MINING AND THE GREEN ENERGY TRANSITION

REVIEW OF INTERNATIONAL DEVELOPMENT CHALLENGES AND OPPORTUNITIES

NOVEMBER 2021

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ACRONYMS AND ABBREVIATIONS

2DS	Two-degree (global warming) scenario
3TG	Tantalum, tin, tungsten, and gold
AMPR	Artisanal Mining and Property Rights
ASM	Artisanal and Small-Scale Mining
ASX	Australian Securities Exchange
BRI	Belt and Road Initiative
CAHRA	Conflict-Affected and High-Risk Area
CCCMC	China Chamber of Commerce of Metals, Minerals and Chemicals Importers & Exporters
CIGS	Copper Indium Gallium Selenide Solar Cell
CRIRSCO	Committee for Mineral Reserves International Reporting Standards
CSO	Civil Society Organization
DOL	United States Department of Labor
DRC	Democratic Republic of the Congo
EITI	Extractive Industries Transparency Initiative
ERG	Eurasian Resources Group
ERGI	Energy Resource Governance Initiative
ESG	Environmental, Social, Governance
ESIA	Environmental and Social Impact Assessment
EU	European Union
EV	Electric Vehicle
FATF	Financial Action Task Force
FIU	Financial Intelligence Unit
GDA	Global Development Alliance
GDP	Gross Domestic Product
GHG	Greenhouse Gas
HDI	Human Development Index
ICMM	International Council on Mining and Metals
IEA	International Energy Agency
IGF	Intergovernmental Forum on Mining, Metals, and Sustainable Development

ILO	International Labour Organization
IPO	Initial Public Offering
IRENA	International Renewable Energy Agency
LCP	Local Content Policy
LME	London Metals Exchange
LRG	Land and Resource Governance
LSM	Large-Scale Mining
NGO	Nongovernmental Organization
NMC	Nickel-Manganese-Cobalt
NRGI	Natural Resource Governance Index
NYSE	New York Stock Exchange
OECD	Organization for Economic Cooperation and Development
OGP	Open Government Partnership
OHS	Occupational Health and Safety
PPA-RMT	Public Private Alliance for Responsible Minerals Trade
PRADD	Property Rights and Artisanal Diamond Development
PV	Photovoltaic
REE	Rare Earth Elements
SDG	Sustainable Development Goal
SEC	United States Securities and Exchange Commission
UK	United Kingdom
USAID	United States Agency for International Development
USG	United States Government
USGS	United States Geological Survey

EXECUTIVE SUMMARY

In order to meet the 2015 Paris Agreement goal of keeping global warming below two degrees Celsius, the world's energy systems need shift their reliance from fossil fuels to alternate energy sources. The technological solutions from photovoltaic cells to lithium-ion batteries, known colloquially as green energy, may be less fuel intensive, but they are more material intensive than non-renewable technologies. The growing global demand for green energy and the critical raw materials that fuel its production, including minerals, will significantly impact the environment, social and economic structures, and livelihoods of people around the world. Recent global studies (Drexhage et al., 2017; Hund et al., 2020; IEA, 2021) predict demand increases of up to ten times current production levels for minerals like cobalt, graphite, and lithium. No matter the mix of alternate energy sources the world turns to, the mining sector will be a key player in the years ahead.

The projected increase in mineral demand from green energy is already influencing commodity markets, supply chains, and geopolitics. Unlike raw materials needed for fossil-fuel source energy, minerals needed for green energy technologies are diverse and dispersed widely: over two dozen minerals are mined across more than 100 countries. The potential for an international mining boom is already sparking concern among development experts. While it could foster growth and employment benefitting millions, more mining also carries significant environmental, governance, national security, human rights, and social risks. Failure to address these risks could lead to increased fragility, poverty, and conflict in many developing countries. That, in turn, could create bottlenecks that affect global mineral supply, create market uncertainty, slow the global clean energy transition (IEA, 2021, p. 192) and ultimately jeopardize important the national security goals of the United States (US) and its allies.

Just as fossil fuels have been the backbone of global energy needs for over a century, several dozen minerals will make possible the green technologies of tomorrow's energy systems. Addressing the development challenges associated with mining is vital for a low-carbon future.

This report reviews the challenges and opportunities for donors such as USAID to engage in the mining sector in developing countries as it relates to the green energy transition. Although 29 minerals were identified as playing a current or potential role in green energy technologies, this study reviewed 16 mined in USAID-presence countries that are projected to be particularly important, including 9 that are on the 2018 US Critical Minerals list. The table below presents the reviewed minerals based on a demand risk matrix produced by the World Bank. The matrix classifies minerals based on absolute and relative demand increase projections under a two-degree warming scenario, as well as their crosscutting nature, defined as the extent to which the minerals are used in multiple green energy technologies (Hund et al., 2020, p. 77).

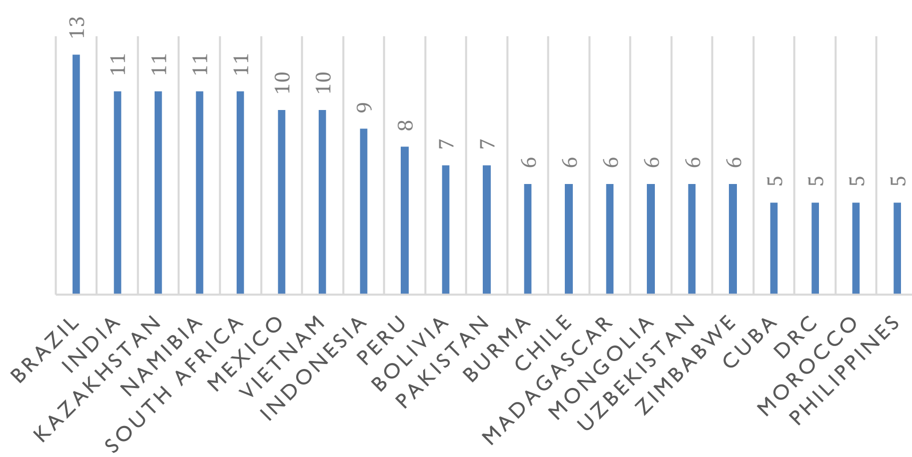
Table ES-1. Classification of minerals by impact and importance

	Definition	Reviewed Minerals
High-impact minerals	These minerals are critical to major green energy technologies, notably batteries used in electric cars and to store energy produced by wind, solar, and other sources. Demand for these minerals is set to increase the most dramatically compared to today's production levels. Because of this surge, they are more vulnerable to price volatility and supply shocks that could spur efforts to find substitutes.	*Cobalt** *Graphite** *Lithium** *Aluminum**

	Definition	Reviewed Minerals
Medium-impact minerals	These minerals are important for specific green energy technologies like wind turbine permanent magnets. In some cases, there are more substitution options compared to high-impact minerals, and overall demand is linked to more industries outside of green technology. For these reasons, demand risk is medium.	*Rare Earth Elements** *Silver* *Titanium** *Vanadium**
Cross-cutting minerals	These minerals are used in numerous green energy technologies. Green energy demand will lead to large absolute increases in demand, but lower relative increases as green energy is just part of overall demand. These roles don't have substitutes on the market so their uses in green energy technology are set. Aluminum is a special case because it is cross-cutting and multi-industry but also high-impact because of the significant quantities required for green energy technology by mid-century.	*Aluminum** *Chromium** *Copper* *Iron* *Molybdenum* *Lead* *Manganese** *Nickel*** *Zinc***
* 2018 US Critical Mineral; ** Recommended by US Geological Survey to add to US Critical Mineral List		

The report found that at least 70 USAID-presence or limited-presence countries mine at least one of these minerals. USAID-presence countries producing the largest number of reviewed minerals are **Brazil** (13), **South Africa** (11), **Namibia** (11), **Kazakhstan** (11), **India** (11), **Vietnam** (10), **Mexico** (10), **Indonesia** (9), and **Peru** (8).

Figure ES-1. USAID-presence countries with most green energy minerals



In addition, USAID-presence countries are among the top three global producers for certain minerals:

Table ES-2. USAID-Presence countries that are top-three producers of certain green energy minerals

Brazil	*Graphite, iron ore*	**Kazakhstan**	*Chromium*
Chile[1]	*Copper, lithium, molybdenum*	**Mexico**	*Silver*
DRC	*Cobalt*	**Mozambique**	*Graphite*
Gabon	*Manganese*	**Peru**	*Copper, silver, zinc*
Guinea	*Aluminum*	**Philippines**	*Nickel*
Indonesia	*Nickel*	**South Africa**	*Chromium, manganese, titanium*

How the mining sector evolves in each unique country context is difficult to predict and depends not just on new demand from green energy technologies, but also complex dynamics in the mining industry

1 Limited-presence country.

and material supply chains. This report delves into some of the classic factors that affect mining project development such as expected prices, logistics, and political risk. This report also summarizes emerging dynamics in the mining industry. These include geopolitics and the likelihood of a new resource scramble, resource hype, and an evolving reality around a commodity "super cycle." Some of these trends include supply chain vertical integration, fragmentation, and the growing importance of smaller players including junior companies and artisanal and small-scale miners (ASM), and increasing pressure to adopt corporate governance and responsible sourcing guidelines on both mining companies and supply chain actors.

For each of the 16 minerals, this report summarizes key information and data in fact sheets (Annex 1) to help development practitioners understand their use, importance, demand projections, and key information on where they are mined and known development challenges. Throughout this review, several observations stand out:

- **Latin America will be the center of attention for many minerals.** The Andean highlands in particular concentrate much of the world's copper and lithium potential. Importantly for USAID, Brazil, Chile, Peru, and Bolivia will be "hot" markets for mining, but environmental impacts such as the water-intensive nature of lithium mining and risks of tailing dam failings may increase opposition from the public concerned with environmental and social impacts. These countries will face challenges mediating contentious interests and political pressures around current mining and future mine development.
- **In Africa, the Democratic Republic of the Congo (DRC) is already experiencing negative impacts from the demand for green energy minerals.** This trend is due to corruption and the use of child and forced labor in the copper-cobalt sector in the country's south. Addressing the issues associated with the copper-cobalt supply chains should be as much of a priority as addressing conflict minerals in the east. However, when it comes to green energy minerals, South Africa, Guinea, and Mozambique merit attention. Indeed, besides cobalt, the DRC will be less important for other minerals critical for green energy.
- **China will play an outsized role.** While this report does not focus on China, its outsized role is apparent in USAID-presence countries. These countries receive investments and increasingly involve China-based midstream and downstream actors, like smelters, who collaborate with state-backed mining and commodity companies. Besides cobalt in the DRC, this review highlights Chinese investments in manganese in Ghana, bauxite in Guinea, iron in Congo-Brazzaville and Sierra Leone, nickel and rare earth elements in Burma, and chromium in Cuba (to name a few). Improving governance—including advancing international norms regarding environmental protection, human rights, fair trade, and countering corruption and criminal activity—will need to take into account the challenges posed by Chinese influence and how Chinese mining and trading operations function.
- **Large scale industrial mines are associated with the most severe environmental and social issues.** Conflicts with communities and issues around land rights and water management and pollution are some of the most recurrent issues in large-scale mining (LSM) contexts. Governance challenges such as corruption, conflict, and human rights abuses are associated with many of the reviewed minerals, from opaque offshore companies controlled by oligarchs to poor mineral policies. These connections underscore the importance for donors to shift their focus beyond ASM. Notable exceptions include copper-cobalt in the DRC and chromite in Zimbabwe and South Africa where significant ASM occurs.
- **Even if a USAID-presence country is not a top producer or mineral reserve-holder, the impact of mining in that particular national context can be dramatic**. It is therefore important to address mining governance challenges in the smaller and emerging mining countries like Madagascar that are particularly vulnerable in the face of speculation and soaring demand.

Over the past 15 years, USAID has funded several mining-focused activities on topics like ASM formalization, conflict minerals, criminal mining, and livelihood diversification in mining communities. USAID has also supported Extractive Industry Transparency Initiative (EITI) implementation around the world. In addition, mining has been indirectly addressed in other sectorial programming, ranging from land use planning in Zambia, to small and medium enterprise loan guarantees in Ghana, to HIV/AIDS and tuberculosis in southern Africa, and to civil society organization (CSO) capacity building in Mozambique. Future engagement could continue this cross-cutting approach, integrating mining-focused activities into other sectors such as labor rights, civil society capacity building, environmental protection, economic growth and democracy and governance activities. It is also important to work toward developing secure, resilient, and reliable supply chains for these minerals in coordination with other Department and Agencies within the United States Government (USG) as well as private sector and other stakeholders. Specific opportunities include:

- **Support sustained policy-oriented activities.** These include studies/assessments, multi-stakeholder dialogue, training for stakeholders and key interest groups, embedding technical advisors, and exchange visits. These activities could be organized in collaboration with mining governance specialists from organizations like the Intergovernmental Forum on Mining, Metals, and Sustainable Development (IGF), the World Bank and other US Government partners like the US Geological Survey (USGS). Existing policy-level support on mining tends to be short-term, expert-driven, and too focused on mining ministries (as opposed to other parts of government and non-government stakeholders)**. Supporting medium-term cross-sectoral reform processes could lead to more consensus and meaningful improvements**.
- **Support land and resource governance interventions.** These activities might include land-use and territorial development planning to support inclusive dialogue on mining's impacts and risks, reduce land use conflicts, improve relationships between mining companies and communities, and create the conditions for investment in local and national development. Land-use planning can also assist post-mining transition as well as mitigating and remediating environmental impacts.
- **Strengthen the capacity and involvement of local CSOs.** CSOs need support in human rights and environmental monitoring, advocating for open government and transparency, combatting corruption and transnational organized crime, building awareness on challenges and opportunities around mining, and advocating for labor rights.
- **Review USAID country strategies and existing programmatic portfolios to identify ways to address mining challenges through integrated programming**. USAID could integrate mining specialists into forest-management programming or involve experts on ways to generate employment and support mining industries in economic growth programming.
- **Forge new public-private partnerships and alliances**. Opportunities exist to work with mining companies, financial institutions, and supply chain actors to leverage technical and financial resources while increasing impact. This could include **engagement with other international initiatives and partners** on mining, notably with respect to due diligence in supply chains, responsible sourcing, and financial and conservation crimes related to mining and minerals trade.

1.0 DRIVERS AND DYNAMICS

1.1 INTRODUCTION AND BACKGROUND

1.1.1 REPORT BACKGROUND AND PURPOSE

The United States Agency for International Development (USAID) Bureau for Development, Democracy, and Innovation commissioned this report on the development challenges and opportunities around mining and the green energy transition. Renewable energy technologies required to meet climate change mitigation targets under the 2015 Paris Agreement rely on mining of nearly 30 priority minerals. This report contributes to a growing number of studies and initiatives aimed at understanding and preparing for increased demand for these minerals critical to the production of photovoltaic solar power, wind turbines, and batteries for power storage and electric vehicles.

While comprehensive studies have examined supply and demand projections, fewer have focused on the development challenges and opportunities associated with increased mining due to the green energy transition. Because many of these minerals are mined or will be mined in fragile states, negative impacts associated with mining could increase dramatically. These negative impacts include conflict, corruption, environmental damage, and labor exploitation (including child labor and human trafficking). The present report aims to help USAID and other United States Government (USG) stakeholders better understand the trends and dynamics around these minerals in developing countries and presents programming opportunities and recommendations.

The report seeks to answer three core questions:

1. For each mineral identified as a priority for renewable energy, what are the key trends and how much of global supply is currently mined in USAID-presence countries?
2. What are the development challenges and opportunities associated with increased mineral production in these countries?
3. What development interventions are available for USAID to address these challenges and opportunities?

The report is organized as follows:

- Section 1 summarizes **the *dynamics around supply and demand for minerals*** critical to the green energy transition and offers a ***primer on key terms and concepts in mining***.
- Section 2 summarizes ***development challenges*** associated with mining of these minerals.
- Section 3 offers ***programming ideas*** related to these development challenges.

The report also includes fact sheets in Annex 1 which present key data on each of the 16 reviewed minerals, as well as a list of all USAID-presence and limited-presence countries with mining or active exploration of the 16 minerals reviewed in the report (Annex 4).

1.1.2 FOCUS MINERALS

CHOICE OF MINERALS

Based on a literature review, this report identified 29 minerals with links to green energy technologies. This list was narrowed to 16 minerals based on the following criteria:

1. The minerals are currently mined at significant levels or the subject of active exploration in USAID-presence or limited-presence countries.
2. The minerals are primarily used in solar, wind, batteries, and/or geothermal industries. If the mineral is only used in hydroelectric, nuclear or carbon capture and storage, the mineral was excluded.
3. Minerals that are exclusively recovered as byproducts of zinc and copper smelting were excluded, since extractive risks and impacts will be like those of the primary mineral.
4. Minerals with only potential use in experimental technologies were excluded.
5. Minerals peripherally related to renewable technologies such as electronics were excluded unless demand from renewables is projected to significantly impact production.

This list of included and excluded minerals (highlighted in red) is summarized below.

Table 1. Green energy minerals (those reviewed by this report in black)

Mineral	Applications in Green Energy Technologies
Aluminum	Wind, solar and batteries
Chromium	Wind and batteries; also hydro and geothermal
Cobalt	Batteries
Copper	Wind, solar and batteries; also hydro, geothermal
Graphite	Batteries
Iron	Wind and batteries
Lead	Wind, solar and batteries; also hydro
Lithium	Batteries
Manganese	Wind and batteries; also hydro and geothermal
Molybdenum	Wind, solar and batteries; also hydro and geothermal
Nickel	Wind, solar and batteries; also hydro and geothermal
Rare Earth Elements (REEs)	Wind
Silver	Solar
Titanium	Geothermal; potential use in experimental battery technology
Vanadium	Batteries
Zinc	Wind, solar and batteries; also hydro
Antimony	Potential use in an experimental large-scale energy storage.
Cadmium	Used in Cadmium telluride thin-film PV technology. Zinc byproduct.
Gallium	Used in copper indium gallium selenide solar cell (CIGS) thin-film photovoltaic (PV) technology. Bauxite and zinc byproduct.
Germanium	Used in transistors for electronic devices. Zinc byproduct.
Indium	Used in CIGS thin-film PV technology; zinc and copper byproduct.
Niobium	Potential use in experimental solar and battery technologies, minor role as steel alloy.
Platinum	Used as a catalyzer in hydrogen-based fuel, whose widespread adoption remains highly uncertain.
Selenium	Used in CIGS thin-film PV technology. Copper byproduct.
Silicon	Used in photovoltaic cells. Silicon used in PV cells generally not produced with silica from USAID-presence countries.
Tantalum	Used in electronics used in electric cars and other applications
Tellurium	Used in Cadmium telluride thin-film PV technology. Produced mainly from copper anode slimes and smelting residues.
Tin	Used in electronics and other components of cars, including electric

Mineral	Applications in Green Energy Technologies
Tungsten	Used in super alloys and electronics, potential use in experimental battery technologies

US CRITICAL MINERALS

Of the 16 minerals chosen for review, nine are currently on the US List of Critical Minerals released by the US Department of the Interior in 2018 (Federal Register, 2018), and two have been recommended by the USGS for inclusion in the next iteration of the list.[2] The fact sheets in Annex 1 indicate which minerals are on the list of critical minerals. Critical minerals are defined by current dependence on foreign imports of minerals necessary for security and economic prosperity. By definition, this includes a wider array of minerals used in defense and other industries. In addition, critical minerals tend to have limited domestic sources and therefore dependence on one or few trading partners. Importantly, a 2021 US Geological Survey (USGS) review of the List of Critical Minerals recommended the inclusion of two other minerals reviewed in this study, zinc and nickel (Nassar & Fortier, 2021), which would bring the total number of US Critical Minerals reviewed in this report to 11 of the 16.

CONFLICT MINERALS AND CONFLICT-AFFECTED AND HIGH-RISK AREAS

Conflict minerals are defined in Section 1502 of the Wall Street Reform and Consumer Protection Act of 2010 (the US Dodd-Frank Act) as tin, tungsten, tantalum (3Ts), and gold, collectively known as 3TG. Section 1502 requires all Securities and Exchange Commission reporting companies to disclose whether their products contain minerals from the Democratic Republic of the Congo (DRC) or adjoining countries. If companies disclose that they source 3TG from the DRC, they are required to file an additional Conflict Minerals Report describing the due diligence undertaken to locate the source of the minerals. The purpose of the regulation is to address the gross human rights abuses and financing of rebel groups in the DRC associated with the mining and trade of gold, and the 3Ts ores of cassiterite, wolframite, and coltan.[3]

Section 1502 sparked an effort by hundreds of companies to examine their supply chains and develop systems to conduct due diligence. The Organization for Economic Cooperation and Development (OECD) developed the Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas (CAHRA) that forms the basis of many industry standards. The OECD due diligence framework focuses on identifying risks related to human rights and conflict financing, putting in place systems and plans to manage those risks, and public reporting on those measures. The OECD due diligence guidance covers all minerals.

The European Union (EU) Conflict Minerals Regulation adopted in 2017 (European Commission, 2020), which went into effect in 2021, covers other countries, but like Dodd-Frank focuses on the 3Ts and gold supply chains. The EU maintains a list of CAHRAs, and companies that import 3Ts and gold into the EU must prove that they adhere to the OECD due diligence framework.

Two aspects are important with respect to conflict minerals and this review:

1. **None of the 16 minerals covered in this study are conflict minerals** as defined by the US or the EU. While the 3Ts are indirectly linked to the green energy transition through their role in electronics and steel alloys, as well as several experimental and theoretical applications, they have no direct role in major green energy technologies and therefore did not meet the review's criteria. However, the 3Ts are all US Critical Minerals because of their vital role in other applications.

[2] See "USGS Seeks Public Comment on Draft List of 50 Minerals Deemed Critical to US National Security and the Economy" (November 8, 2021). https://www.usgs.gov/news/usgs-seeks-public-comment-draft-list-50-minerals-deemed-critical-us-national-security-and

[3] An ore is a naturally occurring rock that contains a metal or mineral that can be extracted. Minerals are natural inorganic compounds that may contain metals, which are elements. When mineral ores are smelting, heat is used to chemically alter the ore to extract intermediary substances or minerals. Refining is using various processes to increase the percentage of the desired metal, i.e., reduce impurities.

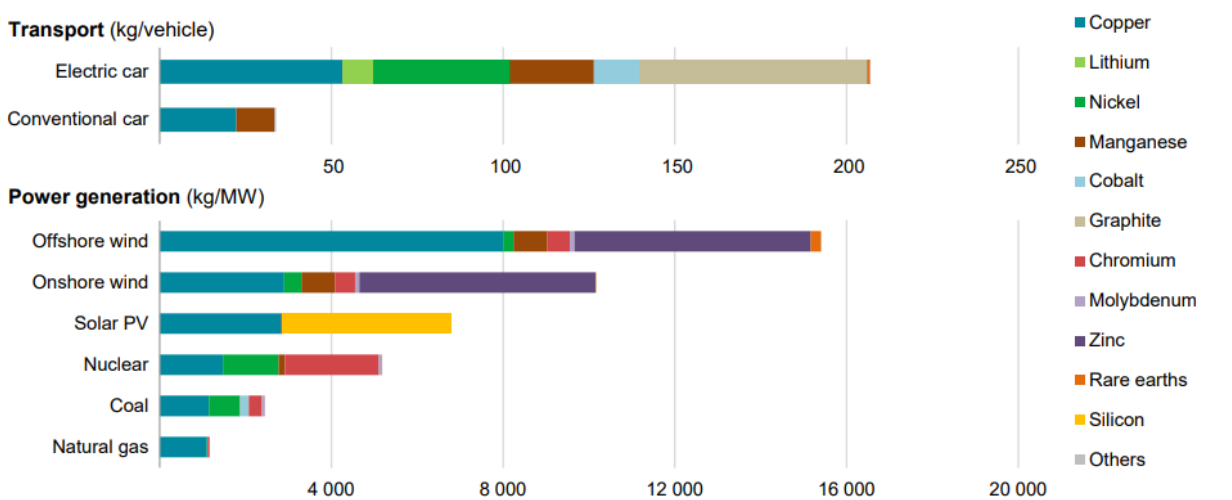
2. **Several countries considered CAHRAs are sources of green energy minerals** reviewed in this study. The EU classifies the following USAID-presence countries as CAHRA: Azerbaijan, Burkina Faso, Burma, Burundi, Colombia, the DRC, India, Mali, Mexico, Mozambique, Nigeria, Pakistan, Philippines, Sudan, Ukraine, and Zimbabwe.[4] There are therefore risks associated with conflict, human rights abuses, and green energy minerals. These are addressed in Section 2.

1.2 DRIVERS OF INCREASED MINERAL DEMAND FROM GREEN ENERGY

1.2.1 DEMAND PROJECTION SCENARIOS

The technologies needed to facilitate the transition to a low-carbon economy use significantly more materials, including minerals, compared to traditional fossil-fuel energy technologies (Drexhage et al., 2017, p. 58). This is illustrated by the figure below from the International Energy Agency's (IEA) comprehensive report *The Role of Critical Minerals in Clean Energy Transitions* (IEA, 2021, p. 26).

Figure 1. Minerals used in selected clean energy technologies



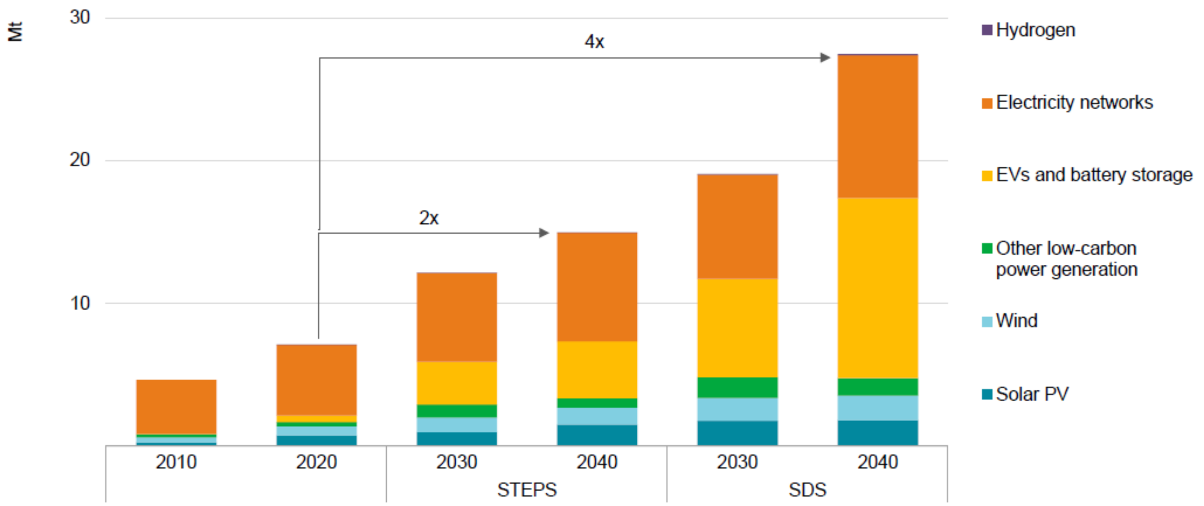
The IEA report projects demand for key green energy minerals using two scenarios:

1. **The Stated Policies Scenario** is a conservative estimate of where the energy system is heading based on a sector-by-sector analysis of today's policies.
2. **The Sustainable Development Scenario** estimates the demand required to meet the Paris Agreement goals. This is an ambitious scenario involving major investments such as a threefold increase in annual installation for solar, wind, and electricity network upgrades by 2040, and a 25-fold increase in the sales of electric cars by the same year.

The divergent figures in each scenario show the high level of uncertainty over future mineral demand. This reflects uncertainty around the extent, means and speed at which the green energy transition will occur. The differences are further evident in Figure 2 from the IEA report (IEA, 2021, p. 46):

[4] CAHRA List available here https://www.cahraslist.net/cahras

Figure 2. Total mineral demand from clean energy technologies is set to quadruple if Paris Agreement goals are to be met by 2040



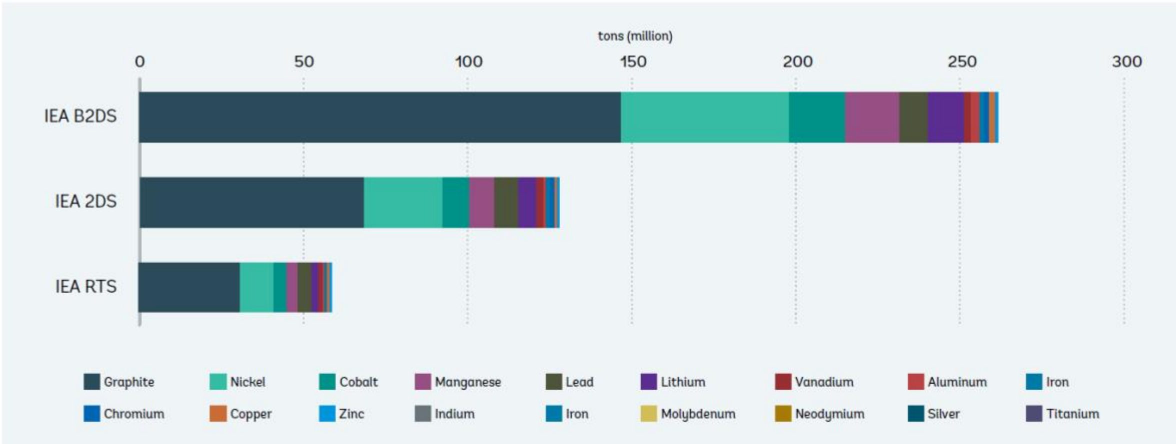
Notes: Includes all minerals in the scope of this report, including chromium, copper, major battery metals (lithium, nickel, cobalt, manganese and graphite), molybdenum, platinum group metals, zinc, REEs and others, but does not include steel and aluminium (see Annex for a full list of minerals). Mt = million tonnes.

The other major report on this topic, the World Bank's *The Mineral Intensity of the Clean Energy Transition* (Hund et al., 2020), analyzed several green technologies (termed "technology-based mitigation scenarios") to arrive at additional scenarios including:

- **4DS**, a 4-degree scenario where the world makes little progress in the green energy transition;
- **RTS**, reference technology scenario, based around countries meeting Nationally Determined Contributions under the Paris Agreement;
- **2DS,** a 2-degree scenario where the world adopts technologies contributing to a 50% chance that average temperatures stay below 2 degrees by 2100; and
- **B2DS,** an ambitious scenario where temperature increases are limited to 1.75 degrees by 2100.

The World Bank report made assumptions about the likely technology mix by 2050, such as a projection that a sixth of solar PV will be thin-film CIGS technology (Hund et al., 2020, p. 42). The authors also accounted for current manufacturing practices for those minerals as well as current recycling rates and came up with projected mineral demand for different scenarios for battery-related minerals as illustrated in Figure 3 below (Hund et al., 2020, p. 62).

Figure 3. Cumulative demand for minerals needed for energy storage through 2050



Note: Demand in the 4DS scenario is not presented because energy storage is not modeled in that scenario. 2DS = 2-degree scenario, B2DS = beyond 2-degree scenario, IEA = International Energy Agency, RTS = reference technology scenario.

As shown in Figure 3, demand for each mineral varies tremendously depending on each scenario. For the purposes of this report—the fact sheets in Annex 1—demand projections from the middle 2-degree scenario (2DS) are cited. The key takeaway, however, is the high level of uncertainty around the exact mix of metals that will be required. This in turn will have an impact on developing countries, including the 70 USAID-presence countries where the above minerals are mined, and especially those that are top producers or top reserve-holders.

Indeed, a recent report from the Columbia Center on Sustainable Investment cautioned policymakers against "overly zealous expectations [that] can drive suboptimal behaviors, resulting in resource-rich countries experiencing slower economic growth before any minerals are even extracted" (Toledano et al., 2020). This can be due to over-investment which leads to supply gluts and price crashes or over-investment in hyped minerals that become obsolete due to innovation. Capacity-building of governments in countries set for a green energy minerals boom should aim to help policymakers understand and consider the uncertainties, including the additional factors cited in the next section.

1.2.2 FACTORS AFFECTING MINERAL DEMAND

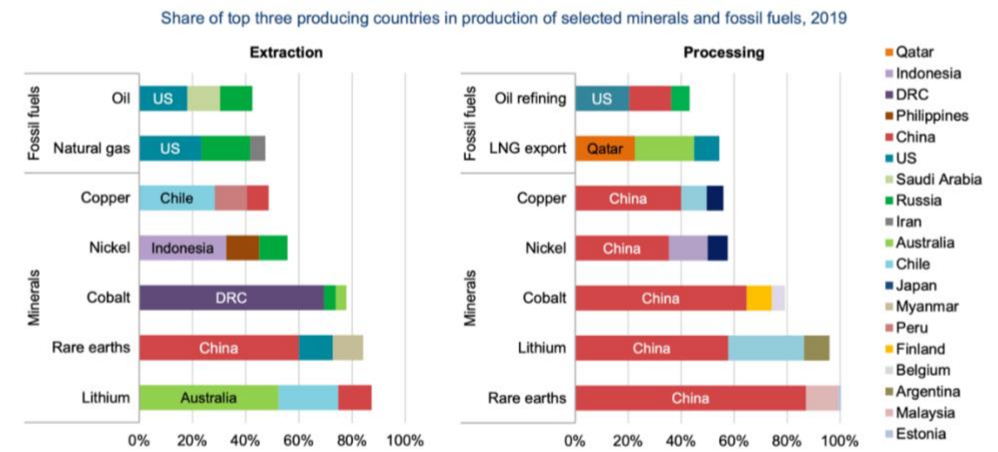
Besides uncertainty around the extent of adoption of green energy technologies based on different climate change mitigation scenarios, there are other factors that will influence demand for metals and minerals reviewed in this study:

- **Material performance and innovation** could dramatically change demand for particular metals. For example, alternative battery technologies that do not rely on cobalt could gain market share, driven by industry leaders like Tesla, who has already announced its intention to develop cobalt-free batteries (Morris, 2020).
- **Mineral price dynamics** will also affect the mineral mix. For example, a sustained surge in the price of lithium could accelerate efforts to find lithium-ion battery substitutes. While market speculation drives many mineral prices, the fundamentals of the mine cycle and its inertia in responding to supply and demand changes is key, addressed in more detail in Section 1.3.
- **Supply chain vulnerabilities** ranging from investor and consumer concern over labor conditions to political uncertainty in top producing countries can cause manufacturers to invest in alternative

technologies to reduce risk. It follows that the extent to which development challenges are addressed will affect the green energy transition.

It is equally important to consider not just vulnerabilities in mining countries but also in countries where minerals are smelted and refined. As the figure below illustrates (IEA, 2021, p. 13), China's dominance in midstream mineral processing can undermine efforts to diversify mining sources—since much ends up in China for processing and manufacturing. The White House recently highlighted this fact in its report on the 100-day review of critical supply chains (White House, 2021, p. 7). Figure 4 contextualizes the risk, showing that mineral processing is more geographically concentrated than oil and natural gas.

Figure 4. Production of many energy transition minerals today is more geographically concentrated than that of oil or natural gas



Notes: LNG = liquefied natural gas; US = United States. The values for copper processing are for refining operations.
Sources: IEA (2020a); USGS (2021), World Bureau of Metal Statistics (2020); Adamas Intelligence (2020).

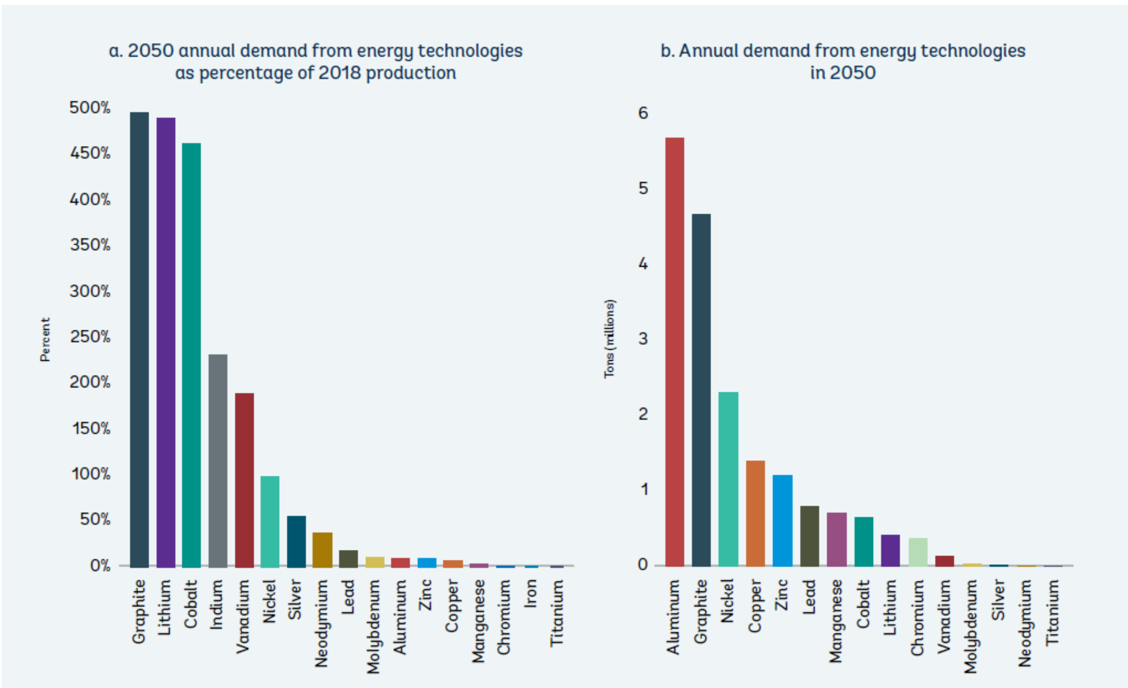
- **Exploration investment and data availability** could have an impact on demand projections, especially projections on where the minerals will be mined. Existing data—including data compiled by the USGS—has limitations, especially when it comes to areas that suffer from under-investment in research and exploration like parts of Africa and Asia. These areas may have significant reserves of minerals, including those discussed in this report, that are not captured in existing data. New discoveries and improved data availability could impact known reserves and mine project pipelines. Similarly, discoveries in arctic areas like Greenland could reduce demand projections for mining in USAID-presence countries.

- **Reduction in primary mineral need due to recycling** is a final uncertainty. The World Bank projections included available data on end-of-life recycling (the percent of products with a given mineral that are recycled upon discarding) and recycled content (the percent of a given metal in a new product that is recycled rather than mined). While recycling is set to increase and presents its own challenges and opportunities in USAID-presence countries, no projections anticipate that recycling can offset all increased demand for mineral used in green energy technologies (Hund et al., 2020, p. 95). Moreover, some metals are difficult to recycle, like the cobalt in lithium-ion batteries which needs a high purity level impossible to attain through recycling.

1.2.3 CLASSIFICATION OF MINERALS BY DEMAND PROJECTIONS

The World Bank 2020 report presents demand projections for 17 minerals, including the 16 reviewed in this report.[5] Mineral demand projections can be ranked in absolute terms or in relative terms. As seen Figure 5, a metal like aluminum, for example, will increase the most in absolute terms (Graph B) but will only increase modestly relative (Graph A) to current production levels. This trend is due to aluminum's value as a key base metal used in many industries, not just renewables. Conversely, rare earth elements (REEs) used in wind turbines will see only a miniscule increase in absolute demand but a significant increase in relative demand because most future demand is linked to green energy.

Figure 5. Relative and absolute demand increases by 2050 of 17 minerals



Source: World Bank ((Hund et al., 2020, p. 73)*)*

Based partly on the divergence between absolute and relative changes, the World Bank report offers a useful classification into four categories based on demand projection characteristics:

- **High-impact minerals** will need to increase production significantly over current levels and most of future demand will come from renewables. High-impact minerals could therefore be vulnerable to supply chain risks, especially if concentrated in one or more countries. The minerals in this category are ***graphite, lithium, and cobalt.***
- **Medium-impact minerals** will also need to increase production but not as dramatically. Like high-impact minerals, a significant portion (but not all) of future demand will stem from renewables. In some cases, these minerals can be substituted if their price increases too much—i.e., they are not as critical to current green technology as the high-impact minerals. The minerals in this category covered by this report are ***vanadium, REEs, titanium, silver, and zinc***.

[5] The report covers neodymium, one of the 4 Rare Earth Elements (REE) used to manufacture permanent magnets. The others are praseodymium and to a lesser extent dysprosium and terbium.

- **Cross-cutting minerals** are used in a wide range of renewables technologies as well as in other industries. Their supply and demand dynamics are therefore less linked to dynamics in specific green energy technologies. While the percentage increases are less dramatic compared to high-impact minerals, absolute supply of these minerals will still need to increase, which could affect their overall market, especially if new projects are scarce. The minerals in this category covered by this report are ***manganese, iron, nickel, lead, chromium, copper, and molybdenum***.

- **High-impact, cross-cutting minerals** are cross-cutting across renewables and various industries, but because they are vital for essentially every type of green energy technology, changes in their availability could have an outsize impact on the green energy transition. The mineral in this category covered by this report is ***aluminum***.

1.3 DYNAMICS IN MINING INDUSTRY

To better understand the development challenges and opportunities related to an expected increase in mining in USAID-presence countries, it is vital to understand the basic mechanics of the mining sector, as well as the significant ways in which the industry is evolving. For example, it is simplistic to assume that the increased demand will automatically translate into increased mining in USAID-presence countries. Investment decisions depend on expected market prices but also supply chain configurations, financing options, and political pressures and constraints. This section aims at to present some basic concepts and trends to better contextualize projected development challenges.

1.3.1 KEY FEATURES AND CONCEPTS

Mining is characterized by the **diversity of interests** of various actors in complex and global value chains. However, there can be balance if interface points, such as investment, permitting, product sales and taxation are orchestrated to create consensus rather than conflict.

Figure 6. Mining and metals stakeholders

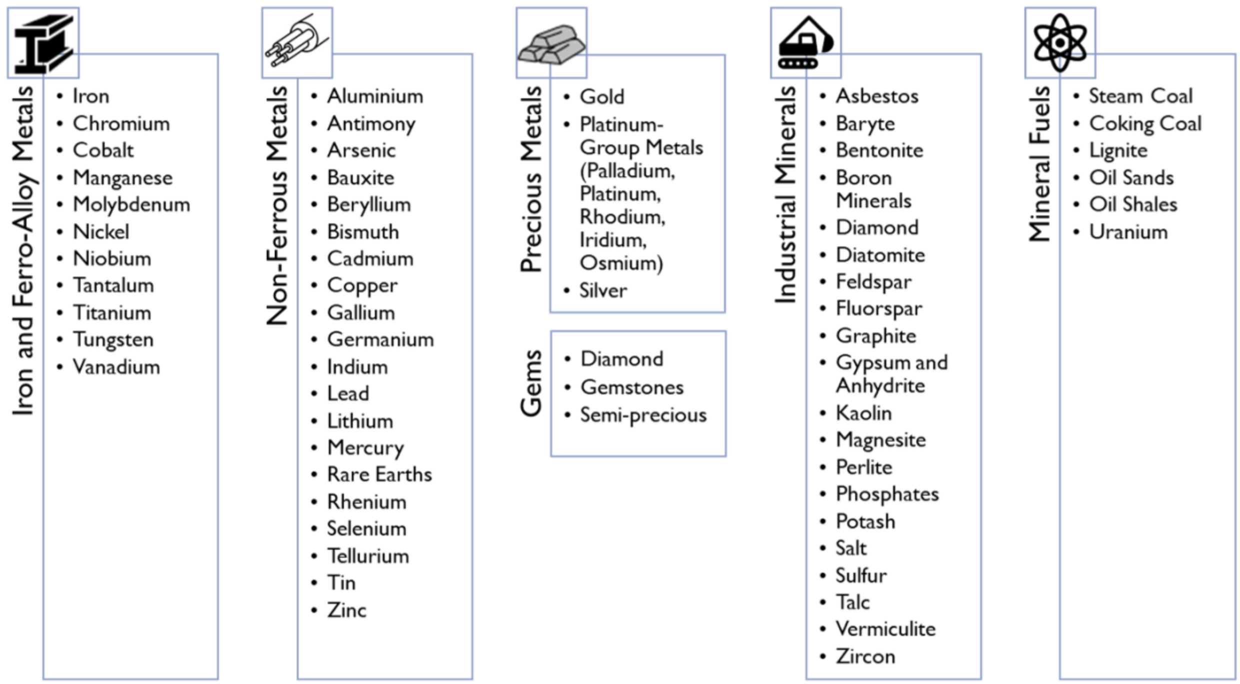
(Source: Latitude Five)

Mining is very **local** and site-specific but at the same time **global** and globalized across diverse cultural, social, and political contexts. This tension makes it challenging to strike the right balance between local or group-specific issues and international policy objectives. There is also a **disparity of realities** within the mining sector in which highly automated, futuristic operations coexist with rudimentary operations run by the poorest of the poor, including a high proportion of women (Romano & Papastefanaki, 2020).

Another key feature of mining is **risk**, derived from factors including uncertainty around the exact nature of a deposit, the long lifecycle and strategic nature of metals and minerals, and the use of minerals in industries that can shift rapidly based on technology and consumption patterns. As a result, mining is notoriously cyclical with volatile prices and investment patterns. Mining also must contend with significant political, legal, environmental, and social uncertainties where it occurs.

There is a great diversity of metallic and non-metallic minerals, which can usually be grouped as follows:

Figure 7. Key terms – Standard minerals categorization



(Source: Latitude Five)

Most definitions of mining exclude petroleum products, natural gas, and water because of their distinct extraction methods, although they are also mineral products, whereas energy minerals such as coal and uranium are mined by conventional methods and thus included. In addition, bulk construction materials, such as sand, gravel, aggregates, and dimension stones are often excluded despite their importance in emerging economies. In ASM, these have recently been dubbed "development minerals."[6]

Reporting and disclosure standards is an important concept in the sector. Because mining is based on depleting mineral assets, the knowledge of which is imperfect prior to the commencement of extraction, the industry needs standards to communicate with investors and regulators about those assets. Since the mid-1990s, the Committee for Mineral Reserves International Reporting Standards **(CRIRSCO)**, a grouping of national mineral reporting organizations under the auspices of the International Council for Mining and Metals (ICMM), has promoted this.

CRIRSCO's *International Reporting Template* sets the global standard for classifying tonnage and grade estimates by level of geological confidence and technical and economic evaluation. Mineral reporting standards are distinct from **disclosure standards**, which define the type and quality of information provided to investors. The Canadian National Instrument 43-101 is the most widely known reference.

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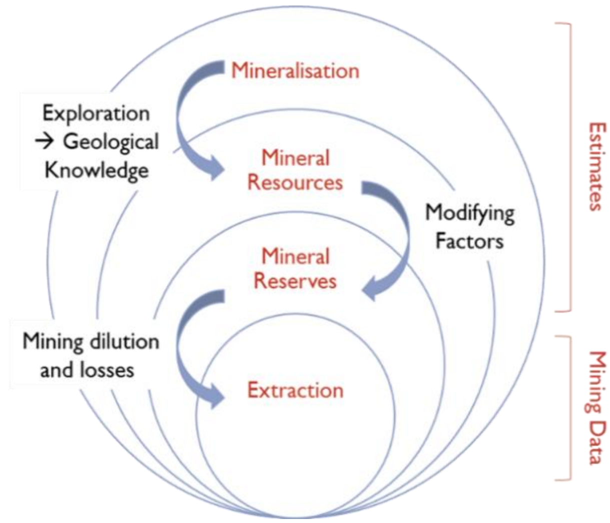
[6] See UNDP/AU program definition: "Development Minerals' are minerals and materials that are mined, processed, manufactured and used domestically in industries such as construction, manufacturing, and agriculture." http://www.developmentminerals.org/index.php/en/

A **mineral resource** is a mineralization presenting reasonable prospects for eventual economic extraction (CRIRSCO, 2019, Clause 7.1). Mineral resources are subdivided, in order of increasing **geological confidence**, into three categories:

- **Inferred**: quantity and grade are estimated on the basis of limited geological evidence, insufficient to verify geological and grade continuity (CRIRSCO, 2019, Clause 7.4);
- **Indicated**: quantity, grade and physical characteristics are estimated with sufficient confidence to support mine planning and evaluation of economic viability (CRIRSCO, 2019, Clause 7.8); and
- **Measured**: quantity, grade, and physical characteristics are similarly estimated but to within closer limits, requiring a high level of confidence in the geology and the controls of the mineral deposit (CRIRSCO, 2019, Clause 7.10).

Figure 8. Mineral reporting



(Source: Latitude Five)

Mineral reserves are the sub-set of mineral resources that are **economically mineable** and result from the application of modifying factors affecting extraction (mining, processing, metallurgical constraints, infrastructure, economic, marketing, legal, environmental, social, and governmental). Reserves are classified as proven or probable depending on the level of confidence.[7] All of the above are subject to technical studies such as the preliminary economic assessment, pre-feasibility study, and the feasibility study.

Recognizing and understanding this industry terminology helps elucidate, in a given USAID-presence country, the type and quality of data for select resources, technical standards applied to industrial mine development, and defining the importance of project milestones help show potential impact.

1.3.2 MINERAL RESOURCES DEVELOPMENT CYCLE

MINING PROJECT STAGES

The timeline of a mineral resource development project is punctuated by a series of decision points, with each step increasing confidence in the project and the likelihood that it will be realized. Figure 9 summarizes the steps.

The first of these decisions, concerning **exploration investment**, typically weighs mineral potential and public policy risks. One of the most significant indicators of this is the Investment Attractiveness Index published annually by the Fraser Institute, based on a survey of exploration and mining companies who systematically attribute approximately 40% of their investment decision to policy factors (Fraser Institute, 2021). This shows the importance of mining governance in developing countries in attracting investment even in the early stages of a project.

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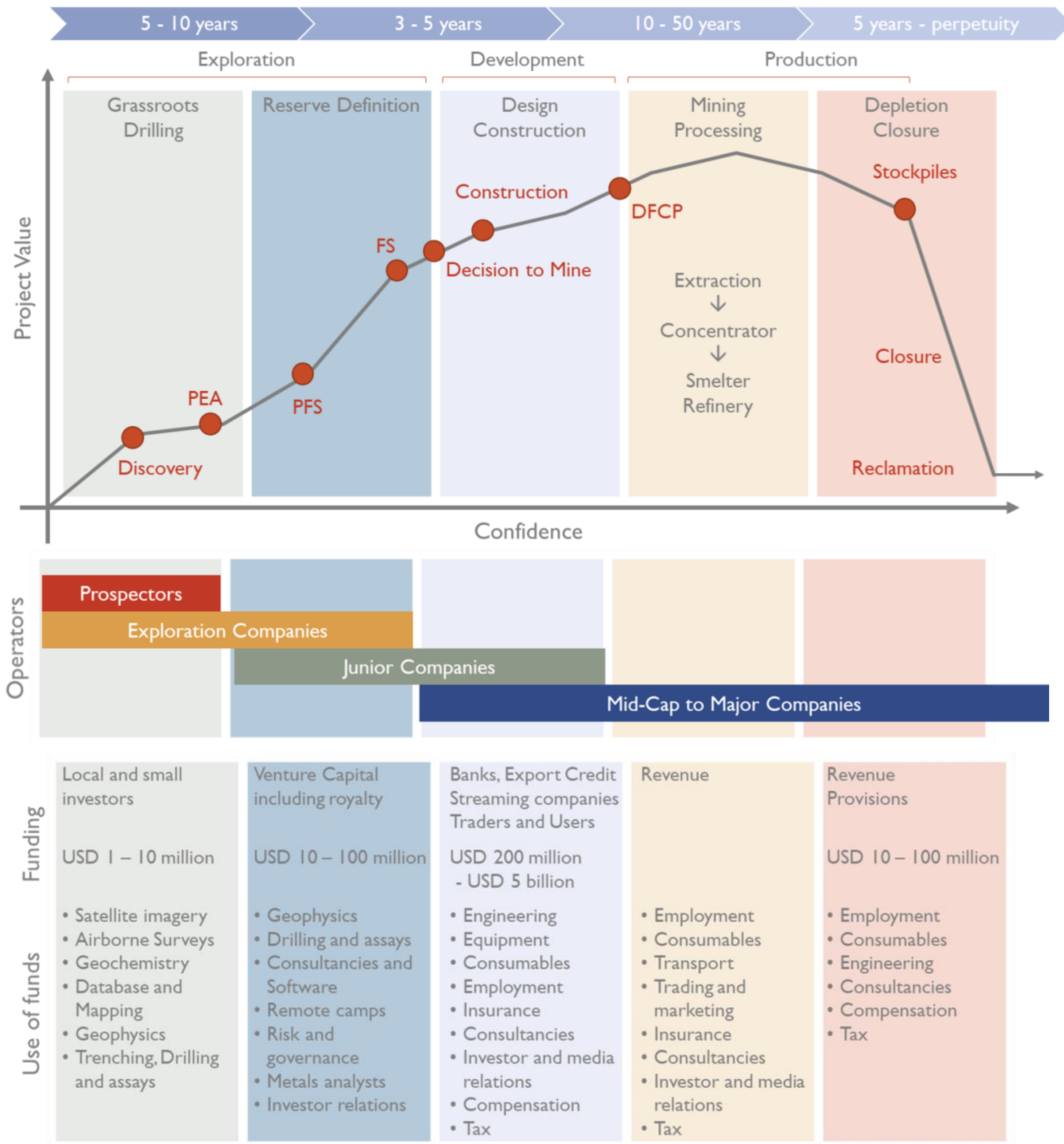
[7] Note that a measured mineral resource converts to a probable mineral reserve when the confidence in modifying factors is less than the level of geological confidence; it does not indicate a reduction in geological confidence. (CRIRSCO, 2019, Clause 4.7)

Figure 9. Mineral resources development cycle



(Source: Latitude Five)

Subsequent **exploration decision points** are primarily linked to exploration results and technical studies. The exploration success ratio most cited in the industry is that typically 1 of 100 or more exploration projects will become a mine. Moreover, it is generally considered that easy-access, easy-find deposits have been or are now being mined. Brand new projects are, overall, increasingly rare.

The exploration timeline is often longer, and more erratic, than Figure 9 suggests. Projects can be suspended for lack of funds, access or alignment with a company's priorities, and technological changes in mining or in downstream markets using the mineral. These factors can cause shelved projects to come back to life or green-lighted projects to suddenly become suspended.

Once a company has decided to **mine**, there is a reasonable expectation that all permits, ancillary rights and authorizations required for mining, and to the extent applicable, processing and marketing, can be obtained in a timely fashion, and maintained for ongoing operations. As design and engineering are finalized, permitting is completed, long-lead items are ordered and preliminary construction works commence. Offtake or other commercialization arrangements are arranged at this phase, integral to financing and insurance.

After construction and commissioning, mining begins and ramps up to optimal capacity over a period which can span from three months to more than a year depending on the mine, mineral and process. The **date of first commercial production** is a key moment for regulatory and taxation regimes: generally, this is defined as the date of the first sale of product from the operation.

Box 1. Fairness is in the eye of the beholder

The term 'economically mineable' in the definition of mineral reserves implies that extraction has been demonstrated to be viable under reasonable financial assumptions based on the expectation that companies will attempt to achieve an acceptable return on capital invested, and that returns to investors in the project will be **competitive** with alternative investments of comparable risk. This is important to understand the expectations gap between operators and investors on one hand, and regulators and civil society on the other hand: LSM profitability models are often misunderstood and can create the impression of an "unfair deal" – whether or not financial conditions bear that out.

A striking example of this was provided by the Burkina Faso Chamber of Mines in 2013 when it commissioned KPMG to analyze allocation of gold mining profits and found that 30% of profits went to investors and 70% to the government over the life of the project. While there are cases of truly unfair deals, which need to be identified and rectified, it is important for governments and civil society to better understand real profitability of LSM operations in determining policy. It is important to also recognize the role of donors and others in building capacity in many countries to better negotiate and re-negotiate balanced deals.

Exploration or development projects, as well as mining assets, can and most often will change ownership at several points through acquisitions, earn-ins and joint ventures. Other factors that cause ownership changes are permitting constraints and the specialization of the operators (some companies specialize in exploration, for example, while others focus on "end-of-life" assets.

MINERAL RIGHTS

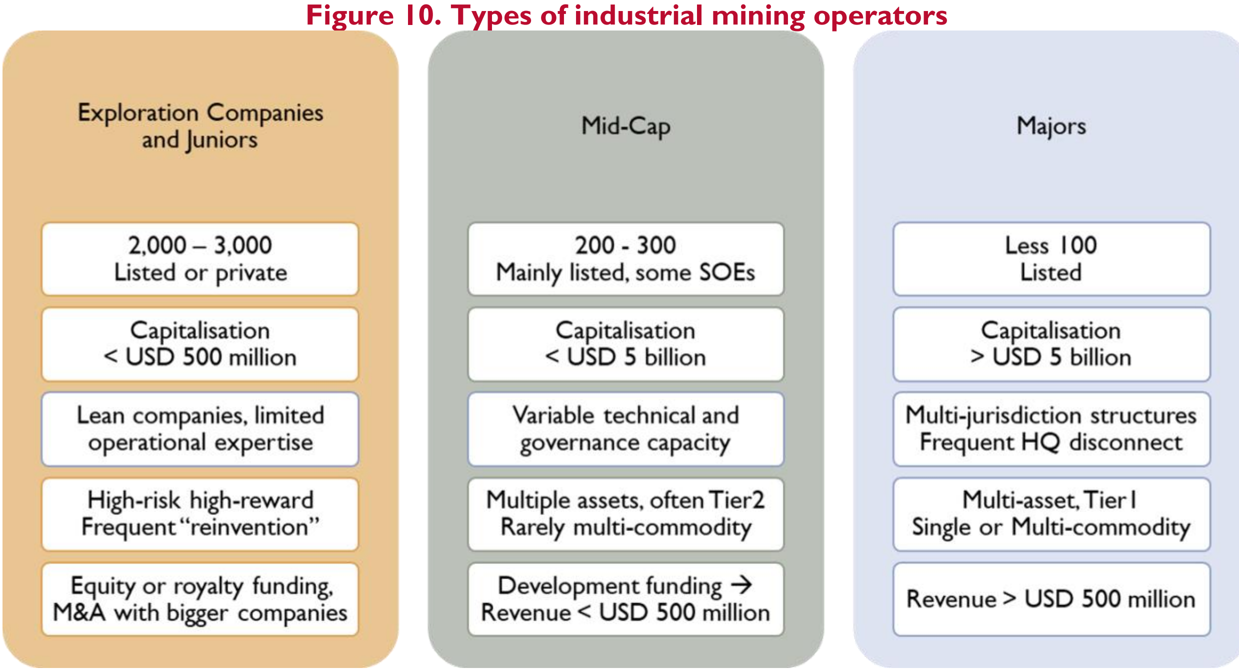
Exploration and mining are subject to specific title granting **mineral rights** which typically define perimeter access rights, authorize certain activities, and organize regulatory reporting obligations. In most cases, mineral rights are distinct from land or surface rights, including ownership, and derived from a principle of State ownership of minerals and jurisdiction over sub-surface rights.

Mineral rights can be issued on a first-come, first-served basis (which does not exclude application of technical and financial conditions to issuance) or through competitive process (generally where value has already been defined). Rights can also be granted under an administrative act (exploration or mining license) or by contract with a public authority (concession, investment agreement) or a State-owned enterprise (joint ventures, service contract). Regulators usually rely on a hybrid of mining laws granting mineral title and agreements setting specific terms and conditions for that particular LSM operation. Mining agreements that appear to contradict mining law in favor of mining companies have come under scrutiny over the last decade, and there is a clear trend to more legislated terms and the use of model agreements that are limited to implementing existing legal provisions (Bastida, 2020, p. 158).

The basic principle of traditional mineral tenure regimes is **precedence of mineral title**, on the assumption that mining is a more valuable land use: these rules usually facilitate access to land for exploration and/or mining use and establish (sometimes minimal) processes for compensation and expropriation. This has been at the root of conflicts between miners, surface owners or users and local communities. Increasing recognition of the multiple values and economic, social, environmental, and cultural benefits of other land uses (conservation and wilderness, landscape, forestry or farming, settlement, and recreation, etc.) is redefining not only the extent of land made available to mining but also the rules of engagement between mineral rights holders and other users or holders of land rights (Bastida, 2020, p. 174).

TYPES OF MINING OPERATORS

Figure 10. Types of industrial mining operators



(Source: Latitude Five)

1.3.3 MINING FINANCE

Trends in mining finance shape how and where mining occurs. Australia, Canada, and the United Kingdom remain the key mining finance markets, and equity from retail investors, private investors specialized in mining and institutional investors is essential to fund exploration and development. Among equity markets, Toronto, London, and Johannesburg operate a two-tier market with TSX-Venture,

Table 2. Top equity markets for mining companies

Exchange Name	Location	Mining Issuers	Proportion
TSX-TSXV	Toronto	1,164	52%
ASX	Australia	715	32%
LSE - AIM	London	178	8%
HKEx	Hong Kong	107	5%
SSE	Shanghai	44	2%
JSE - AltEx	Johannesburg	41	2%
		2,249	100%
Exchange Market Data, 5 July 2021[1]			

AIM and AltEx offering junior companies a market distinct from the main market for more established companies.

However, the mix of funding options has evolved significantly over the last decade, with the emergence and continuous growth of alternative financing options filling gaps where more traditional equity and debt have been more constrained (Mareels et al., 2021). In a cyclical market, investor sentiment sees significant fluctuations and differences between markets: early-stage and even development projects have been difficult to fund with variable commodity pricing and a deteriorating geopolitical environment, though 2020 saw new financing highs as mining's necessity to the green energy transition and strategic importance of certain minerals drove investor interest.

There are also some successful examples of crowdfunding[8] or other platform-based funding initiatives for junior companies over the last few years: these are particularly interesting given the recent rise in resource nationalism. Investors were previously uninterested in exploration and mining; instead, they preferred to align their work with geostrategic interests and/or political convictions. [9]

Box 2. Chinese financing in mining

Chinese financing has come under scrutiny for state-backed financing as well as resource for infrastructure deals (Scungio, 2021). A review of recent deals showed limited public data (Scungio, 2021, p. 17). However, based on available data, most Chinese investments in mining overseas are financed by Chinese banks. In several cases state-owned policy banks like China Development Bank and the Export-Import Bank of China support Chinese state-owned enterprises abroad. Large state-owned commercial banks often join these deals in syndicates, or they operate as sole lenders to mining projects. There are rare cases of private mining companies also receiving financing from policy banks or commercial banks (Scungio, 2021, p 19).

"Resource for infrastructure" deals have been documented in Peru, Ghana, and the DRC (Scungio, 2021, p. 21). In some cases, companies have acquired mineral rights through privatization of state assets, competitive tendering or non-competitive processes that have been criticized for lack of transparency. The practice of compensating for some or all of infrastructure through mineral rights was apparently practiced in China by Japanese companies in the 1980s (Scungio, 2021, p. 21).

Mining financing hit an eight-year high in 2020, with all commodity groups increasing their fundraising levels in the same year. Strong gold prices, driven by the economic impacts of the COVID-19 pandemic, spurred investors into gold equities in particular (+40% year-on-year). Fundraising for base/other metals (copper, nickel, zinc, lead and cobalt, as well as nongold precious metals such as silver and platinum group metals) was up 37% year-on-year, nearly matching gold's rate of increase. This movement took place exclusively in the second half of the year after the COVID-19 pandemic brought entire economic sectors and supply chains to an abrupt halt in the first half.

Strengthening battery demand pushed specialty commodity fundraising up 17% in 2020, with lithium still accounting for almost half of the increase despite remaining relatively flat in 2020. On the other hand, REE financing increased 184% year-on-year, surging from 8% to 20% of specialty commodity fundraising (S&P Global Market Intelligence, 2021).

Amid the positive sentiment around fundraising in the middle of the year, initial public offering (IPO) activity heated up in late 2020. Of the 52 IPOs completed, 33 were for gold, ten for copper, four for silver, with the remainder for nickel, REE, graphite, tungsten, and titanium. Typically accounting for the largest volume of IPOs, the Australian Securities Exchange (ASX) led all other exchanges with 24 of 2020's IPOs — with most of those exploring for gold and/or copper — a significant increase from 2019 when just four IPOs hit the ASX (S&P Global Market Intelligence, 2021).

This activity denotes a return of positive investor sentiment which had fluctuated in previous years and illustrates the imbalance of the market favoring gold: easy to mine and present in many jurisdictions, gold

[8] See for example the example of Cornish Lithium Ltd, *Cornish Lithium raises £6 million in new Crowdfunding Raise*, June 2021 (link)

[9] See IGF's *Innovation in Mining: Report to the 2018 International Mines Ministers Summit*, 2018 (link)

attracts more companies among the junior and mid-tier companies and dominates mining finance news despite representing a less significant portion of mined value. The combination of stimulus plans in the US, European Union, and China as well as demand for green energy minerals are set to keep prices high or even higher in 2021 especially for copper, nickel, lithium, REE, and graphite (S&P Global Market Intelligence, 2021).

1.3.4 INDUSTRY CHALLENGES IN DEVELOPING COUNTRIES

As noted above, risks associated with developing country political and economic environments are decisive in mining investment decisions for most companies listed on major mining-focused exchanges. Information used by the industry often comes from two publications of reference: KPMG's Risks and Opportunities for Mining Global Outlook published annually in March for the current year (KPMG, 2021), and EY's Top 10 Business Risks and Opportunities for Mining and Metals, published annually in September for the upcoming year (EY, 2021). Both are based on surveys of mining industry executives.

In addition to those summarized below, classic emerging market risks include corruption and excessive administrative burden, security concerns and the difficult multilateral relationship between LSM, ASM and the supervisory authorities struggling to manage their interaction.

RESOURCE POLICY SHIFTS

The shifting geopolitical landscape is changing many dynamics for mining and metals companies in terms of investment choices, competition, and product commercialization, but also driving economic protectionism globally (EY, 2021). In emerging markets, this is bolstering **resource nationalism**, with governments continuing to position around "fair share of resource wealth" claims. Though resource nationalism is sometimes still linked to nationalist or anti-colonial rhetoric where this continues to resonate with voters, it is now generally driven by economic motives: the vulnerability of resource-dependent economies and governments budgets can exacerbate social and political tensions and the frustration of unrealized expectations as to sustainable development and positive impact. The chronic disconnect between perceived and actual returns for mining companies and/or their shareholders is also a factor, particularly in commodity price surges, as is the rising political voice of local communities to express their intolerance of poverty and challenge national governments in this regard.

There is a sense that emerging markets did not reap enough benefits of the "commodity super cycle" of the early 2000s and will seek to position themselves more strongly on critical materials. Corollary issues of governance, capacity, and economic diversification are sometimes overlooked. Donors and policy makers will continue to seek to strike a balance in their positions between supporting additional mining for the green energy transition and critical mineral supply chains, while also increasing benefits and minimizing negative impacts on affected countries and communities. The same tensions are at play in some developed countries as they seek to expand mining as part of critical mineral strategies. The ongoing debates could lead to a new paradigm for mineral extraction.

LICENSE TO OPERATE AT RISK

While previously social and community relations were treated as a problem or a threat, investors and other stakeholders are increasingly demanding that mining companies build and maintain positive relations with communities and consider risks more holistically, as demonstrated in Figure 11.

Increasingly, global and local **expectations of transparency and fairness** will require miners to work with governments and sector associations to shape clearer messaging about the societal contribution and value derived from the mining sector (EY, 2021). For these expectations to shape business strategies, communication with stakeholders will have to go both ways: mining companies need to be able to hear what stakeholders want, and then demonstrate they are acting on it. This can be an opportunity for mining to step outside its current paradigm. Without such efforts, social movements and investor pressure could affect mining operations everywhere, including in emerging markets. There is therefore a business case for addressing development challenges through donor assistance but also through better industry practices and partnerships to improve them.

SKILLS GAP

Figure 11. Multi-faceted permitting risk

The enabling environment that allows a new mining project to become green-lighted is becoming more complex than just financing and mineral title, as the following conditions show:

Mineral Title
- Regulatory frameworks
- Processes & timelines
- Permitting criteria
- Compliance & reporting
- Political / regime change
- Regulatory changes
- Governance, transparency

Environmental
- ESIA, spatial planning
- Water and mine waste
- Emissions
- Hazardous substances
- Vegetation clearance
- Rehabilitation and financial assurance

Business
- Customs
- Labour
- Exchange rate fluctuations
- Procurement
- Change of control
- Tax compliance
- Responsible supply chains

Social
- Employment
- Land use and resettlement
- CSR commitments
- Human rights
- Regional politics
- NGO/civil society
- Illegal ASM

Each of these factors can be derived from sources including regulation, contractual terms, market standards, or local practice, and increasingly link directly to mineral title under national mining regulation and mining conventions: non-compliance and weak social license to operate can invalidate permitting. While expanded expectations can be positive, it is creating challenges for mining companies given the sheer number of stakeholders that are in constant flux. In addition, many lack risk management tools and work cultures to deal with these multifaceted challenges. This is increasingly a problem when investors and financial partners are assigning more weight to environmental, social, and governance (ESG) performance.

The mining industry labor force is changing as mines become more automated, making it more challenging for local workers in developing countries to keep up with the high pace of technological change. The COVID-19 pandemic also triggered a rethink of working arrangements in mining as in every other industry, accelerating adoption of remote working and virtual teams and highlighting the benefits of technologies such as automation, artificial intelligence, and blockchain to support business continuity. This is receiving attention in leading mining jurisdictions such as Australia. However, adoption of new technology could increase the **innovation and skills gap**, impacting jobs and benefits in and around mining operations. Creating a globally mobile, competitive mining workforce requires investment in high-quality education and training, with a focus on technology, which is likely to pose a challenge for many emerging markets.

As for building the monetary value of exports, 23 percent comes from affiliated services (18 percent domestic and five percent foreign). Demand for services creates a strong link with the wider economy and in mineral-rich countries can be a significant pathway to development. However, mining operations in emerging markets tend to import a higher and increasing share of foreign services because of specialization. In fact, the main providers of services to mining are often not located in mineral-rich countries, indicating that not all mining countries have developed their services sectors to a level competitive with foreign mining markets (Korinek, 2021).

Innovation significantly impacts productivity in mining, as well as the potential for minerals-rich countries to extract value from their national resource endowments. However, digitalization and increasing acceptance of remote work and virtual teams may reinforce the **concentration of high-skilled services and knowhow** in the more developed mining countries, to the detriment of emerging markets and their workforce, as strong innovation systems seem to be strongly correlated with robust performance in the export of services for mining (Korinek, 2021).

Developing local skills is particularly challenging given the risks of mining. As noted by one analyst:

> Mining is a risky and long-term business: halting the mine exploitation even for a short time can be very costly, and investments have an economic cycle of at least 15 or 20 years. Thus, mining companies usually adopt a very risk-averse attitude, favoring incumbents over new potential suppliers. Rarely they forge long-term formal links with local suppliers and engage in innovation projects in collaboration with them. (Pietrobelli, 2019)

As mining becomes more complex and innovation progresses, exploration and mining companies may struggle to balance expectations of controlling costs and improving productivity with increasingly stringent local employment and contracting policies.

1.3.5 ARTISANAL AND SMALL-SCALE MINING

ASM—low-tech, labor-intensive mineral extraction and processing—is performed by individuals, groups, families, or cooperatives across 80 countries worldwide (World Bank, 2021). This includes the extraction of several minerals outlined in this report which are crucial for a shift towards a green economy. For example, ASM supplies 15–30% of the world's cobalt, which is an important component of lithium-ion batteries (World Economic Forum, 2019). The ASM sector makes up the world's largest mining workforce providing direct employment for an estimated 44.75 million people and 134 million people who work in associated industries (World Bank, 2021).

Offering easily accessible and viable livelihood options through low-skilled labor-intensive work, the sector is home to a heterogeneous workforce providing opportunities to those who struggle to find it elsewhere. This includes migrant or seasonal workers, women, so-called "fortune-seekers," opportunistic entrepreneurs, and both necessity- and poverty-driven miners. However, it is generally understood that the majority of those who operate in the sector are largely poverty-driven (Hilson, 2009; Hilson & Garforth, 2013; Van Bockstael, 2014; Verbrugge 2017).

Though the sector contributes to production and employment in the mining sector, ASM is more often associated with its negative social and environmental impacts. These include the hazardous working conditions, relatively high levels of child labor, money laundering, and human rights abuses by rebel groups. Additionally, land conflicts between ASM and local land owners and between ASM and LSM are widespread. Common environmental impacts include land degradation, pollution of water bodies through siltation and the use of chemicals, such as the extensive use of cyanide and mercury in the gold mining sector, and deforestation and the defacement of land (Aryee et al., 2003; Banchirigah, 2006; Duffy, 2005; Even-Zohar, 2003; Hilson, 2002 and 2010; Kitula, 2006; Le Billon, 2005; Tschakert & Singha, 2007).

However, these problems are generally considered expressions of the sector's informality, rather than an inherent characteristic of the sector as a whole. It is estimated that between 80-90 percent of the

ASM workforce operates informally, leaving the sector unmonitored (World Bank, 2021). Operators often lack access to legal protection, formal finance, appropriate equipment and training and security of land tenure. Miners are more focused on satisfying their daily needs than the management of sustainable practices. The informal nature of ASM also makes governments and development partners overlook its contribution to growth and economic development compared to LSM. The informality of ASM leaves the sector at risk for corruption, embezzlement, and criminality, and results in lost revenue for local and national governments (Hilson & McQuilken, 2014, World Bank, 2021).

ILLEGALITY, CRIMINALITY, AND INFORMALITY

It is important to understand the difference between (il)legal and (in)formal as well as legalization and formalization.

- **Illegal ASM** refers to the legal regulatory framework for the mining sector. In most countries, ASM is regulated under specific permits and licenses. Illegal ASM refers to operators who mine without a license or permit and/or in forbidden areas as identified by the law. Examples include the concessions of LSM or in nature reserves. A subset of illegal ASM is criminal ASM which is directly or indirectly controlled by criminal networks and organizations.
- **Informal ASM** refers to the status of the sector in relation to social and cultural norms. Informal ASM operations may lack licenses, but they may have a strong 'social license to operate' through local social and cultural norms – often even stronger than nearby LSM operations. Understanding and engaging with customary landowners is therefore a core part of formalizing ASM, not just facilitating the acquisition of licenses.

Indeed, legalization is narrower than formalization, which entails a **process** of bringing informal income-earning activities and economies into the formal sector through legal, regulatory, and policy frameworks, as well as the extent to which such laws and regulations are successfully activated, implemented, and enforced by the relevant authorities. Formalization includes activation, monitoring and enforcement under the existing regulatory framework as well as enabling those who are confined to informal space, such as marginalized ASM communities, to become legally active (IGF, 2017).

Increasingly the formalization of ASM has become a priority for many (inter)national organizations, nongovernmental organizations (NGOs), and national governments. The objective is to tackle the associated negative social and environmental impacts, allow operators to benefit from legal protection, access support services and provide decent working conditions, and enable the sector to contribute to sustainable development. However, in most countries the formalization of ASM presents many challenges including a general lack of commitment by governments and partners to grant ASM its legitimate place (World Bank, 2021).

In many countries, ASM legislation is simply added to existing mineral governance frameworks originally designed for LSM and to prioritize LSM investment. Consequently, the poverty-dimension of most ASM operators is often overlooked, resulting in the design and implementation of an inappropriate mineral governance framework for ASM. This can manifest itself in overly expensive and complicated licensing procedures, excessive bureaucracy, lack of geologically viable land for ASM and a lack of access to formal finance, equipment, and training. In many countries, illegal and informal ASM operators who want to become legal experience difficulties in entering the formal economy because of these challenges. In order to streamline formalization processes for ASM across mineral-rich countries, these entry barriers need to be removed and ASM communities should be assisted and supported to become legally active (Hilson & McQuilken, 2014; IGF, 2017).

For ASM to "promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all" (Sustainable Development Goal [SDG] 8), the World Bank (2021) outlines six key reflections:

- Investment in health and safety are urgently needed for ASM, since improved occupational health and safety (OHS) is a collective responsibility which is feasible and beneficial to all;
- Better data on ASM's economic contributions through improved national statistics can prove the value of ASM to national and global growth;
- Targeted interventions in relevant areas can help to improve miners' lives and improve their pay, health, and well-being;
- Engaging the socio-economic network of actors involved in ASM can help overcome entrenched behaviors and change labor practices which continue to undermine OHS advancement in the sector;
- Concerted partnerships with ASM associations advance the decent work agenda; and
- Focusing on women's work in ASM is essential to the goal of decent work for all.

1.3.6 MINERAL VALUE CHAIN

Mineral value chains are characterized by often commodity-specific overlapping and interconnected relationships and multiple intermediaries between each stage. In general, transformation of raw minerals into marketable products can be divided into four steps (Extractives Hub, n.d.):

(i) extraction and concentration (upstream)

(ii) processing into a bulk commodity or an intermediate good such as a metal alloy (upstream/midstream[10])

(iii) conversion into a refined product, ready for purchase by industries and (midstream)

(iv) manufacturing of end product(s) that can reach consumers (downstream)

This process often entails multiples changes of location, technology and ownership depending on the material mined and its end uses. Specific ecosystems may be created due to interlinkages between metals during smelting,[11] refining and recycling during which different co-occurring metals are separated and extracted as long as their market value outweighs the cost (Wyns and Khandekar, 2019). For example, tellurium is extracted during the smelting of copper or iron; whether it is recovered in addition to the primary metal depends on the additional cost of separation and market price.

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[10] Depends on if the miner is also doing processing at the mine or if unprocessed ore is shipped elsewhere for smelting.

[11] Smelting refers to a generally heat-driven process to transform a raw mineral ore into another intermediary or final metal or mineral, whereas refining refers to a gradual removal of impurities from a single metal or mineral.

Key actors upstream and midstream in the value chain include mining operators who are involved in extraction, concentration and some level of processing, traders and exporters, mineral re-processors and smelters and refiners. Midstream and downstream companies include traders and brokers who provide hedging and stability for downstream component manufacturers (like batteries) as well as end-product manufacturers and retailers. China dominates the midstream for many minerals (see Box 3).

Box 3. Rare earth elements – Chinese monopoly and the importance of midstream

In recent years, China's share of global rare earth mine production has fallen slightly as a handful of new rare earth mines, in Burma for example, have come on stream. However, its share of midstream and downstream capacity to convert rare earth mine outputs into oxides, metals, alloys, and magnets has grown.

In 2011 there were about 100 companies working on the separation, smelting, and refining of rare earth elements in China. The industry subsequently underwent significant consolidation at the government's initiative. Companies were often forcibly merged or closed, and the government imposed strict regulations requiring technology upgrading and the reduction of environmental impacts. However, extracting specific rare earths from ores remains technically complicated, power-intensive and a source of significant and dangerous waste.

For a producer bringing online a new rare earth mine outside of China in the coming years, there is a high probability that rare earth mine outputs are going to flow through China's value chain, leaving the producer (and its investors and the host government) subject to a higher degree of opacity and uncertainty. Rare earths show that until other countries invest in processing capacity, increasing control over mines will not reduce supply chain vulnerability due to China's dominant position in the midstream.

The most prominent metal exchanges that provide price stability through hedging and future markets are the London Metals Exchange (LME), the New York Mercantile Commodity Exchange (NYMEX-COMEX), Hong Kong Mercantile Exchange (HKMEx) and the Shanghai Futures Exchange (SHFE) for non-ferrous metals. For non-ferrous metals, the LME remains the predominant player, connecting market participants including upstream companies (miners, smelters, and refiners), metal consumers such as industrial manufacturers, merchants and physical traders, banks, financial funds and commodity trading advisers, proprietary traders and brokers and clearing institutions.

A distinguishing characteristic of these metals is that no single company can fix the price of its own products independently: one ton of metal of a standard quality from any individual plant can be replaced by material of a similar quality from another. The LME settlement price is therefore a reflection of market expectations based on demand and supply (including stockpiles). LME prices are therefore the reference for the global industry. This also means that producers cannot pass additional costs related to performance (such as EU regulatory costs) to customers without losing market share because of competition from actors (such as those in China) that receive state support and have different regulations (Wyns and Khandekar, 2019).

In the context of developing countries and emerging markets, accurate pricing is important as it helps determine royalties and other revenue-based taxes. However, despite international benchmarks pricing is not always straightforward as many minerals are not traded on LME and other public platforms. In addition, adjustments off benchmark prices are made based on quality or grade, deductions for transportation and insurance as well as related party sales, i.e., when a subsidiary sells to a parent company.

This is increasingly the case where downstream actors are full or part owners of upstream mines. While vertical integration is not new—with major companies often taking positions in downstream processing companies for metals like aluminum, copper, and zinc—but more recently users of battery metals are going to source and investing in mining. This is often linked to downstream requirements to improve supply chain transparency and thus their own environmental, social, and governance (ESG) performance, reduce exposure to price volatility and/or position competitively for strategic supply security (S&P Global Platts, 2021; L.E.K. Consulting, 2019).

This trend could increase the number and volume of related-party transactions involving producers of these minerals, thus increasing risks of undervaluation of mine production for tax evasion or profit shifting particularly if the mine and its related parties are part of a private, or state-owned group, rather than a publicly listed company. Private ownership results in a lack of public reporting and compliance requirements, such as those noted at the outset of Section 1.3. Transparency initiatives will therefore be ever more important for the green energy minerals.

1.3.7 KEY TRENDS

Despite COVID-19, 2020 was a good year for the commodities sector and mining equities. After its initial shock, the mining sector benefitted from the rebound in global economic activity and stimulus packages. China has led the recovery, but government and central bank stimulus packages have helped. Notably, COVID-19 impacted both demand and supply; mining assets could not operate at full capacity. Consequently, inventories have been low and tight supply for most mining companies has boosted prices (Blackrock World Mining Trust PLC, 2021).

Although there is strong optimism for metals and minerals, and the mining sector producing them, there is also increasing pressure to improve societal outcomes. This will require balance between the need for minerals for green technologies and mining's environmental and social performance.

THE NEW (SUPER)CYCLE ?

In 2020 and 2021 the sector has seen a significant increase in demand as governments begin vast infrastructure investment programs as well as expectations of market recovery. Mining companies themselves are in good health, with strong balance sheets and buoyant margins. This is leading to belief by analysts that an up-cycle is beginning. However, key risks remain: the end of COVID-19 and the dependance of global recovery on the success of the vaccine rollout, but also any escalation in the trade war between the US and China which would likely have a dampening effect on global growth.

Sector stakeholders and analysts believe the mining cycle is still growing, with little risk of over-supply. Four key elements drive the performance of both commodities and the mining sector as a whole:

- **Underinvestment:** Global capital expenditure for the mining sector peaked in 2012 and almost halved in the intervening years. It takes a long time to reverse the tide – find economic deposits, finance the project, and finally develop them into producing mines. In addition, the increased permitting burden has only added time to the development process for new supply.
- **Synchronized infrastructure spending:** Investments across major economies including China, the US, UK and Europe, with a focus on green technology, renewables and investment into the grid, will create long-term demand for strategic and critical metals and minerals.
- **Inflation:** Should the low interest rate environment, combined with excess savings and the US Federal Reserve Bank's tolerance for sustain higher average inflation, this will prove positive for commodity prices and mining equities more widely.
- **Net zero targets**: One of the key announcements in 2020 was China's plan to become net zero by 2060, which is likely to drive a key part of its fixed asset investment over the next few years with capital directed toward renewables, solar, electric vehicle, and grid investment. Copper is one of the commodities likely to see a material pickup from the demand this creates,

as well as battery materials, such as nickel, cobalt, lithium, and rare earths, particularly in combination with the lack of supply growth (Blackrock World Mining Trust PLC, 2021).

This positive metals-price outlook, coupled with the persistent lack of project pipeline investment which is leading many metals toward market deficits over the next several years, should in turn stimulate an increase in exploration expenditure. Over the past few years, the mining industry has changed its focus from greenfield exploration (new sites) to brownfield (old or existing) mines. The shift is led by junior companies who opt to spend scarce funding on proven assets while major companies focus on maximizing value at their existing mines.

This trend has been reflected in consistently lower numbers of initial resource announcements over the past several years. Observers and policymakers have raised red flags over negative impacts to future production from the lack of grassroots exploration, spurring some governments to address the issue through incentive programs. Although these trends have not yet appeared to affect current production levels, explorers and producers could be forced to refocus on finding new discoveries at grassroots projects over the coming years, as metal prices are forecast to rise while the project pipeline narrows. Until that shift, we will likely see the current focus on existing assets over the medium term (S&P Global Market Intelligence, 2021b).

ESG parameters have risen to the fore in mining over the last few years. COVID-19 accelerated this trend as consumers and producers increased their focus on social performance and the risk management and resilience aspects of governance. The ecosystem of stakeholders is driving change with increasing expectations, all of which converge around mining's impact – positive and negative. With a plethora of standards, frameworks and initiatives, exploration and mining companies are scrambling to adapt to sometimes uncertain and conflicting expectations. Extractives are at the center of much of the debate about balancing sustainability constraints, requirements, and opportunities, which is spreading to other industries, from textile to agribusiness. This aligns with wider societal trends focused on tackling global challenges around climate, ecosystem destruction and inequalities.

One of the most effective tools to "cut through the noise," understand ESG stakes for mining, and assess the reality of their integration is the Responsible Mining Foundation's **Responsible Mining Index** (RMI).[12] The index is an evidence-based assessment of the economic, environmental, social and governance policies and practices of 38 large-scale mining companies that operate in more than 780 mine sites and together account for 28% of the world's mining activity by value of production.

This methodology provides an analysis **tool**[13] for sound practices that differentiates three types of indicators: commitment (statements and policies), action (measures to maximize potential benefits and/or avoid, minimize, or mitigate negative impacts) and effectiveness (monitoring and improving outcomes). Although showing some progress since the first publication in 2018, the RMI Report 2020 highlights three important observations (Responsible Mining Foundation, 2020):

1. Significant gaps remain with respect to societal expectations, even in the performance of the best-scoring companies, and stronger efforts are required by all companies to ensure their practices are managed effectively.

2. Though companies are increasingly aligning their sustainability reporting with the Sustainable Development Goals (SDGs), their selective reporting risks "SDG-washing" as it generally omits any mention of negative impacts potentially impeding SDG achievement.

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[12] For further reading, see Responsible Mining Foundation, Responsible Mining Index (RMI) Framework, Methodology and Report 2020 (link)

[13] The RMI Framework maps to 50 international initiatives, standards or guidelines related to responsible mining or corporate accountability (link)

3. External requirements drive performance, with more transparent companies generally subject to specific requirements set by investors, producing country or home country governments or actors further down in the mineral value chain.

This global drive for sustainability in mining could materialize in several ways, including focus on:

- **Decarbonization**. Amid growing demands to reduce climate impact, mining companies will need to move past risk identification and mitigation to execute their decarbonization agenda. This is a critical area for companies to meet environmental mandates to reduce greenhouse gas emissions and win back the trust of investors (Deloitte Insights, 2021).
- **Positive social legacy.** For decades companies have tried to achieve social performance through investment in corporate social responsibility initiatives yet struggle to earn community trust. Companies will need to collaborate with stakeholders to redefine the concept of "value" beyond the financial, tax, or royalty paradigm, avoid repetition of past failures of philanthropic funds which lacked strategic focus on a sustainable legacy and overturn deep-seated and largely negative perceptions of mining. The stakes for miners are high: tumultuous stakeholder relations can spill over into community protests, anti-mining campaigns and dramatic changes in regulatory regimes, effectively revoking their license to operate.
- **Sustainability in company governance**. Corporate governance actions are a tool for the integration of stakeholder interests and sustainability concerns, serving both to protect against downside risk (e.g., regulatory, reputational) and improve companies' competitive advantage vis-à-vis various stakeholders including investors, host governments, communities and even workers. Mining management and boards will be expected to strengthen their governance processes, particularly around rapidly shifting issues that have only recently begun to make their way onto corporate agendas: human rights, ethical conduct, cybersecurity, and diversity.

While the above will remain major topics of discussion in mining circles, not all companies will engage equally on these issues. Indeed, those that do and those that do not will become a major division as well as a front for strategic competition, including with China.

STRATEGIC COMPETITION IN MINING INVESTMENT

Chinese mining companies have played an increasing role in international mining investment, although Chinese overseas exploration budgets have fallen, in line with global trends. Most decline was in Canada, Southeast Asia, and Australia, whereas Chinese exploration budgets in Africa and Latin America over the past decade have been constant or increased. This reflects shifts in China's general overseas strategy, with more companies preferring to invest in regions where they have had past success and focusing on metals required for China's growth priorities (S&P Global Market Intelligence, 2021).

Mining investment under the Belt and Road Initiative has been mostly funded by state-owned enterprises, but participation by the private sector has grown steadily. The charge was led by Zijin Mining Group Co. Ltd., which has been growing its overseas footprint in the last decade and currently has the most foreign mining assets of any Chinese company (46 in total). Zijin's positive experience in frontier locations is likely to boost confidence among other Chinese companies.

Zijin and other state-owned companies with clear ambitions to become major actors on the international mining scene, including China Moly, MMG and CITIC, have built on their experiences from mining and trading in China and gradually learnt from activities overseas since the early 2000s. They have been under watch from Beijing but have also attracted international capital to build their businesses and are forced to adhere to international operational standards. They are also under scrutiny by international NGOs and are likely to soon become equal in terms of skills with the traditional transnational companies in both mining and engineering (Ericsson et al., 2020).

In addition, steel companies primarily interested in securing their supply of iron ore were among the first Chinese overseas investors in mining and have in general been more successful than many other Chinese ventures. They are financially robust and have strong State backing, often have mining experiences of their own and have left management to the other joint-venture partners (Ericsson et al., 2020).

Looking ahead, China will continue to invest in mining to secure its resource base. China's structural deficit in key minerals such as iron ore, copper and uranium will likely drive a revived strategy of securing direct access to mines in emerging markets, Sub-Saharan Africa, Central Asia and South America, as diplomatic relations between China and developed markets deteriorate. Diversifying away from Australia will be particularly appealing given that the country accounted for around 40% of China's total mining imports in 2019. However, China's slowing real GDP growth rates will limit the acceleration of outward mining investments despite more positive commodity prices in the coming years. This is due to a challenging macroeconomic environment, ongoing crackdown on privately held debt and capital outflows, and an increasingly onerous debt load limiting the amount of credit available to fund future investment and growth while increasing the burden of interest payments (Fitch Solutions, 2020).

1.3.8 MINING GOVERNANCE STANDARDS AND PLATFORMS

The governance landscape in which exploration and mining operate has become complex, with different layers of binding standards (laws and regulations), frameworks (reporting parameters), standards (disclosure requirements), and guidelines (voluntary recommendations) and self-regulatory instruments (policies and practices). While ESG information gathering has increased in the past decade, many ESG standards are recent, and coalesce around the principles of accountability, transparency, sustainability, and fairness. The proliferation of requirements and standards is a challenge for many companies.

Although some of these trends and standards are not specific to mining, the sector's diversity of interests and global reach create particular challenges. High levels of interest in ESG have generated a storm of disclosure demands. and led to a rise in using ESG performance by investors and public-facing ESG rating agencies. Data-disclosure exasperation is expressed repeatedly. Mining companies are inundated with data requests from investors, data providers, and downstream manufacturers.

Importantly, as discussed in Section 1.2, external stakeholders are driving the transformation of mining. Mining companies are largely reactive instead of proactive. The industry's lack of cohesive representation and sometimes inadequate internal dialogue may play into this dynamic. Even industry organisations like ICMM struggle to connect to the diversity of operators, leaving a gap filled by intergovernmental and NGOs (World Bank, IGF Mining, NRGI) who drive the agenda. At the national level, miners do not always invest the time and capacity to unify their positions and influence policy.

In many emerging markets in particular, the industry could usefully leverage the existence of mining industry platforms to better inform both government and civil society stakeholders and represent industry demands. A more unified mining sector could even lobby international organizations involved in natural resource policy to address what is sometimes perceived as passing off too much ESG burden onto the mining industry.

1.3.9 STRATEGIC THINKING AROUND MINING AND GREEN ENERGY TRANSITION

A final dynamic important to highlight in this section is the strategic attention being paid to critical minerals and more specifically minerals essential to the green energy transition. This attention is translating into new policies. As discussed in Section 1.3.7, green energy mineral mining is driving commodity market speculation as well as new investments. Several key trends are of note:

- The US government completed a 100-day review of critical supply chains (White House, 2021) which included sections focused on minerals covered in this report such as cobalt and lithium. At present the US Critical Minerals List, while it includes green energy minerals, does not have a specific policy priority around green energy transition minerals. The 100-day review report includes several policy recommendations relevant to this report such as:
  - Improve standards for the extraction and processing of critical minerals (p.14)
  - Identify potential U.S. production and processing locations for critical minerals (p. 15)
  - Support sustainable domestic extraction and refining of lithium (p. 87)
  - Invest in nickel refining in coordination with allies (p. 87)
  - Invest in the development of next generation batteries that reduce or eliminate critical or scarce materials needed for EV or stationary storage, including cobalt and nickel (p.13)

- In comparison, the European Commission's critical raw materials list places an explicit emphasis on raw materials linked to clean energy technologies. This is in the context of the EU Green New Deal as well as preparatory analyses including a "foresight report" projecting mineral needs under a 2050 climate-neutrality scenario as well as a report on the circular economy. The EU also created the European Raw Materials Alliance which is currently focusing on REEs but may expand to secure the supply of other materials.

- China does not have a public and explicit policy around green minerals or critical minerals, but it has invested in shoring up supply routes since the 2000s. As noted in Section 1.3.7 these have included "resources for infrastructure" deals but most investments involve state-owned enterprises or private enterprises accessing state-backed financing. Going forward, China will continue to support its companies as they acquire supplies and invest abroad, though in recent years they are increasingly joining international sourcing standards such as the China Chamber of Commerce of Metals, Minerals and Chemicals Importers & Exporters (CCCMC) developing the Chinese Due Diligence Guidelines for Responsible Mineral Supply Chains based on the OECD.

The key feature of strategic thinking of the US and EU focuses on reducing dependency on adversaries through some collaboration with allies but mainly building as much independence as possible and competing for supplies through markets as needed. This is in a sense an attempt at deglobalizing mineral supply chains. In addition, while investment to find alternatives to "problematic" minerals like cobalt make sense on several levels, the underlying premise that countries can isolate themselves from the consequences of the mineral boom is not realistic. Whether at home or in emerging markets, the increase in mining will have impacts no matter what technological innovation is found.

One risk with this trend is that should public opposition to new mining "at home" in the US and Europe grow, companies and government backers may be pressured to move into emerging markets with a less developed civil society and lower governance standards. The competition for resources in these countries by actors who are not on the same level playing field with respect to standards could also open the door to furthering lowering of performance.

A bulwark against this will be a combination of coherent standards and pressure by activists and investors on public companies operating in these contexts, as well as efforts by government and civil society in these emerging markets to monitor and control mining practices and mining development. Nevertheless, unscrupulous actors may find ways to sidestep accountability by operating as private companies not subject to public scrutiny or reporting standards, for example.

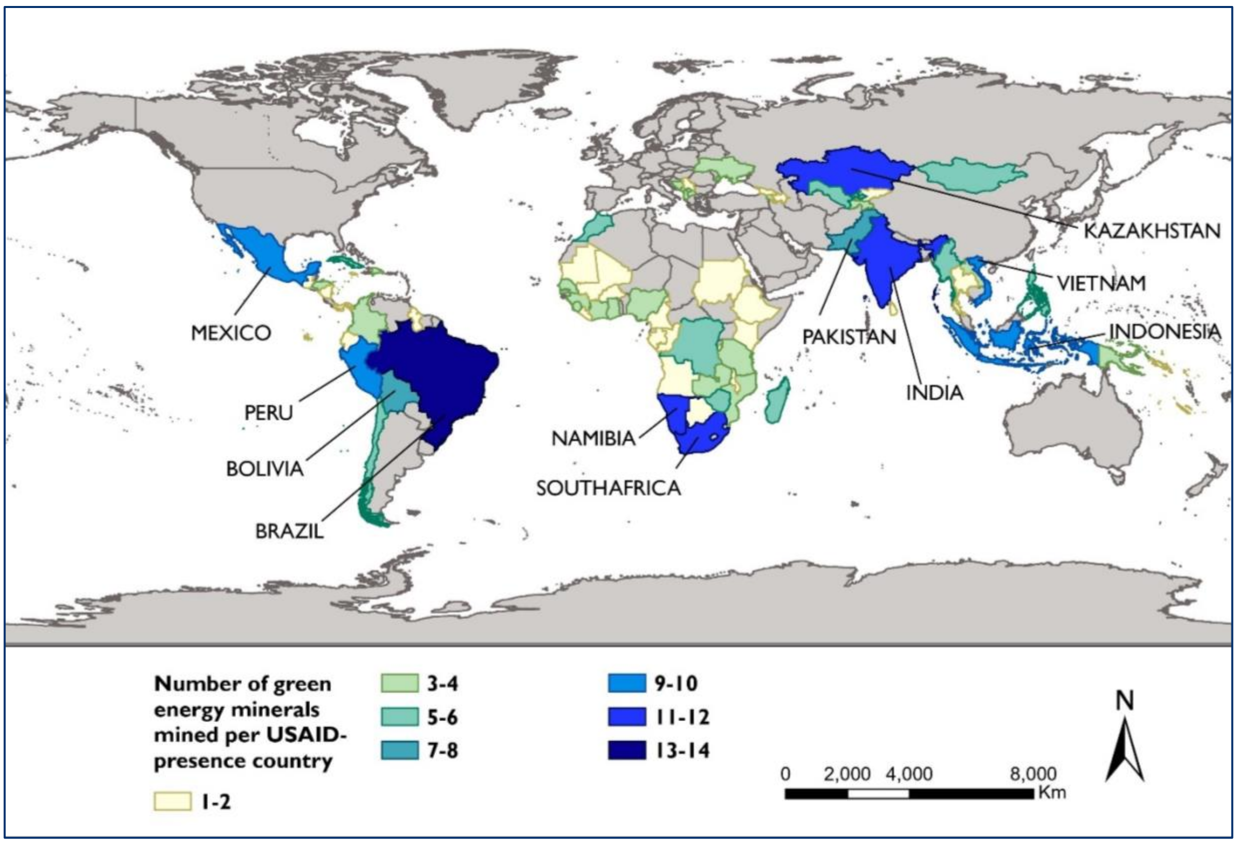
In summary, the combination of industry trends as well as policy choices around critical minerals sets up many developing countries for a time of opportunity but also risk as high mineral prices and geopolitical competition will put pressure on already fragile governance contexts. While competition over these resources may be difficult to tamp down, coordination and collaboration over performance standards and addressing development challenges is vital and in the interests of all, including development partners like USAID.

1.4 MINING IN USAID-PRESENCE COUNTRIES

Based on a review of publicly available information,[14] 70 USAID-presence countries or limited-presence countries[15] mine at least one of the 16 minerals examined in this report. The full list of USAID-presence or limited-presence countries with associated mining or exploration of the 16 minerals reviewed in this report can be found in Annex 4.

Figure 12 below shows USAID-presence countries ranked by the number of minerals reviewed in this report that they mine. In descending order, the countries with the largest range of minerals are: Brazil (13), South Africa (11), Namibia (11), Kazakhstan (11), India (11), Vietnam (10), Mexico (10), Indonesia (9) and Peru (8).

Figure 12. USAID-presence countries with largest number of green minerals



Source: USGS data / Tetra Tech

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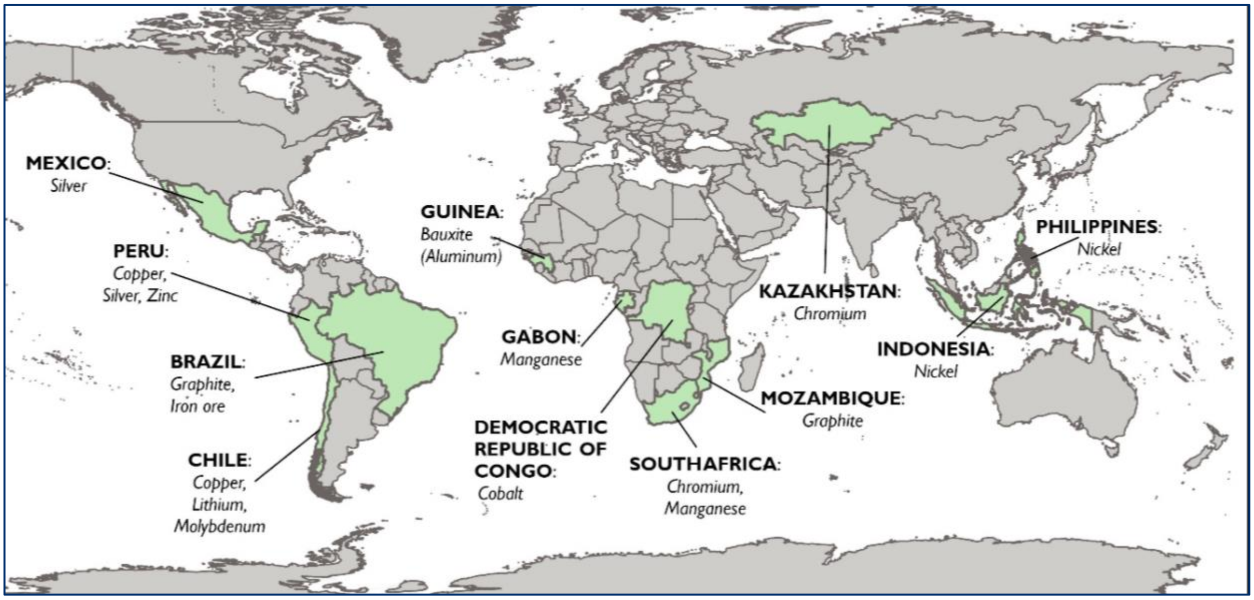
[14] Main data sources where USGS and British Geological Survey. Reports of mining or exploration in certain countries were corroborated by searching credible news and trade media sources.

[15] Limited-presence countries are defined as those without a USAID mission but with some activities managed by regional missions. Limited-presence USAID countries covered by this report are **Chile, Bolivia, Gabon, Papua New Guinea and the Solomon Islands**. For the purposes of this review, **China** was considered a non-presence country even though USAID has some activities managed by the Regional Development Mission for Asia based in Thailand.

However, the above does not consider countries that are major producers of a specific mineral. Figure 13 below shows USAID-presence countries that occupy the number one or number two position among all producers worldwide, including non-USAID countries. The fact sheets in Annex 1 also note the percentage of world production accounted for by top producers, including those that are USAID-presence.

Figure 13. Top USAID-presence producers of green energy minerals



Source: USGS data / Tetra Tech

The review also considered widely cited governance indices of these top producers of key minerals, mainly, the Natural Resource Governance Index (NRGI) when scored for mining (NRGI, 2021), Transparency International's 2020 Corruption Perception Index, the 2021 Fragile States Index, and the 2020 Human Development Index (HDI). Countries in the lowest quartile are highlighted in red.

Table 3. Governance and development indices for top USAID-presence mineral producers

TOP USAID-PRESENCE PRODUCERS	NRGI SCORE (/100)	CORRUPTION PERCEPTION RANK (/180)	FRAGILE STATES RANK (/179)	HDI RANK (/189)
Brazil	N/A	94	70	84
Chile (limited presence)	81	25	144	43
DRC	33	**170**	**5**	**175**
Gabon	N/A	129	101	119
Guinea	62	**137**	**14**	**178**
Indonesia	68	102	99	107
Kazakhstan	N/A	94	116	51
Mexico	60	124	90	74
Mozambique	N/A	**149**	**22**	**181**
Peru	75	94	85	79
Philippines	58	115	49	107
South Africa	57	69	89	114

2.0 DEVELOPMENT CHALLENGES

While mineral wealth can contribute to public revenue and direct and indirect employment opportunities in the mining sector and associated industries, the sudden increase in demand for certain minerals can unleash several environmental, resource governance, and societal challenges. Most of these challenges are not new, including those related to governance (Section 2.1), environment (Section 2.2), conflict and human rights abuses (Section 2.3), labor and working conditions (Section 2.4) and national and local development (Section 2.5). These challenges and how they are articulated in the focus minerals of this review are covered in the sections below. Importantly, a failure to address these challenges could lead to supply disruptions of the respective minerals and consequently slow down the pace of the green energy transition (IEA, 2021, p. 192).

2.1 GOVERNANCE

If harnessed properly, mineral wealth could deliver lasting development in a group of countries that have long occupied the bottom of the UN's Human Development Index (UNDP, 2016). Increasing demand for energy transition minerals can increase public revenue, contribute to sustainable economic growth, and benefit national governments, companies, and communities. The central role of a government to manage these funds responsibly therefore plays an important role whether the mineral wealth brings social and economic benefits to a country (NRGI, 2015).

Many mineral-rich countries, however, have experienced a "resource curse": they fail to benefit from their mineral wealth for a variety of reasons, including corruption, rent-seeking behavior by a national government, weak institutions, and a tendency to become or remain authoritarian (NRGI, 2015). These problems are more common in countries over-dependent on revenues generated by the export of mineral production, such as Guinea, Suriname, DRC, and Zambia (UNCTAD, 2019). Many countries that are dependent on revenues generated from minerals can be found at the bottom of the UN's Human Development Index, underscoring the need for transparent mineral wealth management especially as they represent significant portions of the fiscal revenue of a national government. In Chile, for example, revenue from copper production averaged around 10% of the fiscal revenue between 2010 and 2019 (COCHILCO, 2020).

Box 4. Corruption in the Guinean mining sector

On January 22, 2021, Israeli mining tycoon Benny Steinmetz was found guilty of corrupting foreign agents and forging documents and sentenced to five years in jail by a Geneva court. The trial has been described as the mining sector's biggest-ever corruption case and centered on alleged payouts of $8.5 million to Mamadie Touré, a former wife of late president Lansana Conte of Guinea to secure rights to the country's Simandou iron-ore mine. The Simandou Mountain range is the world's largest known deposit of untapped iron ore.

The case is from 2006 when, according to the prosecution, Steinmetz's company paid bribes in exchange for mining rights in Simandou. These had originally been held by mining major Rio Tinto. Steinmetz was found guilty of setting up elaborate schemes to hide the link between his company and Conté's fourth wife. The prosecution presented a trail of bribery and corruption stretching from Geneva, via Liechtenstein, to the Virgin Islands.

The case not only highlights the risks of little control over financial practices in the mining industry in countries with governance shortcomings, but is also illustrative of its consequences. Whilst business and their shareholders have made millions trading Guinean mining rights, Agathe Duparc of Swiss NGO Public Eye explains that "the people of Guinea themselves have got precisely nothing and the iron ore deposits […] lie untouched, the Simandou region undeveloped and lacking in investment" (Foulkes, 2021, January 22).

Additionally, the rent-seeking behavior by national governments to secure control of national resources can manifest itself in a prioritization of LSM over ASM. This so-called "LSM bias" can lead to the design of a legal and regulatory framework that does not differentiate between LSM and ASM; land occupation by LSM leaving little geologically viable zones for ASM; and excessive bureaucracy and costs for ASM, leaving most ASM activities informal or illegal and outside the control of government (Hilson, 2019; Sauerwein, 2020).

In other cases, corrupt public officials subvert entrusted power over resources for private gain. An OECD survey highlights the fact that that almost 20% of bribery cases occurred in the extractive sector, a category that includes oil and gas production as well as mining (OECD, 2014). Additionally, countries where energy transition minerals are produced score below average in measures of perceived corruption risk (IEA, 2021, p. 230). This has been reported for minerals needed for a shift towards green economy, such as the cobalt industry in DRC marred in both the LSM and ASM sectors by corruption, money laundering, tax evasion and fraudulent misrepresentation of the origin of the mineral. Corruption, bribery allegations and risk of arbitrary license revocation has been reported in the iron mining sector in Guinea and the Republic of Congo (see text box on previous page). Corruption has also been highlighted as an issue in the nickel mining industry in Burma and Zimbabwe, and the chromium industry in South Africa.

Mining in countries with low governance scores present additional risks related to money laundering and the finance of terrorism, tax evasion, transnational organized crime, and fraudulent misrepresentation of minerals. These challenges are more substantial where regulatory safeguards are inadequate and systemic governance issues persist, such as in ASM (IEA, 2021, p. 192). Around 10-15% of copper, lithium, and cobalt production and almost half of nickel production in 2019 came from regions with low governance scores (IEA, 2021, p. 131).

Besides general governance challenges related to mining, there are also technical capacity gaps with respect to mineral governance. For example, mining officials may be experienced in a mineral they have mined for decades but less familiar with project life cycles and other dynamics around minerals new for that country. This could lead to suboptimal mining conventions or difficulties in tax recovery because of lack of capacity for that specific mineral. Environmental officers may also lack capacity to ensure that best practices are implemented when it comes to mine closure and land reclamation.

Other mining governance technical problems include lack of data management and mining cadasters. Additionally, many countries experience problems with coordination and information-sharing. Many mineral agencies lack high quality and up-to-date geological data because of under-investment in research, poor record management and lack of technical expertise and/or staff. Finally, many mineral rich countries lack sufficient disclosure of public data around licensing and beneficial ownership limiting transparency and accountability in the sector. Without sufficient capacity and functioning institutions, mineral management systems may be designed well on paper but not implemented well in practice.

2.2 ENVIRONMENT

In both ASM and LSM, mining's inherently disruptive nature almost inevitably results in a significant environmental footprint. Common environmental impacts of mining include deforestation and degradation of land; air pollution from mine dust; noise pollution due to blasting and transporting activities; soil contamination; and erosion and other forms of land degradation (Bian et al., 2009; Edwards et al., 2014; Hilson, 2002; Kitula, 2006; Ogola et al., 2002; UN Environment, 2017). All issues have been documented in DRC's cobalt sector, for example (Sovacool, 2019). Biodiversity loss and the destruction of natural habitats through mines and disposal sites is observed across a wide range of minerals, such as bauxite mining in Ghana and the Solomon Islands (Gbadamosi, 2020). Also, the contamination of drinking water and water used for agriculture and its related impacts on surrounding communities is a common impact of mining, such as mercury contamination by ASM (Tschakert & Singha 2007), unsafe levels of lead and uranium concentrated due to titanium or lead extraction (Obiora et al., 2019; Reid, 2019) or as a result of manganese mining in India (Goswami et al., 2009).

Environmental impacts related to LSM include acid mine drainage and risks associated with tailings, such as contamination of downstream water bodies and potential dam failure (Aryee et al., 2003). For example, the processing of lateritic deposits for nickel mining in Southeast Asia and Africa and Madagascar require acid leaching and deep-sea tailings disposal. This poses problems for marine ecosystems (Morse, 2020). Due to the leaching process, the production of hard-rock lithium such as that produced in Australia involves the highest risks of environmental pollution although the brine lithium in Chile brings negative hydrological effects (Jiang et al., 2020).

Box 5. Water stress and mining in northern Chile

Chile was the world's largest copper producer and the second largest lithium producer in 2020. Most of these minerals are mined in the region of Antofagasta and the Atacama Desert; one of the driest places on earth. Lithium and copper are vulnerable to water stress as 50 percent of today's lithium production is concentrated in areas with high water stress and 80% of copper output in Chile is produced in mines located in high water stress and arid areas (IEA, 2021, 131).

The mining industry in the Antofagasta region is the largest consumer of water in the region (Aitken et al., 2016). Water is mainly used for dust control and extraction, separation, and transport of ore, but can also potentially contaminate the scarce water resources due to acid mine drainage, dewatering and the disposal of tailing. Most water sources are located in high conservation value areas or territories claimed by indigenous communities increasing competition for water resources that is threatening the subsistence of living systems in this part of Chile (Romero et al., 2012).

The government has focused on improving legislation to address water stress but faces capacity constraints such as inadequate monitoring and enforcement, often leading to the over-allocation of water use rights. In addition, watershed management approaches are not implemented. The result is that many water sources are overexploited, highlighting the need for early-stage adoption of water management strategies in the context of mining in water-stressed areas (IEA, 2020, p. 218).

These impacts and risks can vary depending on the mineral and associated extraction method. The main challenge for environmental impact is to minimize the impact while maximizing the contribution to sustainable development. There are, however, several impacts specific to the 17 minerals needed for green energy.

Significant greenhouse gas emissions (GHG) arise from energy intensive mining and processing activities. While these emissions do not negate the climate advantages of clean energy technologies, energy transition minerals involve higher GHG emission intensities compared to other minerals, particularly the mining and processing of neodymium oxide, cobalt sulfate, aluminum, nickel, and lithium carbonate (IEA, 2020, p. 195). For example, the production of aluminum accounts for about 1% of global GHG emissions (Holmberg et al., 2017, Paraskevas et al., 2016). However, emissions intensity can vary significantly depending on operational practices, power sources, and production pathways. Emissions cause challenges such as energy supply disruptions in the South African ferrochrome market and the dependency of nickel processing in Indonesia on coal power. GHG levels can be significantly reduced by fuel switching, low-carbon electricity, and investment in energy efficiency (IEA, 2020). However, GHG emissions from mining and smelting is a broader problem than the minerals covered in this study. For example, steel production currently accounts for nearly 7–9 percent of total GHG emissions worldwide; cement production is also a major contributor of GHG (Hund et al., 2020, p. 97).

Water stress is another environmental issue that is prevalent in many green mineral extraction processes. Many energy transition minerals have high water requirements and are in areas that experience more frequent drought events, underling the importance of sustainable water sourcing (IEA 2021, 128). Lithium and copper are vulnerable to water stress as 50% of today's lithium production is concentrated in areas with high water stress and 80% of copper output in Chile is produced in mines located in high water stress and arid areas (see box) (IEA, 2021, p. 131). In 2019, severe droughts impacted mining operations in Chile, Australia, and Zambia (CRU, 2020). Climate risks present additional environmental risks through extreme heat and flooding. Flooding can lead to hazardous mine waste spilling and tailings dam failure. Mining producing regions such as Australia, China, and Africa are particularly vulnerable to climate risks (IEA, 2021, 131).

As a result of declining resource quality, the production and processing of minerals involve increasingly higher emissions and energy-intensive processing. This is particularly relevant to green energy minerals many of which occur in low concentrations in their ores and therefore require heavy processing. For example, the metal content in iron ore is typically 50-70%, where the average ore grade for nickel is less than 2% and under 1% for copper. Consequently, mining companies need to process much more material, resulting in higher energy consumption levels and more mining waste (IEA, 2021, 197). For example, in Chile the average ore grade for copper declined from 1.25% in 2001 to 0.65% in 2017 and electricity consumption per unit of mined copper increased by 130% and 32% respectively over the same period (Azadi et al., 2020).

2.3 CONFLICT AND HUMAN RIGHTS ABUSES

Many conflicts related to mining, whether ASM or LSM, are land related. In terms of land use, mining affects up to 50 million square kilometers of Earth's surface, with 8% coinciding with protected areas, 7% with key biodiversity areas, and 16% with remaining wilderness; 82% of these mining areas target minerals needed for renewable energy production (Sonter et al., 2020). It is estimated that of the total terrestrial land surface between 0.3-1% is disturbed by mining activities (Tost et al., 2018). Depending on the type of mining and minerals produced, the land use change can be significant. For example, open-pit mines and ASM can cover several kilometers and therefore drastically change a landscape.

This land use can disrupt the activities of local communities by displacing villages or creating long-term loss of agricultural land. Underground mining covers less land surface, but still occupies land for the processing, waste management, and transport of the extracted minerals. Comparing different types of copper mining with respect to land use occupation, a study showed that open-pit mining in Indonesia occupied the most space, and underground mining in a Chilean desert the least (Murakami et al., 2020). Declining ore grades, as described in Section 3.2, also lead to increased land occupation by the mining industry (IEA, 2021, p. 210). Additionally, mining can cause spill-over effects in local communities, such as increased urbanization and inflation of local prices. This is particularly disruptive for more rush-type migration related to certain ASM activities.

Land use change and land conflicts can manifest in a range of ways. Some examples are intercommunity conflict, conflict between impacted communities and the mining industry (both LSM and ASM), and conflicts between ASM communities and LSM. Often these conflicts are a consequence of uneven distribution of benefit-sharing, unrealistic expectations by local communities and/or unmet obligations by the mining industry. For example, Rio Tinto's general manager of their mineral sands mine in South Africa was murdered in May 2021 as a result of violent protests by contractors fueled by general insecurity and high unemployment in the province (Mining.com, 2021a).

Conflicts can also arise as a result of different interpretations to 'who owns the land'. This particularly applies to rural land areas where customary land practices prevail over statutory, such as in vast areas of sub-Saharan Africa and Southeast Asia. For example, in Papua New Guinea conflicts between the indigenous population and mining companies result in communal land rights not being protected (Hance, 2010). Additionally, the disappointing levels of social and economic development experienced by the communities most impacted by mining are a cause of conflict between these communities, the mining industry, and national governments. This can be reinforced by a lack of clarity on the compensation for customary land rights holders.

In the context of mine closure, abandoned mines across the world pose multiple hazards ranging from mine shaft collapse to soil contamination and water contamination and can impact communities depending on the land for their livelihoods, such as agriculture. These types of conflicts have been reported across many different mining regions and are not particular to the extraction of a certain mineral (De Jong & Sauerwein, 2021; Gutierrez, 2020; Hilson, 2002 and 2016; Hilson et al., 2020; Maconachie, 2011; Rosales, 2019; Rugadya, 2020; Verbrugge, 2016; Verbrugge & Geenen, 2019).

Mining regions with low governance scores present additional risks related to armed conflict financing, modern slavery, human trafficking, and human rights abuses. These risks can be particularly profound in CAHRAs because of "the presence of armed conflict, widespread violence or other risks of harm to people" (OECD, 2019).[16]

The financing of conflict has been mainly reported for the mining of precious minerals and stones such as jade, gold and diamonds in countries such as Burma, DRC, Liberia, Sierra Leone, and Venezuela (Le Billon, 2013; Rosales 2019; Global Witness 2013, 2015). The ASM sector is particularly vulnerable to these risks. For example, men, women, and children in ASM zones in the eastern DRC operate in conditions of slavery through forced labor, often at the hands of military groups (Haider, 2017). Additional forms of modern slavery that have been reported for the mining industry in the DRC include debt bondage and sex slavery. Debt bondage characterizes some informal financing arrangements in ASM. Sex slavery has been reported for Congolese women in mining areas turning to prostitution to meet basic needs under false promises of financial support (Haider, 2017).

Human rights abuses in the mining sector have been reported across numerous countries and different types of operations. Amnesty International has highlighted human rights violations and abuses in the DRC for both LSM and ASM, including forced evictions of communities from mine sites and violations of the rights of artisanal miners. In the DRC, mine security of different mining companies operated without any adequate legal safeguards in place to prevent abuse. In South Africa 34 protesters were killed and at least 70 injured by members of the South African Police Service during a mining strike in August 2012. Protesters were on strike after a mining company failed to improve worker's living conditions. In Mozambique, a Chinese mining operation contributed significantly to a flash flood destroying 48 homes of a nearby community (Amnesty International, 2013 and 2020; Human Rights Watch, 2010; Global Witness, 2021; Truthout, 2015). While these issues have been more widely

Box 6. Human rights abuses by mining security forces

Human rights abuses by military and private security forces of mining companies are a recuring problem and reported across many different countries. In Zimbabwe police and private security guards hired by mining companies in the Marange diamonds fields have been shooting, beating, and unleashing attack dogs on local unlicensed miners. Similar human rights abuses have been reported in relation to ASM chromite.

In northern Burma's Kachin state, the control of jade mines by armed groups and Burma's military forces lies at the heart of a vicious circle of exploitation and conflict that has ravaged the region for decades. This has increased levels of corruption in the sector and led to destructive mining practices. REE and lead/zinc are mined in this area as well.

In Peru public-private partnerships between the National Police and mining companies have been found to result in repressive violence and are deemed unconstitutional and a conflict of interest between social well-being and private interest. A department of the Peruvian National Police was caught on video planting a weapon on a protestor during a protest against the Tia Maria copper mine. After detaining and torturing the protestor, the case was framed by the police as an armed attack of a protestor to justify the repression.

[16] Although the CAHRA list includes countries, it is important to note that conflict-affected and high-risk areas are often subnational and should therefore not lead to the exclusion of entire countries from supply chains. To illustrate, whilst Mozambique features as a CAHRA only the Cabo Delgado region presents increased risks.

reported and are perhaps more prevalent in the precious metals and minerals sectors, they remain of concern for green energy minerals as well.

2.4 LABOR AND WORKING CONDITIONS

Many development challenges relate to labor and working conditions in the mining sector, including child labor, occupational health and safety, and gender. These issues are not specific to energy transition minerals but apply to mining in general. However, certain challenges are more prevalent in the LSM sector (e.g., gender inequality) and others in the ASM sector (e.g., child labor).

The LSM sector operates under strict health and safety standards to avoid accidents that may incur costs from lost productivity, civil liability, and damage to public relations. The degree of performance depends on the existence of adequate laws and regulations, stakeholder pressure, investor pressure, integrated occupational health and safety management rules and organizational culture (Chen & Zorigt, 2013). However, in cases of large-scale risks and lack of investor pressure, the mining industry may not be capable of self-regulating all types of safety risk. For example, weak enforcement may have played a role in the tailings dam collapses of Vale's iron ore mine near Brumadinho in Brazil, killing over 270 people in 2019 as a result of an enormous wave of mud that stretched over 10km covering multiple villages (Watson, 2020). Private and Chinese companies that are not subject to investor pressure might be particularly prone to these risks.

For its part, the largely informal state of the ASM sector across many different minerals in developing countries amplifies risks related to child labor and occupational health and safety. This is due to a lack of monitoring by national governments and the connection of ASM to poverty more broadly. With few possibilities to secure formal finance and appropriate equipment, people immersed in the sector often find themselves trapped in a vicious circle of poverty and having little means to address issues related to occupational health and safety as well as child labor.

Box 7. Child labor in the cobalt sector in the DRC

The DRC provided nearly 70% of mined cobalt in 2020, making it by far the most important cobalt producer. Between 15-30% of the global cobalt supply is from DRC's ASM copper-cobalt sector (World Economic Forum, 2019), with an estimated workforce between 60-80,000 miners though these numbers can fluctuate strongly (Pact UK, 2020). Most of the production takes place in a region known as the 'Copper belt' in Southern DRC and northern Zambia.

Numerous reports have highlighted the high levels of child labor in the Congolese cobalt sector. One in four ASM sites observed found children present at the mine site. Most of these children accompanied their parents or worked independently (OECD, 2019). Main tasks included collecting minerals from mine tailings, working in streams and lakes close to the concessions to wash and sort stones and carrying heavy sacks of mineral ore. Most of these children indicate they work in the mines as a result of poverty to support their parents or to be able to pay for school fees (Amnesty International, 2016).

The OECD underscores the weak due diligence practices regarding child labor in the DRC, such as low levels of disclosure, insufficient efforts to put in place child labor risk mitigation plans, an emphasis on livelihoods programming often insensitive to the place of ASM in the economy, and de-risking strategies prompting premature disengagement from ASM without considering their impact on local livelihoods and potential harm to children (OECD, 2019).

According to the International Labor Organization (ILO), child labor in the mining industry is mostly found in ASM with an estimated 1 million children involved (ILO, 2019). While most children either work alongside their parents or are adolescents working independently, the children most vulnerable to abuse tend to be those working for third-party adults (OECD, 2019, p. 37). A survey in the DRC found children present in about 30% of ASM sites visited in the DRC (BGR, 2019).

The ILO considers mining and quarrying as hazardous work and one of the worst forms of child labor (ILO 2019). Disengagement from the sector by the companies as a result of consumer pressure to source ASM-free cobalt in order to mitigate child labor, has shown to, paradoxically, exacerbate the problem. This is because most children work in the sector to provide additional income for their parents. Disengagement from ASM can push people to continue operating in informal spaces, likely rendering ASM working conditions more hazardous (OECD, 2019, p. 39). It therefore illustrates and highlights the need for support for ASM to address these issues, both from a customer, company, government and, most importantly, artisanal miner perspective.

Finally, compared to other industries, gender issues are particularly prevalent in the mining sector, where women have historically been excluded. In the US, only 14% of the mining workforce are women (US BLS, 2021). The issue is more persistent in LSM than ASM, which often provides a safety net for marginalized groups in society, such as women. For example, it is estimated that 30% of the ASM workforce comprises women, with numbers varying significantly per country (Delve, n.d.). However, gender discrimination also exists in ASM, where women are often underpaid for their work. Additionally, they lack access to finance to invest in equipment and are subject to increased risk of sexual and gender-based violence (IEA, 2021, p. 238; IGF, 2018; GIZ, 2020; OECD, 2019).

2.5 NATIONAL AND LOCAL DEVELOPMENT

Many of the most mineral-rich countries are also at the bottom of the UN Human Development Index. For example, Guinea is home to the largest bauxite reserves in the world. Total natural resources tax revenue as a share of the gross domestic product (GDP) were 21.8% in 2017, accounting for 72% of export earnings. However, the country ranks 172 on the UN Human Development Index. Similar statistics apply to mineral export dependent countries such as Botswana, Suriname, DRC, and Zambia (UNCTD, 2021, 101). The disappointing social and economic development experienced in mineral-rich countries is often explained by the lack of linkages between the mineral wealth and the broader economy (Hilson, 2019).

One reason often cited for these low outcomes is that value addition in the supply chain takes place outside the country, making these countries heavily dependent on the export of raw ores whose price fluctuates. Along with low levels of financial transparency and relative low taxes, exported value addition can lead to limited opportunities to translate mineral wealth into economic development. These dynamics are observed in numerous mineral-export dependent countries and increasingly lead to resource nationalism, because citizens question the

Box 8. Challenges of local content policies

Many developing countries struggle to develop a local mine services industry that can compete on the international market and has the confidence of foreign mining companies. This leaves them dependent on the procurement of goods and service of international companies, preventing linkages to develop. Additionally, there is a general lack of in-country skilled labor with a shortage of scientists and engineers in the mining sector globally. Countries like Ghana, Guinea and Tanzania have difficulty competing with more developed mining countries such as Canada and Australia to train engineers and geologist and retain them (Hilson, 2019).

LCPs set standards for hiring nationals but generally do not include the regional dimensions of labor supply. Local communities most impacted by mining often have high expectations that jobs will be created by LSM but struggle to compete with more skilled and better trained nationals from the country's educated, urban community. This can inflame company-community conflicts. ASM as part of LCP remains overlooked even though a well-organized small-scale sector provides more local employment and local spending and investment compared to large-scale mining in many cases.

benefits of foreign LSM. Examples include the mining industry in Chile (Reuters, 2021), Indonesia, Mongolia, and Tanzania (Ganbold & Ali, 2017; Kinyondo & Huggins, 2019; Warburton, 2017). Evidence from Tanzania shows that this could possibly result in a shift of government support towards a more pro-ASM stance and against foreign investment in LSM (Pedersen et al., 2019).

In order to overcome these issues, national governments increasingly implement local content policies (LCPs) to create opportunities for local procurement and employment, although their implementation has generated mixed results (Lebdioui, 2020). At least 49 countries currently apply one form of LCPs (Hilson & Ovadia, 2020). Other measures include the establishment of mining development funds, although these funds can be at risk for mismanagement due to elite capture and unequal distribution of benefits for the community when communities are characterized by unequal social relations (Chimhowu & Woodhouse, 2006; Hirons, 2014; Putzel et al., 2015).

Contrary to LSM, ASM is often integrated into the local economy creating economic opportunities in associated downstream and upstream industries in the process contributing to local development (Hentschel et al., 2002; ILO 1999; Ledwaba & Nhlengetwa, 2016; Maconachie & Binns, 2007; Persaud et al., 2017). However, the often-informal state of the sector leaves the sector untaxed, resulting in millions of dollars of missed public revenue for national governments.

3.0 PROGRAMMATIC OPPORTUNITIES

3.1 OVERVIEW OF USAID AND OTHER DONOR APPROACHES

There has been increasing discussion and interest by development agencies and academics on better integrating mining into the UN SDGs framework. In 2016, several organizations released an atlas that linked mining to each of the SDGs (Columbia Center for Sustainable Development et al., 2015). ASM has also garnered attention recently in its contributions to the SDG agenda (Pact, 2020). Efforts like the DELVE ASM database are fostering coordination and data collection on ASM (Delve, n.d.). Despite these trends, many donors do not invest in many mining-related development activities compared to other sectors.

Among multilateral development institutions, the World Bank is the most engaged with 24 active mining projects at the time of writing (World Bank, n.d.) and hundreds more completed. Historically the Bank has programmed in a variety of ways, from direct financing of small-scale mining operations in Bolivia and Morocco in the 1970s and 1980s to assisting in privatization efforts of state-owned enterprises in the 1990s. In recent years many projects have focused on EITI implementation, regulatory/institutional reform, capacity building, and formalization of ASM. IGF, while not a development institution, provides policy support and training to its 75 member governments.

Among bilateral donors, the German government is among the most engaged through GIZ-implemented projects. GIZ has worked on mining and the green economy transition in five South American countries since 2016 (GIZ, 2021). GIZ is also supporting reduced greenhouse gas emissions from mining in Chile and Colombia (GIZ, n.d.a). Other types of activities supported by GIZ include standards/formalization in the DRC (GIZ, n.d.d), regional cooperation on mining governance in West Africa (GIZ, n.d.c), and management of mineral wealth in Mongolia (GIZ, 2020). GIZ also has a worldwide advisory extractives and development project implemented in partnership with the German geological service (GIZ, n.d.b). Other donors that engage on mining to a limited degree include the United Kingdom (UK), United Nations Development Programme/Environment Programme/Institute for Training and Research, the European Commission,[17] and the governments of Australia and Switzerland.

USAID has worked on mining through several projects that focus on ASM formalization and conflict minerals in South America and Central and West Africa (see USAID ASM Issue Brief). In addition, activities in other sectors including economic growth, democracy and governance, public health and environment have touched upon mining to various degrees. Outside of USAID, the Department of Labor and the USGS have also engaged on mining in their international programming.[18] The table below presents a non-exhaustive list of some USAID activities in the last 15 years in which mining was a primary or secondary focus.

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[17] The EU's main development funds (EDF) used to include a special instrument called Sysmin for supporting mining industries in developing countries but this was abolished in 2000. (See https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=LEGISSUM:r12102). Today the EDF generally does not engage on the mining sector. However, the European Commission's special instruments like the Instrument contributing to Stability and Peace (IcSP) work on mining in the context of fragile states.

[18] For example, the CARING Gold Mining Project help convene stakeholders to reduce child labor and improve working conditions in ASM gold in Ghana and the Philippines. See https://www.dol.gov/agencies/ilab/caring-gold-mining-project-convening-stakeholders-develop-and-implement-strategies. The USGS was a partner in Afghanistan and has worked on Kimberley Process monitoring in Africa.

PROJECT (YEARS)	COUNTRY	MINING-RELATED ACTIVITIES
Extractive Technical Assistance (2018-2022)	Afghanistan	Through main partner USGS, aims to compile and analyze data on the deposit type, infrastructure, resources, and current commodity value of Afghanistan's mineral resources to inform new mining contracts.
Mining Investment and Development for Afghan Sustainability (2012-2017)	Afghanistan	Project with three components: improve legal and regulatory framework, support geological research and exploration, and strengthen capacity of local private sector and communities.
Artisanal Mining and Property Rights (2018-2023)	Central African Republic	With primary focus on diamonds, and secondary focus on gold, project improves governance of mining sector while promoting social cohesion and women's economic and social inclusion
Property Rights and Artisanal Diamond Development (2007-2013)	Central African Republic, Liberia, Guinea	Project supported miner land rights formalization, tax and fiscal reform and post-mining environmental rehabilitation
Oro Legal – Artisanal Gold Mining Activity (2015-2020)	Colombia	Objective to improve the effective capacity of the government to regulate and administer gold mining activities, promote responsible mining and alternative livelihoods, and rehabilitate the territories degraded by illegal mining.
Women of Gold (2018-2023)	Colombia	A Global Development Alliance (GDA) between USAID and a local mining company aimed at promoting women's economic and social inclusion in mining communities
Property Rights and Artisanal Diamond Development II (2013-2018)	Côte d'Ivoire, Guinea, Central African Republic	Project supported Kimberley Process Certification Scheme implementation, community land rights formalization in mining areas and livelihoods diversification of ASM diamond miners
Commercially Viable, Conflict-free Gold (2018-2023)	DRC	Seeks to scale-up exports and sales of conflict-free, artisanal gold from eastern DRC by developing market linkages with responsible gold buyers, particularly in North America and Europe.
Capacity Building for Responsible Minerals Trade (2014-2018)	DRC	Aimed at increasing capacity to implement due diligence and traceability systems for gold and the 3Ts through legal reform, awareness-raising and implementing supply chain initiatives.
Sustainable Mine Site Validation (2018-2022)	DRC	Aims to improve the monitoring and validation of mine sites to support clean gold and 3T exports sourced from the DRC.
Copper Cobalt Conflict (2009-2011)	DRC	Aimed to promote peace and security in the ASM sector in and around Kolwezi with awareness-raising, conflict resolution mechanisms and safety trainings.
Public-Private Alliance for Responsible Minerals Trade (2020-2022)	DRC, Global	A multi-sector initiative between leaders in civil society, industry, and government that supports projects in the DRC that improve the due diligence and governance systems needed for responsible supply chains.
Initiative for Conservation in the Andean Amazon, Phase II (2012-2016)	Ecuador, Peru, Colombia	Multi-partner regional program that included some mining-related activities including studies, legal assistance to communities to defend rights, support to develop strategy for formalizing illegal miners, awareness-raising on mining
Ghana Ecobank Development Credit Authority Guarantee (2005-2012)	Ghana	USAID implemented a loan guarantee program that included loans to small-scale miners. The program allowed EcoBank to develop knowledge of the mining sector and issue additional loans.
Indonesia Forest And Climate Support (2010-2015)	Indonesia	Project included partnership with subsidiary in Papua of mining company Freeport-McMoRan to develop and implement Conservation Management and Monitoring Plan.
Economic Management for Stability and Growth (2007-2010)	Kosovo	Project included support for drafting new mining laws aimed at attracting foreign investment
Governance and Economic Management Assistance (2006-2010)	Liberia	Governance project that included an embedded mining concessions advisor, improvement of mining cadaster and reform to concession tender process. Overall project aimed to create and institutionalize effective financial and asset management procedures.
Program Contribution to the World Bank Global	Mexico	Project implemented by the World Bank with USAID funding. Included a pilot program in Sonora to increase public participation

PROJECT (YEARS)	COUNTRY	MINING-RELATED ACTIVITIES
Partnership for Social Accountability Multi-Donor Trust Fund (2017-2020)		in allocation of resources from the Mining Fund consisting of public funds derived from royalties.
Mozambique Support Program for Economic and Enterprise Development (2010-2014)	Mozambique	Under the program, a 2012 study evaluated government and donor initiatives to build economic linkages to extractives sector including mining
Parceria Cívica para Boa Governação (2016-2020)	Mozambique	Cooperative agreement with 11 civil society organizations (CSOs), including one focused on transparency and good governance in the extractives sector
Innovating Solutions for Gold Mining in the Amazon (2020-2022)	Peru	With private partner Conservation X Labs, engages regional innovators and the private sector in developing and implementing solutions to help make ASM gold operations more environmentally responsible and socially equitable
Prevent (2019-2024)	Peru	Includes activities aimed at decreasing illegal mining in the Madre de Dios region of the Peruvian Amazon.
Governance, Accountability, Participation and Performance (2012-2019)	Uganda	Broad project co-funded with UK (Department for International Development) that included support to CSOs who successfully advocated for transparency measures to be integrated into national mining law.
Tenure and Global Climate Change (TGCC) (2013-2018)	Various	Project with a variety of interventions aimed at strengthening resource tenure to promote resilience and better resource use. In Zambia, TGCC land use planning and rights formalization dealt with industrial and ASM mining.
Integrated Land and Resource Governance (ILRG) (2018-2022)	Various	In Ghana, ILRG helped assess the impacts and management of ASM gold in cocoa-growing regions. ILRG also supports a mining and conflict mapping exercise in the DRC.
Vietnam Governance for Inclusive Growth (2013-2018)	Vietnam	Supported study of the natural resources tax contributed by extractive industries including mining
Emerging Pandemic Threats Program (2009-present)	Worldwide	Under the program, informational and awareness-raising material has been produced on the high risks of zoonotic disease spillover in mining areas.
GDA to Combat HIV/AIDS in the Agribusiness and Mining Sectors (2008-2012)	Zambia	A program that included activities aimed at reducing the impact of HIV/AIDS in the agribusiness and the mining sectors by increasing productivity, reducing absenteeism, increasing retention.
Strategic Economic Research & Analysis (2011-2015)	Zimbabwe	Sectoral study on mining policy was prepared as well as training on mining taxation.

Table 4 illustrates how USAID mining-focused activities have been related to conflict minerals (in the case of West and Central Africa), illegal/criminal mining (in Colombia) and ASM formalization and community livelihoods (in both areas). Afghanistan is the only country with a project dedicated to general mining governance. However, mining has been addressed indirectly as part of numerous programs focused on general good governance, economic growth, public health, and the environment. The following sections present activities that could form the basis of mining-specific programming or activities in other sector programming that address mining issues and opportunities.

3.2 MINING GOVERNANCE

As noted above, mining governance activities can be divided into sector-specific programming (mining governance) as well as addressing mining as part of broader governance activities. The former is a specialized area of programming that donors like the World Bank and GIZ tend to focus on. On the policy level, IGF supports governments with guidance documents and framework assessments.

While USAID could engage more on core mining governance activities, continuing to address mining as a component of other programming will add value. Given how multisectoral mining issues are—touching on the environment, human rights, security, land tenure, conflict, and economic growth—mining can become an entry-point or an anchor issue to obtain broader outcomes like greater civic engagement, a more diversified economy, and better environmental management. Conversely, a failure in mining governance will have negative impacts on the broader governance and economic landscape—fostering the so-called "resource curse." This makes it critical to address mining in countries where extractives are important or ascendant.

3.2.1 LEGAL, POLICY, AND REGULATORY REFORM

Supporting legal, policy and regulatory reforms is a complex process that requires sound political economy analysis and coordination with diplomatic missions to create technical-political synergies. Thinking and working politically is important to understand and adapt to the political dynamics of a drive for reform. Typical activities in this area include funding consultants to review mining codes and mining policies. The World Bank, for example, generally takes this approach, as does the African Development Bank's Legal Support Facility.

IGF also provides assessments and trainings built around its policy framework that addresses legal and policy environment, financial benefit optimization, socioeconomic benefit optimization, environmental management, post-mining transition, and ASM. USAID could add value through more sustained government and stakeholder engagement to advance these complex and politically charged policy issues. Programming examples include:

Box 9. ASM policies and regulations

A major challenge in ASM formalization is poor legal and regulatory frameworks. Mining code consultants are rarely ASM specialists and tend to focus on issues related to industrial mining. ASM regulations are often designed as "mini" industrial mines, which make them difficult to implement as the realities of ASM are quite different. Ensuring a parallel but coordinated and participatory process to design an ASM policy and draft ASM regulations is vital to making a workable framework. USAID has supported participatory regulatory reform for ASM as part of the Property Rights and Artisanal Diamond Development (PRADD) programs and the USAID AMPR project. This has included ASM-focused regulatory studies as well as participatory activities around the revision of mining laws and policies in Côte d'Ivoire in 2014 and the Central African Republic in 2012 and 2021.

- Support studies and assessments but involve as much as possible national government experts along with external experts as a strategy to increase buy-in and ownership of recommendations.
- Support ongoing community and private sector consultations and dialogue on key policy issues.
- Encourage governments to sequence reform activities starting with strategic assessments, then working on one or more policies on topics like ASM or gender, and then proceeding to draft laws and regulations. Often revision of laws is the starting point rather than policy dialogue and analysis.
- Embed technical advisors into government ministries for sufficient periods of time so they can build relationships and understand and leverage an understanding of the institutional dynamics.
- Support national industry lobbies and working groups, such as an association of women miners, an association of artisanal and small-scale mining and a mining chamber of commerce. This helps create platforms for unified industry voices to participate in public policy discussions.
- Encourage and fund experience-sharing and exchanges at a regional or international level as part of a reform process, as well as travel and "study tours" by government officials within their own countries to better understand the mining issues first-hand. Exchanges can also help foster intra-government coordination and information-exchange (such as between environment and mining).

3.2.2 TRANSPARENCY AND PUBLIC ACCOUNTABILITY

Because mining carries high risks of corruption at different levels, programming that focuses on transparency and building government and non-government oversight mechanisms is key. Examples of activities that can be built into existing governance reforms or designed as stand-alone projects are:

- Build the capacity of civil society and investigative journalists to better understand the mining sector, including local and international study tours and trainings, prizes, or special media products (radio series or videos).
- Encourage governments to join and participate in transparency initiatives like the EITI.
- Support open mining cadasters and license management software and other portals.[19] When information on concessions and licenses are available to the public, this provides a vital tool for accountability. Other information can also be published such as the terms of mining conventions, the names of local suppliers, trade and export data, or beneficial ownership information.
- Support general data management systems improvement for collecting, storing, and reporting on data related to mine project development, production (including ASM), geological information and compliance/stewardship.

3.2.3 GOVERNMENT CAPACITY-BUILDING

In the context of a surge of interest in mining in a given country, government capacity constraints can lead to suboptimal deals, lost opportunities for revenue collection and vulnerability to corruption. Building the capacity of government services is vital to avoid these issues. Sample activities could include:

- Support capacity assessments that identify specific needs and issues not only in mining agencies but also environmental and tax agencies.
- Support cross-agency training that focuses on specific issues, such as training for revenue, tax and financial crime stakeholders on tax-based erosion and profit shifting, including transfer pricing. Another example could be a training with environmental, mining, and finance stakeholders on specific mine environmental practices for a new type of mining for the country. This approach fosters intra-government coordination and capacity-building.
- Collaborate with private sector platforms (like ICMM) and intergovernmental policy mechanisms (like IGF) to make national policy-makers aware of best practices and discourse.
- Support mining schools and training institutes for the next generation of mining professionals, including curriculum development, and developing activities that encourage women to join the mining profession or mining government oversight agencies.

3.2.4 COMMUNITY AND STAKEHOLDER DIALOGUE

Development partners have convening power that makes them well placed to support dialogue at multiple scales and levels. When done strategically, dialogue can reduce tensions, increase coordination and knowledge, and create the conditions for effective reform. Sample activities are:

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[19] The World Bank has funded FlexiCadastre in several countries. The Revenue Development Foundation has also provided license management and mining cadaster software solutions.

- Support inter-agency coordination through joint projects and information-sharing platforms, notably between environmental regulators, mining regulators and revenue officials.
- Support participatory processes to get private sector and community input, including grievance mechanisms and management of royalty percentages attributed for community development.
- Support regional information-sharing and experience-sharing mechanisms, both between neighboring countries but also between the national capitals and regions/municipalities.
- Support CSOs and industry groups in efforts to foster policy dialogue.
- Ensure that under-represented groups (women, migrants, indigenous peoples) are given sufficient voice in all efforts to support multistakeholder coordination.

3.2.5 FINANCIAL AND OTHER CRIMES RELATED TO MINING

Engaging on mining-related criminal activities including money laundering and transnational organized crime could include:

- Support investigative studies by local and international researchers on illicit financial flows related to mining and encourage law enforcement strategies to focus on midstream and downstream rather than on the miners/laborers alone in the case of ASM.
- Support existing law enforcement coordination efforts and activities to ensure they have an accurate understanding of mining dynamics, including cross-participation in activities (law enforcement in multistakeholder mining groups and mining stakeholders in law enforcement).
- Support access to formal finance for ASM as an alternative to informal finance which is highly vulnerable to financial crimes.
- Build the capacity of financial intelligence units (FIUs) with respect to mining and mining authorities with respect to anti money laundering/terrorist financing.
- Integrate law enforcement into mainstream mining and ASM policy-making processes and encourage a balanced and coordinated approach to crackdowns on illegal mining that clearly differentiates informal from criminal mining.

3.2.6 GEOLOGICAL RESEARCH

Supporting geological research and the capacity of geological data management is a major investment. Activities like digitizing exploration and geological records and conducting nationwide aerial surveys can help map out resources and guide government planning and incentivize investment. These initiatives can be organized in collaboration with the USGS and/or other geological research agencies. However, the prohibitive cost has generally been a disincentive for development partners.

Partners like USAID could focus on specific parts of geological data service capacity-building. The Energy Resource Governance Initiative (ERGI) identifies six core areas (ERGI, n.d.):

- Geological mapping and assessments
- Scientific data management (hydro, remote sensing and geological)
- Publishing research as a strategy to attract investment
- Government advisory such as helping identify ASM zones
- Geophysical exploration such as aerial surveys

- Geological record-keeping including company exploration reports

3.2.7 STANDARDS AND INTERNATIONAL FRAMEWORKS

Support for the implementation of standards and norms related to the mining sector are a focus of several development programs and merit continued support. Several prominent frameworks include:

- **Extractive Industries Transparency Initiative**. The EITI Standard implemented in 55 countries requires the disclosure of information on revenues from extractives industries including mining as well as how that revenue is spent. The EITI is implemented with a multi-stakeholder framework involving government, companies, and civil society (EITI, n.d.).
- **Financial Action Task Force** (FATF). FATF is an intergovernmental policy-making body that sets standards, called the FATF Recommendations, to fight money laundering and terrorist financing. A key component of the FATF framework are country-level FIUs. Mining is covered by the standards, with a focus on precious metals and stones (FATF, n.d.).
- **Open Government Partnership** (OGP). OGP is an initiative involving governments and civil society organizations aimed at promoting transparency. The approach consists of two-year action plans monitored by an independent reporting mechanism (OGP, n.d.).
- **OECD Due Diligence Guidance on Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas**. The OECD due diligence guidance is a supply chain approach to managing and mitigating risks associated with conflict minerals. The guidance is voluntary but has become the basis of other industry standards (like the Responsible Minerals Assurance Process [Responsible Minerals Initiative, n.d.]) and government laws (such as the EU Conflict Minerals Regulation [European Commission, 2020]).
- **Voluntary Principles on Security and Human Rights**. The Voluntary Principles is a multistakeholder standard and effort focused on the responsible engagement of public and private security providers, such as those employed by mining companies (Voluntary Principles, n.d.).

3.3 LAND TENURE AND PROPERTY RIGHTS

Land and resource governance (LRG) encapsulates mining governance. LRG encompasses the "rules, rights, policies, processes, institutions and structures created to manage the use, allocation of, access to, control, ownership, management, and transfer of land and land-related natural resources" (Stevens et al., 2020, p. 13). Unlike mining governance programming, however, LRG activities include specific approaches such as land use planning, community land rights formalization and land administration that are particularly relevant to mining's development challenges.

3.3.1 LAND USE PLANNING

Land use planning is a process of analysis, stakeholder dialogue and decision-making around different and often competing land uses and users with the aim of achieving sustainable, equitable, and economically optimized use of land and land-based resources. Approaches to land use planning are myriad, but best practice in the context of development places an emphasis on participatory bottom-driven processes as opposed to expert-driven or top-down approaches. Land use planning is relevant to an anticipated upsurge in mining due to the green energy transition in the following ways:

- **Social license to operate.** Land use planning can help achieve a "social license to operate" for mining by creating a holistic and inclusive process for communities to understand the mine's impacts and articulate and defend their interests. This can avert future conflict if issues like corollary infrastructure development and environmental waste are clarified from the outset and if there is an ongoing process of communication and adjustment. In this context land use planning is a way to operationalize industry principles such as the triple bottom line and value beyond compliance.[20]

- **Territorial development planning.** A subset of land use planning called territorial development planning is vital for directing investments from community mining funds derived from mining taxes and royalties. When there is an existing development plan which identifies priority investments (such as schools, roads, commerce), this reduces conflict and increases efficiency around the use of these funds.
- **Framework for policy trade-offs.** At a regional or national level, land use planning can create a framework for policy trade-offs and dialogue, such as between mining, agriculture, and other uses. This type of planning is facilitated by accurate geological information as it helps predict future mining zones and enables active mine development through competitive tenders of pre-identified exploration blocks rather than passive development based on open access and direct negotiation. It can also avert overlapping rights such as forestry concessions and industrial agriculture. In some cases, regional and national governments may decide not to develop mining due to community opposition or other economic interests; land use planning creates a technical and social framework for that type of complex decision-making.
- **Post-mining land use planning.** Planning is also a key part of the mining development process that is often overlooked, including the ownership and use of land after remediation. In the case of land that remains damaged (often the case in ASM) post-mining planning can identify ways in which agricultural support and other investments can put damaged land to productive use.

In summary land use planning can play an invaluable role in averting conflicts and optimizing development. It can also ensure that the voices of under-represented groups including women, youth and indigenous peoples are adequately heard.

3.3.2 COMMUNITY LAND RIGHTS FORMALIZATION

The formalization of community land rights, especially if combined with capacity-building and training, can help protect vulnerable populations from arbitrary evictions and loss of land important for cultural and economic reasons. While most mining laws require various levels of free and prior informed consent as well as community compensation, legislation tends to give primacy to mineral rights. In many cases, these mineral rights belong to the national government and supersede customary rights.

Depending on the regulatory framework, projects can help communities obtain titles or other forms of recognition of their rights. These tools can empower communities to better negotiate compensation around large land-based investments, including mining, as well as stand up to powerful interests. When rights formalization also involves legal education, awareness-raising and grassroots organizing, this can help foster a balance of power. Groups like Namati have developed community land protection guides relevant to investments like mining (Knight et al., 2017).

3.3.3 LAND ADMINISTRATION AND TITLING

Supporting land administration and titling in mining areas can reduce conflict and uncertainty around mining investments. Often mining companies find it difficult to identify the owners of farms and other

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[20] The *triple bottom line* (3BL) refers to people, profit, and planet. *Value beyond compliance* is a framework and approach for companies to go beyond the minimum required by law and thereby realize the triple bottom line and broader value for the company. See https://ergi.tools/stewardship/social-license/step-1

land-based assets that are affected by their operations. Property rights clarification and formalization can help avert those issues.

However, titling programs will generally be beneficial only prior to mining; if speculation has already begun titling land can be a tool for elite land grabbing and can exacerbate inequalities. It is therefore important for titling and land administration programs to ensure safeguards in areas where mining is occurring or is imminent. These safeguards can be built into land administration program design.

3.4 ENVIRONMENT

Like other areas, environmental programming can focus on mining or mining can be a sectoral component of an environmental program. Several programming areas are presented below.

3.4.1 ENVIRONMENT AND SOCIAL IMPACT ASSESSMENTS

Environmental and social impact assessments (ESIAs) are the primary mechanism in many countries to manage potential damage from a large-scale investment such as mining. When done well, ESIAs help articulate community concerns and present potential future consequences of proposed actions during and after mining. ESIAs are a vital governance tool to foresee and forestall negative impacts.

However, ESIAs have limitations and problems in implementation that can be the subject of programming. For example, ESIAs can be expert-driven instead of participatory, can be well-done but left unimplemented, and in the case of small-scale mining can become an administrative hurdle that hinders formalization and opens the door to rent-seeking. Moreover, there are often dysfunctional relationships between environmental protection agencies and mining authorities.

Capacity-building for better implementation of ESIAs and better institutional coordination is therefore a programming opportunity. Groups like the IGF have new guidance and norms on ESIAs, and groups like the Environmental Law Alliance Worldwide published a guidebook for evaluating mining project ESIAs. Activities that help community, government and CSO monitoring of the implementation of ESIAs is also a key part of transparency and accountability.

3.4.2 GREENHOUSE GAS EMISSIONS IN MINING INDUSTRY

As part of climate-change programming, addressing greenhouse gas emissions by the mining industry is an opportunity. For example, the Andean highlands where the “lithium triangle” is located is also among the world’s best locations for wind and solar energy. In Chile, for example, investments in solar energy by copper mining companies has increased low-carbon electricity in the country’s grid (IEA, 2021). There are therefore synergies between increased mining needed for the green energy transition as well as opportunities to increase renewable energy generation capacity. It is also important to identify renewable energy opportunities around smelters and refineries in locations like South Africa and Indonesia which use enormous amounts of energy, the majority of which is derived from coal. Partnerships with the many major mining companies that have committed to reducing GHG emissions through low-carbon electricity could also be an opportunity.

ASM can also contribute greenhouse gas emissions through deforestation as a direct effect of mining as well as a secondary effect of miners moving into forest areas. Land use planning, community engagement and coordination with law enforcement efforts to crack down on criminal mining are all important strategies. In addition, improving mining techniques and exploration can also reduce damage to forests.

3.4.3 RECYCLING/CIRCULAR ECONOMY

As noted above, promoting circular economy approaches including recycling will be key to reducing the overall negative impacts from mining and the green energy transition. While this has been a focus in developed countries, most USAID-presence countries have recycling markets that include metals covered under this report. The USAID Energy Division's Scaling Up Renewable Energy includes a pillar on the circular economy and waste management. A particular opportunity is to integrate recycling into sanitation and waste management support projects.

A related development issue with respect to recycling is the existence of informal recycling organized around the labor of vulnerable populations (poor, elderly, women, children) for collection, sorting, breaking down and consolidating material. The World Bank estimates that up to 15 million people—or 1% of urban populations in developing countries—survive by salvaging recyclables from garbage (Medina, 2008).If demand for green energy minerals push up prices for metals that can be recycled, this could pull more people into waste collection, potentially exposing more people to hazardous working conditions. Exposure to toxic materials including heavy metals in waste dumps is particularly damaging for children working in the sector.

3.4.4 WATER QUALITY AND WATER MANAGEMENT

Technical assistance for watershed and water management in water-stressed mining regions like the Andean highlands is a potential programming opportunity. Engaging with communities with respect to monitoring and compliance is also important. Building capacity of communities, research institutions and CSOs on water management issues could be helpful. This capacity-building and monitoring can also include awareness-raising and testing of heavy metal levels in drinking water which is common not only in LSM but also in ASM.

Box 10. ASM and environmental rehabilitation

USAID programming has grappled for years with how to prevent and remediate the environmental impacts from ASM. In the Central African Republic's PRADD program, a post-mining land reclamation program through fish farming was highly successful, especially when combined with property rights clarification. Under USAID AMPR, also in the Central African Republic, community agreements to establish artisanal mining zones include rules regarding the need to respect protected area boundaries. Technical assistance to miners is made contingent on respecting the rules. In Côte d'Ivoire under PRADD II, hand augers were used to reduce destructive prospection practices and identify diamond reserves. Damaged land from mining, especially in wetlands, was also developed for use by women agricultural groups. These approaches that combine livelihoods, land tenure and technical assistance offer pathways to address this problem.

3.4.5 WASTE MANAGEMENT, MINE CLOSURE AND RECLAMATION

As part of government capacity-building, authorities undergo training in best practices on waste management and mine closure, especially in countries that are mining a green energy mineral for the first time. This can increase the capacity for monitoring and compliance to avert accidents. In ASM, remediation is trickier but no less important. Best practices involve preventive measures like better mining techniques and prospection so that resources are mined more efficiently, and so that backfilling is integrated into ore extraction. Post-mining rehabilitation is often best done in the context of livelihood and land tenure programming as it gives incentives for reclamation. On a broader scale, building a community of practice around land reclamation as well as innovative models to finance the cost of reclamation is key as the costs of reclamation generally surpass the amounts set aside by mining companies or governments. As community concerns around reclamation increase, it is important to also improve the standards and accountability of LSM mining companies for adequately restoring damaged land.

3.4.6 BIODIVERSITY AND PROTECTED AREAS

Large mining companies will sometimes plan for forest and biodiversity offsets to compensate for destruction of high-conservation value areas. For example, Rio Tinto's ilmenite mine in Madagascar included support to new reserves as part of its strategy. High-quality ESIAs are particularly important to identify endangered species and ecosystems that can be affected by mining. Building capacity of government and CSOs to monitor implementation of all mitigation measures is important, as well as adequately consulting and involving local communities. Monitoring can include classic species counts or satellite monitoring or more cutting-edge techniques like metagenomics to measure and monitor species diversity periodically.

In the case of protected areas, mining companies often lack the time and expertise to engage, creating opportunities for synergies with development partners. ASM in or near protected areas is a particular challenge because it is hard to control. Approaches like artisanal mining zones, community rule-setting, conditional support to miners who respect boundaries and targeted enforcement can yield results. Programs like the USAID Central African Regional Program for the Environment (CARPE) have grappled with illegal mining in their priority landscapes, such as illegal ASM gold mining in the Garamba-Chinko landscape. Given that such pressures could increase in other areas of ecological importance due to increased mining, integrating mining expertise into future conservation programming is key.

3.5 CONFLICT AND HUMAN RIGHTS ABUSES

3.5.1 ARMED CONFLICT AND GROSS HUMAN RIGHTS ABUSES

As noted above, while the 16 minerals covered by this report are not "conflict minerals" in the strict sense of the term, several USAID-presence countries with green energy minerals are considered CAHRAs by the European Union.[21] While the EU Conflict Minerals Legislation and the US Dodd-Frank framework for the DRC focus on 3TG, it is possible that other minerals could become linked to armed group financing and/or major human rights abuses. This report has already noted areas of concern such as chromite mining in Zimbabwe and REE mining in Burma.

Besides supporting and engaging with supply chain initiatives based around the OECD due diligence framework that could cover additional minerals besides the 3TGs, programming in these countries related to conflict prevention and human rights can include mining as an explicit area of focus. Some examples:

- Monitoring and assessments related to rebel movements and violent extremism can track if and how governance issues in mining or the extractives sector more broadly can create the conditions for financing or complicity with communities/criminal networks.
- Capacity-building and support to CSOs with respect to human rights monitoring and advocacy can include modules and trainings focused specially on mining.
- Conflict prevention and mitigation strategies can ensure to include mining-related triggers and grievances that could escalate. For example, environmental mismanagement, land expropriation and abuses by private security can all create and contribute to conflict dynamics.
- Advocacy and programming related to sexual and gender-based violence as well as human trafficking and modern slavery can make sure to examine the mining sector for risks. This is more prevalent in ASM diamond and gold but could be of concern in other minerals.

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[21] These include Mexico, DRC, Zimbabwe, Mozambique, Ukraine, Azerbaijan, India, Pakistan, Afghanistan, Burma, and the Philippines.

3.5.2 ASM-LSM CONFLICTS AND COMMUNITY RELATIONS

Conflicts between large-scale and small-scale mining are particularly common in gold mining, but among the minerals examined in this report, such conflicts exist in cobalt and potentially with chromite. Addressing underlying causes of ASM-LSM conflict requires improvements in mining governance, especially addressing the "LSM bias" through regulatory reform and developing an ASM policy that gives ASM a legitimate place alongside LSM.

In some cases, support for ASM-LSM cohabitation and collaboration can also aid in formalization and conflict reduction, such as the Mutoshi project in the DRC where an industrial cobalt mine/processor allows formalized ASM in designated areas of its concession (Trafigura Foundation, 2021). Organizing forums and exchanges on best practices in ASM-LSM cohabitation can help identify solutions tailored to each circumstance.

Conflicts between mining companies and communities similarly calls for addressing underlying governance causes including the legislative framework and how it is applied in practice. Industry and government guidance documents by the ICMM can help build capacity on tools like grievance mechanisms (ICMM, 2019). As previously noted, LRG approaches like multi-stakeholder dialogue, land use planning and alternative dispute resolution are also important tools that can be used in activities with governments and/or CSOs.

3.6 LABOR AND WORKING CONDITIONS

3.6.1 CHILD LABOR

While "worst forms of child labor" as defined by the ILO is a type of gross human rights violation covered in the previous section, programming in child labor covers both the worst forms and other forms. Indeed, the first step is to understand the specifics of child labor in a given context – the role of children in mining, social norms and underlying economic incentives and constraints. Programming in this area includes the following types of activities:

- Awareness-raising, education, and social behavior change communication
- Special education models and curriculum for children transitioning from mining
- Collaboration with local leaders and mining authorities on formalization and enforcement
- Focusing programming on women miners and their needs, notably with respect to childcare

Successful programs have been multi-stakeholder and often implemented in collaboration with companies and mining groups.

Box 11. Approaches to addressing child labor

USAID and the US Department of Labor have worked on child labor in coal, gold and cobalt mining in Colombia and the DRC. The Department of Labor-funded *Somos Tesoro* provided educational services to 13,000 children and adolescents and offered livelihood support to 3,500 households. In the DRC, the ongoing USAID-Pact Sustainable Mine Site Validation project aims at stemming child labor and other issues in mine sites. Pact adapts its approach to each context but includes capacity-building for enforcement of child labor regulations, assistance to formalize ASM, development of child protection policies and increasing awareness of the dangers of child labor among miners and mining communities.

3.6.2 OCCUPATIONAL HEALTH AND SAFETY

As part of capacity-building of government authorities, best practices with respect to occupational health and safety (OHS) can be covered to ensure their inclusion in government mine site monitoring. With respect to ASM, OHS should be integrated into any programming aimed at supporting miner formalization. Activities can include training and support on benching/terracing, tunnel support engineering and other facets. The DELVE annual State of the ASM Sector report for 2020 included case studies on supporting OHS improvements in ASM (World Bank, 2021).

3.6.3 PUBLIC HEALTH

Miners and mining communities consist of populations vulnerable to specific disease burdens. Depending on the intervention, public health programming can integrate mining-related aspects. For example, ASM and LSM mining towns can be vectors of diseases like tuberculosis, as documented by the US Centers for Disease Control, which is working with the World Bank on mapping hotspots in mining areas of southern Africa (CDC, 2017).

Sexually transmitted diseases are also prevalent among migrant workers and ASM sites that attract sex workers. Mining can also contribute to emerging pandemics and zoonotic diseases especially in West and Central Africa due to risks of spillover from animals to miners working in remote forest areas (USAID, n.d.). Ensuring that miners as a population and mining industry trends are considered in public health programming is therefore important both for the mining sector and the countries that benefit from programming.

3.7 NATIONAL AND LOCAL DEVELOPMENT

3.7.1 COMMUNITY DEVELOPMENT

Most mining legislation foresees percentages of royalties and/or taxes earmarked for community development. In some cases, these funds are managed nationally and redistributed across the country; in other cases, the funds are managed by decentralized entities and focus on mining-affected areas. In order to address the issues of mismanagement and conflict around these funds, activities could include:

- Support governments to integrate best practices and experience-sharing in legislative and policy reviews to identify improvements to their models and learn from others.
- Support territorial development planning capacity-building and implementation in order to create participatory and transparent processes for identifying investments from mining funds.
- Support cost-sharing or partnership models that leverage funds between development projects, mining company corporate social responsibility and government-managed development funds.
- Support investments that focus on women including women-led businesses.
- Strengthen the capacity of CSOs and communities to fully participate in decision-making around the use of these funds.

Community development funds are relevant not only to LSM but also to ASM. In some cases, ASM production is taxed at the point of export and percentages can be earmarked for communities. In addition, programming can support parallel revenue generation and investment by communities and ASM mining entities like cooperatives. There are examples in gold and diamond mining in West Africa, for example, of formalizing community management of ASM including taking percentages from miners and traders in order to invest in community development (De Jong & Sauerwein, 2021). Many of these practices are informal but community-managed funds can be complementary.

3.7.2 ECONOMIC LINKAGES AND DIVERSIFICATION

Supporting policies and projects that build diversification and economic linkages is important for economic stability and long-term development. At a national level, country-level development strategies in mining-dependent countries like Guinea have sought to diversify the economy away from mining. At the local level, programming like the USAID PRADD project have also invested heavily in livelihood diversification to build resilience to shocks caused by market fluctuations.

Recently, discourse on mining has focused less on diversification and more on the concept of linkages, which describe the ways in which good policy can leverage mining to enhance other economic sectors (Extractives Hub, n.d.). This is relevant for both the ASM and LSM sectors. For example, upstream linkages include the provision of goods and services to miners, whether small food vendors at ASM sites or drilling equipment providers for LSM.

Downstream linkages (or forward) linkages focus on value-addition to minerals before export, such as Gabon's building of a manganese smelter or Indonesia's ban on exporting raw nickel ore. Side linkages refer to how mining can facilitate infrastructure development, such as investment in a railway or the power grid, or at a community level how mining revenue can spur investment in agriculture. Finally, consumption linkages refer to the effects of increased earnings and spending by those who are directly or indirectly employed by mining.

Activities that can support diversification and linkages include:

- Economic studies that examine and quantify the potential value from different types of linkages.
- Support to develop policies, such as *local content policies* (a type of upstream linkage mandating local procurement and/or local employment) and infrastructure strategies that maximize gains from linkages. IGF has several in-depth guidance documents (IGF, n.d.).
- Invest in education and vocational training to create the conditions for increased local workforce development in mining and sectors like equipment manufacturing and servicing.
- Support the development of viable ASM sectors as a strategy to increase employment and develop resources that may be sub-economic for LSM.
- Support macroeconomic best practices that hedge against revenue volatility in highly mining-dependent economies.
- Support women-owned businesses linked to mining as well as a dedicated community development fund targeting women.

3.8 PUBLIC-PRIVATE PARTNERSHIPS AND ALLIANCES

3.8.1 SUPPLY CHAIN INITIATIVES

Mineral supply chain actors—commodity traders, battery manufacturers, consumer product retailers—are driving many of the changed expectations with respect to conflict and human rights. The OECD due diligence guidance and the various industry standards and norms driven by the private sector are therefore key tools for addressing some of the development challenges associated with mining. Donors play a key role in field implementation of these standards through pilot programs and capacity-building, for example, as well as addressing challenges that may be difficult to address with responsible sourcing alone.

Donors like USAID also play a role in supporting multistakeholder platforms for learning, experience-sharing, and contributions from the private sector like the PPA-RMT (see text box). Future programming could go beyond current conflict minerals and support evolving supply chain standards and norms related to green energy minerals. Future PPAs could also consider approaches like the European Raw Materials Alliance that bring together private and public stakeholders with the aim of increasing collaboration around critical minerals especially those related to the green energy transition (European Raw Materials Alliance, n.d.).

Box 12. Public private alliance for responsible minerals trade (PPA-RMT)

USAID funds the Secretariat and is a member of the PPA-RMT, a multi-sector initiative that supports projects in the DRC that improve the due diligence and governance systems needed for responsible supply chains. Projects focus on developing tools and building civil society capacity. PPA-RMT also provides a platform for discussion and coordination. Since its launch in 2011, PPA-RMT has raised nearly $2.5 million in private sector contributions, which has served to test tools for enhanced upstream due diligence and reporting, made grants to assess models for collecting and disseminating due diligence data, and supported civil society training and mechanisms to monitor and report fraud and smuggling.

3.8.2 PARTNERSHIPS WITH THE PRIVATE SECTOR

USAID has some examples of collaboration with mining companies on development challenges, such as the engagement with Freeport-McMoRan in Indonesia. Mining companies working in countries with green energy minerals often lack capacity and dedicated resources to deal with issues including conflict with communities and implementing local content policies. This is especially the case with junior companies who often lack dedicated in-house community relations specialists. In addition, at the stage of exploration there is often little investment in community outreach. Partnerships with development actors like USAID could help improve mining companies' ability to engage on these issues, many of which surpass their manageable interest. Collaboration can also leverage additional resources from the companies. Collaboration can range from coordination and synergies in existing projects to more formal arrangements like public-private partnerships or GDAs.

Besides mining companies, downstream commodity traders and actors like the LME and Trafigura are increasingly funding development-related projects (LME, 2021; Trafigura Foundation, n.d.). Partnerships with donors like USAID could leverage these resources for greater impact. Finally, partnerships with financial institutions like banks can also play an important role. At an international level, partnerships on implementing environmental, social and governance (ESG) criteria in lending could create unique opportunities. At a national level, loan guarantees can open financing to responsible small-scale mining related to green energy minerals. For example, the GDA with EcoBank in Ghana mentioned in the table in Section 4.1 reportedly helped EcoBank gain the experience required to do additional lending to small-scale miners (USAID, 2008).

3.8.3 ENGAGEMENT WITH MINING PLATFORMS

Engagement with international mining-related platforms can help identify new areas for collaboration and synergies. The US Department of State often leads US engagement in international platforms and communication and collaboration is important. For example, Energy Resource Governance Initiative (ERGI) helps build reliable supply chains for clean energy minerals and metals through bilateral, multilateral, and private sector engagement, as well as technical assistance. The State Department is also the lead US liaison with international entities working on these issues such as the International Energy Agency (IEA), the Extractive Industries Transparency Initiative (EITI), the Intergovernmental Forum on Mining (IGF), and the International Renewable Energy Agency (IRENA). Participation in mining-related conferences could also yield opportunities.

4.0 CONCLUSION

The tradeoffs, risks, and inequities around increased mining needed for the green energy transition require critical reflection and choices around the world. In wealthier countries investing heavily in the transition to renewables, policymakers should determine how the urgent need to transform energy systems and secure supply chains could negatively impact poorer countries where minerals are extracted, many of which will be the same countries to undergo devasting impacts from climate change.

Ensuring that the green energy transition does not lead to greater instability, environmental devastation and human rights abuses is a responsibility, but also a necessity, since without these countries the green energy transition may be harder to achieve. While finding substitutes for certain "problematic" minerals may help limit some of the most egregious impacts, it is not possible nor desirable to disengage given the sheer volume of minerals and countries that feed the global supply chains needed for the transition.

Governments must therefore work together with industry to support these countries to mitigate impacts, as well as support avenues for citizen engagement and participation in these countries around these hard decisions. This will increase the chances that well-governed and accountable mining and mineral supply chains.

ANNEX 1. GREEN ENERGY MINERALS: KEY FACTS

The fact sheets that follow present key information for each of the 16 minerals profiled in this report, including: the mineral's use in renewable energy, demand projections, current production/reserves, price dynamics in the last five years, USAID-presence countries where the mineral is mined, major industrial companies, artisanal small-scale mining (ASM) if applicable, development issues, mining project and supply chain dynamics, industry groups and engagement opportunities.

For comparison, the 2020 World Bank study *Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition* was used for all figures citing demand projections. The projections used were those calculated under a two-degree warming scenario and take into accounting recycling. For production and reserves, annual production figures were taken from the USGS 2021 Mineral Commodity Summaries which report on 2020 production levels (USGS, n.d.). It is important to note that there is a margin of error on production figures and especially demand projections, but using a uniform source gives an order of magnitude. For mineral prices, London Metals Exchange (LME) cash spot prices were cited unless otherwise noted. Maps were generated by the OECD data portal Compare My Country with underlying data provided by the USGS.

The following symbols are used in the tables:

Green Energy Technology		Key Development Issues	
	Solar		Governance
	Wind		Environment
	Energy storage		Labor and working conditions
	Electric cars (not including batteries)		Conflict
	Geothermal		Land tenure
			Leveraging minerals for economic growth (local/national)

ALUMINUM

US CRITICAL MINERAL?	Yes

MAIN USES IN GREEN ENERGY TECHNOLOGY	KEY DEVELOPMENT ISSUES IN MINING

DEMAND PROJECTIONS

Aluminum is used in multiple renewable technologies, including in electric vehicles which work better with lighter-weight bodies, but nearly 90% of projected use in the green energy transition stems from photovoltaic cells, specifically the panel frames. Of the 16 minerals, aluminum demand will increase the most in absolute terms with more than 5.5 million tons per year required for renewables by 2050 under a two-degree scenario (Hund et al., 2020). However, this is not a huge increase in relative terms, representing 9% of 2018 production levels. This reflects aluminum's widespread use in a variety of industries, meaning that an increased use in renewables will increase but will not radically reshape demand. Gallium, a metal used in a subset of photovoltaic cell technologies, is obtained as a byproduct of bauxite refining. However, increased demand for gallium will unlikely influence the fundamentals of bauxite mining in USAID-presence countries.

PRODUCTION/RESERVES

Source: OECD

Global resources of bauxite, the ore for aluminum, are estimated between 55 and 75 billion tons, which is sufficient to meet world demand for many years into the future. **Australia** was the world's largest producer of bauxite in 2020 with 110 million tons (nearly 30% of global production) followed by **Guinea** (82 million tons) and **China** (60 million tons).

Bauxite is refined into alumina (aluminum oxide) and then smelted into aluminum. Alumina production is dominated by **China** (74 million tons, or 54% of production) followed by **Australia** (21 million tons). **China** is also the main producer of aluminum, accounting for 57% of global production, followed by **Russia, India and Canada**. The **US** accounted for less than 2% of aluminum production in 2020.

Between 42% and 70% of aluminum products are recycled, and new products with aluminum contain between 34% and 36% of recycled aluminum (Hund et al., 2020). Recycling will therefore offset future demand, but it will not replace the need for new mined aluminum.

Unrefined bauxite prices vary based on their quality but are generally between $30 and $50 per ton. Aluminum metal prices have generally been stable at an average of around $2,000 per ton over the last five years, with a low at just below $1,500 and a high of just under $2,500 (NASDAQ, n.d.; LME, n.d.a). However, like many commodities, aluminum is facing increased volatility and upward pressure on prices.

MINING IN USAID-PRESENCE COUNTRIES

As the world's second largest producer in 2020 and holder of the world's largest reserves, **Guinea** is the most important USAID-presence country for bauxite (7.4 billion tons, or nearly 25% of global known reserves). Other USAID-presence countries with significant production or reserves are **Vietnam** (3.7 billion tons in bauxite reserves), **Brazil** (world's 4th largest producer in 2020), **India, Indonesia, Jamaica, Kazakhstan,** and **Guyana**. Smaller or emerging producers include **Bosnia-Herzegovina, Cameroon, Colombia, Ghana, Montenegro, Mozambique, Sierra Leone, Solomon Islands** (limited presence), and **Tanzania**.

MAJOR INDUSTRIAL COMPANIES	ARTISANAL AND SMALL-SCALE MINING (ASM)
NYSE-listed **Alcoa** has ownership in seven active bauxite mines, including a minority stake in Guinea's main mine. Alcoa is also a major refiner and smelter. **Rio Tinto** (headquartered in London with public listings in London and Australia) also has a stake in the	None known

Guinea mine and like Alcoa is involved in mining, refining, and smelting worldwide. **Aluminum Corporation of China** (also called **Chalco**, listed in New York, Shanghai, and Hong Kong) is China's largest alumina refinery and aluminum smelter, and is increasingly involved in mining, including Guinea.	

ISSUES IN USAID-PRESENCE COUNTRIES

Environment, governance, and land tenure issues are common in USAID-presence countries with bauxite mining. In **Guinea**, for example, there have been complaints about land expropriation, a lack of transparency and negative health effects caused by bauxite mining (Human Rights Watch, 2018). In **India,** there are tensions between promoters of bauxite and detractors who note the presence of indigenous populations who consider mining areas as sacred land (Oskarsson, 2017). In **Brazil,** there is also concern around the environmental impacts of bauxite mining concentrated in the Amazon region though companies invest significant amounts in rehabilitation (ABAL, 2017). Bauxite mining has also been linked to "minerals-for-infrastructure" deals such as the $2 billion agreement between **Ghana** and Chinese company Sinohydro to build infrastructure in exchange for bauxite. Ghana's bauxite mining has also been controversial due to its location in a high-biodiversity forest area (Gbadamosi, 2020). Bauxite mining in the **Solomon Islands** (limited presence) has also been highly criticized for devasting environmental impacts (Puia, 2021).

MINE DEVELOPMENT AND SUPPLY CHAIN DYNAMICS

Bauxite mining development is a long-term major investment often requiring infrastructure investments to export or refine massive quantities of ore. Like many industrially mined base metals, project development is influenced not by a shortage of bauxite but rather by deposit grade, politics, and logistics. When possible, it is optimal for refineries and smelters to be located near a bauxite source, such as AluHydro Norte in Brazil. Most large players like Alcoa and Rio Tinto tend to vertically integrate as much as possible.

Outside the majors, newer frontier projects consist of consortia that bring together shipping/logistics, refining and mining under one effort, such as smelter Shandong Weiqiao which is part of one of Guinea's major bauxite mining companies (SMB-Guinee, n.d.). Similarly, the smelter Emirates Global Aluminium is a shareholder in the Guinea Alumina Corporation SA, a new project (NS Energy, 2021c). In Jamaica, similarly, commodities trader Nobles Group is the majority shareholder in the country's main bauxite mine (Majumder, 2020).

ORGANIZATIONS AND INDUSTRY GROUPS

The **Aluminum Association** is a US-based industry group that includes all the majors (The Aluminum Association, n.d.). The **Aluminium Stewardship Initiative (ASI)** is a global nonprofit organization that sets standards for sustainability in the aluminum value chain (ASI, n.d.).

CHROMIUM

US CRITICAL MINERAL?	Yes
MAIN USES IN GREEN ENERGY TECHNOLOGY	**KEY DEVELOPMENT ISSUES IN MINING**
	

DEMAND PROJECTIONS

While chromium is used in some battery technologies, most of its use in renewable energy stems from its role in steel alloys. Chromium-based ferroalloys are especially important in wind turbines and geothermal facilities due to anti-corrosive properties. Indeed, 36% of its demand linked to renewables comes from geothermal (Hund et al., 2020).

Chromium demand linked to green energy technology is projected to reach 366,000 tons per year by 2050 under a two-degree scenario (Hund et al., 2020). This represents only 1% of 2018 global production. Given that 90% of chromium is used in the steel industry, and steel is used in a variety of sectors, the increased demand from renewables is unlikely to have a major impact on its underlying economics.

PRODUCTION/RESERVES

Source: OECD

The main ore for chromium is chromite. Worldwide resources of chromite are estimated at 12 billion tons, which is sufficient to meet demand for centuries. Current mining and known economic reserves are concentrated in southern Africa and Kazakhstan. **South Africa** dominated chromite mining in 2020 with 40% of global production, followed by **Kazakhstan** and **Turkey** with approximately 15% each.

China is the leading chromium-consuming country, which is linked to its role as the leading producer of steel. Indeed, 90% of chromium is used in the steel industry. The chromium used in steel is called ferrochromium which is derived from chromite. Ferrochromium can be further refined into chromium metal used in electroplating and other applications.

China also leads the world in ferrochromium production, but South Africa is close behind. Producing ferrochromium requires a large quantity of electricity, which has historically been low-priced in South Africa but is rising in cost in recent years. Most ferrochromium is produced at or near chromite mines.

Prices are cyclical and generally follow steel demand. Chromium is not traded in open markets like the LME so price data is less available. According to USGS figures, in the last five years, chromite has varied between $180 and $279 per ton, ferrochromium between $1,800 and $2,549 per ton and chromium metal between $7,900 and $11,344 per ton. The lower prices were in 2020 driven by COVID-19 causing a reduction in steel demand.

MINING IN USAID-PRESENCE COUNTRIES

Both of the world's top producers of chromium ore (**South Africa** and **Kazakhstan)** are USAID-presence countries. Other important USAID-presence producers are **India, Mexico, Vietnam,** and **Brazil** (ScienceDirect, n.d.). Smaller or emerging producers include **Albania, Cuba, Madagascar, Pakistan, Sudan, Philippines,** and **Zimbabwe**.

MAJOR INDUSTRIAL COMPANIES

Switzerland-based **Glencore**, the world's largest metals and mining company by revenue, is also the current leader in chromite mining with majority ownership of assets in South Africa. The second-largest producer in the world is **Samancor** (Samacor, n.d.), based in South Africa, but with a complex and controversial beneficial ownership structure (see below). **Eurasian Resources Group (ERG)**, based in Luxembourg with 40% owned by the Kazakh government, is the world's largest producer of high-carbon chromium (ERG, n.d.). **Tata Steel** is the main operator in India.

ARTISANAL AND SMALL-SCALE MINING (ASM)

There is small-scale chromite mining in **Zimbabwe**, mainly the Mapanzure area of Zvishavane, but both mining and trade is dominated by Chinese operators (Chinembiri, 2020). Zimbabwean miners rely on Chinese partners to provide equipment and then get 15-30% of the sales at sometimes below-market prices, resulting in disputes and conflict. Much of the chromite is sold to local companies like the Zimbabwe Mining and Alloy Smelting Company, in which the Chinese are major shareholders. There are also informal artisanal chromite miners in Limpopo in **South Africa** (Ledwaba, 2019).

ISSUES IN USAID-PRESENCE COUNTRIES

Financial crimes, corruption and other governance issues are linked to major chromite miners in South Africa and Kazakhstan, who together control over 50% of global production. Since 2004, leading company Samancor has undergone a series of ownership changes following the exit of multinationals BHP Billiton (60% ownership) and Anglo American (40%). The new majority owner is the Kermas Group, controlled by Croatian billionaire Danko Konkar. Investigative journalists and the leaked "Paradise Papers" highlighted transfer pricing through commissions in Malta-listed companies and the involvement of Kazakh oligarchs in Samancor deals, including those who founded company ENRC, which was taken private in 2013 as ERG (listed above) in part due to fraud and bribery charges (Goodley & Luyendijk, 2013). The reports also highlight alleged corruption around a subsidiary sale to Chinese steel manufacturer Sinosteel. Samancor's current beneficial ownership structure starts in Mauritius and continues through a chain of companies in tax havens (Rensburg, 2019).

Madagascar's small chromite company Kraoma SA has also been in the spotlight for corruption when a little-known Russian company Ferrum Mining took an 80% stake in 2019 (Malina, 2018; African Intelligence, 2018b). The company is reportedly owned by US-sanctioned Russian national Yevgeny Prigozhin who may have received the shares in exchanges for election interference in favor of the ruling party (Marten, 2020).

South Africa's chromite mines also have labor relations issues related to opposition to the creation of labor unions at Glencore-owned mines (Jamasmie, 2013), wage disputes and a lawsuit regarding the transfer pricing and other financial crimes allegedly committed by Samancor. In India, environmentalists have denounced leaching and worker exposure to the carcinogen hexavalent chromium in the Sakinda valley mines in the state of Odisha (Das et al., 2021; Mishra & Sahu, 2013). Environmental concerns are also an issue with the ASM chromite mines in the Mapanzure area of Zimbabwe which has left a pock-marked landscape (Mhlanga, 2018). Conflicts between Zimbabwean miners/landowners and Chinese ASM operators are also widespread, including an incident whereby a Chinese manager shot two Zimbabwean employees (Chinembiri, 2020).

MINE DEVELOPMENT AND SUPPLY CHAIN DYNAMICS

Major chromite producers tend to refine to ferrochromium prior to export, but they also export chromite ore, showing some supply chain integration. Further vertical integration has been a recent phenomenon with Chinese and Indian steel companies (like Sinosteel and Tata Steel) becoming stakeholders in chromite mines and ferrochromium refineries. Japan is also a major investor in chromium mining and trading in South Africa. South African Platinium Group Metals (PGM) companies also recover chromium as a byproduct which helps diversify income streams (James, 2018). As noted chromium and chromite are not traded on public exchanges like the LME. Zimbabwe is an active frontier market at present with Chinese and South African investment (Whitehouse, 2018). South Africa's electricity crisis is also affecting the chromium mining sector.

ORGANIZATIONS AND INDUSTRY GROUPS

The **International Chromium Development Association** (ICDA) founded in 1984 provides market research and health and safety studies.

COBALT

US CRITICAL MINERAL?	Yes
MAIN USES IN GREEN ENERGY TECHNOLOGY	**KEY DEVELOPMENT ISSUES IN MINING**
	

DEMAND PROJECTIONS

Cobalt is an important component of lithium-ion batteries used in electric cars, as well as energy storage batteries important for intermittent renewable technologies like wind and solar. Cobalt forms part of the battery's cathode and helps stabilize the chemistry. If cobalt-containing lithium-ion batteries continue to dominate in the coming decades, demand for the metal is projected to be 644,000 tons per year by 2050 under a two-degree scenario (Hund et al., 2020). This would represent a 460% increase over 2018 production levels. However, the evolution of battery technologies is uncertain, and cobalt may therefore play a less important role in the types of batteries used by 2050. Cobalt's relative scarcity and controversies around its production in the DRC is already motivating research to find cobalt-free alternatives (Oberhaus, 2020).

PRODUCTION/RESERVES

Source: OECD

The **DRC** provided nearly 70% of mined cobalt in 2020, making it by far the most important cobalt producer. Most is a by-product of copper mining, but the DRC also has rich primary cobalt deposits. Besides the DRC, only **Morocco** has a primary cobalt deposit that is being mined. Other cobalt producers extract the metal as a by-product of nickel mining, but at lower concentrations compared to the DRC deposits. More than 120 million tons of cobalt resources have been identified in manganese deposits on the floor of the Atlantic, Indian, and Pacific Oceans, making cobalt a possible candidate for deep sea mining.

China is the biggest producer of refined cobalt and is also cobalt's biggest consumer (80% of annual production worldwide) used mainly in the production of batteries. Around 68% of products with cobalt are recycled and 32% of cobalt in new products is recycled (Hund et al., 2020). However, cobalt used in lithium-ion batteries needs to be extremely pure, which limits the amount of recycled cobalt that can be utilized. Cobalt prices have fluctuated wildly in the last five years due to speculation linked to the green energy transition. Price have gone from a low of $23,500 per ton in 2016 to a high of $94,250 in 2018 to $45,000 at the time of writing (LME, n.d.b).

MINING IN USAID-PRESENCE COUNTRIES

The **DRC** is the most critical cobalt-producing country, with 8 of the 14 largest cobalt mining companies being Chinese-owned (OECD, 2019). Smaller USAID-presence producing countries in descending order of importance are the **Philippines, Cuba, Morocco, South Africa, Madagascar, and Papua New Guinea** (limited presence country). With the exception of Morocco's industrial primary cobalt mine, other producers mined cobalt as a by-product of industrial nickel mining. Foreign companies involved in cobalt mining outside of the DRC include Japanese and Koreans (Madagascar), joint Canadian/Filipino (Philippines), Canadian (Cuba), Chinese/Canadian (Papua New Guinea), and Moroccan (Morocco) (NS Energy, n.d.b).

MAJOR INDUSTRIAL COMPANIES	ARTISANAL AND SMALL-SCALE MINING (ASM)
Glencore, the world's largest minerals and metals companies, owns the first and third largest mines in the DRC. **China Molybdenum** owns the second largest and **Zhejiang Huayou Cobalt** owns the fourth largest (called Congo Dongfang International Mining, or CDM). An Indian healthcare entrepreneur owns the fifth largest (**Shalina Resources**, Chemaf mine).	Between 15 and 30% of the **DRC**'s cobalt production comes from ASM (World Economic Forum, 2019). This translates to around 60-80,000 miners of DRC's 2 million artisanal miners in total (Pact UK, 2020). This number fluctuates; the 2017/2018 season had between 150-200,000 miners (BR, 2019). ASM functions as a swing producer in the DRC responding to international price movements (OECD, 2019). ASM and LSM supply chains are not fully segregated; LSM operators often buy from ASM or intermediaries for integration into their refining capacity.

ISSUES IN USAID-PRESENCE COUNTRIES

Cobalt mining in the DRC has attracted heavy media attention in the last few years. Numerous news reports have documented concerns around child labor, fatal workplace accidents, poor working conditions including exposure to toxins causing birth defects, human rights abuses, forced displacement, forced evictions, modern slavery, and environmental devastation. Most of the concerns focus on the ASM sector, but some have also highlighted ways in which the LSM sector directly or indirectly create the conditions for poor practices. News outlets and institutions that have reported on cobalt in the DRC in the last two years include the World Economic Forum, The New Yorker, Foreign Policy, Council on Foreign Relations, the BBC, CBS News and Amnesty International. In 2019, a lawsuit was filed against companies including Apple and Google over the deaths of children in Congolese cobalt mining (Kelly, 2019).

The DRC also has numerous governance issues in its mining sector including corruption and transnational organized crime. This is a concern now that the government has created a state-owned enterprise monopoly over ASM cobalt trade. DRC armed groups also gain funding from the minerals trade, though there is no evidence that cobalt is a "conflict mineral" like tin, tungsten, tantalum, and gold (3TG) in the east. (Cobalt is mined in the copper belt in the south of the country, around 1,000 miles from Eastern DRC) (Ndagano, 2020).

MINE DEVELOPMENT AND SUPPLY CHAIN DYNAMICS

China is the dominant supply-chain figure given its role as the main refiner and consumer of cobalt used in lithium-ion battery manufacturing. Some Chinese companies like Zhejiang Huayou Cobalt, owner of the

The Congo Dongfang International Mining company has come under scrutiny for their role in spurring unsafe ASM production and have since announced that they no longer buy from ASM (NA, n.d.). Besides upstream miners, downstream consumers of cobalt have also sought to disassociate themselves from DRC cobalt. For example, Tesla announced that it would purchase cobalt from LSM producer Glencore and ensure there was no ASM contamination in its supply chain (Shead, 2020). Carmaker BMW also announced a deal with Moroccan miner Managem for cobalt produced in its mine (Berdikeeva, 2021).

Such decisions to step away from ASM cobalt in the DRC have been criticized as they do not help improve conditions for the thousands of people who depend on it for a livelihood and could arguably lead to more impoverishment. In response, some like Glencore have reversed course and are committing to buy from ASM with responsible sourcing standards (Biesheuvel, 2020). Glencore, Tesla and Zheijian Huayou Cobalt have also joined the Fair Cobalt Alliance created in 2020 (The Impact Facility, n.d.). In another initiative, commodities company Trafigura collaborated with NGO Pact and DRC company Chemaf to create a formal ASM cooperative on part of its concession. This has led to an offtake agreement announced this year between Trafigura and a new state-owned-enterprise called the *Entreprise Générale du Cobalt* (EGC) that officially has a monopoly on ASM cobalt (Jamasmie, 2021). This year, Trafigura released the EGC Responsible Sourcing Standards which Pact and Kumi Consulting will help implement (PACT, 2021).

ORGANIZATIONS AND INDUSTRY GROUPS

The **Cobalt Institute** is the main industry group founded in 1982 producing research and advocating on behalf of its members including both upstream and downstream supply chain actors (Cobalt Institute, n.d.). The Institute has developed the Cobalt Industry Responsible Assessment Framework (CIRAF). The **Fair Cobalt Alliance** launched this year is hosted by The Impact Facility, a business supply chain initiative founded by TDI Sustainability and the Fairtrade Foundation. The **Chinese Chamber of Commerce for Metals, Minerals & Chemicals (CCCMC)** collaborated with the OECD to launch the Responsible Cobalt Initiative in 2016 (Respect International, n.d.).

COPPER

US CRITICAL MINERAL? No

MAIN USES IN GREEN ENERGY TECHNOLOGY	KEY DEVELOPMENT ISSUES IN MINING
	

DEMAND PROJECTIONS

Copper is the most cross-cutting metal in renewable technologies. Around three-quarters of future demand will come from solar photovoltaics and wind generation (Hund et al. 2020), but copper is also used in batteries, in electric vehicle wiring, grid transmission and geothermal plants. In photovoltaics, the copper-indium-gallium-selenide (CIGS) technology will be used in about a fifth of panels by 2050, and copper coils are an essential component for induction generators used in wind turbines. By 2050, annual copper demand due to renewables is projected at 1.38 million tons per year under a two-degree scenario (Hund et al., 2020), which is about how much copper the DRC produced in 2020. This amount is only 7% of 2018 production, demonstrating how copper demand is spread across multiple industries. However, some industry leaders have recently expressed concern about the capacity to respond to an economy-wide doubling of copper demand anticipated by 2050 (Reuters, 2021c).

PRODUCTION/RESERVES

Source: OECD

Copper is abundant but not always in sufficient grades for profitable mining. USGS estimated, for example, that there are 2.1 billion tons of copper resources. However, global production and reserves today is dominated by South American producers. **Chile** was the largest copper producer in 2020 with 5.7 million tons or around 30% of global production in that year. In second position was **Peru** with 2.2 million tons and **China** in third with 1.7 million tons. The **US** produced roughly 1.2 million tons, which was slightly less than the **DRC**'s 1.3 million tons.

Products containing copper are recycled at rates between 43 and 53%, and recycled copper is around 20-37% of total copper content in new products (Hund et al., 2020).

Copper prices fluctuate based on worldwide economic conditions given its role a broad range of industries. In the last five years, the price per ton was lowest in 2016 at $4,350. After growing steadily, it plummeted to about that level in March 2020 at the outset of the COVID-19 pandemic. It has since rallied to record highs, going past $10,000 per ton in early 2021.

MINING IN USAID-PRESENCE COUNTRIES

Top producer **Chile** is a limited USAID presence country, and the second largest producer **Peru** is a USAID presence country. Other major producers with USAID presence are the **DRC, Zambia, Mexico, and Kazakhstan.**

Smaller production or likely future production exists in more than 30 USAID-presence countries including **Albania, Armenia, Azerbaijan, Bolivia (limited presence), Botswana, Brazil, Burma, Colombia, Dominican Republic, Ecuador, Georgia, India, Indonesia, Kyrgyz Republic, Laos, Mauritania, Mongolia, Morocco, Namibia, North Macedonia, Pakistan, Panama, Papua New Guinea (limited presence), Philippines, South Africa, Tajikistan, Tanzania, Uzbekistan, Vietnam, and Zimbabwe.**

MAJOR INDUSTRIAL COMPANIES	ARTISANAL AND SMALL-SCALE MINING (ASM)
Codelco, the national company of Chile, is the largest, followed by **BHP** which also operates in Chile. BHP also operates in Australia and the US. American company **Freeport-McMoRan** operates the world's largest gold mine in Indonesia which produces copper as a by-product. **Glencore** is the largest copper company active in the DRC, and Mexico-based **Southern Copper** operates in Mexico and Peru (NS Energy, 2021a). **Jiangxi Copper** is a major Chinese company in copper and other metals; it is also the fifth largest overall mining company in the world (Murray, 2021).	While ASM cobalt has garnered widespread international attention, the same **DRC** miners that produce cobalt are also producing copper as both metals occur in the same ore bodies. A 2019 German study noted that average reported copper grades in ASM core was 13.6% and cobalt grade was 4.2%, and prices are set based on both metals' content; however, DRC's copper exports are likely less than 1% from ASM at those levels (BGR, 2019). ASM copper has also been documented in **Chile** though generally as a by-product of gold (Castro, 2003). ASM was also documented in **Tanzania** with Chinese buyers operating widely until 2014 price drops (Schoneveld et al., 2018).

ISSUES IN USAID-PRESENCE COUNTRIES

The same labor and human rights issues cited in DRC's cobalt sector apply to its copper, albeit with less acuteness given the relatively small proportion of DRC copper from ASM. DRC's general mining governance challenges with respect to corruption also are relevant to its copper sector.

In the industrial copper sector in South America, development challenges revolve more about how mineral wealth contributes to the broader economy and macroeconomic stability. For the last two decades, for example, 10% of Chile's GDP has come from copper mining (International Copper Association, 2018). Policy-makers and academics have studied how the broader economy can suffer from price shocks as well as how to build better economic linkages (Rehner & Rodriguez, 2021).

Industrial copper mining is also a major policy issue in national politics, including recent elections in Peru and Chile where the benefits of multinational mining companies on average citizens were called into question by left-leaning candidates. Indeed, resource nationalism is an issue affecting the copper industry, including proposals for higher taxes or nationalization. Mining companies also wield considerable influence in producing countries as evidenced by their request to participate in revising Chile's constitution (Reuters, 2021e).

MINE DEVELOPMENT AND SUPPLY CHAIN DYNAMICS

Copper supply and demand dynamics are linked to the broader global economy, especially China, which is by far the largest consumer of copper followed by Germany at a distant second. China's imports are therefore closely followed by market analysts. China also actively influences prices such as the recent release of copper and other metals from its strategic reserves in a bid to bring down record high prices of several metals that were creating a risk of inflation given their broad role in the economy (Nguyen, 2021). Copper like other base metals is also influenced by investor speculation (commodities are used as a hedge against inflation) as well as fiscal policy, mainly interest rates, which move inversely to prices.[22]

Like other base metals, there is inertia in responding to price movements given the amount of capital and time required to develop new mines. As a result, there can be periods of supply deficit as well as excess supply if new mining projects are ill-timed with market demand. Analysts point to a current supply deficit.

The COVID-19 pandemic showed other vulnerabilities such as the dependence on South American mines in Chile and Peru. Indeed, the closure of some mines due to COVID-19 has been a factor limiting supply and pushing up prices, as well as worldwide shipping logistic constraints (Wallace, 2021). As noted politics and resource nationalism is also a feature in the copper sector, with some recent calls for nationalization in Peru (Marques, 2021) as well as a copper mining company nationalization in Zambia this year (Mushinge, 2021).

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22 As the cost of borrowing increases, companies tend to reduce commodity reserves, which puts downward pressure on market prices. Conversely, when borrowing is cheap, companies will be able to hold more reserves, which decreases overall supply and puts upward pressure on prices. See recent market reaction: Reuters (2021, June) Home: funds flee cyclically confused copper market. *Mining[dot]com*. Accessed via https://www.mining.com/web/home-funds-flee-cyclically-confused-copper-market/

ORGANIZATIONS AND INDUSTRY GROUPS
The **International Copper Association** is the main industry group (Copper Alliance, n.d.). In Chile, the Copper Commission (**COCHILCO**) is an important national and international actor (COCHILO, n.d.).

GRAPHITE

US CRITICAL MINERAL? Yes

MAIN USES IN GREEN ENERGY TECHNOLOGY

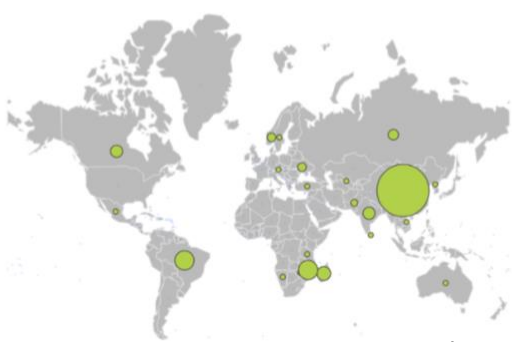
KEY DEVELOPMENT ISSUES IN MINING

DEMAND PROJECTIONS

Graphite is a form of carbon that is used in a variety of applications including brake linings, lubricants, and steelmaking. Lithium-ion batteries used in electric vehicles and renewable energy storage use graphite as the anode. The stable structure of graphite hosts the charged lithium ions before they move through the electrolyte towards the cathode releasing the electrical current.

Graphite is projected to account for over 50% of minerals used in batteries by 2050, far surpassing lithium and cobalt (Hund et al., 2020). Lithium-ion batteries now account for 25% of graphite demand and this is set to increase in the coming decades (Northern Graphite, n.d.a). By 2050 under a two-degree scenario, over 4.5 million tons of graphite will be needed each year, which is 494% higher than 2018 production levels. However, like cobalt there is uncertainty as battery technologies evolve. For example, graphite demand will be less should there be widespread adoption of solid-state batteries, for example, in which graphite is not required.

PRODUCTION/RESERVES



Source: OECD

China has been the world's leading graphite producer for some time. In 2020, China produced an estimated 650,000 tons or 62% of total world output. China is followed by **Mozambique** and **Brazil** who produce around 10% of world production each. **China, Turkey, and Brazil** have the largest known reserves. There are also significant reserves in **Madagascar** and **Mozambique**.

Graphite is not traded in the open market so price data is not readily available. In addition, prices vary widely depending on flake size. The average flake graphite imported into the US in the last 5 years varied between $1,350 (2019) and $1,920 (2016) according to USGS data. However, the price has been relatively stable between 2017 and 2020 at around $1,500 per ton.

MINING IN USAID-PRESENCE COUNTRIES

As noted **Mozambique** and **Brazil** were the second and third largest graphite producers in 2020 respectively, though both combined were less than a third of China's output. Other USAID-presence countries with current or expected graphite mining are **Madagascar, India, Pakistan, Vietnam, Mexico, Sri Lanka, Tanzania, Uzbekistan, Zimbabwe,** and **Namibia.** Countries with particular growth potential are Mozambique and Madagascar.

MAJOR INDUSTRIAL COMPANIES	ARTISANAL AND SMALL-SCALE MINING (ASM)
China has dozens of mines and intermediaries, making it hard to pinpoint dominant companies. However, **BTR** is cited as the largest supplier of natural graphite from its own mines as well as other mines, accounting for up to 75% of China's supply (Whoriskey, 2016; BTR, n.d.). In Mozambique the main producer is Australian company **Syrah Resources** (Syrah Resources, n.d.a). Brazil's main graphite mining companies are privately held and information is hard	None known

to come by, but **Nacional de Grafite** is apparently an important player (*Nacional de Grafite*, n.d.).	

ISSUES IN USAID-PRESENCE COUNTRIES

Graphite mining has garnered relatively little attention compared to other minerals. In China there have been concerns about the health effects of dust from graphite mines on miners and surrounding communities, though no such issues have been raised in USAID-presence countries with graphite mining.

In Mozambique, the largest graphite mine is located in Cabo Delgado, which is a region faced with terrorist groups affiliated with Al Qaeda. The future of Mozambique's graphite mining therefore depends on how the security-development challenges in this region are dealt with (Ker, 2018).

Madagascar is also emerging as a place of interest. While the country's 100-year-old graphite industry has been in the northwest, southern Madagascar is emerging as a new hub with several projects in the pipeline. This area has many areas of biological importance (Reach Markets, 2019).

MINE DEVELOPMENT AND SUPPLY CHAIN DYNAMICS

Graphite is not inherently scarce but economic resources are highly influenced by world market prices. China dumped graphite on the world market in the 1990s to raise foreign reserves which depressed prices for over a decade and led to little investment in new projects until prices began recovering in 2005 (Northern Graphite, n.d.b). The graphite supply chain is also complex with many intermediaries and privately held companies making it difficult to get clear information.

In recent years, relatively high graphite prices and speculation around the green energy transition and need to diversify from China has led to several new projects being developed in Mozambique, Tanzania (ECOGRAF, n.d.), Brazil (GRAPHCOA, n.d.), India, Namibia (Mining Journal, 2020), and Madagascar. Junior companies listed in Australia, Toronto, and London are involved in these projects (Mining Technology, n.d.b; Mining Technology n.d.c).

ORGANIZATIONS AND INDUSTRY GROUPS

There are no major graphite-focused industry organizations or supply chain initiatives.

IRON

US CRITICAL MINERAL? No

MAIN USES IN GREEN ENERGY TECHNOLOGY

KEY DEVELOPMENT ISSUES IN MINING

DEMAND PROJECTIONS

Iron is a widely used metal generally combined with carbon and other elements to produce steel, which is a foundation of the modern economy worldwide. Iron is an essential component in wind turbines used in the induction generator core as well as rotor hubs. Iron represents 85% of the mineral demand foreseen from wind technologies. Iron is also used in newer battery technologies such as iron-based flow batteries used for grid-level energy storage as well as a cobalt-free battery type called lithium-iron phosphate. The evolution of batteries will impact projected iron demand but is projected to reach 7.5 million tons per year by 2050 which is 1% of 2018 global production levels (Hund et al., 2020). This projection does not include any increased use of steel which is used for wind turbine towers, grid installations and other parts of energy infrastructure.

PRODUCTION/RESERVES

Source: OECD

The main iron ores are hematite and magnetite. **Australia** produced 900 million tons in 2020, representing nearly 40% of the world total of 2.4 billion tons. Australia was followed by **Brazil** which produced a sixth of world production (400 million tons) and **China** (340 million tons). World resources are widespread (iron is the fourth most abundant element in the earth's crust). There is an estimated 800 billion tons of iron ore containing more than 230 billion tons of iron metal. However, economic iron ore deposits generally require more than 50% iron for hematite and 25% iron for magnetite.

Nearly 98% of iron ore is used to make steel. **China** is the world's largest steelmaker (producing over 50% of global supply) and as such is the world's top iron ore consumer. In the last five years, iron ore prices per ton ranged from $73.11 in 2016 to $108.00 in 2020. In 2021, prices rose over 100% to more than $200 per ton (Dela Cruz).

MINING IN USAID-PRESENCE COUNTRIES

Brazil is the world's second biggest iron ore producer, representing a sixth of world production (400 million tons). **India** is the fourth largest producer at 240 million tons produced in 2020. Other current or likely future producers include: **Bosnia-Herzegovina, South Africa, Ukraine, Kazakhstan, Chile** (limited presence), **Peru, Bolivia** (limited presence), **Colombia, Republic of Congo, Egypt, Guinea, Indonesia, Laos, Liberia, Mauritania, Mexico, Mongolia, Namibia, Nigeria, Pakistan, Republic of Congo, Senegal, Sierra Leone, Thailand,** and **Vietnam.**

MAJOR INDUSTRIAL COMPANIES

Three companies have dominated iron ore mining for decades. In 2020 they remained in the top 3: Brazilian **Vale** with 300 million tons from its mines alone, Australia-based **Rio Tinto** and Australia-based **BHP**. **Fortescue Metals Groups**, also Australia-based but with mining and exploration in USAID-presence countries, was fourth. In fifth place was London-listed **Anglo-American** with mines in both South Africa and Brazil (NS Energy, 2021b).

ARTISANAL AND SMALL-SCALE MINING (ASM)

None

ISSUES IN USAID-PRESENCE COUNTRIES

Governance shortcomings and geopolitics around iron mining concessions in frontier countries, especially in West and Central Africa, are a major development challenge. Guinea's Simandou range, for example, hosts over 2 billion tons of high-grade iron ore reserves, making it potentially one of the most lucrative mines in the world. However, mining rights have been in dispute and turmoil for many years, including corruption and bribery allegations against Israeli diamond investor Benny Steinmetz, and involving iron majors Rio Tinto and Vale (Keefe, 2013).

Corruption and risk of arbitrary license revocation under the guise of resource nationalism is a risk for major investments which require stability over a long period of initial investment. Recently the Republic of Congo revoked iron mining licenses of Australian firms in favor of a local company backed by Chinese investors with no iron mining experience. The case is in international arbitration (Reuters, 2021b). Sierra Leone similarly revoked licenses from its two iron ore mines and went against an international arbitration ruling to give the rights to a private Chinese company Kingho Investment (Kinch & Hao, 2020). Chinese operators have an advantage in these markets partly because they can more easily access finance from state-backed funds like the $5-billion China-Africa Development Fund.

Another challenge but also opportunity is the fact that iron mining requires significant infrastructure in order to transport and export enormous quantities of ore. This increases the capital expenditure requirements significantly and partly explains the "mine-for-infrastructure" deals with China, but some countries are seeking to develop infrastructure separately to attract mines investment. Senegal, for example, is seeking to develop a rail system to support its iron ore potential (Whitehouse, 2020). Senegal is also aiming at processing its iron ore before export in order to keep more value in-country (Africa Intelligence 2020). If done right iron mining can therefore prove structurally transformative given associated infrastructure investments. These investments will not happen if there is not a minimum level of stability, however. For a time, Mali was also hoping to develop the infrastructure needed to develop its iron ore (Diallo & Felix, 2014), but militant groups and general instability have dampened these plans.

Environmental concerns are also issues in iron ore mining. In Laos, for example, Chinese mining has brought protest from communities due to pollution (Radio Free Asia, 2021). In Mongolia, India and Liberia, similarly, negative impacts from iron ore mining have been studied by academics and advocacy groups (B. Das, 2014; Gleekia, 2016; Steinweg & Schuit, 2014).

MINE DEVELOPMENT AND SUPPLY CHAIN DYNAMICS

The iron ore market used to be governed by a "benchmark" system whereby an annual price was negotiated between steelmaker giant Japan and the three major miners (Rio Tinto, BHP, and Vale). The rapid rise of China, however, led companies to favor short-term contracts in a spot market instead. Iron prices have since been characterized by instability driven mainly by the ups and downs in China's economy. Prices have been as low as $41 per ton in 2015 to well over $200 in the current record-setting boom linked to production and logistical bottlenecks due to COVID-19 in 2020 as well as speculative behavior.

Another key feature of the iron ore sector is its long project development cycle and very high capital expenditures even though operating costs themselves are low. This has placed China at an advantage in newer USAID-presence countries. Western banks are less likely to finance these large, long-term investments in risky environments while Chinese state-backed financiers are less risk averse. Developing iron ore in emerging markets could be transformational, however, given its potential to spur infrastructure investment as well as provide facilitate local steelmaking essential for construction and industrial development.

ORGANIZATIONS AND INDUSTRY GROUPS

There are multiple steel-focused industry groups. The **International Iron Metallics Association**[23] groups some iron actors. However, most iron mining companies are diversified mining majors who are members of national industry groups as well as the ICMM.

[23] https://www.metallics.org/

LEAD

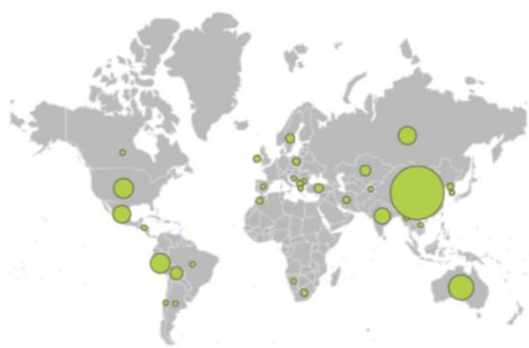
US CRITICAL MINERAL?	No

MAIN USES IN GREEN ENERGY TECHNOLOGY	KEY DEVELOPMENT ISSUES IN MINING
	

DEMAND PROJECTIONS

Lead is a main component of lead-acid batteries used in conventional cars as well as renewable energy storage. While lithium-ion batteries are lighter and more efficient, lead-acid batteries are low-cost and are projected to maintain a third of market share in decentralized energy storage by 2050. At centralized grid levels, however, lead-acid batteries are projected to hold a maximum market share of 5%. Lead is also used in soldering electronic components of photovoltaic panels and wind turbines. Lead usage stemming from renewable energies is projected to reach 781,000 tons per year by 2050 under a two-degree scenario, representing an 18% increase over 2018 global production levels (Hund et al, 2020).

PRODUCTION/RESERVES



Source: OECD

China is the largest producer of lead. In 2020, Chinese mines and smelters produced 1.9 million tons representing around 40% of global production. **Australia** was a distant second with 480,000 tons produced in 2020. However, Australia has the world's largest known lead reserves. The most common ore for lead is galena, which can also contain 1-2% silver. Galena tends to occur together with sphalerite, the main ore for zinc. As such, lead and zinc (and sometimes silver) are often produced from the same mines, and the lead-zinc industries are intertwined. Identified worldwide resources of lead are more than 2 billion tons. In the last five years, lead has hovered around $2,000 per ton, with a high of $2,700 in 2018 and a low near $1,600 in early 2020.

MINING IN USAID-PRESENCE COUNTRIES

In 2020, medium-size lead producers in descending order of production volumes were **Mexico, Peru, India, Bolivia, Tajikistan,** and **Kazakhstan**. Smaller and emerging producers include **Bosnia-Herzegovina, Brazil, Burma, Cuba, Guatemala, Honduras, Indonesia, Kosovo, Mongolia, Montenegro, Morocco, Mozambique, Namibia, Nigeria, North Macedonia, Pakistan, South Africa, Uzbekistan,** and **Vietnam.**

MAJOR INDUSTRIAL COMPANIES	ARTISANAL AND SMALL-SCALE MINING (ASM)
Teck Resources in Canada is a major producer of lead. Chinese mines and smelters are numerous and data is limited, but **Zijin Mining Group** operates the second largest zinc/lead mine in China Xinjiang's region, where major zinc/lead reserves are located, in addition to Inner Mongolia. State-owned company **China Minmetals Corp** is a major miner, trader, and smelter for numerous metals, including lead.	A study from 20 years ago noted that 30% of China's lead and zinc comes from ASM (Gunson & Jian, 2001), but there is no recent information on this.

ISSUES IN USAID-PRESENCE COUNTRIES

Large lead/zinc mines have similar environmental and social challenges to other large-scale mining operations. For example, a large lead/zinc project in Indonesia faced opposition due to the placement of a tailings dam in a seismically unstable area of Sumatra above a dozen villages (Pearce, 2021). This has led to advocacy from local and international environmental organizations (Inclusive Development International, n.d.).

Lead’s well-known toxicity also poses a health hazard to miners as well as surrounding community water supply. Often issues of lead poisoning occur during other types of mining, such as the case in Zamfara state in Nigeria in 2010 when hundreds of children died from lead exposure linked to artisanal gold mining (Avakian, n.d.). Lead exposure has also been a growing concern in China around its smelters (Hornby, 2009). In USAID-presence countries, some studies have been produced on drinking water contamination in or near lead mining areas, such as in Nigeria (Obiora et al., 2019).
MINE DEVELOPMENT AND SUPPLY CHAIN DYNAMICS
Lead demand and prices are likely to remain relatively stable in the coming decades. However, the increasing price of scrap metal combined with flat recycled (secondary) lead prices means margins will tight for secondary smelters.
ORGANIZATIONS AND INDUSTRY GROUPS
The **International Lead and Zinc Study Group**, founded in 1959, is an intergovernmental organization that produces research (International Lead and Zinc Study Group, n.d.).

LITHIUM

US CRITICAL MINERAL? Yes

MAIN USES IN GREEN ENERGY TECHNOLOGY	KEY DEVELOPMENT ISSUES IN MINING
	

DEMAND PROJECTIONS

Lithium is fundamental to lithium-ion battery technologies. Lithium's reactiveness and small size enables a higher voltage and charge per unit mass and volume compared to other options. Lithium-ion batteries have some downsides, such as a risk of fire, but so far no alternatives have been found that outperform at the same cost. As such analysts anticipate that lithium-ion batteries will be used in 100% of electric vehicles in 2050, 70-84% of energy storage at a grid level and about a third of storage at a decentralized level (Hund et al., 2020). With these assumptions, even taking into account increased efficiency of lithium usage, around 415,000 tons per year of lithium will be required by 2050 under a two-degree scenario, which translates to 488% above 2018 production levels.

PRODUCTION/RESERVES

Source: OECD

Most lithium is produced from two sources: a mineral source (spodumene crystals found in pegmatite) and lithium brine from seawater or salts. **Australia** is currently the world's main lithium producer with 40,000 tons produced in 2020, or almost half of the world's production. **Chile** was second with 18,000 tons, followed by **China** with 14,000 tons. In terms of reserves, the so-called "lithium triangle" between Argentina, Chile, and Bolivia dwarfs Australia's known reserves. Most resources are salt pans bordering or in the Atacama Desert.

Less than 1% of lithium is currently recycled, and future prospects for recycling lithium from batteries are not good given technical complexities though research is ongoing (Hund et al., 2020). Lithium is sold in several forms. Battery-grade lithium carbonate prices have varied between $8,000 and $17,000 per ton in the last five years. In 2021 the price has reached $1,350. Pure lithium metal sells for as high as $80,000 per ton.

MINING IN USAID-PRESENCE COUNTRIES

As noted, **Chile** (limited presence) is the world's second largest producer and has developed resources faster than **Bolivia** (limited presence) and **Argentina** (non-presence), the other countries forming the "lithium triangle." In 2020 there were smaller producers in **Brazil** and **Zimbabwe**. Due to increasing demand and prices, many junior exploration companies developing projects in other frontier markets, including the **DRC** (Australian/Chinese) (Mining Technology, n.d.a), **Mexico** (Chinese) (Deslandes, 2020), **Peru** (Canadian) (Aquino, 2020), **Mali** (Australian/Chinese) (Reuters, 2021a), **Ghana** (Australian) (Mining Review Africa, 2021), **Kazakhstan** (unknown), and **Namibia** (Australia) (Mining Journal, 2019).

MAJOR INDUSTRIAL COMPANIES	ARTISANAL AND SMALL-SCALE MINING (ASM)
Albermarle Corporation (US) and US-listed **Sociedad Quimica y Minera de Chile (SQM)** were the largest lithium producers in the world until recently, along with **FMC Corp**, and both remain in the top five. FMC Corp spun off its lithium interests in company **Livent** in 2019. The largest lithium producer today is **Gangfeng Lithium** (China) that mines and	None

refines. **Tianqi Lithium** (China) and **Mineral Resources** (Australia) are also important companies.	

ISSUES IN USAID-PRESENCE COUNTRIES
The main issue associated with lithium mining, especially in the lithium triangle, is environmental. Current mining practices in the salt flats are water intensive and produce large amounts of waste (Flexer et al., 2018). The use of water has even led to the decline in water tables for surrounding communities (Liu & Agusdinata, 2021). Community opposition to lithium mining has been a feature in Chile (Liu & Agusdinata, 2020). There have also been issues around human rights and free-and-prior informed consent (Heredia et al., 2020). More broadly the scramble for lithium in South America has set off public debates on beneficiation and economic linkages, which is "creating space for a more dynamic debate about the social value of mining and the proper role of the state in development" (Barandiarán, 2019). In some countries this debate has swung between resource nationalism and inviting foreign investment, such as in Mexico (Garcia, 2021). In other frontier markets community conflicts and capacity constraints might be key issues. Countries that have never engaged in lithium mining could become designated hubs for speculative "maverick" exploration companies, which can also raise the risk of corruption.
MINE DEVELOPMENT AND SUPPLY CHAIN DYNAMICS
Lithium has been in a "resource scramble" linked almost entirely to the anticipated surge in demand due to the green energy transition. This scramble has been driven by the supply chain rather than traditional mining actors. Strategic alliances and joint ventures between lithium-ion battery users like vehicle manufacturers, battery supply companies and junior mining companies have been burgeoning. There has also been increasing vertical integration across the supply chain.
ORGANIZATIONS AND INDUSTRY GROUPS
No major lithium mining focused industry groups

MANGANESE

US CRITICAL MINERAL? Yes

MAIN USES IN GREEN ENERGY TECHNOLOGY	KEY DEVELOPMENT ISSUES IN MINING
	

DEMAND PROJECTIONS

Manganese is used in steel to decrease brittleness and increase strength, as well as serving as an alloying agent that removes oxygen and sulfur during iron ore smelting. In renewable technologies it is mainly used in batteries; by 2050, 6% of battery metals will be manganese. Manganese forms part of the cathode compound in certain types of lithium-ion batteries, namely, the nickel-manganese-cobalt oxide (NMC) design. Small amounts of manganese are also used as part of steel components of wind turbines and in geothermal plants. By 2050, annual manganese demand from renewables is projected to be 694,000 tons under a two-degree scenario, or 4% above 2018 production levels (Hund et al., 2020). This projection does not account for potential use of manganese as part of carbon capture and storage technologies.

PRODUCTION/RESERVES

Source: OECD

South Africa is the world's largest producer with 5.2 million tons in 2020, or nearly 30% of world production. In second place is **Australia** with 3.3 million tons followed by **Gabon** with 2.8 million tons. South Africa, **Brazil** and Australia have the largest known reserves. Land-based manganese resources are abundant but irregularly distributed. There are also undersea manganese deposits. In the last five years, the price per ton of manganese ore (44% grade) imported to the US from China varied from $4.32 in 2016 to $7.16 in 2018. Prices today are around $4.50 per ton and are expected to remain relatively stable.

MINING IN USAID-PRESENCE COUNTRIES

South Africa and **Gabon** are in the top three producers. Other important producers include **Ghana, Brazil, India, Ukraine, Côte d'Ivoire, Burma, Mexico, Georgia, Vietnam,** and **Kazakhstan.** Smaller or emerging producers are **Bolivia (limited presence), Indonesia, Kenya, Namibia, Peru, Ukraine,** and **Zambia**.

MAJOR INDUSTRIAL COMPANIES	ARTISANAL AND SMALL-SCALE MINING (ASM)
Like South Africa's chromium industry, its manganese industry has little public information. Of its estimated 22 mines, only four are owned by publicly listed companies (Creamer, 2020). The largest operator in terms of resources/reserves is **Assmang Manganese**, controlled by **Assore Limited** and **African Rainbow Resources**, both publicly listed South African holding companies. South African **Jupiter Mines** owns a 50% stake in South Africa's second largest mine, the Tshipi Borwa. France-based **Eramet** owns and operates Gabon's main mine.	ASM manganese mining has been documented in West Timor, Indonesia, especially between 2009 and 2011 when an estimated 325,000 people were involved (Fisher et al., 2019). An academic study found that mining had few negative impacts when it was conducted in a way complementary to farming and other livelihoods (Fisher et al., 2019; Ling, 2018).

ISSUES IN USAID-PRESENCE COUNTRIES

Manganese mining has been the subject of less controversies compared to other minerals, but challenges with respect to governance, environmental management and community relations exist in both major and minor producers. For example, an NGO report from this year reviewed human rights issues, especially affected women, in South Africa's manganese sector (Somo, 2021). Community land tenure has been an issue in Kenya.

For example, a community leased its land to a manganese company but complained it did not receive its agreed upon benefits (Muingi, 2020). Communities around Gabon's major mine, the third largest in the world, are also divided as to the extent to which they have benefitted from the mine which has been operating for decades (France24, 2021).

Governance challenges also feature in the literature. In Ghana, for example, the country's main mine is owned by a Jersey-headquartered Chinese holding company linked to a major manganese metal producer Ningxia Tianyuan Manganese Industry (The Chronicle, 2019). In 2019, the government of Ghana temporarily shut down the mine over accusations of hundreds of millions of dollars of tax evasion through transfer pricing and other maneuvers. Ghana has recently also capped annual exports in order to retain more value in country and stabilize extraction (Roskill, 2020). Dynamics around Indonesia's manganese mining have also highlighted governance challenges related to decentralization (Sahin et al., 2012).

Manganese mining has been linked to fewer environmental concerns, though at least one study from India pointed to potential water contamination (Goswami et al., 2009). Infrastructure governance challenges such as South Africa's electricity crisis is also negatively impacting its mining industry, including manganese mines. Indeed, the conversion of manganese ore to ferromanganese used in steel requires significant power (Creamer, 2020).

MINE DEVELOPMENT AND SUPPLY CHAIN DYNAMICS

South Africa's manganese producers generally process a portion of manganese ore into ferromanganese prior to export to steel manufacturers, mainly in China. Gabon exported unprocessed ore until opening a $400-million smelter in 2015 (Mining Review Africa, 2015). Other countries like Ghana and Côte d'Ivoire export unprocessed ore.

China has been in the spotlight recently for actions to further consolidate control over the manganese supply chain (Yap, 2021). According to a Wall Street Journal article, China controls 90% of manganese products including its use in steel and batteries, illustrating how the location of midstream and downstream mineral processors is crucial to take into account. As with other minerals, Chinese manganese processors are also increasingly getting involved in sourcing, such as the Ghana project controlled by a major Chinese processor that has explicitly cited the Belt and Road Initiative as a motivation for its involvement in mining (Shanghai Nonferrous Metals Network, 2018).

ORGANIZATIONS AND INDUSTRY GROUPS

The **International Manganese Institute (IMnI)** represents over 80 industry players (The International Manganese Institute, n.d.). Manganese processors and manufacturers in China have recently created a state-backed **manganese innovation alliance**, described as a cartel, according to the aforementioned WSJ article.

MOLYBDENUM

US CRITICAL MINERAL? No

MAIN USES IN GREEN ENERGY TECHNOLOGY	KEY DEVELOPMENT ISSUES IN MINING
	

DEMAND PROJECTIONS

Molybdenum is a ferroalloy used in steel production because of its exceptionally high melting point. This makes it an important component for steels used in wind turbines and geothermal plants. In addition, a small layer of molybdenum is used as part of the emerging thin-film solar technology CIGS, thanks to its superior electrical and heat conductivity, and its ability to bond to glass. By 2050, around 33,000 tons of molybdenum are forecast to be used in renewables each year, which represents approximately 11% above 2018 production levels (Hund et al., 2020).

PRODUCTION/RESERVES

Source: OECD

Molybdenum's ore is called molybdenite which can occur in primary form (mainly in China) as well as in association with copper-bearing minerals (in the Americas especially). In 2020, China was the world's largest producer with 120,000 tons, or 40% of global production. China was followed by Chile with 58,000 tons and the US with 49,000 tons. China has the world's largest known reserves followed by Peru. The price per kilo has varied from $14.40 in 2016 to $27.04 in 2018, and back down to around $20 in 2020. Molybdenum is tracked by the LME; the price was around $20 at the time of writing.

MINING IN USAID-PRESENCE COUNTRIES

Among top producers, **Chile** (limited presence) is the second most important after China. Other major producers with USAID presence include **Peru, Mexico, Armenia, Mongolia, and Uzbekistan. Kazakhstan** is also a small producer.

MAJOR INDUSTRIAL COMPANIES	ARTISANAL AND SMALL-SCALE MINING (ASM)
Freeport-McMoRan is the largest producer thanks to its copper and molybdenum mines in the US and Chile. State-owned **Codelco** produces the bulk of Chile's molybdenum, along with **Southern Copper Corporation**. **China Molybdenum Company** is China's largest molybdenum miner. **Jinduicheng Molybdenum** operates the world's largest molybdenum mine located in China.	None

ISSUES IN USAID-PRESENCE COUNTRIES

Because most molybdenum in USAID-presence countries is mined as a secondary product of copper mining, the same key issues highlighted for copper in South America apply, including governance for national and local economic development and environmental management.

Environmental issues, notably water contamination, have been highlighted in other smaller molybdenum producers including Mongolia's Erdenet copper-molybdenum mine (Battogtokh et al., 2014). Governance issues have also been highlighted in Armenia, mainly lack of transparency around Russia-linked politically exposed persons who are alleged beneficial owners of a privatized molybdenum mining company (Karapetyan, n.d.).

MINE DEVELOPMENT AND SUPPLY CHAIN DYNAMICS

Exploration budgets for molybdenum projects have decreased from highs in 2016 but significant spending is underway on projects in the US, Canada, and Australia. Because the majority of new projects are driven by copper, with molybdenum as a secondary product, copper supply chain dynamics are important in driving investment decisions.

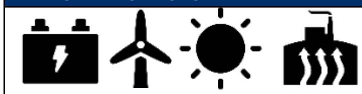
There is considerable vertical integration in the molybdenum supply chain with mining companies generally also doing the smelting and manufacturing. For example, Freeport-McRohan subsidiary Climax Molybdenum is the processing and trading arm for its production from South America, even though the company began over a century ago with mining molybdenite in Colorado (Climax Molybdenum, n.d.). Similarly, the major Chinese producers mine, process, and market end products.

ORGANIZATIONS AND INDUSTRY GROUPS

The **International Molybdenum Association** (IMOA) is a trade association for the industry (International Molybdenium Association, n.d.). In China, the **China Nonferrous Metals Industry Association** (CNIA) with 726 members has a **Molybdenum Branch** (Asian Metal, n.d.).

NICKEL

US CRITICAL MINERAL?	Not yet, but under review for inclusion

MAIN USES IN GREEN ENERGY TECHNOLOGY	KEY DEVELOPMENT ISSUES IN MINING
	

DEMAND PROJECTIONS

Nickel is a widely used base metal. About two-thirds of global production ends up in stainless steel thanks to nickel's anti-corrosive properties. For this reason, China is the world's largest consumer of nickel, given its central role in steel production. Nickel is also used in other steel alloys employed in various applications including geothermal plants and wind turbines. However, the bulk of nickel demand from renewables stems from its central role in lithium-ion batteries, forming part of the nickel-manganese-cobalt (NMC) cathode chemistry. By 2050, each year renewable energy manufacturers will use 2,268,000 tons of nickel, or 99% above 2018 global production levels (Hund et al., 2020). Overall nickel demand is set to triple by 2050.

PRODUCTION/RESERVES

Source: OECD

Indonesia was the largest producer of nickel in 2020, with 760,000 tons or 30% of world production. The second largest producer was the **Philippines** with 320,000 tons and the third **Russia** with 280,000 tons. The fourth largest producer is **New Caledonia**, a French overseas territory. Globally there are over 300 million tons of known reserves, not including nickel found on the ocean floor in manganese crusts.

Nickel is classified per its ore and final use. Class I nickel is the purest (above 99.8%) used in applications like batteries and historically is derived from sulfide deposits. Class II nickel is less than 99.8% used in the steel industry and is historically derived from lateritic deposits. Most ores are lateritic. Smelting lateritic ores and refining nickel to Class I requires a complex metallurgical process.

The price per ton of nickel is closely tracked by the LME and has ranged from $9,594 to $14,000 between 2016 and 2020. Despite some industry projections of oversupply, nickel has rallied to a record high of $18,611 per ton in early 2021.

MINING IN USAID-PRESENCE COUNTRIES

The top two producers in the world are **Indonesia** and the **Philippines**, accounting for half of all 2020 production. Both are USAID-presence countries. Other significant producers with USAID presence in decreasing order of 2020 production area **Brazil, Cuba,** and the **Dominican Republic**. Smaller and emerging USAID-presence producers are **Albania, Burma, Colombia, Côte d'Ivoire, Guatemala, Kosovo, Madagascar, Papua New Guinea, South Africa, Zambia,** and **Zimbabwe**. Some of the emerging projects have the potential to become major. The Ambatovy project in Madagascar, for example, jointly owned by Japanese Sumitomo Corporation and Korean Resources Corporation, is projected to become the world's largest lateritic nickel mine.[24]

MAJOR INDUSTRIAL COMPANIES	ARTISANAL AND SMALL-SCALE MINING (ASM)
Brazil-based **Vale** is the world's largest producer, with mines in Brazil, Canada, Indonesia, and New Caledonia (France), as well as refineries in China, South Korea, Japan, the UK, and Taiwan. **Norilsk Nickel** is Russia's top nickel miner and **Jinchuan Group** is China's top	None

[24] See the Ambatovy project page https://ambatovy.com/ang/

miner. Switzerland-based **Glencore** and **Australia BHP** are also in the top five (NS Energy, 2020b).	

ISSUES IN USAID-PRESENCE COUNTRIES

Nickel mining poses environmental risks. Processing lateritic deposits, like those that dominate in Southeast Asia and Africa, requires high-pressure acid leaching and deep-sea tailings disposal in order to process to battery-grade purity. This is a particularly important public policy issue in **Indonesia** pitting miners/smelters against environmental activists who are concerned about the effects on the high-value marine ecosystems (Morse, 2020a). As the world's top producer, Indonesia's environmental management is under increasing international scrutiny. Processing lateritic deposits to battery grade nickel also requires intense energy usage (Morse, 2021). Environment is also a major issue in the **Philippines**. The country banned new nickel mining projects for nine years under pressure from activists before announcing a reversal in April 2021 in a bid to increase revenues (Crus, 2021).

Environmental concerns can create tensions with surrounding communities. In **Papua New Guinea** (limited presence), a Chinese-owned company spilled toxic waste into the sea in 2019 (Burton & Daly, 2019). The issue has caused tensions with local communities who sued the company in 2020 (Morse, 2020b). In **Guatemala**, similarly, investigative journalists and activists have denounced environmental degradation and human rights violations of indigenous people (Garside, 2020).

Opportunities and challenges around local processing is another issue in Indonesia. Starting in January 2020, Indonesia banned the export of unprocessed nickel ore in order to incentivize local smelting by smelters in three industrial parks. Most smelters in the parks will produce ferronickel or "nickel pig iron" which is semi-processed and used in the steel industry.

Corruption and other governance issues are also a concern, including the ways in which Chinese nickel mining companies in **Burma** have facilitated the military junta's recent crackdown on protests (Daly & Zhang, 2021). In **Zimbabwe**, similarly, activists have scrutinized the purchase of the country's top nickel mine by a presidential advisor (Ndlovu, 2019).

MINE DEVELOPMENT AND SUPPLY CHAIN DYNAMICS

Nickel is a more complex supply chain than other base metals like copper due to different deposits and processing techniques depending on end use. As sulfide deposits decrease against increasing overall demand, the environmental impacts of more complex lateritic deposit processing will increase. Several frontier nickel mining projects have taken significant losses due to these complexities. The increasing scrutiny over these practices in Southeast Asia in particular is an important factor.

The overall nickel sector is characterized by likely oversupply with prices at historic highs due to speculation around the energy transition as well as post-COVID recovery expectations. The price is expected to decrease as the market takes into account supply. Nickel prices are also set to become increasingly decoupled from China as the country is reportedly become self-sufficient with regards to its metal nickel needs (Hu, 2020).

ORGANIZATIONS AND INDUSTRY GROUPS

The Nickel Institute is an industry group consisting of primary nickel producers from around the world (Nickel Institute, n.d.). The International Nickel Study Group (INSG) is an intergovernmental organization producing studies and data on the sector.

RARE EARTH ELEMENTS

US CRITICAL MINERAL? Yes

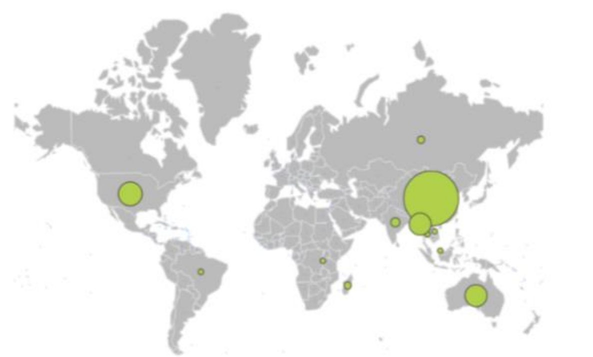
MAIN USES IN GREEN ENERGY TECHNOLOGY

KEY DEVELOPMENT ISSUES IN MINING

DEMAND PROJECTIONS

Rare Earth Elements (REEs) comprise the 15 elements in the lanthanides group (57-71 on the periodic table) plus scandium and yttrium. REEs are often grouped together because they occur in similar deposits and because of their similar chemical properties. REEs are used to create permanent magnets, which are powerful magnets vital to generating power in a wind turbine's induction generator. Four REEs can be used: neodymium, dysprosium, praseodymium, and terbium. Neodymium is the most used sometimes in combination with others. By 2050, demand for neodymium is projected to be 8,400 tons per year, or 37% higher than 2018 production levels (Hund et al., 2020). Permanent magnets are also used in electric vehicle motors (Dias et al., 2020).

PRODUCTION/RESERVES



Source: OECD

Most REEs come from monazite, which often occurs as a sand, and bastnaesite. **China** accounted for 60% of global REE production in 2020 with 140,000 tons. China has the bulk of refinery capacity and is the lead important of REE ores from other producers. The **US** is the second most important producers with 38,000 tons followed by **Burma**'s 30,000 tons which are all exported to China for processing (Reuters, 2021d). Prices for dysprosium oxide at 99.5% purity has risen steadily from 2016 at $198 per kilo to $258 per kilo in 2020. Prices for neodymium oxide at 99.5% purity have fluctuated from $40 in 2016 to $50 in 2018 and $47 in 2020.

MINING IN USAID-PRESENCE COUNTRIES

Burma is the third-largest REE producer. Other small and emerging producers include Madagascar (Chinese/Singapore investment; Reuters, 2019), India, Thailand, Vietnam (Japanese owner; Fuyuno, 2012), Brazil and Burundi (UK-based owner; NS Energy, n.d.a). Exploration projects that could lead to new mines are located in Namibia (Namibia Critical Metals, n.d.), Angola (Reuters, 2020), and Malawi (NS Energy, 2020a). The same company developing the Burundi deposit has a project in South Africa to extract REEs as a byproduct from processing gypsum residue from phosphate mining (Rainbow Rare Earths, n.d.).

MAJOR INDUSTRIAL COMPANIES

The major Chinese companies involved in rare earths are **China Northern Rare Earth, China Minmetals, Aluminum Corporation of China Limited (Chinalco), and China Non-Ferrous Metal Mining (CNMC)**. At present the only company outside of China with REE refining capacity is Australia-based **Lynas Resources**, though its refinery is in Malaysia and there are plans to open refineries in the US (Subin, 2021).

ARTISANAL AND SMALL-SCALE MINING (ASM)

Some rare earth mining in China has been characterized as small-scale and illegal, though there has been a crackdown on such mines (Standaert, 2019).

ISSUES IN USAID-PRESENCE COUNTRIES

There is little REE mining in USAID-presence countries. In Burma, REE mining in Kachin state has been linked to criminal networks protected by the military junta and the Chinese government (Bangkok Post, 2021). In Madagascar, a REE project came under scrutiny and local opposition due to its location in a high conservation value location (Carver, 2017) REE mining and processing can generate radioactive waste which could be a problem as new projects are developed.

Mine development and supply chain dynamics

REE have been a focus of the geopolitical "resource scramble" in recent years, especially given China's dominance in mining and in processing. The US in particular is keen to create domestic refining capacity. However, many of the new projects in frontier locations including USAID-presence countries are signing offtake agreements with Chinese companies, making it unlikely that they will feed into non-Chinese supply chains. Moreover, with respect to REE use in renewables, the manufacturers of permanent magnets are also dominated by China-based enterprises, with a 90% market share (PR Newswire, 2019).

ORGANIZATIONS AND INDUSTRY GROUPS

China has several regional REE industry associations, plus the national **Association of China Rare Earth Industry**. The EU spearheaded the creation of the **Rare Earth Industry Association (REIA)** in 2019 aimed at creating a unified industry voice (Mine, n.d.).

SILVER

US CRITICAL MINERAL? No

MAIN USES IN GREEN ENERGY TECHNOLOGY

KEY DEVELOPMENT ISSUES IN MINING

DEMAND PROJECTIONS

Silver's high conductivity is harnessed in photovoltaic cells in the form of a paste that collects the electrons generated when sunlight hits the panel. Like gold, silver is used as a store of value, as an investment, as jewelry and in a variety of electronic and industrial applications. Silver's importance for renewables—and specifically photovoltaic cells—will lead to a 15,000 tons demand per year by 2050, which represents a 56% increase over 2018 global production levels (Hund et al., 2020).

PRODUCTION/RESERVES

Source: OECD

Mexico is largest producer of silver with 5,600 tons in 2020 (22% of global production), followed by **Peru** (3,400 tons) and **China** (3,200 tons). The largest known reserves are in Peru, followed by Australia and Poland. Although silver is the principal product at several mines, most silver is obtained as a byproduct from lead-zinc mines, copper mines, and gold mines, in descending order. Silver prices were stable from 2016-2020 at around $17 per troy ounce but moved dramatically from below $12 in March 2020 to historic highs approaching $30 in August 2020 and February 2021 driven by investors and speculation around industrial demand.

MINING IN USAID-PRESENCE COUNTRIES

Silver is produced in many USAID-presence countries, mainly as a byproduct of other mining. The top two producers **Mexico** and **Peru** are USAID-presence countries. Other important producers by volume are **Chile** (limited presence) and **Bolivia** (limited presence). Smaller producers include: **Armenia, Azerbaijan, Brazil, Burkina Faso, Colombia, DRC, Côte d'Ivoire, Dominican Republic, Ecuador, Ethiopia, Ghana, Honduras, India, Indonesia, Kazakhstan, Kyrgyz Republic, Laos, Mali, Mongolia, Morocco, Namibia, Nicaragua, North Macedonia**, **Panama, Papua New Guinea, Philippines, Senegal, South Africa, Tajikistan, Tanzania,** and **Uzbekistan.**

MAJOR INDUSTRIAL COMPANIES

Fresnillo is the world's largest producer with gold and silver mines in Mexico. **KGHM Polska Miedz** is the second largest producer based in Poland. **Glencore** (Switzerland-based, with copper and lead/zinc) is third, followed by **Newmont** (the world's largest gold miner, US-listed) and **CODELCO**, the main producer of Chile's copper (Basov, 2021).

ARTISANAL AND SMALL-SCALE MINING (ASM)

Some artisanal gold miners in **Chile** are reported to recover silver as a byproduct (Castro & Sánchez, 2003; Espinoza et al., 2020). In theory silver could be recovered by the millions of artisanal gold miners worldwide but this is not standard practice.

ISSUES IN USAID-PRESENCE COUNTRIES

Most academic literature on silver mining in Latin America tends to look at it from a historical rather than contemporary perspective. However, given that silver is generally a byproduct, the governance, environmental and land tenure issues in copper, lead-zinc, and gold mines that produce silver are relevant by extension.

MINE DEVELOPMENT AND SUPPLY CHAIN DYNAMICS

Because most silver is a byproduct of other mining, supply dynamics are linked to trends in the gold, copper, lead, and zinc markets. Supply from these other sources can push prices down to a point where silver-only mining becomes unprofitable. Silver prices, on the other hand, are dependent on a few factors. Because roughly half of silver is used by investors, prices can be subject to speculation but also represent a form of insurance during market turmoil, just like gold. The other half is driven by industry trends in jewelry, electronics, and manufacturing, including the solar photovoltaic panel industry.

ORGANIZATIONS AND INDUSTRY GROUPS

The **Silver Institute** is the main industry group consisting of miners, refiners, and traders (The Silver Institute, n.d.).

TITANIUM

US CRITICAL MINERAL? Yes

MAIN USES IN GREEN ENERGY TECHNOLOGY	KEY DEVELOPMENT ISSUES IN MINING
	

DEMAND PROJECTIONS

Titanium is a metal that is as strong as steel but weighs half as much, making it valuable for a variety of applications including aerospace, sporting goods, and medical equipment. However, 95% of titanium use stems not from its refined metal form but from titanium dioxide which is used as a pigment in paint, ink, plastics, and cosmetics (Titanium, n.d.). In renewables titanium metal is an important component of geothermal technologies since titanium is one of the few minerals that can survive extremely corrosive environments for more than a few years. Titanium also features in experimental energy storage and PV technologies. Titanium demand in renewables is projected to reach 3,440 tons per year by 2050, which represents no increase over 2018 global production levels (Hund et al., 2020).

PRODUCTION/RESERVES

Source: OECD

Titanium's main ores are rutile and ilmenite, which are considered mineral sands along with zirconium. **China** is the largest producer of ilmenite (2.3 million tons, or 30% of global supply), followed by **South Africa** (1 million tons) and **Australia** (800,000 tons). **Australia** is the world's largest producer of rutile (200,000 tons in 2020, or 30% of global supply), followed by **Sierra Leone** (120,000 tons) and **South Africa** (100,000 tons). Rutile prices based on Australian trade data rose from $740 per ton in 2016 to $1,200 per ton in 2020. For ilmenite, prices rose from $142 per ton to $210 per ton in the same period.

MINING IN USAID-PRESENCE COUNTRIES

South Africa is a top producer of both ilmenite and rutile, and **Sierra Leone** is a top producer of rutile. Other significant ilmenite producers are **Mozambique, Ukraine, Senegal, Madagascar, Kenya, India, Vietnam,** and **Brazil**. Other significant rutile producers are **Ukraine, Kenya, India, Senegal, and Mozambique**. Smaller or emerging mineral sand producers are located in **Sri Lanka, Burundi, Kazakhstan,** and **Malawi**.

MAJOR INDUSTRIAL COMPANIES	ARTISANAL AND SMALL-SCALE MINING (ASM)
Rio Tinto (Australia) owns the largest mineral sands producer in South Africa called Richard Bay Minerals as well as the ilmenite mine in south Madagascar. Australian **Iluka Resources** owns Sierra Rutile, the producer of most of Sierra Leone's rutile. **Kenmare Resources** (London-listed) is the main company operating in Mozambique. **Tronox** is an American chemical company that owns mines in South Africa and Australia as well as trading titanium-based products.	Sierra Leone has some artisanal mining of mineral sands, often as a byproduct of artisanal gold mining (EITI, 2021).

ISSUES IN USAID-PRESENCE COUNTRIES

In South Africa, Rio Tinto's operations have been affected by violent protests by contractors in addition to shootings of employees, including the murder of its general manager in May 2021 (Mining.com, 2021). The issues which have led to the suspension of operations are different points in recent years appear to be linked to general insecurity and high unemployment in the province.

In Madagascar, Rio Tinto's mine has come under scrutiny for negative environmental impacts, namely the contamination of drinking water in surrounding communities by unsafe levels of lead and uranium concentrated due to extraction (Reid, 2019). While mineral sand mining is generally considered less destructive than open-pit mining and other minerals requiring chemical extraction, it is known to concentrate naturally occurring radioactive material. Rio Rinto has also been criticized for its handling of indigenous community land rights in its program of creating biodiversity offsets from its mining operation (Orengo, 2020).

MINE DEVELOPMENT AND SUPPLY CHAIN DYNAMICS

Sierra Leone's rutile sector is uncertain as its main company suspended operations for six months in order to reduce costs and boost productivity (Iannucci, 2021). Companies like Iluka must determine based on costs as well as deposit characteristics the induce price at which a project begins to produce an adequate return. Investment decisions also take into account technical and socio-political risk.

Titanium metal is derived from titanium sponge which is produced in an energy-intensive and high-cost process. Most titanium sponge is produced in China (36%), Japan (25%) and Eastern Europe (34%) (ILUKA, 2013).

ORGANIZATIONS AND INDUSTRY GROUPS

The **Zircon Association** (Zircon Industry Association, n.d.) members include the major rutile and ilmenite producers.

VANADIUM

US CRITICAL MINERAL?	Yes

MAIN USES IN GREEN ENERGY TECHNOLOGY	KEY DEVELOPMENT ISSUES IN MINING
	

DEMAND PROJECTIONS

Vanadium is an alloy agent used in specialty steels as well as titanium alloys used in aerospace. In renewables, the vanadium redox flow battery technology is used in grid storage. Vanadium redox batteries have several advantages including no risk of fire, little charge capacity degradation over time, and no risk of damage if left uncharged for long periods. Vanadium batteries are too large and bulky for use in electric vehicles, at least in their current form. Based on projected use of vanadium redox batteries, 138,000 tons of vanadium will be used in renewables by 2050, a 189% increase over 2018 annual production (Hund et al., 2020).

PRODUCTION/RESERVES

Source: OECD

Vanadium is usually found in other ore bodies, including bauxite and phosphate rock, but most comes from titaniferous magnetite, which is a form of iron ore. As such most vanadium (around 60%) is a co-product of steel production (VANITEC, n.d.). **China** is the largest producer of vanadium with 53,000 metric tons produced in 2020, or 60% of worldwide production. Most of this was a co-product of steel production using titaniferous magnetite. China is followed by **Russia** with 18,000 metric tons and **South Africa** with 8,200 metric tons. **Australia** has reserves and exploration projects but no production yet. In the US, vanadium has been mined as a by-product of uranium mining in Utah, but new primary vanadium mining may begin in the near future (Associated Press, 2020). Vanadium's price has varied between $3.38 and $16.4 per pound in the last five years. At the time of writing vanadium was around $9 per pound, and ferrovanadium used in steel was trading around $40 per kilo.

MINING IN USAID-PRESENCE COUNTRIES

South Africa is the third largest producer, mainly with primary vanadium mining operations (as opposed to refining vanadium from steel slag). Brazil is the fourth largest producer. Exploration projects are ongoing in Guinea (Africa Intelligence, 2018a), Namibia (Bromby, 2021), and Mozambique (Syrah Resources, n.d.b).

MAJOR INDUSTRIAL COMPANIES	ARTISANAL AND SMALL-SCALE MINING (ASM)
In China, the largest vanadium producers are **Pangang Group Vanadium Titanium & Resources** and **HBIS Chengsteel** (PR Newswire, 2018). In Russia, **Evraz** is the main producer. In South Africa, **Bushveld Minerals** and **Glencore** are the key operators. In Brazil, US company **Largo Resources** (Costa, 2021) is the main vanadium producer at present.	None

ISSUES IN USAID-PRESENCE COUNTRIES

The metallurgical processes used in extracting vanadium are energy-intensive and can release toxic elements into the environment. However, vanadium mining has been largely under the radar until recently and there is little information on issues in USAID-presence countries. The speculation and resource scramble for vanadium and other minerals could increase risks of corruption and governance challenges.

MINE DEVELOPMENT AND SUPPLY CHAIN DYNAMICS

Vanadium has been tied to steel industry dynamics, which has contributed to its price volatility. However, as demand for vanadium increases for renewables, vanadium mine development is being increasingly decoupled from steel production. In addition, new rules in China's steel industry related to environmental controls as well as a ban on the import of vanadium slag is projected to decrease supply. China's steel industry is also becoming more reliant on imported iron derived from hematite, which does not contain vanadium, and the steel industry tends to run at capacity which limits its ability to respond to vanadium supply changes (Bushveld Minerals, n.d.). As such there is significant speculation and exploration with respect to primary vanadium production.

ORGANIZATIONS AND INDUSTRY GROUPS

There are no vanadium-specific industry groups.

ZINC

US CRITICAL MINERAL? Not yet, but under review for inclusion

MAIN USES IN GREEN ENERGY TECHNOLOGY	KEY DEVELOPMENT ISSUES IN MINING
	

DEMAND PROJECTIONS

Zinc is used to coat (galvanize) steel in order to prevent rusting, providing many of the benefits of stainless steel at a lower cost. Nearly 98% of zinc demand from renewables comes from its use to galvanize wind turbines. Zinc is also used in less-used zinc-ion batteries as well as experimental zinc-air batteries for grid-level storage. Zinc oxide is used to increase the efficiency of newer solar panel technologies through increased conversion of solar energy into electricity. Zinc demand from renewables to projected to reach 1.2 million tons per year by 2050, which is around 9% more than 2018 global production levels (Hund et al., 2020).

PRODUCTION/RESERVES

Source: OECD

The main zinc ore is sphalerite which tends to co-occur with galena, the main ore for lead. As such mines are general "lead-zinc" mines or "lead-zinc-silver" mines for galena that contains silver. Like lead, **China** is world's largest producer of zinc with 4.2 million tons mined in 2020 or 35% of world production. China was followed by **Australia** with 1.4 million tons and **Peru** with 1.2 million tons. Australia and China have the largest known reserves. Zinc prices have ranged from $1,800 to $3,500 per ton in the last five years, with an average around $2,500. At the time of writing in 2021, the price was approaching $2,900.

MINING IN USAID-PRESENCE COUNTRIES

Peru is third largest producer with significant reserves. Other important producers include: **India, Mexico, Bolivia** (limited presence), and **Kazakhstan**. There are numerous smaller zinc producing countries with USAID presence such as: **Armenia, Bosnia-Herzegovina, Burkina Faso, Burma, Chile** (limited presence), **Cuba, DRC, Dominican Republic, Honduras, Indonesia, Kosovo, Mongolia, Montenegro, Morocco, Namibia, Nigeria, North Macedonia, Pakistan, Serbia, South Africa, Tajikistan, Uzbekistan, Vietnam,** and **Zambia**. Namibia has a unique deposit that produces special high-grade zinc that commands a premium.

MAJOR INDUSTRIAL COMPANIES	ARTISANAL AND SMALL-SCALE MINING (ASM)
Major zinc producing mining companies are **Glencore** (Switzerland-based), **Hindustan Zinc** (India), **Teck Resources** (Canada), **Boliden AB** (Sweden), **Zijin Mining Group** (China) and **MMG** (owned by China Minmetals Corporation).	A study from 20 years ago noted that 30% of China's lead and zinc comes from ASM (Gunson & Jian, 2001), but there is no recent information on this. Another report from over a decade ago notes ASM zinc in Bolivia (IIED, 2002).

ISSUES IN USAID-PRESENCE COUNTRIES

The same environmental concerns noted in the section on lead apply to zinc miners as they are generally the same mines. Most public reporting and academic literature focuses on the environmental impacts of zinc mining and smelting in China. Heavy metal contamination of soils and water are the top issues. USAID-presence countries are susceptible to the same problems. While most smelting is in China, there is a smelter in Namibia at its major zinc mine Skorpion which produces high grade zinc that fetches a market premium (Wadlow, 2002). The public participation process used in establishing the mine and refinery was highlighted as a positive case study by the US Environmental Protection Agency (EPA, n.d.).

MINE DEVELOPMENT AND SUPPLY CHAIN DYNAMICS

Zinc mines generally produce a concentrate which is then processed and refined by a smelter. Many smelters are located in China, though the larger multinational mining companies like Glencore run both mines and smelters/refineries (Glencore, n.d.). Many analysts have a mixed outlook on zinc due to potential oversupply of both zinc concentrate and zinc metal, but so far prices have remained relatively stable and are foreseen to stay that way (Wood Mackenzie, n.d.). Zinc and lead prices are often tracked together, though they can diverge significantly (Home, 2020).

ORGANIZATIONS AND INDUSTRY GROUPS

The **International Zinc Association** is the main global industry group. The **International Lead and Zinc Study Group** is an intergovernmental organization dedicated to zinc and lead research and communication.

ANNEX 2. FURTHER READING

The following list includes key institutional and NGO reports on mining and the green energy transition, as well as selected mining governance guidance documents and reference materials.

- Earthworks (2019). *Responsible minerals sourcing for renewable energy*. https://www.earthworks.org/cms/assets/uploads/2019/04/MCEC_UTS_Report_lowres-1.pdf

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ANNEX 4. USAID-PRESENCE COUNTRIES

The following list shows which of the 16 minerals are mined in each USAID-presence country. Apart from China, this list includes countries with mining that do not have a USAID mission ("limited-presence") but with some USAID-funded activities managed by regional missions. Data was sourced from the USGS, the British Geological Survey and commodity market insight reports. Former mines and potential reserves were not included; only active mines or active exploration projects were considered.

Figure A-1. Green energy mineral production in USAID-presence countries

(countries with no current mining not include; star denotes the country is a current top producer of a given mineral)

** limited presence country*	Aluminum	Chromium	Cobalt	Copper	Graphite	Iron	Lead	Lithium	Manganese	Molybdenum	Nickel	Silver	Titanium	Vanadium	Zinc	Rare Earths
Albania		✓		✓							✓					
Angola																✓
Armenia				✓						✓		✓			✓	
Azerbaijan				✓								✓				
Bolivia*				✓		✓	✓	✓	✓			✓			✓	
Bosnia and Herzegovina	✓					✓	✓								✓	
Botswana			✓	✓												
Brazil	✓	✓		✓	★	★	✓	✓	✓		✓	✓	✓	✓		✓
Burkina Faso												✓			✓	
Burma				✓			✓		✓		✓				✓	★
Burundi													✓			✓
Cameroon	✓															
Chile*				★		✓		★		★		✓			✓	
Colombia	✓			✓							✓	✓				
Côte d'Ivoire									✓		✓	✓				
Cuba		✓	✓				✓				✓				✓	
DRC			★	✓				✓				✓			✓	
Dominican Republic				✓							✓	✓				
Ecuador				✓								✓				
Ethiopia												✓				
Gabon*									★							
Georgia				✓					✓							
Ghana	✓							✓	✓			✓				
Guatemala							✓				✓					
Guinea	★					✓								✓		
Guyana	✓															
Honduras							✓					✓			✓	
India	✓	✓		✓	✓	✓	✓		✓			✓	✓		✓	✓
Indonesia	✓		✓	✓		✓	✓		✓		★	✓			✓	
Jamaica	✓															
Kazakhstan	✓	★		✓		✓	✓	✓	✓	✓		✓	✓		✓	
Kenya									✓				✓			
Kosovo							✓				✓				✓	
Kyrgyz Republic				✓								✓				
Laos				✓		✓						✓				
Liberia						✓										

* *limited presence country*	*Aluminum*	*Chromium*	*Cobalt*	*Copper*	*Graphite*	*Iron*	*Lead*	*Lithium*	*Manganese*	*Molybdenum*	*Nickel*	*Silver*	*Titanium*	*Vanadium*	*Zinc*	*Rare Earths*
Madagascar		✓	✓		✓						✓		✓			✓
Malawi													✓			✓
Mali								✓				✓				
Mauritania				✓		✓										
Mexico		✓		✓	✓	✓	✓	✓	✓	✓		★			✓	
Mongolia				✓		✓	✓			✓		✓			✓	
Montenegro	✓						✓								✓	
Morocco			✓	✓			✓					✓			✓	
Mozambique	✓				★								✓	✓		
Namibia			✓	✓	✓	✓	✓	✓	✓			✓		✓	✓	✓
Nicaragua												✓				
Nigeria						✓	✓								✓	
North Macedonia				✓			✓					✓			✓	
Pakistan	✓	✓		✓	✓	✓	✓								✓	
Panama				✓								✓				
Papua New Guinea*			✓	✓							✓	✓				
Peru				★		✓	★	✓	✓	✓		★			★	
Philippines		✓	✓	✓							✓	★				
Republic of the Congo						✓										
Senegal						✓						✓	✓			
Serbia															✓	
Sierra Leone	✓					✓							✓			
Solomon Islands*	✓															
South Africa		★	✓	✓		✓	✓		★		✓	✓	★	★	✓	
Sri Lanka					✓								✓			
Sudan		✓														
Tajikistan				✓			✓					✓			✓	
Tanzania	✓			✓								✓				
Thailand						✓										✓
Ukraine						✓			✓				✓			
Uzbekistan				✓	✓		✓			✓		✓			✓	
Vietnam	✓	✓		✓	✓	✓	✓		✓				✓		✓	✓
Zambia			✓	✓					✓		✓					
Zimbabwe		✓	✓	✓	✓			✓			✓					

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