Box 4.4. Managing tailings: Challenges for a Global Industry Standard

An analysis of tailings incidents showed that about 80% of the root causes of dam failures are related to controllable factors (e.g. slope stability), while only the remaining 20% result from uncontrollable failures, such as earthquakes (Accenture, 2019). The most common cause identified was overtopping (i.e. when water flows over the dam) as a result of overfilling. This suggests that improving tailings management can mitigate associated risks. Best practice benchmarks are a step towards better management, even if companies' actions often face shortcomings. In the Brumadinho case, the German TÜV SÜD had certified the dam as safe months prior to the collapse, and Vale's automated monitoring equipment had displayed worrying signs days before the event (BBC, 2019).

The Global Industry Standard on Tailings Management aims to provide global best practices for tailings storage facilities and enable zero harm to people and the environment. It is the result of a joint effort of the International Council on Mining and Metals, the United Nations Environment Programme, and the Principles for Responsible Investment. Underpinned by an integrated approach to tailings management, the standard's goal is to prevent catastrophic failure and enhance the safety of mine tailings facilities worldwide. It is directed at operators and will be supported by implementation protocols that provide detailed guidance for certification.

The standard comprises six key topics and related principles:

1. Respect the rights of project-affected people and meaningfully engage them at all phases of the tailings facility life cycle.
2. Develop and maintain an interdisciplinary knowledge base with associated technical, environmental and social information.
3. Design plans and criteria for the tailings facility to minimise risk for all project phases – including closure and post-closure – and implement a related monitoring system.
4. Establish systems and accountabilities to support the safety and integrity of the tailings facility.
5. Prepare for emergency response to accidents and long-term recovery in the event of catastrophic failure.
6. Publicly disclose and provide access to information about the tailings facility to support public accountability.

As is often the case, managing impacts can help mitigate related risks and vice versa. The use of tailings for backfilling, for example, can lower water consumption and minimise land use impacts, as well as reduce subsidence or dam failure risks.

Air quality: Tailored solutions for tackling air pollution

Sources of air pollution are concentrated in mine exploration and development, but also present further down the value chain during smelting, refining and distribution. The main sources of air pollution include (ELAW, 2010):

- Particulate matter mobilised due to excavations, blasting, ore crushing, transport of materials and wind erosion. It is also present in fugitive dust from tailings facilities, stockpiles, waste dumps and haul roads – as well as in exhaust emissions from mobile sources (e.g. trucks).
- Gaseous emissions from fuel combustion in stationary sources (e.g. drying and smelting operations) and mobile sources, explosions and mineral processing.

Particle emissions contribute to the majority of air quality problems at mines, whereas gaseous emissions can affect a broader area and be more problematic in smelting and refining. Gaseous emissions include sulfur, nitrogen and carbon oxides; photochemical oxidants; volatile organic compounds and hydrocarbons. These pollutants have detrimental health effects and cause environmental impacts, such as those associated with acid rain. Of note, some pollutants present in mineral deposits are released into the air during mining activities, such as heavy metals and radioactive emissions in REE extraction, posing occupational hazards.

Typically, each source of emissions requires a different control technology. Dust control can be addressed during mine planning with the aid of air dispersion modelling and the development of wind barriers. During operations, dust management may involve the use of containment measures, including soil stabilisation and vegetation growth, as well as moisture control (e.g. by spraying water onto stockpiles and roads).

Stationary sources can reduce emissions by using filters, wet scrubbers, electrostatic precipitators and other treatment technologies. Meanwhile, mobile sources can benefit from increased electrification and the use of clean fuels (e.g. low-carbon hydrogen), which enable both lower gaseous emissions and a reduced overall carbon footprint.

Air pollution can be tackled by many of the same policy instruments presented earlier in this section. For example, ESIAs and EMPs can affect project design and ensure the implementation of measures to control particulates and stationary sources. Additionally, jurisdictions often set requirements for pollutant emissions, define overall air quality standards and monitor pollution levels. In this context, the Initiative for Responsible Mining Assurance outlines requirements related to the management of air contaminants in its Standard for Responsible Mining and references the European Union's Air Quality Standards.

Responsible minerals development

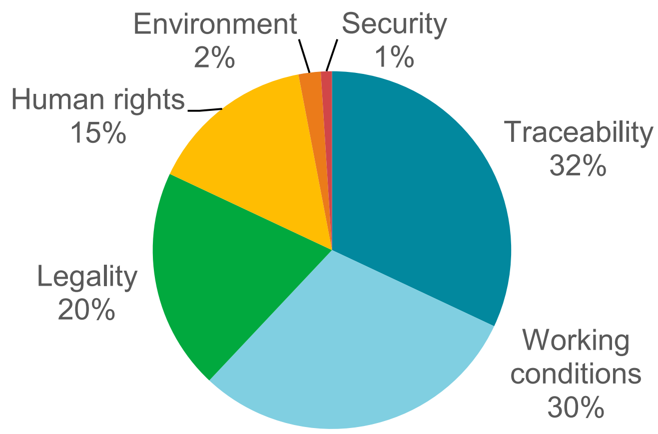
Mineral wealth has great potential to bring social and economic benefits to the local population, but many challenges remain to ensure responsible development of energy transition minerals

In most countries, mineral deposits are public resources and the government is charged with managing them in a manner that brings a public benefit. As demand grows for energy transition minerals, so does the potential for these public resources to contribute to economic growth and deliver just outcomes for national governments, companies and communities. Unfortunately, there are myriad examples where development of resources has not led to sustainable economic growth or has caused corresponding social harm.

There are many causes for this so-called "resource curse". In many cases, public officials may act to subvert entrusted power over public resources into private gain – i.e. corruption. These problems may be particularly problematic in countries where mineral extraction contributes a large share of fiscal revenues. In addition to corruption, mining operations may have negative impacts on people and communities due to environmental damage, inadequate safety and health protections and human rights violations. Downstream consumers also contribute to these problems.

Some forms of harm are more attention grabbing than others, particularly child labour concerns. However, other impacts may ultimately be more widespread than child labour. Governments and companies increasingly cannot afford to ignore any of these impacts.

Incidents at mine sites in the Democratic Republic of the Congo categorised by type of risk

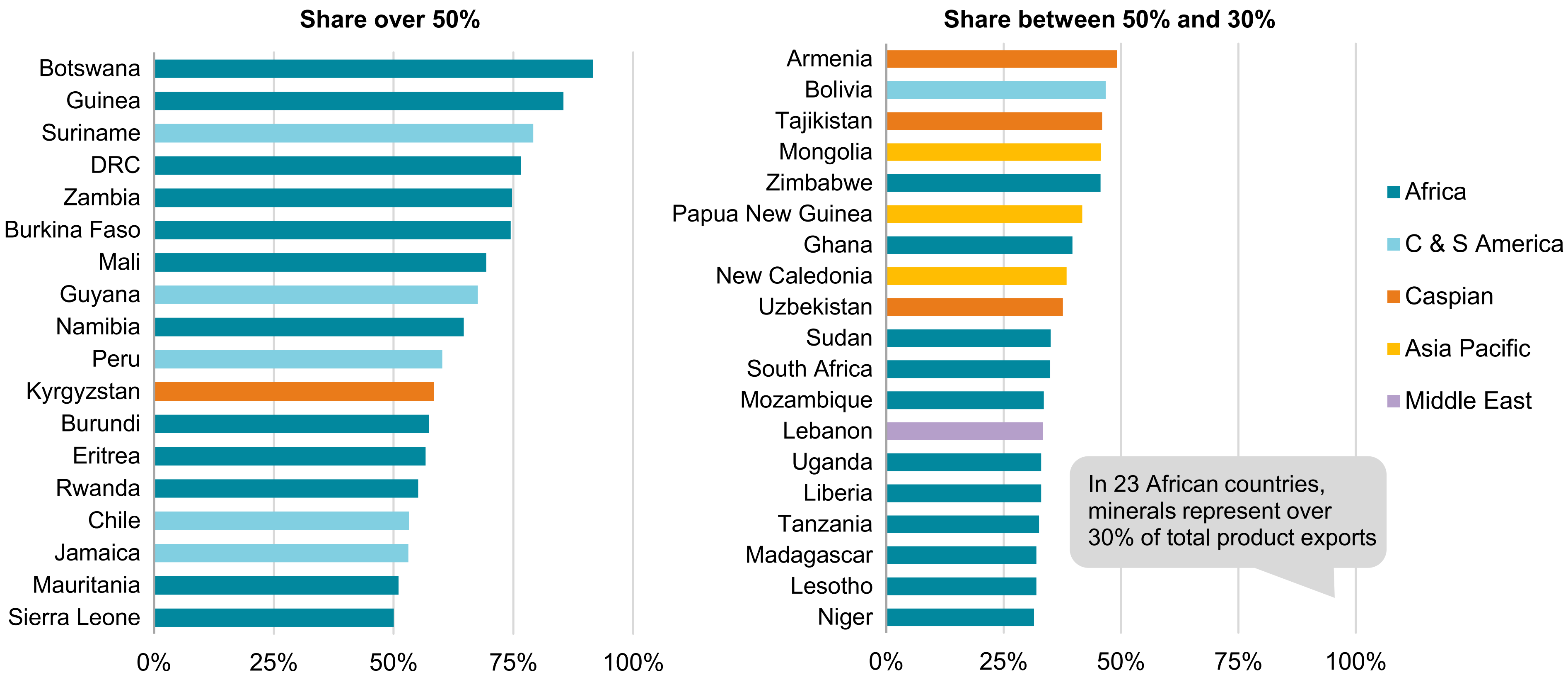


Notes: The data reflects the proportion of registered incidents fitting the risk category at artisanal and small-scale mine sites.
Source: RCS Global Group (2019).

This section begins with a discussion of the potential for mineral development to contribute to economic growth and create sustainable jobs. Then, it turns to the primary forms of social harm associated with energy transition minerals, including public corruption, risks to public safety and health, child labour and gender discrimination, with a focus on policy and regulatory strategies to mitigate these risks.

Many mineral-producing countries rely heavily on revenue from mineral extraction, underscoring the need for transparent management of mineral wealth

Share of minerals and metals in total product exports for mineral producing countries, 2019



Notes: The chart shows countries whose share (based on monetary value) is above 30%. Standard international trade classification codes 27, 28, 68, 667 and 971 were included in the minerals and metals category. C & S America = Central and South America.

Source: IEA analysis based on UNCTAD (2021).

The economic benefits of mining must be managed with carefully designed legal frameworks

Although mineral production contributes to economic development in many ways, the most direct contribution is through tax and royalty revenue. In many countries this revenue source can be significant. In Chile, for example, revenue from copper production averaged around 10% of the fiscal revenue between 2010 and 2019 (Cochilco, 2020). However, without careful management, translating mining revenue into economic prosperity can be a daunting task. Volatile commodity prices often lead to procyclical public spending, which undermines the effectiveness of government expenditure in promoting economic growth. In addition, a high reliance on export revenue from minerals could lead to underinvestment in other sectors, making the economy more vulnerable to changes in global commodity prices. This underscores how fiscal revenues from mining must be used wisely to support diversification of the national economy.

The relationship between companies and communities

While mining brings in large amounts of revenue, the contribution to labour demand may be relatively small and may vary throughout the project life cycle. Governments have used various strategies to define expectations for the relationship between companies and communities and to foster "links" to other aspects of the domestic economy, such as the development of a local supplier industry to support mine operators (GIZ, 2016) (see Box 4.5).

Clear expectations for each phase of the project will help to ensure a sustainable relationship between the project developer and the local community and to enable the community to prepare for expected shifts in economic activity. Further, if the economic contribution is stable throughout these phases, it is likely to contribute to the project developing a social license to operate.

Mine operators often contribute to local communities by developing local infrastructure, providing training opportunities or making direct financial payments to community institutions. Given these contributions, companies and governments often negotiate "community development agreements" either voluntarily or pursuant to legislative requirements (Otto, 2018). In Canada, for example, there is a well-developed practice of developing impact and benefit agreements between companies and indigenous communities (NRCan, 2020). Provided that community development agreements are implemented in an inclusive and transparent fashion, they can create a structured framework for stakeholder engagement and define expectations for community investment.

Separately, governments may require companies to assess socio-economic impacts of mining projects and develop appropriate mitigation plans prior to obtaining approval. This can take place alongside assessment of environmental impacts where already required.

Box 4.5. Fostering local "linkages" in Chile

Resource-rich countries often adopt policies designed to facilitate inter-sectoral "linkages" that create jobs, transfer technology, encourage entrepreneurship and increase local equity (Ramdoo, 2016). In many cases, the role of local suppliers is difficult to assess due to inconsistent or limited data. Initiatives like the Local Procurement Reporting Mechanism aim to provide better data for governments and companies to manage the economic impacts and benefits of local procurement.

Rule-based numerical local content requirements, although common, can be difficult to implement if not clearly defined – in Zambia, for example, an earlier law had no definition for "local" (IGF, 2018b) – and may give rise to trade disputes (Korinek and Ramdoo, 2017). As an alternative, countries may pursue horizontal policies targeted at fostering industrial development, innovation and skills training (OECD, 2019b). Chile, for example, directs revenues from mining to support innovative projects through a government-funded partnership, Fundación Chile, which operates like a venture capital firm. This funding is not limited to the mining sector and has helped to develop the salmon and wine industries. Chile has also established royalty-supported funds to support science and technology R&D and to provide local entrepreneurs with seed capital and technical support (IGF, 2018c).

Chile also supports local suppliers directly through programmes such as the World Class Suppliers Programme, which identifies and funds innovative local suppliers to address specific operational challenges. Suppliers are supported throughout the implementation phase to allow testing of ideas within real-time operations, and eventually to scale up to international markets (Navarro, 2017).

Despite some successes, Chile has not yet developed a competitive cluster of mining services suppliers. Critics have noted that the scale of supplier support programmes is too small to have the desired impact, and that a comprehensive industrial policy is needed to support the transition of the sector towards higher-value products and services (Lebdioui et al., 2020).

Although intended to foster the development of a local industry that can support economic livelihoods and drive economic development, it is clear from these examples that policies designed to increase local linkages can stumble without robust policy co-ordination. As there are many drivers of local industrial development, including access to capital, innovation funding and skilled labour, policy makers must develop a comprehensive approach that addresses the barriers to local industry without creating unintentional market distortions.

Corruption and bribery pose major liability risks for companies, but can be managed with supply chain due diligence policies

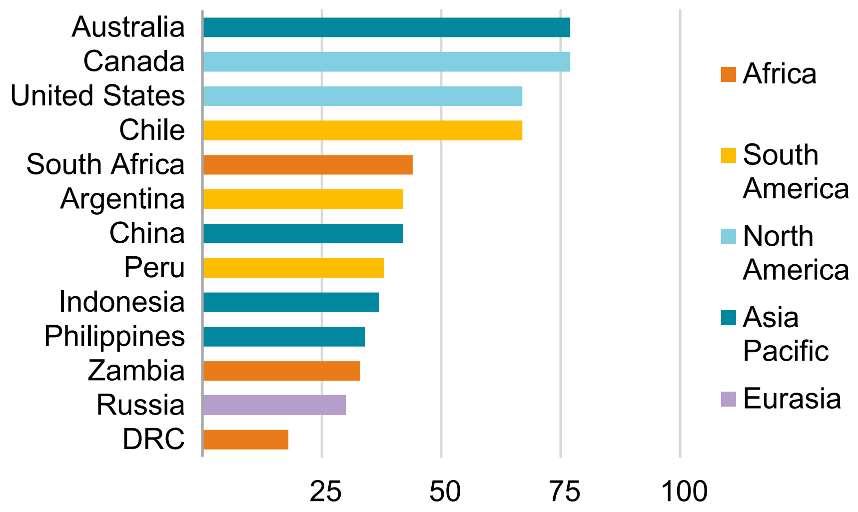
Mining operations are exposed to higher risks in locations with political instability, weak institutions and weak rule of law. The risk that mineral revenues may be used to finance armed conflict has received particular attention recently, with regulations coming into force requiring mandatory supply chain due diligence (see Box 4.8).

Although conflict-related risks are currently low for energy transition minerals, corruption and bribery risks remain high. A survey of foreign bribery enforcement actions by the Organisation for Economic Co-operation and Development (OECD) found that almost 20% of cases occurred in the extractive sector, a category that includes oil and gas production as well as mining (OECD, 2014). Further, energy transition minerals are often produced in countries that score below average in measures of perceived corruption risk.

Companies cannot afford to ignore the risk that their employees and business partners may engage in bribery. In many countries, corporations can be prosecuted for failing to prevent bribery within their overseas operations. The potential liability can be enormous, with fines reaching hundreds of millions of dollars and potential imprisonment for executives. Even short of prosecution, responding to an investigation can be extremely costly. The average investigation under the US Foreign Corrupt Practices Act lasts 38 months and costs USD 1.8 million per month (Stanford Law School, 2020).

Most major mining companies prohibit bribery among their employees, but in order to be effective, such policies must be backed up with additional measures, including risk assessments, training for employees and investigation mechanisms (RMF, 2020a). Critically, given the risks involved, companies should implement processes to identify, prevent and mitigate risks across their full supply chains, including risk-based due diligence (OECD, 2021a).

Corruption Perceptions Index for selected countries, 2020



Note. The index ranks perceived levels of public corruption where 100 is “very clean” and zero is “highly corrupt”.
Source: Transparency International (2021).

Governments in both producing and consuming countries can do more to mitigate corruption by increasing transparency and supporting development of institutions and the rule of law

Corruption leads to numerous pernicious effects, including decreased fiscal revenue, reduced economic growth and erosion of the rule of law (OECD, 2021a). Policy makers in both producing and consuming countries are increasingly recognising these impacts as negative social externalities that must be addressed through expanded support for legal institutions, transparency and the rule of law.

Transparency is often presented as a critical tool for addressing corruption. If governments publicly disclose contracts and payment and expenditure data, the argument goes, the public will be able to hold governments accountable for their actions, which can reduce corruption and ensure that mineral wealth actually translates into public benefit.

To support development of transparency practices, a coalition of supporting governments, companies and civil society organisations established the Extractive Industries Transparency Initiative (EITI) to help countries improve governance in the sector. In order to receive support, countries must apply to become an "implementing country", and in turn must agree to international oversight, including regular assessment of progress and adherence to specific reporting requirements. EITI has developed a global standard setting out transparency principles for governments with respect to licensing and contracting, managing extraction operations, collection of revenue and government expenditure.

EITI reports that most implementing countries are making at least "meaningful progress" against key metrics (EITI, 2020a). For example, following EITI recommendations, Madagascar changed its practices regarding publication of data about mining revenues owed to local governments (EY, 2019). This has led to constructive dialogue between the government and local officials, and EITI has rated Madagascar's progress on the issue as "meaningful" (EITI, 2020b).

EITI has been particularly successful in calling attention to vulnerabilities that increase the risk of corruption and in increasing the availability of data (Sahla et al., 2021). However, scholars have noted that simply adopting transparency processes may not necessarily reduce corruption. In order to have a meaningful impact on corruption, this type of information must actually reach the public and the public must be able to sanction corrupt conduct (Lindstedt and Naurin, 2010). Thus, further effort is needed to support the distribution of information in a format and language the public can understand, and to further develop local institutions to reduce corruption risks and ensure that corrupt officials are held to account.

Minerals workers and the public face various health and safety risks, including accidents and exposure to toxic chemicals

Although it is difficult to compare countries, existing evidence indicates that mineworkers are subject to significant health and safety risks. In the United States, for example, the extractive sector has among the highest fatality rates – 14.6 per 100 000 workers, compared to 9.7 for the construction sector (US BLS, 2020).

Types of risk to the health and safety of mine workers

Category	Examples
Safety	Accidents involving machinery, vehicles or rockfalls in underground mines
Chemical	Exposure to acids, carbon monoxide or particulate matter such as silica dust
Biological	Insect bites or contact with animals
Physical	Loud noise, radiation or heat
Ergonomic	Frequent weight lifting or exposure to vibration
Psychological	Sexual harassment or workplace violence

Practices vary among companies

According to the Responsible Mining Foundation, most companies show a commitment to ensuring safe and healthy working conditions (RMF, 2020a). However, only two-thirds of these back this commitment with resources, including staff or financial capital. Furthermore, only a few engage with workers' representatives on the identification of occupational health and safety risks or have systems in place to ensure their operations provide gender-appropriate safety equipment. Even fewer have systems in place to protect women workers from sexual harassment and violence.

Adopting clear risk management policies can help companies to reduce potential harm, both to workers and to the public at large. Risk is a function of the frequency of an event and the magnitude of its potential consequences, and policies can act on both inputs to this equation. Prevention policies include work permit systems, which assess and set requirements to ensure the safety of work procedures, and the installation of monitoring equipment (e.g. flammable gas detectors). In parallel, policies can help to mitigate the consequences should an incident occur by requiring personal protective equipment (e.g. helmets and gloves) and developing and exercising emergency response plans.

Box 4.6. Tailings dam collapses at Brumadinho (Brazil)

On 25 January 2019 a dam failure at an iron ore mine operated by Vale S.A. near the city of Brumadinho, Brazil, released an enormous wave of mud that flowed for nearly 10 km, killing over 270 people (Watson, 2020). This disaster has led to major pressure on mine operators across all minerals from regulators and investors alike, especially as it came on the heels of high-profile dam failures in the same state in Brazil in 2015, which killed 19 and caused vast environmental damage, and at the Mount Polley copper mine in Canada in 2014 (Cornwall, 2020).

Much of the commentary following the Brumadinho failure has centred on the method of construction – known as upstream construction. Some evidence suggests that liquefaction (when the solids in the tailings pond act as a fluid, allowing material to flow downstream as the dam collapses) is more likely with upstream construction (Kossof et al., 2014). However, commenters have also noted that poor management and operational practices are more likely to blame (Santamarina et al., 2019).

Within days of the Brumadinho disaster, the government announced a ban on new "upstream" dams and ordered existing dams to be decommissioned by 2021 (Reuters, 2019b). This prohibition was subsequently enshrined into legislation. It is not yet clear whether these laws will lead to safety improvements given the history of weak enforcement and relaxation of environmental laws (Fernandes et al., 2016). Despite having been established in 2017 with the aim of increasing regulatory autonomy and budgets, the National Mining Agency has had continued budgetary difficulties and limited resources for inspections, with just 34 inspectors responsible for nearly 800 dams (Jucá, 2019).

There are signs that these high-profile disasters have been a wake-up call for the industry. Faced with potentially enormous liability, Vale has created a new safety executive board, updated emergency plans and begun de-characterising nine dams built using the upstream method (Vale, 2020). A number of other companies have adjusted their safety practices as well, including Glencore, which has committed to upgrade 17 dams that could pose stability concerns under certain conditions (Glencore, 2019). As discussed above, the industry pushed for the development of a new Global Industry Standard on Tailings Management in August 2020, designed to enhance safety at tailings facilities. Though these actions are promising, the response has not been uniform. Since 2019 the Church of England Pensions Board, a major institutional investor, has requested information about tailings dams from 726 companies. Of these companies, only about 50% responded (Church of England, 2020).

Health and safety protections are not uniform between large and small-scale mines

Operators of large-scale mines, smelters and refineries are typically subject to occupational and public health and safety regulations, and evidence indicates that effective regulation can lead to a reduction in risks to workers from accidents and other adverse working conditions (Holland, 2019). The International Labour Organization has developed many international labour standards and voluntary codes of practice that can reduce the risks to workers in these operations.

To a certain extent, companies can be expected to address safety risks through voluntary action to avoid accidents that may incur costs from lost productivity, civil liability and damage to public relations. As companies pay increasing attention to maintaining a social licence to operate, they may take greater effort to adhere to such voluntary safety standards. Many international standards on safety already exist, such as the Mining Association of Canada's Towards Sustainable Mining safety and health protocol and framework.

However, industry may not be capable of self-regulating for all types of safety risk – particularly where large-scale risks are involved or where there is a lack of investor pressure. In these contexts, effective enforcement or regulatory standards will be critical. For example, weak enforcement may have played a role in the Mariana and Brumadinho dam collapses (see Box 4.6).

Artisanal and small-scale mining risks remain high

Conditions are usually worse where regulatory protections are unenforced or non-existent. The problem is particularly acute for ASM, where workers are typically paid only for what they produce and lack access to health care or compensation in the event of an accident (OECD, 2019b). A 2019 survey of cobalt ASM workers in the Democratic Republic of the Congo (DRC) found that the working conditions of most miners were "unacceptable". Conditions in ventilation shafts and underground mines tended to be hazardous and all workers used protective equipment at only 2 of 58 mine sites. The survey also found that the preceding year had seen more than 60 fatal accidents and over 100 accidents involving injury (BGR, 2019).

Efforts to "formalise" ASM activities may improve health and safety conditions to the extent that formalisation allows the application of safety practices. A study of one such site in the DRC showed that the co-operative responsible for the site removed overburden to allow workers to access deposits safely, provided personal protective equipment for workers, and carried out weekly briefings on safety and other aspects (WEF, 2020). However, the long-term viability of this model remains in question as the site closed down in 2020 (Reuters, 2020a).

Artisanal and small-scale mining of cobalt gives rise to child labour concerns

The International Labour Organization has estimated that over a million children work in mines and quarries (ILO, 2019). Child labour primarily occurs in ASM activities and is associated most closely with the mining of gold and cobalt. The problem is particularly acute in the DRC, where 10-20% of supply comes from ASM (Roskill, 2021). Although there is no reliable data on the prevalence of child labour, surveys have found children present in about 30% of the visited ASM sites in the DRC (BGR, 2019).[4] Studies have shown that children working outside the home in the DRC is directly linked to poverty, as children take on work to earn additional income (Faber et al., 2017).

The DRC has signed international conventions prohibiting child labour, including ILO Conventions No. 138 on the Minimum Age of Employment and No. 182 on the Worst Forms of Child Labour, and its labour and mining codes generally meet international standards in prohibiting child labour, forced labour and child trafficking (US DOL, 2019). However, child labour persists where ASM activities take place outside the legal structure.

Following the publication of a major report by Amnesty International calling attention to this issue (Amnesty International, 2016), some companies initially committed to sourcing ASM-free cobalt in order to mitigate child labour practices. However, in the years since, companies have evolved their thinking in recognition of the fact that ASM provides a critical source of income for many people. Removing that source of income could paradoxically exacerbate the problem (OECD, 2019b). This evolution is represented by the LME's decision to adopt a policy of non-discrimination between large-scale mining and ASM (LME, 2019). Current industry initiatives such as the Fair Cobalt Alliance and the Responsible Minerals Initiative now emphasise formalisation of ASM sites to ensure that standards are upheld and actions taken to address the root causes of child labour.

There is some evidence that ASM formalisation can be successful at reducing child labour concerns (WEF 2020; OECD, 2019b). However, successes have so far been limited in scale (BGR, 2019), and the DRC's efforts in particular have been limited by regulatory ambiguity in the mining code (OECD, 2019b). Continued multi-stakeholder engagement is needed, bringing together governments, companies and civil society to improve the situation. In this regard, the recent announcement that the DRC Minister of Mines is joining the Cobalt Action Partnership is a positive step.

[4] The simple presence of children at a mine site does not necessarily indicate a human rights violation. The ILO Convention on the Worst Forms of Child Labour applies to work that is by its nature "likely to harm the health, safety or morals of children".

Inclusive legal frameworks and voluntary industry action can reduce the prevalence of the worst forms of child labour

Existing legal and regulatory frameworks do not always differentiate between large-scale mining and ASM, essentially applying the same requirements and limitations to all mines. This generally means that ASM activities will be "informal" or "illegal", as individuals will not be able to obtain an exploitation permit via a system designed for large companies. Even where there are special provisions for ASM, there may still be obstacles that discourage workers from working at formalised ASM sites. If enforcement is lax, or if the legal regime is burdensome, workers may continue to work at unregulated sites (IGF, 2017; IMPACT, 2018).

To be effective, policy and regulatory measures must address the root cause – i.e. poverty – and create an alternative to mining for poor children and families. While investment and technical support to develop new formalised mine sites is needed, community development and support for education and other social programmes will be important complementary strategies. The IGF has developed guidance on establishing a comprehensive ASM strategy to aid policy makers in improving the legal framework.

Industry initiatives can be scaled up

For their part, companies can do more to address the worst forms of child labour in the mineral supply chain. It is not necessarily a good solution for companies to adopt blanket "ASM-free" policies as a mitigation strategy because complete disengagement may exacerbate the causes of child labour. As an alternative, companies can seek to engage with formalised ASM and to work together with multi-stakeholder groups to promote formalisation (OECD, 2019b).

Separately, companies should seek to apply enhanced due diligence measures to their operations. Although supply chain due diligence remains voluntary for energy transition minerals, they are being increasingly adopted into regulations and market rules, and a mandatory due diligence requirement for all companies is currently under discussion at the European Parliament (European Parliament, 2021). The OECD has developed a set of practical actions that companies can take to address child labour based on the existing OECD Due Diligence Guidance, discussed in the next section.

Several industry initiatives already exist that combine several of these elements, including the Responsible Cobalt Initiative, launched by the Chinese Chamber of Commerce for Metals, Minerals and Chemicals and the Fair Cobalt Alliance. While promising, the proliferation of initiatives may cause some concern as they are not necessarily co-ordinated and risk overlapping. Thus, continued engagement throughout the value chain is needed, particularly to ensure consistency and interoperability of standards.

Box 4.7. Formalising artisanal and small-scale mining in the DRC

Despite longstanding recognition of the potential for formalisation, as of 2019 the DRC had no more than five active formalised (or semi-formalised) ASM cobalt sites (OECD, 2019b). The government has promised reforms that may support formalisation. In November 2019 the government mandated that all ASM cobalt be sold to the newly formed Entreprise Générale du Cobalt, a subsidiary of the state mining company. In March 2021 it released a responsible sourcing standard designed to support establishing new ASM sites in the DRC (EGC, 2021), although the impact of the standard remains to be seen.

There are currently two models for formalisation of projects in the DRC. In the first model, a registered co-operative can establish an ASM site within an area designated by the government for ASM – known as a Zone d'Exploration Artisanal (ZEA). The DRC currently has 92 ZEAs in the cobalt producing region. However, these are mostly in geologically underexplored areas with less developed mining infrastructure, and a 2019 study found only two producing sites within these zones (BGR, 2019).

In the second model, the concession holder enters into an agreement with a registered co-operative to operate the site, with the concession holder setting standards for production and purchasing all material (OECD, 2019b). It is unclear how many such agreements exist, but there have been at least two documented projects so far – both initiated by buyers. A 2020 study found mixed results. While both sites had eliminated child labour and made improvements in safety practices, workers did not routinely use protective equipment and critics have noted that the sites have not led to economic or social benefits for workers (WEF, 2020). Since that study, one of the two sites has shut down (Reuters, 2020a), while for the other, the buyer announced that it would suspend purchases until it could confirm that it was free of human rights abuses (Reuters, 2020b).

From these examples, it is clear that long-term engagement with the buyer is critical to ensure that the mines are economically viable. Even with buyer support, structural barriers remain to scaling up this approach. Significant up-front investment is needed for geological analysis and to purchase the necessary infrastructure, including fences, machinery and protective equipment. In parallel, there is a need for community development to provide alternative options for children (WEF, 2020). While formalisation has the potential to improve conditions for ASM workers, a long-term commitment from buyers and mining companies alike will be necessary to ensure that it actually leads to the expansion of opportunities for ASM workers.

Government and industry can do more to address persistent, unequal impacts on women

Historically, women have been largely excluded from large-scale mining. In the United States, women make up only about 14% of the mining workforce (US BLS, 2021). IEA analysis shows that this figure is similar in the European Union (IEA, 2020d). Although data is poor, there is little reason to think the situation is different in developing countries.

Women's participation may be greater at ASM sites, as some estimates place women at around 30% of the workforce (IGF, 2018d). However, women are most often employed in less lucrative "auxiliary activities" at these sites due to cultural barriers and gendered assumptions that mining is "man's work" (OECD, 2019b; IGF, 2018d). Women also may lack access to finance to invest in equipment and often remain fully responsible for domestic responsibilities, which limits the time and energy they have available for work. Worse, they are subject to increased risk of sexual and gender-based violence (GIZ, 2020) and can be driven to engage in sex work by financial exploitation (IGF, 2018c).

Changes in the community associated with mining may also have a disparate impact on women, even if they do not engage directly in mining activities. For example, women may be marginalised from community outreach by companies (RMF, 2020b), and the move from a subsistence to a cash economy may also give rise to family disputes and increased risk of domestic violence (GIZ, 2020).

Industry responses have so far been lacking. The Responsible Mining Foundation found that the mining sector ranked low in respect of Sustainable Development Goal 5 on gender equality (RMF & CCSI, 2020). Similarly, the foundation found in 2020 that among the 38 companies it surveyed, none had a system to regularly assess the company's impact on women (RMF, 2020b).

Creating an inclusive environment for women

The industry can do more to create an inclusive environment for women, both in their operations and in stakeholder consultations concerning community impacts and working conditions. As a first step, companies can conduct dedicated assessments of the impact of their activities on women and seek to improve gender-disaggregated data.

Governments can also play a role in promoting the inclusion of women miners and community members in multi-stakeholder consultations, as recommended by EITI (EITI, 2018). Regulatory authorities can also implement training for government and law enforcement personnel to ensure that they are prepared to intervene and address rights violations. Governments may also fund programmes designed to reduce the barriers for women to work, including providing reliable access to finance and social services to assist with childcare and domestic responsibilities.

International co-ordination

International co-ordination on sustainable and responsible extraction already exists

Selected initiatives categorised by activity area

Name	Climate	Sustain-ability	Responsible sourcing	Rights of workers	Fairness and inclusivity	Governance	Security of supply
World Bank Climate Smart Mining Initiative	🟠	🟠				🟠	🟠
European Battery Alliance							🟡
European Raw Materials Alliance							🟡
Extractive Industries Transparency Initiative						🟠	
Global Battery Alliance	🟣	🟣	🟣				
Energy Resource Governance Initiative		🟠	🟠	🟠		🟠	
Fair Cobalt Alliance				🟡	🟡		
International Council on Mining & Metals	🟣	🟣	🟣	🟣	🟣	🟣	
Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development		🟠	🟠	🟠	🟠	🟠	
Initiative for Responsible Mining Assurance		🟣	🟣			🟣	
Towards Sustainable Mining	🟣	🟣	🟣	🟣	🟣		
OECD Responsible Business Conduct			🟠	🟠	🟠	🟠	
Responsible Minerals Initiative			🟣	🟣			
Responsible Minerals Foundation	🔵	🔵	🔵	🔵	🔵	🔵	
Women’s Rights and Mining			🔵		🔵		

Note: Primary activity type: 🟠 = Technical assistance. 🟣 = Industry standardisation. 🟡 = Investment/funding. 🔵 = Research and analysis.

International co-ordination continues to play a critical role in encouraging companies to identify and address risks across their entire supply chains

Growing demand for energy transition minerals entails the expansion of supply chains and an increase in associated environmental and social risks for upstream and downstream companies alike. Identifying and addressing risks across jurisdictions with a patchwork of legal frameworks and local contexts is indeed technically challenging and resource-intensive. But ignoring supply chain risks is increasingly costly in light of pressure from consumers, investors and regulators. For instance, mining companies and traders have faced criminal probes and financial sanctions due to corrupt practices in their supply chains in the DRC (OECD, 2019c).

A prime strategy to mitigate risks is enhancing traceability, accountability, audits and other measures that allow companies to assess their supply chains. These efforts are supported by international frameworks for due diligence, such as the OECD Guidance (see Box 4.8). The operationalisation of these frameworks can be tailored to specific supply chains through industry standards. The growth of an entire industry catering to the needs of companies looking to implement these frameworks speaks to their broad uptake. Certain industry initiatives are calling attention to a broader set of risks beyond conflict financing, serious violations of human rights and economic crime, with increasing attention paid to environmental concerns. For example, the Responsible Minerals Initiative, the Cobalt Industry Responsible Assessment Framework and the Copper Mark adhere to the principles set out in the OECD Guidance, but go beyond the risks explicitly covered by its Annex II. The expanding coverage of due diligence frameworks and legislation reflects a broader trend of investors, consumers and civil society increasingly calling on companies to look more closely at their supply chains and reduce environmental and social harms through proactive engagement, rather than “de-risking” by exiting fraught supply chains altogether.

Innovation and due diligence

Innovation can also play a role in enhancing supply chain transparency. For example, shifting internal management systems from paper-based to digital documentation facilitates traceability and public access. The European Union, the Global Battery Alliance and the LME are all looking at increasing traceability through digital “passports” attached to individual batteries or metals. Market players are also considering distributed ledger technologies (blockchain) to ensure integrity of mineral supply chain data. While technological solutions alone cannot replace a company’s due diligence obligations, they can play an important role in streamlining these efforts.

Box 4.8. OECD due diligence guidance for responsible supply chains

The *OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas* (OECD Guidance) aims to help companies achieve responsible sourcing of minerals and avoid contributing to conflicts, human rights violations and economic crime. It serves as a global reference for public and private stakeholders. Although it initially focused on minerals from conflict-affected and high-risk areas, e.g. tin, tantalum, tungsten and gold, the scope is much broader: it can be applied to all minerals and all types of upstream and downstream risks. It covers both ASM and large-scale mining and is applicable globally, making it increasingly difficult for companies to "opt out". The OECD is working on a complementary tool addressing environmental risks to enhance coverage of supply chain issues.

The OECD Guidance facilitates the prevention and mitigation of human rights abuses, support to armed forces, and other risks such as tax evasion, fraud and bribery. This is achieved through a five-step framework involving establishing internal management systems, identifying and assessing risks, developing a mitigation strategy, carrying out independent audits and annual reporting. Supply chain stakeholders must establish traceability or a chain of custody system to track minerals and undertake on-the-ground assessments for "red-flagged" supply chains. Critically, companies are instructed to remedy shortcomings in supply chains rather than disengage. In energy transition mineral supply chains, the OECD Guidance has *de facto* become a core component of countries' legal frameworks for responsible sourcing. Responsible sourcing requirements based on the OECD Guidance are incorporated into the EU Regulation on Conflict Minerals (currently only applicable to tin, tantalum, tungsten and gold) and the proposed Batteries Regulation. Similar requirements were implemented through the U.S. Dodd-Franck Act and in several African countries (OECD, 2021b). The shift from a voluntary approach to mandatory legal frameworks or market rules reflects broad global consensus regarding enhanced supply chain due diligence.

In 2016 the OECD launched an Alignment Assessment project aimed at measuring the extent to which recommendations had been incorporated into industry standards and effectively implemented. This first exercise revealed significant gaps between the standards under review and OECD Guidance, which were subsequently largely remedied (OECD, 2018). Uptake studies are now underway to evaluate implementation at a company level. While these exercises alone cannot drive full compliance, they ensure a measure of accountability in the rapidly expanding world of industry initiatives, and highlight implementation gaps for policy makers.

The international trade and investment regime is key to maintaining reliable mineral supplies, but policy support is needed to improve application of environmental and social regulations

The global trade and investment regime has helped to reduce tariffs, subsidies and other barriers to trade, enabling companies to weave global supply chains to meet the market's needs. At the same time, this regime can be seen as limiting the policy options available to governments to address environmental and social issues. Although the trade system recognises governments' authority in these areas, for example through exceptions to Article XX of the General Agreement on Tariffs and Trade, progress on incorporating sustainability norms into the international trade regime has been limited and debate continues about including enforceable standards in free-trade agreements (Bronckers and Gruni, 2021).

Governments are therefore looking to update their trade policies in line with civil society's expectations and to balance this goal with stability of supply and national security considerations. Export controls, subsidies to state-owned enterprises in the mining and processing sectors, or carbon border taxes could also lead to distortions in free trade. Such measures reflect the potential tension between international trade disciplines and the mainstreaming of environmental and social concerns.

Further, the international trade regime remains largely deadlocked at the World Trade Organization level, notably in respect of industrial subsidies reform. Due to the lack of impetus for global trade agreements, countries are increasingly shifting to bilateral or regional agreements to secure supplies of raw materials. EU trade policy strongly favours including environmental and social standards in such agreements. For example, agreements under negotiation with Chile, Australia and China, and the completed Comprehensive Economic and Trade Agreement with Canada, all include commitments to multilateral labour and environmental agreements and responsible business conduct. Apart from the draft agreement with China, they all include specific language on supporting uptake of the OECD Due Diligence Guidance for responsible supply chains of minerals from conflict-affected and high-risk areas. They reflect the important role of international trade to promote consistency in standards. However, these commitments remain largely unenforceable as they are not subject to the agreements' dispute settlement chapter.

Although international trade undoubtedly plays a role in ensuring the stability of energy transition mineral supplies, governments must achieve both security aims and a just transition. Encouragingly, responsible and sustainable sourcing of energy transition minerals is increasingly perceived as a pillar of security of supply, and not as a necessary trade-off. As such, trade policies should reflect these standards rather than rely on them to erect new trade barriers.

Enhancing capacity building and knowledge sharing can address critical resource gaps between countries…

Capacity building and knowledge transfer can be a particularly fruitful area of co-operation, as experience and capacity varies greatly between countries. Australia, Canada and the United States, all of which have well-developed regulatory systems addressing environmental and social concerns, are increasingly offering technical assistance to countries with nascent regulatory regimes.

Role of multilateral initiatives

At a government-to-government level, countries work together through institutions like the World Bank and the OECD to support sustainable mining and supply chain practices. Separately, governments have set up extraction-specific initiatives such as the Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF) and the Energy Resource Governance Initiative (ERGI) to provide technical assistance.

The IGF provides a platform for more than 75 member countries to discuss issues related to mineral resource governance and promote sustainable mining practices. In particular, it provides technical capacity building and shares best practices through its Mining Policy Framework. Similarly, ERGI shares best practices on mining governance through its ERGI Toolkit, which is primarily designed for mineral-producing economies and focuses on responsible and sustainable mining. In particular, these high-level initiatives can help ensure consistent communications with all relevant ministries in resource-rich countries, and more generally ensure issues receive appropriate levels of attention. To harness this potential, synergies between initiatives could be better exploited, and new areas for knowledge sharing could be explored beyond mining frameworks.

Public-private collaboration

Some companies have achieved high levels of sustainability performance, and governments can facilitate sharing of these experiences and good practices. For example, the Mining Association of Canada's TSM standard covers issues such as tailings management, worker safety, child labour and relationships with indigenous communities. The Canadian government actively promotes the TSM standard and supports uptake by other countries (Government of Canada, 2021b). The World Bank's Climate Smart Mining initiative also brings together public and private actors across the mineral sector to facilitate collaboration. Industry and governments have thus stepped in to facilitate knowledge sharing on a significant scale, but more is needed to achieve a comprehensive minerals governance framework.

...but there is scope for better alignment and co-ordination

To be sure, the proliferation of international initiatives has led to encouraging success stories, including the global adoption and implementation of the OECD Due Diligence Guidance, the LME's responsible sourcing criteria and sustainability initiative, and continued improvement of transparency standards in producer economies via the EITI. However, uncoordinated efforts can lead to potential duplication – where multiple initiatives form around the same issue with different membership – or discontinuity when competing standards follow different approaches. Even where a harmonised approach emerges, to the extent that initiatives are voluntary, some important players may opt out.

As discussed in Chapter 3, a high-level forum for co-ordination could be pivotal in standardising environmental and social standards and co-ordinating activity on security of supply. There has been some success at co-ordinating competing efforts, but only on certain issues, for instance due diligence practices through the OECD Guidance. Generalised organisations like the G7 and G20 have also played this role in the past. For example, the Brisbane 2014 G20 Principles of Energy Collaboration reflected the need to make minerals governance an integral part of countries' energy security policies. New or long-standing fora such as the Climate Smart Mining Initiative or the IGF can also play an important role in channelling discussion and co-operation on energy transition minerals.

An international governance framework

Despite increasing levels of global adherence to environmental and social standards, they generally offer few avenues for collective action among governments. Policy integration through the European Union or other regional blocs alone is also insufficient to ensure consistency on a global scale. Therefore, a systemic approach is needed to ensure countries take action not only in certain notoriously fraught supply chains or in specific regions, but also for all minerals that underpin the energy transition and across jurisdictions.

A governance framework for minerals should provide countries with the tools they need to address GHG emissions, local and regional environmental impacts and social and human rights risks. It could ultimately contribute to maintaining a reliable supply of minerals necessary for the energy transition. As such, the UN Environment Programme's International Resource Panel has underlined that "[t]here is a need for an international body with a similar role to that of the International Energy Agency in the energy sector" (IRP, 2020, 131). The IEA's energy security framework could thus serve as a template for international minerals governance, underpinned by data sharing, co-ordination mechanisms and collective actions, fostering sustainable and responsible supply chains that contribute to a low-carbon economy.

Annexes

Scope

This report assesses the mineral requirements for the following clean energy technologies:

- **Solar PV** (utility-scale and distributed)
- **Wind** (onshore and offshore)
- **Concentrating solar power** (parabolic troughs and central tower)
- **Hydropower**
- **Geothermal**
- **Bioenergy for power**
- **Nuclear power**
- **Electricity networks** (transmission, distribution, and transformer)
- **Electric vehicles** (battery electric and plug-in hybrid electric vehicles)
- **Battery storage** (utility-scale and residential)
- **Hydrogen** (electrolysers and fuel cells).

All of these energy technologies require metals and alloys, which are produced by processing mineral-containing ores. Ores – the raw, economically viable rocks that are mined – are beneficiated to liberate and concentrate the minerals of interest. Those minerals are further processed to extract the metals or alloys of interest. Processed metals and alloys are then used in end-use applications. While this report covers the entire mineral and metal value chain from mining to processing operations, we use “minerals” as a representative term for the sake of simplicity.

Minerals are not only used in the clean energy sector, but are also used widely across the entire energy system, in technologies that improve efficiency and reduce emissions. For example, the most efficient coal-fired power plants require a lot more nickel than the least efficient ones in order to allow for higher combustion temperatures. However, here we focus specifically on the use of minerals in clean energy technologies, given that they generally require considerably more minerals than fossil fuel counterparts. Our analysis also focuses on the requirements for building a plant (or making equipment) and not on operational requirements (e.g. uranium consumption in nuclear plants).

Our report considers a wide range of minerals used in clean energy technologies listed in the table below. They include chromium, copper, major battery metals (lithium, nickel, cobalt, manganese and graphite), molybdenum, platinum group metals, zinc, rare earth elements and others.

Steel is widely used across a broad range of technologies, but we have excluded it from the scope given that it does not have substantial security implications and the energy sector is not a major driver of growth in steel demand. Steel and aluminium are widely used across many clean energy technologies, but we have excluded it from the scope of this analysis. Steel does not have substantial security implications and the energy sector is not a major driver of growth in steel demand. Aluminium demand is assessed for electricity networks only as the outlook for copper is inherently linked with aluminium use in grid lines, but is not included in the aggregate demand projections. Overall aluminium demand projections are regularly assessed as part of the *WEO* and *Energy Technology Perspectives* series.

Projection results are available for download from the report webpage: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions.

Minerals in scope

Focus minerals	Other minerals	
Cobalt	Arsenic	Niobium
Copper	Boron	Platinum
Lithium	Cadmium	Selenium
Nickel	Chromium	Silicon
Rare earth elements (Neodymium, Dysprosium, Praseodymium, Terbium, others)	Gallium	Silver
	Germanium	Tantalum
	Graphite	Tellurium
	Hafnium	Tin
	Indium	Titanium
	Iridium	Tungsten
	Lead	Vanadium
	Magnesium	Zinc
	Manganese	Zirconium
	Molybdenum	

Methodology

Demand

For each of the clean energy technologies, we estimate overall mineral demand using four main variables:

- clean energy deployment trends under different scenarios;
- sub-technology shares within each technology area;
- mineral intensity of each sub-technology; and
- mineral intensity improvements.

Clean energy deployment trends under the Stated Policies Scenario (STEPS) and the Sustainable Development Scenario (SDS) are taken from the projections in the *World Energy Outlook 2020*, complemented by the results in the *Energy Technology Perspectives 2020*.

Sub-technology shares within each technology area (e.g. solar PV module types; EV battery chemistries) are also taken from the *World Energy Outlook 2020*, complemented by the *Energy Technology Perspectives 2020* and other sources.

Mineral intensity assumptions were developed through extensive literature review (see Table) and expert and industry consultations, including with IEA Technology Collaboration Programmes.

The pace of mineral intensity improvements varies by scenario, with the STEPS generally seeing minimal improvement over time as compared to modest improvement (around 10% in the longer term) assumed in the SDS. In areas that may particularly benefit from economies of scale or technology improvement (e.g. silicon and silver use in solar PV, platinum loading in fuel cells, REE use in wind turbines), we applied specific improvement rates based on the review of underlying drivers.

The report assesses demand from other sectors for the five focus minerals using historical consumption by end-use applications, relevant activity drivers (e.g. GDP, industry value added, vehicle activities, steel production) and material intensities.

Supply

Annual mineral production estimates are based on the analysis of the individual project data provided by S&P Global (2021) and BloombergNEF (2020), and supplemented with public data sources.

Operating projects are defined as mines of which development stage is operating, expansion or limited production due to some reasons. Under-construction projects are taken to be mines of which development stage is commissioning, construction planned, construction started or preproduction.

Secondary production is estimated with two parameters: the average recycling rate and the lifetime of each end-use sector. The recycling rate is the combination of the end-of-life collection rate (the amount of a certain product being collected for recycling) and the yield rate (the amount of material a recycling process can actually recover). For existing waste streams (e.g. industrial applications), we assume only marginal improvement in collection rates, while for emerging technologies such as lithium-ion batteries, we assume collection rates increase at a faster pace. For batteries, the collection rates gradually increase from around 45% in the early-2020s to 80% by 2040. For batteries, the yield rate is assumed to vary according to the technical limitations for the extraction of each mineral using the currently available recycling methods. The reuse rates are much lower than the collection rate for recycling as the use of second-life batteries faces many technical and regulatory obstacles.

Sources for mineral intensity assumptions

Technology	Sources
Solar PV	Candelise, C. et al. (2011), Materials availability for thin film (TF) PV technologies development: a real concern? *Renewable and Sustainable Energy Reviews*, *15*(9), 4972-4981, https://doi.org/10.1016/j.rser.2011.06.012 Carrara S. et al. (2020), Raw materials demand for wind and solar PV technologies in the transition towards a decarbonised energy system, European Commission Joint Research Centre (JRC), http://dx.doi.org/10.2760/160859%20 Elshkaki, A., and Graedel, T. E. (2013), Dynamic analysis of the global metals flows and stocks in electricity generation technologies, *Journal of Cleaner Production*, *59*, 260-273, https://doi.org/10.1016/j.jclepro.2013.07.003 Fizaine, F. and Court, V., (2015), Renewable electricity producing technologies and metal depletion: a sensitivity analysis using the EROI, *Ecological Economics*, *110*, 106–118, https://doi.org/10.1016/j.ecolecon.2014.12.001 Frischknecht, R. et al. (2020), Life Cycle Inventories and Life Cycle Assessment of Photovoltaic Systems, *IEA PVPS Task 12*, Report T12-19:2020. https://iea-pvps.org/key-topics/life-cycle-inventories-and-life-cycle-assessments-of-photovoltaic-systems Giurco, D. et al. (2019). Requirements for minerals and metals for 100% renewable scenarios, In: Teske S. (eds) Achieving the Paris Climate Agreement Goals, https://doi.org/10.1007/978-3-030-05843-2_11 IRENA (International Renewable Energy Agency) (2017), Renewable Energy Benefits Leveraging Local Capacity for Solar PV, https://www.irena.org/publications/2017/Jun/Renewable-Energy-Benefits-Leveraging-Local-Capacity-for-Solar-PV World Bank (2017), The Growing Role of Minerals and Metals for a Low Carbon Future, https://doi.org/10.1596/28312 Private communication with researchers of early-stage technologies
Wind	Carrara S. et al. (2020), Raw materials demand for wind and solar PV technologies in the transition towards a decarbonised energy system, European Commission Joint Research Centre (JRC), http://dx.doi.org/10.2760/160859%20 Månberger, A. and Stenqvist, B. (2018), Global metal flows in the renewable energy transition: Exploring the effects of substitutes, technological mix and development, *Energy Policy*, *119*, 226-241, https://doi.org/10.1016/j.enpol.2018.04.056 Private communication with companies