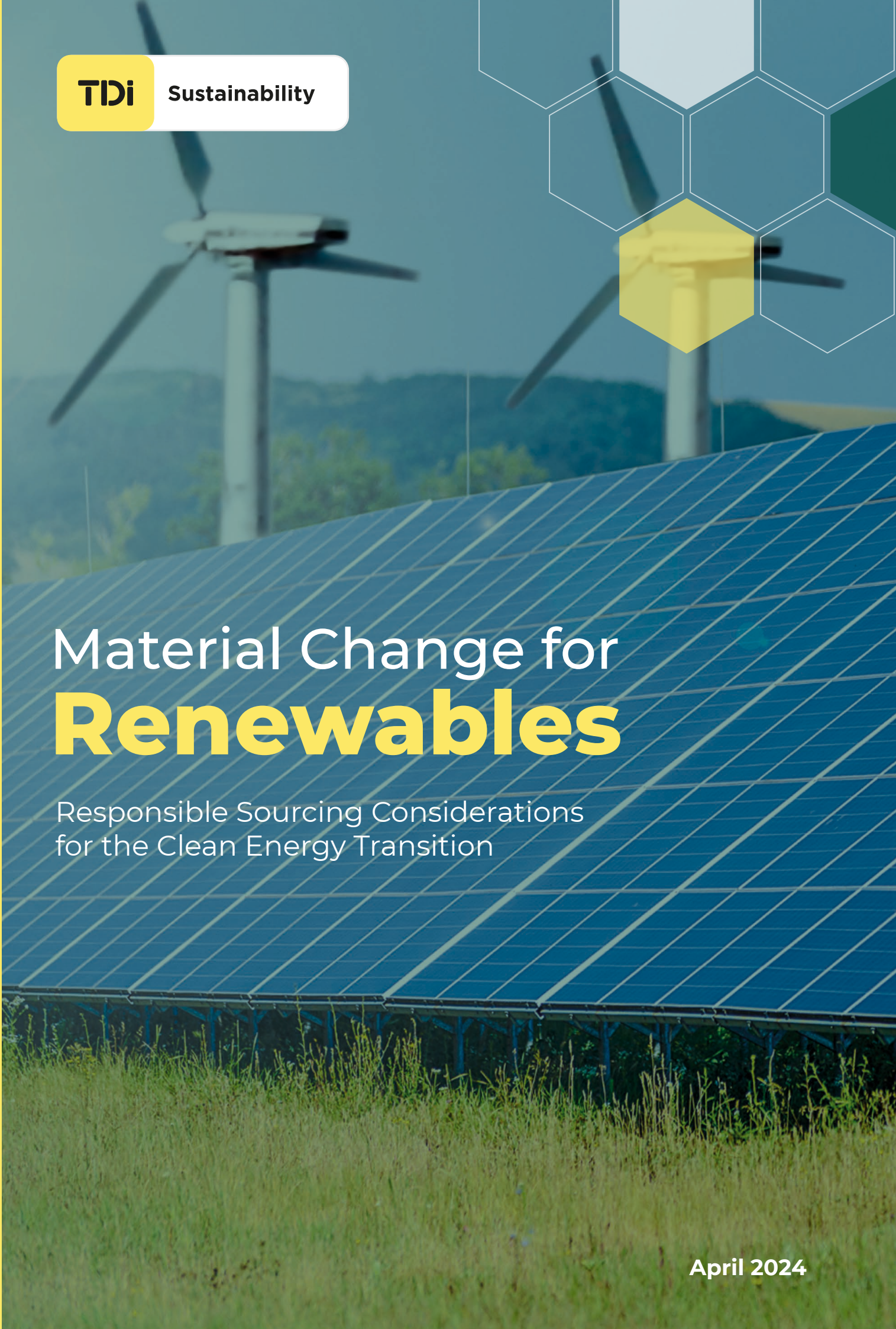
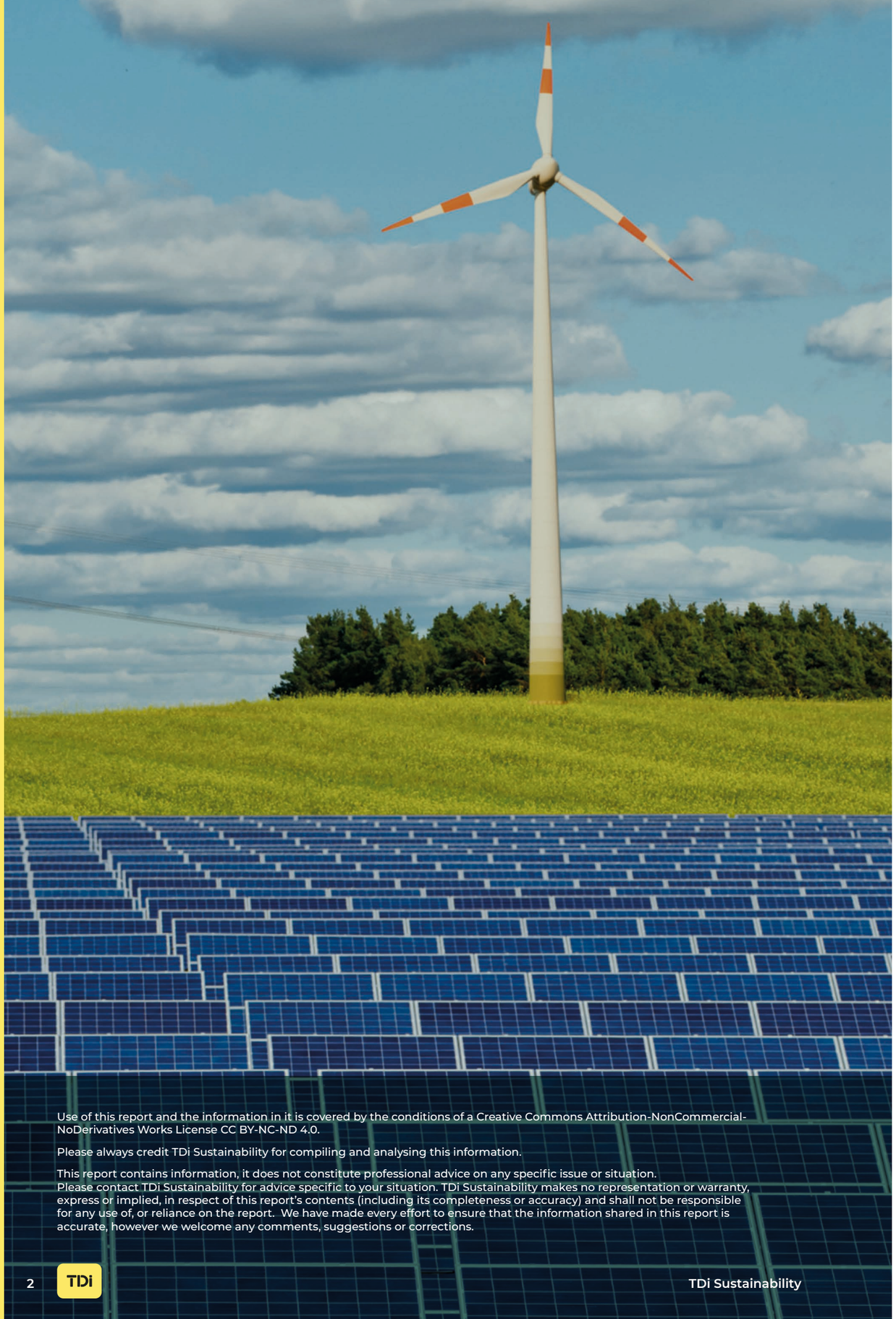
TDi Sustainability



Material Change for **Renewables**

Responsible Sourcing Considerations for the Clean Energy Transition

April 2024



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1. The Challenge and its Solutions

The future of clean energy lies in metals. An estimated three billion tons of metals will be required to produce the clean energy technology necessary to keep global warming under 2°C. To do this, production rates of some minerals may need to increase by up to 500 percent.[1]

While mineral production and recycling are rising, so are stakeholder expectations for strong Environmental, Social, and Governance (ESG) performance in supply chains. The challenge this presents for producers is broad. Localised negative ESG impacts must be minimised, resource use must be sustainable, supply chains must be resilient, and fundamental decisions must be made on how and where to extract the materials that are critical to the clean energy transition. In 20 years, the nickel in wind turbines and solar panels could just as easily come from the deep seabed as the forests of Indonesia. Sustainability considerations will play a key part in shaping future mineral sourcing.[2]

For purchasers and producers of clean energy, two key priorities are to ensure that the production of clean energy technologies does not cause undue harm to people and the environment when these technologies are sited and along the supply chain, and to ensure that production does not generate excessive amounts of the very greenhouse gasses that such technology is designed to reduce.

Some actions can be taken by companies individually, such as instituting supplier ESG codes of conduct, requiring suppliers to attain relevant voluntary sustainability standards, actively supporting capacity for the improvement of practices, and, where necessary, responsibly disengaging from poor-performing suppliers. However, as has been the case in other sectors, the greatest impetus for change builds when companies with a common purpose – such as buyers of clean energy – act collectively. Coordinated action and ESG expectations from buyers can ensure consistent messaging to suppliers and allow buyers' resources to be pooled and target improvements more effectively. This in turn ensures that suppliers can more easily and efficiently demonstrate how they are meeting buyers' ESG expectations.

This report considers the ESG challenges in sourcing faced by buyers of clean energy.

It examines where the key challenges lie in the mineral supply chains for solar panels and wind turbines, and presents approaches and resources for meeting these challenges. In Section 2, the subject of supply chain due diligence is introduced. In Section 3, the key minerals and metals used in solar panels and wind turbines are compared side-by-side for their association with a range of ESG risks, alongside a demonstrative sample of voluntary sustainability standards' ESG risk mitigation potential. Notable observations within the table are discussed. Section 4 presents profiles of three key materials for wind turbines and solar panels: aluminium, steel, and silicon. The profiles focus on ESG considerations for the materials, and how these considerations may affect, and be affected by, future rises in metal demand.

Based on this analysis, TDi Sustainability recommends that producers and purchasers of clean energy act individually and collectively to:

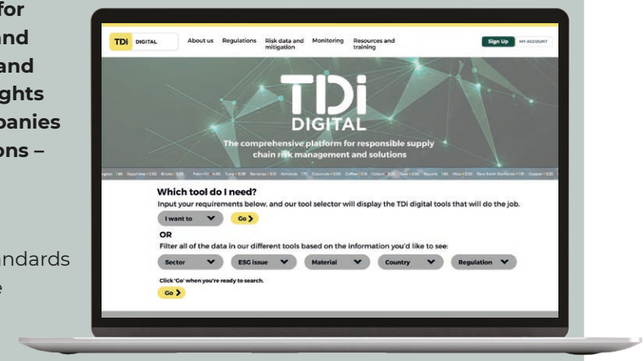
1. Assess, and prioritise for mitigation, the highest risk ESG issues present in supply chains for clean energy technology.
2. Develop supplier codes of conduct to ensure that companies in the clean energy technology supply chain institute strong management systems for ESG performance.
3. Evaluate and score supplier ESG performance using risk-based approaches.
4. Support and build the capacity of suppliers to achieve higher ESG performance where supplier resource and knowledge gaps exist.
5. Identify applicable voluntary sustainability standards to address priority ESG issues and engage suppliers to encourage the adoption of these standards.
6. Influence and support initiatives at the mining, processing, and manufacturing stages of the supply chain to directly address and mitigate the ESG issues that are present.
7. Leverage existing, publicly, and commercially available resources to facilitate the achievement of recommendations 1-6.

1 https://www.worldbank.org/en/topic/extractiveindustries/brief/climate-smart-mining-minerals-for-climate-action
2 https://www.weforum.org/whitepapers/decision-making-on-deep-sea-mineral-stewardship-a-supply-chain-perspective

This is not intended to be a comprehensive diligence of all input materials to renewable energy technologies, rather it is intended as a summary of the most salient issues, to raise awareness about priority potential and actual environmental and social issues in renewables' supply chains, and galvanise action for change. TDi Sustainability holds extensive databases on minerals and metals supply chains and analyses of corporate risk.

The box below contains more information on these databases and tools.

TDi Digital is a comprehensive platform for responsible supply chain management and end to end sustainable digital solutions and services. Its tools provide actionable insights for sourcing requirements, helping companies to meet market and regulator expectations – quickly, robustly, and cost-effectively.



TDi Digital includes tools to:

- Compare legislation, regulations, and standards by country, material, sector, and risk type
- Interrogate and monitor risk data
- Help engage suppliers
- Put in place integrated management systems

tdi-digital.com

It also provides management solutions for specific ESG issues and impacts, as well as resources and toolkits to build knowledge and capacity around ESG requirements.

The TDi CAHRA Index combines data from eleven international institutions and civil society to assess a country's likelihood to meet the OECD's CAHRA criteria as high, moderate, or low risk.

CAHRA

The Integrated Compliance Assurance Tool (ICAT): Quickly identify the ESG standards most relevant to your operations and risk exposure (more information on page 9).

ICAT

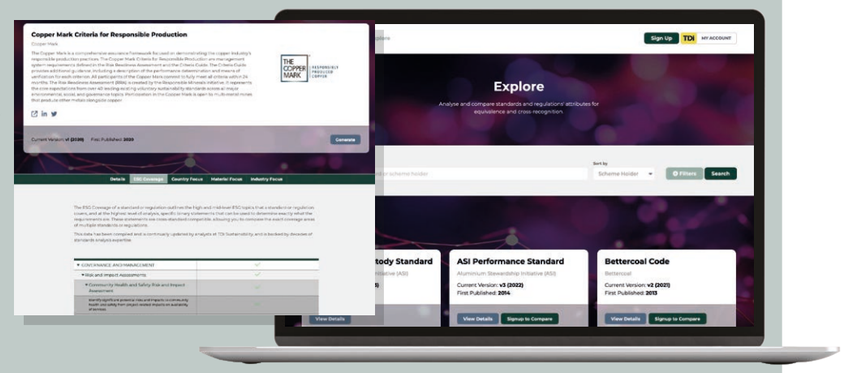
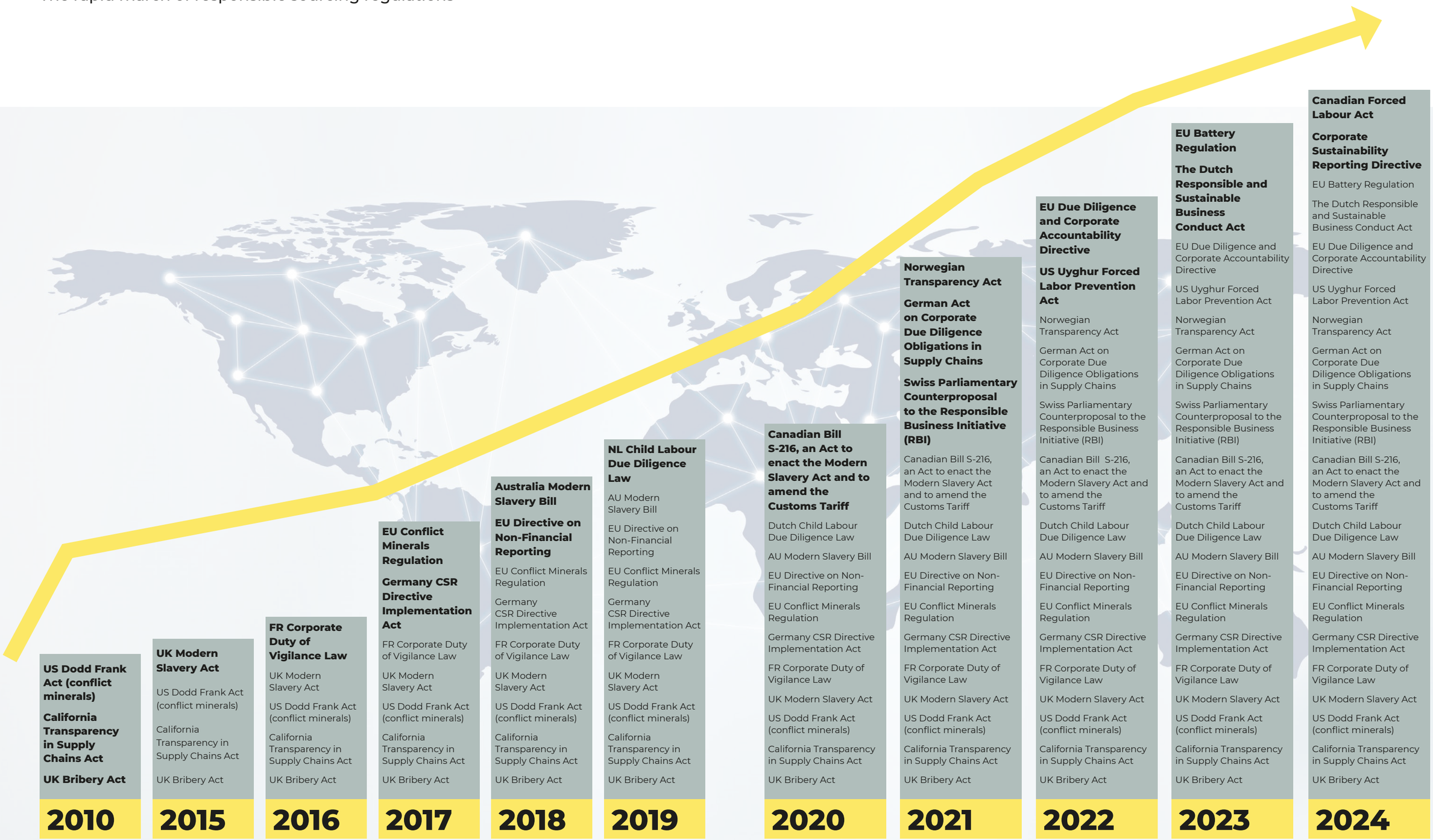


Figure 1.

The rapid march of responsible sourcing regulations



2. Supply Chain Due Diligence and Stakeholder Expectations

Solar panels, wind turbines, and other clean energy technologies need large quantities of minerals, and mineral extraction and processing can – when poorly managed – be associated with harm to people and planet.

Recent media articles, like 'The Green Economy's Heart of Darkness'[3] highlight ESG issues such as forced and child labour and dangerous working conditions of artisanal and small-scale cobalt mining in the DRC. The Guardian identified manganese as causing water pollution resulting in significant chronic health conditions and harm to the Indigenous Batek group in Malaysia.[4]

Bauxite, an input material for aluminium, has been cited as being strongly associated with company-community conflict in Brazil and West Africa. Aluminium is also likely to come under ever-increasing scrutiny over its contribution to climate change, as its production processes are responsible for approximately 6% of all global coal power generation.[5]

These examples indicate how much potential exists for reputational damage, when responsible and well-intentioned clean energy initiatives do not take a proactive approach to due diligence and to promoting and enabling responsible practices in their mineral supply chains.

Expectations for supply chain due diligence are growing steadily higher in general, for all industries, minerals, and origins. As Figure 1 shows, responsible sourcing legislation has greatly increased since 2010 in many jurisdictions worldwide. This rise in legislation correlates with growing public, civil society, and stakeholder scrutiny of companies' environmental and social impacts in their supply chains.

There is an expanding landscape of frameworks and norms for how assurance of supply chain safeguards can be met. Supply chain due diligence is a process through which negative impacts in supply chains are identified, and supplier engagement is undertaken to help mitigate these impacts. A widely accepted process for supply chain due diligence is set out in the OECD Due Diligence Guidance for Responsible Business Conduct, the steps for which are shown Figure 2. Many compliance instruments have invoked or adopted similar processes as the OECD's. In line with step two of the OECD due diligence process, identifying and assessing adverse impacts, the following sections of this report examine the adverse impacts most frequently reported in supply chains for key minerals in solar panels and wind turbines. Mitigation measures, focussing on the adoption of appropriate voluntary sustainability standards, are then identified for each issue in line with step three; cease, prevent or mitigate impacts.

Figure 2.

The due diligence process as described in the OECD Due Diligence Guidance for Responsible Business Conduct.[6]

3 https://compactmag.com/article/the-green-economy-s-heart-of-darkness
4 https://www.theguardian.com/world/2019/sep/07/from-jungle-to-death-trap-fate-of-malaysia-last-nomads
5 https://ember-climate.org/insights/research/coal-power-plants-aluminiums-dirty-little-secret/
6 https://mneguidelines.oecd.org/Flyer-RBC-Due-Diligence.pdf

3. ESG Issue Salience and Voluntary Standards Coverage Comparison

Figure 3A, on the next page, tabulates a range of ESG issues commonly associated with mineral supply chains in the renewables industries' supply chains.

The minerals selected form the main composition of solar panels and wind turbines and are predicted to make up future demand of raw materials needed to manufacture these clean energy technologies, according to reports by the International Institute for Sustainable Development (IISD) and the European Commission's Joint Research Centre.[7,8]

Each issue is graded for the significance, or 'salience', of its association with minerals used to construct solar panels and wind turbines. The examination of salience uses two methodologies to assess ESG issues. The majority of ESG issues in the table below are assessed according to the number of salient public issues reported on an issue in association with a material, the credibility and influence of these reports, and the severity of the adverse impacts. Other ESG issues are determined through our assessment of credible, peer reviewed sources of data and analysis on the association of a material with an issue.

Below that first table, Figure 3B shows which issues are covered by a selection of prominent voluntary sustainability standards. These standards aim to verify that companies' management and control systems are in place and can avoid and mitigate adverse effects from their activities.

It should be noted that voluntary sustainability standards are initiated and designed to cover a specific set of sustainability topics of interest to stakeholders, which means they can purposefully exclude some topics in their coverage. Figure 3, therefore, is not intended to imply all standards should cover all sustainability topics or a level of performance or a 'rating' of any kind. Rather, it is intended to objectively inform the reader which topics in summary and generally are covered by each of the standards. For a very detailed analyses of these standards and their applicability and utility to your business, please get in touch with TDi for an introduction to our Integrated Compliance Assurance Tool (see Box 1 below).

Methodological notes on the matrix presented below are given in Annex 2: Methodology Guide. Unabbreviated names of the featured voluntary sustainability standards and brief descriptions are given in Annex 1: Voluntary sustainability standards featured in Section 3.

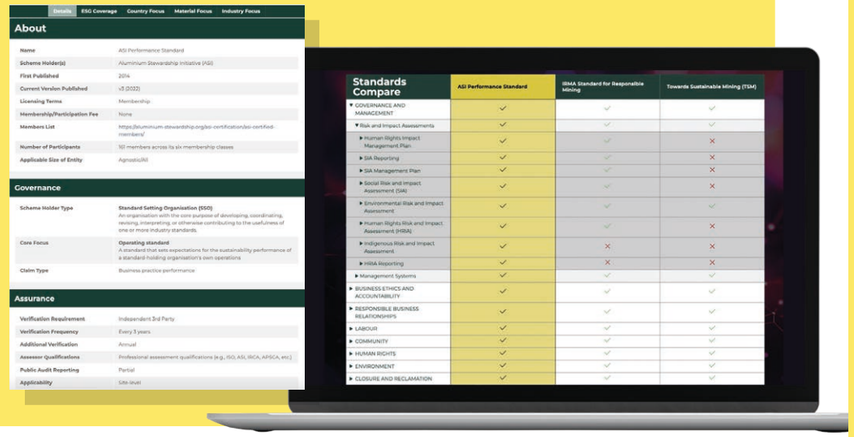
Box 1. Integrated Compliance Assurance Tool (ICAT)

TDi Sustainability provides a searchable database of sustainability standards and generates checklists for compliance with the requirements, allowing supply chain companies to quickly identify and comply with the standards that are most relevant to their sourcing, operations, and their ESG risk exposure.

These checklists allow companies to gather data in a structured format from multiple sites and for multiple standards at once to accelerate compliance and reporting.

Standards provide assurance to companies and consumers that negative ESG impacts are managed and that benefits are realised by communities associated with the production and processing of materials.

Please visit tdi-digital.com to find out more about ICAT and TDi's other digital tools that together provide a comprehensive platform for responsible supply chain management and solutions.



7 https://www.iisd.org/system/files/publications/green-conflict-minerals.pdf
8 https://eitrawmaterials.eu/wp-content/uploads/2020/04/rms_for_wind_and_solar_published_v2.pdf

Figure 3A.

ESG issues commonly associated with mineral supply chains in the renewable industry.

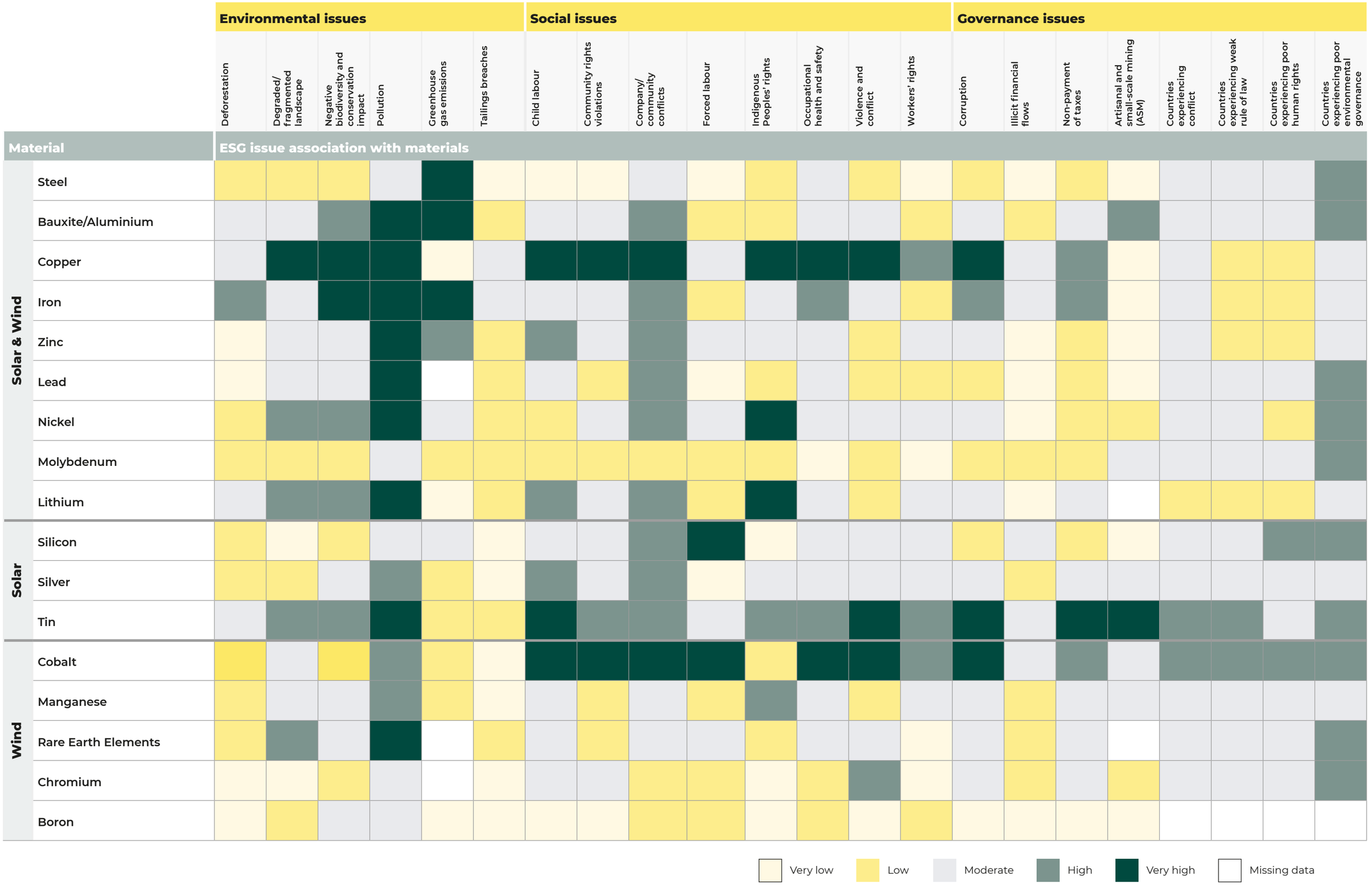


Figure 3B.

Salient ESG issues in material supply chains, and the voluntary standards that cover them.

	Environmental issues						Social issues								Governance issues							
	Deforestation	Degraded/ fragmented landscape	Negative biodiversity and conservation impact	Pollution	Greenhouse gas emissions	Tailings breaches	Child labour	Community rights violation	Company/ community conflicts	Forced labour	Indigenous peoples' rights	Occupational health and safety	Violence and conflict	Workers' rights	Corruption	Illicit financial flows	Non-payment of taxes	Artisanal and small-scale mining (ASM)	Countries experiencing conflict	Countries experiencing weak rule of law	Countries experiencing poor human rights	Countries experiencing poor environmental governance
Voluntary standard	**Voluntary sustainability standard coverage of ESG issues**																					
1. ASI Performance Standard*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■
2. Responsible Steel Standard^	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
3. Copper Mark Criteria^	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
4. IRMA Standard*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5. Towards Sustainable Mining*	■	■	■	■	■	■	■	■	■	■	■	■	■	■							■	■
6. EO100™ Standard for Responsible Energy Development^^	■	■	■	■	■		■	■	■	■	■	■		■	■	■	■			■	■	■
7. Solar Stewardship Initiative ESG Standard**	■		■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
8. Joint Due Diligence Standard^							■	■	■	■			■	■	■	■	■	■	■	■	■	
9. Global Industry Standard on Tailings Management*	■	■				■		■	■		■	■										
10. EPEAT Ecolabel**					■							■	■									

■ Covers

Does not cover

*Covers the mining stage of the supply chain
^Covers the mining and refining stages of the supply chain
**Covers the manufacturing stage of the supply chain
^^Covers wind and solar siting and sourcing

3.1. Observations

The matrix in Figure 3A ranks ESG issues associated with materials by their saliency. These issues are identified by analysing public reports of negative actions or consequences of companies' activities and expert review of credible and peer reviewed literature.

We do not present here a balanced score card weighing the benefits of solar and wind energy and manufacturing with the adverse effects in supply chains. While such a balanced view of these supply chains should be considered in decisions at all levels of an organisation, and is the subject of other TDi Sustainability analyses, it is not the purpose of this report. Rather, our aim here is to provide information relevant to complying with mounting legislation and regulation on due diligence and customers' expectations for management of adverse ESG impacts. The matrix gives an accurate set of indicators on supply chain ESG risks that companies are being asked to know about, monitor, and take action to avoid or mitigate.

Media headlines reporting on mineral and metal supply chains are dominated by a few ESG issues, most of which are allegations of human rights breaches, such as the presence of child labour, forced labour, and unsafe working conditions. These are often noted in popular news articles on minerals and metals in supply chains, such as lithium, copper, and nickel. These issues, however, are very often linked to minerals and phases of the supply chain where informal production takes place, especially artisanal mining. While artisanal mining can be found in many different minerals, it is most common where the geology of the mineral is relatively shallow allowing unmechanised forms of extraction, such as for cobalt in the DRC, and alluvial tin deposits, and where processing is simple, such as smelting gold and silver. It is relatively uncommon in copper, nickel, or zinc, which generally rely on large industrial scale mining for viable operations. Companies reading this report should be cautious about generalising the prevalence of some ESG issues.

Our analysis, for which the above matrix is a summary presentation, also reveals that the landscape of ESG issues is not restricted to just a few topics; it is a more complex picture. There are multiple ESG issues in these supply chains that procurement managers should be concerned about, and incidences that give rise to controversies occur in the production phases of multiple minerals and metals. A concentration of high and very high saliency grades is notable for conflict between companies and communities in many of the materials in the matrix. This is important not only because of the negative impacts experienced by these communities and the risks to employees, but also because such conflicts can result in stoppages at mines and processing facilities and interruption to trade flows and longer term supply surety. This risk is especially salient where there is a geographical concentration of production capacity, such as is the case with silicon, copper, cobalt, and silver.

As parts of the world and international organisations raise the alarm over stresses on the health of our forests, ecosystems, and species – the implications of a changing climate, environmental issues, and companies' responsibilities for addressing them have become mainstream. The summary analysis in the matrix shows that many materials are associated with pollution, landscape degradation and fragmentation, and negative impacts on biodiversity and conservation efforts. Mining and mineral development is invasive, requiring removal of surface materials to discover and extract ore-bearing rock. The ore needs to be separated from its host material, a process often requiring chemicals. Mostly, this disruption is unavoidable, but its negative effects can be managed at well financed and professionally run operations. Processing using chemicals can be controlled, waste dumps with the potential to leach pollutants can be contained, and land disturbed can be restored or made ready for other productive activities in the long term, even if the negative impacts can rarely be fully eliminated in the short term. Where mining and mineral processing is not well managed, catastrophe can follow for surrounding areas. The importance of standardised ESG frameworks to aid systemic management operations and verification of their performance is evident.

Supply chain and due diligence regulations have caught up with the need to recognise the array of potential ESG issues. While some regulations, such as the EU's Conflict Minerals Regulation, are selective about the minerals they cover and the ESG risks and topics on which companies are required to disclose, new and emergent regulations either are agnostic and expect business themselves to identify the ESG aspects and salient risks relevant to their activities, or have a far broader range of issues that they expect to be identified and reported. Voluntary ESG standards and frameworks will reflect and even anticipate this broadening of the ESG issues of concern. To source responsibly, companies should take a comprehensive view and seek to avoid and address multiple potential and actual adverse ESG impacts.

As the lower section of the matrix in Figure 3B shows, voluntary sustainability standards one to seven provide coverage of a broad range of ESG issues relevant to the mining of minerals destined for wind turbines and solar panels. We generally refer to these as 'comprehensive standards'. By encouraging suppliers to adopt such comprehensive standards, producers and purchasers of clean energy can place orders in the knowledge that the company has been verified for their appropriate management of most or all prevailing ESG issues.

Standards eight to ten are not designed to provide a broad coverage of ESG issues, rather these 'issue-specific' standards go more in-depth in their requirements for the topic areas they do cover. The Joint Due Diligence Standard for Copper, Lead, Molybdenum, Nickel, and Zinc, for example, is a due diligence standard aligned with the requirements of the OECD and the London Metal Exchange and focusses on conflict and gross human rights abuses in copper mining and related metal supply chains. The Global Industry Standard for Tailings Management is designed specifically to manage facilities to avoid and mitigate issues associated with tailings dam leaks and breaches. The Electronic Product Environmental Assessment Tool Ecolabel focuses on select environmental and energy-saving criteria, with some additional provisions for 'conflict minerals' disclosure.

The two newest standards are the Solar Stewardship Initiative (SSI) ESG Standard, and Equitable Origin's (EO) Standard for Renewable Energy Development. The SSI ESG Standard was published in October 2023, and seeks to address environmental, social, and governance sustainability for sites engaged in manufacturing of polysilicon, ingots, wafers, cells and modules, and other component manufacturing for solar panels. SSI is currently working on its second Standard – the SSI Supply Chain Traceability Standard. The combination of the SSI ESG Standard and the SSI Supply Chain Traceability Standard will mean the SSI will be able to certify exactly how each link of the supply chain is connected. The draft EO standards for wind and solar development were launched in March 2024, and are the only comprehensive standards specifically designed for the regulation of ESG performance at renewable development sites.

While voluntary standards are useful tools for systematising commitment to sound ESG risk management at operations and for communicating performance to customers and regulators, putting in place the management systems and reporting requirements can be costly. Not all producers have the means to implement advanced environmental and social management systems, at least not within a short period. A key principle of supply chain due diligence is progressive and continual improvement. As such, purchasers should engage the companies in their supply chain to uplift performance, rather than automatically disengaging from suppliers whose environmental and social assurance frameworks are not yet fully in place.

For the solar panel and wind turbine industries to implement effective responsible sourcing, a layered approach should be adopted. In some supply chains, it may be sufficient to ensure that suppliers adopt narrowly focused voluntary sustainability standards, which target a specific set of the most prominent ESG issues. Examples of such standards are given in rows eight to ten of Figure 3B, but there are others.

In other supply chains, depending on the spread of ESG issues present and the requirements of customers and regulators, it may be necessary to ensure that suppliers adopt more comprehensive, and more resource-intensive, voluntary sustainability standards. Rows one to seven of Figure 3B give examples of such standards, though again there are others. In cases where upstream companies' resources are lacking, downstream companies, including producers and purchasers of clean energy, can act collectively to support the suppliers they have in common to adopt and build the capacity to meet comprehensive voluntary sustainability standards.

Cost savings can also be achieved by encouraging the adoption of standards that have a recognition or equivalency mechanism. Such enlightened standard schemes establish equivalency between the provisions of third-party standards to avoid duplication of effort for suppliers. For example, a site certified against the IRMA Standard and a site certified against Toward Sustainable Mining would both satisfy the requirements of the Copper Mark, a multi-metal standard, for stakeholder engagement and most other ESG topics.[9] There would be no need for either site to attain further certifications for stakeholder engagement in order to achieve the Copper Mark, as their existing certifications would provide sufficient assurance. By emphasising the recognition of such standards in their responsible sourcing programmes, producers and purchasers of clean energy can help supply chain companies to meet downstream expectations of ESG performance as cost-effectively as possible.

Lastly, producers and purchasers of clean energy can support responsible sourcing by engaging directly in initiatives that improve environmental and social conditions upstream. The Fair Cobalt Alliance (FCA) and Clean Energy Buyers Institute (CEBI) illustrate this possibility. The FCA works with small scale producers in the Democratic Republic of Congo to improve conditions in cobalt mining areas and is directly supported by companies throughout the supply chain, including the electric vehicle manufacturer Tesla, and the electronics giant Google. CEBI's Beyond the Megawatt Initiative seeks to maximize the environmental and social outcomes of clean energy transition by leveraging the influential demand of energy customers through the procurement of clean energy that is resilient, equitable, and environmentally sustainable.

TDi Digital is a comprehensive platform for responsible supply chain management and solutions. It contains tools to help companies within supply chains quickly identify those standards most relevant to their sourcing, operations, and ESG risk exposure, and gather data in a structured format to demonstrate compliance. Visit **tdi-digital.com** for more information, or see page 5.

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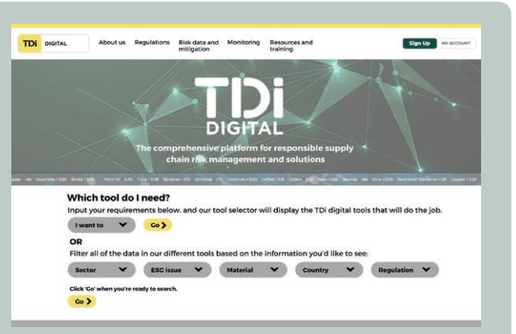


9 https://coppermark.org/wp-content/uploads/2021/01/RRA-Copper-Mark-Equivalence-Matrix_REV18Dec2020v2.pdf

4. Material Profiles

The section presents quick-scan material profiles for aluminium, steel, and silicon. TDi holds extensive databases on over 50 materials' ESG issues and can provide analysis on multiple aspects of non-technical risk and procurement. Aluminium and steel were selected for this report for the key roles they play in both wind turbine and solar panel production. Silicon was selected due to its importance for solar panels, and the current topicality of associated ESG issues.

Profiles provide details of the ESG issues and supply chain attributes of materials, building on the general insights in the material matrices in the previous section.

Material profiles of the other materials in solar and wind supply chains that are presented in the comparison matrix (Figure 3A) are available by contacting TDi Sustainability.

The profiles are structured into the following six sections:

1. **Material uses:** This section outlines the material's main uses in wind turbines and solar panels, and other common applications of the material in top consumer industries.
2. **Top producer country information:** This section presents production, economic, and governance information on the top five countries where the material is mined or produced. This section is intended to offer a quick snapshot of country-level data; it is not intended to be or to replace a comprehensive country risk assessment.
3. **Association with Environmental, Social, and Governance issues:** This section indicates the strength of association of the material with 23 ESG issues considered in the study that are relevant to responsible sourcing (reproduced from Section 3).
4. **Environmental, Social, and Governance risk analysis:** This section summarises the material's association with ESG issues graded 'high' or 'very high' salience and provides brief examples of the ESG impacts that can be associated with the material's production. The information is drawn from various source reports and media, including peer reviewed papers, industry reports and media articles. This section is strictly illustrative and should not be considered generally representative of companies' performance or production practices in the industry.
5. **Supply significance:** This section includes indicators of the factors influencing the supply of the material, as well as two indicators of EU and USA dependency on imported material that are included to illustrate possible constraints on supply from international trade relations with producer countries.
6. **Future demand trends and associated responsible sourcing challenges:** This section highlights the predicted future demand of the material and the factors driving this change, including examples of countries that have high production potential and are expected to become a key future supplier.

Methodological notes on the indicators presented below are given in Annex 2: Methodology Guide.

4.1 Aluminium*

Aluminium is mined from bauxite ore, and it is the second most abundant metallic element on Earth.

Aluminium is essential for many industries, including transportation, construction, and packaging. It is valued for its high strength to weight ratio, conductivity, and ductility.

Material Uses

Wind turbine	Nacelle (the housing for the generator and other components), wiring, heat sinks, supporting structures (e.g., ladders).
Solar panel	Supporting structures, frames and backing.
Other top consuming industries	Vehicle manufacture (aircraft and automobiles), building materials, consumer durables (refrigerators, air conditioners, cooking utensils, etc), electrical transmission lines, chemical and food processing equipment.

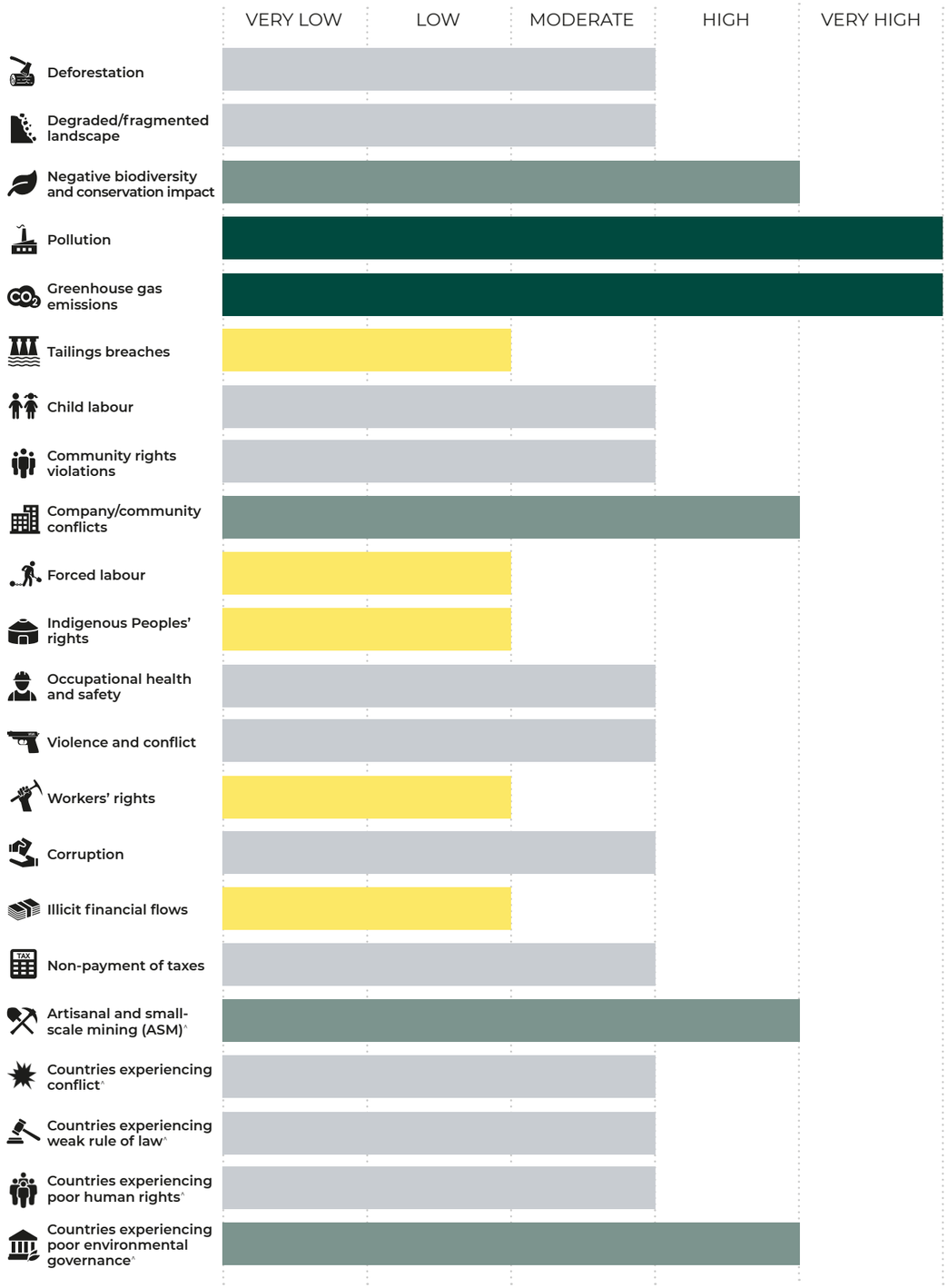
Top Producer Country Information

	Australia	China	Guinea	Brazil	Indonesia
% Global mined production (Bauxite)	26	24	23	9	6
% Global production (Alumina)	15	56	0	8	1
% Global reserves	16	2	24	9	3
% Mining sector contribution to GDP	13	2	5	8	5
Human Development Index	0.951	0.768	0.465	0.754	0.705
Rule of law	Very strong	Strong	Weak	Moderate	Moderate
Experience of corruption	Low	Moderate	Very high	High	High
Experience of state conflict (Heidelberg Conflict Barometer)	Very low (No conflict)	Low (Non-violent crisis)	Moderate (Violent crisis)	Low (Non-violent crisis)	Low (Dispute)

Very low · Weak/Low · Moderate · Strong/High · Very strong/Very high

* Note: Production data in this profile refers to bauxite. The analysis covers both bauxite and aluminium.

Association with Environmental, Social, and Governance issues



^ Indicators are for bauxite ore

Environmental, Social, and Governance Risk Analysis

Although bauxite mining is typically conducted in very large industrial mines by companies with formal environmental and social management systems, negative impacts still occur.

Many of these impacts are associated with the sheer scale of bauxite mining, and the predominance of open-cast mines. Land use for bauxite mining can cause displacement and disruption for local communities and wildlife, as reflected in the high salience scores for 'negative biodiversity and conservation impact' and 'company/community conflicts'. Instances of these issues are most frequently reported in Brazil and Guinea.

Primary bauxite processing creates large quantities of alkaline residue, known as 'red mud', which are typically stored in large lakes near mine sites. This residue can be highly polluting if storage lake leaks occur. In recent years, there have been reports of communities being negatively impacted by such leaks in Brazil, Guinea, and elsewhere. Although such events might not be frequent, the scale of bauxite mining makes them significant in terms of corporate risk related to ESG issues in supply chains.

Aluminium production is rated 'very high' for greenhouse gas emissions because the refining stage requires very large amounts of electrically generated power for electrolysis. The aluminium sector is responsible for approximately 1.1 billion tonnes or about 2 percent of global carbon emissions each year.[11] Emissions are particularly high for the many plants in China that draw power from dedicated coal-fired power stations.[12] Cleaner production is provided by hydroelectric-powered smelting plants, which currently produce approximately 40 percent of aluminium worldwide. Emissions are even lower for recycled aluminium, though recycling is insufficient to fully meet aluminium demand.

Supply Significance*

EU dependency on imported material	High
US dependency on imported material	High
Supply chain concentration risk	Moderate
Price volatility risk	Moderate
Depletion risk	Very high
Recycling risk	Moderate

*Indicators are for aluminium metal

11 https://www.worldclimatefoundation.org/post/aluminium-a-sustainable-metal-for-a-sustainable-world and https://www.globalefficiencyintel.com/new-blog/2022/global-aluminum-industrys-ghg-emissions

Future Demand Trends and Associated Responsible Sourcing Challenges

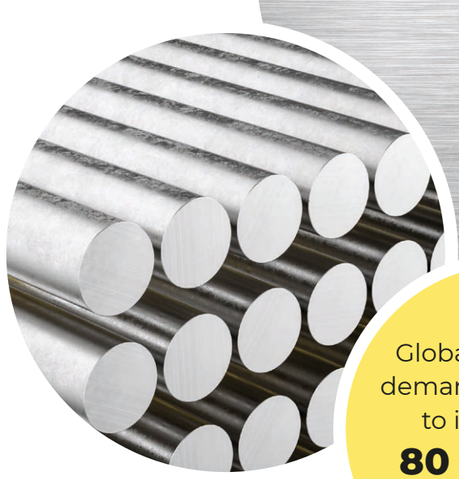
Global aluminium demand is expected to increase by 80 percent by 2050. The majority of this increase will be driven by the transportation, electrical, construction and packaging sectors.[13]

One factor driving demand will be the rise in the number of electric vehicles, which typically contain more aluminium and less steel than conventional vehicles.[14] Aluminium's low weight can increase fuel efficiency and reduce emissions.

Chinese governmental emission reduction targets will challenge its domestic coal-powered aluminium smelting plants[15] and China will face continued international pressure to reduce aluminium industry subsidies.[16]

Guinea, meanwhile, is set to significantly boost bauxite production[17] and Ghana has plans for an alumina refinery, allowing it to capture a greater share of the aluminium value chain than is currently possible by exporting unprocessed bauxite.[18]

The coming years may see a general trend in bauxite, alumina, and aluminium production away from China and toward Africa and other producing regions worldwide. As production patterns shift, responsible companies downstream in the aluminium supply chain should ensure that their suppliers buy from producers with appropriate voluntary sustainability standards, and from smelters with low-carbon power sources such as hydroelectric plants.



Global aluminium demand is expected to increase by **80 percent by 2050**

12 https://www.weforum.org/reports/the-net-zero-industry-tracker/in-full/aluminium-industry/
13 https://international-aluminium.org/report-reveals-global-aluminium-demand-to-reach-new-highs-after-covid/
14 https://www.fortunebusinessinsights.com/industry-reports/aluminium-market-100233
15 https://www.woodmac.com/press-releases/carbon-neutrality-goal-forces-chinese-aluminium-smelters-away-from-captive-coal-power/
16 https://www.usgs.gov/news/interior-releases-2018-s-final-list-35-minerals-deemed-critical-us-national-security-and
17 https://www.bloomberg.com/news/articles/2021-06-17/china-s-top-bauxite-supplier-set-to-boost-output-as-rail-starts-kq0nfbqv
18 https://www.forbes.com/sites/forbesbusinesscouncil/2023/02/07/building-ghanas-aluminium-empire-leveraging-resources-and-infrastructure-to-become-a-major-player-in-the-global-market/

4.2 Steel

Steel is a highly versatile material, well suited to construction purposes due to its strength, durability, and ductility. The main input material for steel is iron ore, to which many other metals can be added as alloying materials, such as manganese, chromium, nickel, and molybdenum.

Iron is the fourth most common element in the Earth's crust.[19] By volume, much more iron ore (in steel) is used by humans than all other metals combined.

Material Uses

Wind turbine	Support tower, nacelle (the housing for the generator and other components), rotor hub, blades (in some designs), reinforcement for foundations.
Solar panel	Mounting and support structures, brackets, rails and foundations, solar tracking mechanisms.
Other top consuming industries	Construction (used for beams, reinforcing rods and other building components). Vehicles, industrial equipment, machinery, bridges, highways, water pipes, canned food, and paints.

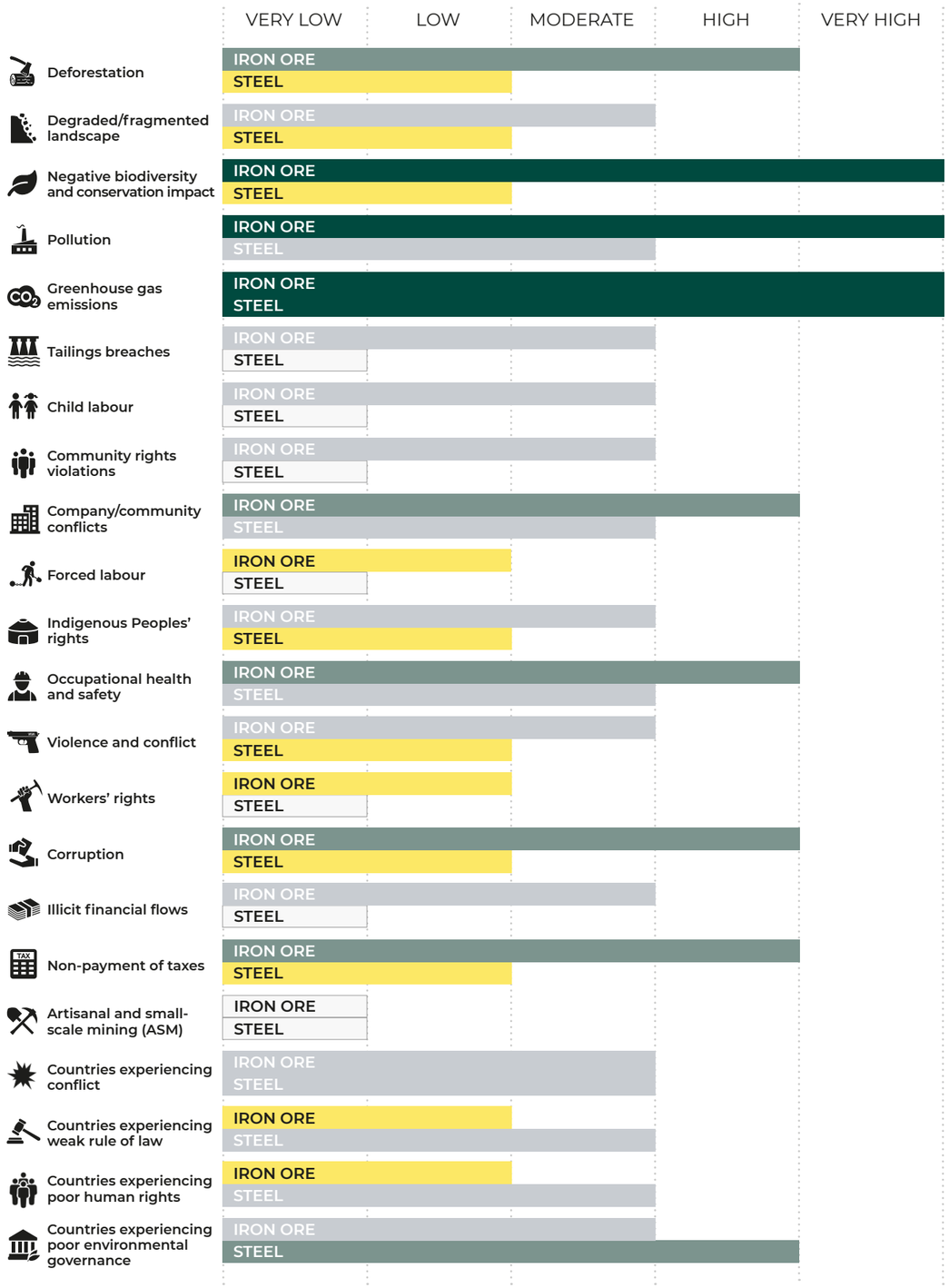
Top Producer Country Information

	Australia	Brazil	China	India	Russian Federation
% Global mined production (iron)	34	16	15	11	4
% Global production (steel)	Not applicable	2	52	7	4
% Global reserves (iron)	31	17	8	4	16
% Mining sector contribution to GDP	13	8	2	3	19
Human Development Index	0.951	0.754	0.765	0.633	0.822
Rule of law	Very strong	Moderate	Strong	Strong	Weak
Experience of corruption	Low	High	Moderate	High	Very high
Experience of state conflict (Heidelberg Conflict Barometer)	Very low (No conflict)	Low (Non-violent crisis)	Low (Non-violent crisis)	Low (Non-violent crisis)	Very high (War)

Very low · Weak/Low · Moderate · Strong/High · Very strong/Very high

19 https://pubs.acs.org/doi/pdf/10.1021/cb300323q

Association with Environmental, Social, and Governance Issues



Environmental, Social, and Governance Risk Analysis

Iron ore and steel production are associated with a range of ESG issues, as the risk matrix in Section 3 shows. Iron ore production is not inherently more environmentally or socially harmful than most other types of mining, but the sheer scale of iron ore mining, with more than 917 mines operating globally,[20] means that negative impacts are widely reported. In 2022, 1.6 billion tons of iron were produced,[21] dwarfing the 69 million tons of production of aluminium, the second most common industrial metal.[22]

The most salient ESG issues that occur at the local level, identified in the table above, can be mitigated by strong mine site management systems. However, this is not always the case in practice. High profile events in recent years, resulting from management systems failings, have caused reputational damage for the iron ore mining industry.

A number of high profile, but ultimately 'moderate' grade salience issues have also caught media attention in recent years. The catastrophic failure at the Brumadinho tailings dam in Brazil in 2019, operated by Vale, killed 270 people,[23] and released millions of tonnes of toxic mining waste that polluted soils and waterways. The disaster led to the establishment of a global database of tailings dams and the development of the Global Industry Standard for Tailings Management assurance system. Brumadinho was the second major tailings dam to collapse in Brazil in the space of four years. The Samarco dam disaster in November 2015 killed 19 people and caused widespread environmental damage.

In Australia, the destruction of the Juukan Gorge Cave cultural heritage site in 2020 during iron ore mining operations by Rio Tinto caused widespread outrage. The site was over 40,000 years old and was a sacred site of significant spiritual value for the traditional owners of the land, the Puutu Kunti Kurrama and Pinikura Indigenous Peoples.[24]

Australia, Brazil, and India are the three countries in which the greatest number of public issue reports about negative ESG impacts in the iron and steel supply chain have been reported, in recent years.

Greenhouse gas emissions are rated a 'very high' salience issue for iron and steel production. Iron oxide in iron ore is most commonly reduced to elemental iron in coal-burning blast furnaces, and further carbon dioxide is released when the carbon in pig iron is removed to make steel. Overall, iron and steelmaking account for a minimum of seven to nine percent of global carbon emissions.[25]

Supply Significance*

EU dependency on imported material	Low
US dependency on imported material	Low
Supply chain concentration risk	High
Price volatility risk	Low
Depletion risk	Not available
Recycling risk	Low

*Indicators are for steel

20 https://www.mining-technology.com/marketdata/five-largest-iron-ore-mines-the-us/?cf-view
21 https://pubs.usgs.gov/periodicals/mcs2023/mcs2023-iron-ore.pdf
22 https://pubs.usgs.gov/periodicals/mcs2023/mcs2023-aluminum.pdf
23 https://www.churchofengland.org/media/finance-news/investors-banks-and-insurers-review-global-progress-addressing-tailings-dam
24 https://www.theguardian.com/australia-news/2020/may/26/rio-tinto-blasts-46000-year-old-aboriginal-site-to-expand-iron-ore-mine
25 https://www.sciencedirect.com/science/article/abs/pii/S2214629622000706

Future Demand Trends and Associated Responsible Sourcing Challenges

Global demand for iron ore is expected to rise 30 percent by 2050,[26] driven by the construction sector, particularly in emerging economies, and the automotive sector, particularly for electric vehicles.

Meanwhile, steel supply is constrained, with China pledging to reduce production output as well as shut down the most outdated and polluting plants, in a bid to reduce emissions.[27]

The combination of rising demand and constrained supply could lead to steel price rises, particularly as the industry moves to adopt more costly low-carbon technology, such as carbon capture and hydrogen-based iron ore reduction.[28,29]

Local-level ESG considerations can also constrain steel supply, as recent history indicates. The collapse of the Brumadinho tailings dam in 2019 led to several other mining operations being suspended in Brazil, resulting in a 12 percent fall in export volumes in 2019 and pushing global prices higher.[30]

The destruction of the Juukan Gorge Cave in Australia during an iron ore mine expansion could contribute to more scrutiny on developers hoping to obtain expansion permits in Australia, the world's biggest supplier of iron ore. As a general trend, growing stakeholder aversion to the negative impacts of large-scale mining worldwide could mean that permission for new projects becomes increasingly difficult to obtain, further constraining supply and driving prices upward.

Global demand for iron ore is expected to rise **30 percent by 2050**

26 https://www.weforum.org/reports/the-net-zero-industry-tracker/in-full/steel-industry/
27 https://www.mining.com/iron-ore-prices-stable-while-chinas-steel-output-hit-15-month-low/
28 https://read.oecd-ilibrary.org/energy/iron-and-steel-technology-roadmap_3dcc2a1b-en#page1
29 https://www.weforum.org/reports/the-net-zero-industry-tracker/in-full/steel-industry/
30 https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/electric-power/063021-china-may-cut-iron-ore-imports-by-79-mil-mtyear-over-next-5-years-analyst

4.3 Silicon

Silicon is the second most common element on Earth,[31] constituting approximately 25 percent of the Earth's crust.[32]

It primarily occurs as silica (SiO_2), or SiO_2-containing minerals known as silicates. Pure silicon is a metalloid material, meaning it exhibits properties typical of both metals and non-metals.

Material uses

Wind turbine	No significant uses.
Solar panel	Polysilicon is essential to modern solar panels, as thin wafers of silicon are the key component in electricity-generating photovoltaic cells.
Other top consuming industries	Steelmaking (as an alloying material and deoxidiser), general electronics (as a semiconductor), construction (silicone sealants and adhesives), silicone automotive parts and medical devices.

Top Producer Country Information

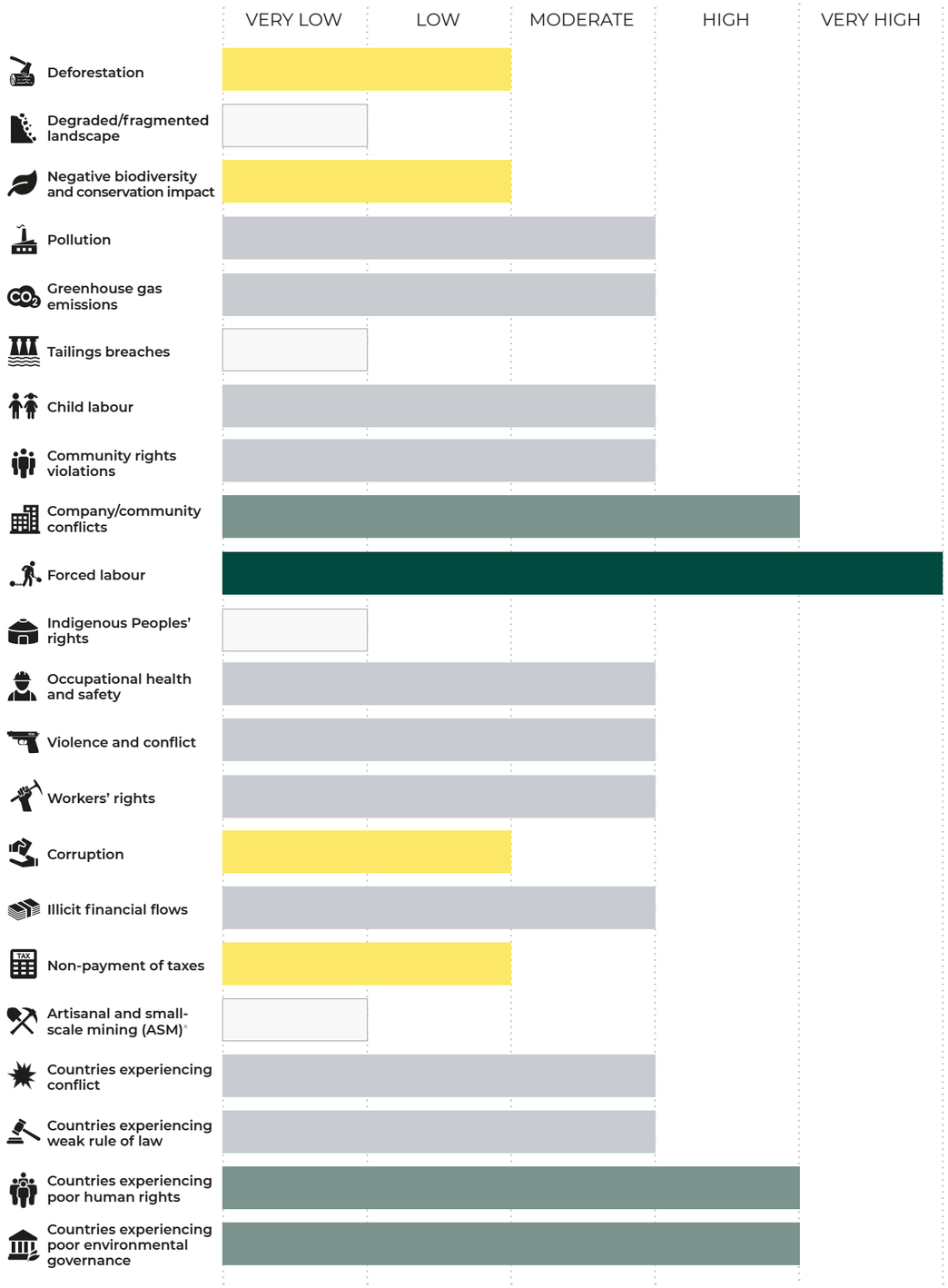
	China	Russian Federation	Brazil	Norway	United States
% Global production*	68	7	5	4	4
% Global reserves^	Not available	Not available	Not available	Not available	Not available
% Mining sector contribution to GDP	2	19	8	10	1
Human Development Index	0.768	0.822	0.754	0.961	0.903
Rule of law	Strong	Weak	Moderate	Very strong	Strong
Experience of corruption	Moderate	Very high	High	Low	Low
Experience of state conflict (Heidelberg Conflict Barometer)	Low (Non-violent crisis)	Very high (War)	Low (Non-violent crisis)	Low (Dispute)	Low (Non-violent crisis)

Very low | Weak/Low | Moderate | Strong/High | Very strong/Very high

* Silicon is mined as a by-product from a broad range of sources, so mining-specific data is not available.
^ Global silicon reserves are vast, and disproportionately large in relation to demand, so quantitative estimates of silicon reserves are not available.

31 https://www.britannica.com/science/silicon
32 https://pubs.usgs.gov/periodicals/mcs2023/mcs2023-silicon.pdf

Association with Environmental, Social, and Governance Issues*



*Indicators are for silicon metal and ferrosilicon, except those marked with a ^, which are for natural silica

Environmental, Social, and Governance Risk Analysis

Unlike most mined materials, silicon's strongest association with salient ESG issues occurs at the manufacturing stage, rather than the mining stage. The ESG issue area given a 'high' salience grade for silicon supply chains is forced labour, which reflects the numerous reports of labour rights violations in polysilicon manufacture in the Xinjiang region of China.

Polysilicon (short for 'polycrystalline silicon') is a high-purity form of elemental silicon made up of small interlocking silicon crystals. It is produced in Xinjiang and elsewhere as a critical input material for solar panels' photovoltaic cells. Studies based on public reporting have claimed that all polysilicon manufacturers in Xinjiang either participate in Chinese government 'labour transfer programmes' or are supplied by companies that do. These programmes are widely seen to be a tool for governmental coercion, ideological inculcation, and forced labour for approximately 2.6 million – mainly Muslim and ethnically Uyghur – residents of the region. Polysilicon produced in Xinjiang accounts for approximately 45 percent of global solar-grade polysilicon supply.[34,35]

The level of greenhouse gas emissions associated with global silicon production currently lies in the 'Moderate' category in TDi's methodology. However, studies predict that emissions could rise sharply in coming years, as solar panel production ramps up. According to one estimate, photovoltaic panel production could consume approximately 12 percent of the total planetary carbon budget that is available if the 1.5°C total warming goal is to be met. Most greenhouse gas emissions associated with polysilicon production arise in the Siemens process, which is used in 95 percent of polysilicon production and involves the deoxidisation of silica by coke in electric arc furnaces.[36] Additionally, in China, the electric power for polysilicon factories is typically supplied by coal-fired power plants.[37]

Supply significance*

EU dependency on imported material	High
US dependency on imported material	Moderate
Supply chain concentration risk	High
Price volatility risk	Moderate
Depletion risk	Not available
Recycling risk	Very high

* Indicators are for silicon metal

34 https://www.shu.ac.uk/helena-kennedy-centre-international-justice/research-and-projects/all-projects/in-broad-daylight
35 https://ofac.treasury.gov/media/44066/download?inline
36 https://grist.org/energy/solar-is-one-of-the-cleanest-power-sources-weve-got-but-it-could-be-even-greener/
37 https://www.bloomberg.com/graphics/2021-xinjiang-solar/

Future Demand Trends and Associated Responsible Sourcing Challenges

Demand for silicon is expected to grow significantly in coming years – one source estimates a 66 percent increase in production between 2021 and 2030.[38] Demand increase will be driven by the manufacture of solar panels and electronic devices.

Polysilicon production is highly geographically concentrated. China accounts for approximately 77 percent of global production,[39] and it is estimated that just four factories in Xinjiang account for the bulk of this production.[40]

This geographic concentration makes polysilicon highly vulnerable to supply chain shocks. For example, in 2021, a decrease in silicon production in China (partially because of national efforts to reduce power consumption) was one of the key drivers of a temporary 300 percent surge in the price of silicon globally.

Geographic concentration also places significant constraints on companies that seek to source polysilicon responsibly. With almost half the world's supply coming from Xinjiang, where widespread labour abuses have been reported, companies may struggle to secure sufficient polysilicon stock that comes with adequate labour rights assurances. Companies may also struggle to source polysilicon with a low carbon footprint, given the predominance of coal-fired power stations in energy supply for polysilicon factories.

Demand for silicon is **expected to grow** significantly in coming years

38 https://straitsresearch.com/report/silicon-metal-market
39 https://viewpoint.bnpparibas-am.com/what-you-need-to-know-about-polysilicon-and-its-role-in-solar-modules/
40 https://www.mining.com/web/silicons-300-surge-throws-another-price-shock-at-the-world/

ANNEX 1: Voluntary Sustainability Standards Featured in Section Three

Aluminium Stewardship Initiative (ASI) Performance Standard

The Aluminium Stewardship Initiative (ASI) is a membership initiative, the mission of which is stated to drive responsible production, sourcing, and stewardship in the global aluminium value chain.

The ASI Performance Standard covers a broad range of environmental, social, and governance topics, and can be applied at each stage of the aluminium value chain. It is currently in its third version. Members of the ASI are required to demonstrate conformance to version 3 of the Standard in all new and re-certification audits conducted from 1st June 2023 onwards. Audits conducted between 1st June 2022 and 31st May 2023 may be against either version 2 or version 3 of the Standard.

Copper Mark Criteria for Responsible Production

The Copper Mark is a comprehensive assurance framework focused on demonstrating the copper industry's responsible production practices. The Copper Mark Criteria for Responsible Production are management system requirements defined in the Risk Readiness Assessment (RRA) and the Criteria Guide. All participants of the Copper Mark commit to fully meet all criteria within 24 months. Each copper-producing site is independently verified to meet the standard's criteria through a site-level assessment process. Participation in the Copper Mark is open to multi-metal mines that produce other metals alongside copper.

Electronic Product Environmental Assessment Tool (EPEAT) Ecolabel

The Electronic Product Environmental Assessment Tool (EPEAT) Ecolabel is a global ecolabel that covers products and services from the technology sector, developed by the Global Electronics Council. The EPEAT supports purchasers, manufacturers, resellers, and others to buy and sell environmentally preferable electronic products.

It requires manufacturers and brands to disclose the outcomes of lifecycle-based environmental performance criteria, ranking products as Gold, Silver, or Bronze.

Equitable Origin EO100™ Standard for Responsible Energy Development

Equitable Origin (EO) is the world's first stakeholder-based, independent, voluntary standards system designed to enable higher social and environmental performance, greater transparency, and more accountability in energy development. The Equitable Origin system applies to energy development sites, including oil and gas production, wind farms, and solar installations. EO works with a variety of stakeholders, including communities, companies, governments, and investors to foster dialogue, benchmark performance and promote best practices through the EO100™ Standard.

In March 2024, EO launched draft Technical Supplements for onshore wind and onshore solar projects, developed with the help of an expert technical committee and extensive public comment period. These lifecycle-based technical supplements to the EO100™ Standard are designed to differentiate and recognise environmental, social, and ethical leadership in onshore utility-scale wind and onshore utility-scale photovoltaic solar projects.

Global Industry Standard on Tailings Management (GISTM)

The Global Industry Standard on Tailings Management strives to enable the ultimate goal of zero harm to people and the environment, with zero tolerance for human fatalities from incidences associated with tailings. It requires mine operators to take responsibility for and prioritise the safety of tailings facilities, through all phases of a facility's lifecycle, including closure and post-closure. It also requires the disclosure of relevant information to support public accountability.

Initiative for Responsible Mining Assurance (IRMA) Standard for Responsible Mining

The Initiative for Responsible Mining Assurance (IRMA) is a multi-stakeholder body created to meet global demand for more socially and environmentally responsible mining. The Standard for Responsible Mining v.1.0 was created by IRMA through a multi-year collaborative process, led by a multi-stakeholder board of directors. The Standard is designed to support four overarching principles: Business integrity; Planning and Managing for Positive Legacies; Social Responsibility; and Environmental Responsibility.

The IRMA certification is third-party assured against a comprehensive standard for all mined materials (except thermal coal) from industrial scale mines.

Joint Due Diligence Standard for Copper, Lead, Molybdenum, Nickel, and Zinc

The Joint Due Diligence Standard was developed collaboratively by the Copper Mark (CuMark), the International Lead Association (ILA), the International Zinc Association (IZA), the Nickel Institute, and the Responsible Minerals Initiative (RMI).

The Standard enables companies in the supply chain to comply with the London Metal Exchange Responsible Sourcing requirements, and covers risks associated with conflict and human rights abuses in mineral supply chains. The Standard is designed to enable effective due diligence for producers and traders. It builds on existing standards, and it intends to provide flexibility for multi-metal producers that extract both primary and secondary (by-product) minerals at their production sites.

ResponsibleSteel Standard

ResponsibleSteel is an international, non-profit multi-stakeholder membership organisation and certification initiative. It contains twelve principles for the responsible sourcing and production of steel, across a broad range of environmental, social, and governance topics.

The Standard aims to maximise steel's contribution to a sustainable society. It sets benchmark levels of company performance in the implementation of its principles to encourage broad participation by businesses while meeting the expectations of civil society stakeholders.

Solar Stewardship Initiative ESG Standard

The Solar Stewardship Initiative (SSI) was established by SolarPower Europe and Solar Energy UK to enhance transparency and promote responsible production, sourcing, and stewardship of materials in the solar value chain. The SSI works collaboratively with manufacturers, developers, installers, and purchasers across the global solar value chain. It is currently in the process of becoming a multi-stakeholder initiative.

The SSI ESG Standard is the basis for the certification programme for production sites engaged in manufacturing of polysilicon, ingots, wafers, cells and modules, and other component manufacturing. It sets out ESG requirements to evaluate a site's performance in three key areas: Governance and Business Ethics; Environment; and Human and Labour Rights.

Towards Sustainable Mining (TSM)

Towards Sustainable Mining (TSM) is an initiative curated by the industry membership organisation, the Mining Association of Canada (MAC). The Standard evaluates eight topics related to social and environmental performance. TSM was the first mining sustainability standard in the world to require site-level assessments. It is mandatory for all companies that are members of the MAC for their Canadian operations and has been adopted by several other mining chambers around the world.

ANNEX 2: Methodology Guide

ESG Issue Salience & Voluntary Standards Coverage Comparison Matrix

Issue salience

TDi Sustainability collects and categorises published reports on ESG issues in a wide range of material supply chains and applies a proprietary methodology to systematically grade the significance, or 'salience' of each issue, in a way that allows objective comparison between issues and between materials.

The salience of each issue for each material is determined by the number of public issue reports identified (from January 2017 to the present day), the severity of any allegations, and the prominence and credibility of the source.

The more reports that are identified, the more serious the allegations, and the greater the prominence and credibility of the source, the higher the salience score assigned. Numerical salience scores are then converted to a grade ranging from 'very low' salience to 'very high' salience.

The exception to this methodology is the assessment of each material's association with seven ESG issues: greenhouse gas emissions; potential for acid discharge to the environment (not used in this report – used in other materials' analyses by TDi); artisanal and small-scale mining; countries experiencing conflict; countries experiencing weak rule of law; countries experiencing poor human rights; and countries experiencing poor environmental governance. These indicators are determined through research into credible literature sources on the material's association with an issue. The figures are then assigned a grade from 'very low' to 'very high', based on TDi's standardised thresholds.

Salience scores for steel reflect public issue reports associated with iron production, but not those associated with the production of other minor metals used in steelmaking as alloying elements.

Environmental, Social, and Governance (ESG) Indicators

Deforestation
The conversion of forests to other land uses, such as agriculture, mining, or human settlement. The indicator does not include tree cover loss from logging within production forests, natural fire, disease, or storm damage.

Degraded/fragmented landscape
Changes to landscapes by human activity that permanently and negatively affect the landscape's productivity, capacity to deliver ecosystem services and/or result in the landscape being broken-up into disconnected fragments. Landscape degradation may include soil, vegetation and water degradation, climate deterioration, and losses to urban/industrial development.

Negative biodiversity and conservation impact
Harm caused to wildlife and plant species and the ecosystems of which they are part, including terrestrial, marine, and other aquatic ecosystems, because of human activities. The indicator includes negative impacts on species and ecosystem diversity, and protected areas or other areas of conservation importance.

Pollution
The introduction of harmful materials or substances into the environment that degrade the quality of water, soil, and air. This may include unauthorised releases to water, soil and air, hazardous and non-hazardous chemical pollutants in the solid, liquid, or gaseous phases, releases of particulates into the atmosphere, and thermal discharge to water. The indicator does not include greenhouse gas emissions.

Greenhouse gas emissions
The relative level of CO_2 emissions associated with the production or processing stages of a material's life cycle. The indicator excludes emissions associated with the use of the final product.

Tailings breaches
The failure of a tailings dam or storage facility, resulting in the uncontrolled release of stored materials that could cause harm to humans or the environment.

Potential for acid discharge to the environment
(not used in this report – used in other materials' analyses by TDi)

NO	YES
No or very low potential for acid discharge to the environment	Potential for acid discharge to the environment

This criterion identifies whether the material is associated with the potential of acid discharge into the environment. This is assessed according to whether the material is likely to be found in acidic sulphide ores, heightening the possibility of acid-mine drainage (AMD), as well as the use of acid (leachates) during the recovery of the material (leaching). The impacts from uncontrolled acid discharge to the environment can be severe. Unmanaged acidic discharge from mines creates further contamination impacts by leaching metals (such as copper and nickel) into local soil and water systems, which is exacerbated during comminution (crushing and grinding of ore and rock). The likelihood of acid discharge is highly dependent on the management practices and systems being implemented at operating sites and facilities. It should be noted that with good management practices the risk of acid discharge to the environment can be dramatically reduced.

Child labour
The employment of children in work that is harmful to their mental, physical, or social development, is dangerous, or interferes with their education, as defined by the ILO.[41] 'Worst' forms of child labour[42] include all forms of slavery, trafficking and forced labour, commercial sexual exploitation, children used in the commission of crime, and work by its nature that is likely to harm the health, safety, or morals of children. 'Hazardous' child labour[43] includes sexual abuse, work underground, under water, at dangerous heights or in confined spaces, work with dangerous machinery, equipment and tools, exposure of children to hazardous substances, agents or processes, and work under particularly difficult conditions such as work for long hours or during the night.

Community rights violations
Violations of the human rights of community members, including their rights to life, health, property, and a healthy environment, arising from business operations. The indicator includes gross human rights violations and actions by public or private security forces that contravene the Voluntary Principles on Security and Human Rights (VPSHR) against community members, such as execution, abduction, torture, cruel, inhuman, or degrading treatment or punishment, widespread sexual abuse, wrongful or arbitrary arrests, excessive use of force by security forces, and other gross human rights violations.

Company/community conflicts
Violent or non-violent protests, disputes or conflicts involving companies and the local communities that are affected by their operations, resulting from perceived or actual differences in the interests and priorities of these stakeholders. The main causes of company/community conflicts include environmental concerns, land and resource rights, use of force, health and safety concerns, economic concerns, consultation, artisanal and small-scale mining, corporate power, resettlement, corruption, and security issues.

Forced labour
The employment of persons in work that is performed involuntarily and under the menace of any penalty, as defined by the ILO.[44]

The indicator refers to situations in which persons are coerced to work using violence or intimidation, or by more subtle means such as manipulated debt, retention of identity papers, or threats of denunciation to immigration authorities. It includes all forms of modern slavery,[45] human trafficking, debt bondage and unauthorised compulsory labour.

The indicator intends to exclude forced child labour as it is covered under the child labour indicator, however some overlap may occur due to inconsistencies with the categorisation of forced child labour across the literature.

41 See ILO Minimum Age Convention No. 138.
42 See ILO Worst Forms of Child Labour Convention No. 182.
43 See ILO Worst Forms of Child Labour Recommendation No. 190.
44 See ILO Forced Labour Convention No. 29.
45 Forced labour encompasses 'modern slavery' to shed light on working and living conditions contrary to human dignity.

ANNEX 2:

Indigenous Peoples' rights
Violations of Indigenous Peoples' human rights and threats to the preservation of their cultural heritage, as set out by the United Nations Declaration on the Rights of Indigenous Peoples. This includes their rights to self-determination, equality and non-discrimination, traditional lands and resources, participation and consultation, subsistence and development, and customs and institutions.

Workers' rights
Violations of international standards on the rights of workers in relation to working conditions and employment relationships. The indicator includes collective bargaining, non-discrimination, employment security, wages, working time, diversity, equity and inclusion, and protection from harassment and violence. The latter condition considers gross human rights violations and actions by public or private security forces that contravene the Voluntary Principles on Security and Human Rights (VPSHR) against workers, such as execution, abduction, torture, cruel, inhuman or degrading treatment or punishment, widespread sexual abuse, wrongful or arbitrary arrests, excessive use of force by security forces, and other gross human rights violations.

Occupational health and safety
Violations of standards intended to ensure a safe and healthy working environment and protect workers and contractors from work-related injuries, fatalities, and illnesses. The indicator includes the requirement for health and safety inspections, accident reporting and investigations, hazard assessment, reporting and management, training in the achievement of adequate levels of safety and health, emergency response, and workers' rights to participate in workplace health and safety decisions, be informed of occupational hazards, and to remove themselves from dangerous workplace situations.

Violence and conflict
The contribution to armed conflict and widespread violence or harm to people from actors engaged in business operations. The indicator includes war crimes, crimes against humanity, genocide, direct or indirect support to non-state armed groups, direct or indirect support to security forces illegally involved in material supply chains, direct or indirect support to organised crime and other serious violations of international humanitarian law.

Corruption
The abuse of power to acquire illicit benefits or private gain. The indicator often involves payment or receipt of bribes; but also includes extortion, fraud, embezzlement, collusion, trading in influence, abuse of position, misrepresentation of the origin of materials, the use of unethical auditors, conflicts of interest and other forms of deception. The indicator excludes money laundering and non-payment of taxes, which are covered separately.

Production from artisanal and small-scale mining

Very low: less than 5%
Low: 5% to 10%
Moderate: from 10% to 15%
High: from 15% to 20%
Very high: more than 20%

This criterion describes the percentage (%) of global production reportedly attributable to artisanal and small-scale mining (ASM). In general, the greater the proportion of production from ASM, the more likely it is that the material could be associated with serious environmental and human rights impacts.

There is no accepted universal definition of ASM. However, for the purpose of this report, we define ASM as follows:

ASM comprises all types of mining operations, non-mechanised or mechanised, that do not represent conventional industrial mining enterprises. Artisanal mining involves only individuals or families and is purely manual. Small-scale mining, however, is more extensive and usually more mechanized. ASM takes place mostly in rural areas where operations may be formal or informal. These operations can be described as low technology and labour-intensive mineral extraction and processing activities, which exploit commodities.

Illicit financial flows
The movement of money across borders that is illegally earned, transferred, or utilised. The indicator includes the utilisation of funds that originate from corruption, criminal activities, tax evasion, and transfer mis-pricing for money laundering and terrorism financing.

Non-payment of taxes
The illegal evasion of taxes, fees and royalties, or use of legal practices to reduce tax liability. The indicator includes the non-payment and underpayment of taxes, the misuse of tax reliefs and allowances, the exploitation of international tax instruments, and the mis-invoicing of a transaction.

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 0 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.

Countries experiencing weak 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 measures the material's strength of association with key producer countries that have weak rule of law. This is determined by the following country-level indices:

- **World Governance Indicators Control of Corruption;**
- **Transparency International Corruption Perceptions Index;**
- **World Governance Indicators Rule of Law;**
- **World Governance Indicators Regulatory Quality.**

For each of the indices, the given ratings are normalised onto a 0-100 scale, where scores closer to 0 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 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 conflict.

ANNEX 2:

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 0 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 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 conflict.

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 0 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.

Voluntary standards issue coverage:

To arrive at a determination of whether a voluntary sustainability standard covers an ESG issue, the provisions of each included standard were examined in detail. A standard was determined to 'cover' an ESG issue if it was judged that the provisions of the standard, if implemented in full, would lead to a significant mitigation of the issue at the implementing site.

For the purpose of this determination, only a standard's mandatory criteria were considered. Standards' optional criteria, where they exist, were not considered in the coverage mapping exercise.

For very detailed information on standards, please contact TDi regarding its Integrated Compliance Assurance Tool or see page 9 for more information.

Quantitative Indicators Used In Material Profiles

Top producer country information

% Global mined production
Percentage of global production originating from the country, as calculated by the United States Geological Survey (USGS).

% Global reserves
Percentage of global reserves located in the country, as estimated by USGS.

% Mining sector contribution to GDP
Percentage of gross domestic product (GDP) attributable to mineral rents, where 'mineral' excludes coal, oil and gas. Mineral rents are the difference between the value of production for a stock of minerals at world prices and their total costs of production. Minerals included in the calculation are tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite, and phosphate. Information is from the World Development Indicator 'Total natural resource rents (% of GDP)' based on 2021 data.

Human Development Index
Score of 0-1, where 0 = no human development and 1 = highest potential human development.

The Human Development Index (HDI) is an index of potential human development, assuming no inequality. It is a composite index combining life expectancy, education, and per capita income indicators, which are used to rate countries into four tiers of human development. A country scores a higher HDI when the lifespan is higher, the education level is higher, and the GDP per capita is higher. Switzerland currently has the highest HDI value at 0.962 while South Sudan has the lowest, at 0.385, according to the latest dataset from 2021.

Rule of Law

Very strong rule of law	Country falls into the top quartile of the WGI Rule of Law indicator ranking.
Strong rule of law	Country falls into the third quartile of the WGI Rule of Law indicator ranking.
Moderate rule of law	Country falls into the second quartile of the WGI Rule of Law indicator ranking.
Weak rule of law	Country falls into the bottom quartile of the WGI Rule of Law indicator ranking.

This criterion identifies whether the key producing countries of each material are associated with weak rule of law.

The Worldwide Governance Indicator (WGI) for Rule of Law is the primary source of information. The WGI describes its Rule of Law indicator as 'capturing perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence'. It should be noted that the WGI's indicator captures 'perceptions' of the rule of law in a country, providing aggregate measures constructed by averaging together data from multiple underlying sources.

Experience of corruption

Low levels of corruption	Country falls into the top quartile of the WGI Control of Corruption indicator ranking.
Moderate levels of corruption	Country falls into the third quartile of the WGI Control of Corruption indicator ranking.
High levels of corruption	Country falls into the second quartile of the WGI Control of Corruption indicator ranking.
Very high levels of corruption	Country falls into the bottom quartile of the WGI Control of Corruption indicator ranking.

This criterion identifies whether the key producing countries of each material are associated with corruption.

The Worldwide Governance Indicator (WGI) for Control of Corruption is the primary source of information. The WGI describes its Control of Corruption indicator as 'capturing perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests'. It should be noted that the WGI's indicator captures 'perceptions' of corruption in a country, providing aggregate measures constructed by averaging together data from multiple underlying sources.

ANNEX 2:

Heidelberg conflict barometer

Levels of political conflict:

- Dispute (1)

- Non-violent crisis (2)

- Violent crisis (3)

- Limited war (4)

- War (5)

The Heidelberg Conflict Barometer is the work of the Heidelberg Institute for International Conflict Research (HIIK). HIIK adopts the concept of political conflict, which is a positional difference between at least two assertive and directly involved actors regarding values relevant to a society and which is carried out using observable and interrelated conflict measures that lie outside established regulatory procedures and threaten core state functions, the international order, or hold the prospect of doing so. The HIIK methodology distinguishes between five levels of conflict intensity: dispute, non-violent crisis, violent crisis, limited war, and war. The violent crises levels are considered medium intensity conflicts, while wars and limited wars are high intensity conflicts.

Supply significance indicators

EU dependency on imported material

Score of 0-100%, where 0 = no reliance on imports, and 100 = total reliance on imports.

- Low: less than 25%
- Moderate: from 25% to 50%
- High: from 50% to 75%
- Very high: more than 75%

The criterion describes the degree to which the EU relies on imports of the material from sources outside the EU. These data alert industry to the possibility that future supply of the material may depend on strategic trade relations and therefore might imply that the surety of its supply is vulnerable. The 'import reliance rate' – a parameter used to balance the risks linked to the global supply mix and the actual EU sourcing mix (domestic production plus imports) – considers global supply and actual EU sourcing in the calculation of supply risk, and it is calculated as follows: EU net imports / (EU net imports + EU domestic production). The indicator does not account for a circular life cycle (e.g. input of recycled materials).

US dependency on imported material

Score of 0-100%, where 0 = no reliance on imports, and 100 = total reliance on imports.

- Low: less than 25%
- Moderate: from 25% to 50%
- High: from 50% to 75%
- Very high: more than 75%

The criterion describes the degree to which the US relies on imports of the material from sources outside the US. These data alert industry to the possibility that future supply of the material may depend on strategic trade relations and therefore might imply that the surety of its supply is vulnerable. The USGS National Minerals Information Center tracks how much the United States relies on other countries for minerals critical to the economy and national security. The indicator is calculated using the same methodology as the EU dependency indicator. It does not account for a circular life cycle (e.g. input of recycled materials).

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 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 it is predominantly produced in just a few key countries, and therefore more prone to supply disruptions, or whether production is more evenly distributed worldwide.

Price volatility

- Very low: less than 0.1
- Low: from 0.1 to 0.15
- Moderate: from 0.15 to 0.3
- High: from 0.3 to 0.4
- Very high: more than 0.4

This index measures the degree of fluctuation in the price of a mineral or a material on listed market exchanges, over the last 5 years, with large fluctuations indicating a risk to the resilience of supply chains.

This index is calculated using a formula that measures the degree of fluctuation in the price of a material 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.

Depletion

- Very low: less than 0.6
- Low: from 0.6 to 0.85
- Moderate: from 0.85 to 1
- High: from 1 to 1.2
- Very high: more than 1.2

The depletion risk index measures the shift in the reserves relative to production, in the past five years. If the fraction of production relative to global reserves increases in those five years, the depletion risk is greater than 1, and vice versa.

Recycling

- Very low: more than 0.4
- Low: from 0.3 to 0.4
- Moderate: from 0.2 to 0.3
- High: from 0.05 to 0.2
- Very high: less than 0.05

The recycling rate measures the percentage of the raw material that enters the production system from recycling of 'old scrap'. This measure is known as the End-of-Life Recycling Input rate (EOL-RIR). 'Very low' to 'very high' risks are assigned based on the level of recycling. If the recycling rate is low, this represents a high risk to supply chain resilience.

TDi Sustainability

Material Change for Renewables is an essential guide for producers and purchasers of clean energy. It examines where the key challenges lie in the mineral supply chains for solar panels and wind turbines, and presents approaches and resources for meeting these challenges.

The report includes:

- Key ESG risks associated with the minerals and metals used in solar panels and wind turbines
- The risk mitigation potential of voluntary sustainability standards
- Profiles for three key materials: aluminium, steel, and silicon
- How ESG considerations may affect, and be affected by, future rises in demand
- Supply chain due diligence recommendations for producers and purchasers of clean energy

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