also be 70% reduction in GHG emissions. Advancements in battery technology have made this fully electrified mine possible (Susan Taylor, 2018[39]).

Mining equipment manufacturers and mining companies are increasingly experimenting with developing hybrid diesel/electric or full electric versions of mining trucks and machinery. The benefits of this are even more substantial in underground mines, where exhaust fumes pose a health and safety hazard and must be continuously ventilated. By relying on electric vehicles and machinery, the need for that ventilation is reduced.

Electric motors have significantly fewer parts than internal combustion motors, require less maintenance, do not create emissions, and are much quieter. However, the upfront cost can be significant. Beyond electrification of vehicles, electric equipment at underground mines hold significant benefits in terms of reduced ventilation requirements. However, to benefit fully mines need to be designed with electrification.

2.2.3. Renewable energy

Renewable energy is increasingly a viable option to provide energy for off-grid sites, particularly through hybrid diesel-renewable energy systems. Although there are not yet commercial scale solutions for battery technology that would provide the needed stability of supply for purely renewable energy, diesel systems mated with solar or wind provide reduced emissions and reduced cost with regard to trucking in diesel fuel to remote locations. There have been successful deployments of renewable/diesel hybrid systems in different contexts, including Canada and Australia, but in most cases they have benefited from government support for their development.

Box 5. The mining sector as a driver for on- and off-grid renewable energy

Globally, mining enterprises are taking advantage of renewable energy in order to cut emissions, cut fuel costs and increase reliability. Opportunities exist for both on-grid and off-grid mines. For on-grid mines in countries with expensive electricity, purchasing agreements with renewable energy companies can cut costs and drive the development of new renewable energy generation. Where mines are operating off-grid, renewable energy can reduce dependency on diesel and heavy fuel oil, cutting costs and increasing reliability.

On-grid renewable energy and mining in Chile

Copper mining is a major industry in Chile and it requires substantial amounts of energy. However, electricity rates in Chile are relatively high - over the past decade prices have doubled, hitting $100 per megawatt hour in August 2015, twice as much as in neighbouring copper producer Peru. While Peru has the advantage of domestic hydropower and natural gas reserves, Chile has had to rely on imported fuel for its power sector.

The confluence of high energy prices, declining costs for solar photovoltaic (PV) technology and wind turbines, and high wind levels as well as world-leading levels of solar irradiation in northern Atacama Desert have created rich potential for renewable energy in Chile for both industrial and consumer use. Although the north is relatively sparsely populated compared to the south, it is the centre of Chile's mining activity. This has driven more and more renewable power capacity to be built. Although in their current technology level renewables are not sufficient to entirely replace baseload generation capacity, they have capacity to augment existing power use and reduce the need for fossil fuels or added generation capacity. For instance, at a power procurement auction held by the Chilean government in October 2015, all 1,200 GWh of the available contracts went to wind and solar projects, outcompeting proposals for coal plants based on price alone.

Off grid renewable energy in Australia

Sandfire Resources NL's DeGrussa copper mine is located about 900 km north of Perth, in a remote area without access to the electricity grid. The mine was powered initially by an on-site 20 megawatt diesel generation station that requires substantial amounts of diesel fuel to be trucked to the site. In order to reduce the use of diesel fuel and lower both costs and emissions, Sandfire decided to employ the use of a large solar power generation (10.6 megawatts) and storage (6 megawatts) facility. It is one of the largest integrated off-grid solar and storage facility on a mining site in the world.

The project was commissioned in May 2016. The diesel generation is fully integrated with the hybrid plant. During the day, power is largely drawn from the solar panels, with the battery acting to make up for short term drops due to cloud cover. During this time, some percentage of the power is still supplied by the diesel power generators. During the night, the diesel generators provide full power. A possibility is envisaged that the battery will be used during night to help smooth fluctuations and support system reliability. In total, it will result in an offset of over 20% of the mine's annual diesel fuel use.

The project was supported by repayable finance from two Australian federal government agencies - ARENA, which provided almost AUD 21 million in a recoupable grant, and the Clean Energy Finance Corporation which provided AUD 15 million in debt finance. ARENA was able to fill the "risk gap" for financing faced by first of kind projects.

Source: OECD (2017), PD-NR Compendium of Practices, http://www.oecd.org/dev/policy-dialogue-on-natural-resource-compendium.htm

2.2.4. Digitalisation

Advances in digital technology have drastically changed the quality and quantity of data that mining companies have access to, and support the deployment of automation. Exploration companies can now rely on a range of different technologies to show them what is underneath the surface, to sample, and to make the decision on whether to develop a mine or not.

- Exploration: using remote sensing tools such as unmanned aerial vehicles (UAVs) and satellites, the ecological footprint of mining operations can be substantially reduced. (European Commission, 2018[40]).
- Site operation: the deployment of networked sensors, machinery, and devices, combined with imagery data from satellites and other sources, has provided mine operators with unprecedented data. Widespread use of sensor technology ensures that mining operations are better aware of what is happening, where. This includes monitoring emissions, tracking water and air quality, and minimizing energy use.
- Environmental impact: remote sensing technology, including drones, also holds significant benefits for ensuring good environmental outcomes following the closure of a mining site. Tailings and waste rock sites can remain toxic for decades or even centuries after; ensuring that releases from them are monitored and reacted to as quickly as possible is vital, especially in remote locations that make in-person examination difficult. Remote sensing allows for ecosystem monitoring of land and water impacts (Charou et al., 2010[41]).

Through the use of digital sensors, mining companies have vastly more data at their fingertips than ever before. This trove of data also enables and supports automation.

2.3. How new technology is driving demand for different minerals

As recently as a decade ago, much was being written about peak oil, and how in a time of rising prices and spiralling global demand, we were set to run out of fossil fuels. Instead, the world has seen accelerating developments in renewable energy and electrical vehicles (EVs) shift demand projections for raw materials. Some metals, such as copper, have always been important economically. Considering that a single EV can require upwards of a ton of copper, it will only become more so. This same demand pattern then extends to renewable energy installations, with wind turbines in particular requiring significant copper. Broadly, anything electronic will continue to require substantial amounts of copper, and as the world shifts away from a fossil fuel based economy, this will become ever more important. The same trends are also driving mining companies' interest in lithium – an essential ingredient in contemporary battery technology (McKinsey Global Institute, 2017[42]).

Over time, demands for certain minerals may shift again. Already there are researchers who argue that lithium-ion batteries have limitations in terms of how much they can be scaled up, and that a different technology will be needed in order to change renewable power generation into baseload generation. From an environmental perspective, it is vital that improved environmental performance for the mining sector be agnostic when it comes to the specific material being mined. Rare earth minerals, another key ingredient for many high tech devices, as well as cobalt, are often mined in ways that are fraught environmentally. As such, many of the most important supplying mines are in countries with more permissive environmental regimes (McKinsey Global Institute, 2017[42]). While government policies do not determine what minerals become in demand, it is vital that policies are flexible enough to respond to new technological developments.

3. Connecting the mining sector to the green economy

This chapter explores different areas where public policy can support better environmental performance in the mining sector, and build linkages to the green economy. This includes developing a whole of government approach and engaging a broad range of stakeholders. The chapter discusses regulatory approaches at different stages of the mining process, as well as the challenge of orphaned mines, and the potential to reprocess abandoned mines. It also looks at policies to support innovation and capacity building, as well as developing linkages to the circular economy. It concludes with a series of key recommendations.

3.1. Introduction

Effective environmental regulation is necessary but not a sufficient condition for improving the performance of active mines and for ensuring that closed as well as abandoned mine sites are properly monitored and rehabilitated. Many of the countries in the EECCA region have stringent environmental standards on paper but, due to inconsistent compliance assurance and non-compliance enforcement, do not have good environmental outcomes. The top-down, command and control approaches held over from the Soviet Union are difficult to enforce due to the wide number of pollutants covered and do not incentivise compliance or going beyond compliance due to low non-compliance penalties (OECD, 2017[43]).

Public policies can impact the environmental performance of mining companies in ways that go beyond regulatory decisions. This includes supporting and formalising collaborative efforts on innovation, linking the mining sector to other segments of the economy, developing policies that ensure information transparency and active stakeholder consultation, and building capacity to ensure that the skills exist to tackle new roles in the green economy.

The tools presented are starting points for developing these policies, providing a basis of discussion between policy makers, industry, and other stakeholders. The specific implementation of solutions is unique to each national context, and will vary based on national and subnational priorities. The broad range of different policies related to better environmental performance in the mining sector are presented here because, despite the fact that they are normally treated differently due to the different policy dimensions they target, they are linked with each other and reinforcing.

3.2. Government coordination and strategy

Governments need to have a coordinated approach to improving the environmental performance of the mining sector, as inevitably it will involve more than just a single ministry, and more than just a single layer of government.

Having a national strategy for the mining sector that clearly identifies goals helps governments coordinate their approach. In developing that strategy, engaging with a broad range of stakeholders – including civil society, different levels and branches of government, local communities, as well as the mining industry itself - provides legitimacy to the outcomes, and helps ensure that final product is actionable. Different goals – to attract investment while ensuring that new mines reduce their environmental footprint; to limit new mines and establish ecologically sensitive areas that are off-limits for development; to focus on cleaning up old contaminated sites – require different mixes of policies to achieve them.

A strategy resting at a supra-national level helps ensure continuity overtime, and reduces duplication and policies from different government branches that contradict each other. These principles are fundamental to the OECD concept of policy coherence for sustainable development (PCSD). The potential impact of mining on water supplies and quality, energy use, transportation infrastructure, and employment, as well as the broader environmental impact, mean that many different branches and levels of government may be involved – and integrated and coherent policies, supported by strong institutional mechanisms, are vital (OECD, 2018[44]). If mining activities are located close to the border or their impacts may be potentially felt in other countries (e.g. downstream water pollution), transboundary cooperation and coordination with regard to the risk assessment and management is also vitally important. The UNECE Industrial Accidents Convention is relevant in this regard, supporting countries, notably competent authorities and operators, in the prevention of, preparedness for and response to industrial accidents with potential transboundary effects.

3.3. Stakeholder engagement and transparency

Large-scale industrial projects have stakeholders beyond simply the project proponent and the regulator. With the construction of a mine, the stakes are exceptionally high. In a sense the resources constitute the wealth of the nation or community, as there is only one chance to develop a given deposit. Mines have environmental impacts, no matter how well executed, impacts that will be felt by the people living in the area as well as those further abroad, if the larger systems (hydrological or climate) are damaged. As with any audit or even with writing a paper, third parties can often bring insight, perspective and objectivity that may otherwise be missed.

The most successful mining jurisdictions in terms of environmental performance have processes that ensure broad stakeholder involvement, and resources and information to ensure that stakeholders can be informed participants in the approvals process for mines, as well as for ongoing operations and post-operations time periods.

Ensuring that companies go above and beyond the letter of the law requires that local communities have a voice. It can also be beneficial to mining operations, as people living in the area are often more sensitive to environmental changes that do not occur in the immediate vicinity of a mining site. Rather than being seen as an ignored factor or an obstacle to run roughshod over once official licensing processes have been followed, ensuring public participation should be central to environmental assessments and ongoing operations.

While modern communication technology means that this is often a factor whether companies want it to be or not, making it explicitly part of the environmental assessment process provides clarity to mining companies. Requiring public consultation as part of any Environmental Impact Assessment (EIA) or Strategic Environmental Assessment (SEA) process ensures that it happens. However, governments also need to ensure not just that stakeholder consultations occur but that the results are taken seriously and that concerns raised are addressed by project proponents. It is also vital that proponents – and regulators – are transparent about ongoing mining operations and closed mines, clearly informing the public about actual or potential environmental concerns.

The OECD is now developing an OECD Recommendation on Open Government, which aims to help the countries that will adhere to it to design and implement successful open government reforms by identifying a clear, actionable, evidence-based, and common framework for the governance of open government (OECD, 2017[45]).

The UNECE Aarhus Convention on Access to Information, Public Participation in Decision Making and Access to Justice in Environmental Matters (0) is also relevant. It pledges countries to make the necessary provisions at the national, regional and local level to ensure that the public have access to environmental information, access to justice around environmental issues, and the right to participate in environmental decision making processes.

3.4. Regulatory tools

How governments regulate the mining sector shape its environmental impact, its attractiveness to investors, its value to public coffers, and its acceptability to local communities. The Fraser Institute Survey of Mining Companies, an annual study of companies active in the mining sector including both major multinational giants and small junior exploration companies, found that public policy is a major determining factor for companies to invest. Respondents on average valued it at 40% of their investment decision – almost as important as the geology (Fraser Institute, 2017[46]). In conjunction with policy itself however, another important deciding factor in whether or not mining companies see a jurisdiction as favourable to investment, stability and predictability in the business climate (Wilkerson, 2010[47]).

Strong environmental protections are not a disincentive to investment. Jurisdictions that are consistently ranked as amongst the most attractive[8] in terms of policy environment for mining also have some of the most stringent environmental regulation (Fraser Institute, 2017[46]). In 2017, the top five jurisdictions in the Fraser Institute's annual survey of mining companies were Ireland, Finland, Saskatchewan, Sweden, and Nevada. This may be because international mining companies face significant scrutiny from regulators and the public, and either develop or adopt the newest technologies first, which tend to be more environmentally friendly. At the same time, companies based in less stringently regulated environments, such as countries in the EECCA region, may initially have difficulty transitioning to more stringent regulations (Hilson, 2000[48]). Even in developed economies, it might take years for industry to adapt to a new regulatory paradigm. For instance, when Canada enacted its Metal Mining Liquid Effluent Regulations in 1977, it took until 1994 to reach a 98% industry compliance rate (Hilson, 2000[48]).

Drawing on the Porter hypothesis (Porter and Linde, 1995[49]), well-designed environmental regulation can stimulate innovation, and potentially increase economic productivity as well. Over the past decades, that hypothesis has been tested frequently. While the latter "strong" conclusion (increase economic productivity) has lately begun to show evidence for validity, the former "weak" conclusion (stimulate innovation) is considered well established (Ambec et al., 2013[50]).

3.4.1. Exploration

In all major mining jurisdictions, proponents of mines need to get permits for their activities, sometimes including separate permits for exploration and mine operations. Depending on the regulatory structure, environmental impact assessments may be included as a precondition for the granting of the mining permit, or as a separate process.

Whether or not exploration activities result in mine construction, they can have a significant environmental impact. Exploration traditionally requires cutting survey lines through vegetation as well as constructing roads capable of transporting heavy machinery. It can have a substantive impact on ecosystems by destroying or otherwise disturbing them, and by breaking up contiguous areas, making it hard for animals to move around or have the necessary territory they need to live.

The requirements that governments put in place for new mining projects are where they can set the stage for the expectations for the project. However, because there remains enormous uncertainty about whether and how a mine will even be constructed at this point, most jurisdictions approach it as a separate matter with its own distinct environmental impact assessment process.

Environmental impact assessment processes for the exploration stage are vitally important. They should also require that companies consult with communities in the area, whether or not the land being assessed is controlled by them or they have legal veto on it. Making community consultation a requirement is also beneficial to mine proponents, as it can help ensure that there is some degree of social licence for the inevitable disturbance of the natural ecology. In this sense, environmental assessments have at least a dual purpose – they constitute a means for project proponents to demonstrate to regulators that they have properly assessed the risks associated with the project and have plans to mitigate them. They also provide a way for companies to convince the public of the same (Kokko et al., 2015[51]).

The junior companies that conduct most exploration tend to be, as their name suggests, smaller than the companies that actually build and operate mines. They do not necessarily have the resources or knowledge for thorough environmental or biodiversity assessments. Companies may need to rely on environmental consultants to support environmental assessments at the exploration phase.

Although environmental assessments at the exploration phase are typically less onerous than those for a full mine, they should still have requirements for mitigating environmental damage and rehabilitating any damage caused. In addition, even at this preliminary stage, environmental regulators need to assess whether or not the area is suitable for mining, and whether there are unacceptable threats to ecosystems or human health in the area. The exploration stage thus provides an initial point of entry for regulators to determine whether it is environmentally feasible to develop a mine there. As there are other factors that will not be determined during the exploration phase – what kind of mine would eventually be developed if an economically viable deposit is discovered, how large, what techniques, and detailed surveying of the water table and local geology, amongst others – the bar will be lower than for permitting the developing of the mine itself.

Box 3.1. NeXT – New Exploration Technologies

NeXT, an EU-funded multi-country project coordinated by Finland, focuses on supporting the development and adoption of new exploration technologies into the mining sector. It brings together partners from the research institutes, academia, service providers and industry. The project aims to develop new geological models, analysis techniques, and exploration technologies that are cost-effective, environmentally sensitive and socially acceptable. In addition to supporting the reduction of costs and exploration time, it also aims to enhance the participation of impacted stakeholders including civil society, supporting social license to operate for mining exploration. The project runs from 2018 until 2021, and covers the most significant metallogenetic belts in the EU.

Source: (European Commission, 2018[52])

As discussed in section 2.2.4, new remote sensing technology means that exploration companies typically have a better idea of where valuable deposits might be found before they need to do more environmentally invasive and expensive physical sampling. Governments can set out requirements for the use of remote sensing techniques through limits on environmental impacts for a given exploration permit, as well as as a Best Available Techniques (BAT) approach that lays out recommended practices and technologies to meet emission standards.

3.4.2. Mine approval and operation

Economic and environmental reasons may both factor into consideration in approving a mine. In every major mining jurisdiction, mines are considered on a case-by-case basis. The regulatory process governing the construction of new mines tends to be complex, because of the potential for environmental impact, as well as the wide variety of impacted stakeholders.

Environmental Impact Assessments (EIA) and Strategic Environmental Assessments (SEA) are the first entry point that governments have into whether or not a mine should be allowed to go ahead. Properly done, EIAs and SEAs serve multiple important purposes. They force companies to clearly identify the environmental risks for their mining project, and to illustrate the mitigation measures they will use during mining operations as well as after mine closure. In turn, they also can help the government provide regulatory clarity to mine proponents by clearly delineating the requirements. Crucially, assessment processes also allow governments to mandate consultations with impacted stakeholders, including communities likely to be impacted by the mine, as well as opening up mining proposals for scrutiny from interested stakeholders such as environmental organisations with expertise in the sector.

Box 3.2. Balancing economic benefits and environmental risks in the mining lifecycle

Mines provide valuable opportunities for public revenue and local employment. However, any given resource deposit can only be extracted once, so it should be done well, as it constitutes the collective wealth of the people living in a given country or area. If the mine proponent argues that environmental regulations make it economically unfeasible to develop the mine, than the time may not be right for the mine to be developed. Perhaps the technology needs to be advanced further until it is economical to do it in a way that does not engender significant environmental risks, prices for the commodity need to rise, or perhaps the area under consideration is simply too sensitive.

The other period to consider is the enormous length of time that stretches after a mine is closed. Much of the most significant environmental impacts from mining operations occur after mine closure, when monitoring and scrutiny weakens. If the geology raises the risk of acid rock drainage, the need for vigilance is severe and once it slips it is hard to turn back the clock. Determining this at the onset – rather than along the way – can help ensure that environmentally unsound projects, such as ones with a high propensity for acid rock leakage or damage to vulnerable ecosystems do not get built in the first place.

Once a mine has gone through an EIA process and been approved, the regulatory regime is what ensures that it stays within the guidelines and constraints established. This entails more than just setting the standards for compliance. There are two broad points to consider in this conception – what the underlying philosophy of the environmental regulatory system is, and how it functions. In the first case, there has been a shift over the past decades towards regulatory systems that focus on incentivising and encouraging compliance, rather than those that are structured to punish non-compliance. In many EECCA countries, regulation of the mining sector remains focussed on the latter.

In terms of functionality, the adoption of integrated permitting for proposed mine sites and environmental assessment approaches that harmonize different levels of government and reduce duplication supports better environmental performance. It also reduces the regulatory burden on governments.

Although different OECD jurisdictions regulate mining emissions in different ways, most focus on reducing ecosystem harm rather than on punishing non-compliance. At the same time, the polluter pays principle ensure that companies are responsible /and liable for the damage they cause to ecosystems. This approach can foster an environment that supports mining companies to go beyond the bare minimum requirements for compliance and excel, reducing their environmental footprint.

Permitting and ensuring environmental compliance

The requirements for permitting a mine vary widely by country, but conceptually they balance the same considerations – economic and environmental impacts of a mine. In a study comparing the environmental regimes governing mining in Sweden, Finland, the Russian Federation, Canada, and Australia, there was a significant diversity in approaches, stemming from the different governance structures of the countries (Söderholm et al., 2014[53]).

- The Russian Federation's approach has been based on a licensing regime, which requires proponents to conduct an EIA before a license is issued. The license obligated the licensee to follow specific environmental requirements, such as preventing the contamination of water sources through waste accumulation, as well as other technical requirements. Despite having more stringent technical and emission standards than other jurisdictions, enforcement was not necessarily consistent or effective (Söderholm et al., 2014[53]). As of 2018, the Russian Federation is currently transitioning to a system of integrated permits modelled on the EU's Industrial Emissions Directive (IED), while adding a BREF on the Best Available Techniques (BATs) for the mining sector. This establishes emission limit values.
- Sweden and Finland share similar mining regulatory regimes, shaped in part by their shared membership to the EU, in that both require environmental permits based on national legislation, an EIA, and general environmental requirements drawn from a BAT approach. In both countries, mining facilities are also impacted by EU BREFS for specific processes, even though there is no EU BREF for mining.
- Canada and Australia's governance of the mining sector is characterised by variation across different states and territories. In Australia, the federal government is only involved in specific cases triggered by national legislation like the Environmental Protection and Biodiversity Conservation Act. In Canada, the development of new mines is regulated at the provincial and federal level, with requirements for both provincial permitting as well as federal environmental impact assessments (Söderholm et al., 2014[53]).

Environmental permitting requirements that support the mining sector in becoming more environmentally innovative needs to be performance based, even if the limit values are drawn from analysis of the best available techniques. This helps drive innovation, as well as allowing flexibility in reaching targets (Bergquist et al., 2013[54]). Although governments need to set limits that reduce the environmental impact of mining, mine operators are generally best suited to know what technique or technology can ensure that they are in compliance.

The purpose of compliance assurance and non-compliance responses should be to ensure good environmental performance, rather than as a revenue generating tool. At the same time, compliance monitoring and enforcement is resource intensive and complex. Political considerations, as well as socio-economic ones, can also impact compliance enforcement, especially when a given mining facility is a vital local source of employment (OECD, 2009[55]).

Compliance activities should be risk-based, to prioritise resources, and should be transparent, to promote public knowledge of specific mining operations. They should aim to support non-compliant operations to become complaint, with the use of monetary penalties as a potential tool but not as the first resort. Support for compliance can also include technical advice and support on best available techniques to improve environmental performance in specific circumstances (OECD, 2009[55]). An important consideration is how long operators have to come into compliance with regulatory changes – longer compliance periods extend environmental damage, but allow more potential time for operators to innovate and come into compliance (Bergquist et al., 2013[54]).Thus, the focus of compliance assurance becomes better environmental outcomes, rather than punishing companies for non-compliance.

3.4.3. Mine closure, site rehabilitation and biodiversity offsets

Most major OECD mining jurisdictions include a requirement that mining companies restore a mine site to something approaching its original state, and that details are provided in a closure plan that are part of the initial permitting process. Traditionally, this was interpreted narrowly – stabilising the immediate mine site, and revegetating it (CSIRO, 2014[56]). More recently, site rehabilitation has evolved to focus on ecosystem restoration – restoring the interlinked relationships between flora and fauna that existed before the mining operation. Thus, top soil that is removed during mine construction is stored to be replaced on top once the site is closed. Native plant and tree species are seeded, and native animals are reintroduced.

Although this sounds ideal, it is exceptionally difficult to restore an ecosystem to be exactly as it was. Generally, ecosystems are the by-product of decades, centuries, or even millennia of environmental changes. The soil bacteria, funguses, and other organisms living in the top soil may not survive years or decades of storage. The geological material that is now beneath the topsoil may have changed the hydrological conditions. While the term "ecosystem" suggests something knowable, a whole made up of an assemblage of parts whose interactions are understood, the falsity of this is belied by the difficulty in recreating them.

In acknowledgement of that, mining companies are increasingly pursuing biodiversity "offsets" in addition to rehabilitation. Biodiversity offsets are an acknowledgement that ecosystem services and biodiversity will be damaged through the construction of a mine, and even after closure will not necessarily return. To offset that, project proponents will support conservation efforts in an equivalent ecosystem or area. This in turn is part of a broader movement towards "no net loss" or "net gain" approach to mining projects (Virah-Sawmy, Ebeling and Taplin, 2014[57]). Often, this involves protecting an equivalent amount of land from use, providing funding to a conversation organisation, or in some cases buying "offset credits" from an established market (UNDP, 2017[58]).

However, the use of offsets potentially creates moral hazard if mining companies no longer feel they need to properly rehabilitate the site, so it is vital that these requirements (for rehabilitation) remain. It also raises the questions of how we properly value ecosystems, what is considered an "equivalent" ecosystem, and whether it makes sense to permit the destruction of an ecosystem while protecting another ecosystem, which should potentially be protected anyway (Grinlinton, 2017[59]).

In some cases, in conjunction with offsets protecting an equivalent area, it may make sense to permit the development of novel ecosystems on a reclaimed mine site, rather than an exact reclamation. Developing a mine, whether surface or underground, changes the hydrology, geography and geology of the area. By the time a mine is closed, and assuming that the loss of the site has already been offset, rehabilitation can potentially be adapted to the new reality of the site. For instance, rather than filling in an open-pit mine with the removed overburden and trying to ineffectively recreate what was there, it may be possible to develop a new functional ecosystem (Doley and Audet, 2013[60]). With that said, these sorts of decisions must only be done through consultation with objective environmental experts.

Site rehabilitation can take decades before it is completed. Regardless of whether biodiversity offsets are established, environmental monitoring of closed sites must be regular and ongoing, with regular reporting by third party environmental services organisations to ensure that hazards are contained and that progress continues on reclamation.

In addition, during the mining process itself, new deposits are often discovered and greater knowledge gained of the geology of the area. Mine plans are modified, expanded, or sometimes reduced. All this means that the timeline and footprint of mining sites often change beyond what was initially envisioned, affecting the eventual site closure and site rehabilitation. Closure plans needed to be updated to reflect any changes in a mine's circumstances.

3.4.4. Orphaned mine sites

Most historic mining jurisdictions grapple with the legacy of orphaned mines – closed mines that no longer have an active entity who can be considered responsible for cleaning up the site. This is an issue for countries in the EECCA region, due to the legacy of Soviet-era development, compounded by the fact that most mines from that time were abandoned when no longer productive and were operated by state-owned enterprises. While liability passes to the state when the operator no longer exists, site rehabilitation is exorbitant and most governments do not have the funds to address it on that scale. For example, in Canada, estimate on the total number of abandoned sites are over 10 000. In northern Ontario alone, the Canadian Office of the Auditor General of Canada in 2002 estimated the cost of rehabilitation at CAD 555 million (Hogan and Tremblay, 2006[61]). In the US, the US Government Accountability Office (GAO) estimates that in the 12 western states and Alaska, there are at least 161 000 abandoned sites, of which 33 000 have contaminated the environment, with the US Environmental Protection Agency (EPA) spending a median of over USD 221 million a year on rehabilitation between 1998-2008 (US Government Accountability Office, 2011[62]).

One approach to this problem is to have present operators feed into an industry-wide fund that supports the rehabilitation of orphaned sites. In Alberta, Canada, companies operating in the oil and gas sector pay annual fees into a fund, with the annual contributions set by the regulator based on what the current liabilities are estimated to be. Variations of this have also been tried in other jurisdictions, including Western Australia, as well as across the United States, through the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), better known as the Superfund. However, this approach has been criticised as raising insufficient funds, as it is difficult to estimate total liabilities for abandoned mines. For instance, of 52 mining operations on federal land, the US Government Accountability Office (GAO) estimated that financial assurances provided by operators were USD 61 million short of what was required for reclamation.

Developing an approach to orphaned mine sites is best done through a collaborative process that shares the cost burden between public funds and industry. Because of the cost involved and the number of sites that need rehabilitation, efforts need to be prioritised through a risk-based approach that also prioritises transparency with impacted stakeholders, including civil society, as they can be valuable sources of information.

3.4.5. Reprocessing non-operational mine sites

One of the most direct applications of circular economy principles in the mining sector is the reprocessing of tailings and waste from old mining operations. This holds potential in the EECCA region, where there are significant numbers of abandoned mines where waste could be processed to recover metals, potentially creating jobs and improving environmental conditions. Reprocessing tailings can be profitable, and it also has the potential to leave an abandoned mine site in better environmental condition than it began.

However, as Box 3.3 shows below, government policies can also impact feasibility of these projects, and they may need to be treated differently from traditional mines. Reprocessing waste from non-operational mine sites in a sense straddles the line between a mining operation and a recycling operation. Governments may want to adopt a specific tax regime to mine waste reprocessing operations that incentivises investment by having more flexibility around royalty rates, to take into account the potential environmental benefits of cleaning up a hazardous site. This shift in how mining operations are defined is also relevant for the reprocessing of non-mining waste sites with significant metal, which can be integrated into commodity value chains (Knapp, 2016[63]).

Box 3.3. Mining waste – examples from Australia and Kazakhstan

Mount Morgan Mine, Australia

In Australia, the Mount Morgan mine in Central Queensland was initially operational from 1882-1982, with a brief closure. During that time, environmental controls were extremely weak, and reactive waste rock and tailings were dumped into a nearby river. There was extensive environmental damage, including acid rock seepage that resulted in dead fish as much as 40km downstream from the site.

In 1982, a tailings reprocessing operation was undertaken, but due to low commodity prices and technical difficulties with recovery, further environmental damage was caused and after 8 years operations were halted (Lèbre, Corder and Golev, 2017[64]). Following this, the mine became the responsibility of the government, which invested in measures such as new earthworks to prevent further leaking into the river but was unable to pay the full cost of site rehabilitation, which was estimated at AUD 450 million for a partial rehabilitation. Site maintenance costs alone for the government estimated at AUD 3 million per year (Terzon, 2018[65]).

In 2016, the company Carbine Resources completed a feasibility study to reprocess the waste at the Mount Morgan site. It determined that it would be economic to process the tailings for copper (in the form of copper sulphate), pyrite (in the form of iron pyrite concentrate), and gold bullion. The processing would also remove main acid forming materials in the tailings (in the form of sulphur) (Carbine Resources, 2018[66]).

However, in March 2018, Carbine Resources announced it could no longer continue with the project – due to a lower level of recoverable metal than initially anticipated, and changes in the exchange rate, returns were too marginal. This was further impacted by the project's classification as a mining operation, which would require paying royalties (Terzon, 2018[65]).

Central Asia Metals, Kazakhstan

In Kazakhstan, near the city of Balkhash, the Kounrad copper mine was operational from 1936 until 2005, leaving behind significant waste dumps containing recoverable copper. In 2007, Central Asian Metals PLC acquired an interest in the site, and by 2012 had constructed a solvent extraction – electrowinning (SX-EW) plant. The process produces copper cathode by using in-situ leaching to remove copper and other metals from the waste dump, before using a concentrating and electro winning process to make copper cathode, which is exported mostly to Turkey (Central Asian Metals, 2018[67]).

The mine has been profitable and has a low environmental impact, as it involves only reprocessing existing waste dumps. In 2016, the facility was further expanded, to continue extracting more copper. Although it is a publically traded company which has pursued the project based on market principles, Central Asia Metals' Kounrad operation also demonstrates the potential opportunities for a circular economy approach to abandoned mining sites in EECCA region countries (Central Asian Metals, 2018[67]).

3.5. Innovation and capacity building

Public policy can support technical development and technology domestication in a range of different ways. Directly, some mining jurisdictions such as Canada, Australia, and Norway have public research institutions focused on developing new technologies and approaches, contributing to better environmental performance of the mining sector. Some research is also done in collaboration with educational institutions (universities), as well as directly with mining companies themselves. At a more indirect level, policy can also support technical development and innovation in the mining sector by supporting access to finance, whether by developing low interest loans, research grants, or tax policies that reward spending on research and development.

3.5.1. Public sector-led support for innovation

The government can help fund, coordinate, and facilitate innovation and research in the mining sector with the same approaches that support innovation throughout the economy. At a direct level, governments can establish national research laboratories that work on developing new technologies that can be used by industry. Collaboratively, these institutions can also work with academia, other research institutes, and the private sector to develop and commercialise new technologies. Governments can also support innovation through providing access to finance for companies attempting to develop and commercialize new technology for the mining sector.

Box 3.4. Canada's approach to supporting innovation in the mining sector

Canada's Ministry of Natural Resources has a broad range of support programs for the mining sector. Through its Green Mining Innovation program, this includes support for:

- enhancing mine productivity,
- energy efficiency in mining,
- minimizing and managing mine waste, and
- managing water in the mining cycle.

Within each category there are other research programs, including improving automation and equipment, developing safer underground mines, electrifying mine sites, and improving water recycling. In all of these cases, the Ministry of Natural Resources' CanmetMINING laboratory is leading research in collaboration with mining companies, equipment supplies, and academia. This helps ensure that the research being conducted is directly relevant for industry needs, and encourages the development and deployment of new sustainable mining practices.

Source: Natural Resources Canada, 2018, https://www.nrcan.gc.ca/mining-materials/green-mining/18312

3.5.2. Facilitation of equipment upgrading

Public policy can facilitate mining companies to upgrade their equipment in order to improve their environmental performance. In part, this is simply the removal of barriers that disincentivise companies to improve their environmental performance beyond what is required by investing in more efficient and effective equipment. Import duties on new equipment that supports better environmental performance can be waived. Companies can gain tax credits by investing in new equipment that improves environmental performance, whether through efficiency gains or better pollution control. This is especially important in countries with high import duties on equipment.

3.5.3. Support for skills development and vocational training

Improving the environmental performance of the mining sector requires potentially new skills from both the public and private sector. Environmental regulators need to have the capacity and skills – as well as the numbers – to effectively regulate the sector. At the same time, mining companies need to be able to hire employees with the appropriate educational background, third-party environmental service providers need to have the human capacity to conduct assessments and monitor mine sites, and machinery and equipment companies need to be able to develop and construct new products. In order to effectively support innovation, research institutions also need to have capacity in house.

By supporting environmental education criteria for mining and engineering programmes, governments can help ensure that the curriculum being taught is reflective of new developments in the industry. At the same time, public funding for education can also help ensure that courses are being taught, and that they are accessible to students.

3.6. Developing linkages to other parts of the green economy

3.6.1. Environmental services

Any attempt to improve the sustainability of the mining sector depends in part on having environmental service providers who can assist in assessment, monitoring, and mine site rehabilitation, amongst other roles. As noted in section 3.5.3, public policies can support skills development and capacity building in this area by developing vocational training programmes. Meanwhile, environmental policies in the country and the region largely impact demand for environmental services; unlike traditional service sectors, such as finance, telecommunications or transportation, growth in demand for environmental services tends to be driven by more stringent environmental regulation (Adlung, n.d.[68]). Markets for environmental services are largely shaped by regulation and social pressure, rather than economic demand.

The benefits of developing an environmental services sector go beyond the mining sector, and potentially beyond the country itself. Any significant industrial project requires environmental impact assessments, ongoing monitoring, and potentially, ecosystem rehabilitation. Although some characteristics of environmental impact assessments rely on industry specific knowledge, much of it is transferable across sectors. The development of a capable environmental services sector can potentially help improve environmental performance across the board. On a regional basis, it also creates the potential for service exports.

3.6.2. Green infrastructure

In addition to their direct environmental footprint, mining projects in remote areas also require significant infrastructure to support their operations. This includes transportation infrastructure to move mine output to market and to import mine inputs, power generation (whether off-grid or grid connected), and water infrastructure to support mine development and mineral and metal beneficiation (OECD, 2016[69]).

The benefits of mine development can be enhanced by ensuring that infrastructure is constructed with environmental performance as well as shared usage considerations taken into account. Infrastructure should be subject to low-carbon and climate resiliency requirements, minimizing its environmental impact during construction while ensuring its long-term stability. At the same time, in regions that would benefit from infrastructure, such as those with weak transportation linkages, water processing, or power generation, mining projects can be harnessed as a mean to provide broader benefits, including industrial development and local procurement (OECD, 2016[69]).

3.7. The circular economy, mining, and waste as resources

The circular economy, a conceptual re-envisioning of economies from linear patters of material use (raw materials, production, use, and disposal) to one without waste (materials reused, repurposed or recycled at every economic stage) is gaining interest globally among governments, consumers and industry. Initially, the focus was on manufactured products, and transferring from ownership models to "goods as services". Mining was not featured prominently in the picture – some of the most influential models of the circular economy, such as that created by the Ellen MacArthur Foundation (EMF), has mining and beneficiation processes outside of the circular loop (Lèbre et al 2017, (Ellent MacArthur Foundation, 2014[70]). Perhaps in part because there is something that seems inherently like the antithesis of circular economy considerations about removing raw materials from the ground (Thimmiah, 2014[71]).

However, over the last few years mining has quickly caught up. Major business consultancies and mining industry associations have published analysis and position papers that frame the circular economy transition as an opportunity rather than a threat (World Economic Forum, 2014[72]) (ICMM, 2018[73])). The common themes that run through the analysis are:

- Metal is infinitely recyclable, and recycling can be significantly more cost effective than mining new metal. Some analyses are now referring to the "urban mine" of industrial appliances and electronics that can be recycled and processed.
- Tailings sites from older mining facilities may contain metals due to inefficient or uneconomic extraction techniques during their initial processing; technology developments, higher mineral prices or policy incentives may now make them economic.
- The increased ability to track metal and mineral commodities from their point of origin enables the potential for new business models, where mining companies stay responsible for the processing and recycling of the metals they sell.
- Integrated business models where mining companies act more like commodities companies – focussing on selling metals from both their own recycling facilities as well as mines.

Different analysis – coming from disparate sources that include national governments, industry associations, management consultancy firms and environmental NGOs – have different takes on how significant the impact will be. However attractive the idea of a zero-waste society is, it is highly likely that for the foreseeable future there will still be a market and demand for virgin resources. However, circular economy principles at the level of the economy can, when supported by public policy and consumer buy-in, support new models for how the extractive industry fits into the global economy.

At the firm- or mine-level, circular economy principles can also help drive much more efficient operations. Inputs can be reused as much as possible on site, in some cases practically infinitely, and waste from beneficiation and metallurgic processes can be reused or repurposed. For large vertically integrated firms, recycling may already be part of their business model. For example, Mitsubishi Materials has adopted circular economy concepts across the range of different firms within its group. That includes a recycling focussed approach that combines new commodities with metal recovered from home appliances, aluminium cans, metal processing plants, and non-ferrous smelters, with the waste material sent to cement plants as inputs for cement. Mitsubishi's smelting plants then use clinker dust waste from cement creation as inputs in the smelting process (Mitsubishi Materials, 2018[74]).

At the operational level, circular economy principles can also have a powerful impact. Non-operational mines can represent enormous environmental risk factors. At the same time, they can often contain substantial amounts of valuable metals within waste rock and tailings that can be reprocessed using modern techniques. Public policy can play a role in supporting these developments. Circular economy principles can have broadly beneficial impacts on the environmental impact of mining by reducing or eliminating waste, and reducing the need to new mines to be developed in the first place.

3.8. Key recommendations

Successful OECD jurisdictions demonstrate a confluence of policies that together incentivise, support and regulate mining companies to adopt greener technologies, improve the efficiencies of their processes, and reduce their environmental impact.

- **Implement comprehensive, clear, and consistently enforced regulation.** This includes the environmental assessment process, as well as regulation and enforcement during operations. The regulatory system should be aimed at promoting good environmental management and preventing environmental harm, rather than at punishing transgressors. The ultimate goal should be compliance with the regulations, or even going beyond, not generating revenue through penalties and taxes. This also means that the regulatory framework needs to extend beyond the life of the mine, to ensure that waste dumps and tailings are properly managed and land affected by the mining operations rehabilitated.
- **Support innovation and environmental performance in the mining sector through the funding of sector-specific and applied research.** In mining intensive regions, governments should develop innovation plans specifically targeted at the sector, independently or as part of national innovation policies. This helps facilitate collaboration between government researchers, universities, institutions, and the private sector. Government can also assist with financing to commercialise innovations.
- **Build human capacity through education, training and work experience.** Although mining companies conduct their own in-house training, ensuring that environmental concerns, solutions and new technologies are part of the curriculum in mining-related engineering and vocational programs is an enabling factor for better environmental performance. It also helps ensure that there are skills available for third parties to provide environmental services to mining companies and potentially certify performance to the government or be employed directly by the regulating agency.
- **Develop policies to address abandoned and orphaned mine sites.** Legislation that ensures mine sites are monitored and rehabilitated is a relatively recent development, emerging in step with the growing recognition of environmental destruction in the latter half of the 20th century. This leaves significant numbers of mine sites that have been abandoned, with no party clearly responsible for their rehabilitation. If the operating company still exists, there can be legislation in place to oblige them to cover it. However, if, as in many cases, the mines were created under entirely different economic systems or the company no longer exists, the government needs to have an approach to orphaned mine sites. Approaches include setting aside funds by operators to cover post mining activities, environmental liability insurance, environmental payments, or earmarked royalties.
- **Ensure that mine operators are able to implement and if necessary import more efficient and environmentally sensitive equipment.** Governments need to ensure that companies are encouraged to access and uptake new technology, and remove barriers to importing it. This may include tax structures that incentivise the purchase of new equipment or import duty exceptions on new equipment that meets environmental criteria.

- **Raise awareness about the mining industry's need to put safety and environmental sustainability first and to ensure a zero-failure objective to tailings management facilities.** Governments can facilitate this in part by requiring mine operators to regularly update and publish disaster management plans, mandate third party monitoring of mine and mine waste sites, requiring financial securities for the life of the mine, and requiring transparent sharing of information with potentially impacted stakeholders.

- **Facilitate broad stakeholder participation in support of good environmental performance from mining operations.** Regulations governing the establishment, operation and closure of mines can require that all stakeholders are included in the process. Industry associations are valuable sources of information, and can help legitimise and communicate new policy developments to firms. Informing the public (both locally and broadly) about new and potentially high-impact industrial development and allowing their concerns to be raised and addressed by the operator facilitates the involvement of environmental groups and other civil society organisations in environmental assessment processes as well as compliance exercises.

- **International conventions and agreements provide valuable conduits for standards, coordination and information.** From transboundary pollution to industrial incidents to general good practices, there is a broad array of international conventions, agreements and support efforts by organisations including UNECE and UNEP that establish standards and frameworks for improving environmental performance in the mining sector. The legislation of common European standards, for instance for machinery operating within hazardous underground atmospheres, for energy efficiency, or dust management, are also valuable benchmarks.

- **Whole of government, coordinated approach to improving environmental performance in the mining sector.** Regulatory responsibility for a mining project may be shared over multiple agencies, depending on the pollutants, the stage of the project, and the medium. Responsibility may also fall under different levels of government, with different aspects shared between local, sub-national, and national governments, introducing challenges for governance and fiscal arrangements. Ensuring multi-level coordination between those actors and minimizing duplication helps improve clarity and efficiency with regard to communicating with operators. It also helps ensure that operators have social license to operate.

- **Support the development of a market for third-party green service providers in the mining sector, including accreditation processes.** Improving the environmental performance of the mining sector can be a catalyst for bringing green service providers into a country. Governments can support this through access to capacity building programs for independent consultants and support for vocational training. Policies should include accreditation for domestic and foreign green consultancy services, to encourage market entrants and provide confidence to mining companies.

- **Quick wins should be prioritised, but depend on specific country context.** On an ongoing basis, the public sector, in collaboration with industry and civil society stakeholders, should work to diagnose the barriers and enabling factors for enhancing environmental performance in the sector in order to prioritise areas of action.

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[1] In the International Council of Mines and Metals' (ICMM) 2016 Mining Contribution Index (MCI), which measures the significance of the mining sector's contribution to national economies, three EECCA countries (Uzbekistan, Kyrgyzstan and Tajikistan) rank among the top ten globally, together with two others (Ukraine and Armenia) in the top twenty. In 2015, in the Kyrgyz Republic, Uzbekistan, and Armenia mineral rents constituted 7.5, 4.6 and 3.2% of GDP respectively. In the same year, ores and metal exports contributed 44.4, 15.6 and 12% of total merchandise exports in Armenia, Georgia and Kazakhstan.

[2] Although this report does not deal with the mining of hydrocarbons, fugitive gas (CH_4) from open coal mines is also a GHG contributor.

[3] ICMM is a mining and minerals industry association that includes the world's largest mining companies and associations among its 23 members.

[4] The MCI is included in the publication *the Role of Mining in National Economies*. The MCI is scored based on a composite of four different indicators: the total contribution of mining to export earnings, the change in export earnings in the preceding five years, the value of mineral production as a percentage of GDP, and mineral rents as a percentage of GDP. Available at: https://www.icmm.com/website/publications/pdfs/society-and-the-economy/161026_icmm_romine-supplement_third-edition.pdf.

[5] http://www.oecd.org/env/outreach/sustainablemininginkazakhstan.htm.

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[7] http://www.oecd.org/cfe/regional-policy/mining-regions.htm.

[8] Factors considered in the Fraser survey for policy attractiveness include "current regulations, environmental regulations, regulatory duplication, the legal system and taxation regime, uncertainty concerning protected areas and disputed land claims, infrastructure, socioeconomic and community development conditions, trade barriers, political stability, labor regulations, quality of the geological database, security, and labor and skills availability." ((Fraser Institute, 2017[46])

MINING AND GREEN GROWTH IN THE EECCA REGION

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BETTER POLICIES FOR BETTER LIVES

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