Minerals for Energy Transition

Guiding Principles

GREENPEACE

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Introduction

Minerals such as lithium, nickel, copper, and cobalt – often called "transition minerals" or "critical minerals"* – are playing an increasingly pivotal role globally. These minerals have many different uses across the economy, which include renewable energy and electric transport. Industries and governments are concerned about the supply of such minerals in the future.[1]

The use of these minerals must be prioritised for a fast, just, and green energy transition away from fossil fuels. At the same time, the current economic model — focused on constant growth and resource extraction — needs to shift toward one that is sustainable, fair, and stays within the planet's limits.

There are many solutions that reduce mineral demand and the need for mining. These include sufficiency measures such as improved public services, measures to increase efficiency, technological substitutions, and circularity policies and investments that extend product lifespans and generate new mineral supply through recycling. However, even with these solutions, studies project that some new mining will likely still be necessary for the energy transition[2].

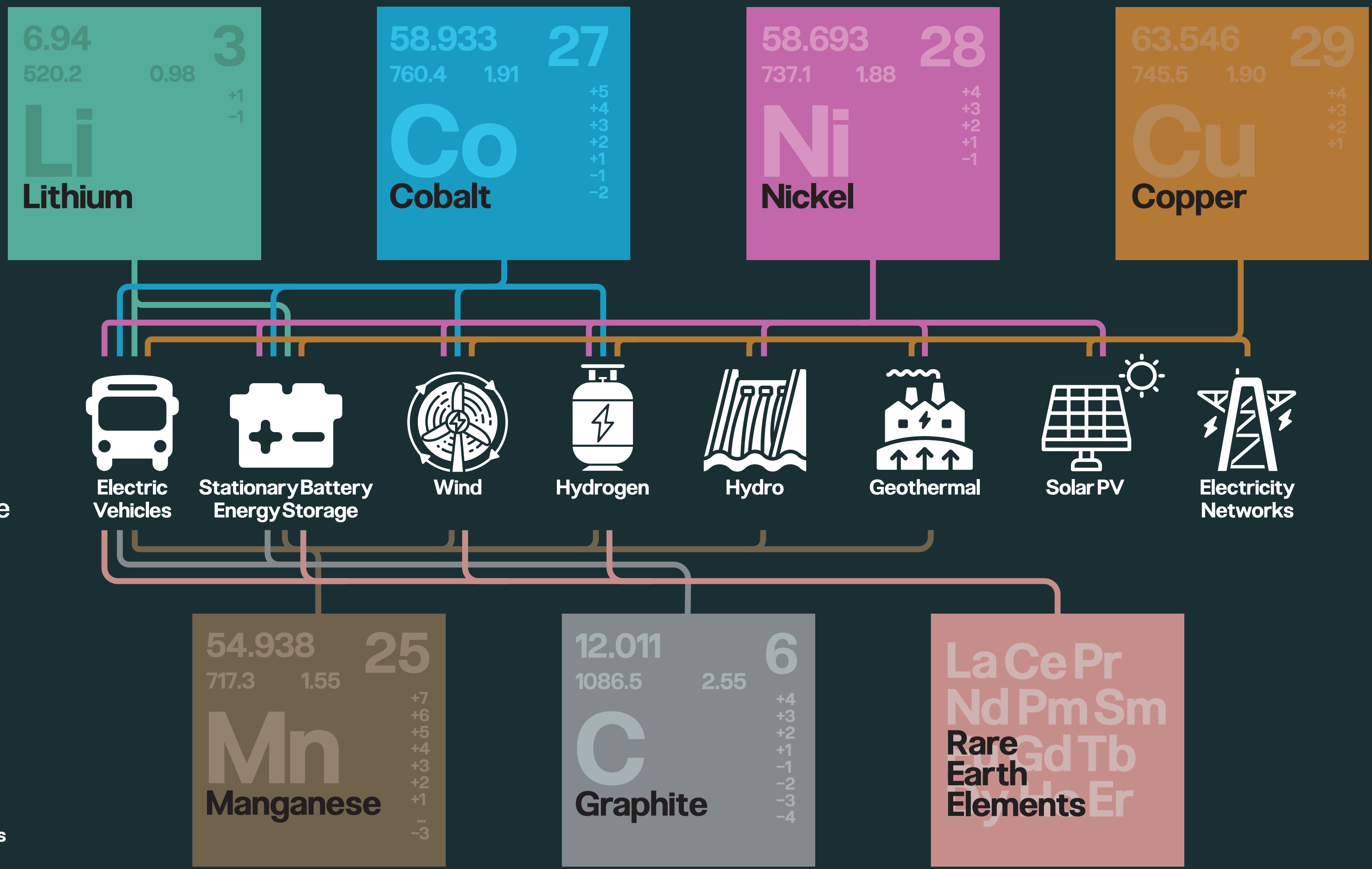
As mining continues to pose significant risks to ecosystems, Indigenous Peoples, and local communities, mining must not occur within no-go zones and environmental impacts must be minimised, with companies acting responsibly and respecting human rights.

The purpose of these principles is to set out a pathway for ensuring that the supply and use of transition minerals is both just and equitable, and they can be adapted into local contexts.

*Other terms include "energy transition minerals" (ETMs) or "critical energy transition minerals" (CETMs). Governments, industry and organisations like the International Energy Agency tend to use "critical" or "strategic" minerals. In some cases, 'Critical Minerals' could imply that other resources (e.g., water) are not critical. The term also feeds a narrative that justifies trade-offs when there is opposition to "critical" development. In this document, we use "critical minerals" in contexts that may extend beyond transition purposes.

Which minerals are most important for energy transition technologies?

These minerals are key examples of those considered “critical” for energy transition technologies and infrastructure. They are mined and processed in a wide range of geographies.



Modified from the United Nations Environment Programme, 2024[3]

Where in the world?

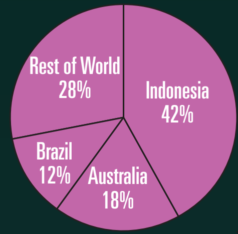
Critical minerals are found globally. This map shows countries with the highest reserves* of select minerals.

Global Reserves for Select Minerals

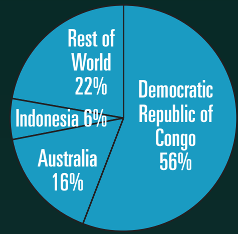
(United States Geological Survey, 2025)[5]

Global Lithium Reserves

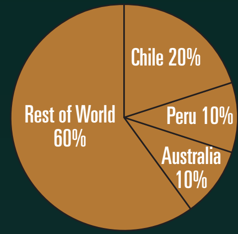
Global Nickel Reserves

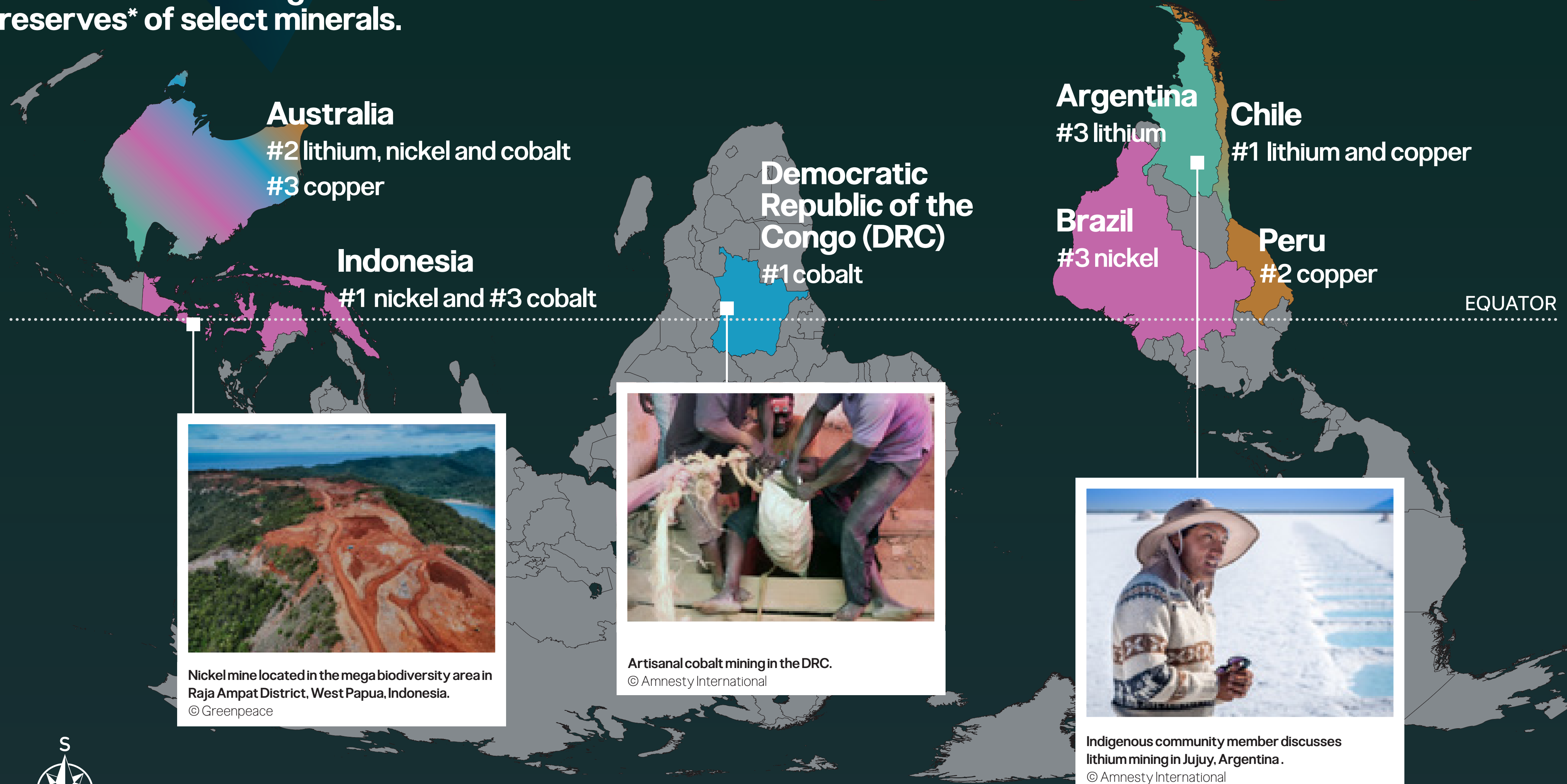


Global Cobalt Reserves



Global Copper Reserves





Nickel mine located in the mega biodiversity area in Raja Ampat District, West Papua, Indonesia.
© Greenpeace

Artisanal cobalt mining in the DRC.
© Amnesty International

Indigenous community member discusses lithium mining in Jujuy, Argentina.
© Amnesty International

*Deposits classified as "reserves" means they are currently economically feasible to extract. Reserves numbers change over time as deposits are discovered and developed.[4]

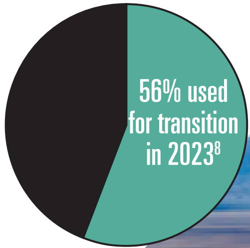
Examples of Mineral Mining Impacts, Amounts, and Uses Globally

Lithium

Salt brine mining in and around the drought-prone Andes evaporates millions of litres of water from the arid ecosystems.[6] Many Indigenous communities are adversely affected. This can also lead to tensions and conflicts within and between communities.[7]

Besides transition use, Lithium is also used in pharma, electronics, glass, and ceramics.[8]

Amount mined in 2024: 0.24 million tons[9]



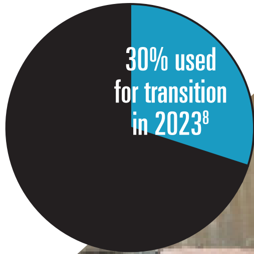
Aerial view of lithium fields in the Atacama desert in Chile, South America. ©Shutterstock

Cobalt

Many small scale facilities in the DRC can lack safety measures. Workers suffer fatalities, accidents, and serious health issues. Workers can include children as young as seven years old.[10]

A major non-transition use of cobalt is superalloys for military and aerospace.[8]

Amount mined in 2024: 0.29 million tons[9]



Artisanal miners load cobalt ore to a truck in the DRC. ©Afrewatch 2020

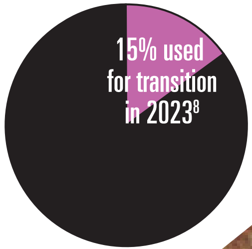
Nickel

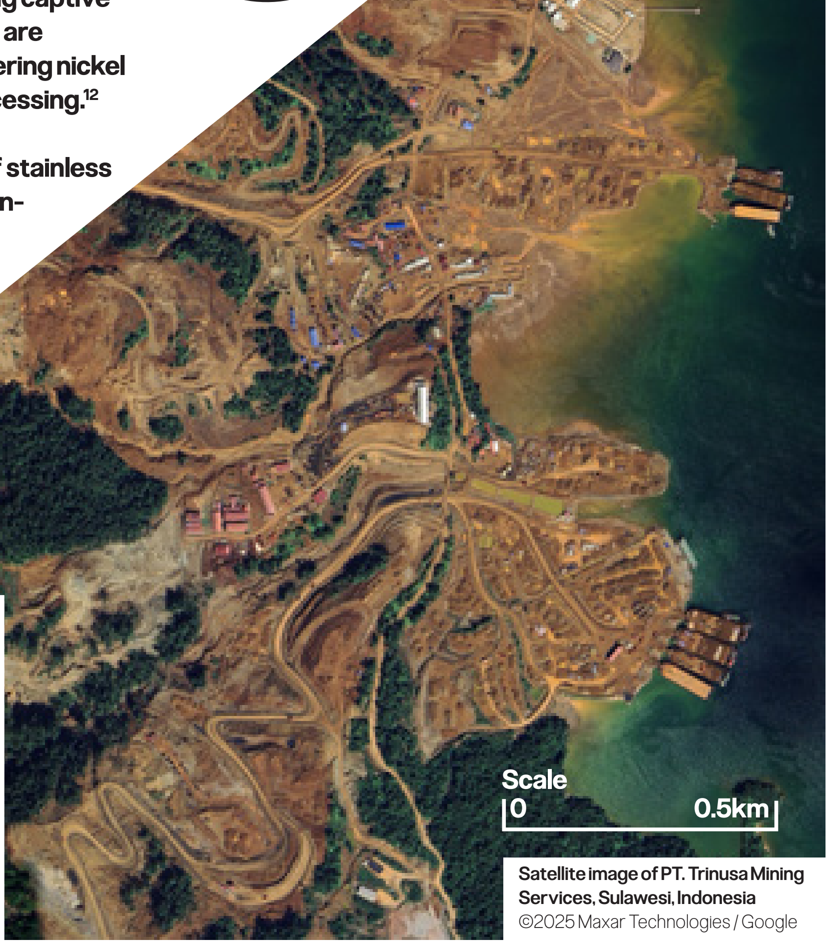
Strip-mining extraction and processing in Indonesia is driving deforestation and coastal waters/reef pollution. Mining is also leading to land grabbing, Indigenous and labour rights violations, and corruption.[11]

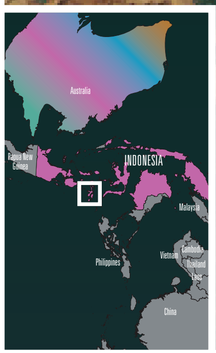
High-GHG emitting captive coal power plants are increasingly powering nickel smelting and processing.[12]

The production of stainless steel is a major non-transition use of nickel.[8]

Amount mined in 2024: 3.7 million tons[9]







Satellite image of PT. Trinusa Mining Services, Sulawesi, Indonesia
©2025 Maxar Technologies / Google

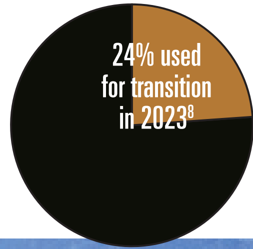
Copper

It has been reported that copper mining to date has generated almost half of global tailings.[13]

Tailings are a type of mine waste resulting from the extraction of many different minerals. Some pose significant risks to people and the environment, and need continuous risk mitigation.[14]

Non-transition uses of copper include construction[8] and jewelry.

Amount mined in 2024: 23 million tons[9]



Mount Polley, Canada, pictured one month after its tailings dam failed in 2014, releasing mine waste into Polley Lake, Hazeltine Creek watershed, and Quesnel Lake.
© Terrasaurus Aerial Photography Ltd

Minerals and Geopolitics

Governments, notably the U.S. and in Europe,[15] are reshaping critical minerals supply chains. They are attempting to expand mining in their territories (and others) amidst geopolitical tensions to compete with other nations.[16] This is likely to shape the future of mineral supply chains in the long term.

The military is another non-energy transition market for a number of minerals considered 'critical'. Many of these minerals are used to build munitions, jets, tanks, or specialised equipment.[17]

Left: ©Shutterstock
Right: ©Unsplash

Future supply and demand for minerals depends on choices made today

Many projections outline significant growth in demand for transition minerals in the coming decades.[18] These projections are then used to justify expansion of mining.

Yet demand projections are highly variable, and are likely to evolve over time. They depend on many assumptions – about societal changes, future technologies, policy, and circularity.[19]

As a result, the extent of future demand for these minerals is uncertain and likely to change from current estimates. Choices that governments and industries make today and in the future can reduce demand, and the need for mining.[20]

Factors that are likely to affect supply and demand for minerals significantly include:

Ambition on climate policy and speed of travel, and the scale and speed of investment in less mineral-intensive solutions like public transport.[21]

Investment in energy-related technologies and circularity. Using different battery chemistries, improving the performance of current technologies, improving recycling rates and better repairability and reuse of products could all reduce mineral demand.[22]

Systemic shifts in society can reduce excessive demand for minerals, energy, land, water and other natural resources. This is sometimes called 'sufficiency', which aims to decrease the need for resources overall in an equitable manner through structural changes and policies.[23]

Greenpeace's Guiding Principles on Minerals for Energy Transition

The principles outlined in the following pages present a pathway for ensuring the just and equitable use of minerals for a fast, just, and green energy transition. Reducing demand, and finding alternative supplies where available (for example through circularity and recycling) are key parts of this.[24]

Governments must play an important role through policy, regulatory, and accountability measures for mineral use and sourcing. Companies should act responsibly even if States lack the ability or willingness to protect and respect human rights and the environment.

Recognising that each country and community has unique realities shaping feasibility and impact, the following principles can support energy transition when adapted into local contexts.

1. Minimise Warming to no more than 1.5°C

The Guiding Star

Limiting global warming to no more than 1.5°C is critical for the sake of climate, nature and humanity. As such, minerals must be prioritised for energy transition above other non-essential uses.

2. Find Just and Equitable Solutions

The Foundation

Justice and equity is foundational to energy transition and must be embedded in all the related solutions for the use and sourcing of minerals.

3. Reduce Demand

Use Less

Slowing mineral demand growth is essential. There are many ways to reduce demand, such as improving public services and transport, fostering sharing and reuse, enhancing the efficiency of technology, and substituting technologies.

4. Source from "Above Ground"

Use What we Already Have

Recycling must become a preferred source of transition minerals in the coming decades. Recycling infrastructure, incentives, and supporting policies must be key priorities for governments to maximise this supply.

5. Protect Sensitive Areas, and the Rights of Indigenous Peoples and Local Communities

Restrict Mining

Mining and ore processing activities continue to pose serious risks to people and the environment. "No-Go Zones" should be off-limits, and stronger protections are needed to prevent harm. The rights of Indigenous Peoples and local communities must be respected.

©Michael Amendolia/Greenpeace

1. Minimise Warming to no more than 1.5°C

The Guiding Star

It is imperative that the world limits global warming to no more than 1.5°C for climate, nature and humanity. As such, minerals use and sourcing must serve a swift phase out of fossil fuels.

Fortunately, the quantities of raw materials needed in a renewable energy system (minerals) are much smaller than in a fossil fuel-based energy system (gas, oil, and coal).[25] And unlike fossil fuels, transition minerals can be reused and recycled repeatedly in a circular economy.[26]

Most critical raw materials are used not only for green energy and transport, but also in military equipment, and everyday items like portable electronics. **Prioritising current and future mineral use for a green energy transition** is crucial – for example in regions where the coal phase out is a top priority – unless there is a strong reason not to, such as for some health applications[27].

2. Find Just and Equitable Solutions

The Foundation

Left: Community leader advocates for equity in Vanuatu. ©Arlene Bax/Greenpeace
Right top: Fighting inequality in Manila. ©Jilson Tiu /Greenpeace
Right bottom: Youth advocate for justice in Tanzania. © Magsman Media/Greenpeace

Embedding justice and equity in every aspect of using and sourcing minerals – from reducing demand, to recycling and mining – is foundational for achieving a just energy transition.

The energy transition must not deepen global inequality by exploiting the Global South to fuel the Global North's shift to green energy. Solutions must tackle global injustices, including the uneven risks and benefits of mineral use and sourcing. Affected people must have a real voice in decision-making, international human rights must be respected, and strong, enforceable standards and transparency measures must be put in place.

Where mining does take place, the countries and communities endowed with these resources must be the ones to benefit the most.

2. Find Just and Equitable Solutions

The Foundation

This principle incorporates the following:

2.1 Equitable approaches: Minerals sourcing and use must be fair and just. For example, high-consuming countries should focus on reducing mineral demand and maximising recycling before looking to mining domestically or abroad. Where mining does take place, mineral-rich nations and regions should benefit the most, including through clean, equitable local development.

2.2 Inclusive development: Decision-making must actively involve Indigenous Peoples and local communities impacted by energy transition development. Their rights, cultures, and traditional lands must be respected and preserved.[28] This includes seeking current and retroactive Free, Prior and Informed Consent (FPIC) and ensuring their other rights under the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP), and under domestic and international law.

2.3 Human rights and safety standards: Whether companies focus on mining, recycling, or manufacturing, all of them must ensure they respect human rights, including the right to a healthy, clean, and sustainable environment.[29] In addition, business enterprises must ensure their suppliers at all stages of the supply chain uphold labour and safety rights.[30] This includes paying fair living wages, fair compensation to workers for occupational diseases and injuries sustained while at work and for loss or damage to property, and freedom of association and collective bargaining. This also means ensuring suppliers involved with private security respect Indigenous Peoples' and local communities' rights. Employment practices should also promote equity, diversity, and inclusion.

2.4 Effective governance: State authorities must establish robust legal and regulatory frameworks. This includes mandatory international standards and incorporating best possible anti-corruption standards. Standards should enforce effective environmental and social protections across supply chains and address power imbalances between corporations and communities. They must also ensure local and national economic benefits from energy transition development. Industry must work with governments to follow international law and best practices, while exercising thorough due diligence. These frameworks support community wellbeing and sustainable development.[31] Importantly, corporate responsibility to respect human rights stands regardless of whether States are able—or willing—to fulfill their own human rights obligations.[32]

2.5 Transparency and Access to Justice: Transparency is an essential component of accountability and building trust. There are many steps between mining and making a solar panel, and then later recycling it. Transparency at the individual steps, and throughout supply chains, is an essential part of an accountable system. This includes accessible chains of custody and beneficial ownership information. States must require companies to establish open and accessible reporting mechanisms for communities, for example, to monitor water use, or track the environmental and social impacts of mining or processing. Transparency measures adopted by companies should not substitute the actions required to uphold their responsibility to respect human rights. Companies should also put in place robust grievance mechanisms, respecting the Århus convention and Escazu agreement, and other national and international law.[33] These should allow communities to report any concerns so they can be resolved promptly and fairly. These measures will ensure that affected communities have a voice, and access to justice.[34] Moreover, institutional access to justice for all affected people must be guaranteed at all times.

3. Reduce Demand

Use Less

Technology repaired. ©Unsplash

For a just energy transition, governments should prioritise slowing mineral demand growth, especially in the Global North. All actors must avoid overstating demand, which could lead to unnecessary extraction and investment. This approach will reduce the pressure on Earth's systems, vulnerable ecosystems, and communities facing urgent risks.[35] It is important that demand reduction considerations are equitable, considering local development needs and historic material use.

To use less, sufficiency and efficiency are useful concepts. They are distinct yet complementary, and both are crucial.

Sufficiency

Reduces the need for resources overall

- **Avoids excessive demand for materials, energy, land, water and other natural resources.**
- **Delivers a decent living standard for all within planetary boundaries.[36]**
- **Emphasises an equitable approach to the use of resources.**

Efficiency

Enhances the effectiveness of resource use

- **Optimises the use of resources to achieve the same level of output with less input.**
- **Focuses on improvements that enhance productivity and reduce waste.**
- **Makes the best possible use of available resources and reduces the demand for new resources.**

Reducing demand can happen through:

©Paul Langrock/Greenpeace

3.1 Systemic Changes

Economies designed to be less dependent on growth while also embracing sufficiency,* will help to reduce excessive energy and material needs while improving social wellbeing.[37]

3.2 Substitution

Technical innovation can remove or reduce the need for certain materials in products, such as new battery chemistries or alternative technologies.[39]

3.3 Efficiency

Using materials and products efficiently reduces the volume of recycled and raw materials needed. This includes designing products for highest performance, durability, longevity, and repairability.

*Sufficiency measures include ensuring everyone's access to basic needs, regulating wasteful production, fostering sharing economies, improving public services and infrastructure, and increasing public and active transport. These can reduce consumption of natural resources, and less mining needs to happen as a result.[38]

Top: recycled battery materials. ©Ascend Elements
Right: lithium ion battery recycling. ©Ascend Elements
Left: Electronic waste recycling, India. © PradeepGaurs/Shutterstock

4. Source from "Above Ground"

Use What We Already Have

Recycling must become a key source of transition minerals in the coming decades. Compared to mining, recycling 'above-ground' supply can significantly decrease environmental and social impacts.[40]

Potential sources include spent batteries, production wastes, household e-waste, and industrial scrap piles.

Recycling of EV batteries has the potential to reduce new mining significantly.[41]

In one scenario, annual lithium, nickel, cobalt, and manganese demand for use in certain EVs could be reduced by up to 28% by 2050 through recycling.[42]

To ensure ample 'secondary' supplies,[43] collection and recycling levels* for key products must be maximised.[44] Recycling infrastructure, incentives, and supporting policies must be key priorities for governments.

*Collection rate is the percentage of a technology or infrastructure retiring that is collected and eventually recycled. Material recovery is specific to a particular mineral (e.g., lithium) and is typically expressed as a % of mass recovered in the recycling process.

Above-ground ('secondary') supply is supported by:

4.1 Maximising reuse, repurposing, and recycling:

Governments must demand strong circularity standards for collection, recovery and reuse of products and materials. This may include targets for levels of recycled materials in new products.

Stringent Extended Producer Responsibility (EPR) regulations would require manufacturers to retain responsibility for their products throughout their lifecycle. Producers should establish processes for collection and valuable material recovery. They should also design products for easier reuse and repair, and provide take-back schemes for recycling.

Measures like Battery Passports, which are documents with lifecycle battery data and tracing could support these goals. Their aim is to ensure transparency and accountability in the recycling process. Battery Passports are required in the EU starting in 2027, and increasing recycled content will be required in batteries (e.g., 16% recycled cobalt content by 2031, increasing to 26% in 2036).[45]

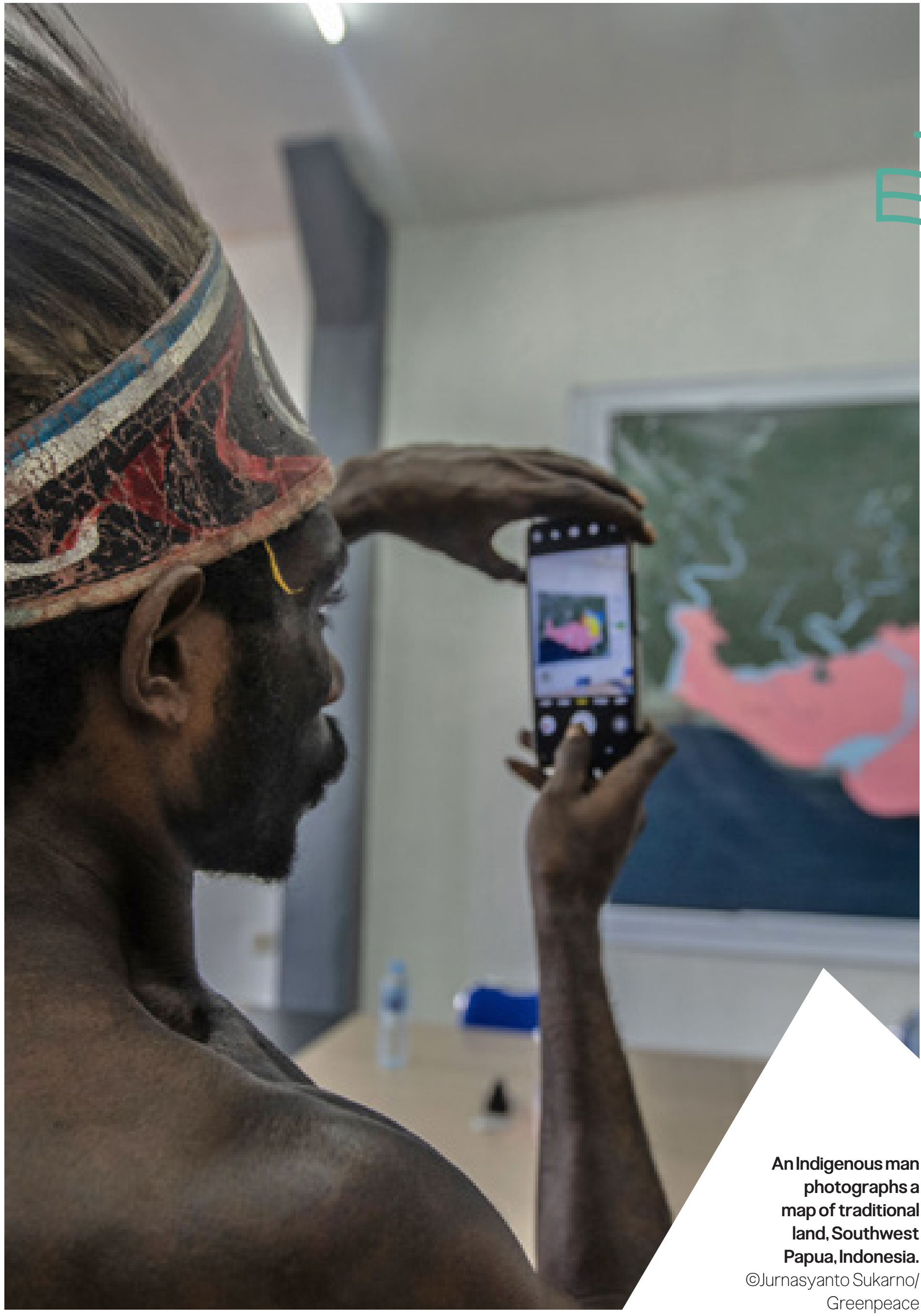
4.2 Addressing barriers to recycling at scale:

This may involve improving recycling technologies, or streamlining collection and processing systems. It may involve governmental incentives for businesses to invest in recycling infrastructure and innovation. Consumer awareness of, and participation in, recycling programs is also essential.

Lithium ion battery recycling to date has focused on recovering only a narrow range of high value metals. Widening the range of metals recycled, while maximising recycling efficiencies, are part of this effort.[46]

4.3 Evaluate the risks of mining tailings:

Tailings are waste materials left after minerals are extracted from ore, and could offer a potential source of minerals,[47] but the feasibility and risks remain uncertain. Further study, and application of the precautionary principle, is essential to understand amounts available and the related risks of development, which could be similar to primary mining.[48]



An Indigenous man photographs a map of traditional land, Southwest Papua, Indonesia.
©Jurnasyanto Sukarno/ Greenpeace

5. Protect Sensitive Areas, and the Rights of Indigenous Peoples and Local Communities

Restrict Mining

There are many global initiatives pushing for improved mining practices.[49] Despite these, mining and ore processing activities continue to pose serious risks to people and the environment, including from human rights abuses and toxic pollution.[50]

Mining activities include prospecting, the expansion of existing operations, and development of new areas. To address these serious risks, when sourcing transtion minerals the Precautionary Principle[51] should be applied through the protection of 'No-Go' Zones and rights, and rigorous social and environmental due diligence assessments. These requirements must be followed:

5.1 Protect 'No-Go' Zones.

5.2 Respect the rights of Indigenous Peoples and local communities.

5.3 Companies must act responsibly, preventing and mitigating environmental damage and impacts, and respecting human rights.

5.1 Protect 'No-Go' Zones

These include:

1) Protected Areas and areas recognised by international conventions and agreements: all categories, including IUCN protected areas I-VI, Indigenous Protected Areas (IPAs) and community conservation and protected areas (ICCAs), World Heritage Areas, Ramsar sites, UNESCO Global Geoparks and Biosphere Reserves.

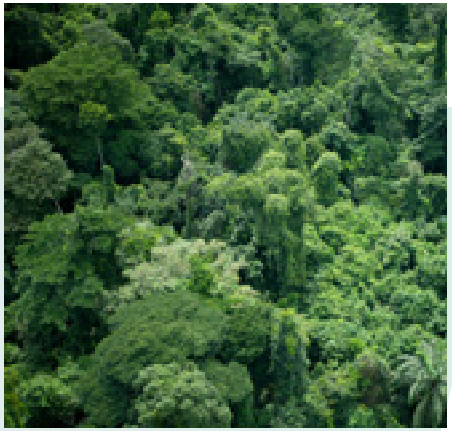
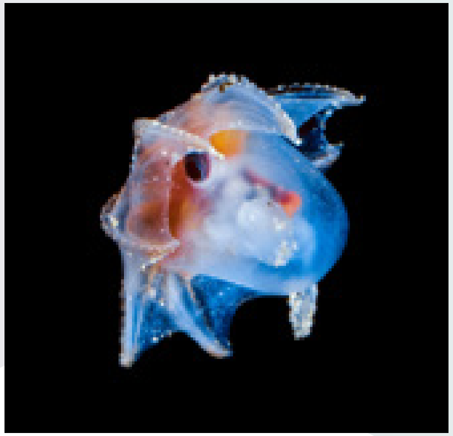
2) High Conservation Value (HCV) areas.[52] These are areas with biological, ecological, social, or cultural significance, including Intact Forest Landscapes (IFLs – HCV2). They are identified as having one or more of the following six HCVs: species biodiversity, landscape-level ecosystems, habitats, ecosystem services, community needs, and cultural values. These areas need to be appropriately managed to maintain or enhance their intrinsic values.

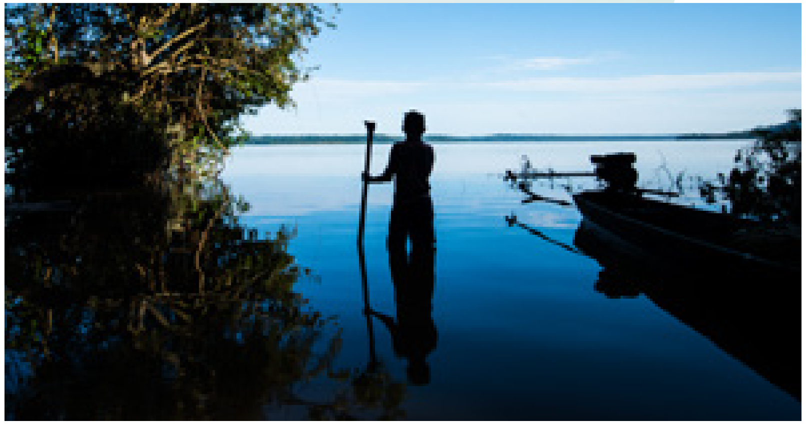
3) High Carbon Stock (HCS) areas.[53] This refers to areas of vegetation or soils, particularly forests, that have high amounts of stored carbon. These areas act as carbon sinks, absorbing carbon dioxide from the atmosphere and storing it in their biomass and soil. They also serve as a proxy for high biodiversity. HCS areas include all tropical primary forests, mangroves, and high-biomass peatland soils. Other forests, such as old growth boreal forests, as well as certain wetlands or grasslands are also potential HCS areas. Protecting HCS areas is crucial to maintain their carbon storage capacity and prevent the release of stored carbon into the atmosphere.

4) Significant natural ecosystems. This includes coral reefs, and the deep sea where a moratorium on deep sea mining is essential. Scientists still have much to learn about the ancient, as-yet untouched ecosystems of the deep ocean. Other ecologically important natural grasslands, wetlands, mangroves, shrublands, and savannah systems[54] can be misinterpreted as having little value, and must be evaluated for significance in local contexts.

5) Critical water bodies. These include all rivers, lakes, glaciers, significant streams, and other types of water bodies or drinking water supply sources, as well as a buffer zone that is sufficient to ensure their protection.

6) Indigenous Peoples' and local communities' territories. These include traditional and customary lands, waters, deep ocean areas, coastal and communally-owned areas, and the natural resources on which they depend, where their free, prior, and informed consent has not been obtained.



Top Left: Forest in Indonesia. ©Ulet Ifansasti /Greenpeace. **Top Right: Forest in DRC.** ©Greenpeace/ Kate Davison. **Middle Left: Deep sea dwelling Umbrella Octopus** ©Blue Planet Archive / David Wrobel. **Middle Right: Peatland Forest in Indonesia,** ©Will Rose/ Greenpeace. **Bottom: River in the Amazon Rainforest, Brazil,** ©Valdemir Cunha/ Greenpeace.

5.2 Respect the rights of Indigenous Peoples and local communities.

Indigenous Peoples and local communities have customary rights, whether legally recognised or not, over their lands and resources. These rights[55] – including to traditional territories, waters, coastal and communally-owned areas, the natural resources on which they depend, as well as their cultural rights – must be respected through applying the principle of free prior and informed consent (FPIC)* in advance of all mining-related activities. This includes rights to determine priorities for the development or use of such lands and resources, and to the use of traditional knowledge. In the case of the traditional territories of uncontacted or voluntary isolation communities, these areas should be off-limits.

Governments, companies and society must protect sites of cultural, religious or spiritual significance to Indigenous Peoples on land and in the ocean. Protection of these sites must be agreed according to ILO Convention 169[56] and the UN Declaration on the Rights of Indigenous Peoples.[57]

Economic objectives must not overshadow the rights of Indigenous Peoples and local communities living in or near mining areas. Companies should bear the costs of all short and long term mining impacts on communities. They should also uphold the UN Guiding Principles on Business and Human Rights[58] through human rights due diligence processes.[59] Indigenous Peoples and local communities living near mining should have access to relevant grievance mechanisms.[60]

Photo left: Indigenous Hawaiians protest against Deep Sea Mining.
© Marco Garcia / Greenpeace
Photo right: Sami 'No Consent No Access' Banner in Finland.
© Jani Sipilä / Greenpeace

*Many local communities are "tribal peoples", "traditional communities", "local resource dependent communities" or other categories of local communities that have collective decision-making processes and hold a strong collective connection to, and cultural reliance on, customary lands or natural resources. For these categories of local communities, FPIC is required to be applied as per Indigenous Peoples. This however in no way undermines the self-determination, non-discrimination, and collective rights basis of FPIC of Indigenous Peoples. In cases where the local community groups in question do not have collective rights and governance structures, the use of the concept FPIC, which is a collective decision-making right, would be inappropriate, and alternative concepts such as informed consultations leading to broad community support, should be considered.

5.3 Companies must act responsibly, preventing and mitigating environmental damage and impacts, and respecting human rights.

Mining's legacy of harm to ecosystems and people cannot continue. Companies engaged in mining and ore processing activities must follow all local, national and international laws. They must be transparent about their operations, finance, beneficial ownership, human rights and social due diligence, and supply chain information. It is widely recognised that business enterprises have a responsibility to respect human rights[61] – this is independent from States' ability and willingness to protect human rights.[62]

In advance of any mining-related activity, companies and governments must assess the ecological capacity of ecosystems to continue to sustain life, and minimise disruption in sensitive areas. This must include the consideration of cumulative effects, which are the combined impact of multiple extraction activities over time and space on the environment and local communities.

Mining and ore processing must also decarbonise, using renewable energy to power operations. Minimising energy, water, chemical, and material inputs during mining and processing is essential. Continuous rehabilitation of mining sites should be managed using adequate policy, regulation, and finance instruments including bonds and legacy funds.[63]

All companies making products that contain these minerals should seek to improve business practices relating to the extraction and use of these raw materials. Enforcing comprehensive international due diligence requirements with regular third party audits can help ensure that transition minerals do not cause or contribute to adverse social, environmental, and human rights impacts.[64]

Office building ©Unsplash.
Forest ©Răzvan Dima/Greenpeace.

What are the solutions to reduce the need for mining?

Top left: EV bus, Indonesia. © Dentjes/Shutterstock. **Top right: Lithium-ion High-voltage Battery Component for Electric Vehicle.** © IM imagery/Shutterstock. **Bottom left: Powdered, recyced Lithium iron phosphate cathode material, to make new lithium Ion batteries** © Unsplash. **Bottom right: Conveyor belt carries batteries to be 'wet shredded'.** © Ascend Elements

Sufficiency

This means a decent living standard for all while reducing the total energy and material needs across economies.

For example, rather than a "like for like" replacement of internal combustion engines with EVs, overall reductions in car use can be achieved by investing in more efficient and less energy intensive mobility options (e.g., affordable and accessible public transport).

Efficiency

Investments in this area can increase products' longevity and help technologies do the same or better job with less materials.[65]

Today we need less material input for the same battery performance – this must continue to improve through research and development efforts.

Substitution

This removes or reduces the need for certain minerals in products by using different types of technology or energy solutions.

Lithium iron phosphate (LFP) batteries require neither nickel nor cobalt. LFP improvements have led to reductions in projected EV nickel demand,[66] and now make up about half of the global EV battery market.[67]

Recycling

Compared to mining, recycled supply has far fewer environmental and social impacts[68] and should be maximised.

Programs and policies, such as minimum recycled content regulations and extended producer responsibility (EPR) schemes, can boost recycled supplies.[69]

Endnotes

1 Critical Minerals: A Primer (Intergovernmental Forum on Mining, Materials, Metals and Sustainable Development, 2023) Please note: reference cites an example of projected demand estimates from the IEA (2022). Estimates of future demand vary considerable between studies, as this Introduction outlines.
2 Achieving Zero Emissions with More Mobility and Less Mining (Climate and Community Institute, 2024); Critical minerals and the green transition: do we need to mine the deep seas? (Environmental Justice Foundation, 2024); The Battery Mineral Loop (Rocky Mountain Institute, 2024); The Future is Circular: Circular Economy and Critical Minerals for the Green Transition (Sintef, 2022)
3 Critical Transitions: Circularity, equity, and responsibility in the quest for energy transition minerals - Working Paper, Table 1 (United Nations Environment Programme, 2024). Note - reference also outlines the use of many other minerals used in a range of other technologies.
4 What's the difference between mineral reserves and resources?, Our World in Data (Ritchie & Roser, 2024)
5 United States Geological Survey (USGS) Commodity Summaries for Lithium Nickel Copper & Cobalt (USGS, 2025)
6 Dry Andes more sensitive to lithium mining than previously thought – study (Mining.com, 2024); Contemporary and relic waters strongly decoupled in arid alpine environments, PLOS Water (Moran et al., 2024); Lithium mining is slowly sinking Chile's Atacama salt flat, study shows (Reuters, 2024)
7 Mining indigenous territories: Consensus, tensions and ambivalences in the Salar de Atacama, The Extractive Industries and Society (Lorca et al., 2022)
8 Global Critical Minerals Outlook 2024 (IEA, 2024). Reference cites projected demand estimates from the IEA (2024). Estimates of future demand vary considerable between studies, as shown in Critical Mineral Outlooks Comparison (International Energy Forum, 2023)
9 USGS Commodity Summaries for Lithium Nickel Copper & Cobalt (United States Geological Survey, 2024)
10 Democratic Republic of Congo: "This is what we die for": Human rights abuses in the Democratic Republic of the Congo power the global trade in cobalt (Amnesty, 2016); Cobalt Red (Kara, 2023)
11 The Deadly Mining Complex Powering the EV Revolution (Bloomberg, 2024); Fast and Furious for Future: The Dark Side of Electric Vehicle Battery Components and their Social and Ecological Impacts on Indonesia (Rosalux, 2023); Dirty Nickel, Clean Power: Making the Ocean Bleed Red (The Nation, 2023)
12 Indonesia Can Cost-effectively Supplant Captive Coal-fired Power Plants with Solar Energy (Chojkiewicz et al., 2024)
13 Visualizing the size of mine tailings (Mining.com, 2021); Annual tailings production from copper mining worldwide from 2010 to 2018 (Statista, 2024)
14 The looming risk of tailings dams (Reuters, 2021)
15 EU Critical Raw Materials Act (European Commission, 2024); EU plans for battery supply chain face delays as US lures components producers (Financial Times, 2023); Minerals Security Partnership (US Department of State, 2024)
16 World Energy Outlook (IEA, 2023)
17 Elevating the Role of Critical Minerals for Development and Security (Centre for Strategic and International Studies, 2023); NATO releases list of 12 defence-critical raw materials (North Atlantic Treaty Organization, 2024)
18 Critical minerals and the green transition: do we need to mine the deep seas? (Environmental Justice Foundation, 2024); Global Critical Minerals Outlook 2024 (IEA, 2024); Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition (World Bank, 2020)
19 Critical Mineral Outlooks Comparison (International Energy Forum, 2023)
20 Challenging the Need for Deep Seabed Mining From the Perspective of Metal Demand, Biodiversity, Ecosystems Services, and Benefit Sharing, Frontiers in Marine Science (Miller et al., 2021); Critical Mineral Outlooks Comparison (International Energy Forum, 2023)
21 Achieving Zero Emissions with More Mobility and Less Mining (Climate and Community Institute, 2024)
22 Critical minerals and the green transition: do we need to mine the deep seas? (Environmental Justice Foundation, 2024); The Future is Circular: Circular Economy and Critical Minerals for the Green Transition (Sintef, 2022)
23 Bend the trend: Pathways to a liveable planet as resource use spikes (UNEP, 2024)
24 Recycling 'end-of-life' solar panels, wind turbines, is about to be climate tech's big waste business (CNBC, 2023); Status of PV Module Recycling in Selected IEA PVPS Task12 Countries (IEA, 2022); Outlook for battery and energy demand (IEA, 2024); Jump starting lithium battery recycling starts with investing in innovation (World Economic Forum, 2024)
25 Critical materials are fundamentally different to fossil fuels since they are not combusted, see More transitions, less risk: How renewable energy reduces risks from mining, trade and political dependence, Energy Research & Social Science (Krane & Idel, 2021); Energy transition will require substantially less mining than the current fossil system, Joule (Nijnens et al., 2023); Sustainable energy transitions require enhanced resource governance, Journal of Cleaner Production (Watari et al., 2021)
26 The Battery Mineral Loop (Rocky Mountain Institute, 2024)
27 Effectiveness of copper as a preventive tool in health care facilities. A systematic review, Am J Infect Control. (Aillón-García et al., 2023); Cobalt in medicine (Cobalt Institute, n.d.)
28 Recharging community consent: Mining companies, battery minerals, and the battle to break from the past (Oxfam, 2023)
29 Eleven fundamental instruments of the ILO Conventions and Recommendations (ILO, n.d.); Guiding Principles on Business and Human Rights (UN, 2011); The Core International Human Rights Instruments and their monitoring bodies (UN, n.d.); Durban Declaration and Programme of Action - World Conference Against Racism, Racial Discrimination, Xenophobia and Related Intolerance, 2002 (UN, 2002); UNGA Declaration on the Right to Development resolution 41/128 (UN, 1986); Vienna Declaration and Programme of Action (UN, 1993); Special Rapporteur on the human right to a healthy environment (UN, n.d.)
30 International Labor Organisation (ILO) Convention on Child Labour (ILO, n.d.); Declaration on the Fundamental Principles and Rights at Work (ILO, 1998)
31 Mining Policy Framework (IGF, 2023)
32 Guiding Principles on Business and Human Rights (UN, 2011)
33 Theme and Variations: The Aarhus Convention and Escazú Agreement (GNHRE, n.d.)
34 Exploring the Remedy Gap in the Large-Scale Mining Sector – The Role of Grievance Mechanisms to promote Human Rights in Mineral Supply Chains (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2024)
35 Goal 12: Sustainable Consumption and Production (UN Sustainable Development Goals, 2023)
36 Climate Change 2022, Mitigation of Climate Change (IPCC, 2022)
37 Socio-economic conditions for satisfying human needs at low energy use: An international analysis of social provisioning, Global Environmental Change (Vogel et al., 2021)
38 Bend the trend: Pathways to a liveable planet as resource use spikes (UNEP, 2024); Socio-economic conditions for satisfying human needs at low energy use: An international analysis of social provisioning, Global Environmental Change (Vogel et al., 2021)
39 Global EV Outlook: Trends in Batteries (IEA, 2023); Critical minerals and the green transition: do we need to mine the deep seas? (Environmental Justice Foundation, 2024); The Role of Critical Minerals in Clean Energy Transitions (IEA, 2023)
40 Recycling of Critical Minerals, Strategies to scale up recycling and urban mining, A World Energy Outlook Special Report (IEA, 2025); Life cycle comparison of industrial-scale lithium-ion battery recycling and mining supply chains, Nature and Communication (Machala et al., 2025)
41 Critical minerals and the green transition (Environmental Justice Foundation, 2024); The Battery Mineral Loop (Rocky Mountain Institute, 2024)
42 Scaling up reuse and recycling of electric vehicle batteries: Assessing challenges and policy approaches (International Council on Clean Transportation, 2023)
43 The Role of Critical Minerals in Clean Energy Transitions (IEA, 2023)
44 Tracking Flows of End-of-Life Battery Materials and Manufacturing Scrap, Batteries (Gaines et al., 2023)
45 REGULATION (EU) 2023/1542 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL (EU, 2023)
46 A Review of Lithium-Ion Battery Recycling: Technologies, Sustainability, and Open Issues (Zanoletti et al., 2024, Batteries)
47 Recovery of strategically important critical minerals from mine tailings, Journal of Environmental Chemical Engineering (Sarker et al., 2022)
48 Remining for Renewable Energy Metals: A Review of Characterization Needs, Resource Estimates, and Potential Environmental Effects, Minerals (Maest, 2023)
49 ISO/PC 348 Sustainable raw materials (International Standards Organization, 2024); UN Secretary-General's Panel on Critical Energy Transition Minerals (UNSG, 2024); Investing in innovation will secure vital critical minerals for the energy transition – here's where to start (World Economic Forum, 2024)
50 Transition Minerals Tracker (Business & Human Rights Resource Centre, n.d.); Why Responsible Mining is a Human Rights Imperative (CSIS, 2023)
51 The Ten Principles of the UN Global Compact. Principle Seven: Environment (UN Global Compact, n.d.)
52 High Conservation Value Approach (HCV Network, n.d)
53 For peatlands: Global Peatlands Assessment: The State of the World's Peatlands (UNEP, 2022)
For tropical moist forests: High Carbon Stock Approach (HCSA, 2017) For global forest carbon stocks: Forest Carbon Stocks (WRI, 2022)
54 For example, Grasslands and Savannah Ecosystems (WWF, 2020)
55 Including claims, overlapping claims, and unresolved rights disputes by Indigenous Peoples and Local Communities
56 C169 - Indigenous and Tribal Peoples Convention (ILO, 1989)
57 United Nations Declaration on the Rights of Indigenous Peoples (UN, 2007)
58 Guiding Principles on Business and Human Rights (UN, 2011)
59 OECD Due Diligence Guidance for Responsible Business Conduct (OECD, n.d.)
60 National Contact Points (NCPs) for Responsible Business Conduct (OECD, n.d.)
61 African Commission on Human and People's Rights. State Reporting Guidelines and Principles on Articles 21 And 24 of the African Charter relating to Extractive Industries, Human Rights and the Environment (ACHPR, 2021); Inter-American Standards for Business and Human Rights (OAS, 2019); Report of the Special Representative of the Secretary-General on the issue of human rights and transnational corporations and other business enterprises (UN, 2008); Guiding Principles on Business and Human Rights (UN, 2011); Working Group on Business and Human Rights (UN, n.d.)
62 Guiding Principles on Business and Human Rights (UN, 2011)
63 UN Secretary-General's Panel on Critical Energy Transition Minerals (UNSG, 2024)
64 Due Diligence Guidance for Responsible Supply Chains (OECD, n.d.)
65 The Battery Mineral Loop (Rocky Mountain Institute, 2024); Advancing sustainable growth and energy transition in the United States through the lens of green energy innovations, natural resources and environmental policy, Resources Policy (Ullah et. al, 2023)
66 Global EV Outlook: Trends in Batteries (IEA, 2023)
67 The battery industry has entered a new phase (IEA, 2025)
68 Life cycle comparison of industrial-scale lithium-ion battery recycling and mining supply chains, Nature Communications (Machala et al., 2025)
69 Recycling of Critical Minerals (IEA, 2024)

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