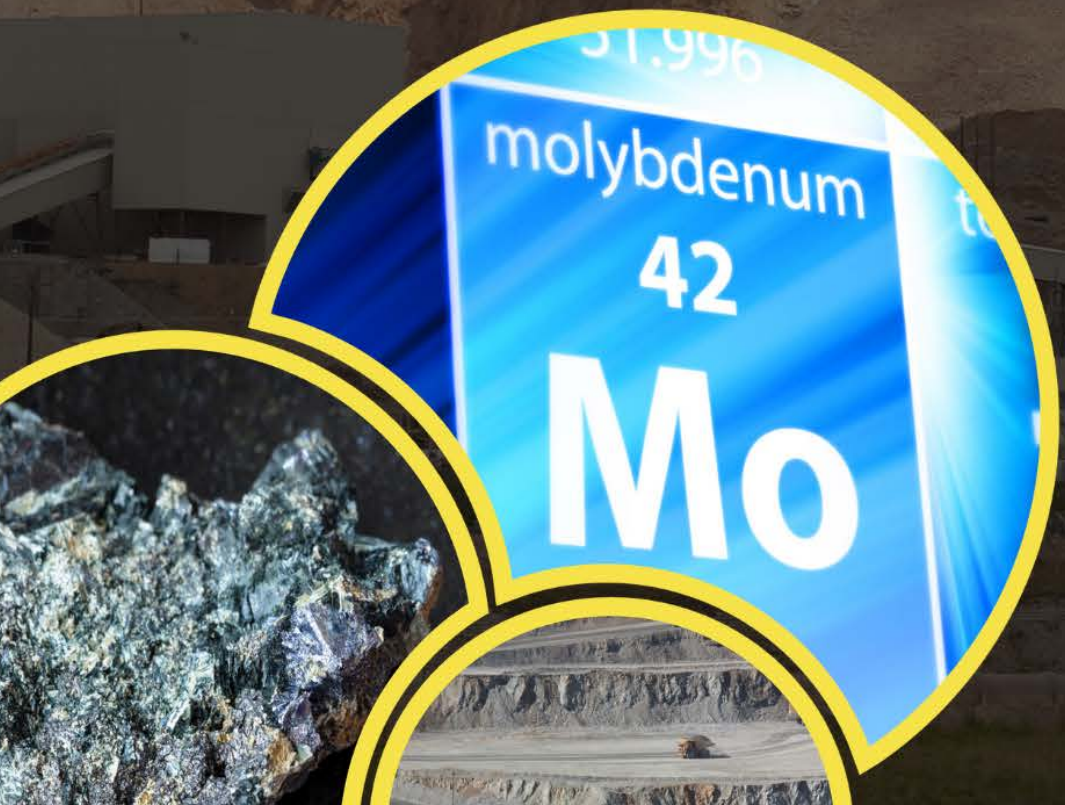
TDi Sustainability

Molybdenum Profile

for Supply Chain Due Diligence and Responsible Sourcing



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

Lead author (Version 1.1):

Graham Lee, Head of Research, TDi Sustainability

Lead update author (Version 2.1)

Arianna Fabri, Associate Consultant, TDi Sustainability

Contributing authors:

Assheton Carter, CEO, TDi Sustainability

Alessandra Gargiulo, Senior Consultant, TDi Sustainability

Jumana Miqdadi, Analyst, TDi Sustainability

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Version 2.1 (December 2025)

Introduction

The objective of this paper is to provide standards-setters, steelmakers, 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 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 is the production of unroasted molybdenite concentrate (UMC), roasted molybdenite concentrate (RMC), and ferro-molybdenum.

Trading takes place globally for these material types. Roasted molybdenite concentrate can be produced from blended 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 mining and metals industries.

English-language media from the past five years were 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, compared to many other minerals

studied by TDi Sustainability. It also showed the relatively low 'salience' of many of the issues reported, compared to those reported for other minerals. Salience, within TDi Sustainability's methodology, measures the importance of issues to the people or environments that they affect, as well as the reputation risk for businesses that use the corresponding material in their products. The data indicate that the 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 2025 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 among those surveyed. Of the 12 mine sites surveyed, 85% of total production volume is covered by ISO 14001 and ISO 45001, while 28% is covered by ISO 50001. When it comes to roasting and ferromolybdenum facilities, the percentage of production covered by ISO 14001 is even higher, amounting to 93% and 97% respectively. The International Council on Mining and Metals (ICMM) Performance Expectations and the Copper Mark/Molybdenum Mark responsible production standard are also adopted by some molybdenum-producing mines and downstream processors.[1] Among the 12 mine sites surveyed, 88% of total production volume is covered by the Copper Mark or Molybdenum Mark, while 100% meets the ICMM Performance Expectations. For the eight roasting sites surveyed, 67% of total production is covered by the Copper Mark/Molybdenum Mark, and 42% by the ICMM Performance Expectations. Several of the copper-molybdenum mines that do not currently adopt the Copper Mark/Molybdenum Mark[2] are considering doing so in the future.

The Molybdenum Mark has made significant progress within the molybdenum industry since its August 2022 inclusion in the Copper Mark Joint Due Diligence Standard for Copper, Lead, Molybdenum, Nickel and Zinc. The Copper Mark reports that the standard has been adopted by 21 copper- molybdenum by-product mine sites, and seven molybdenum-only-producing mine sites and downstream processors.[3] Three additional molybdenum-producing sites have signed Letters of Commitment and participate in The Copper Mark Assurance Framework in order to receive the Copper Mark/Molybdenum Mark. Steel makers, manufacturers, fabricators and downstream standards-setters, have roles to play to ensure that the environmental, social and governance risks inherent to the molybdenum industry remain well-managed, and to promote continuous risk management improvements.

[1] IMOA 2025 Survey Data
[2] As of September 2025
[3] The Copper Mark website. The Copper Mark participants. (Accessed July 1, 2025)

Approximately 80% of molybdenum production is used to make engineering steels, molybdenum-containing stainless steel, tool and high-speed steel, cast iron and super alloys.[4] An important milestone for the molybdenum industry was reached in November 2024 when ResponsibleSteel, the steel industry's standard and certification programme, recognised The Copper Mark standard for steel raw material suppliers[5]. Another important development is the Consolidated Mining Standard Initiative (CMSI), which was launched in 2023. This is a collaborative effort to consolidate four existing mining standards into a single standard and to establish a multi-stakeholder oversight system. The Copper Mark, ICMM, the World Gold Council, and the Mining Association of Canada's Toward Sustainable Mining (TSM) plan to bring together the best aspects of four well-established standards, reduce complexity and create a unified global mining standard. Finalisation of the Consolidated Mining Standard and Assurance Process is currently planned for 2026.[6]

[4] International Molybdenum Association website. IMOA Facts & Figures. (Accessed 1 July 2025)
[5] The ResponsibleSteel website. Responsible Steel: Recognising other Programmes (Including The Copper Mark) (Accessed 2 July 2025)
[6] The Consolidated Mining Standard Initiative website. About the Initiative. (Accessed 1 July 2025)

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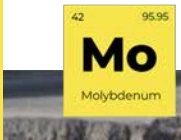
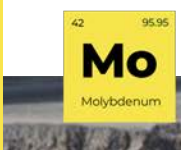




Properties and applications

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.[7] Figure 1, below, shows the applications for which newly-mined molybdenum is used.[8] 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.[9]

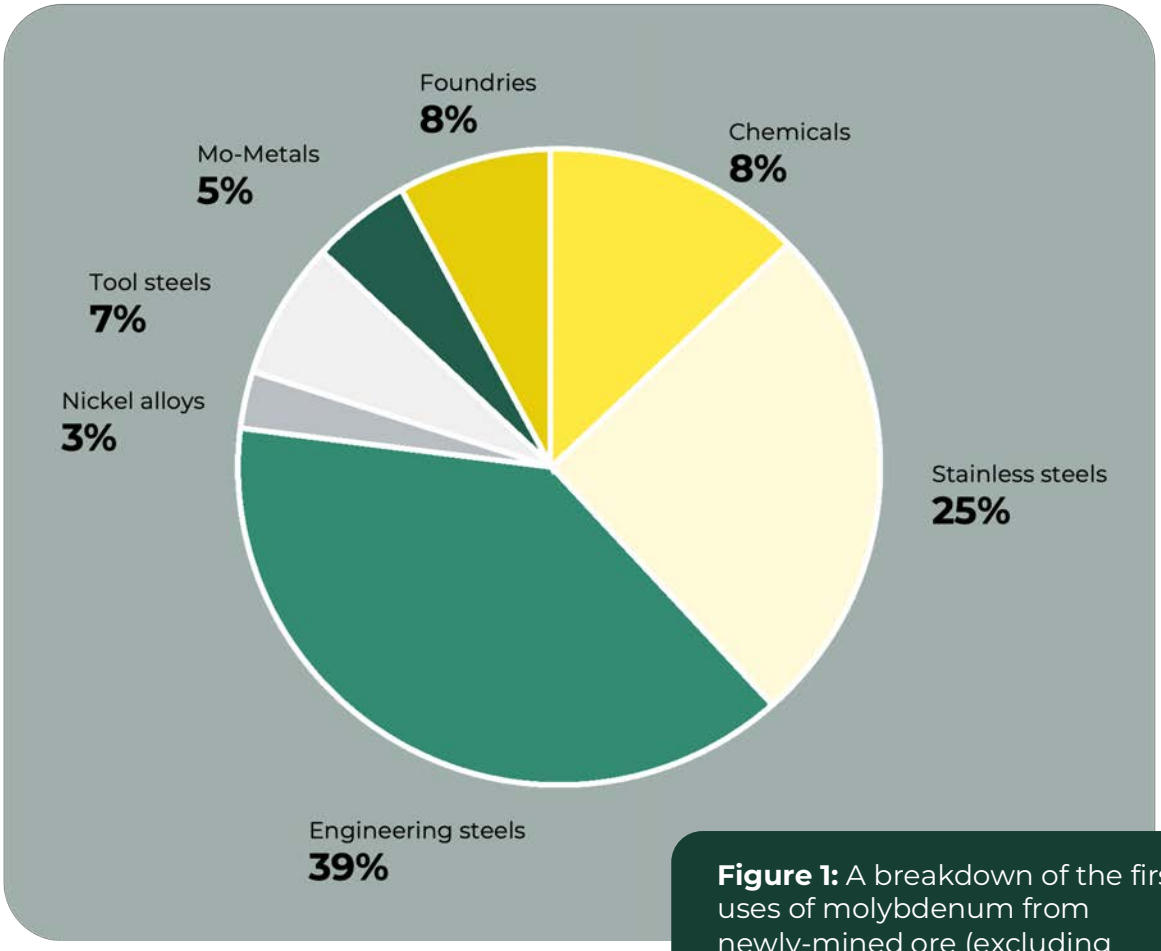


Figure 1: A breakdown of the first uses of molybdenum from newly-mined ore (excluding scrap materials). Source: IMOA.

[7] International Molybdenum Association website. Molybdenum Properties. (Accessed 6 May 2025)
[8] International Molybdenum Association website. Molybdenum Use. (Accessed 6 May 2025)
[9] International Molybdenum Association website. Molybdenum – Essential for Life. (Accessed 6 May 2025)

42 95.95
Mo
Molybdenum

Supply chain attributes

Supply chain resilience

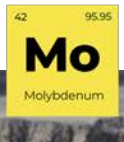
The United States Geological Survey (USGS) estimated global molybdenum production in 2024 was 260,000 metric tons, an increase of 4.8% compared with that in 2023. In descending order of production; China, Peru, Chile, the United States, and Mexico provided 91% of total global production. The USGS estimated global reserves in 2024 at 15 million metric tons, more than 55 years of 2024 annual demand. Additional molybdenum reserves will be added to the global figure as deposits are explored and evaluated, and the USGS states that "resources of molybdenum are adequate to supply world needs for the foreseeable future".[10]

Two dashboard indicators of the resilience of the molybdenum supply chain are given below. These numerical indicators, *Price Volatility* and *Supply Chain Concentration*, are graded for supply chain resilience risk from very low to very high, benchmarked against a range of mined materials through a standardised methodology described in Appendix III.

'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. The TDi Price Volatility index for the Platts Molybdenum Oxide Daily Dealer global price index in the 2016 to 2021 time period was 0.39, resulting in a supply chain risk assessment of High. This has been recalculated to 23.66% using the new TDi Price Volatility Index methodology for molybdenum drummed molybdic oxide 57% Mo min, in-whs Rotterdam, $/lb Mo as reported by Fastmarkets. The update for the five-year September 2020 - August 2025 time period is 26.02% resulting in a supply chain price volatility grade of "moderate" as shown in the table below. Some of the driving factors of the volatility during the measured time period can be attributed to the COVID pandemic in 2021, the upstream production concerns in Chile and Peru contributing to reduced molybdenum output in 2023, and some new supply tightness especially in concentrates feedstock with Chinese mines increasing import volumes and holding back supply for domestic use.

Price volatility[11]	Molybdenum drummed molybdic oxide 57% Mo min, in-whs Rotterdam, $/lb Mo
5-year annualised volatility (Sep 2020-Aug 2025)	26.03 %
Volatility grade	Moderate

[10] US Geological Survey Mineral Commodity Summary. Molybdenum. 2025. (Accessed 3 December 2025)
[11] Annualised volatility (%) is calculated as the sample standard deviation of daily log returns over the observation period, adjusted to a 1-year horizon by multiplying by the square root of the number of trading days per year (252). Daily log returns are defined as $r_t=ln(P_t/P_{t-1})$, where P_t is the observed price on trading day t.



'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.

Supply chain concentration by country			
TDi supply chain market concentration by country index	0.24	Supply chain resilience risk indicated by the degree of country market concentration	Moderate[12]

The coronavirus pandemic caused widespread uncertainty in mineral markets. The molybdenum market was no exception. 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. Prices recovered and steadied in 2021 and 2022 as industries restarted and demand for metals picked up. Near the end of 2022, prices increased once more, with prices peaking in early 2023, driven by tight supply chains and a surge in demand, particularly from the steel sector. In 2023, prices fell due to increasing supply from China and Peru, partially offset by continued weakness in existing mine production, increasing Chinese imports, and a slowdown in consumption as steel mills reduced their intake. Since 2024 and Q1 2025, prices have steadied as the market was mainly in balance.

[12] Please refer to "Appendix II: Methodology guide for supply chain resilience" for full supply chain concentration methodology.

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 near 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. 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 used primarily outside of China, with rotary kiln roasters mainly used in the Asia region. SO2 emissions can be captured using sulphuric 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).[13]

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 ferromolybdenum for use in steelmaking.

RMC may also be used directly in the steelmaking process, without first being converted to ferromolybdenum. This route accounts for approximately 40% of global RMC production.

The production that is not used for steel and alloy making is used in the manufacture of chemicals and pure molybdenum metal.

[13] International Molybdenum Association website. Facts and Figures. (Accessed 6 May 2025).

The figure below illustrates the described features of a generalised molybdenum supply chain. For further information on many of the molybdenum end uses please consult page 14 of IMOA's Annual Review publication.[14]

Supply chain visualisation and comparison

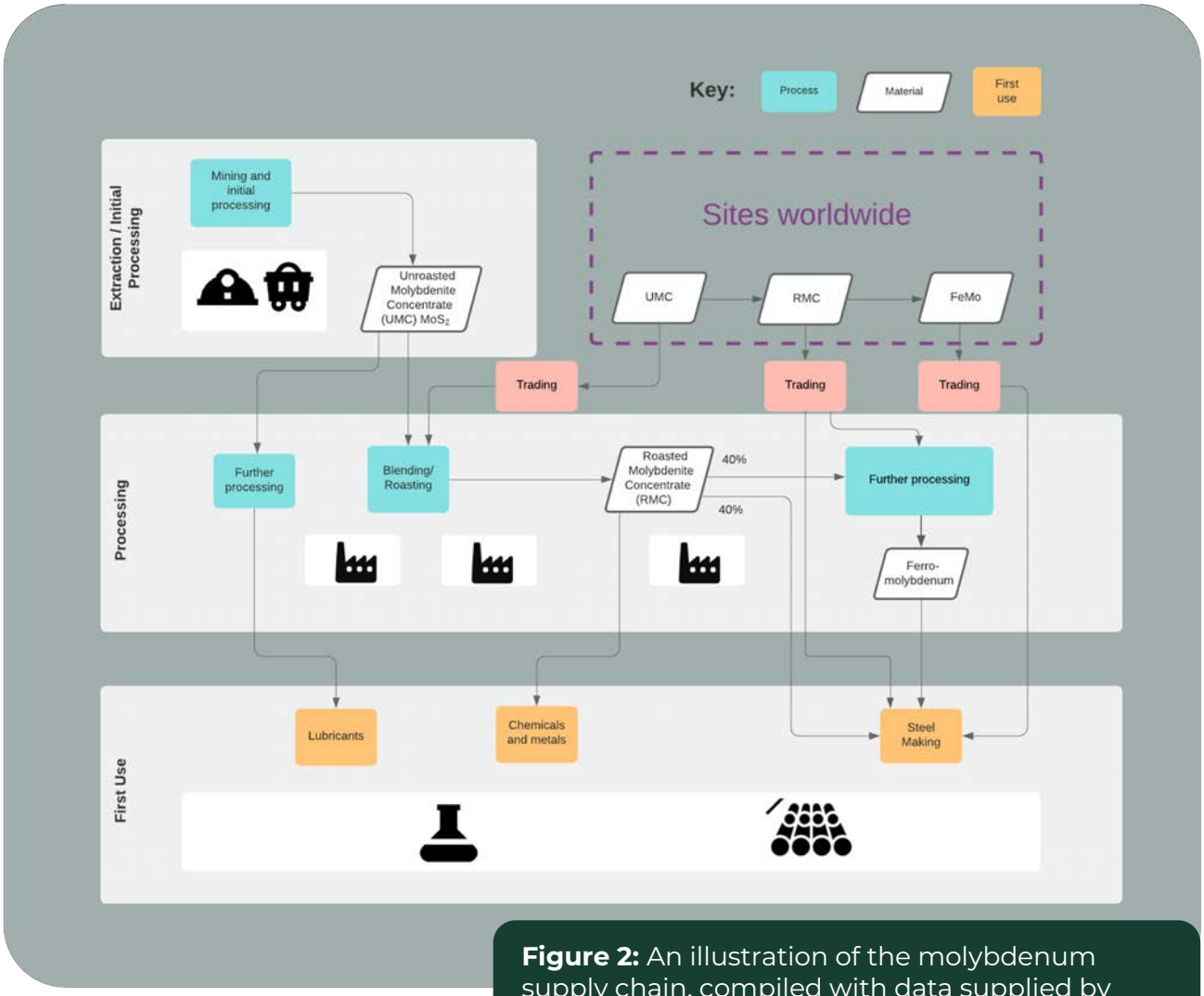


Figure 2: An illustration of the molybdenum supply chain, compiled with data supplied by IMOA.

[14] IMOA Annual Review 2023/2024. International Molybdenum Association. (Accessed 6 May 2025)

How molybdenum is mined

Molybdenum occurs naturally as molybdenite ore (which contains molybdenum disulphide, MoS_2).

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 in 2025 contributed approximately 5% 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 primary 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. [15] 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).[16]

[15] International Molybdenum Association website. Facts and Figures. (Accessed 6 May 2025)
[16] Shen, L., and Gunson, A., 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.

Shen, L., and Gunson, A. 'The Role of Artisanal and Small-Scale Mining in China's Economy.' Journal of Cleaner Production, vol. 14, 3-4, 2006, pp. 427 -435. (Accessed 6 May 2025)

National Energy Administration (China). 'The Mineral Resources Law of the People's Republic of China.' (Accessed 6 September 2025)

Geographic distribution of molybdenum mining

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

World production figures are given in figure 3, below.

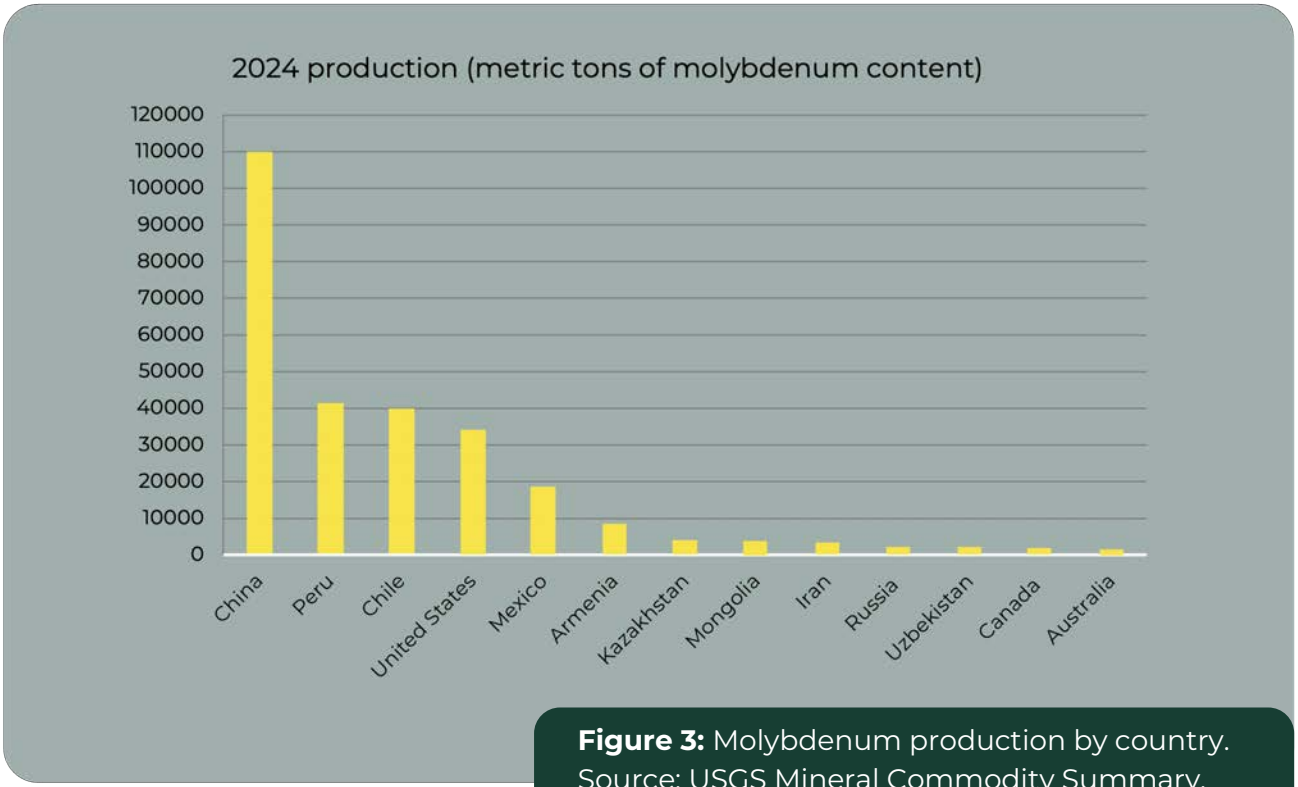


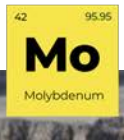
Figure 3: Molybdenum production by country. Source: USGS Mineral Commodity Summary, Molybdenum, 2025.[17]

Key players in the molybdenum mining sector

World molybdenum production was approximately 260,000 metric tons in 2024.[18] 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

[17] US Geological Survey Mineral Commodity Summary. Molybdenum. 2025. (Accessed 3 December 2025)
[18] Ibid.



companies are generally also highly regulated and scrutinised in the jurisdictions where they operate. Government regulations and companies' adoption of voluntary certifications and assurance frameworks help mitigate risks in the molybdenum mining industry.

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

Several new mine projects and restarts are planned that may add to molybdenum supply in the next five years. Teck's Quebrada Blanca, Chile mine expansion) is continuing to ramp up molybdenum production in 2025.[19] In September 2024, Centerra Gold announced the restart of its Thompson Creek primary mine with production scheduled for the second half of 2027.[20] Average annual molybdenum production is estimated to be approximately 13 million pounds (5900 metric tonnes) after initial ramp-up.[21] Almonty Resources plans to develop a molybdenum mine adjacent to its Sangdong tungsten mine in South Korea and is targeting production by the end of 2026. Almonty plans to produce 5600 metric tons of molybdenum per year. Almonty Resources announced in January 2025 that it had entered into an exclusive molybdenum offtake agreement with SeAH M&S, South Korea.[22] Origin Mining announced in 2024, its planned construction and restart of its Mineral Park, Arizona mill and concentrator. Mill commissioning is scheduled for 2025.[23] Greenland Resources announced on June 19, 2025, that it has received a 30-year exploitation license from Greenland for molybdenum and magnesium production at its Malmbjerg project in eastern Greenland.[24] Greenland Resources plans to produce an average of 24 million pounds (10,886 metric tons) per year per its feasibility study.[25] On August 28, 2025, Zijin Mining Group announced that its acquisition of the Shapinggou Molybdenum Mine project in Anhui China had been completed. Zijin Mining holds 84% equity interest while Jinduicheng Molybdenum Co. and Jinzhai Urban Development Investment Co. hold the remaining 10% and 6% equity interest, respectively. The construction period is 4.5 years. After the completion of construction and reaching the designated production capacity, the average molybdenum output will be approximately 22,100 tonnes per year.[26]

China

Key molybdenum-producing companies in China include Jinduicheng Molybdenum Corp., China Molybdenum Co., Ltd. (CMOC), and Yichun Luming. Both Jinduicheng Molybdenum

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[19] Teck. Q3 2025 News Release. 21 October 2025. (Accessed 5 December 2025)
[20] Centerra Gold. May 2025 Investor Presentation. (Accessed 10 December 2025)
[21] Centerra Gold website news release. Centerra Gold Announces Thompson Creek Feasibility Study Results and Strategic Plan for US Molybdenum Operations, Including a Restart of the Thompson Creek Mine and Ramp-Up of Langeloth. 9 December 2024. (Accessed 2 October 2025)
[22] Almonty website news release. Almonty announcement. 31 January 2025. (Accessed 9 July 2025
[23] Origin Mining Company website. Mill and Concentrator Restart. (Accessed 9 July 2025)
[24] Greenland Resources press release. Greenland Resources Receives 30 Year Exploitation License for Molybdenum and Magnesium. 19 June 2025. (Accessed 9 July 2025)
[25] Greenland Resources Feasibility Study. Malmbjerg Molybdenum Deposit Feasibility Study, NI 43-101 Technical Report, pages 17-16 and 17-17. (Accessed 2 October 2025)
[26] Zijin Mining Group Co., Ltd. Announcement in relation to the Completion of Acquisition of the Shapinggou Molybdenum Mine Project in Anhui. 28 August 2025. (Accessed 8 October 2025)

Corp. and CMOC are vertically integrated; they mine and concentrate molybdenum ore and produce products such as RMC and ferromolybdenum.

Jinduicheng Molybdenum Corp. is one of the world's top six primary molybdenum mines, with substantial reserves and high-grade ore.[27] In 2021 Jinduicheng Molybdenum Corp reported that it supplied 8% of the total global molybdenum market, and it still ranks as the largest producer in China and the third largest globally.[28] [29]

Yichun Luming operates China's largest open-pit molybdenum mine, with a capacity of 50,000 tons per day, processing 15 million tons of raw ore annually. [30] This operation yields 22,500 tons of molybdenum concentrate (50+% Mo).[31]

CMOC is a leading mining company with significant molybdenum operations. It owns major mines such as the Sandaozhuang molybdenum-tungsten mine in Luanchuan County and the Donggebi molybdenum mine in Hami. In 2024 it reported 15,396 tons of molybdenum production, a slight decrease compared to 2023, when CMOC produced 15,635 tons.[32]

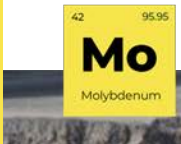
Much of the molybdenum produced in China is also consumed in the country by the domestic steelmaking industry.

Peru

Nationally, Peru's molybdenum production rose by 4.2% in 2024, driven by increased output from major mines such as Antamina, Quellaveco, and Southern's operations. This growth contributed to Peru's new status as the second-largest molybdenum producer globally, with total production reaching approximately 41,000 metric tons in 2024.[33]

In Peru, molybdenum is mined and concentrated at eight mines: the Toquepala and Cuajone mines, owned by the Southern Copper Corporation,[34] the Cerro Verde mine, owned by Freeport-McMoRan,[35] Antamina owned by BHP, Glencore, Teck Resources and Mitsubishi, the Las Bambas mine operated by MMG[36], the Toromocho mine operated by Chinalco, Constancia owned by Hudbay Peru, and Quellaveco owned by Anglo American and Mitsubishi Corporation. All these mines produce molybdenite concentrate as a by-product, which is roasted elsewhere. According to Southern Copper Corporation's 2024 annual report, molybdenum production in their Peru mines reached 13,390 metric tons in

[27] Jinduicheng Molybdenum Group website. About Jinduicheng Molybdenum Group Co. Ltd (JDC). (Accessed 5 December 2025)
[28] Jinduicheng Molybdenum Group website. China's Molybdenum City - Jinduicheng. (Accessed 5 December 2025).
[29] Jinduicheng Molybdenum Group website. About Jinduicheng Molybdenum Group Co. Ltd (JDC). (Accessed 5 December 2025)
[30] Wuxi Semiconductor Technology Co. Ltd. Case Study – Heilongjiang Yichun Luming Molybdenum Mine. (Accessed 5 December 2025)
[31] China Railway Group Limited website. Luming Molybdenum Mining Co., Ltd (Accessed 10 December 2025)
[32] CMOC 2024 Annual Results, CMOC press release (Accessed 2 December 2025)
[33] US Geological Survey Mineral Commodity Summary. Molybdenum. 2025. (Accessed 3 December 2025)
[34] Southern Copper (Grupo Mexico) website. About Southern Copper Corporation. (Accessed 6 May 2025).
[35] Freeport-McMoRan (FCX). South America. (Accessed 15 September 2021)
[36] MMG. Las Bambas. (Accessed 6 May 2025).



2024, marking a 33% increase from the previous year as supply chain disruptions in Peru eased.[37] When the Southern Copper's Mexico mines are added to the Peru production, the total company 2024 molybdenum production was 29,000 metric tons, second in the world. Freeport-McMoRan's Cerro Verde mine reportedly produced approximately 9,072 metric tons of molybdenum in 2024 an 8% decrease from 2023 .[38] In 2024, Antamina's production was 8,200 metric tons, a large increase of 4,700 metric tons over 2023. Antamina's variable annual molybdenum production is not unusual for by-product mines.[39] MMG's Las Bambas mine produced 2,482 metric tons of molybdenum as of September 2024, down from 3,017 metric tons in September 2023.[40]

Chile

Chile is the third-largest molybdenum producer globally producing 38,000 metric tons in 2024. Molybdenum in Chile is produced at 12 mines and all are copper/molybdenum by-product mines. Total production volume has been declining for several years due to falling ore grades partially offset by mine expansions. State-owned company Codelco is reportedly the largest molybdenum producer in Chile, and the third largest in the world. Molybdenum is produced by the company at multiple sites, where copper is the primary ore.[41] In 2024, its molybdenum output was approximately 16,100 metric tons, a decrease from 17,250 metric tons in 2023.[42]

Other large by-product molybdenum mines include the Los Pelambres and Centinela mines operated by Antofagasta, the Caserones mine operated by Lundin and the Sierra Gorda mine operated by KGHM Polska Miedz.[43] Antofagasta's Los Pelambres mine produced 8,100 metric tons of molybdenum in 2023, a 13% year-on-year increase due to higher throughput rates. In 2024, production slightly increased to 8,300 metric tons, attributed to lower grades, offset by increased processing rates.[44] In 2025, Antofagasta's Los Pelambres molybdenum production is forecasted to be around 12,000–13,000 tonnes.[45] The combined Los Pelambres and Centinela mine production in 2024 was 10,700 metric tons., a small decrease from 11,000 metric tons in 2023. The Caserones mine (100% basis) produced 3,183 metric tons of molybdenum in 2024 and 4,417 metric tons in 2023.[46] [47] The Sierra

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[37] Southern Copper Corporation. Results | Fourth Quarter and Year 2024. (Accessed 3 December 2025)
[38] Freeport-McMoRan. News Release. Freeport Reports | Fourth Quarter and Year Ended 2024 Results. (Accessed 3 December 2025)
[39] Platform of the Peruvian State. Ministry of Energy and Mines. December Bulletin 2024. (Accessed 2 October 2025)
[40] MMG Limited. Third Quarter Production Report 2024. (Accessed 3 December 2025)
[41] Landerretche, O.M. 'Codelco: Recent Developments and Perspectives', BMO Capital Markets 25th Global Metals and Mining Conference, *Codelco*, February 28 2016 (Accessed 6 May 2025)
[42] Statista. Codelco's Molybdenum Production from 2010 to 2023. (Accessed 3 December 2025)
[43] KGHM Polska Miedz. Sierra Gorda (Accessed 06 May 2025)
[44] Antofagasta PLC. Focused on Copper | Annual Report and Financial Statements 2024. (Accessed 3 December 2025)
[45] Antofagasta PLC. Los Pelambres (Accessed 3 December 2025)
[46] Lundin Mining. News release | Lundin Mining Announces Closing of the Acquisition of Majority Interest in the Caserones Copper-Molybdenum Mine in Chile and Commitments for New $800 Million Term Loan. (Accessed 20 November 2025)
[47] Lundin Mining. 2024 Annual Filings. Including Caserone mine 2024 Results. Page 19. (Accessed 3 December 2025)

Gorda mine (100% basis) produced 2,884 metric tons in 2024 and 2,284 metric tons in 2023.[48]

Much of the molybdenite concentrate produced in Chile is refined by the independent company Molymet[49] and Codelco's Molyb.[50]

United States of America

Molybdenum in the United States is produced at nine mines. Five of these mines are owned by Freeport-McMoRan and its subsidiary, Climax Molybdenum, the world's leading producer and supplier with total global 2024 production of 81.0 million pound (36,700 metric tons).[51] Two of these, the Climax and Henderson mines in Colorado produce molybdenum as a primary product. In 2024 and again in 2023, the two primary mines produced 30 million pounds (13,607 metric tons) total. The Henderson mine produced 12 million pounds (5,443 metric tons) of molybdenum, a decrease from 13 million pounds (5,897 metric tons) in 2023. The Climax mine molybdenum production totalled 18 million pounds (8,164 metric tons) in 2024, 17 million pounds (7,711 metric tons) in 2023.[52]

Seven mines produce molybdenum as a by-product to copper. Three of these mines, Bagdad, Morenci and Sierrita mines in Arizona, are also owned by Freeport-McMoRan.[53] Freeport-McMoRan reported that its North America by-product mines produced 31 million pounds (14.061 metric tons) in 2024 and 2023. The Sierrita mine produced 15 million pounds of molybdenum (6,804 metric tons), while Bagdad and Morenci mines produced 13 million and 3 million pounds (5,897 and 1,362 metric tons) in 2024 respectively.[54]

Rio Tinto's Bingham Canyon mine produced 2,600 metric tons of molybdenum in 2024 and 1,800 metric tons in 2023.[55]

Three refining plants in the USA convert molybdenite concentrate to RMC, ferromolybdenum, molybdenum chemicals and lubricants.[56]

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 2024, the company reported a total molybdenum production in Mexico of 15,610 tons, a 7% decrease over 2023. The decrease was attributed to lower production at La Caridad, which fell 14.5%

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[48] KGHM Polska Miedź. Preliminary Production and Sales Data of the KGHM Polska Miedź Group for December 2024. Page 5. (Accessed 3 December 2025)
[49] Molymet. Global Presence. (Accessed 6 May 2025)
[50] Codelco Molyb website. Molyb Chile - Molybdenum Processor. (Accessed 3 July 2025)
[51] Climax Molybdenum website. Climax Molybdenum - A Freeport-McMoRan Company. (Accessed 21 October 2025)
[52] United States Securities and Exchange Commission. Form 10-K. Freeport-McMoRan Inc. (Accessed 6 May 2025)
[53] United States Securities and Exchange Commission. Form 10-K. Freeport-McMoRan Inc. (Accessed 6 May 2025)
[54] FCX Freeport-McMoRan website. North America. (Accessed 6 May 2025).
[55] Rio Tinto. Annual Report 2024. (Accessed 3 December 2025)
[56] US Geological Survey Mineral Commodity Summary. Molybdenum. 2025. (Accessed 3 December 2025)

due to lower grades and recoveries.[57] [58] Molybdenite concentrate is produced at both sites and then sold onward to customers for roasting.

Significant molybdenum downstream processing, including toll-processing, hubs

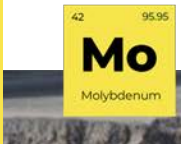
Molymet is the world's leading downstream molybdenum processor. It is a Chilean company with production facilities in four countries with global commercial activity. Their website states that they "supply 35% of the global demand for molybdenum". Molymet sites, located in Chile (Molymet Nos and Molynor), Mexico (Molymex), Belgium (Molymet Belgium) and Germany (Molymet Germany), produce roasted molybdenum concentrate, ferromolybdenum, molybdenum chemicals and molybdenum metal. Molymet also provides toll-processing services.[59]

Freeport-McMoRan and its subsidiary, Climax Molybdenum, have the following downstream molybdenum processing operations: roasting and chemical production in Fort Madison, Iowa; roasting and chemical production in Rotterdam, The Netherlands; roasting at the Sierrita mine in Green Valley, Arizona; oxidation at the Bagdad mine, Bagdad, Arizona and ferromolybdenum production in Stowmarket, UK. Climax Molybdenum also provides toll processing services.[60]

The most extensive downstream processing in China is conducted by Jinduicheng Molybdenum, CMOC, New China Dragon and Chaoyang Jinda Molybdenum Co., Ltd. Codelco has downstream processing (roasting and ferromolybdenum production) within its Molybdenum subsidiary, Molyb, in Chile.[61]

Centerra Gold's Langeloth metallurgical facility in Langeloth, Pennsylvania, has several roasters and ferromolybdenum production. SeAH M&S has a multi-hearth roaster in South Korea and ferromolybdenum production. In January 2025, SeAH M&S signed an exclusive molybdenum offtake agreement with Almonty Resources.[62] Treibacher Industrie manufactures ferromolybdenum through its Steel and Foundry Products Unit in Austria.

[57] Southern Copper Corporation. Results | Fourth Quarter and Year 2024. (Accessed 3 December 2025)
[58] Grupo México. Results Fourth Quarter 2024. (Accessed 3 December 2025)
[59] Molymet website. (Accessed 3 December 2025)
[60] United States Securities and Exchange Commission. Form 10-K. Freeport-McMoRan Inc. (Accessed 6 May 2025)
[61] Codelco website. Codelco Celebrates 20-Year Anniversary of the Japan Moly Working Group With Visit From Japanese Executives. (Accessed 3 December 2025).
[62] Nasdaq. Almonty Pens Molybdenum Offtake Deal With SpaceX Contractor SeAH. (Accessed 3 December 2025).



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.

To augment the work already done on the Molybdenum Profile on mapping relevant ESG issues, this section analysed public issue reports and review of authoritative literature sources, and collected information on 26 Environmental, Social and Governance (ESG) issues relevant to the molybdenum supply chain.

The ESG issues have been selected for their prevalence in these supply chains, the heightened scrutiny they receive from advocacy groups, and because they are covered in supply chain, sourcing and due diligence legislation and regulations. These 25 issues were also benchmarked against the latest version of the ResponsibleSteel standard (version 2.1), which was launched in May 2024, and the ESG risk typology from the Copper/Molybdenum Mark Criteria to align with expectations.

The ESG issues are split into 57 sub-issues that indicate the state of an issue. The selection of ESG indicators is based on their relevance to key regulations, including the German Supply Chain Act, the EU Battery Directive, and the EU's Conflict Minerals Regulation.

Two types of information - public issue reports and authoritative literature – were used for the saliency analysis. For a more in-depth explanation of the methodology, please see Appendix I.

Risks inherent to industrial mining and mineral processing

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

Risks can be posed to workers' health and safety through industrial accidents, incidents and diseases, or unfair employment practices that may infringe workers' rights. 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 gases. 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.

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:

ESG Issue	Salience Grade
Environmental	
Deforestation	Low
Degraded / fragmented landscapes	Low
Greenhouse gas emissions	Very low
Mismanagement of hazardous substances	Very Low
Air pollution	Moderate
Water pollution	High
Soil pollution	Moderate
Tailings breaches	Low
Threat to biodiversity and conservation efforts	Low
Social	
Forced labour	Very Low
Poor occupational health and safety	Very Low
Indigenous Peoples rights violations	Moderate
Involuntary displacement	Very Low

Labour rights violations	Very Low
Child labour	Very Low
Security (forces) and human rights	Very Low
Community rights and interests violations	Moderate
Company-community conflict	Moderate
Conflict and human rights	Low
Threat to community health	Moderate
Governance	
Corruption	Moderate
Money laundering	Low
Non-compliance with legal obligations	Very Low
Non-conformance of employment terms	Very Low
Non-payment of taxes	Very Low

The results indicate that environmental, social and governance risks are relatively well managed overall in molybdenum supply chains. Many of the companies that operate molybdenum mines are headquartered in OECD countries, where they are subject to stringent regulatory control and public scrutiny of their global ESG performance.

Molybdenum was, however, found to have a very strong association with pollution due to acid mine drainage (AMD) and sulphur dioxide (SO_2) emissions, both of which are byproducts of intensive mining and metallurgical activities. It should be noted that at modern molybdenum mine sites, the risks from acid mine drainage and sulphur dioxide emissions are much lower than in the past, thanks to widely used environmental protection measures.

Acid mine drainage is managed by carefully storing waste rock to keep it dry or covered and by treating any affected water before it is released into the environment. Sulphur dioxide is captured using modern filtration and scrubbing systems. Whether molybdenum is mined on its own or as a by-product of other metals like copper, these mitigation practices are now standard, and the environmental risks are well understood and actively managed, making modern molybdenum mining far safer for the environment than it used to be. Nevertheless, these risks are intrinsic to molybdenum mining and should be monitored.

Although molybdenum is an essential trace element for all animal and plant life[63] [64], there are circumstances in which molybdenum can be linked to environmental pollution affecting water, soil, and air, even in the absence of major accidents. Studies from the

[63] International Molybdenum Association website. Molybdenum - Essential for Life. (Accessed 6 October 2025)
[64] International Molybdenum Association website. Molybdenum in Biology – An Essential Trace Element. (Accessed 6 October 2025

Jinduicheng and Luanchuan mining regions of China[65] [66], show that molybdenum and associated metals may contaminate local water supplies, both surface and groundwater, at levels exceeding safe limits, posing risks to drinking water and aquatic ecosystems.

Air pollution also plays a role, as mining dust and atmospheric deposition spread contaminants over a wide area, affecting both human health and agriculture.[67] These impacts are often worse in regions with poor regulation or limited environmental monitoring. To provide peer-reviewed and robust scientific information regarding the potential environmental impact of molybdenum, the International Molybdenum Association has led research in this area for nearly two decades.[68]

Acid rock drainage

Molybdenite, the most important ore for commercial extraction of molybdenum, contains the sulphide mineral molybdenum disulphide, with chemical composition MoS_2. 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.[69] [70]

Managing the risk of acid rock drainage is an important part of responsible mining, when sulphide ores are being extracted. 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.

Emission to air of sulphur dioxide

Concentrated molybdenum disulphide is roasted, to produce roasted molybdenite concentrate (RMC). The reaction results in the production of sulphur dioxide gas, which must be captured through desulphurisation systems such as sulfuric acid plants or lime

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[65] Zhang, H., Wang, X., Wang, H., Yin, J., Wang, R., Shi, Z., & Ni, S., 'Distribution of Uranium and Molybdenum in River Sediment near Molybdenite Mining Region: A Case Study in SW China,' Minerals, vol. 13, no. 11, 1435, 2023. (Accessed 30 September 2025)
[66] Song, X., He, S., Li, R., Mao, Z., Ge, S., Bai, X., & Ji, C., 'Evaluation of Metal Pollution Characteristics Using Water and Moss in the Luanchuan Molybdenum Mining Area, China.' Environmental Science and Pollution Research, vol 31, pages 5384-5398, 2023. (Accessed 6 May 2025)
[67] Song, X., He, S., Li, R., Mao, Z., Ge, S., Bai, X., & Ji, C., 'Evaluation of Metal Pollution Characteristics Using Water and Moss in the Luanchuan Molybdenum Mining Area, China.' Environmental Science and Pollution Research, vol 31, pages 5384-5398, 2023. (Accessed 6 May 2025)
[68] International Molybdenum Association website. List of Scientific Journal Publications Relating to IMOA-MoCon Research into Molybdate Effects.
[69] Geological Survey of Sweden. Chapter 5: Sulphide Minerals and Acid Rock drainage. (Accessed 6 May 2025).
[70] Dold, B., 'Evolution of Acid Mine Drainage Formation in Sulphide Mine Tailings.' Minerals, vol. 4, pp. 621-641, 2014. (Accessed 6 May 2025)

scrubbers[71]. 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.[72]

A potential risk exists of sulphur dioxide emissions at poorly managed or regulated molybdenum roasting facilities. 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.

It should be noted that ESG issues have been linked to molybdenum through its association with copper mining, particularly in Colombia. In 2023, environmental and Indigenous activists raised the alarm about plans by a Canadian company to extract molybdenum at a copper deposit in Colombia's Putumayo *departamento*. Those opposing the project believe it could threaten biodiversity in both the Amazon rainforest and Andes Mountains ecosystems, raising concern about environmental risks.[73] However, Colombia's Council of State has upheld Decree 044 of 2024, empowering the government to declare temporary natural reserves in ecologically sensitive zones, thereby suspending mining operations until environmental assessments confirm whether mining is compatible with long-term ecosystem conservation.[74]

Greenhouse gas emissions associated with molybdenum production and processing

In 2000, IMOA conducted its first Life Cycle Inventory (LCI), the first phase of a Life Cycle Assessment (LCA), for three metallurgical molybdenum feedstock products. The Association then updated the LCI in 2008, 2018, and 2024 to enhance its representativeness, refresh facility and background data, and refine modelling methods in line with advancing science and industry-specific practices.

[71] International Molybdenum Association. Molybdenum Processing Flowsheet. (Accessed 6 May 2025)
[72] United States Environmental Protection Agency. Sulfur Dioxide Basics. (Accessed 6 May 2025)
[73] Torres Garzón, N. 'Plan to Mine 'Clean Energy' Metals in Colombian Amazon Splits Communities.' Monga Bay, March 2023. (Accessed 3 December 2025)
[74] Velasco, E. R., 'Colombia's Mining Sector in Peril as Sweeping Environmental Law Takes Hold.' The Deep Dive, 2024. (Accessed 15 October 2025)

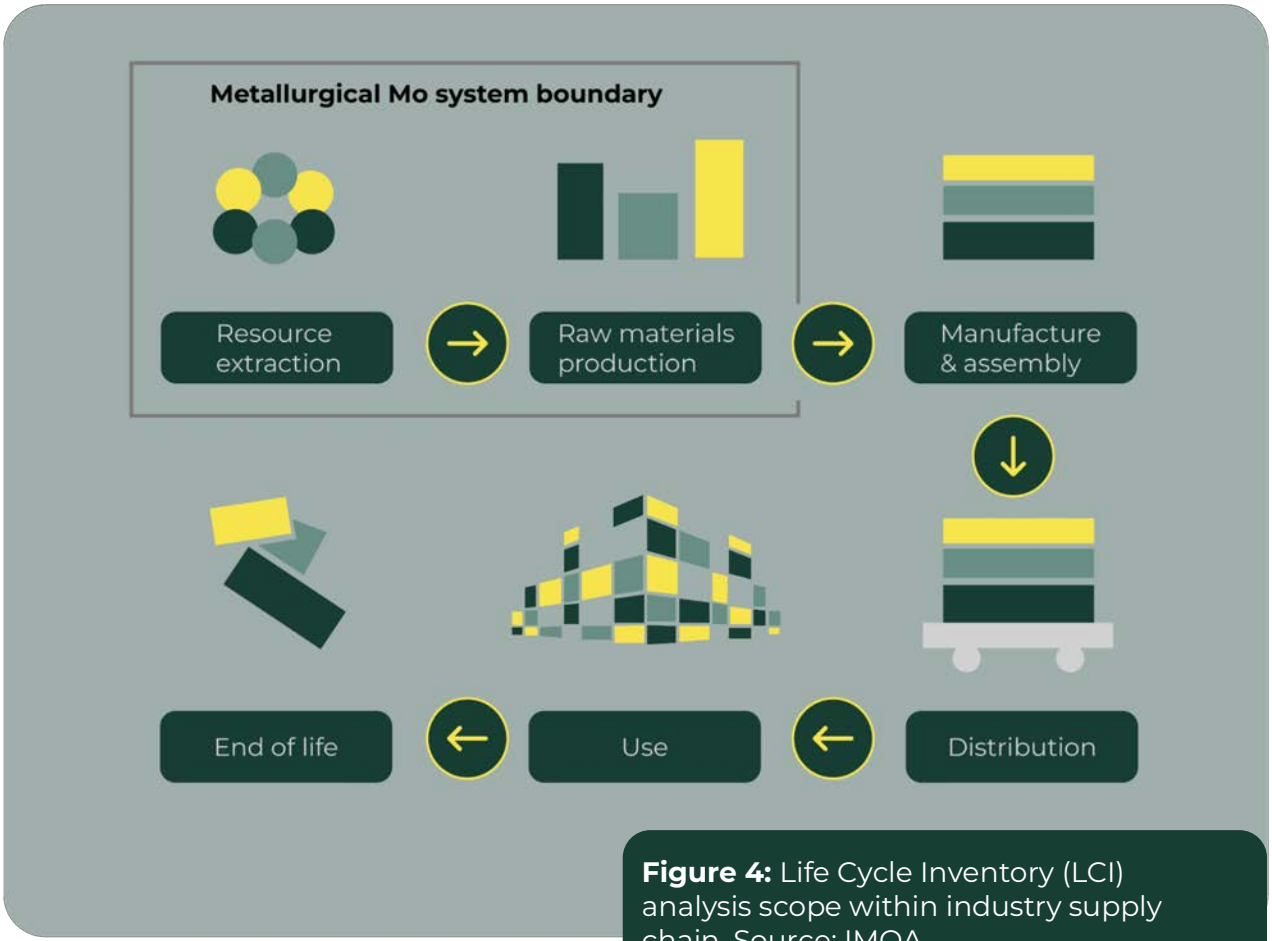

Figure 4: Life Cycle Inventory (LCI) analysis scope within industry supply chain. Source: IMOA

A peer-reviewed 'cradle to gate' life cycle analysis of molybdenum gives a figure for greenhouse gas emissions associated with 1 Kg of RMC production of 3.79 kg CO_2 equivalent / kg, down 24% from 2018. The CO_2 equivalent / kg of both RMC briquette and FeMo was also found to be down 20% and 8% respectively from 2018. For the first time the 2024 study included molybdenite concentrate as a separately calculated process unit. The 2024 update study showed a reduction in the Carbon Footprint (CFP) compared to the 2018 study, thanks to the growing share of renewable energy in electricity grids, improvements in processing efficiency, and several participating companies' commitments to using renewable energy through legitimate contractual instruments like renewable energy certificates (RECs), among other factors.[75]

[75] International Molybdenum Association. Life Cycle Inventory & Carbon Footprints of Molybdenum Products for Metallurgical Applications – Update Study. 2024. (Accessed 3 December 2025).

Year	Unit	1 kg Molybdenite Concentrate (~50% Mo)	1 kg RMC (~60% Mo)	1 kg RMC briquette (~59% Mo)	1 kg FeMo briquette (~67% Mo)
2024	kg CO_2-eq	2.84	3.79	4.03	7.41
2018	kg CO_2-eq	Not calculated	4.96	5.04	8.04
% reduction between 2018 & 2024 values		n/a	↓ 24%	↓ 20%	↓ 8%

Figure 5 | Carbon footprint per kg of product. Source: IMOA

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).[76]

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%.[77] 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 most significant role in the variation, and molybdenum, which 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.[78]

The 2024 IMOA LCI study indicates that the majority of emissions associated with molybdenum production occur at the concentration stage.[79]

[76] Nuss, P. and Eckelman, M.J. 'Life Cycle Assessment of Metals: A Scientific Synthesis.' Plos One Journal, Vol. 9, 7, pp. 1 – 12, 2014. (Accessed 6 May 2025)
[77] International Molybdenum Association. Molybdenum Grade Alloys and Steels. (Accessed 6 May 2025)
[78] Wei, W., and Samuelsson, P.B et.al, 'Energy Consumption and Greenhouse Gas Emissions During Ferromolybdenum Production.' Journal of Sustainable Metallurgy, Vol. 6, pp. 103 -112, 2020. (Accessed 06 May 2025)
[79] International Molybdenum Association. Metallurgical Molybdenum LCI Summary. (Accessed 3 December 2025)

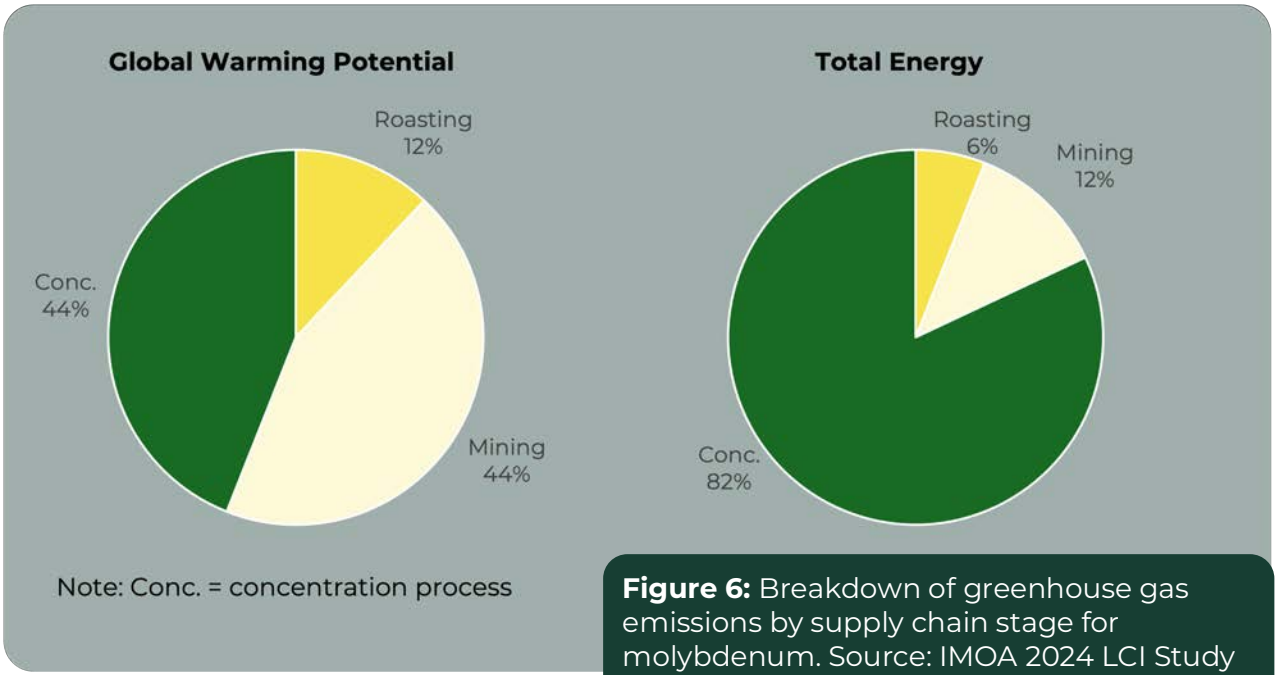

Figure 6: Breakdown of greenhouse gas emissions by supply chain stage for molybdenum. Source: IMOA 2024 LCI Study

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.

This section analyses governance risks at the country level that affect nations involved in the molybdenum supply chain. These include both general governance risks not directly tied to molybdenum production, as well as risks specifically related to the conditions under which molybdenum is produced. The analysis shows that while producing countries may face broader governance challenges, there are no country-level risks uniquely associated with molybdenum production itself.

Figure 7, below, displays aggregated Conflict Risk, Human Rights Risk, Rule of Law Risk, and Environmental Risk ratings for the top molybdenum-producing countries. These ratings are

based on relevant and reputable public indicators. Full explanations of the country-level risk indicators are provided in Annex I.

Aggregated molybdenum producing countries – Conflict Risk Rating	Aggregated molybdenum producing countries – Human Rights Rating	Aggregated molybdenum producing countries – Rule of Law Rating	Aggregated molybdenum producing countries – Environment Rating
Moderate	High	Moderate	High

Figure 7: TDi Country-level governance risk indicators

The high Human Rights Rating is due to the presence of countries scoring poorly on that indicator among some of the top molybdenum producing countries. Specifically, Iran, China, Russia, and Kazakhstan.

Similarly, the Environment Rating is influenced by low performing countries such as China, Mongolia, Iran, and Mexico.

The pie charts below show the market share of countries with high ratings for human rights and environment ratings. Note that China is the largest contributor to the high ratings while 54% (human rights) and 49% (Environment) of the supply chain are in low-risk countries.

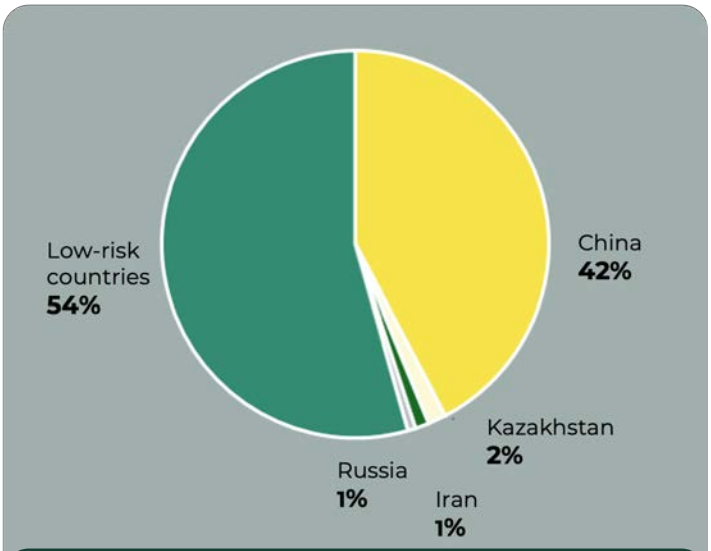

Figure 8a: Industry market share of countries rating "high" in the Human Rights Rating

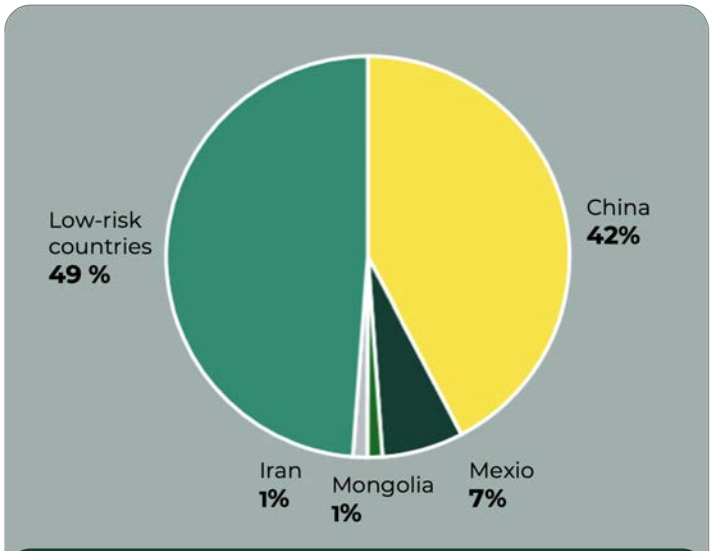

Figure 8b: Industry market share of countries rating "high" in the Environment Rating

42 95.95 Mo Molybdenum

Risk profiles for each of the countries rated as High-Risk in the TDi CAHRA Index and that fall in the 4th and 5th quartile of the indicators used to determine the other country risk ratings are provided in Appendix IV.

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[80], and high-level corruption risk in the jade mining industry of Myanmar.[81]

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 performing poorly in the governance indicators, 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).[82]

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 III.

[80] Amnesty International. Is My Phone Powered By Child Labour? (Accessed 7 September 2021).
[81] Global Witness. Jade: Myanmar's "Big State Secret". (Accessed 7 September 2021)
[82] See footnote on ASM in China, in the section *How Molybdenum is Mined*

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, compared to many other minerals studied by TDi Sustainability. It also showed a relatively low 'salience' for many of the issues that were identified, compared 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 the future, and can drive continuous improvement in risk management performance.

Risk Management, due diligence and systems for responsible sourcing

Uptake of voluntary standards schemes by molybdenum producers and processors

In mid-2025, IMOA conducted a survey of its members in order to illustrate the current uptake of key sustainability frameworks in the molybdenum industry. Uptake of eight sustainability frameworks was assessed: ISO 14001; ISO 45001; the ICMM Performance Expectations; the Copper Mark/Molybdenum 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 V.

In 2021, IMOA began its collaboration with the Copper Mark. This resulted in the implementation of the Molybdenum Mark, which has become part of the Copper Mark's assurance framework for responsible production. In addition to the Molybdenum Mark, the Copper Mark also developed individual marks for the zinc and nickel value chains. Sites can earn the respective Marks by undergoing the Copper Mark assurance process, which involves independent, third-party assessments to verify that they meet the Copper Mark's Responsible Production Criteria.

In another notable development, in 2024 ResponsibleSteel officially recognised the Copper Mark as a credible input material programme for Progress Levels 1 to 3 under its International Production Standard. Following a self-assessment of its Risk Readiness Assessment (RRA 3.0) and a public consultation, the Copper Mark became the fourth programme to meet ResponsibleSteel's requirements for responsible sourcing under Principle 3. This recognition not only supports the steel sector's ability to source key minerals - such as copper, molybdenum, nickel, and zinc - from suppliers that meet strong environmental, social, and governance (ESG) criteria, but also allows 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.

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 Molybdenum Mark covers sites in the extraction, processing, treatment, mixing, recycling, handling, or otherwise manipulating of molybdenum. 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.[83]

It is, however, important to distinguish between voluntary standards that are certifiable, those that are based on third party assurance, and those that represent a membership-based commitment. For instance, the ICMM Performance Expectations (PEs) are not a certifiable standard but rather a set of principles that member companies commit to as part of their ICMM membership; therefore, only ICMM members are required to implement them. Not all molybdenum or ferro-molybdenum producers are ICMM members, and participation depends on organisational membership decisions rather than open certification. Similarly, the Towards Sustainable Mining (TSM) program, developed by the Mining Association of Canada (MAC), is a voluntary third-party assurance framework that provides externally assured performance ratings but is not a certification scheme. It is a country-specific assurance framework primarily applicable to companies operating within or associated with MAC. As such, producers located outside their coverage zone may not have access to or reason to implement TSM. Consequently, comparing adoption across these initiatives should take into account their differing scopes, eligibility criteria, and geographic or membership limitations.

[83] The Responsible Mining Initiative and The Copper Mark. 'RMI's Risk Readiness Assessment Voluntary Standard System (VSS) Equivalency Benchmark Results.' 2021. (Accessed 6 May 2025)

Despite these factors, examining the overall landscape of all types of initiatives is valuable in order to understand the breadth and diversity of sustainability commitments across the molybdenum mining and processing industry. Both membership-based frameworks and certifiable standards, as well as third-party–assured schemes, demonstrate responsible practices through different mechanisms. Understanding uptake of these standards can help identify gaps in assurance coverage and contextualise varying approaches to ESG performance and transparency within the sector.

Data was collected on 10 companies in the Molybdenum supply chain comprising a total of 33 producing sites: 12 mining sites, eight roasting sites and six ferromolybdenum production sites, and seven unspecified sites. Some of the results of the survey are shown below.

Uptake of voluntary standards schemes at mine sites

Below is the uptake of voluntary standards at mines reported through the IMOA survey.

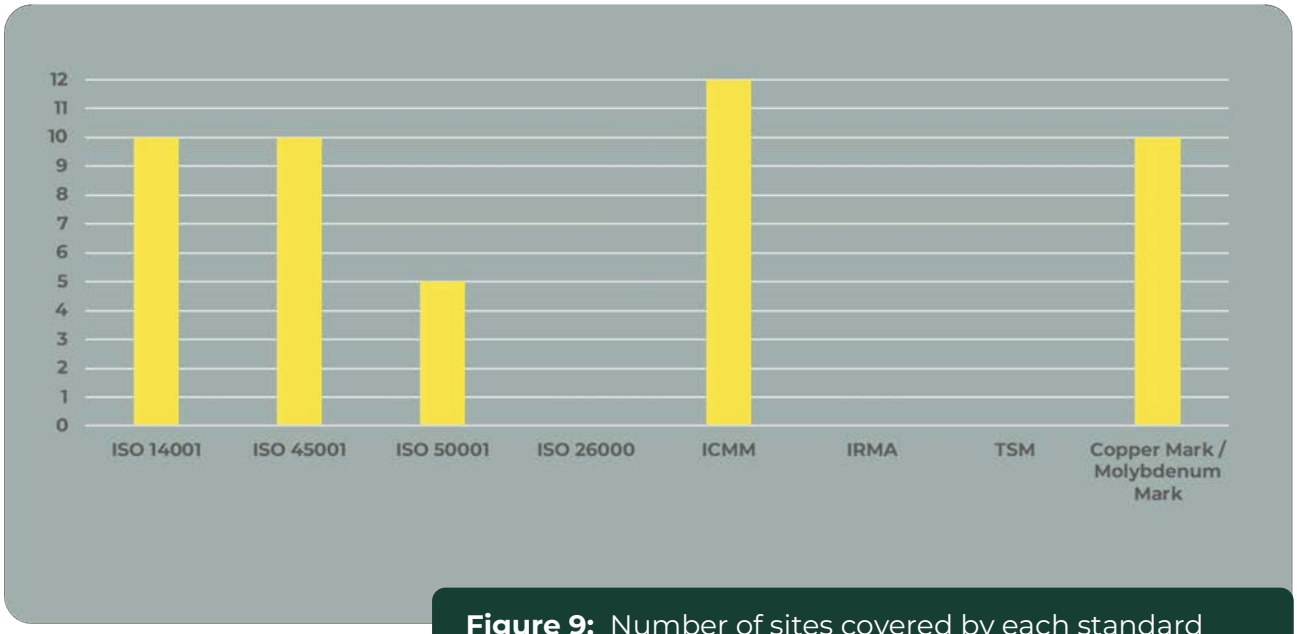

Figure 9: Number of sites covered by each standard

Of the 12 mining sites surveyed:

- 10 sites are covered by both ISO 14001 and IS0 45001
- 2 sites are not covered by ISOs, and are covered by ICMM and the Copper Mark/Molybdenum Mark
- 9 sites are covered by both ISOs plus ICMM and the Copper Mark/Molybdenum Mark
- 10 sites are covered by both ISOs plus ICMM

Uptake of voluntary standards schemes at roasting sites

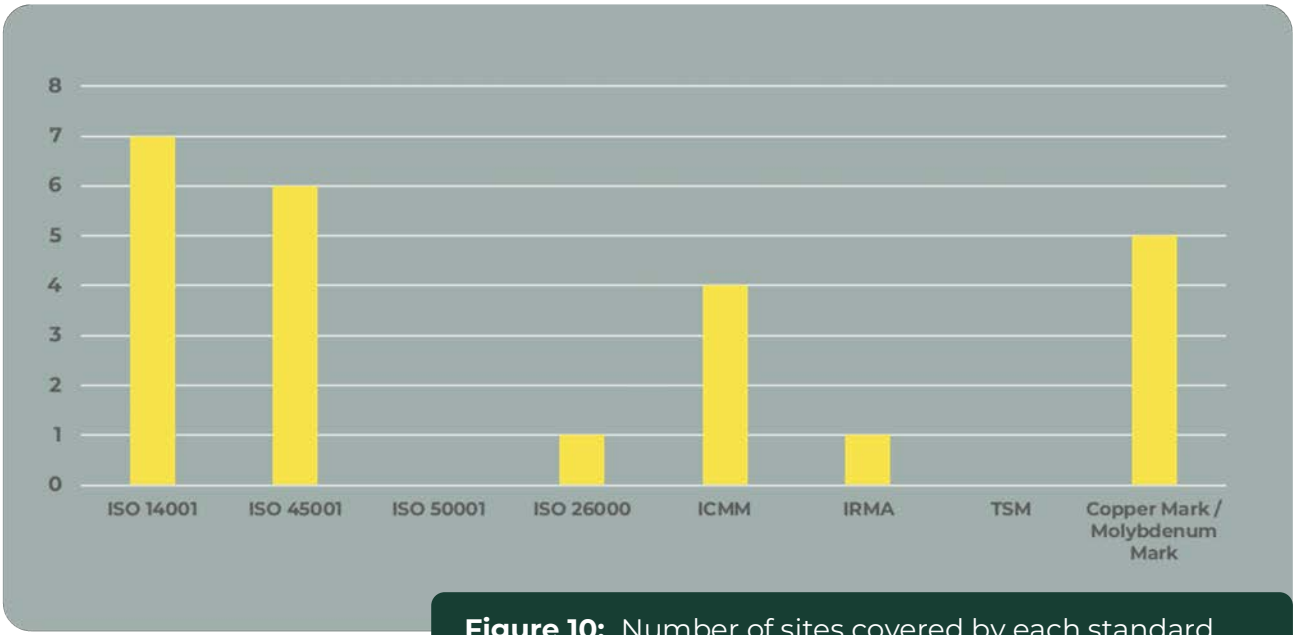

Figure 10: Number of sites covered by each standard

Of the 8 roasting sites surveyed

- 7 sites have an ISO 14001 certification
- 6 sites have an ISO 45001 certification
- 4 sites are covered by ICMM, 1 is covered by IRMA, and only 1 is covered by both
- 5 sites are covered by the Copper Mark/Molybdenum Mark

Uptake of voluntary standards schemes at ferromolybdenum production sites

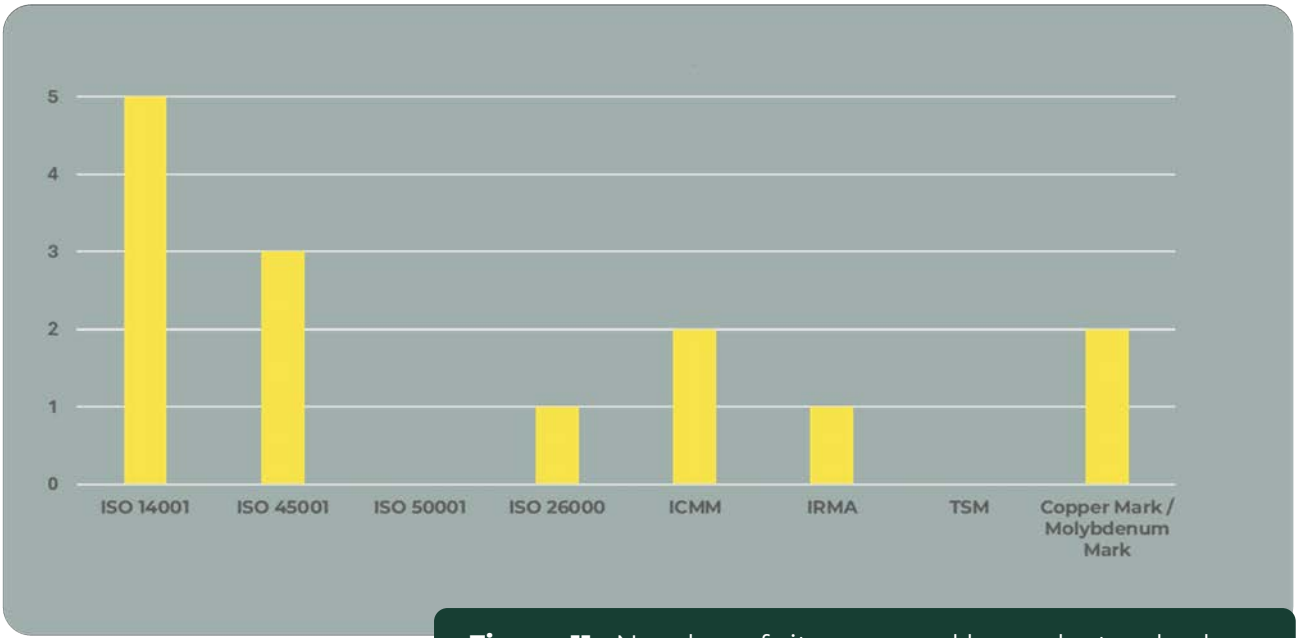

Figure 11: Number of sites covered by each standard

Of the 6 Ferro-molybdenum production sites surveyed

- 5 sites out of 6 have an ISO 14001 certification
- 3 sites out of 6 have an ISO 45001 certification
- 2 sites out of 6 have the Copper Mark/Molybdenum Mark

In addition to the mine sites that have reported their certifications through the IMOA survey, as of September 2025, 21 copper-molybdenum by-product mine sites, and seven molybdenum-only-producing mine sites and downstream processors have been awarded the Molybdenum Mark[84]. Three additional molybdenum-producing sites have signed Letters of Commitment and participate in the Copper Mark Assurance Framework in order to receive the Copper Mark/Molybdenum Mark.

[84] The Copper Mark website. Participants. (Accessed July 1, 2025)

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, and given the availability of the Molybdenum Mark.

ResponsibleSteel is an international, not-for-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, since its inception, has developed further components, which steel sites can choose to be assessed against, and which 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 now 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.

ResponsibleSteel has officially recognised the Copper Mark as a credible input material programme for Progress Levels 1 to 3 under its International Production Standard. This recognition supports the steel sector's ability to source key minerals - such as copper, molybdenum, nickel, and zinc - from suppliers that meet strong environmental, social, and governance (ESG) criteria. Following a self-assessment of its Risk Readiness Assessment (RRA 3.0) and a public consultation, the Copper Mark became the fourth programme to meet ResponsibleSteel's requirements for responsible sourcing under Principle 3. This solution now allows 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 Initiative for Responsible Mining Assurance's Standard for Responsible Mining and the Mining Association of Canada's Towards Sustainable Mining (TSM) have also been recognised by ResponsibleSteel as options to meet their site-level performance expectations under given conditions. However, the standards do not provide coverage of subsequent steps in the supply chain, such as molybdenum roasting and ferro-alloying, and uptake of IRMA and Mining Association of Canada standards is generally low in the molybdenum mining industry.

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.

In addition to the developments around recognition by ResponsibleSteel, Copper Mark is currently partnering with the International Council for Mining and Metals (ICMM), the World Gold Council (WGC), and the Mining Association of Canada's Towards Sustainable Mining initiative to develop a unified global standard. This Consolidated Mining Standard Initiative (CMSI)[85] aims to harmonise existing voluntary frameworks into a single, comprehensive benchmark for responsible mining.

The Copper Mark is also developing a voluntary global Midstream Standard for copper, molybdenum, nickel, and zinc processing sites. This new standard aims to help midstream companies demonstrate responsible practices, meet regulatory and customer expectations, and strengthen their role in responsible supply chains. It will also allow current midstream participants to retain their Copper Mark recognition as the CMSI standard becomes limited to mining, smelting, and refining operations.[86]

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)[87] 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[88] and EU law[89] (for gold, tin, tungsten, and tantalum) and the London Metal Exchange (LME) listing requirements[90] (for base metals, though not for molybdenum, which is not currently listed on the LME[91]).

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".[92] The determination of the identified point, within a supply chain, is the individual responsibility of each company that applies the OECD DDG. 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. To this end, the Copper Mark Joint Due Diligence Standard was updated to include molybdenum and roasting was designated as the identified point.

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[85] Consolidated Mining Standard Initiative website. Home – Consolidated Mining Standard Initiative. (Accessed 16 October 2025)
[86] The Copper Mark website. Standard Development – The Copper Mark. (Accessed 16 October 2025)
[87] OECD. OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas. OECD Publishing, Third Edition, 2016. (Accessed 06 May 2025)
[88] U.S. Securities and Exchange Commission. Fact Sheet | Disclosing the Use of Conflict Minerals. (Accessed 06 May 2025).
[89] Official Journal of the European Union, The EU Conflict Minerals Regulation. The European Commission, 2017 (Accessed 06 May 2025)
[90] LME website - LME Responsible Sourcing Requirements. Sustainability at the LME | Responsible Sourcing. LME, 2019. (Accessed 06 May 2025)
[91] 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
[92] OECD. OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas. OECD Publishing, Third Edition, 2016. (Accessed 06 May 2025)

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:[93] [94]

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

Although there are currently no material-specific due diligence regulations that impact the molybdenum sector, larger companies operating on the European market may fall in scope of the Corporate Sustainability Due Diligence Directive (CSDDD)[95] and the Corporate Sustainability Reporting Directive (CSRD) in their revised form under the February 2025 omnibus proposal[96]. While the overall scope of these regulations is limited and their rollout delayed, key environmental and human rights supply chain requirements for large companies are preserved despite the omnibus.

In light of the above criteria, and in alignment with the updated Copper Mark Joint Due Diligence Standard for Copper, Lead, Molybdenum, Nickel and Zinc[97] [98], 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 molybdenum 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).

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[93] 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

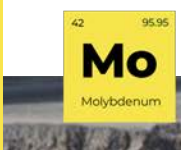
[94] China Chamber of Commerce of Metals, Minerals and Chemicals Importers and Exporters. Chinese Due Diligence Guidelines for Responsible Mineral Supply Chains. 2016. (Accessed 06 May 2025)

[95] The European Union. Directive (EU) 2024/1760 of the European Parliament and of the Council of 13 June 2024 on Corporate Sustainability Due Diligence and Amending Directive (EU) 2019/1937 and Regulation (EU) 2023/2859. European Commission, Brussels. (Accessed 06 May 2025)

[96] The European Union. Proposal for a Directive amending Directives 2006/43/EC, 2013/34/EU, (EU) 2022/2464 and (EU) 2024/1760 as Regards Certain Corporate Sustainability Reporting and Due Diligence Requirements. European Commission, Brussels, 2025. (Accessed 06 May 2025)

[97] The Copper Mark website. Standard Development – The Copper Mark. (Accessed 16 October 2025)

[98] The Copper Mark website. Joint Due Diligence Standard for Copper, Lead, Molybdenum, Nickel and Zinc. (Accessed 21 October 2025)



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 designated "refining" step in the molybdenum supply chain. Roasted Molybdenite Concentrate (RMC) 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 ferromolybdenum. 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.

IMOA welcomes the approach taken by the Joint Due Diligence Standard for Copper, Lead, Molybdenum, 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 MoS_2 lubricants produced from UMC.

Examples of molybdenum contributions to sustainability

IMOA has published a series of case studies that demonstrate some of the contributions molybdenum-containing products make to sustainability worldwide.

The Myllysilta Bridge, Finland[99]

A Life Cycle Assessment (LCA) of the Myllysilta Bridge in Finland, 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 in accordance with 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

[99] International Molybdenum Association and WSP. 'Benefits of Molybdenum Use: The Myllysilta Bridge, Finland', London, WSP UK Limited, 2015. (Accessed 06 May 2025)

include the electricity requirements to produce chromium- and nickel-based additives.[100] 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.

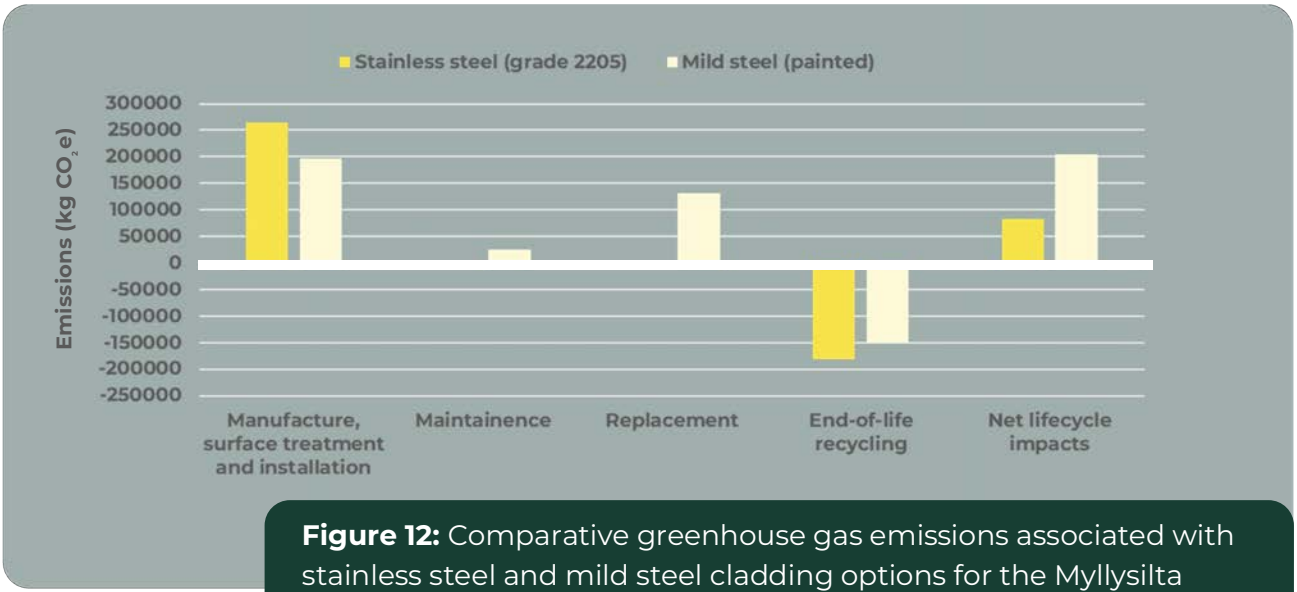


Figure 12: Comparative greenhouse gas emissions associated with stainless steel and mild steel cladding options for the Myllysilta Bridge, Finland (kg CO_2 e)

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 IMOA, include studies of ship hulls[101], equipment for desalination plants[102] and bolts used on offshore platforms[103]. 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.

[100] International Stainless Steel Forum. Stainless Steel and CO_2: Facts and Scientific Observations. 2015. (Accessed 06 May 2025)
[101] International Molybdenum Association. Making Eco-Friendly Waves | An Excerpt from MolyReview 2/2020. (Accessed 06 May 2025)
[102] International Molybdenum Association. Molybdenum in the Water Industry, Desalination Plants. (Accessed 6 May 2025)
[103] International Molybdenum Association. Lighter and Safer Offshore Platforms. 2018. (Accessed 06 May 2025)

Wind turbines and the role of molybdenum[104]

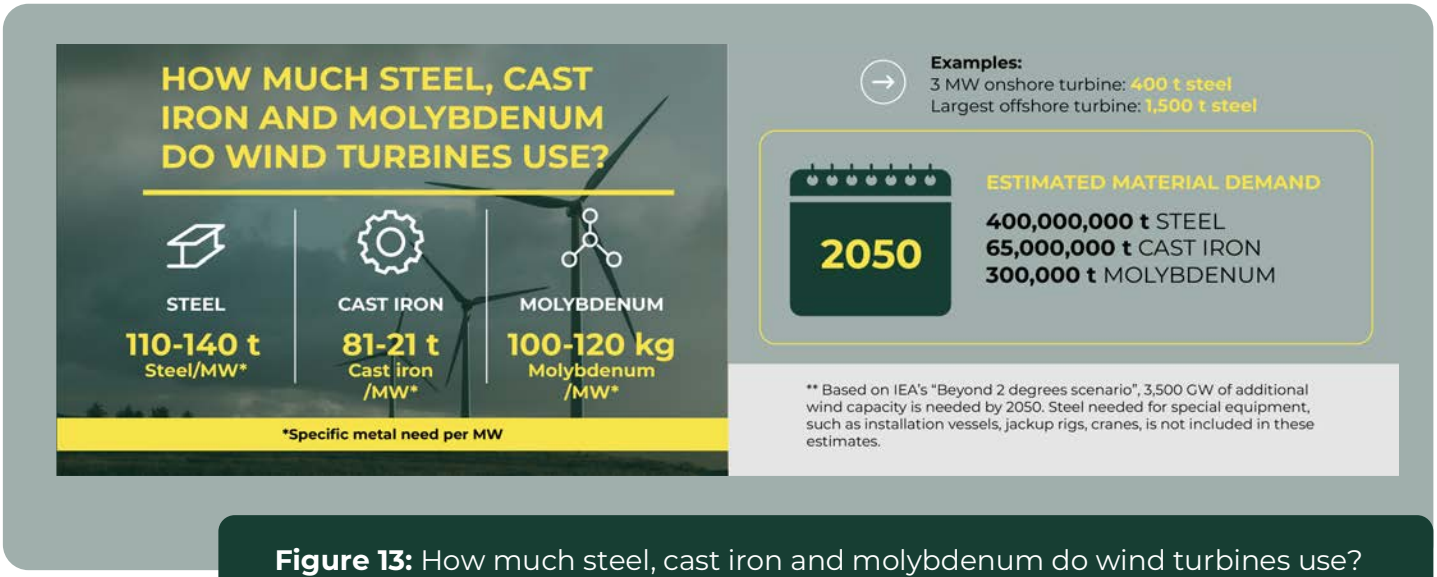


Figure 13: How much steel, cast iron and molybdenum do wind turbines use?

The global expansion of wind power is creating new demands for high-performance materials capable of withstanding increasing mechanical and environmental stresses. Modern wind turbines, particularly large onshore and offshore units, require substantial quantities of alloyed steels and cast irons for components such as main shafts, gearboxes, bearings, and fasteners.

Molybdenum plays a key role in enhancing the strength, toughness, and fatigue resistance of these materials, thereby extending service life and reducing maintenance requirements. Current industry practice employs gear steels containing 0.2–0.3% Mo, but as turbines scale up in size and torque output, the molybdenum content is expected to increase to 0.5–0.8%. Studies of modern wind turbine components show that each megawatt of installed capacity requires approximately 100–120 kilograms of molybdenum. As wind turbine technology advances, especially with the trend toward higher power ratings, a growing portion of the wind energy sector is expected to rely heavily on molybdenum-intensive materials. Projections indicate that by 2050, wind power infrastructure alone could consume around 300,000 metric tons of molybdenum, exceeding present annual global production. This trend underscores how renewable energy technologies not only reduce operational carbon emissions but also drive structural shifts in raw material demand, positioning molybdenum as a critical enabler of long-term energy transition infrastructure.

[104] International Molybdenum Association. Molybdenum: Essential for Wind Turbines. (Accessed 2 November 2025)

Reducing friction through molybdenum-enhanced materials[105]

Frictional losses in mechanical systems represent a major but often overlooked contributor to global energy inefficiency, accounting for an estimated 20–33% of total energy consumption and significant associated CO_2 emissions. Innovations in both lubrication and material engineering offer powerful opportunities for improvement, with molybdenum playing a pivotal role in both domains. Molybdenum disulfide (MoS_2) and organo-molybdenum additives are used to reduce friction within lubricants, while molybdenum-alloyed steels inherently improve surface hardness, wear resistance, and efficiency in moving parts such as gears and bearings.

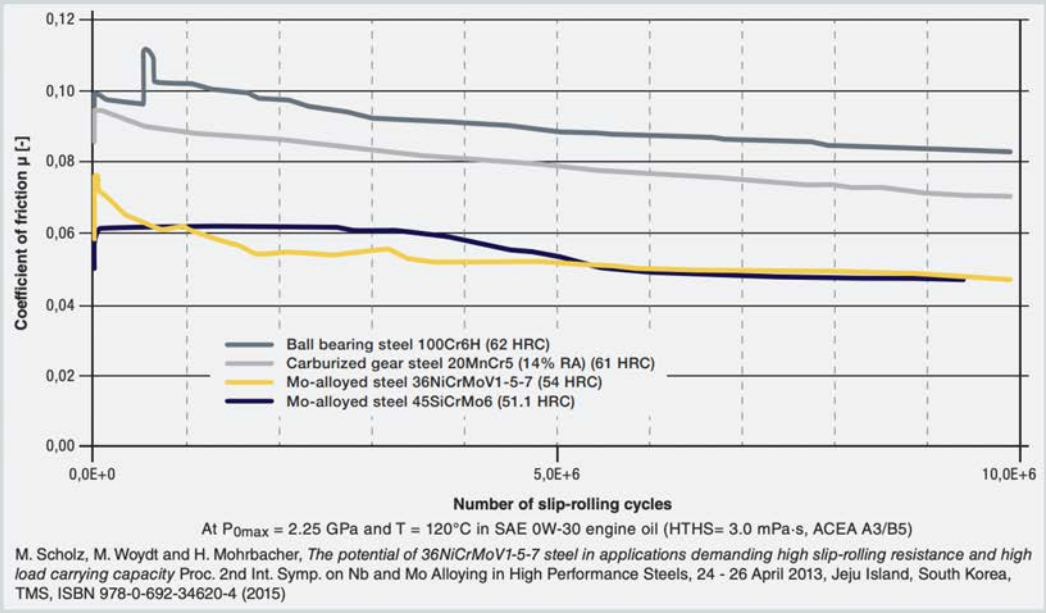


Figure 14: Development of coefficient of friction over 10 million slip rolling cycles between uncoated alloys of the same grade.

Field testing of Mo-alloyed gear steels has demonstrated reductions in friction coefficients of up to 30–40% compared to conventional steels, translating into measurable performance and energy gains across industrial applications. By integrating molybdenum into core mechanical systems, manufacturers can achieve not only longer component lifespans but also substantial reductions in energy loss, positioning material innovation as a key strategy in global decarbonisation efforts.

[105] International Molybdenum Association. Running Smoothly with Moly — Friction: a Headache for the Environment and Economics. (Accessed 2 November 2025)

Molybdenum disulfide (MoS_2) is an exceptional lubricant due to its layered structure, where molybdenum atoms are sandwiched between sulphide layers that slide easily over one another, resulting in a very low coefficient of friction. It remains stable at temperatures up to 350°C in air and 1200°C in vacuum or inert atmospheres, making it suitable for high-temperature applications such as greases, coatings, and friction materials. In addition, solid MoS_2, organo-molybdenum compounds, such as molybdenum dialkyldithiocarbamate and molybdenum di(2-ethylhexyl) phosphorodithioate, act as chemical friction modifiers in engine oils, forming thin protective films that can lower friction coefficients to around 0.04, though the effect diminishes over time. Typically added at concentrations of 0.3–0.7% by weight, similar to molybdenum content in alloyed steels, these additives greatly enhance lubrication efficiency. Overall, molybdenum-based lubricants and alloys can nearly halve frictional losses, offering significant energy savings and supporting global efforts to reduce emissions and achieve net-zero climate targets by 2050.

Molybdenum in carbon capture and storage infrastructure[106]

The implementation of Carbon Capture, Utilisation, and Storage (CCUS) technologies is essential for achieving net-zero targets, particularly in sectors where emissions are difficult to eliminate. However, the process environments involved, which are characterised by high pressures, low temperatures, and the presence of corrosive impurities in CO_2 streams, pose significant material challenges for pipelines, storage wells, and associated infrastructure. To ensure safety and reliability under these extreme conditions, engineers increasingly rely on duplex and super-duplex stainless steels as well as nickel-based alloys containing elevated molybdenum levels (typically 3% or more). These alloys offer exceptional corrosion resistance and toughness, even under cryogenic and acidic conditions.

According to the Association for Materials Protection and Performance (AMPP) Guide 21532, Type 316 stainless steel, which contains molybdenum, is suitable for compressors, cooling systems, and onshore pipelines that handle dense or liquefied CO_2, even at temperatures as low as –80 °C. For offshore and coastal pipelines, where chloride exposure is greater, higher-alloyed 6% molybdenum stainless steels or coated Type 316 are recommended for enhanced corrosion protection. Other critical process components, such as valves, flowmeters, and adsorption or desorption towers, also rely on stainless steels for durability. In more corrosive well environments, nickel-based Alloy 625, containing about 9% molybdenum, is preferred for wellheads and trees exposed to acidic or water-bearing conditions. Casings are typically made from low-alloy molybdenum steels like L80, F22, or AISI 4130, while well tubing often employs 25Cr super duplex stainless steel with around 3.5% molybdenum, offering high strength and exceptional corrosion resistance.

[106] International Molybdenum Association. Molybdenum: a Key to Carbon Capture. (Excerpt from MolyReview 2/2024). (Accessed 2 November 2025)

For example, Norway's Northern Lights project employs super-duplex stainless steel with approximately 3% Mo in its deep injection casing to withstand both CO_2 corrosion and low-temperature brittleness. This application highlights the critical role of molybdenum-containing alloys in enabling the long-term viability of CCUS infrastructure and, by extension, the broader global decarbonisation strategy.

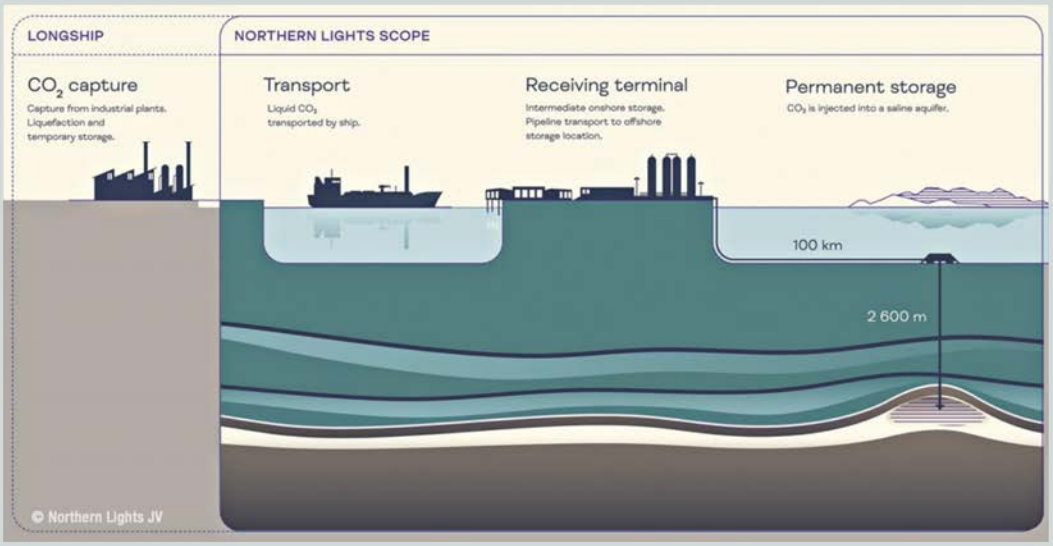


Figure 15: The Longship CCS value chain of the Northern Lights Project

Appendix I: Country risk indicators

Countries experiencing poor human rights

Very low risk: 0-20

Low risk: 20-40

Moderate risk: 40-60

High risk: 60-80

Very high risk: 80-100

This criterion measures the material's strength of association with key producer countries that experience poor human rights. This is determined by the following country-level indices:

- The Cato Institute Human Freedom Index;
- World Governance Indicators Government Effectiveness;
- World Governance Indicators Voice and Accountability; and
- International Trade Union Confederation Global Rights Index.

For each of the indices, the given ratings are normalised onto a 0-100 scale, where scores closer to 100 indicate a greater risk. The country rating is calculated by taking the average of its underlying indices. The rating for this criterion is then determined by multiplying the percent of global production of each of the top producer countries of the material with points attributed to five levels of poor human rights determined by the relative position of each country in the country-level indices indicator ranking. It should be noted that this criterion does not illustrate/measure the direct association between each material and poor human rights.

Countries experiencing poor environmental governance

Very low risk: 0-20

Low risk: 20-40

Moderate risk: 40-60

High risk: 60-80

Very high risk: 80-100

This criterion measures the material's strength of association with producer countries that have poor environmental governance. This is determined by the Yale Environmental Performance Index (EPI). The EPI provides a summary of the state of sustainability around the world. It ranks 180 countries on their progress toward improving environmental health, protecting ecosystem vitality and mitigating climate change, using 40 performance

indicators across 11 issue categories. The given ratings are normalised onto a 0-100 scale, where scores closer to 100 indicate a greater risk. The rating for this criterion is then determined by multiplying the percent of global production of each of the top producer countries of the material with points attributed to five levels of poor environmental governance determined by the relative position of each country in the country-level indices indicator ranking. It should be noted that this criterion does not illustrate/measure the direct association between each material and conflict.

Rule of law

Very low risk: 0-20

Low risk: 20-40

Moderate risk: 40-60

High risk: 60-80

Very high risk: 80-100

This criterion identifies whether the key producing countries of each material are associated with weak Rule of Law. This is determined by the following country-level indices:

- The Transparency International Corruption Perceptions Index
- World Governance Indicators Political Stability and Absence from Violence and Terrorism
- World Governance Indicators Rule of Law

For each of the indices, the given ratings are normalised onto a 0-100 scale, where scores closer to 100 indicate a greater risk. The country rating is calculated by taking the average of its underlying indices. The rating for this criterion is then determined by multiplying the percent of global production of each of the top producer countries of the material with points attributed to five levels of weak Rule of Law determined by the relative position of each country in the country-level indices indicator ranking. It should be noted that this criterion does not illustrate/measure the direct association between each material and weak rule of law.

Countries experiencing conflict

Very low risk: 0-20

Low risk: 20-40

Moderate risk: 40-60

High risk: 60-80

Very high risk: 80-100

This criterion measures the material's strength of association with key producing countries experiencing conflict. This is determined by the following country-level indices:

- The Heidelberg Institute Conflict Barometer;
- Fund for Peace Fragile States Index;
- World Governance Indicators Political Stability and Absence of Violence; and
- Vision of Humanity Global Peace Index.

For each of the indices, the given ratings are normalised onto a 0-100 scale, where scores closer to 100 indicate a greater risk. The country rating is calculated by combining its underlying indices using the geometric mean. Using the geometric mean causes countries with significant governance weakness in every area to be rated worse than countries with a mix of governance strengths and isolated (but more severe) governance weakness. Averaging in this way reflects the reality of responsible sourcing environments, in which the greatest risk is presented by systemic weakness across all aspects of governance. High risk countries for responsible sourcing are typically those in which governance failings compound each other. The rating for this criterion is then determined by multiplying the percent of global production of each of the top producer countries of the material, with points attributed to five levels of conflict determined by the relative position of each country in the country-level indices indicator ranking. It should be noted that this criterion does not illustrate/measure the direct association between each material and conflict.

Appendix II: 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: Annualised volatility (%) is calculated as the sample standard deviation of daily log returns over the observation period, adjusted to a 1-year horizon by multiplying by the square root of the number of trading days per year (252).
Daily log returns are defined as $r_t=ln(P_t/P_{t-1})$, where P_t is the observed price on trading day t.

Scoring range (benchmarked by TDi Sustainability):

Price volatility grade

Very low: less than 0.10

Low: from 0.1 to 0.2

Moderate: from 0.2 to 0.3

High: from 0.3 to 0.4

Very High: more than 0.4

Supply chain concentration

Very low: less than 0.15

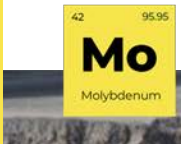
Low: from 0.15 to 0.2

Moderate: from 0.2 to 0.3

High: from 0.3 to 0.5

Very High: more than 0.5

This index measures the geographic concentration of mineral production via the Herfindahl- Hirschman market concentration index. This indicates whether a mineral is predominantly mined in just a few key countries, and is therefore more prone to supply disruptions, or whether production is more evenly distributed worldwide. A hypothetical score of 1 would mean that 100% of all production is concentrated in one country. The index



is calculated using a formula based on country production shares. It measures the geographic concentration of production, indicating whether the material is predominantly produced in just a few key countries, and therefore more prone to supply disruptions, or whether production it is more evenly distributed worldwide.

Appendix III: 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 1.000, and is a product of the properties described below:

Adapted from the UN Guiding Principles on Business and Human Rights (UNGPs) and Mitchell, Agle and Woods' (MAW) 1997 theory of stakeholder salience.

Each ESG issue is graded for the significance, or 'salience', of its association with a material's production and processing in such a way that allows objective comparison between materials.

The salience methodology reviews public issues as mentioned in public issue reports and authoritative literature sources, rating:

- **Gravity:** severity of the allegations
- **Evidentiality:** credibility of the source
- **Reach:** Influence of the source and number of public issue reports on a single public issue identified over the last five years

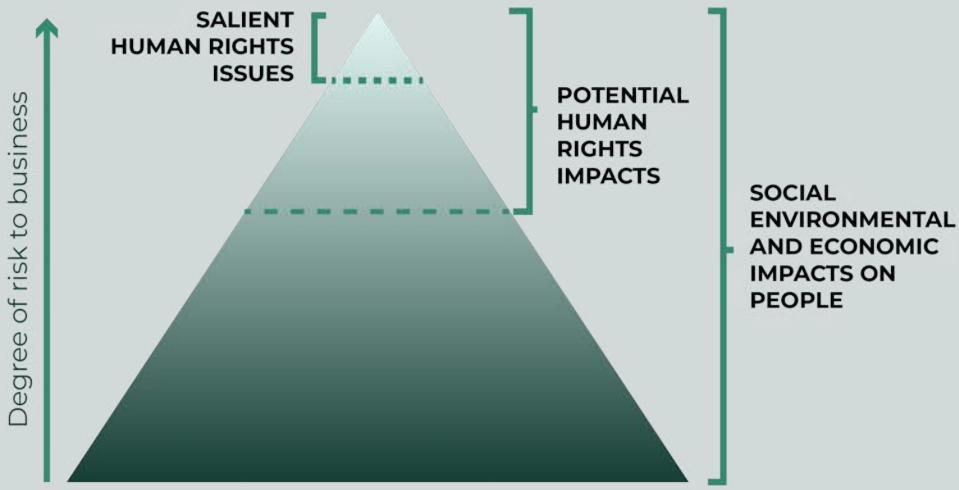


Figure 16: Salience methodology

The salience methodology is applied to two types of data:

- **Public reports** such as articles, civil society reports, academic and peer-reviewed papers, on ESG incidences or allegations reported in association with a material. This allows the measure the salience of the impact, including the impact on people and planet and the impact on corporate reputation. See the below charts for further detail.
- **Authoritative literature** - an adapted version of the same salience criteria is applied to authoritative literature sources (e.g. studies, seminal work, analyses) for which an ESG issue is the subject.

Criteria rating guidelines

Gravity

DETERMINNG AN OVERALL GRAVITY RATING			
Impact Scale Rating	Permanence Rating		
	Short-term harm (1)	**Medium-term (2)**	**Long-term (3)**
Very serious (3)	2	3	3
Serious (2)	1	2	3
Somewhat serious (1)	1	1	2

Evidentiality

Score	Description
1	• Vague or broadly general allegations or claims lacking specific detail, direct/indirect accounts of events, verification and references to source information.
2	• Evidence is presented, but the evidence does not conclusively support the assertion of an issue, and the source of information has not been triangulated/verified. For example, there is video footage of alleged abuses but there is doubt as to whether footage was filmed around the mine site (i.e., fake news), or documentary evidence is circumstantial. • Evidence is limited to testimony by allegedly affected individuals and secondary reporting from other sources.
3	• Direct evidence has been presented that strongly supports the assertion of an issue, and the source of information is conclusive and has been triangulated. For example, there is video footage of alleged abuses, company/government officials publicly confirming the issue, legal verdict in favour of the affected individuals. • The methodology used to determine an impact has reached consensus in the science community and is replicable. For example, deforestation is presented through remote sensing.

Reach

Score	Description
1	• Confined to blogs and social media.
2	Single report: • Coverage by national/local media or think tanks • Coverage by international/national/local consultancy or NGO Unique Issue: • Uptake by 1-4 sources graded with a reach score of 2 • Uptake by 1 influential source (i.e. with a reach score of 3) • Uptake by 10 blogs

3	Single report: • Coverage by major international organisations (e.g., UNHRC) or major intervention by government regulator • Coverage by international media with an established international readership. 'International media' is defined as media with an established and large readership outside the country in which the issue occurred • Coverage in peer reviewed academic journals and white papers, or by educational or governmental institutions, or sustained NGO / legal campaigns • Listed as a Key Source by TDi Unique Issue: • Uptake by 2 or more influential sources • Uptake by 5 sources graded with a reach score of 2

More information on the salience score calculation can be provided on request.

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.[107] In recent years, however, China has undertaken a vigorous drive to improve environmental performance at mines, even at the cost of lower production.[108]

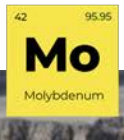
Operational health and safety standards in Chinese mines are generally lower than those in developed countries. While the country has made strides in reducing mining accidents with fatalities dropping by 31.9% and overall accidents decreasing by 25.6% as of August 2024,[109] safety standards remain a concern.

Authorities stated in 2015 that approximately 37,000 illegal mineral mines were operating in China.[110] As of 2025, specific data on the number of illegal mining operations in China is limited. However, authorities have been actively addressing illegal mining activities. In 2017, the government announced plans to shut down 6,000 non-coal mines by 2020 to improve safety standards, while in 2022, China launched a separate year-long campaign targeting illegal gold mining to mitigate environmental damage and prevent accidents.[111] This is significant because operational health, safety and environmental performance is often lower at illegal mining operations than at legal ones. Efforts are on-going to curtail illegal mining in the country.[112]

In terms of labour rights, China has faced international scrutiny over its treatment of ethnic minorities in regions like Tibet and Xinjiang. Reports indicate that over 930,000 rural Tibetans are expected to be relocated to urban areas by the end of 2025, often under pressure, disrupting traditional livelihoods and raising concerns about forced labour and human rights abuses.[113]

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.[114] However, civil society

[107] The Washington Post. Chinese Metal Mines Feed the Global demand for Gadgets. They're also Poisoning China's Poorest Regions. 2019. (Accessed 6 May 2025)
[108] S&P Global Market Intelligence. China And The Environment – Industry Versus Air. 2019. (Accessed 6 May 2025)
[109] China Daily. China Records Double-Digit Drop in Mining Accident Deaths. 2024. (Accessed 10 Dec 2025)
[110] Ibid.
[111] Asia News Network. Chinese Government Cracks Down on Illegal Gold Mining. 2022.
[112] Reuters. China To Step Up Crackdown on Rare Earth Sector: Ministry. 2019. (Accessed 6 May 2025)
[113] AP. China is Accelerating the Forced Urbanization of Rural Tibetans, Rights Group Says. 2024. (Accessed 3 December 2025)
[114] China Chamber of Commerce of Metals, Minerals & Chemicals Importers & Exporters. Chinese Due Diligence Guidelines for Responsible Mineral Supply Chains. (Accessed 10 December 2025)



observers have commented that implementation of responsible sourcing remains very low in the Chinese minerals industry.[115]

Iran

Iran is governed by a clerical elite that exerts tight ideological control and has little tolerance for dissent.[116] 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.[117] [118] 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.[119] This exemption has been a point of contention, with environmental authorities, such as the Department of Environment (DOE), expressing concerns that it undermines sustainable development and environmental protection. In response, the DOE has sought to mitigate environmental impacts through other legislative measures, such as the Soil Protection Law, enacted in 2019. This law prohibits soil trade and mandates compliance from various industries, including mining, to prevent soil contamination.[120] However, there is a risk that environmental impacts associated with minerals sourced from Iran have not been comprehensively accounted for and addressed.

Kazakhstan

Kazakhstan faces persistent criticism for its restrictions on civil liberties, including limited freedom of expression, assembly, and association. The government maintains tight control over political participation, with elections lacking genuine competitiveness and independent media often facing censorship or intimidation.[121] Dissent is frequently suppressed, and those who challenge the authorities - whether activists,

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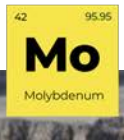
[115] Business and Human Rights Resource Centre. Responsible Mineral Supply Chain Efforts in China: Progress and Challenges. (Accessed 6 May 2025)
[116] BBC News. Iran Country Profile. 2024. (Accessed 6 May 2025)
[117] IndustriALL Global Union. Flogged and Jailed Workers in Iran Face Repression. 2016. (Accessed 6 May 2025)
[118] Iran News Wire. 7 Iranians, Unable to pay Fine for Peaceful Protests Jailed in NW Iran. (Accessed 6 May 2025)
[119] Bakhtiari, F. 'Mining Must Not Come at Cost of Environmental Degradation.' *Tehran Times*, 2020. (Accessed 6 May 2025)
[120] Bakhtiari, F. 'Mining Must Not Come at Cost of Environmental Degradation.' *Tehran Times*, 2020. (Accessed 6 May 2025)
[121] Human Rights Watch. Kazakhstan, Events of 2022. (accessed 6 May 2025)



journalists, or opposition figures - risk harassment or legal repercussions.[122] The public sector also struggles with inefficiency, corruption, and a lack of transparency, undermining trust in government institutions.[123] Labour rights are particularly constrained, as independent unions face significant barriers, strikes are restricted, and union leaders are often subjected to state pressure or prosecution. These conditions reflect a broader environment where political control and the curtailment of rights limit meaningful civic engagement and democratic governance.

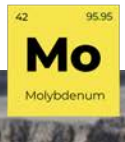
There have been reports of state repression of political dissent, labour activism, and environmental advocacy - particularly in sectors like mining and resource extraction. Independent trade unions face severe restrictions, and workers who organise or protest often do so at great personal risk. This was particularly evident during the January 2022 unrest. Initially sparked by protests over rising fuel prices, the demonstrations quickly escalated into widespread anti-government rallies. In response, security forces responded with lethal force, resulting in the deaths of at least 238 individuals.[124] Human Rights Watch documented instances where security forces used excessive force, including lethal measures, against protesters who posed no immediate threat[125]

Mexico

Until recently, mining activities were afforded special status under Mexican law. They have had preference over all other land uses and were granted unfettered access to natural resources, including the free and unrestricted use of water. However, as of 2025, mining no longer holds preferential status under Mexican law, following major reforms enacted in May 2023. These changes removed mining's legal priority over other land uses and ended its unrestricted access to water and natural resources. Concessions must now be awarded through public bidding, and mining is prohibited in areas with limited water, environmental protection zones, and regions where it poses social risks.[126] Water use for mining is now regulated, with usage subject to reduction or cancellation if it threatens human consumption. Additionally, mining companies must conduct social impact assessments and engage in prior consultations with indigenous and Afro-Mexican communities.[127]

Despite the positive recent legal reforms, issues persist when it comes to Mexico's environmental performance. The country faces significant issues in areas such as forest management, wastewater treatment, and biodiversity conservation. For instance, according

[122] Amnesty International. Kazakhstan. (Accessed 6 May 2025)
[123] Transparency International. Kazakhstan. (Accessed 6 May 2025)
[124] Foreign Policy. Kazakhstan Can't Torture Its Way to Stability. (Accessed 6 May 2025)
[125] Human Rights Watch. Kazakhstan, Events of 2022. (accessed 6 May 2025)
[126] Hogan Lovells. Mexico Approves Mining Reform. 2023. (Accessed 6 May 2025)
[127] UN Trade and Development (UNCTAD) Investment Policy Hub. Reforms the Mining Regime for Enhanced Environmental and Social Protection. (Accessed May 6 2025)



to the Yale Environmental Performance Index (EPI), Mexico ranks 131st in the effectiveness of its protected areas and 141st in biodiversity and habitats. Air quality and waste management are also pressing concerns, with rankings of 129th and 127th, respectively.[128] These shortcomings are compounded by weak enforcement of environmental regulations, limited resources for monitoring and inspection, and insufficient public participation in environmental governance.

Additionally, community rights, including indigenous rights, are often threatened. According to development organisations, deep community divisions still often exist between those who seek to benefit economically from mining and those who wish to preserve the environment and traditional ways of life. Frequent allegations are made of violence and intimidation against anti-mining activists.[129]

Overall high levels of violence and insecurity in Mexico are strongly associated with the country's drug cartels. 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.[130] A risk therefore exists that violent organised crime could in the future affect molybdenum production in Mexico, too.

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%.[131] In 2024, the mining sector accounted for 30% of Mongolia's GDP, 72% of industrial output, 79% of foreign direct investment, 94% of exports, and approximately one-third of state budget revenue. This underscores the sector's central importance to the country's economic framework.[132] Nearly a fifth of Mongolia's land area has been made available for mining exploration.[133] 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.

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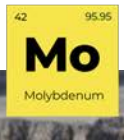
[128] Yale Environmental Performance Index. (Accessed 6 May 2025)
[129] SOMO. There is more than 3TG, The Need for the Inclusion of all Minerals in EU Regulation for Conflict Due Diligence. 2015. (Accessed 6 May 2025)
[130] Daily Mail Online. Mexican Drug Cartels Move Into Lucrative Mining Industry and Exportation Of Iron Ore to China in Mafia-Style Penetration of Country's Economy. (Accessed 06 May 2025)
[131] Helbe, M., Hill, H., and Magee, D. 'Mongolia's Economic Prospects, Resource-Rich and Land Locked Between Two Giants.' Asian Development Bank, Manila. 2020, p.123. (Accessed 6 May 2025)
[132] 'A Review of the Mining Sector in 2024' Mongolian Mining Journal. 2025. (Accessed 4 December 2025)
[133] Reuters. Cash-strapped Mongolia Offers More Land for Mining Projects. Reuters. 2015. (Accessed 6 May 2025)



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,[134] and impacting the livelihoods of local communities, many of whom are dependent on traditional herding lifestyles.[135] Community livelihoods are also reportedly disrupted by the encroachment of industrial activity, infrastructure development[136] and dust emissions associated with mining.[137]

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.[138]

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.[139]

Russia

In 2025, the country risk level of Russia, particularly in relation to mineral supply chains, remains high due to ongoing geopolitical tensions and economic sanctions. Since Russia's invasion of Ukraine in 2022, Western countries have imposed stringent sanctions on the Russian economy, targeting key sectors such as energy, defense, and mineral exports. As a result, international companies operating in or sourcing minerals from Russia face significant challenges, including the risk of supply chain disruptions, higher costs, and the potential for further sanctions. Russia is a key global supplier of minerals like palladium, nickel, platinum, and aluminium, but its trade relationships are increasingly constrained by these geopolitical issues, especially with the EU and the US.[140]

Despite Russia's significant mineral reserves, the risk associated with operating within its borders has prompted companies to seek alternative suppliers or diversify their sources to mitigate potential disruptions. The volatility of the Russian ruble and the country's reliance

[134] Woods, L.'Mining Threatens Mongolia's Fragile Environmental Balance.' Climate Diplomacy. 2016. (Accessed 6 May 2025)
[135] IUCN, et.al. 'Mining in Mongolia, Engaging Local Communities to Help reduce the Impacts of Mining.' (Accessed 6 May 2025)
[136] The Conversation. Mongolian Mining Boom Threatens Traditional Herding. 2019. (Accessed 6 May 2025).
[137] Jackson, S.L. 'Dusty Roads and Disconnections: Perceptions of Dust from Unpaved Mining Roads in Mongolia's South Gobi Province.' Geoforum, Vol. 66, 2015, pp. 94 -105. (Accessed 6 May 2025)
[138] McGrath, Findanka et.al. 'Spirited Away - Mongolia's Mining Boom and the People That Development Left Behind.' CEE Bankwatch Network, 2011, p.5. (Accessed 6 May 2025)
[139] Stern, R. 'Mongolia's Mining Boom.' DW. (Accessed 6 May 2025)
[140] OECD Policy Responses on the Impacts of the War in Ukraine. 'The Supply of Critical Raw Materials Endangered by Russia's War on Ukraine.' OECD Publishing, Paris, 2022. (Accessed 4 December 2025)

on state-controlled enterprises in its mineral sector further complicate the stability of mineral supply chains. Additionally, logistical issues, such as sanctions affecting international shipping routes and the closure of Western financial channels, limit Russia's ability to engage with global markets. In 2025, the mineral supply chains connected to Russia are likely to remain vulnerable to political and economic shifts, making them an uncertain source of stability for international businesses. For companies reliant on Russian minerals or buying from sources outside of Russia not in compliance with Russian sanctions, it is crucial to continuously evaluate the evolving geopolitical landscape and be prepared for changes in trade policies, logistical challenges, and potential disruptions in supply.

Appendix V: Overview of voluntary standards schemes for large-scale mining

ISO 14001:[141] 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:[142] 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.

ISO 50001:[143] The leading international standard for energy management systems, developed by the International Standards Organisation. The standard provides a unified framework for all types of organisations to improve energy performance, increase energy efficiency, and reduce greenhouse gas emissions. ISO 50001 is process-based and emphasises the relationship between an organisation's operations and its energy use, enabling systematic, continual improvement in energy management.

ISO 26000:[144] The key international guidance standard on social responsibility, developed by the International Standards Organisation. The standard offers a comprehensive framework for all types of organisations to operate ethically and transparently, contribute to sustainable development, and address societal, environmental, and stakeholder expectations. Unlike management system standards such as ISO 50001, ISO 14001, or ISO 45001, ISO 26000 is not certifiable and does not set auditable requirements. Instead, it provides guidance rather than a formal system structure, helping organisations embed social responsibility into their culture and operations without offering a conformity certificate

[141] International Organisation for Standardisation website. ISO 14000 Family | Environmental Management. (Accessed 6 May 2025).
[142] International Organisation for Standardisation website. ISO 45001 – All You Need To Know. (Accessed 6 May 2025)
[143] International Organisation for Standardisation website. ISO 50001. (Accessed 4 December 2025)
[144] International Organisation for Standardisation website. ISO 26000. (Accessed 4 December 2025)

The International Council for Mining and Metals (ICMM) Performance Expectations:[145] 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.

The Initiative for Responsible Mining Assurance (IRMA) Standard for Responsible Mining:[146] 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 assessed against 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 organisations, affected communities and organised labour.

The Mining Association of Canada Towards Sustainable Mining (TSM):[147] 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.

[145] International Council on Mining and Metals website. Mining Principles. (Accessed 6 May 2025)
[146] Initiative for Responsible Mining Assurance website. Standards Development Process. (Accessed 6 May 2025)
[147] The Mining Association of Canada website. Towards Sustainable Mining. (Accessed 6 May 2025)

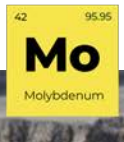
The International Finance Corporation (IFC) Performance Standards on Environmental and Social Sustainability:[148] The IFC Standards were developed for projects that receive IFC financing. They define clients' responsibilities for managing their environmental and social performance, provide guidance 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 Copper Mark:[149] 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 Molybdenum Mark:[150] Established by the Copper Mark organisation was added to its Joint Due Diligence Standard in 2022. The Joint Due Diligence Standard is a comprehensive assurance framework designed to promote responsible production and sourcing of molybdenum. Built on the same principles as the Copper Mark, it assesses environmental, social, and governance (ESG) practices at production sites. The Molybdenum Mark helps molybdenum producers demonstrate their commitment to sustainability and ethical practices, while offering customers and stakeholders greater transparency and confidence in the supply chain.

Joint Due Diligence Standard for Copper, Lead, Molybdenum, Nickel and Zinc [151]**:** The Copper Mark led 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 was to enable LME-listed brands'

[148] International Finance Corporation. Performance Standards. (Accessed 6 May 2025)
[149] The Copper Mark website | Home page. (Accessed 6 May 2025)
[150] The Copper Mark website | The Molybdenum Mark. (Accessed 6 May 2025)
[151] The Copper Mark website | The Joint Due Diligence Standard for Copper, Lead, Molybdenum, Nickel and Zinc. (Accessed 20 October 2025)



compliance with the exchange's responsible sourcing requirements. In August 2022 the Copper Mark Joint Due Diligence Standard was updated in conjunction with the International Molybdenum Association to include molybdenum. [152,153]

Consolidated Mining Standards Initiative: "The Copper Mark, ICMM, the Mining Association of Canada, and World Gold Council are working together to explore options to consolidate their four individual responsible mining standards into a single global standard and multi-stakeholder oversight system." [154] The development process began in 2023 and has been guided by two advisory groups: an Industry Advisory Group, and the other including a wide range of stakeholders (the Stakeholder Advisory Group). The draft Standard will be shared for two rounds of public consultation. The first consultation occurred in the fourth quarter 2024 and is now closed. The second round of public consultation is underway in the 4th quarter of 2025.

[152] The Copper Mark, International Lead Association, International Zinc Association, Nickel Institute, and Responsible Minerals Initiative. Press Release. Multi-Metal Coalition Publishes Joint Standard to Respond to LME Responsible Sourcing Rules. (Accessed 6 May 2025)
[153] The Copper Mark. Joint Due Diligence Standard for Copper, Lead, Molybdenum, Nickel and Zinc. Version 3, 24 August 2022. (Accessed 9 July 2025)
[154] The Consolidated Mining Standard Initiative website. About the Initiative. (Accessed 4 October 2025)