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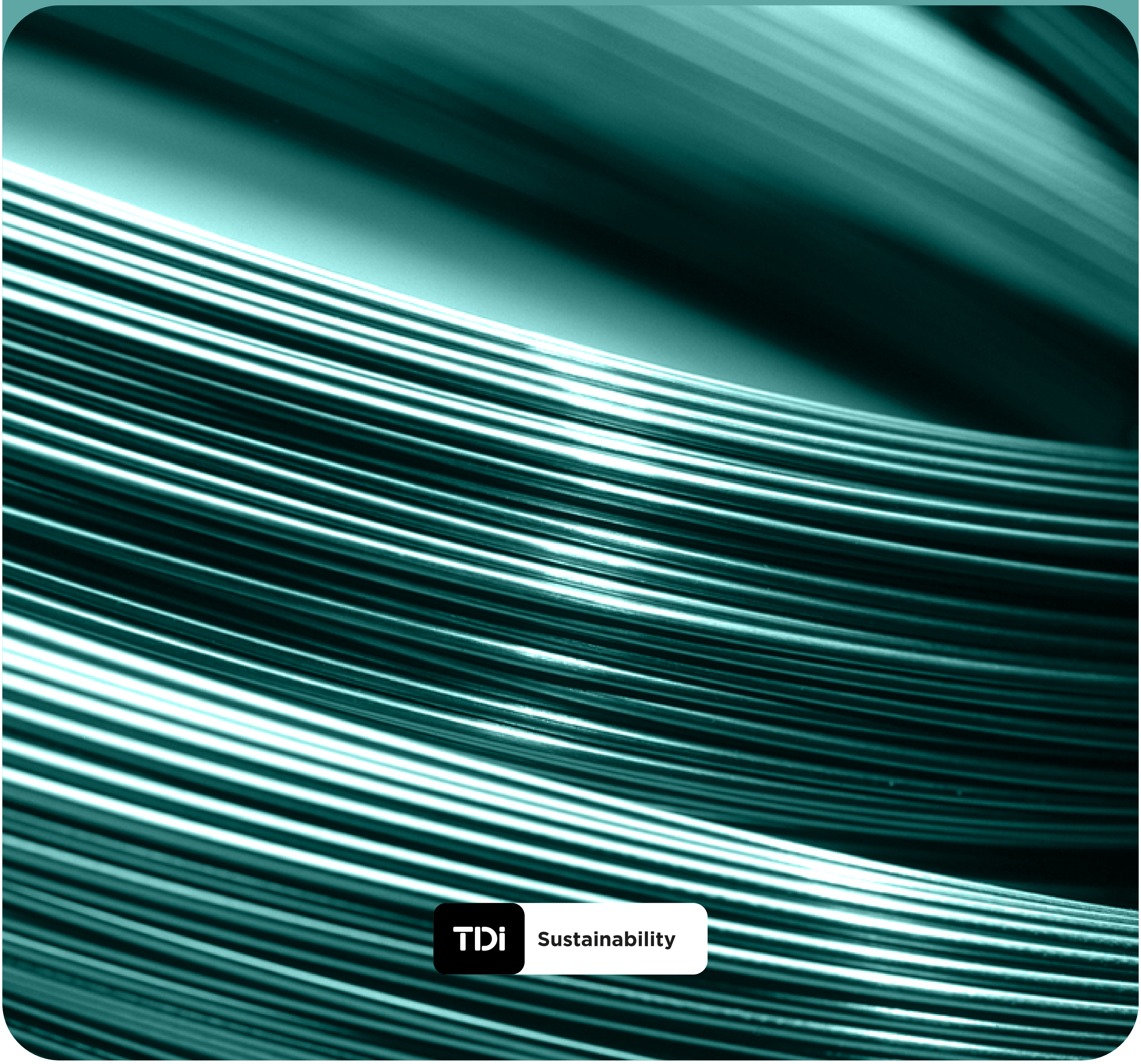
Molybdenum profile for supply chain due diligence and responsible sourcing



TDi Sustainability

Completed by TDi Sustainability with support from the International Molybdenum Association (IMOA)

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INTRODUCTION

The objective of this paper is to provide standards-setters, steel-makers, manufacturers and civil society organisations with a clear understanding of the molybdenum supply chain, of its environmental, social and governance aspects, and of the current landscape of responsible sourcing standards, certifications and initiatives that are applicable to molybdenum.

The paper sets out this information in a format that is designed to allow quick access to relevant indicators to inform a range of decision-making processes associated with the promotion of sustainability and responsible sourcing.

It is written in light of growing expectations from downstream purchasers of minerals, regulators and civil society, that minerals are produced and sourced responsibly, and that appropriate action is being taken throughout supply chains to identify and, where relevant, address negative environmental and social impacts.

EXECUTIVE SUMMARY

Molybdenum plays an important role in the global economy. Its properties make it a critical constituent in the production of high-strength, corrosion- and heat-resistant, durable steels and alloys. These long-lasting products reduce the need for maintenance and replacement of machinery and infrastructure, which can decrease associated carbon emissions and other environmental impacts.

Molybdenum extraction takes place through industrial, large-scale mining, predominantly in the Americas and China. Molybdenum mining projects are typically operated by prominent mining companies that are subject to a high degree of regulatory scrutiny. Outside China, the majority of molybdenum is produced as a by-product at mines where copper is the main commercial focus.

Molybdenum-bearing ore goes through several stages of transformation. Principal among these stages are the production of Unroasted Molybdenite Concentrate, Roasted Molybdenite Concentrate, and Ferro-molybdenum.

Trading takes place globally for these material types, and Roasted Molybdenite Concentrate can be blended from multiple sources, even at vertically integrated facilities. This trading and blending system, involving multiple intermediary forms of molybdenum, is similar to trading and blending systems for other metals including copper and zinc.

Molybdenum production and processing, like any industrial activity, carries inherent environmental, social and governance risks. Some of these inherent risks are common to all forms of large-scale mining, and some are more specific to molybdenum. At the mining stage, the potential for acid rock drainage is more strongly associated with sulphide ores than oxide ores. Molybdenite, the most important ore for commercial extraction of molybdenum, is a sulphide ore. At the roasting stage, the transformation process results in the production of sulphur dioxide gas, which must be captured through desulphurisation systems. Sulphur dioxide released into the atmosphere can harm the human respiratory system and damage plant life, and it is a precursor to acid rain. These risks and others inherent to molybdenum production and processing can be mitigated when companies in the supply chain adopt sound and stringent risk management systems, as can risks associated with the storage and disposal of waste material from ore processing, known as tailings. Tailings management is increasingly a focal area for the metals industries.

English-language media from the past five years was surveyed for reports of negative environmental, social and governance impacts associated with the production and processing of molybdenum. The reports identified were analysed using TDi Sustainability's Search360 process and salience methodology, which benchmark the level of negative reporting in molybdenum supply chains against extensive data from other mineral supply chains.

The analysis showed a relative global scarcity of negative reporting on environmental, social and governance issues in molybdenum supply chains, comparative to many other minerals studied by TDi Sustainability. It also showed the relatively low 'salience' of many of the issues reported, comparative to those reported for other minerals. Salience, within TDi Sustainability's methodology, measures the importance of issues for the people or environments that they affect, and the reputation risk for businesses using the corresponding material in their products. The data indicates that environmental, social and governance risks associated with molybdenum production and processing are relatively well managed overall. The application of site-level and supply chain voluntary standards schemes can ensure that inherent risks remain well-managed for the molybdenum industry, and can drive continuous improvement in risk management performance. A survey of major molybdenum producers and processors, conducted by the International Molybdenum Association, found that ISO 14001 and ISO 45001, international standards covering environmental performance and occupational health and safety, respectively, are the most widely adopted standards in the molybdenum industry. The International Council on Mining and Metals (ICMM) Performance Expectations and the Copper Mark responsible production standard are also adopted by some molybdenum-producing mines, and many of the copper-molybdenum mines that do not currently adopt the Copper Mark[1] are considering doing so in future.

Manufacturers, steel-makers, and downstream standards-setters, including ResponsibleSteel (the steel industry's standard and certification programme), have roles to play to ensure that the environmental, social and governance risks inherent to the molybdenum industry remain generally well-managed, and to promote continuous risk management improvements. These downstream entities can formally recognise upstream voluntary standards in their due diligence frameworks, and support efforts to widen the scope of standards, including the Copper Mark, to cover concentration, roasting and ferromolybdenum conversion stages of the molybdenum supply chain, and to cover non-copper producing molybdenum mines.

By taking these steps, downstream entities can facilitate and incentivise molybdenum producers' and processers' adoption of strong voluntary standards, promoting the sustainable production, processing and usage of molybdenum in future years.

[1] As of September 2021, sites that have received the Copper Mark are: Kennecott Utah Copper (Rio Tinto); Oyu Tolgoi (Rio Tinto); Atlantic Copper Smelter & Refinery (Freeport-McMoRan); Sociedad Contractual Minera El Abra (Freeport-McMoRan); Sociedad Minera Cerro Verde (Freeport-McMoRan); Miami Smelter & Mine (Freeport-McMoRan); El Paso Refinery (Freeport-McMoRan); Morenci Mine (Freeport-McMoRan); Aurubis Bulgaria (Aurubis); Minera Centinela (Antofagasta); Glogów (KGHM); Legnica (KGHM). Sites that are participants of the Copper Mark are: Minera Escondida Limitada (BHP), Minera Spence Limitada (BHP), Olympic Dam (BHP); Compañia Minera Zaldivar SpA (Antofagasta); Onsan Smelter & Refinery (LS Nikko Copper); Compañía Minera Condestable S.A. (Southern Peaks Mining); Bagdad (Freeport-McMoRan); Chino (Freeport-McMoRan); Tyrone (Freeport-McMoRan); Sierrita (Freeport-McMoRan); Safford (Freeport-McMoRan); Hamburg (Aurubis); Lünen (Aurubis).

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PROPERTIES AND APPLICATIONS

Molybdenum is a transition metal that is valued for several characteristics, including in particular its performance at high temperatures. Its melting point is one of the highest of all elements, and molybdenum is used in steel alloys to enhance strength, hardenability, weldability, toughness and corrosion resistance. It is also used widely in non-steel alloys to improve corrosion resistance and high temperature performance.[2] Figure 1, below, shows the applications for which newly-mined molybdenum is used.[3] Additional information on end-uses of molybdenum, and on its essential biological role in human, plant and animal life can be found on the International Molybdenum Association (IMOA) website.[4]

Uses of molybdenum from mined ore

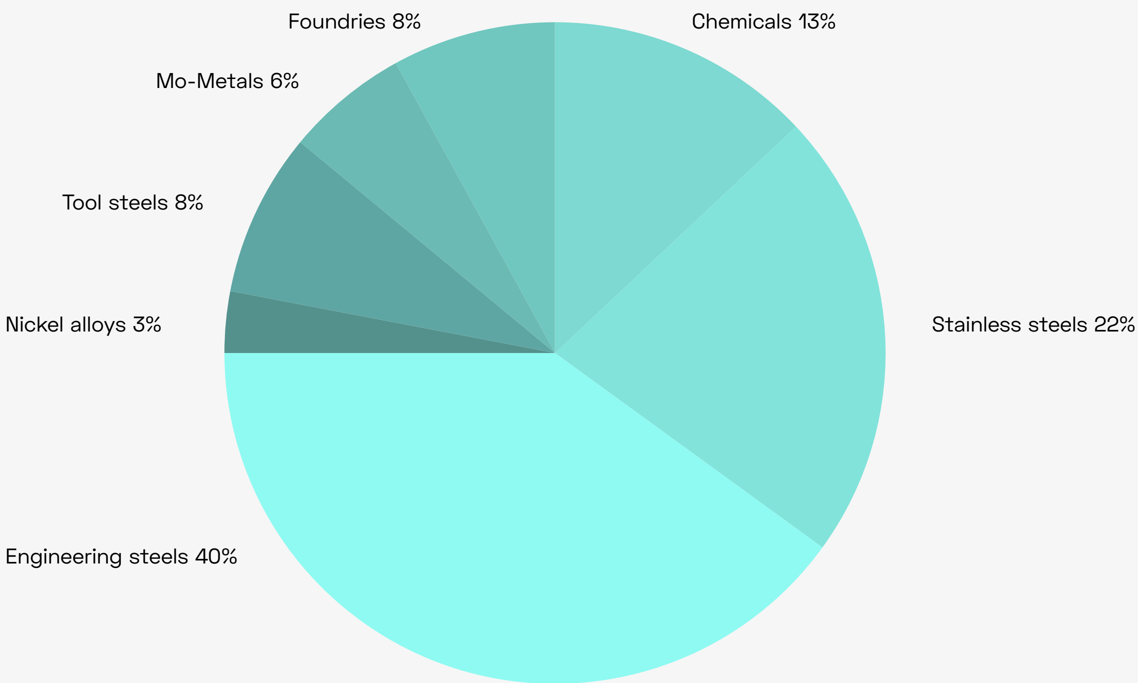

Figure 1: A breakdown of the first uses of molybdenum from newly-mined ore (excluding scrap materials). Source: IMOA.

[2] Molybdenum Properties, International Molybdenum Association, https://www.imoa.info/molybdenum/molybdenum-properties.php, (accessed 06 September 2021).

[3] Molybdenum Use, International Molybdenum Association, https://www.imoa.info/molybdenum-uses/molybdenum-uses.php, (accessed 6 September 2021).

[4] Molybdenum – Essential for Life, International Molybdenum Association, https://www.imoa.info/essentiality/molybdenum-essential-for-life.php (accessed 6 September 2021).

SUPPLY CHAIN ATTRIBUTES

SUPPLY CHAIN RESILIENCE

The IMOA estimates annual total molybdenum production in 2020 at 273,000 metric tons (molybdenum content). The United States Geological Survey (USGS) estimates global reserves in 2020 at 18 million metric tons. Additional molybdenum reserves will be added to the global figure as deposits are further explored and evaluated, and the USGS states that "resources of molybdenum are adequate to supply world needs for the foreseeable future."[5]

Two dashboard indicators of the resilience of the molybdenum supply chain are given below. These numerical indicators are graded for supply chain resilience risk from very low to very high, benchmarked against a range of mined materials through a standardised methodology. 'Price volatility' measures the degree of fluctuation in the price of a material on the open market, over time. Large fluctuations indicate a risk to the resilience of supply chains, particularly when the material purchased represents a large proportion of a company's operating costs, and when it cannot be easily substituted. 'Supply chain concentration' measures the geographic concentration of mineral production, indicating whether it is predominantly mined in just a few key countries, and therefore more prone to supply disruptions, or whether production is more evenly distributed worldwide.

Methodology notes on the indicators are given in Appendix III.

Price volatility			
TDi price volatility index	0.39	Supply chain resilience risk indicated by the degree of price volatility	High

Market concentration			
TDi market conconcentration index	0.25	Supply chain resilience risk indicated by the degree of market concentration	Low

The coronavirus pandemic has caused widespread uncertainty in mineral markets, to which the molybdenum market is no exception. Early in the pandemic, output at some molybdenum mines was interrupted due to Covid-19. Freeport-McMoRan's cut production at their Climax Molybdenum mine in the United States due to reduced demand in the developed world.[6] The price of molybdenum was, on average, lower in 2020 than in the previous two years, as the global effects of the pandemic on industry, and on the demand for metals, were felt.

SUPPLY CHAIN STRUCTURE

MINING AND CONCENTRATION

After molybdenum ores are mined, they are concentrated to produce Unroasted Molybdenite Concentrate (UMC), which is composed of 85% to 92% molybdenum disulphide (MoS_2). The concentration process normally happens at or nearby the mine site.

PROCESSING (ROASTING)

More than 95% of all UMC is passed to molybdenum roasters, where molybdenum disulphide is converted to molybdenum oxide and may also undergo a leaching step, at some roasting plants. The remaining UMC is used in other applications, including lubricants. Two types of roasters, multi-hearth and rotary kiln, are used for roasting UMC. The multi-hearth roasters are mainly used outside of China, with rotary kiln

[5] United States Geological Survey, 'Molybdenum', National Minerals Information Center, USA, Author, 2021 http://www.southerncoppercorp.com/ENG/intope/Pages/PGProdVolume.aspx

[6] Freeport-McMoran to cut molybdenum production at Colorado mine, Reuters, https://www.reuters.com/article/us-freeport-mcmoran-molybdenum-idUSKBN22H23Y, (accessed 6 September 2021).

roasters mainly used in the Asia region. The process to capture SO2 emissions can be through sulfuric acid units or off-gas scrubbers to produce gypsum. Molybdenum roasters can be located at or near the mine site or may be far removed from it. Mines and roasters may be owned by the same company or corporate group, in a 'vertically integrated' structure (which accounts for approximately 30%-35% of the UMC production) or roasters can be independent. Both vertically integrated and independent roasters often blend UMC from multiple mine sites. External UMC can be purchased, or it can be toll processed (processed at a company's site on behalf of another company, which owns the UMC). Blending is done in order to maximise capacity utilisation at the roaster and in some cases to achieve commercial specifications for technical grade oxide. The output of the roasting process is known as Roasted Molybdenite Concentrate (RMC), and is also known as technical grade molybdic oxide (TGMO).[7]

FURTHER PROCESSING AND END USE

RMC may be transported to a range of processing facilities depending on its intended end use and may be combined with RMC from other roasters based locally or internationally. Approximately 40% of RMC is processed into Ferro-molybdenum for use in steel-making.

RMC may also be used directly in the steel-making process, without first being converted to Ferro-molybdenum. This route accounts for approximately 40% of global RMC production.

The remaining share of production that is not used for steel-making is used for non-steel alloying purposes or is used in the manufacture of chemicals and pure molybdenum metal.

The figure below illustrates the described features of a generalised molybdenum supply chain.

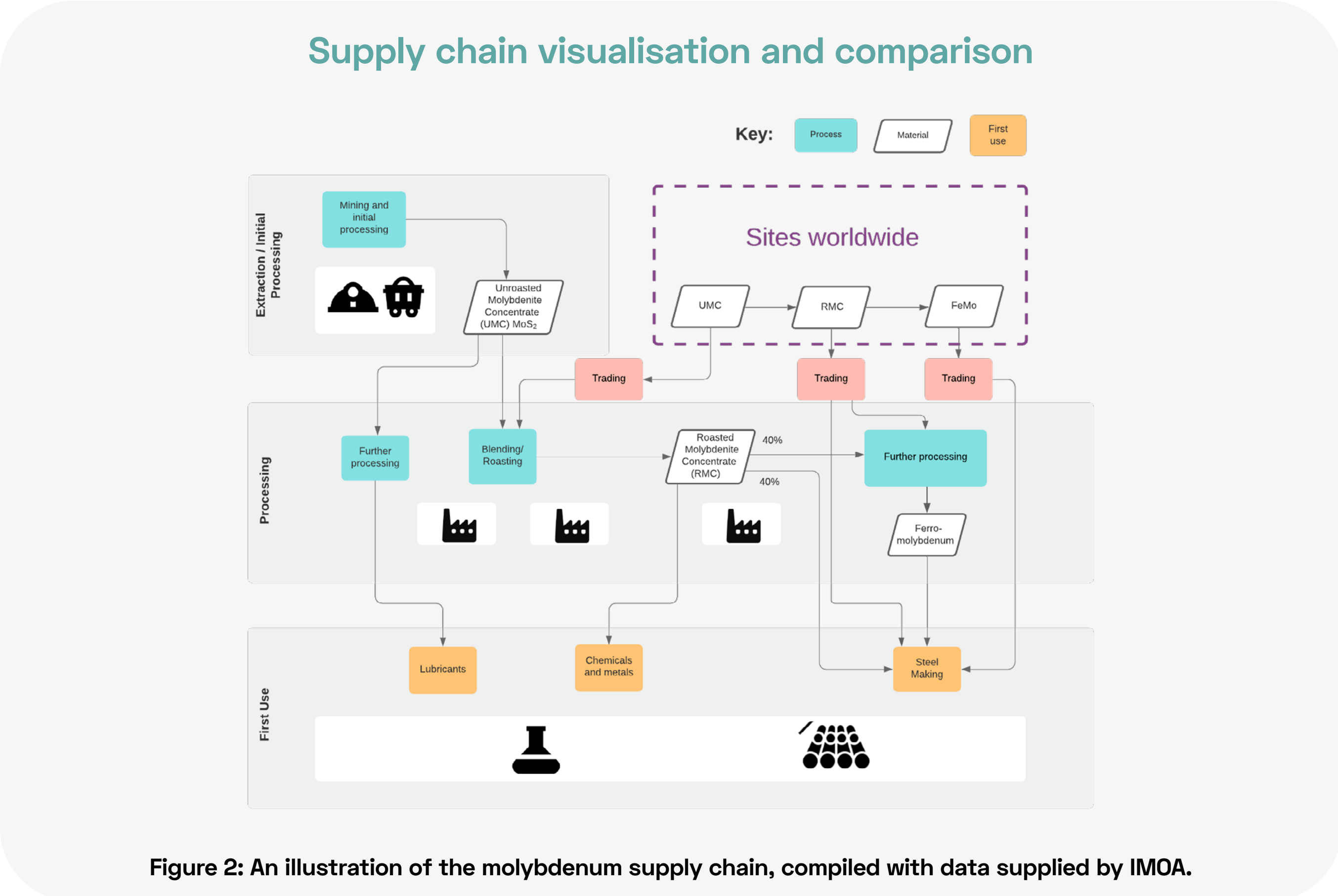

Figure 2: An illustration of the molybdenum supply chain, compiled with data supplied by IMOA.

[7] Facts and Figures, International Molybdenum Association, https://www.imoa.info/molybdenum-media-centre/facts-and-figures.php, (accessed 6 September 2021).

HOW MOLYBDENUM IS MINED

Molybdenum occurs naturally as molybdenite ore (which contains molybdenum disulphide, MoS2).

Commercial molybdenum extraction takes place in mines where molybdenum is the primary product (approx. one third of global production), and mines where molybdenum is a by-product to copper (approx. two thirds of global production). Mining for molybdenum as a primary product generally takes place in China. The only two operating primary mines outside of China are Henderson and Climax, in the United States which contribute approximately 3.6% of global molybdenum production (see the section Key players in the molybdenum mining sector for figures). In other mines outside China, molybdenum is produced as a by-product, and copper is the main commercial ore.

Commercially-viable deposits of molybdenum generally have molybdenum concentrations between 0.01% and 0.25%. Mines where molybdenum is extracted as a by-product of copper are often on the lower end of this range, while mines where molybdenum is a primary product are on the higher end. This is because copper, is the main mineral target in by-product operations.

Even at primary mines, large amounts of host rock must be extracted to retrieve economically viable quantities of molybdenum, **so extraction is generally highly mechanised and takes place on industrial scales**, in both open cast and underground mines.[8] This is the case with most modern mining for industrial minerals, such as iron, copper, zinc, nickel, lead and aluminium.

No recent reporting has been identified that links molybdenum production to artisanal and small-scale mining (ASM).[9]

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[8] Facts and Figures, International Molybdenum Association, https://www.imoa.info/molybdenum-media-centre/facts-and-figures.php, (accessed 6 September 2021).

[9] L. Shen and A. Gunson, 2006, suggest that 15.4% of Chinese molybdenum production in 1997, or 30,000 tons, was attributable to ASM. The paper utilises Chinese government classification of mines as large, medium or small, with the latter category commonly comprising collectively-owned township and village mines. China instituted a significant curtailment of township and village mines in the period 2013-2014 and thereafter, as part of a wider drive to industrialisation and environmental reform of its mining sector. Consequently, it is reasonable to infer that ASM molybdenum mining in China is currently at a significantly lower level, if it exists at all. No reporting subsequent to the 2006 Shen and Gunson paper has been identified which discusses the practice.

L. Shen and A. James Gunson, 'The role of artisanal and small-scale mining in China's economy', Journal of Cleaner Production, Vol. 14, 3-4, 2006, pp. 427 -435. https://doi.org/10.1016/j.jclepro.2004.08.006, (accessed 6 September 2021).

National Energy Administration (China), 'The Mineral Resources Law of the People's Republic of China', http://www.nea.gov.cn/2017-11/02/c_136722865.htm (accessed 16th September 2021).

GEOGRAPHIC DISTRIBUTION OF MOLYBDENUM MINING

93% of the world's molybdenum production takes place in five countries: China, Chile, the United States, Peru and Mexico (listed in declining order of production volumes).

World production figures are given in figure 3, below.

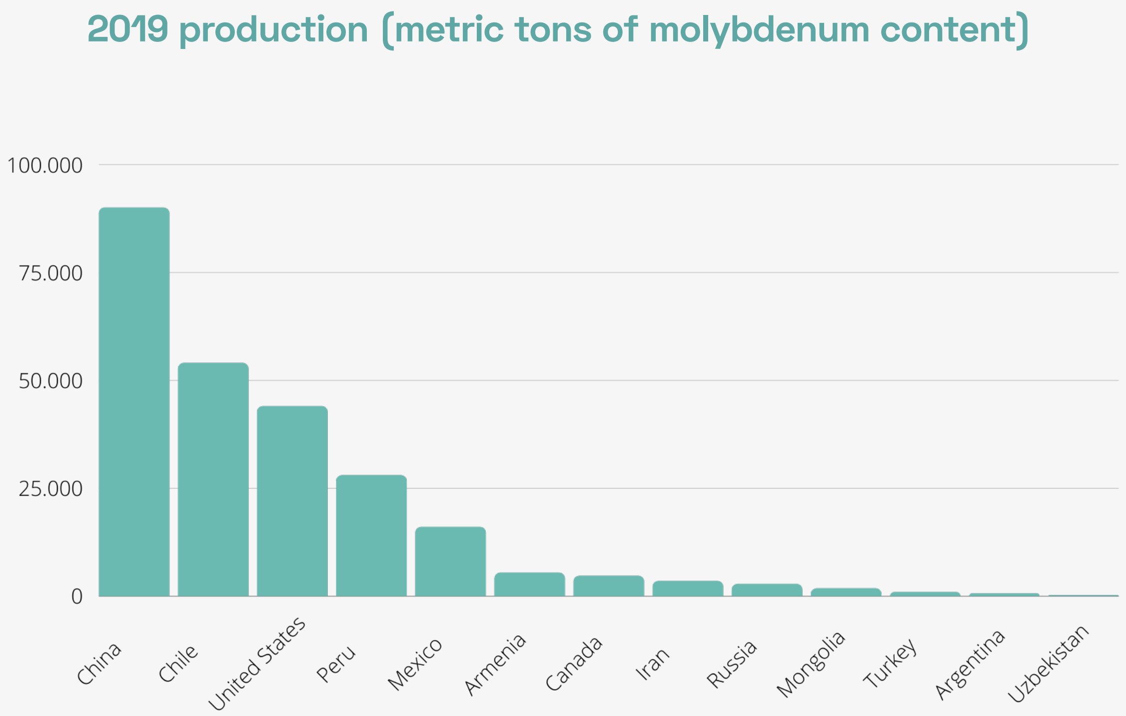

Figure 3: Molybdenum production by country. Source: USGS Mineral Commodity Summary, Molybdenum, 2020, and IMOA figures.[10]

[10] D.E. Polyak, 'Molybdenum', U.S. Geological Survey , United States, U.S. Geological Survey, Author, 2020, p.110, https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-molybdenum.pdf, (accessed 6 September 2021).

KEY PLAYERS IN THE MOLYBDENUM MINING SECTOR

World molybdenum production was approximately 300,000 metric tons in 2020.[11] The majority of the world's molybdenum is produced from around 20 large industrial mines.

Many of the companies that operate these mines are headquartered in OECD countries, where they are subject to a high degree of regulatory control and public scrutiny regarding their global environmental, social and governance performance. Large industrial mining companies are generally also highly regulated and scrutinised in the jurisdictions where they operate.

A survey of the key players in the molybdenum mining sector, in each top producer country, is given below:

CHINA

Key molybdenum-producing companies in China include Yichun Luming, Jinduicheng Molybdenum Corp. China Molybdenum and Manzhouli China Gold.[12] Both Jinduicheng Molybdenum Corp. and China Molybdenum are vertically integrated. They mine and concentrate molybdenum ore, and produce RMC and Ferro-molybdenum.

Jinduicheng Molybdenum Corp reports that it supplies 8% of the total global molybdenum market, and is the largest producer in China and the third-largest globally.[13]

Yichun Luming is China's largest open-pit molybdenum mine. It did not publicly report on its production figures in 2020, but states that it has the capacity to produce 22,500 metric tons of molybdenum each year.[14]

China Molybdenum describes itself as one of the top five molybdenum producers in the world. It reportedly produced 13,780 tonnes of molybdenum in 2020.[15]

Much of the molybdenum produced in China is also consumed in the country, by the domestic steel-making industry.[16]

CHILE

The state-owned company Codelco is reportedly the largest molybdenum producer in Chile, and the second largest in the world. Molybdenum is produced by the company at multiple sites, where copper is the primary ore.[17] In 2020, Codelco's mines in Chile produced a total of 27,911 metric tons of molybdenum.[18]

Other large by-product molybdenum producers include the Los Pelambres mine operated by Antofagasta and the Sierra Gorda mine operated by KGHM Polska.

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[11] Ibid.p.110. https://pubs.usgs.gov/periodicals/mcs2021/mcs2021-molybdenum.pdf.
[12] T. Outteridge, et.al, 'Editorial relevance of Molybdenum in China', Advances in Manufacturing, vol. 8, 2020, pp.35 -39.
[13] Molybdenum industry, JDC Jinduicheng Molybdenum Group Co. Ltd, http://en.jdcmmc.com/INFO/184.aspx, (accessed 07 September 2021).
[14] Yichun Luming Molybdenum Mine in Heilongjiang Province, China Railway Group Limited, http://www.crecg.com/english/2745/2804/41514/index.html, (accessed 7 September 2021)
[15] CMOC Releases 2020 Annual Result, CMOC, https://en.cmoc.com/html/2021/News_0322/41.html, (accessed 07 September 2021).
[16] Global Molybdenum Suppliers, Supply Regions and Production, metals hub, https://www.metals-hub.com/blog/global-molybdenum-suppliers-supply-regions-production-metalshub/, (accessed 07 September 2021).
[17] O.M. Landerretch, "Codelco: Recent Developments and Perspectives", BMO Capital Markets 25th Global Metals and Mining Conference, Codelco, February 28 2016, https://www.codelco.com/prontus_codelco/site/artic/20160229/asocfile/20160229171749/pta_pdte_directorio_bmo_29022016.pdf, (accessed 07 September 2021).
[18] Mining Production, Comision Chilena del Cobre, https://www.cochilco.cl/Paginas/Estadisticas/Bases%20de%20Datos/Producci%C3%B3n-Minera.aspx, (accessed 07 September 2021).

Miedz[19] [20] The Los Pelambres mine produced 10,928 metric tons in 2020, and Sierra Gorda produced 7,614 metric tons in the same year.[21]

Much of the molybdenite concentrate produced in Chile is refined by the independent company Molymet.[22]

UNITED STATES OF AMERICA

Molybdenum in the United States is produced at eight mines. Two of these, the Climax and Henderson mines in Colorado, owned by Climax Molybdenum as subsidiary of Freeport-McMoRan, produce molybdenum as a primary product. In 2020, the Henderson mine produced 10 million pounds of molybdenum (4,535 metric tons), and the Climax mine produced 14 million pounds (6,350 metric tons).[23]

The remaining six produce molybdenum as a by-product to copper. Three of these mines, the Bagdad, Morenci and Sierrita mines in Arizona, are also owned by Freeport-McMoRan.[24] In 2020, Freeport-McMoRan reported that its Sierrita mine produced 17 million pounds of molybdenum (7,711 metric tons), while Bagdad and Morenci mines produced 11 million and 6 million pounds (4,990 and 2,722 metric tons) in 2020 respectively.[25]

Rio Tinto's Bingham Canyon mine produced 20,440 metric tons of molybdenum in 2020.[26] Three roasting plants in the USA convert molybdenite concentrate to RMC.[27]

PERU

In Peru, molybdenum is mined and concentrated at the Toquepala and Cuajone mines, owned by the Southern Copper Corporation,[28] the Cerro Verde mine, owned by Freeport-McMoRan,[29] and the Las Bambas mine operated by MMG.[30] All these mines have copper as their primary product, and produce molybdenite concentrate as a by-product, which is roasted elsewhere. In 2020, Southern Copper Corporation produced 30,248 metric tons of molybdenum concentrates.[31] In 2020 the Toquepala mine produced 10,019 metric tons of molybdenum, while the Cuajone mine produced 4,225 metric tons.

Freeport-Mc-MoRan's Cerro Verde mine reportedly produced approximately 8,844 metric tons of molybdenum in 2020. MMG's Las Bambas mine produced 3,167 metric tons of molybdenum in 2020.[32]

MEXICO

Much of the molybdenum produced in Mexico is mined at the La Caridad and Buenavista copper mines, which are both owned by the Southern Copper Corporation. In 2020, the La Caridad mine produced 10,535 metric tons of molybdenum.[33]

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[19] Sierra Gorda, KGHM Polska Miedz, https://kghm.com/en/our-business/mining-and-enrichment/sierra-gorda, (accessed 07 September 2021).
[20] Ibid.
[21] Op.cit. Mining Production, https://www.cochilco.cl/Paginas/Estadisticas/Bases%20de%20Datos/Producci%C3%B3n-Minera.aspx.
[22] Global Presence, Molymet, https://molymet.com/en/, (accessed 8 September 2021).
[23] Form 10-K, United States Securities and Exchange Commission, https://s22.q4cdn.com/529358580/files/doc_financials/10-K/10_k2020.pdf, (accessed 07 September 2021).
[24] North America, Freeport-McMoRan (FCX), https://www.fcx.com/operations/north-america, (accessed 07 September 2021).
[25] Op.cit. Form 10-K, https://s22.q4cdn.com/529358580/files/doc_financials/10-K/10_k2020.pdf.
[26] RioTinto Annual Report 2020, RioTinto, https://www.riotinto.com/-/media/Content/Documents/Invest/Reports/Annual-reports/RT-Annual-report-2020.pdf?rev=6df52113b92840648d05a4ac9e4cc1d8, (accessed 07 September 2021).
[27] Op.cit. Molybdenum, U.S Geological Survey, https://pubs.usgs.gov/periodicals/mcs2021/mcs2021-molybdenum.pdf.
[28] About Southern Copper Corporation, Southern Copper (Grupo Mexico), http://www.southernperu.com/ENG/about/Pages/HomeMore.aspx, (accessed 07 September 2021).
[29] South America, Freeport-McMoran (FCX), https://fcx.com/operations/south-america, (Accessed 15 September 2021).
[30] Las Bambas, MMG, https://www.mmg.com/our-business/las-bambas, (accessed 7 September 2021).
[31] Southern Copper Annual Report 2020, Southern Copper, https://www.annualreports.com/HostedData/AnnualReports/PDF/NASDAQ_SCCO_2020.pdf, (accessed 7 September 2021).
[32] Op.cit, MMG, https://www.mmg.com/our-business/las-bambas, (accessed 7 September 2021).

The Buenavista mine is reportedly the third largest copper producer in the world, though no information was identified on its market share for molybdenum.[34]

Molybdenite concentrate is produced at both sites, and then sold onward to customers for roasting.[35] [36] [37]

GLOBAL TOLL-PROCESSING AND TRADING HUBS

The Freeport-McMoRan subsidiary Climax Molybdenum Rotterdam, in the Netherlands, produces RMC and molybdenum-containing chemical products.[38] The Climax Stowmarket plant in the United Kingdom produces Ferro-molybdenum from feedstock from multiple suppliers, including Climax Molybdenum Rotterdam. Molymet operates a molybdenum roaster, a Ferro-molybdenum plant and molybdenum chemical plant, at a single site in Belgium.[39]

Austria-based Treibacher Industrie manufactures Ferro-molybdenum through its Steel and Foundry Products Unit.[40]

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[33] Op.cit. Southern Copper Corporation, https://www.annualreports.com/HostedData/AnnualReports/PDF/NASDAQ_SCCO_2020.pdf, (accessed 7 September 2021).
[34] About Us, Grupo Mexico, https://www.gmexico.com/en/Pages/divisions.aspx, (accessed 7 September 2021).
[35] Summary Operating Data, Southern Copper Corporation, http://www.southerncoppercorporation.com/ENG/intope/Pages/PGProdVolume.aspx, (accessed 7 September 2021).
[36] Mining Data Solutions, Mining Data Online, https://miningdataonline.com/property/1092/Buenavista-Mine.aspx, (accessed 7 September 2021).
[37] Ibid.
[38] Worldwide Molybdenum Operations, Climax Molybdenum, https://www.climaxmolybdenum.com/operations, (accessed 7 September 2021).
[39] Sadaci.N.V, Molymet Germany, https://molymet.de/index.php/en/group-of-companies/sadaci-n-v, (accessed 7 September 2021).
[40] Steel and Foundry Products, Treibacher Industries AG, https://www.treibacher.com/en/business-units/steel-and-foundry-products.html#, (accessed 7 September 2021).

ENVIRONMENTAL, SOCIAL AND GOVERNANCE RISKS

Large-scale mining and mineral processing, like all industrial activities, carries inherent risks. However, these risks can generally be mitigated when companies in the supply chain adopt sound and stringent risk management systems.

This section examines the inherent environmental, social and governance risks associated with industrial mining and mineral processing in general, those associated with molybdenum-producing countries, and those associated with molybdenum production and processing specifically. It then examines the extent to which these risks are effectively managed in modern molybdenum supply chains.

The risk typology employed in this section is based on the principles of the ResponsibleSteel standard (version 1.0)[41] , which was chosen as a structure because of the predominance of steel production as an end use for molybdenum. The typology omits principles 1 and 2 of the standard, which address companies' industry leadership and management systems respectively. It also omits principle 6 of the standard, which covers stakeholder engagement and communication.

The risk typology given by the remaining principles of the ResponsibleSteel standard is as follows:

- **Occupational Health and Safety**
- **Labour Rights**
- **Human Rights**
- **Local Communities**
- **Climate Change and Greenhouse Gas Emissions**
- **Noise, Emissions, Effluents and Waste**
- **Water Stewardship**
- **Biodiversity**
- **Decommissioning and closure**

[41] Responsible Steel, 'Responsible Steel Standards and Certification', Responsible Steel, Australia, Responsible Steel, 2019, p.6, https://www.responsiblesteel.org/wp-content/uploads/2019/11/ResponsibleSteel_Standard_v1-0.pdf, (accessed 7 September 2021).

RISKS INHERENT TO INDUSTRIAL MINING AND MINERAL PROCESSING

Large-scale mining and mineral processing can have inherent risks in all of the categories above.

Risks can be posed to workers' health and safety through industrial accidents and diseases, workers' rights may be infringed by unfair employment practices, and local communities may be negatively impacted by the actions of a mining or mineral processing company, its subcontractors or security forces. In some cases, mineral revenues can be a source of funding for non-state armed groups.

Mining and mineral processing can be resource intensive, consuming significant quantities of water and energy, and generating airborne and waterborne pollutants and greenhouse gasses. Mines and processing facilities can impact local biodiversity, and the effects of a mining or mineral processing project on the surrounding environment can persist long after operations have ceased.

A full breakdown of inherent risks associated with industrial mining and mineral processing is given in Annex VI.

RISKS INHERENT TO MOLYBDENUM-PRODUCING COUNTRIES

COUNTRY-LEVEL RISK INDICATORS

Country-level governance shortfalls can serve as an initial indicator that risks could exist of negative social and environmental impacts associated with mineral production and processing. The approach of first examining country governance, before proceeding to other risk assessment steps, is adopted in many bodies of literature on supply chain due diligence, including the OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas (OECD DDG). While this approach does not exclude the existence of well-managed, low risk mining and processing sites in countries with significant governance challenges, it considers country-level indicators the best first step toward building a comprehensive picture of a supply chain risk exposure. Figure 4, below, tabulates molybdenum producing countries against their corresponding grades in the TDi Conflict-Affected and High Risk Areas (CAHRA) Index, and their quartiles in the Yale Environmental Performance Index. Full explanations of these two indices are given in Appendix I.

Molybdenum producer rank	Country	TDi CAHRA index grades	Yale Environmental Performance Index quartile
1	China	Orange	3
2	Chile	Green	2
3	USA	Green	1
4	Peru	Orange	3
5	Mexico	Red	2
6	Armenia[42]	Orange	2
7	Canada	Green	1
8	Iran	Red	3
9	Russia	Orange	3
10	Mongolia	Green	4
11	Turkey	Red	3
12	Argentina	Green	2
13	Uzbekistan	Red	3

Figure 4: TDi CAHRA index grades[43] and Yale Environmental Performance Index quartile for molybdenum-producing countries.

Risk profiles for each of the countries in figure 4 that are graded red in the TDi CAHRA index or fall in the 4th quartile of the Yale Environmental Performance Index are given in Appendix IV.

[42] Armenia is currently graded orange in the TDi CAHRA list. This grading is likely to change in future, due to the 2020 Armenia-Azerbaijan conflict, as the conflict is not yet reflected in the indices that underpin the TDi CAHRA list. There is typically a gap of a year or more between events occurring and indices changing as a result. The effects of the 2020 Armenia-Azerbaijan conflict on the responsible sourcing of molybdenum are discussed in the section Risk Management in Molybdenum Supply Chains.

[43] TDI CAHRA (Conflict-Affected and High Risk Areas) Index, TDI Sustainability, https://tools.tdi-sustainability.com/cahra_map, (accessed 7 September 2021).

COUNTRY-SPECIFIC RISKS FOR MOLYBDENUM PRODUCTION AND PROCESSING

Country-specific risks are present in some mineral supply chains. These are risks that arise from weaknesses in country-level governance, which directly relate to the circumstances of production. Examples of such risks include child labour risk in the artisanal production of cobalt in the Democratic Republic of Congo[44], and high-level corruption risk in the jade mining industry of Myanmar.[45]

Research conducted for this profile paper identified no country-specific risks in molybdenum supply chains.

Although risks associated with country-level governance may arise for molybdenum producers, particularly in countries graded red or orange in figure 4, there is no reason to believe from the available data that these risks would be more severe for molybdenum production than for any other industrial activity in those countries.

Artisanal and small-scale mining (ASM), while providing an important source of income for millions worldwide, is interpreted by some due diligence practitioners as an indicator of social and environmental risk.

No contemporary reporting has been identified that links molybdenum production to artisanal and small-scale mining (ASM).[46]

RISKS INHERENT TO MOLYBDENUM PRODUCTION AND PROCESSING

Inherent risks in production and processing can vary from mineral to mineral, depending on the properties of the mineral, the properties of the deposits in which it occurs, and the methods by which it is extracted and refined. The significant risks inherent to molybdenum production and processing are as follows:

Inherent Risk	Acid rock drainage

Molybdenite, the most important ore for commercial extraction of molybdenum, contains the sulphide mineral molybdenum disulphide, with chemical composition MoS2. Of the two classes of mined minerals, sulphide and oxide, sulphide minerals are more strongly associated with the mine-site process of acid rock drainage. This process occurs when sulphide materials with a large surface area, such as tailings and waste rock, decompose in atmospheric oxygen to release acid- and metal-rich water. If such releases are not controlled and prevented, then there can be adverse environmental impacts.

Managing the risk of acid rock drainage is an important part of responsible mining, when sulphide ores are being extracted. As shown in the section Risk Management in Molybdenum Supply Chains, no contemporary reporting (within the last five years) has been identified of violations of environmental safety limits or standards due to acid rock drainage at molybdenum-producing mines.

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[44] Is My Phone Powered By Child Labour?, Amnesty International, https://www.amnesty.org/en/latest/campaigns/2016/06/drc-cobalt-child-labour/, (accessed 7 September 2021).
[45] Jade: Myanmar's "Big State Secret", Global Witness, https://www.globalwitness.org/en/campaigns/oil-gas-and-mining/myanmarjade/, (accessed 7 September 2021).
[46] See footnote on ASM in China, in the section How Molybdenum is Mined
[47] Chapter 5: Suphide Minerals and Acid Rock drainage, SGU Geological Survey of Sweden, https://www.sgu.se/en/geointro/lecture-5-sulphide-minerals-and-acid-rock-drainage/, (accessed 7 September 2021).
[48] B. Dold, 'Evolution of Acid Mine Drainage Formation in Sulphidic Mine Tailings', Minerals, vol. 4, 2014, pp. 621-641, https://www.mdpi.com/2075-163X/4/3/621, accessed 7 September 2021.

Inherent Risk	Emission to air of sulphur dioxide

Concentrated molybdenum disulphide is roasted, to produce Roasted Molybdenite Concentrate. The reaction results in the production of sulphur dioxide gas, which must be captured through desulphurisation systems such as sulfuric acid plants or lime scrubbers.[49] Sulphur dioxide released into the atmosphere is a significant pollutant. It can harm the human respiratory system and damage plant life, and it is a precursor to acid rain.[50]

A potential risk exists of sulphur dioxide emissions at poorly managed or regulated molybdenum roasting facilities. As shown in the section Risk Management in Molybdenum Supply Chains, no contemporary reporting (within the last five years) has been identified of violations of environmental safety limits or standards due to sulphur dioxide emissions, or of significant harm arising though sulphur dioxide emissions, at roasting facilities.

The IMOA has generated a molybdate effects dataset, which is an accredited dataset within the OECD Mutual Acceptance of Data scheme. The scheme allows the results of non-clinical safety tests studies on chemicals and chemical products to be shared across the OECD group of countries. The dataset can be used to assess the effects of molybdate within environment and human health hazard and risk assessments.

RISK MANAGEMENT IN MOLYBDENUM SUPPLY CHAINS

The risks discussed above can be mitigated when companies in the supply chain adopt sound and stringent risk management systems. In order to assess the extent to which environmental, social and governance risks are managed in molybdenum supply chains in practice, TDi Sustainability surveyed English-language reporting from the past five years of alleged site-level negative environmental, social and governance impacts associated with the production and processing of molybdenum.

Relevant reports were identified and analysed using TDi Sustainability's Search360 process and salience methodology, which are described in Appendix V.

This structured search process, employed by TDi Sustainability in many mineral supply chains, gives assurance that most, if not all, relevant reports published in the past five years were identified.

The search process revealed a relative global scarcity of negative reporting on environmental, social and governance issues in molybdenum supply chains, comparative to many other minerals studied by TDi Sustainability. It also showed a relatively low 'salience' for many of the issues that were identified, comparative to those reported for other minerals.

The analysis indicates that environmental, social and governance risks are relatively well managed overall, in molybdenum supply chains.

Full results of the analysis are available upon request from TDi Sustainability.

The application of site-level and supply chain voluntary standards schemes, which are discussed in the next section, can ensure that these risks remain well-managed in future, and can drive continuous improvement in risk management performance.

[49] Molybdenum Processing, International Molybdenum Association https://www.imoa.info/molybdenum/molybdenum-processing.php, (accessed 7 September 2021).
[50] Sulfur Dioxide Basics, United States Environmental Protection Agency, https://www.epa.gov/so2-pollution/sulfur-dioxide-basics#effects, (accessed 7 September 2021).

GREENHOUSE GAS EMISSIONS ASSOCIATED WITH MOLYBDENUM PRODUCTION AND PROCESSING

A peer-reviewed 'cradle to gate' life-cycle analysis of molybdenum gives a figure for greenhouse gas emissions associated with molybdenum metal production of 5.7 kg CO_2 equivalent / kg.

This figure is somewhat higher than other base metals such as iron (1.5 kg CO_2e / kg), copper (2.8 kg CO_2e / kg) or zinc (3.1 kg CO_2e / kg), though lower than nickel (6.5 kg CO_2e / kg) or aluminium (8.2 kg CO_2e / kg).[51]

Molybdenum's contribution to the overall greenhouse gas emissions associated with molybdenum-containing products may often be lower than these comparative figures suggest. Molybdenum content in steel, for example, is typically less than 1%, and rarely above 9%.[52] Iron, by comparison, generally makes up 85% of steel or more. Its contribution to the greenhouse gas emissions associated with steel production is therefore significantly higher, despite its smaller footprint per kilogram.

A second peer reviewed study finds that greenhouse gas emissions associated with Ferro-molybdenum production can vary from 3.16 kg CO_2e / kg to 14.79 kg CO_2e / kg. It attributes the variance in the range primarily to the mining and beneficiation (concentration) stages of production. Mine type was found to have the largest role in the variation, and molybdenum that is produced as a by-product of copper was found to have relatively lower associated emissions than other types. Ore grade played an important, but lesser, role in the variation.[53]

Since the late 1990s, the IMOA has undertaken several Life Cycle Inventory (LCI) analyses of metallurgical molybdenum intermediate products. The emissions range presented here is aligned with the western-world industry average for Ferro-molybdenum calculated in the IMOA's 2018 LCI study, of 8.25 kg CO_2e / kg Ferro-molybdenum.[54]

The 2018 IMOA LCI study, and data produced for a European Union research programme in 2017, indicate that the majority of emissions associated with molybdenum production occur at the concentration stage:[55] [56]

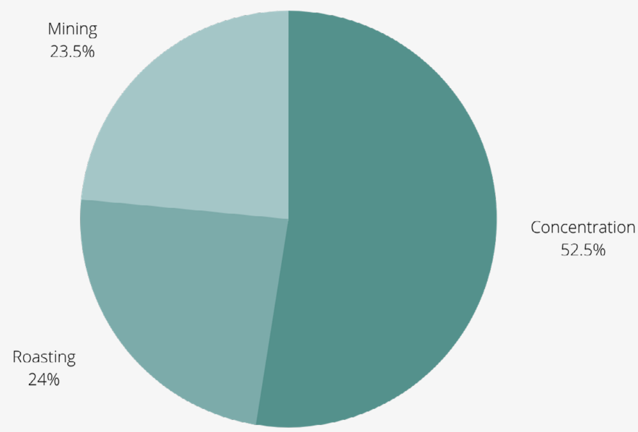


Figure 5: Breakdown of greenhouse gas emissions by supply chain stage for molybdenum. Source: IMOA 2018 LCI Study

[51] P. Nuss and M. J. Eckelman, 'Life Cycle Assessment of Metals: A Scientific Synthesis', Plos One Journal, Vol. 9, 7, 2014, pp. 1 – 12, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0101298, accessed 7 September 2021.

[52] Molybdenum Grade Alloy Steels and Irons, International Molybdenum Association, https://www.imoa.info/molybdenum-uses/molybdenum-grade-alloy-steels-irons/molybdenum-grade-alloys-steel-irons.php, (accessed 7 September 2021).

[53] W. Wei, P. B. Samuelsson, et.al, 'Energy Consumption and Greenhouse Gas Emissions During Ferromolybdenum Production', Journal of Sustainable Metallurgy, Vol. 6, 2020, pp. 103 -112, https://link.springer.com/article/10.1007/s40831-019-00260-8, accessed 7 September 2021.

[54] Overview of the Life Cycle Assessment Program, International Molybdenum Association, https://www.imoa.info/HSE/LCI/life-cycle-assessment-program.php, (accessed 8 September 2021).

[55] cycle Four Elements Consulting, LLC, 'Life Cycle Inventory of Molybdenum Products for Metallurgical Applications: Update Study', International Molybdenum Association, 2018. A. Politis, L. Paspaliaris, and M. Taxiarchou, 'Management of Wastes from Primary Resource Processing: Identification, Environmental Evaluations', European Commission, https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5b043d9de&appId=PPGMS (accessed 7 September 2021).

[56] A. Politis, L. Paspaliaris, and M. Taxiarchou, 'Management of Wastes from Primary Resource Processing: Identification, Environmental Evaluations', European Commission, 2015, https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5b043d9de&appId=PPGMS, (accessed 7 September 2021).

RISK MANAGEMENT, DUE DILIGENCE AND SYSTEMS FOR RESPONSIBLE SOURCING

UPTAKE OF VOLUNTARY STANDARDS SCHEMES BY MOLYBDENUM PRODUCERS AND PROCESSORS

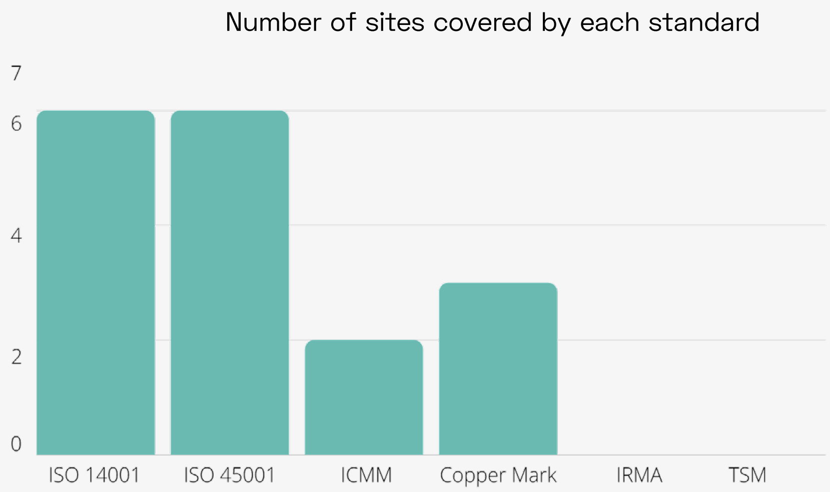
In early 2021 the IMOA conducted a survey of its members in order to illustrate the current uptake of key sustainability frameworks in the molybdenum industry. Uptake of six sustainability frameworks was assessed: ISO 14001; ISO 45001; the ICMM Performance Expectations; the Copper Mark; the IRMA Standard for Responsible Mining; and the Mining Association of Canada's Towards Sustainable Mining. Descriptions of these sustainability frameworks and others are provided in Appendix II.

ISO 14001 and ISO 45001 can cover any industrial facility. The Copper Mark covers each step of copper production and is applicable to mine sites where molybdenum is produced as a by-product to copper, including the vast majority of molybdenum-producing mines in the Americas. The Copper Mark covers molybdenum refining processes that take place at integrated copper-molybdenum refining plants at such mines. The ICMM Performance Expectations, the IRMA Standard for Responsible Mining and Towards Sustainable Mining are applicable to all minerals, but only cover the mining step of the supply chain. Mining sites certified against these standards can use certifications when applying to receive the Copper Mark, since the Copper Mark approach recognises the performance expectations of these standards as equivalent to its own.[57]

Data was collected on 7 mining sites, 5 roasting sites and 8 Ferro-molybdenum production sites that, combined, produce 35-45% of the global supply of molybdenum that flows into the steel supply chain.

Some of the results of the survey are shown below.

UPTAKE OF VOLUNTARY STANDARDS SCHEMES AT MINE SITES

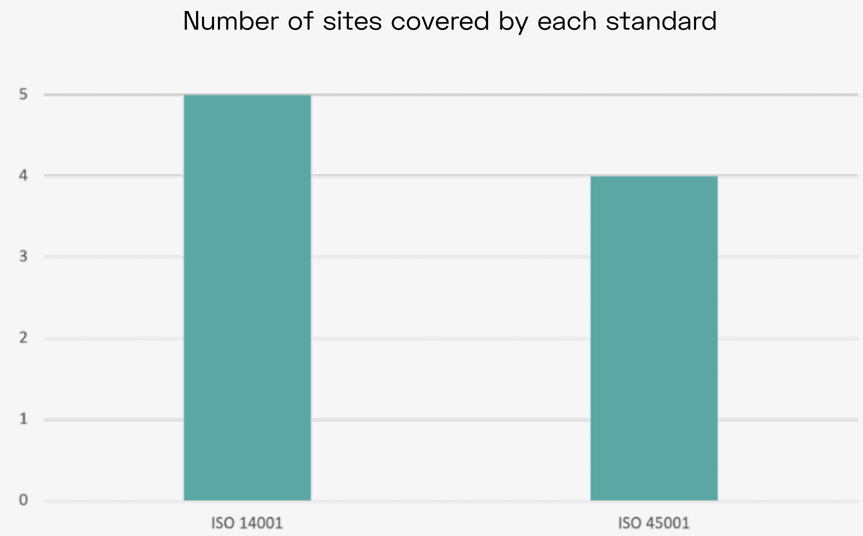


Of the 7 mining sites surveyed:

- 6 sites are covered by both ISO 14001 and ISO 45001
- 1 site is not covered by ISOs, and is covered by ICMM and the Copper Mark
- 1 site is covered by both ISOs plus ICMM and the Copper Mark
- 3 sites have received the Copper Mark and 4 have signed letters of commitment as of June 2021.

[57] The Copper Mark, 'RMI's Risk Readiness Assessment Voluntary Standard System (VSS) Equivalency Benchmark Results', Copper Mark, Responsible Mining Initiative and The Copper Mark, 2021, https://coppermark.org/wp-content/uploads/2021/01/RRA-Copper-Mark-Equivalence-Matrix_REV18Dec2020v2.pdf, (accessed 15 September 2021).

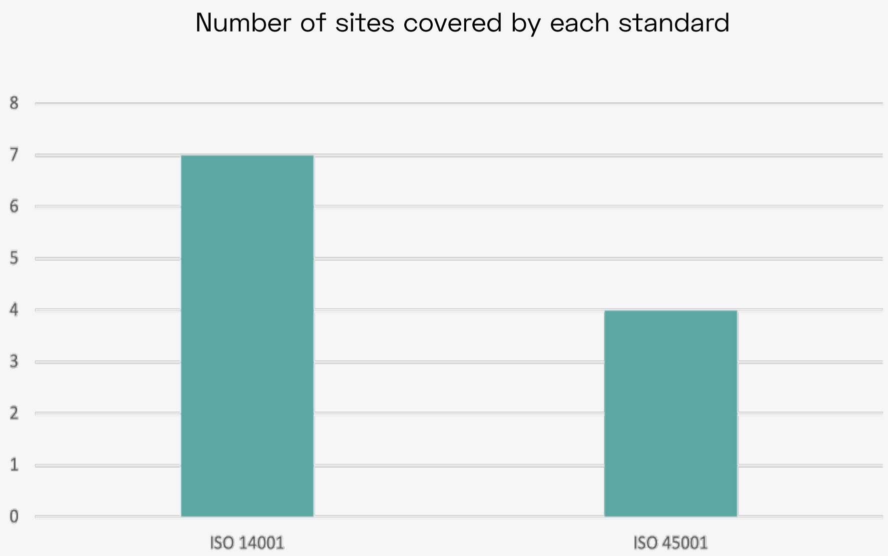
UPTAKE OF VOLUNTARY STANDARDS SCHEMES AT ROASTING SITES



Of the 5 roasting sites surveyed:

- All have an ISO 14001 certification
- 4 out of 5 have an ISO 45001 certification

UPTAKE OF VOLUNTARY STANDARDS SCHEMES AT FERRO-MOLYBDENUM PRODUCTION SITES



Of the 8 Ferro-molybdenum production sites surveyed:

- 7 out of 8 have an ISO 14001 certification
- 4 out of 8 have an ISO 45001 certification

FUTURE CERTIFICATION TRENDS

The prevalence of voluntary standards certification for molybdenum producers and processors may increase in future years, in part due to the introduction of new responsible sourcing requirements for input materials within the ResponsibleSteel Standard.

ResponsibleSteel is an international, non-profit multi-stakeholder membership organisation and certification initiative, which, in November 2019, launched the ResponsibleSteel Standard to recognise steel sites that are operated in a responsible manner. ResponsibleSteel is now developing further components (currently in draft and under stakeholder consultation), which steel sites can choose to be assessed against, and which will allow steel sites to not only make claims about the way their site is operated, but also about the steel products they offer. Such additional requirements concern the responsible sourcing of input materials and greenhouse gas (GHG) emissions.

In particular, responsible sourcing requirements for input materials will require that steel sites: commit to sourcing from verified supply sites; map and obtain visibility over their supply chains; assess and proactively address ESG risks and impacts in their supply chains; and report on their responsible sourcing efforts and achievements.

IMOA is in the process of discussing solutions that would allow companies in the molybdenum industry to meet the expectations of ResponsibleSteel for input materials, while managing the audit burden on the molybdenum supply chain by leveraging the frameworks that members already adopt.

The ICMM, IRMA and the Mining Association of Canada have applied to ResponsibleSteel for their standards (the ICMM Performance Expectations, the IRMA Standard for Responsible Mining, and Towards Sustainable Mining, respectively) to be recognised as meeting the ResponsibleSteel site-level performance expectations. If their applications are successful, the standards could be used by companies that mine molybdenum to demonstrate that they meet the expectations of ResponsibleSteel. However, the standards do not provide coverage of subsequent steps in the supply chain, such as molybdenum roasting and ferromolybdenum conversion, and uptake of the ICMM, IRMA and Mining Association of Canada standards is generally low in the molybdenum mining industry.

If the Copper Mark were to successfully apply for recognition by ResponsibleSteel, this would present a path through which some molybdenum producers could meet ResponsibleSteel requirements since molybdenum is often produced as a by-product at copper mines. As noted in the section "Uptake of voluntary standards schemes at mine sites", three of seven mine sites have received the Copper Mark with four currently considering participation in the Copper Mark voluntary standard.

An additional solution to allow molybdenum producers and processors to meet ResponsibleSteel requirements would be for ResponsibleSteel to recognise ISO 14001 and ISO 45001 as fulfilling its site-level performance expectations. Both are already widely adopted within the molybdenum industry.

IMPLEMENTING OECD DUE DILIGENCE GUIDANCE FOR MOLYBDENUM

The OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas (the OECD DDG)[58] aims to combat instances of conflict funding, serious human rights abuses and financial crime in mineral supply chains and is a cornerstone of responsible mineral sourcing worldwide. It is published as voluntary guidance, and is also embedded into US law[59] and EU law[60] (for gold, tin, tungsten and tantalum) and forthcoming London Metal Exchange (LME) listing requirements[61] (for base metals, though not for molybdenum which is not currently listed on the LME).[62]

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[58] OECD, 'OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas', OECDiLibrary, Paris, OECD Publishing, Third Edition, 2016, http://dx.doi.org/10.1787/9789264252479-en, (accessed 15 September 2021).
[59] Fact Sheet, U.S. Securities and Exchange Commission, https://www.sec.gov/opa/Article/2012-2012-163htm---related-materials.html, (accessed 7 September 2021).
[60] The European Union, 'The EU's new Conflict Minerals Regulation', European Commission, Brussels, The European Commission, 2017, https://trade.ec.europa.eu/doclib/docs/2017/march/tradoc_155423.pdf, (accessed 7 September 2021).
[61] LME Responsible Sourcing Requirements – Summary, LME, 2019, https://www.lme.com/-/media/Files/About/Responsibility/Responsible-Sourcing/LME-responsible-sourcing-factsheet.pdf?la=en-GB, (accessed 7 September 2021).
[62] Molybdenum prices are, as of June 2020, reported by LME. However Platts is the source of the prices used by the molybdenum industry since efforts to establish an LME molybdenum offering were not successful.

Although there are currently no regulatory requirements for companies to apply the OECD DDG to their molybdenum supply chains, a growing market expectation for due diligence means that companies may come under increasing pressure to do so in future.

For companies applying the OECD DDG, step four of the five-step approach to due diligence requires "independent third-party audit of supply chain due diligence at identified points in the supply chain".[63] The determination of the identified point, within a supply chain, is the individual responsibility of each company that applies the OECD DDG. However, a consensus within an industry on where the identified point lies can help to ensure that due diligence efforts are harmonised, and that audit burdens are minimised overall.

The China Chamber of Commerce of Metals, Minerals & Chemicals Importers, working closely with the OECD, has developed criteria for the determination of identified points as follows: [64] [65]

1. Key points of transformation in the supply chain
2. Stages in the supply chain that generally include relatively few actors that process a majority of the commodity
3. Stages in the supply chain with visibility and control over the mineral production and trade
4. Key points of leverage over mineral production and trade

In light of the above criteria, the IMOA and TDi Sustainability view the production of RMC at roasting facilities as the most appropriate choice for an identified point in the molybdenum supply chain.

As discussed in the section Supply Chain Structure, roasting is a key point of transformation (satisfying criterion 1) for all molybdenum products except for lubricants, which account for less than 1% of total molybdenum production. UMC is not blended prior to the roasting stage, so the roaster has good visibility to the producer and overview of related trade (satisfying criterion 3), and can exert leverage on its suppliers from a due diligence perspective (satisfying criterion 4).

The section Geographic distribution of molybdenum mining illustrates that in many molybdenum supply chains UMC from multiple mines is consolidated at independent roasters (satisfying criterion 2).

In many other metal supply chains, the refiner is often selected as the identified point. However, there is no refining step in the molybdenum supply chain. Roasted Molybdenite Concentrate is supplied directly to industry. About 80% of RMC is consumed by the steel and foundry industries, either directly as RMC, or after processing into Ferro-molybdenum. The remaining 20% of RMC is processed into chemical feedstock for the production of chemicals and high purity molybdenum metal including metal used in nickel alloy production. Molybdenum metal accounts for about one third of the chemical feedstock use.

The identification of the roaster as the identified point is in line with the approach taken by the Joint Due Diligence Standard for Copper, Lead, Nickel and Zinc, which designates entities that trade material on the London Metals Exchange the identified point. Although physical molybdenum is no longer traded on the London Metals Exchange, the form in which it was previously traded is RMC.

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[63] Op.cit. OECD, https://read.oecd.org/10.1787/9789264252479-en?format=pdf, (accessed 7 September 2021).

[64] Note that in the CCCMC's documentation, and elsewhere in literature on the OECD DDG, these points are referred to as "Choke Points" or "Control Points" rather than "Identified Points". This paper adopts the term "Identified Point" because it is in keeping with the terminology used in the OECD DDG itself, and because the term does not give undue emphasis to points in the supply chain where materials are aggregated, which, as the CCCMC guidance establishes, should not be the sole criterion for determining identified points.

[65] Chinese Due Diligence Guidelines for Responsible Mineral Supply Chains, China Chamber of Commerce of Metals, Minerals and Chemicals Importers and Exporters, 2016, http://www.cccmc.org.cn/docs/2016-05/20160503161408153738.pdf, (accessed 7 September 2021).

IMOA welcomes the approach taken by the Joint Due Diligence Standard for Copper, Lead, Nickel and Zinc to introduce the concepts of the “additional” and “alternative” identified points, to cover supply chains that may follow a different production route. In the molybdenum industry, concentrate producers may be an “alternative” identified point, for supply chains of pure MoS2 lubricants which are produced from UMC.

EXAMPLES OF MOLYBDENUM CONTRIBUTIONS TO SUSTAINABILITY

The IMOA has published a series of case studies, which demonstrate some of the contributions to sustainability that are made by molybdenum-containing products worldwide.

A Life Cycle Assessment (LCA) of the Myllysilta Bridge in Finland,[66] built with molybdenum-containing stainless steel cladding, found significant savings in overall greenhouse gas emissions throughout the bridge's life compared to the alternative of constructing the bridge with mild steel cladding and corrosion-resistant paint. The LCA was conducted following the ISO 14040 Standard, which describes a common set of principles and a framework for life cycle assessment.

Higher greenhouse gas emissions (measured as kg of CO_2-equivalent) are generated by the manufacture of stainless steel than the manufacture of mild steel, due to factors that include the electricity requirements to produce chromium- and nickel-based additives.[67] However, the inherent corrosion resistance of stainless steel cladding eliminates the need for periodic repainting and replacement, which mild steel requires. Consequently, the LCA concluded that the total CO_2-equivalent emissions associated with the stainless steel bridge throughout its life cycle were only 38% of what the total would have been, had mild steel been used for construction. The comparative associated emissions of the two construction alternatives are shown below.

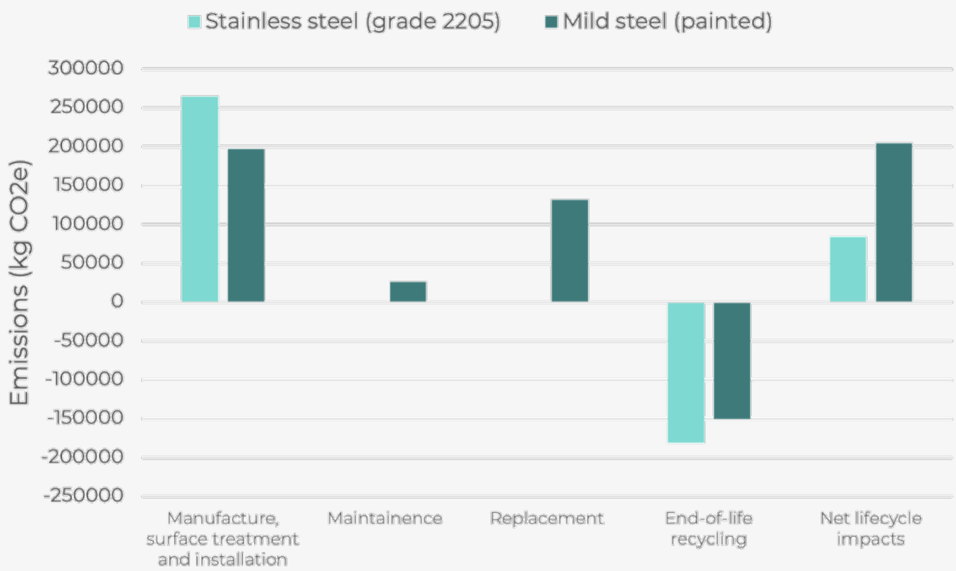

Figure 6: Comparative global warming potential associated with stainless steel and mild steel cladding options for the Myllysilta Bridge, Finland (kg CO_2 e)

[66] International Molybdenum Association, 'Benefits of Molybdenum Use: The Myllysilta Bridge, Finland', International Molybdenum Association and WSP, London, WSP UK Limited, 2015, https://www.imoa.info/download_files/sustainability/IMOA_Myllysilta-Bridge-Case-Study.pdf, (accessed 7 September 2021).

[67] International Stainless Steel Forum, 'Stainless Steel and CO_2: Facts and Scientific Observations', International Stainless Steel Forum, Brussels, ISSF, 2015, Stainless Steel and CO_2: Facts and Scientific Observations (aceroplatea.es), (accessed 15 September 2021).

In addition to the savings in CO_2-equivalent emissions, the LCA also found savings in acidification potential (associated with acid rain), eutrophication potential (associated with ecosystem disruption in water bodies), photochemical ozone creation potential (associated with impacts on respiratory health) and non-renewable primary energy demand (associated with the consumption of fossil fuels).

Other case studies of the contributions to sustainability of molybdenum-containing products, conducted by the IMOA, include studies of ship hulls,[68] equipment for desalination plants[69] and bolts used on offshore platforms.[70] In the case of ship hulls, molybdenum-containing stainless steel was shown to reduce hull weight, increasing fuel efficiency. The stainless steel products used at desalination plants and on offshore platforms increased corrosion resistance and reduced requirements for maintenance and replacement.

[68] Making eco-friendly waves, International Molybdenum Association, 2020, https://www.imoa.info/download_files/molyreview/excerpts/20-2/Ships.pdf?m=1599130734&, (accessed 7 September 2021).

[69] International Molybdenum Association, 'Molybdenum in the Water Industry, Desalination Plants' International Molybdenum Association, London, International Molybdenum Association, https://www.imoa.info/download_files/sustainability/IMOA_Desalination.pdf, (accessed 7 September 2021).

[70] International Molybdenum Association, 'Lighter and Safer Offshore Platforms', International Molybdenum Association, London, International Molybdenum Association, 2018, https://www.imoa.info/download_files/molyreview/excerpts/18-1/Offshore_platforms.pdf, (accessed 7 September 2021).

APPENDIX I: THE TDI CAHRA INDEX AND YALE ENVIRONMENTAL PERFORMANCE INDEX

The term CAHRA originates in the OECD DDG. It refers to a country or subnational region that is affected by conflict or widespread human rights abuses.

Companies that implement the OECD DDG are individually responsible for making a CAHRA determination, and several organisations publish indicative lists of CAHRAs to aid this process. The TDi CAHRA list is one of these. The best-known indicative list of CAHRAs is published by the EU,[71] though countries are only in scope of this list when they produce gold, tin, tungsten or tantalum. Other countries are not assessed.[72]

The TDi CAHRA list is calculated using a weighted set of publicly-available indices.[73] The weighting, and “red country” threshold, are calibrated to achieve close parity with the CAHRA indications given in the EU list. The TDi CAHRA list therefore uses the EU CAHRA list as a core benchmark, and extrapolates a CAHRA indication globally.

Orange countries on the TDi CAHRA list are not indicated as CAHRAs, but may be experiencing governance shortfalls, insecurity or human rights issues. Such countries can exhibit heightened social risks in their extractive sectors, including company-community conflicts, community rights issues, issues over access to land and resources, and corruption and mismanagement of mineral exploitation projects.

The Yale Environmental Performance Index[74] uses 32 performance indicators to rank countries on environmental health and ecosystem vitality. These indicators provide a gauge at a national scale of how close countries are to established environmental policy targets. According to the publishers of the index, the ranking indicates which countries are best addressing the environmental challenges that every country faces. In figure 4, molybdenum-producing countries are tabulated against the quartile of the Environmental Performance Index scoring range in which they fall. A country in quartile 1 lies in the top 25% of the scoring range (indicating best performance), while a country in quartile 4 lies in the bottom 25% of the scoring range (indicating worst performance).

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[71] Indicative, Non exhaustive list of Conflict-Affected and High-Risk Areas under Regulation (EU) 2017/821, European Union, 2021, https://www.cahraslist.net/, (accessed 7 September 2021).

[72] Identifying Conflict-affected and High-risk Areas for EU Importers of Minerals, Rand Corporation, https://www.rand.org/randeurope/research/projects/identifying-conflict-affected-and-high-risk-areas-for-eu-importe.html, (accessed 7 September 2021).

[73] Op.cit. TDI CAHRA (Conflict-Affected and High Risk Areas) Index, https://tools.tdi-sustainability.com/cahra_map, (accessed 7 September 2021).

[74] About the EPI, Environmental Performance Index, https://epi.envirocenter.yale.edu/, (accessed 7 September 2021).

APPENDIX II: OVERVIEW OF VOLUNTARY STANDARDS SCHEMES FOR LARGE-SCALE MINING

ISO 14001:[75] A family of environmental standards developed by the International Standards Organisation, which provides both requirements and guidance for implementing environmental management systems. It helps organisations to minimise the environmental impacts of their operations and processes, comply with applicable environmental requirements, and achieve continuous improvement in environmental performance. ISO 14001 can be used in any industry, and is adopted by some molybdenum producers at each stage of mining and processing.

ISO 45001:[76] The primary international standard for occupational health and safety, developed by the International Standards Organisation. The standard offers a single framework for all types of organisations to improve occupational health and safety performance and prevent work accidents and fatal diseases. ISO 45001 is process-based, and focuses on the interaction between an organisation and its business environment.

The International Council for Mining and Metals (ICMM) Performance Expectations:[77] The ICMM is a membership organisation of major mining companies and mining associations. Its member companies commit to ten principles for sustainable mining that are benchmarked through a series of performance expectations, which cover a wide range of environmental social and governance issue areas. Companies' progress with implementing the Mining Principles and related performance expectations can be validated by an independent third-party on an asset-by-asset basis, the outcomes of which are publicly disclosed.

In 2020 the ICMM, the UN Environment Programme and Principles for Responsible Investment launched a Global Industry Standard on Tailings Management. The Standard was developed by a multi-disciplinary expert panel, with input from a multi-stakeholder advisory group. The Standard seeks to achieve zero harm to people and the environment with zero tolerance for human fatality. It contains 77 auditable requirements and will be supported by implementation protocols in future. The standard was developed in reaction to the Brumadinho disaster in Brazil, in which 270 people lost their lives when a tailings dam burst at an iron ore mine.

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[75] ISO 14000 Family Environmental Management, International Organization for Standardization, https://www.iso.org/iso-14001-environmental-management.html, (accessed 7 September 2021).
[76] ISO 45001 – All You Need To Know, International Organization for Standardization, https://www.iso.org/news/ref2271.html, (accessed 7 September 2021).
[77] Mining Principles, International Council on Mining and Metals, https://www.icmm.com/mining-principles, (accessed 7 September 2021).

The Initiative for Responsible Mining Assurance (IRMA) Standard for Responsible Mining:[78] The IRMA Standard is targeted at industrial-scale mines and works across all locations, commodities and mine types, excluding energy. It sets benchmarks for business integrity, planning for positive legacies, social responsibility and environmental responsibility, and companies are assessedagainst these benchmarks by independent auditors. IRMA has a multi-stakeholder leadership structure, with equal-part board representation from the mining industry, downstream purchasers, non-government organizations, affected communities and organised labour.

The Mining Association of Canada Towards Sustainable Mining (TSM):[79] The TSM standard is a site-level sustainability program for mining companies, to manage a range of environmental and social risks. TSM evaluates eight key aspects of social and environmental performance using 30 performance indicators, and the evaluation is independently validated and publicly reported. TSM is mandatory for all members of the Mining Association of Canada, and is widely recognised as a global best-practice standard. Mining associations in Europe, Africa, South America and Southeast Asia have adopted the programme in recent years.

The International Finance Corporation (IFC) Performance Standards on Environmental and Social Sustainability:[80] The IFC Standards were developed for projects that receive IFC financing. They define clients' responsibilities for managing their environmental and social performance, provide guidance on how to identify risks and impacts, and help companies to avoid, mitigate, and manage risks and impacts in order to do business in a sustainable way. The Performance Standards cover eight key environmental and social issue categories, and include stakeholder engagement and disclosure obligations at the project level.

The The Copper Mark:[81] The Copper Mark is a comprehensive assurance framework that covers the full range of environmental, social and governance issues, and promotes continuous improvement toward responsible production and contributions to the UN Sustainable Development Goals. It takes an efficient approach to assurance, incorporating sites' existing certifications through an equivalency system, which minimises the assessment burden for participants. The Copper Mark is considering expanding its scope to additional metals: lead, nickel and zinc, and the Copper Mark and IMOA have initiated discussions to also include molybdenum among the materials in scope. The Copper Mark covers by-product production at copper mine sites, in addition to copper production.

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[78] Standard, Initiative for Responsible Mining Assurance, https://responsiblemining.net/what-we-do/standard/, (accessed 7 September 2021).
[79] Towards Sustainable Mining, The Mining Association of Canada, https://mining.ca/towards-sustainable-mining/, (accessed 7 September 2021).
[80] Mining Performance Standards, International Finance Corporation, https://www.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/Sustainability-At-IFC/Policies-Standards/Performance-Standards, (accessed 7 September 2021).
[81] The Copper Mark, https://coppermark.org/, (accessed 7 September 2021).

Joint Due Diligence Standard for Copper, Lead, Nickel and Zinc:[82] The Copper Mark is leading the development of a supply chain due diligence standard for base metals, based on the OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas, in conjunction with the International Lead Association, the International Zinc Association, the Nickel Institute and the Responsible Minerals Initiative. One of the aims of the standard is to enable LME-listed brands' compliance with the exchange's responsible sourcing requirements. Application to the LME for the standard's approval is expected in 2021 or early 2022.

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[82] Multi-metal Coalition Publishes Joint Standard to Respond to LME Responsible Sourcing Rules, The Copper Mark, https://coppermark.org/wp-content/uploads/2021/02/Joint-Communication-Due-Diligence-Standard-Publication-FINAL-09FEB21.pdf, (accessed 7 September 2021).

APPENDIX III: METHODOLOGY GUIDE FOR SUPPLY CHAIN RESILIENCE

PRICE VOLATILITY

WHAT IS INDICATED

The degree of fluctuation in the price of a material on the open market, over time. Large fluctuations indicate a risk to the resilience of supply chains, particularly when the material purchased represents a large proportion of a company's operating costs, and when it cannot be easily substituted.

METRIC

The Coefficient of Variation for the price of the material on the global market over a five-year interval. The interval used was from 13th October 2016 to 13th October 2021 and price sampling was taken annually within the interval. Price data was obtained from the London Metals Exchange platform and tradingeconomics.com.[83]

SCORING RANGE (BENCHMARKED BY TDI SUSTAINABILITY)

Very low: 0 to 0.1
Low: 0.1 to 0.2
Moderate: 0.2 to 0.3
High: 0.3 to 0.4
Very high: greater than 0.4

SUPPLY CHAIN CONCENTRATION

WHAT IS INDICATED

The degree of geographic concentration of mineral production, measuring whether it is predominantly mined in just a few key countries, and therefore more prone to supply disruptions, or whether production is more evenly distributed worldwide.

METRIC

The Supply chain concentration is measured by TDi Sustainability using the formula adopted by the Herfindahl- Hirschman Index:[84]

$$H = \sum_{i=1}^{N} s_i^2$$

Where S_i is the production share of country 'i' in the market, and 'N' is the number of countries. Data on country production shares was obtained from the United States Geological Survey.[85]

SCORING RANGE (BENCHMARKED BY TDI SUSTAINABILITY)

Very low: 0 to 0.2
Low: 0.2 to 0.3
Moderate: 0.3 to 0.4
High: 0.4 to 0.5
Very high: 0.5 to 1

[83] LME Molybdenum (PLATTS), LME, https://www.lme.com/Metals/Minor-metals/Molybdenum-Platts#tabIndex=2, (accessed 7 September 2021).
[84] A. Hayes and D. Kindness, 'Herfindahl-Hirschman Index(HHI)' Investopedia, https://www.investopedia.com/terms/h/hhi.asp, (accessed 7 September 2021).
[85] Op.cit. Molybdenum, https://pubs.usgs.gov/periodicals/mcs2021/mcs2021-molybdenum.pdf, (accessed 7 September 2021).

APPENDIX IV: COUNTRY RISK PROFILES

CHINA

China's rapid economic expansion over the past 30 years has come at the cost of significant mining industry pollution, which has reportedly contaminated approximately 20% of the country's farmland and impacted public health.[86] In recently years, however, China has undertaken a vigorous drive to improve environmental performance at mines, even at the cost of lower production.[87]

Operational health and safety standards in Chinese mines are generally lower than those in developed countries. More than 500 people died in accidents at non-coal mines in China in 2015, though this is a significant reduction from the more than 1000 fatalities recorded in 2010, and legislation and inspections are steadily improving.[88]

Authorities stated in 2015 that approximately 37,000 illegal mineral mines were operating in China.[89] This is significant because operational health and safety and environmental performance are often lower at illegal mining operations than at legal ones. Efforts are on-going to curtail illegal mining in the country.[90]

The Chinese government has been accused of rights infringements against indigenous ethnic groups in the provinces of Tibet and Xinjiang, and anti-mining protests in Tibet are frequent.[91]

China has made efforts to promote responsible mineral sourcing in recent years. Notably, the China Chamber of Commerce of Metals Minerals & Chemicals Importers & Exporters adopted voluntary guidance for mineral importers in 2014, based on the OECD.[92] However, civil society observers have commented that implementation of responsible sourcing remains very low in the Chinese minerals industry.[93]

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[86] Chinese Metal Mines Feed the Global demand for Gadgets. They're also Poisoning China's Poorest Regions, The Washington Post, https://www.washingtonpost.com/world/asia_pacific/chinese-metal-mines-feed-the-global-demand-for-gadgets-theyre-also-poisoning-chinas-poorest-regions/2019/12/29/c90eac2c-0bcb-11ea-8054-289aef6e38a3_story.html, (accessed 7 September 2021).

[87] China And The Environment – Industry Versus Air, S&P Global Market Intelligence, https://www.spglobal.com/marketintelligence/en/news-insights/research/china-and-the-environment-industry-versus-air, (accessed 7 September 2021).

[88] China to Shut 6,000 Non-coal Mines by 2020 to Improve Safety, Reuters, https://www.reuters.com/article/us-china-mining-safety/china-to-shut-6000-non-coal-mines-by-2020-to-improve-safety-idUSKCN1B607M, (accessed 7 September 2021).

[89] Ibid.

[90] China To Step Up Crackdown on Rare Earth Sector: Ministry, Reuters, https://www.reuters.com/article/us-china-rareearths-idUSKCN10Y0R3, (accessed 7 September 2021).

[91] Tibetans In Anguish As Chinese Mines Pollute Their Sacred grasslands, The Washington Post, https://www.washingtonpost.com/world/asia_pacific/tibetans-in-anguish-as-chinese-mines-pollute-their-sacred-grasslands/2016/12/25/bb6aad06-63bc-11e6-b4d8-33e931b5a26d_story.html, (accessed 7 September 2021).

[92] China And OECD To Co-operate On Promoting The responsible Sourcing Of Minerals, OECD, https://www.oecd.org/china/china-oecd-cooperation-responsible-sourcing-of-minerals.htm, (accessed 7 September 2021).

[93] Responsible Mineral Supply Chain Efforts in China: Progress and Challenges, Business and Human Rights Resource Centre, https://www.business-humanrights.org/en/blog/responsible-mineral-supply-chain-efforts-in-china-progress-and-challenges/, (accessed 7 September 2021).

IRAN

Iran is governed by a clerical elite that exerts tight ideological control and has little tolerance for dissent.[94] Protests targeting mining companies in the country, and industrial action by mine workers, have been characterised by the authorities as an endangerment of national security. They have typically resulted in harsh prison sentences for those involved, and corporal punishments including public flogging. Permitted worker unions in the country are state-controlled, and protest actions are forbidden under law.[95] [96] Due to the repressive effect of such measures on public discourse, it is highly unlikely that worker or community grievances against mining projects are redressed effectively when they arise.

In 2011, the Iranian parliament passed a law that exempted mining projects that lie outside protected areas from the requirement for environmental assessment.[97] There is therefore a risk that environmental impacts associated with minerals sourced from Iran have not been comprehensively accounted for and addressed.

[94] Iran Country Profile, BBC News, https://www.bbc.com/news/world-middle-east-14541327, (accessed 7 September 2021).

[95] Flogged and Jailed Workers in Iran Face Repression, Industrial Global Union, http://www.industriall-union.org/workers-flogged-and-jailed-repression-continues-in-iran-as-capital-moves-in, (accessed 7 September 2021).

[96] 7 Iranians, Unable to pay Fina for Peaceful Protests Jailed in NW Iran, Iran News Wire, https://irannewswire.org/7-iranians-unable-to-pay-fine-for-peaceful-protests-jailed-in-nw-iran/, (accessed 7 September 2021).

[97] F. Bakhtiari, 'Mining Must Not Come at Cost of Environmental Degradation' Tehran Times, https://www.tehrantimes.com/news/454441/Mining-must-not-come-at-cost-of-environmental-degradation, (accessed 7 September 2021).

MEXICO

Mining activities are afforded special status under Mexican law. They have preference over all other land uses[98] and are granted unfettered access to natural resources, including the free and unrestricted use of water.[99]

The preferential status of mining relative to community rights, including indigenous rights, is a source of significant controversy in Mexico. According to development organisations, deep community divisions often exist between those who seek to benefit economically from mining and those who wish to preserve the environment and traditional ways of life.[100] Frequent allegations are made of violence and intimidation against anti-mining activists.[101]

Overall high levels of violence and insecurity in Mexico are strongly associated with the country's drug cartels.[102] No contemporary reporting has been identified that links molybdenum production to the financing of violent criminality in Mexico but, according to NGO and media reporting, drug cartels draw funds from other minerals mined in the country. Reportedly, cartels are engaged in illegal iron ore mining operations, transportation, processing and exportation to China, and iron ore is now the main funding source for the Knights Templar cartel.[103] [104] [105] A risk therefore exists that violent organised crime could in future affect molybdenum production in Mexico, too.

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[98] Mining in Mexico, Fresnillo, http://www.fresnilloplc.com/who-we-are/mining-in-mexico/, (accessed 7 September 2021).

[99] D. Green, 'Legal Earthquakes and the Struggle Against Mining in Mexico', FP2P Blog [web blog] 19 October 2018, https://oxfamblogs.org/fp2p/legal-earthquakes-and-the-struggle-against-mining-in-mexico/, (accessed 7 September 2021).

[100] Ibid.

[101] Environmental Defenders Describe Human rights Abuses Linked with the Mining Industry at the Inter-American Commission on Human Rights, Center for International Environmental Law, https://www.ciel.org/news/environmental-defenders-describe-human-rights-abuses-linked-with-the-mining-industry-at-the-inter-american-commission-on-human-rights/, (accessed 7 September 2021).

[102] Criminal Violence in Mexico, Global Conflict Tracker, https://www.cfr.org/global-conflict-tracker/conflict/criminal-violence-mexico, (accessed 7 September 2021).

[103] SOMO, 'There is more than 3TG, The Need for the Inclusion of all Minerals in EU Regulation for Conflict Due Diligence', SOMO Paper, Amsterdam, SOMO, 2015, https://www.somo.nl/wp-content/uploads/2015/02/There-is-more-than-3TG.pdf, (accessed 7 September 2021).

[104] Mexican Drug Cartels Move Into Lucrative Mining Industry and Exportation Of Iron Ore to China in Mafia-Style Penetration of Country's Economy, Mail Online, https://www.dailymail.co.uk/news/article-2515685/Mexican-drug-cartels-lucrative-mining-industry-exportation-iron-ore-China-mafia-style-penetration-countrys-economy.html#ixzz3QEBKgeW7, (accessed 7 September 2021).

[105] Mexican Cartel earns More From Mining and Logging than Drugs, CBC News, https://www.cbc.ca/news/business/mexican-cartel-earns-more-from-mining-and-logging-than-drugs-1.2575826, (accessed 7 September 2021).

MONGOLIA

Mongolia is experiencing a sustained mining boom. Mining's share of Gross Domestic Product almost doubled from 2000 to 2017, from 12% to 23.9%.[106] Nearly a fifth of Mongolia's land area has been made available for mining exploration.[107] The mining industry has the potential to act as a significant driver of development in Mongolia, though its rapid growth also brings many environmental and social challenges.

Mongolia is a vast and sparsely populated country, with many fragile ecosystems. Ecological activists claim that mining has put intense pressure on local groundwater availability, increasing the threat posed to several endangered species,[108] and impacting the livelihoods of local communities, many of whom are dependent on traditional herding lifestyles.[109] Community livelihoods are also reportedly disrupted by the encroachment of industrial activity, infrastructure development[110] and dust emissions associated with mining.[111]

Some critics claim that mining projects in the country are progressing without sufficient scientific knowledge in key areas for biodiversity conservation, such as species migration and connections between deep water aquifers and shallow water tables.[112]

Mongolia has made some progress toward stronger environmental protections in recent years. In 2009, the Mongolian Parliament passed a "Law on the Prohibition of Mining Operations at Headwaters of Rivers, Protected Zones of Water Reservoirs and Forested Areas". The law is a significant step toward stronger environmental protections, though observers state that enforcement of the law is incomplete, and its provisions are ambiguous.[113]

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[106] M. Helbe, H. Hill and D. Magee, 'Mongolia's Economic Prospects, Resource-Rich and Land Locked Between Two Giants', Asian Development Bank, Manila, Asian Development Bank, 2020, p.123, https://www.adb.org/sites/default/files/publication/611416/mongolia-economic-prospects.pdf, (accessed 7 September 2021).

[107] Cash-strapped Mongolia Offers More Land for Mining Projects, Reuters, https://www.reuters.com/article/mongolia-mining-idUSL3N0UV2AH20150116, (accessed 7 September 2021).

[108] L. Woods, 'Mining Threatens Mongolia's Fragile Environmental Balance' Climate Diplomacy, 2016, https://climate-diplomacy.org/magazine/environment/mining-threatens-mongolias-fragile-environmental-balance, (accessed 7 September 2021).

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[110] Mongolian Mining Boom Threatens Traditional Herding , The Conversation, https://theconversation.com/mongolian-mining-boom-threatens-traditional-herding-121791, (accessed 7 September 2021).

[111] S.L. Jackson, 'Dusty Roads and Disconnections: Perceptions of Dust from Unpaved Mining Roads in Mongolia's South Gobi Province', Geoforum, Vol. 66, 2015, pp. 94 -105, https://www.sciencedirect.com/science/article/abs/pii/S0016718515002638, (accessed 7 September 2021).

[112] Fidanka McGrath, et.al, 'Spirited Away - Mongolia's Mining Boom and the People That Development Left Behind,' Bankwatch, Czech Republic, CEE Bankwatch Network, 2011, p.5, https://bankwatch.org/sites/default/files/spirited-away-mongolia-mining.pdf, (accessed 7 September 2021).

[113] Mongolia's Mining Boom raises Environmental Concerns, DW, https://www.dw.com/en/mongolias-mining-boom-raises-environment-concerns/a-17534285, (accessed 7 September 2021).

TURKEY

Multiple challenges to security and political stability are present in Turkey. The Turkish military is deployed in neighbouring Syria, and Islamist terror groups have launched attacks inside Turkey in recent years in retaliation for its involvement in the Syrian conflict. Turkey is also fighting a protracted insurgency against pro-independence Kurdish forces.[114] The Turkish government has changed four times in military coups since 1960. Many unsuccessful coup attempts have also been made. The most recent was in 2016.[115]

These factors and others cause Turkey to score poorly on governance indices that measure country-level association with conflict and weak governance, though there is little evidence to suggest that conflict issues in Turkey have significant linkages to the mining sector.

The Turkish mining industry has a relatively poor health and safety record, in comparison to OECD countries. Approximately 100 deaths occurred per year in Turkish mines from 2001-2012.[116] A disaster at a Turkish coal mine in 2014 claimed at least 301 lives, which the IndustriALL global workers' union blamed on lax safety standards. Following the disaster, the Turkish government ratified the International Labour Organization's (ILO) Convention on Health and Safety in Mining, in order to improve safety standards.

Turkey's biodiversity is rich, due to its unique position joining Europe, Asia and the Middle East, its terrain, and its coastlines on three separate seas. Most of Turkey's land area is covered by biodiversity hotspots (known as the Caucasian, Irano-Anatolian and Mediterranean).[117] Turkey ranks 172nd out of 180 countries for biodiversity and habitat in the Environmental Performance Index, indicating significant governance shortfalls in biodiversity safeguarding.[118]

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[114] F. Merz, 'Security and Stability in Turkey', CSS Analyses in Security Policy, No. 221, 2018, pp.1 -4, https://css.ethz.ch/content/dam/ethz/special-interest/gess/cis/center-for-securities-studies/pdfs/CSSAnalyse221-EN.pdf, (accessed 7 September 2021).

[115] Timeline: A History of Turkish Coups, Aljazeera, https://www.aljazeera.com/news/2016/7/16/timeline-a-history-of-turkish-coups, (accessed 7 September 2021).

[116] K. Ritter, 'How dangerous is Turkey's Mining Industry', Global News, https://globalnews.ca/news/1331647/how-dangerous-is-turkeys-mining-industry/, (accessed 7 September 2021).

[117] C.H. Sekercioglu, S.S. Anderson, et.al, 'Turkey's Globally Important Biodiversity in Crisis', Biological Conservation, 144 (2011), pp. 2752 -2769, https://www.researchgate.net/publication/216236176_Turkey's_globally_important_biodiversity_in_crisis, (accessed 7 September 2021).

[118] Country Profile Turkey, Environmental Performance Index, https://epi.yale.edu/sites/default/files/2018-tur.pdf, (accessed 7 September 2021).

UZBEKISTAN

Uzbekistan is a former constituent of the USSR, with a historically authoritarian system of governance and a largely state-run economy.[119] Some reforms have been instituted since 2016, however, when a new president, Shavkat Mirziyoyev, came to power upon the death of Uzbekistan's long term post-Soviet ruler, Islam Karimov.[120]

Uzbekistan has attracted international censure for its use of forced labour and child labour in the annual cotton harvest. There are signs of downward long-term trends for both issues, in particular for child labour.[121] There is no evidence to suggest that either forced labour or child labour are present in Uzbekistan's mining industries.

Legal reforms in Uzbekistan are bringing the country's mining industry towards international norms. A presidential resolution from January 2019 established that major mining companies should "Publish reports on the economic, social and ecological issues in accordance with the Global Reporting Initiative".[122]

Little public reporting is available on environmental or social aspects of mining in Uzbekistan. This may in part be due to the extremely limited role that civil society has historically played in public discourse in the country, though there are signs that this, too, may be changing. A 2018 presidential decree set legal and political conditions that observers believe could lead to the meaningful emergence of civil society in the country.[123]

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[119] Uzbekistan Country Profile, BBC News, https://www.bbc.com/news/world-asia-16218112 (accessed 7 September 2021).
[120] Uzbekistan, BTI Transformation Index, https://www.bti-project.org/en/reports/country-report-UZB-2020.html, (accessed 7 September 2021).
[121] In Uzbekistan, Child labour Escalates and Forced Labour Persists; says HRW World Report, Business and Human Rights Resource Centre, https://www.business-humanrights.org/en/latest-news/human-rights-watch-world-report-in-uzbekistan-child-labour-escalates-and-forced-labour-persists/, (accessed 7 September 2021).
[122] Large-scale reforms initiated in the mining industry in Uzbekistan, Dentons, https://www.dentons.com/en/insights/alerts/2019/january/30/reforms-in-the-mining-industry-in-uzbekistan, (accessed 15 September 2021).
[123] Uzbekistan, BTI Transformation Index, BTI 2020: Uzbekistan : BTI 2020 (bti-project.org), (accessed 15 September 2021).

APPENDIX V: TDISEARCH360 AND SALIENCE ANALYSIS METHODOLOGY

TDi Sustainability provides a web monitoring service that identifies and analyses reports of negative environmental, social and governance issues associated with mineral production and processing. The service, TDiSearch360, combines data from a custom-built automated web search tool with reports identified manually by skilled analysts. Although no process can guarantee complete coverage of online reporting, Search360 offers a systematic approach and the assurance that most, if not all, relevant reports within set search parameters have been found.

Identified reports are categorised by 'salience', which is an expression of the seriousness and relevance of the issues described in the report, benchmarked against TDi Sustainability's database of several hundred reports of negative environmental, social and governance issues in mineral supply chains. Salience is expressed as a score from 0 to 1000, and is a product of the properties described below:

ALLEGATION REACH

The reach of an allegation describes the uptake which it has achieved in the worldwide media, and with civil society, academia, international organisations and regulatory bodies.

ALLEGATION GRAVITY

The gravity of an allegation describes its seriousness, if true, in terms of the degree and scale of human suffering and irreparable damage it represents, its moral severity and its pattern of recurrence.

ALLEGATION LEGITIMACY

We measure the level of legitimate responsibility that a supply chain entity bears for the alleged events, supposing they are true. We do not seek to make a judgement on whether or not an allegation is true, but rather the strength of association between the allegation and the entity's actions or business interests.

ALLEGATION URGENCY

We measure the phase of life of the allegation, in order to judge its current relevance for affected stakeholders. An allegation that has already been investigated and resolved is considered less urgent than an allegation that is freshly made and not yet substantively addressed.

Each of these properties is given a score from 1 to 5, against a set of concrete benchmarks. Salience is then computed using the formula: Salience = Reach + Gravity + Legitimacy + Urgency.

Salience scores are graded according to the table below:

Salience score	Salience grade
4-7	Very low
8-10	Low
11-13	Moderate
14-16	High
17-20	Very High

APPENDIX VI: RISKS INHERENT TO INDUSTRIAL MINING AND MINERAL PROCESSING

Occupational Health and Safety: Most forms of mining, particularly underground mining, carry a degree of inherent risk. Mining employs 1% of the world's workforce, but is responsible for 8% of deaths at work worldwide.[124] Approximately 80% of these deaths occur in China, according to 2010 data.[125] Occupational health and safety standards can be low in the developing world, particularly in small mines. Mine collapse and traumatic injury are prominent risks. Worker health can also be impacted by disease, such as through dust inhalation.

Labour Rights: Like any industrial activity, large-scale mining is associated with rights violations in certain instances, particularly in areas of the developing world where the supporting regulatory framework is poor. Labour rights violations can include excessive working hours, anti-union activities and dismissal of workers who make complaints. Forced labour can also occur. In small-scale mines, labour conditions are often worse than in their large-scale counterparts. Child labour is an especially prominent issue in many small mines in the developing world. Mining accounts for approximately 1% of the world's workforce, and approximately 20% of these workers are employed in small mines.[126]

Labour Rights: In countries that suffer from physical insecurity and weak central governance, mineral revenues can provide revenue streams to both state-sponsored and non-state armed groups. These "conflict resources" can sustain armed violence and associated human rights abuses. Without adequate supply chain oversight, downstream purchasers of these minerals can unintentionally provide revenue flows to such conflicts.

Local Communities: Industrial-scale mining and processing is typically performed by large national or international companies, with limited ties to the local communities nearby to production sites. Mining and refining can be associated with a range of contentious issues for local communities, including displacement, environmental degradation, perceptions of inequality, labour migration and disruption to ways of life. When they are not adequately managed and resolved, including through appropriate consultation, consent and redress mechanisms, these contentious issues can lead to conflict.

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[124] Mining: A Harzadous Work, International Labour Organization, https://www.ilo.org/safework/areasofwork/hazardous-work/WCMS_356567/lang--en/index.htm, (accessed 7 September 2021).
[125] The Dangers of Mining Around the World, BBC News, https://www.bbc.com/news/world-latin-america-11533349, (accessed 7 September 2021).
[126] Op.cit. Mining: A Hazardous Work, https://www.ilo.org/safework/areasofwork/hazardous-work/WCMS_356567/lang--en/index.htm (7 September 2021).

Climate Change and Greenhouse Gas Emissions: A range of greenhouse gas emissions occur during the mining and processing of industrial materials, contributing to global climate change. These gasses can be produced directly, in the form of energy inputs to mining, transportation and refining processes, or indirectly, such as through methane emissions from exposed coal seams.

Noise, Emissions, Effluents and Waste: Mining and refining of industrial materials is associated with a range of harmful discharges, affecting humans, animals and plants. These can range from airborne toxins, released during refining processes, to chemical run-off and seepage from processing sites and tailings ponds, to acid mine drainage, radioactive discharges, and more. Noise emissions can disturb communities, livestock and wildlife, and dust from mine-site activities and ore transportation can affect communities and crops.

Water Stewardship: Mining and processing of industrial materials often requires the consumption of large quantities of water. In severe cases, industrial activity can cause water tables to fall, and can lower the quality of ambient water sources, negatively impacting nearby communities, agriculture, plant and animal life.

Biodiversity: Biodiversity and conservation impacts occur when mining and processing of materials takes place in important or unique natural habitats, or in special conservation areas (such as glaciers). Biodiversity and conservation impacts are typically caused by the development of industrial sites, so the impacts of material production on biodiversity are typically somewhat lower than other, more land-intensive industries such as agriculture. However, impacts can be more significant when multiple mining, processing and supporting facilities are clustered in a small area.

Decommissioning and closure: Mining, particularly open cast mining, can have a transformative effect on the area from which material is extracted. If the area is not responsibly reclaimed at the end of the mine's operating life, the local landscape can remain severely impacted for decades to come. In the absence of effective remediation, legacy environmental issues including acid rock drainage can continue to pollute soils and watercourses. Addressing such issues can represent a significant burden on public finances if mining companies do not set aside adequate funds for the closure process.